Climate Change and Transportation Impacts

Robert Kafalenos, FHWA
Sustainable Transport and Climate Change Team

May 21, 2012

Why Should Transportation Agencies Be Concerned with Climate Change Impacts?

- Need to protect integrity of transportation investments, promote safety
  - Infrastructure has long design life (decades)
  - Infrastructure needs to handle new conditions as climate changes
  - Adaptation means ensuring that we plan our infrastructure for the future
- FHWA Goal: Systematic consideration of climate change vulnerability and risk in transportation decision making, at system and project level

Flooded roadways in Houston

FHWA Climate Change Adaptation Activities and Resources

- Potential Impacts of Global Sea Level Rise on Transportation Infrastructure: Mid-Atlantic Focus (2008) (U.S. DOT)
- Regional Climate Change Effects: Useful Information for Transportation Agencies [Climate Effects Typology] (2010)
- Vulnerability and risk assessment conceptual model (2010), update (2012)
- Pilots of vulnerability / risk assessment conceptual model (2011)
- Gulf Coast Study: Impacts of Climate Variability and Change on Transportation Systems and Infrastructure (U.S. DOT)
  - Phase 1 – Gulf-wide (2008) [SAP 4.7]
  - Phase 2 – Mobile, AL (ongoing)

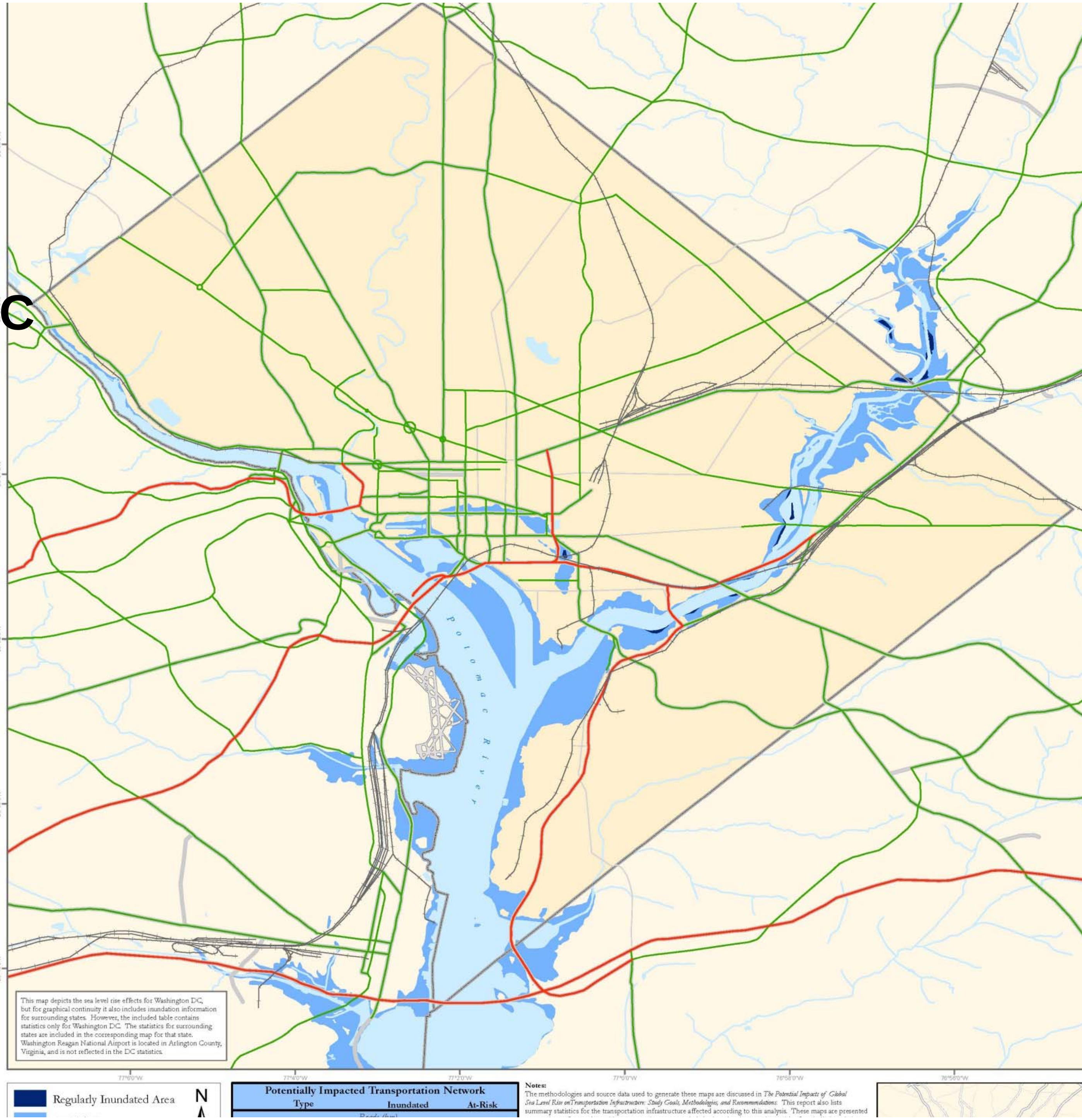
Mid-Atlantic SLR study (2008)

Goal: first look at how SLR could affect transportation assets

- Develop current (2000) sea level surface models
- Create future sea level surface models (MHHW plus SLR increment: regularly underwater)
- Create future storm surge surface models (HOWL plus SLR increment: flooded during storms)
- Identify land areas, transportation infrastructure that could be affected

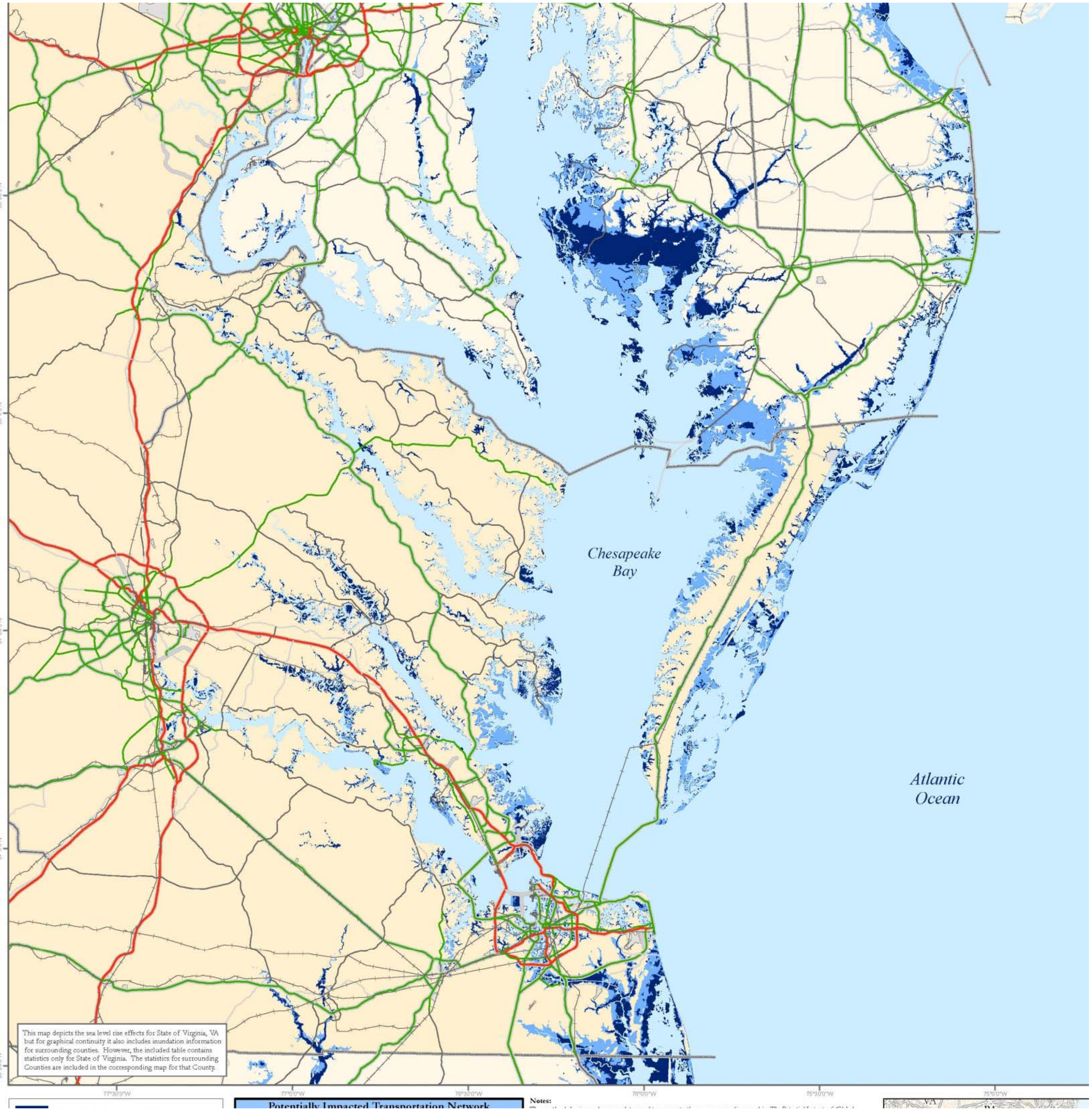
Washington, DC

59 cm



Virginia

59 cm



More recent projections of Sea Level Rise are much higher

Study	Global Sea Level Rise, to 2100
IPCC (2007)	**7" to 23"**
Newer studies	**20'' to 79"**

Local sea level rise may differ from global estimates due to:

- Subsidence/uplift of land
- Sedimentation and erosion
- Ocean circulation patterns
- Gravitationally induced changes
- Ocean density (ocean salinity and temp)

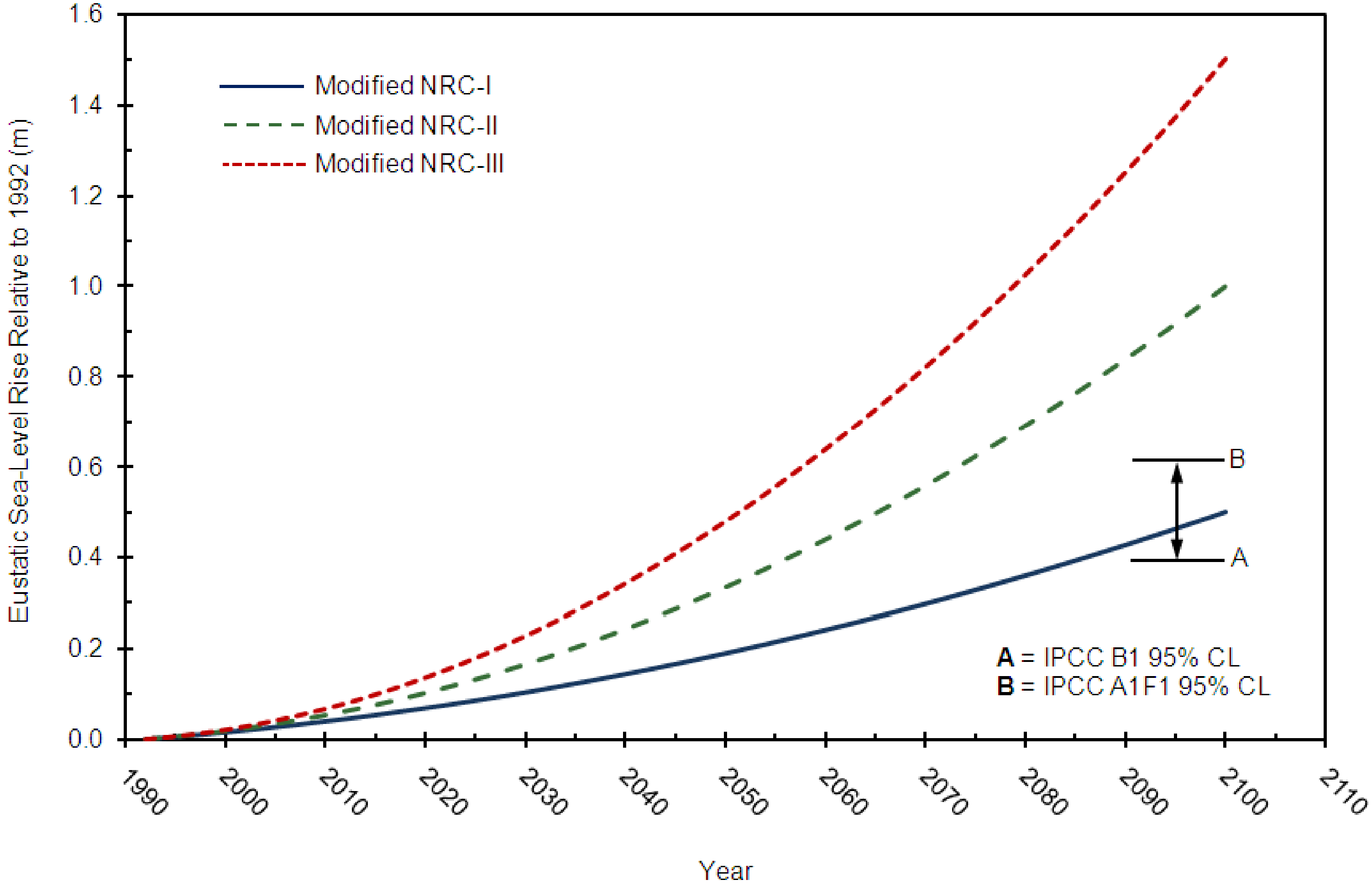
Tropical storms & Hurricanes: Consensus today suggests projected <u>global</u> conditions by 2100:

- Increase in intensity, decrease in frequency
- Increase in frequency of most intense storms

Other SLR scenarios

- **California**
  - 2070: 23 to 27 inches
  - 2100: 40 to 55 inches
- **US Army Corps**
  - "Sea-Level Change Considerations for Civil Works Programs" (EC 1165-2-212) (2011)
  - Analyze 3 levels of SLR, up to 1.5 m (5 ft) by 2100
  - Land subsidence/uplift (an issue for some mid-Atlantic states)

Global Mean Sea Level (USACE)



Climate Effects, Transportation Impacts

CLIMATE CHANGE EFFECT	IMPACTS
Higher high temperatures, more hot days	• Asphalt deterioration, road buckling • Thermal expansion of paved surfaces (bridge joints?) • Changes to biodiversity (impacting pest management, wetlands commitments) • More night time work, longer construction season • Pavement & structural design changes
Wind speeds	• More frequent sign damage, truck rollovers • Changes to testing of and design factors for wind speed • Need for stronger materials
More frequent, intense precipitation	• Loss of visibility, lane obstruction • Increase in weather-related delays, traffic disruption • Increased flooding of roads, evacuation routes • Increased peak stream flow could affect scour rates, influence size requirements for culverts • Standing water could affect road base adversely

Climate Effects, Transportation Impacts

CLIMATE CHANGE EFFECT	IMPACTS
Increased coastal storm intensity	• Increased storm surge and wave impacts on roads, bridge structures , signs, etc. • Decreased expected lifetime of highways exposed to storm surge • Damage to infrastructure caused by the loss of coastal wetlands and barrier islands • Erosion of land supporting coastal infrastructure and highways
Sea level rise	• Permanent inundation of some roads and areas, reduced route options/redundancy • Erosion of road base • Reduced clearance under bridges • Exposes new areas to effects of storm surge/wave action, potentially causing more frequent interruptions to coastal roads • May amplify storm surges in some cases, requiring greater evacuations

Flooding - More Frequent Floods

Lateral Migration

Flooding – Larger Floods

Increased debris potential, scour & embankment failure

Impact of More Frequent High Intensity Storms

- Gutter flow encroachment on driving lanes
- Hydroplaning and safety issues
- Surcharged storm drains
- Flooded underpasses

Road Buckling – Oklahoma

Road Buckling - Texas

Adaptation Responses

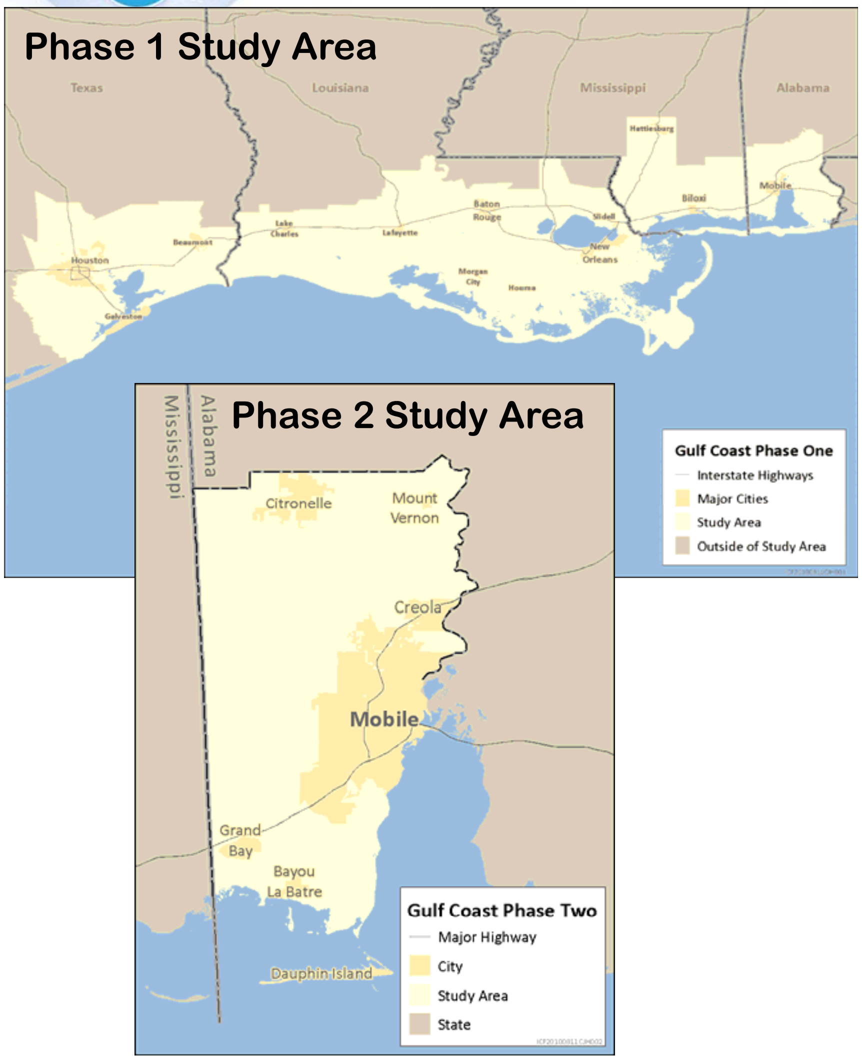
- **Maintain & Manage**
  - Higher maintenance costs
- **Protect, Strengthen**
  - Sea walls and buffers
  - Design changes when rebuilding
- **Relocate & Avoid**
  - Move key facilities, site new facilities in less vulnerable locations
- **Abandon and Disinvest**
- **Enhance Redundancy**

Sources: WSDOT and Caltrans

Climate Change Vulnerability Assessments

- **Understanding how climate change will affect your transportation network is key first step for planning**
- **Two major projects testing approaches to vulnerability assessments:**
  - Gulf Coast 2 Study
  - Pilot program

Gulf Coast Project



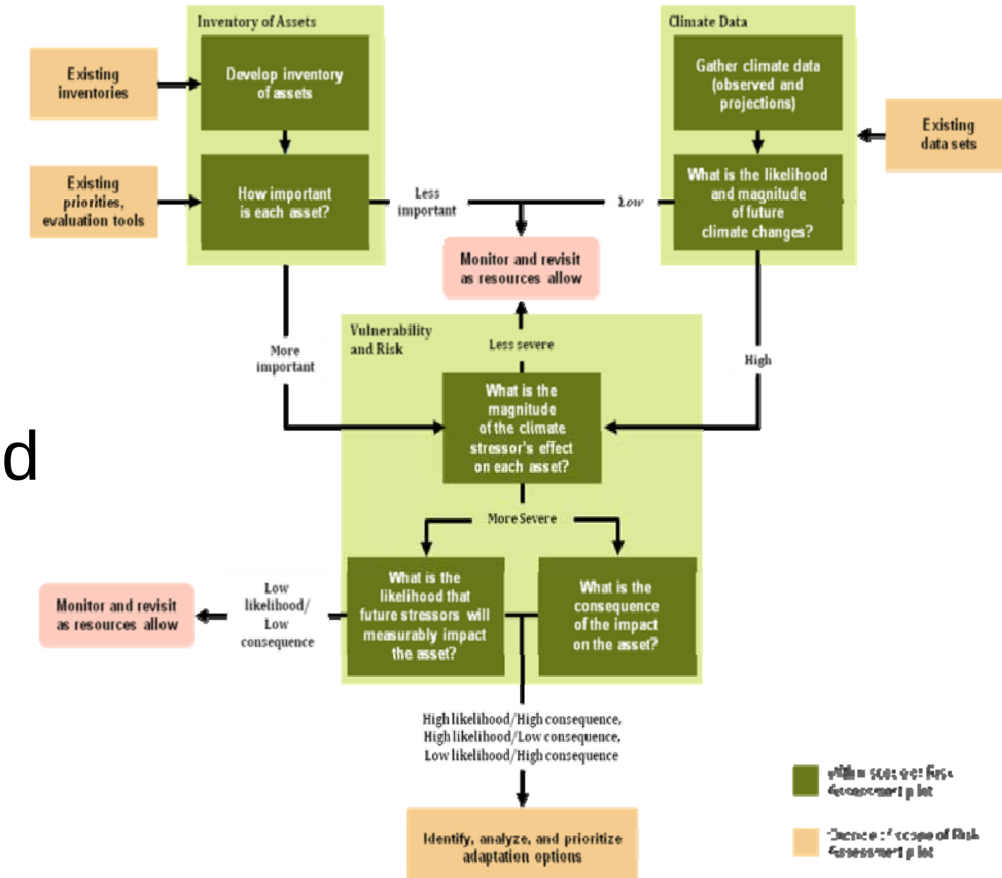
- **Primary Phase 2 Tasks**
  - Task 1: Identify critical transportation assets in Mobile (complete)
  - Task 2: Identify climate impacts (summer 2012)
  - Task 3: Assess vulnerability of critical assets (2012-2013)
  - Task 4: Develop risk management tools
- **Task reports posted as completed**

Use Relevant Thresholds To Determine Climate Data Needed…

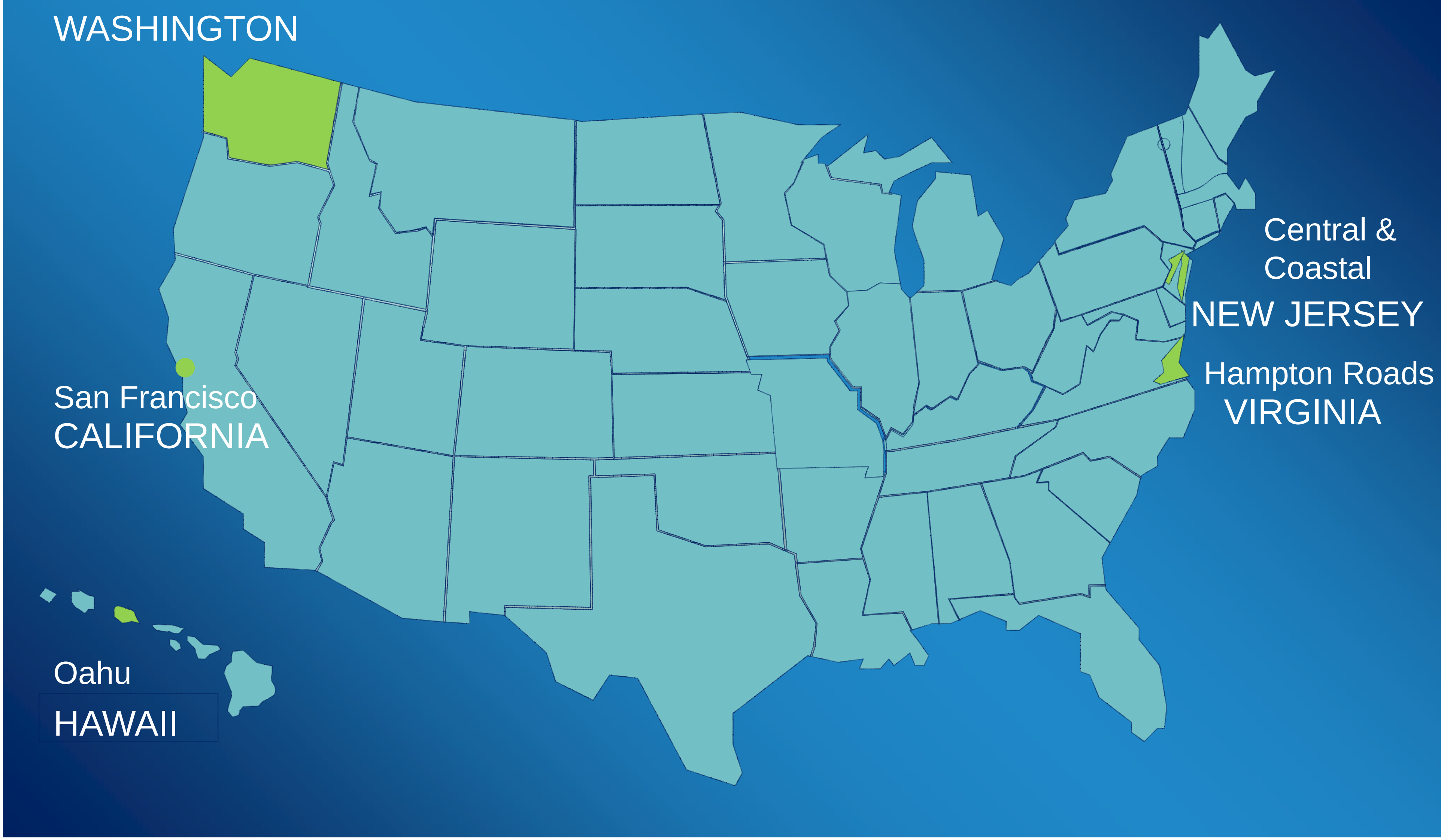
Variable	Analysis
Annual, Seasonal and monthly precipitation	Pavement Design
Annual, seasonal, and monthly average minimum, maximum, and mean temperature	Runway Design
Daily high temperature: mean, 50 %ile, 95 %ile, and warmest day in the year during each 30-yr period	AREMA Rail design / buildings
Maximum 7-day average air temperature per year with the % probability of occurrence during each 30-yr period (mean, 50%, 90%, 95%, 99% occurrence)	Pavement Design (Asphalt)
Exceedance probability precipitation for 24-hour period with a 0.2%, 1%, 2%, 5%, 10%, 20%, and 50% exceedance precipitation events (e.g., 500-yr, 100-yr, 50-yr, ..)	Drainage / Liquid Storage

Vulnerability and Risk Assessment Conceptual Model/Framework

- Develop inventory of infrastructure assets
- Gather climate data
- Assess vulnerability and risk of assets to projected climate change
- Analyze, prioritize adaptation options
- Monitor and revisit



Climate Change Vulnerability and Risk Assessment Pilot Locations



Pilot: Metropolitan Transportation Commission

Asset Risk Profile

Coliseum / Oakland Airport BART Station (T-04)

Asset Location / Jurisdiction
Oakland / BART

Summary
The Coliseum / Oakland Airport BART Station is a transit facility serving East Oakland neighborhoods and includes bus transfer and parking facilities. Pedestrian connections are available to Oakland Coliseum Amtrak Station, and frequent and direct bus service is provided from the BART station to Oakland International Airport. The future Oakland Airport BART Connector, currently under construction, will provide an automated guideway transit connection between the station and the airport. Due to lack of data, this asset was not rated with respect to sensitivity. Exposure is rated low, due to inundation under only 100-year SWEL + wind waves for both the 16" and 55" SLR scenarios. No adequate alternative station exists for the Coliseum / Oakland Airport BART Station, resulting in a medium vulnerability rating. Consequence is rated high for capital improvement costs, commuter use, and socioeconomic impact; moderate for time to rebuild; and low for public safety and goods movement, which does not apply. The overall consequence rating is 3.33, making this a medium-risk asset.

Characteristics:
- Elevated
- Commuter route
- Transit routes [3 BART Lines; AC Transit: 45, 46, 73, 98, 356, 805]

Sensitivity	
Data unavailable in project timeframe.	
Liquefaction Susceptibility	Medium
Exposure: Low	
Maximum Inundation Depths	
16" + MHHW	0 ft
16" + 100-yr SWEL	0 ft
16" + 100-yr SWEL + wind waves	YES
55" + MHHW	0 ft
55" + 100-yr SWEL	0 ft*
55" + 100-yr SWEL + wind waves	YES
Inadequate Adaptive Capacity (16" SLR): High	
No adequate alternative station	
Vulnerability Rating (mid century): Medium	

*The asset is inundated to 0.3 ft at 55" + 100-yr SWEL SLR scenario, which was rounded down to 0 ft due to resolution limitations of the mapping

Projected Inundation with 16 inch SLR + 100-yr SWEL

Projected Inundation with 55 inch SLR + 100-yr SWEL

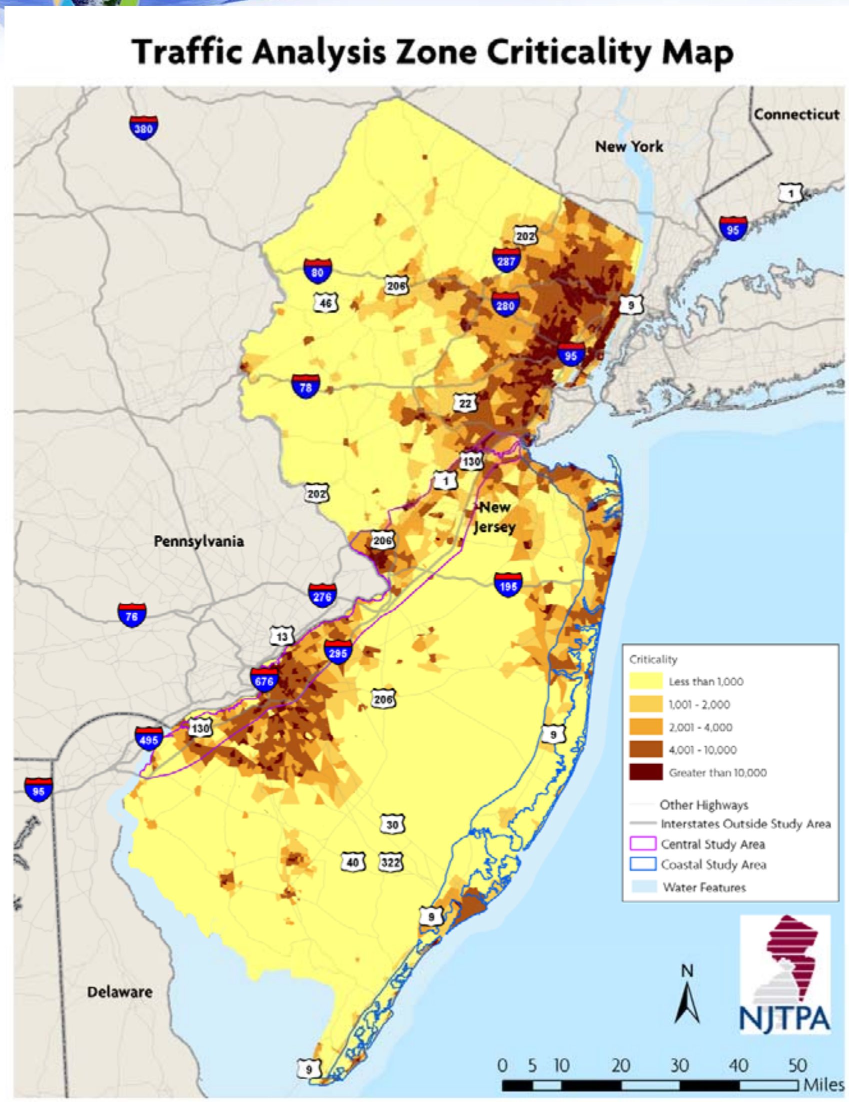
- **Sea level rise analysis for San Francisco Bay**
- **Looked at sample of road, transit, facility, and ped/bike assets**
- **Created "asset risk profiles"**
- **Explored potential near term and long term adaptation strategies**
- **Next Steps:**
  - Communicate findings
  - More detailed adaptation planning
  - Move toward implementation

Pilot: Oahu MPO

Asset	Overall Value	Impact to Society from:		
		Storm Surge	Sea Level Rise	Heavy Rain/Storm Events
Honolulu Harbor		Moderate	Low	Low
Honolulu International Airport				
TheBus (811 Middle Street)	High	Low	Low	Low
Oahu Baseyard (727 Kakoi Street)	Low	Low	High	Low
Honolulu International Airport and Access	High	High	Low	Low
Kalaeloa/Barbers Point				
Kalaeloa Airport	Low	Low	High	Low
Campbell Industrial Park	High	High	Low	Low
Kalaeloa Barbers Point Harbor	High	High	Low	Low
Three Waikiki Bridges	Moderate	High	High	Low
Farrington Highway on Waianae Coast	High	High	High	Low

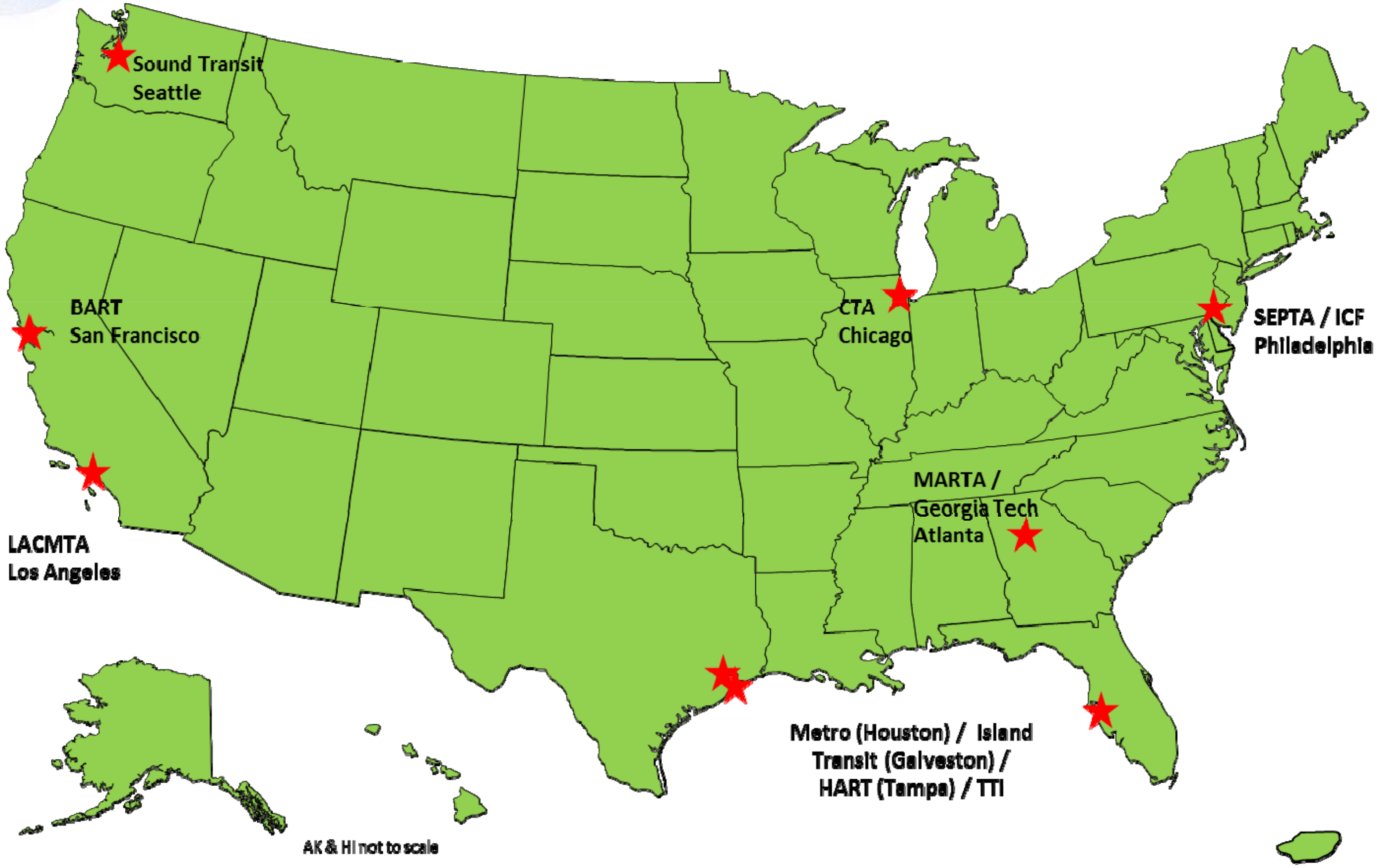
- 2 day interagency workshop to select assets
- Performed qualitative risk assessment on each asset
- Limited resources
- Emergency management and interagency collaboration

Pilot: NJTPA



- Coastal and riverine study areas
- Criticality ranking of assets based on mapping of TAZs
- Hired consultant to do climate downscaling
- Estimated future changes to 100-year floodplain due to heavier rainfall from climate change

FTA Adaptation Pilots (Complete by May 2013)



Lessons Learned

- **It's an iterative process, not linear**
  - Findings in one area influence data gathering or analysis in another.
- **Collecting data on transportation assets was challenging**
  - Inconsistent availability
  - Piecing together networks, differing formats
- **Pilots focused on "vulnerability"**
- **Collaboration was key part of success**
  - Broke down barriers within and between agencies

Next Steps

- **Update and deploy the vulnerability assessment framework with pilot findings**
  - Represent the framework as a series of modules rather than a linear flow chart
  - Articulate objectives upfront
  - Less focus on likelihood
  - Add resources and examples
- **Considering doing additional pilots**
  - Inland areas
  - Developing adaptation options
- **Developing adaptation strategies based on findings from vulnerability assessments**

Implications for Transportation Planning

- **…still evolving, as we learn more through vulnerability assessments, studies, etc.**
- **Identify facilities, areas at risk**
- **Higher maintenance and operations costs; potentially costlier designs**
  - Funding is already tight
  - Adaptation can potentially save funding

Implications for Transportation Planning

- **Focus on solutions and asset management**
  - Emphasize strategies that work rather than always “disaster”
- **Decision making based on uncertain information**
- **Non-stationarity – thresholds changing**
- **Consider environmental conditions over project life**
  - Local road; Interstate; Major bridge

Thank You

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

Robert Kafalenos

Sustainable Transport and Climate Change Team

FHWA Office of Natural Environment

Robert.Kafalenos@dot.gov