3rd Annual Probabilistic Flood Hazard Assessment Workshop
Rockville, MD – December 4-5, 2017

Coastal and Hydraulics Laboratory ERDC

Panel Discussion Flood Hazard Assessment Research and Guidance Activities in Partner Agencies

Victor M Gonzalez

Coastal Hazards Group (CHG)

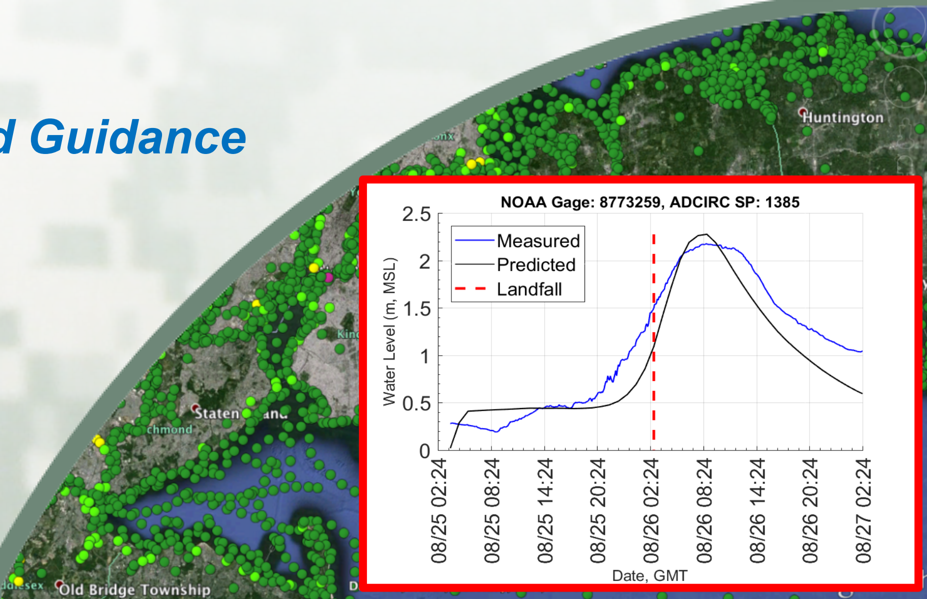
Coastal and Hydraulics Laboratory

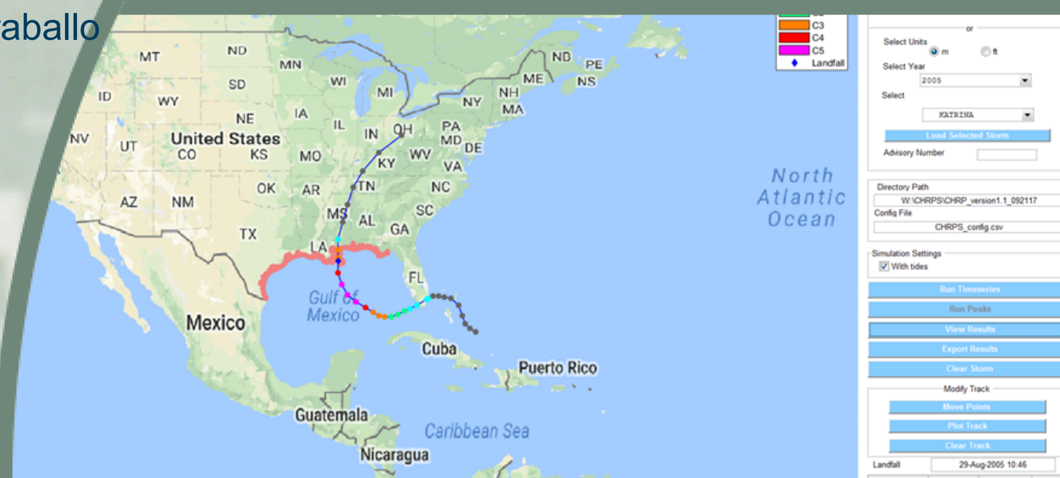
NRC Panel Discussion

December 5, 2017

PI: Dr. Norberto C. Nadal-Caraballo

CHG:
Amanda B. Lewis
Fatima Diop
Debra R. Green
Efrain Ramos-Santiago





US Army Corps of Engineers®

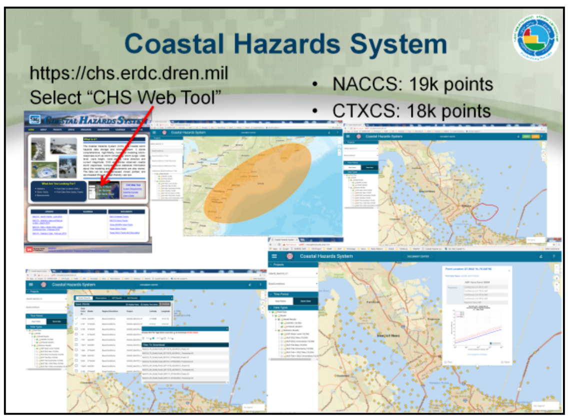
Coastal hazards group
Harbors entrances and structures

Development of probabilistic coastal hazard assessment (PCHA) studies and tools

Risk = **Hazard** × Exposure × Vulnerability

Hazard = Intensity × Probability of Occurrence

Results:
- -Surge
- -Waves
- -Wind
- -Currents



Statistics:
- -Hazard curves
- -Storm Recurrence Rate
- -Storm Relative Probabilities

Tools

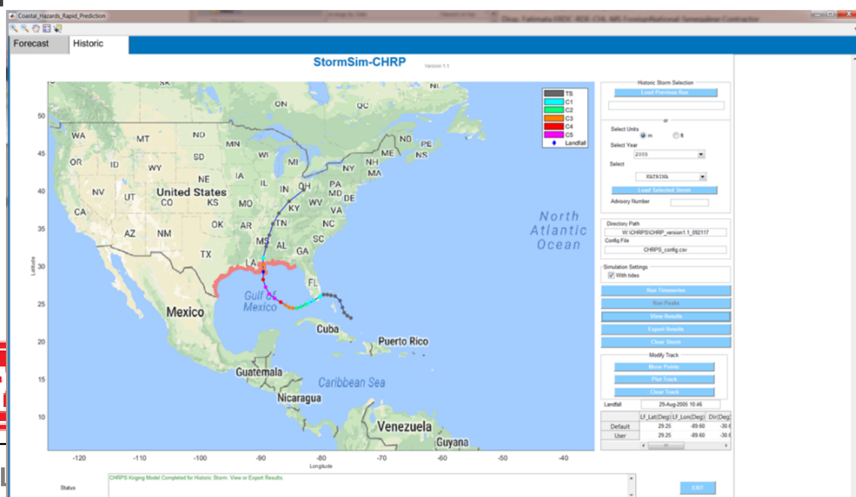
StormSim: suite of computer scripts for advanced stochastic analyses.
- -PCHA
- -**Coastal Hazards Prediction System**
- -Monte Carlo Simulation
- -Extreme Value Analysis
- -Stochastic Simulation Technique
- -Coastal Structure Reliability

- CHS: only national resource for PCHA results and statistics. Supports probabilistic design and risk assessment.
  - Based on regional high-resolution numerical modeling of coastal storms

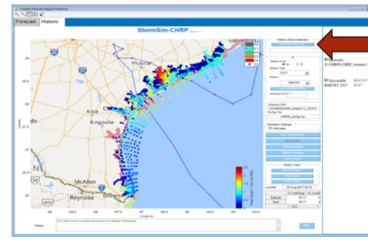
Coastal hazards group
Harbors entrances and structures

StormSim-CHRP
Coastal Hazards Rapid Prediction

- Provides rapid prediction of coastal hazards for operations and emergency management.
- Uses Gaussian Process Metamodels (GPM) constructed on:
  - CHS high fidelity hurricane-response data
  - Hurricane parameters (latitude, longitude, central pressure deficit, radius of maximum winds, forward speed, heading)
- Hurricane parameters(for an active storm) are read from NOAA 6-hour update web service and used to predict waves and water levels in seconds.

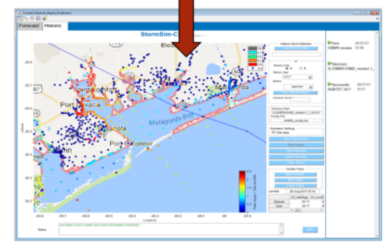


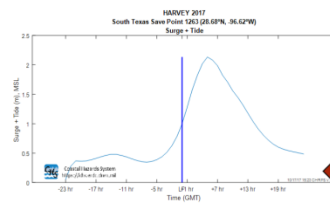
Example simulation for Hurricane Harvey



Peak water level output

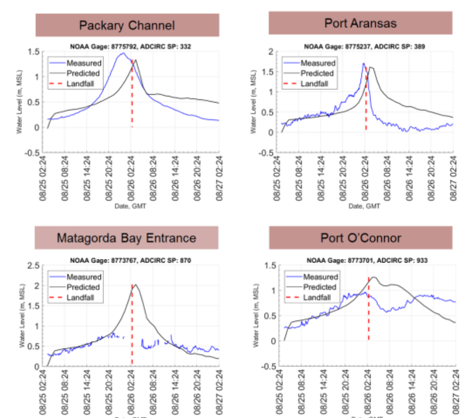
Zoom in and select a point





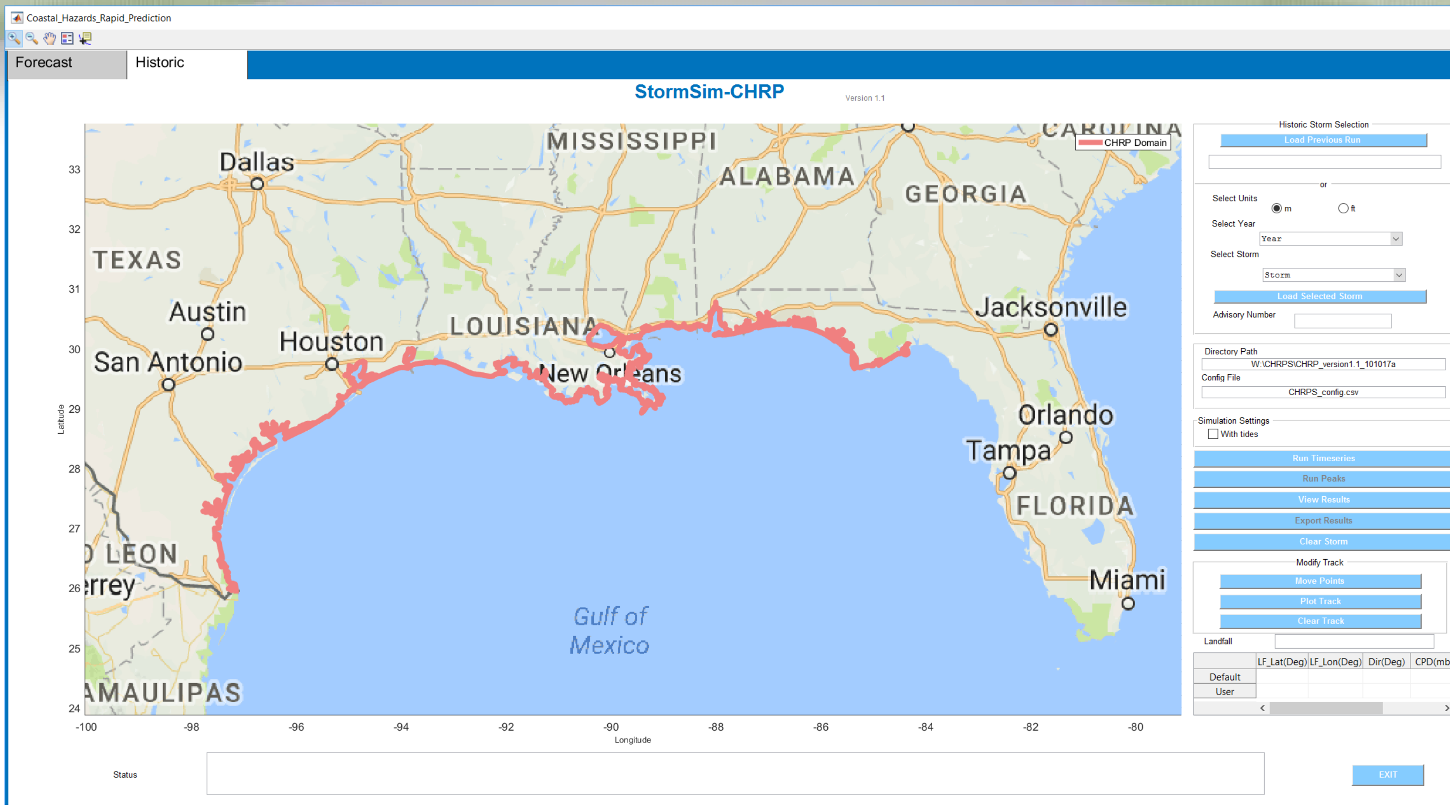
Get a plot of time series of surge+tide with landfall indicated

Validation: Hurricane Harvey – Advisory 16 –



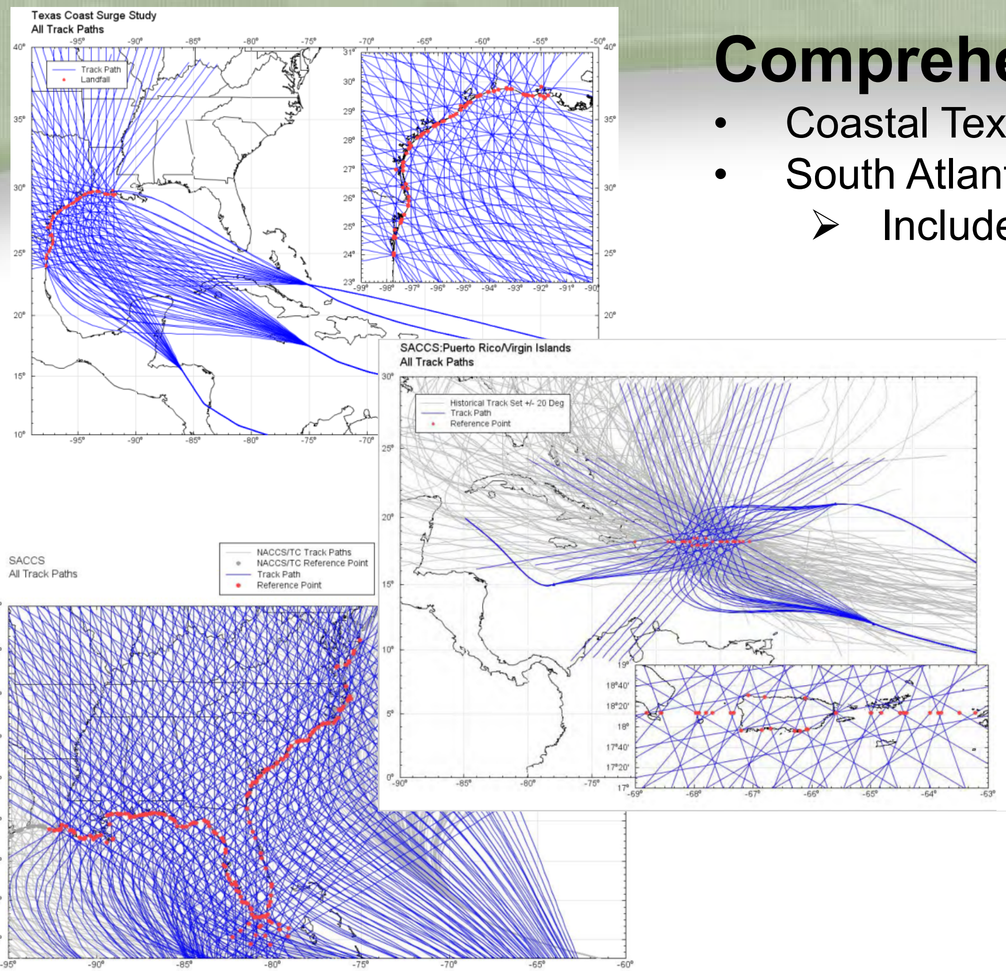
ERDC

StormSim-CHRP
Models and Domain



•Predicts surge or surge+tide for 6427 locations in TX, 829 in LA/MS in 0.1 sec, 1100 in AL/Panhandle

Ongoing Studies



Comprehensive

- Coastal Texas Study (CTXS)
- South Atlantic Study (SACCS)
  - Includes Puerto Rico & USVI

Region Specific

- 1) Metropolitan Washington, DC Coastal Storm Risk Management Feasibility Study
- 2) New Jersey Back Bays Coastal Storm Risk Management Feasibility Study
- 3) Nassau County Back Bays Study
- 4) Passaic River Levee System Tidal Flooding Study
- 5) Mississippi and Atchafalaya Rivers Flood Event and Structure Operations Assessment
- 6) ACCP Vulnerability Mapping Data (Alabama)

Hydrologic Hazards for Risk-Informed Dam and Levee Safety

Some Concepts and Progress

John England, Ph.D., P.E., P.H., D.WRE

Hydrologic Hazards Lead Civil Engineer

USACE Risk Management Center

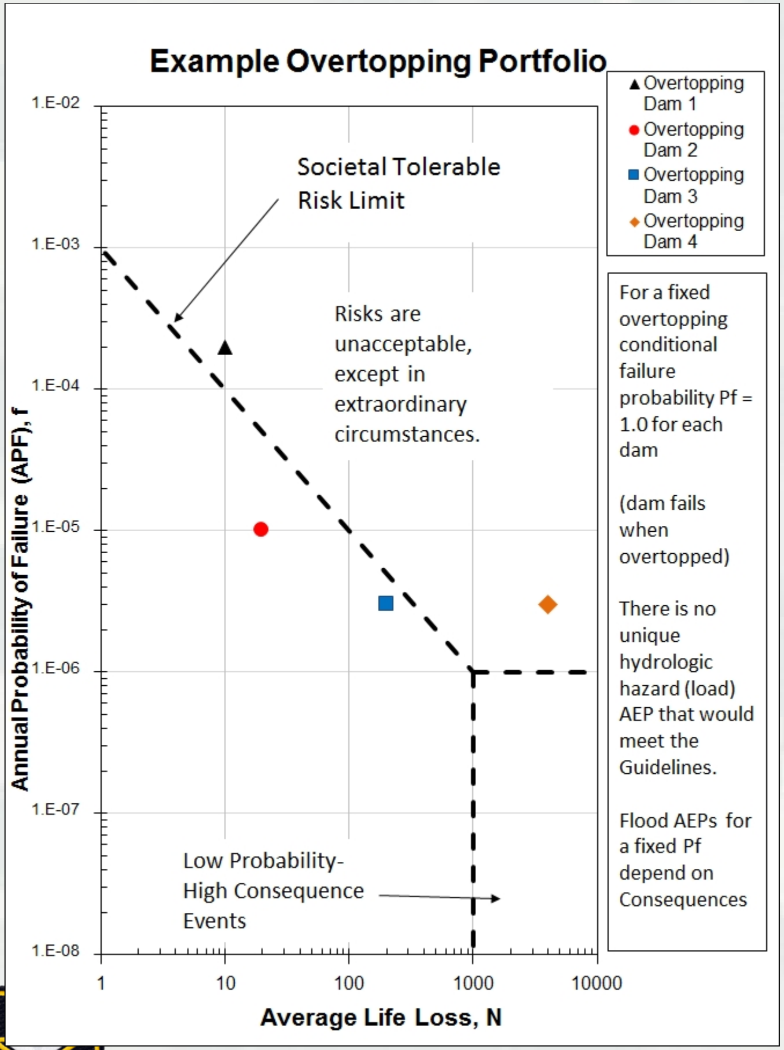
U.S.NRC 3rd PFHA Workshop

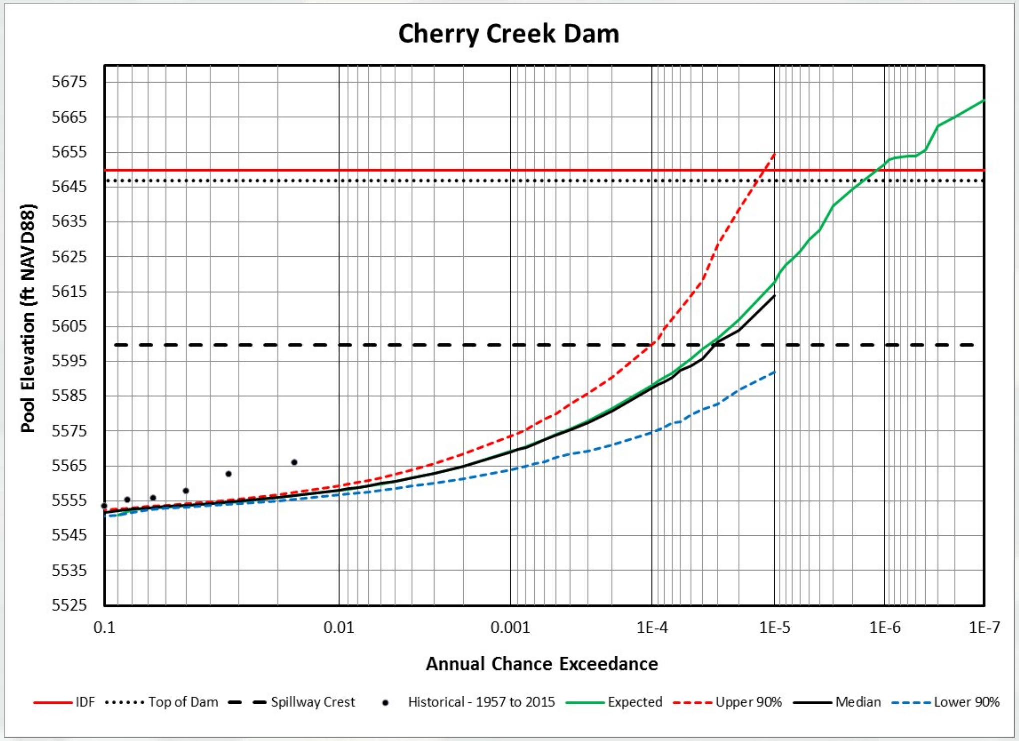
05 Dec 2017

U.S. ARMY

US Army Corps of Engineers
Dam Safety Program
Levee Safety Program

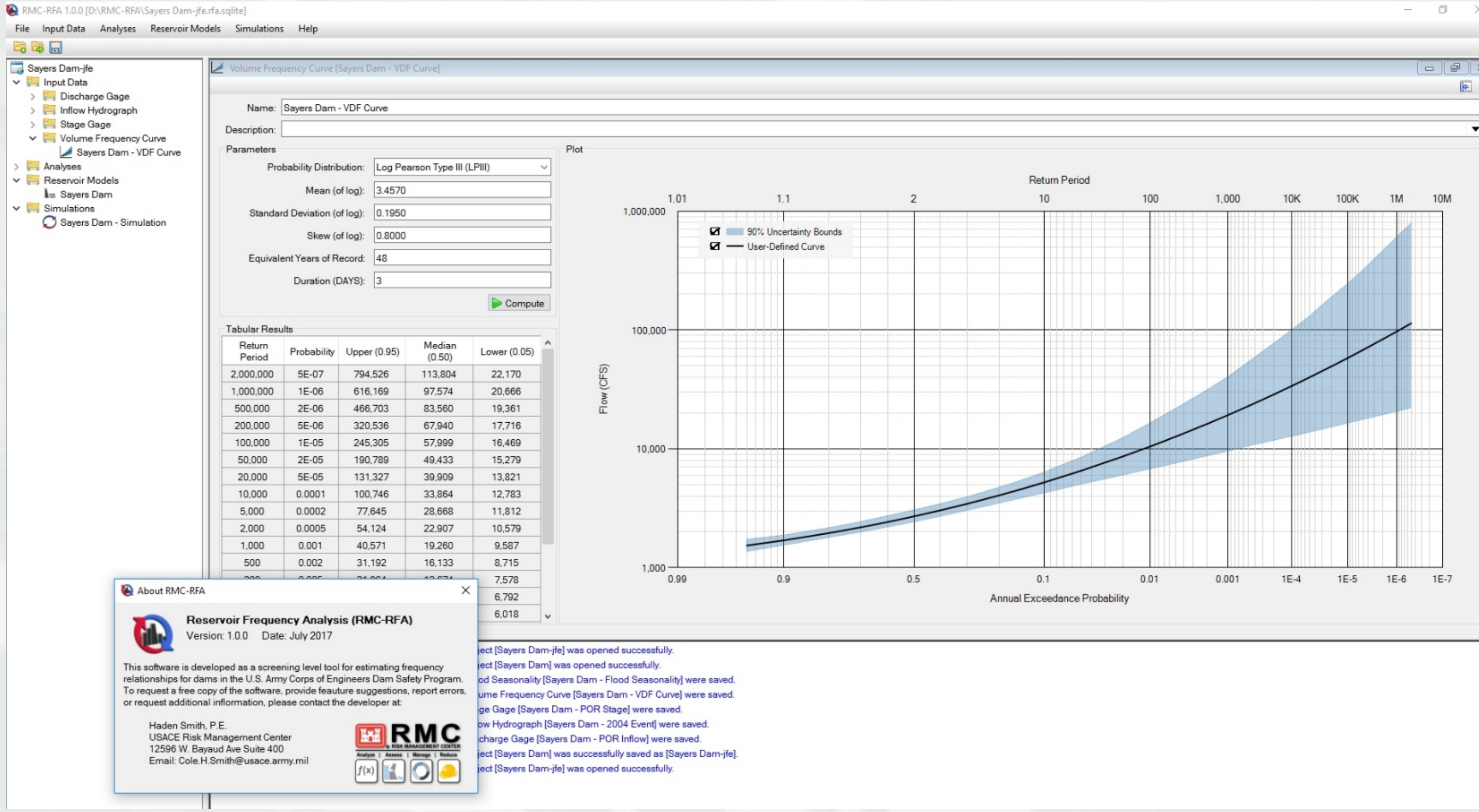
Risk-Informed Decision Making (RIDM) for Dam Safety and Hydrologic Hazards





Hazard curves: reservoir and river stages
Full distributions (unbounded) with uncertainty and expected probability
Data and methods depend on level of study

Hydrologic Hazards for Periodic Assessments: RMC-RFA



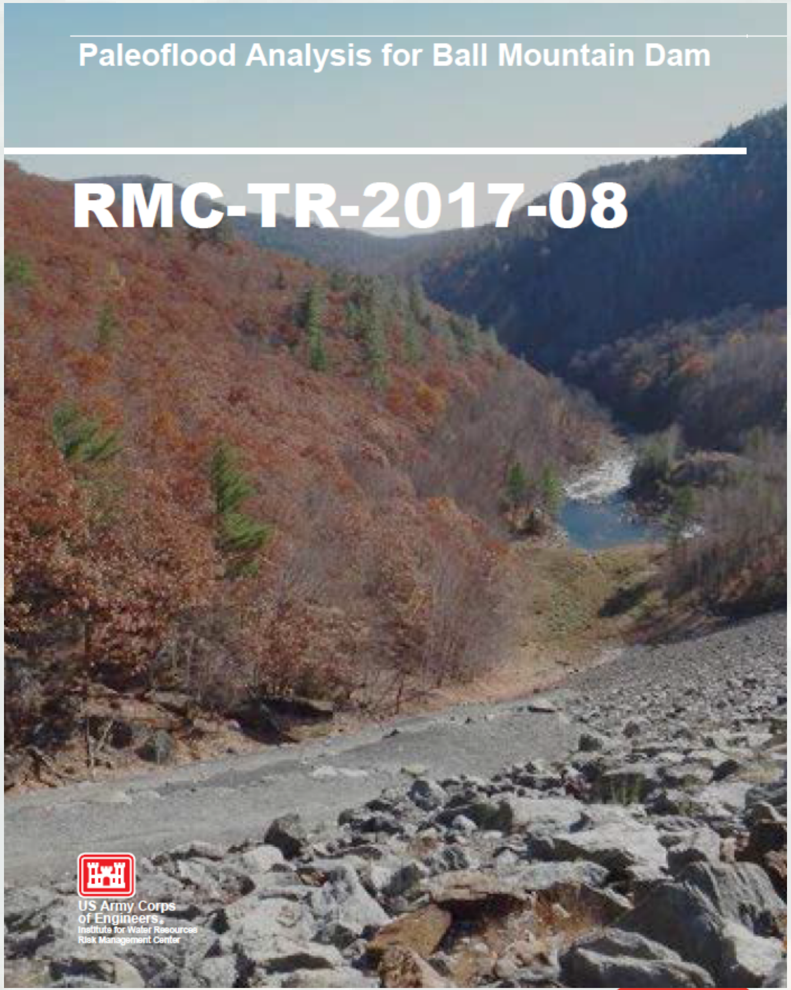
- ***Inflow Volume-based stochastic modeling approach***
- ***Streamflow, historical flood, paleoflood data (inputs from Bulletin 17C)***
- ***Hydrograph shapes***
- ***Flood season***
- ***Initial reservoir level***

- Natural Variability
  - Irreducible, function of the natural system
- Knowledge Uncertainty
  - Reducible through further study & measurement
  - Focus in RMC-RFA is on sampling error

Contact: Haden Smith, RMC

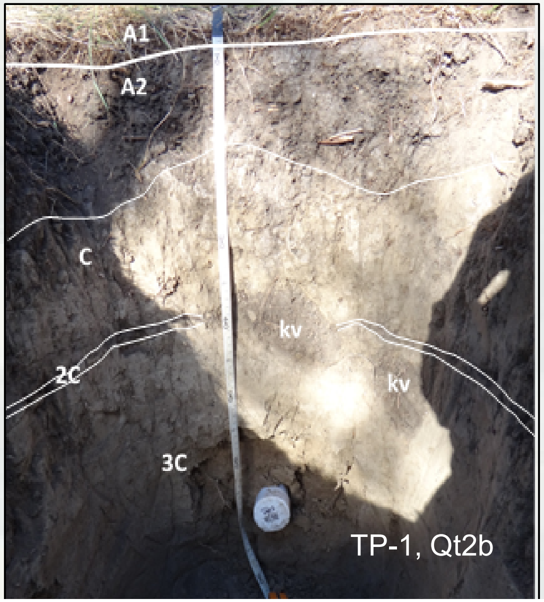
Paleoflood Studies for SQRA/IES/DSMS

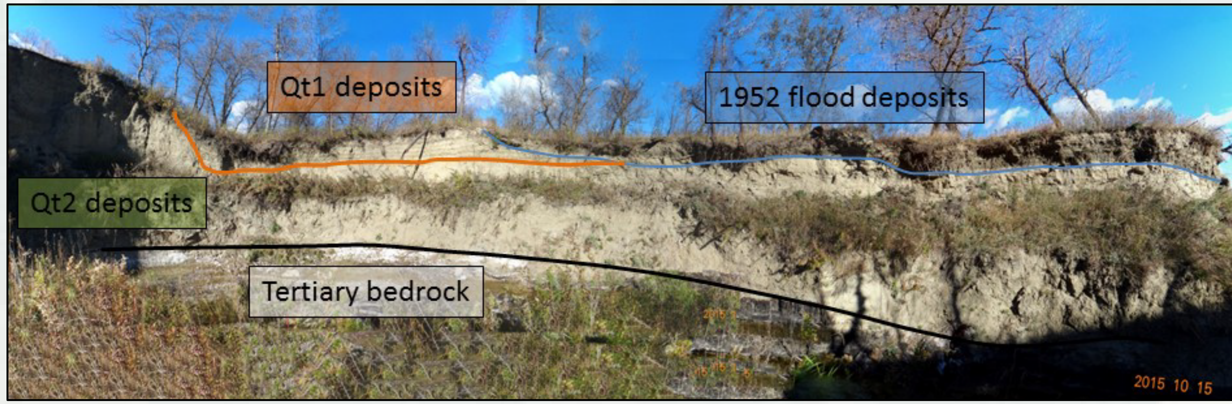
- Ball Mountain Dam
  West River, VT
- Garrison Dam
  Missouri River, ND
- Lookout Point Dam
  Middle Fork Willamette River, OR
- Stillhouse Hollow Dam
  Lampasas River, TX

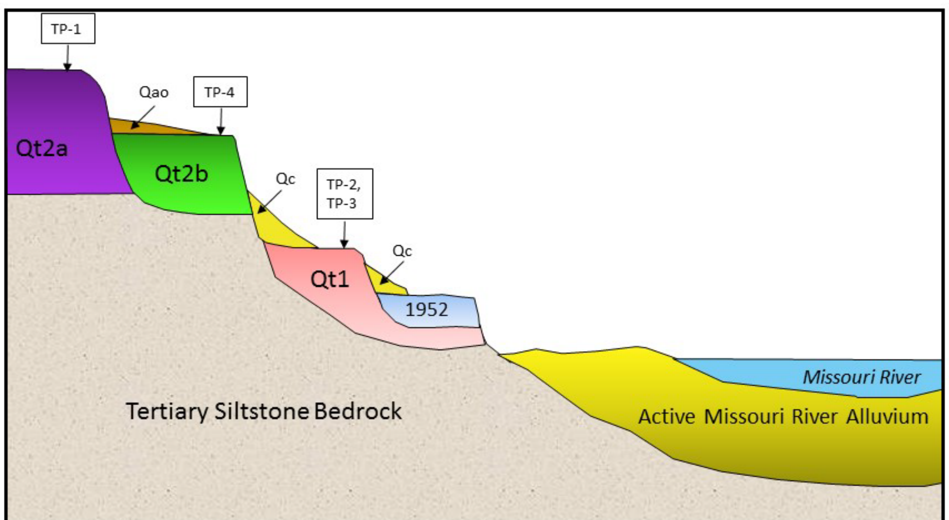


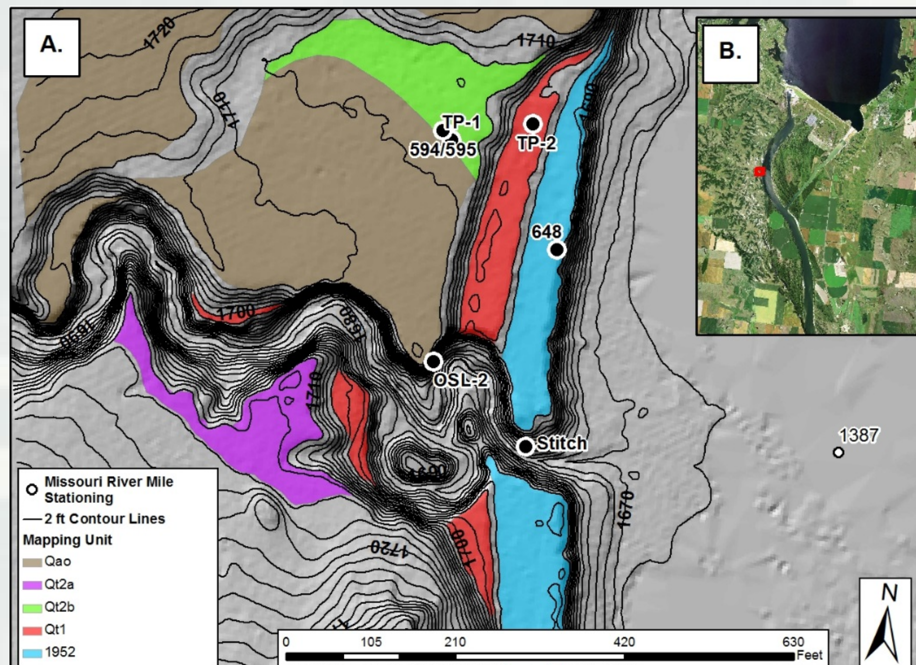
Studies led by Keith Kelson, Justin Pearce

Paleoflood Data Collection - Garrison Dam



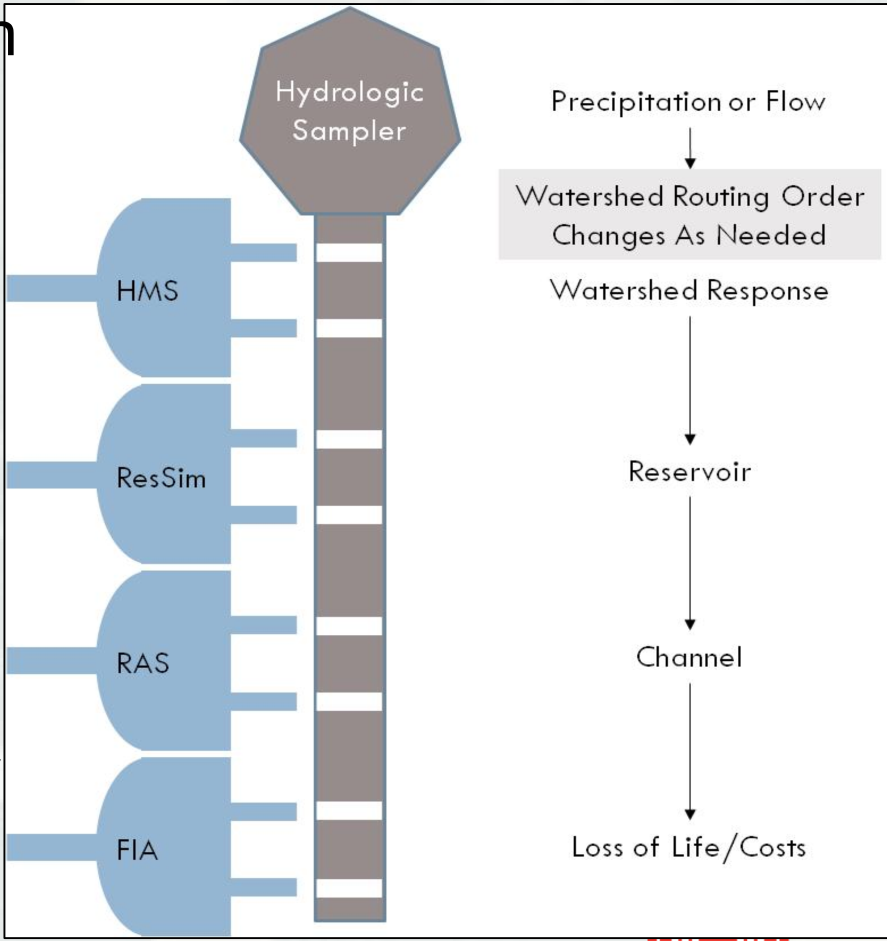






Hydrologic Hazard Analysis IES/DSMS System of Reservoirs: Ingredients

- Extreme Storm Data Collection
  - Spatial/temporal patterns
- Regional Precipitation Frequency Analysis
  - Seasonality
  - Storm typing
  - Stochastic Weather Generation
- Stochastic Rainfall-Runoff Modeling (HEC-WAT)
- Combine with Flow Frequency Curves (HEC-SSP)
- Uncertainty with Expected Probability Curves



Hydrologic Hazard Analysis IES/DSMS System of Reservoirs

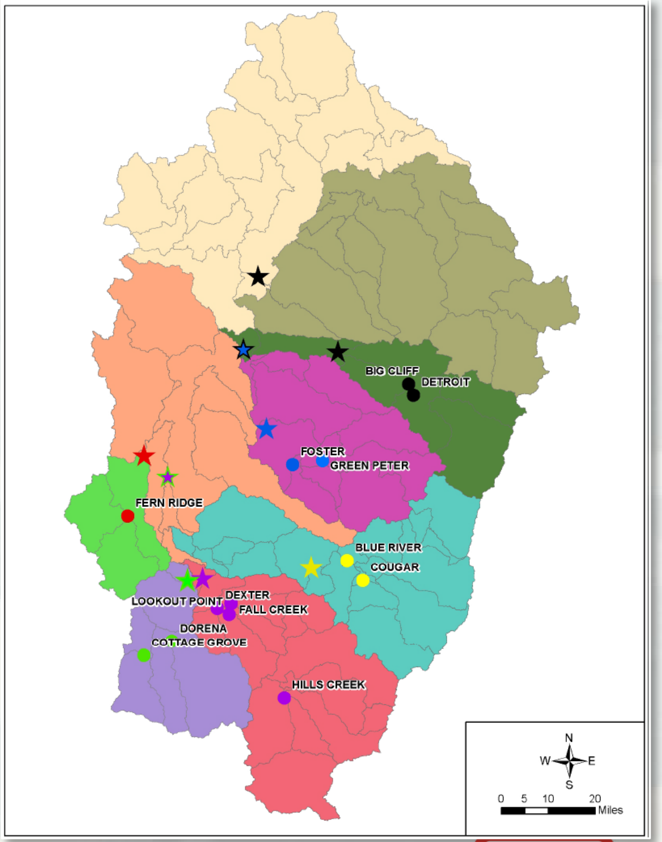
Willamette River Basin
Western Oregon
7 dams focus (13 total)
11,200 sq. mi.

Willamette Dams Hydrologic Loading-

Major Subbasin Modeling

Provides Dam-Specific Loading Curves

- Regional precipitation frequency curve for each major watershed
- Soil loss, unit hydrograph distribution analysis
- Starting elevation distribution analysis
- Gate Failure/Debris Loading Scenarios
- 60 synthetic temporal and spatial pattern sampling
- Critical precipitation duration analysis
- SWE distribution analysis



Flood Hazard Assessment Research and Guidance Activities in Partner Agencies

FERC

Ken Fearon, P.E., Deputy Director,
Dam Safety and Inspections, FERC

SSHAC Seismic Fragility Analysis

- Wanapum Dam on the Mid-Columbia River has a river closure embankment with liquefaction issues.
- A SSHAC fragility analysis is being conducted to evaluate the risk and uncertainty of failure of this dam section
- Currently the second SSHAC workshop has been held and second Technical Integration team meeting is schedule for early January

Risk-Informed Decision-Making Program

- Draft Guidelines issued March 2016
  - 4 Policy Guidance Chapters
  - 6 Technical Methodology Chapters
- Two additional RIDM pilots are being conducted in Michigan and California
- Both have hydrology and hydraulics issues.

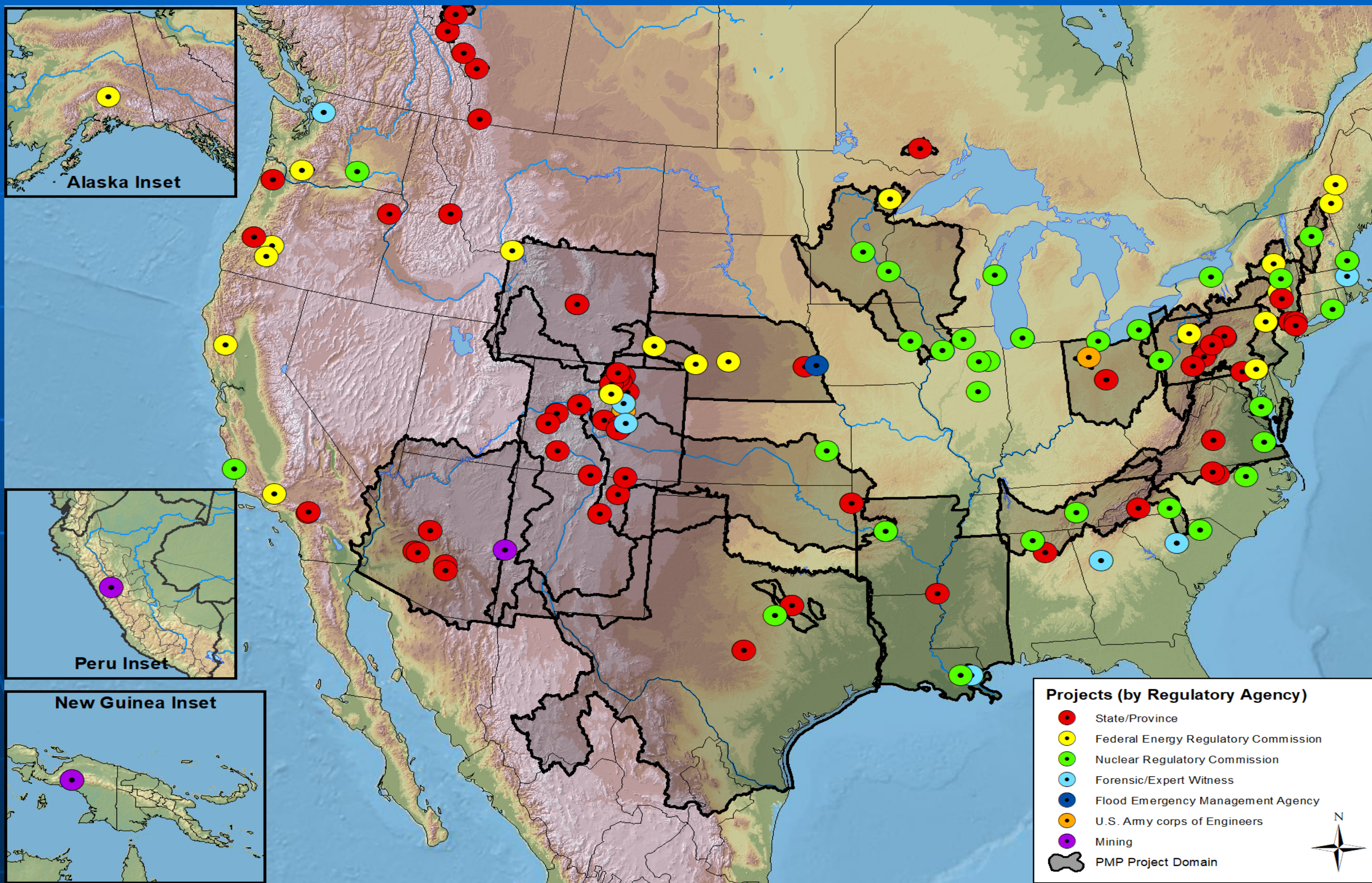
Risk-Informed Decision-Making Program

- Working on a simplified hydrologic model for our Semi-Quantitative Risk Analysis (Level 2) program.
- This program (still in draft) is intended to provide a somewhat conservative result for flood frequencies out to 0.00001 and greater AEPs

RIDM Evaluations

- In both pilots, the uncertainties associated with the structures are more likely to influence decisions about the dams than those associated with the hydrologic loading
- For this reason, further calculation of hydrologic uncertainties are not likely to be useful
- Each FERC regulated dam is unique, so other situations could require a more rigorous evaluation of uncertainty.

State SSPMP Studies



Oroville Dam


Prior to February 2017


February 2017


Spillway Flow: 100,000 cfs


Nearly 1.8 million cy of material eroded and deposited into the Feather River

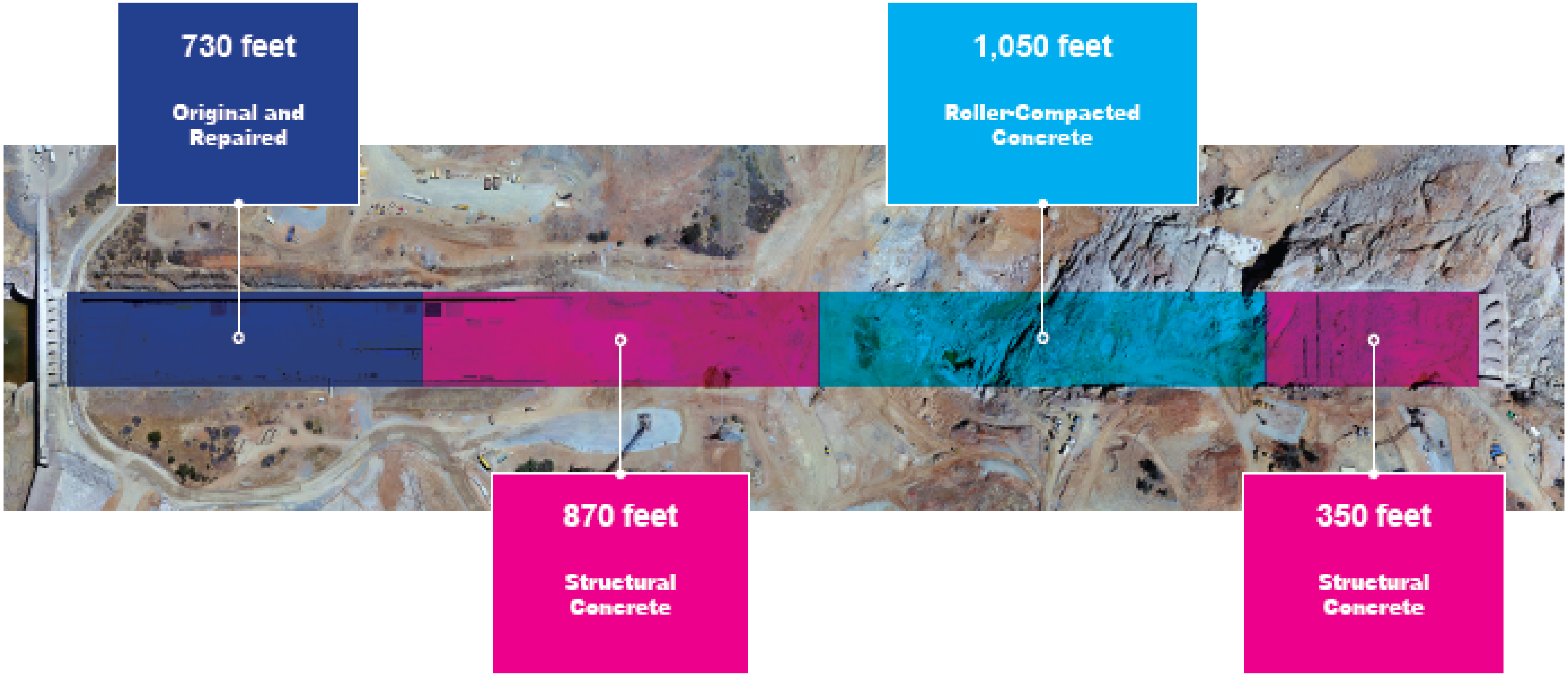
Emergency spillway erosion as the result of 12,600 cfs discharge

The Work

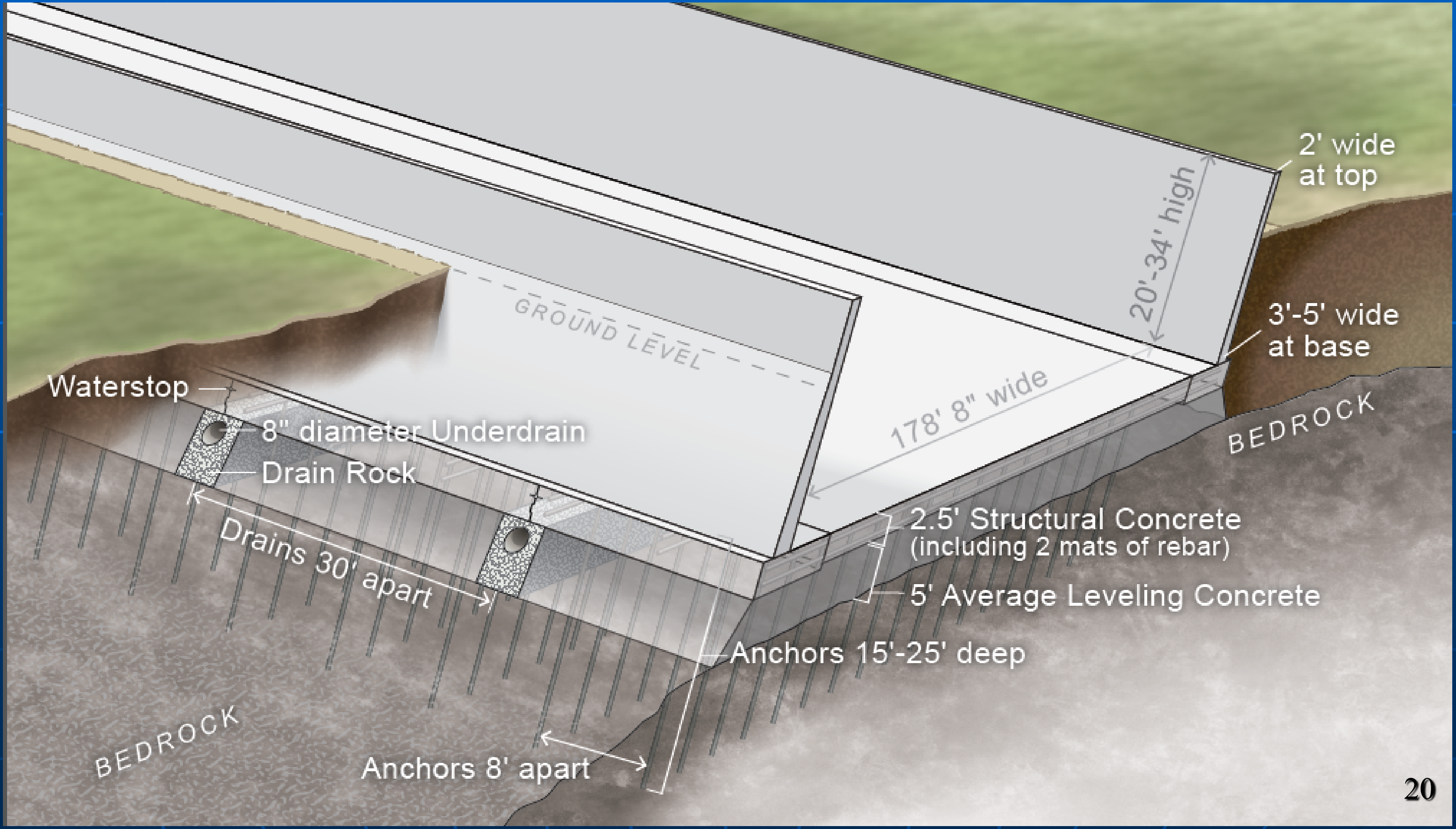
The Work

- Spillways contract awarded to Kiewit Construction on April 17, 2017
- Interim requirement was to be able to pass service spillway flows by November 1, 2017
- Final completion by November 1, 2018
- Bid amount = $274 million

By November 1, 2017



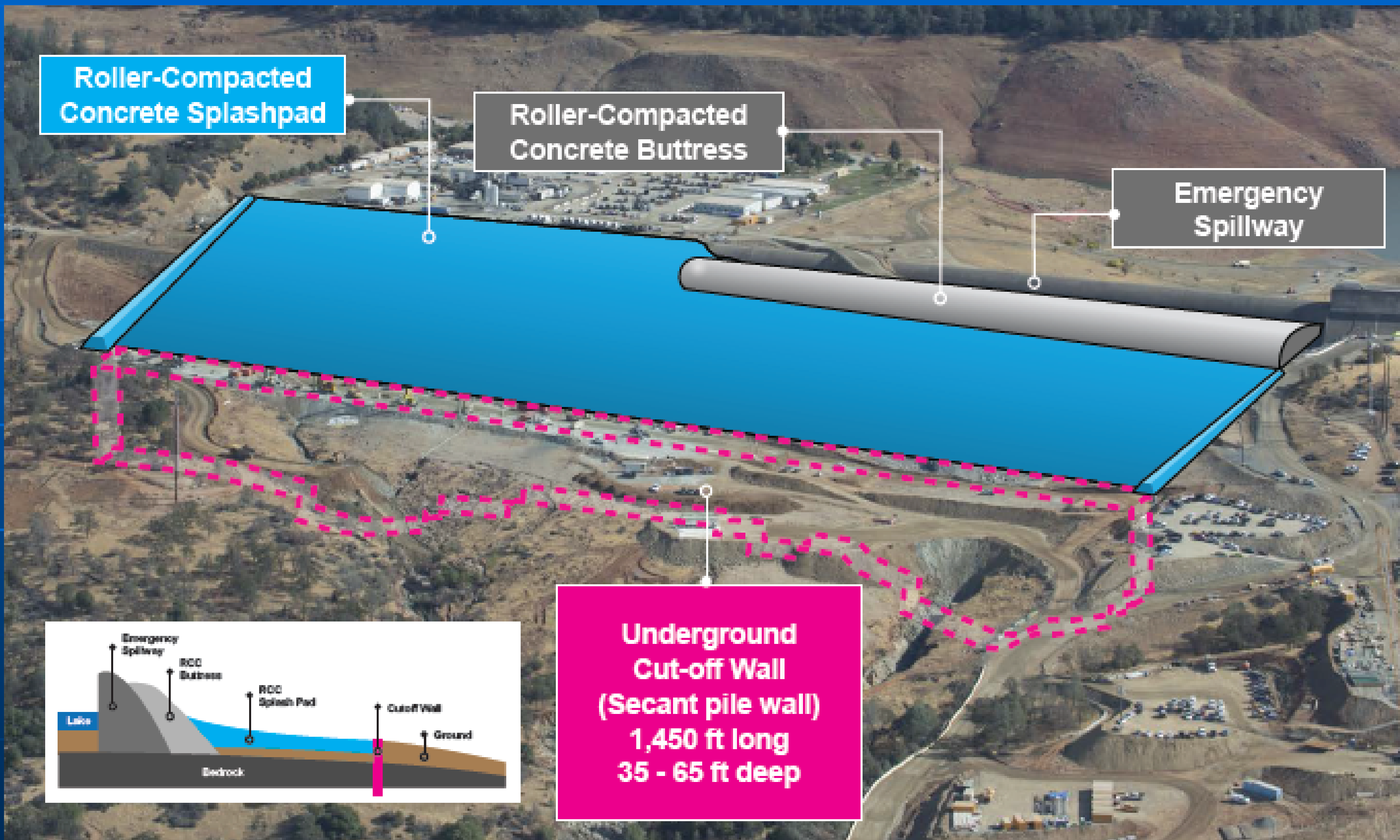
Replace Service Spillway Chute



Service Spillway Progress

Emergency Spillway

Emergency Spillway



Summary of Significant Work Items

- 50,000 cy foundation concrete
- 30,000 cy structural concrete
  - 264 concrete slabs
  - 78 wall panels
- 3,000 sy shotcrete
- 340,000 cy RCC
- 220,000 cy rock excavation
- 605 secant piles (still in progress)

Enough concrete to place a 4-foot-wide sidewalk 4 inches deep from Washington, DC to Cheyenne, WY

Summary of Work Effort

- 5 months duration
- Over 1000 construction workers a day at the peak
- Almost $3 million dollars a day over the last 2 months
- $220 to $235 million construction in costs so far
  - That's a 3-year project anywhere else!

Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities

Sharon Jasim-Hanif, Ph.D.
U.S. Department of Energy
Office of Nuclear Safety Basis & Facility Design (AU-31)

December 2017

Overview

- DOE NPH Program Summary
- DOE Standard NPH Requirements
- DOE Flood Design Criteria & Guidelines

NPH Program Summary

- DOE Office: Office of Nuclear Safety (AU-30)
- Mission: Develop & maintain requirements, standards and guidance for DOE facilities (new/existing/owned/leased) exposed to NPHs
- Driver: Established through DOE Order (O) 420.1C, Facility Safety
- Direction & Guidance: Ensure that SSCs will perform assigned safety functions during and after design basis NPH events; provide requirements and guidance in the use of building codes and voluntary consensus standards
- How: Provides assistance, training, communications & support to facilitate effective implementation of DOE's NPH Requirements to assure public & worker health & safety

DOE NPH Requirements

NOT MEASUREMENT SENSITIVE

DOE-STD-1020-2016
December 2016
superseding
DOE-STD-1020-2012

DOE STANDARD
Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities

U.S. Department of Energy
Washington, D.C. 20585

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

DOE Standard 1020

NOT MEASUREMENT SENSITIVE

DOE-HDBK-1220-2017

DOE HANDBOOK

NATURAL PHENOMENA HAZARDS ANALYSIS AND DESIGN HANDBOOK FOR DOE FACILITIES

U.S. Department of Energy
Washington, D.C. 20585

DOE Handbook 1220

DOE STD 1020/DOE HDBK 1220
Overview

Section 1. Introduction

Section 2. General Criteria for NPH Design

Section 3. Seismic Design

Section 4. Wind, Tornado, and Hurricane Design

Section 5. Flood, Seiche, and Tsunami Design

Section 6. Lightning Design

Section 7. Precipitation Design

Section 8. Volcanic Eruption Design

Section 9. Evaluation and Modification of SSCs in Existing Facilities

Section 10. Quality Assurance and Peer Review

NPH Analysis & Design

Overview

Step 1
New Facility: Select Site

Non-Nuclear Requirements

Step 2
Establish regulatory requirements for site

Nuclear Hazard Category 1,2,3 Requirements

Step 3
Safety Analyses(DSA)
To identify safety SSCs

Step 4
Common-cause failure
& system interaction

Step 5
NPH categorization
Establish performance criteria

Step 6
Design/evaluate identified SSCs ensuring functionality

Flood Design
Criteria & Guidelines

Section 5:

- 5.1 Determine Flood Design Categorization
  - General Approach
  - Return Periods for Design Basis Floods
- 5.2 Perform Site Characterization for Flood-Related Design
  - General Requirements
  - Characterization of Site Hydrological/Meteorological Data
- 5.3 Determine Flood-Related Hazards
- 5.4 Perform Probabilistic Flood Hazard Assessment & Determine Flood Design Parameters
  - Design Basis Flood Level FDC1-2
    - IBC-2015 (II/IV) Requirements
  - Design Basis Flood Level FDC3-5
    - Flood Screening Analysis/Comprehensive Flood Hazard Assessment
    - “Extreme Load” category ACI 349-13 & ANSI/AISC N690-12 criteria
- 5.5 SSC Design & Evaluate of SSCs to Mitigate Flood-Related Hazards

DOE HDBK 1220
(Appendix B)
Probabilistic Flood Hazard Analysis

- B.1 Flood Hazards Overview
- B.2 Probabilistic Framework
  - (Overview, taxonomy of Uncertainties, PFHA Results, Flood Hazard Characterization)
- B.3 Probable Maximum Methods
- B.4 PFHA Goals, Elements and Models
- B.5 PFHA for Riverine Flooding
  - (probabilistic aleatory uncertainty model & probabilistic epistemic uncertainty model)
- B.6 PFHA for Flood Associated with Controlled & Uncontrolled Releases from Dams
  - (events & effects of Dam Failures on downstream releases, hydrologic events-extreme precipitation and dam failure, dam failures caused by seismic events, sunny day failures, evaluation of dam break flooding, probabilistic aleatory uncertainty model & probabilistic epistemic uncertainty model)
- B.7 PFHA for Storm Surge Due to Hurricanes, Tropical Storms & Tropical Depressions
  - (analysis, models, probabilistic aleatory uncertainty model & probabilistic epistemic uncertainty model)
- B.8 PFHA for Flooding Induced by Seiches
  - (models, probabilistic epistemic uncertainty model)
- B.9 PFHA for Flooding Due to Tsunamis
  - (model, probabilistic aleatory uncertainty model, probabilistic epistemic uncertainty model)
- B.10 Potential Flood Damage to SSCs
  - (submergence, hydrostatic loads & hydrodynamic loads)

Contacts

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  Office of Nuclear Safety Basis and Facility Design (AU-31)
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  Office of Nuclear Safety Basis and Facility Design (AU-31)
  Phone: 301/903-4664;
  E-mail: sharon.jasim-hanif@hq.doe.gov

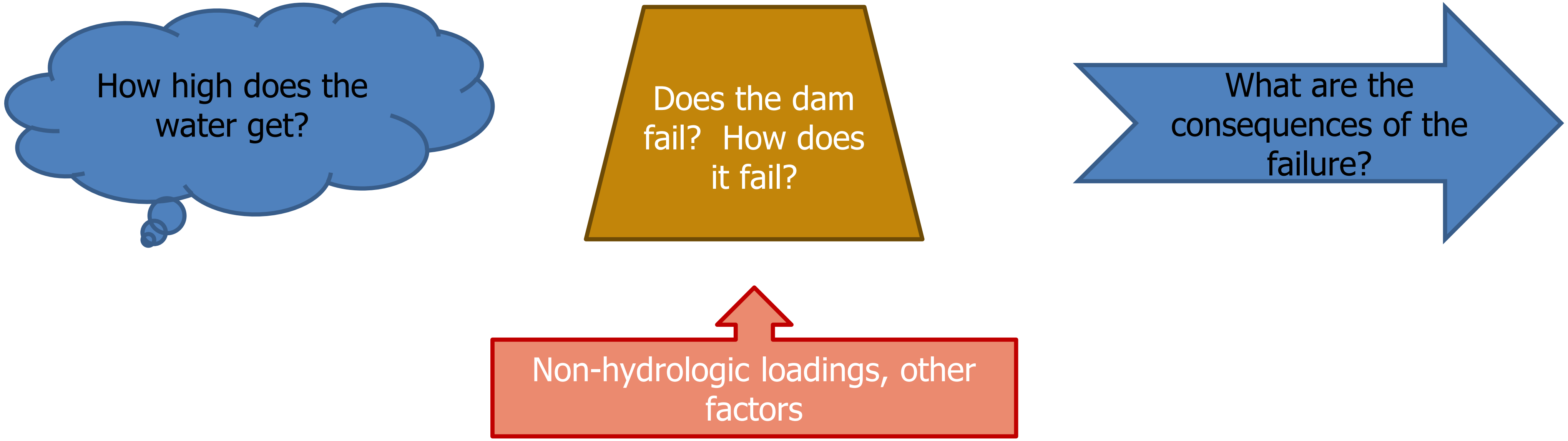
http://www.energy.gov/ehss/natural-phenomena-hazards-program

Flood Hazard Analyses Update

Gabriel Miller
Hydrologist

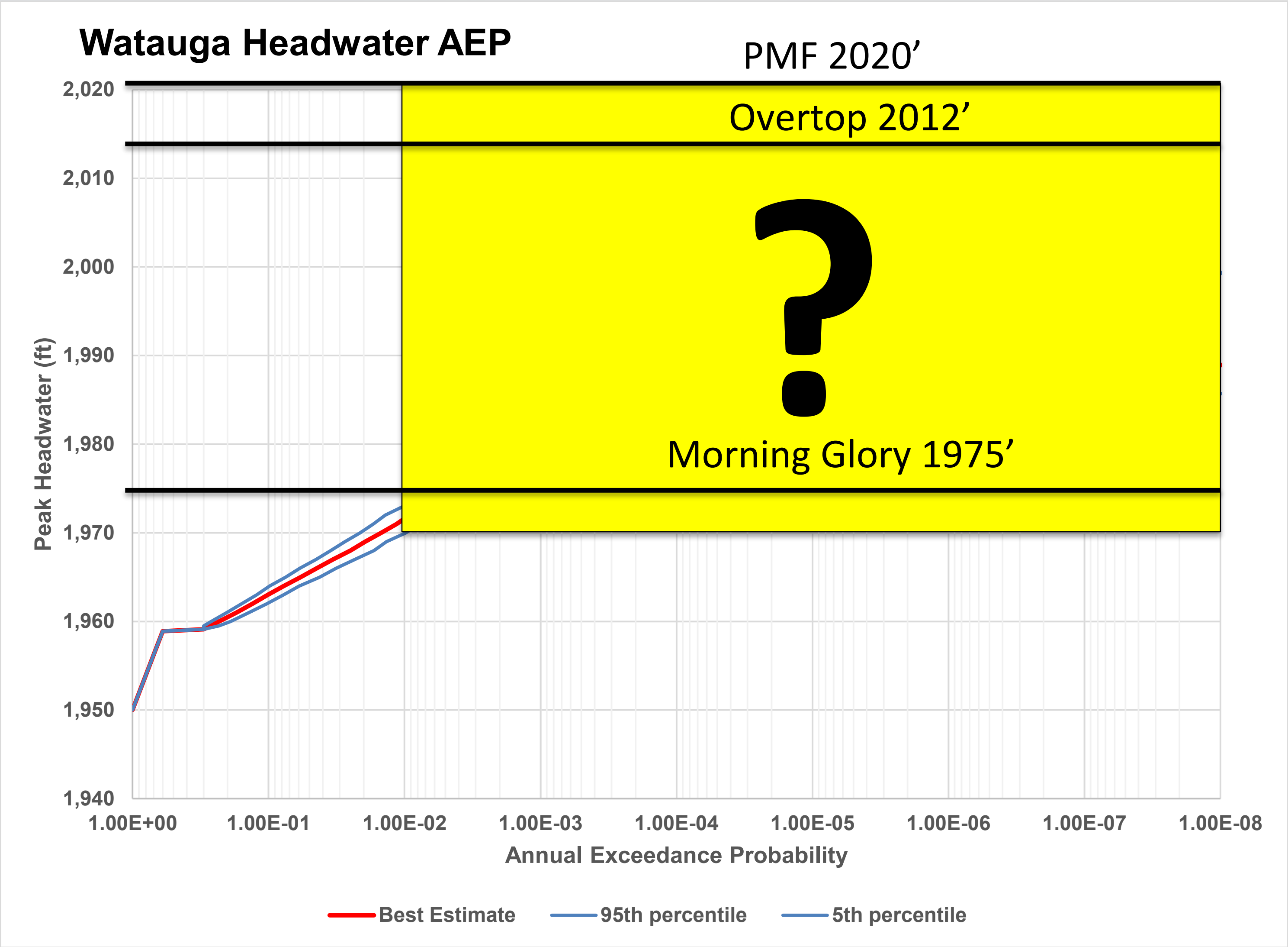
Why should we care about flood hazards?

- Risk consists of
  - Loading (Hydrologic hazard curves)
  - System response (Does a dam fail?)
  - Consequences (Life loss, economic, other)



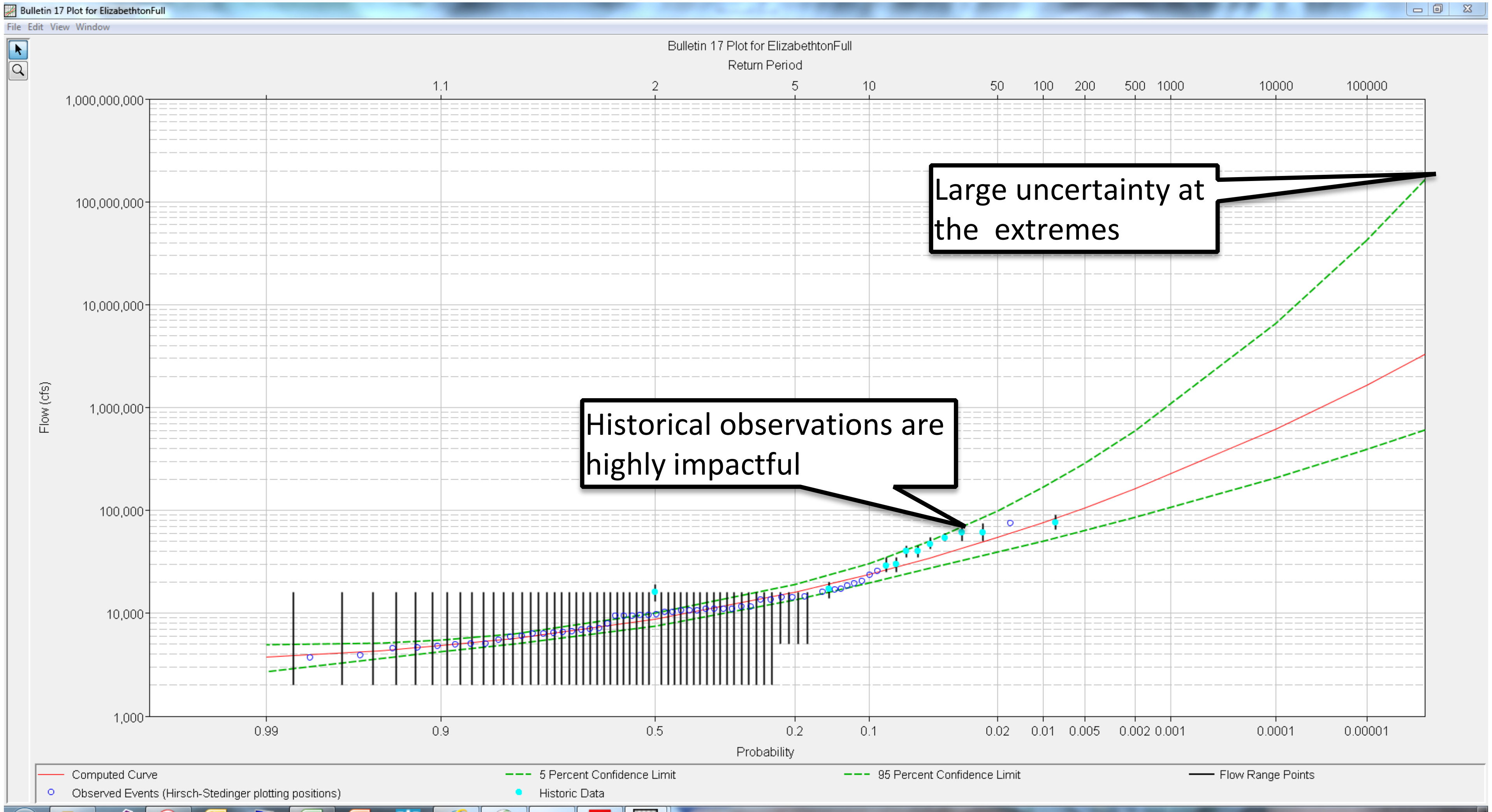
Let’s use Watauga as an example

- PMF overtops dam by 8’
- However, morning glory has never even been used
- What decisions would a 1:1,000-yr overtopping trigger?
- What decisions would a 1:1,000,000,000-yr overtopping trigger?

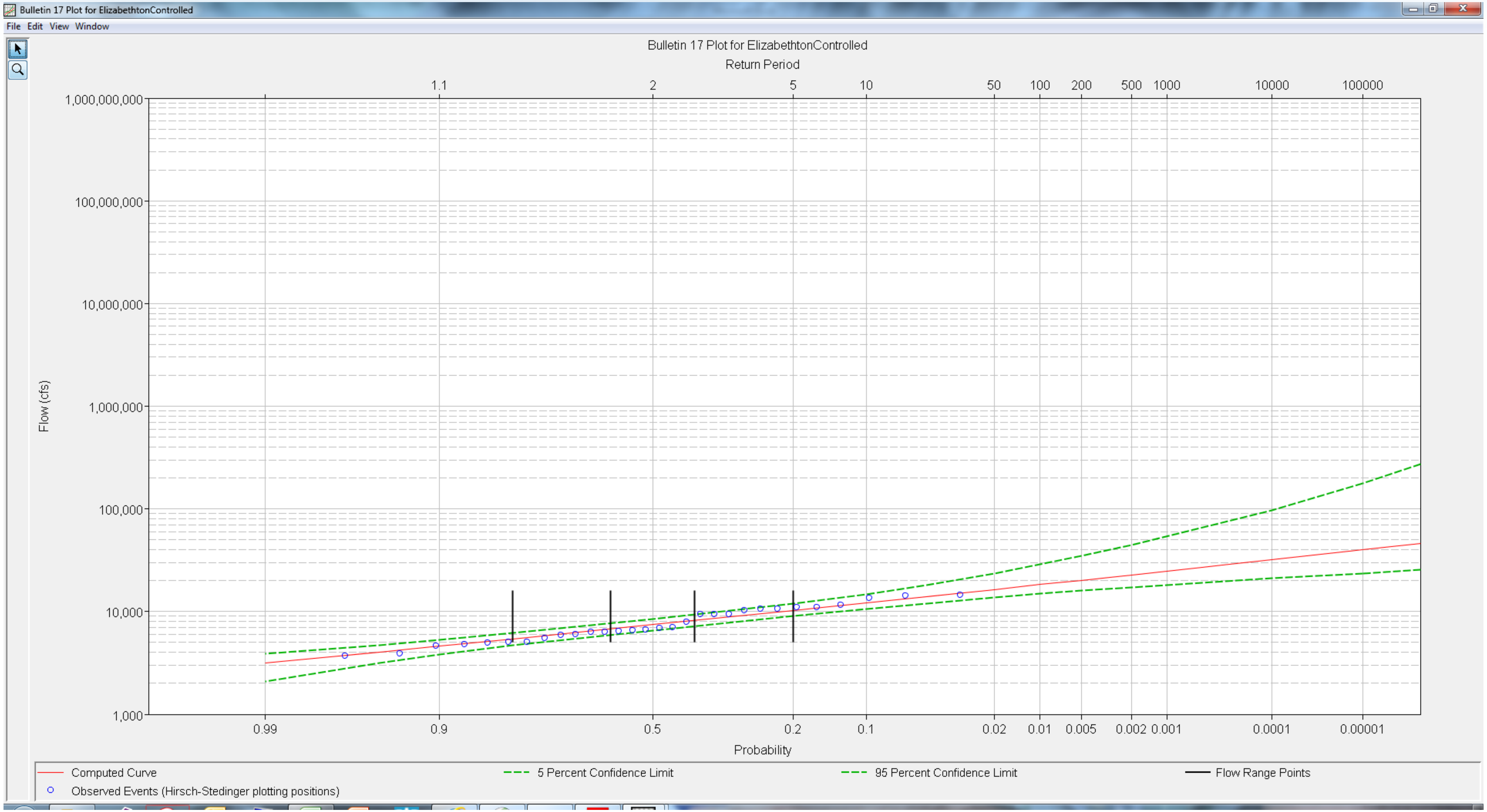


AEP curve for Watauga @ Elizabethton

- AEP Curve developed using annual maximum streamflow
- Done with HEC-SSP

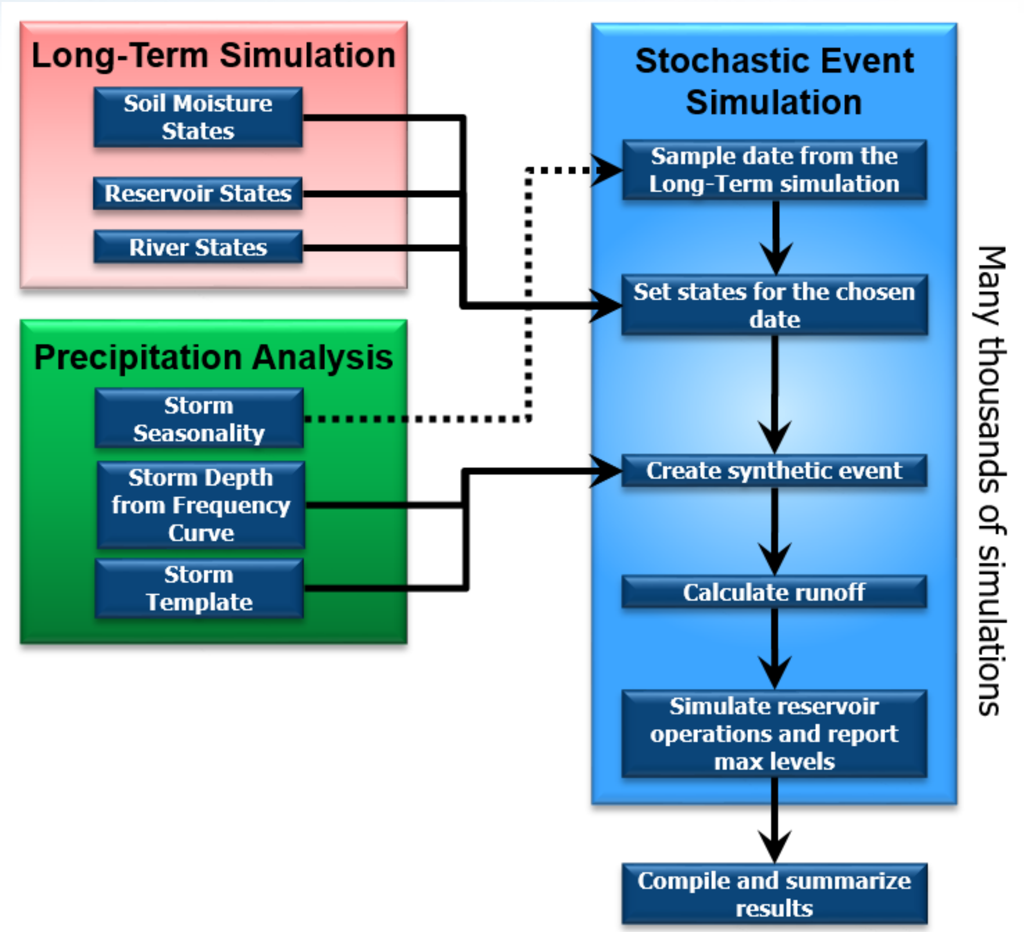


Statistics for only controlled years



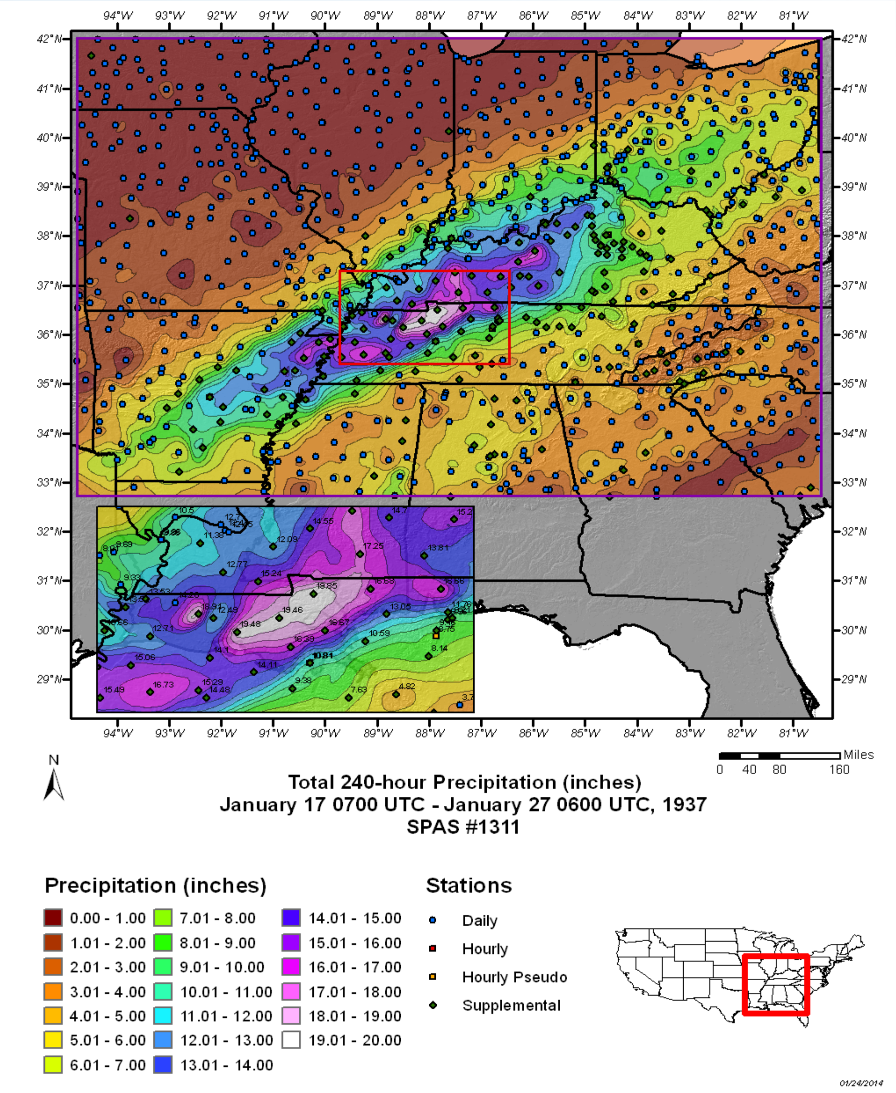
TVA PFHA System

- For each storm type:
  - Sample a date
  - Sample starting states from the long-term simulation
  - Sample storm depth from rainfall frequency maps/stats
  - Sample a storm template, scale to depth and place randomly
  - Calculate runoff
  - Route flow
  - Capture statistics



Precipitation Inputs

- Observed storms transposed, scaled and placed randomly over the basin.
- Storm split into types
  - Big winter frontal storms (MLC)
  - Summer thunderstorm complexes (MEC)
  - Tropical storm remnants (TSRs)



Bonus of storm Typing

- We are extrapolating to very extreme levels, so reducing uncertainty is very important
- Separating storm types helps reduce uncertainty a lot, because each storm type is very different
- At right, is the example of a farmyard. Storms behave in a similar manner.

Mixed Population

Animal #	Species	Weight (lbs)
1	Pig	400
2	Cow	1000
3	Chicken	8
4	Pig	375
5	Cow	1100
6	Chicken	7
7	Pig	390
8	Cow	950
9	Chicken	6.5
10	Pig	420
11	Cow	1150
12	Chicken	7.2
13	Pig	365
14	Cow	1050
15	Chicken	6.9
	Average	482
	Stdev	448

Animal Separation

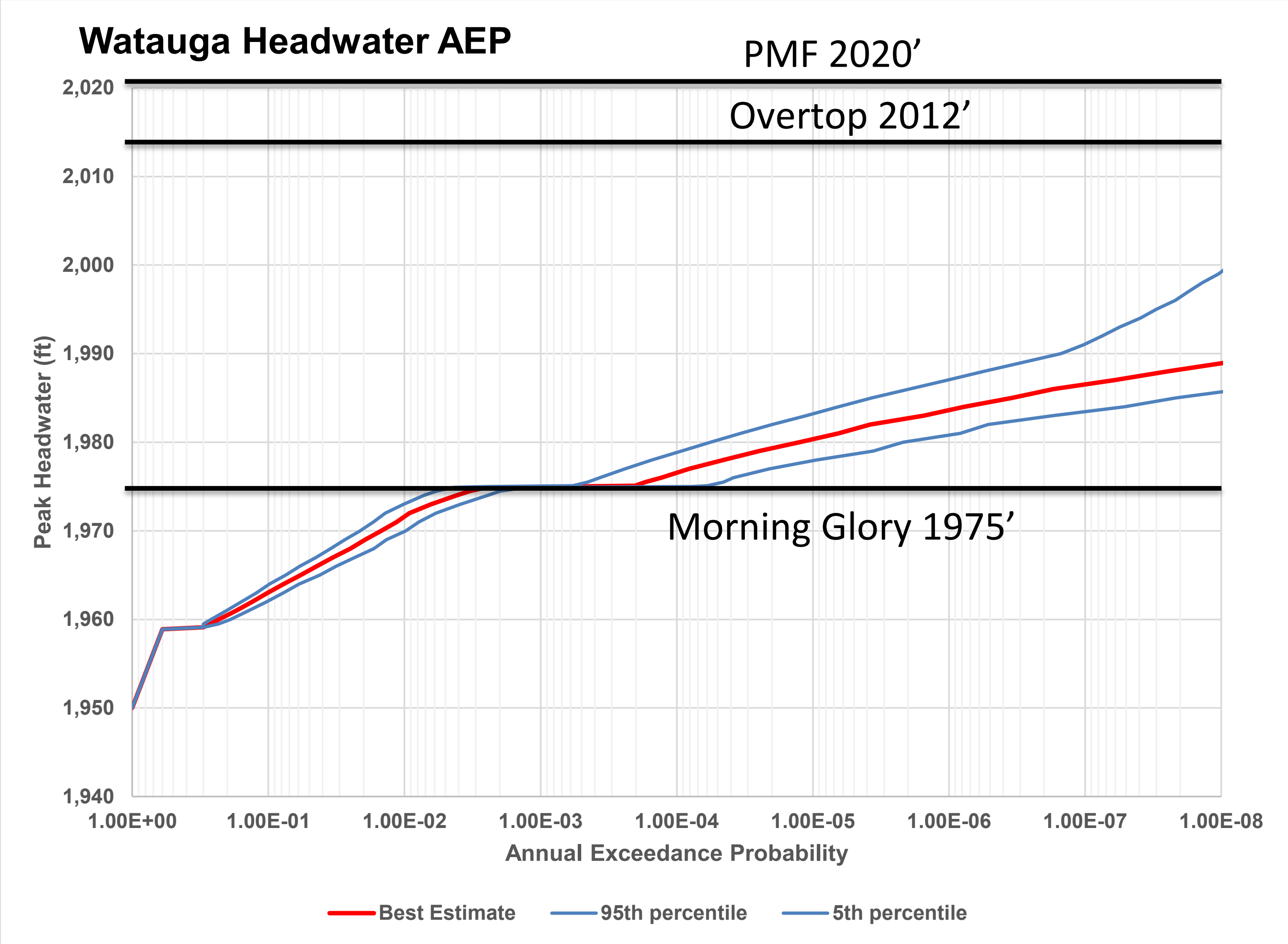
Animal #	Species	Weight (lbs)
3	Chicken	8
6	Chicken	7
9	Chicken	6.5
12	Chicken	7.2
15	Chicken	6.9
	Average	7.1
	Stdev	0.6

Animal #	Species	Weight (lbs)
2	Cow	1000
5	Cow	1100
8	Cow	950
11	Cow	1150
14	Cow	1050
	Average	1,050.0
	Stdev	79.1

Animal #	Species	Weight (lbs)
1	Pig	400
4	Pig	375
7	Pig	390
10	Pig	420
13	Pig	365
	Average	390.0
	Stdev	21.5

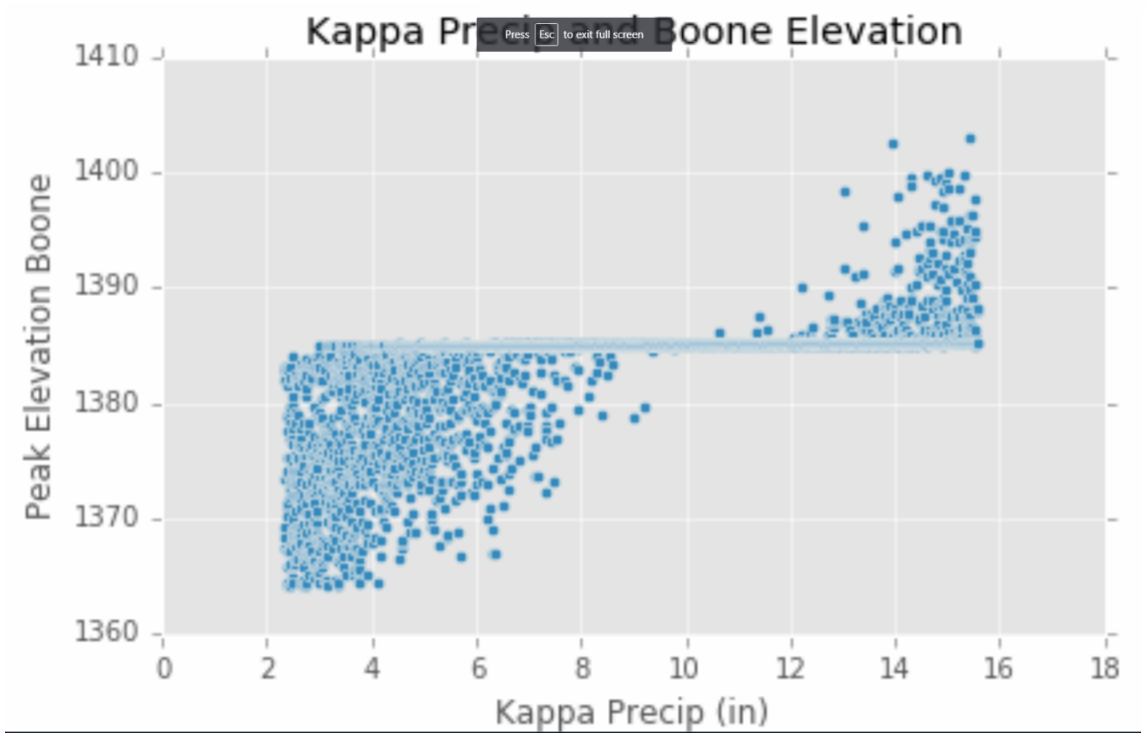
Our Results

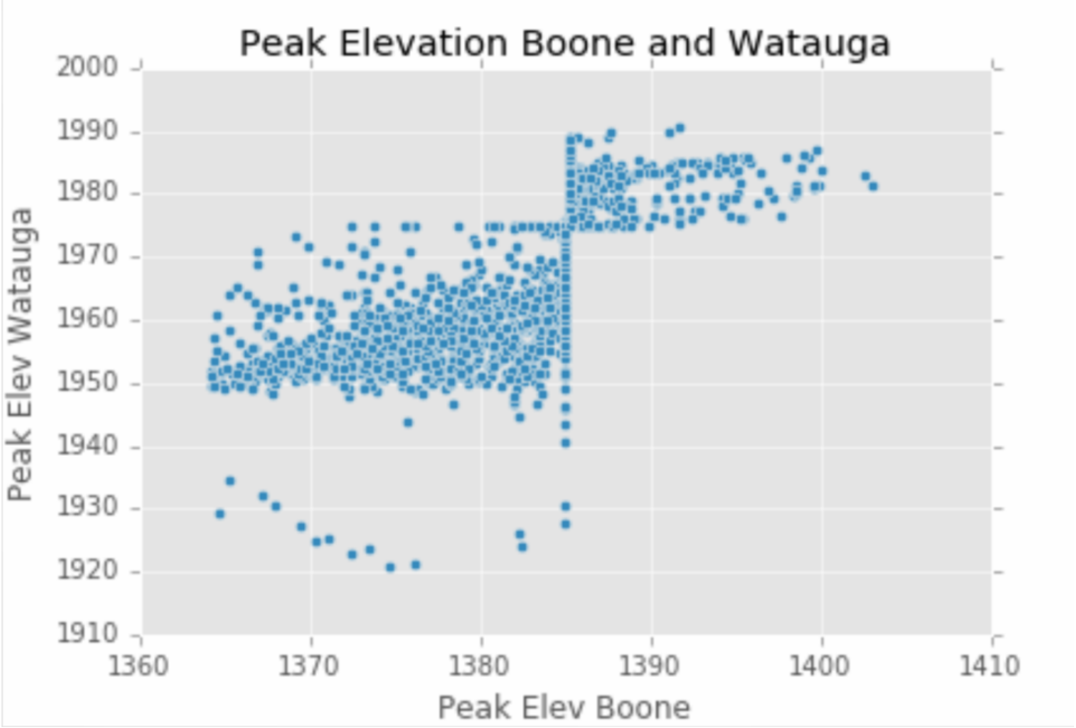
- Likelihood of PMF is REMOTE
- Likelihood of overtopping is REMOTE
- Raising the dam would be a poor risk-reduction measure ($$$$)
- Investing elsewhere would reduce more risk (lives)



Typical insights available

Boone doesn’t lose control until *at least* 10” of rainfall





Boone only loses control if Watauga loses control

Framework Documentation

- Our documentation (available upon request)
  - Overview Calculation
  - SOP and User Manual
  - Point Precipitation Frequency Calculation
  - Methods for Preparation of Rainfall Inputs Calculation
  - Technical Documentation Calculation
  - RiverWare Model Calculation

- Peer Review
  - John England: Main driver behind USBR and national flood hazard methods
  - Dr. Jery Stedinger: Internationally-recognized water statistics expert
  - Review was extremely positive

Evaluating the Science Project

- Unique aspects of our PFHA framework
  - Storm type separation
  - Watershed precip-frequency for bigger watersheds than have ever been analyzed
  - Watershed precip-frequency for statistically chaotic thunderstorms
  - Bootstrapped 1,000-yr simulation for start states
  - Automated storm scaling and placement
  - Automated convergence monitoring for solutions
  - Results explorer for the most complex river system PFHA ever performed