Assessing Extreme Events and Climate Change in the Coastal Environment:

New Technical Guidance from the FHWA

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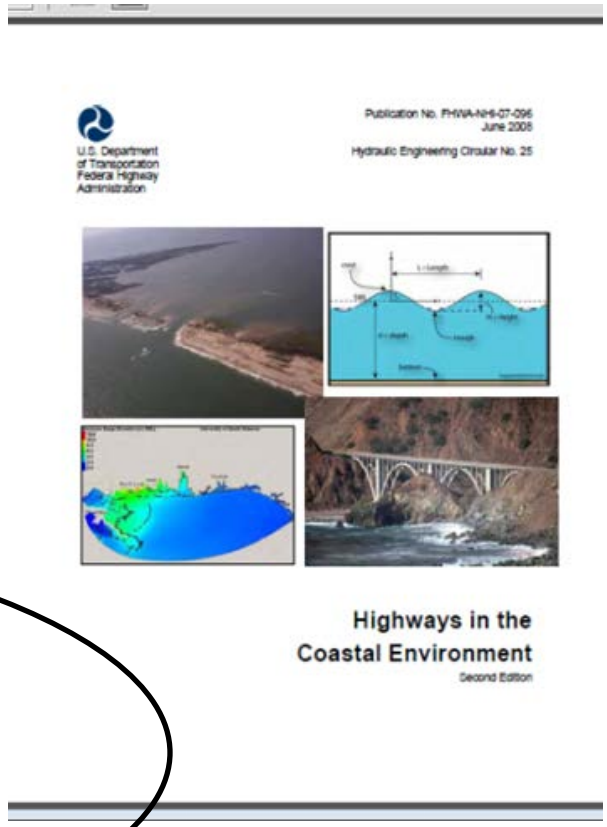
U.S. Department of Transportation
Federal Highway Administration

Need for HEC 25 Volume 2

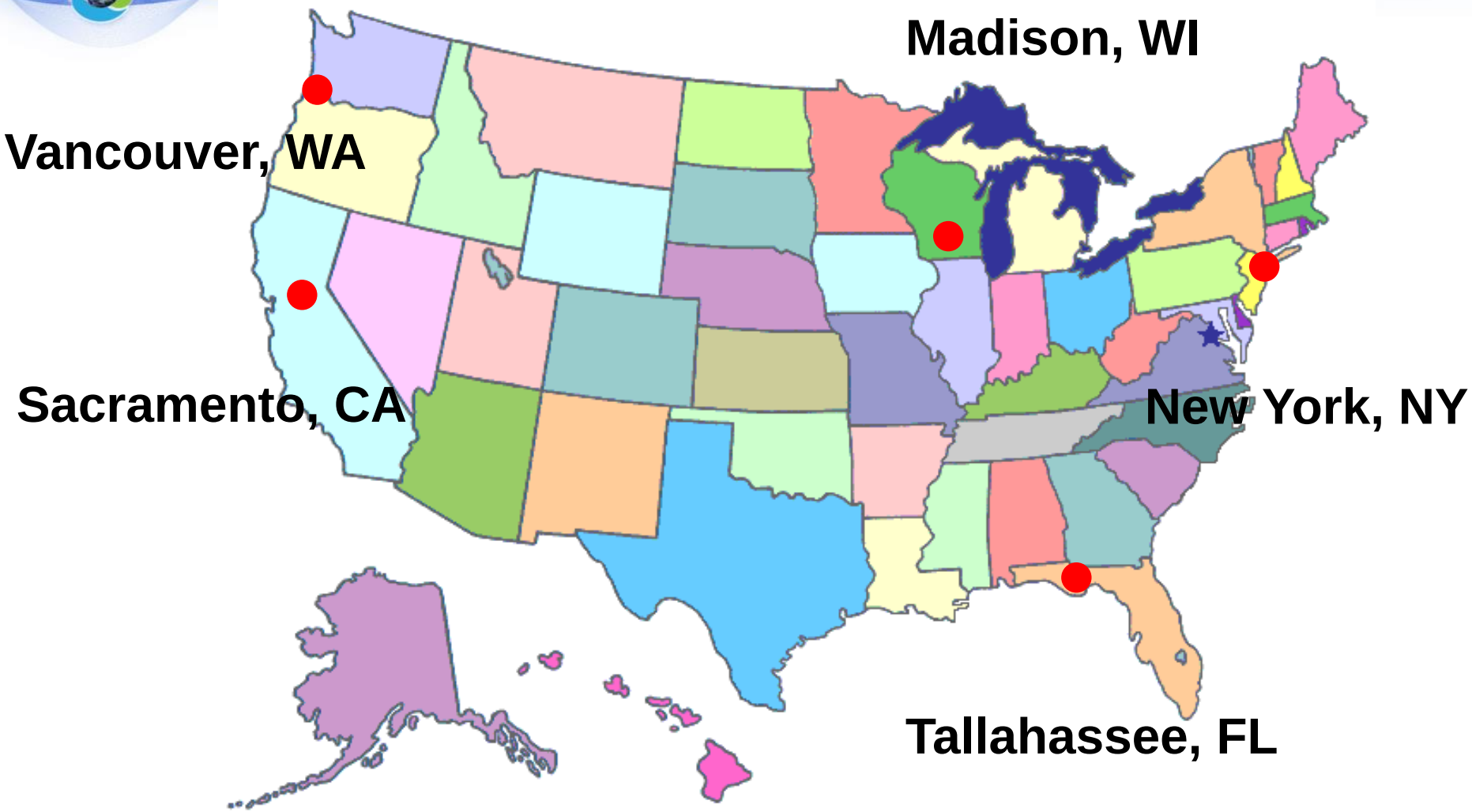
- **60,000 miles of coastal roads and 36,000 bridges near the coast**
- **Coastal environment is dynamic with extreme events and climate change**
- **HEC 25 provides an overview of coastal issues, but not detailed guidance on assessing vulnerability**



Objectives for HEC 25 Volume 2

- **Provide technical guidance and methods for incorporating extreme events and climate change for highway planning and design in coastal environments**
- **Focus on issues related to:**
  - Sea level rise
  - Storm surge
  - Wave action

Regional Peer Exchanges



Participants

- 19 Coastal engineers or modelers
- 4 Civil engineers
- 6 Climate scientists
- 11 state and local transportation members
- 15 FHWA members
- 3 KCM/SCE members

Manual Table of Contents

Glossary

1. Introduction
2. Identification of relevant coastal processes and climate change impacts
3. Risk, vulnerability and adaptation
4. Analysis methods for assessing extreme events and climate change
5. Case studies of exposure & vulnerability assessment

Introduction: Purpose of Manual

- **Provide technical guidance and methods for assessing the vulnerability of coastal transportation facilities to extreme events and climate change**
- **Uses:**
  - Risk and vulnerability assessments
  - Planning activities
  - Design procedure guidance

Introduction: Target Audience

- Transportation engineers
- Transportation planners
- Coastal engineers

- Tool for identifying the key regional coastal processes, incorporating the impacts of climate change, and using that information to evaluate risk and vulnerability

Regional Coastal Processes: Mid-Atlantic and New England

- Storm surge and waves due to tropical and extratropical (e.g., northeaster) storms
- Effect of tide on coastal flood levels particularly as it relates to the phasing of the storm surge and fluvial discharge
- Episodic storm-induced shoreline change
- Watershed contributions of precipitation and r bodies

Example of regional discussions in new manual

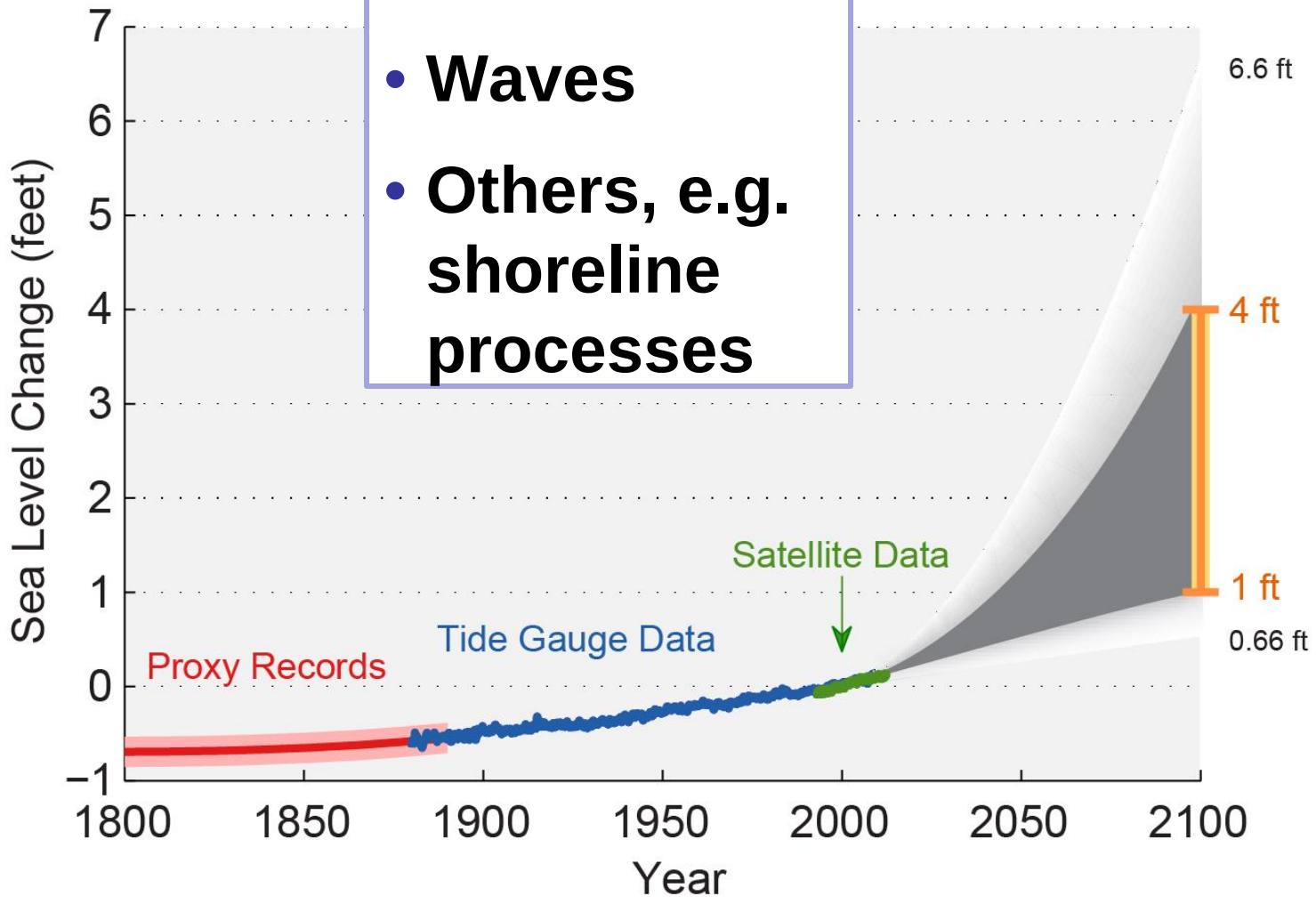
Damaging Coastal Processes

- **The first step for all levels of analysis in all regions is to identify the damaging coastal processes of interest.**

Region	Damaging Coastal Processes
Gulf of Mexico/South Atlantic	Storm surge, waves
Mid-Atlantic/New England	Storm surge, waves, tides, runoff
Great Lakes	Storm surge, waves, bluff erosion
Pacific Coast (Storms)	Water levels, wave runup, erosion
Pacific Coast (Tsunamis)	Flood depth, velocity, runup

Relevant Coastal Processes: Climate Change Impacts

- **Sea levels**
- **Waves**
- **Others, e.g. shoreline processes**



Sea Level Rise Projections:

- **New manual will include an example of how to estimate projected sea levels**
  - Site-specific example
  - Will demonstrate how to incorporate existing relative sea level changes (including subsidence/uplift) into future projections
- **New (June 30, 2014) US Army Corps of Engineers guidance on "Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptations" will be cited**

Risk, Vulnerability and Adaptation

- **Engineering risk at the coast**
- **Coastal vulnerability assessments**
- **Climate change and extreme events: damage mechanisms**
- **Adaptation/countermeasure strategies for coastal highway infrastructure**

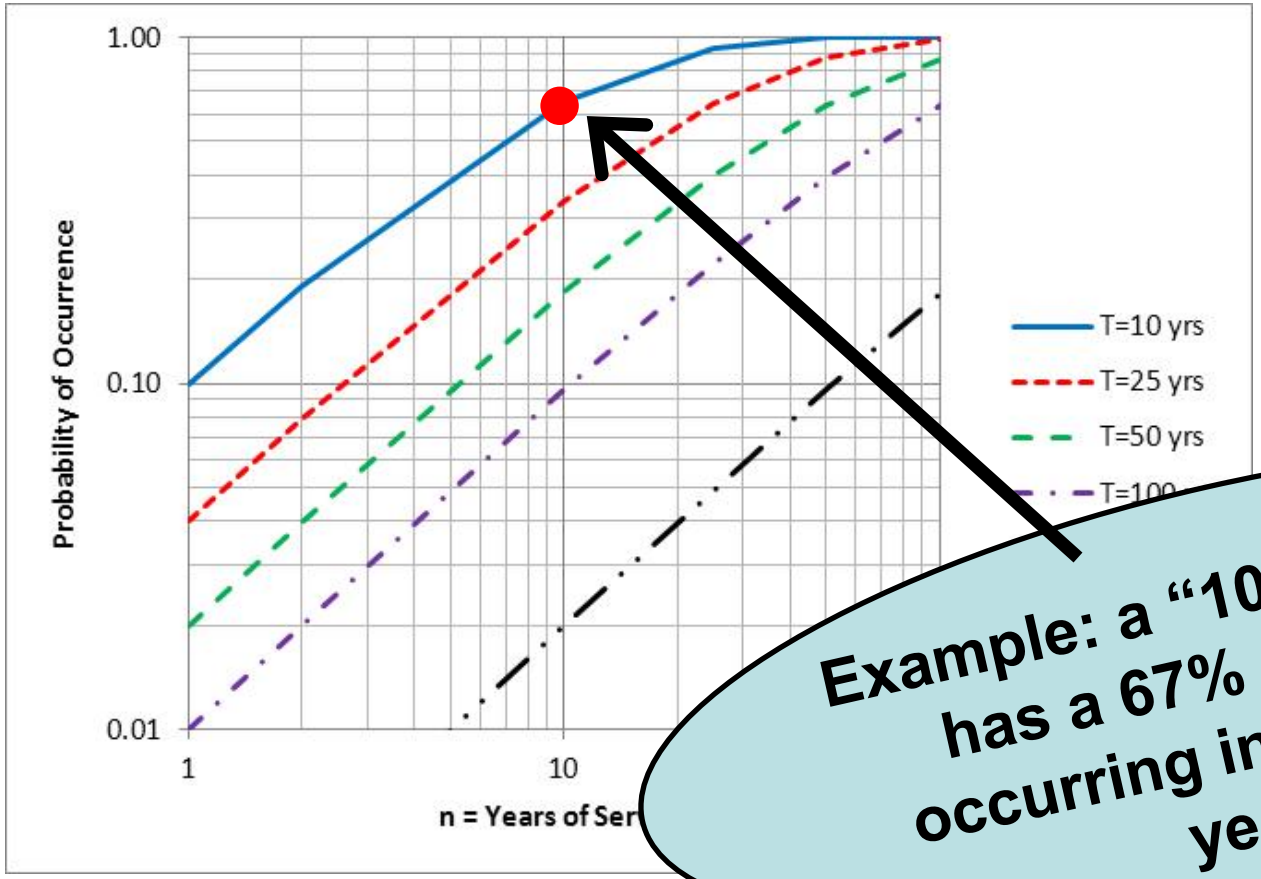
Vulnerability = *f* (Exposure, Sensitivity, Adaptive Capacity)

Focus of HEC 25 Volume 2 is "Exposure"

- **Risk = f (exposure, sensitivity)**
  - Exposure is characterized by the magnitude and probability of occurrence of a hazard
  - Sensitivity describes the resulting damage or consequence
- **Vulnerability = f (exposure, sensitivity, adaptive capacity)**
  - Vulnerability adds the concept of adaptive capacity, that is, the ability to adjust to or moderate damage

Exposure Probability

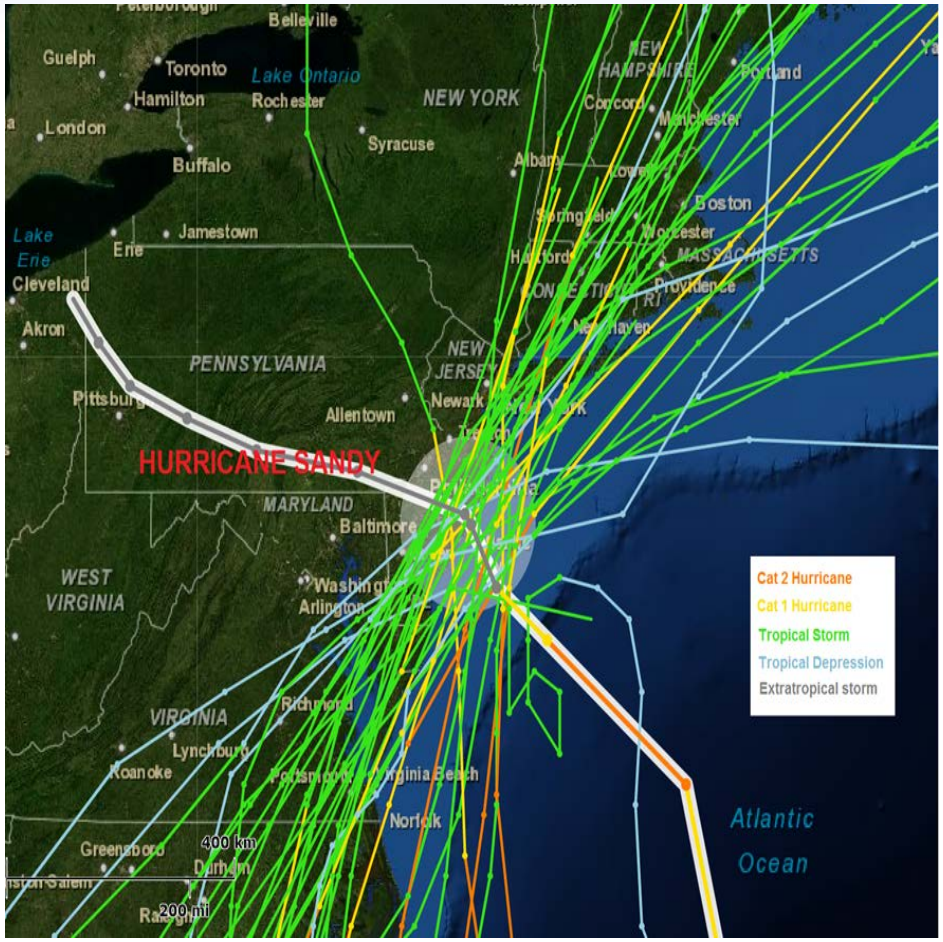
- **Probability that an event of a given return period, T, will occur at least once during the service life of the asset, n.**



Example: a "10-year storm" has a 67% chance of occurring in the next 10 years!

Coastal Storm Flood Frequencies

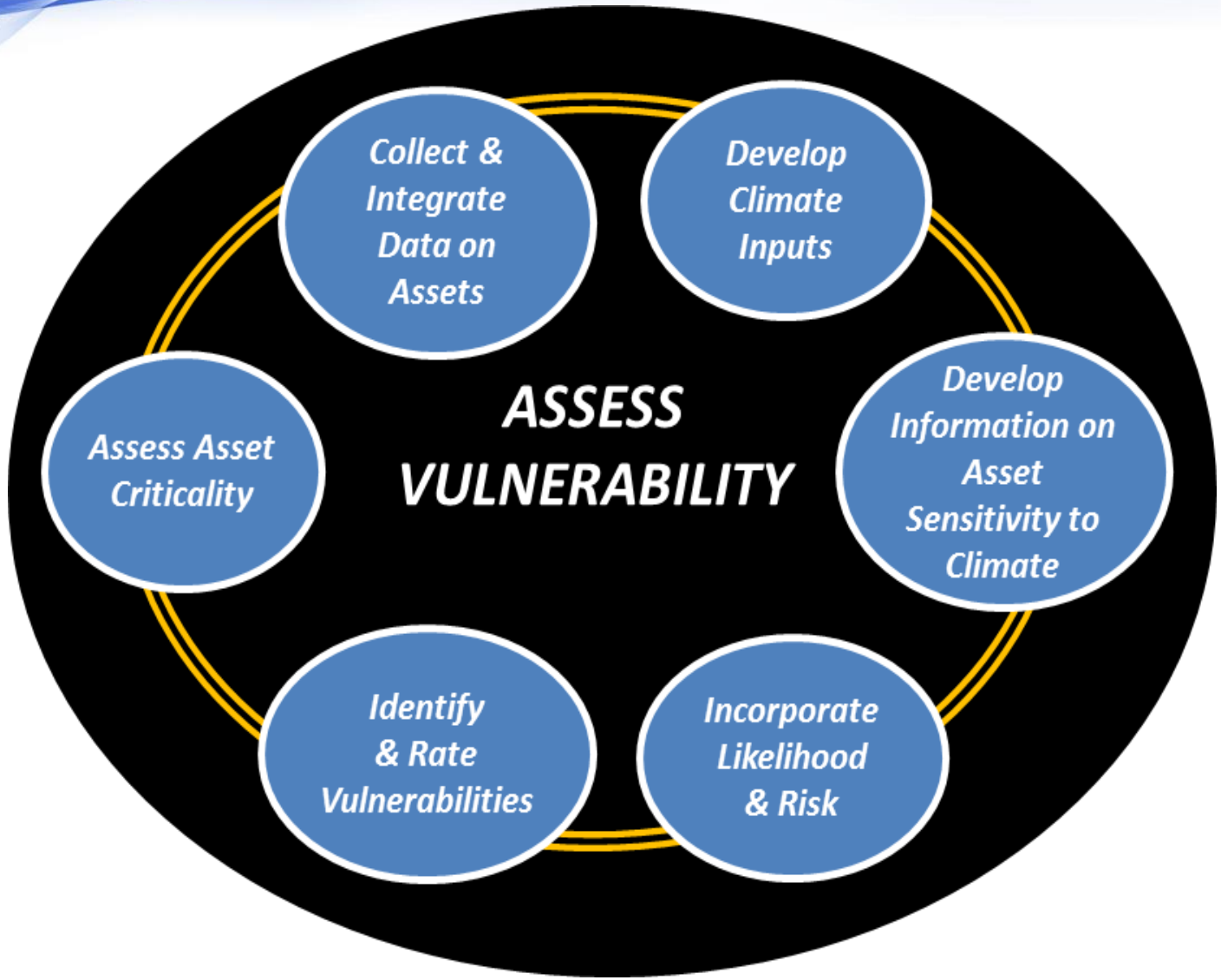
- **Multiple model runs with variations in input parameters**
  - Storm surge
  - Waves
- **Historical analysis**
- **Joint probability method**
- **Total water level**



Coastal Vulnerability Assessments

- **Mapping overlay (bathtub) approach**
- **Site-specific modeling**
  - non-linear relationship between sea-level rise and storm surge depths
- **Vulnerability Assessment Framework**
  1. Define scope
  2. Assess vulnerability
  3. Integrate into decision making

Assess Vulnerability



Climate Change and Extreme Events: Damage Mechanisms

- **Roadway damage due to wave attack**
- **Roadway and railway damage due to coastal “weir-flow”**
- **Roadway damage by bluff erosion and shoreline recession**
- **Bridge deck damage by waves on surge**
- **Structure damage by wave runup**
- **Tunnel and road damage by overtopping**
- **Damage by tsunamis.**

Adaptation/Countermeasure Strategies for Coastal Highway Infrastructure

- **Manage and maintain**
- **Increase redundancy**
- **Protect**
- **Accommodate**
- **Relocate**

Analysis Methods: “Levels of Effort”

- **General Level of Effort 1: Use of existing data and resources**
- **General Level of Effort 2: Modeling of storm surge and waves**
- **General Level of Effort 3: Modeling in a probabilistic risk framework**

Analysis Methods: “Levels of Effort”

- **Specific analysis steps are outlined,**
  - **for each region,**
    - Mid-Atlantic and New England Coast
    - Gulf of Mexico/South Atlantic Coast
    - Great Lakes Coast
    - Pacific Coast
      - »Storms
      - »tsunamis
  - **for each “Level of Effort”**

Analysis Methods: Example of steps

Table 4.5. Exposure Assessment Steps for Level of Effort 2: Mid-Atlantic/New England Coast.

Step	Activity
1	Identify damaging coastal processes of interest (e.g. storm surge, waves, tides, runoff, etc.)
2	Select and characterize storm and climate change scenarios of interest
3	Select, develop, and prepare appropriate numerical modeling tools
4	Validate and/or calibrate the models through hindcast simulations and analysis
5	Incorporate climate change scenarios into numeri simulations
6	Perform model simulations o change scenarios
7	Map the damaging
8	Evaluate exposur infrastructure for e

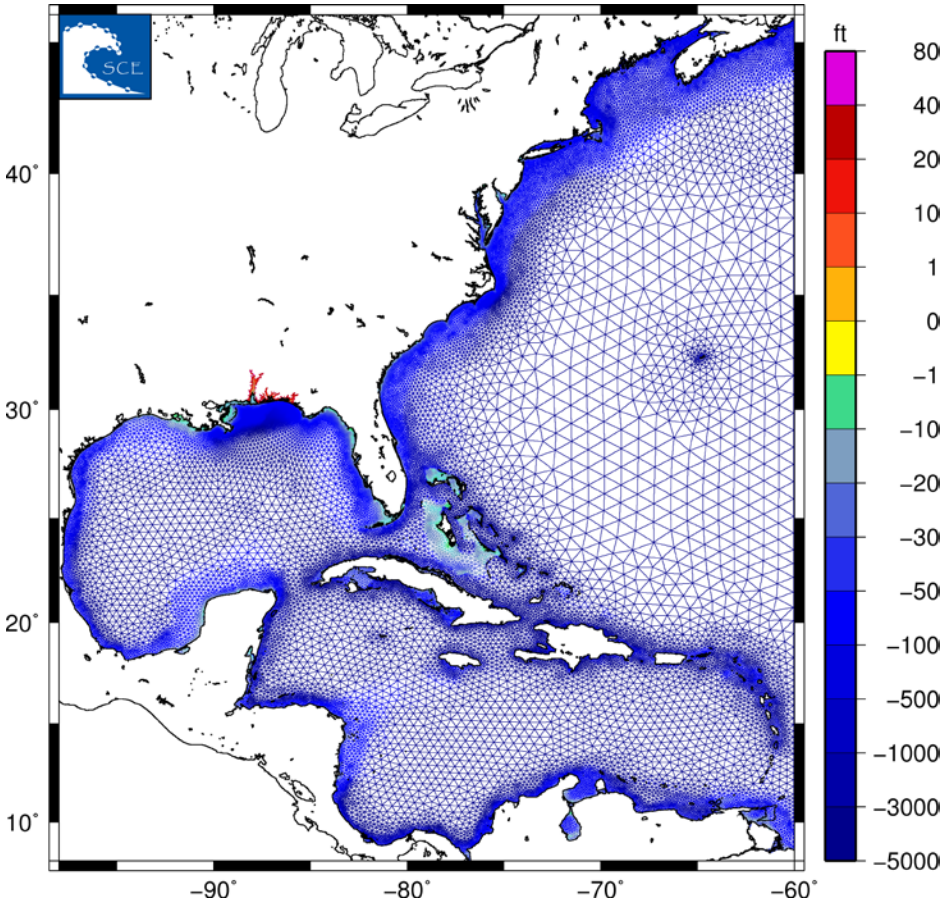
Example of Recommended Steps for Assessing Exposure

Analysis Methods:

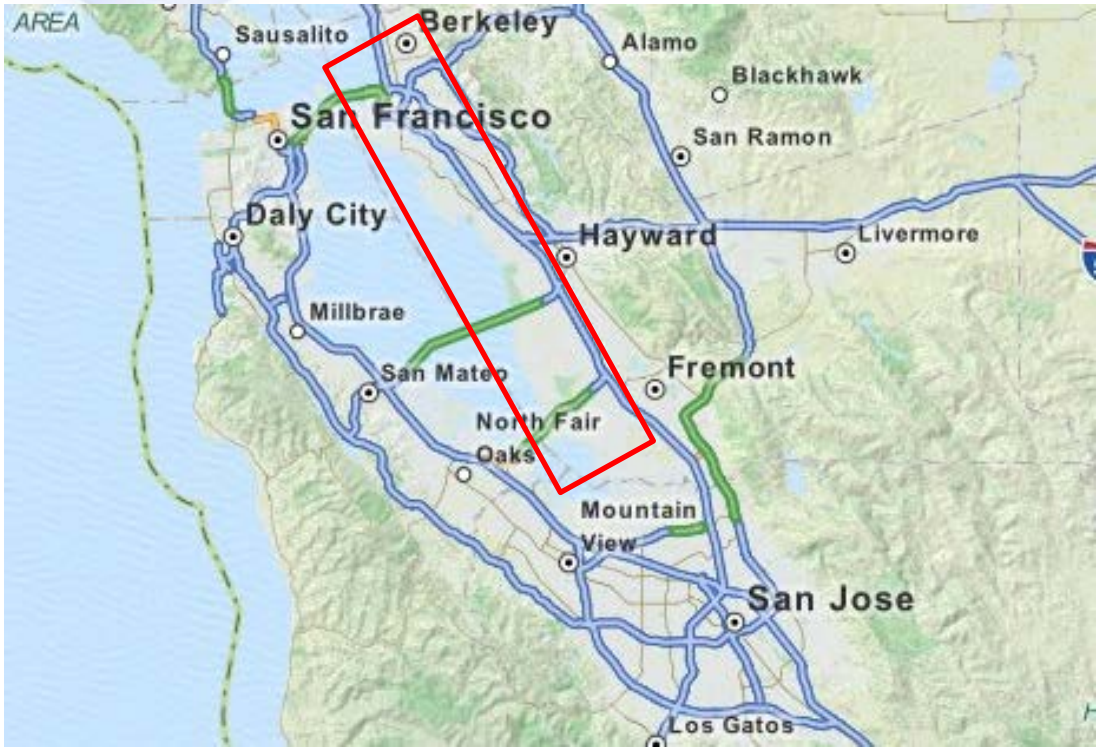
- Damaging coastal processes vary by region
- Great Lakes region focuses on lake rather than sea levels
- Sea/lake levels may be forecast to decrease rather than increase
- FEMA products differ between the Atlantic/Gulf coasts and the Pacific coast
- For a Level 1 analysis, the water levels and waves are determined by a series of simplified calculations
- Level 3 generates probabilities not included in level 2 or level 1 analyses

Case Studies:

- From existing literature
- 3 Case Studies: One for each “Level of Effort”
- Each case study had a coastal engineer on the team

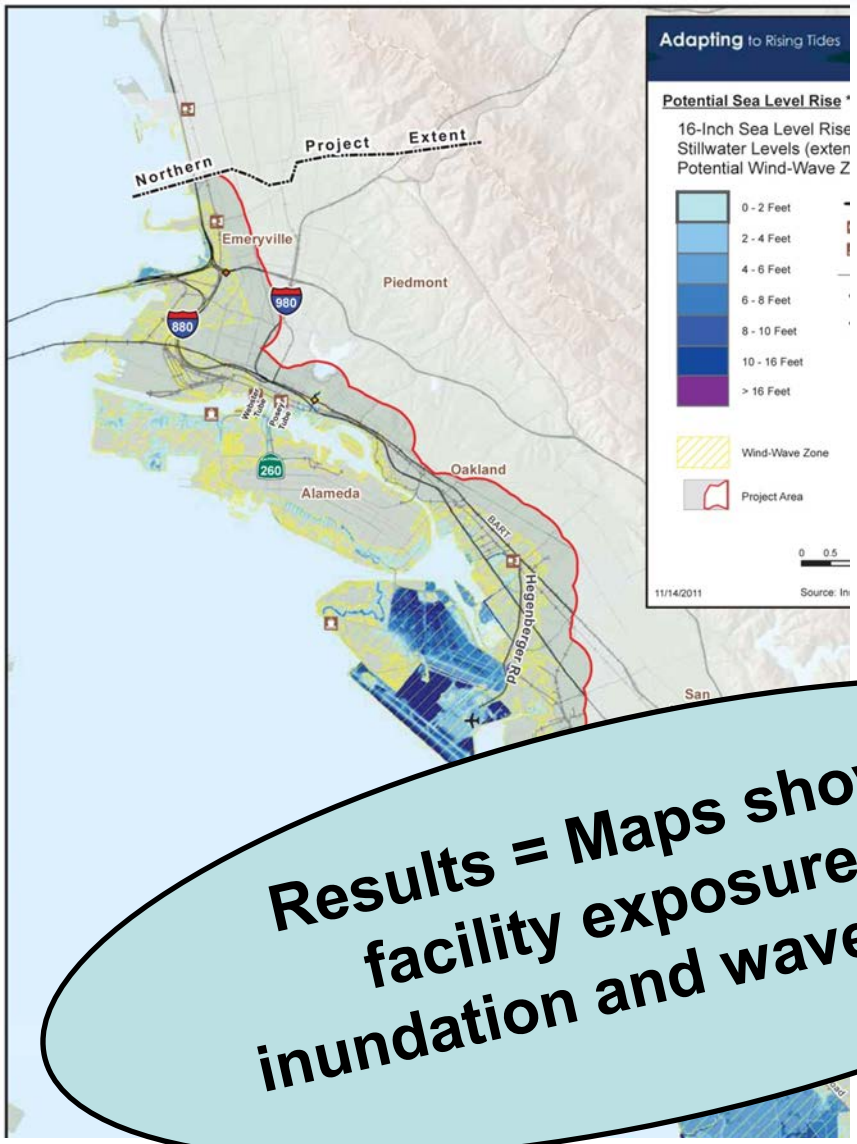


Case Study (Level 1): Adapting to Rising Tides – SF Bay



- **Purpose: Provide input to a vulnerability rating of transportation assets**
- **Modified, basic inundation mapping**
- **FHWA sponsored pilot study**

Case Study (Level 1): Adapting to Rising Tides – SF Bay

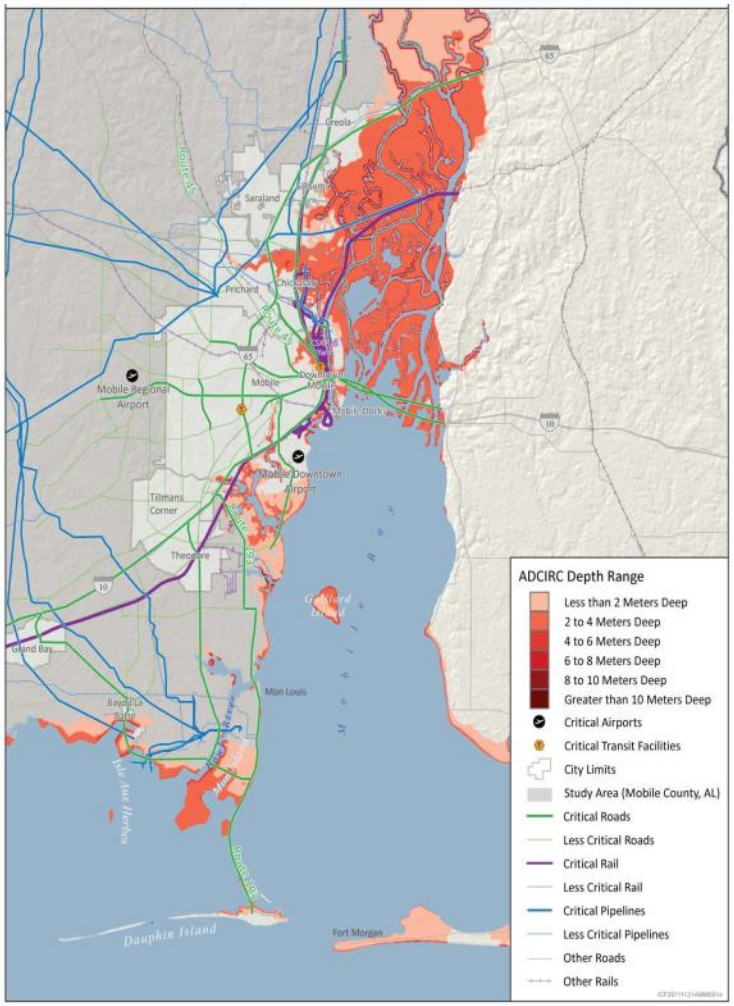


- **Water surface elevation from 100-yr flood plus 16-in sea level rise**
- **Wind wave zone identified**
- **Airport, commuter rail, ferry terminal, roads, mp stations ed**

Results = Maps showing facility exposure to inundation and wave action

Case Study (Level 2): Gulf Coast 2 – Mobile, Alabama

- **Purpose: Assess vulnerability of road, bridge, tunnel, railway, port, and airport facilities**
- **Scenario-based**
- **Storm surge and wave modeling**

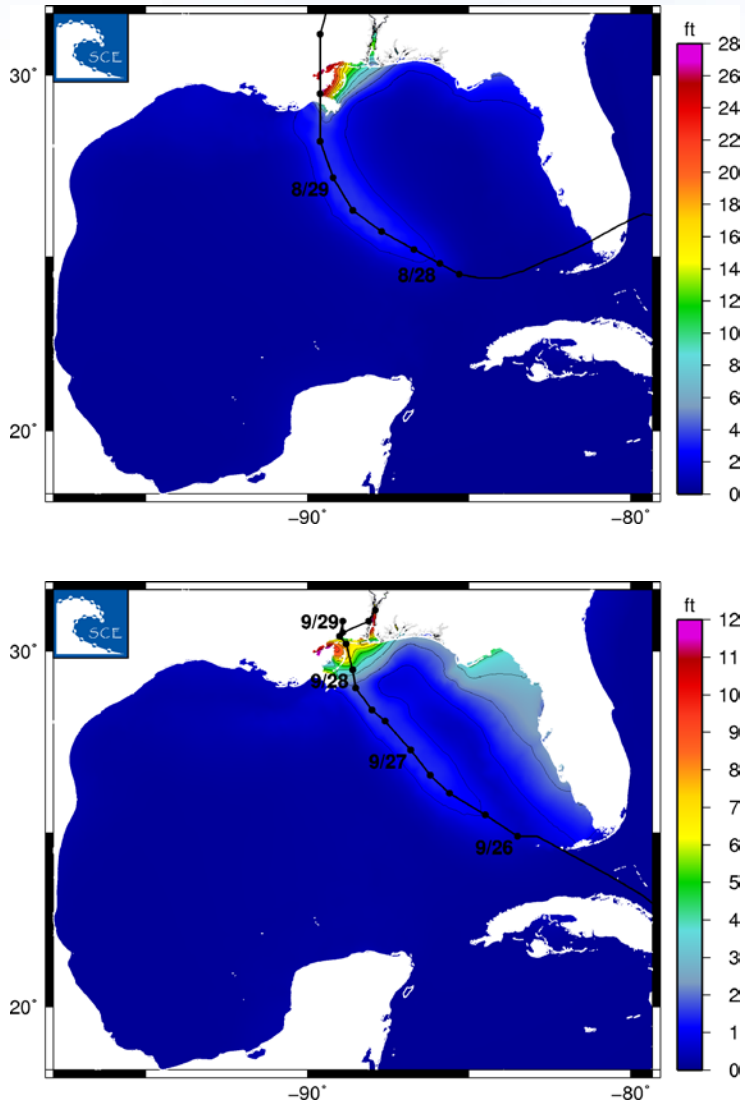


Case Study (Level 2): Gulf Coast - Scenarios

- **Model Impacts of RSLR**
  - 0.30 m by 2050
  - 0.75 m by 2100
  - 2.00 m by 2100
- **Historical Storms**
  - Katrina
  - Katrina shifted
  - Georges

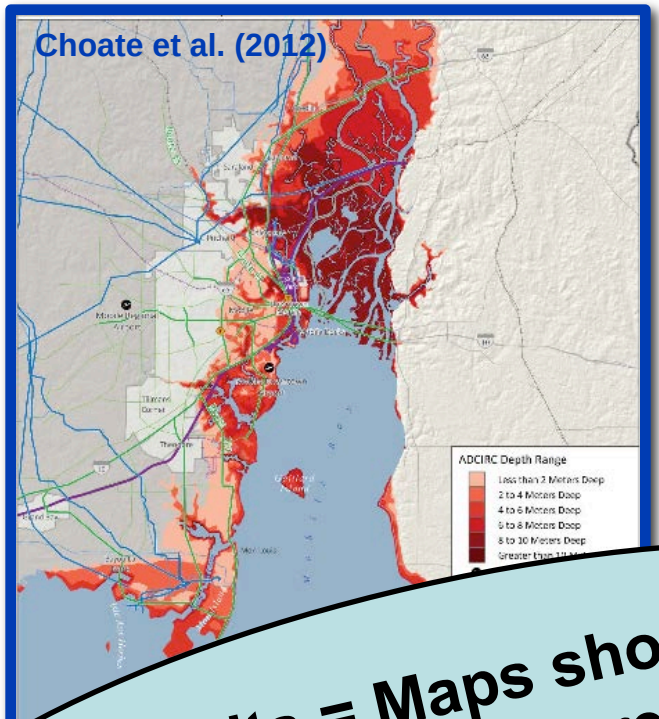
Case Study (Level 2): Gulf Coast 2: Methods

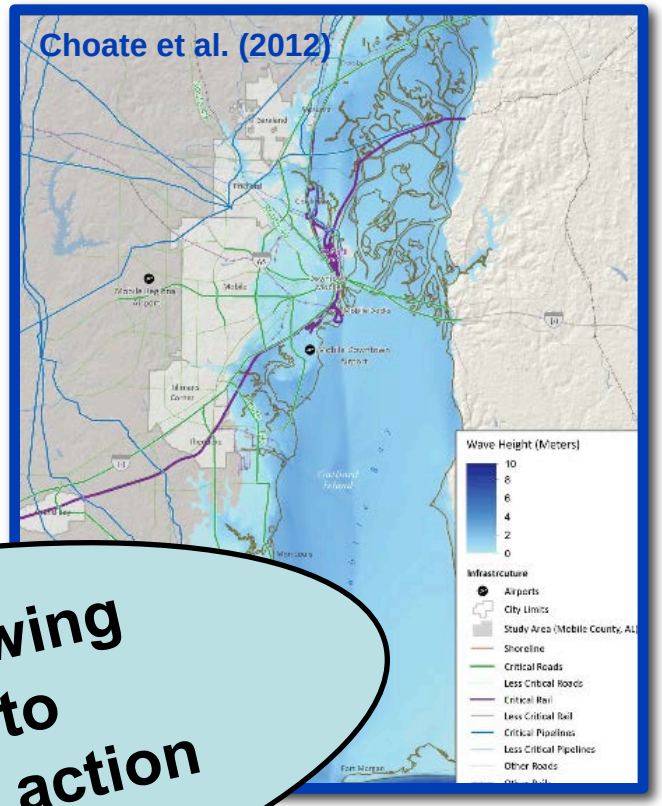
- **Storm Surge: ADCIRC**
  - Historical storms
  - Increased water level
  - Modified tracks/ winds/pressures
- **Waves: STWAVE**
  - RSLR + MEOW
  - Maximum winds



Case Study (Level 2): Gulf Coast 2: Results

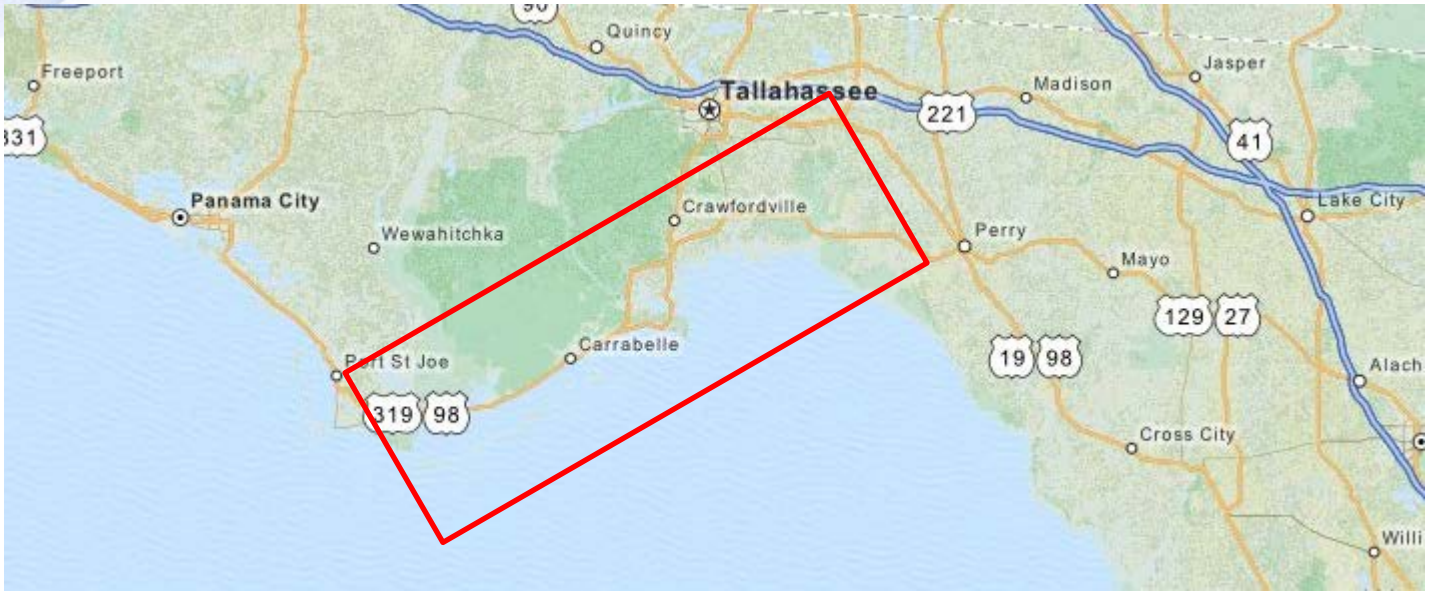
- **Storm Surge**
- **Waves**





Results = Maps showing facility exposure to inundation and wave action

Case Study (Level 3): Synthetic Storm Analysis - Florida

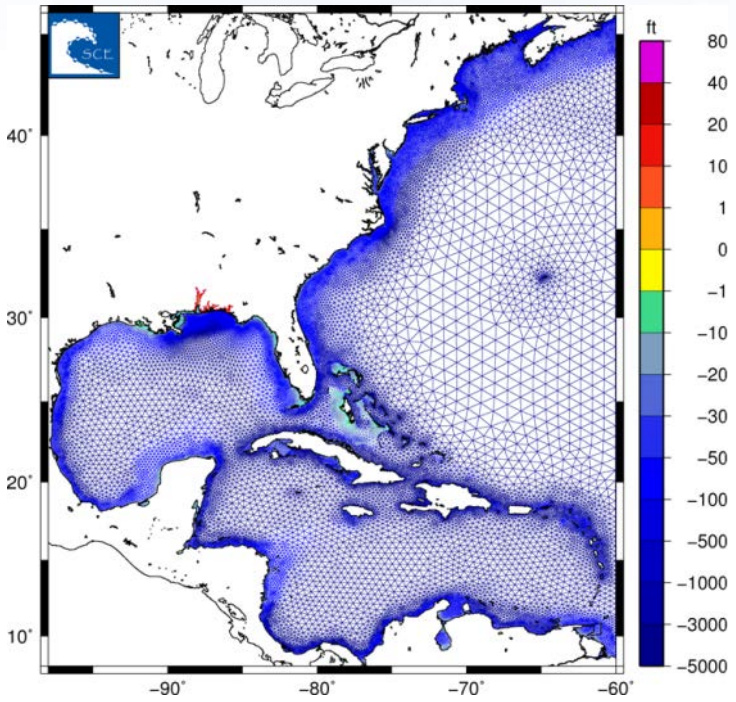


- **Purpose: Magnitude and characteristics of storms and sea level rise**
- **Scenario/probability based**
- **Storm surge and wave modeling**

Summary: HEC-25- Volume 2

- **Provide technical guidance and methods for incorporating extreme events and climate change for highway planning and design in coastal environments**
- **Regional Approach**
- **Sea Level Rise Guidance**
- **Methods: 3 “Levels of Effort”**
- **Case Studies**

HEC 25 - VOLUME 2



Questions or Suggestions?

Technical Development Team

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- **KCM/SCE**
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