SEA{RCH}

Systems Engineering Approaches for Barrier Island Community Resilience

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Resilience

USCRP
US COASTAL RESEARCH PROGRAM

Presentation Outline

- Overview
- Approach
- Methods
- Results
- Next Steps
- Sneak Peek???

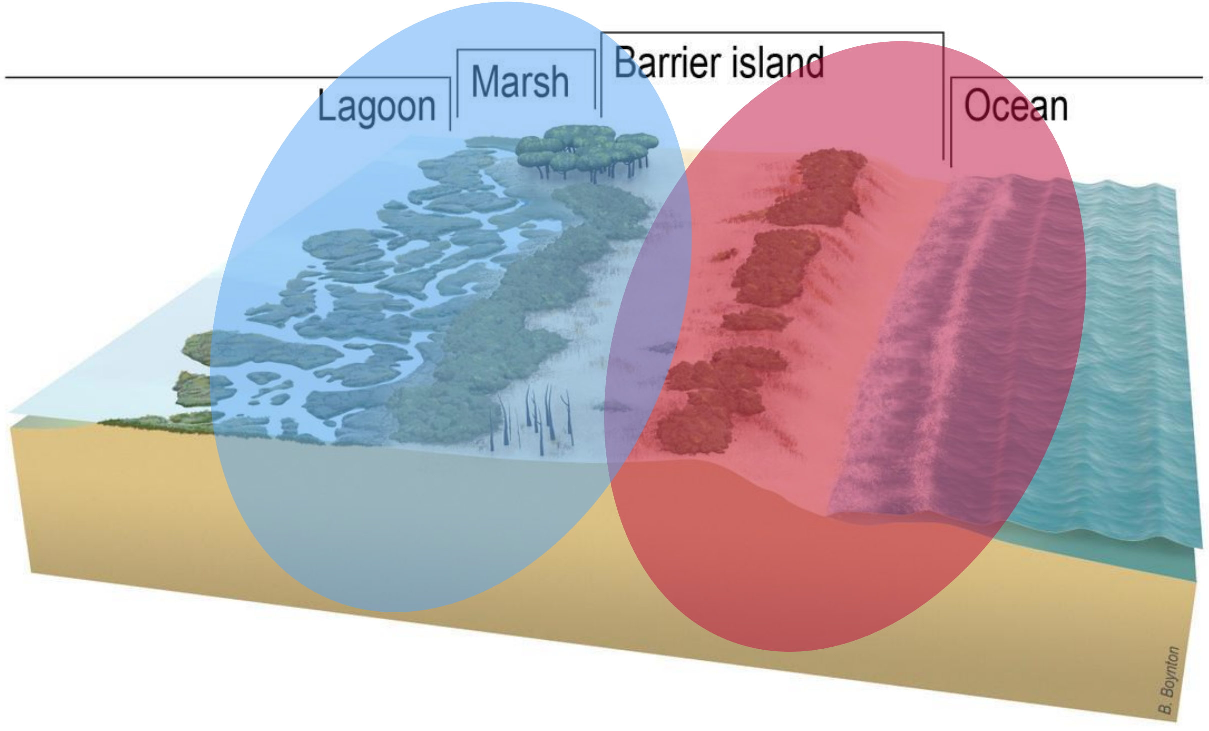
Overview

Overarching Goal

Flood Risk Management (FRM)

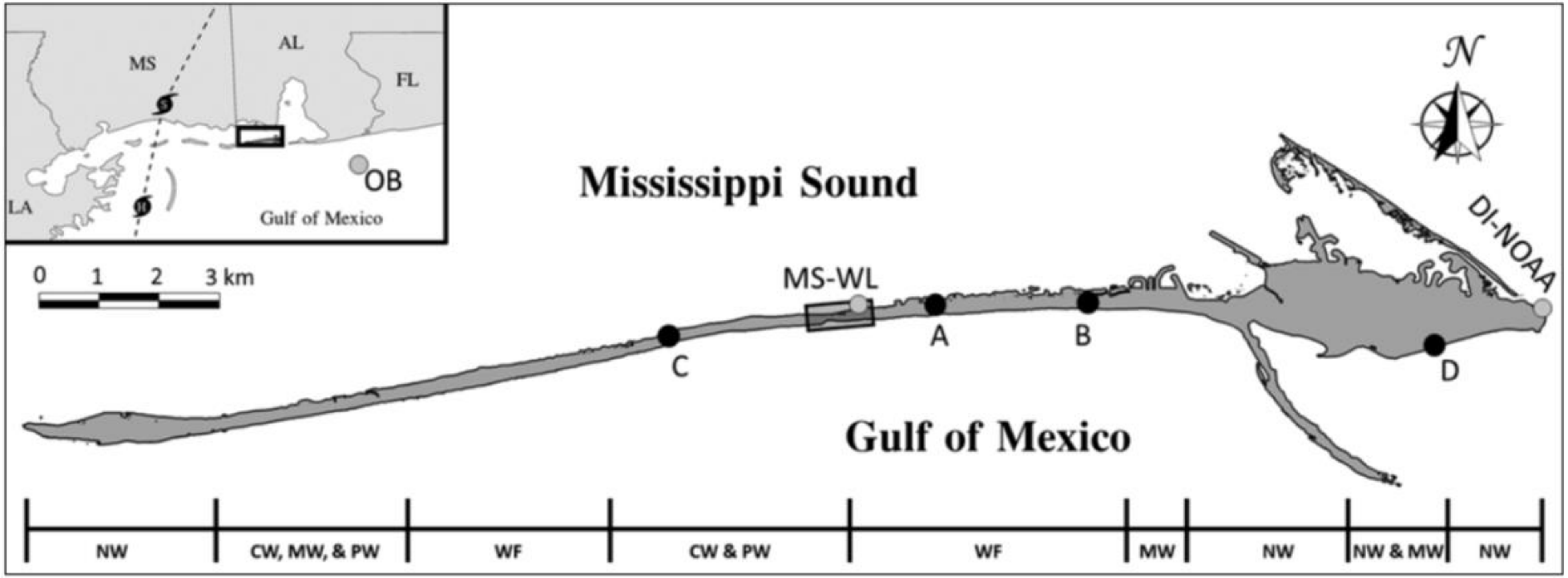
- Beach Nourishment
- Dune Restoration
- Fortification (strength, elev.)

- Back Barrier Resilience
- Cross-Section Management



https://www.usgs.gov/media/images/illustration-describes-barrier-island-ocean-lagoon

Dauphin Island, Alabama



Dauphin Island, Alabama

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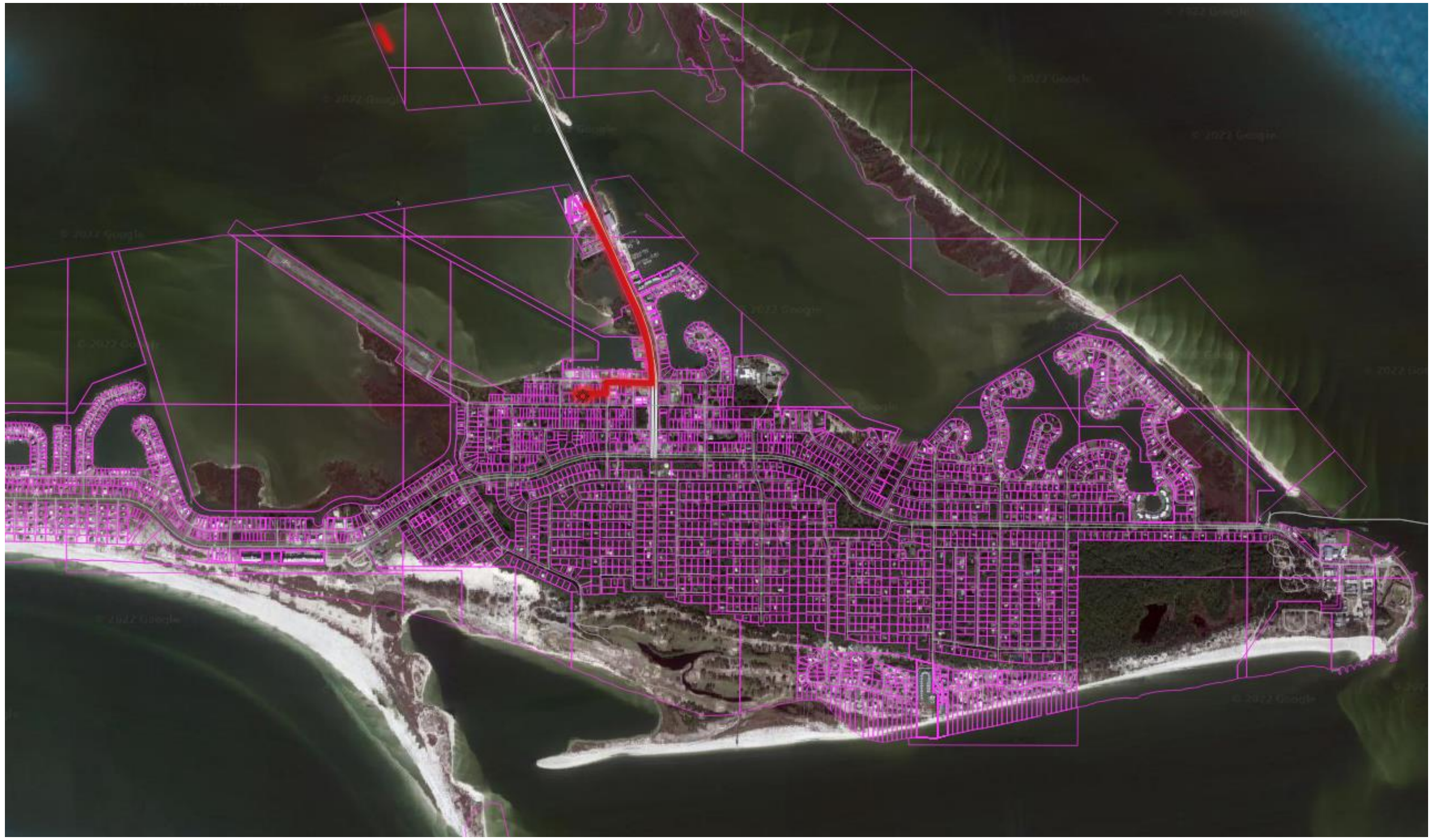
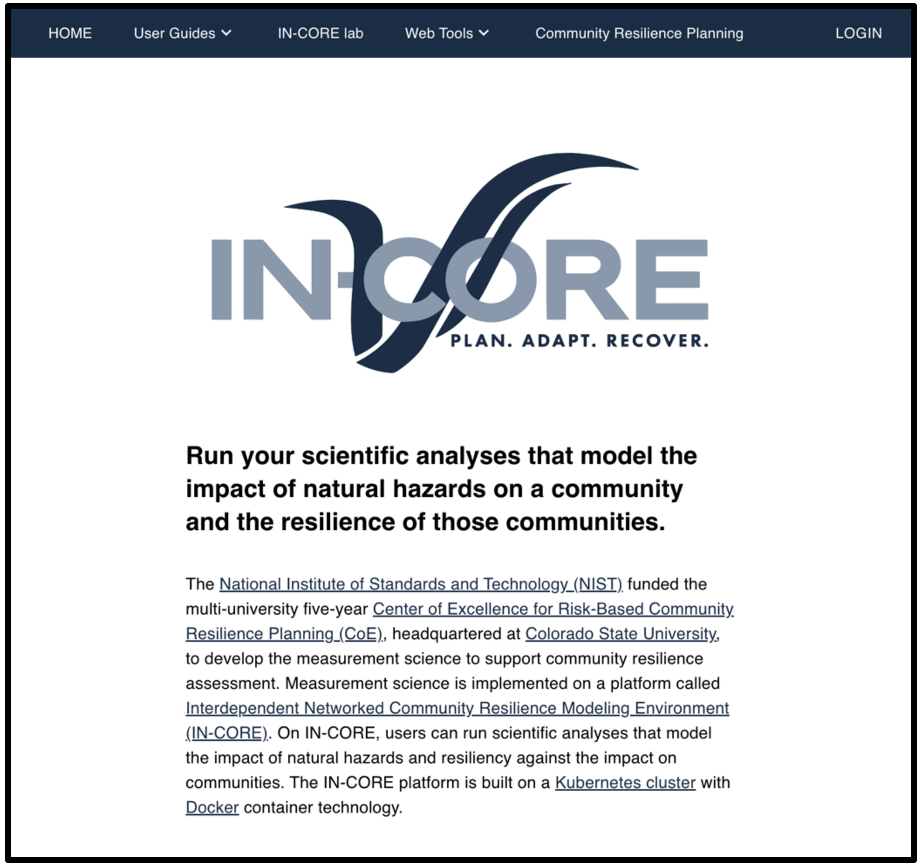
- Parcel Data
- Building Footprints
- Transportation
- Power
- Water
- Sewer
- Critical Facilities



Approach

Approach

- Analyze Existing Data
- Model Coastal Hazards
  - Existing Conditions
  - Future Conditions
  - With / Without Adaptations
- Model Resilience
  - IN-CORE



https://incore.ncsa.illinois.edu/

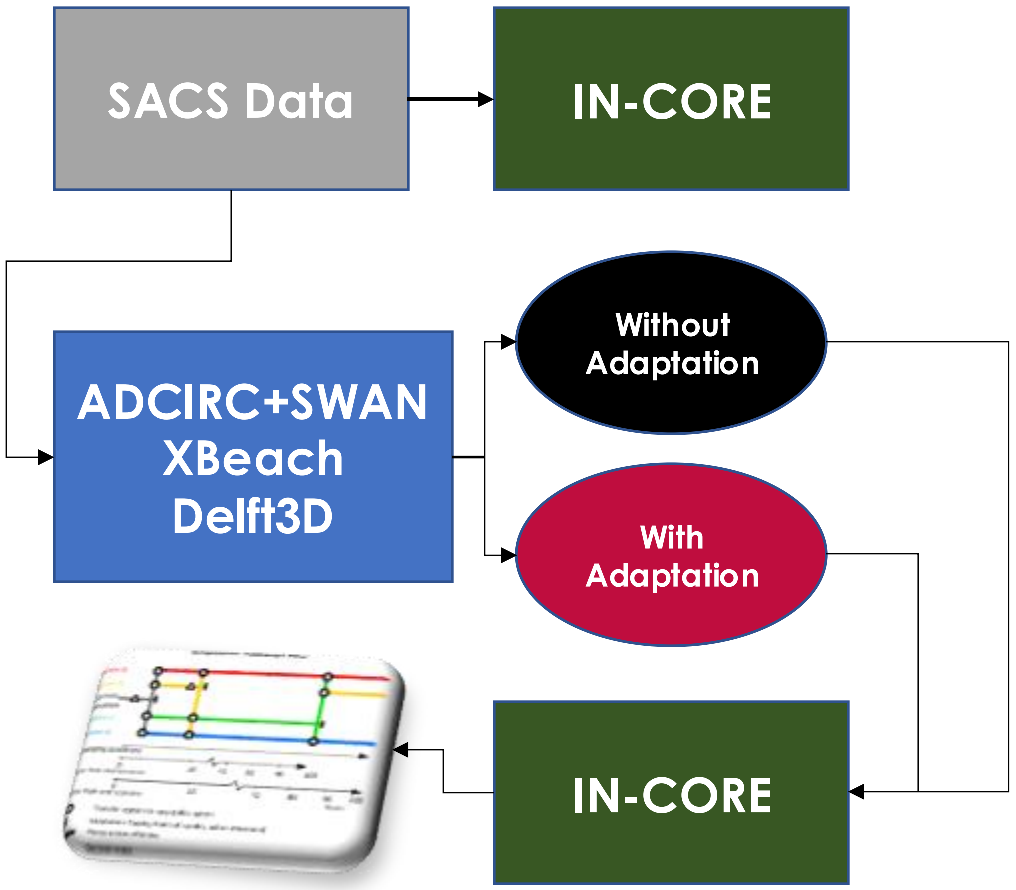
Approach

1. Establish Baseline Community Resilience

2. Model Future Flood Risk Hazards

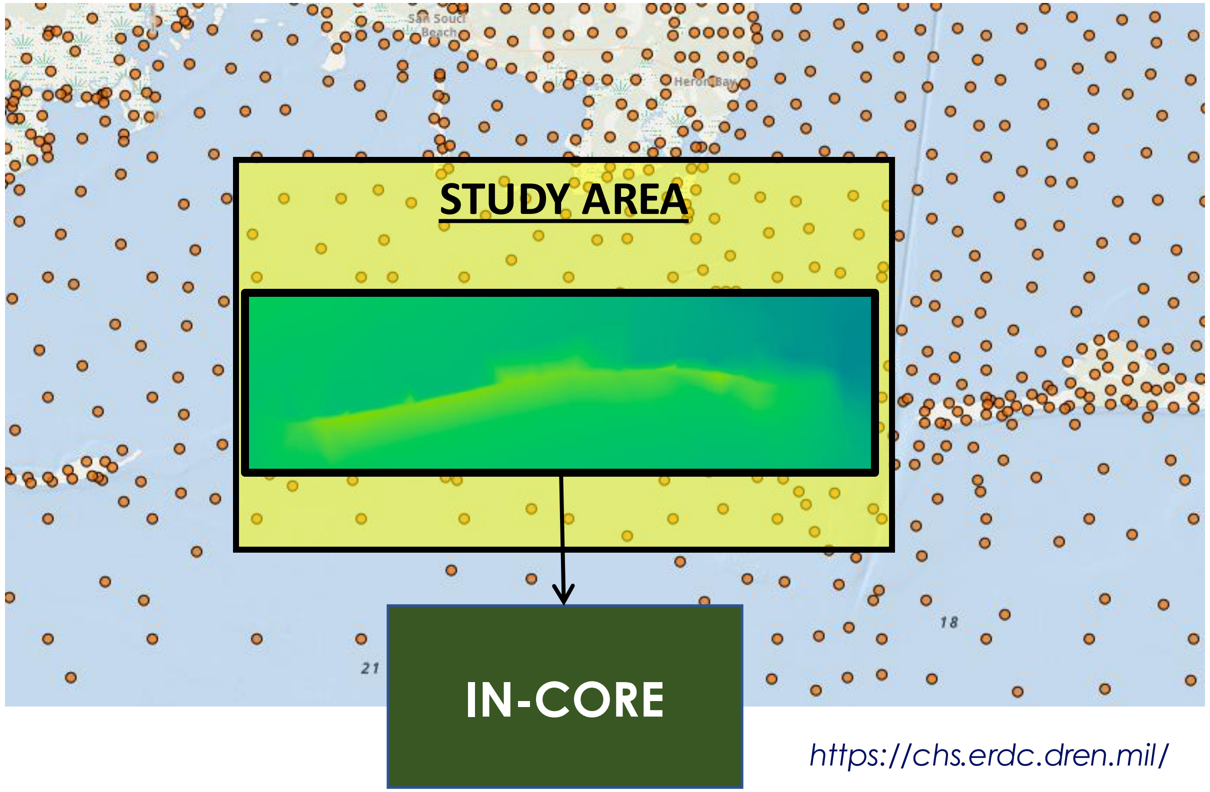
3. Predict Future Community Resilience

4. Create Adaptation Pathways



Using CHS Data (example)

- South Atlantic Coastal Study
- Coastal Hazards System v2.0
- Coastal Storm Hazards
  - Extratropical Cyclones
  - Tropical Cyclones
- AEP Values



https://chs.erdc.dren.mil/

Approach


Combined Wind-Wave-Surge Hurricane-Induced Damage Prediction for Buildings

Hassan Masoomi, S.M.ASCE[1]; John W. van de Lindt, F.ASCE[2]; Mohammad R. Ameri, S.M.ASCE[3]; Trung Q. Do, S.M.ASCE[4]; and Bret M. Webb[5]

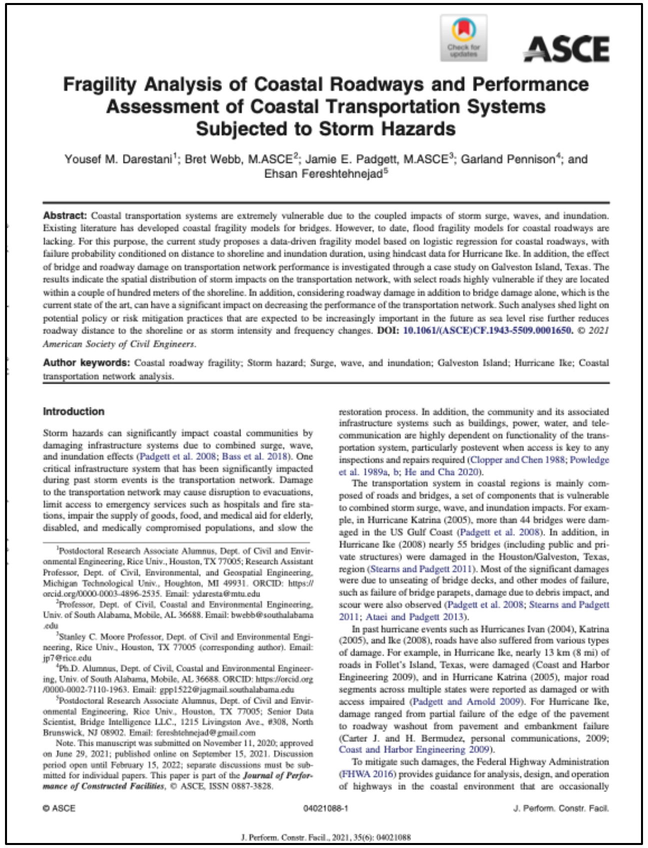
Abstract: Coastal structures are subjected to multihazard events such as hurricanes which consist of hurricane-induced surge and waves as well as winds. Hurricanes are a common natural hazard in the United States and cause considerable damage every year, with resulting annualized losses in the United States in the tens of billions of dollars. Although improvements in construction practices have been notable over time for individual hazards, there is still a dearth of risk and damage prediction methods in the area of multiple hazards that are based on principles of mechanics. In this study, a methodology to develop multihazard damage fragilities is summarized and illustrated for a wood-frame residential-building archetype subjected to hurricane winds, storm surge, and waves. The National Flood Insurance Program (NFIP) requires new buildings along the US coastline to be constructed with the first finished floor set at an elevation that exceeds a minimum necessary elevation. Therefore, two different elevations are considered for the lowest horizontal structural member of the archetype to also examine its effect on damage fragilities. The developed multihazard fragilities are used to calculate the time-dependent probability of each damage state at a given location over the timeframe of an event, i.e., hurricane. In this regard, the spatial and temporal data of wind speeds, flood depths, and significant wave heights for Hurricane Ike are simulated by the ADCIRC + SWAN model (a tightly coupled version of the ADvanced CIRCulation model and the Simulating WAves Nearshore model for simulating the propagation of storm surge and waves from deep water to the coastal region). The performance of nonelevated and elevated archetypes is examined at different locations in southeast Texas for Hurricane Ike and a scenario of damage states predicted for this area for the elevated archetype. DOI: 10.1061/(ASCE)ST.1943-541X.0002241. © 2018 American Society of Civil Engineers.

Author keywords: Multihazard; Fragility; Advanced circulation model (ADCIRC); Simulating waves nearshore model (SWAN); Hurricane Ike; Coastal area.

© ASCE 04018227-1 J. Struct. Eng.

J. Struct. Eng., 2019, 145(1): 04018227

Masoomi et al. (2019)


ASCE

Fragility Analysis of Coastal Roadways and Performance Assessment of Coastal Transportation Systems Subjected to Storm Hazards

Yousef M. Darestani[1]; Bret Webb, M.ASCE[2]; Jamie E. Padgett, M.ASCE[3]; Garland Pennison[4]; and Ehsan Fereshtehnejad[5]

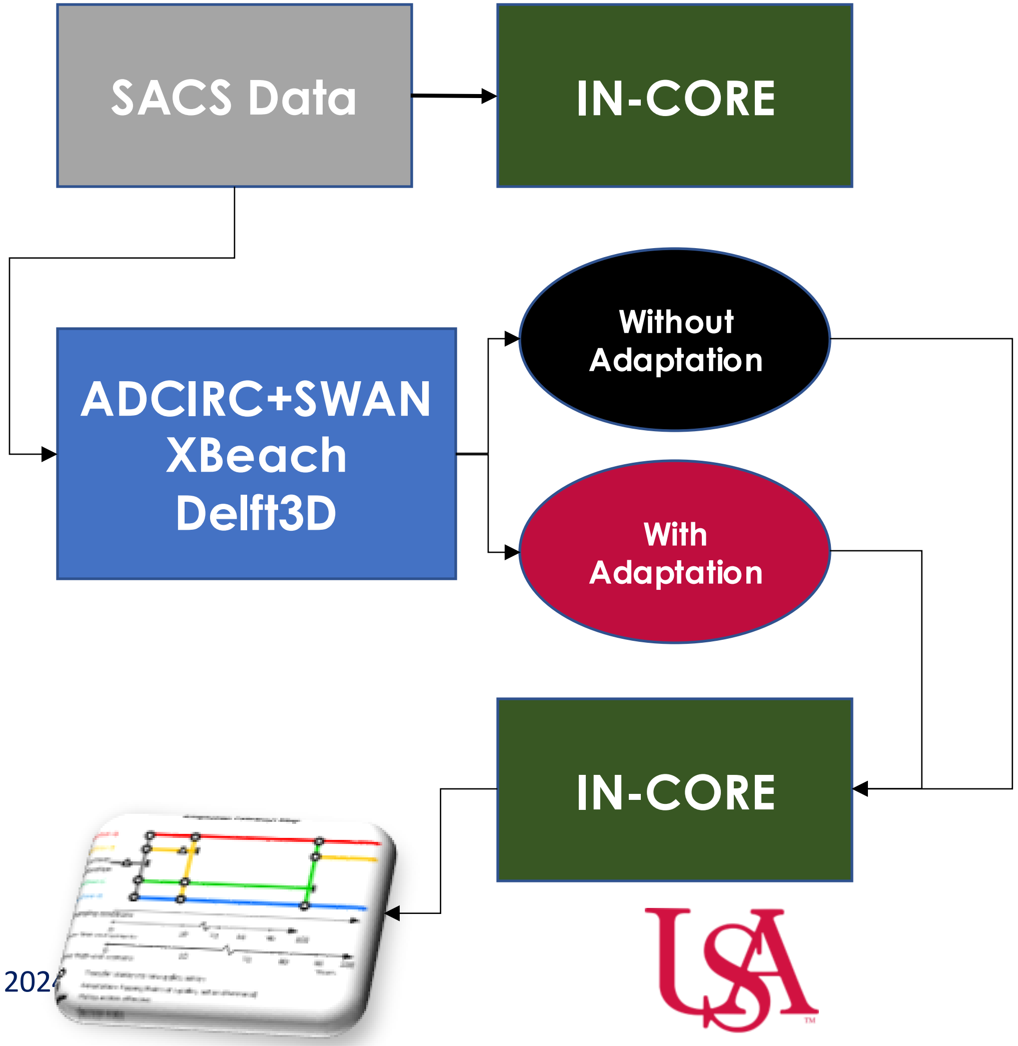
Abstract: Coastal transportation systems are extremely vulnerable due to the coupled impacts of storm surge, waves, and inundation. Existing literature has developed coastal fragility models for bridges. However, to date, flood fragility models for coastal roadways are lacking. For this purpose, the current study proposes a data-driven fragility model based on logistic regression for coastal roadways, with failure probability conditioned on distance to shoreline and inundation duration, using hindcast data for Hurricane Ike. In addition, the effect of bridge and roadway damage on transportation network performance is investigated through a case study on Galveston Island, Texas. The results indicate the spatial distribution of storm impacts on the transportation network, with select roads highly vulnerable if they are located within a couple of hundred meters of the shoreline. In addition, considering roadway damage in addition to bridge damage alone, which is the current state of the art, can have a significant impact on decreasing the performance of the transportation network. Such analyses shed light on potential policy or risk mitigation practices that are expected to be increasingly important in the future as sea level rise further reduces roadway distance to the shoreline or as storm intensity and frequency changes. DOI: 10.1061/(ASCE)CF.1943-5509.0001650. © 2021 American Society of Civil Engineers.

Author keywords: Coastal roadway fragility; Storm hazard; Surge, wave, and inundation; Galveston Island; Hurricane Ike; Coastal transportation network analysis.

© ASCE 04021088-1 J. Perform. Constr. Facil.

J. Perform. Constr. Facil., 2021, 35(6): 04021088

Darestani et al. (2021)



Methods

1D XBeach Modeling

Extreme Event Scenarios

- Present Day MSL
- 2055 MSL*
- 2085 MSL*
- 1% AEP
- 4% AEP
- 10% AEP

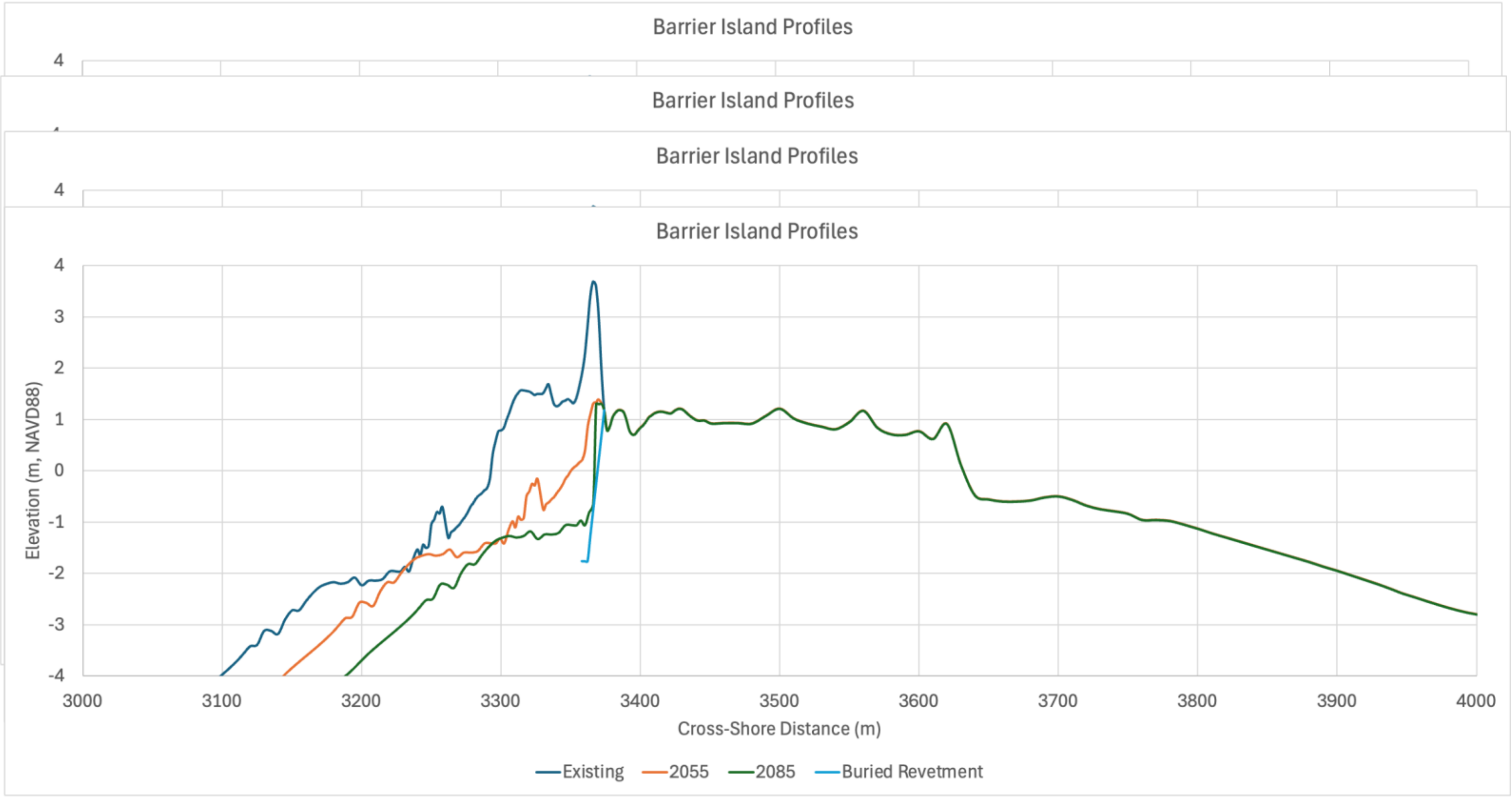
**IPCC AR6 SSP5-8.5 50th Percentile*

Adaptation Scenarios

- Do Nothing
- Beach+Dune Restoration
- Beach+Dune+Island Lift
- Beach+Dune+Lift+Bayside
- Buried Revetment
- Seawall
- Elevate Homes

1D XBeach Modeling

- Background Erosion Rate
  - -1.2 m/yr
- Bruun Rule
  - 2055: -30.7 m
  - 2085: -51.2 m



1D XBeach Modeling

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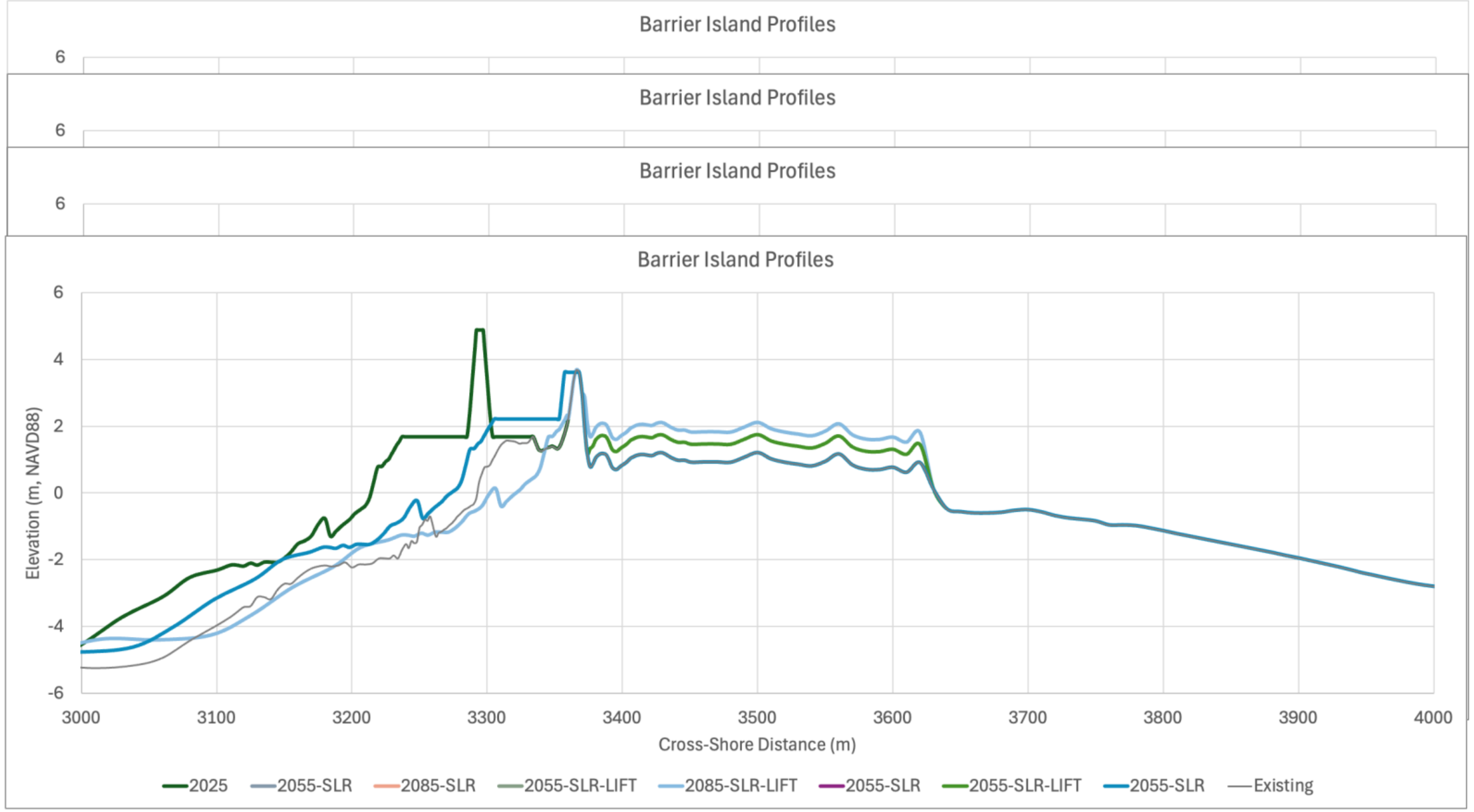
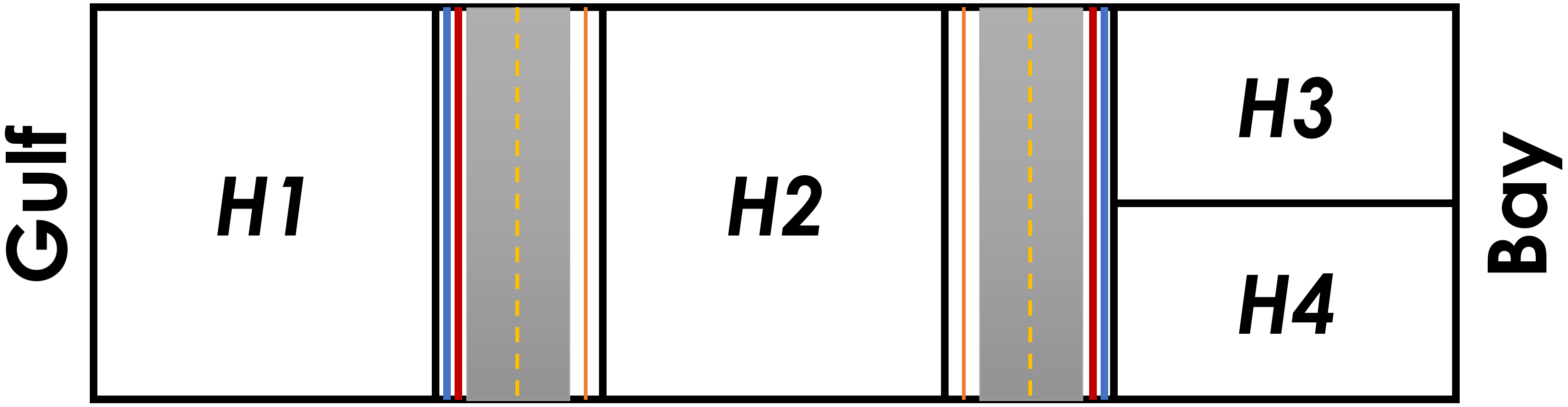


Infrastructure Model

- Homes
- Roads
- Telecoms
- Water
- Sewer



Infrastructure Model

- Homes
- Roads
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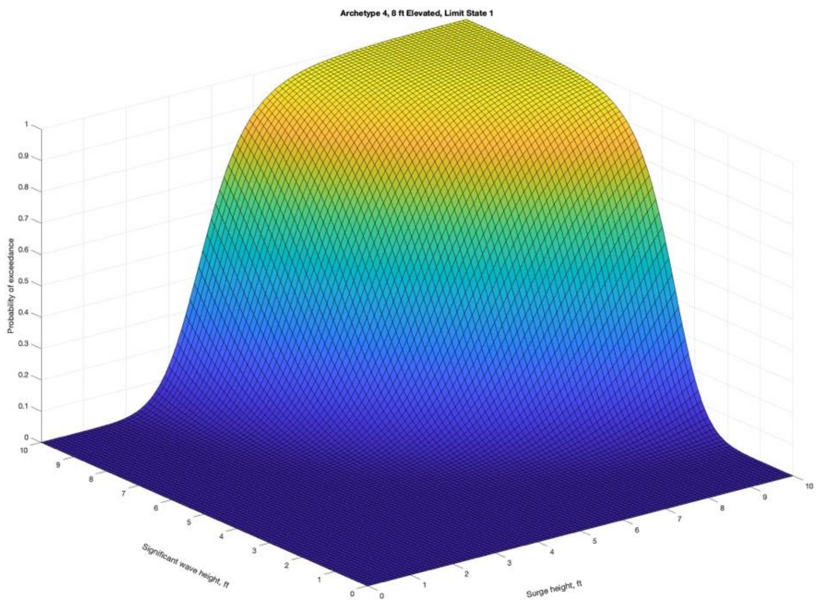
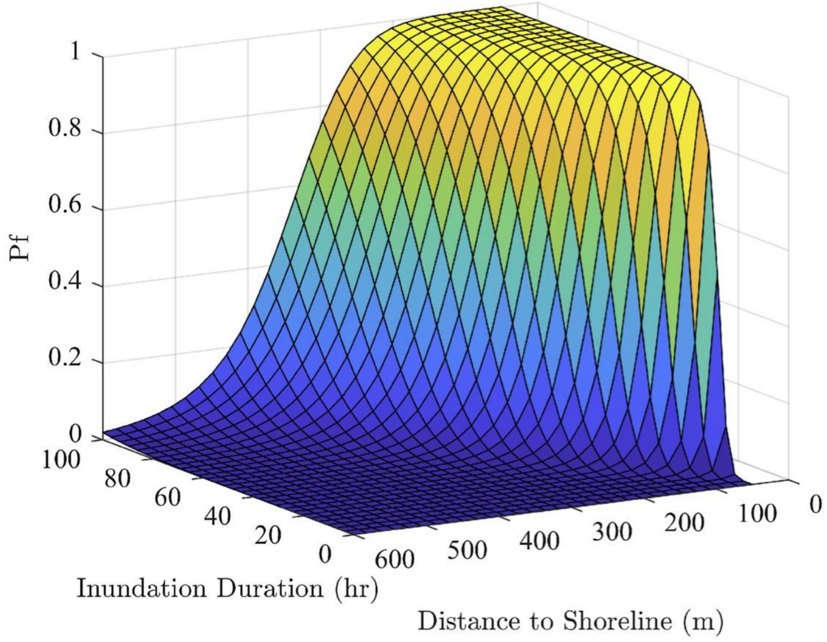
- Sewer

Elevated Structure Fragility



Do et al. (TBD)

Coastal Roadway Fragility



Darestani et al. (2021)

Infrastructure Model

Damage State Classification

DS=1

DS=2

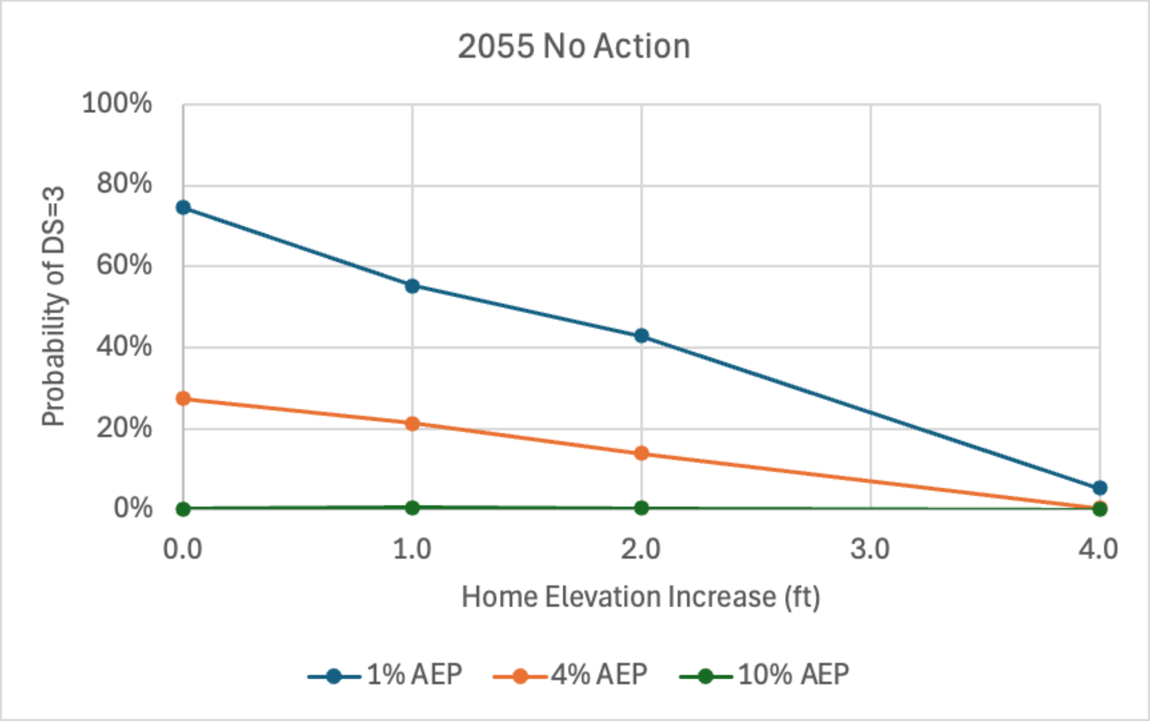
DS=3

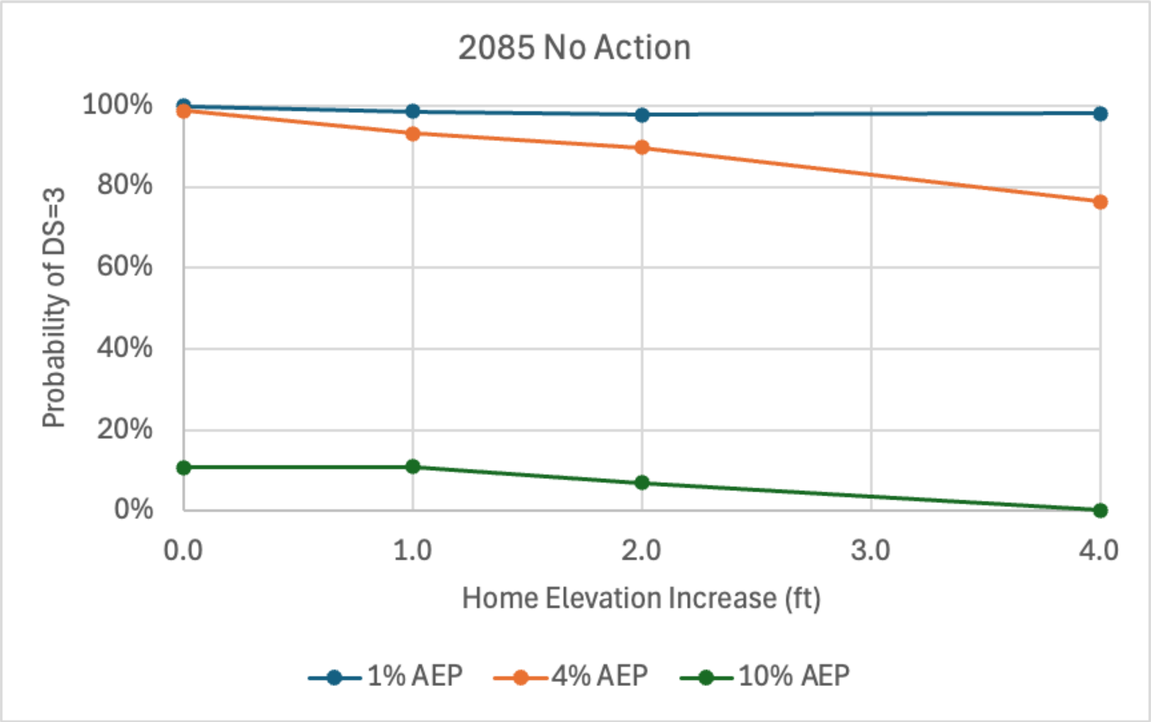
Conventionally Built Homes: Assessing Damage

	Flood Damage
Affected	• Any waterline in the crawl space or an unfinished basement when essential living space or mechanical components are not damaged or submerged. • Damage to a porch, carport, garage, and/or an outbuilding, etc.
Minor	• Waterline at 1 to 3 inches in an essential living space. • When waterline exceeds 3 inches but is below 18 inches, damage may be major or minor depending on the following factors: duration of the flood; contaminates in the water; if waterline reached outlets; and number of essential living spaces flooded. • Any waterline in a finished basement.
Major	• Waterline above 18 inches or the electrical outlets in an essential living space. • Waterline on the first floor (regardless of depth) of a residence when basement is completely full. • When waterline exceeds 3 inches but is below 18 inches, damage may be major or minor depending on the following factors: Duration of the flood; contaminates in the water; if waterline reached outlets; and number of essential living spaces flooded.
Destroyed	• Waterline at the roofline or higher, or complete failure of two or more major structural components (e.g., collapse of basement walls, foundation, walls, or roof).

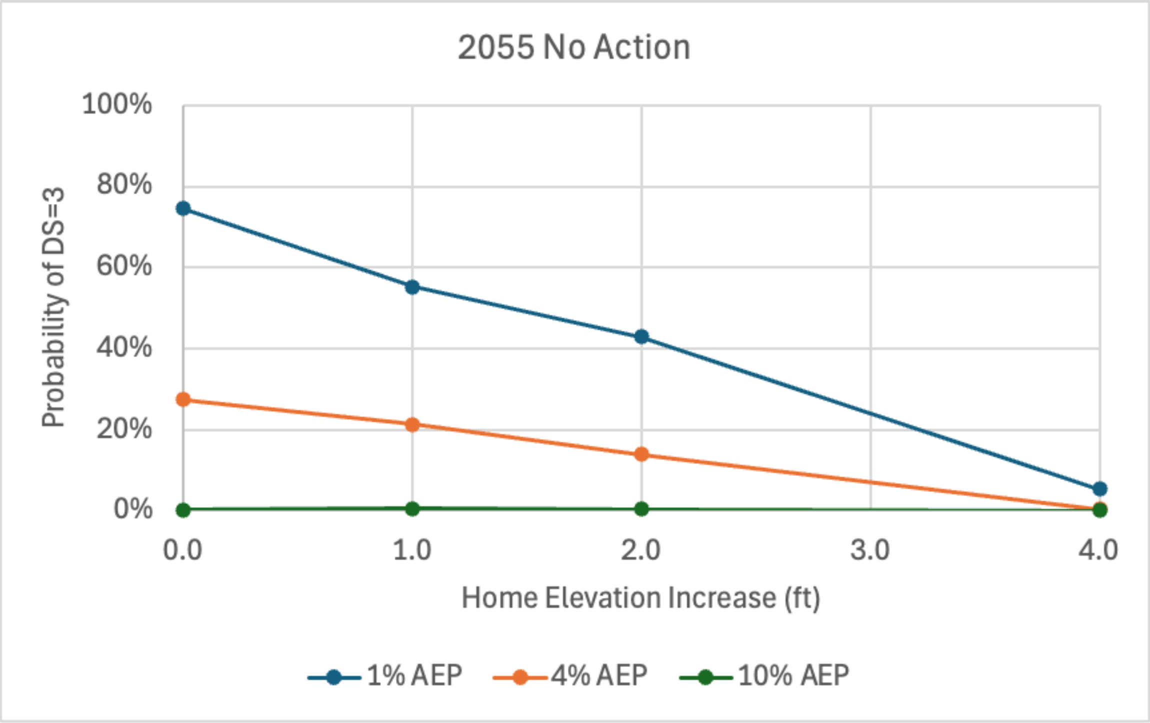
Results/Findings

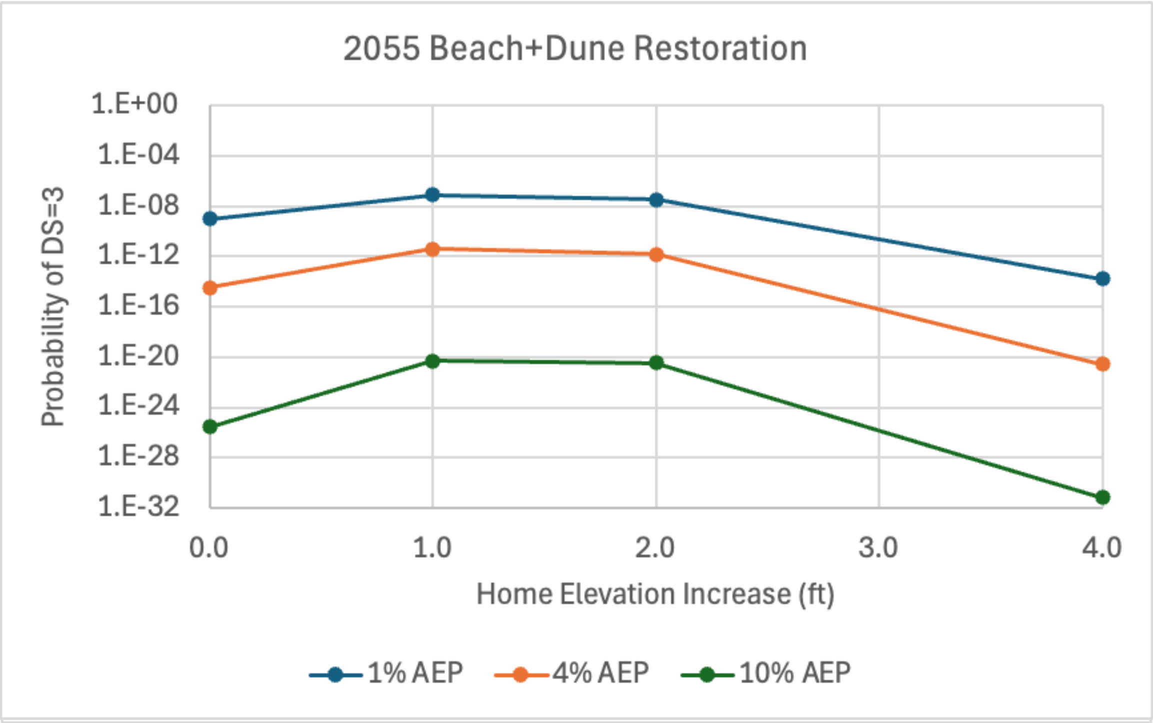
Results/Findings: Elevate Homes - P(f)



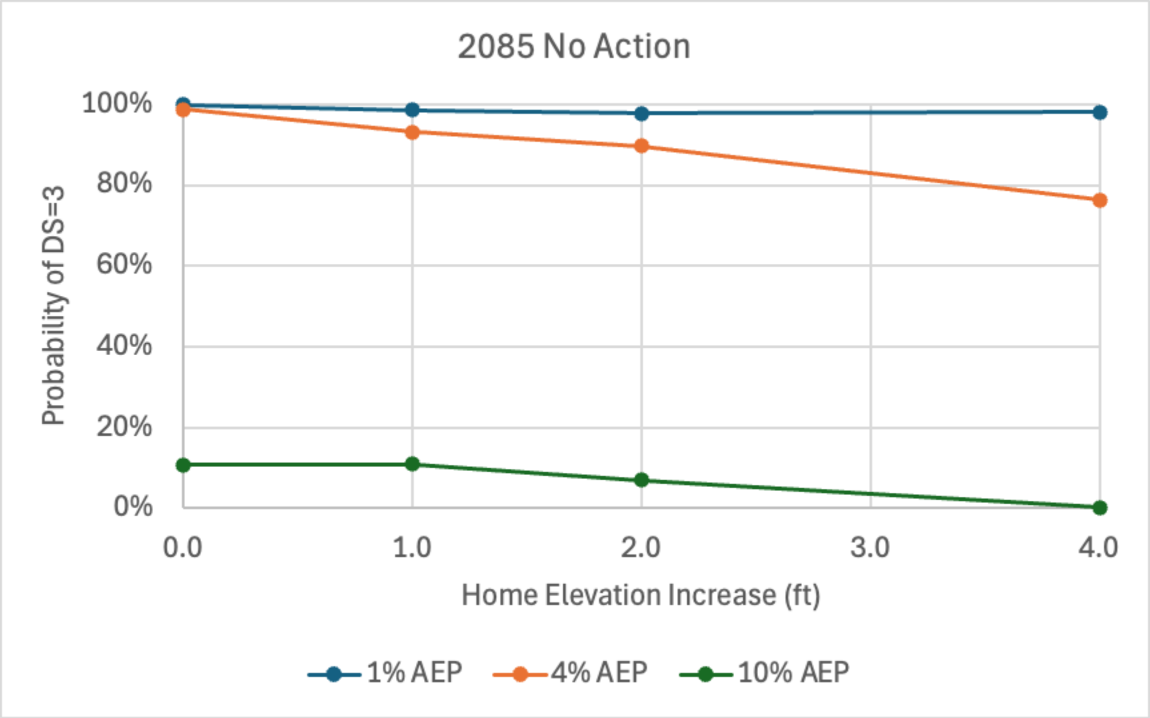


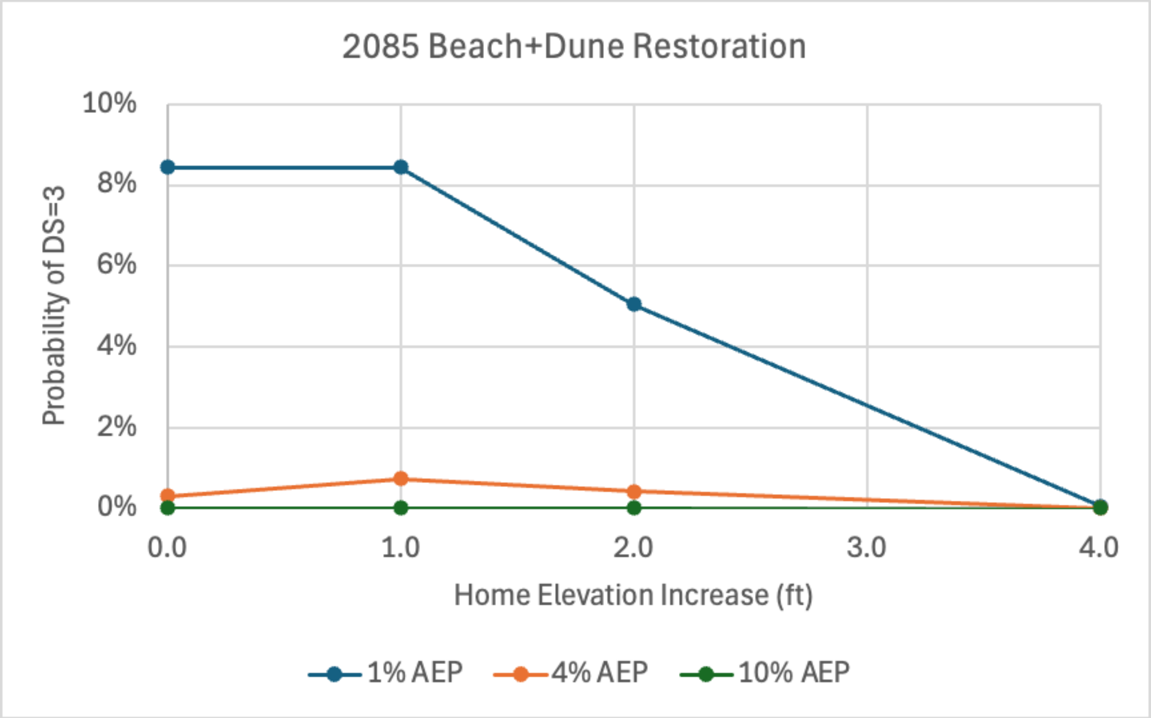
Results/Findings: Elevate Homes - P(f)



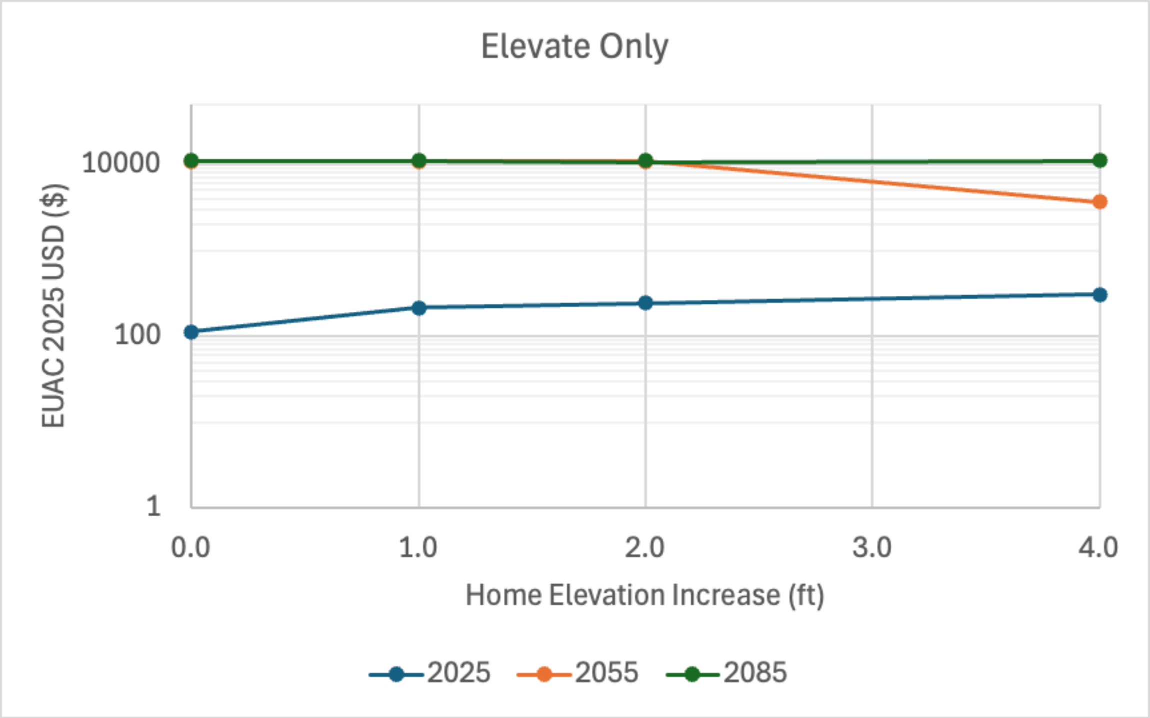


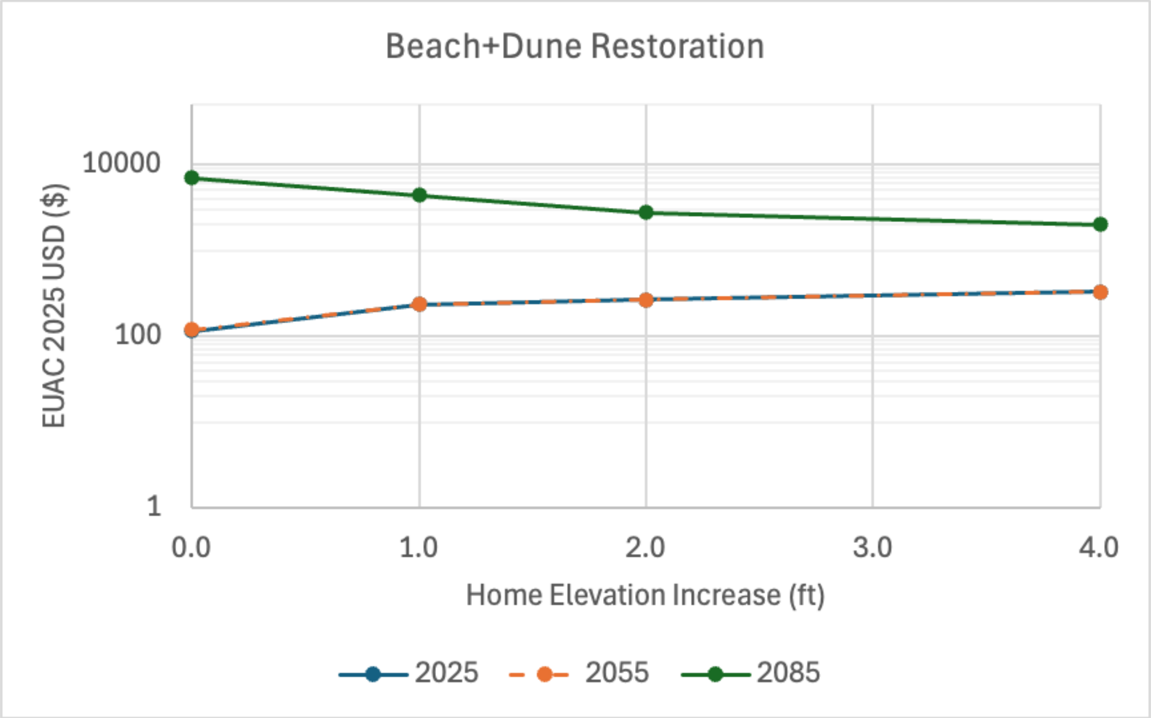
Results/Findings: Elevate Homes - P(f)





Results/Findings: Elevate Homes - $



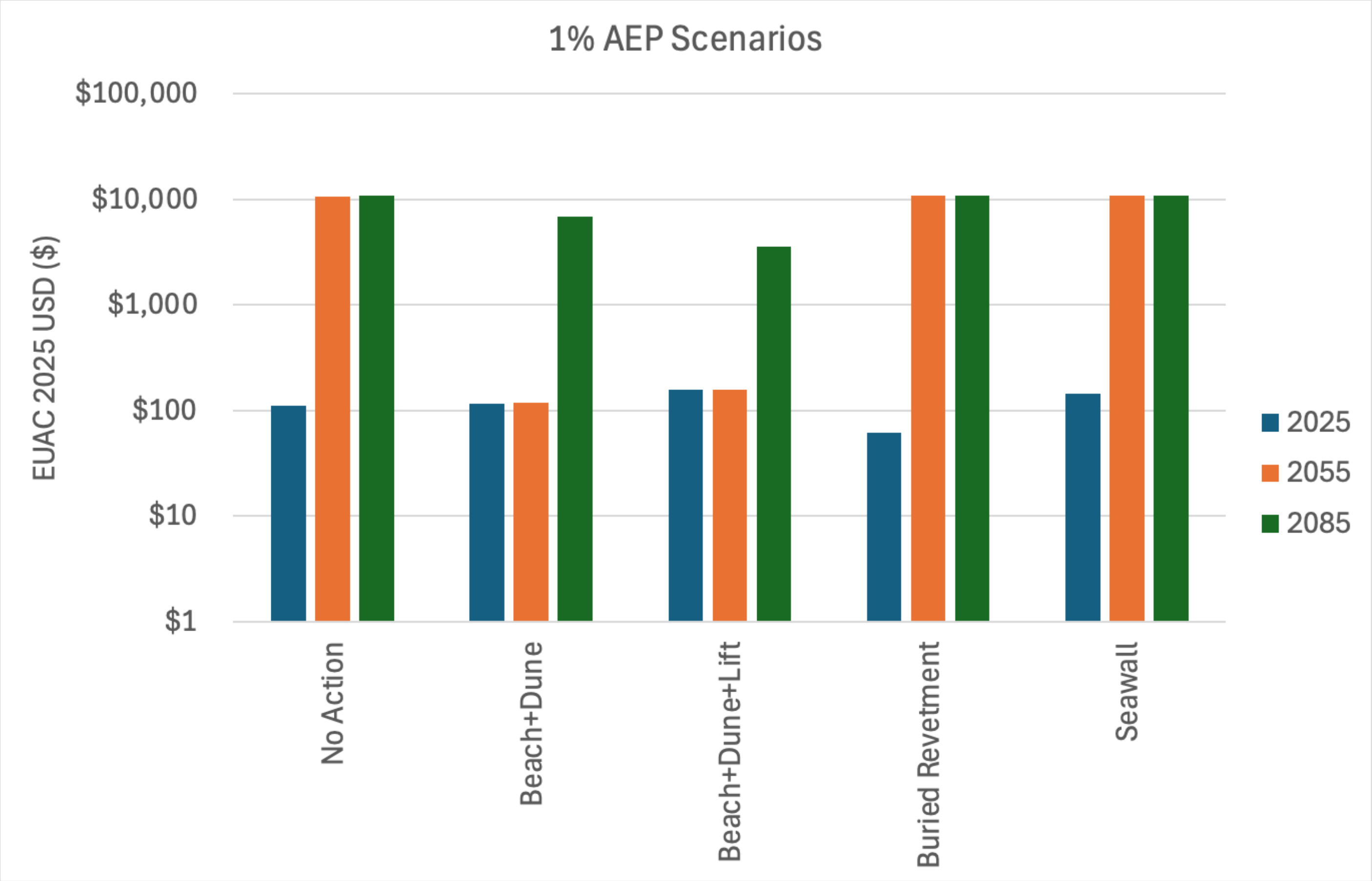


Results/Findings: Adaptation Costs

$$EUAC\ of\ First\ Cost = P(i)\frac{(1+i)^N}{(1+i)^N - 1}$$

- P: cost of adaptation
- i: avg CPI (3.7%)
- N: time (30 yrs, 60 yrs)

Total EUAC = First Cost + Damage ($) x Scenario Probability



Results/Findings: EUAC Ratios

1% AEP		2055 Conditions
		do nothing
2025 Conditions	do nothing	95.7
	beach+dune	92.5
	beach+dune+lift	68.4
	buried revetment	173.9
	seawall	73.8

1% AEP / Raised +4 ft		2055 Conditions				
		do nothing	beach+dune	beach+dune+lift	buried revetment	seawall
2025 Conditions	do nothing	11.8	1.1	1.2	11.1	36.2
	beach+dune	11.1	1.0	1.1	10.4	33.9
	beach+dune+lift	9.8	0.9	1.0	9.2	30.1
	buried revetment	13.3	1.2	1.4	12.4	40.6
	seawall	10.2	0.9	1.0	9.5	31.1

Next Steps

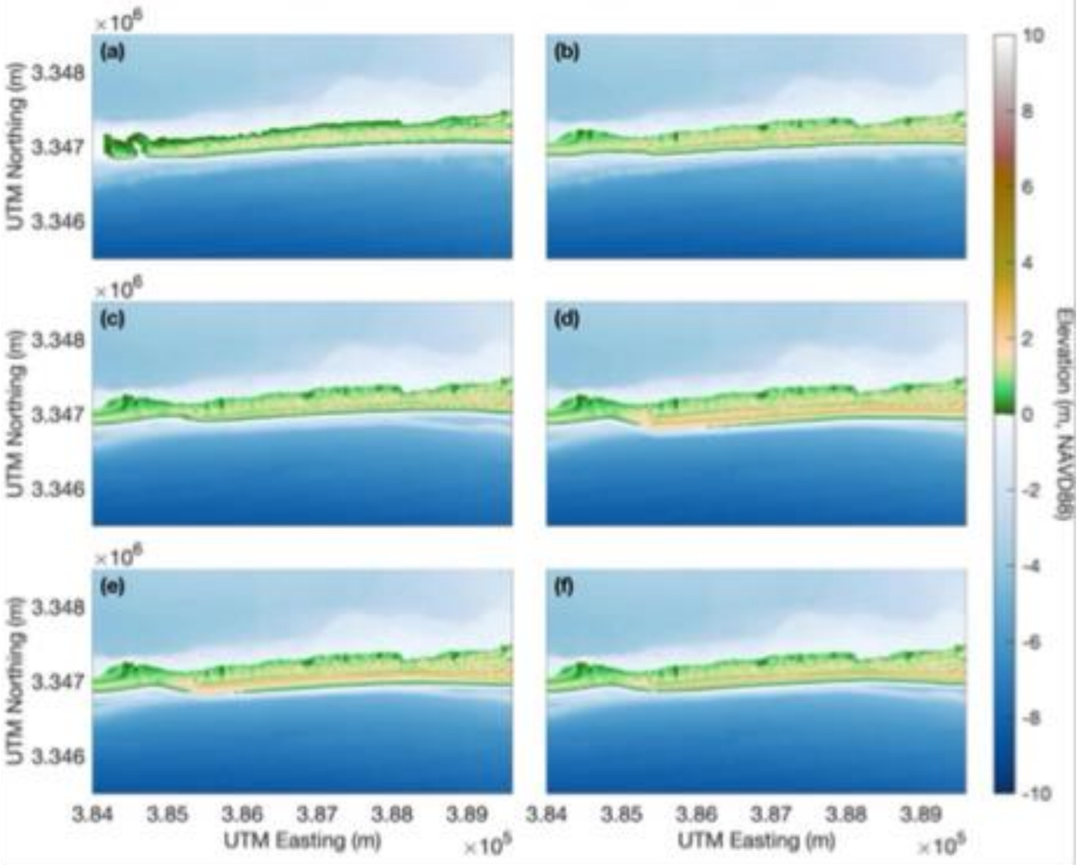
Next Steps

1. Complete residential building vulnerability assessment
2. Reassess residential building vulnerability with resilient adaptations (in 2D)
3. Perform economic analysis
4. Finalize videos/tutorials for coastal data integration into IN-CORE

https://www.expedia.com/Dauphin-Island.dx182896

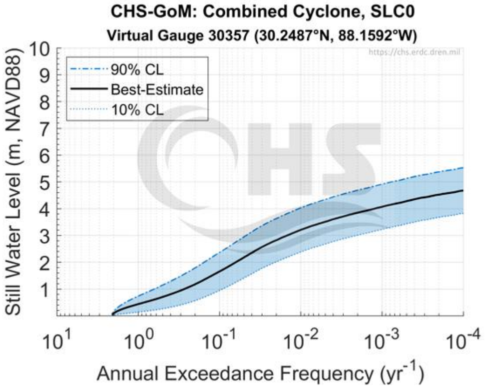
Sneak Peek – 2D Modeling

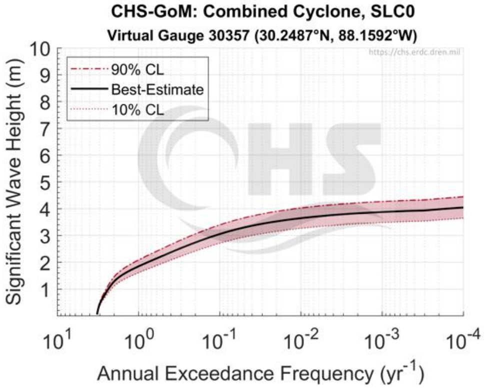
1. **2D XBeach Simulations**
   - Resilient Adaptations
   - AEP and SLR
2. Existing + Future AEP Conditions
   - Baseline and Future
3. Preliminary Assessments

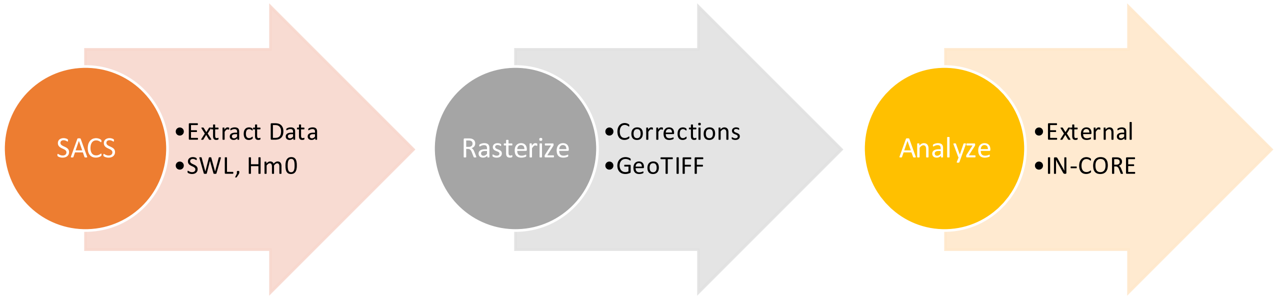


Sneak Peek – 2D Modeling

1. 2D XBeach Simulations
   - Resilient Adaptations
   - AEP and SLR
2. **Existing + Future AEP Conditions**
   - 0.2% AEP / SLR1 / SLR2
3. Preliminary Assessments





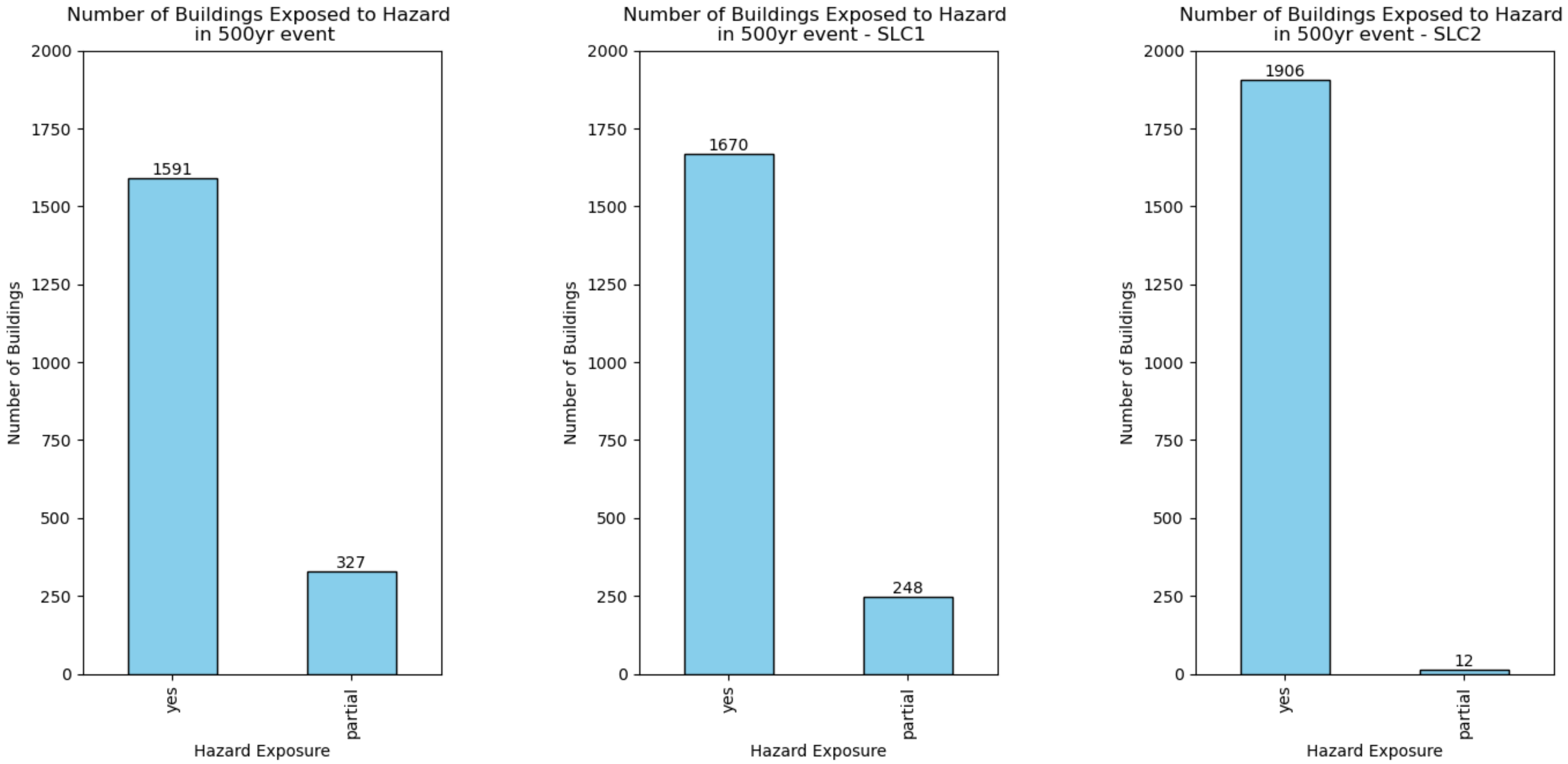


Sneak Peek – 2D Modeling

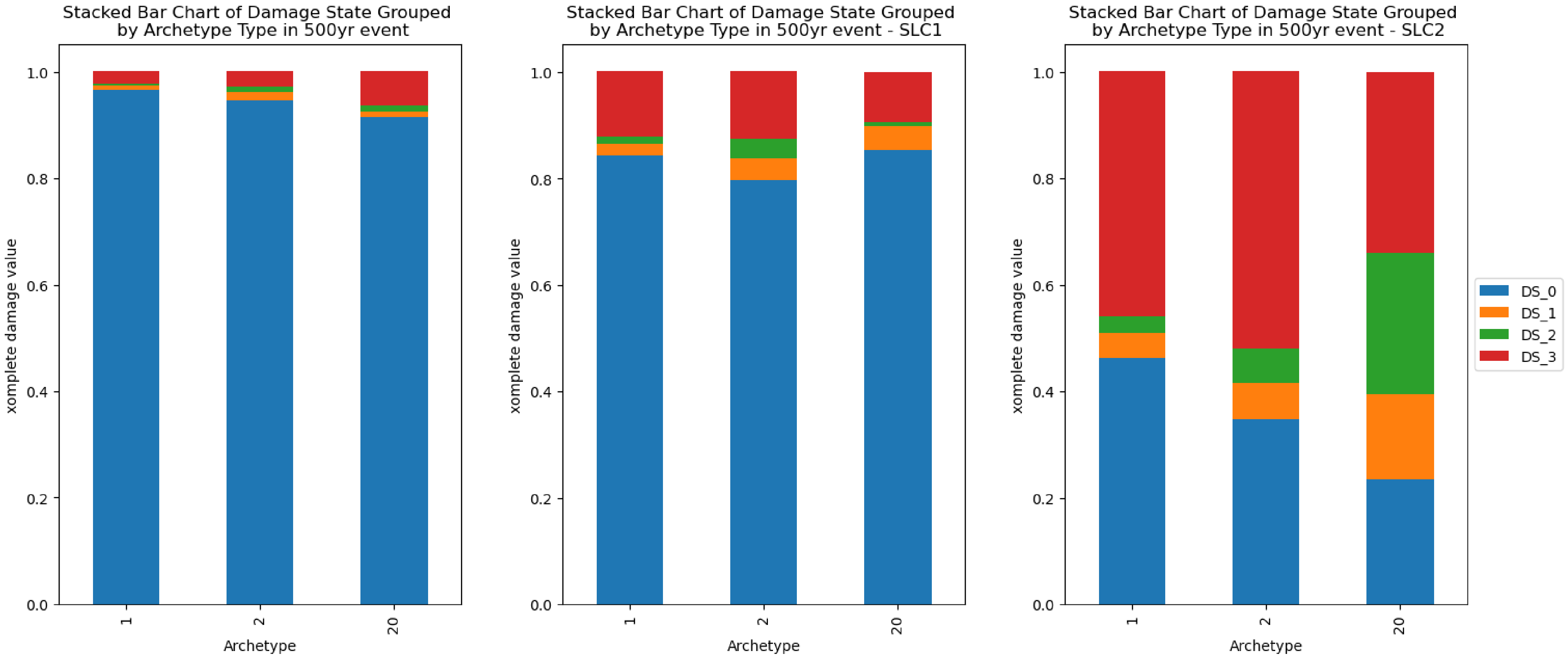
1,910 buildings of archetype 1, 2, 20

3. Preliminary Assessments

Sneak Peek – 2D Modeling



Sneak Peek – 2D Modeling



Sneak Peek – 2D Modeling

0.2% AEP

$28M

+0.83 m SLR

$94M

+2.24 m SLR

$322M

Please contact me if you are interested in our work or would like to be contacted with updates.

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