U.S. Department of Transportation
Federal Highway Administration

Office of Planning, Environment and Realty
Office of Infrastructure

Adaptation to Extreme Weather Events and Climate Change

SASHTO Meeting

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August 25, 2014

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Planning for the Future…

- What we know:
  - Future will not be like the present
  - Present is not like the past
  - Transportation infrastructure is sensitive to extreme weather & climate change
- What we don't know:
  - Exactly when or how much
- Approach:
  - FHWA funds can be used for adaptation activities
  - Research and Technical Assistance: information, tools that State DOTs and MPOs can use to assess risk and improve resilience
  - GROW AMERICA would add consideration of resilience, adaptation

"U.S. average temperature has increased by 1.3°F to 1.9°F since 1895, and most of this increase has occurred since 1970." – NCA

"Temperatures are projected to rise another 2°F to 4°F in most areas of the United States over [just] the next few decades." – NCA

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Climate Change Adaptation at FHWA

Goal: Regular/Systematic consideration of climate change vulnerability and risk in transportation decision making, at:

- 1) **Systems Level**: Transportation Planning, Asset Management
- 2) **Project Level**: Environmental process, Preliminary Engineering, Design, Construction, Operations, Maintenance

Systems Level Goal: Consideration in Transportation Planning, Asset Management

Key Product:

- Updated *Climate Change & Extreme Weather Vulnerability Assessment Framework* (2015)

Activities:

- Climate Resilience Pilots – round 2
- *Gulf Coast 2 (Mobile)*
- *Hurricane Sandy Follow-up and Vulnerability Assessment & Adaptation Analysis*
- *Central NM Climate Change Scenario Planning Project*

Project Level Goal: Consideration in Environmental Process, Preliminary Engineering, Design, Construction, Operations, Maintenance

Key Products:

- Updated engineering manuals, methods and processes

Activities:

- Engineering Assessments
  - *Gulf Coast 2 (Mobile)*
  - *Hurricane Sandy Follow-up and Vulnerability Assessment & Adaptation Analysis*
  - *Transportation Engineering Approaches to Climate Resiliency*
  - Climate Resilience Pilots
- *HEC 25 - Vol 2: Highways in the Coastal Environment: Extreme Events*
- Hydrology, hydraulic engineering research efforts, etc.

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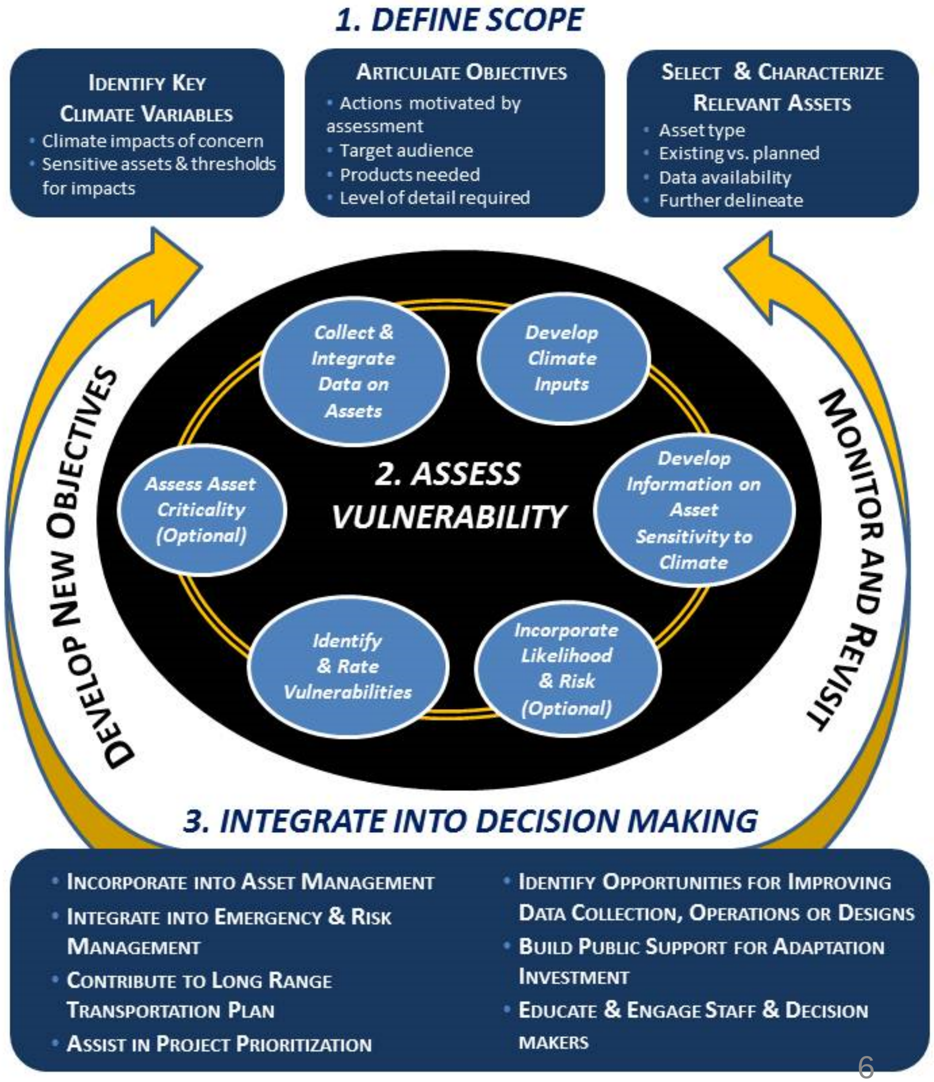
FHWA's *Climate Change & Extreme Weather Vulnerability Assessment Framework* (2012)

1. Define Project Scope
    - Objectives
    - Relevant Assets
    - Climate Variables
2. Assess Vulnerability
    - Climate Inputs
    - Asset data, criticality, sensitivity
    - Vulnerabilities, risk
3. Integrate Vulnerability Into Decision Making



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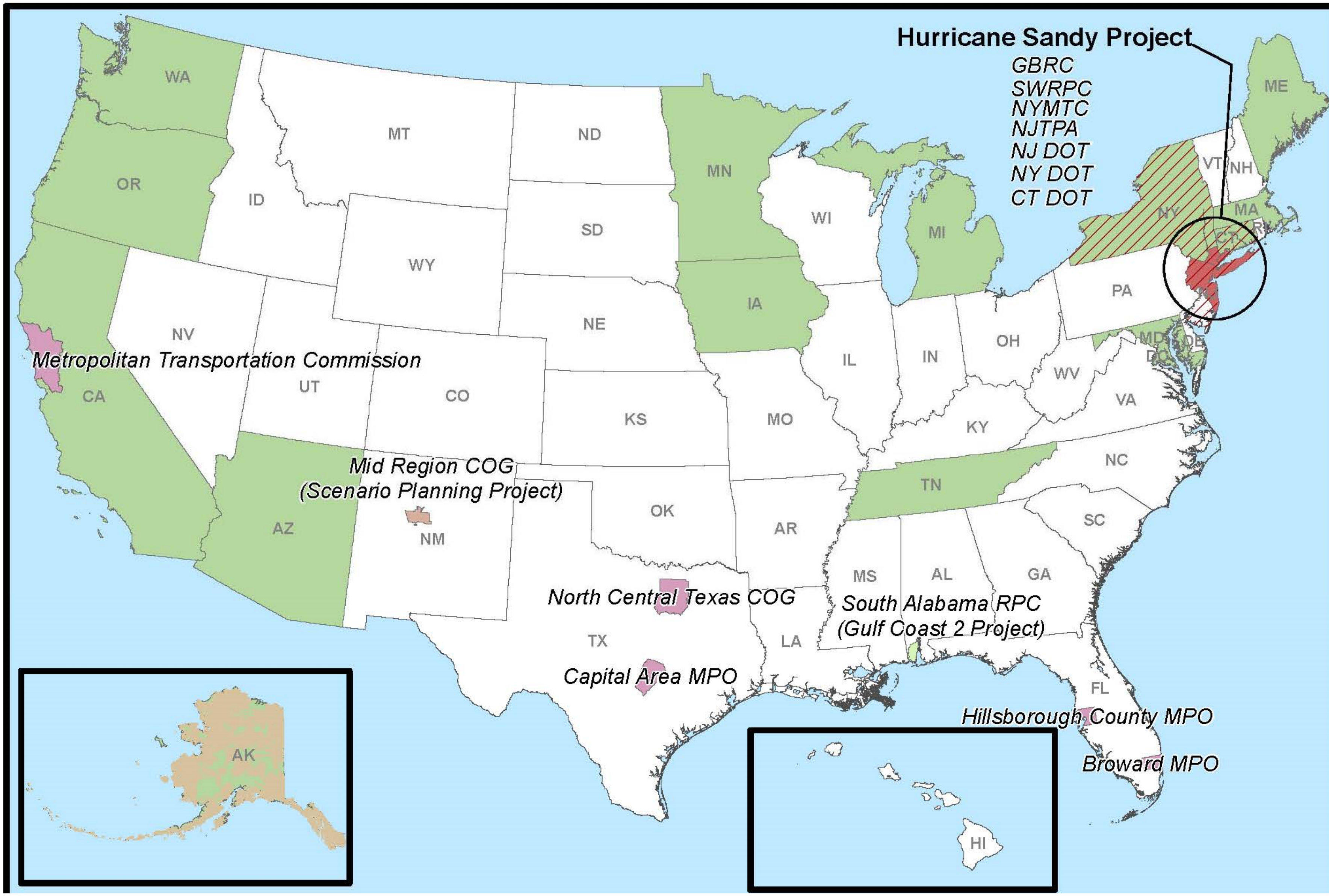
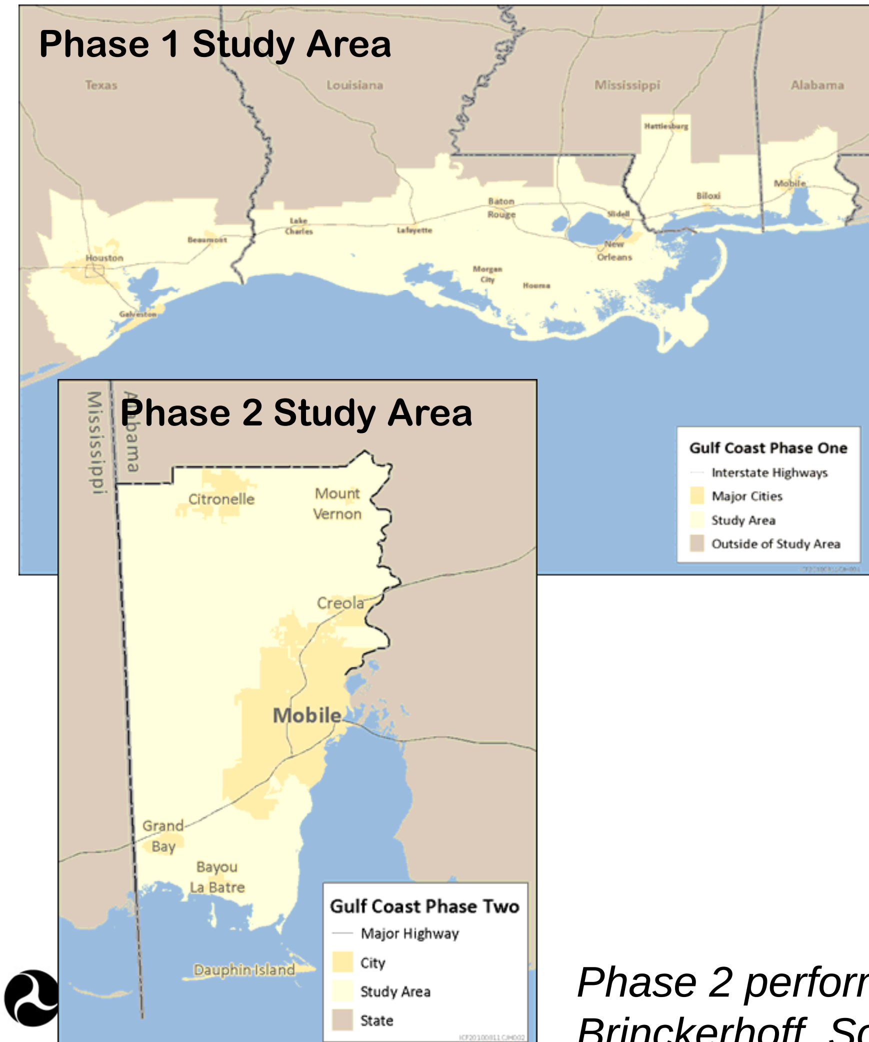
Climate Resilience Pilot & Other Project Locations



Gulf Coast 2 Project (Mobile, AL)



- **Primary Phase 2 Tasks**
  1. Identify critical transportation assets in Mobile (complete)
  2. Identify climate effects, assess infrastructure sensitivity (complete)
  3. Assess vulnerability of critical assets (September 2014)
  4. Develop transferable risk management tools (October 2014)
- **Completed tasks: FHWA website**

Phase 2 performed by ICF International (prime), Parsons Brinckerhoff, South Coast Engineers, and Texas A&M, with support from USGS and Katharine Hayhoe (Texas Tech)

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Projected Climate Change in Mobile: *Temperature and Precipitation*

- **Increases in Temperature**
  - The number of heat events above **95°F** and **100°F** are projected to increase dramatically

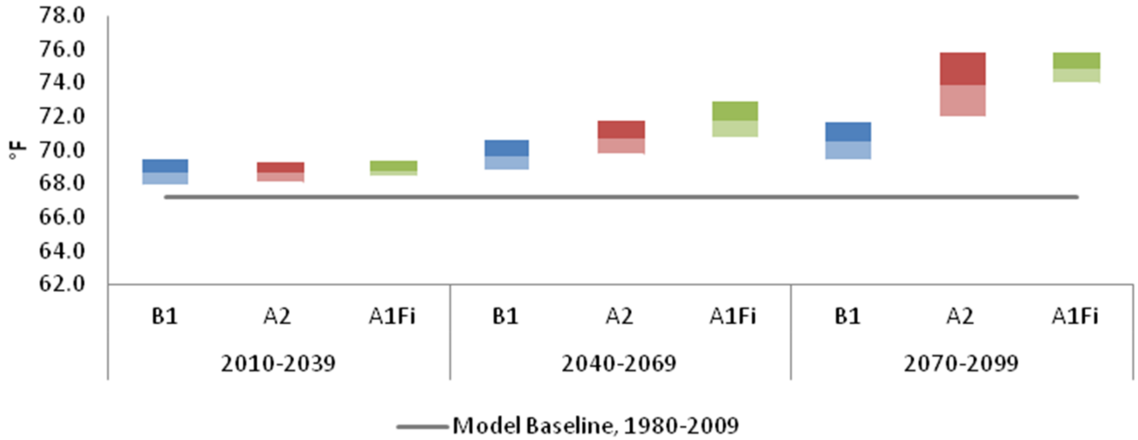
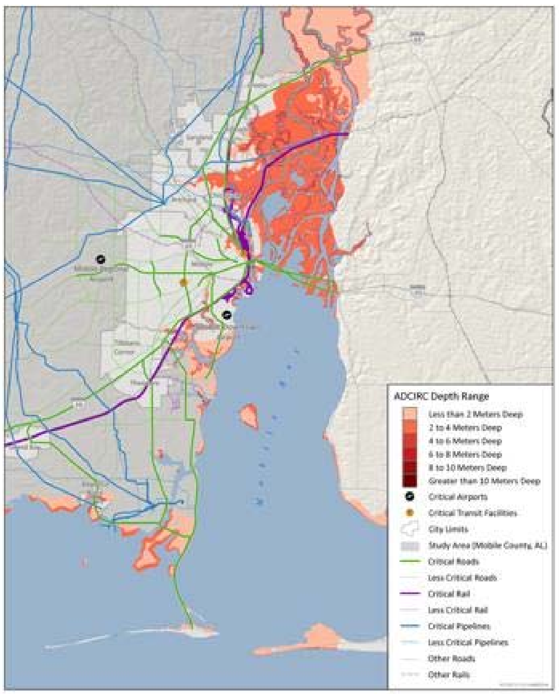


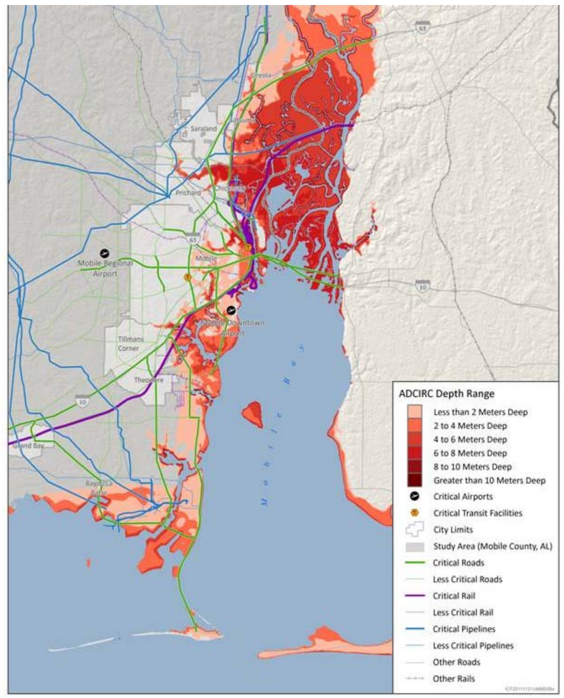
Figure: Projected average mean temperature (°F)

- **Changes in Precipitation are Less Certain**
  - 100-year precipitation event is projected to be more intense in the future, though there is a wide spread of results across models

Sample of Storm Surge Analyses, etc.



Hurricane Katrina Natural Path Scenario



Hurricane Katrina Shifted Path Scenario with 0.75 meter Sea-Level Rise

- Scenarios based on historic hurricanes, with varying
  - Track
  - Intensity
  - Sea level rise
- Temperature, precipitation projections

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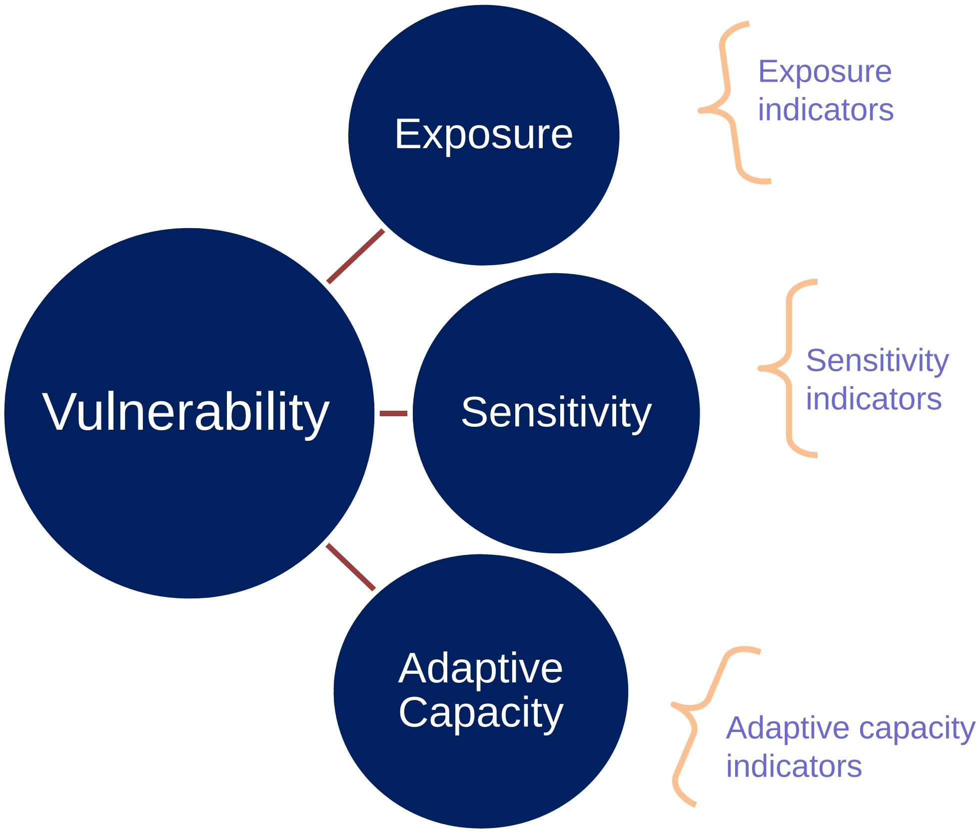
Vulnerability Assessment: Planning & Project levels

- Vulnerability Screen
  - High-level analysis to find assets most likely to be vulnerable to future changes
- Engineering Assessments
  - Detailed assessments of specific assets in Mobile
  - Eleven case studies

Using Indicators to Score Vulnerability

- V = Function of (E, S, A)
- Chose indicators to represent exposure, sensitivity, and adaptive capacity
  - Characteristics that could indicate an asset may or may not be vulnerable
- Averages of indicators drive scoring
  - Weighting



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Example Indicators

Exposure

- **Temp**-Days above 95°F
- 24-hour **precipitation**
- **Storm surge** height
- **Wind** speed exceeds threshold above which impacts may occur (yes/no)
- Inundated by **sea level rise** (yes/no)

Sensitivity

- **Temp** - Pavement binder, traffic (roads)
- **Precip** - FEMA flood zones, ponding, surface permeability (all modes)
- **Storm surge** – Height & condition (bridges), electric signaling & soil type (rail), access (transit)
- **Wind** - Building height, materials, roof type; road sign or signal density (road and rail)
- **Sea level rise** – Drainage (air), protection (transit, roads)

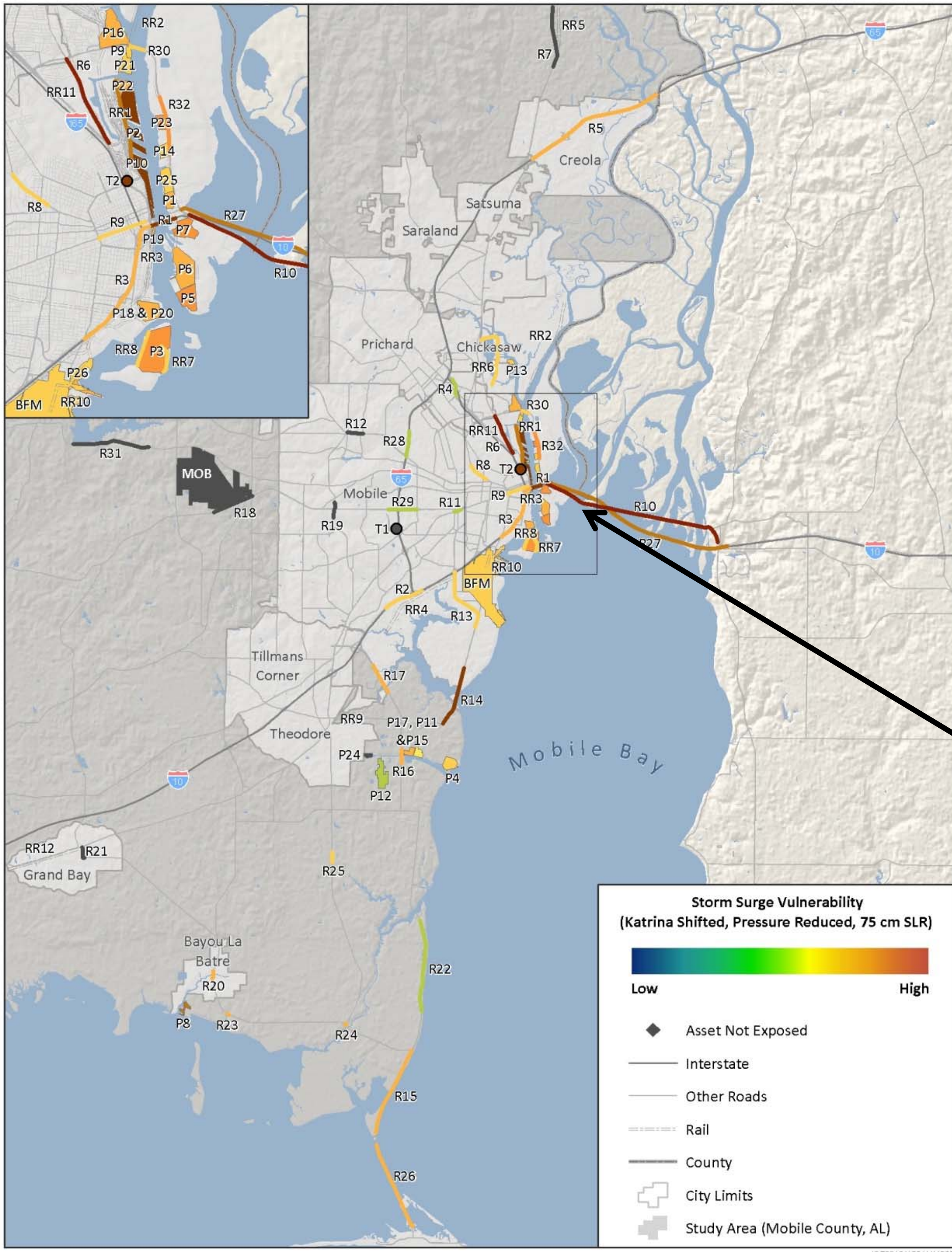
Adaptive Capacity

- **Speed to recover asset** – cost of improvement (bridges), identified as a priority in emergency planning (rail, air, transit)
- **Redundancy** - detour length (bridges, air), number of terminals/ runways (air), ability to reroute (transit and rail), rail yard interchange utility (rail)
- **System disruption duration** (climate variable-specific)

Highways Storm Surge Vulnerabilities

Segment Name	Vulnerability Score (Least Extreme)	Vulnerability Score (Most Extreme)	Data Availability*
Telegraph Road, from Downtown to Baybridge Road	3.2	4.0	92%
The Causeway (Battleship Parkway)	3.2	4.0	91%
I-10 Tunnel (Wallace Tunnel)	3.2	3.6	87%
SR-163 (Dauphin Island Parkway), from Island Road to Terrell Road	3.2	3.6	81%
I-10 Bridge across Mobile Bay	2.5	3.3	86%
Old Spanish Trail, between Cochrane Bridge and the tunnels	2.7	3.1	87%
Dauphin Island Bridge	2.6	3.0	100%
SR-188, where it crosses the river just North of Bayou la Batre	2.5	2.9	87%
Intersection of SR-188 and CR-59 (Bellingrath Road), near Fowl River	2.5	2.9	87%
SR-193 (Dauphin Island Parkway), from Dauphin Island Bridge to CR-188	2.5	2.9	92%

Storm Surge Vulnerability



- Highest where Mobile River meets Mobile Bay
- Low-lying coastal roads and bridges
- Location is biggest driver

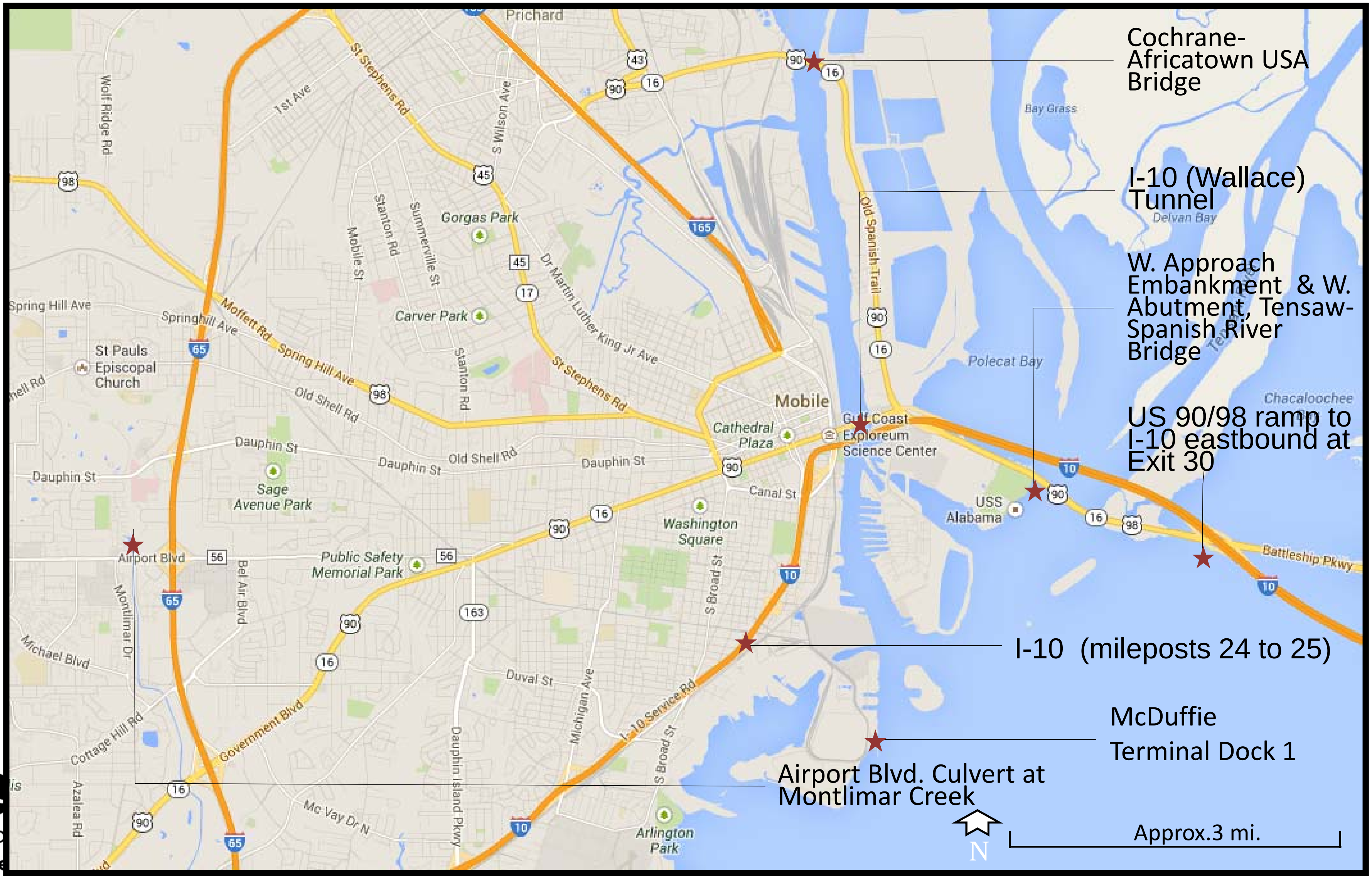
Example: The Causeway (R10)

- 17-29 ft. of storm surge/waves
- Damaged in past, unprotected, low approach, low embankment
- High replacement cost

Engineering Case Studies

Climate Stressor	Asset Type	Specific Assets Studied
Precipitation	Major culvert	Airport Blvd. at Montlimar Creek
SLR	Navigable River Bridge	Cochrane Africatown USA Bridge
SLR	Embankment (erosion)	US 90/98 Tensaw Bridge
Storm Surge	Commercial shipping pier	McDuffie Coal Terminal, Dock 1
Storm Surge	Bridge abutment	US 90/98 Tensaw Bridge
Storm Surge	Bridge structural system	Exit 30, EB Ramp to I-10 Bayway Bridge
Storm Surge	Roadway alignment	I-10, Between Mileposts 24 and 25
Storm Surge	Tunnel	Wallace Tunnel
Temperature	Pavement	Generic
Temperature	Continuously – welded rail	Generic
All	Operations and maintenance	Generic

Engineering Case Studies

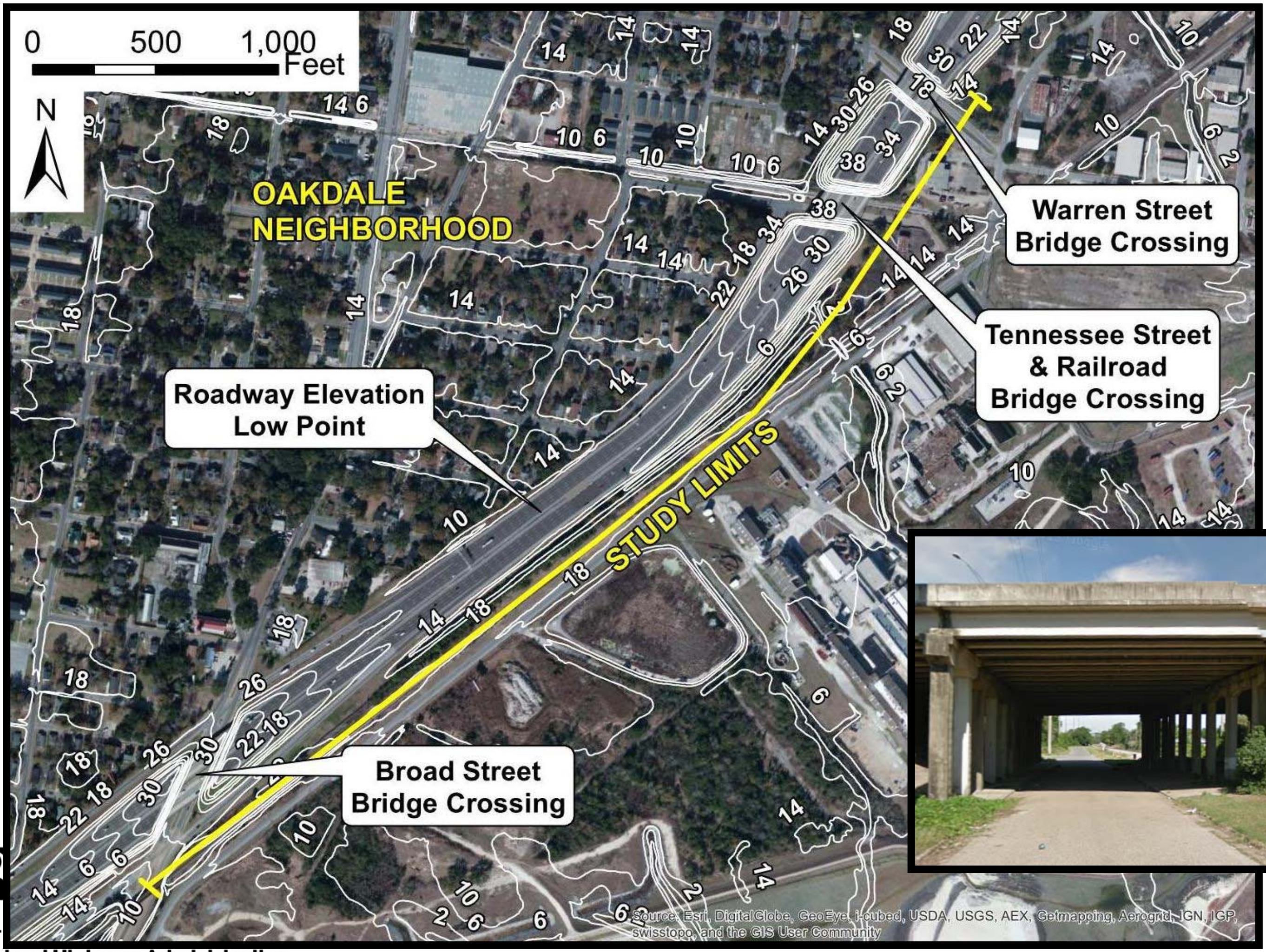


Engineering Analyses

Eleven-step adaptation approach

1. Describe the site context
2. Describe the existing or proposed facility
3. Identify environmental factors that may impact infrastructure components
4. Decide on climate scenarios and determine magnitude of changes
5. Assess performance of the existing or proposed facility
6. Develop adaptation option(s)
7. Assess performance of the adaptation options
8. Conduct an economic analysis
9. Evaluate additional decision-making considerations
10. Select a course of action
11. Plan and conduct on-going activities

I-10 – Mileposts 24 to 25
Road Alignment Exposure to Storm Surge



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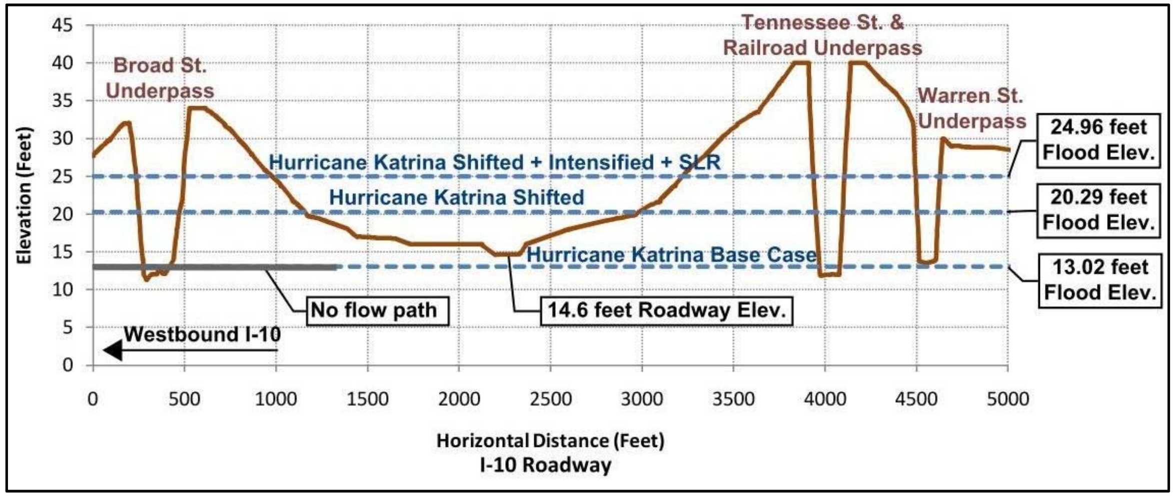
I-10 – Mileposts 24 to 25
Road Alignment Exposure to Storm Surge

Step 4: Climate scenario – Coastal storm surge with sea level rise added to most extreme scenario

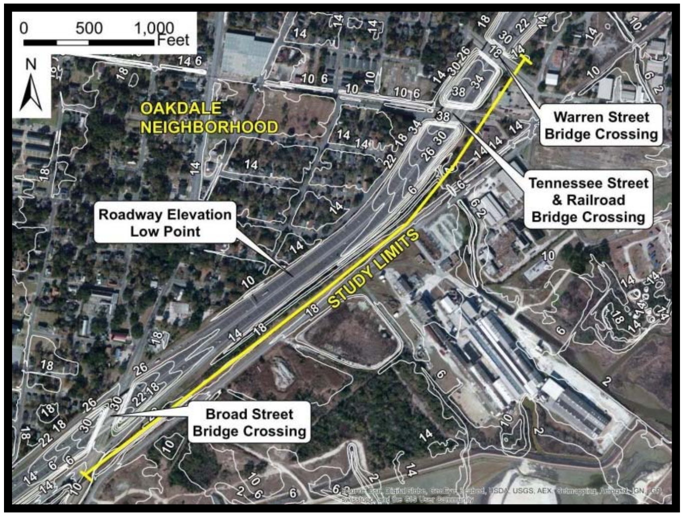


Step 5: Assess Facility Performance

Surge Scenario	Overtop I-10?	Inland Flooding Acre-Feet (Cu.Meters)	Flow Velocities at Tenn. St. &Rail Underpass fps (m/s)
Hurricane Katrina Base Case Scenario	NO	40 (51,700)	3.4 (1.0)
Hurricane Katrina Shifted Scenario	YES	1,300 (1,581,000)	6.6 (2.0)
Hurricane Katrina Shifted + Intensified + Sea Level Rise (SLR) Scenario	YES	2,800 (3,412,000)	6.8 (2.1)

Permissible velocities: Grass: 2 to 4 fps; RR ballast: 3 to 6 fps; Concrete: 18 fps

I-10 – Mileposts 24 to 25
Road Alignment Exposure to Storm Surge



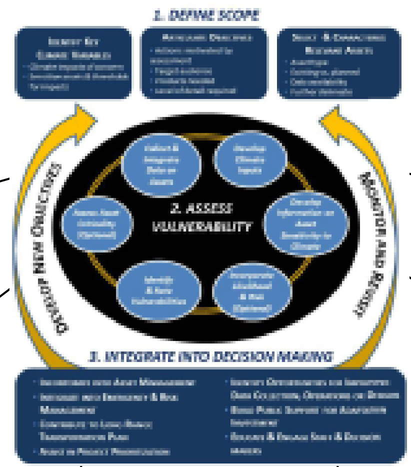
Step 6: Develop Adaptation Options

- Harden one or more of the underpasses
- Armor I-10 roadway embankment
- Raise the roadway

Lessons Learned

- Roadway embankment breaching is an area with little research data on prediction methods.
- Additional erosion protection should be considered when designing roadway crossings that could be subjected to reverse flow from storm surges.

Tools Development and Deployment



Module 1
Articulate Objectives

Module 2
Identify Climate Stressors

Sensitivity Matrix

Module 3
Select Assets

Criticality Guidance

Module 4
Assess Vulnerabilities

CMIP Climate Data Processing Tool

Vulnerability Assessment Scoring Tool

Module 5
Integrate in Decision Making

Engineering Case Studies

Module 6
Monitor and Revisit

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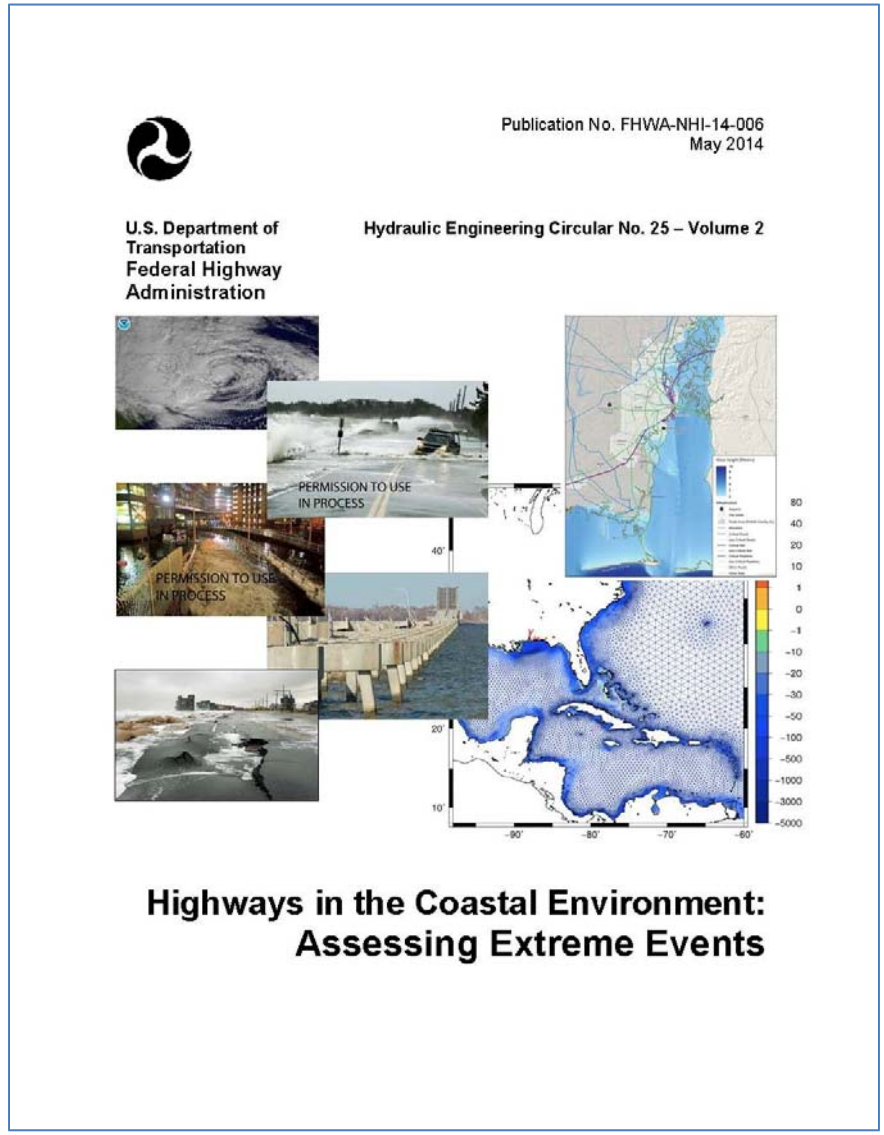
http://www.fhwa.dot.gov/environment/climate_change/adaptation/

Technical guidance: HEC-25 Volume 2

- *Highways in the Coastal Environment: Assessing Extreme Events*
- Technical guidance, methods for incorporating extreme events and climate change into coastal highway designs
- Focus on sea level rise, storm surge, wave action
- Summer 2014



Asset Management

- All State DOTs will develop asset management plans that address risks. Examples of risks:
  - Financial, Under-investment in maintenance, etc.
  - Economic
  - Seismic
  - Extreme weather
  - Climate change (worse and/or more frequent EWE, etc.) - accelerated deterioration cycles

- Virtually all 50 States have used Emergency Relief funds for weather related damage over the last decade

Implications

Impacts (and implications) will vary by region…

- Climate change will affect:
  - Decisions on when/where to invest or reconstruct
  - Maintenance cycles
- Expect higher maintenance and operations costs; potentially costlier designs
- Adaptation can save funding over the long term
  - Emphasize proactive strategies vs. reacting to “disaster”
  - Focus on solutions

Photo credit: AECOM

Thank you.

http://www.fhwa.dot.gov/environment/climate_change/adaptation/