HEC-17: Highways in the River Environment – Flood Plains, Extreme Events, Risk, and Resilience

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Workshop on Engineering Methods under a Changing Climate
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Hydraulic Engineering Circular 17 (HEC-17)

- Title: *Highways in the River Environment-Floodplains, Extreme Events, Risk, and Resilience.*
- Intent:
  - Best *available* and *actionable* engineering and scientific data and approaches.
  - Compatibility with existing hydrologic design methods and techniques.

All Models are Wrong, but some are Useful

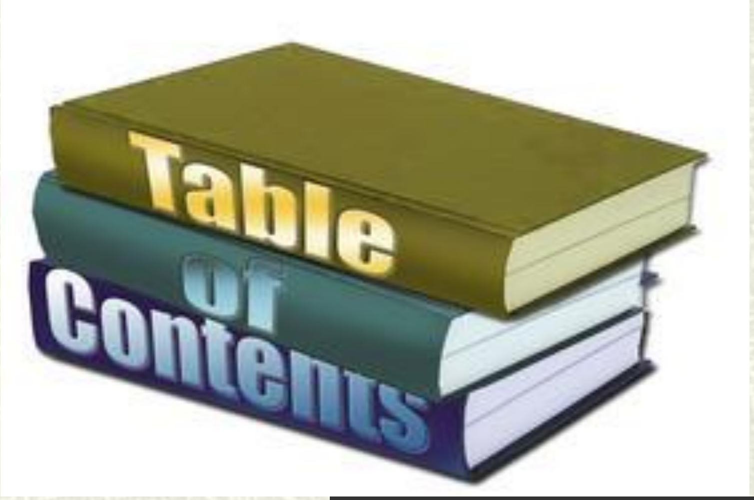
Since all models are wrong the scientist cannot obtain a "correct" one by excessive elaboration. On the contrary following William of Occam the scientist should seek an economical description of natural phenomena. Just as the ability to devise simple but evocative models is the signature of the great scientist so overelaboration and overparameterization is often the mark of mediocrity. (George Box)

Embrace Uncertainty

- Precision
- Data uncertainty
- Model uncertainty
- Scenario uncertainty
- Risk and reliability
  - Design/service life (exposure duration)
  - Criticality
  - Consequences of failure

Topics Covered in HEC-17

1. Introduction
2. Floodplains and Federal Policies for Dev.
3. Riverine Flood Events
4. Nonstationarity and Climate Change
5. Climate Modeling
6. Risk and Resilience
7. Analysis Framework
8. Case Studies

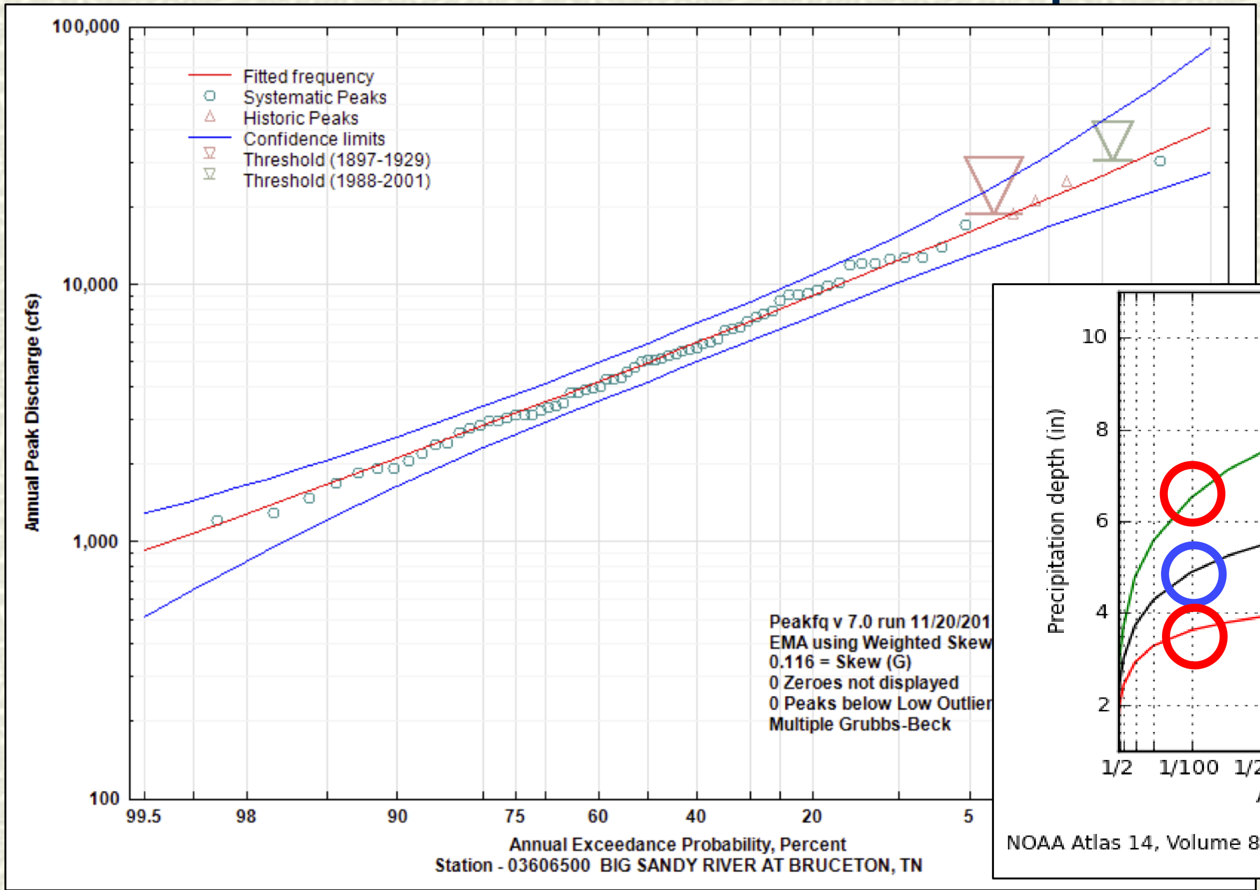


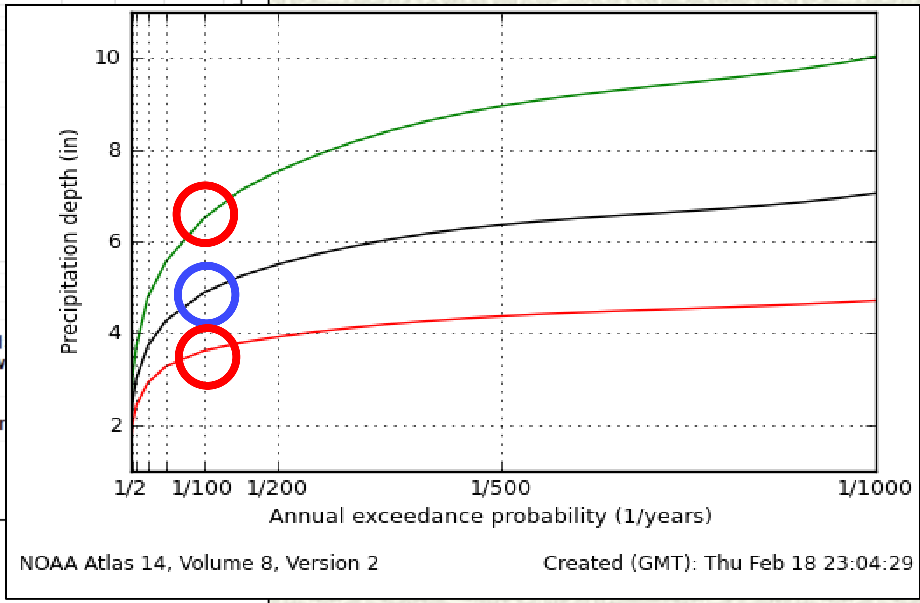
Analysis Framework (Chapter 7)

- Recognizes data and model ***uncertainty***.
- Acknowledges that all plans and projects ***do not*** merit that same level of effort.
- Considers ***risks*** and ***service life***.
- ***Adapts*** as new methods and data become available.

Confidence limits

- Broadens the range of evaluation; consideration of consequences ➔ resilience





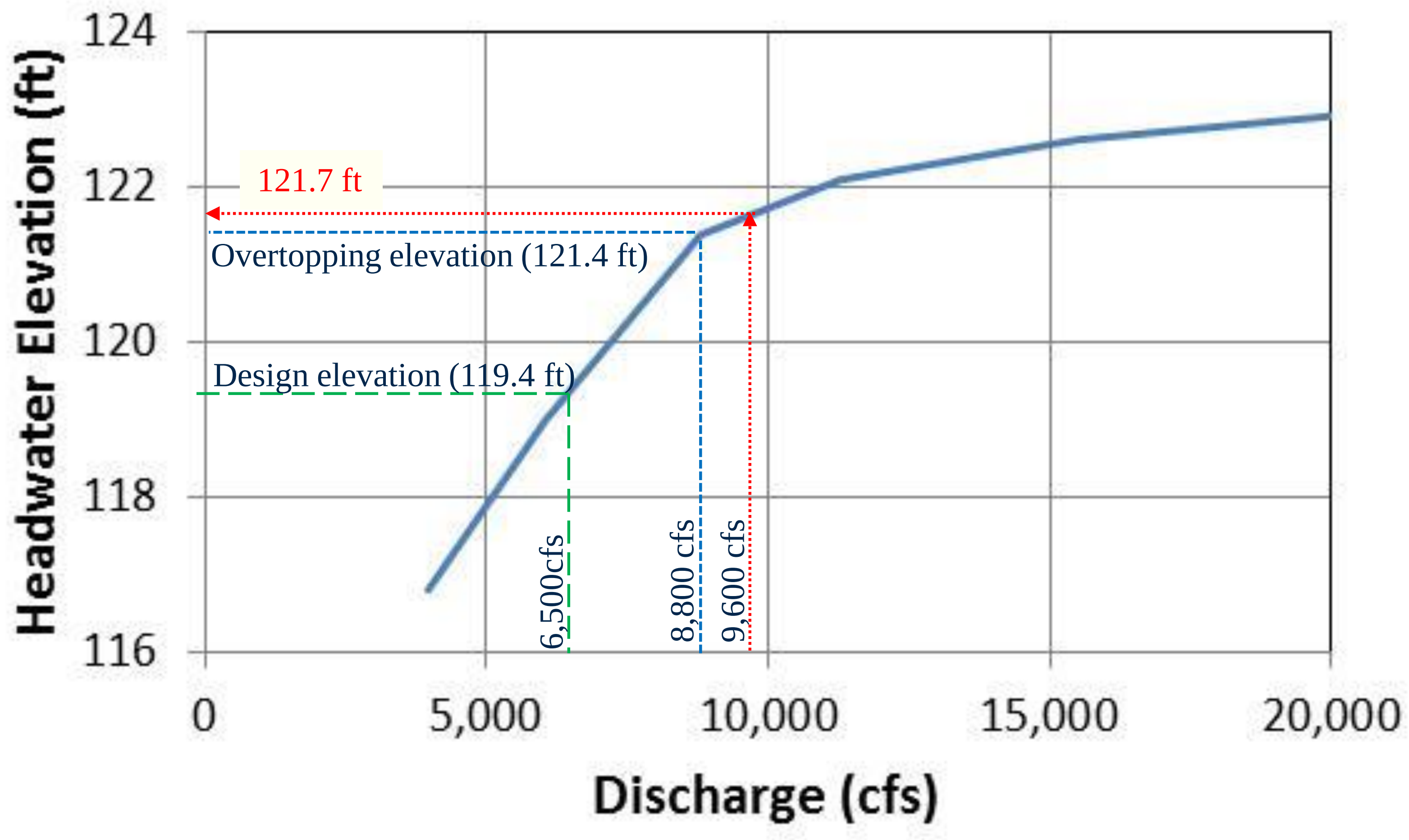
Confidence Intervals Based on Hydrologic Service Life

Hydrologic Service Life (years)	Confidence Interval
Less than 30	38%
Between 30 and 75	68%
Greater than 75	90%

Example Application

- Consider a culvert design project with:
  - 50-year design discharge
  - 2-ft overtopping freeboard (safety factor)
  - 80-year hydrologic service life
- Example 90% confidence *interval*
  - 50-year design flow: 6,500 cfs (expected value)
  - 95% confidence *limit:* 9,600 cfs
  - 5% confidence *limit:* 4,400 cfs

Culvert Performance Curve

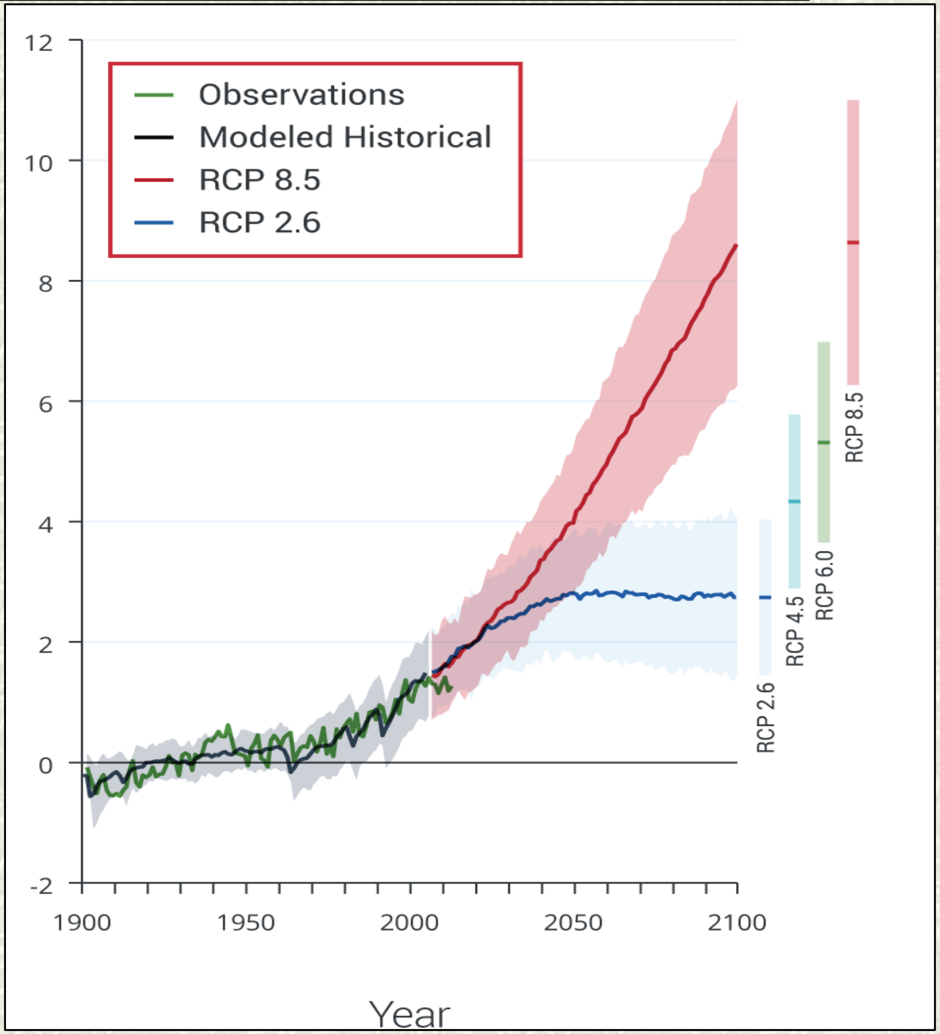


Implications for T-year design based only on historical data

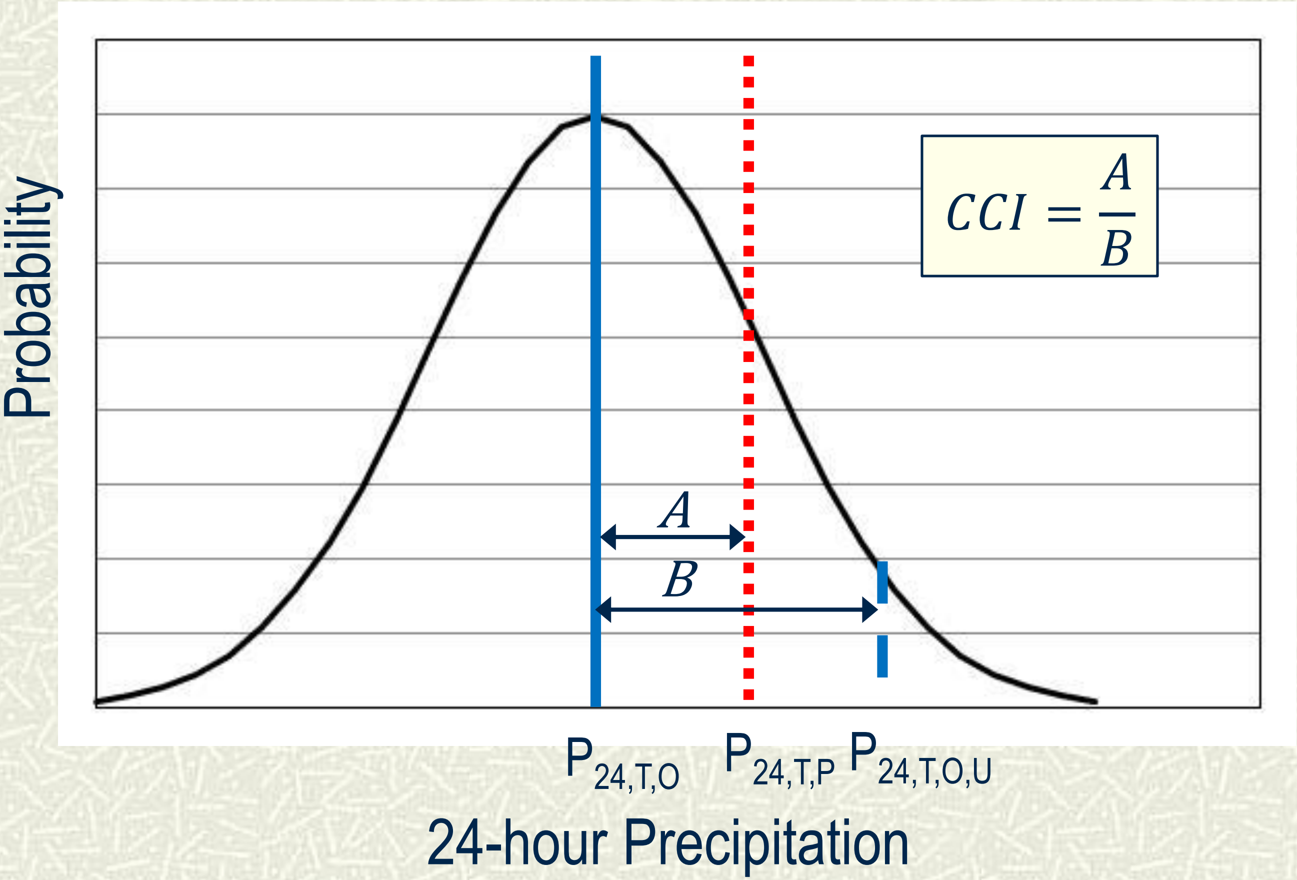
- Higher upstream flooding elevation
- Higher outlet velocity
- Embankment overtopping
- Maintenance/debris
- ***Result when considered:*** More robust design

Climate Change and Uncertainty

- Emissions scenarios: Representative Concentration Pathways (RCPs): 2.6, 4.5, 6.0, and 8.5
- Global climate models: 12 – 21+



Climate Change Index



A measure of projected versus historical precipitation

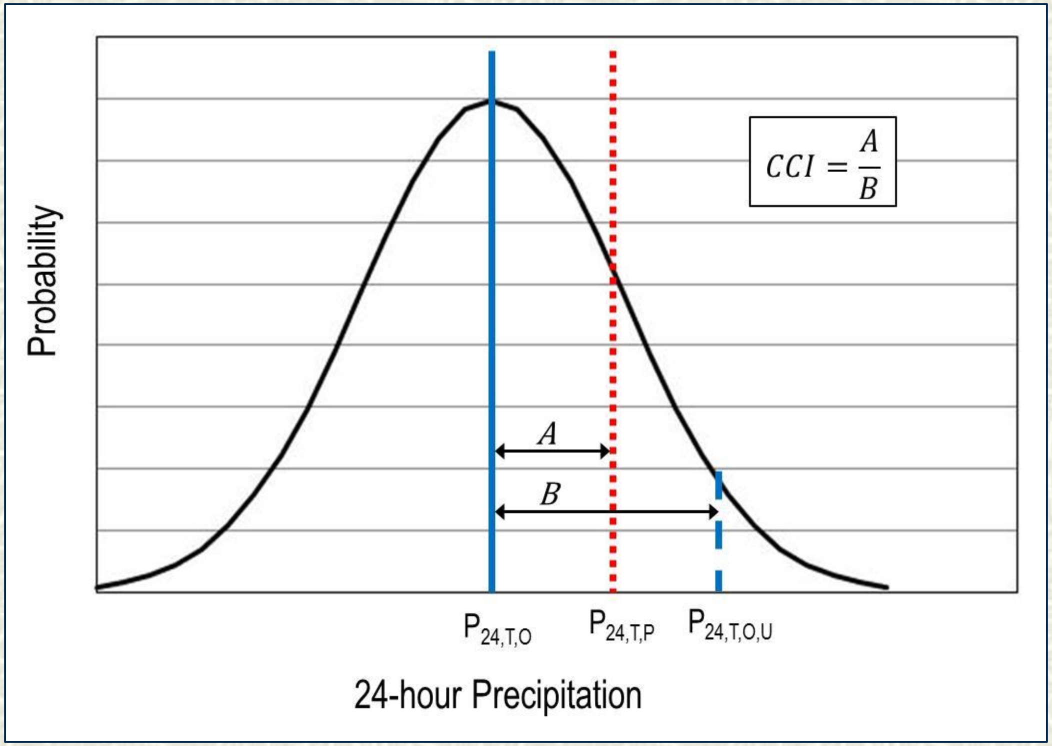
Historical and Projected Precipitation Example

- From NOAA Atlas 14
  - $P_{24,100,O}$ = 4.88 inches
  - $P_{24,100,O,U}$ = 6.5 inches
- From climate projections
  - Δ (projected minus modeled historical)
  - $P_{24,100,P} = P_{24,100,O} + \Delta$ = 5.5 inches

B = 6.5–4.88
=1.62 inches

A = 5.5–4.88
= 0.62 inches

Computed Climate Change Index



$$CCI = \frac{A}{B} = \frac{0.62}{1.62} = 0.38$$

- If CCI < 0.4, historical data likely sufficient.
- If CCI > 0.8 further analysis of projected conditions may be warranted.

Limits of Climate Change Index

- Q_{100} not necessarily proportional to P_{100}.
- Climate models are limited in their ability to project distribution tails, e.g. 100-year precipitation.
- Projected precipitation depends on the models and scenarios included.
- ***But, it provides a measure of projected change compared with historical variability.***

Other Tools in the Toolbox

- Trend projections (location, scale, and shape parameters)
- Rainfall/runoff modeling (projected versus historical 24-hour T-year precipitation from CMIP5 DCHP database)
- Statistical models

$$Q_T = aA^{b_1}P^{b_2}$$

  - Regression equations with climate variables
  - New regression equations with larger geographic scale

Analysis Framework Recap

- Adapted to project criticality – majority of projects can be addressed by historical data
- Flexible to incorporate a variety of models and information sources
- Broadens range of flows considered by considering ***model*** and ***data*** uncertainty
- Actionable tools and guidance
- Decisions made by planning/design team

Thank you

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For a copy of HEC-17 (2nd Edition):

http://www.fhwa.dot.gov/engineering/hydraulics/