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
• 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 10\textsuperscript{th} grade students
• Students proposed website & name in Fall 2003.
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.
MISSION OF OUR TEAM

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

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
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<tbody>
<tr>
<td>Air Pressure</td>
<td>High - Dry, more dense air; Low - wet, less dense air</td>
</tr>
<tr>
<td>CPC</td>
<td>NOAA Climate Prediction Center</td>
</tr>
<tr>
<td>Indicators</td>
<td>Indices such as North Atlantic Oscillation</td>
</tr>
<tr>
<td>Models</td>
<td>Global Forecast System, Climate Forecast System</td>
</tr>
<tr>
<td>Nino/Nina</td>
<td>ENSO- El Nino Southern Oscillation</td>
</tr>
<tr>
<td>Polar Vortex</td>
<td>Arctic Oscillation/Labrador Low</td>
</tr>
<tr>
<td>SST</td>
<td>Sea Surface Temperatures</td>
</tr>
<tr>
<td>Westerlies</td>
<td>Northern hemisphere global wind pattern</td>
</tr>
<tr>
<td>WPC</td>
<td>NOAA Weather Prediction Center</td>
</tr>
</tbody>
</table>
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
What a lovely year it has been for managers...
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?
The big question to address:

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

Mark Twain:

“Climate is what we expect, Weather is what we get.”
At least 17 major climate factors (drivers) which influence regional weather outcomes.

Let’s discuss each one briefly...
Or... how about 3?
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.

A three-month mean of temps in “Region 3.4” is the El Nino data reported by NOAA.
How to measure an El Nino or La Nina phase?

If Region 3.4 reports a temp anomaly of

- 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)

<table>
<thead>
<tr>
<th>Years Selected</th>
<th>Region 3.4 SSTA</th>
<th>Significant Weather</th>
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</thead>
<tbody>
<tr>
<td>1997-98</td>
<td>+ 2.3°</td>
<td>Low snow, Floyd (99)</td>
</tr>
<tr>
<td>2002-03</td>
<td>+ 1.3°</td>
<td>Blizzard, Isabel</td>
</tr>
<tr>
<td>2004-05</td>
<td>+ 0.4°</td>
<td>Ice storms, Katrina</td>
</tr>
<tr>
<td>2007-08</td>
<td>- 1.4°</td>
<td>Ice storms (07)</td>
</tr>
<tr>
<td>2009-10</td>
<td>+ 1.3°</td>
<td>Multiple blizzards</td>
</tr>
<tr>
<td>2011-12</td>
<td>- 1.1°</td>
<td>Irene, Derecho, Sandy</td>
</tr>
<tr>
<td>2015-16</td>
<td>+ 2.3°</td>
<td>Joaquin, Blizzard</td>
</tr>
</tbody>
</table>
COMPARISON CHART: ENSO & WEATHER EVENTS

MAJOR SNOW/ICE EVENTS

- T.S./HURRICANES
  - Agnes
  - Gloria
  - Floyd
  - Isabel
  - Sandy

- 1978
- 1985-1986
- 1993
- 1996
- 2002
- 2007
- 2010
- 2016
A gauge of large scale air mass movement every 2-3 days between the **Azores High** and the **Icelandic Low**

**North Atlantic Oscillation (NAO)**

**NAO: Observed & GFS forecasts**

500mb Z (Obs: 26Jan2016 – 24May2016)

Mean $= 0.4011$
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
A daily NOAA satellite estimate of depth and extent of snow cover across the northern Hemisphere, prepared by the National Snow & Ice Data Center.
As of 5/24/2016, less sea ice observed in Hudson Bay

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

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

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.
“So, you’re saying there’s a chance....?”
- Jim Carrey
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
Given new indicators of La Nina & snow cover, what is likelihood for the following events to reoccur?

<table>
<thead>
<tr>
<th>YEAR</th>
<th>EVENT</th>
<th>REPEAT IN 2016-17?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>Ice storms</td>
<td>Less likely</td>
</tr>
<tr>
<td>2003</td>
<td>Isabel</td>
<td>Equal to more likely</td>
</tr>
<tr>
<td>2004</td>
<td>Florida landfalls</td>
<td>Less likely</td>
</tr>
<tr>
<td>2010</td>
<td>Double blizzard</td>
<td>Less likely</td>
</tr>
<tr>
<td>2012</td>
<td>Derecho/Sandy</td>
<td>Equal to more likely</td>
</tr>
</tbody>
</table>
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?

<table>
<thead>
<tr>
<th>What’s the status?</th>
<th>TRENDS</th>
<th>INDICATORS</th>
<th>PROJECTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delayed Winters, cool Springs humid, wet Summers</td>
<td>El Nino in rapid decline, La Nina expected by late Summer 2016.</td>
<td>Residual cool air in Canada may influence severe outbreaks into Summer.</td>
</tr>
<tr>
<td>What’s most probable ahead?</td>
<td>Continuation of this trend, with more active hurricane season possible.</td>
<td>Data over 30 years shows significant tropical storms in “transition” Nino/Nina years</td>
<td>High impact tropical system in Gulf, M/A or Southeast has some potential</td>
</tr>
</tbody>
</table>
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
Comparing climate trends & weather patterns may show some correlation with:

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:
rich.foot@footsforecast.org
keith.krich@footsforecast.org
CLIMATE RESILIENCE IN RECENT REGULATION

• Moving Ahead for Progress in the 21\textsuperscript{st} 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
• 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”
Goal: Mainstream consideration of climate change vulnerability and risk in transportation decision making
TOOLS, RESOURCES, AND GUIDES

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 Change Vulnerability Assessment and Adaptation Options Study

Final Report – December 2014

This report was developed by the Oregon Department of Transportation in accordance with a grant administered by FHWA. The climate change vulnerability assessment and adaptation options study do not necessarily reflect the views of FHWA or the U.S. Department of Transportation.

The Federal Highway Administration’s (FHWA) Climate Resilience Pilot Program seeks to assist state Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), and state and local management agencies (USMAs) in enhancing resilience of transportation systems to severe weather events and climate change. In 2013, FHWA convened a team to develop a methodology to assess transportation vulnerability to severe weather events and climate change and evaluate options for improving resilience. This report provides an overview of the pilot program methodology and results.

Scope

The study area covered two counties in Oregon’s north coast: Clatsop and Tillamook Counties. The vulnerability assessment focused on the state-owned highway corridor, including nearly 300 miles of roadway. Primary climate change impacts were identified as increased precipitation events, coastal flooding, and storm surge.

Objectives

Assess the vulnerability of Oregon’s north coast highway corridor to severe weather events and climate change. Develop and evaluate a set of site-specific adaptation strategies for the vulnerable infrastructure and reduce the associated costs associated with these strategies. Collaborate with stakeholders, including state and local agencies and communities, to plan for resilience to climate hazards on the north coast.

Maryland State Highway Administration

Climate Change Adaptation Plan with Detailed Vulnerability Assessment

Final Report – October 11, 2014

The Maryland State Highway Administration (MSHA) Climate Resilience Pilot Program seeks to assist state Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), and state and local management agencies (USMAs) in enhancing resilience of transportation systems to severe weather events and climate change. In 2013, MSHA convened a team to develop a methodology to assess transportation vulnerability to severe weather events and climate change and evaluate options for improving resilience. This report provides an overview of the pilot program methodology and results.

Scope

The study area covered two counties, selected for their differing representative locations and exposure to climate events (including sea-level rise, storms, and flooding) and increased intensity of precipitation. The counties, located in Maryland’s Eastern Shore, represent a range of severe weather climate hazards. The assessment identified the need for adaptation strategies to address these hazards.

Objectives

Assess the vulnerability of transportation assets to sea-level rise, storms, and flooding. Develop and evaluate a set of adaptation strategies for the vulnerable infrastructure and reduce the associated costs associated with these strategies. Collaborate with stakeholders, including state and local agencies and communities, to plan for resilience to climate hazards on the Eastern Shore.
Comprehensive Assessment of Climate Impacts on Gulf Coast Transportation

- 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 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 mi²)
POST-HURRICANE SANDY PROJECT

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

Aerial photo of Atlantic City following Hurricane Sandy. Source: Michael Reynolds/European Pressphoto Agency

SLR 1 Meter, 2100, Coastal Study Area (Roadways). Source NJTPA
TRANSPORTATION ENGINEERING APPROACHES FOR CLIMATE RESILIENCE (TEACR)

• **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/
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

- 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)
THANK YOU!

For more information:

www.fhwa.dot.gov/environment/climate_change/
Maryland Adaptation and Vulnerability Assessment

Maryland State Highway Administration

May 25, 2016
Pilot Study Objectives

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

“Improve Resiliency of Maryland’s Transportation System”
Key Step
Identify Climate Stressors
Studied in Detail for Maryland

- **Sea Level Change**
  - 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

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

<table>
<thead>
<tr>
<th>County</th>
<th>Tidal Station</th>
<th>MSL</th>
<th>MHHW</th>
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<td>Worcester</td>
<td>Ocean City</td>
<td>2.06</td>
<td>3.25</td>
<td>5.86</td>
<td>7.05</td>
</tr>
</tbody>
</table>
Permanent Inundation for Anne Arundel

Legend
Permanent Inundation
At Risk

Data Sources: ESRI, MDOT, MD DNR, Salisbury University, SHA, Stantec, US Census Bureau, USDA

Maryland Department of Transportation
Permanent Inundation
Somerset County

2050

2100
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
## Results of Screening

<table>
<thead>
<tr>
<th>Assets</th>
<th>Anne Arundel County</th>
<th>Somerset County</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Assets</td>
<td>Evaluated in More Detail</td>
</tr>
<tr>
<td>Bridges including large culverts</td>
<td>517</td>
<td>150</td>
</tr>
<tr>
<td>Small culverts and conveyances</td>
<td>Culverts-12,024</td>
<td>Culverts-1,174</td>
</tr>
<tr>
<td></td>
<td>Conveyances-8,601</td>
<td>Conveyances-843</td>
</tr>
<tr>
<td>Miles of roadway</td>
<td>2,554.28 miles</td>
<td>114.99 miles</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Structure ID</th>
<th>VAST Score</th>
<th>Evacuation Route</th>
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<tbody>
<tr>
<td>134</td>
<td>3.1</td>
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<tr>
<td>44</td>
<td>2.8</td>
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<td>30</td>
<td>2.8</td>
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</tr>
<tr>
<td>43</td>
<td>2.8</td>
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<td>45</td>
<td>2.8</td>
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<td>46</td>
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<td>1</td>
<td>2.6</td>
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<td>22</td>
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</tr>
<tr>
<td>95</td>
<td>2.5</td>
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</tbody>
</table>
Hazard Vulnerability Index (HVI)

\[ \text{Risk} = \left( \text{Evacuation Code} \times 0.5 + 1 \right) \times \left( \frac{\left( \text{Flood Depth Code} + 0.01 \right)}{4} \right) \times \left( \frac{0.7}{\text{Functional Classification}} \right) \]

<table>
<thead>
<tr>
<th>Evacuation</th>
<th>Code</th>
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<tbody>
<tr>
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<td>Yes</td>
<td>1</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Flood Depth (Feet)</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Flood</td>
<td>0</td>
</tr>
<tr>
<td>0 – 0.5</td>
<td>1</td>
</tr>
<tr>
<td>0.5 - 1</td>
<td>2</td>
</tr>
<tr>
<td>1 - 2</td>
<td>3</td>
</tr>
<tr>
<td>&gt;2</td>
<td>4</td>
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<table>
<thead>
<tr>
<th>Value</th>
<th>SHA Functional Class</th>
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<tbody>
<tr>
<td>1</td>
<td>Interstate</td>
</tr>
<tr>
<td>2</td>
<td>Principal Arterial – Other Freeways and Expressways</td>
</tr>
<tr>
<td>3</td>
<td>Principal Arterial – Other</td>
</tr>
<tr>
<td>4</td>
<td>Minor Arterial</td>
</tr>
<tr>
<td>5</td>
<td>Major Collector</td>
</tr>
<tr>
<td>6</td>
<td>Minor Collector</td>
</tr>
<tr>
<td>7</td>
<td>Local</td>
</tr>
</tbody>
</table>
HVI for Anne Arundel County
HVI for Somerset County

Legend
Hazard Vulnerability Indicator
- Critical
- High
- Moderate
- Low

Data Sources: ESR, MDOT, MD DNR, Salisbury University, DMA, ISCI, US Census Bureau, USDA
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
Percentage of Traversable Trace Paths in AA County with MSL SLC
Origin to Destination Analysis

2050 vs. 2100

No Flooding - MSL 2050
Increase in Path Length (ft)
- No Increase
- 1 - 1,000
- 1,001 - 5,000
- 5,001 - 10,000
- 10,001 - 15,000
- Unreachable Origins
- Destinations
- Inundation Area

No Flooding - MSL 2100
Increase in Path Length (ft)
- No Increase
- 1 - 1,000
- 1,001 - 5,000
- 5,001 - 10,000
- 10,001 - 15,000
- Unreachable Origins
- Destinations
- Inundation Area
Questions

Elizabeth Habic
Office of Planning and Preliminary Engineering
ehabic@sha.state.md.us
410-545-8563

Climate Change Adaptation Plan with Detailed Vulnerability Assessment, October 2014

Baltimore Climate and Resiliency Planning & Implementation Projects
Overview

• Plan Background
• Implementation
• Integration
<table>
<thead>
<tr>
<th>Natural Disasters</th>
<th>Increased Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal Storms</td>
<td>more severe</td>
</tr>
<tr>
<td>Floods</td>
<td>more extensive</td>
</tr>
<tr>
<td>Severe Thunderstorms</td>
<td>more severe</td>
</tr>
<tr>
<td>Wind</td>
<td>increase intensity</td>
</tr>
<tr>
<td>Winter Storms</td>
<td>less snow, more flooding</td>
</tr>
<tr>
<td>Extreme Heat/Drought</td>
<td>more severe and intense</td>
</tr>
<tr>
<td>Sea Level Rise</td>
<td>increased threat</td>
</tr>
<tr>
<td>Air Quality</td>
<td>lower quality and increase risk</td>
</tr>
</tbody>
</table>
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.
Baltimore's Unique Approach

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.

- New Shiloh Baptist Church (location of Gray's funeral)

BLACK/AFRICAN AMERICAN POPULATION
As a percentage of total population

INCOME PER CAPITA IN THE PAST 12 MONTHS
In 2013 inflation-adjusted dollars

UNEMPLOYMENT
Unemployed population* as a percentage of total

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.Chen, 28/04/2015
Disaster Preparedness Plan

Adopted unanimously in October, 2013
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
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
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

Percentage Change in Very Heavy Precipitation

Percentage Change

- 0-10
- 10-20
- 20-30
- 30-40
- 40-50
- >60

Map showing percentage changes in very heavy precipitation across the United States.
Updated Ordinance in April, 2014 establishing:

- Two (2) feet of freeboard (plus additional foot for critical facilities)
- 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
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
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%.
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.
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

<table>
<thead>
<tr>
<th>CREDIT POINTS</th>
<th>CLASS</th>
<th>PREMIUM REDUCTION SFHA*</th>
<th>PREMIUM REDUCTION NON-SFHA**</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,500+</td>
<td>1</td>
<td>45%</td>
<td>10%</td>
</tr>
<tr>
<td>4,000 – 4,499</td>
<td>2</td>
<td>40%</td>
<td>10%</td>
</tr>
<tr>
<td>3,500 – 3,999</td>
<td>3</td>
<td>35%</td>
<td>10%</td>
</tr>
<tr>
<td>3,000 – 3,499</td>
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<td>30%</td>
<td>10%</td>
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<td>2,500 – 2,999</td>
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<td>2,000 – 2,499</td>
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<tr>
<td>500 – 999</td>
<td>9</td>
<td>5%</td>
<td>5%</td>
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<tr>
<td>0 – 499</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Special Flood Hazard Area
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.
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
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 (°C)

- Yellow: 10.559000 - 11.118000
- Orange: 11.118001 - 11.643000
- Orange: 11.643001 - 12.111000
- Red: 12.111001 - 12.612000
- Red: 12.612001 - 13.503000

Scale: 0.15 0.3 0.6 km
Food Resilience
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
Make a Plan, Build a Kit, Help Each Other
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
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
- 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)

Incorporating Recent Science

Regional Sea Level
Factors that Affect Regional and Local Sea Level

- Vertical Land Movement: subsidence, tectonic land movement, water and resource extraction, and glacial isostatic adjustment
- Dynamical Sea Level: surface and deep ocean circulation changes
- Ice Melt Effects: gravitational and other changes due to redistribution of land-based ice mass

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

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

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

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

Uncertainties:
- Climate forcings
- Physical system response
- Human behavior

Source: CARSWG Report (Hall et al., 2016) Fig. 2.8
CARSWG SLR Scenarios: All are considered equally probable. NOAA expressed high confidence that global MSL in 2100 would not fall outside the range of these bounding scenarios (0.2 – 2.0m).

Source: CARSWG Report (Hall et al., 2016) Figure 2.4
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:  FEMA
Other Adaptation Options

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

Other Adaptation Options

Source: cdn.londonreconnections.com/assets/Thames_BARRIER underspill_512.jpg

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
Irene
Irene
Before and After
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 LAKES
REDUCE SPEED
Long-term Environmental Changes
Long-term Environmental Changes
What is Adaptation?

**Climate Changes**
- Extreme Precipitation
- Rising Sea Levels
- Temperature Spikes
- ...

**Impacts on Transportation**
- Roadway flooding
- Damage/destruction of bridges
- Pavement and rail buckling
- Subway flooding
- Seaport & airport flooding
- Slope failures
- Curtailment of barge operations
- ....

**Consequences**
- Freight traffic disrupted for days or weeks
- Power plants, water facilities, homes, businesses, hospitals cut off
- Passenger travel delays
- Higher transportation costs for government, businesses, and households
- Evacuations
- ....

**Adaptive Strategies to Reduce Impacts**
- Retrofitting facilities
- Relocation of facilities
- Upgraded stormwater drainage facilities
- Building new facilities to climate-ready standards
- Protect existing infrastructure
- Flexible infrastructure design
- Risk-based approach

**Adaptive Strategies to Reduce Consequences**
- Reroute freight and passenger flows
- Shift to alternative modes
- Land use regulations relating to development in vulnerable areas
- Evacuation/contingency strategies
- Building in network flexibility
- Traveler information systems
- Rapid rebuilding of damaged facilities
- Improved air traffic management
NCHRP 20-83(5) Adaptation Planning Framework

1. Identify key goals and performance measures
2. Define policies on assets, asset types or locations that will receive adaptation consideration
3. Identify predominant climate change trends and their likelihoods for region
4. Identify likely changes on local environmental conditions
5. Identify vulnerabilities of asset(s) to changing environmental conditions
6. Conduct risk appraisal of asset(s) given vulnerabilities
7. Conduct site analysis (see Chapter 6) or programmatically change design standards, change operating strategies, change maintenance practices, change construction practices, etc.
8. Identify other agency plans, strategies, or actions relating to climate change
9. Identify adaptation options for high-risk assets and assess feasibility, cost effectiveness and defensibility of options.
10. Is action necessary, e.g., are current or future (expected) thresholds reached?
   - Yes: Monitor climate conditions/asset performance
   - No: For those assets already identified as being high risk and for which adaptation options are known, proceed to site analysis
11. Identify agency and public risk tolerance and set trigger thresholds that will initiate implementation of adaptation options (optional)
12. Coordinate agency functions for adaptation program implementation

Planning, Design, Operations, Maintenance, Construction, Other Functions
NCHRP 20-83(5) Adaptation Planning Framework

Identify key goals and performance measures

Define policies on assets, asset types or locations that will receive adaptation consideration

Identify predominant climate change trends and their likelihoods for region

Identify likely changes on local environmental conditions

Identify other agency plans, strategies, or actions relating to climate change

Identify agency and public risk tolerance and set trigger thresholds that will initiate implementation of adaptation options (optional)

Identify vulnerabilities of highway system to these changing conditions

- Conduct site analysis (see Chapter 6) or programmatically change design standards, change operating strategies, change maintenance practices, change construction practices, etc.

- Is action necessary, e.g., are current or future (expected) thresholds reached?
  - yes
    - Monitor climate conditions/asset performance
  - no
    - Coordinate agency functions for adaptation program implementation

Planning, Design, Operations, Maintenance, Construction, Other Functions
NCHRP 20-83(5) Adaptation Planning Framework

1. Identify key goals and performance measures
2. Define policies on assets, asset types or locations that will receive adaptation consideration
3. Identify predominant climate change trends and their likelihoods for region
4. Identify likely changes on local environmental conditions
5. Identify other agency plans, strategies, or actions responding to climate change
6. Identify agency and public risk tolerance and set trigger thresholds that will initiate implementation of adaptation options (optional)
7. Conduct risk appraisal of vulnerabilities and environmental changes
8. Conduct site analysis (see Chapter 6) or programmatically change design standards, change operating strategies, change maintenance practices, change construction practices, etc.
9. Is action necessary, e.g., are current or future (expected) thresholds reached?
10. Monitor climate conditions/asset performance
11. Coordinate agency functions for adaptation program implementation

Planning, Design, Operations, Maintenance, Construction, Other Functions
NCHRP 20-83(5) Adaptation Planning Framework

Identify key goals and performance measures

Define policies on assets, asset types or locations that will receive adaptation consideration

Identify predominant climate change trends and their likelihoods for region

Identify likely changes on local environmental conditions

Identify vulnerabilities of asset(s) to changing environmental conditions

Conduct risk appraisal of asset(s) given vulnerabilities

Conduct site analysis (see Chapter 6) or programmatically change design standards, change operating strategies, change maintenance practices, change construction practices, etc.

Identify other agency plans, strategies, or actions relating to climate change

Identify adaptation options for high-risk assets and assess feasibility, cost effectiveness and defensibility of options.

Is action necessary, e.g., are current or future (expected) thresholds reached?

yes

no

Identify affected highway agency functions

Monitor climate conditions/assess performance

Identify agency and public risk tolerance and set trigger thresholds that will initiate implementation of adaptation options (optional)

Coordinate agency
NCHRP 20-83(5) Adaptation Planning Framework

1. Identify key goals and performance measures
2. Define policies on assets, asset types or locations that will receive adaptation consideration
3. Identify predominant climate change trends and their likelihoods for region
4. Identify likely changes on local environmental conditions
5. Identify vulnerabilities of asset(s) to changing environmental conditions
6. Conduct risk appraisal of asset(s) given vulnerabilities
7. Identify other agency plans, strategies, or actions relating to climate change
8. Identify adaptation options for high-risk assets and assess feasibility, cost-effectiveness and defensibility of options.

Additional steps:
- Change design standards
- Change operating strategies
- Change maintenance practices
- Change construction practices
- Etc.

Coordinate agency functions for adaptation program implementation

Monitor climate conditions/asset performance

Planning, Design, Operations, Maintenance, Construction, Other Functions
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, Anchovoy and Cheese Pizza Analogy
## Highways Agency: Maintenance Implications

<table>
<thead>
<tr>
<th>Risk</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced asset condition and safety</td>
<td>Assets deteriorate more quickly due to changes in average climatic conditions; assets are more badly damaged as a result of more extreme climatic events.</td>
</tr>
<tr>
<td>Reduced network availability and/or functionality</td>
<td>Need for restrictions on the network to maintain safety; increased need for road works.</td>
</tr>
<tr>
<td>Increased costs to maintain a safe, serviceable network</td>
<td>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.</td>
</tr>
<tr>
<td>Increased safety risk to road workers</td>
<td>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.</td>
</tr>
</tbody>
</table>

http://www.highways.gov.uk/publications/climate-change-mitigation/
<table>
<thead>
<tr>
<th>Stressor</th>
<th>Potential Impacts</th>
<th>Consequence</th>
<th>Frequency</th>
<th>Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme Precip.</td>
<td>Flooding</td>
<td>Damage to levee</td>
<td>Today, once every 100 years, but increasing</td>
<td>Raise levee redesign</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Damage to I-75</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disruption to I-24</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Significant Expansion</td>
<td>Major damage</td>
<td>Unknown, but increasing</td>
<td>Alt. route planning</td>
</tr>
<tr>
<td></td>
<td>Slight Pavement Expansion</td>
<td>Major disruption</td>
<td>Unknown, but increasing</td>
<td>Pavement improvements</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Major deterioration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate Change Effects</td>
<td>Climate Change Impacts</td>
<td>System Maintenance Response</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shifting rain/snow line</td>
<td>Fewer snow/ice precipitation events</td>
<td>Reduced need for winter maintenance operations resources and staff</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shifting rain/snow line</td>
<td>Less snowfall in areas that were previously impassable due to high and frequent snowfall</td>
<td>Potential for increased winter maintenance operations on routes currently inaccessible in winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shifting rain/snow line</td>
<td>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</td>
<td>Shift in resources from winter maintenance to winter flooding monitoring and traveler information</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shifting rain/snow line</td>
<td>Temperatures in some areas may shift to or more frequently hover at the freezing point, increasing the probability of ice precipitation instead of snow</td>
<td>Shift in resources from snow to ice management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shifting rain/snow line</td>
<td>Long-term shifting of snow/ice precipitation necessitates reassessment of winter maintenance needs</td>
<td>Monitoring trends to identify and forecast trends of increasing or decreasing snow/ice and frequency of extreme precipitation events</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shifting rain/snow line</td>
<td>Longer construction season due to higher temperatures, fewer days with temperatures below freezing, and less snow/ice precipitation</td>
<td>Altered construction and maintenance schedules</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Changes in freeze/thaw cycle</td>
<td>Potential for longer duration and/or shifting of freeze/thaw period</td>
<td>Increased staff and resources to monitor vulnerable areas to post seasonal weight restrictions and make repairs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased frequency, duration and intensity of droughts; increase in average air temperature</td>
<td>Roadside vegetation dies off</td>
<td>Changes to vegetation management activities</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Climate Event Impacts

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

A Synthesis of Highway Practice
With respect to maintenance.....
• Separate sites for debris and sand removed from streets

• Assessment of sinkhole-related issues and most appropriate traffic control measures at the local level

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

• 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
• Under a disaster declaration, assistance to municipalities in the form of staff and heavy equipment

• Re-assigned existing contracting group working on culverts in one region to respond and repair damaged roads in region affected by flooding

• Employee preparedness and safety through the acquisition and pre-positioning of two response trailers with protective gear
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*
“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”

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
In Conclusion......
Thank you.