Hydrologic Risk Analysis: Extreme Floods and Probability Estimates

Hydrologic Risk Analysis: Extreme Floods and Probability Estimates

- PMF and (Single) Deterministic Floods No Longer Adequate – more information required
- Need Probability Estimates and Full Distributions
- Hydrologic Hazard Curves

  (Peak Flow and Volume Frequency Curves)
  - 1,000-year to 10,000-year (typical for failure probability)
  - beyond 10,000-year Return Period - extrapolation!
- Hydrographs
  - range of basin response- volume, timing, shape and include uncertainty
- Maximum Reservoir Levels
  - integrate initial reservoir, hydrographs, probabilities

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Probable Maximum Flood (PMF)

PMF: The maximum runoff condition resulting from the most severe combination of hydrologic and meteorological conditions that are considered reasonably possible for the drainage basin under study.

Design-Based Standard – Maximum Condition; NO Estimate of Likelihood

Reclamation uses the PMF as the upper limit of flood potential (maximum) at a site for storm durations defined by the PMP

PMF used as initial screen for overtopping

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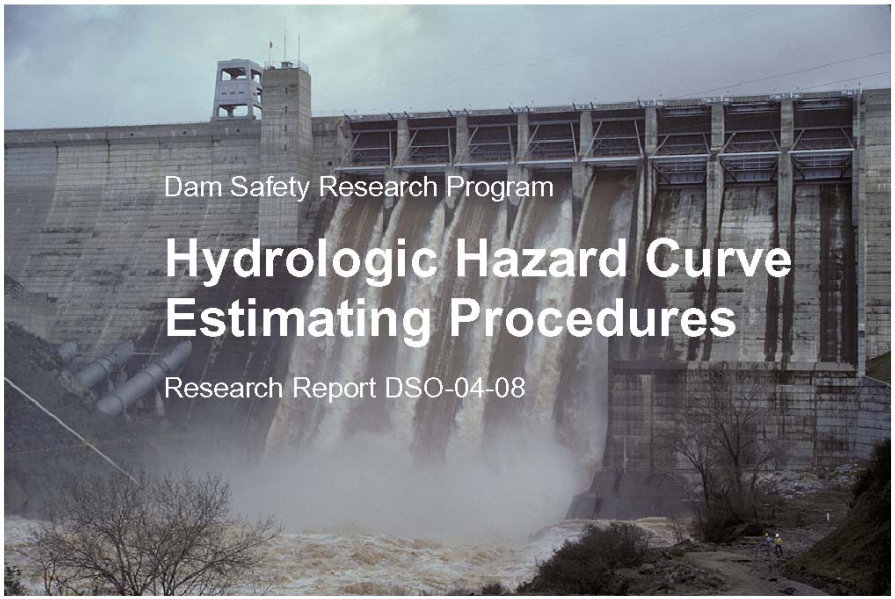
Reclamation Flood Hazard Methods

RECLAMATION
Managing Water in the West



U.S. Department of the Interior
Bureau of Reclamation

June 2004

See also USACE (2008) Inflow Flood Hydrographs Report

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Reclamation Flood Hazard Methods

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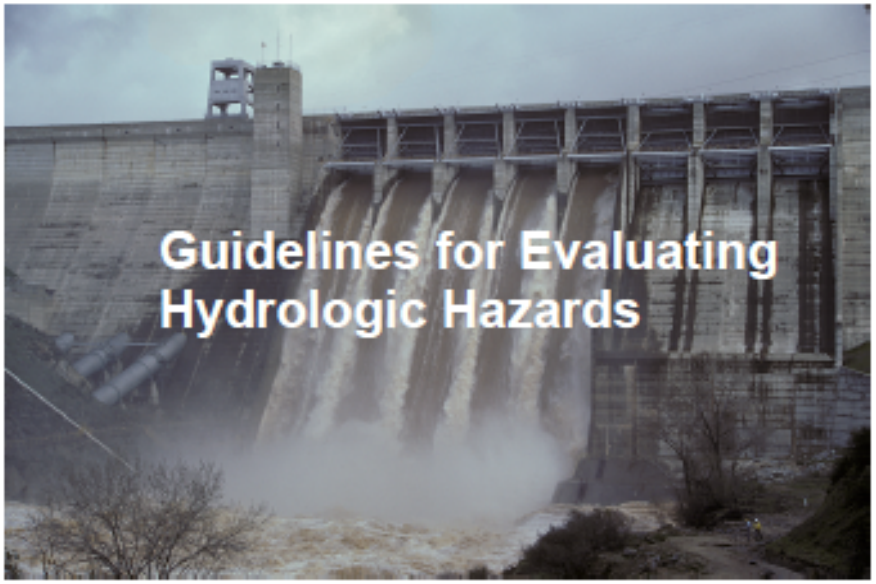

U.S. Department of the Interior
Bureau of Reclamation

June 2006

See also USACE (2008) Inflow Flood Hydrographs Report

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Hydrologic Hazard Curves: Extreme Flood Probability Estimation Methods

- Flood Frequency Analysis with Historical/Paleoflood Data
- Hydrograph Scaling and Volumes
- GRADEX Method
- Australian Rainfall-Runoff Method
- Stochastic Event-Based Precipitation Runoff Modeling (SEFM)
- Stochastic Rainfall-Runoff Modeling with TREX

Swain et al. 2004, 2006

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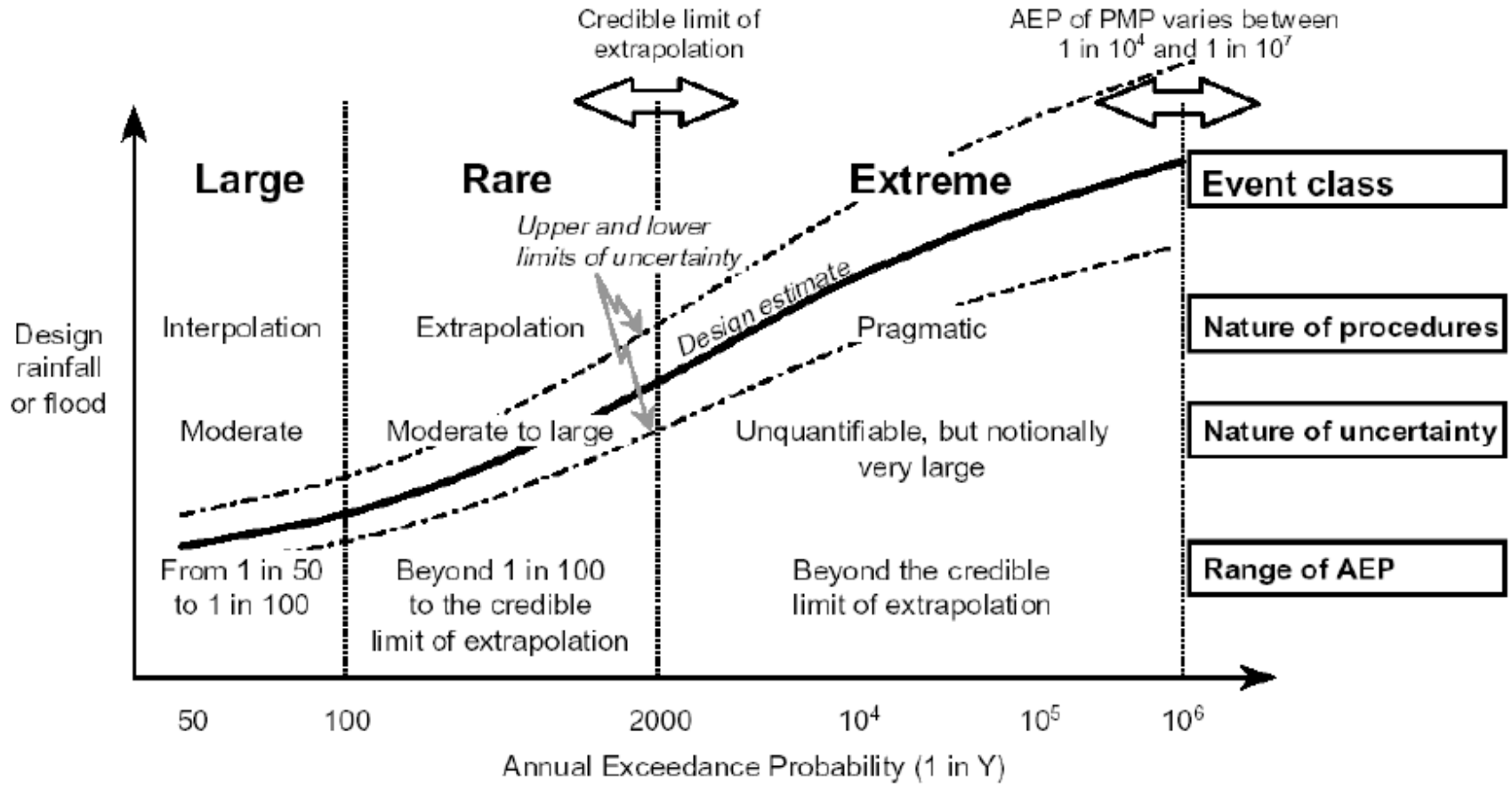
Hydrologic Hazard Curves and Extrapolation



Hydrologic Hazard Data

Type of data used for flood frequency analysis	Range of credible extrapolation for Annual Exceedance Probability	
	Typical	Optimal
At-site streamflow data	1 in 100	1 in 200
Regional streamflow data	1 in 500	1 in 1,000
At-site streamflow and at-site paleoflood data	1 in 4,000	1 in 10,000
Regional precipitation data	1 in 2,000	1 in 10,000
Regional streamflow and regional paleoflood data	1 in 15,000	1 in 40,000
Combinations of regional data sets and extrapolation	1 in 40,000	1 in 100,000

USBR (1999)

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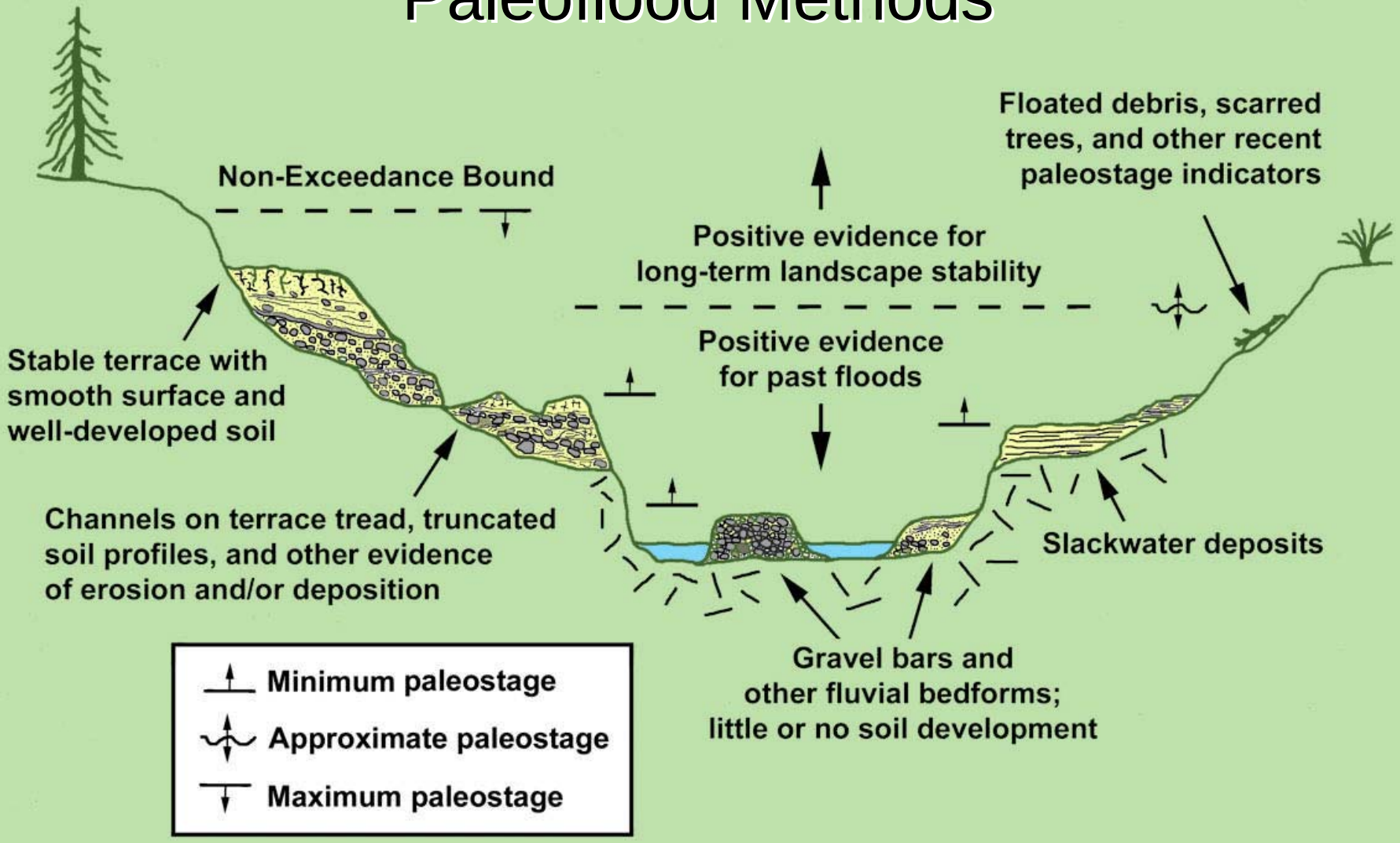
Paleoflood Methods



House et al. (2002) AGU Paleoflood Monograph

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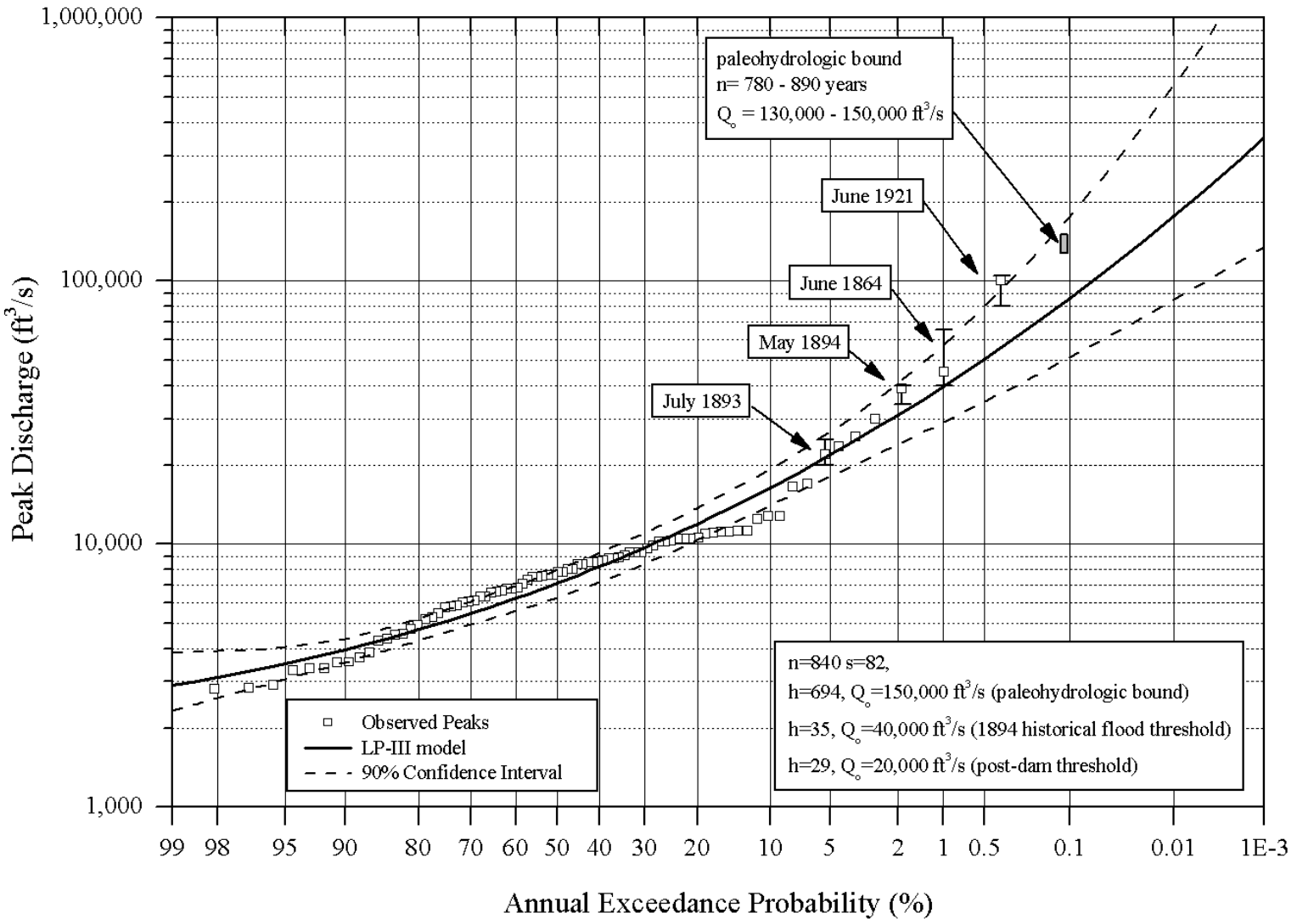
Peak Flow Frequency Curve



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Extreme Flood Probability Estimation Methods: *Rainfall-Runoff*

- Flood Frequency Analysis with Historical/Paleoflood Data
- Hydrograph Scaling and Volumes
- GRADEX Method
- Australian Rainfall-Runoff Method
- Stochastic Event-Based Precipitation Runoff Modeling (SEFM)
- Stochastic Rainfall-Runoff Modeling with TREX

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Extreme Flood Probability Estimation Methods

Principles for Improving estimation with annual exceedance probabilities on the order of 10^{-3} or smaller

1. Substitution of space for time
2. Introduction of more ‘structure’ into models
3. Focus of extremes or ‘tails’ as opposed to or even to the exclusion of central characteristics

NRC (1988) Estimating Probabilities of Extreme Floods

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Stochastic Event-Based Rainfall-Runoff Model (SEFM) Key Elements

- Regional Rainfall Frequency using L-Moments
- Hydrometeorological parameters treated as random variables (snowpack , infiltration..)
- Utilize Storm Patterns and Sequence of Storms
- Runoff Computed using HRU Approach with Unit Hydrograph
- Perform Monte Carlo Simulations - Frequency Analysis on output; examine combinations that cause largest floods

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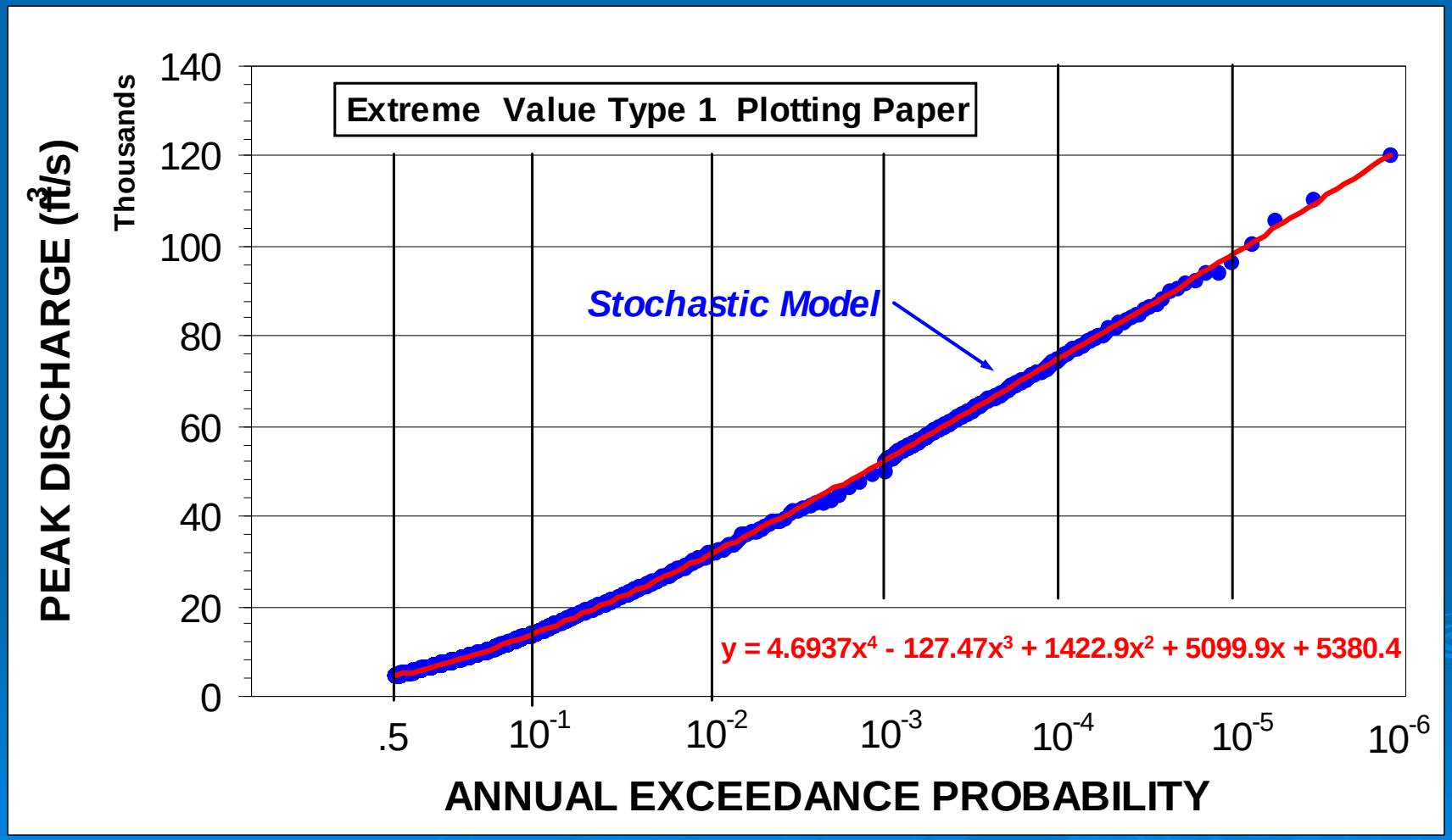
Stochastic Event Flood Model: Peak Flow



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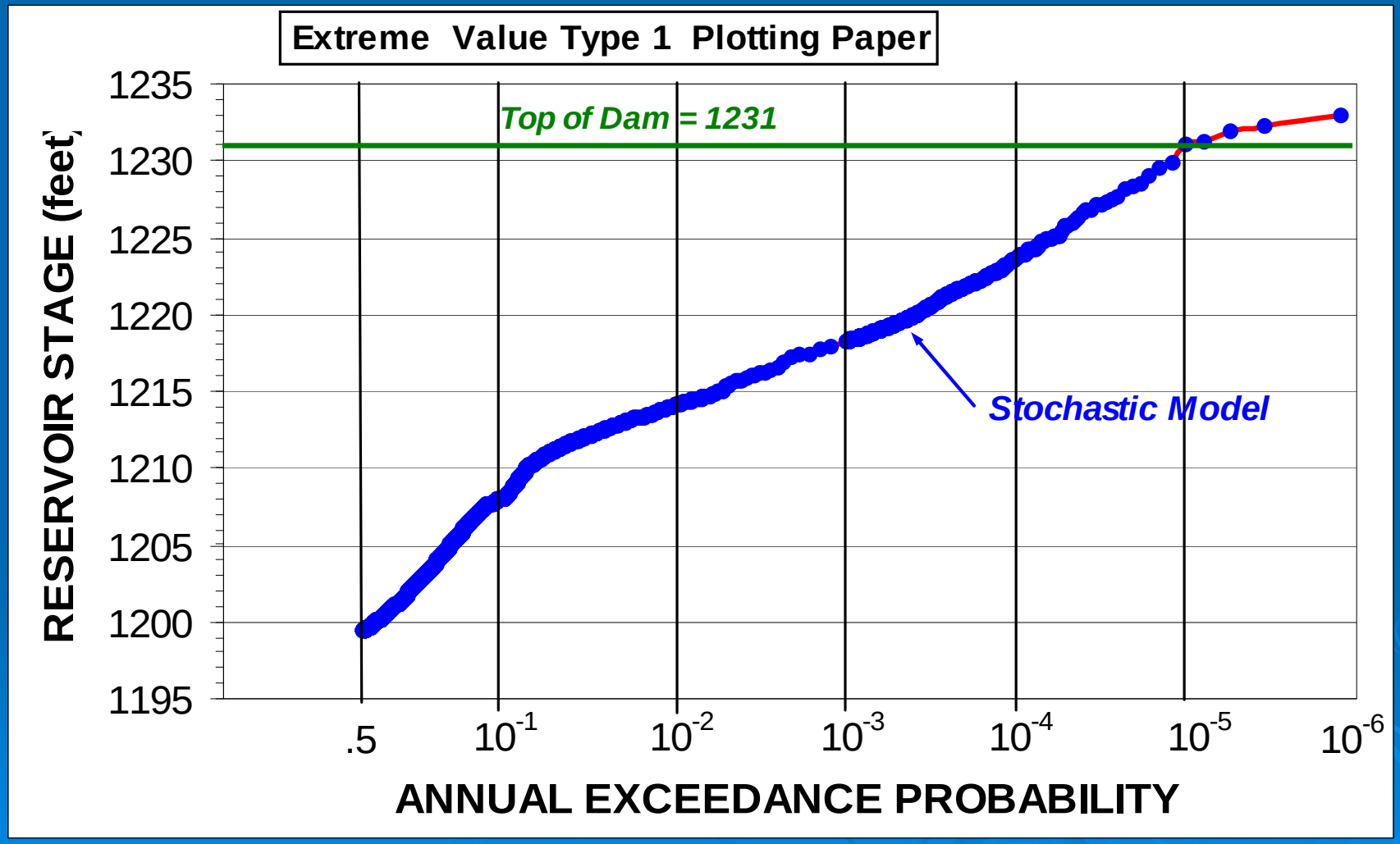
Stochastic Event Flood Model: Reservoir Elevation



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Hydrologic Hazard Summary

- Reclamation utilizes a suite of methods for estimating hydrologic hazard curves for dam safety
- Combining streamflow, paleoflood and rainfall data allows more confidence in extrapolated flood frequency curves
- The procedure relies on extracting information from existing studies and available data
- Initial characterization of hydrologic hazard can usually be accomplished with minimal effort

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Final Hydrologic Hazard Curve

- The amount of effort expended on analyzing a hydrologic hazard is dependent on the nature of the problem and potential cost of the solution
- When multiple methods are used, best estimate is based on sound physical and scientific reasoning for weighting or combining results
- Initial characterization is usually replaced by more detailed studies
- Reclamation uses the PMF as the upper limit of flood potential at a site for storm durations defined by the PMP

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Key Concepts

- Hydrologic Hazard methods are an extension of existing flood frequency and rainfall-runoff modeling tools
- Substantial increase in data and modeling efforts needed for high-level decisions at a particular site
- Critically examine flood data and modeling hypotheses at every step; no longer just about (e.g.):
  - 72-hour maximum rainfall over watershed
  - maximum initial reservoir elevation
  - maximum snowpack and minimum infiltration
- New tools (e.g. FLDFRQ3, SEFM) already developed, tested, and applied at many sites for various risk analysis levels
- Substantial gain in information for multiple purposes

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Key Concepts (continued)

- integration of meteorology, flood hydrology and paleoflood hydrology data and disciplines
- response of reservoir and facility important (PFMs, response probabilities)
  - not focus in this workshop; see Best Practices in Risk Analysis
- multiple methods required at high level of study (CAS)
- honestly describe uncertainty
- temporal, spatial (regional) and causal information needed
- no standard “cookbook” approach; requires custom tools, studies/products, innovation and specific technica expertise – specialists in extreme flood hydrology

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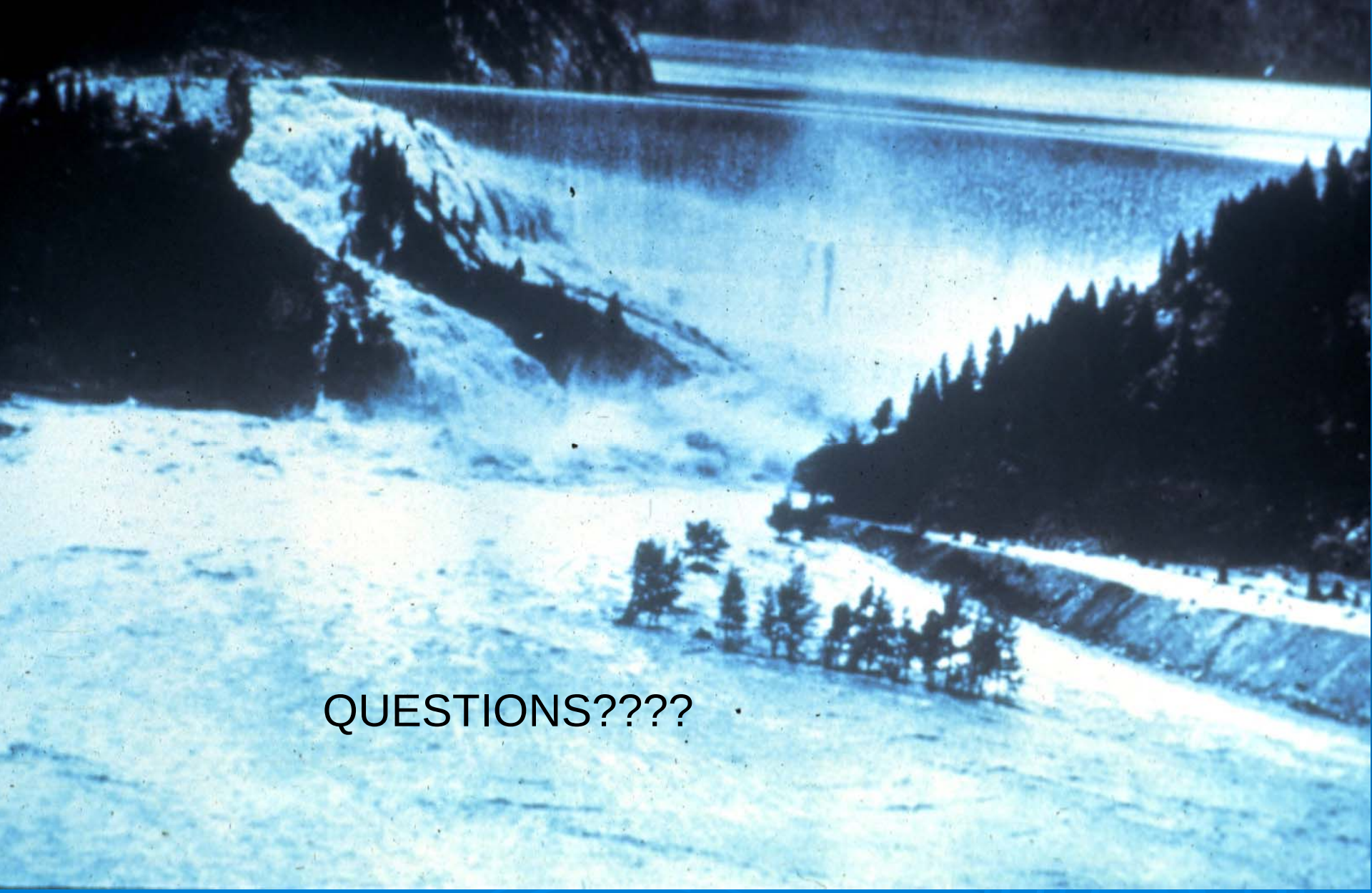

Gibson Dam, MT June 1964