HEC 17: Highways in the River Environment :: Floodplains, Extreme Events, Risk and Resilience

Webinar A: Chapters 1 through 4
Presenters: Joe Krolak and Cynthia Nurmi
Webinar Logistics

Mute Phone
- Press *6

Questions During Presentation
- Type in Chat Box
- Designated times

Presentation Recorded
- Slides available at end of webinar
- Posted to FHWA site
Webinar A: Introduction, Floodplains, Riverine Flood Events, Non-Stationarity (Chapters 1-4)
January 25, 2017, 10 am to 12 pm (Eastern Std Time)
https://connectdot.connectsolutions.com/hec17rollouta/

Webinar B: Climate Modeling and Risk and Resilience (Chapters 5 & 6)
February 8, 2017, 10 am to 12 pm (Eastern Std Time)
https://connectdot.connectsolutions.com/hec17rolloutb/

Webinar C: Analysis Framework and Case Studies (Chapters 7 & 8)
February 22, 2017, 10 am to 12 pm (Eastern Std Time)
https://connectdot.connectsolutions.com/hec17rolloutc/
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Chapter 1

Introduction

HEC-17 – Why’s, What’s, How’s, & Who’s
Caveats to Consider

Bismarck was totally correct about Sausages and Laws ...
Knowledge to Know

❖ What the Heck is a HEC?
❖ HEC = Hydraulic Engineering Circular
  ❖ Published by Bureau Public Roads / FHWA
  ❖ Began to publish HECs in 1960

❖ HDS = Hydraulic Design Series
Why HEC-17?

Intent

- Provide
  - Best currently available science, technology and information
  - National consistency and relevance to our highway programs
- Focus Areas
  - Floodplains
  - Extreme Events
  - Risk
  - Resilience
- Assist
  - Our transportation partners
  - FHWA
  - Other agencies
Why the River Environment?

614,387 Bridges
509,358 over water
≈ 485,000 in River Environment

Source: 2016 NBI

Missing: nationally applicable riverine information on focus areas
Why Change?

A Federal Design Standard

Designs for all [Interstate] culverts and bridges over streams shall ... accommodate floods at least as great as that for a 50-year frequency or the greatest flood of record, whichever is the greater, with the runoff based on the land development expected in the watershed 20 years hence ....”

Policy and Procedure Memorandum 20-4
Bureau of Public Roads
August 10, 1956
What’s Change?

Just design it 10% bigger!

Make it resilient!

Ignore it!

Easily solved if you pay me ...

I have a friend who says ...
What Do We Know?

What Don’t We Know?
What’s Covered?

Webinar A

Chapter 1: Introduction

Chapter 2: Floodplains and Federal Policies for Development

Chapter 3: Riverine Flood Events

Chapter 4: Nonstationarity and Climate Change

Webinar B

Chapter 5: Climate Modeling

Chapter 6: Risk and Resilience

Webinar C

Chapter 7: Analysis Framework

Chapter 8: Case Studies
What other Resources?

www.fhwa.dot.gov/engineering/hydraulics
www.fhwa.dot.gov/environment/sustainability
Questions?
Chapter 2

Floodplains & Federal Policies for Development
Historical :: Floods & Highways

- U.S. highways affected by floods & flood risks even before the 1915 creation of the Bureau of Public Roads.
- From 1900 to 1937 floods caused roughly 9,000 highway bridges failures.
- Floods occurring between December 1935 and April 1936 resulted in loss of 911 highway bridges.
- No Private Flood Insurance
- Government Paid For Repairs
1966 :: Beginning of Federal Action

A Unified National Program for Managing Flood Losses

Executive Order 11296

Presidential Documents

Title 3—The President
Executive Order 11296
EVALUATION OF FLOOD HAZARD IN LOCATING FEDERALLY OWNED OR FINANCED BUILDINGS, ROADS, AND OTHER FACILITIES AND IN PROTECTING FEDERALLY OWNED OR FINANCED LANDS AND PROPERTIES

WHEREAS, economic losses due to floods are occurring and potential flood losses are increasing despite substantial efforts to control floods; and
WHEREAS, Federal involvement in the purchase and disposal of property subject to flooding results in a further increase in flood damages, loss of life, and destruction of life and business; and
WHEREAS, the Federal Government has extensive and continuing programs for the construction of buildings, roads, and other facilities and has control over thousands of sites of Federal lands in flood hazard areas, all of which activities significantly influence patterns of commerce, recreation, and industrial development; and
WHEREAS, the vulnerability of Federal lands and structures owned and leased by the Federal Government to floods is a significant factor in planning programs for flood control and disaster relief; and
NOW, THEREFORE, by virtue of the authority vested in me as President of the United States, it is hereby ordered as follows:

Section 1. The heads of the respective agencies shall provide leadership in encouraging a basis for Federal and non-Federal floodplain use and development of the Nation's floodplains and, in particular, to lessen the risk of flood losses in connection with Federal installations and federally owned or supported improvements.

Subject to the requirements of this Order, and any other applicable statutes, the following shall apply:

(a) All Federal agencies directly responsible for the construction of Federal buildings, structures, roads, or other facilities shall evaluate flood hazards when planning the location of new facilities and, as far as practicable, shall provide, purchase, and construct flood-resistant buildings, structures, or other facilities. The term "flood-resistant" shall mean that the facilities or portions thereof shall not sustain major physical damage with respect to existing Federal or non-Federal structures, facilities, or other properties, the selection of which have resulted from flood damaging or which may be subject thereto, the Federal facilities, and such Federal facilities shall require completion within a period of years from the date of the issuance of this Order and shall thereby or be continued for Federal purposes in accordance with the public interest, yet subject to the requirements of this Order and any other applicable statutes.

(b) All Federal agencies responsible for administration of Federal loan, grant, or mortgage insurance programs involving the construction of buildings, structures, roads, or other facilities shall evaluate flood hazards in connection with such facilities and, in order to minimize the exposure of facilities to potential flood damage and the cost for future Federal expenditures for flood prevention and control, shall, as far as practicable, provide the necessary, hazardous, or unnecessary use of flood plains in such connection.
1974 :: FHWA Floodplain Regulation

- 23 CFR 650 A
- "Hydraulic Design of Highway Encroachments on Flood Plains"
- October 9, 1974

Elements
- 100-year event as base flood
- Set design standards
- Required hydrologic & hydraulic computations & data
- Instituted consideration of RISK
- No NEPA elements!
Federal Agencies must develop floodplain management policies to:

- **Reduce Flooding**
- **Minimize Impact of Flooding**
- **Restore or Preserve Floodplain Values**

**Elements**

- **NEPA**
- **FIA (pre-FEMA)**
- **Avoidance**
1978 :: WRC issues “Guidelines”

- Floodplain Management Guidelines for Implementing E.O. 11988
- Specifically cited in E.O.
- Eight Step Process
- Federal agencies required to BASE their Floodplain process using these Guidelines
1979 :: USDOT & FHWA compliance

DOT Order 5650.2

All USDOT modes

23 CFR 650 A

Updated Regulation

Department of Transportation
Office of the Secretary
Washington, D.C.

ORDER

D0T 5650.8

N-23-79

DEPARTMENT OF TRANSPORTATION

ORDER

D0T 5650.8

N-23-79

1979 :: USDOT & FHWA compliance

DOT Order 5650.2

All USDOT modes

23 CFR 650 A

Updated Regulation

Planning & NEPA
- Public Involvement
- Environmental documents
- Location hydraulics studies
- Significant encroachments
- Preliminary Engineering
- Right of Way
- NEPA Findings

Design & Construction
- Design Standards
- Risk analysis / assessments
- Consistency with NFIP
- Shall contain H&H data and design computations
- Floodplain permits
- ER exemptions
1981 :: Risk Analyses?

- HEC-17, 1st edition
  The Design of Encroachments on Flood Plain Using Risk Analysis
- April 1981
- Economic & Risk focus
- Applicable for design portion of 23 CFR 650 A
1981 to Present :: Status Quo

- FHWA Floodplain Program
  - Part of Planning Process
  - Alignment with NEPA on projects
  - 200,000 Bridges built using Regulation
  - Informs Construction, Maintenance, and ER activities
  - Integrated in State DOT & AASHTO approaches
2005 :: Coastal Storm Events

US 90 – Ocean Springs

Outcome: Use 650 A’s Design Standard
2007 :: I-35W - Mississippi River

Outcome: Risk Based, Data Driven approaches
2011 :: Riverine Flood Events

Outcome: Use 650 A’s Design Standard?
2012 :: MAP-21

- July 2012
- Codified Data Driven, Risk Based approaches
- Required Asset Management approaches & regulation
- Allowed Projects to Consider “Extreme Events”
FHWA Approaches

- MAP-21 & FAST Act
- “Extreme Events”
- FHWA Order 5520

**Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events**

- Defines & places context of “Extreme Events”
- FHWA decides what are appropriate scientific approaches
- FHWA “Eligibility Memo”
2012 :: End of Status Quo?
2015 :: Future Floods & Floodplains

- EO 13690

- Standard
  - Federal Flood Risk Management Standard

- Guidelines
  - Guidelines for Implementing Executive Order 11988, Floodplain Management, as Revised

- Implementation Plan

These next few slides go “beyond” HEC-17 ...
 FFMS :: (aka) Standard

- Issued January 30, 2015
- Introduces “FFRMS Floodplain”
- Describes 3 approaches to achieve “Future Flood” standards:
  - Climate-Informed Science Approach
  - Freeboard Value Approach
  - Use 500-year floodplain elevation and extent.
- Gives each Federal agency choice on approach(es)
- Provides for Exceptions & Exemptions
  - National Security
  - Emergency Actions
  - Demonstrably Inappropriate
  - Mission Critical
Standard :: Climate Informed Science

- Coastal :: HEC-25 V2
  - *Sea level with Sea Level Rise*
  - *Include waves, surge, tide data*

- Riverine :: HEC-17
  - *Changes in riverine conditions resulting from climate changes*
  - *Science still emerging*

- Both
  - *Apply state-of-the-art science in a manner appropriate to policies, practices, criticality, risks & consequences*
Standard :: Freeboard

- Base Flood (100-year floodplain) + 2 feet
Standard :: 500-Year

- Use 500-year floodplain
Guidelines

- Issued October 8, 2015
- Result of
  - 2300+ Public Comments
  - 500 Different Parties
- Describes and Interprets
  - Requirements and information of the EO 13690 and Standard
- Replaces
  - 1979 EO 11988 Implementing Guidelines
- Informs, but does not require agency approach
Implementation Plans

- White House required Implementing Plan
  - 30 days AFTER end of Implementing Guidelines public comment period
- Contains Milestones and Deadlines
- White House reviews and approvals
Implementation Plan :: USDOT

❖ USDOT’s plan
  ❖ Assess FFRMS & EO 13690
  ❖ Update DOT Order 5620.2
  ❖ Obtain White House approval
  ❖ Stakeholder Outreach
  ❖ Seek Public comments
  ❖ Resolve comments as appropriate
  ❖ Issue Final Order
    ❖ Allow each Modal Agency to Implement

Status: on hold!
Implementation Plan :: FHWA

- FHWA
  - Until DOT Order issued
    - Collect current FHWA program areas involving floodplains
    - Determine FFRMS impacts
    - Account & resolve impacts
    - Implement resolutions
    - Develop technical guidance
  - Update Regulation
    - Same Rulemaking Process as DOT Order

Status: ???
Implementation Plan :: Others

- HUD
- FEMA
  - Draft Rule in FR
  - Reviewing comments
  - Final Rule???
- Corps
  - Draft EC in FR
  - Comments due 30 January

FHWA unaware of any other federal agency Regulations placed on hold
Future of Federal Floodplain Policies?

New administration will provide leadership, direction and focus!

Photo Source: WhiteHouse.gov
Takeaways!

FHWA

- awaiting direction from the Administration
- has a good history of involving and communicating with our transportation partners
- will continue to do so with floodplains to the extent possible
- will build upon Risk based, Data driven approaches
- will align approaches with MAP-21 and FAST Act initiatives

NO FHWA programs or project delivery should deviate from EXISTING requirements of 23 CFR 650 Subpart A until promulgation of any new/revised regulation, policies, and guidance.
Floodplains & FHWA

Not Going Away!
509,358 Bridges over Water

Source: 2016 NBI
Questions?
Chapter 3

Riverine Flood Events
Terminology

Base Flow  Bankfull Discharge  Runoff
Flood  Precipitation  Hydrograph
Hyetograph  Variable  Parameter
Methods for Estimating Discharge

Rainfall/Runoff
- Rational
- NRCS Graphical Peak Method
- Others

Statistical Methods
- Log Pearson
- Regression Equations
- Others
Rainfall/Runoff Methods

Relate physical properties to discharge

Simplifying Assumptions

Smaller Structures
Statistical Methods

- Historical gage data
- Specific Gages or Regional
- Larger Structures
**Best Estimates**

- **Understand the Limitations**
  - Drainage Area Size
  - Homogeneity
  - Range of values

- **Best Information**
  - Digitized mapping and analysis
  - Up-to-Date Precipitation Data
  - Longer record
Best Actionable Precipitation Data

FHWA RECOMMENDS:
NOAA Atlas 14
http://www.nws.noaa.gov/oh/hdsc/index.html
Uncertainty of Estimate

Data

Method
# Data Uncertainty

### POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 9, Version 2

<table>
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<th>Duration</th>
<th>1/2</th>
<th>1/5</th>
<th>1/10</th>
<th>1/25</th>
<th>1/50</th>
<th>1/100</th>
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<th>1/500</th>
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<td>10-min</td>
<td>3.86 (3.06–4.97)</td>
<td>4.95 (3.96–6.37)</td>
<td>5.86 (4.65–7.65)</td>
<td>7.16 (5.57–9.53)</td>
<td>8.23 (6.27–11.0)</td>
<td>9.37 (6.94–12.5)</td>
<td>10.6 (7.58–14.7)</td>
<td>12.3 (8.53–17.3)</td>
<td>13.7 (9.24–19.3)</td>
</tr>
<tr>
<td>30-min</td>
<td>3.14</td>
<td>4.02</td>
<td>4.76</td>
<td>5.82</td>
<td>6.69</td>
<td>7.62</td>
<td>8.60</td>
<td>9.99</td>
<td>11.1</td>
</tr>
</tbody>
</table>

1. AMS-based precipitation frequency estimates with 90% confidence intervals (in inches/hour)
Method Uncertainty

- Rainfall/Runoff Methods
  - Uncertainty Unknown

- Statistical Methods
  - Confidence Interval
  - Standard Error
Method Uncertainty

Confidence Interval

- Best Estimate = 27,000 cfs
- Range = 19,000 to 45,000 cfs

Figure 3.5. Example flood frequency curve with confidence intervals.
Uncertainty of Estimate

Method Uncertainty

Data Uncertainty

Sensitivity
Change?

- Land Use Change
  - Curve Number
- Intensity
  - Confidence Limits
Gage Station

Test for trends in annual peak flows.

Regression Equations

Range of values for variables
Questions?
Chapter 4

Nonstationarity or Change
Perspective

Past
- Rainfall
- Flow
- Watershed Characteristics

Present
- Design Standards
- Tolerance for Risk

Future
- Useful life
Past = Future?

Stationarity
Past predicts future

NonStationarity
Patterns and trends of past not necessarily predict the future
Nonstationarity
Which Precipitation?

- Heavy
- Very Heavy
- Extreme Event

Daily or Annual?

Annual or Partial Duration?

6 hours or 24 hours?
Flood Trends

Figure 4.3. Trends in flood magnitude (from Hirsch 2011 and Petersen et al. 2013).

Figure 4.4. Trends in annual instantaneous peak streamflow (from Lins and Cohn, 2011).
Detecting Nonstationarity

Figure 4.6. Annual peak discharges for the Northeast Branch Anacostia River at Riverdale, MD.

Figure 4.7. PeakFQ output for the Northeast Branch Anacostia River at Riverdale, MD.
Detecting Nonstationarity

Detection Tool Example – Abrupt Change

The orange line indicates the presence of a statistically significant abrupt change in the mean of the flood peak distribution in 1992 based on the Pettitt test.

Figure 4.8. Example of the Pettitt test applied for the Blackwater River.
Detecting Nonstationarity

http://www.corpsclimate.us/ptcih.cfm
Adjusting for Nonstationarity

McCuen Index Adjustment Procedure

Figure 4.16. Peak adjustment factors for correcting a flood discharge magnitude for the change in imperviousness (from McCuen, 1989)
Adjusting for Nonstationarity

Homogenous Subperiod of Record

Beginning of Time Period

End of Time Period

20%

30%
Adjusting for Nonstationarity

Frequency Analysis with Time Varying Mean
Projecting Flood Frequency

- Curve Number

Land Use Change
Projecting Flood Frequency

Regression Equations

Range of values for variables

Nonstationarity
Questions?