Highways in the Coastal/Riverine Environments

HEC-25, Volume 2: Highways in the Coastal Environment: Assessing Extreme Events
HEC-17, 2nd Edition: Highways in the River Environment: Floodplains, Extreme Events, Risk and Resilience

Subcommittee on Hydrology Meeting
Turner Fairbank Highway Research Center
McLean, Virginia
April 30, 2015

Brian Beucler, PE, FHWA Office of Infrastructure
Today We’ll Cover:

- HEC-25 Volume 2 (completed Oct 2014)
- HEC-17 2nd Edition (under development, to complete by Spring 2016)
- 1st International Conference on Transportation Resilience to Climate Change (September 16-18, 2015)
Need and Objectives
Need for HEC 25 Volume 2

- 60,000 miles of coastal roads and 36,000 bridges near the coast
- Coastal environment is dynamic with extreme events and climate change
- HEC 25 provides an overview of coastal issues, but not detailed guidance on assessing vulnerability
Objectives for HEC 25 Volume 2

• Provide technical guidance and methods for incorporating extreme events and climate change for highway planning and design in coastal environments

• Focus on issues related to:
  ▪ Sea level rise
  ▪ Storm surge
  ▪ Wave action
Peer Exchanges

HEC 25 VOLUME 2
Regional Peer Exchanges

Vancouver, WA
Sacramento, CA
Madison, WI
New York, NY
Tallahassee, FL
• Large scale climate changes and regional concerns (*Keith Dixon, NOAA*)
• New Jersey adaptation pilot study (*Jeff Perlman, NJTPA*)
• USACE approach to assessing coastal risk and flooding (*Lynn Bocamazo, USACE*)
• Strengths and weaknesses in modeling waves and surge (*Jane Smith, USACE*)
• Storm surge modeling in the NY area (*Jon Miller, Stevens Institute*)
Manual Outline

HEC 25 VOLUME 2
Manual Table of Contents

Glossary

1. Introduction

2. Identification of relevant coastal processes and climate change impacts

3. Risk, vulnerability and adaptation

4. Analysis methods for assessing extreme events and climate change

5. Case studies of exposure & vulnerability assessment
Introduction: Purpose of Manual

• Provide technical guidance and methods for assessing the vulnerability of coastal transportation facilities to extreme events and climate change

• Uses:
  ▪ Risk and vulnerability assessments
  ▪ Planning activities
  ▪ Design procedure guidance
Relevant Coastal Processes: Regional Focus

- Gulf and South Atlantic
- Mid-Atlantic and New England
- Great Lakes
- Pacific
Regional Coastal Processes: Mid-Atlantic and New England

• Storm surge and waves due to tropical and extratropical (e.g., northeaster) storms
• Effect of tide on coastal flood levels particularly as it relates to the phasing of the storm surge and fluvial discharge
• Episodic storm-induced shoreline change
• Watershed contributions of extreme precipitation and runoff to coastal water bodies
Relevant Coastal Processes: Climate Change Impacts

- Sea levels
- Waves
- Others, e.g. shoreline processes
Sea Level Rise Projections

- Manual includes an example of how to estimate projected sea levels
  - Site-specific example
  - Demonstrates how to incorporate existing relative sea level changes (including subsidence/uplift) into future projections

- New (June 30, 2014) US Army Corps of Engineers guidance on “Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptations” is cited
Numerical Models of Critical Coastal Processes

- Storm surge
  - ADCIRC, SLOSH, ET-SURGE
- Waves
  - WAM, STWAVE, SWAN
- Coastal morphology
  - EDUNE, SBEACH
Risk, Vulnerability and Adaptation

• Engineering risk at the coast
• Coastal vulnerability assessments
• Climate change and extreme events: damage mechanisms
• Adaptation/countermeasure strategies for coastal highway infrastructure

\[ \text{Vulnerability} = f(\text{Exposure, Sensitivity, Adaptive Capacity}) \]
Focus of HEC 25 Vol 2 is “Exposure”

• Risk = f (exposure, sensitivity)
  - Exposure is characterized by the magnitude and probability of occurrence of a hazard
  - Sensitivity describes the resulting damage or consequence

• Vulnerability = f (exposure, sensitivity, adaptive capacity)
  - Vulnerability adds the concept of adaptive capacity, that is, the ability to adjust to or moderate damage
Coastal Storm Flood Frequencies

- Multiple model runs with variations in input parameters
  - Storm surge
  - Waves
- Historical analysis
- Joint probability method
- Total water level
Coastal Vulnerability Assessments

- Mapping overlay (bathtub) approach
- Site-specific modeling
  - non-linear relationship between sea-level rise and storm surge depths
- Vulnerability Assessment Framework
  1. Define scope
  2. Assess vulnerability
  3. Integrate into decision making
Climate Change and Extreme Events: Damage Mechanisms

- Roadway damage by wave attack
- Roadway and railway damage by coastal “weir-flow”
- Roadway damage by bluff erosion and shoreline recession
- Bridge deck damage by waves on surge
- Structure damage by wave runup
- Tunnel and road damage by overtopping
- Damage by tsunamis
Roadway Damage by Wave Attack
Roadway and Railway Damage by Coastal “Weir-Flow”
Bridge Deck Damage by Waves on Surge
Structure Damage by Wave Runup
Tunnel and Road Damage by Overtopping

AP Photo
Adaptation/Countermeasure Strategies for Coastal Highway Infrastructure

- Manage and maintain
- Increase redundancy
- Protect
- Accommodate
- Relocate
Analysis Methods: “Levels of Effort”

• Level of Effort 1: Use of existing data and resources
• Level of Effort 2: Original modeling of storm surge and waves
• Level of Effort 3: Modeling in a probabilistic risk framework
Analysis Methods: “Levels of Effort”

• Specific analysis steps are outlined,
  • for each region,
    ▪ Gulf of Mexico/South Atlantic Coast
    ▪ Mid-Atlantic and New England Coast
    ▪ Great Lakes Coast
    ▪ Pacific Coast
      » storms
      » tsunamis
  • for each “Level of Effort”
### Analysis Methods: Example of steps

Table 4.5. Exposure Assessment Steps for Level of Effort 2: Mid-Atlantic/New England Coast.

<table>
<thead>
<tr>
<th>Step</th>
<th>Activity</th>
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<tbody>
<tr>
<td>1</td>
<td>Identify damaging coastal processes of interest (e.g. storm surge, waves, tides, runoff, etc.)</td>
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<tr>
<td>2</td>
<td>Select and characterize storm and climate change scenarios of interest</td>
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<tr>
<td>3</td>
<td>Select, develop, and prepare appropriate numerical modeling tools</td>
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<td>4</td>
<td>Validate and/or calibrate the models through hindcast simulations and analysis</td>
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<tr>
<td>5</td>
<td>Incorporate climate change scenarios into numerical simulations</td>
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<tr>
<td>6</td>
<td>Perform model simulations of climate change scenarios</td>
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<tr>
<td>7</td>
<td>Map the damaging coastal processes for each scenario</td>
</tr>
<tr>
<td>8</td>
<td>Evaluate exposure and sensitivity of transportation infrastructure for each scenario</td>
</tr>
</tbody>
</table>
Case Studies

- From existing literature
- 3 case studies: One for each “Level of Effort”
- Each case study team included a coastal engineer
Case Study (Level 1): Adapting to Rising Tides – SF Bay

- **Purpose:** Provide input to a vulnerability rating of transportation assets
- **Modified, basic inundation mapping**
- **FHWA sponsored pilot study**
Case Study (Level 1): Adapting to Rising Tides – SF Bay

- Water surface elevation from 100-yr flood plus 16-in sea level rise
- Wind wave zone identified
- Airport, commuter rail, ferry terminal, roads, and pump stations assessed

Results = Maps showing facility exposure to inundation and wave action
Case Study (Level 2): Gulf Coast 2 – Mobile, Alabama

- **Purpose:** Assess vulnerability of road, bridge, tunnel, railway, port, and airport facilities
- **Scenario based**
- **Storm surge and wave modeling**
Case Study (Level 2): Gulf Coast 2 Scenarios

- **Model Impacts of RSLR**
  - 0.30 m by 2050
  - 0.75 m by 2100
  - 2.00 m by 2100

- **Historical Storms**
  - Katrina
  - Katrina shifted
  - Georges
Case Study (Level 3): Synthetic Storm Analysis - Florida

- **Purpose**: Magnitude and characteristics of storms and sea level rise
- **Scenario/probability based**
- **Storm surge and wave modeling**
Case Study (Level 3): Synthetic Storm Analysis - Florida

- Provides an established methodology for using existing storm characterizations
- Demonstrates the use of tide, surge, and wave models for mapping the inundation in coastal areas
- Describes the significance of modeling the dynamic versus static response of flooding to sea level rise
- Presents an example of how the effects can be mapped in a probabilistic manner
“Our coastal transportation infrastructure is highly exposed to extreme events today and that exposure is going to increase with sea level rise and climate change”
• Provides technical guidance and methods for incorporating extreme events and climate change for highway planning and design in coastal environments

• Regional approach

• Sea level rise guidance

• Methods: 3 “Levels of Effort”

• Case studies
This manual explains how to properly evaluate the vulnerability of our coastal infrastructure to extreme events...

... today, and,

... in the future considering climate change
Coming Spring 2016

HEC 17 2ND EDITION
Need for HEC 17 2nd Edition

• Non-stationarity and what to do about it

• FFRMS and Executive Order 13690 call for best-available, actionable, climate informed science approach

• Comply with FEMA regulations and 23 CFR 650 Subpart A

• Integrating Bulletin 17C

• Translating climate models to flow data

*Vintage 1981 Version shown
Objectives for HEC 17 2nd Edition

• Provide technical guidance to incorporate floodplain management, risk, extreme events, resilience, and adaptation considerations for highways in the riverine environment

• Focus on issues related to:
  ▪ Hydrology (including using climate models)
  ▪ Statistics/Risk Assessments
  ▪ Regulatory issues
1. Introduction
2. Federal Floodplain Policy
3. Riverine Flood Events
4. Risk and Resilience
5. Climate Change
6. Analysis Framework
7. Case Studies
Activities/Schedule for Completion

• Peer exchange held on March 17
• Reference Manual Outline completed April 20
• 50% draft due mid August
• Presentation at TRB/FHWA/FTA Resilience conference mid September
• 100% draft late January 2016
• Manual completion April 2016
• As FFRMS progresses, updates may follow
First International Conference on Surface Transportation System Resilience to Climate Change and Extreme Weather Events

September 16-18, 2015
National Academy of Sciences Building, Washington, D.C.

Topic Tracks Include:
- Climate Science and Data
- Planning for Resilience
- Project Level Adaptation
- International and Cross Cutting Initiatives
- Resilience Tools and Techniques
- Resilience in Operations and Maintenance Activities

Register for Conference at:

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Thank You!

For more information:
http://www.fhwa.dot.gov/environment/climate_change/adaptation/

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