COMPREHENSIVE MODELING APPROACH TO SHORELINE EROSION CONTROL

PAS STUDY FOR DELLANERA BEACH, GALVESTON, TX

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SUMMARY

- In 2020, the USACE Galveston District entered into a Planning with Assistance to States (PAS) study in partnership with the Galveston Park Board (GPB) to assess the feasibility of an offshore breakwater as a mitigation feature at the Dellanera (west Galveston Island) beach.

- Data collection, numerical modeling, alternatives development, and conceptual design work were all completed to support this study.

- To assess potential benefit of a breakwater in reducing shoreline erosion (and potentially accreting at the beach), numerical models including GenCade, XBeach, FUNWAVE-TVD, and Delft3D were employed.

    - A total of 27 alternatives were analyzed for this project (combination of location & shape)

- A submerged “horseshoe” shoal breakwater, constructed from cut block stone and marine mattresses, and a pre-filled salient was recommended at an OPC totaling roughly $10.3 million.

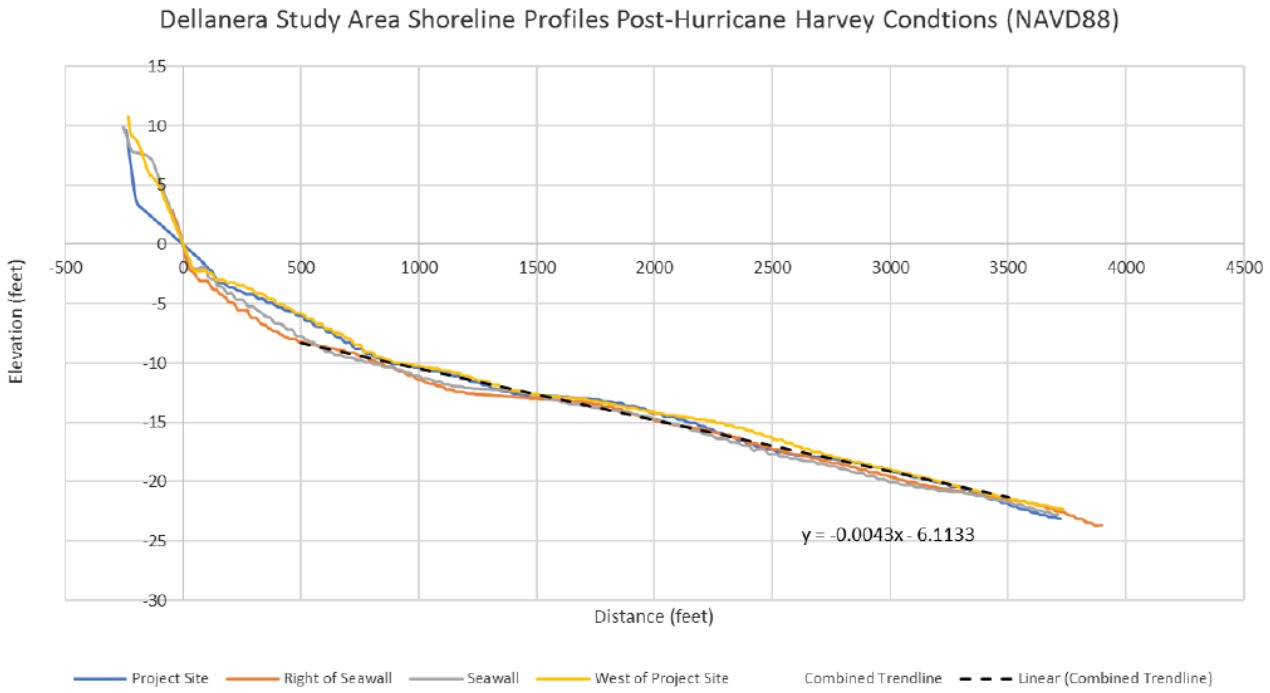
PROJECT AREA

BACKGROUND

- Most highly eroded shoreline on Galveston Island.
  - Historical rates > 8 ft/yr.
  - In 2015, a collaborative effort was made to truck in nearly 113,000 CY of sand, which established a dune height of 11 ft & a berm width of 50-80 ft (pictured below).
- Though weak, the predominant littoral drift on Galveston Island is east to west.
- Whereas the Dellanera shoreline has the greatest local erosion, the shoreline immediately to the west has some of the lowest erosion, due in large part to sediment supply derived from Dellanera's natural erosion and erosion of nourishment material.

DATA COLLECTION

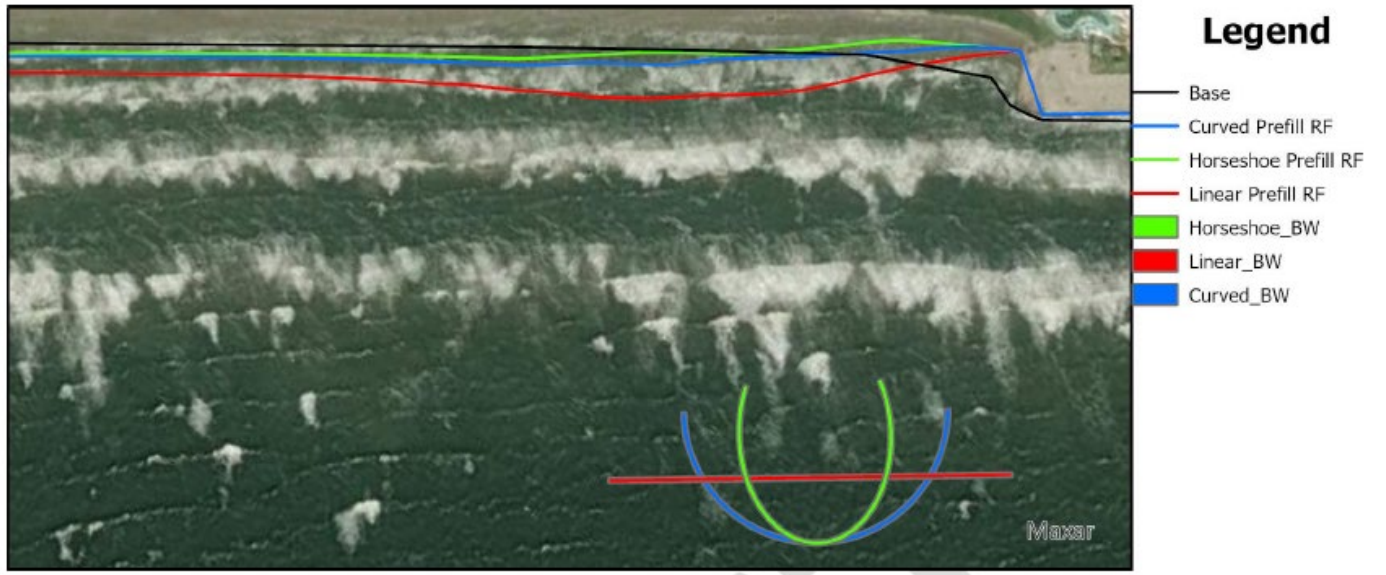
- *Bathymetry*
  - NOAA NCEI Digital Elevation Model (2007)
  - 2018 Coastal Texas Lidar (AECOM)
  - 2016 Wading Depth Surveys (ATKINS)
  - 2018 Pre/Post-Harvey Storm Survey (ATKINS)
- *Sediment & Geology*
  - Historical studies (Galveston Sand Management Plan, 2018)
  - TxSed (GLO)
  - Field samples collected by TAMU-Galveston
    - Findings: Sediment is fine poorly-graded with D_{50} = 0.16 mm.



DESIGN ALTERNATIVES

- Submerged breakwater shapes that were modeled:
  - Linear
  - Curved
  - Horseshoe (shoal)
    - 2 ft freeboard.
- Locations

Right Far	**Right Center**	**Right Near**
Center Far	**Center-Center**	**Center Near**
Left Far	**Left Center**	**Left Near**



- With or without pre-filled salient.

NUMERICAL MODELS OVERVIEW

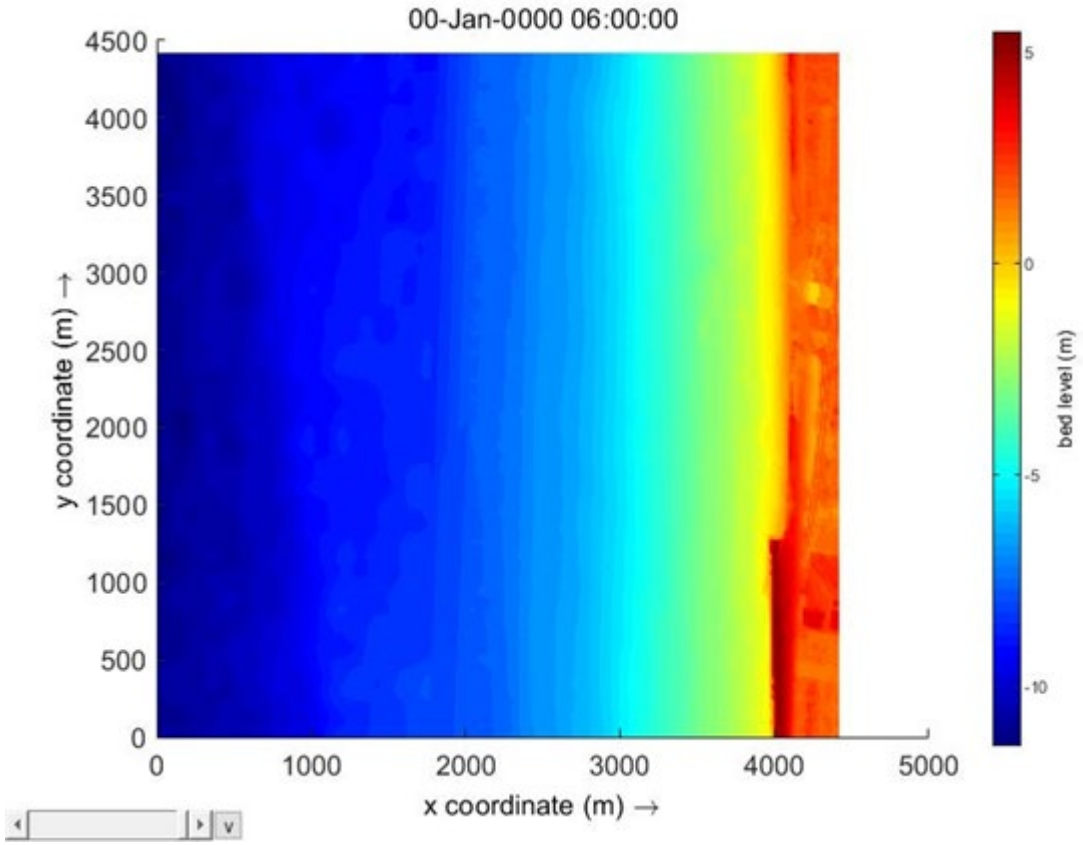
- ***GenCade (1D)***
  - Used to effectively determine the preferred location of the submerged breakwater.
    - Shoreline change, wave-induced long-shore transport, morphology.
    - Quantify downdrift impacts.
    - Long term benefit assessed over 50-yr simulation timeframe.
- ***XBeach (2D)***
  - Used to effectively determine the preferred location of submerged breakwater.
    - Prefilling effect on mitigation of downdrift impacts.
    - Robustness of alternatives in reducing erosion when faced with episodic events.
    - Hurricanes: Harvey, Ike, Rita
- ***Delft3D (3D)***
  - Used to understand long-term impacts (5-year simulation) and ability of mitigation feature in offsetting the nourishment needs.
    - Investigated the breakwater alternatives with/without pre-filled salient at the optimal location as determined by GenCade and XBeach.
    - Demonstrated the pros & cons to the different shapes in terms of downshore effects.
- ***FUNWAVE-TVD (Boussinesq)***
  - Used to quantify recreational hazards, attenuation, and benefit for the different alternatives.
    - Storm conditions were simulated to capture these effects.
    - Hurricanes: Laura, Harvey, Ike, Rita

MODEL METHODOLOGY

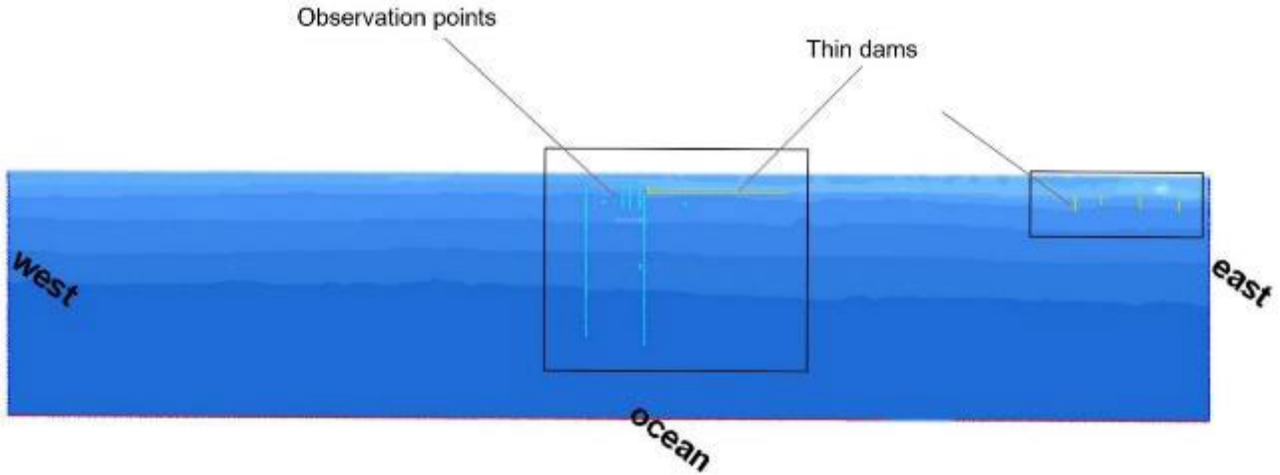
- GenCade
  - Pre-validated for Galveston Island 2016 sand management study.
    - Include structural components through Aquaveo's Surface Water Modeling System (SMS).
    - 50-yr simulation.
- XBeach
  - Develop model domain to capture the beach dunes, seawall, and offshore. (10ft x 10ft)
    - Implement boundary conditions by use of NOAA Tides & Currents, NDBC.
    - Validation made for Hurricane Harvey.
    - Storm simulations (1-day)
- Delft3D
  - Model domain developed from XBeach, with sufficient extent to capture longshore effects.
    - D-Wave developed with nested grid to capture small scale eddies, breakwater effects.
    - Model is calibrated and validated to 2017.
    - Long-term simulation (5-yr)
- FUNWAVE-TVD
  - Model domain from Xbeach. (10ft x 10ft)
    - Validation provided from real data taken during Hurricane Laura (2020) by TAMU-G.
    - Forcing from NDBC, waves are refracted and shoaled to domain boundary.
    - Peak storm (1-hr simulation)

DOMAIN

Xbeach/FUNWAVE



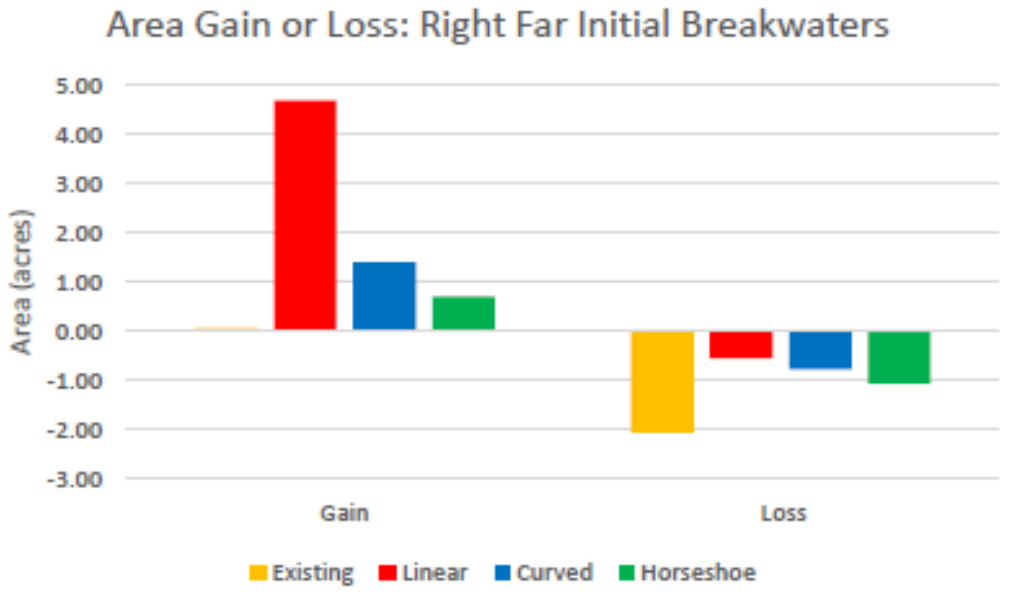
Delft3D

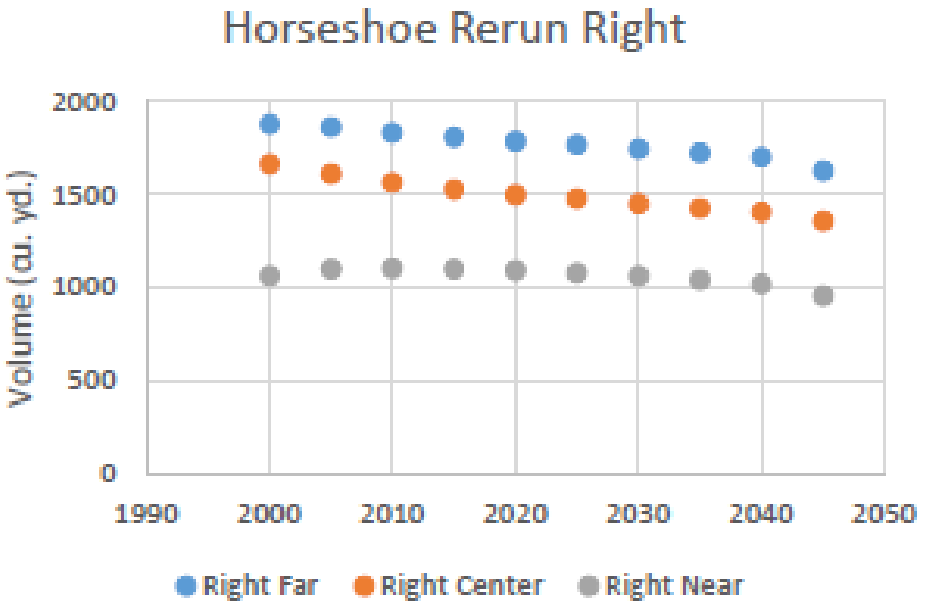


306x69 (50m-20m res)

GENCADE

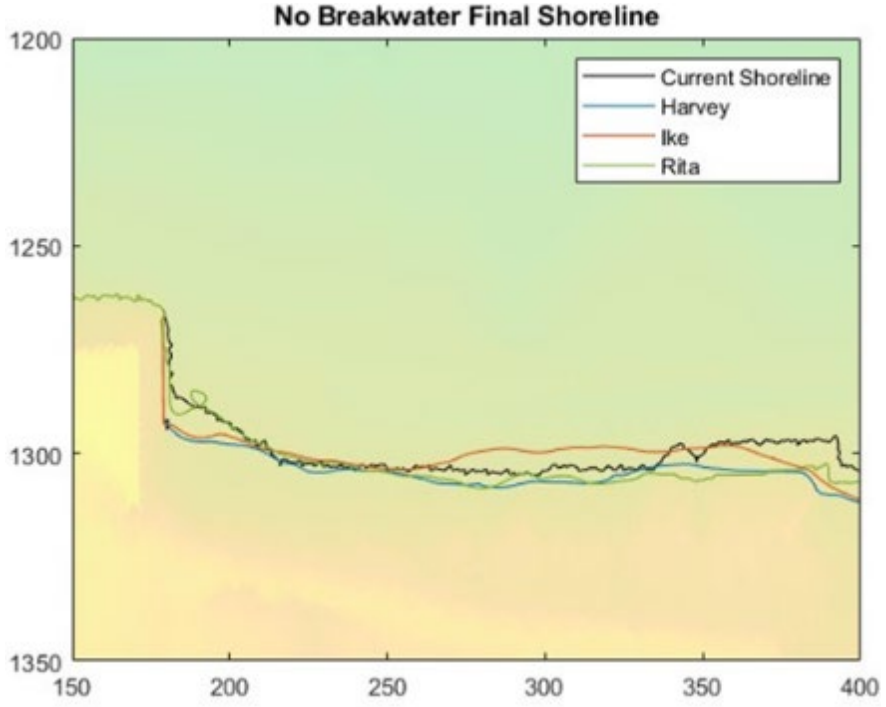
- GenCade determined that the far-right resulted in the least erosion among all the modeled alternatives.
  - This location provides greater protection from the dominant wave direction.
    - The findings from the other models are used to finalize this decision.
  - Results from GenCade were unable to capture the influence of breakwater shape, and demonstrated model limitations, leading to an inconclusive conceptual design.

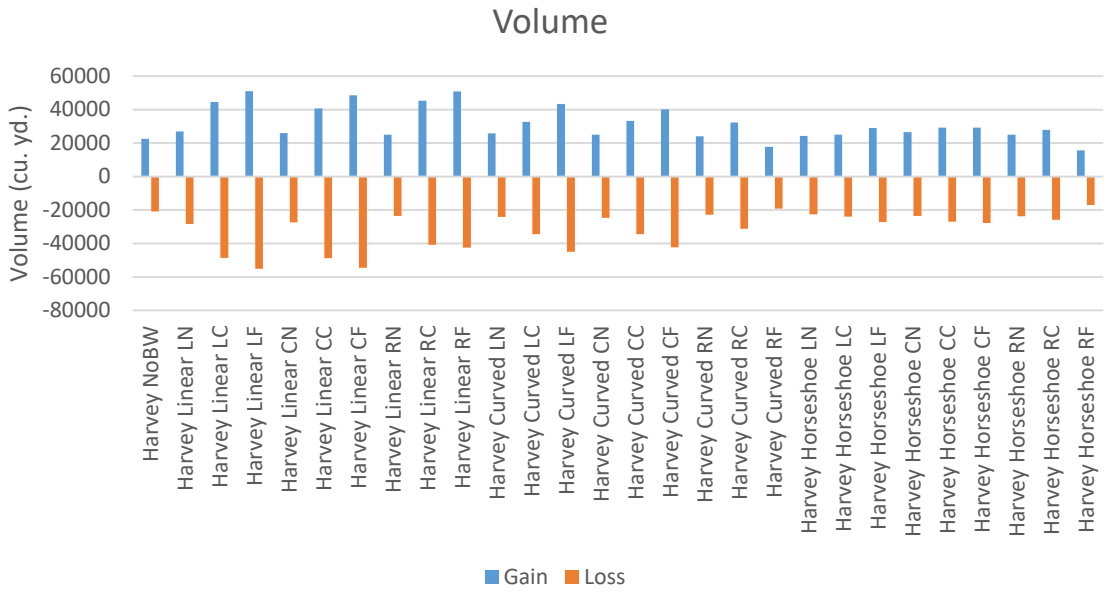




XBEACH

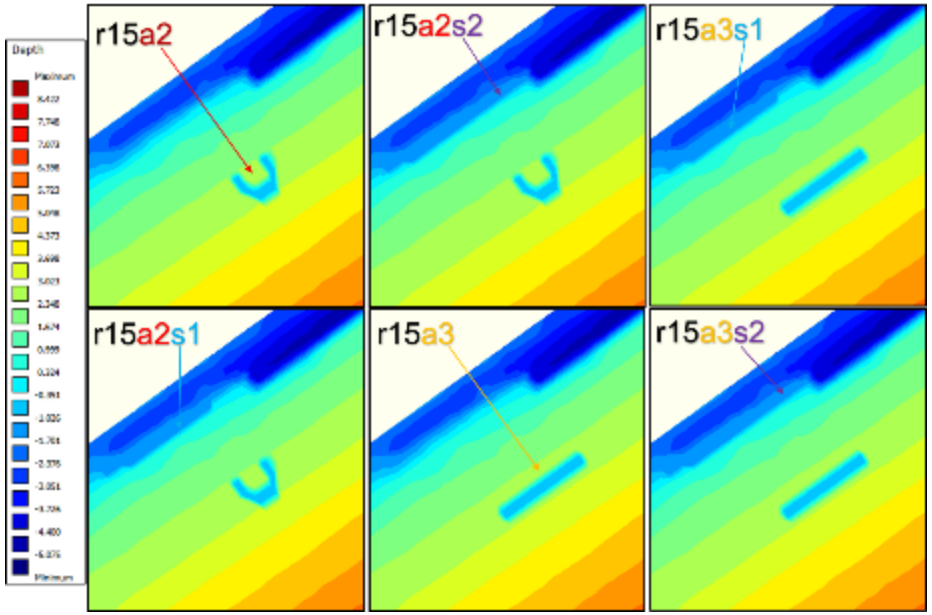
- XBeach supported the Delft3D and GenCade results in demonstrating the effectiveness of the right-far location in minimizing erosion at the project area.
  - XBeach determined the curved or horseshoe configuration to be the preferred design, to be later validated by use of Delft3D and FUNWAVE.

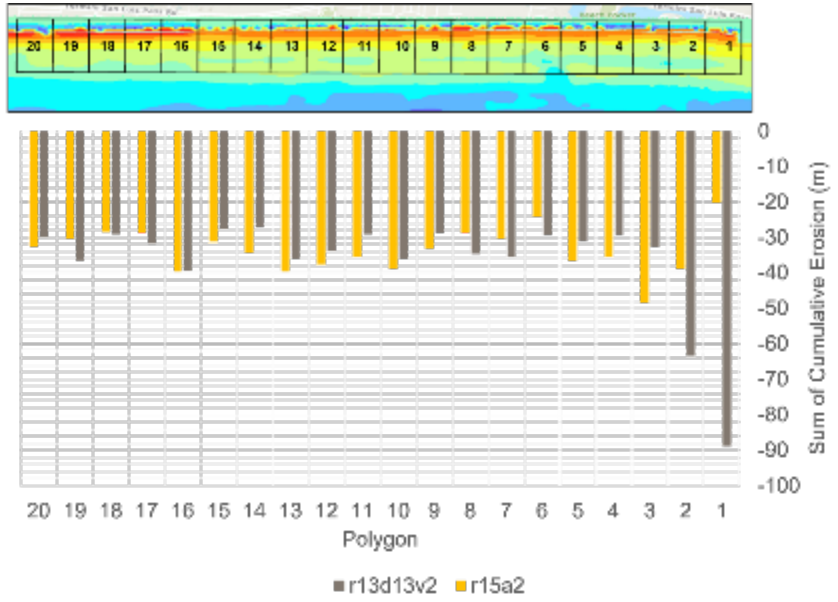




DELFT3D

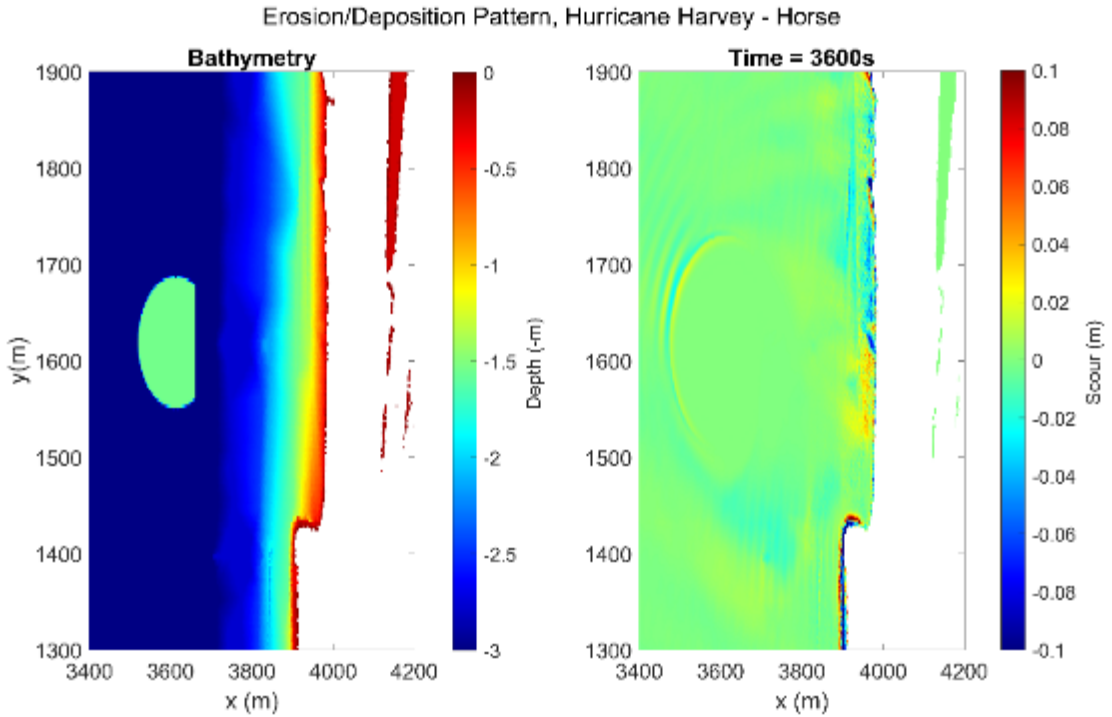
- Delft3D served as the primary tool for assessing the effectiveness of each alternative at the project area. The horseshoe shoal was determined to be the best design:
  - “Down shore effects are present but small (~5% increase in erosion along the 5 km of beach southwest of the project area). For the linear breakwaters, a significantly larger salient is formed in the lee of the structure and along the beach, however, it comes at the cost of greater down shore effects (~40%-15%).”
  - The model demonstrated that the least down shore erosion was achieved with the horseshoe shoal at the far-right location. The salient had a much larger effect in mitigating erosion for the linear case.
  - **r13d13v2** is the without project, while **r15a2** is the horseshoe breakwater with no salient.

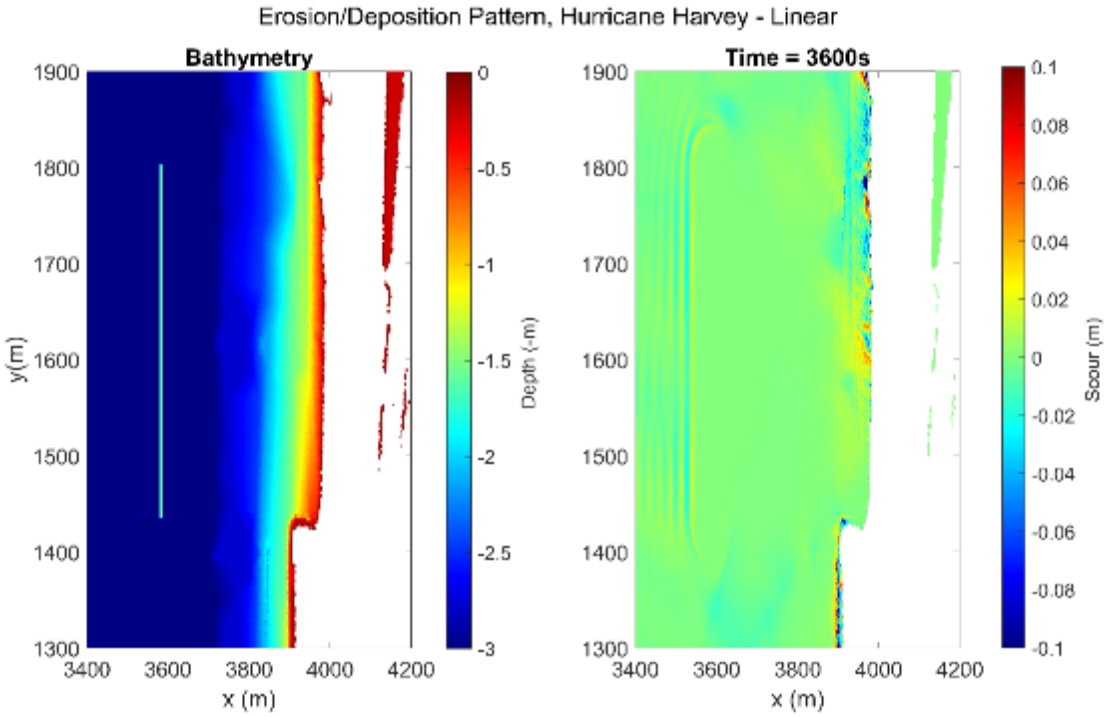




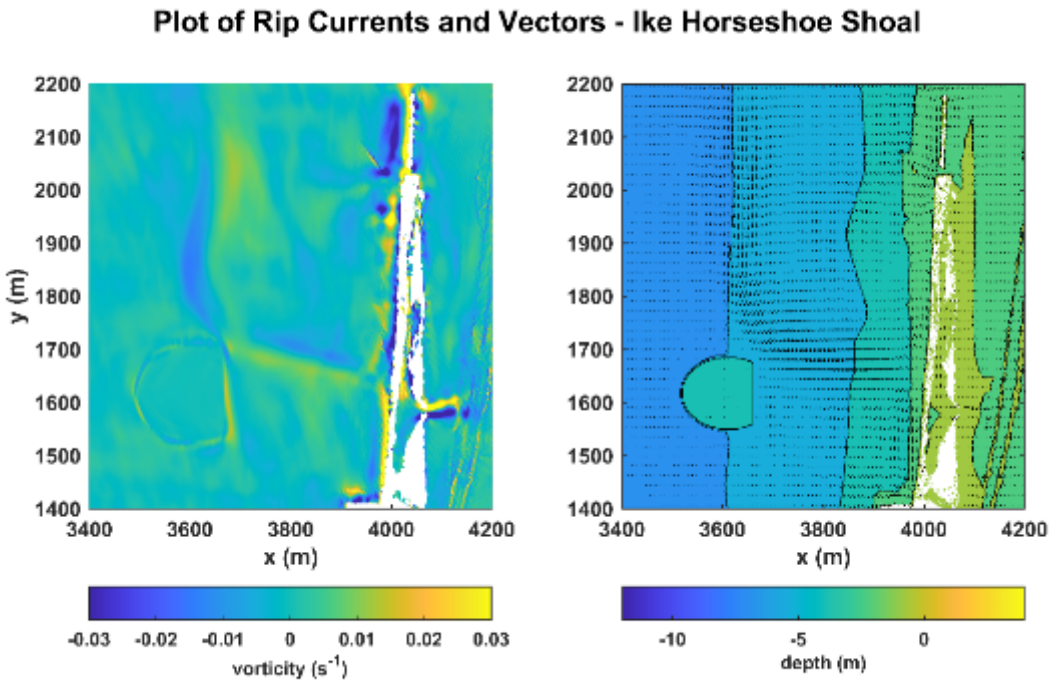
FUNWAVE-TVD

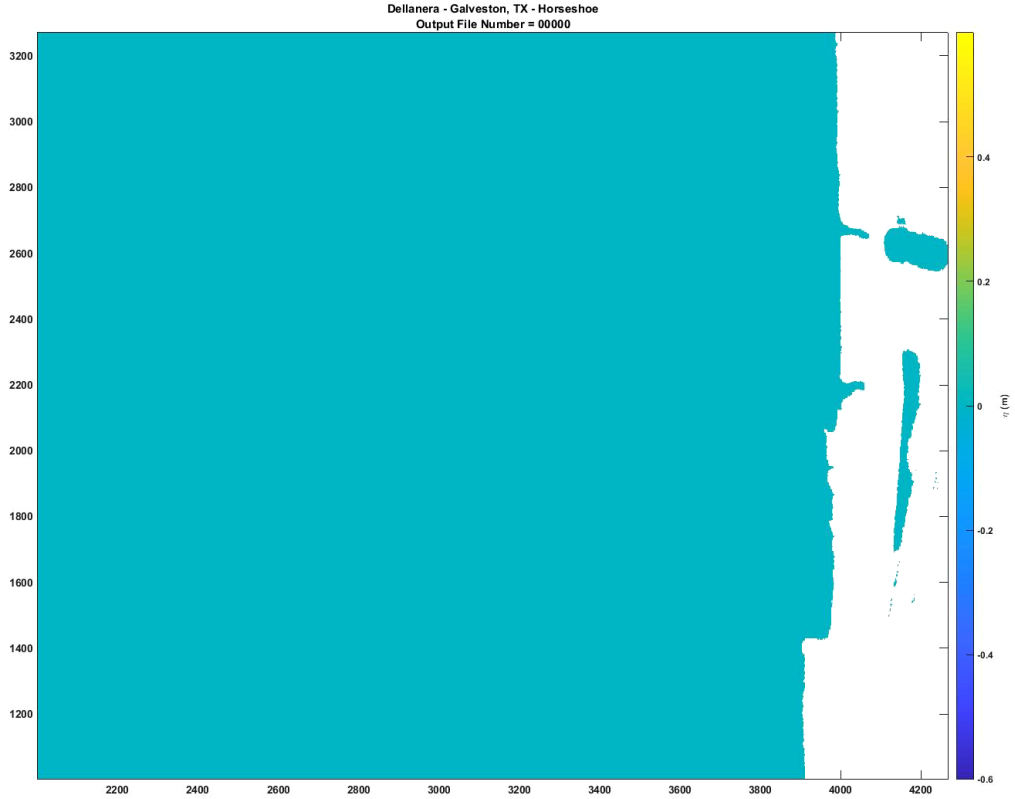
- FUNWAVE highlighted the attenuation benefit for the breakwater alternatives, while also giving insight into the diffraction patterns, rip currents, and sedimentation at the project area.
  - Robustness of tentatively preferred structure in providing and maintaining shoreline protection from radical storm events that trigger high erosion.
  - The linear breakwater displayed the highest attenuation in its lee, but left a signature of higher erosion down shore.





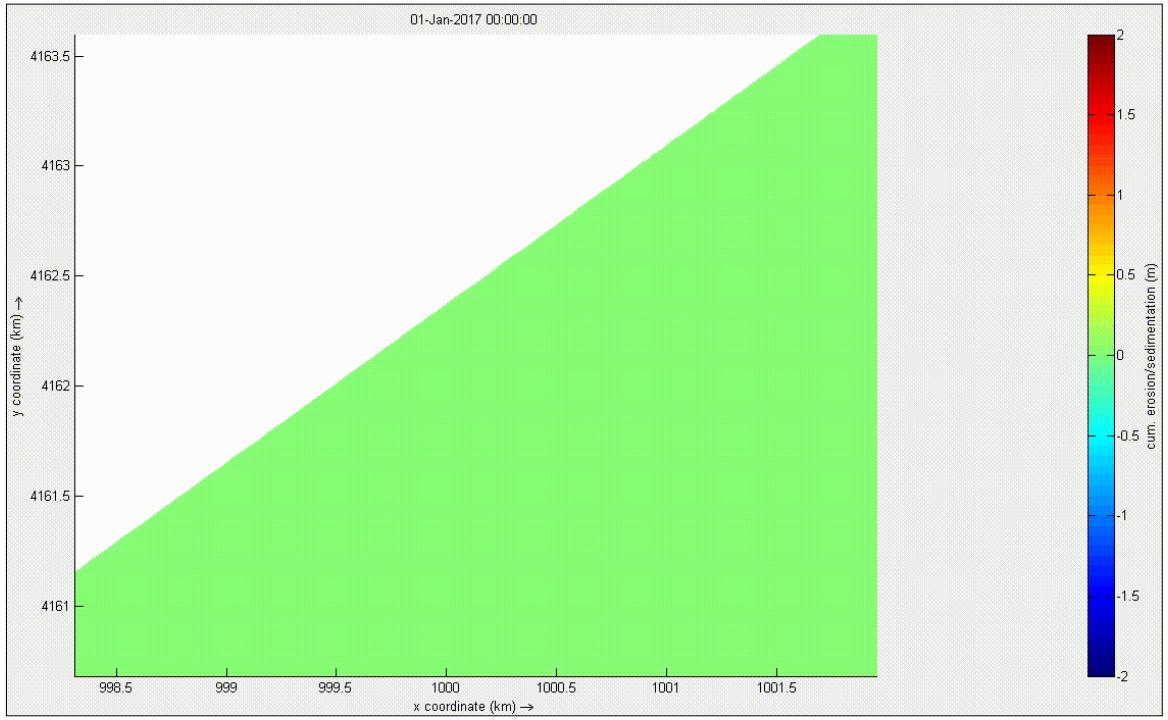
EXTRA – FUNWAVE





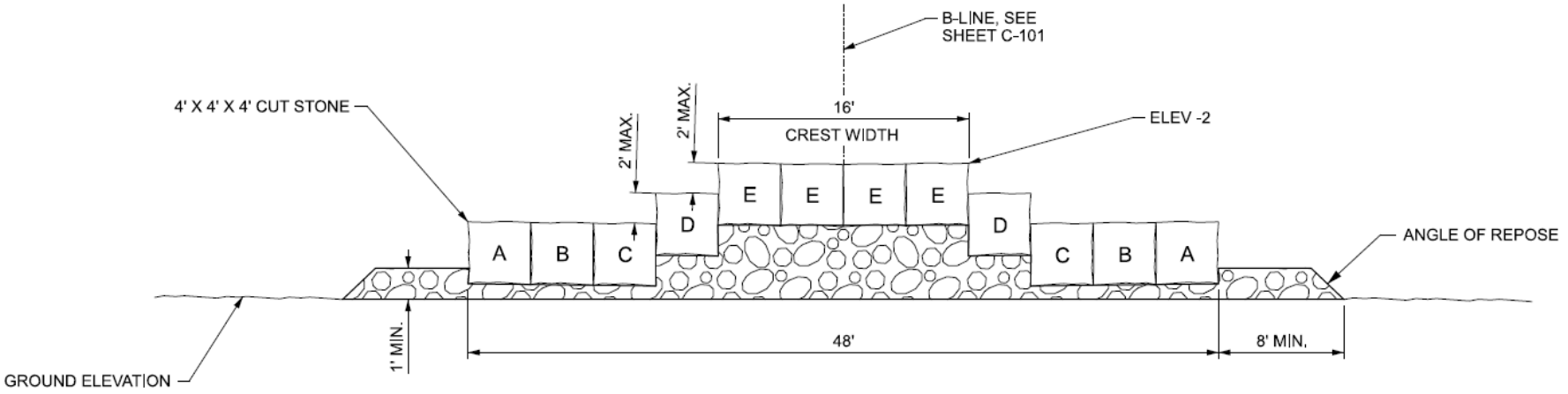
EXTRA – DELFT3D

- On the horseshoe shape not interrupting the longshore sediment transport while still providing benefit in the lee of the structure:
  - “This is likely due to the smaller long-shore footprint of the horseshoe shape. Additionally, there seem to be two primary locations of transport, one along the shoreline, and another at an offshore bar. The horseshoe shape does not significantly affect the long-shore transport at either of these locations.”

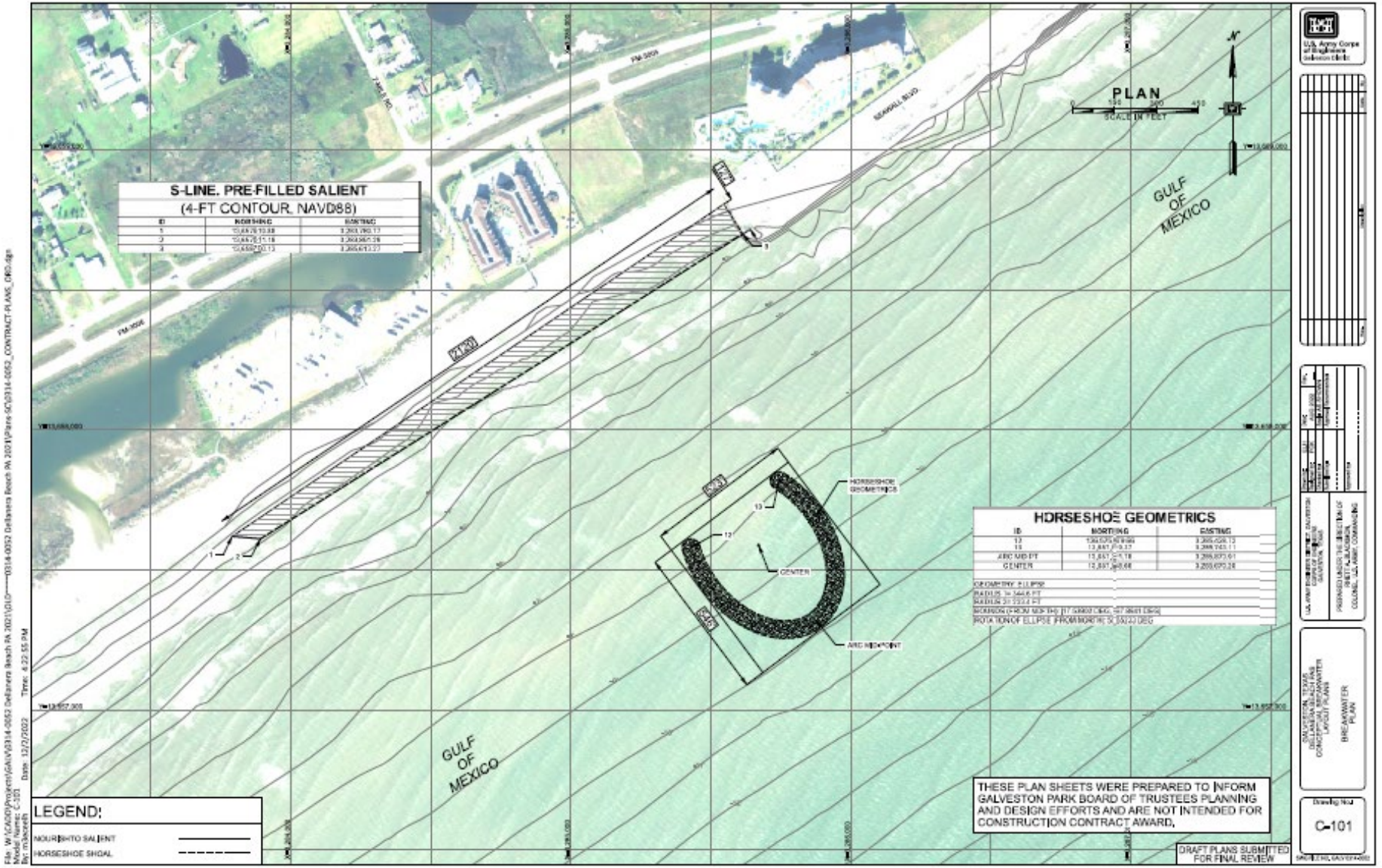


65% DESIGN RECOMMENDATION TO NFS

- The pre-filled salient was conservatively designed to nourish to the seawall under the expectation that the horseshoe may not be chosen for the final design.
- The recommended design is a submerged breakwater, 4’x4’ cut-block stone, marine mattress, and beach fill.
- Design includes: consideration of numerical model findings, traditional stone sizing (Van Der Meer) for 100-yr condition, and anticipated scour through analytical methods.



PLAN VIEW


S-LINE, PRE-FILLED SALIENT
(4-FT CONTOUR, NAVD88)
PLAN
SCALE IN FEET
GULF OF MEXICO
HORSESHOE GEOMETRICS
CENTER
ARC MIDPOINT
HORSESHOE GEOMETRICS
LEGEND:
NOURISHTO SALIENT
HORSESHOE SHOAL
THESE PLAN SHEETS WERE PREPARED TO INFORM GALVESTON PARK BOARD OF TRUSTEES PLANNING AND DESIGN EFFORTS AND ARE NOT INTENDED FOR CONSTRUCTION CONTRACT AWARD.
DRAFT PLANS SUBMITTED FOR FINAL REVIEW
BREAKWATER PLAN
C-101

QUESTIONS?