U.S. Department of Transportation
Federal Highway Administration

Webinar Series

TRANSPORTATION CLIMATE CHANGE & EXTREME WEATHER VULNERABILITY ASSESSMENT

Session 1: Determining Assets to Study and Using Climate Information

May 16, 2013

Missouri River flooding, Jefferson City, Missouri
Photo: Missouri DOT

Agenda

Intro to Vulnerability Assessment Framework	Becky Lupes *FHWA Office of Natural Environment*
Assessing Criticality of Transportation Assets	Mike Flood *Parsons Brinckerhoff*
Developing Projected Climate Information for Transportation Asset Analysis	Joel Smith *Stratus Consulting*
Case study: Gulf Coast II SLR and Storm Surge Projections	Rob Kafalenos *FHWA Office of Natural Environment*
Q & A Session	

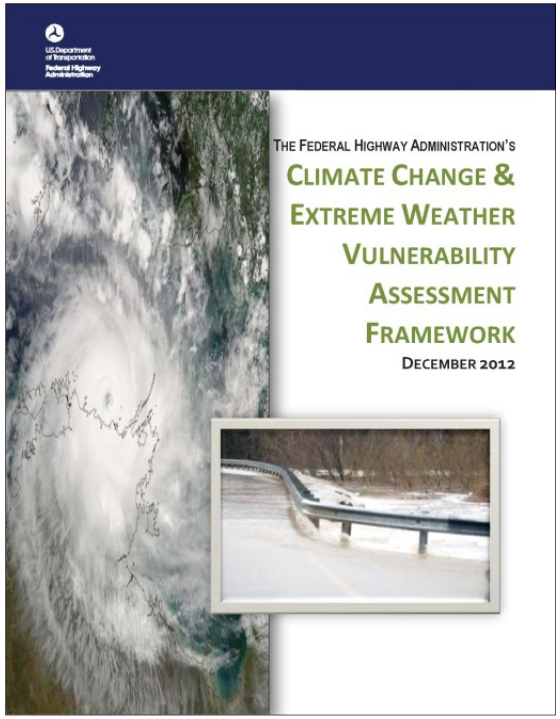
Introduction to Vulnerability Assessment Framework

Becky Lupes
Federal Highway Administration
Sustainable Transport & Climate Change Team

Vulnerability Assessments

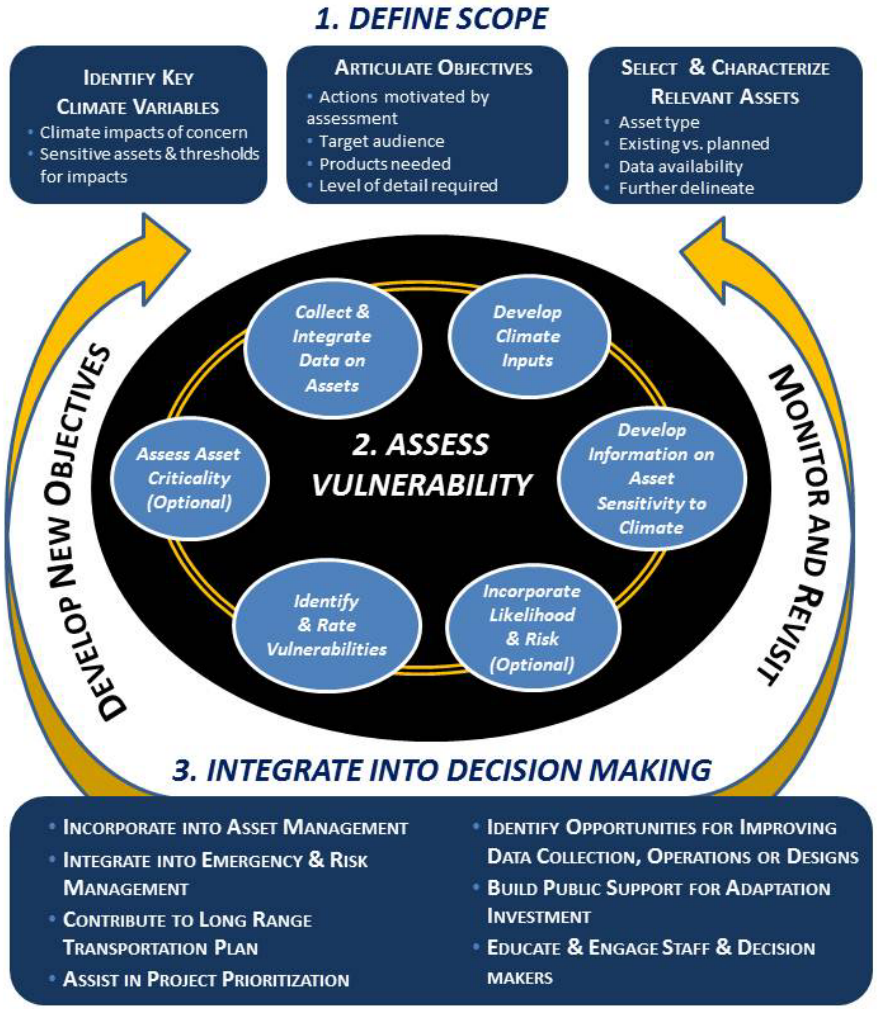
- Understanding how climate change effects and extreme weather will affect your transportation network is key first step for climate change planning

FHWA's Climate Change and Extreme Weather Vulnerability Assessment Framework (December 2012)



Climate Change & Extreme Weather Vulnerability Assessment Framework

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



Defining Project Scope

ARTICULATE OBJECTIVES

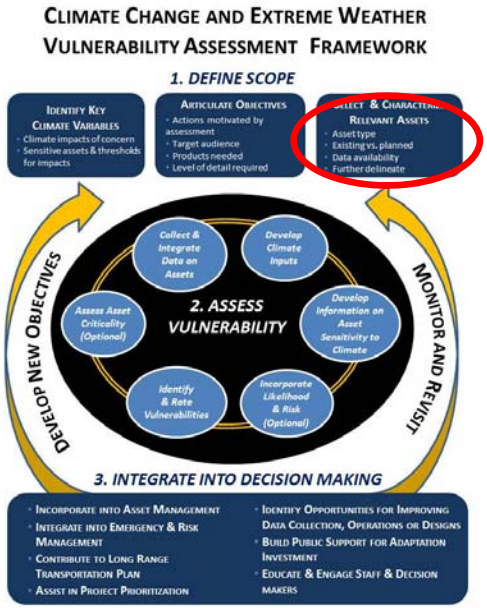
- What actions are motivated by the assessment?
- Who is the target audience?
- What products are needed?
- What level of detail required?

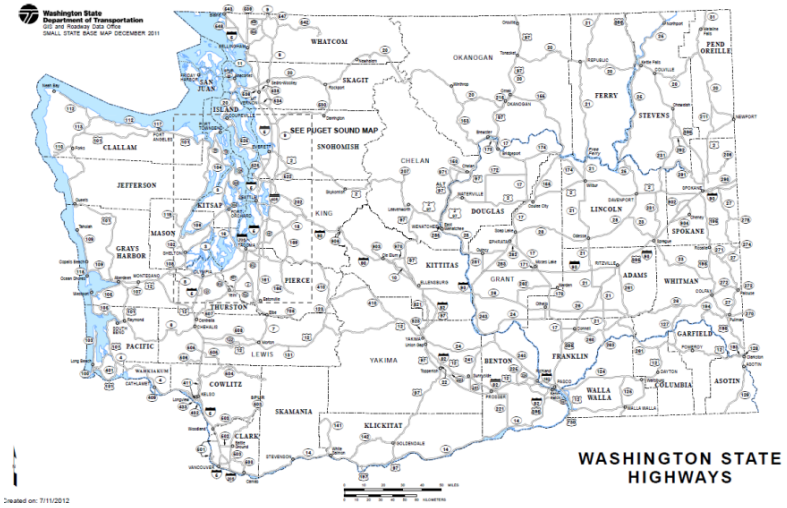
MTC Pilot Study Area

Defining Project Scope

SELECT & CHARACTERIZE RELEVANT ASSETS

- Asset type
- Existing vs. planned
- Data availability
- Further delineate
  - Critical assets?
  - Owned or managed assets?

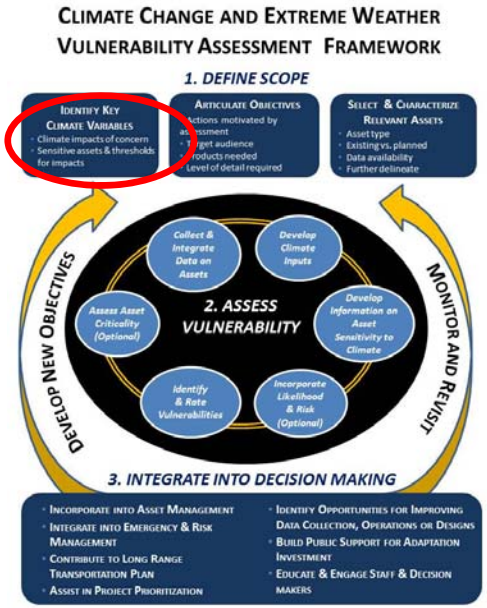




Defining Project Scope

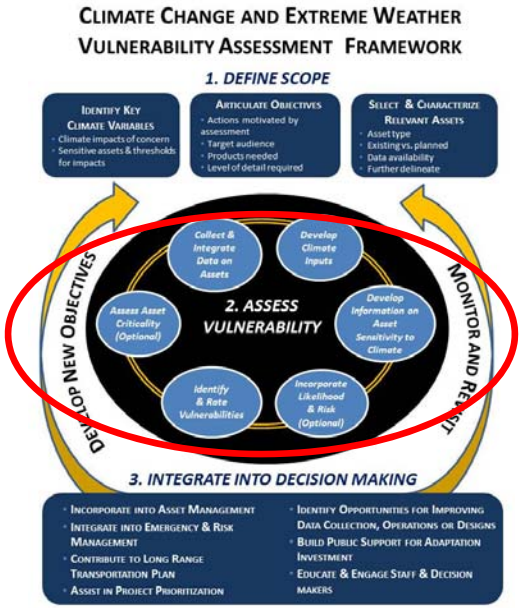
IDENTIFY KEY CLIMATE VARIABLES

- Climate impacts of concern
- Sensitive assets & thresholds for impacts



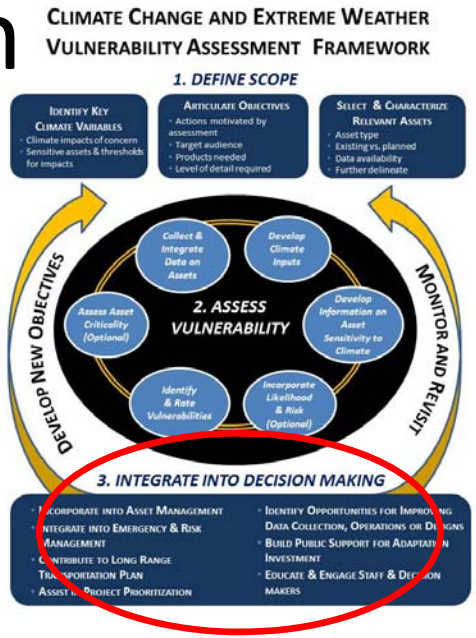
Assessing Vulnerability

- Develop Climate Inputs
- Collect and Integrate Data on Assets
- Assess Asset Criticality
- Develop Information on Asset Sensitivity to Climate
- Identify and Rate Vulnerabilities
- Incorporate Likelihood and Risk



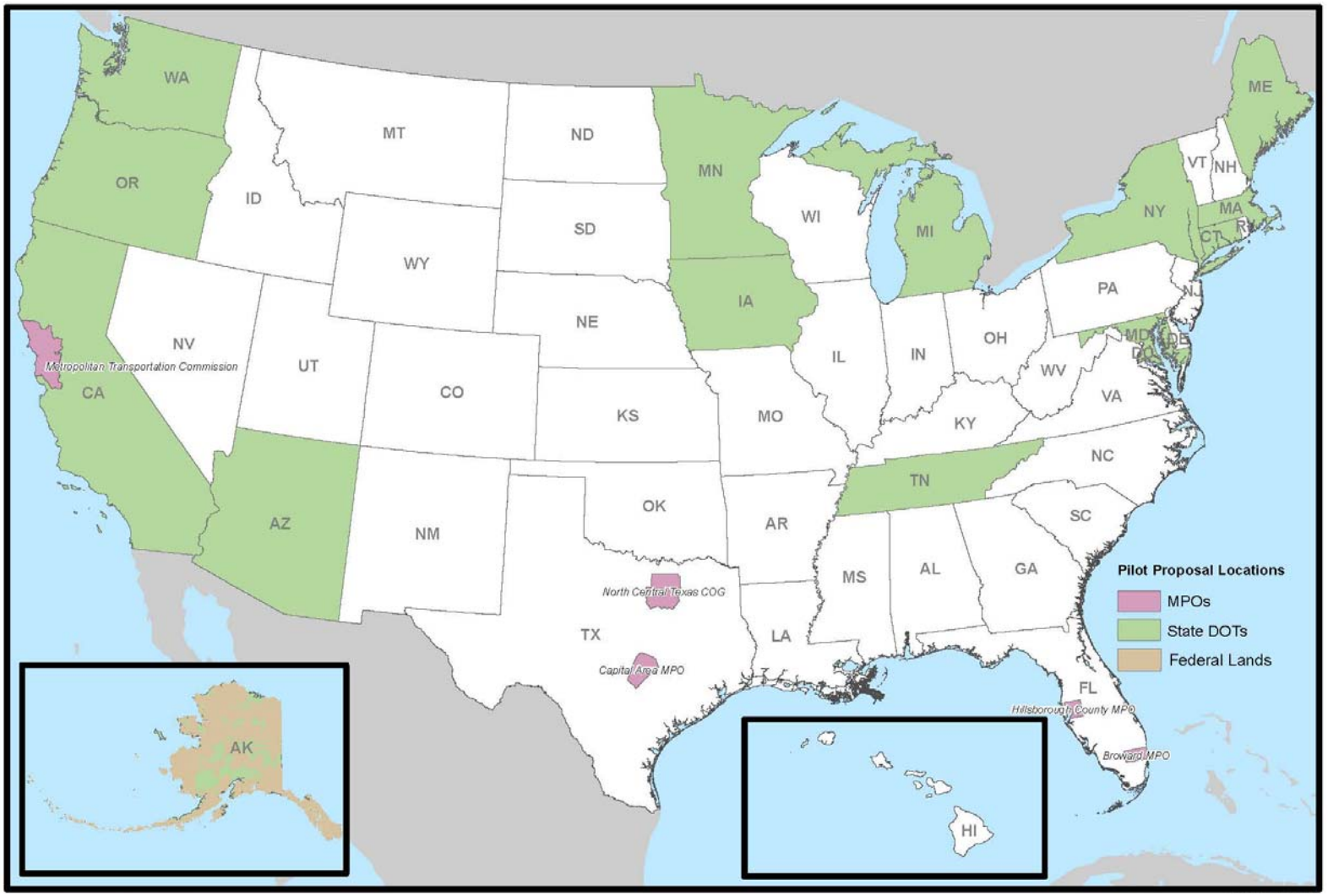
Integrate Results into Decision Making

- Identify, analyze, and prioritize adaptation options;
- Incorporate assessment results into programs and processes



- INCORPORATE INTO ASSET MANAGEMENT
- INTEGRATE INTO EMERGENCY & RISK MANAGEMENT
- CONTRIBUTE TO LONG RANGE TRANSPORTATION PLAN
- ASSIST IN PROJECT PRIORITIZATION
- IDENTIFY OPPORTUNITIES FOR IMPROVING DATA COLLECTION, OPERATIONS OR DESIGNS
- BUILD PUBLIC SUPPORT FOR ADAPTATION INVESTMENT
- EDUCATE & ENGAGE STAFF & DECISION MAKERS

2013-2014 Pilot Locations



Assessing Criticality of the Transportation System

Michael Flood
Parsons Brinckerhoff

Presentation Outline

- Define Usage of Criticality
- Why Determine Critical Systems?
- Discuss Various Methodologies for Determining Critical Facilities

What is Critical?

- Parsing the definition– not those at high risk (critical)
- Instead the focus is - those components of the transportation network that serve functions important (critical) to the viability of the local/regional/state system

Why Ask the Question?

- To Determine Where to Focus Limited Resources on Studies or Projects
- Could Also Be Used To Help Set Agency Policies on Risk Tolerance

Methods to Approach

- **Desktop Method**
  - Determine factors that define network criticality and measure across the system
- **Stakeholder Method**
  - Work with local stakeholder groups to identify critical transportation systems
- **Hybrid Approach**
  - Apply assessment methodology and involve stakeholders to resolve final determinations

Some Drawbacks of Each Method

- **Desktop Method**
  - Can fail to reflect local input
  - Lack of data for private entities for multimodal assessments
- **Stakeholder Method**
  - No assessment basis, can be affected by personal preference
  - Facilitation methods can impact results

Desktop Example: New Jersey

"Collected assets were organized into tiers of criticality, from "Low" to "Extreme" based on their respective roles in connecting critical destinations—in this case approximated by a combination of population and job density."

Climate Change Vulnerability and Risk Assessment of New Jersey's Transportation Infrastructure
http://www.njtpa.org/plan/Element/Climate/documents/CCVR_REPORT_FINAL_4_2_12_ENTIRE.pdf

Desktop Example: Hampton Roads

Four screening criteria were used …. (1) assets on hurricane evacuation routes; (2) assets that carry high traffic volume (AADT > 10,000 vehicles/day); (3) assets that represent a maintenance priority route (e.g. snow removal priority route); and (4) those that are at low--lying elevations."

Vulnerability and Risk of Climate Change Effects on Transportation Infrastructure, Hampton Roads http://www.virginia.edu/crmes/fhwa_climate/files/finalReport.pdf

Desktop Example: Washington DOT

Very low to low				Moderate		Critical to Very Critical			
1	2	3	4	5	6	7	8	9	10
Criticality of asset									

Notice that along with the qualitative terms there is an associated scale of 1 to 10, this is to serve as a facilitation tool for some people who may find it useful to think in terms of a numerical scale – although the scoring by each individual is of course subjective. The scale is a generic scale of criticality where "1" is very low (least critical) and "10" is very critical.

Typically involves:
- Non-NHS
- Low AADT
- Alternate routes available

Typically involves:
- Some NHS
- Non-NHS
- Low to medium AADT
- Serves as an Alternate for other State routes

Typically involves:
- Interstate
- Lifeline
- Some NHS
- Sole Access
- No Alternate routes

Climate Impacts Vulnerability Report – WSDOT
Available at: http://www.wsdot.wa.gov/SustainableTransportation/adapting.htm

Example Hybrid Approach:

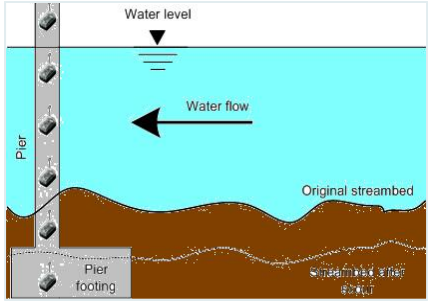
Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study

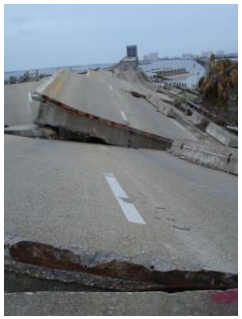
Gulf Coast II

Mobile, Alabama

What was the Purpose of This Effort?

Determine Subset of Entire Transportation Network on Which to Perform Vulnerability Assessment and Identify Adaptive Measures





Establishing a Consistent Methodology Across Modes

What is “critical” infrastructure in the Mobile region?

Effort to define a process applicable to Highways, Rail, Airports, Ports, Pipelines, and Transit

Assessment of Transportation Systems

Key Aspects of Critical Infrastructure (Theory)

CONNECTION	PURPOSE	FUNCTION
Connecting Mobile to the Region & Nation	Distribution Centers Multimodal Centers	Access to Employment Centers, Hospitals, etc.

Assessment Developed Looked at Three Categories

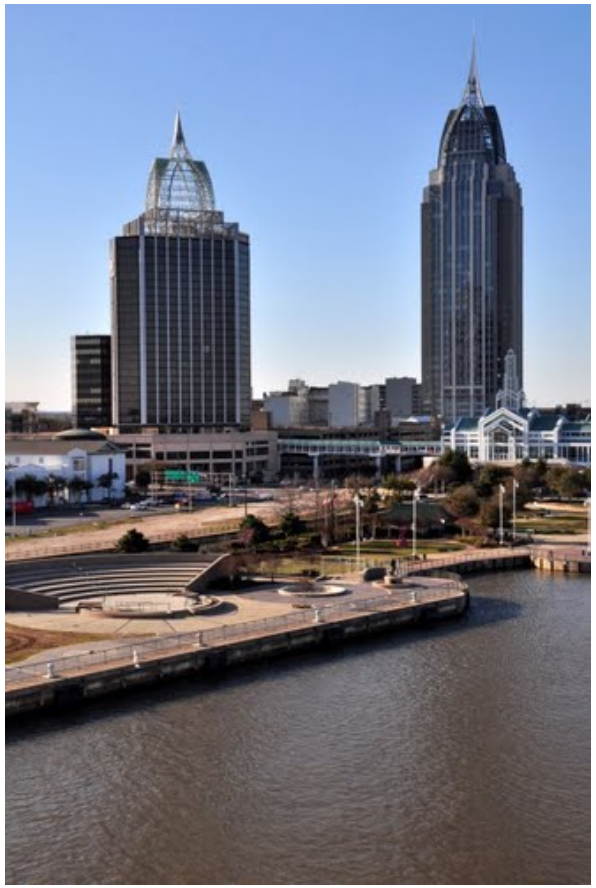
- Socio-Economic
- Operational
- Health and Safety

Methodology To Define Critical Infrastructure

Socio-Economic Assessment

- Serves Regional Economic Centers
- Availability of Redundant System
- Provides Community Connection

Infrastructure Important to the Functioning of the Region



Methodology To Define Critical Infrastructure

Operational Considerations

- **Identify the components of critical infrastructure from a modal perspective**
  - Functional Classification
  - Usage
  - Operations and Maintenance
  - Freight Route
  - Control and Enforcement Centers

Methodology To Define Critical Infrastructure

Health and Safety

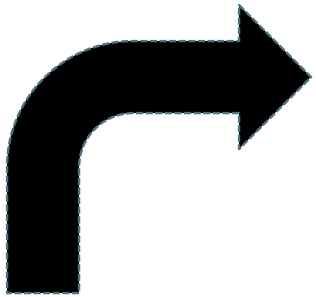
- Emergency evacuation
- Disaster relief
- Disaster recovery
- Access to Hospital Facilities

Both severe events and longer-term environmental changes are considered

Methodology To Define Critical Infrastructure

Bringing it All Together

- **Applying critical infrastructure tools:**
  1. Delineate important assets
  2. Develop scoring summary based on available data
  3. Apply engineering judgment to fill data gaps



Note: Will be rotated on next slide

Facility	Socioeconomic - Locally Identified Priority Corridors	Socioeconomic - Functions as Community Connection	Socioeconomic - System Redundancy	Socioeconomic - Serves Regional Economic Centers	Operational - Functional Classification (Interstate, etc.)	Operational - Usage	Operational - Intermodal Connectivity	Health & Safety - Identified Evacuation Route	Health & Safety - Component of Disaster Relief and Recovery Plan	Health & Safety - Component of National Defense System	Health & Safety - Provides Access to Health Facilities	Criticality Score: (L - Low, M - Medium, H - High)
Airport Blvd (West of Snow Rd)	1	1	1	1	2	2	1	3	1	1	1	L
Airport Blvd (East of Snow Rd)	1	3	1	3	3	3	3	3	1	1	2	**H**

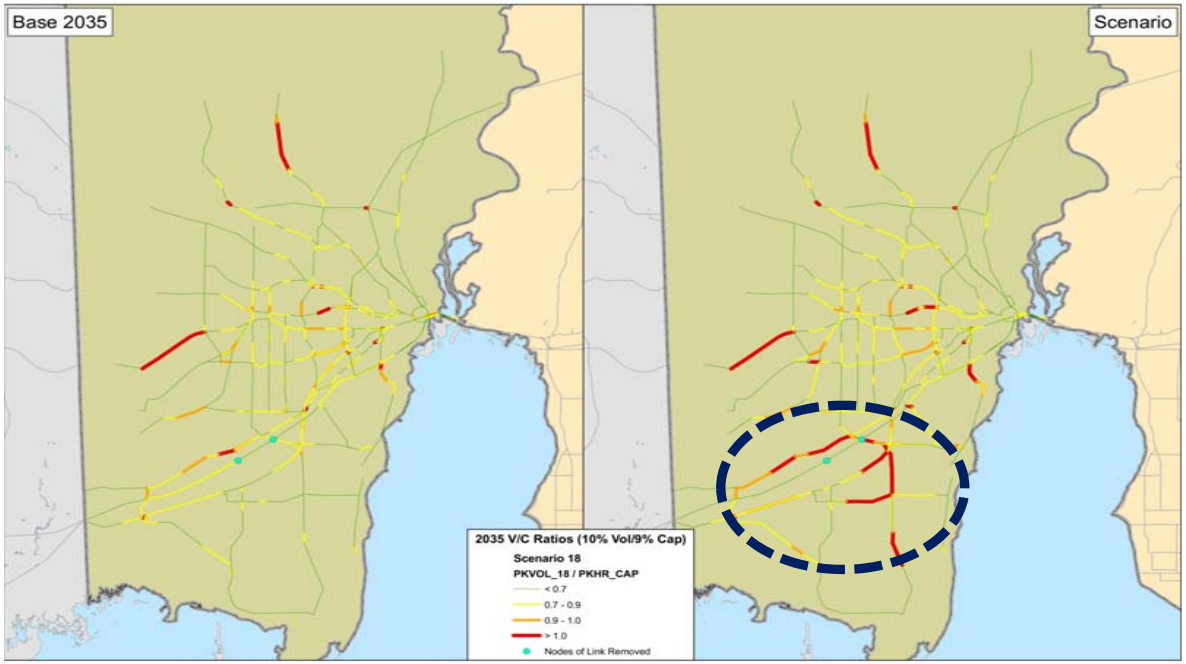
Methodology To Define Critical Infrastructure

1	1	Socioeconomic - Locally Identified Priority Corridors
3	1	Socioeconomic - Functions as Community Connection
1	1	Socioeconomic - System Redundancy
3	1	Socioeconomic - Serves Regional Economic Centers
3	2	Operational - Functional Classification (Interstate, etc.)
3	2	Operational - Usage
3	1	Operational - Intermodal Connectivity
3	3	Health & Safety - Identified Evacuation Route
1	1	Health & Safety - Component of Disaster Relief and Recovery Plan
1	1	Health & Safety - Component of National Defense System
2	1	Health & Safety - Provides Access to Health Facilities
H	L	Criticality Score: (L - Low, M - Medium, H - High)

Methodology To Define Critical Infrastructure

Highway Assessment Included "Redundancy" Test

- **Applied SARPC Forecasting Model**
  1. Test loss of selected links in highway network
  2. Based on V/C ratios for Peak Hour
  3. Determine whether remainder of system can accommodate travel effectively



Methodology - Critical Infrastructure - Rail

Assessment by All Operators

- CSX Transportation
- Norfolk Southern
- Canadian National
- Alabama and Gulf Coast Rail
- Terminal Alabama Railroad State Docks (TASD)

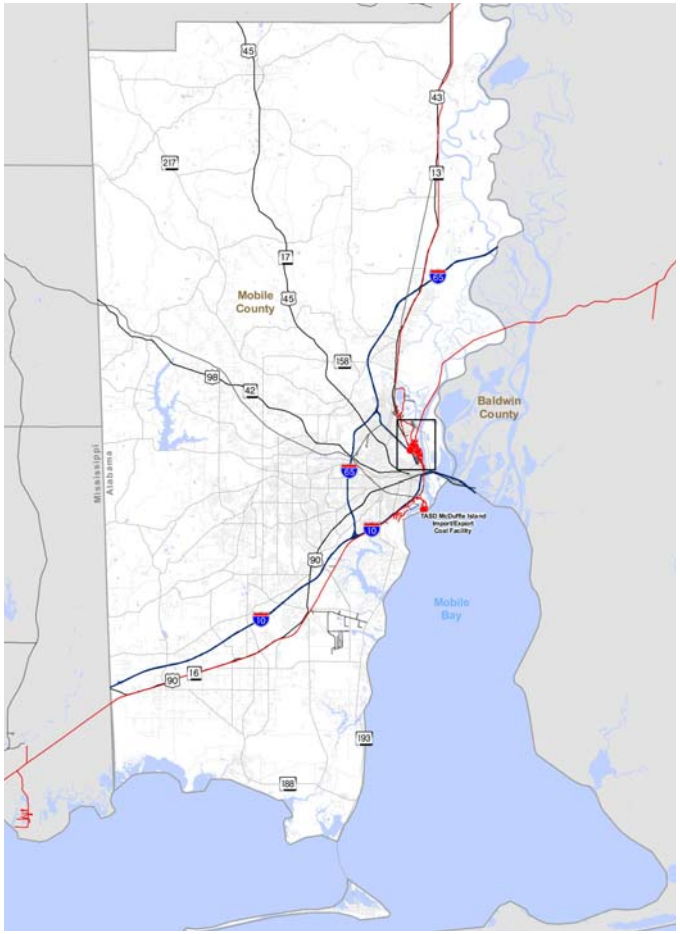
Yards and Shops Included

Field Review Conducted to Fill Data Gaps

Findings - Critical Infrastructure - Rail

Criticality Results

- **CSX Transportation**
  - M&M and NO&M subdivisions
  - Sibert Yard
- **Norfolk Southern**
- **Terminal Alabama Railroad State Docks (TASD)**
  - Main Docks Complex
  - TASD Interchange Yard
  - McDuffie Terminal



FHWA Climate Change and Extreme Weather Vulnerability Assessment Framework

1. DEFINE SCOPE

Identify Key Climate Variables
- Climate impacts of concern
- Sensitive assets & thresholds for impacts

Articulate Objectives
- Actions motivated by assessment
- Target audience
- Products needed
- Level of detail required

Select & Characterize Relevant Assets
- Asset type
- Existing vs. planned
- Data availability
- Further delineate

Develop New Objectives

Collect & Integrate Data on Assets

Develop Climate Inputs

Assess Asset Criticality (Optional)

2. ASSESS VULNERABILITY

Develop Information on Asset Sensitivity to Climate

Identify & Rate Vulnerabilities

Incorporate Likelihood & Risk (Optional)

Monitor and Revisit

3. INTEGRATE INTO DECISION MAKING

- Incorporate into Asset Management
- Integrate into Emergency & Risk Management
- Contribute to Long Range Transportation Plan
- Assist in Project Prioritization
- Identify Opportunities for Improving Data Collection, Operations or Designs
- Build Public Support for Adaptation Investment
- Educate & Engage Staff & Decision makers

Why Optional?

- May Want to Focus on ALL Assets
  - MTC (San Francisco)
- Can Be a Politically Unpalatable Process
- Might Apply During Regular Processes
  - Long Range Plan Development

Where to Find More Information

FHWA Vulnerability Assessment Framework
http://www.fhwa.dot.gov/environment/climate_change/adaptation/resources_and_publications/vulnerability_assessment_framework/

Assessing Criticality in Transportation Adaptation Planning - FHWA
http://www.fhwa.dot.gov/environment/climate_change/adaptation/resources_and_publications/assessing_criticality/index.cfm

Use of Climate Change Information in Assessing Vulnerability of Your Transportation System

Joel B. Smith
Stratus Consulting Inc.

Transportation, Climate Change, and Extreme Weather Vulnerability Assessment:

Getting Started – Determining Assets to Study and Use Climate Information

May 16, 2013

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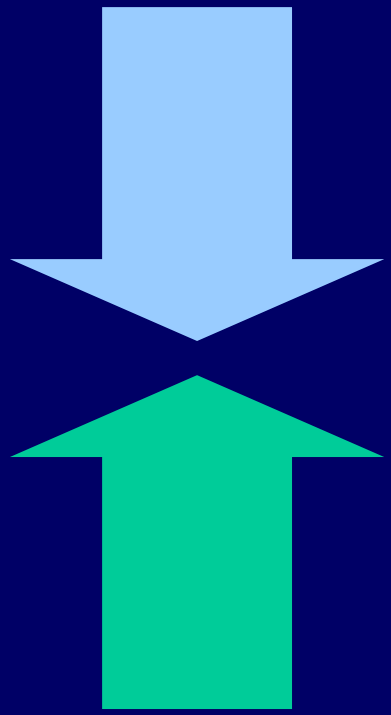
The Challenge of Using Information on Climate Change

- … is we cannot forecast the exact changes
- We know the climate is changing
- We vaguely know how it will change
  - E.g., higher temperatures, sea levels, intense precipitation
- But we cannot make an accurate forecast of precisely how it will change
- So, how do we assess vulnerability?

Two Approaches for Assessing Vulnerability



- The scenario approach
  - Applies a “top-down” perspective
- The threshold approach
  - Based primarily on a “bottom-up” perspective
  - But also draws on top-down scenarios

The Scenario Approach

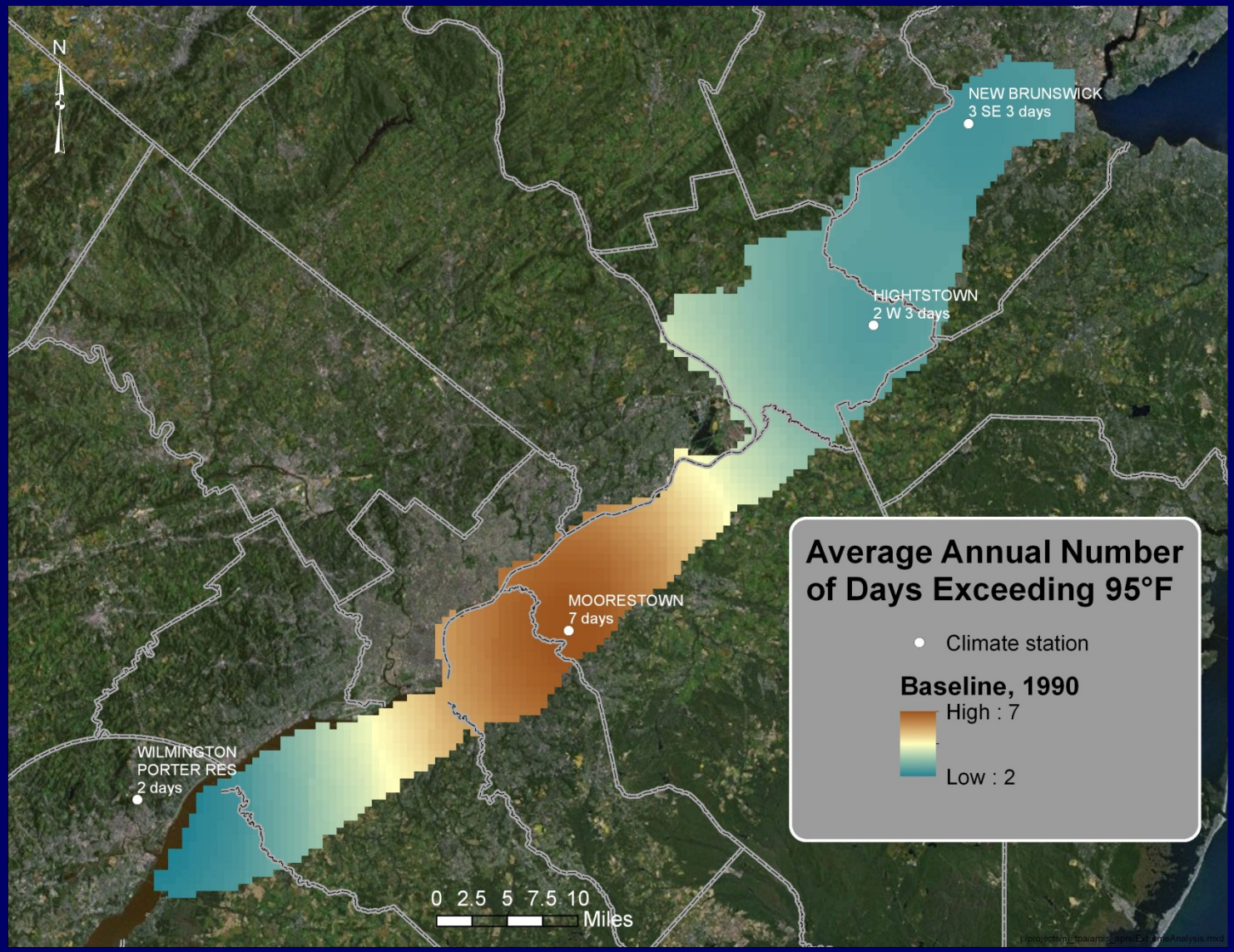
- We use scenarios of climate change to put an envelope around the uncertainty
- The scenarios should reflect ranges of:
  - Different GHG emissions
  - Different changes in the Earth's climate
  - Different changes in regional climate

Stressor Scenarios: NJ TPA

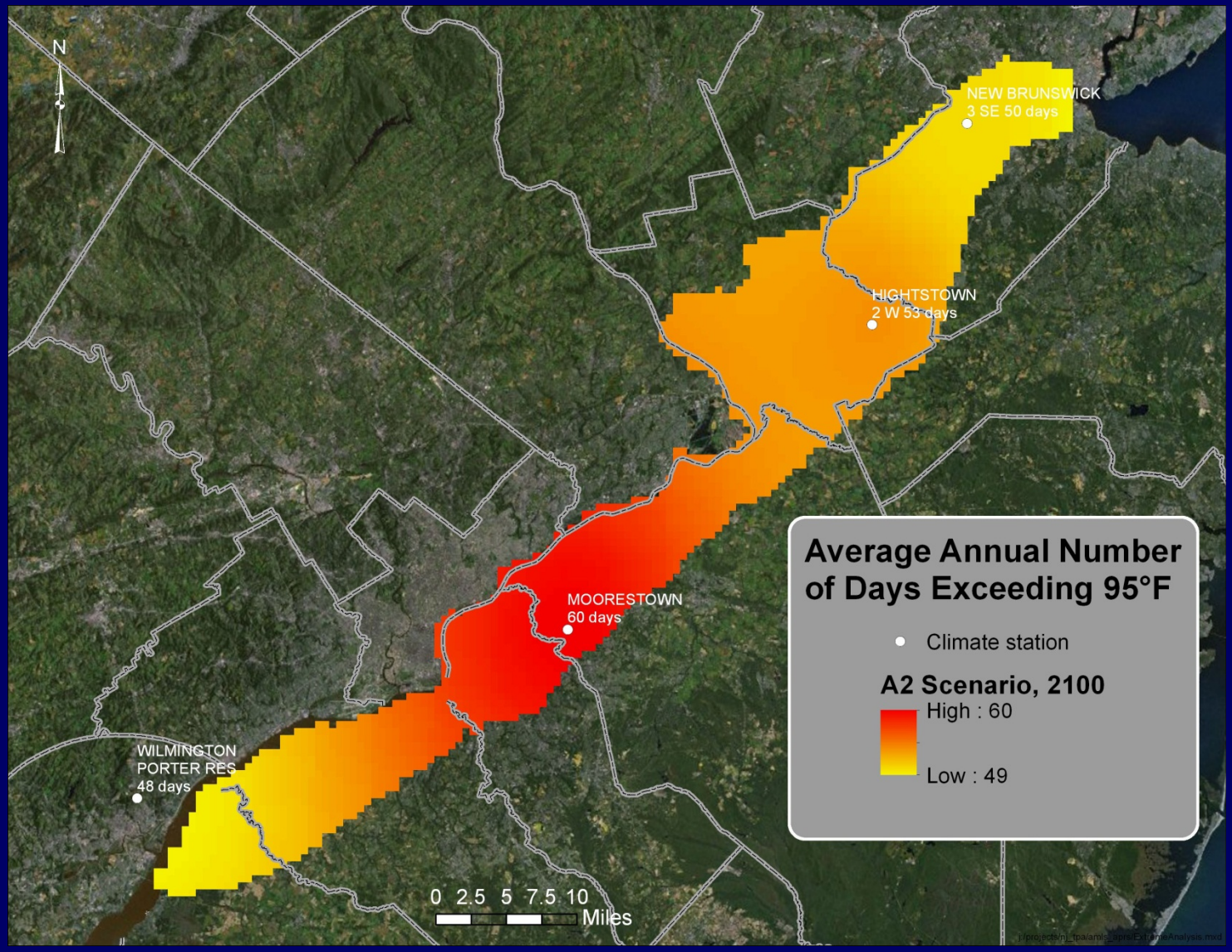
- To address uncertainty, used a bracketed range of projections
- Based on a combination of climate models (GCMs) and emissions scenarios, yielded three scenarios:

Scenario	Emission scenario	Sensitivity (2 x CO_2)	GCM
Low	B1	1.5°C	MIROC-MED
Mid	A1B	3.0°C	Ensemble
High	A2	4.5°C	GISS-ER

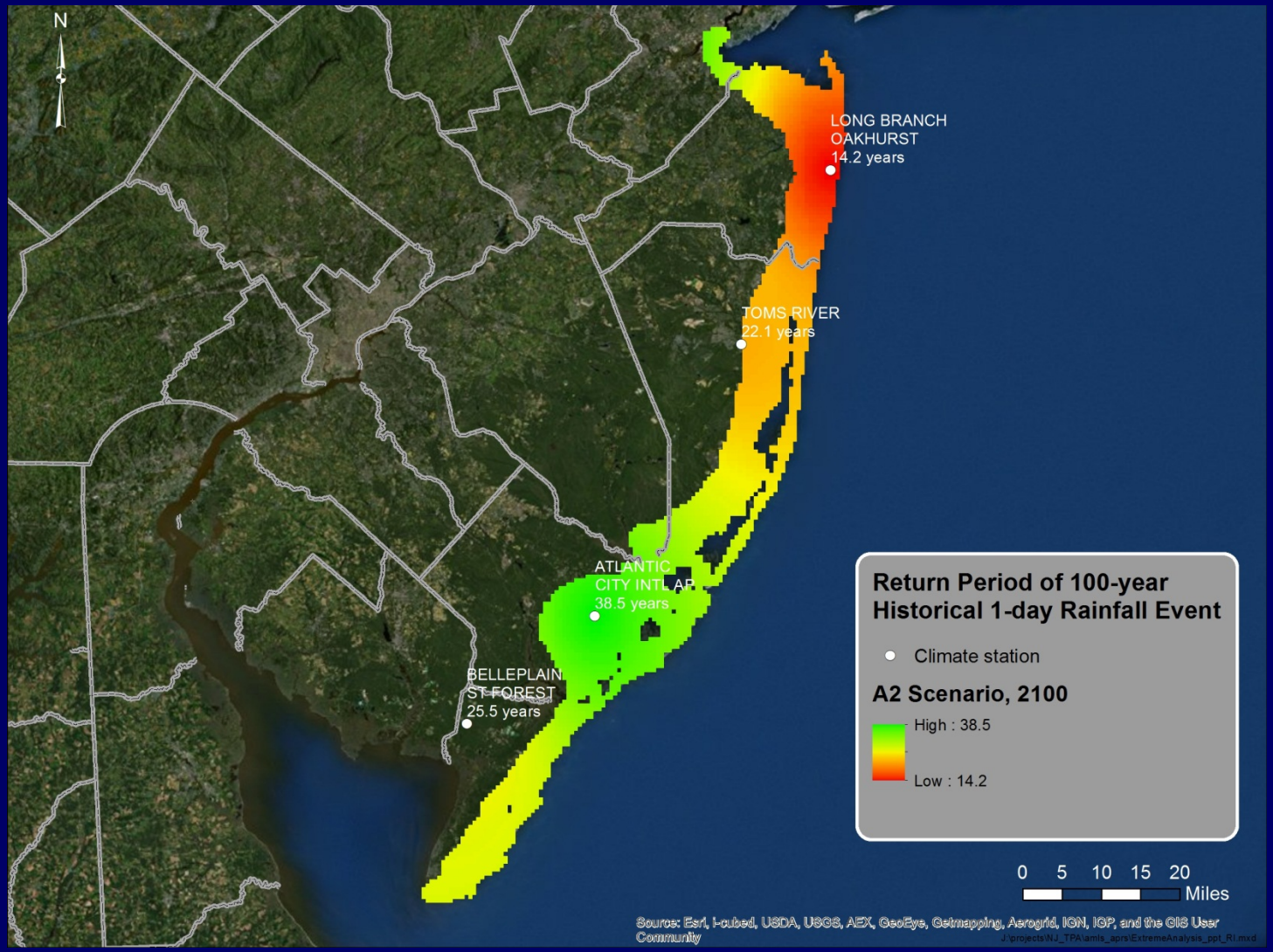
Days Above 95°F (ca 1990)



Days Above 95°F (A2 Scenario, 2100)



Change in 100-yr Precipitation Events (A2 Scenario, 2100)



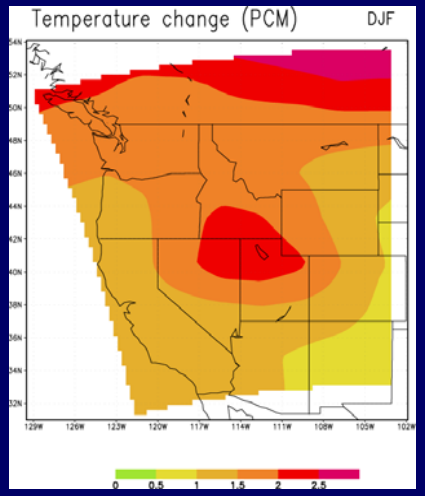
GCM vs. RCMs

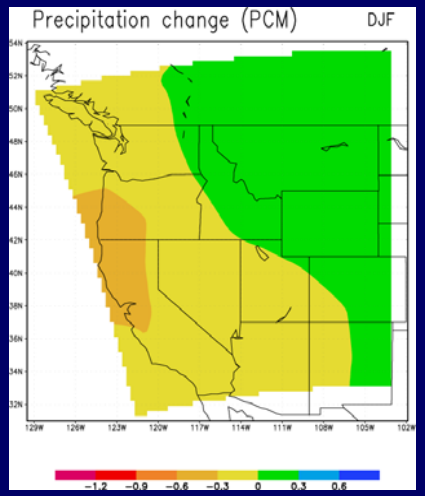
Temperature

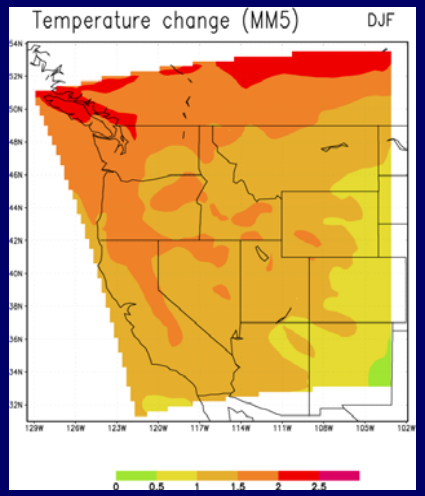
Precipitation

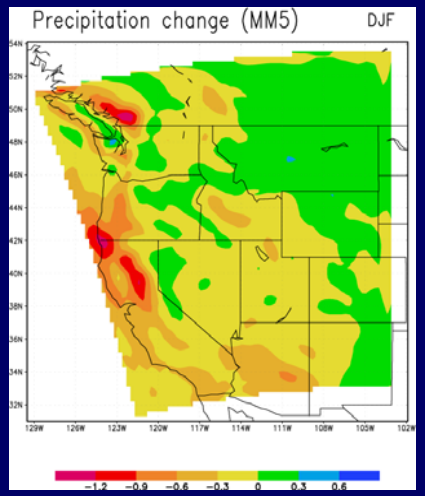
GCM

RCM









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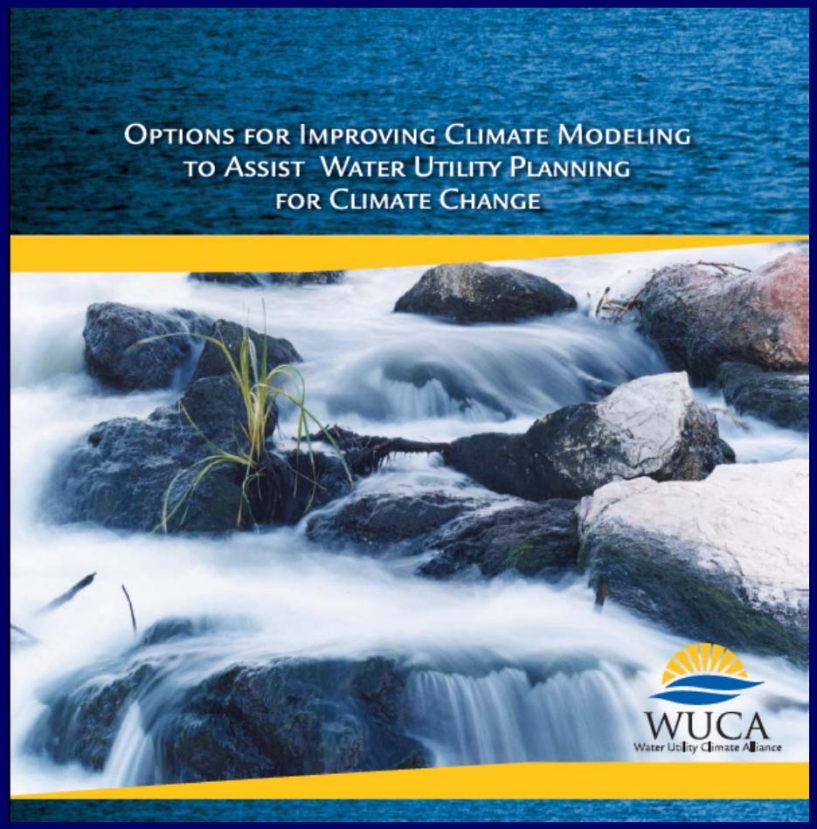
Insights Into Downscaling



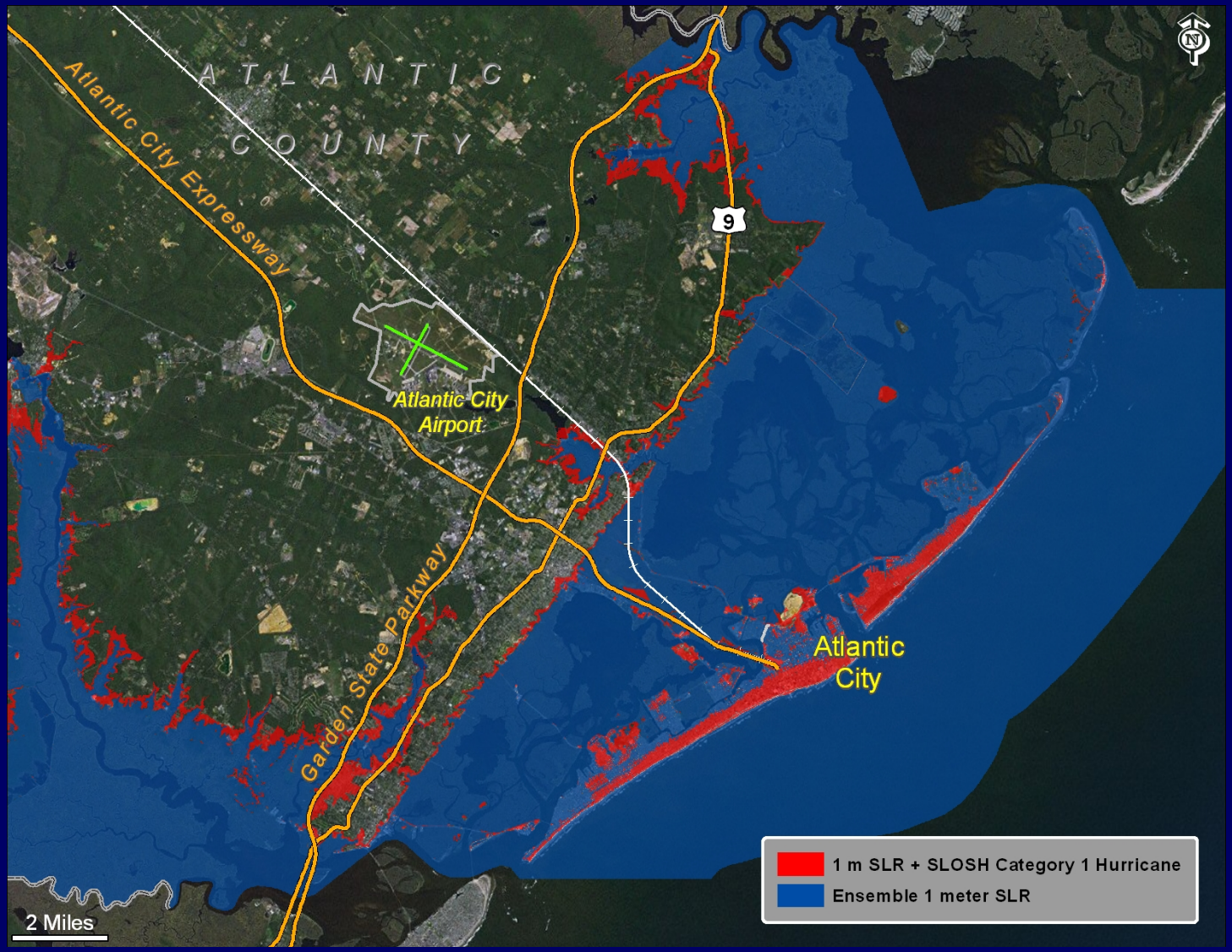
- Downscaling will not reduce uncertainties across GCMs
- May not correct GCM errors
- Do give more insight into regional and local factors
- Is most promising for long run

Storm Surge Scenarios

- Start with global average projections of sea level rise
  - 50 cm by 2100 (Low)
  - 100 cm by 2100 (Central)
  - 150 cm by 2100 (High)
- Add in regional variation from climate models
- HOWL elevations derived from tide gauges and interpolated to study area (NOAA, 2011)

Station name	Station ID	Highest observed water level (station datum)	Mean higher high water (station datum)	HOWL above MHHW (feet)
The Battery	8518750	13.3	8.34	4.96
Atlantic City	8534720	13.94	9.56	4.38
Cape May	8536110	11.23	7.87	3.36
Sandy Hook	8531680	12.6	7.74	4.86

Sea Level Rise + Storm Surge



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Bottom-up Methods

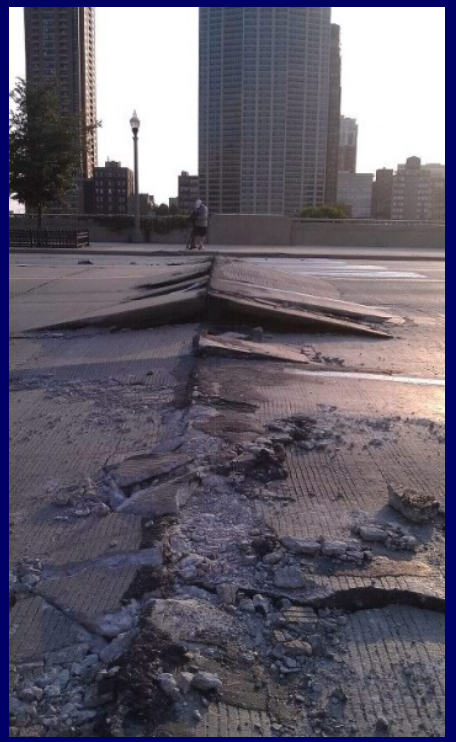
- Understand your transportation system
  - What aspects of climate currently affect it?
    - Extreme heat
    - Flooding
  - What are the critical thresholds?
    - High temperatures and duration
    - Rainfall, river flow, storm surge, and duration
  - What is the current frequency (likelihood) of exceeding these thresholds?

See How Conditions Can Change in the Future

- Examine climate model projections to see
  - Under how many scenarios (models + other assumptions) are thresholds or tolerances exceeded?
  - When is this projected to happen?
- # of models is not a probability but gives an indication of risks based on the models

Advantages of Bottom-up

- Focus on your system rather than model output
- Understand sensitivities to climate
- Get an indication of how soon and with what (imprecise) likelihood thresholds could be exceeded



Advantages of Scenario (Top-down) Approach

- Decision-makers like to see what we expect to happen under climate change
- Approach can identify surprises

Whatever Approach is Taken

- The critical thing is to understand how your transportation system could be vulnerable to:
  - Changes in climate variability
  - Long-term changes in climate
- Begin working on contingency planning and adaptation measures to reduce risks

Thank you!

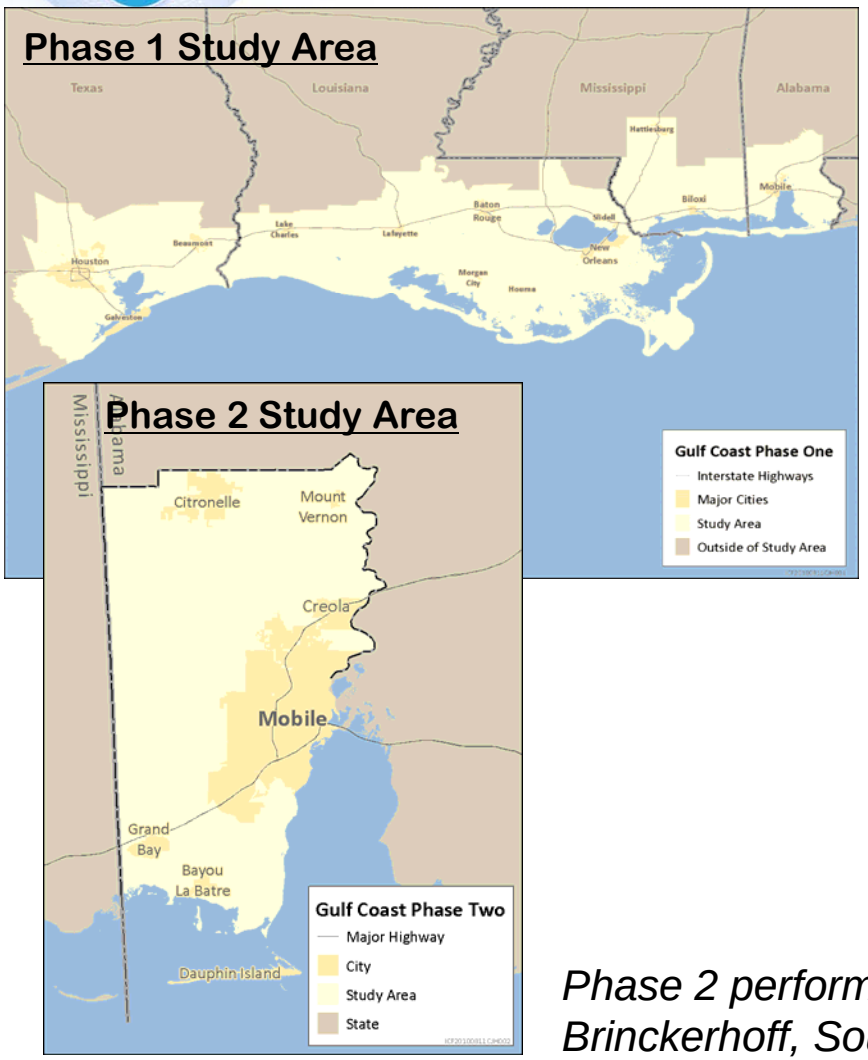
jsmith@stratusconsulting.com

Gulf Coast 2 Sea Level Rise and Storm Surge Projections

Rob Kafalenos
Sustainable Transport and Climate Change Team
FHWA

May 16, 2013

Gulf Coast 2 Project: Vulnerability Assessment at Metropolitan Scale



- **Primary Phase 2 Tasks**
  - Task 1: Identify critical transportation assets in Mobile (complete)
  - Task 2: Identify climate effects, assess infrastructure sensitivity (complete)
  - Task 3: Assess vulnerability of critical assets (2013)
  - Task 4: Develop transferable risk management tools (2014)
- **Completed tasks available from the FHWA website**

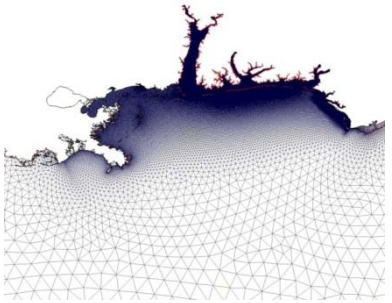
Phase 2 performed by ICF International (prime), Parsons Brinckerhoff, South Coast Engineers, and Texas A&M, with support from USGS and Katharine Hayhoe (Texas Tech)

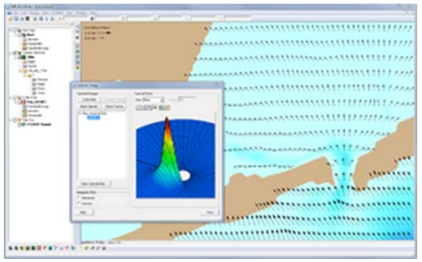
Gulf Coast 2: Climate Effects considered

- **Climate changes examined:**
  - **Local sea level rise** scenarios based on range of recent global SLR scenarios plus local subsidence
  - **Storm surge** modeling looked at range of storm intensities and included **wave** modeling
  - **(Temperature** and **precipitation** statistically downscaled from GCMs)

SLR and Storm Surge Scenarios (Summary)

- **Sea level rise**
  - Range of projected global SLR scenarios
  - Accounts for local land subsidence
- **Storm Surge Modeling (ADCIRC)**
  - Range of storm scenarios
  - Combined with range of SLR scenarios
  - Output includes surge distribution and depth
- **Wave Modeling (STWAVE)**
  - Inputs from ADCIRC output and boundary conditions
  - Outputs include key aspects of wave energy
- **GIS analysis – Potential inundation**
  - **Exposure of transportation systems to SLR, Storm surge**

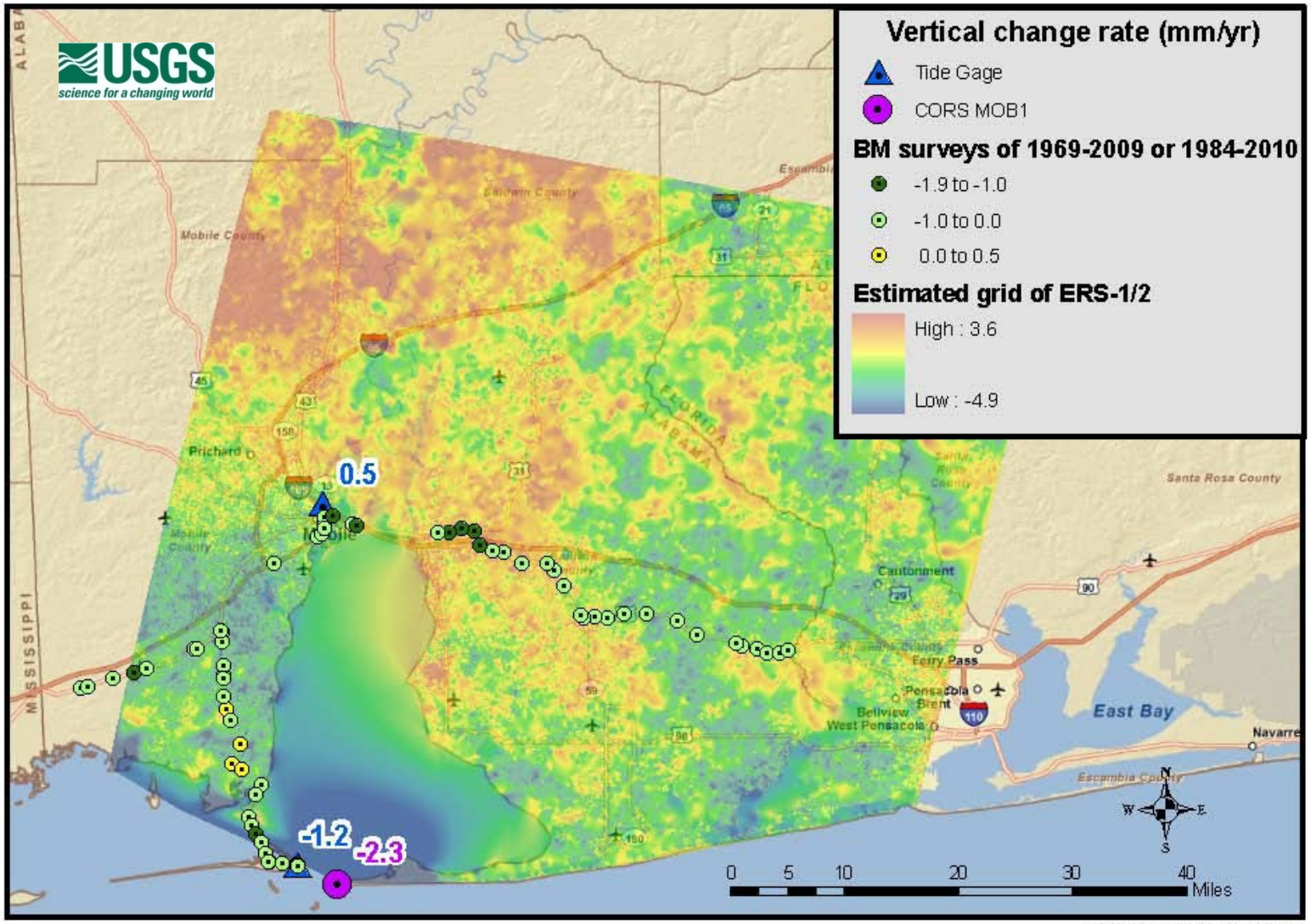




Local Sea Level Rise Scenarios

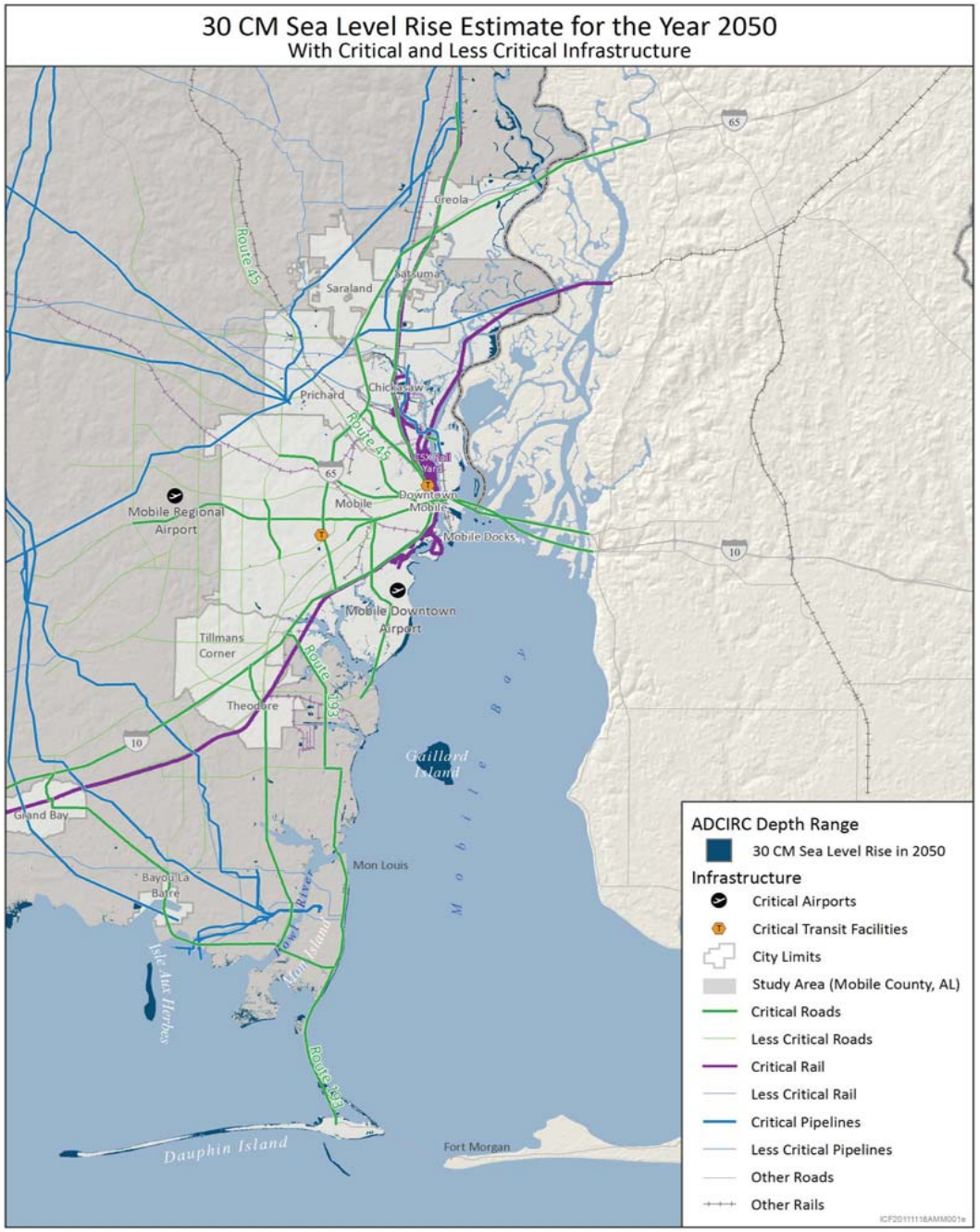
- **Selected scenarios based on recent understanding of Global SLR**
  - **30 cm by 2050**
  - **75 cm by 2100**
  - **200 cm by 2100**
- **Included Land Subsidence/Uplift**
  - **Accounts for land subsidence using survey data and satellite measurements. (Data provided by USGS.)**

Land Subsidence

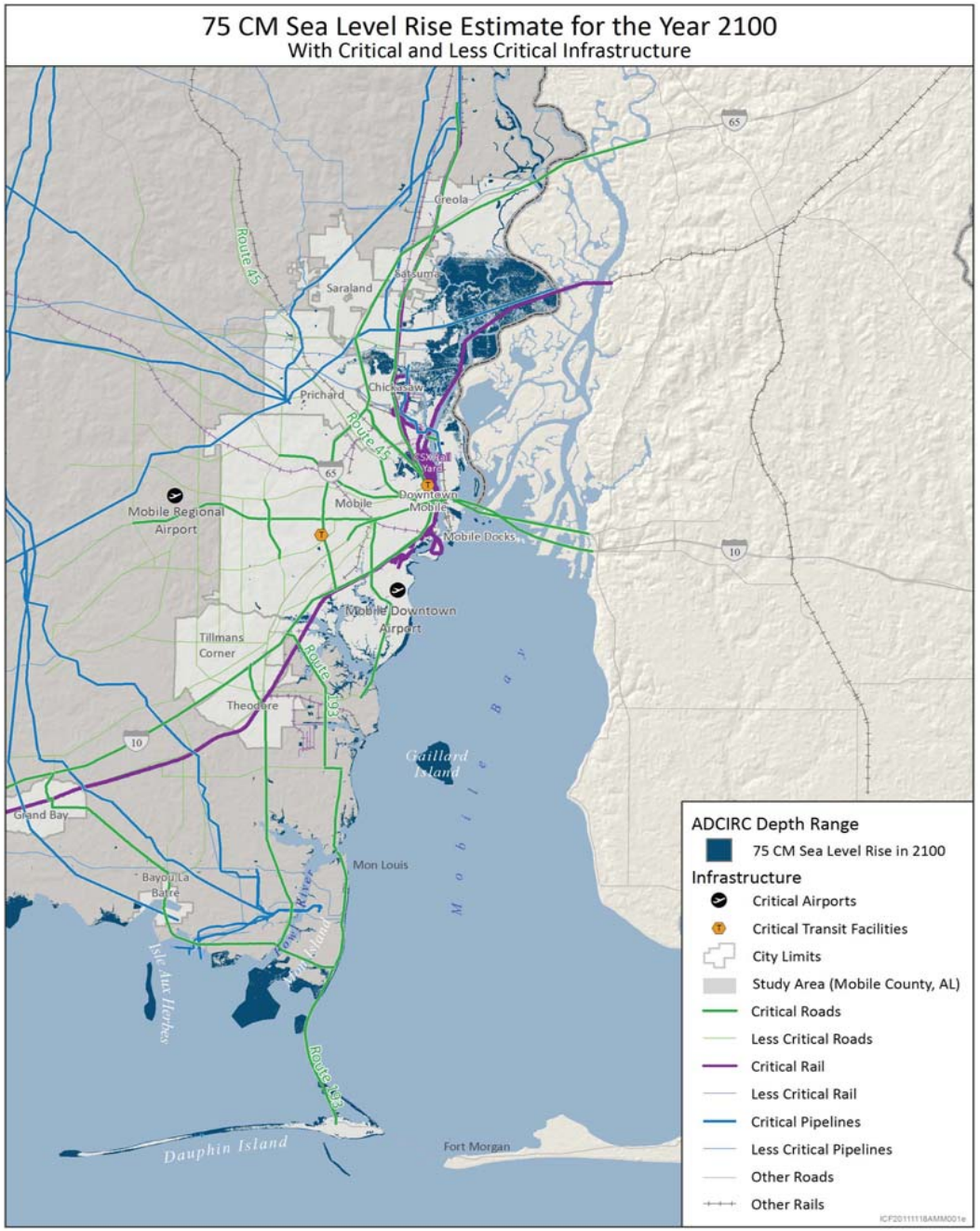


K. Van Wilson, USGS, 02-11-11

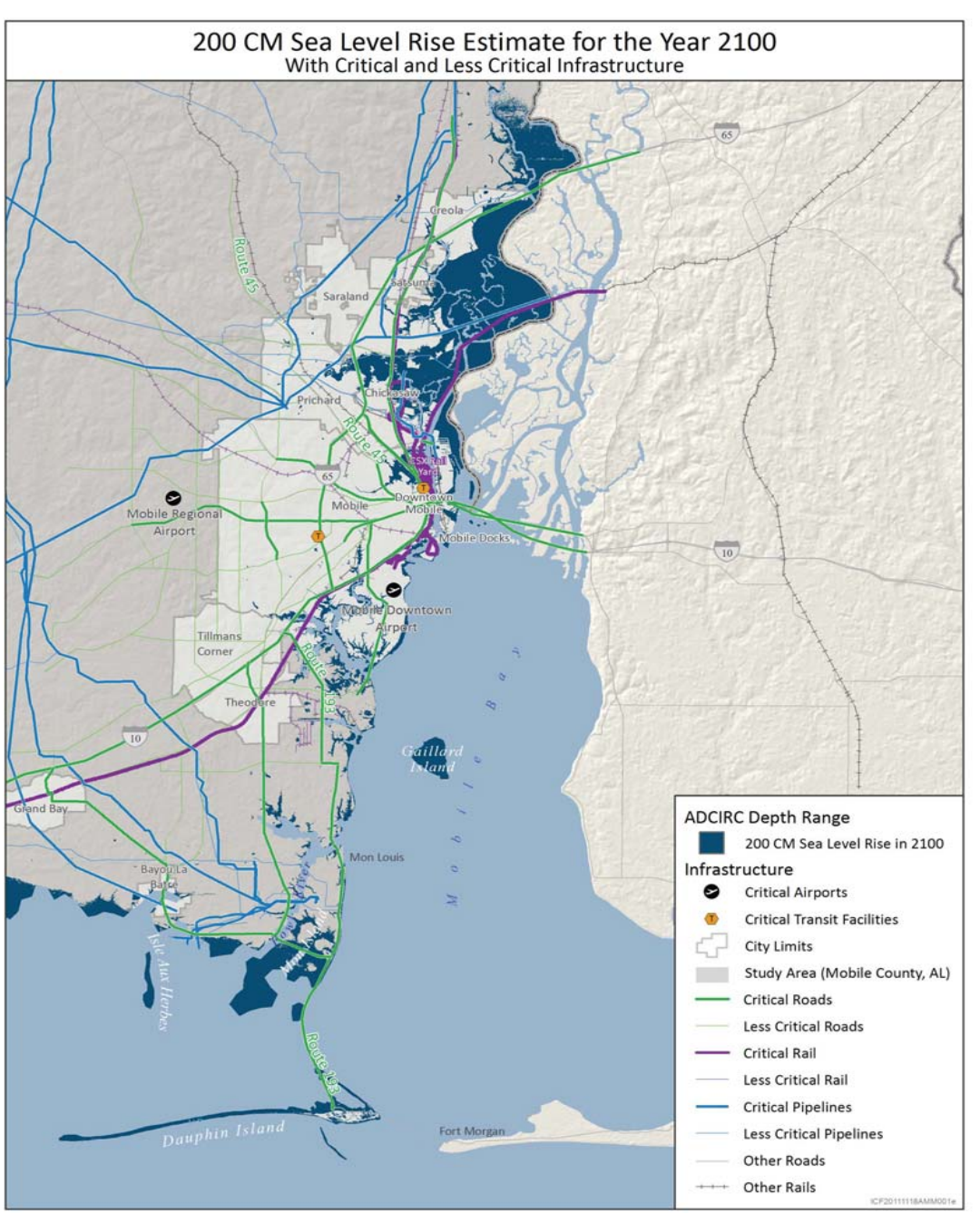
SLR -- 30 cm
Potential Inundation



SLR -- 75 cm
Potential Inundation



SLR -- 200 cm
Potential Inundation



Critical Assets Inundated Under Each SLR Scenario

Scenario	Roads (miles)	Rail (miles)	Ports (#)	Transit Facilities (#)	Mobile Downtown Airport (mi^2)*
2050 0.3m	2 of 203 (1%)	0 of 194 (0%)	0 of 27 (0%)	0 of 2 (0%)	0 of 3 (1%)
2100 0.75m	5 of 203 (2%)	2 of 194 (1%)	0 of 27 (0%)	0 of 2 (0%)	0 of 3 (2%)
2100 2.0m	50 of 203 (24%)	40 of 194 (21%)	5 of 27 (19%)	1 of 2 (50%)	0 of 3 (3%)

Storm Surge Scenarios

- **Scenarios based on historic hurricanes, with varying**
  - **Track**
  - **Sea level rise (30 cm, 75 cm, 2.0 m)**
  - **Intensity**
- **Does not examine loss of barrier islands**
- **Why the ADCIRC model?**

Storm Surge Modeling Scenarios

Hurricane Georges

Natural Path, No SLR

Natural Path, 30 cm SLR

Natural Path, 75 cm SLR

Natural Path, 200 cm SLR

Hurricane Katrina

Natural Path, No SLR

Natural Path, 75 cm SLR

Shifted, No SLR

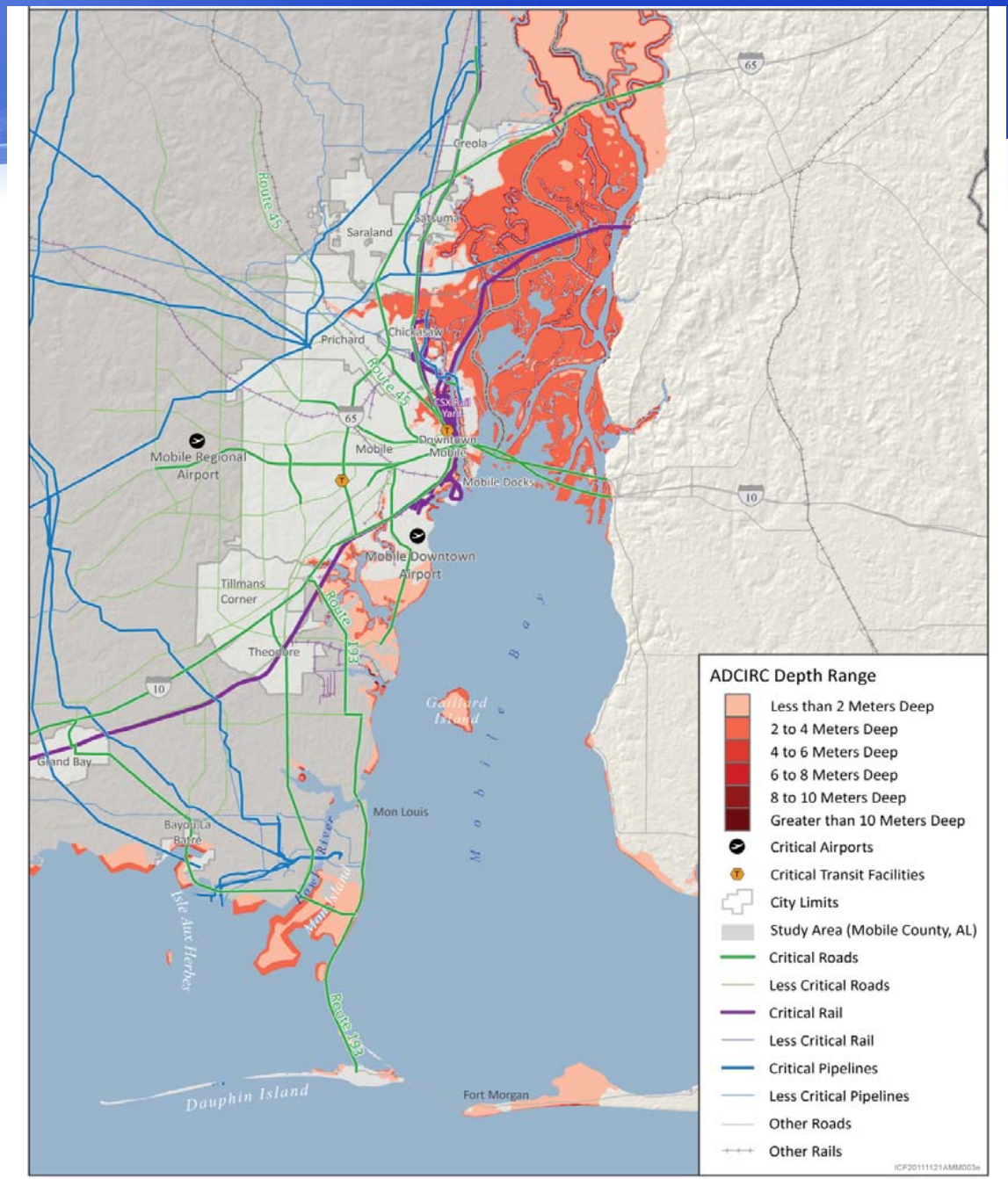
Shifted, 75 cm SLR

Shifted, Reduce Pressure, 75 cm SLR

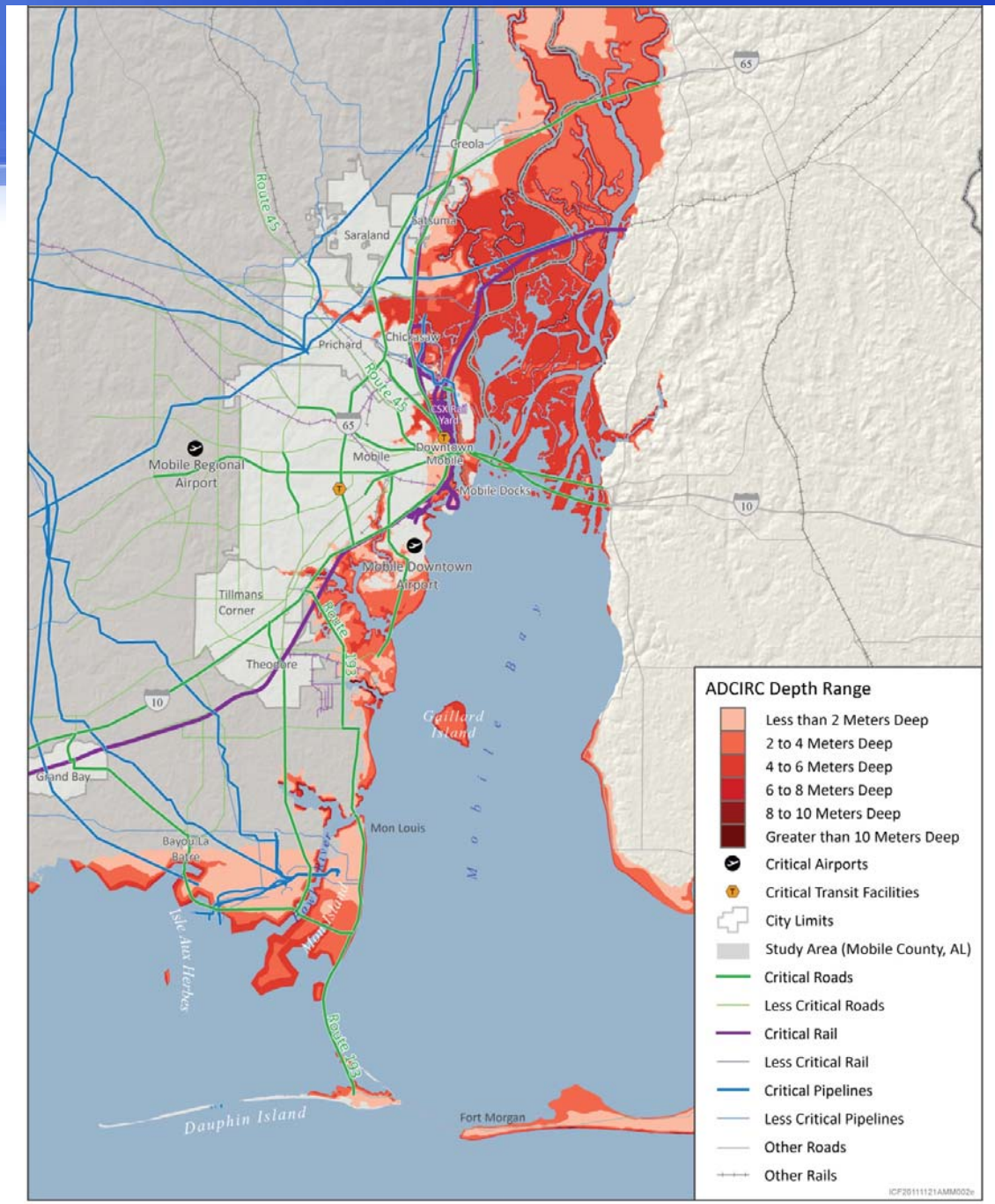
Shifted, Intensified, No SLR

Shifted, Intensified, 75 cm SLR

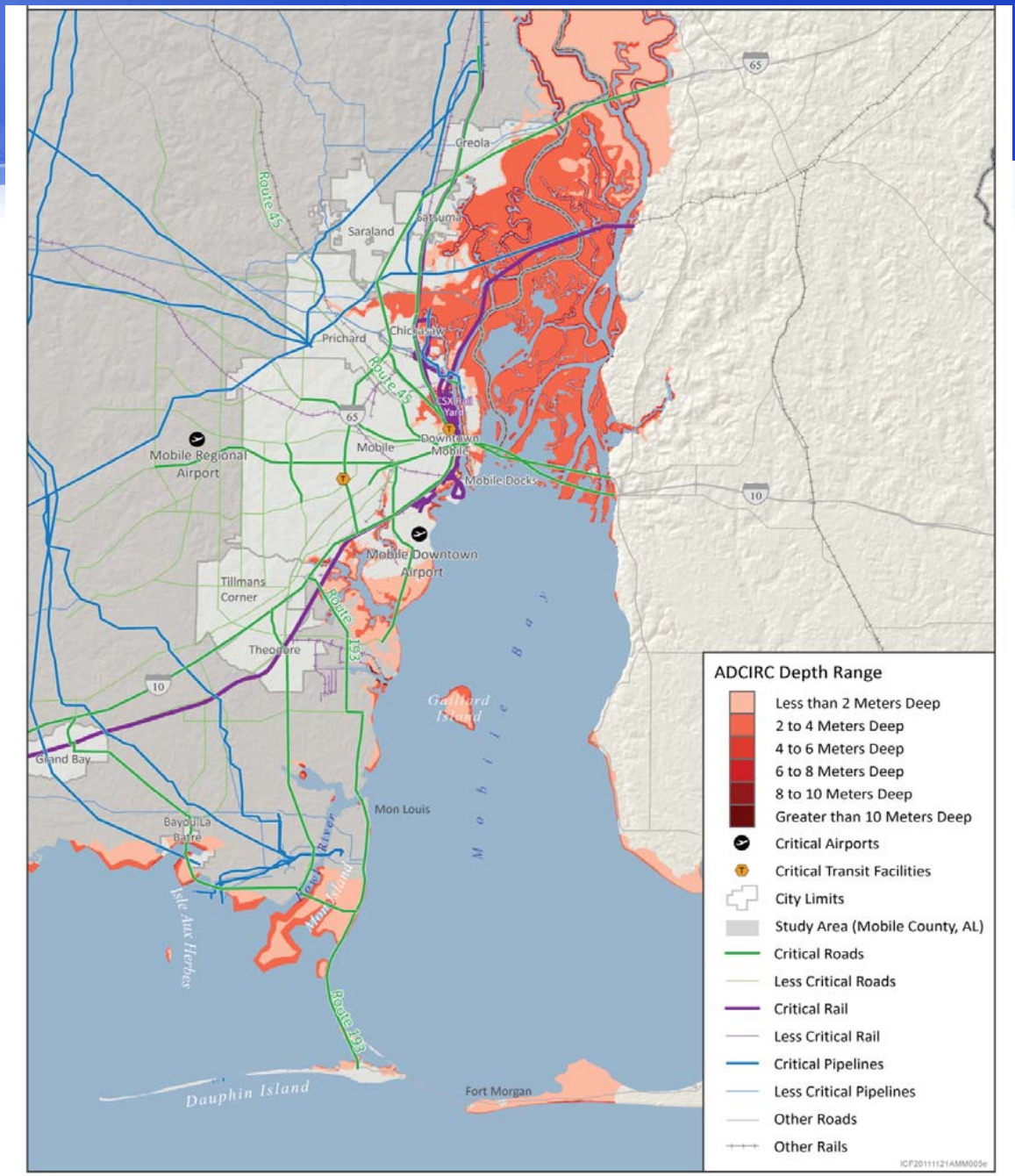
Georges
No SLR



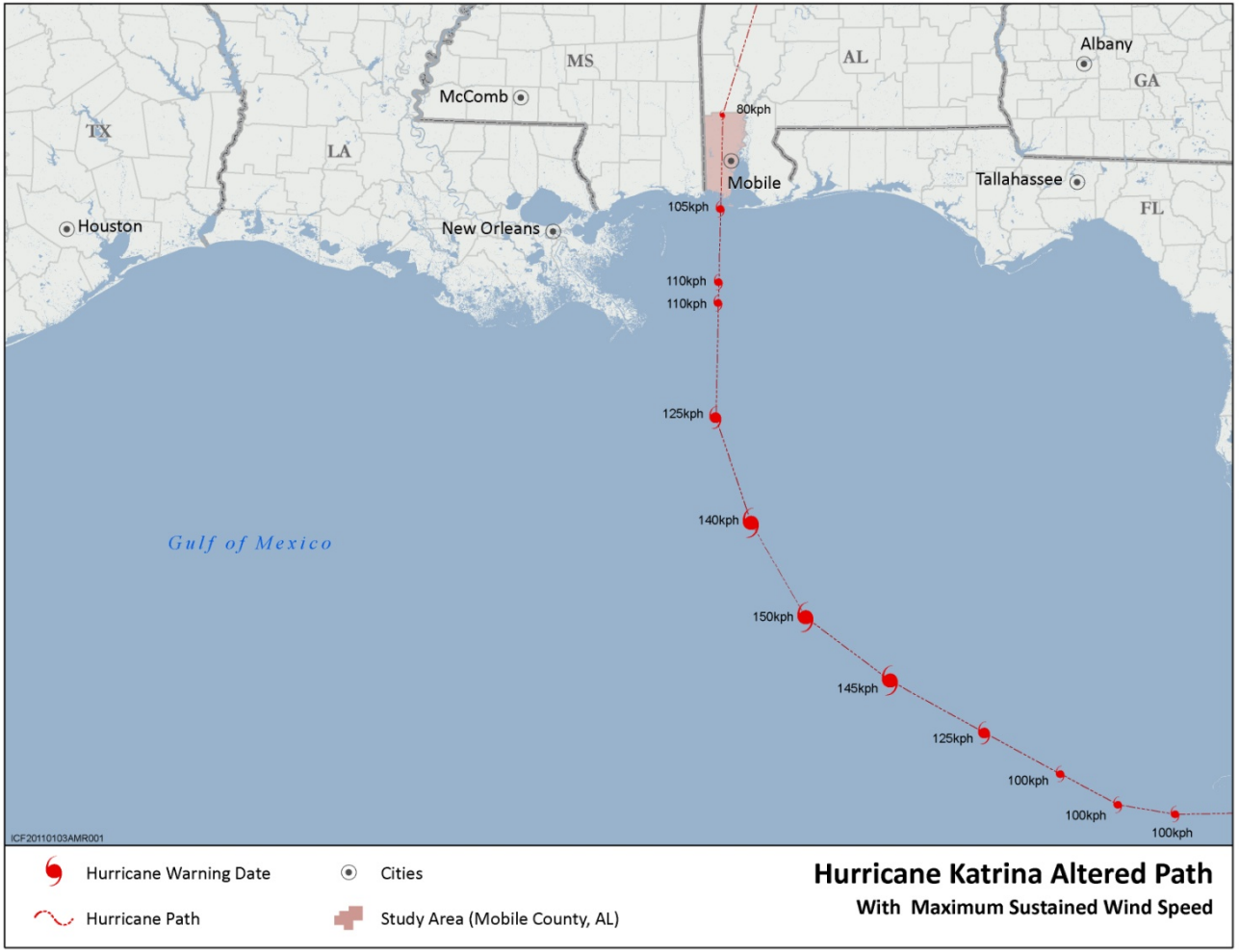
Georges
200 cm SLR



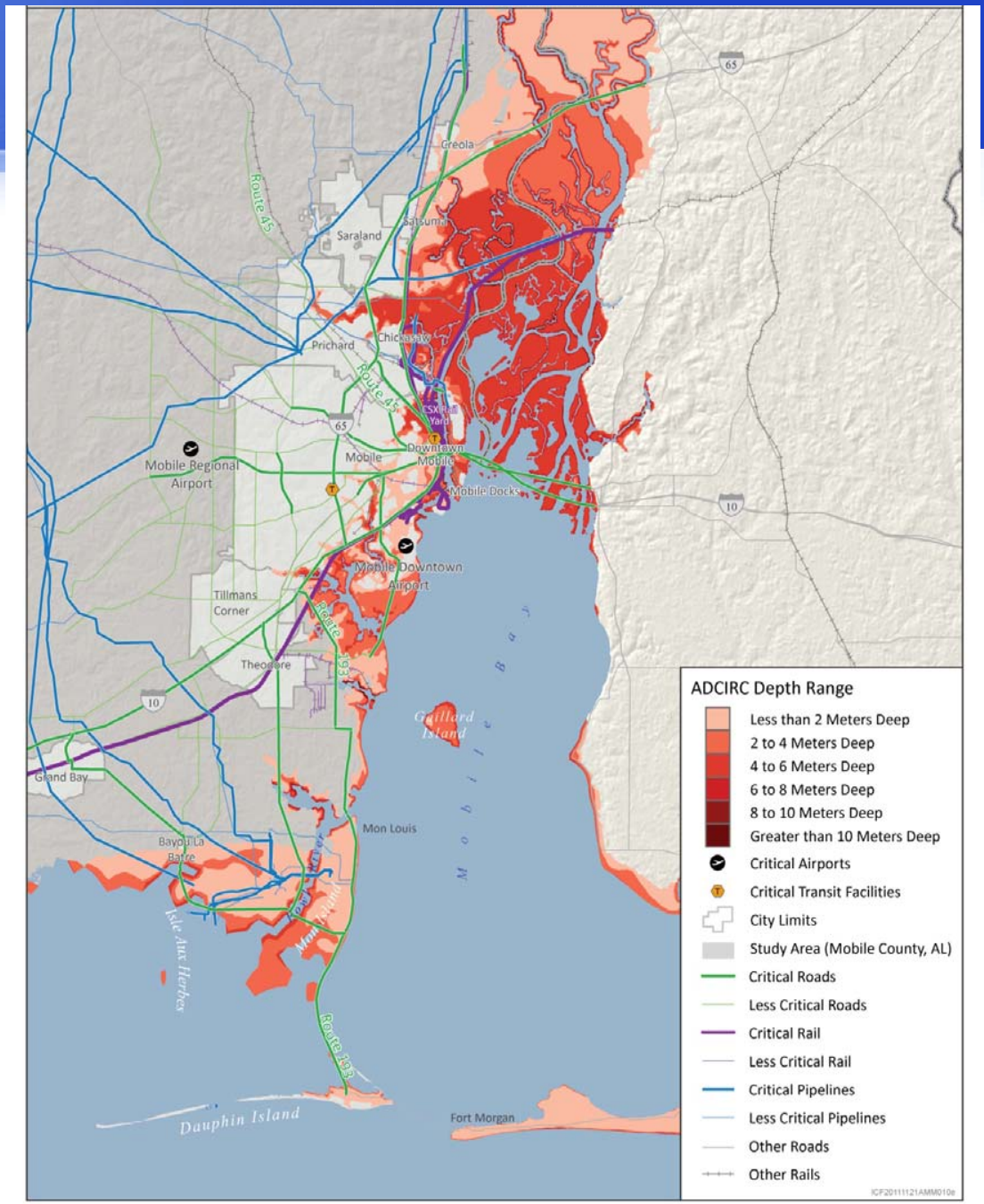
Katrina
Natural Path
No SLR



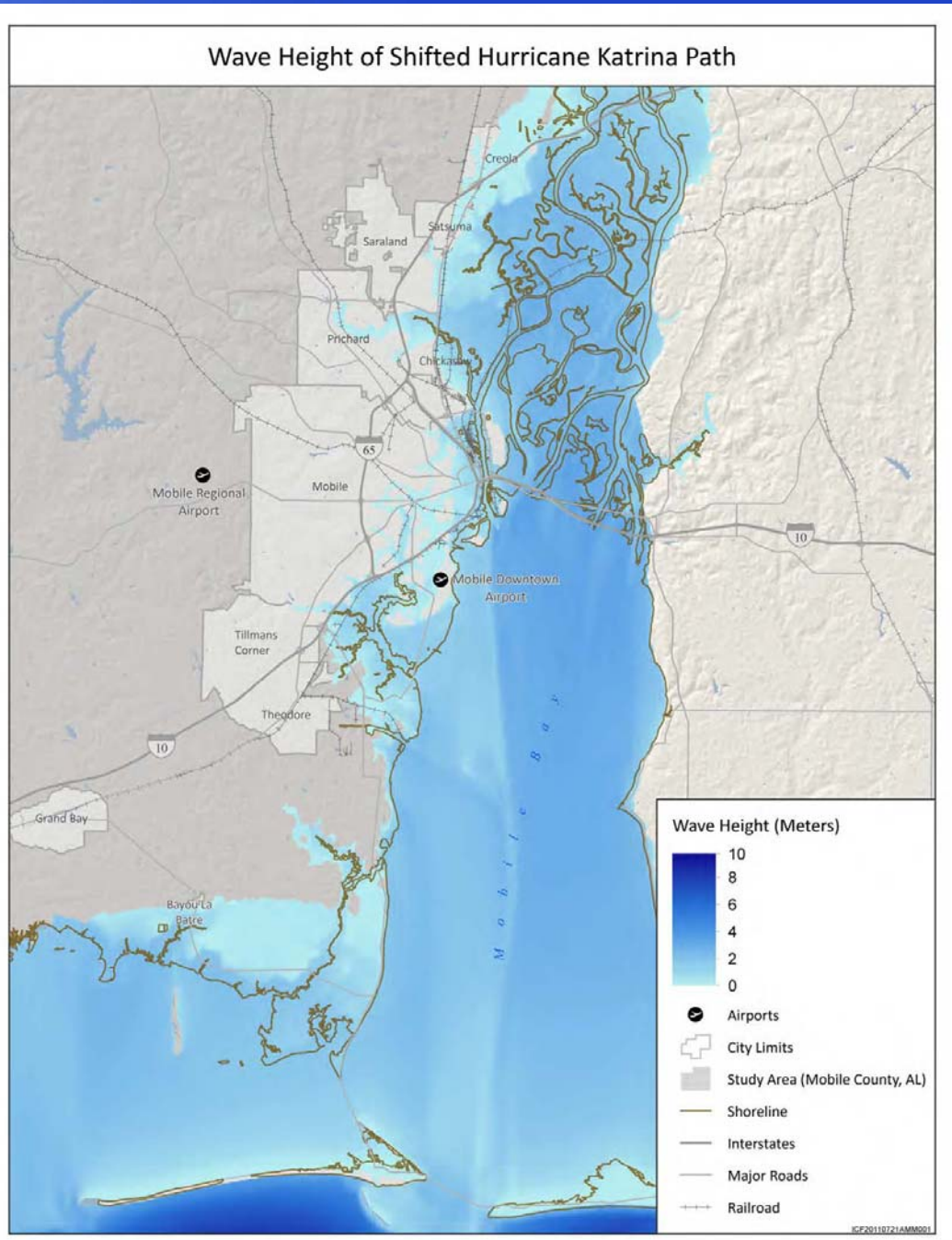
Shifting Hurricane Katrina's Path



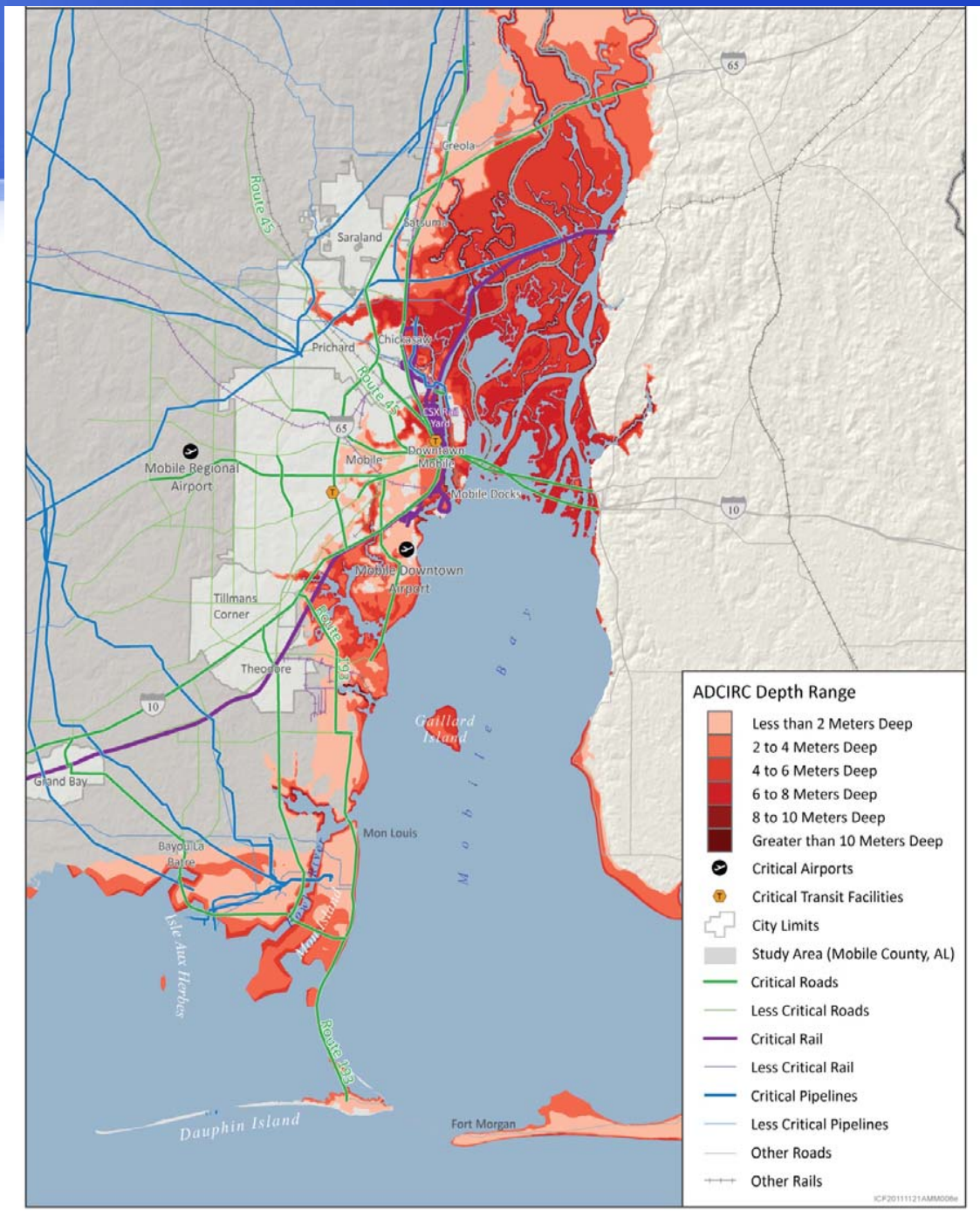
Katrina
Shifted Path
No SLR



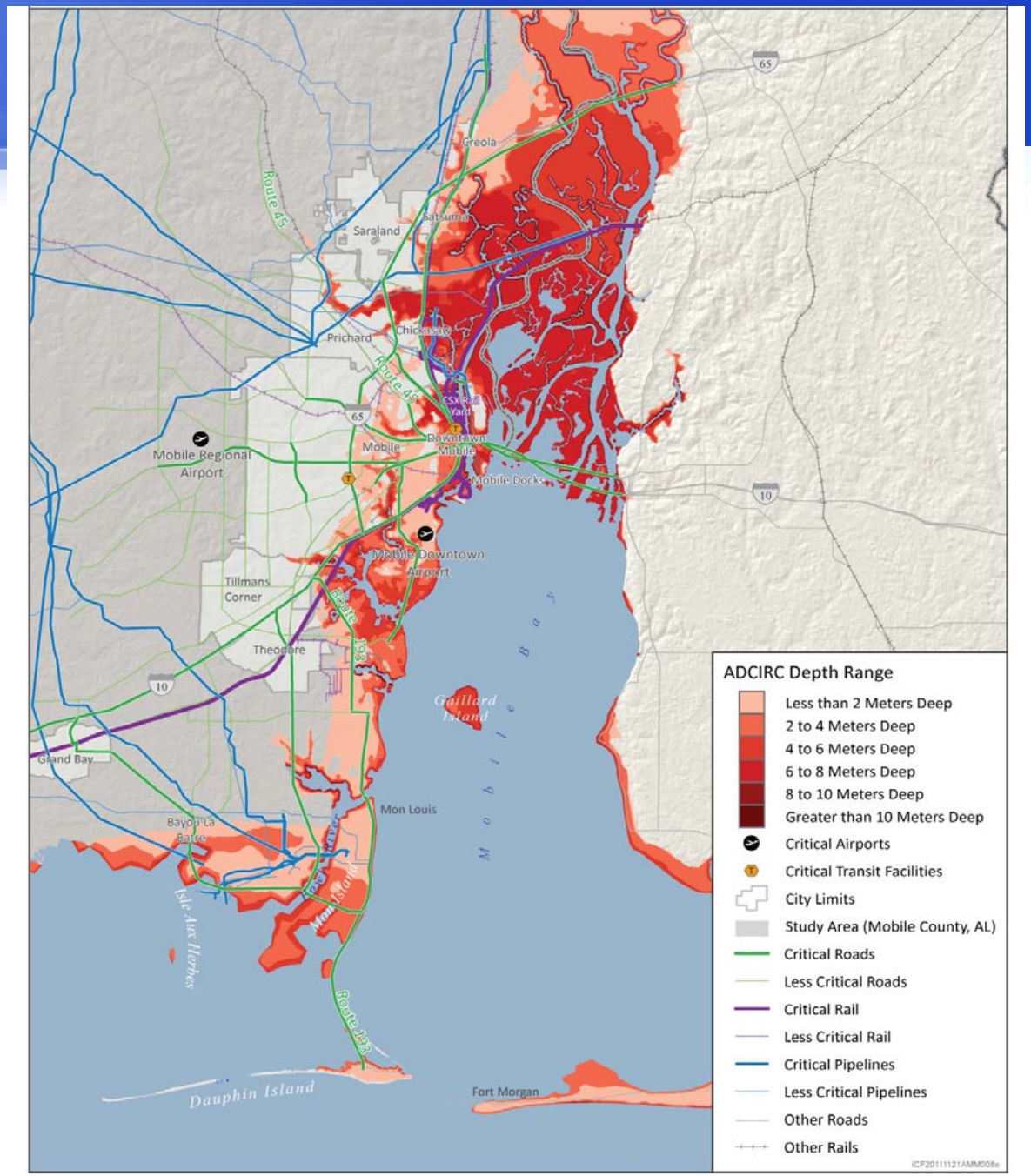
Wave height example



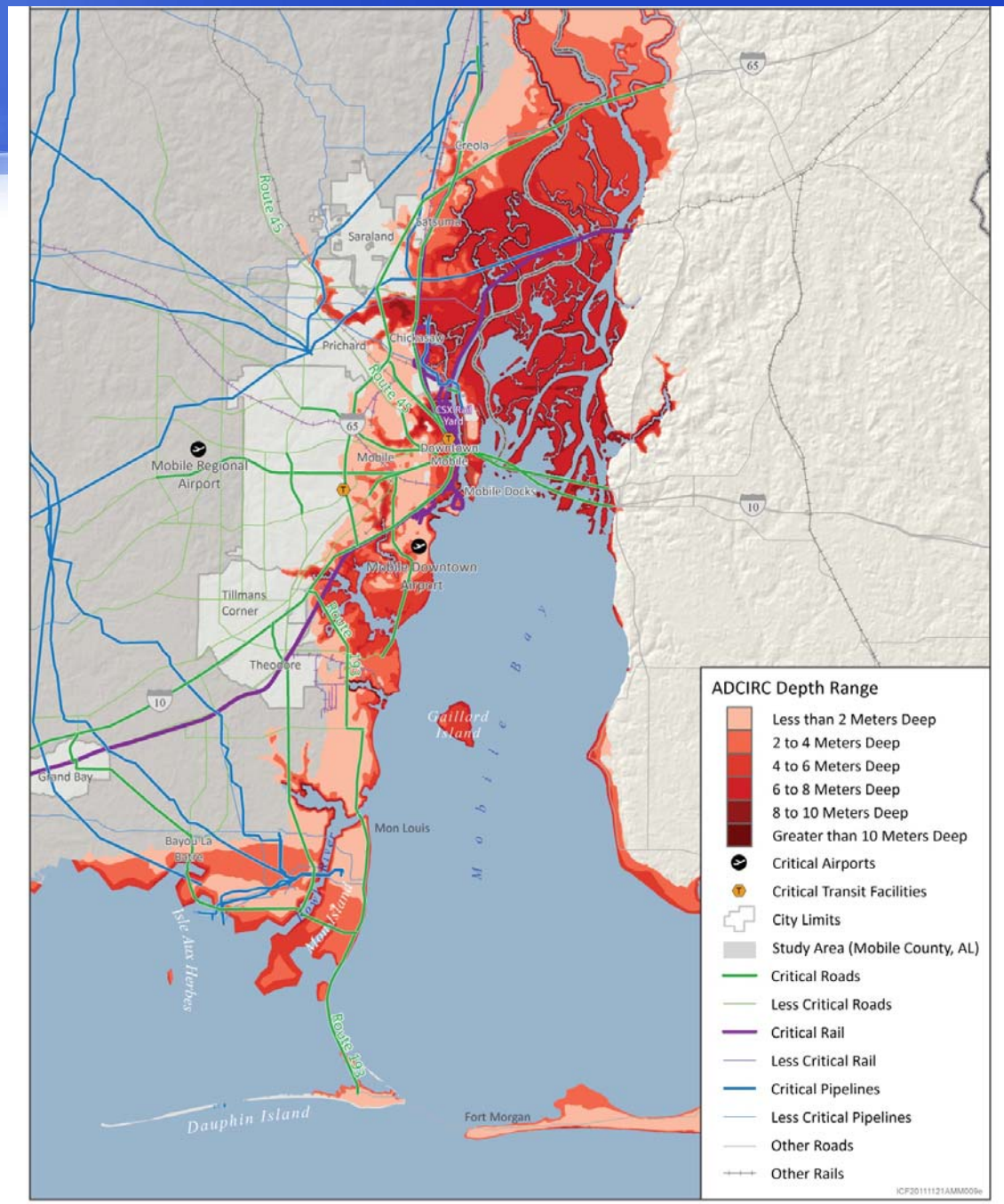
Katrina
Shifted Path
75 cm SLR



Katrina
Shifted Path
Reduced central pressure
75 cm SLR



Katrina
Shifted Path
Intensified
No SLR



Critical Assets Inundated–Storm Surge

Scenario	Roads (mi)	Rail (mi)	Ports (#)	Transit Facilities (#)	Mobile Downtown Airport (mi^2)*
Georges-Natural	33 of 203 (16%)	111 of 194 (57%)	20 of 27 (74%)	1 of 2 (50%)	0 of 3 (4%)
Katrina-Natural	36 of 203 (18%)	116 of 194 (60%)	20 of 27 (74%)	1 of 2 (50%)	0 of 3 (5%)
Georges-Natural-200cm	78 of 203 (38%)	132 of 194 (68%)	24 of 27 (89%)	1 of 2 (50%)	0 of 3 (15%)
Katrina-Natural-75cm	36 of 203 (18%)	127 of 194 (66%)	22 of 27 (81%)	1 of 2 (50%)	0 of 3 (9%)
Katrina-Shift	73 of 203 (36%)	140 of 194 (72%)	24 of 27 (89%)	1 of 2 (50%)	2 of 3 (65%)
Katrina-Shift-75cm	92 of 203 (45%)	144 of 194 (74%)	24 of 27 (89%)	1 of 2 (50%)	2 of 3 (90%)
Katrina-Shift-ReducedPress-75cm	102 of 203 (50%)	146 of 194 (76%)	24 of 27 (89%)	1 of 2 (50%)	3 of 3 (98%)
Katrina-Shift-MaxWind	119 of 203 (58%)	150 of 194 (78%)	26 of 27 (96%)	1 of 2 (50%)	3 of 3 (100%)

Thank you

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

QUESTIONS?

Upcoming Webinars

Session 2: System-Level Vulnerability Assessments

Date: Thursday, May 30, 3:00 – 4:30 pm EDT

This session will focus on use of information on transportation assets and climate projections to identify vulnerabilities. Representatives from the San Francisco Bay Area Metropolitan Transportation Commission, Washington DOT, and the New Jersey Transportation Planning Authority will provide example applications of system-level vulnerability and risk assessments.

Session 3: Applying the Results

Date: Wednesday, June 12, 2:00 – 3:30 pm EDT

Representatives from the Boston Region MPO and Los Angeles Metropolitan Transportation Authority will discuss incorporating vulnerability assessment results into agency decision making processes and developing adaptation options.

Session 4: Hurricane Sandy - Lessons Learned

Date: Thursday, June 20, 2:00 – 3:30 pm EDT

The impacts of Hurricane Sandy underscore the need for proactive planning for extreme weather events. This session will focus on extreme weather preparations, emergency response, recovery, and planning for long term resilience.

Register at http://www.fhwa.dot.gov/environment/climate_change/adaptation/webinars/