Session 2: System-Level Vulnerability Assessments

May 30, 2013

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

Session 1: Getting Started – Determining Assets to Study and Using Climate Information

Session 2: System-Level Vulnerability Assessments

Session 3: Applying the Results
Date: Wednesday, June 12, 2:00 – 3:30 pm EDT

Session 4: Hurricane Sandy - Lessons Learned
Date: Thursday, June 20, 2:00 – 3:30 pm EDT
Agenda

**Introduction**  
Rob Kafalenos, FHWA

**Example Applications of System-Level Vulnerability Assessments**

Washington State DOT  
Carol Lee Roalkvam

Metropolitan Transportation Commission  
Stefanie Hom, Carolyn Clevenger, & Sara Polgar

New Jersey Transportation Planning Authority  
Jeffrey Perlman

Q&As
Vulnerability Assessments

Understanding how climate change effects and extreme weather will affect your transportation network is key first step for climate change planning.
FHWA’s Climate Change and Extreme Weather Vulnerability Assessment Framework
Climate Change & Extreme Weather Vulnerability Assessment Framework

1. Define Project Scope
   • Objectives
   • Relevant Assets
   • Climate Variables

2. Assess Vulnerability
   • Climate Inputs
   • Asset data, criticality, sensitivity
   • Vulnerabilities, risk

3. Integrate Vulnerability Into Decision Making
2013 – 2014 Pilot Locations
2013 – 2014 Pilot Locations

Vulnerability Assessments
- TN DOT
- CAMPO (Austin)
- North Central Texas COG
- Maine DOT
- Michigan DOT
- Arizona DOT
- Alaska

Adaptation Options
- Connecticut DOT
- MassDOT
- MNDOT
- NYSDOT
- Iowa DOT
- Maryland SHA
- MTC
- Broward MPO
- Oregon DOT
- CalTrans
- Hillsborough MPO
- WSDOT
Washington State DOT’s Vulnerability Assessment: Asking the “Climate Question”

Carol Lee Roalkvam
Environmental Policy Branch Manager

Lynn Peterson
Secretary of Transportation

Climate Change & Extreme Weather Vulnerability Assessment
FHWA & TRB Webinar Series
May 30, 2013
Washington State DOT’s Pilot Facts

- FHWA $189,500 funds matched by state staff time
- State DOT test of the model leveraged:
  - Asset management & cost/risk assessment tools
  - Pacific Northwest climate change data
  - Field personnel intimate knowledge of threats
- Easily replicable process:
  - 14 Workshops across state
  - Microsoft Excel & GIS tools
- Qualitative rankings for all state-owned assets!
Washington Climate Change Impacts Assessment

- Funded by the Washington State Legislature
- Published in 2009
- Comprehensive report on climate change impacts in Washington
- Downscaled from global climate models
- Detailed data and technical support available
Changes in Air and Water Temperatures

August Mean Surface Air Temperature and Maximum Stream Temperature (Implications for Salmon)

Source: Mantua et al. 2009, in press
Changes in Flood Risks

- Floods in western Washington will likely increase in magnitude due to the combined effects of warming and increasingly intense winter storms.
- In eastern Washington fall flood risks may increase; spring flood risks may decline due to loss of spring snow cover.

FHWA risk assessment model

1. Inventory of Assets
   - Develop inventory of assets
   - How important is each asset?

2. Climate Information
   - Gather climate information (observed and projections)
   - What is the likelihood and magnitude of future climate changes?

3. Risk
   - Is the asset vulnerable to projected climate effects?
   - What is the likelihood that future stressors will measurably impact the asset?
   - What is the consequence of the impact on the asset?

4. Monitor and revisit as resources allow
   - Low risk
   - High or medium risk

5. Identify, analyze, and prioritize adaptation options

6. Existing data sets
   - Less important
   - Low likelihood/ Low magnitude
   - More important
   - High likelihood/High magnitude
   - High likelihood/Low magnitude
   - Low likelihood/High magnitude

Washington State Department of Transportation
Goal: Preserve assets in a changing environment

• FHWA $189,500 matched by state staff time

• WSDOT Approach:
  – Understand climate change within existing Asset Management framework
  – Create easily replicable process (leverage Cost/Risk Assessment tools)
  – Use internal knowledge and experience
  – Consider impacts on our all WSDOT assets (Highways, Ferries, State-owned Rail and Airports)
WSDOT pilot modifications to FHWA Process

DOT Jurisdictional Role
- Compile inventory of assets
- Determine climate change scenarios to use in workshops OR Develop climate change impacts and probabilities

Workshops
- Establish qualitative criteria for asset criticality
- Determine criticality of asset (road segment, facility, etc.)

Input From Science
- Gather observed and projected climate data
- Monitor climate change science and reassess system as needed

Use scenarios for a vulnerability assessment or impacts and probabilities for a risk assessment.

Develop qualitative criteria for climate change impacts

As focused adaptation strategies are implemented, reassess system

Record the ratings and the information gathered from subject matter experts for inclusion in database and use in mapping

Develop adaptation strategies

Is the asset vulnerable to climate change scenario? If so, what is the magnitude of the impact.
Step 1 – How critical is the asset?

WSDOT Methodology

<table>
<thead>
<tr>
<th>Very low to low</th>
<th>Moderate</th>
<th>Critical to Very Critical</th>
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<tbody>
<tr>
<td>1</td>
<td>2</td>
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<td>9</td>
</tr>
<tr>
<td>10</td>
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</table>

**Criticality of asset**

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

**Typically involves:**
- non-NHS
- low AADT
- alternate routes available

**Typically involves:**
- some-NHS
- non-NHS
- low to medium AADT serves as an alternative for other state routes

**Typically involves:**
- Interstate
- Lifeline
- some NHS
- sole access
- no alternate routes
Step 2: What are the Climate Threats?

• Began with climate change forecast from UW Climate Impacts Group
• Talked about observed changes and extreme events – what is happening now
• WSDOT’s internal experts ranked all WSDOT assets
• Key Questions:
  – “What keeps you up at night?”
  – “What if it gets worse (given the scenario)?”
  – “How resilient is our existing system?”
We used our experience to gauge future impacts

Scour and damage to structures - Just off US 12 Davis Creek
Oct. 4, 2009: Dust storm closes I-90 between Moses Lake and Ritzville
We’ve seen a 9 inch rise over 110 years
Workshops: How might climate impact assets?

<table>
<thead>
<tr>
<th><strong>Primary climate drivers</strong></th>
<th><strong>Can lead to impacts on...</strong></th>
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</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Expansion joints, pavement, rail tracks, construction periods, habitat projects, electrical equipment</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Flooding of surface roads &amp; tunnels, road washout, pump capacity, drainage</td>
</tr>
<tr>
<td>Hydrologic shifts</td>
<td>Soil instability, water supply, bridge and road support structures</td>
</tr>
<tr>
<td>Sea level rise, storm surge</td>
<td>Coastal erosion, coastal and upriver flooding, bridge footings, drainage, roadside stability, salt / corrosion</td>
</tr>
</tbody>
</table>
Bridge Engineering Information System (BEIS)

This site provides access to inventory data, plans, rating reports, inspection reports, photographs, and related files for bridge structures in the WSDOT bridge inventory. This inventory of bridge structures includes some locally owned agency structures.

There are over 8,500 bridge structures in this database, therefore it is necessary to provide information about the structures of interest to reduce the list to a displayable level. Please provide one or more pieces of information about the structure(s) you are interested in:

Structure ID
Bridge Number
County
Contract Number
Route
Milepost Range

Search  Reset  Show Map

Hide Search Criteria
## Mud Bay Bridge (101/508E)

### Bridge Information
- **Bridge Number**: 101/508E
- **Structure Identifier**: 0005677A
- **Location**: 1.3 S JCT SR 8
- **Route**: 00101
- **Mile Post**: 36.283
- **Feature intersected**: Mud Bay
- **Facilities Carried**: US 101
- **Region**: OL
- **Owner**: Washington State

### Inspections Performed

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<th>Inspect Date</th>
<th>Inspect Freq</th>
<th>Inspect Type</th>
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<tr>
<td>Equipment</td>
<td>2010-05-12</td>
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</tbody>
</table>

### MUD BAY Image

[Image of Mud Bay Bridge]

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**Washington State Department of Transportation**
<table>
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<tr>
<th>Impact Score</th>
<th>Description</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Complete catastrophic failure</td>
<td>Asset may be available for limited use after at least 60 days and would require major repair or rebuild over extended period of time. Typically involves: Immediate road closure; Disruptions to travel; Vehicles forced to re-route to other roads; Reduced commerce in affected areas; Reduces or eliminates access to some destinations; May sever some utilities located within right-of-way; May damage drainage conveyance or storage systems.</td>
</tr>
<tr>
<td>3-5</td>
<td>Temporary operational failure</td>
<td>Results in minor damage and/or disruption to asset. Asset would be available with either full or limited use within 60 days and may have immediate limited use still available. Typically involves: Temporary road closure, hours to weeks; Reduced access to destinations served by the asset; Stranded vehicles; Possible temporary utility failures.</td>
</tr>
<tr>
<td>6-10</td>
<td>Reduced capacity</td>
<td>Results in little or negligible impact to asset. Asset would be available with full use within 10 days and has immediate limited use still available. Typically involves: Less convenient travel; Occasional/brief lane closures, but roads remain open; A few vehicles may move to alternate routes.</td>
</tr>
</tbody>
</table>

Figure 2.1 Photo depictions of qualitatively assessed climate change consequences
Statewide Results (map shows results with 2 foot sea-rise & all other threats)
What did we find?

• Intensifies known threats
• Reinforces value of our current maintenance and retrofit programs
• Some surprises
• Unique way to capture knowledge of field staff
Timeline of WSDOT’s Assessment

- **2011**
  - Oct.: FHWA Grant
  - Jan.: Workshops across the state to evaluate all WSDOT Assets

- **2012**
  - Nov.: Map and communicate results
  - Jan.: Published Report/GIS
  - May: Direction & Guidance
  - Sept.: Integrate into asset management paths

- **2013**
  - Jan.: FHWA Phase II Pilot

Begin Skagit Pilot
July 1st
2011 WSDOT Climate Impacts Vulnerability Assessment Results in Skagit Basin

Climate Impacts Vulnerability Results
- High Vulnerability
- Moderate Vulnerability
- Low Vulnerability
- Low Vulnerability State Ferry
- Flood Zone (100-year)

FOR PLANNING ONLY
Not suitable for site specific use. Depicts results of WSDOT Climate Impacts Vulnerability Assessment (2011)
Location of Skagit Bridge Collapse

Current I-5 North Bound Detour Route
Skagit Pilot Project Team Members

- WSDOT (Region Planning, HQ Environment, Design, Emergency Management, Public Transportation)
- FHWA – WA Division and HQ
- U. S. Army Corps of Engineers – Federal Lead for General Investigation
- Skagit County – Local Lead Agency [www.skagitcounty.net/skagitrivergi](http://www.skagitcounty.net/skagitrivergi)

**Task:** Evaluate Corps Skagit study with preferred alternatives. Examine local options and evaluate potential risks and opportunities to improve / enhance resilience and preparedness

**Task:** Develop adaptation options for WSDOT managed infrastructure (Interstate 5, State Highways and Anacortes Ferry Terminal)
Adapting to a changing climate
Statewide study of climate-related infrastructure risks

Our climate is changing. Demand for transportation resources continues to grow. Keeping state-owned and managed infrastructure safe and operational is key to a growing economy and building a more resilient and sustainable transportation system.

Protecting infrastructure, freight routes and keeping drivers safe for the long-haul

Our economy and quality of life can take serious hits when inclement weather floods interstates, closes critical bridges and brings homeless snow to our mountain passes. The past has shown how storms can wreak havoc on our daily lives and prevent goods and services getting to customers.

WSDOT's job is to keep the state's transportation system safe and operational. This means planning and preparing to protect and manage our vital roads, bridges, ferry terminals and other facilities that could be vulnerable to severe weather. We must be resilient and adapt to future environmental conditions. Thanks to a $189,500 Federal Highway Administration (FHWA) national pilot project grant, WSDOT was able to complete the groundwork on assessing how our state-owned and operated transportation assets may fare under extreme weather changes.

WSDOT pilots infrastructure vulnerability assessment

We conducted workshops with our field staff from across the state to assess the vulnerability of our highways, ferry terminals and other infrastructure to changes in our climate and weather extremes. We presented the participants with climate scenarios such as extreme temperatures and sea-level rise, asking "What would be the likely impact on our facilities?" The results from each workshop were used to create a series of planning-level maps.

USDOT Climate Change Policy

In addition to the federal dollars from the FHWA pilot project, United States Department of Transportation (USDOT) policy supports climate adaptation efforts. In a June 2011 policy statement, U.S. Transportation Secretary Ray LaHood directed USDOT agencies (such as the federal highway and transit administrations) to consider climate change impacts on current systems and future investments.

The USDOT climate change policy statement further states that "planning for climate adaptation assists state and local transportation agencies, and DOTs, to identify how climate change is likely to impact their ability to achieve their mission, continue operations, and to meet policy and program objectives."

For more information
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WSDOT Environmental Services
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http://www.wsdot.wa.gov/SustainableTransportation/adapting.htm
Goal

The goal of **Adapting to Rising Tides** is to increase preparedness and resilience of Bay Area communities to sea level rise and other climate change impacts while protecting ecosystem and community assets, such as transportation.
Partnerships

- **Project Management Team**
  - Metropolitan Transportation Commission, Bay Conservation and Development Commission, and Caltrans

- **Consultant Team**
  - AECOM, Arcadis, Geografika, 3D Visions

- **Federal Highway Administration**

- **Local Partnership**
  - Cities of Emeryville, Alameda, Oakland, San Leandro, Hayward, & Union City, and County of Alameda
  - BART, Capital Corridor, AC Transit
  - U.S. Geological Survey, National Oceanic and Atmospheric Administration, California Coastal Conservancy, East Bay Dischargers Authority, East Bay Municipal Utility District, East Bay Regional Park District, Hayward Area Rec. and Park, Port of Oakland, Association of Bay Area Governments, Alameda County Transportation Commission
Alameda County Sub-Region

Study Area

Oakland

Oakland Airport

Hayward
Bay Area Refinements to Pilot Model

1. Data Asset Inventory & Asset Screening and Prioritization
2. Climate and Shoreline Information
3. Vulnerability Assessment
   1. \[ \text{Vulnerability} = \text{Exposure} + \text{Sensitivity} + \text{Adaptive Capacity} \]
4. Risk Assessment
   1. \[ \text{Risk} = \text{Likelihood} + \text{Consequence} \]
5. Adaptation Strategies
1a. Transportation Asset Inventory

- Interstates/Freeways
- Arterial, collector and local streets
- Road tunnels/tubes
- Bay bridges
- Alameda bridges
- BART stations
- BART alignments
- Amtrak stations
- Passenger/freight rail alignments
- Ferry terminals
- Transportation Management Centers
- Bus Maintenance Facilities
- BART System Assets
- Passenger and Freight Yards and Depots
- Pedestrian/ Bicycle Facilities
- Transit associated with all road assets
1b. Asset Selection

- **Physical Characteristics**
  built at-grade, below grade, or elevated on embankments or structures;

- **Functional Characteristics**
  lifeline routes, evacuation routes, goods movement routes, transit routes, and bike routes;

- **Jurisdiction**
  agency, city or other entity with ownership and/or management responsibility for the asset;

- **Social/Economic Functions**
  connecting to jobs, regional importance, and support of transit-dependent populations.
2. Climate Science & Shoreline Assets

- Developed simple, yet distinct, shoreline categories based on primary function and potential to protect against inland inundation

- Using shoreline categories in combination with new inundation maps to understand transportation vulnerability and risk
New Sea Level Rise Maps for Six (6) Climate Scenarios

- Two sea level rise projections
  - 16” (40 cm) of sea level rise ≈ mid-century
  - 55” (140 cm) of sea level rise ≈ end-century

- Three water level conditions
  - High tide (mean high high water, MHHW)
  - Extreme high tide (100-year stillwater level)
  - Extreme high tide + locally generated wind waves
3. Vulnerability Assessment

- **Vulnerability:** “is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes.” (IPCC definition 2007)

- **Vulnerability = exposure + sensitivity + adaptive capacity**

- **Our definition:** *Sea Level Rise exposure + condition of asset + ability to reroute, comparable facilities available*
Exposure to SLR
Measured by depth of inundation at midcentury and end of century
Asset

Sensitivity

- Level of use - Average Daily Traffic (ADT) volume (cars / trucks) etc
- Age
- Seismically retrofitted
- Maintenance (Ongoing Operations and Maintenance [O&M]) Cost
- Foundation condition
- Liquefaction susceptibility

Exposure + Sensitivity + Adaptive Capacity = Vulnerability
Adaptive Capacity

- **Adaptive capacity**: "is the ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities or cope with the consequences." (IPCC definition)

- Our definition: **ability for rerouting or comparable available facilities to maintain all or part of the original functionality**

Exposure + Sensitivity + Adaptive Capacity = Vulnerability
4. Risk Assessment

Risk is the threat posed by an impact or hazard. It depends on the likelihood of an impact and the magnitude of the consequence.

What is the likelihood of the asset being impacted by sea level rise?

If so, what are expected consequences in terms of cost and time to replace asset, economic impact, socio-economic impact, public safety and degree of redundancy in the system?
Likelihood and Consequence

- **Likelihood**: What is the likelihood that the asset will be impacted by SLR?
  - Mid century SLR scenario = ‘highly likely’
  - End of Century SLR scenario = ‘likely’

- **Consequence**: what is the expected impact or consequence to society if the asset is inundated?
  **Criteria selected:**
  - Cost of and time to replace asset
  - Economic impact (goods movement, commuter route)
  - Socio-economic impact (transit dependent communities, MTC Communities of Concern)
  - Public safety (lifeline, mass evacuation route)
  - Degree of redundancy in the system (ability to reroute)
## Asset Risk Profile

### Coliseum / Oakland Airport BART Station (T-04)

#### Asset Location / Jurisdiction
Oakland / BART

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

### Characteristics:
- Elevated
- Commuter route
- Transit routes [3 BART Lines; AC Transit: 45, 46, 73, 58, 356, 605]

### Sensitivity
Data unavailable in project timeframe.

<table>
<thead>
<tr>
<th>Liquefaction Susceptibility</th>
<th>Medium</th>
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</thead>
</table>

#### Exposure: Low

<table>
<thead>
<tr>
<th>Maximum Inundation Depths</th>
<th>0 ft</th>
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<tbody>
<tr>
<td>16” + MHW</td>
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<tr>
<td>16” + 100-yr SWEL</td>
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<tr>
<td>16” + 100-yr SWEL + wind waves</td>
<td>YES</td>
</tr>
<tr>
<td>55” + MHW</td>
<td></td>
</tr>
<tr>
<td>55” + 100-yr SWEL</td>
<td>0 ft*</td>
</tr>
<tr>
<td>55” + 100-yr SWEL + wind waves</td>
<td>YES</td>
</tr>
</tbody>
</table>

#### Inadequate Adaptive Capacity (16” SLR): High
No adequate alternative station

### Vulnerability Rating (mid-century): Medium

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

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**Projected Inundation with 16 inch SLR + 100-yr SWEL**

**Projected Inundation with 55 inch SLR + 100-yr SWEL**
5. Adaptation Strategies

- Explore potential range of near-term and long-term adaptation strategies
  - Structural Adaptation Measures
  - Nonstructural Adaptation Measures
  - Asset-Specific Adaptation Measures
  - Regional Adaptation Measures

- Evaluated risk profiles to identify appropriate adaptation measure for each asset – highest risk assets are to be addressed first

- Next Steps: more detailed adaptation planning needed
Lessons Learned

1. Creating data inventory for transportation and shoreline assets was challenging due to inconsistent availability of data and high level of effort

2. Prioritizing assets was premature prior to consequence analysis and not acceptable to stakeholders,

3. Most important asset selection filter was exposure to flooding and inundation; asset characteristics and functionality were less important

4. Using existing climate science information is insufficient; further mapping of climate impacts is necessary to understand asset vulnerability

5. Need robust definitions or guidance on what exposure, sensitivity and adaptive capacity mean and how to use them for different project types

6. Need early input from stakeholders on how to define consequence impact criteria so that criteria are tailored to local context
Adapting to Rising Tides Adaptation Options: Project Overview

- **Focus Areas:**
  - West Oakland/Emeryville/Bay Bridge Peninsula;
  - Oakland Coliseum Area; and
  - State Route 92 Corridor.

- **Adaptation Strategies will Include:**
  - Structural Measures
  - Non-Structural Measures
  - Asset-Specific Measures
  - Regional Measures
For more information, please contact:

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510.817.5756

Sara Polgar, BCDC  
sarap@bcdc.ca.gov  
415.352.3654

For a report copy of Transportation Vulnerability and Risk Assessment Pilot Project, see:

http://www.mtc.ca.gov/planning/climate/Rising_Tides_Briefing_Book.pdf

Assessing the Vulnerability of New Jersey’s Transportation System to the Impacts of Climate Change

FHWA Climate Change Vulnerability Assessment Webinar

Jeffrey Perlman, AICP, PP, LEED AP
North Jersey Transportation Planning Authority
Steps to Identifying Vulnerable Transportation Assets to Climate Change

- Articulate Objectives
- Select & Characterize Relevant Transportation Assets
- Assess Asset Criticality
- Identify Key Climate Variables
- Identify and Rank Vulnerabilities
Climate Change Impacts on the Transportation System

Climate Stressor
- Drought & Extreme Precipitation
- More Frequent Storms
- Temperature Increases
- Rising Sea Levels

Affected Asset
- Roads and Bridges
- Rail
- Aviation
- Navigation
# Inventory of Assets & Criticality

## Develop Inventory of Assets
- Roadways
  - from the CMS network
- Bridges
- Passenger Rail
  - Amtrak & NJ TRANSIT
- Freight Rail
  - NS and CSX, class 3
- Airports
- Wetlands
- Tunnels
  (Route 29 and Atlantic City Marina)

## Determining Critical Assets
- Roadways & Bridges
- Evacuation Routes
- Access to Jobs
- Volumes
- Passenger Rail
  - All Passenger Rail is Deemed Critical
- Freight Rail
  - Class-1 Very Critical
  - Class-2 & -3 Less Critical
Determining Climate Impacts

Climate Threats

- Sea Level Rise and Storm Surge Impacts
- Temperature and Precipitation
- Inland flooding impacts

Scenario Development

- Three GHG Emissions Scenarios: Low, Medium, & High
- Projected climate impacts for 2050 and 2100
- Collected historic weather data from NJ weather stations

Threshold of Analysis

- Temperature
  - Days above 95 degrees
- Precipitation
  - Max within a five day period
- Drought
- Number of consecutive dry days
- Cold/Frost
  - Number of frost days
Climate Change Projections – select stations and emissions scenarios

### Baseline and Projected for Select Stations from Average Grids

<table>
<thead>
<tr>
<th>Station Name</th>
<th>Precipitation (in)</th>
<th>Avg. Max Temp (F)</th>
<th>Avg. Min Temp (F)</th>
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</thead>
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<tr>
<td></td>
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<td>A1B 2100</td>
<td>A1B 2100</td>
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### Baseline and Projected for Select Stations from Average Grids

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<thead>
<tr>
<th>Station Name</th>
<th>Days above 95F</th>
<th>Consec. dry days</th>
<th>Frost days</th>
<th>Days of &lt;20F</th>
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<td>Baseline</td>
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Vulnerability Analysis

Data Inputs
- Transportation Network
  - Roadway
  - Rail
- LiDAR (Digital Elevation Maps)
- Climate Projections
  - Sea Level Rise and Storm Surge
  - Temperature and Precipitation
  - Inland flooding impacts

Outcomes
- Flooding of Transportation Assets
  - Roadways
  - Passenger Rail
  - Freight Rail
- Climate Extremes
  - More days above 95°F
  - Increased storm intensity
  - Fewer frost days
Determining Infrastructure Vulnerable to Sea Level Rise and Storm Surge

- Utilized three global sea level rise (SLR) scenarios - .5, 1, and 1.5 meters
- Applied high-resolution LiDAR data for ground elevations
- Obtained local subsidence data from NJDEP
- Projected SLR and storm surge impacts for 2050 and 2100 for each SLR scenario
- SLOSH Modeling to determine storm surge impacts from a Category 1 Hurricane
Highways Potentially Vulnerable to Sea Level Rise & Storm Surge – medium GHG scenario for 2100
Highways Potentially Vulnerable to Sea Level Rise & Storm Surge – medium GHG scenario for 2100
Determining Infrastructure Vulnerable to Inland Flooding

- Estimated potential changes in peak 100-year storm (1% annual storm event)
- Used climate change outputs as inputs for analysis
  - Frost days
  - Dry days
  - Rainfall
- Same timeframes and emissions scenarios for 2100
- Estimated changes to impervious coverage due to population growth
- Used updated Digital Flood Insurance Rate Maps from FEMA
Rail Infrastructure Potentially Vulnerable to 1% Storm Event – Medium GHG scenario for 2100
Recent Updates: Analyzing Flooding Impacts from Hurricane Irene and Sandy

- Used TRANSCOM data recorded from Hurricane Irene transportation incidents
- Coded incidents by location and duration
- State Highways and Major Arterials
Impacts from Hurricane Sandy

Duration of Incidents during Sandy:
- Lasted for 1 day
- 1 to 2 days
- 2 to 3 days
- More than 3 days

Excluding construction & delays due to volume
Roadway Incidents (reported, 10/29/13 to 11/2/13)
- Green: Downed infrastructure - pole, manhole, tree, sign or wire
- Pink: Emergency construction, maintenance or electrical repairs
- Blue: Flooding

150 cm SLR by 2100, 90th percentile of GCM's, @2050

Value
- High: 22.1403
- Low: -0

Source: TRANSCOM, 2012
Next Steps: New York – New Jersey – Connecticut Transportation Vulnerability Assessment and Adaptation Analysis
Further Reading

Visit the NJTPA Climate Initiative for more information

http://www.njtpa.org/Plan/Element/Climate/ClimateChangeInitiative.aspx

Thank you!