Extreme Weather in Maryland



Presented To

The Baltimore Metropolitan Council

By the

Long Range Team of Foot's Forecast, LLC

May 25, 2016

The Objective of this Presentation

What Compare known climate trends with recent weather patterns,

How by analyzing data reported in NOAA resources,

Why in order to evaluate reasonable strategies for probable future weather events.

" Everyone talks about the weather, but nobody does anything about it."

-popular, but unverified quote by Samuel Clemens.

Actual source is his friend & co-author Charles Dudley Warner

About The Presenter

- B.S. in Earth Science, Penn State University
- Maryland-certified Science Teacher since 2001
- National Science Foundation Teacher Fellow
- FEMA/Homeland Security ICS series
- Hazardous Materials Responder, United Parcel Service
- Client Advisor, Foot's Forecast & Baltimore Co. teacher

About Foot's Forecast

- Founded January 2004 at Dundalk High School
- Response to impacts of Feb'03 Blizzard and T.S. Isabel
- Short & long range forecasts by 10th grade students
- Students proposed website & name in Fall 2003.

About Foot's Forecast

2009 - Weather events expanded team to other states, reaching over 100 in 30 locations by 2013.

2011 - Students pursued degrees in Meteo., Math, Emergency Mgmt, IT, Media, Planning

2013 - Climate Scientist for Baltimore City DP3 Initiative

2011-present - Partners & clients have ranged from municipalities and school districts to snow removal, asphalt pavers, financial firms and public events.

FF TODAY ~ A CIVIL SOCIETY ENTERPRISE

MISSION OF OUR TEAM

Collaborative, local weather intelligence for decision makers and the public to help save lives and protect property.

EXTREME WEATHER: TOPIC OUTLINE

INTRODUCTION: *WHAT IS IT WITH THE WEATHER?*

MAIN TOPICS

1 ► TERMS & TRENDS FOR WEATHER/CLIMATE

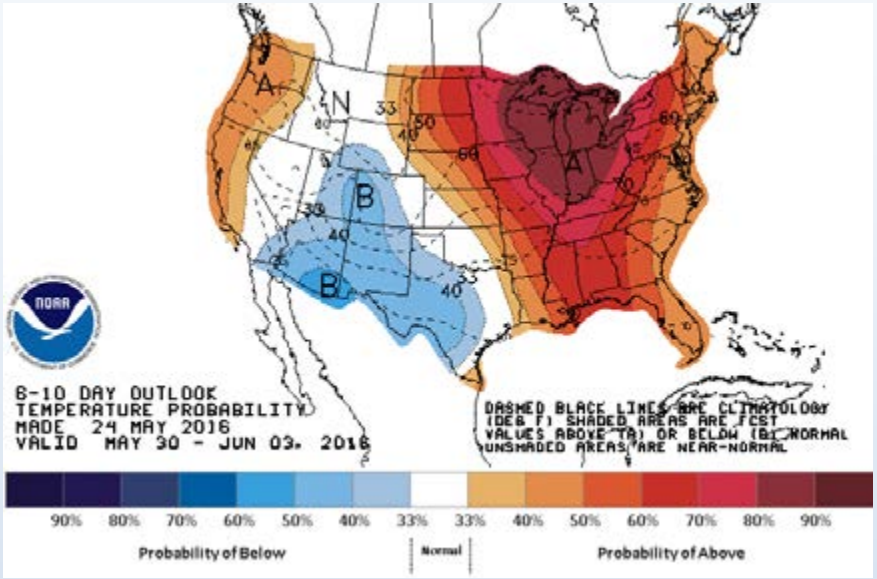
2 ► INFLUENCERS & INDICATORS:

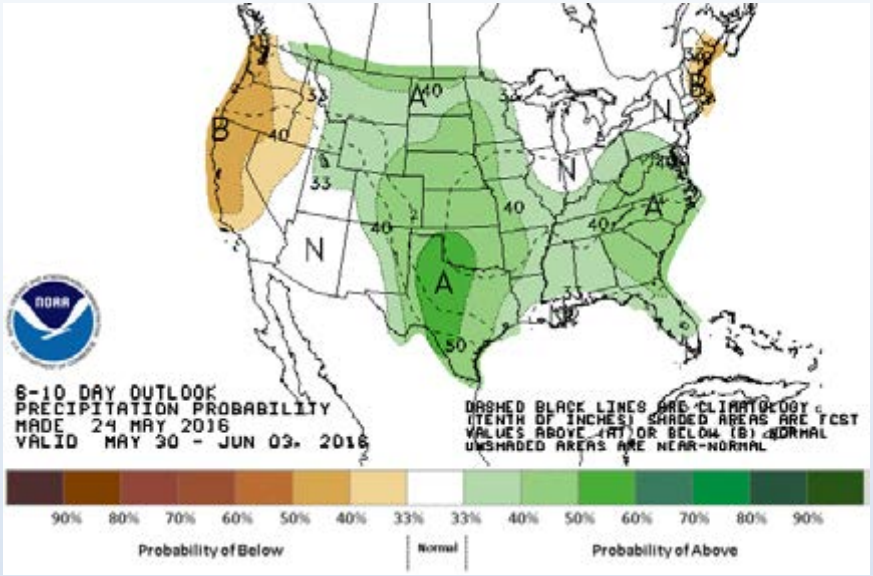
WHAT'S DRIVING MARYLAND WEATHER?

3 ► POSSIBILITIES & PROJECTIONS:

ASSESSING WHAT'S AHEAD FOR 2016-2017

1. WHAT *IS IT* WITH THE WEATHER?





MD TEMPERATURES IN 2016 ?

Near-normal Jan-Mar,
Above normal in Apr,
Below normal in May
Above normal proj. for Jun

MD PRECIPITATION IN 2016 ?

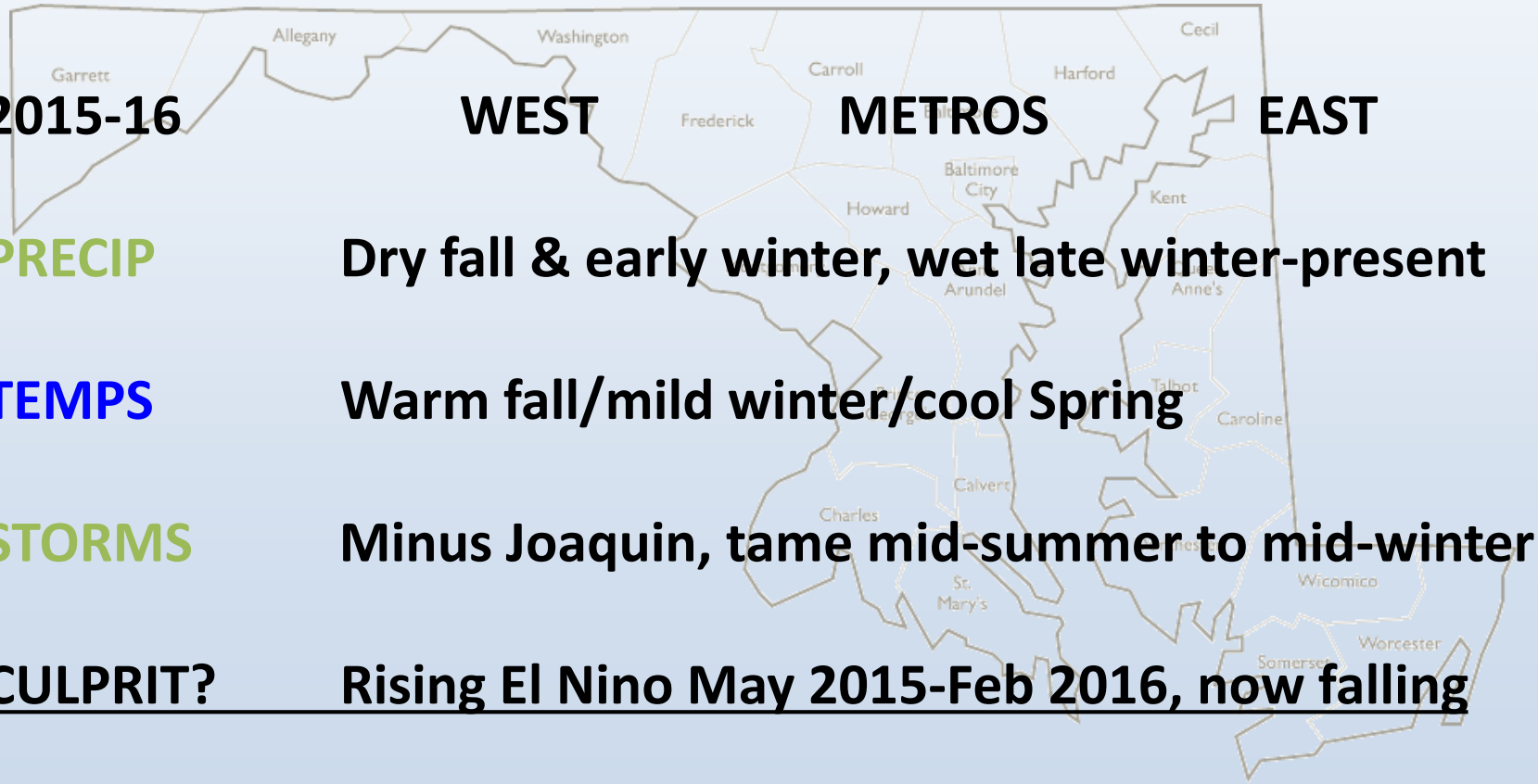
4/27-5/9 was DC's longest rainy period on record (12 days). Annual precip only recently went above normal due to drier winter.

1. Terms & Trends

Air Pressure	High- Dry, more dense air; Low- wet, less dense air
CPC	NOAA Climate Prediction Center
Indicators	Indices such as North Atlantic Oscillation
Models	Global Forecast System, Climate Forecast System
Nino/Nina	ENSO- El Nino Southern Oscillation
Polar Vortex	Arctic Oscillation/Labrador Low
SST	Sea Surface Temperatures
Westerlies	Northern hemisphere global wind pattern
WPC	NOAA Weather Prediction Center

MARYLAND WEATHER OVERVIEW

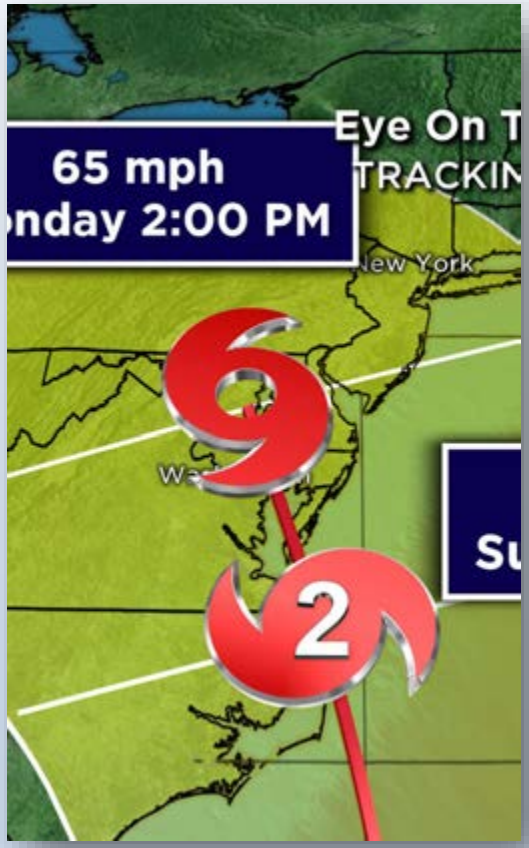
STORM IMPACTS | **PRECIPITATION** | **TEMPERATURE**

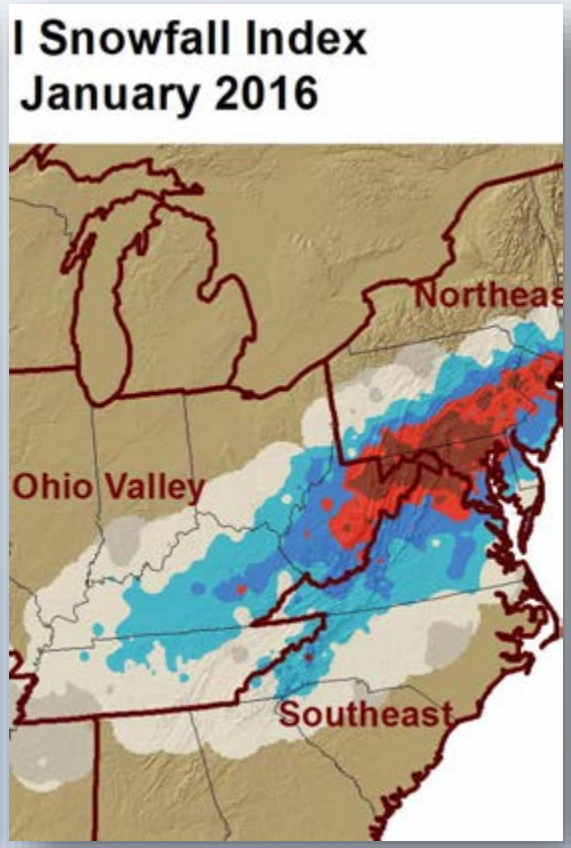


2015-16	WEST METROS EAST
PRECIP	Dry fall & early winter, wet late winter-present
TEMPS	Warm fall/mild winter/cool Spring
STORMS	Minus Joaquin, tame mid-summer to mid-winter
CULPRIT?	Rising El Nino May 2015-Feb 2016, now falling

Maryland Weather: 2015-16

What a *lovely year* it has been for managers…





2. Influencers & Indicators

Assessing questions you may have:

- What is driving these **high impact events**?
- Will a **cool, wet Spring** affect **Summer patterns**?
- What effects on the **hurricane season**?
- Early indicators for **next winter**?

2. Influencers & Indicators

<u>The big question to address</u>:

Is the new normal…**high precipitation events, high impact storms, erratic seasonal shifts?**

<u>Mark Twain</u>:

"Climate is what we expect,

Weather is what we get."

2. Influencers & Indicators

At least 17 major climate factors (drivers) which influence regional weather outcomes

Let's discuss each one briefly…

2. Influencers & Indicators

Or…

how about

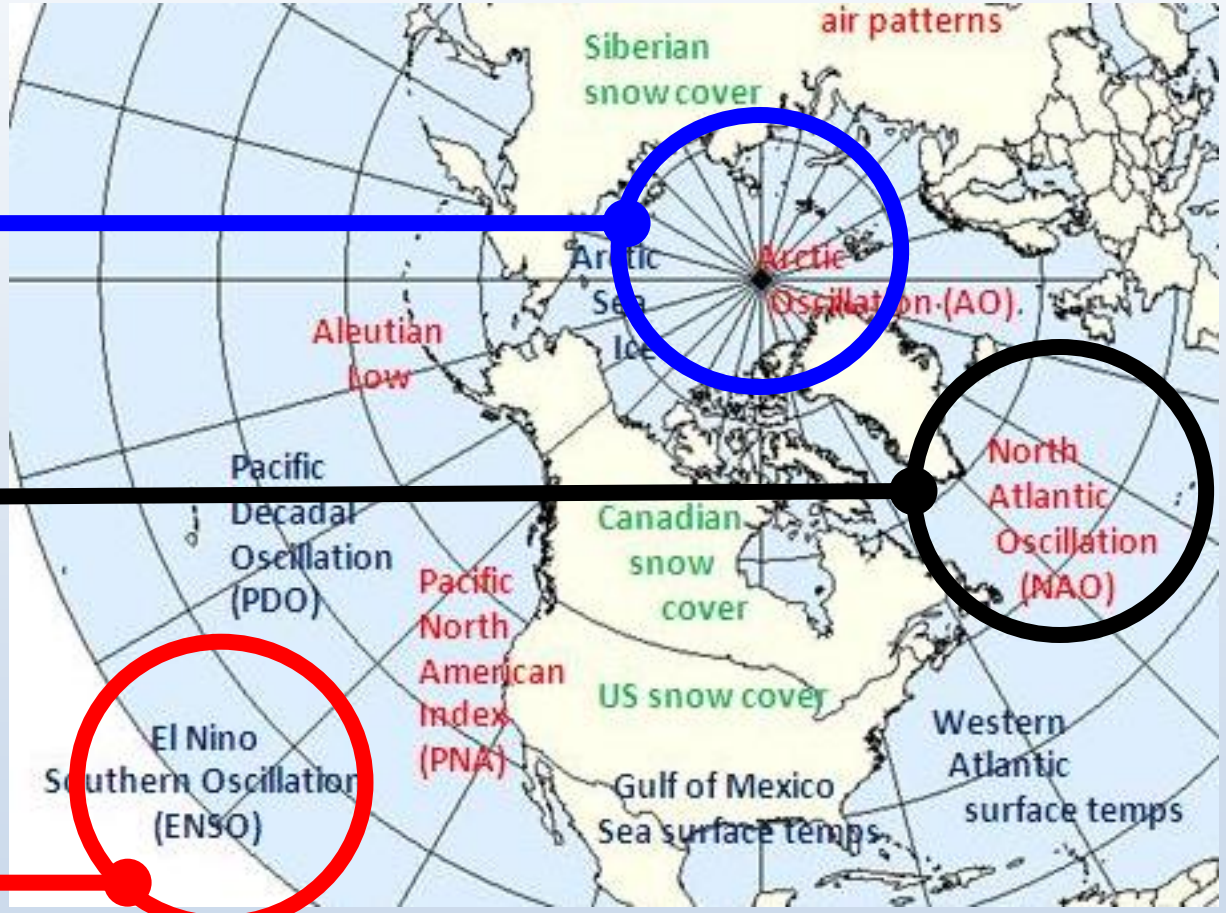
3 ?

2. Influencers & Indicators

Sea ice & snow cover

North Atlantic Oscillation (NAO)

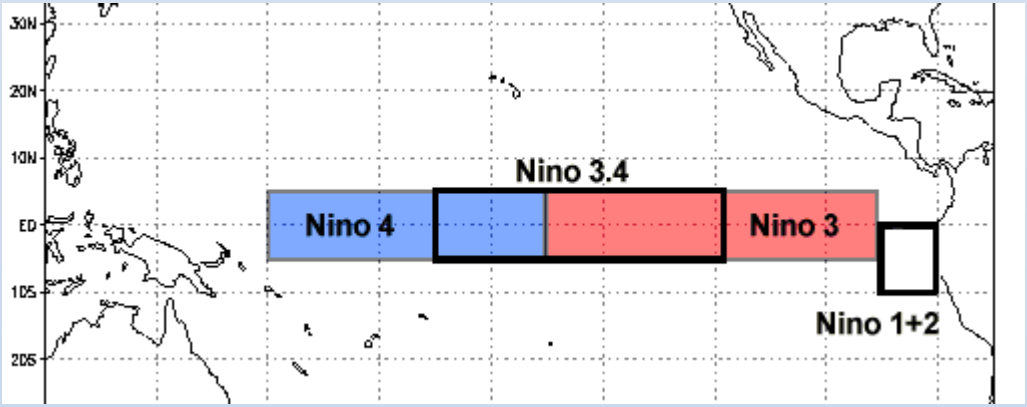
El Nino/La Nina (ENSO)



El Nino / Southern Oscillation (ENSO)

ENSO is a month-to-month measure of sea surface temperature anomalies in the equatorial Pacific.

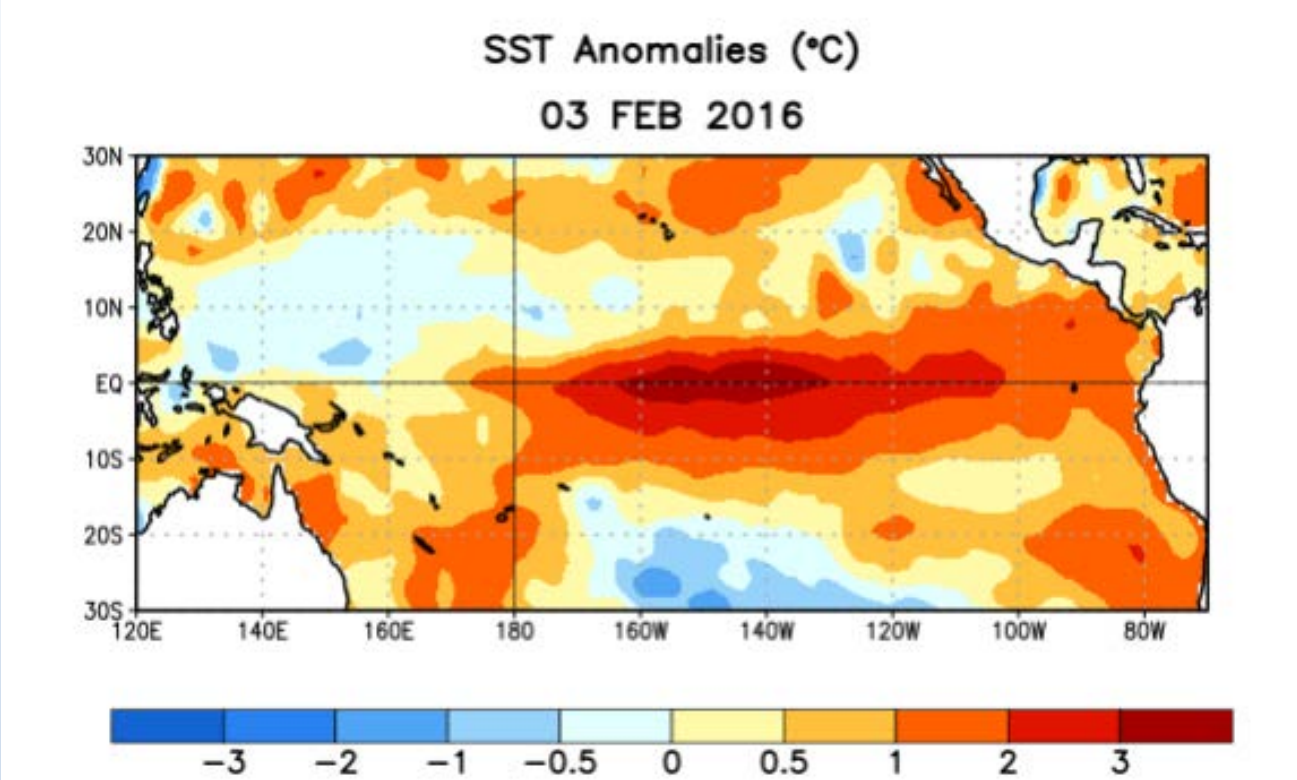
El Nino/ La Nina (ENSO)



A three-month mean of temps in "Region 3.4" is the El Nino data reported by NOAA.

EL NINO / SOUTHERN OSCILLATION (ENSO)

How to measure an El Nino or La Nina phase?



<u>If Region 3.4 reports a temp anomaly of</u>

-> Equal or greater than + 0.5 C = El Nino

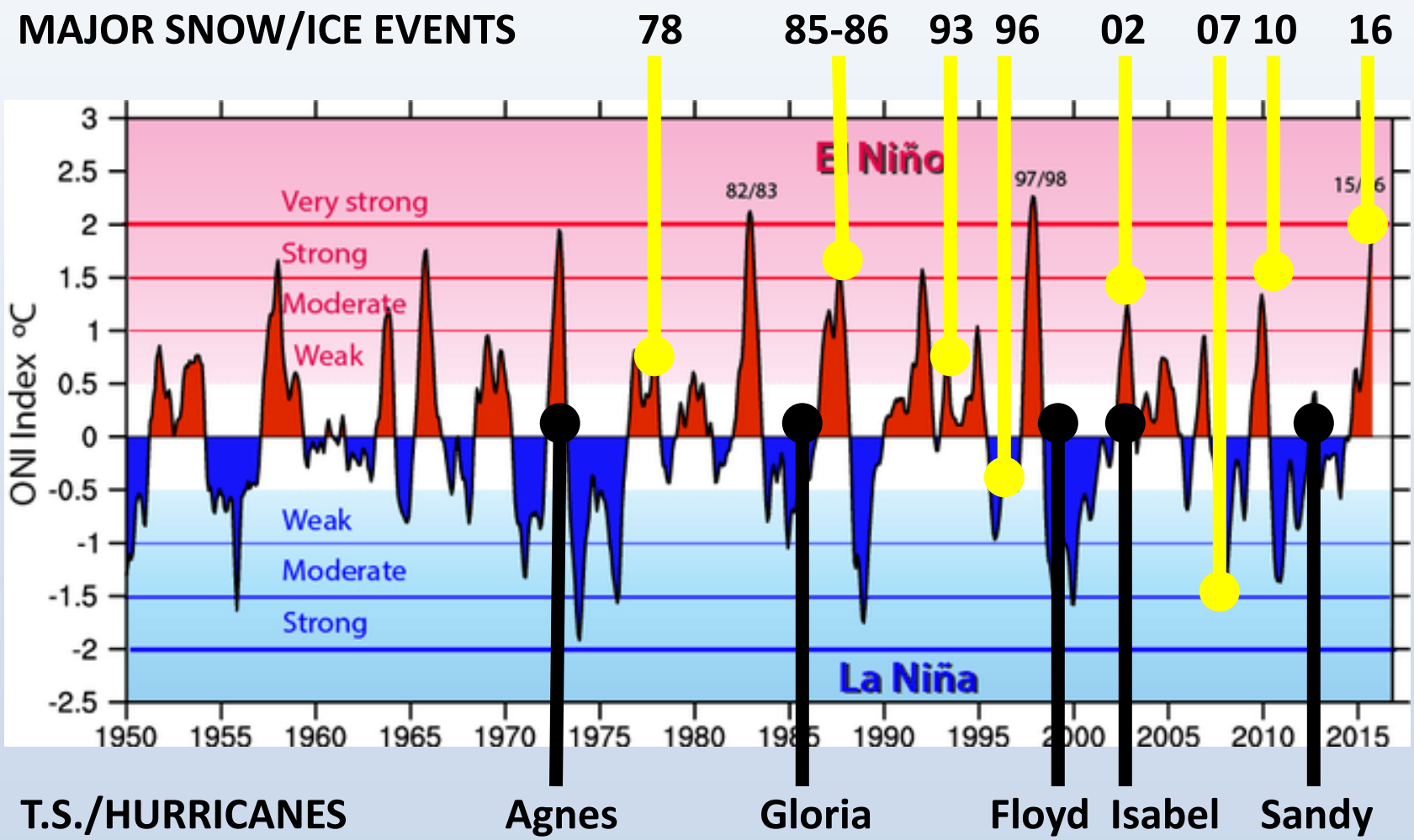
-> Equal or less than – 0.5 C = La Nina

El Nino / Southern Oscillation (ENSO)

Compare recent years of El Nino or La Nina (in deg C)

Years Selected	Region 3.4 SSTA	Significant Weather
1997-98	+ 2.3°	Low snow, Floyd (99)
2002-03	+ 1.3°	Blizzard, Isabel
2004-05	+ 0.4°	Ice storms, Katrina
2007-08	- 1.4°	Ice storms (07)
2009-10	+ 1.3°	Multiple blizzards
2011-12	- 1.1°	Irene, Derecho, Sandy
2015-16	+ 2.3°	Joaquin, Blizzard

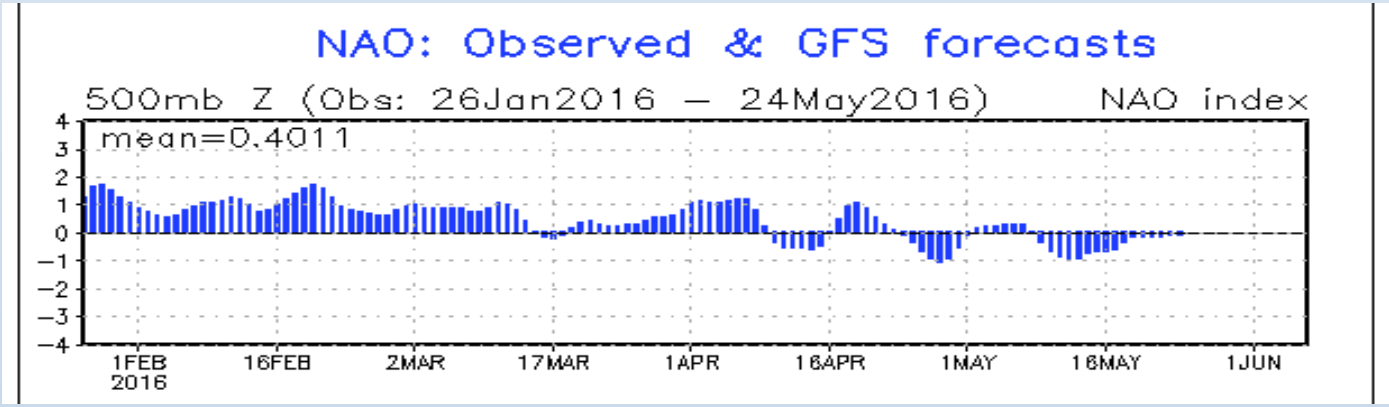
Comparison Chart: ENSO & Weather Events



NORTH ATLANTIC OSCILLATION

A gauge of large scale air mass movement every 2-3 days between the *Azores High* and the *Icelandic Low*

North Atlantic Oscillation (NAO)



North Atlantic Oscillation

Takeaway indicator?

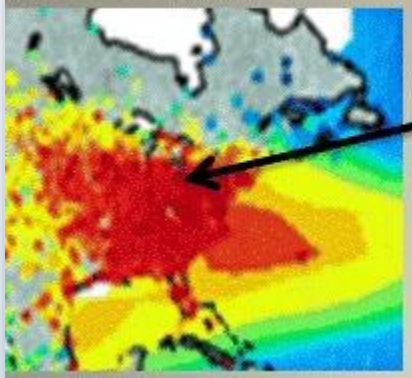
The NAO is linked to storm patterns, cold outbreaks and precip trends over a season.

RECENT RESULTS

Winter 2010-11:
+ NAO / - La Nina

Winter 2015-16:
- NAO / + El Nino

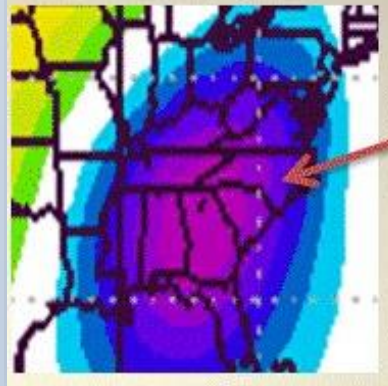
Positive NAO



Effects for the Eastern US:

- **Above** Average Temperatures
- **Wetter** Pattern
- **Stronger** Storms
- **Decreased** Potential for Wintry Weather

Negative NAO



Effects for the Eastern US:

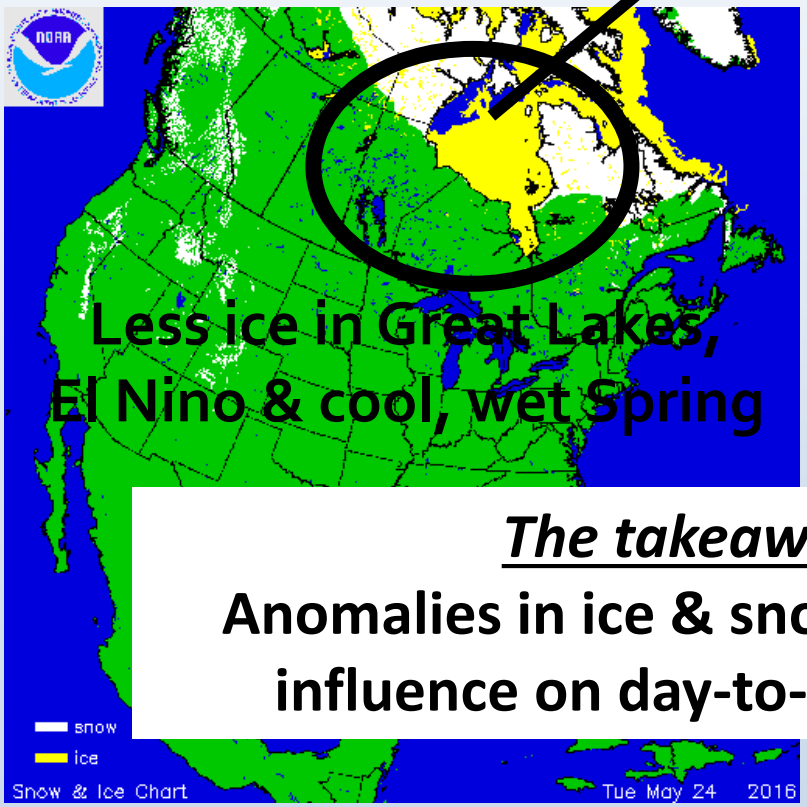
- **Below** Average Temperatures
- **Increased** Potential for Wintry Weather
- **Favorable** for Coastal Storm Tracks

2. Influencers & Indicators

A daily NOAA satellite estimate of depth and extent of snow cover across the northern Hemisphere, prepared by the National Snow & Ice Data Center.

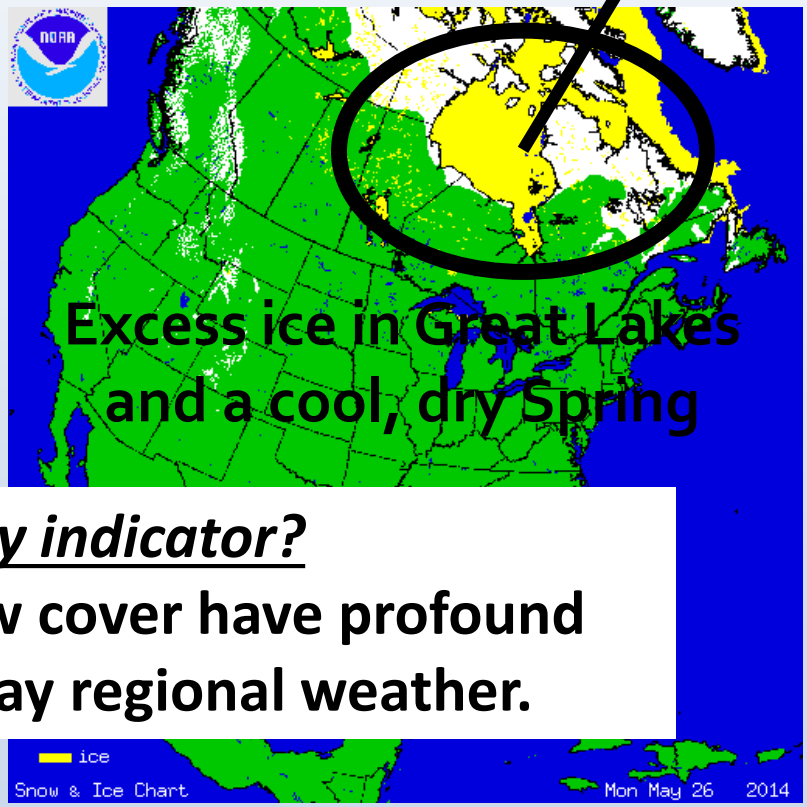
Arctic Sea Ice & Snow Cover

As of 5/24/2016, less sea ice observed in Hudson Bay



Less ice in Great Lakes, El Nino & cool, wet Spring

On 5/26/2014, more sea ice & Canadian snow cover



Excess ice in Great Lakes and a cool, dry Spring

The takeaway indicator?

Anomalies in ice & snow cover have profound influence on day-to-day regional weather.

3. Possibilities & Projections

"So, you're saying there's a chance….?"

- Jim Carrey

3. Possibilities & Projections

UNDERSTANDING PROBABILITY

Probability-based forecasting gauges the climate average leading to a most probable outcome of that weather condition

Vs.

the most extreme solution presented as the only potential outcome

Extreme Weather Possibilities

Given new indicators of La Nina & snow cover, what is likelihood for the following events to reoccur?

YEAR	EVENT	REPEAT IN 2016-17?
1994	Ice storms	Less likely
2003	Isabel	Equal to more likely
2004	Florida landfalls	Less likely
2010	Double blizzard	Less likely
2012	Derecho/Sandy	Equal to more likely

3. Possibilities & Projections

Key Questions To Consider

1. Before going public or to a client, ask:

   "IS this situation the most probable?"

   AND

2. *"How likely COULD the extreme solution become?"*

WHAT ARE THE TAKEAWAY RESULTS?

	TRENDS	INDICATORS	PROJECTIONS
What's the status?	Delayed Winters, cool Springs humid, wet Summers	El Nino in rapid decline, La Nina expected by late Summer 2016.	Residual cool air in Canada may influence severe outbreaks into Summer.
What's most probable ahead?	Continuation of this trend, with more active hurricane season possible.	Data over 30 years shows significant tropical storms in "transition" Nino/Nina years	High impact tropical system in Gulf, M/A or Southeast has some potential

3. Possibilities & Projections

GOOD NEWS

- **SNOW: La Nina seasons usually produce less overall snow and smaller storms (1996 is exception);**
- **PRECIP: Likelihood of frequent liquid precip events is less in La Nina years, with some exceptions (2004-2005)**

BAD NEWS

- **TROPICS: NOAA data shows significant tropical systems affect MD more often than not in transition to La Nina;**
- **ICE: Past La Nina seasons have featured major ice storms;**
- **TEMPS: Much colder, drier, windy conditions than 2010-15;**

Long Range Team: Jason M., Connor M., Mike N., Joey K., Jake S., Mintong N., Nic R., R. Foot
Indicators: NOAA Climate Prediction Center, US Climate Forecast System, ECMWF

Our Takeaway Message for Today

Comparing climate trends & weather patterns <u>may show some correlation with:</u>

1) Changes in sea ice, snow cover and sea temps;

2) Major tropical and winter weather events in Maryland occurring in the transition year following a strong El Nino or La Nina episode.

THANKS FOR WORKING THE STORMS WITH US!

To learn more about resources we use or obtain a written summary of this presentation:

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U.S. Department of Transportation
Federal Highway Administration

FHWA CLIMATE CHANGE RESILIENCE ACTIVITIES

Becky Lupes
Sustainable Transport and Climate change Team
Federal Highway Administration
Rebecca.Lupes@dot.gov

CLIMATE RESILIENCE IN RECENT REGULATION

- Moving Ahead for Progress in the 21st Century (MAP 21) Notice of Proposed Rulemaking (NPRM) on Asset Management
  - Included climate and extreme weather as a risk to be considered in risk-based asset management plans
  - Also addressed requirements of MAP-21 Section 1315(b) - evaluation required to determine if a facility has been repeatedly repaired or replaced, if so need to consider alternatives
  - Final rule forthcoming

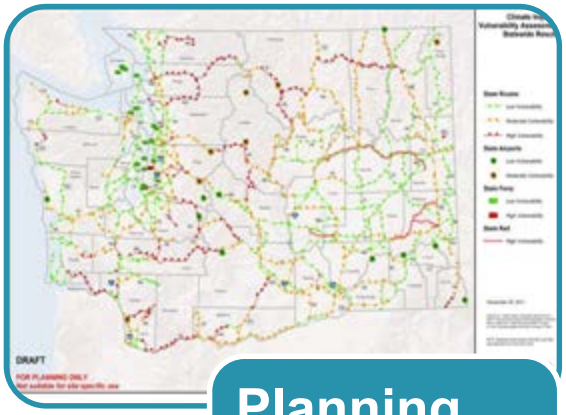
CLIMATE RESILIENCE IN RECENT REGULATION

- Fixing America's Surface Transportation Act (FAST ACT)
  - President Obama signed into law on December 4, 2015
  - Adds consideration and implementation of projects, strategies, and services that will "improve the resiliency and reliability of the transportation system"
  - Metropolitan transportation plans shall contain strategies to "reduce the vulnerability of the existing transportation infrastructure to natural disasters"

INTEGRATING CLIMATE CHANGE RESILIENCE

U.S. Department of Transportation
Federal Highway Administration

Goal: Mainstream consideration of climate change vulnerability and risk in transportation decision making



Planning

- Long Range Transportation Plans
- Asset Management Plans

Project Level

- Environmental Processes
- Engineering
- Design

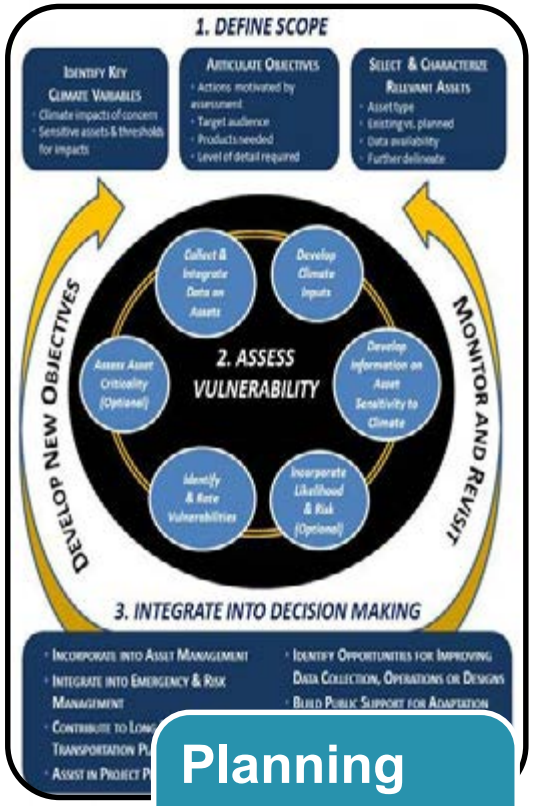
Operations and Maintenance

- Business processes
- Performance Management

CLIMATE CHANGE

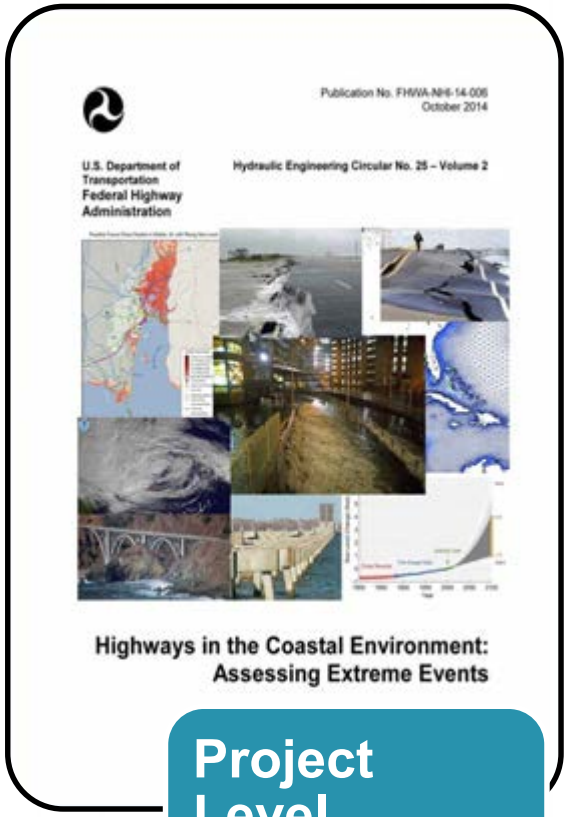
TOOLS, RESOURCES, AND GUIDES

U.S. Department of Transportation
Federal Highway Administration



Planning

- Vulnerability Assessment Framework (2013)



Project Level

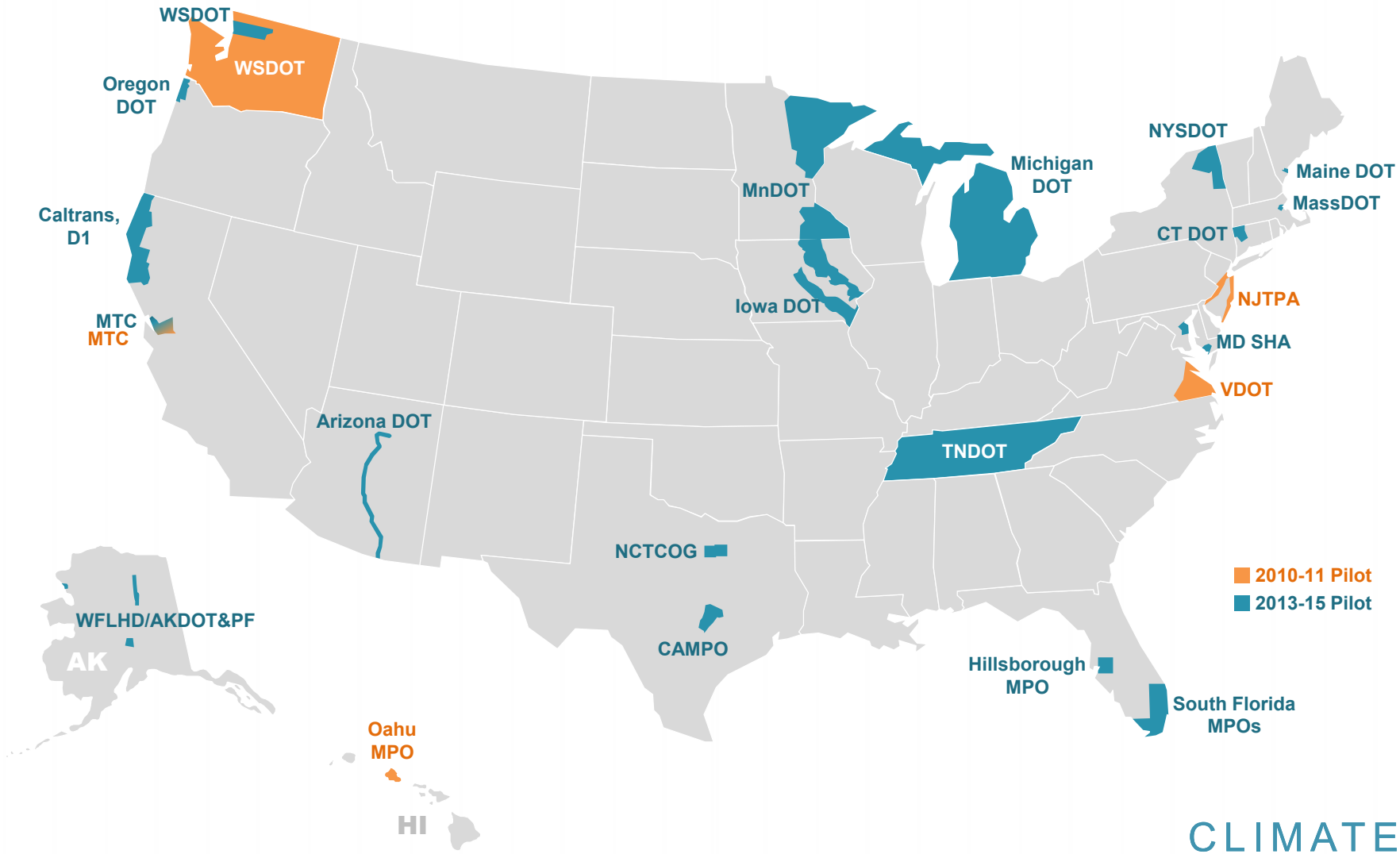
- HEC 25: Highways in the Coastal Environment (October 2014)

Operations & Maintenance

- Climate Change Adaptation Guide (November 2015)

CLIMATE VULNERABILITY ASSESSMENT PILOTS

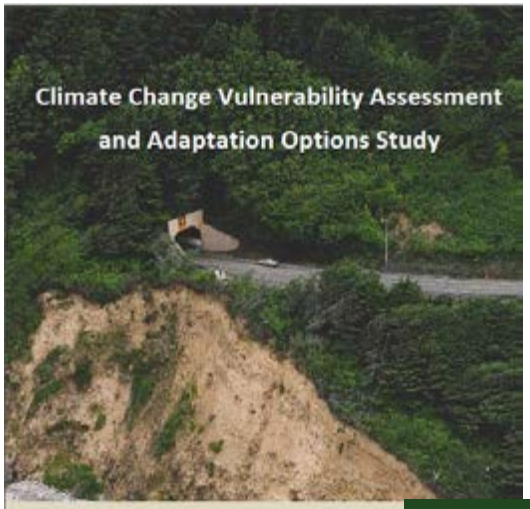
U.S. Department of Transportation
Federal Highway Administration

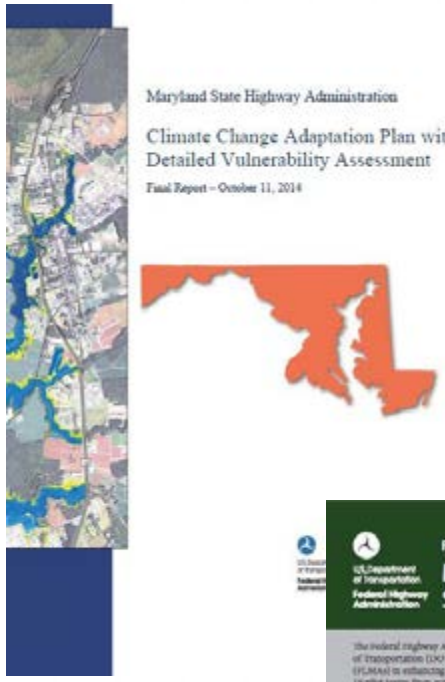


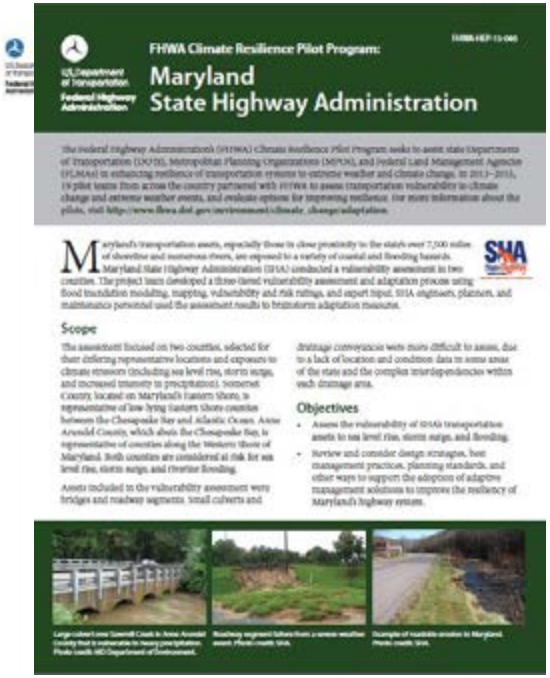
CLIMATE CHANGE

PILOT LESSONS LEARNED

U.S. Department of Transportation
Federal Highway Administration

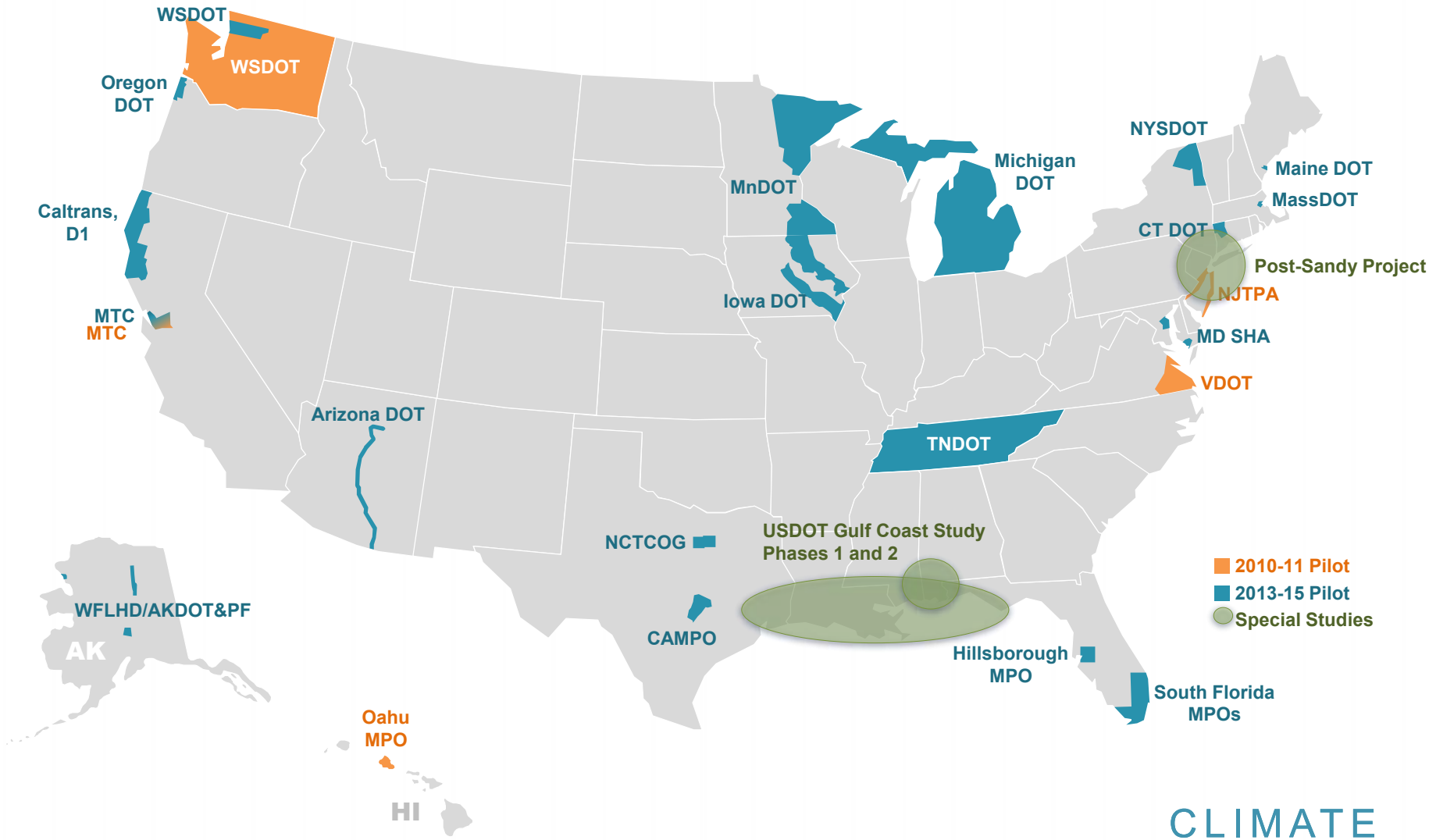






FHWA CLIMATE CHANGE RESEARCH

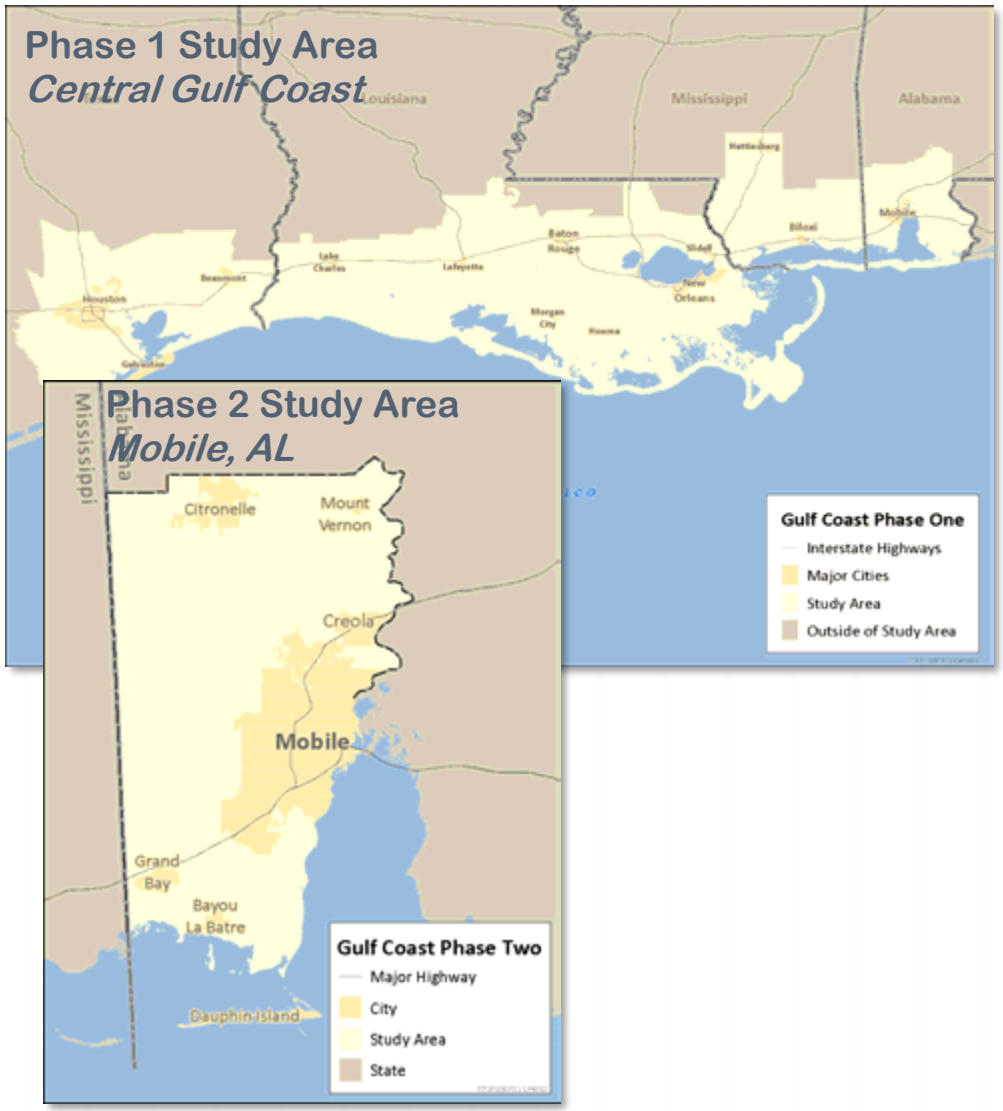
U.S. Department of Transportation
Federal Highway Administration



CLIMATE CHANGE

Comprehensive Assessment of Climate Impacts on Gulf Coast Transportation

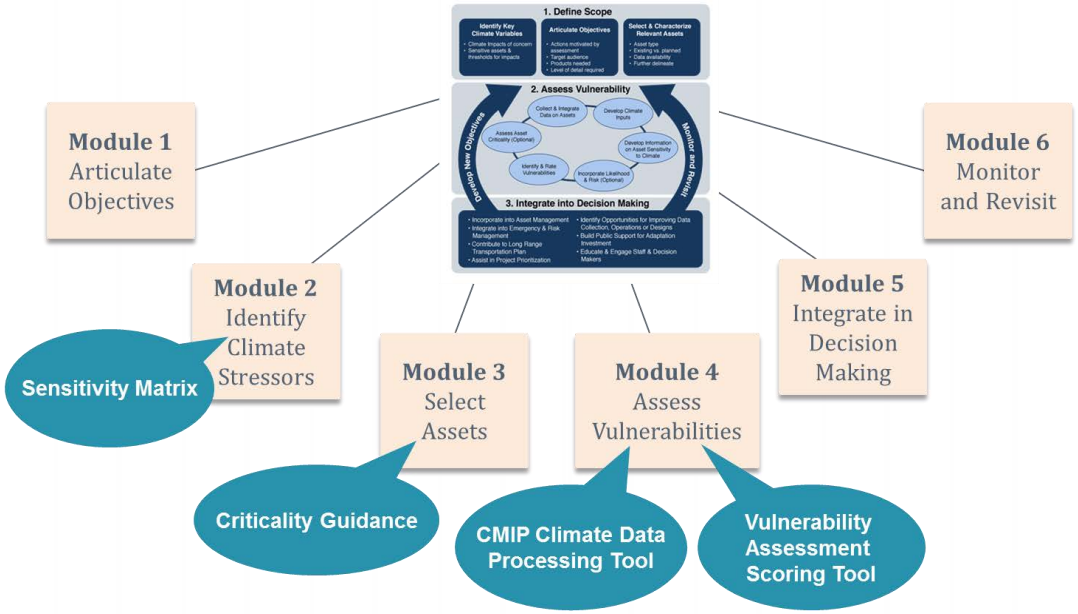
U.S. Department of Transportation
Federal Highway Administration



- DOT Climate Center study
- Managed by FHWA
- Key component of DOT and FHWA efforts to promote climate resilience at system and project levels

VULNERABILITY ASSESSMENT TOOLS

U.S. Department of Transportation
Federal Highway Administration

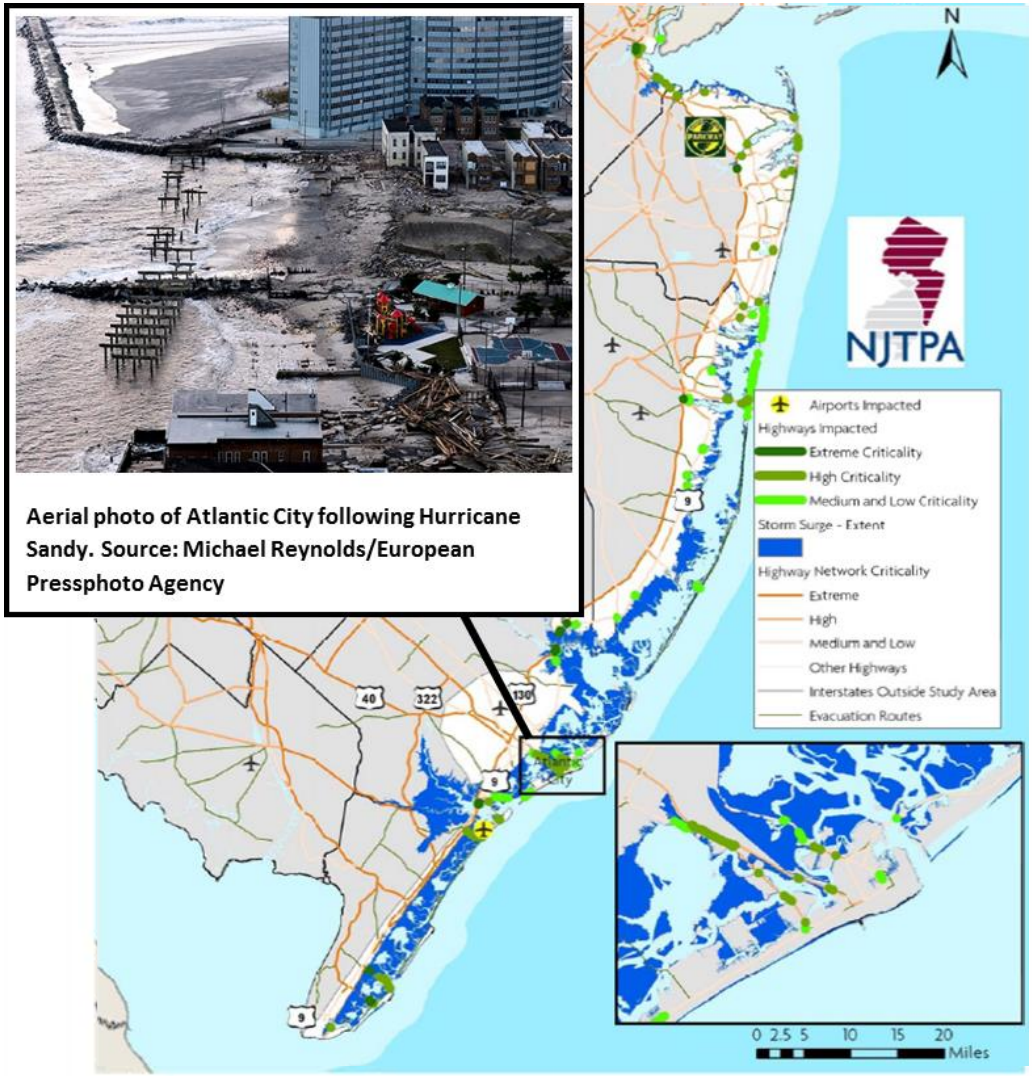


- Vulnerability Assessment Scoring Tool. Guides the user through conducting a quantitative, indicator-based vulnerability screen
- Sensitivity Matrix. Documents sensitivity of roads, bridges, airports, ports, pipelines, and rail to 11 climate stressors
- CMIP Climate Data Processing Tool Helps a user find and access downscaled climate data at the local scale (up to 56 mi^2)

POST-HURRICANE SANDY PROJECT

U.S. Department of Transportation
Federal Highway Administration

- Builds on a FHWA 2011 NJ pilot
- Learn from experience of Hurricane Sandy
- Identify strategies to improve resiliency through planning and transportation engineering



SLR 1 Meter, 2100, Coastal Study Area (Roadways). Source NJTPA

TRANSPORTATION ENGINEERING APPROACHES FOR CLIMATE RESILIENCE (TEACR)

U.S. Department of Transportation
Federal Highway Administration

- **Purpose:** Develop recommendations on ways to incorporate climate change as part of engineering practice

- **Approach:** Approximately 10 engineering case studies of climate vulnerability and adaptation for specific highway facilities.

  Lessons learned from these and other case studies will be synthesized in cross-cutting best practices report

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

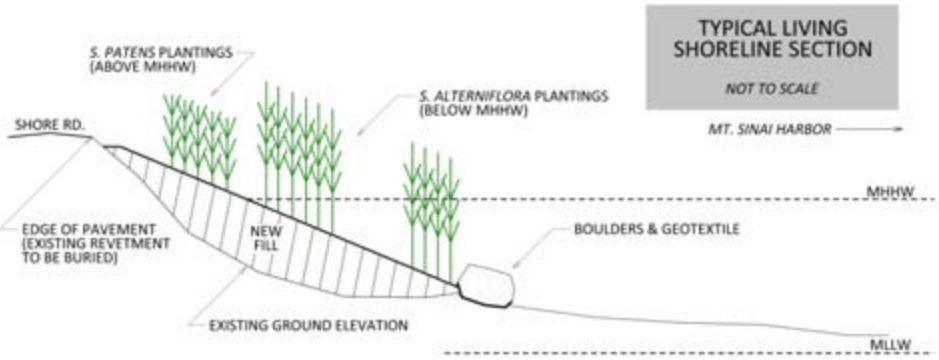
CLIMATE CHANGE RESILIENCY AND OPERATIONS

- Guide to help DOTs as they plan and implement their TSMO, Maintenance, and Emergency Management components with regard to climate change resiliency.
- Task has just gotten underway and should be completed fall 2016.

GREEN INFRASTRUCTURE FOR COASTAL RESILIENCE

U.S. Department of Transportation
Federal Highway Administration

- Goal: transportation system more resilient to climate impacts
- Make use of green infrastructure for climate resilience and other benefits
- Will use findings from the pilots in developing an implementation guide for transportation agencies
- Scope is coastal green infrastructure (dunes, wetlands, living shorelines, oyster reefs, beaches, artificial reefs)

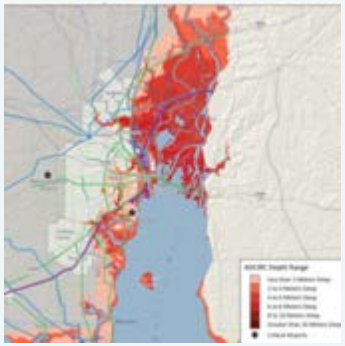


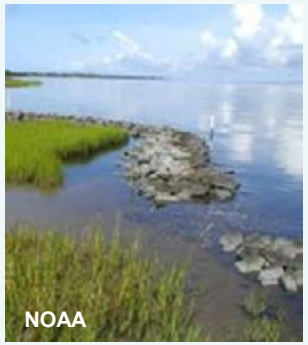
HOW IT ALL FITS TOGETHER

U.S. Department of Transportation
Federal Highway Administration

Research

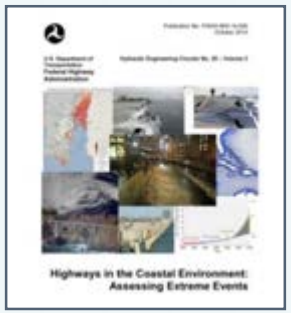
- Gulf Coast 2 Study
- Vulnerability Pilots
- Hurricane Sandy Project
- Engineering Assessments Study
- Green Infrastructure Pilots





Resources

- Vulnerability Assessment Framework
- Guidance (HEC-25 & 17)
- Synthesis Document
- Green Infrastructure Guide



Project Development Approaches for Climate and Extreme Weather Resilience (2016)

VIMS

Green Infrastructure Techniques for Coastal Highway Resilience (2018)

THANK YOU!

For more information:

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

Maryland Adaptation and Vulnerability Assessment

Maryland State Highway Administration

May 25, 2016

Maryland Department of Transportation

Pilot Study Objectives

- Assess Vulnerability to SHA's Assets
- Develop Approaches to Address Current and Future Risk
- Provide Recommendations for Policy or Process Changes

Floating Debris Lodged in a Bridge during Flood Event at Seneca Creek in Germantown, MD
Photo Source: (FEMA/Skolnik 2006)

"Improve Resiliency of Maryland's Transportation System"

Key Step

Identify Climate Stressors

Studied in Detail for Maryland

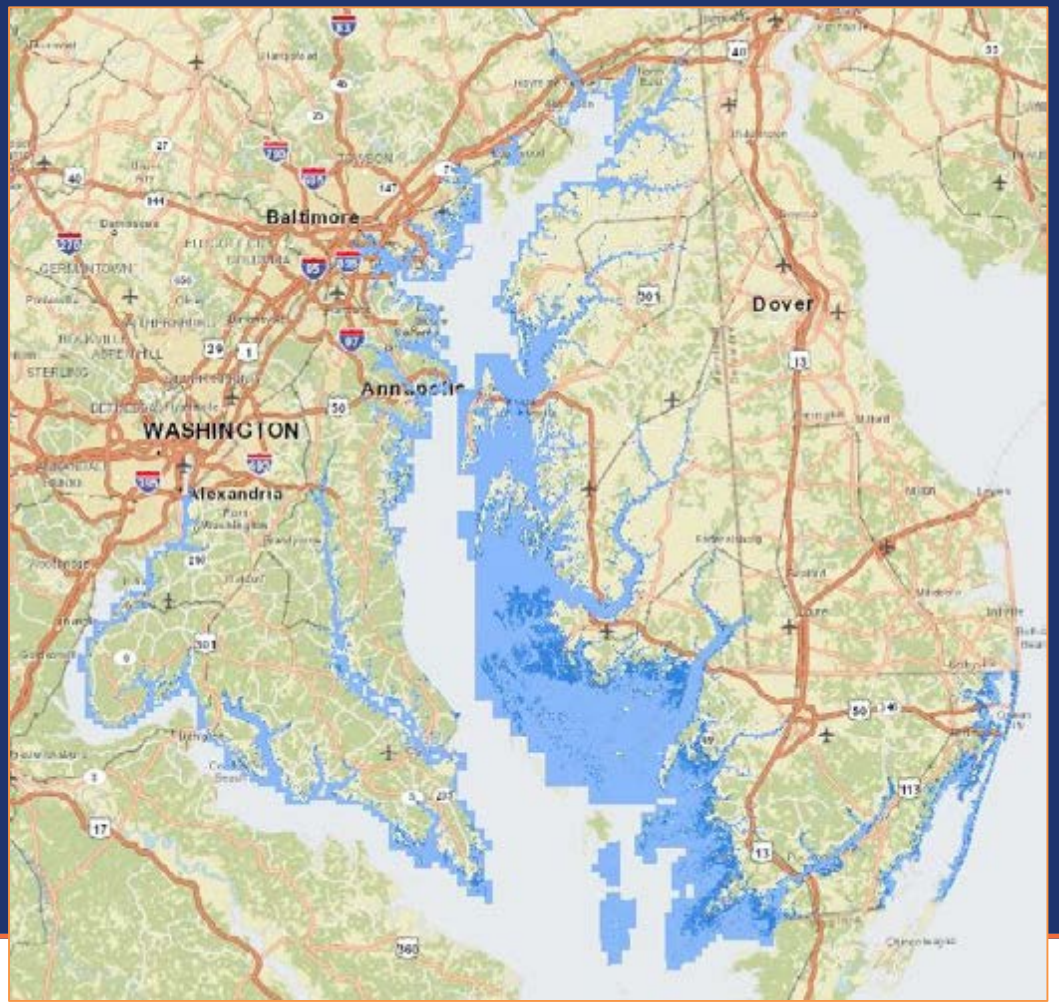
Sea Level Change	• USACE Procedures Established in Circular No. 1165-2-212 (2013) • Newer LiDAR and Assign Nearest Tidal Station
Storm Surge	• HAZUS-MH 2.1 (Category 3 Storm Used) • Stillwater Depth Grids Developed
Precipitation	• Micro-scale Data Obtained from C-MIP • Riverine Modeling in HAZUS-MH2.1 (future)

2050 & 2100 Sea Level Change

Eastern Shore Regional GIS Cooperative – Salisbury University

		2050		2100	
County	Tidal Station	MSL	MHHW	MSL	MHHW
Allegany	None	-	-	-	-
Anne Arundel	Annapolis	2.08	2.79	5.7	6.41
Baltimore	Baltimore	2.01	2.87	5.59	6.45
Baltimore City	Baltimore	2.01	2.87	5.59	6.45
Calvert	Solomons Island	2.1	2.82	5.76	6.48
Caroline	Cambridge	2.11	3.13	5.78	6.8
Carroll	None	-	-	-	-
Cecil	Chesapeake City	1.98	3.63	5.56	7.21
Charles	Washington DC	2.21	3.83	5.78	7.4
Dorchester	Cambridge	2.11	3.13	5.78	6.8
Frederick	None	-	-	-	-
Garrett	None	-	-	-	-
Harford	Baltimore	2.01	2.87	5.59	6.45
Howard	None	-	-	-	-
Kent	Annapolis	2.08	2.79	5.7	6.41
Montgomery	None	-	-	-	-
Prince Georges	Washington DC	2.21	3.83	5.78	7.4
Queen Annes	Annapolis	2.08	2.79	5.7	6.41
Somerset	Cambridge	2.11	3.13	5.78	6.8
St. Mary's	Solomons Island	2.1	2.82	5.76	6.48
Talbot	Cambridge	2.11	3.13	5.78	6.8
Washington	None	-	-	-	-
Wicomico	Cambridge	2.11	3.13	5.78	6.8
Worcester	Ocean City	2.06	3.25	5.86	7.05

Methodology – USACE: Sea-Level Change Considerations for Civil Works Programs, October 2013



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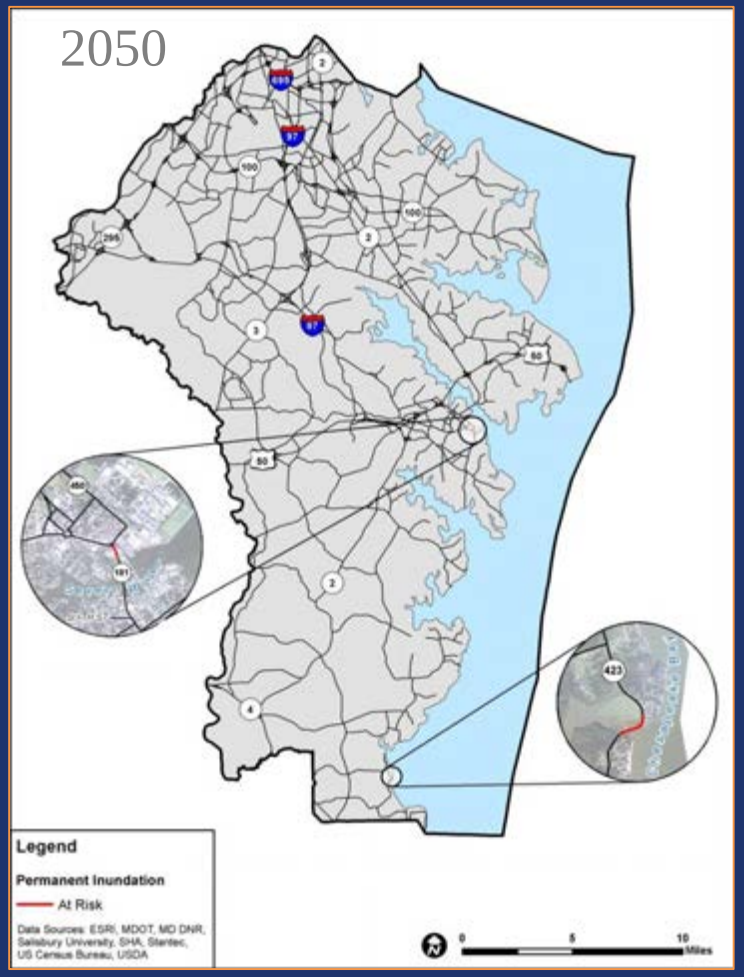
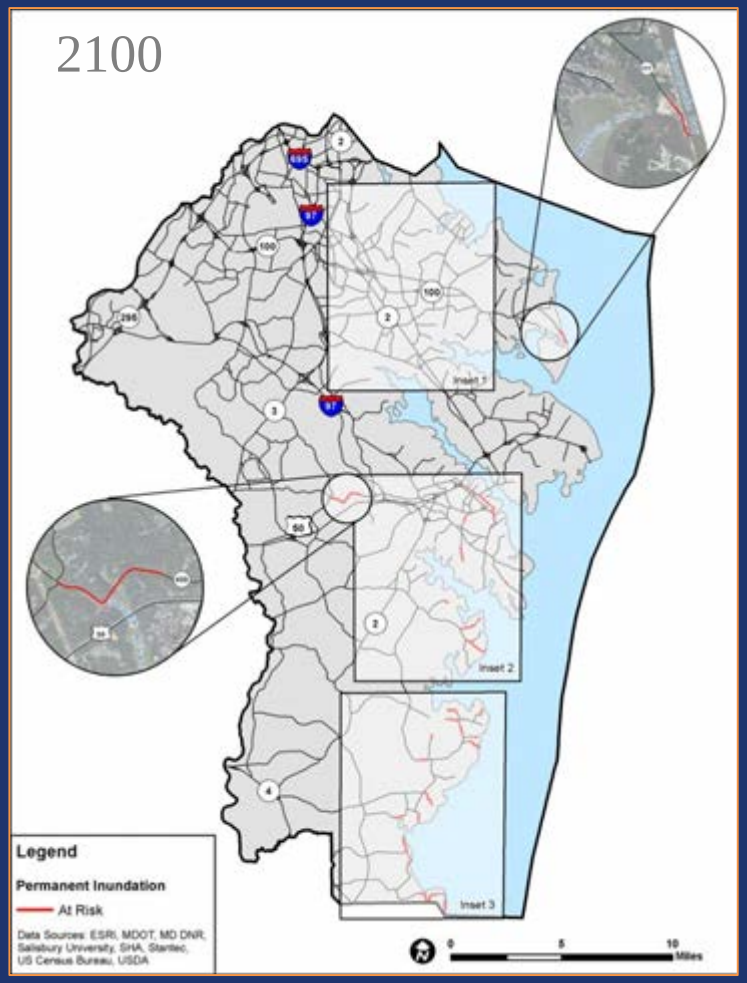
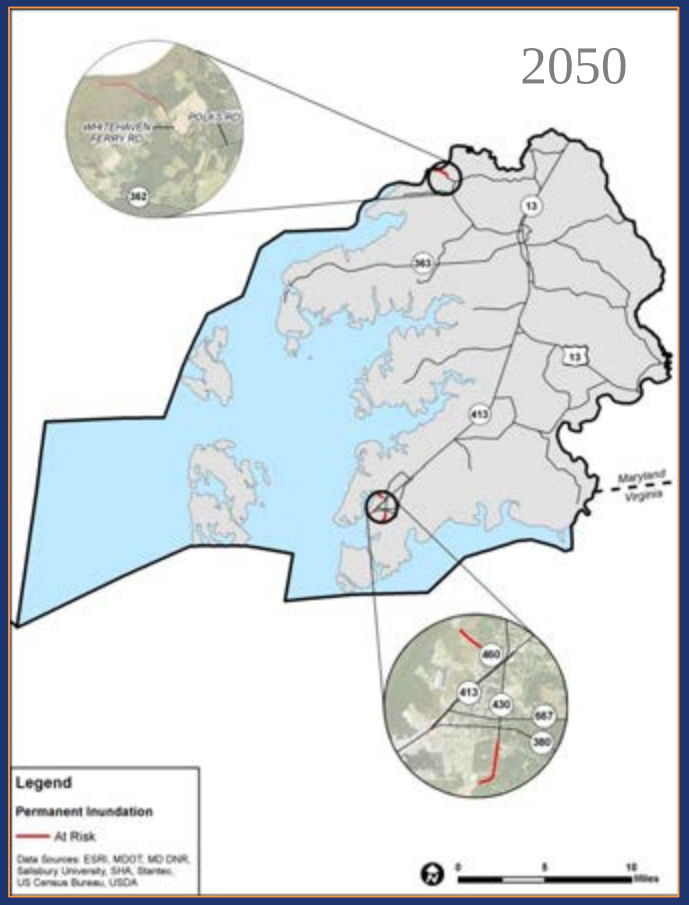
Permanent Inundation for Anne Arundel

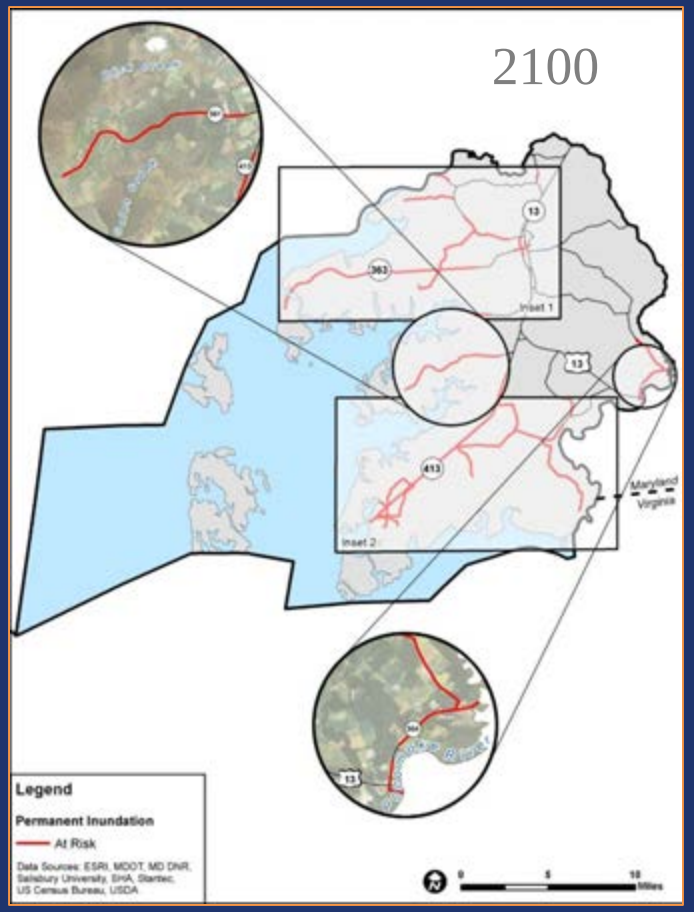




Maryland Department of Transportation

Permanent Inundation
Somerset County



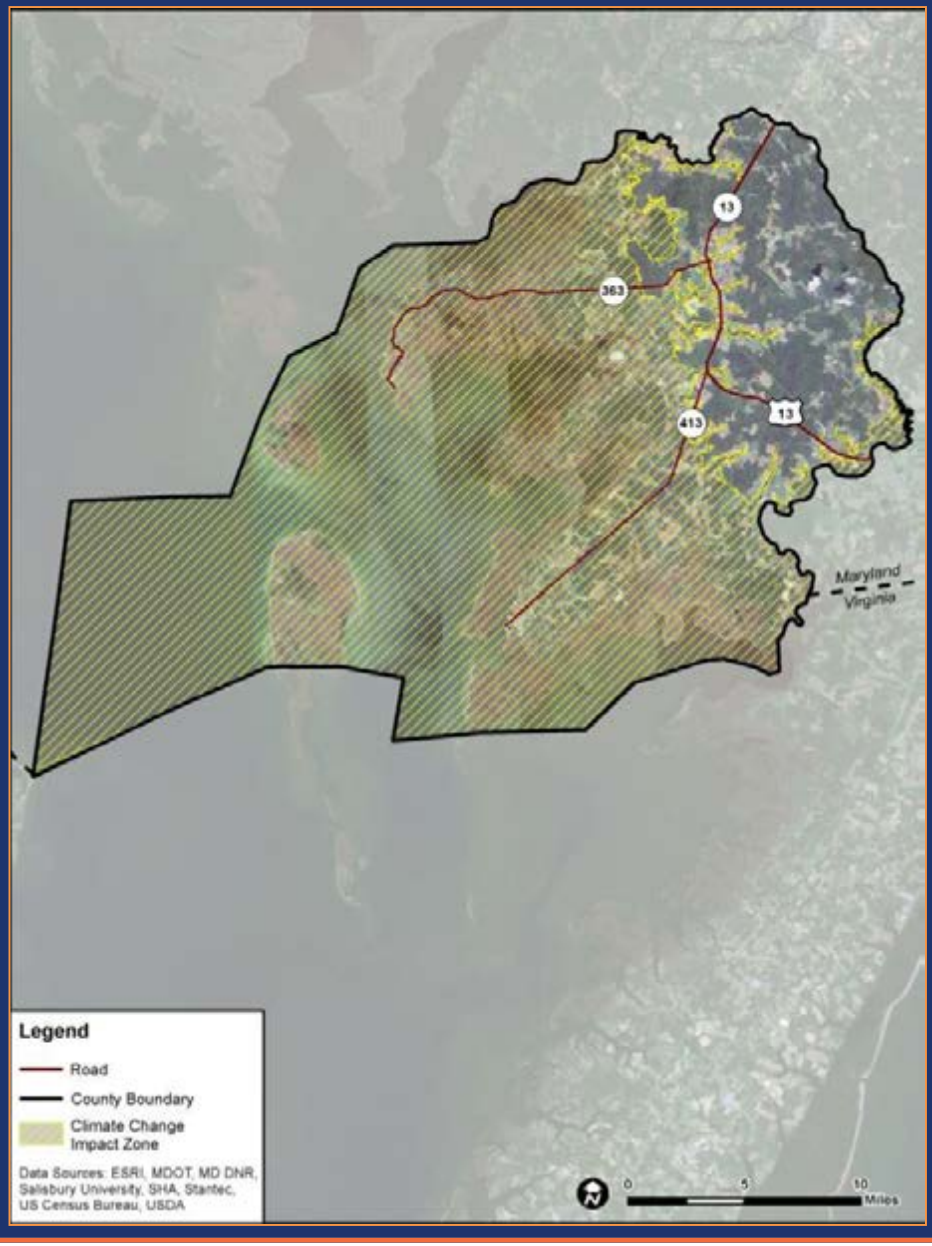


Maryland Department of Transportation

Key Step

Assess Vulnerability

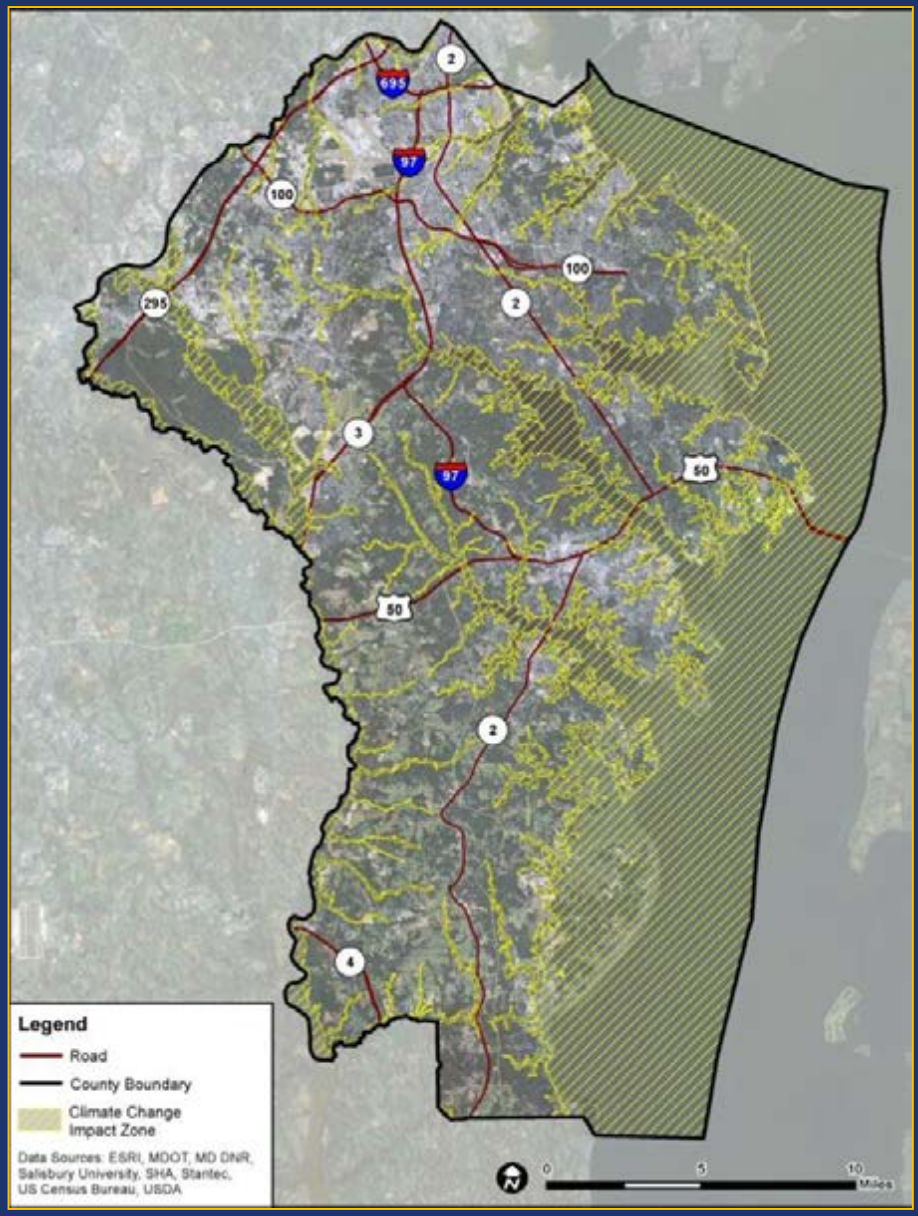
- Two Pilot Counties
- Initial Screening of Assets
- Tools Used
  - Vulnerability Assessment Scoring Tool
  - Hazard Vulnerability Index



Climate Change Impact Zone
Somerset County, MD

Initial Screening

- Climate Change Impact Zone Map Created Using GIS
- Eliminate assets at low to no risk prior to use of VAST
- Used SLOSH (Cat 3), 2100 MHHW, FEMA 100 year Floodplain, plus 50 ft buffer



Maryland Department of Transportation

Climate Change Impact Zone
Anne Arundel, MD

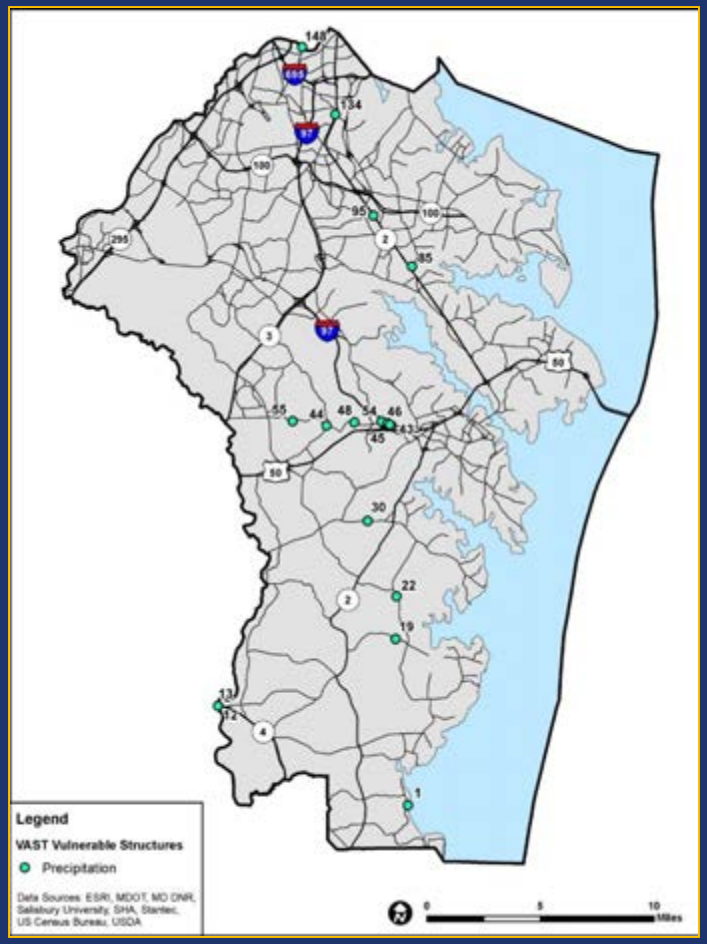
Results of Screening

Assets	Anne Arundel County		Somerset County	
	Number of Assets	Evaluated in More Detail	Number of Assets	Evaluated in More Detail
Bridges including large culverts	517	150	86	72
Small culverts and conveyances	Culverts- 12,024 Conveyances- 8,601	Culverts- 1,174 Conveyances- 843	Culverts- 1153 Conveyances 1135	Culverts- 739 Conveyances 847
Miles of roadway	2,554.28 miles	114.99 miles	503.92 miles	285.2 miles

VAST - Input and Results

- 150 bridge assets in Anne Arundel County
- 72 bridge assets in Somerset County
- Input Information
  - Asset data
  - Exposure data
  - Sensitivity data
  - Adaptive Capacity data
- Output
  - Vulnerability Score for all structures
  - 10 most vulnerable assets to each climate stressor
  - Maps and tables showing most vulnerable structures

FHWA Vulnerability Assessment Scoring Tool Results



Vulnerability to Precipitation		
Structure ID	VAST Score	Evacuation Route
134	3.1	Yes
44	2.8	No
30	2.8	No
43	2.8	No
45	2.8	No
46	2.8	No
1	2.6	No
22	2.6	No
95	2.5	Yes

Hazard Vulnerability Index (HVI)

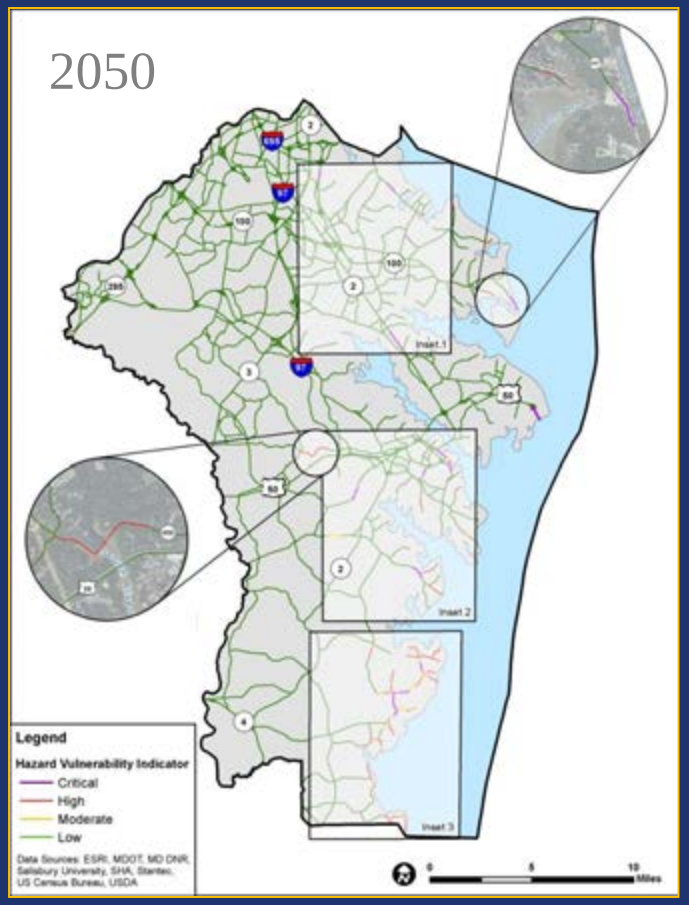
$$Risk = (Evacuation\ Code * 0.5 + 1) * \left(\frac{(Flood\ Depth\ Code + 0.01)}{4}\right) * \left(\frac{0.7}{Functional\ Classification}\right)$$

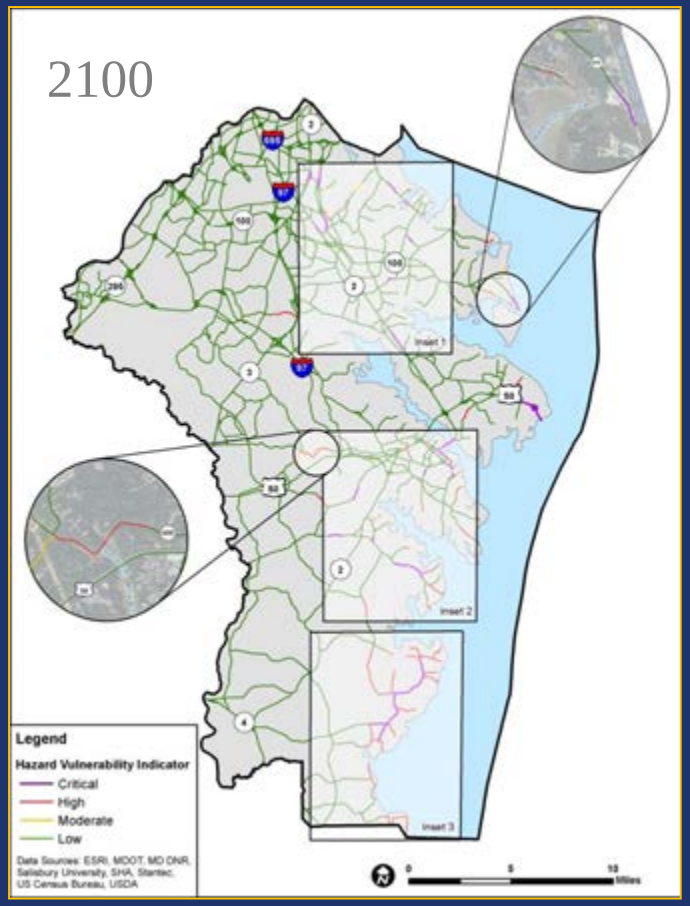
Evacuation	Code
No	0
Yes	1

Flood Depth (Feet)	Code
No Flood	0
0 – 0.5	1
0.5 - 1	2
1 - 2	3
>2	4

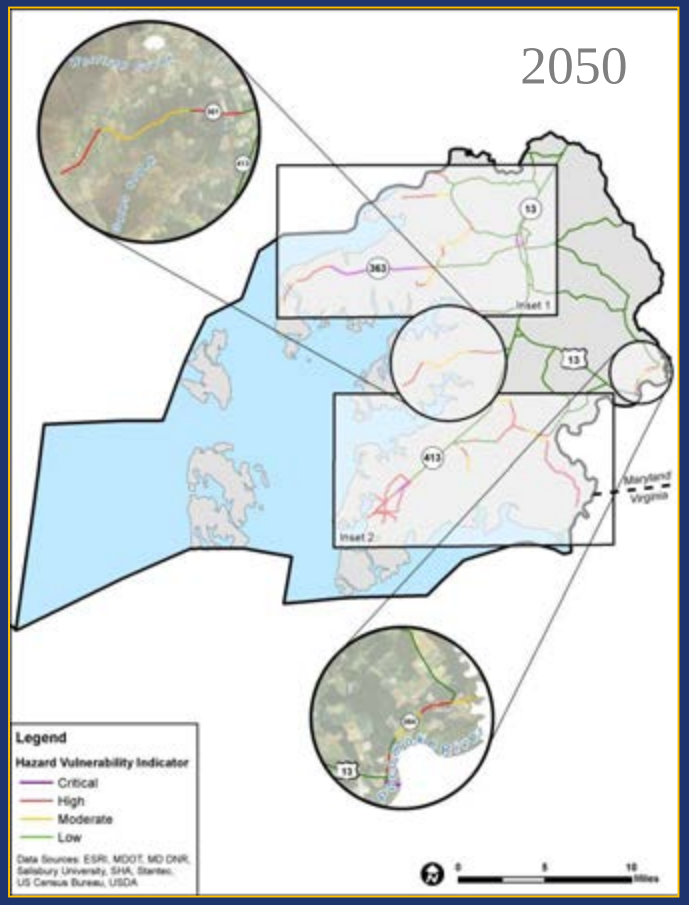
Value	SHA Functional Class
1	Interstate
2	Principal Arterial – Other Freeways and Expressways
3	Principal Arterial – Other
4	Minor Arterial
5	Major Collector
6	Minor Collector
7	Local

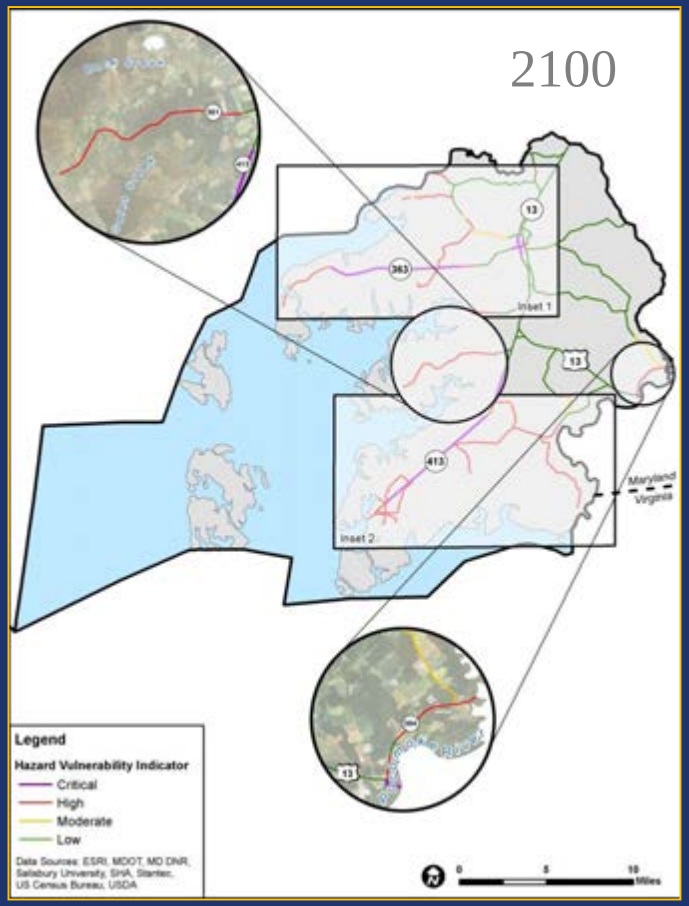
HVI for Anne Arundel County



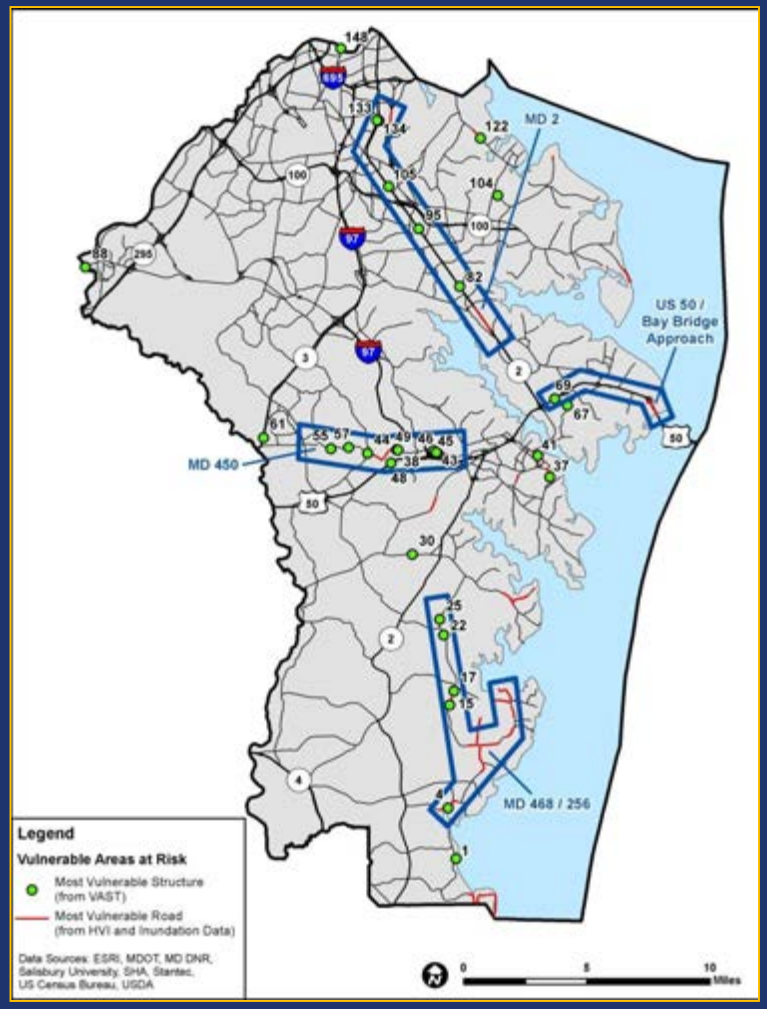


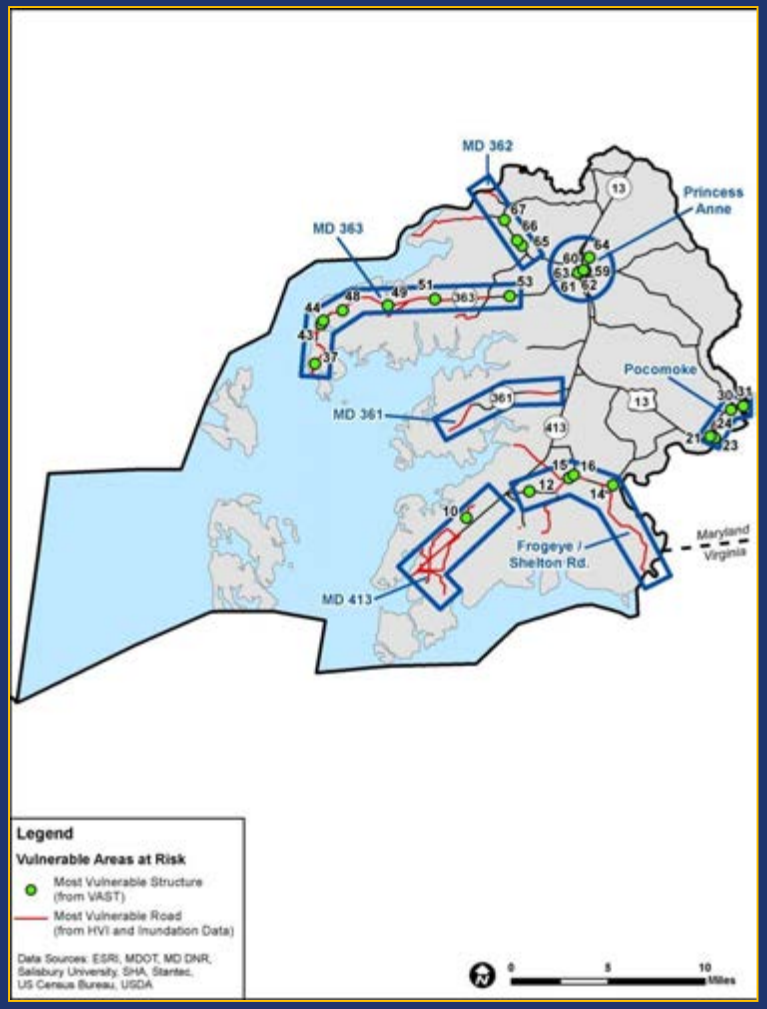
HVI for Somerset County





Vulnerable Areas at Risk





Results

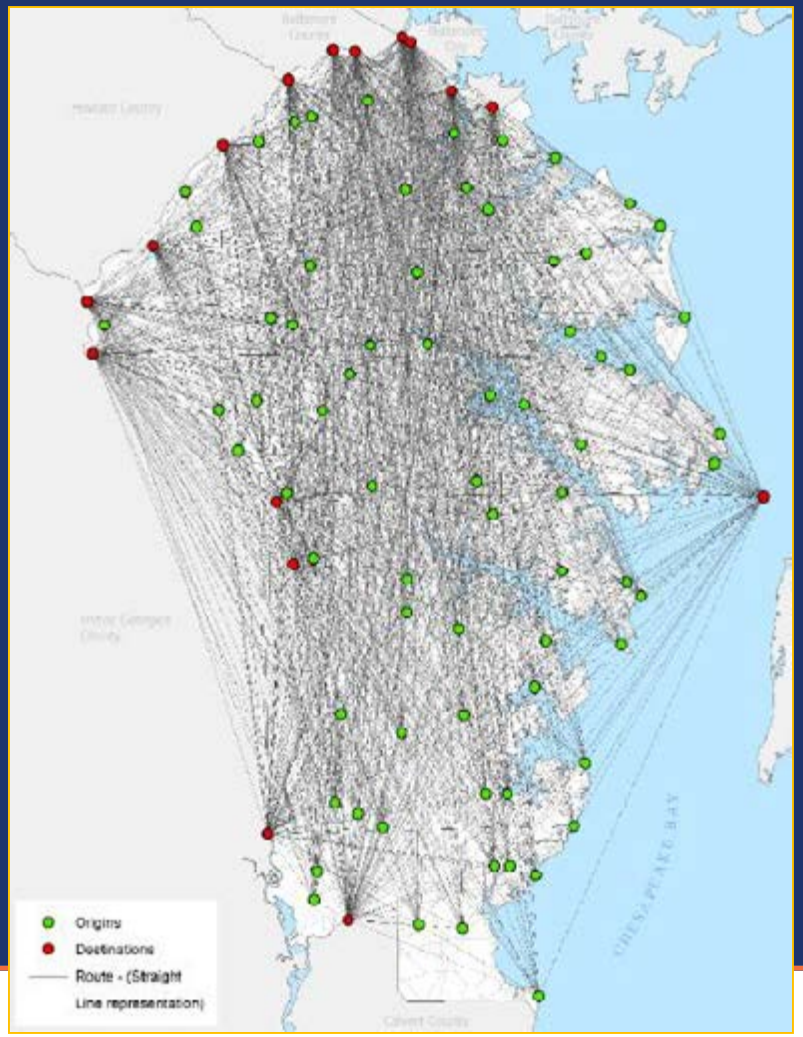
- Anne Arundel County and Somerset County
  - Permanent Inundation
  - 2050 & 2100 Sea Level Change (USACE method)
  - 2050 & 2100 Sea Level Change with 100 Year Storm Event (HAZUS-MH)
  - Storm Surge Considerations (Still Water)
  - Hazard Vulnerability Index (HVI)
  - Vulnerability Scores from VAST for bridges
  - Vulnerable Areas at Risk

Lessons Learned

- Data Collection - Bridge data most available, roadway and small culverts/drainage conveyances vulnerability assessment more difficult due to data gaps
- VAST and HVI were useful tools to quantify results and initial screening helped reduce level of effort
- Adaptation Measures for drainage assets have watershed related interdependencies and the solutions could be outside of DOT's jurisdiction
- Incorporate Climate Change consideration into existing planning and design process
  - Links to current operations and maintenance
  - Require screening of all projects for future climate impacts

Example Origin/Destination Network

- Evaluate the travel times and access to random locations both before and after a flood event
- 69 Random but evenly distributed Origin and Destination points chosen



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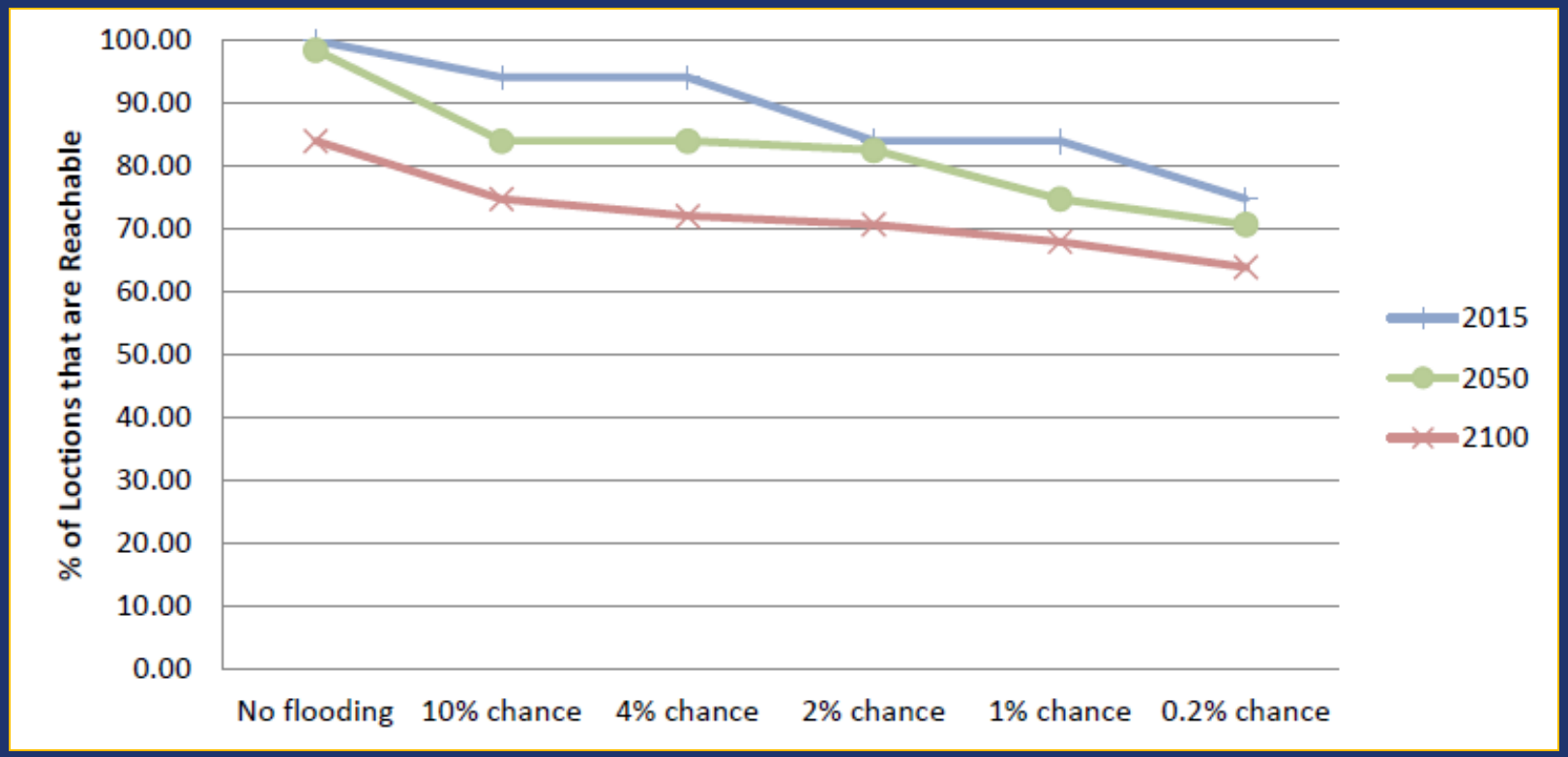
Percentage of Traversible Trace Paths in AA County with MSL SLC



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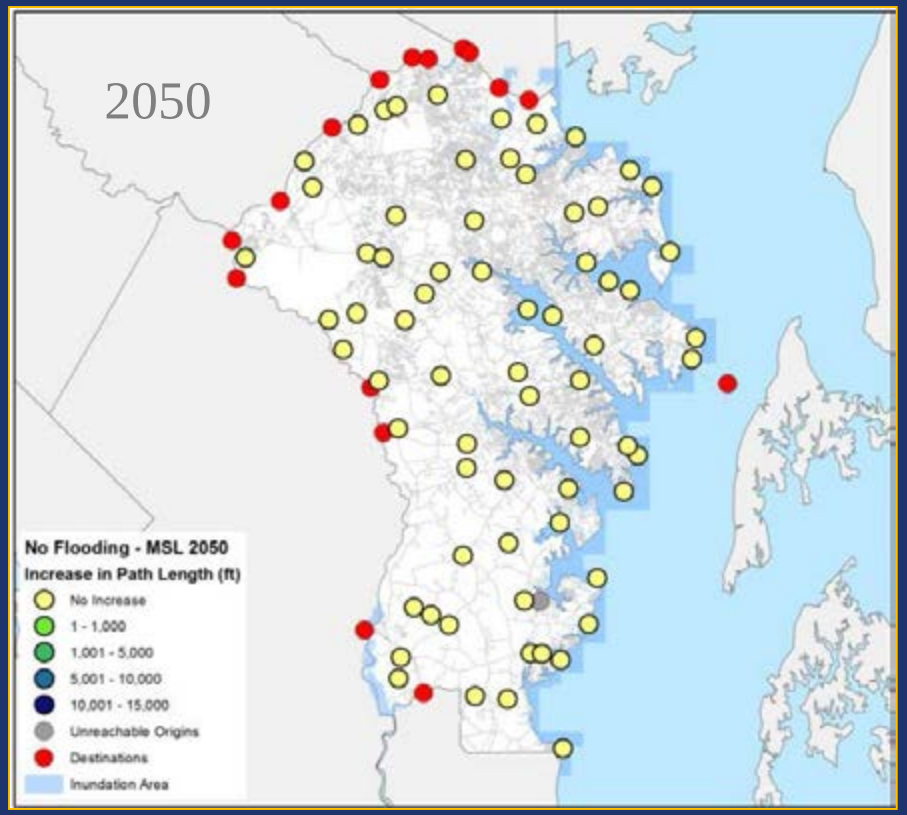
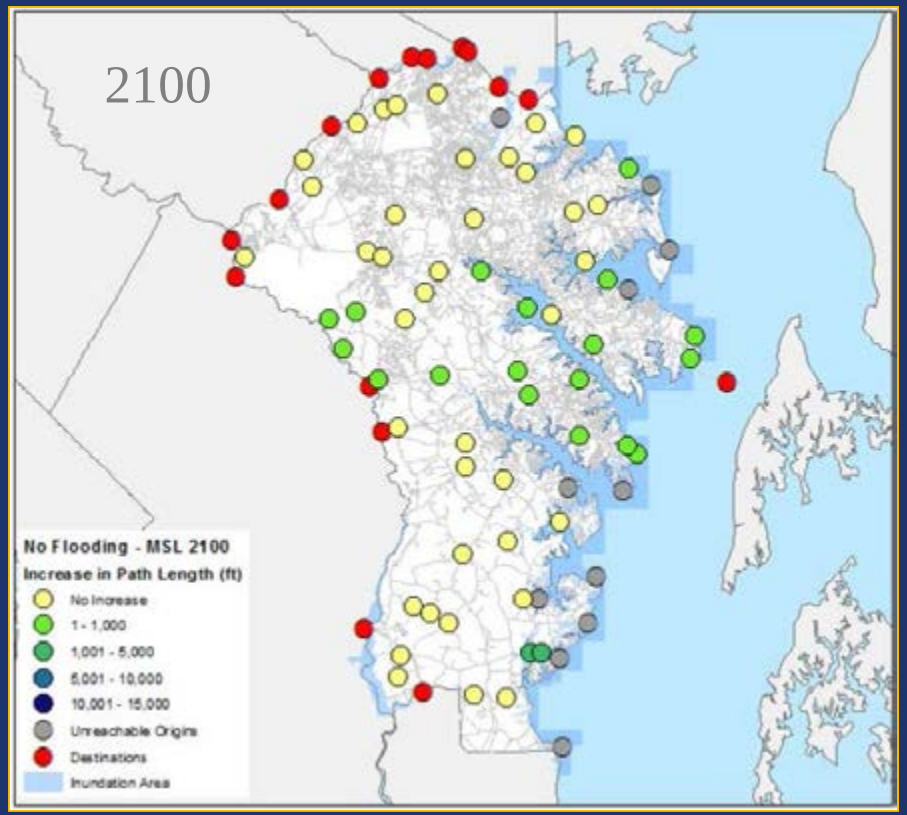
Origin to Destination Analysis





Questions

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410-545-8563

Climate Change Adaptation Plan with Detailed Vulnerability Assessment, October 2014

http://www.fhwa.dot.gov/environment/climate_change/adaptation/ongoing_and_current_research/vulnerability_assessment_pilots/2013-2015_pilots/index.cfm

BMC Information Exchange Forum

May 25, 2016

Baltimore Climate and Resiliency Planning & Implementation Projects

Baltimore Office of Sustainability
People · Planet · Prosperity

Kristin Baja, CFM
Climate and Resilience Planner
City of Baltimore, Office of Sustainability

Overview

- Plan Background
- Implementation
- Integration

Why the Resilience Plan?

Coastal Storms	more severe
Floods	more extensive
Severe Thunderstorms	more severe
Wind	increase intensity
Winter Storms	less snow, more flooding
Extreme Heat/Drought	more severe and intense
Sea Level Rise	increased threat
Air Quality	lower quality and increase risk

Shocks and Stresses

Shocks

Shocks are typically considered single event disasters, such as fires, earthquakes, and floods.

Stresses

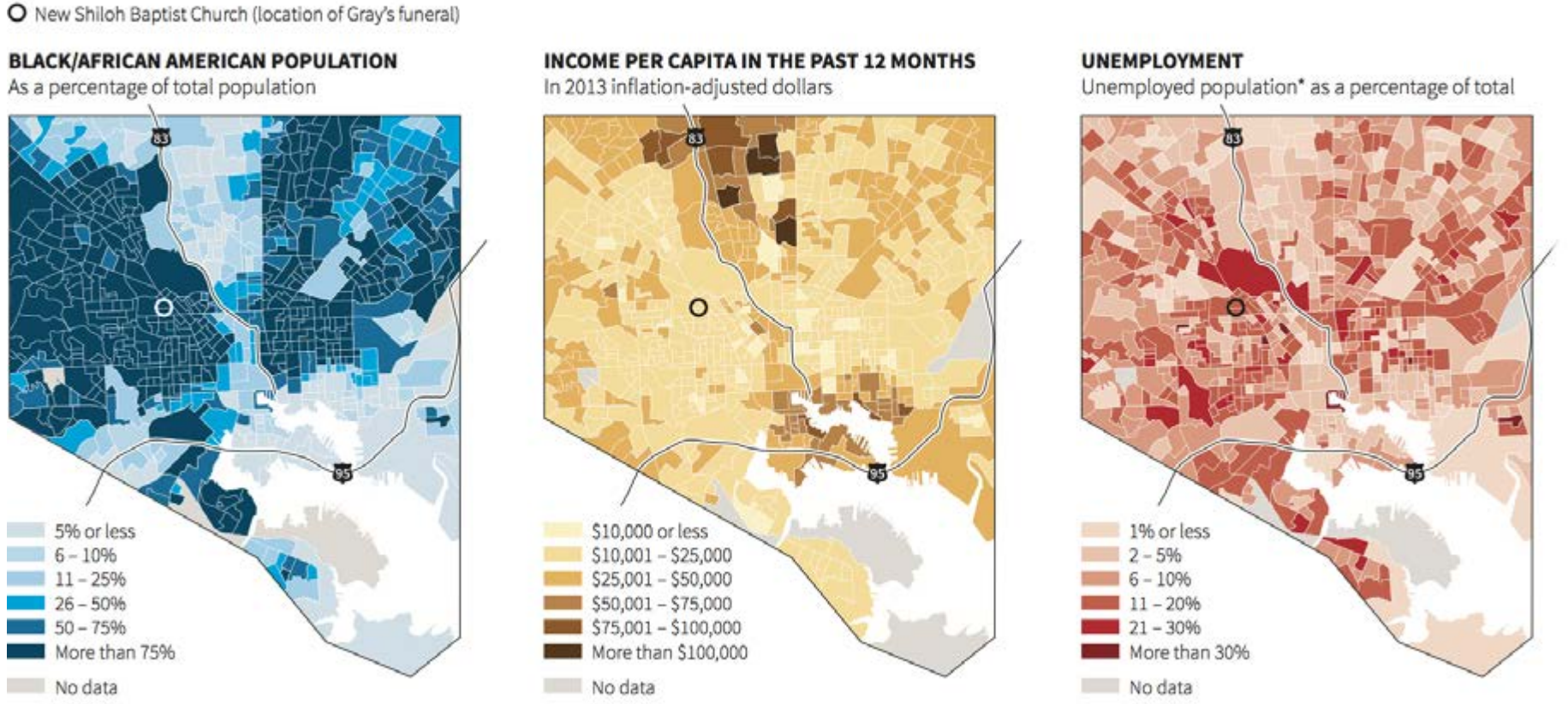
Stresses are factors that pressure Baltimore on a daily or reoccurring basis, such as endemic violence or high unemployment.

Focus on both shocks and stresses to enhance community adaptive capacity and resilience, especially in more vulnerable areas

Stresses

Socioeconomics in Baltimore

Following the funeral of Freddie Gray, a 25-year-old black man who died after he was injured in police custody, disturbances broke out a few blocks from the site of the service. Demonstrations turned violent and spread through parts of Baltimore on Monday.



Sources: 2013 American Community Survey estimates, U.S. Census Bureau; Open Baltimore, City of Baltimore; Reuters

*In civilian labor force, population aged 16 years and above

C.Chan, 28/04/2015

REUTERS

Disaster Preparedness Plan

Adopted unanimously in October, 2013

...ment that evaluates and improves all pipes' ability to withstand ...cold

...m is dated and in need of upgrades. It is important to build extreme weather resilience and disaster prevention into water and wastewater systems by using both adaptation and mitigation actions. Additionally, structural and infrastructural upgrades must be made to reduce loss of water supply from the distribution system.

Baltimore Water Pipe — Source: BaltimoreSun

1. Replace old and malfunctioning pipes with new pipes or retrofit existing pipes with new lining

   Pipes that have already begun experiencing problems, or older pipes which are more vulnerable to the impacts of hazards, should be upgraded using the best available technology.

2. Evaluate and utilize new technology that allows for greater flexibility in pipes as they are replaced

   It is essential to prepare for future changes in hazard events and proactively upgrade pipe systems to prevent cracking and bursting.

IMPLEMENTATION GUIDELINES	
Lead Agency	DPW
Stakeholders	DOT, DPW, Water and Wastewater Utilities
Alignment with Goals	Goal 3
Connection with Existing Efforts	CAP; ORS; MD DNR; ESF-3; ESF-4
Timeframe	

STRATEGIES AND ACTIONS 191

STORMWATER

IN-16 Enhance and expand stormwater infrastructure and systems

Future changes in precipitation frequency and intensity may require reconsideration of the design of existing stormwater infrastructure systems.

Increase resiliency and disaster prevention measures related to stormwater systems by enhancing drainage systems in stream corridors and improving and repairing stormwater conveyance popes and outfalls.

1. Implement the requirements of Baltimore's MS4 (separate stormwater and sewer system) permit (S)

   The City of Baltimore operates under a Municipal Separate Stormwater and Sewer System (MS4) permit, which protects water-quality and requires that Baltimore prevents pollution as much as possible. It is critical that the requirements of these permits are fully met.

2. Prioritize storm drain upgrades and replacement in areas with reoccurring flooding (S)

   While proximity to a floodplain or floodway can increase vulnerability to flooding, certain measures can reduce this vulnerability. Inadequate or older pipes, which cannot accommodate the excessive amounts of stormwater, should be upgraded so as to handle extreme rainfall and storm surge events.

3. Install backflow-prevention devices or other appropriate technology along waterfront to reduce flood risk (M-L)

   Backflow-prevention devices are used to ensure that water does not flow back through drainage infrastructure. Through the installation of backflow-prevention devices, the City can improve the performance of the drainage network and prevent risk of flooding impact along the waterfront.

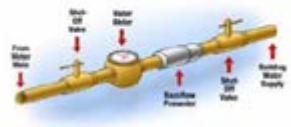
4. Preserve and protect natural drainage corridors (S)

   It is important to utilize natural drainage corridors and green infrastructure to capture more stormwater runoff and enhance the ability of the existing infrastructure to cope with environmental changes.

5. Review and revise storm drain design on a continuous basis, to accommodate projected changes in intense rainfall (O)

   The City's storm drains will require continual revision to incorporate new and projected changes in intense rainfall. This will ensure that the storm drains maintain adequate capacity.

IMPLEMENTATION GUIDELINES	
Lead Agency	DPW
Stakeholders	Community Groups, DOT, DPW, MOEM, MDNR, NGOs, Private Developers, Stormwater Utility
Alignment with Goals	Goals 1, 3, and 6
Connection with Existing Efforts	ORS; MD DNR
Timeframe	



Backflow Preventer — Source: DemanPlumbingNYC

Process

Risk Assessment

Hazard Identification

- Hazard Identification
- Review Historical Impacts
- Conduct an Asset Inventory

Vulnerability Assessment

- Determine likelihood
- Determine economic, social, legal & environmental consequence

Impacts Assessment

- HAZUS Modeling
- Integrate projected climate conditions
- Identify weaknesses

Plan Development

- Vision, Goals, Strategies, Actions
- Prioritization
- Integration
- Plan for implementation & monitoring

Six Goals

1. Protect the health, safety and welfare of Baltimore City residents and visitors
2. **Prevent damage to structures, infrastructure, and critical facilities**
3. Build resilience and disaster prevention and planning into all programs, policies, and infrastructure (public and private)
4. Enhance the City of Baltimore's adaptive capacity and build institutional structures that can cope with future conditions that are beyond past experience
5. Promote hazard mitigation and climate adaptation awareness and education throughout the City of Baltimore
6. **Become a Community Rating System (CRS) classified community**

Structure

Infrastructure

- Energy
- Liquid Gas
- Communication
- Transportation
- Waterfront
- Wastewater
- Stormwater
- Solid Waste
- Policy

Buildings

- City Codes
- Structural
- Non-Structural

Natural Systems

- Urban Parks & Forests
- Water Supply and Management

Public Services

- Emergency Preparedness & Response
- Health
- Education & Outreach
- Food System

Considerations Beyond Requirements

- Historic Buildings and Areas
- **Engineering Studies on Critical Facilities**
- Health Impact Assessment
- Response and Recovery
- **Port Considerations**

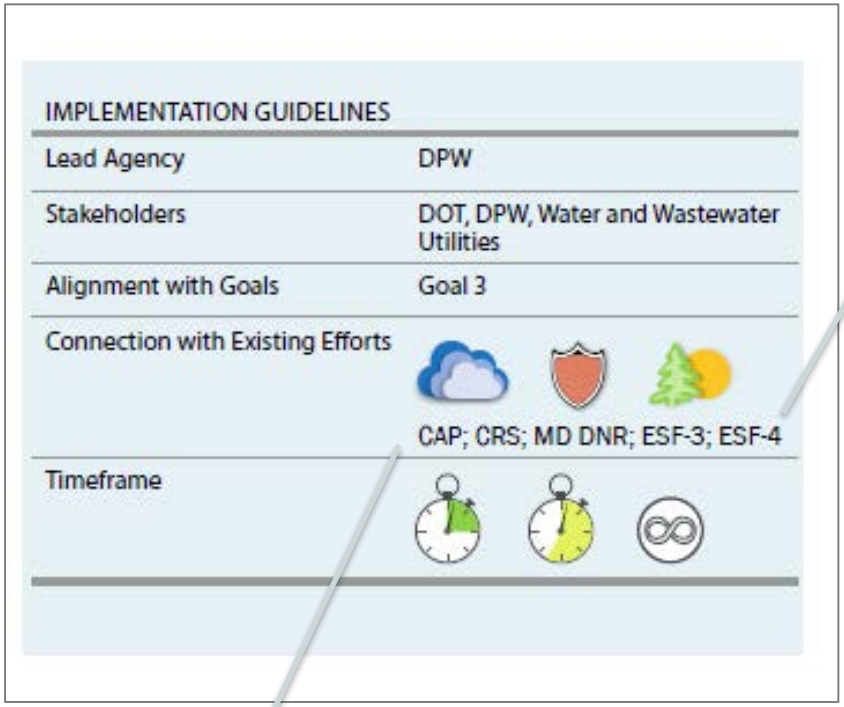

Implementation

Crosswalk

- Identify overlaps with existing planning efforts
- Prioritize Strategies and Actions with lead stakeholders

STRATEGY NUMBER	STRATEGY	ACTION	Water a	C1	C2	C3	PP1	PP2	PP3	PP4	PP5	RC1	RC2	RC3	RC4	G1	G2	G3	G4	T1	T2	T3	T4	T5	EA1	EA2	EA3	EA4	GC1	GC2
		Review and revise storm drain design on a continuous basis, to accommodate projected changes in intense rainfall							x				x																	
IN-17	Modify urban landscaping requirements and increase permeable surfaces to reduce stormwater runoff	Support existing stormwater requirements and continue to evaluate and improve Best Management Practices							x				x			x			x										
		Encourage urban landscaping requirements and permeable surfaces into community managed open spaces							x				x			x		x	x										
		Utilize water conservation elements such as green roofs, rain gardens, cisterns, and bioswales on residential, commercial, industrial, and City-owned properties to capture stormwater							x				x			x		x	x										
		Encourage permeable paving on low-use pathways							x				x					x	x										
IN-18	Evaluate and support DPW's stream maintenance program.	Review and improve status of standing maintenance requirements			x				x										x										
		Ensure adequate funding is in place to support stream maintenance			x				x										x										
		Identify opportunities where stream restoration efforts will off-set maintenance costs			x				x										x										
		Identify interdependencies and benefits of stream maintenance with other transportation programs			x				x										x	x	x	x	x	x						
		Clear streams on a regular basis, prioritize dredging the stream beds, and increase inspection and cleaning of culverts and storm drains to prevent flooding		x	x				x										x										
IN-19	Support and increase coordination and information sharing across jurisdictions to better enable mitigation of cross-border impacts on the regions watersheds (e.g., understanding flood conditions upstream in the County)	Partner with local counties to evaluate major tributaries in all watersheds to determine best management practices for capturing run-off and slowly releasing it (stormwater quantity management)							x				x						x										
		Encourage information sharing within the Chesapeake Bay community to assist in developing best management practices							x				x						x										
IN-20	Reevaluate and support a comprehensive debris management plan for hazard events	Investigate best practices for managing and disposing of downed trees, yard waste, building debris, as well as additional household garbage		x	x									x															
		Expand and integrate existing programs to reduce or intercept debris before it gets into the streams and harbor		x	x									x															
		Develop and promote solid waste management actions for citizens to implement before a hazard event		x	x									x															
		Incorporate consideration of hazards and climate adaptation efforts into all plans, systems,		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Identify Connections



Emergency Support Functions

Governmental and certain private sector capabilities that provide support, resources, and services needed to save lives, protect property and environment, restore essential services and critical infrastructure and help communities.

Climate Action Plan

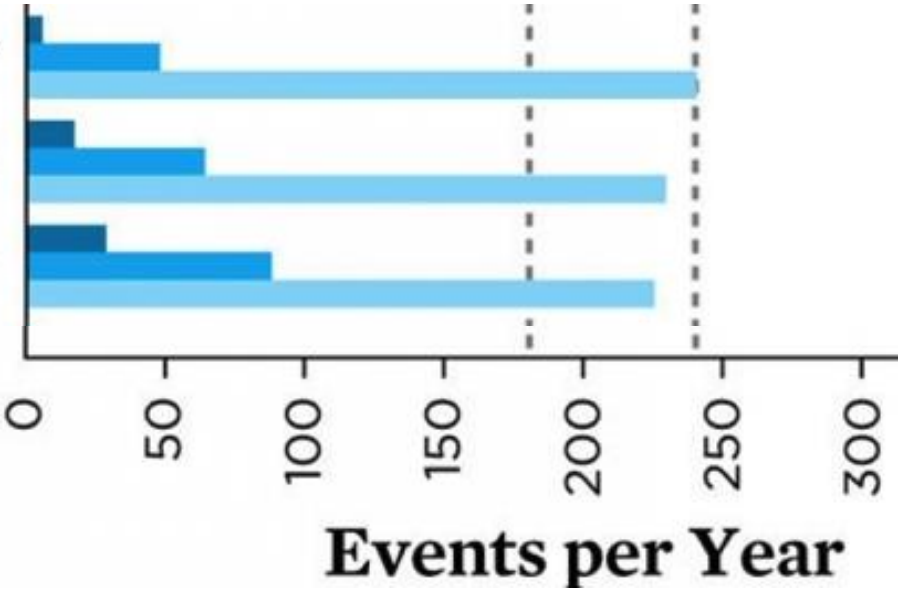
Increasing resiliency of the electricity system and increasing energy conservation efforts

Flooding

- Floods are the most common natural disaster.
- Yearly, almost 200 Americans lose their lives in floods.
- 90 % of all presidential declarations of emergency or major disaster area involve flooding.
- Flood hazard areas exist in almost every American community. 7.4 million buildings are located in flood hazard areas.
- On average, flood damages throughout the nation annually exceed $3 billion.
- Direct and indirect costs of flood recovery are borne by all American taxpayers - not just flood victims.

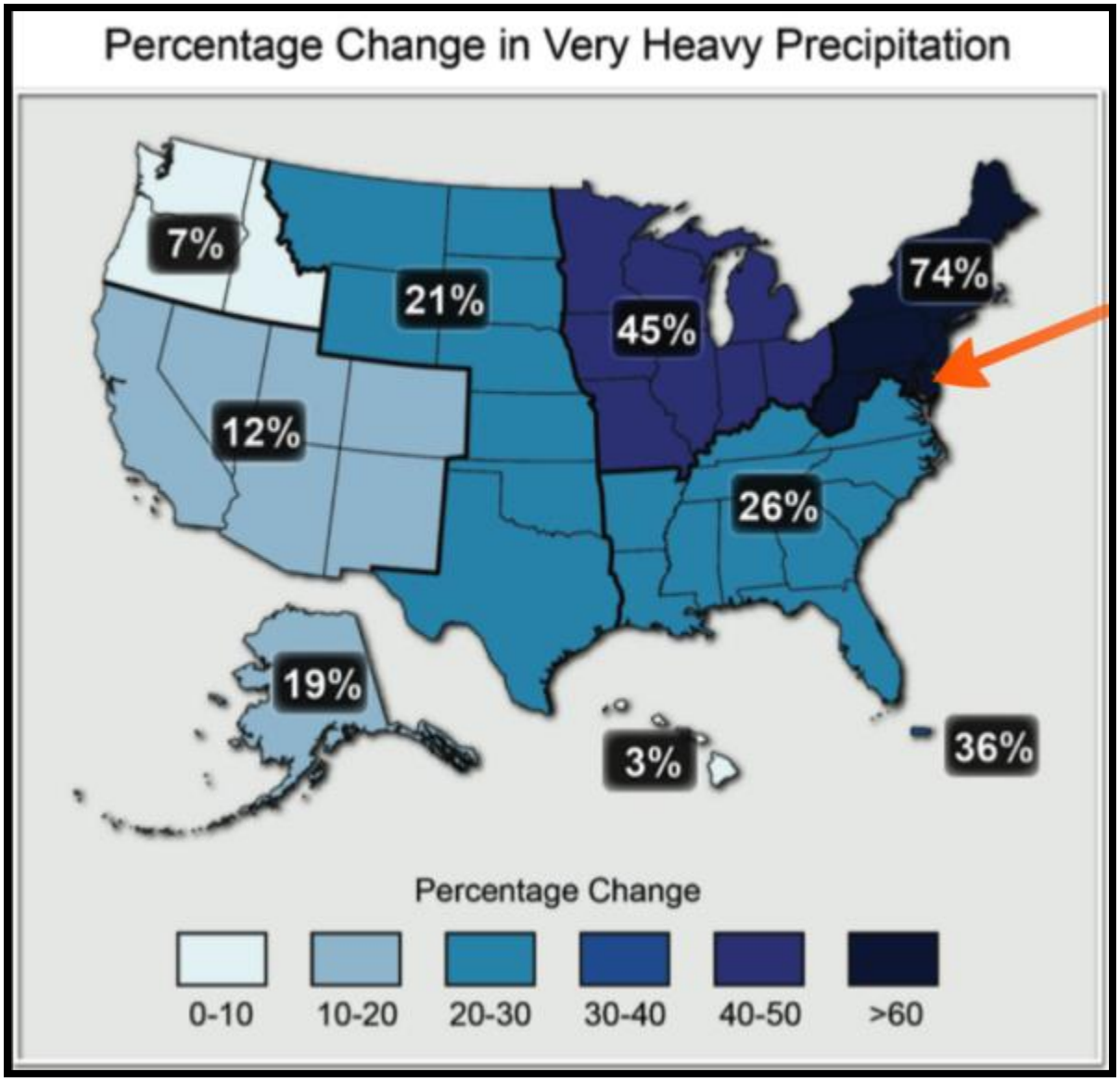
http://www.dcr.state.va.us

Tidal Flooding

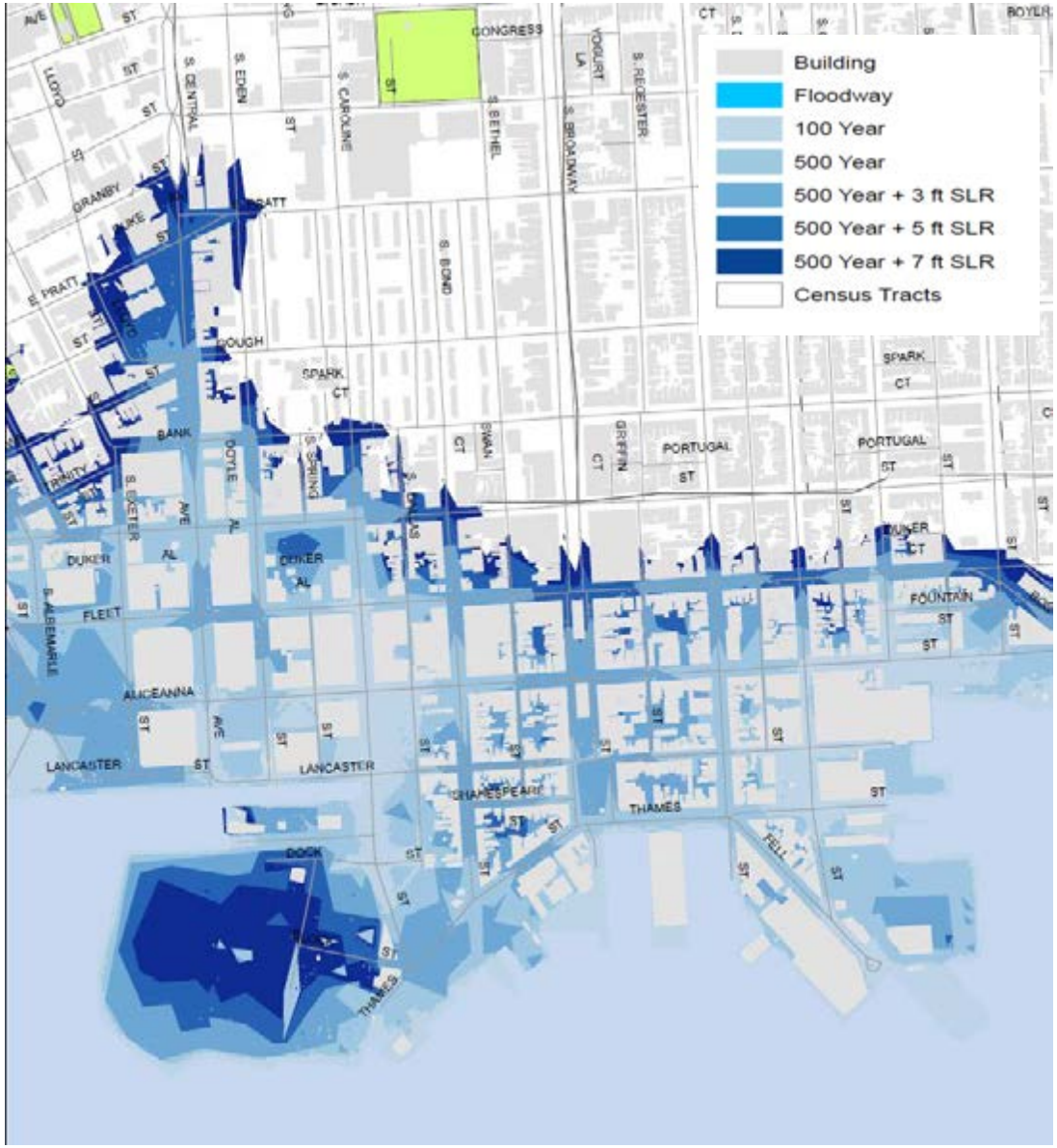


Union of Concerned Scientists, 2014

Precipitation Variability

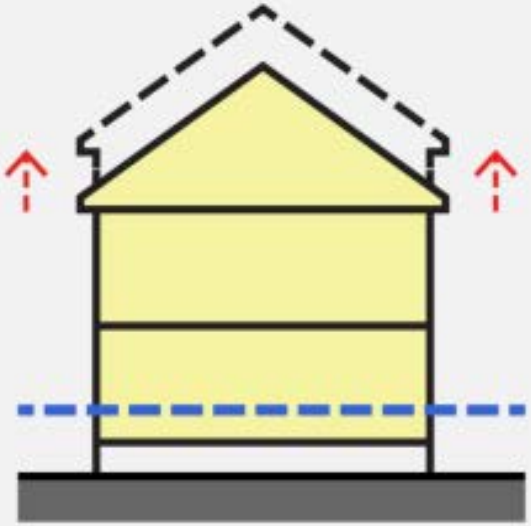


Stormwater: Floodplain

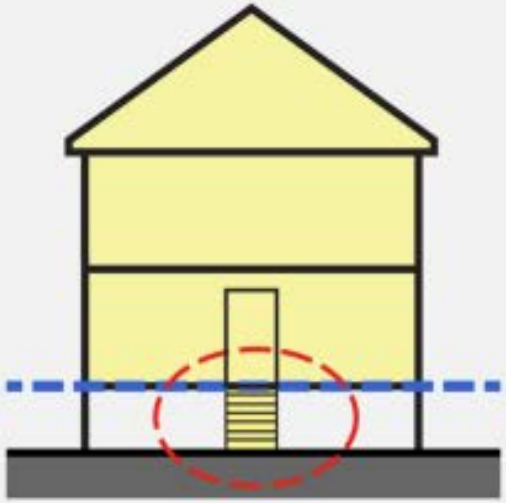


Updated Ordinance in April, 2014 establishing:

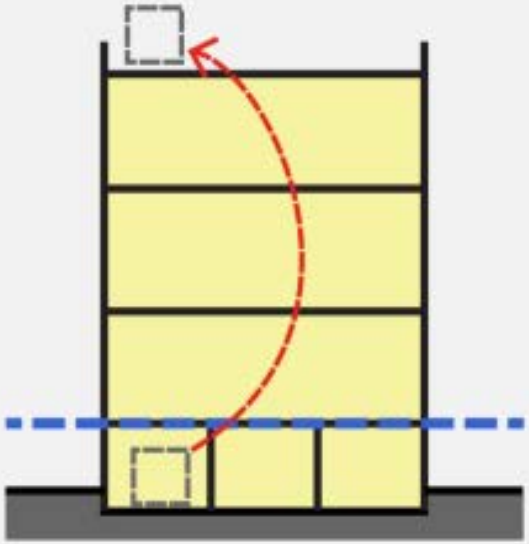
- Two (2) feet of freeboard (plus <u>additional foot for critical facilities</u>)
- Flood Resilience Area and 500-year extent
- ASCE-24 construction standards



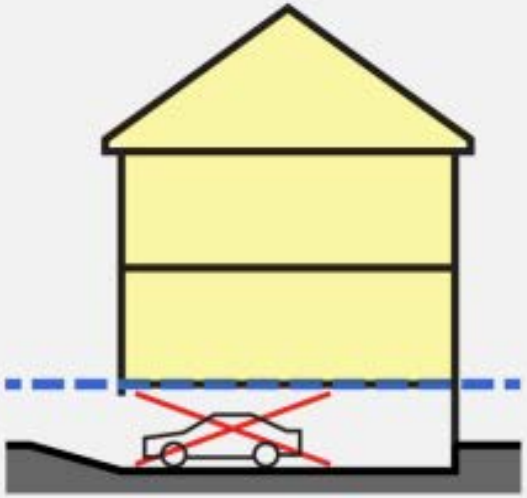
HEIGHT
must recognize elevation requirements in flood zones



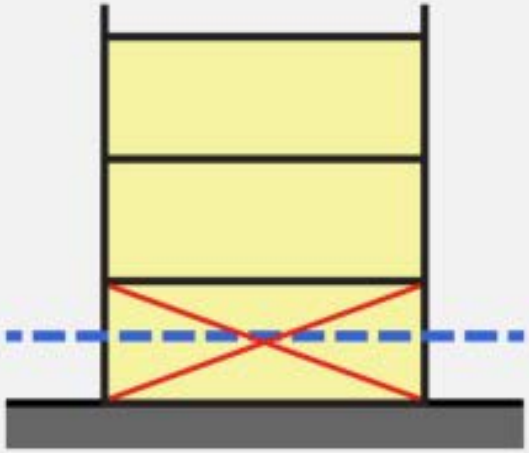
ACCESS
need for stairs or ramps requires imaginative solutions



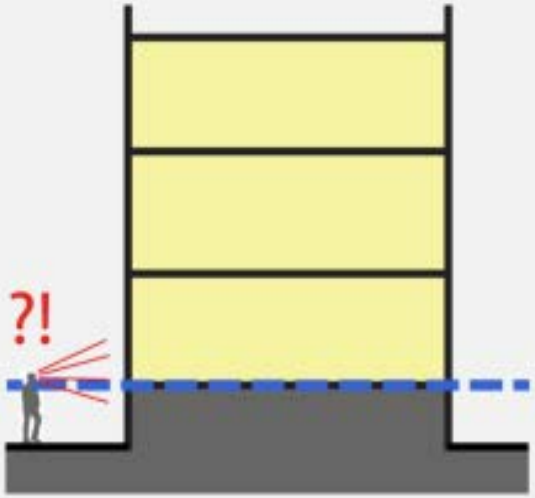
MECHANICAL SYSTEMS
must allow relocation out of flood-prone areas



PARKING
may not be possible below ground



GROUND FLOOR USE
buildings may be allowed only limited use of ground floors



STREETSCAPE
limit negative effect of blank walls on streetscape

Flood Walls Assessment

Big Insurance Changes

Biggert-Waters Flood Insurance Reform Act of 2012

- Intended to phase in increases in flood insurance rate for homes in flood zones
- Proposed loss of subsidies and grandfathered status

Homeowner Flood Insurance Affordability Act of 2014 (HFIAA)

- Repeal and modifies Biggert-Waters
- Slows some flood insurance rate increases
- Phases out subsidies for some older buildings in high-risk areas
- Insurance rates for these buildings will rise quickly until they reach full-risk rates
- All policyholders subject to new assessments and surcharges

Increase this April

Another Round of NFIP rate changes April 1, 2016

- Pre-FIRM subsidized properties (non-primary residential, business properties, severe repetitive loss properties and substantially/damaged/substantially improved properties) must be increased annually by 25% until they reach full-risk rates
- The average annual premium rate increases for all other risk classes are limited to 15% while the individual premium rate increase for any individual policy is limited to 18% and
- The average annual premium rate increase for Pre-FIRM subsidized policies must be at least 5%.

Community Rating System

- The National Flood Insurance Program's (NFIP) Community Rating System (CRS) is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements.

- Currently 1,296 Communities Participate in the CRS

NFIP/CRS

CRS

Communities can participate in any of the 18 activities in the following 4 categories:

- **Public Information Activities**
- **Mapping and Regulatory Activities**
- **Flood Damage Protection Activities**
- **Flood Preparedness Activities**

For a community to be eligible, it must be in full compliance with the National Flood Insurance Program and regulating its code properly.

Points System

CREDIT POINTS	CLASS	PREMIUM REDUCTION SFHA*	PREMIUM REDUCTION NON-SFHA**
4,500+	1	45%	10%
4,000 – 4,499	2	40%	10%
3,500 – 3,999	3	35%	10%
3,000 – 3,499	4	30%	10%
2,500 – 2,999	5	25%	10%
2,000 – 2,499	6	20%	10%
1,500 – 1,999	7	15%	5%
1,000 – 1,499	8	10%	5%
500 – 999	9	5%	5%
0 – 499	10	0	0

*Special Flood Hazard Area

Exceeding Minimum Requirements

- Baltimore joined the NFIP to establish floodplain premium rates for citizens
- Updated Ordinance in April, 2014 establishing:
  - ► Two (2) feet of freeboard
  - ► Flood Resilience Area and 500-year extent
  - ► ASCE-24 construction standards
- Provide floodplain information to citizens
- Improve our floodplain management system

Stormwater Management

Resiliency & Restoration

- Stream Restoration
- Stormwater Capture Systems
- Impervious Surface Removal
- Erosion Control
- DAMS
- Wastewater Treatment Plants
- Blue Alley Projects
- Replace and upgrade pipes

Energy: Residential Pilot

- Identify neighborhoods most vulnerable to impacts from climate change
- Pilot project: solar on row houses in low income area
- Include weatherization and cool roof installation
- Community Resiliency Hub with battery backup

Critical Facilities

Back River Wastewater Treatment Plan

4200 panels on five acres

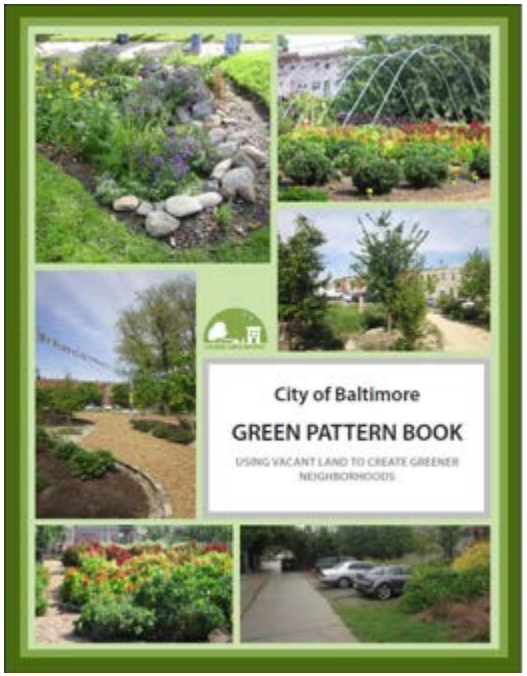
City Initiatives

Using Green Infrastructure as part of a comprehensive strategy for rebuilding Baltimore

- Provides economic, environmental, and social benefits
- Capacity to support the missions and goals of multiple agencies by addressing issues including stormwater management, health issues, and economic development.

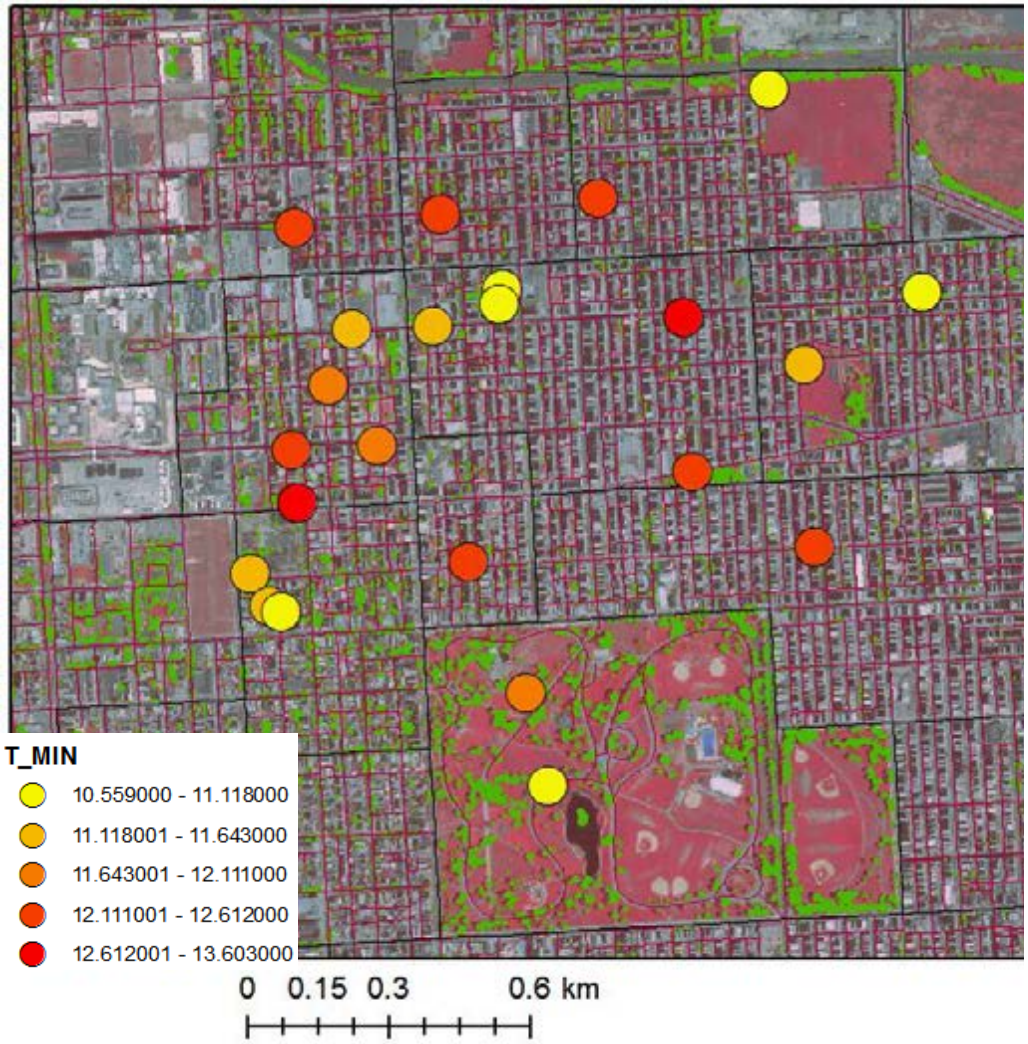
Growing Green

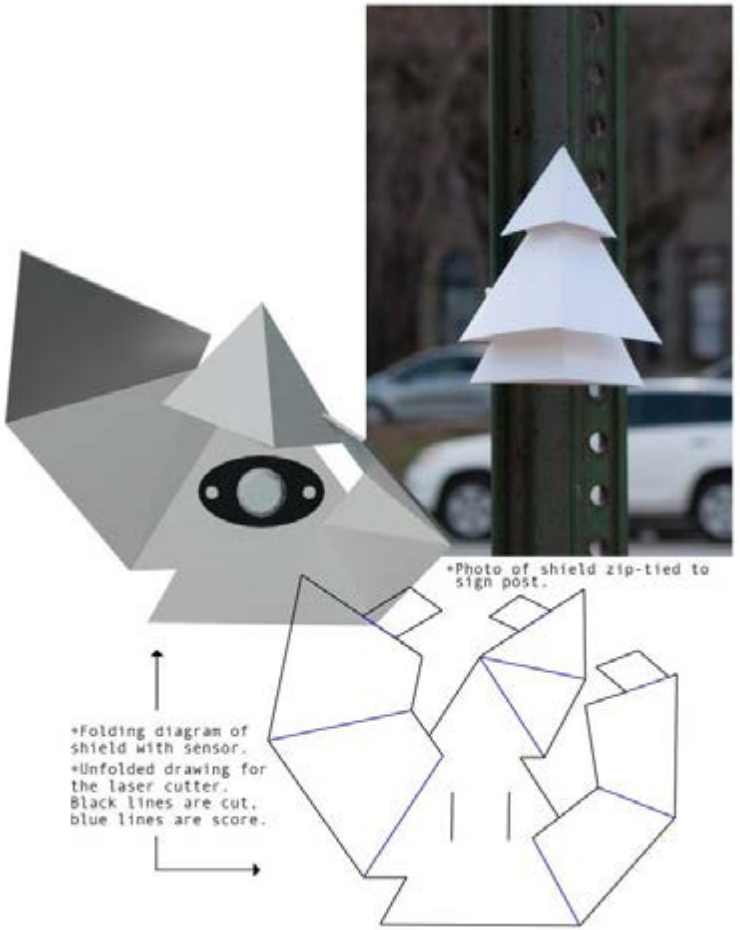
Effort focused on re-using vacant land to green neighborhoods, reduce stormwater runoff, grow food, and create community spaces that mitigate the negative impacts of vacant properties



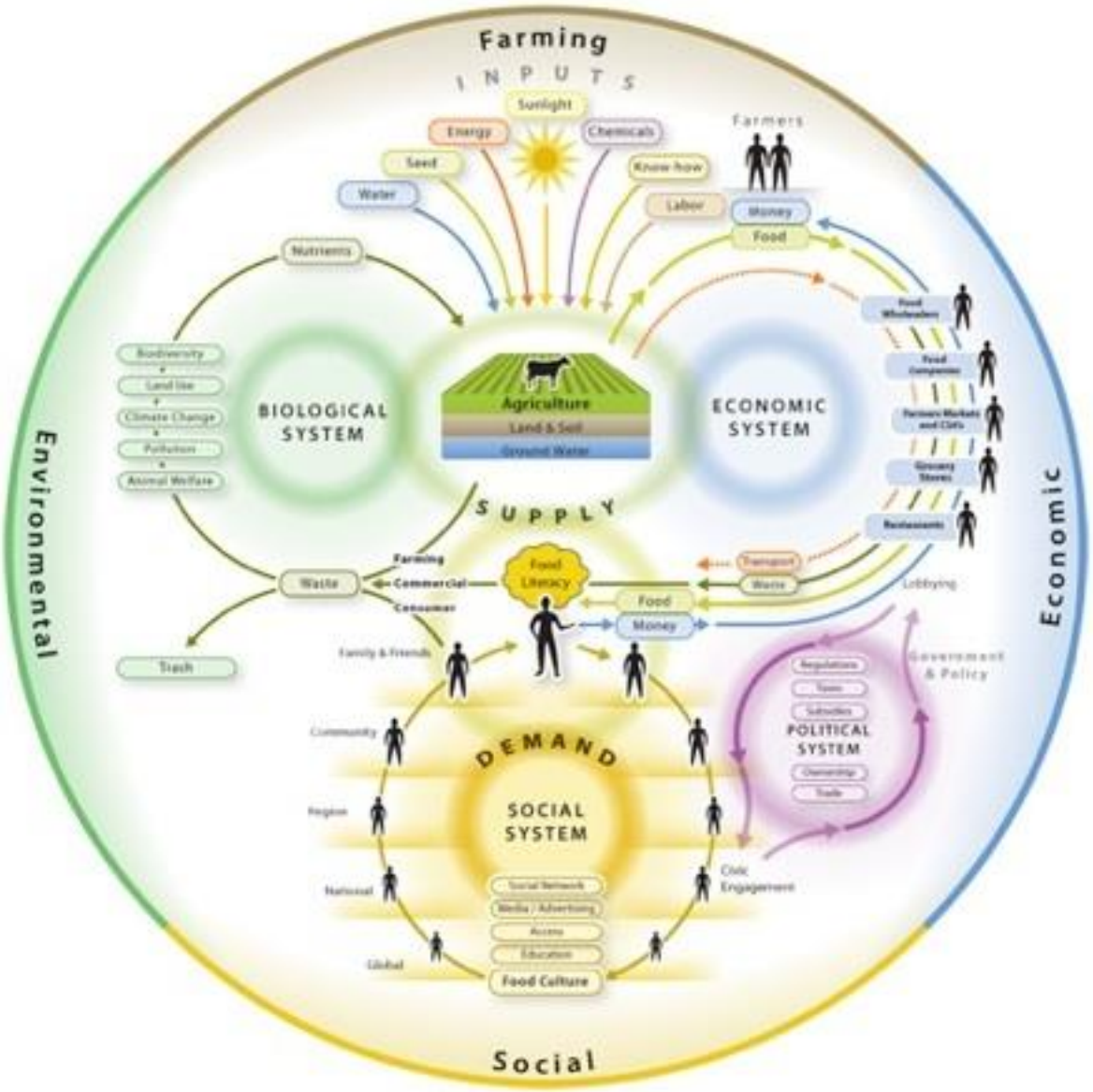
Heat Islands and Sensors

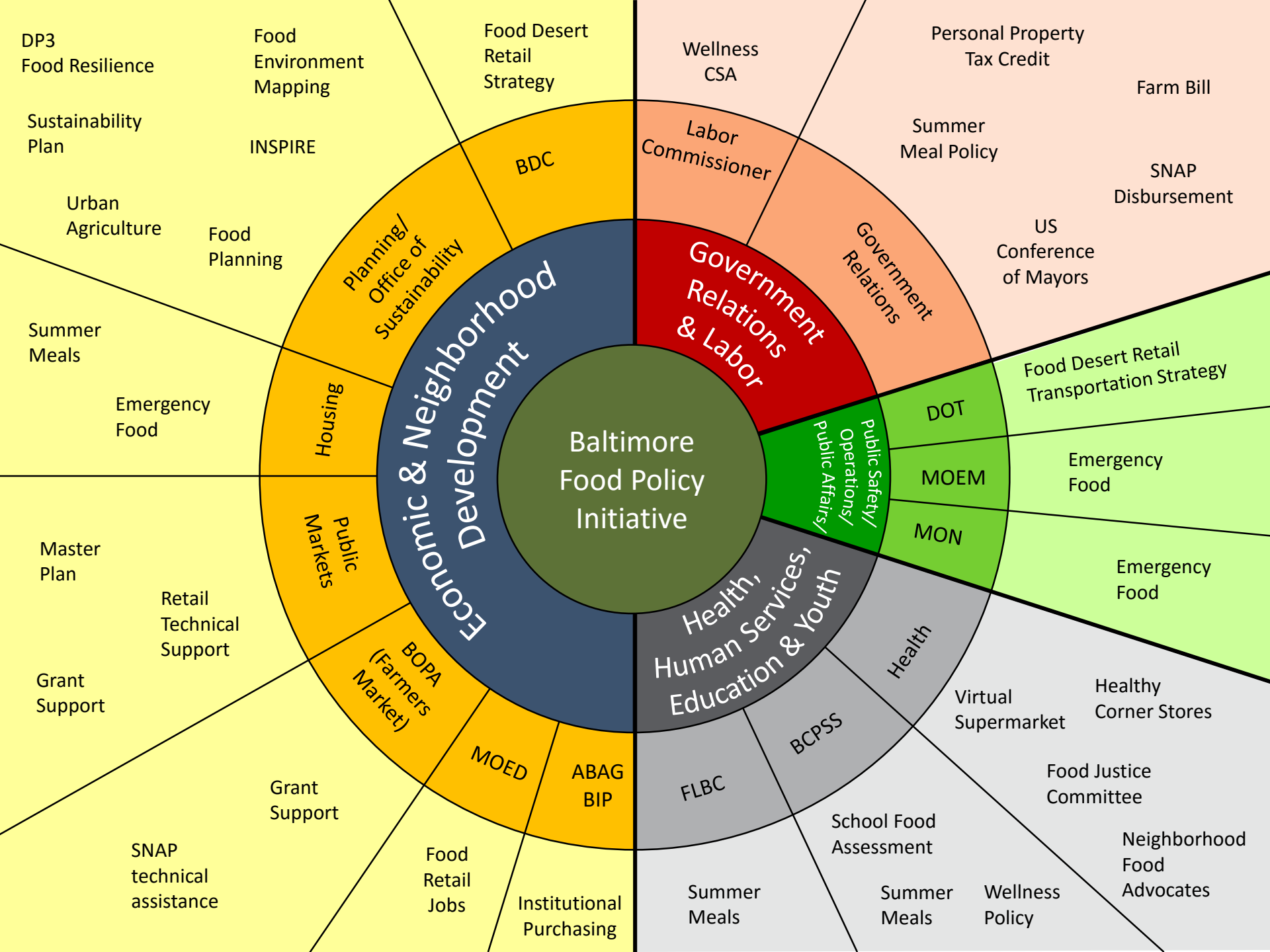
Minimum Temperature (^{O}C)





Food Resilience




Baltimore Food Policy Initiative
Economic & Neighborhood Development
Government Relations & Labor
Health, Human Services, Education & Youth
Public Safety/ Operations/ Public Affairs/
Planning/ Office of Sustainability
BDC
Housing
Public Markets
BOPA (Farmers Market)
MOED
ABAG BIP
Labor Commissioner
Government Relations
DOT
MOEM
MON
Health
BCPSS
FLBC
DP3 Food Resilience
Food Environment Mapping
Food Desert Retail Strategy
Sustainability Plan
INSPIRE
Urban Agriculture
Food Planning
Summer Meals
Emergency Food
Master Plan
Retail Technical Support
Grant Support
SNAP technical assistance
Grant Support
Food Retail Jobs
Institutional Purchasing
Wellness CSA
Personal Property Tax Credit
Farm Bill
Summer Meal Policy
SNAP Disbursement
US Conference of Mayors
Food Desert Retail Transportation Strategy
Emergency Food
Emergency Food
Virtual Supermarket
Healthy Corner Stores
Food Justice Committee
School Food Assessment
Neighborhood Food Advocates
Summer Meals
Summer Meals
Wellness Policy

Equity

- Prioritize neighborhoods with highest vulnerability to impacts from climate change
- Provide job training and green job opportunities
- Improve water and air quality (health)
- Economic benefit- lower electricity costs

Next Steps

Make a Plan, Build a Kit, Help Each Other








Missing Piece

Held over 40 Community Preparedness Meetings. In those meetings, residents identified a need for more than kits and plans. They identified the following missing pieces:

- Safe place to go
- Access to materials and tools
- Access to heat and cooling
- Information center
- Power
- Medical care
- Food and water

Example – Hurricane Sandy

Issues during and after Hurricane Sandy

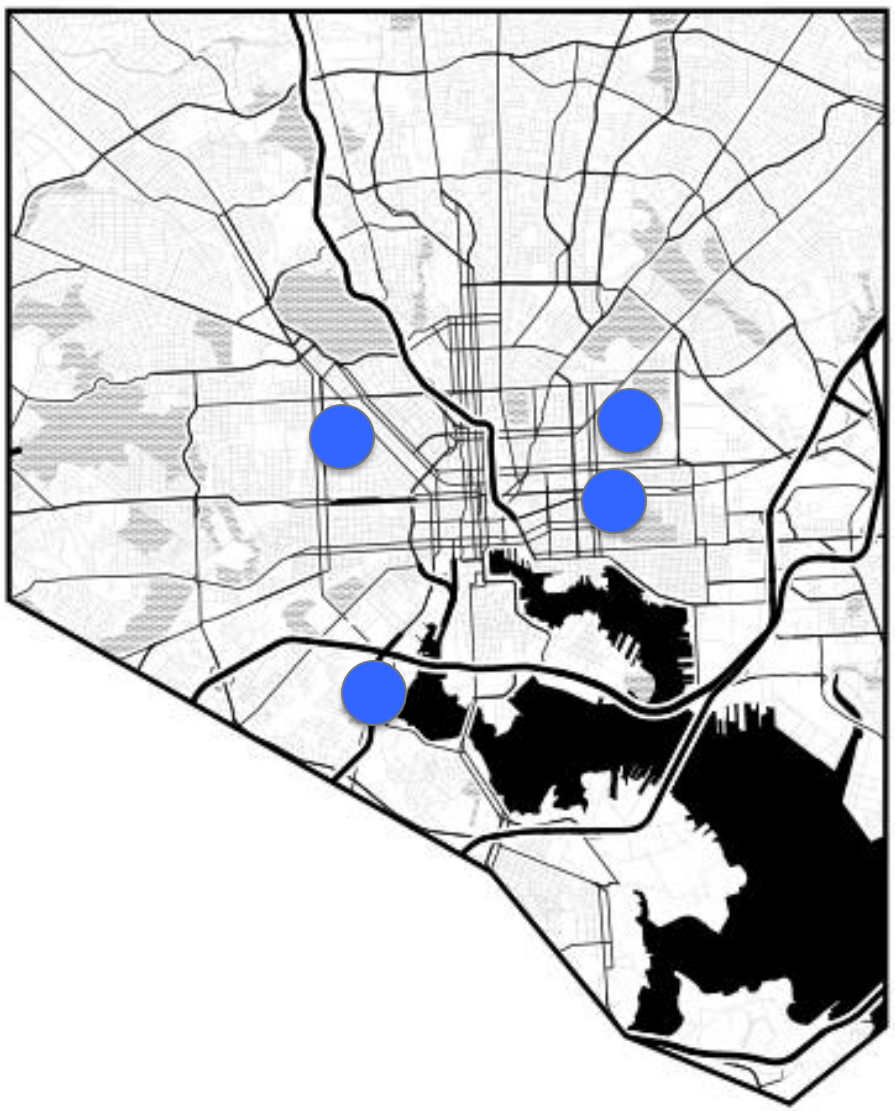
- Energy and reliable energy systems
- Food and water distribution
- Information and communications
- Disproportionate impacts on people with less resources

Resiliency Hubs

Definition: A Resiliency Hub consists of a building or set of buildings and neighboring outdoor space that will provide shelter, backup electricity, access to fresh water, and access to resources such as food, ice, charging stations, etc. in the event of an emergency.

Ideally, hubs will also include additional elements such as a place to grow fresh and local food, increased tree canopy for shade and cooling, and resources for sheltering in place or evacuation as needed.

Resiliency Hubs



Resiliency Hubs are locations that are used year-round and for other activities

Not City-owned buildings- utilizes existing facilities that are trusted in the community

Currently working on four pilot hubs in Baltimore City

Resiliency Hubs: Next Steps

- Develop list of areas to target resiliency hub development
- Choose four resiliency hub locations
- Develop resiliency hub criteria and framework for implementation
- Complete assessments of buildings and resources.
- Obtain commitment from local community NGO or community group interested in running and managing the resiliency hub
- Identify vacant and available lots for greening opportunities
- Build upon preparedness outreach through *Make a Plan. Build a Kit. Help Each Other* program
- Coordinate with energy and water efficiency outreach to residents and businesses in target neighborhoods.
- Install cool roof and solar panel system
- Install battery backup system
- Coordinate partners and resource providers

Integration

Integration: CIP

- Department of Planning manages process
- Developed a Resiliency Checklist for projects
- Identify how each project will help reduce risk and improve the City's ability to adapt and respond to natural hazards
- Projects must take into account anticipated impacts from climate change
- Include extreme weather events, adaptation, SLR, floodplain considerations, and mitigation

Historic Building Design Manual

- 10 Building Typologies in Baltimore City
- Full Inventory – Historic structures in Floodplain
- Critical and Structural Systems (Category IV buildings)
- Design manual with materials and guidelines

In-depth Staff Trainings

- 2016 Grant to provide next level (in-depth) Climate Adaptation Trainings for specific City Departments
- Focus on decision makers and middle managers
- Stormwater, Surface-water, and Transportation Engineers
- Collaboration with Seattle, Toronto, Providence (RI), Fort Lauderdale, and Vancouver

Build into new initiatives

- Continue to build resiliency into all new plans and projects
- Regional collaboration
- Reach out to new partners and identify new opportunities for relationship building

GROWING GREEN INITIATIVE

BALTIMORE ENERGY INITIATIVE

VACANTS TO VALUE

Baltimore Office of Sustainability
People · Planet · Prosperity

Questions?

Kristin Baja
Climate and Resilience Planner
Kristin.Baja@baltimorecity.gov

U.S. Naval Academy Prepares for Rising Seas

CDR Angela Schedel, PhD, PE
Assistant Professor, Ocean Engineering
May 25, 2016

Prepared for the Baltimore Metropolitan Council

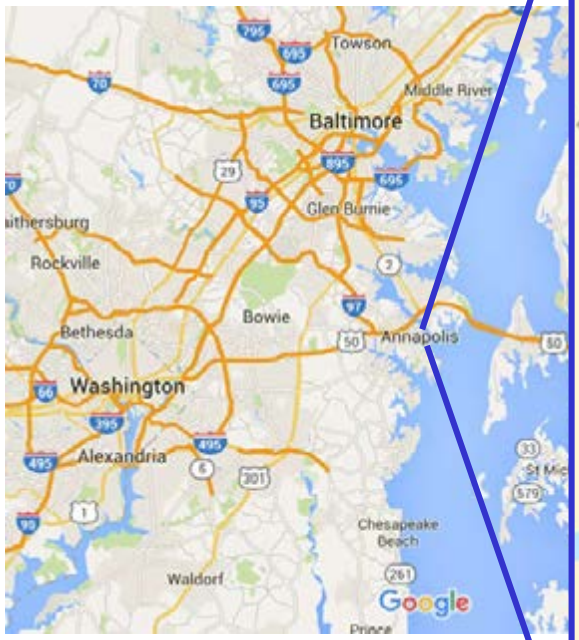
Topics - Overview

- **USNA – Overview**
- **Hurricane Isabel and Follow-up**
- **USNA – SLR Advisory Council**
- **Studies & Directives, Incorporating Science**
- **Adaptation Options**

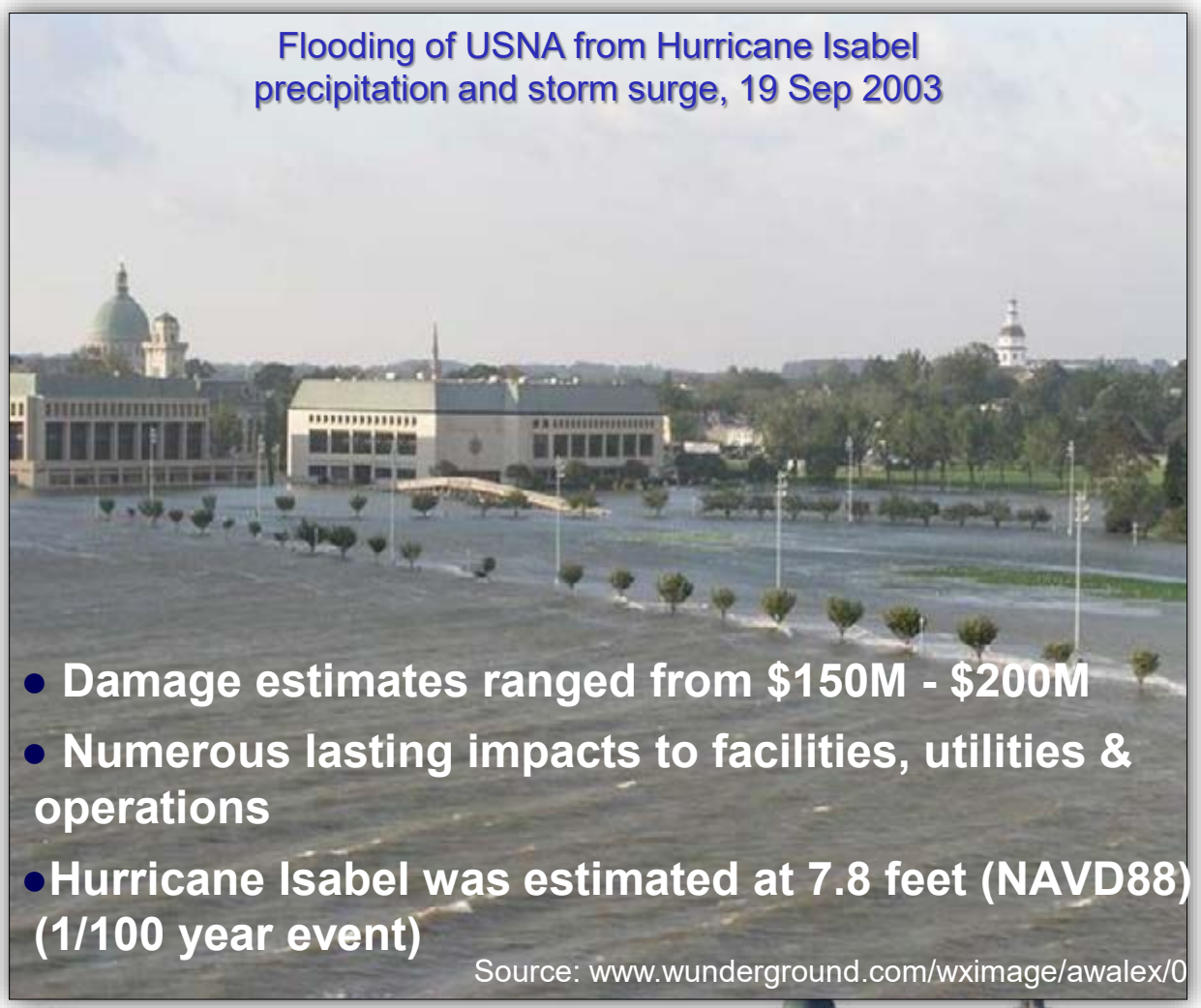
USNA – Historic & Facility Perspective

- **Founded in 1845 – *National Historic Landmark***
- **Educate 4,200 Midshipmen, graduate ~1000 per year**
- **32 of our facilities are "monumental"**
  - **These historic facilities (granite, marble, slate roofs, etc.) cannot be easily duplicated nor easily replaced**
- **Estimated Property Replacement Value (PRV) for USNA "Lower Yard" – major campus area is $1.6 Billion (*Navy iNFADS database estimate*)**

U.S. Naval Academy Location



Hurricane Isabel - 2003



- Damage estimates ranged from $150M - $200M
- Numerous lasting impacts to facilities, utilities & operations
- Hurricane Isabel was estimated at 7.8 feet (NAVD88) (1/100 year event)

Source: www.wunderground.com/wximage/awalex/0

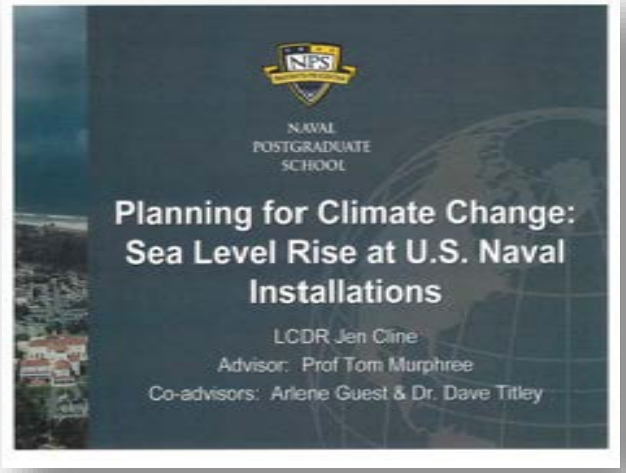
Current Situation - USNA

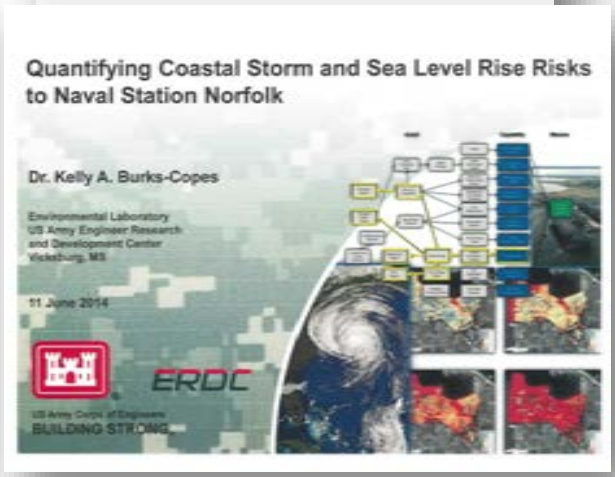
- USNA is experiencing sea level rise & land subsidence
- Visual and physical evidence collected by PWD Annapolis over at least two decades verifies these facts (increased service calls, reports)
- Dr. Richard Moss in his April 2014 SERDP study of USNA (DOD, DON, DOE, TFCC) further verified SLR & the effects of climate change
- Unfortunately, geographic location, elevation above sea level and SLR make Annapolis and USNA vulnerable to periodic coastal storms also

USNA – Sea Level Rise Advisory Council

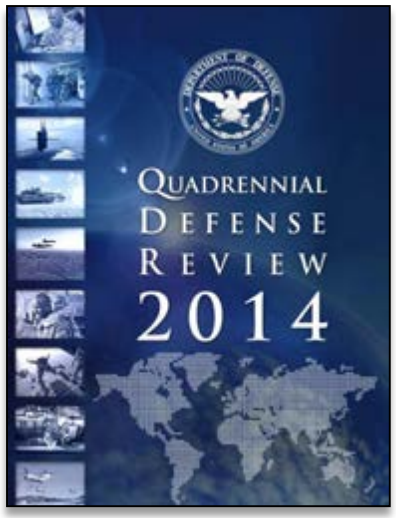
- **Created on July 8, 2015 by the Superintendent**
- **Provides analysis, guidance, and recommendations to the Superintendent**
- **On issues surrounding sea level rise, coastal flooding and increased occurrences of severe weather events**
- **Specific focus on the impacts to operational requirements of the Naval Academy**
- **Mission is to develop a Sea Level Adaptation Plan for the Naval Academy on matters pertaining to flooding due to sea level rise and severe weather events in the Annapolis area**
- **Provide analysis of data, identification of vulnerabilities and prioritization of solution sets with the primary goal of minimizing negative impact to the daily operations of USNA and its support activities**

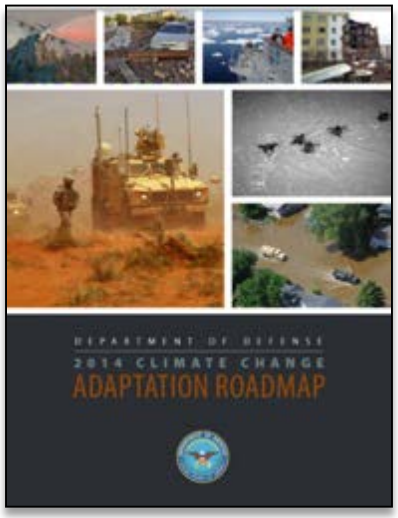
Local & Regional Studies - Planning

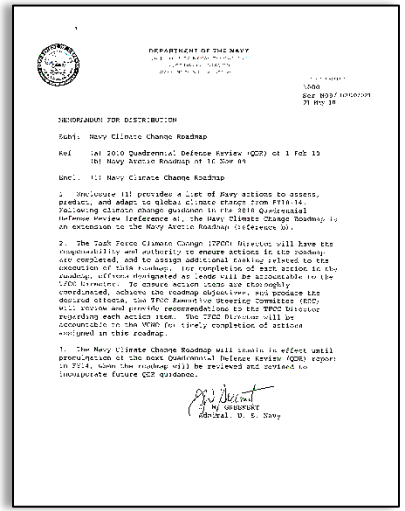




DOD - Navy – Roadmaps - Guidance







- DOD & Dept. of the Navy have published reviews, roadmaps, and guidance documents (latest – DOD Directive 4715.21) – high level
- Task Force Climate Change and other entities working the issues

Sea Level Rise Studies Utilized by SLRAC

2007 IPCC Assessment Report 4 (AR4)

2008 MD SLR Assessment

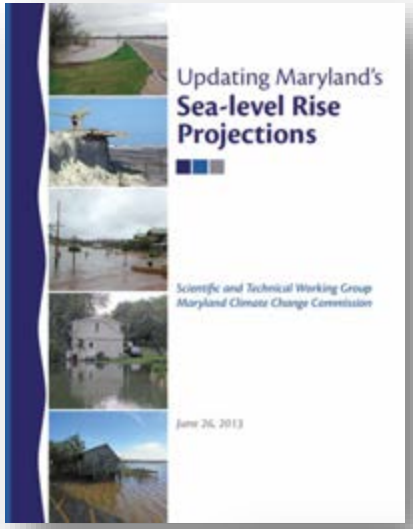
2011 USACE Guidance

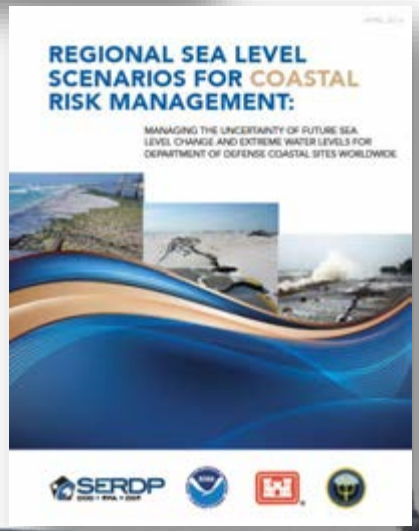
2012 NRC Report on MSLR Processes,
NOAA SLR Scenarios for
National Climate Assessment

2013 IPCC AR5,
MD Update of 2008 Assessment,
Updated USACE Guidance

2014 National Climate Assessment

2016 SERDP Report on Regional SL Scenarios
(CARSWG Study, just released)

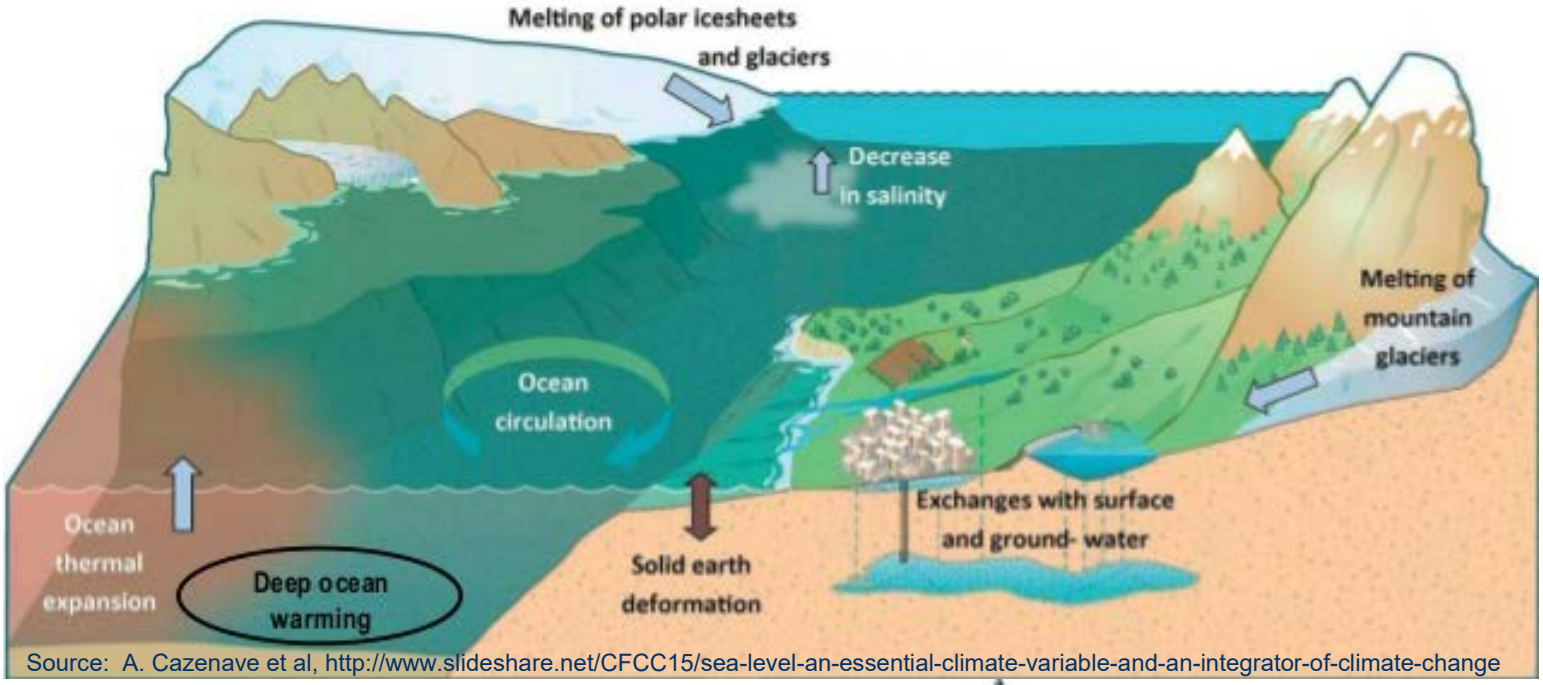




Incorporating Recent Science

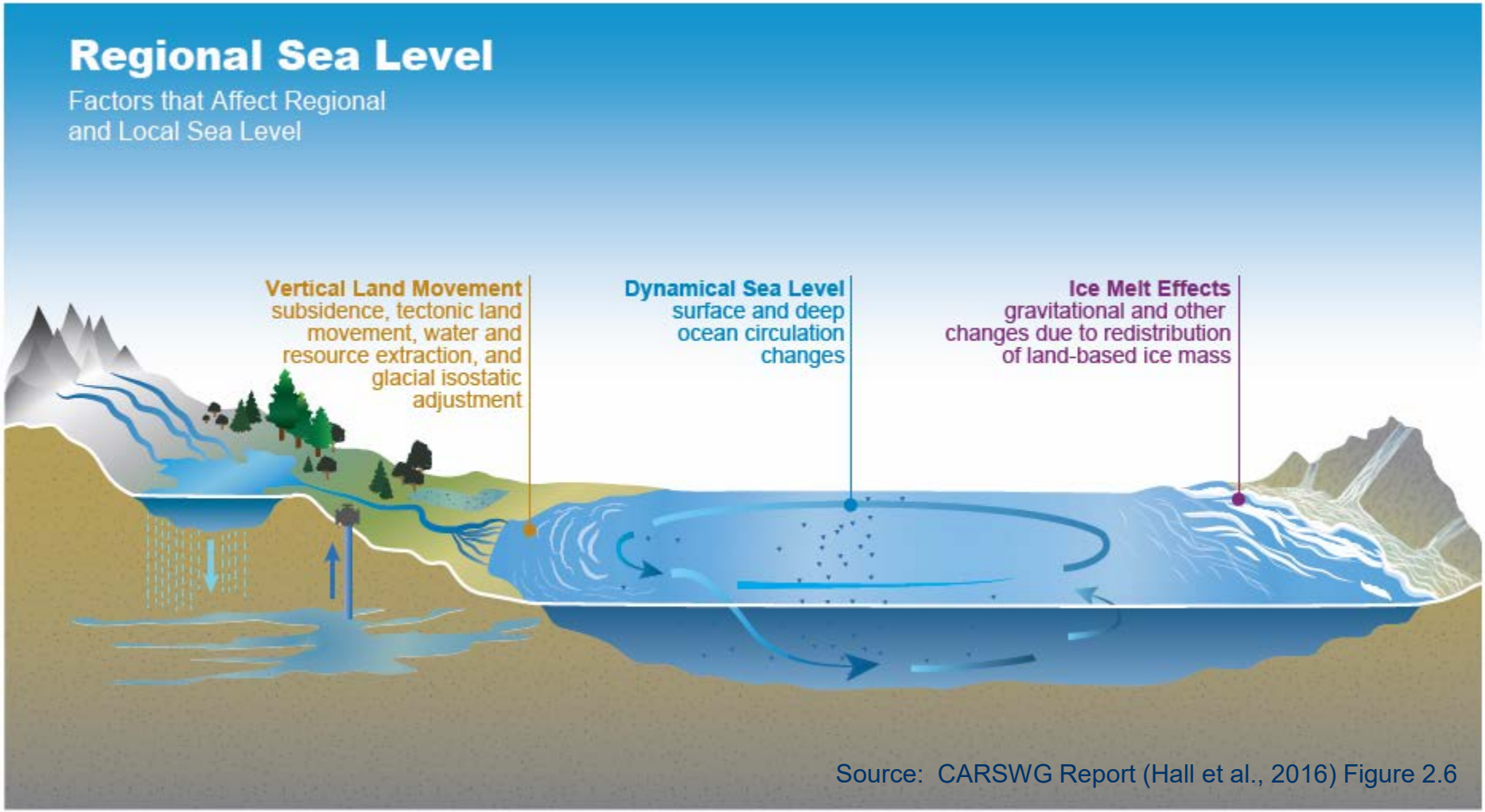
Causes of the global mean sea level rise

- Ocean warming (thermal expansion)
- Land ice melt (glaciers + ice sheets)
- Exchange of water with continental reservoirs (ground water pumping)



Source: A. Cazenave et al, http://www.slideshare.net/CFCC15/sea-level-an-essential-climate-variable-and-an-integrator-of-climate-change

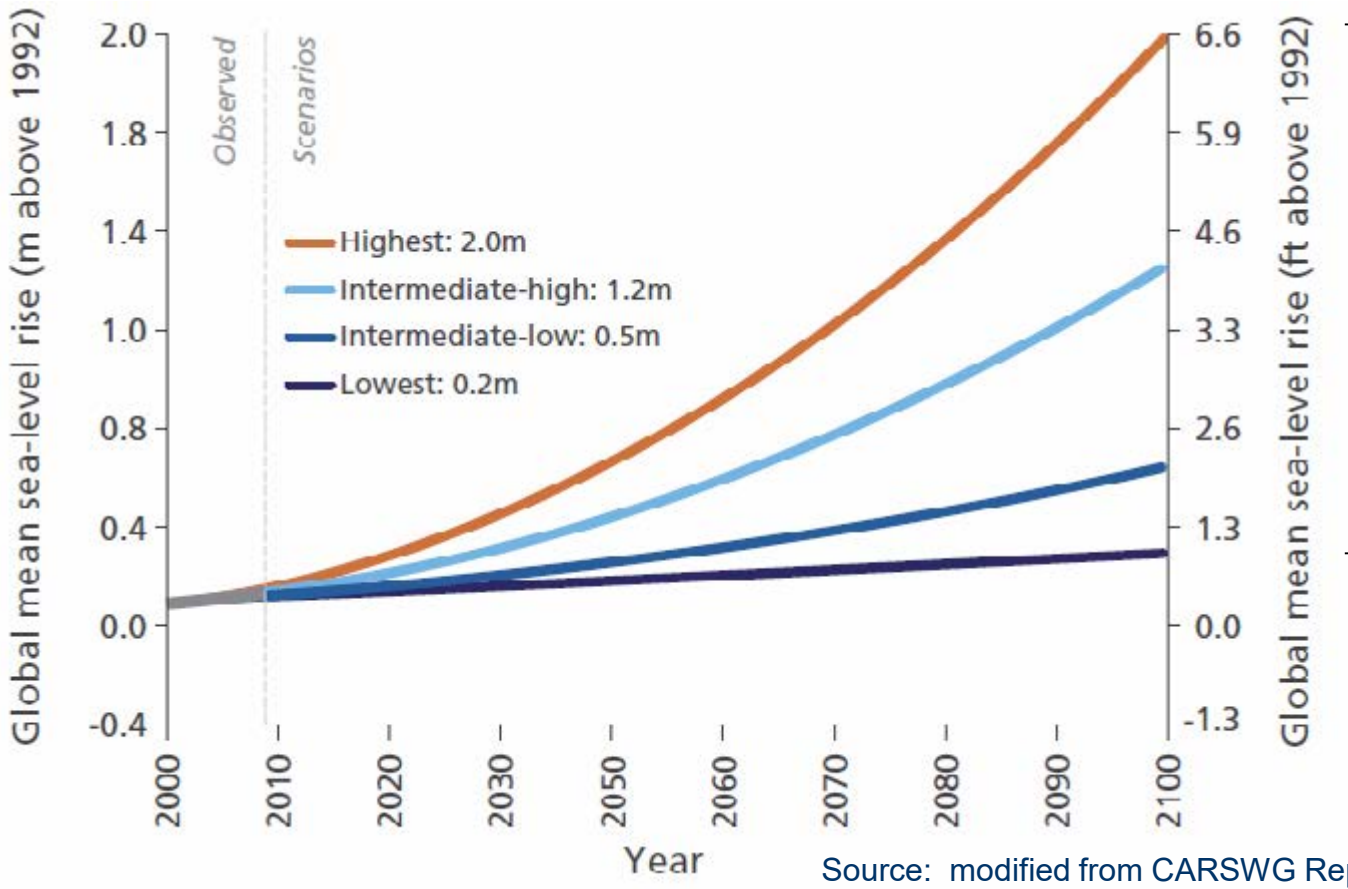
Incorporating Recent Science



Source: CARSWG Report (Hall et al., 2016) Figure 2.6

Incorporating Recent Science

Global Mean SLR scenarios developed by NOAA for the 2014 National Climate Assessment



2.0m: Based on max plausible glacier and ice sheet loss by 2100 and estimated ocean warming (Pfeffer et al. 2008).

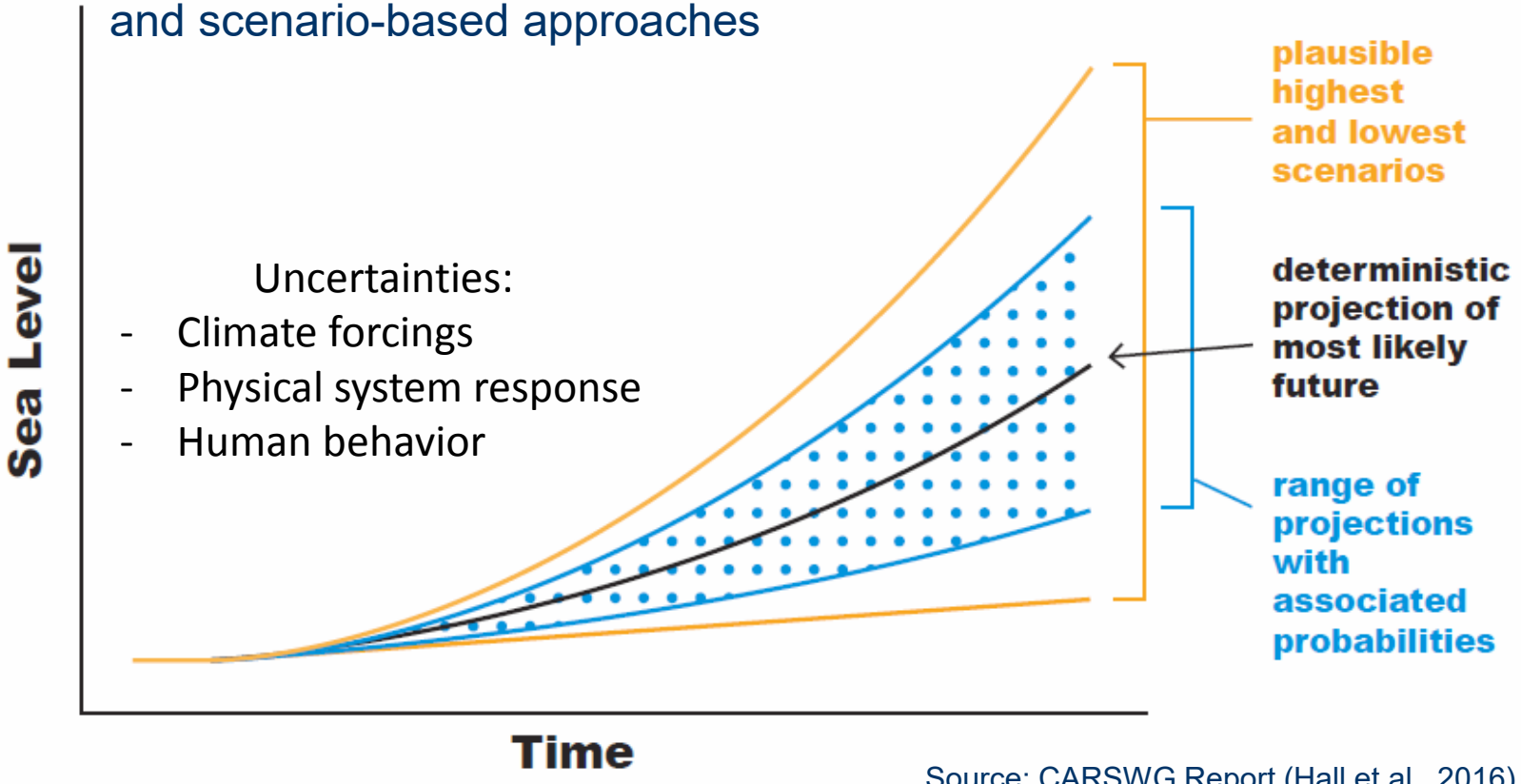
The highest and lowest scenarios developed for the NCA were adopted as the bounds for the CARSWG scenarios.

0.2m: Linear extrapolation of historical trend in tide gauge data (global avg).

Source: modified from CARSWG Report (Hall et al., 2016) Figure 2.3

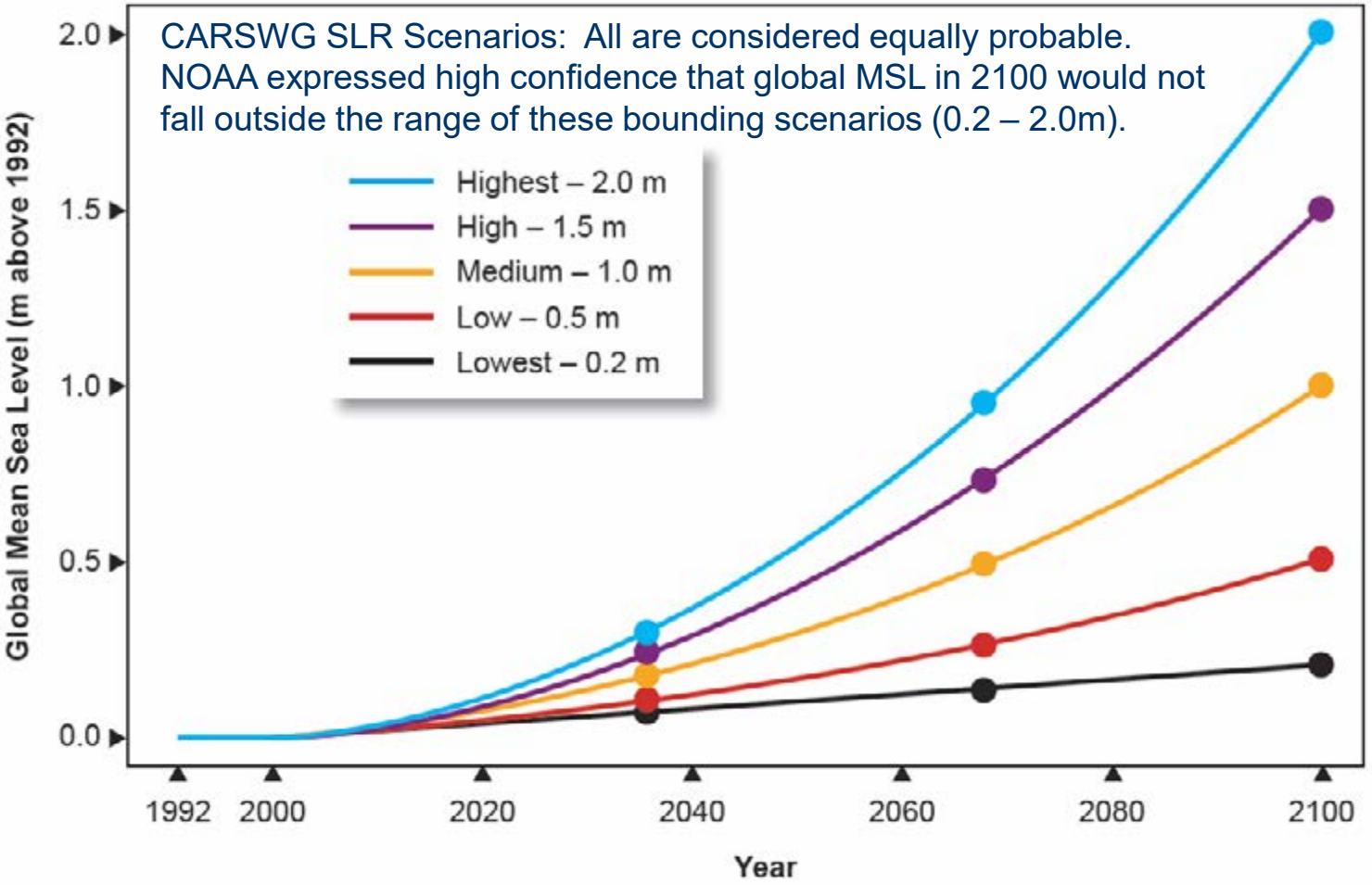
CARSWG Study: Scenario-Based

Conceptual depiction of differences between deterministic, probabilistic, and scenario-based approaches



Source: CARSWG Report (Hall et al., 2016) Fig. 2.8

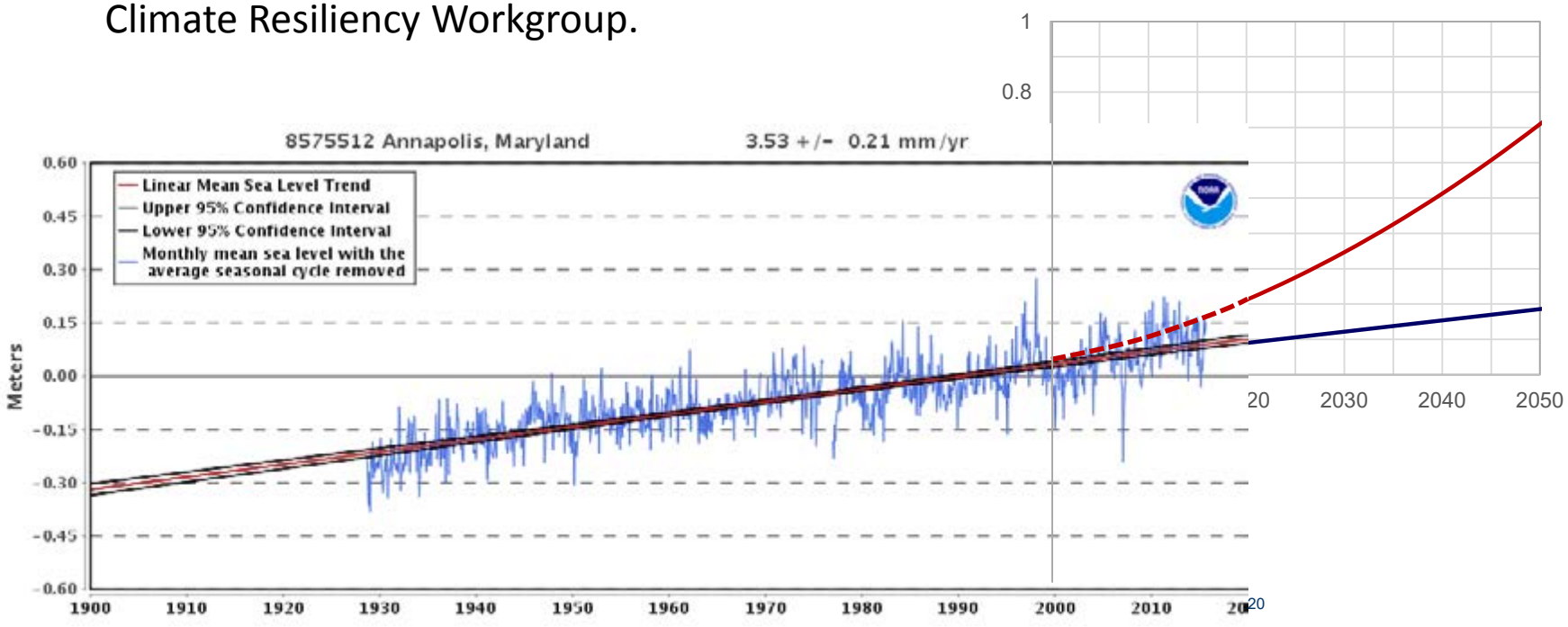
CARSWG Study: Scenario-Based



Source: CARSWG Report (Hall et al., 2016) Figure 2.4

Historical to Predicted SL Trend

Comparison of Mean Sea Level Trend in Annapolis Tide Gauge Data to CARSWG Highest and Lowest Scenarios. The CARSWG curves were adjusted for Vertical Land Movement appropriate for Maryland*, in support of the CBP Climate Resiliency Workgroup.



*VLM value of 1.5mm/yr, following the 2013 MD Climate Change Task Force update of regional SLR projections

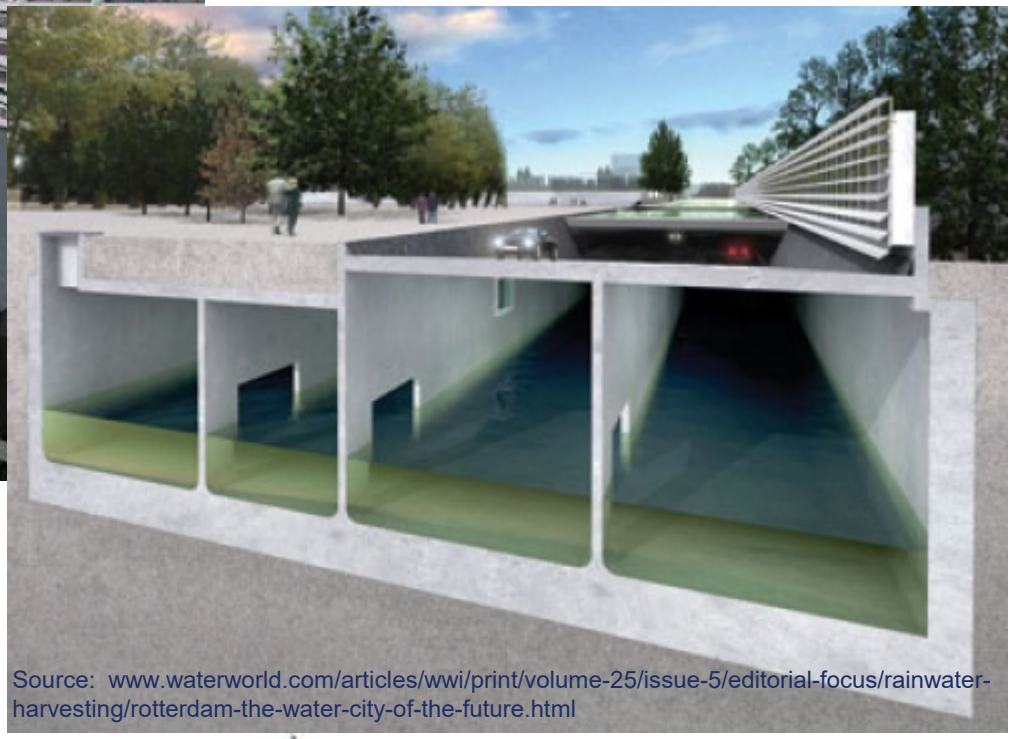
Current USNA Adaptation Measures

Other Adaptation Options

Source: http://floodbreak.com/floodbreak-vehicle-gate-deployed-automatically-to-save-garage-from-overnight-street-flooding/

Other Adaptation Options

Source: stormwater.wef.org/2014/03/first-full-scale-water-square-opens-rotterdam/



Source: www.waterworld.com/articles/wwi/print/volume-25/issue-5/editorial-focus/rainwater-harvesting/rotterdam-the-water-city-of-the-future.html

Other Adaptation Options


Source: cdn.londonreconnections.com/assets/Thames_Barrier_underspill_512.jpg

www.gizmodo.com.au/2013/10/these-gargantuan-gates-keep-europes-largest-port-from-drowning/

What action will you take?

Source: Baltimore City, http://www.baltimoremagazine.net/2015/1/5/the-sea-also-rises

Source: Susan Walsh, Associated Press,
mashable.com/2014/12/20/washington-dc-sea-level-rise

Source: http://www.chesapeakebay.net/issues/issue/weather

Questions?

CDR Angela Schedel, PhD, PE
Assistant Professor, Ocean Engineering
U.S. Naval Academy

aschedel@usna.edu
410-293-6312

SUMMARY OF RESILIENCE / ADAPTATION GOOD PRACTICES

Michael D. Meyer, Ph.D., P.E.

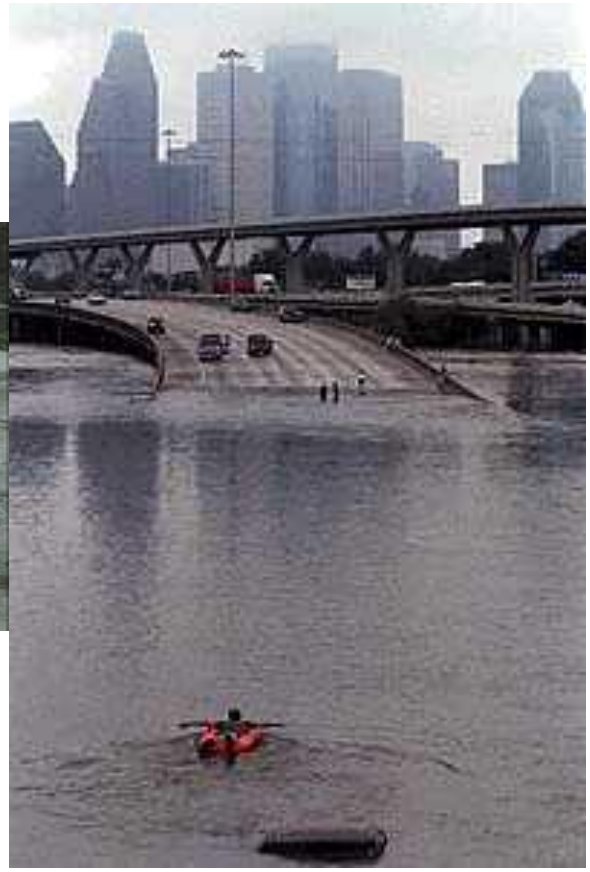
Baltimore Region INFORMATION EXCHANGE FORUM
PLANNING FOR, RESPONDING TO, AND RECOVERING FROM EXTREME WEATHER EVENTS: The New normal?

With support from Transportation Research Board

May 25, 2016

Extreme Events

Katrina



Katrina

Katrina

Katrina

Irene

Irene

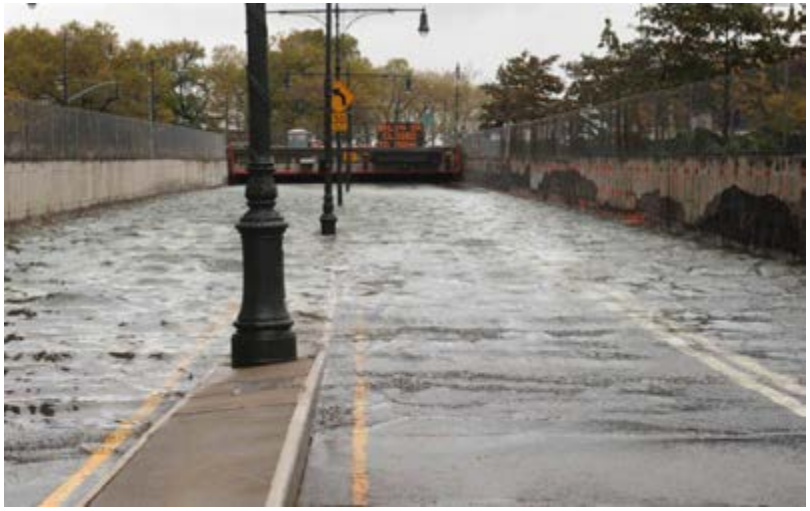
Irene

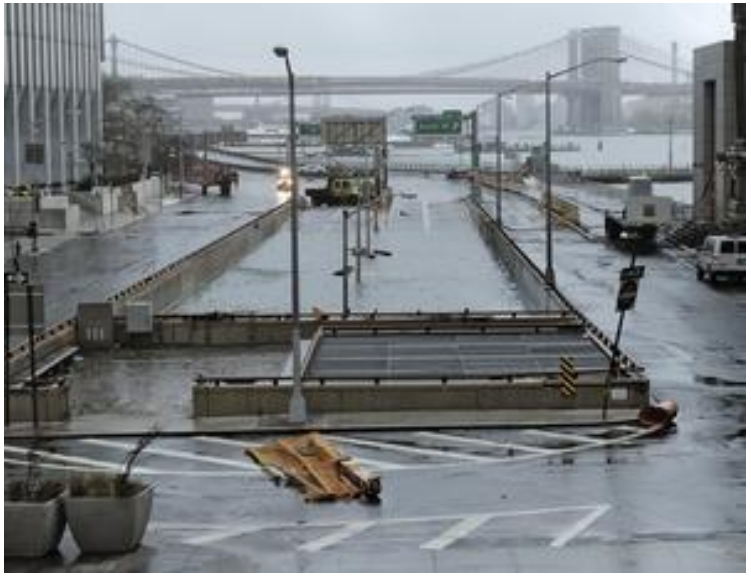
Before and After

Sandy

Sandy

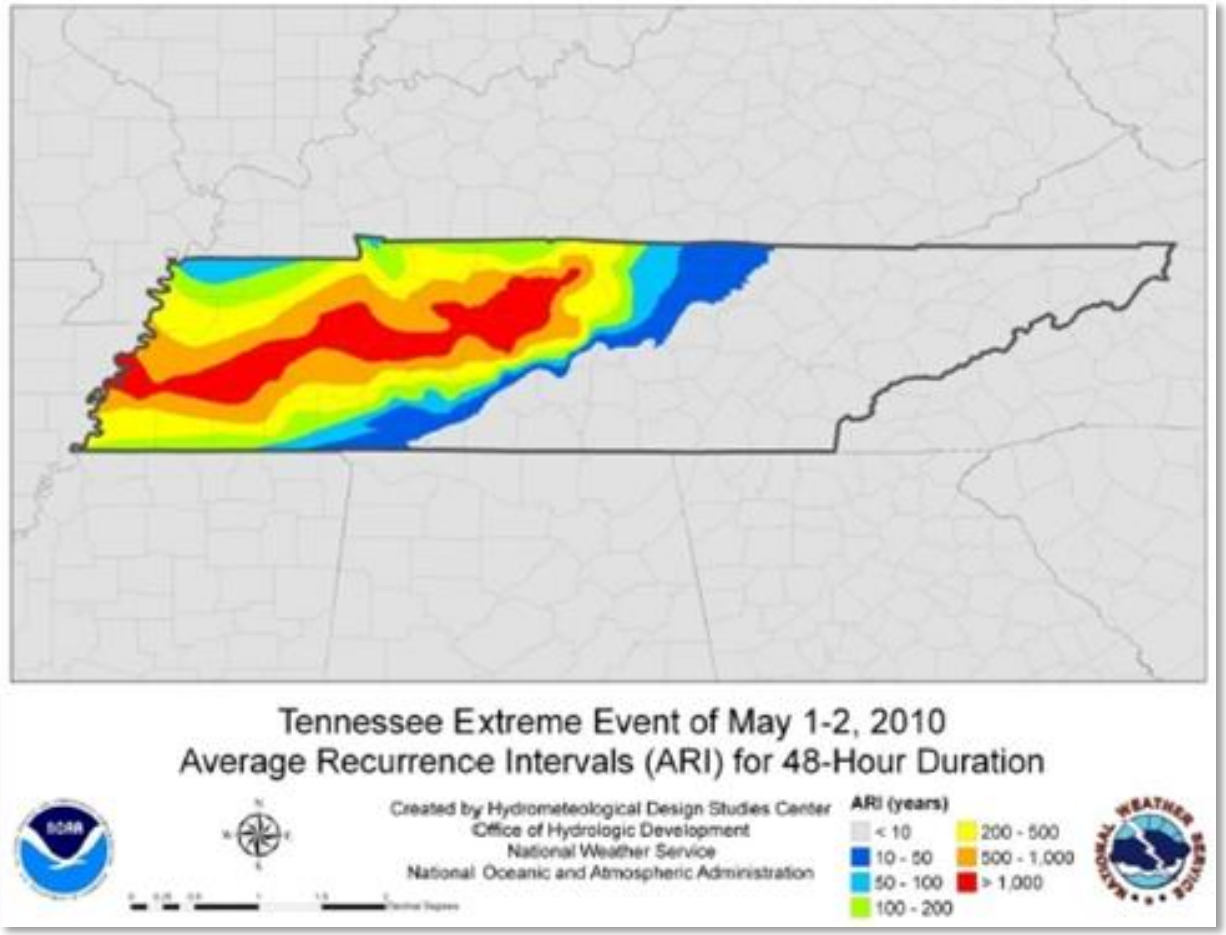
Sandy





Sandy

Tennessee Superflood, 2010



Tennessee Superflood, 2010

Approach Roadway Damage

Structural Damage

Structural Damage

Bridge Scour

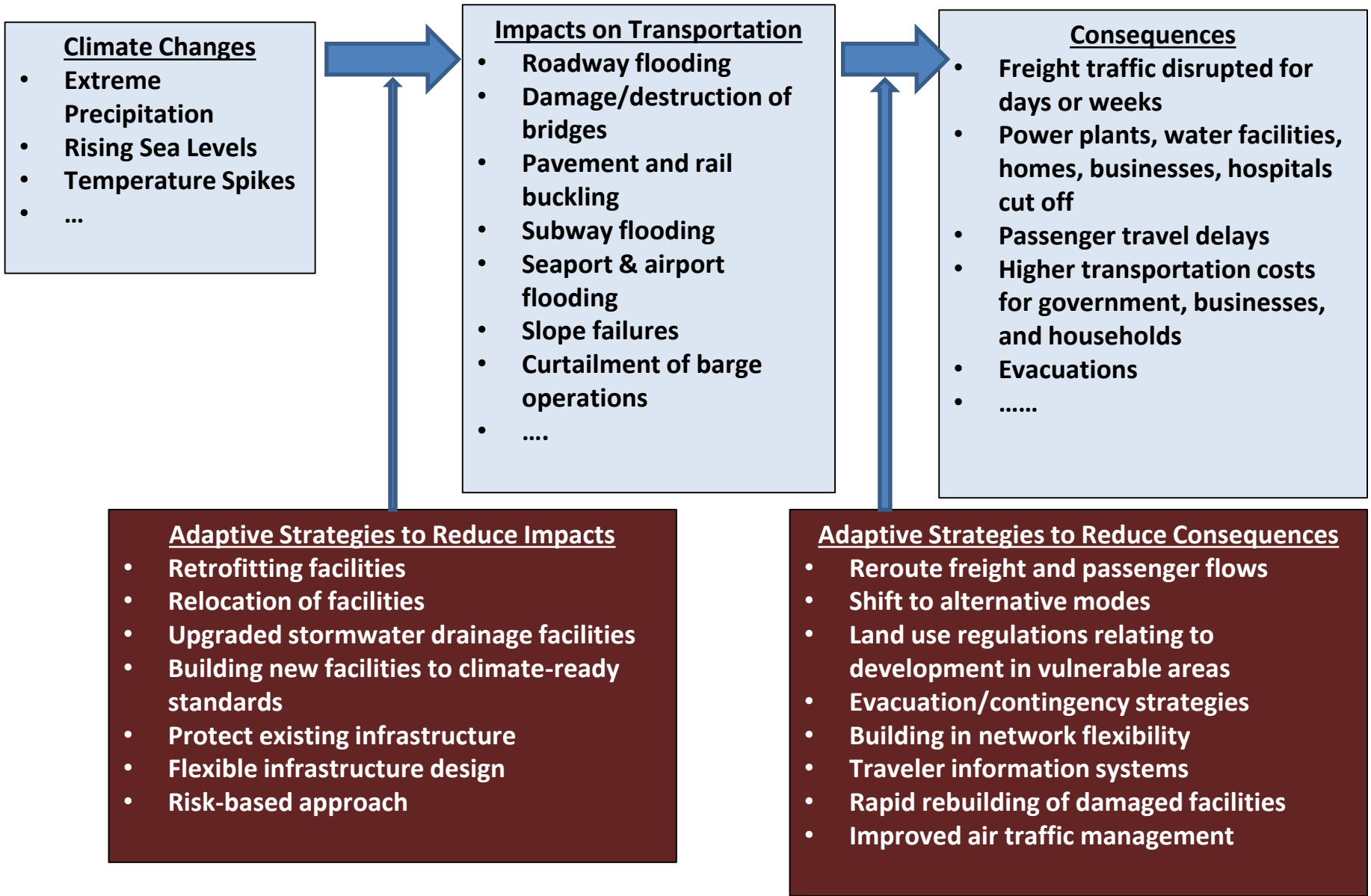
I-680 Iowa

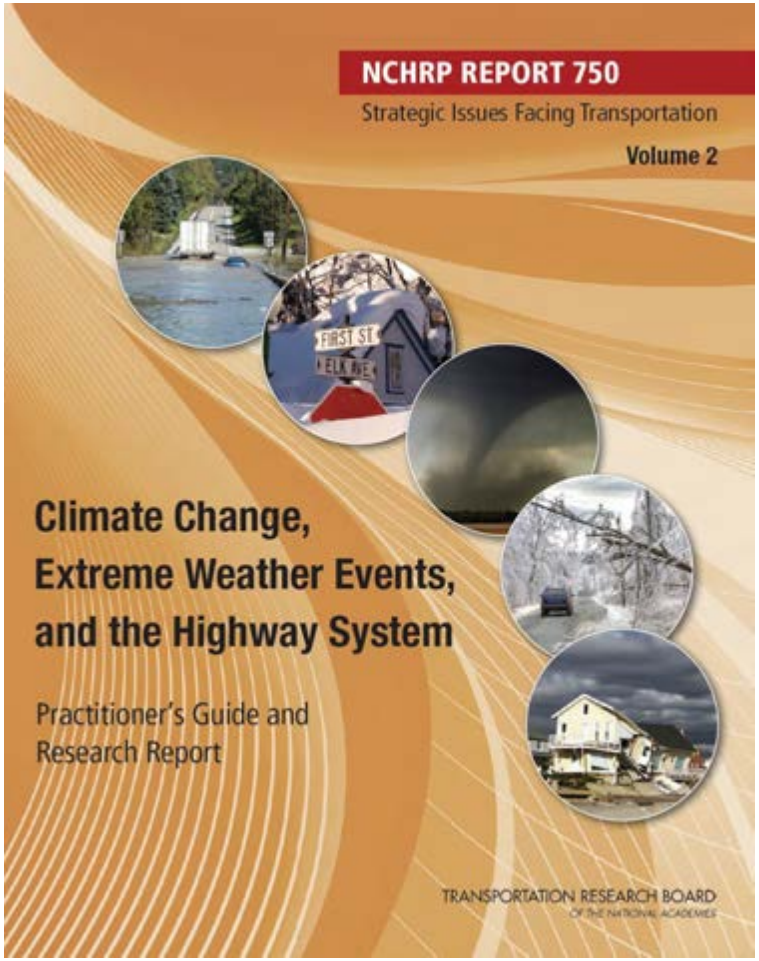

ICY CONDITIONS EXIST
STAY IN TREATED LANES
REDUCE SPEED

Long-term Environmental Changes

Long-term Environmental Changes

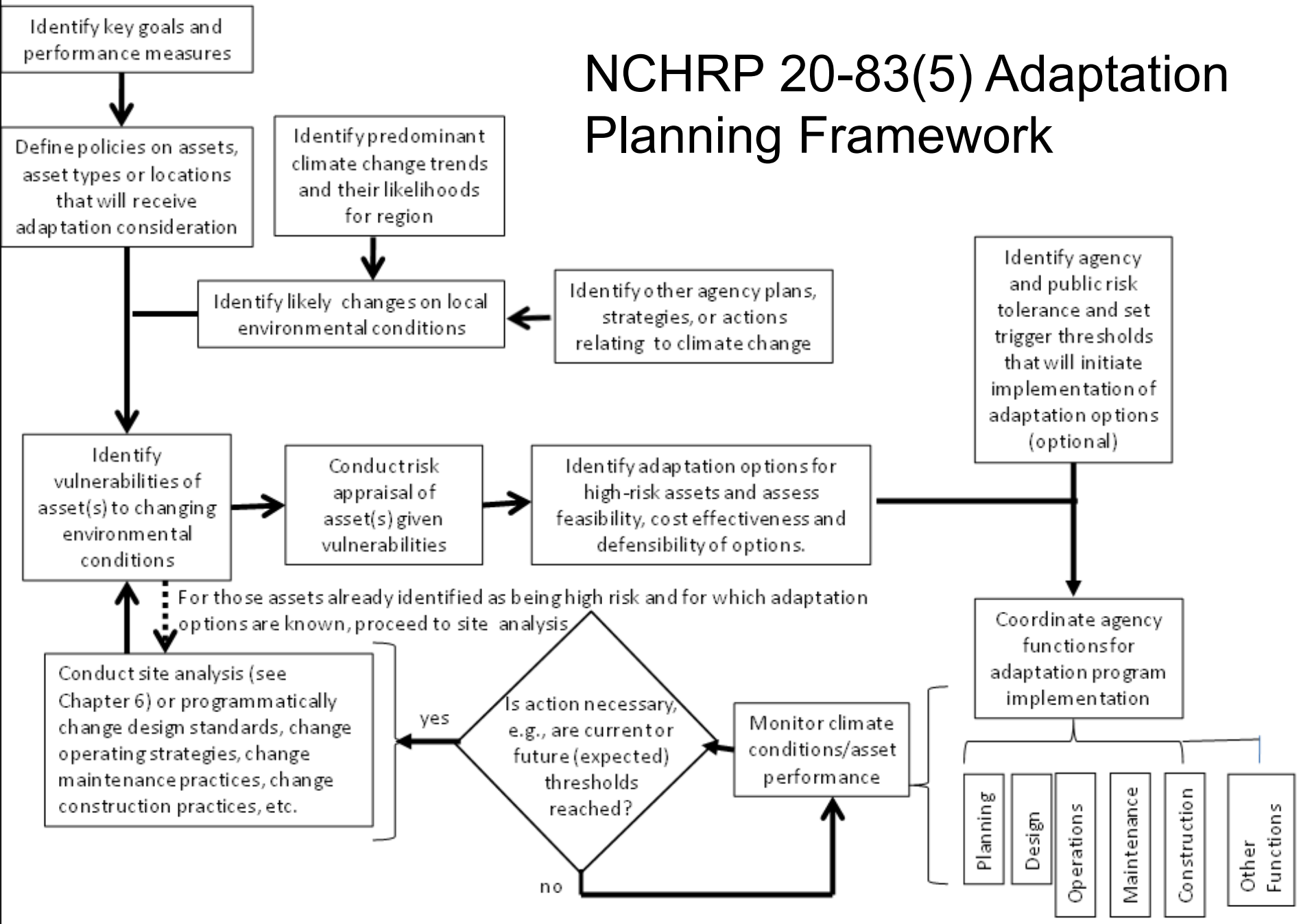
What is Adaptation?



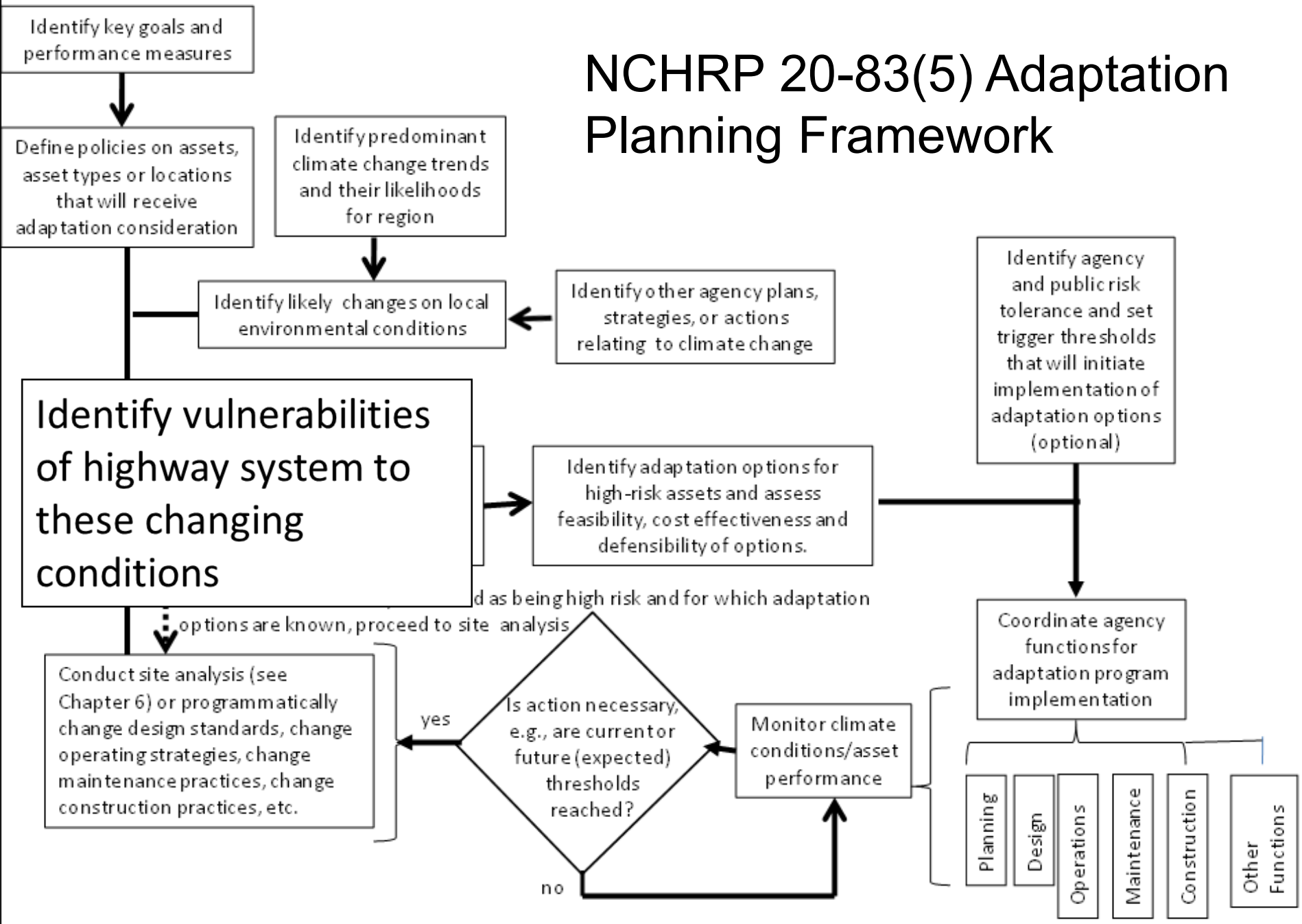


NCHRP 750, VOL. 2

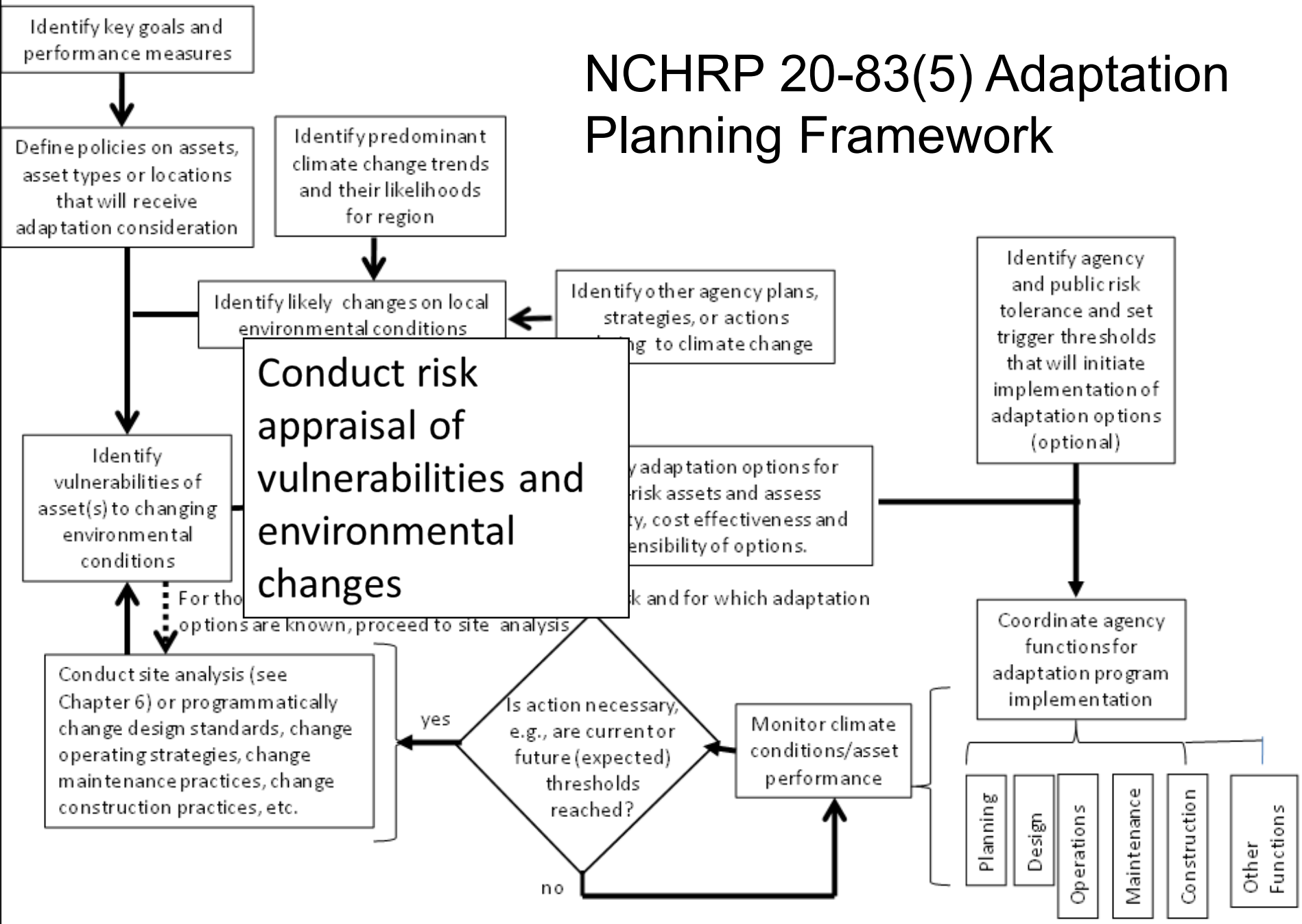
NCHRP 20-83(5) Adaptation Planning Framework



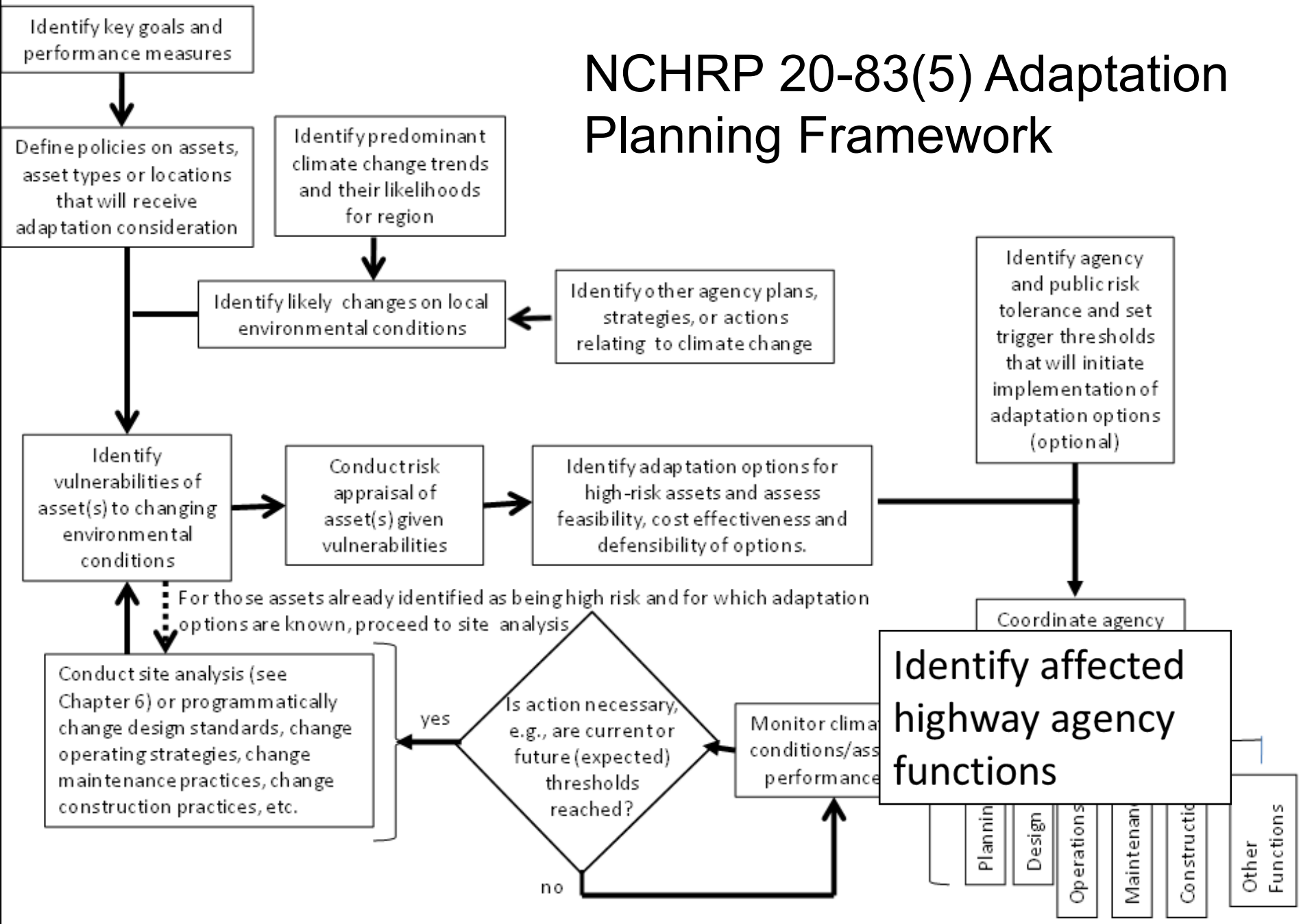
NCHRP 20-83(5) Adaptation Planning Framework



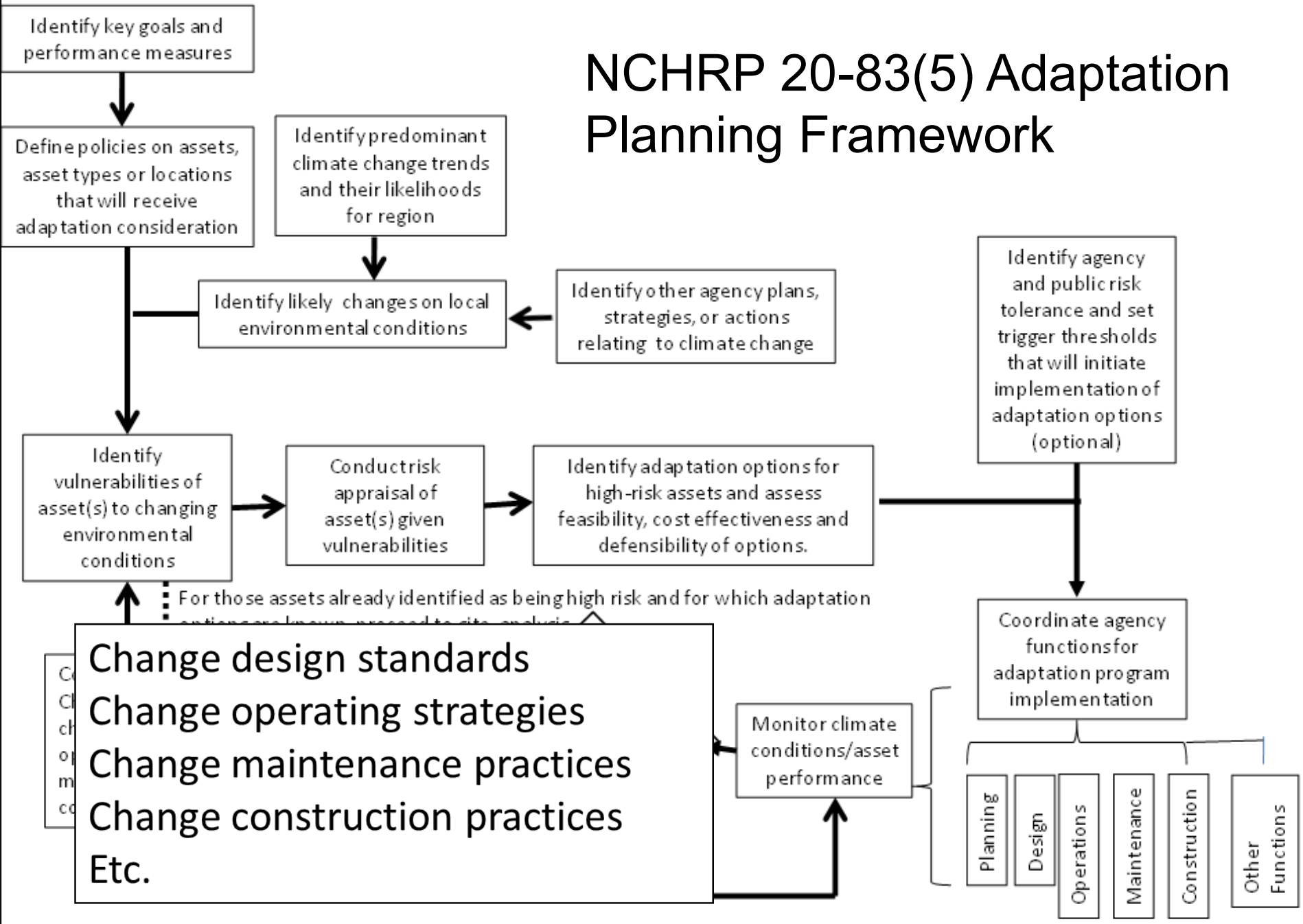
NCHRP 20-83(5) Adaptation Planning Framework



NCHRP 20-83(5) Adaptation Planning Framework



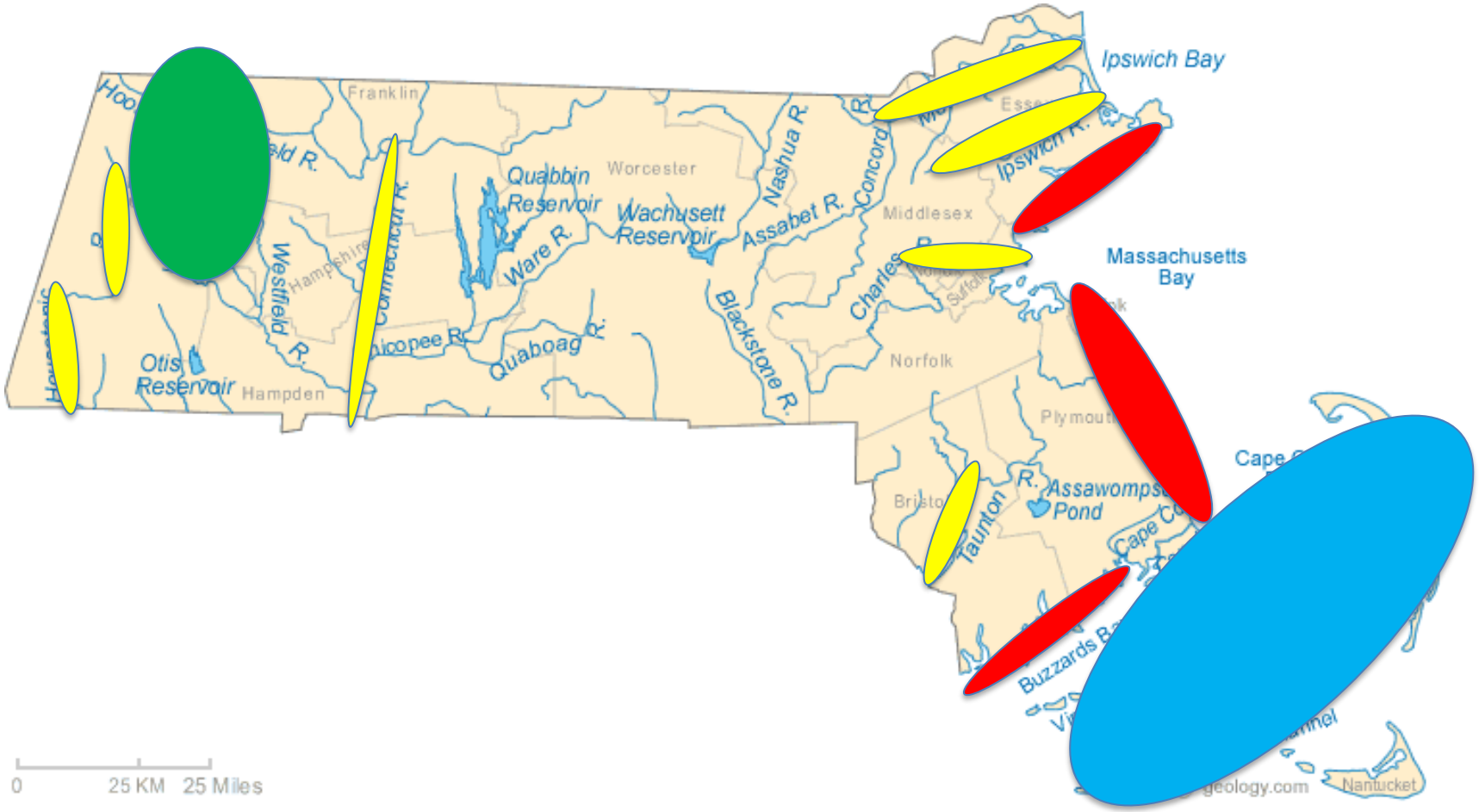
NCHRP 20-83(5) Adaptation Planning Framework



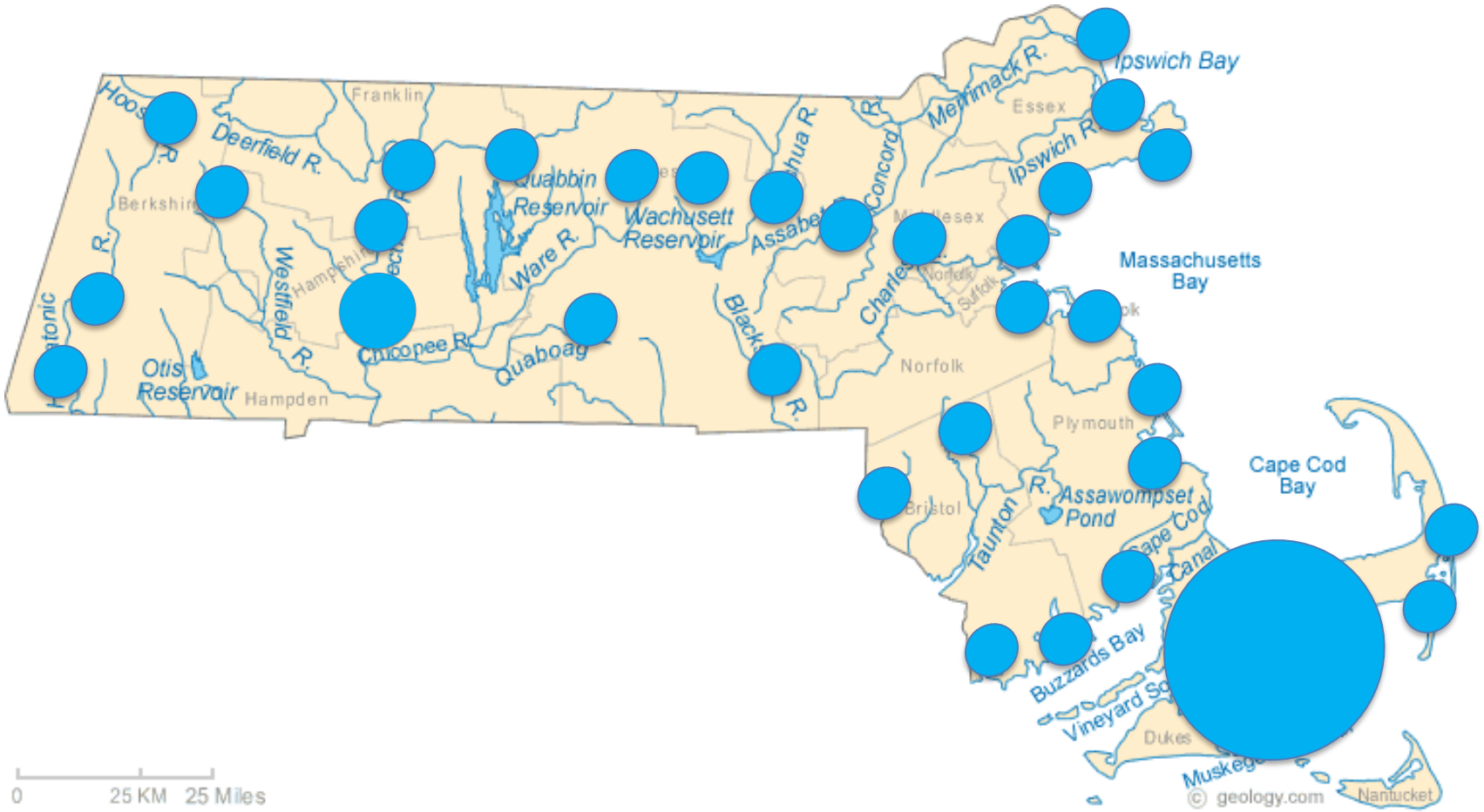
Other Sections of NCHRP 750, Vol. 2

- Projected Changes in the Climate
- Possible Impacts to the Highway System and the Natural Environment and Agency Responses
- Vulnerability Assessments and Risk Appraisals
- Climate Change and Project Development
- Other Agency Functions and Activities

Vulnerability: Meyer's Pepperoni, Anchovy and Cheese Pizza Analogy



“Blue Spots”


Ipswich Bay
Merrimack R.
Essex
Ipswich R.
Franklin
Deerfield R.
Quabbin Reservoir
Wachusett Reservoir
Ware R.
Concord R.
Massachusetts Bay
Berkshire
Westfield R.
Chicopee R.
Quaboag
Otis Reservoir
Hampden
Norfolk
Plymouth
Cape Cod Bay
Taunton R.
Assawompset Pond
Bristol
Cape Cod Canal
Buzzards Bay
Vineyard Sound
Dukes
Nantucket
0 25 KM 25 Miles
© geology.com

Highways Agency: Maintenance Implications

Risk	Examples
Reduced asset condition and safety	Assets deteriorate more quickly due to changes in average climatic conditions; assets are more badly damaged as a result of more extreme climatic events.
Reduced network availability and/or functionality	Need for restrictions on the network to maintain safety; increased need for road works.
Increased costs to maintain a safe, serviceable network	Construction/maintenance/repairs/renewal required more often; more extensive construction /maintenance/repairs/renewal required; new (more expensive) solutions required e.g. designs and materials /components/ construction costs.
Increased safety risk to road workers	Increased risk to construction and maintenance workers and Traffic Officers as a result of climatic change e.g. if need to work on the network more often; if required to work on the network during extreme climatic events or if climate change requires them to perform more 'risky' activities.

http://www.highways.gov.uk/publications/climate-change-mitigation/

Chattanooga

Stressor	Potential Impacts	Consequence	Frequency	Strategies
Extreme Precip.	Flooding	Damage to levee Damage to I-75 Disruption to I-24	Today, once every 100 years, but increasing	Raise levee redesign
Extreme Temp.	Significant Expansion	Major damage Disruption	Unknown, but increasing	Alt. route planning
	Slight Pavement Expansion	Major deterioration	Unknown, but increasing	Pavement improvements

Climate Trends Impacts

Climate Change Effects	Climate Change Impacts	System Maintenance Response
Shifting rain/snow line	Fewer snow/ice precipitation events	Reduced need for winter maintenance operations resources and staff
Shifting rain/snow line	Less snowfall in areas that were previously impassable due to high and frequent snowfall	Potential for increased winter maintenance operations on routes currently inaccessible in winter
Shifting rain/snow line	Increased snowmelt/rain during the winter season increases the likelihood of flooding, which will generally affect specific roadways and locations, as opposed to the whole network	Shift in resources from winter maintenance to winter flooding monitoring and traveler information
Shifting rain/snow line	Temperatures in some areas may shift to or more frequently hover at the freezing point, increasing the probability of ice precipitation instead of snow	Shift in resources from snow to ice management
Shifting rain/snow line	Long-term shifting of snow/ice precipitation necessitates reassessment of winter maintenance needs	Monitoring trends to identify and forecast trends of increasing or decreasing snow/ice and frequency of extreme precipitation events
Shifting rain/snow line	Longer construction season due to higher temperatures, fewer days with temperatures below freezing, and less snow/ice precipitation	Altered construction and maintenance schedules
Changes in freeze/thaw cycle	Potential for longer duration and/or shifting of freeze/thaw period	Increased staff and resources to monitor vulnerable areas to post seasonal weight restrictions and make repairs.
Increased frequency, duration and intensity of droughts; increase in average air temperature	Roadside vegetation dies off	Changes to vegetation management activities

Climate Change Effects	Climate Change Impacts	System Maintenance Response
Climate Trends Impacts		
Climate Event Impacts		
Increased coastal and inland flooding; increases in intense precipitation events	Greater frequency of flooded, blocked (e.g., trees, landslides), damaged, and washed out roads	Mandatory diversion to more robust alternate routes, reducing route options/redundancy
Increased coastal and inland flooding; increases in intense precipitation events	Greater frequency of flooded, blocked (e.g., trees, landslides), damaged, and washed out roads	Increased staff and resources to monitor vulnerable routes and provide traveler information
Increase in magnitude and duration of severe heat waves	Greater risk of structural damage to bridge joints and pavement, e.g., buckling or rutting	Mandatory diversion, particularly for freight, to more robust alternate routes
Increase in magnitude and duration of severe heat waves	Greater risk of structural damage to bridge joints and pavement, e.g., buckling or rutting	Deploy “quick maintenance” patrols to address potholes and buckling issues
Increase in magnitude and duration of severe heat waves	Higher temperatures may inhibit construction activities during certain months, or times of day	Altered construction and maintenance schedules

So, what do you do about it?

Adaptation Strategies (Broward)

Transportation Planning and Prioritization

- Plan goals statement and prioritization criteria
- Tools

Rehabilitation or Reconstruction of Existing Facilities in High Risk Area

- Road and transit design approaches and standards
- SLR as a “given”
- Drainage systems
- Asset and maintenance management systems

Adaptation Strategies

New Facility on New ROW in High Risk Areas

- List above plus, realignments or relocation

Operations and Maintenance

- Detour routes
- Emergency response strategies
- Harden assets
- Maintain drainage systems

Top 10 O&M Things to Do

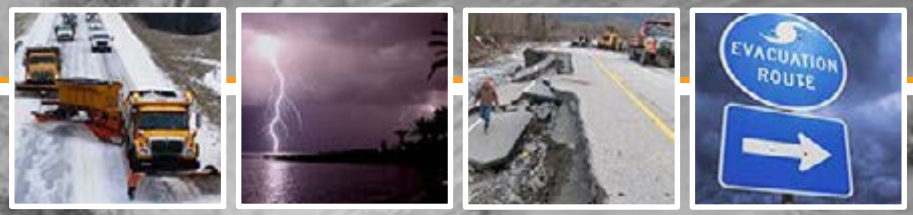
1. *Culverts:* Keeping culverts debris free and maintained to handle above average flows.
2. *Bridge Scour:* In high risk river/stream basins, protecting bridge columns and piers from higher than average flows during extreme precipitation events to reduce probability of bridge scour.
3. *Evacuation Routes*: In coastal and flood prone areas, developing and operating effective evacuation routes.
4. *Traveler Information:* Developing effective public and traveler information systems/services that can be used during weather emergencies to inform travelers of travel options.

Top 10 O&M Things to Do

5. *Pre-Positioning Materials and Equipment:* Developing strategies for responding to transportation system and facility disruptions due to weather-related events, including pre-positioning replacement materials in vulnerable areas
6. *Workforce Protection:* Protecting O&M workers from extreme temperatures during day-to-day activities.
7. *Mudslide and Landslide Strategies:* Identifying facility locations vulnerable to mudslides or landslides, and developing appropriate strategies to minimize such risk.

Top 10 O&M Things to Do

8. *Back-Up Power:* Putting in place power back up for electrical devices in areas prone to extreme weather events, especially for traffic signals.
9. *Early Warning Indicators:* Incorporating "early warning indicators" for potential extreme weather-related risks into asset and maintenance management systems.
10. *Landscaping and Vegetation:* Where appropriate, using drought-proof landscaping and vegetation, and multi-culture families of vegetation



NCHRP
SYNTHESIS 454

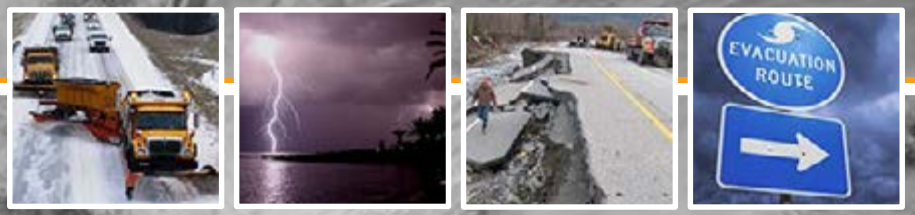
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Response to Extreme Weather Impacts on Transportation Systems

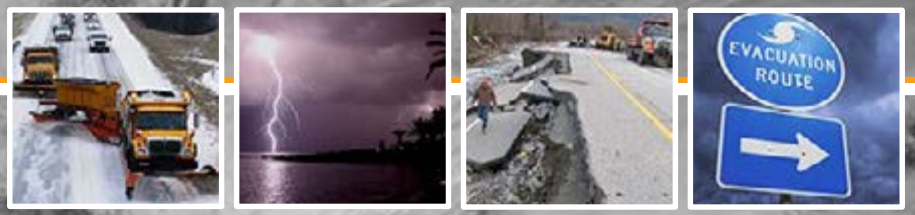
A Synthesis of Highway Practice

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

With respect to maintenance…..



- Separate sites for debris and sand removed from streets — New Jersey
- Assessment of sinkhole-related issues and most appropriate traffic control measures at the local level — New Jersey
- Preparedness activities before a controlled release of water from dams---checking for blocked culverts, defining staging areas, and deploying ITS, such as traffic cameras that could provide a view of inundated roads — Iowa

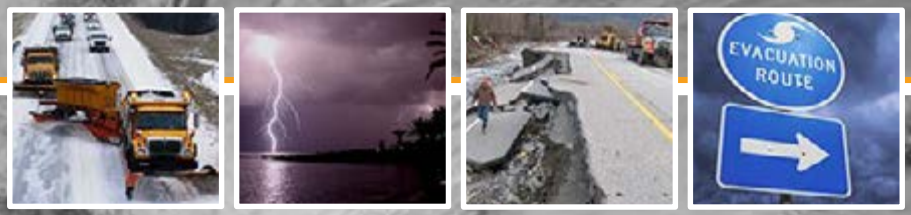


- Flexibility in determining what to ask from localities in the way of reimbursement for state DOT services provided during extreme weather events

Washington

- Equipment staging, including cones, messages boards, portable traffic lights
- Central storage location or garage for equipment needed in a major event
- Maintenance needs tracking with a view to statewide events

Vermont



- Under a disaster declaration, assistance to municipalities in the form of staff and heavy equipment — Alaska
- Re-assigned existing contracting group working on culverts in one region to respond and repair damaged roads in region affected by flooding — Colorado
- Employee preparedness and safety through the acquisition and pre-positioning of two response trailers with protective gear — Texas

FHWA, *Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance*

- Increased and flexible monitoring systems
- Integration of sophisticated weather information at transportation operations centers
- Greater intra- and inter-agency cooperation
- Rapid mobilization and deployment teams
- Flexible resource allocations – Greater variability in the type, nature and intensity of events also poses a unique challenge to budget
- Cross-training of staff
- Training for unusual events

Evacuation Planning

The Future of Evacuations in the Climate Change Era

"As storms increase and sea level rises, a good plan to flee the city becomes a huge part of protecting those who live in it."

Dan Glass, *The Atlantic*, CityLab

FEMA

"The challenges posed by climate change, such as more intense storms, frequent heavy precipitation, heat waves, drought, extreme flooding, and higher sea levels could significantly alter the types and magnitudes of hazards faced by communities and the emergency management professionals serving them. Regardless of why the climate is changing, emergency managers have to be poised to respond to disasters and support preparedness efforts nationwide."

Some examples

- Atlanta: Possible legislation that would require paved surfaces to be covered with “cool pavement;” anti-idling policy to include all vehicles and motors
- Broward County, FL: Short-term and long term strategies for addressing repair of coastal highway and beach erosion
- Dubuque, IA: Green alley program to put permeable pavers in alleys, alleviate flooding
- Eugene, OR: Climate-adapted tree species for planting along streets in the right-of-way
- Milwaukee: green infrastructure improvements to mitigate flooding impacts, including rain barrels, cisterns, rain gardens, green roofs, storm drain restrictors, porous pavement, median and roadside bio- retention projects, catch basin retrofits, storm water planters, vacant lot bio-retention, increased tree canopy, and downspout disconnection.

Some examples

- Milwaukee: green infrastructure improvements to mitigate flooding impacts, including rain barrels, cisterns, rain gardens, green roofs, storm drain restrictors, porous pavement, median and roadside bio- retention projects, catch basin retrofits, storm water planters, vacant lot bio-retention, increased tree canopy, and downspout disconnection.
- Norfolk: green infrastructure of trees, rain gardens, wetlands and open spaces to allow water to slow down, soak in, and spread out
- Salt Lake City: new roads and sewers will be built to handle warmer temperatures and higher runoff volumes

In almost every case, cities are undertaking a vulnerability or risk assessment with respect to future weather-related stresses.

Jurisdictional Perceptions of Impediments by Location

Baltimore

"Evacuation Plan Needs Updating; Infrastructure Impediments-Roadways; and Region Lacks a Coordinated Signal Timing System"

FHWA, *Highway Evacuations in Selected Metropolitan Areas: Assessment of Impediments*, April 2010.


NEW ORLEANS
HOMELAND SECURITY
&
EMERGENCY PREPAREDNESS
CITY ASSISTED
EVACUATION
PICK-UP POINT
REMEMBER
Only one small carry-on bag per person.
45" total size
Bring all medications & prescriptions.
Bring all important papers
and contact information.
Bring official identification if you have it.
ABSOLUTELY NO:
Alcohol
Guns, knives or other weapons
Illegal drugs or prohibited substances
IF TRAVELING WITH PETS:
Must be in a carrier or restrained on a leash
Must have a collar and ID tag.
Must have current vaccinations and
have needed medications
If you need assistance: call: 311
NOLA
READY

In Conclusion……

Thank you.