Extreme Flood Events for the Northwest

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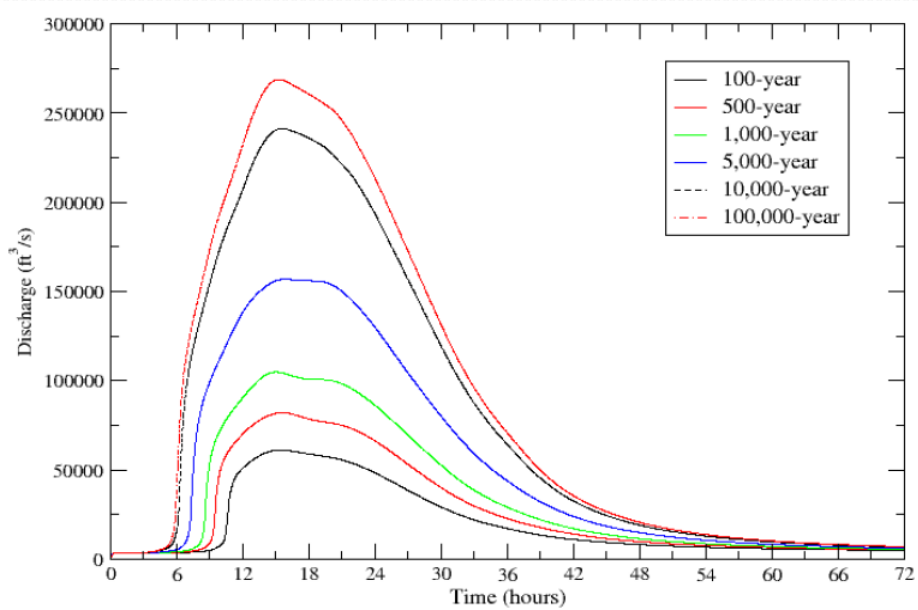
Outline

- What is an Extreme Flood?
- Historic Floods in the Willamette Valley
- Importance of Estimating Extreme Flood
- Methodology for Estimating Extreme Flood
- Paradigm Shift in Design Philosophy

What is an Extreme Flood?

- **An Extreme Flood is considered to have an Annual Exceedance Probability of 0.5% (Return Interval of 200 yr) or less**
- **Based on Runoff Hydrograph (Peak and Volume) and Not Precipitation**

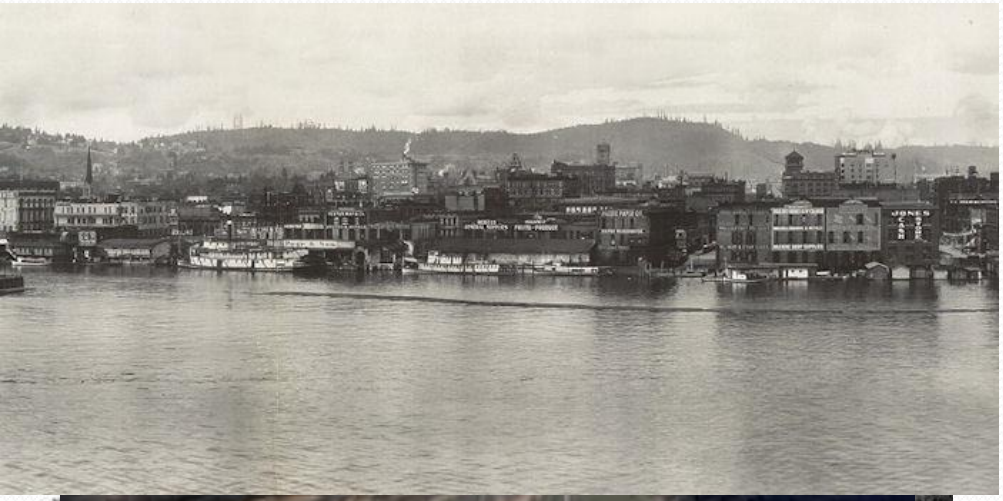


- **A Probable Maximum Flood (PMF) is the most severe flood that is considered reasonably possible at a site as a result of hydrologic and meteorologic conditions**

Extreme Floods

	Probability	Return Interval	Percent Chance of Occurrence over Project Life	
			50 years	100 years
	1%	100	39.5%	63.4%
0.28% (Cancer)	0.5%	200	22.2%	39.4%
	0.2%	500	9.5%	18.1%
0.024% (Motor Accident)	0.1%	1,000	4.9%	9.5%
0.005% (Airline Accident)	0.01%	10,000	0.5%	1.0%
	1.00E-03%	100,000	0.05%	0.10%
	1.00E-04%	1,000,000	0.005%	0.01%

Historic Floods in the Willamette Valley



1891 (Flood of Record)

500,000 cfs

AEP of 0.24% (417 yea

1996

244,000 cfs (Regulated)

AEP of 2.1% (47 year)

1964

308,000 cfs (Regulated)

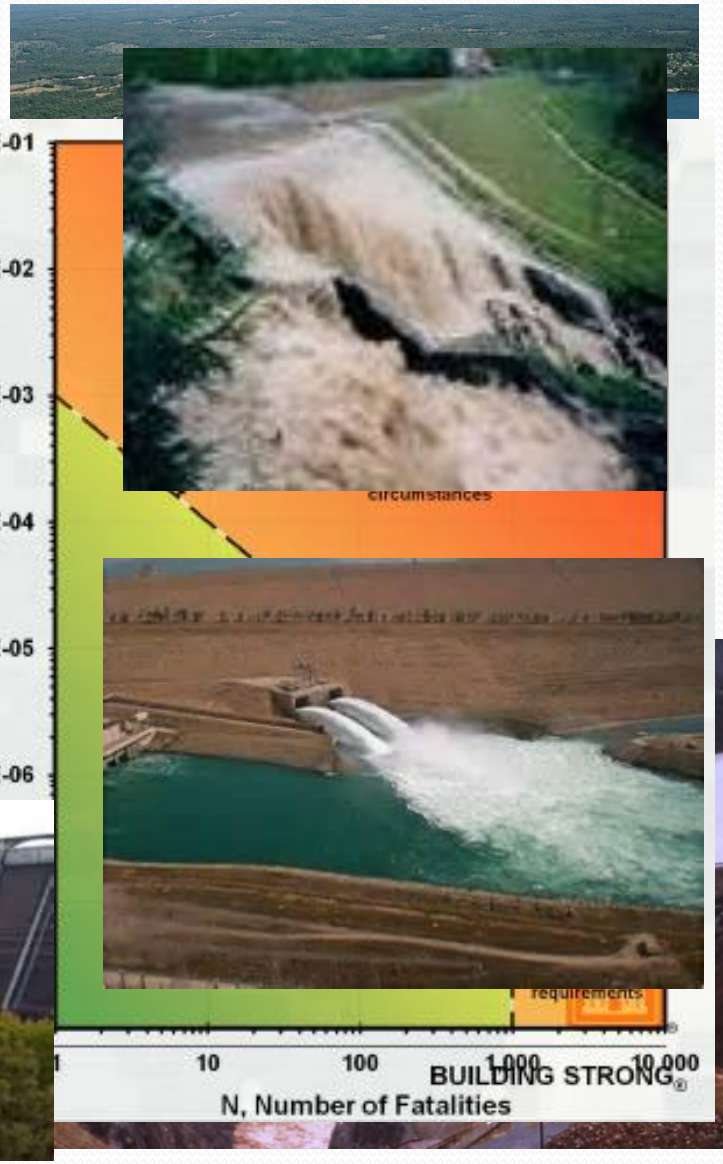
AEP of 0.43% (235 year)

Importance of Extreme Floods

- **Design and Performance**
  - Embankment
  - Outlet Work Structure
  - Spillway Structure

- **Evaluation of Risk**
  - Overtopping
  - Downstream Inundation from Breach Formation

- **Dam Classification and Management of Risk**

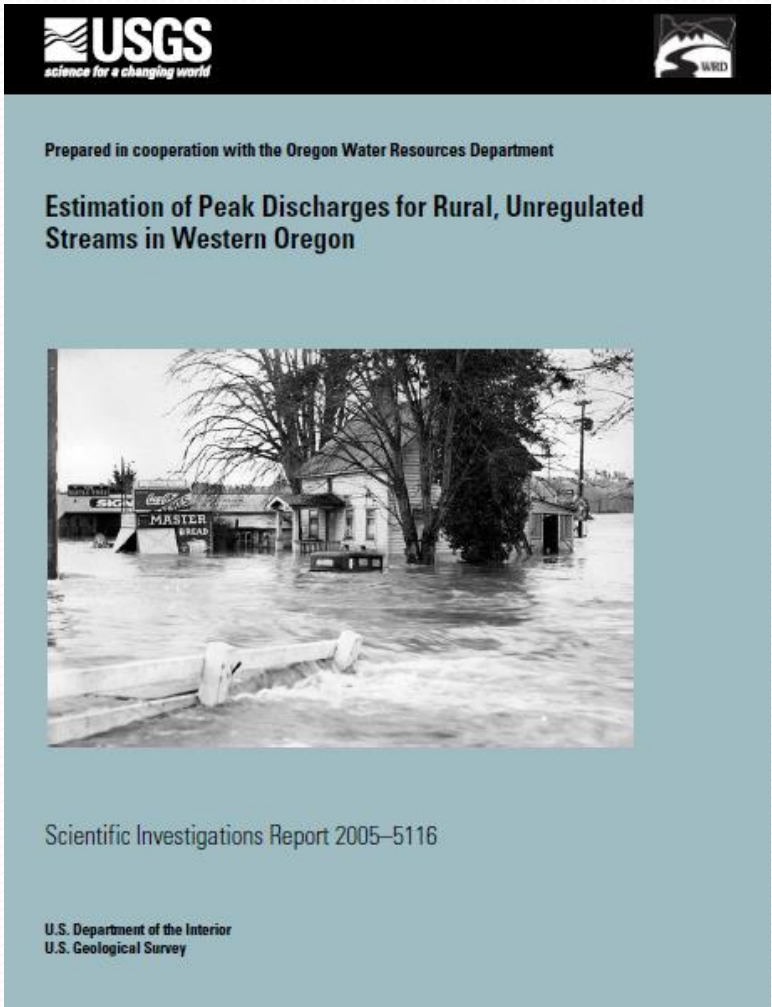


Methodologies for Estimating Extreme Floods

- Regional Regression Equations
- Flood Frequency Analysis
- Rainfall Statistics
- Hydrologic Modeling (Rainfall-Runoff Modeling)

Methodologies for Estimating Extreme Floods

- **Regional Regression Equations**
  - Based on Frequency Analysis of Streamflow Gages in Western and Eastern Oregon
  - USGS in cooperation with OWRD


USGS
science for a changing world

Prepared in cooperation with the Oregon Water Resources Department

Estimation of Peak Discharges for Rural, Unregulated Streams in Western Oregon

Scientific Investigations Report 2005–5116

U.S. Department of the Interior
U.S. Geological Survey

Methodologies for Estimating Extreme Floods

Regional Regression Equations (Continued)

Advantages

- Applicable to Ungaged Watersheds
- Simple and Quick to Apply
- Study Completed in 2005

Challenges

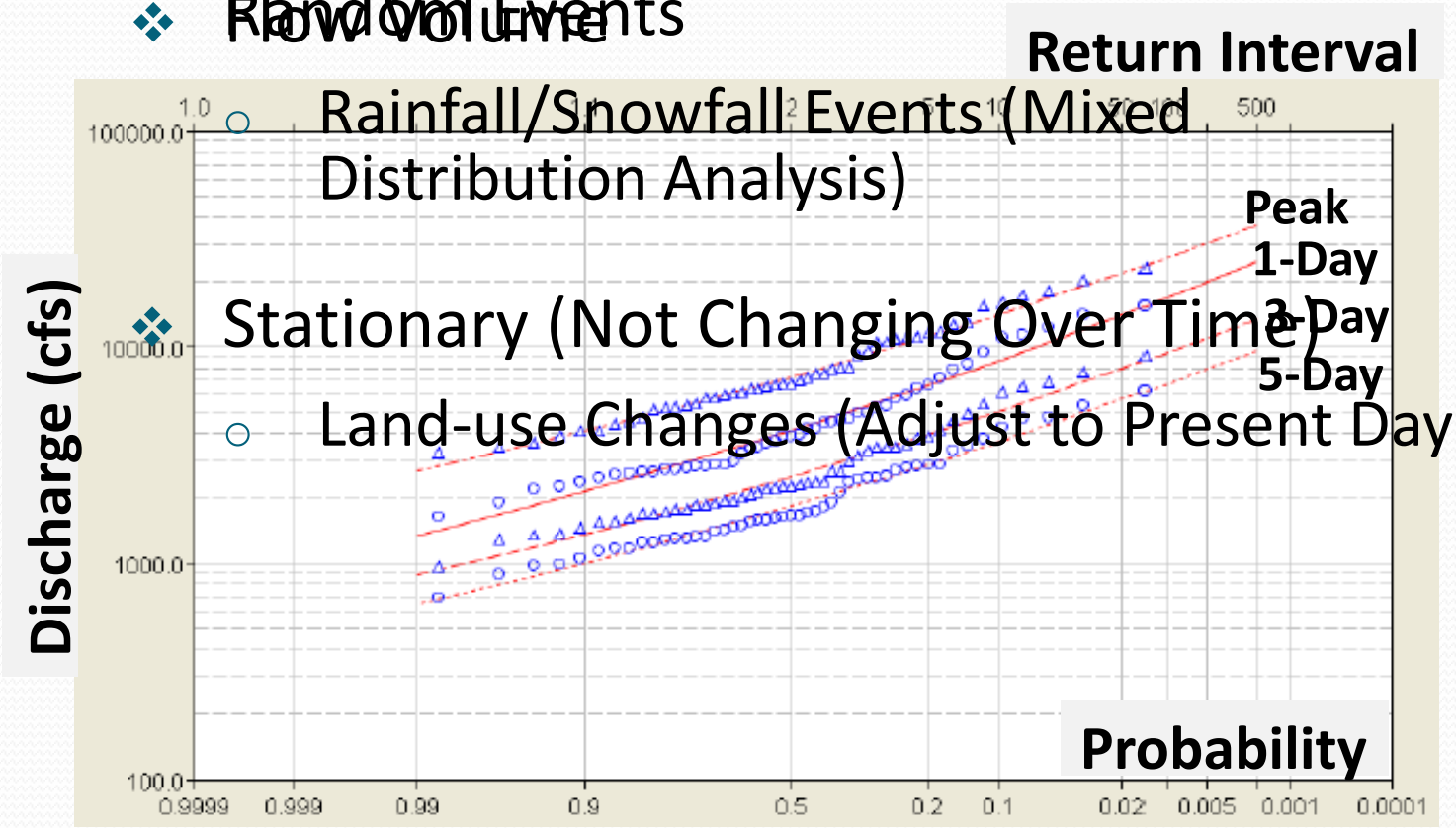
- Estimates only Peak Discharge up to 0.2% AEP Event
- High Level of Uncertainty
  - 33% to 39% for Western Oregon (Equivalent Record Length of 36 yrs = 51%)
  - 48% to 83% for Eastern Oregon (ERL of 35 yrs = 51%)

Methodologies for Estimating Extreme Floods

- Regional Regression Equations
- **Flood Frequency Analysis**
- Rainfall Statistics
- Hydrologic Modeling (Rainfall-Runoff Modeling)

Methodologies for Estimating Extreme Floods

- **Flood Frequency Analysis**
  - Statistical Analysis of Streamflow Data
    - Peak Discharge
    - Flow Volume
    - Stationary (Not Changing Over Time)
    - Land-use Changes (Adjust to Present Day)
  - Assumptions
    - Independent and Identically Distributed Random Events
    - Rainfall/Snowfall Events (Mixed Distribution Analysis)



Methodologies for Estimating Extreme Floods

Flood Frequency Analysis (Continued)

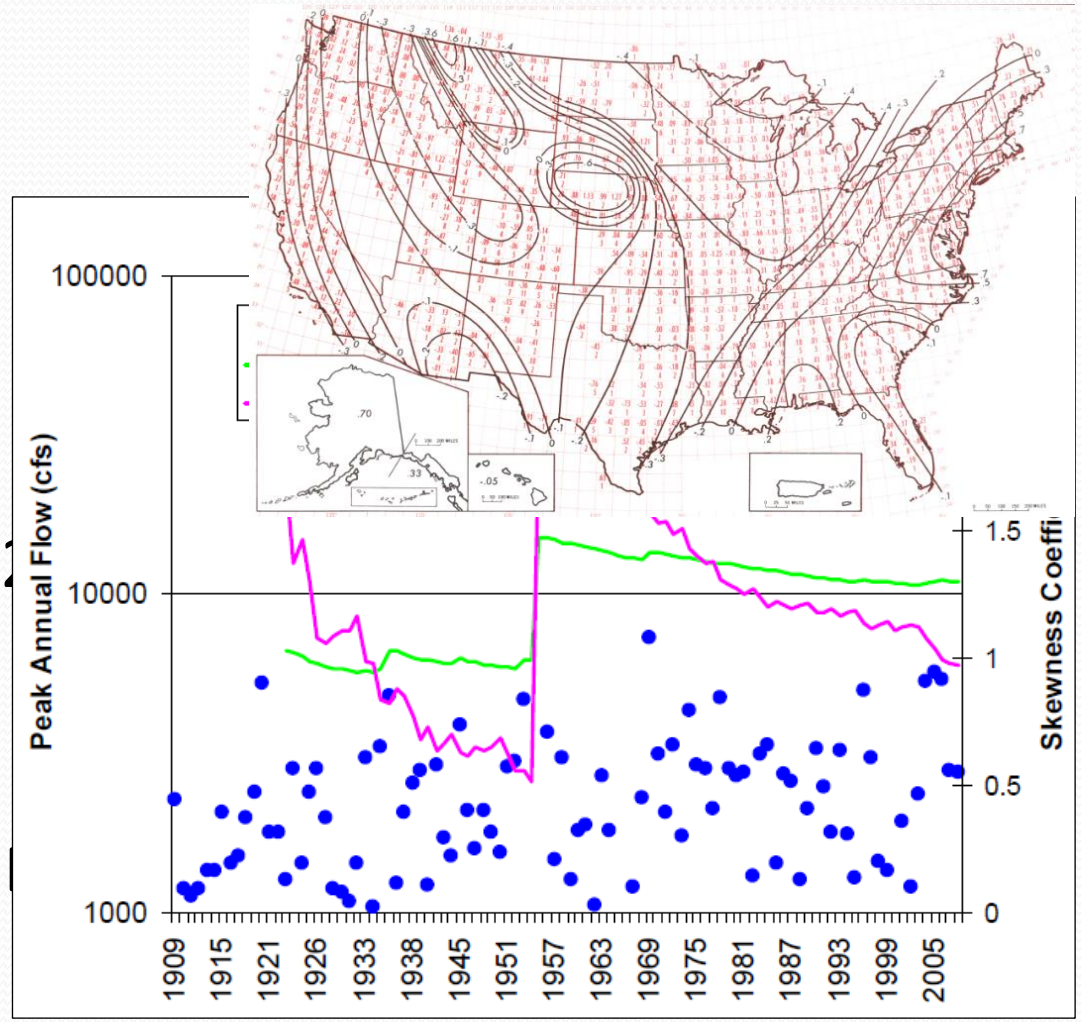
Procedures

- Analytical
  - Log Pearson Type III per Bulletin 17B (Federal Interagencies, 1982)
  - Natural, Unregulated Flows
  - Minimum Length of Record is 10 years
- Graphical
  - Regulated Flows or Unusual Events

Methodologies for Estimating Extreme Floods

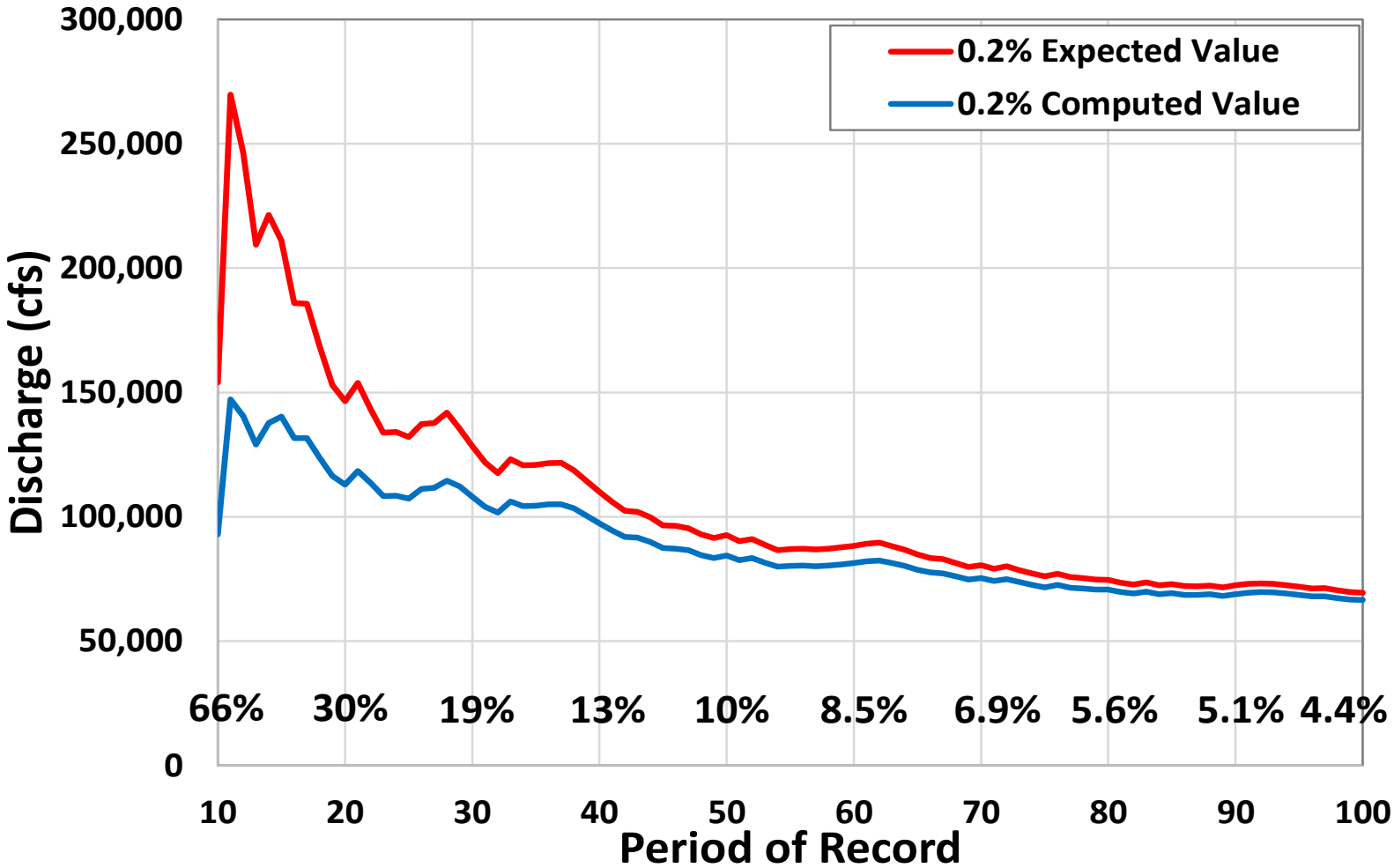
Flood Frequency Analysis Challenges

- **Skew Coefficient**
  - Station Skew
    - Sensitive to Extreme Events
  - Regional Skew
    - 40 Stations with 2
    - Bulletin 17B
  - Weighted Skew
    - Recommended in



Methodologies for Estimating Extreme Floods

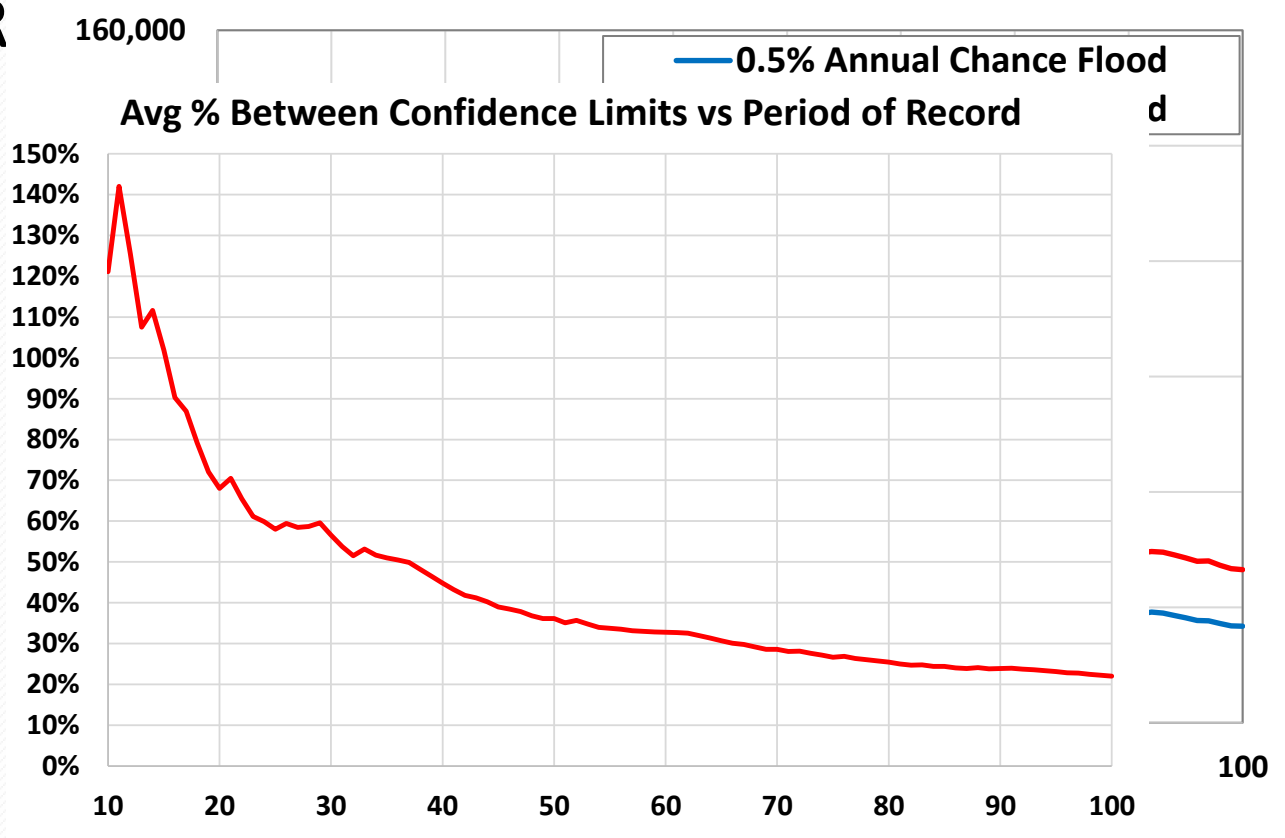
Flood Frequency Analysis Challenges (Continued)



Methodologies for Estimating Extreme Floods

Flood Frequency Analysis Challenges (Continued)

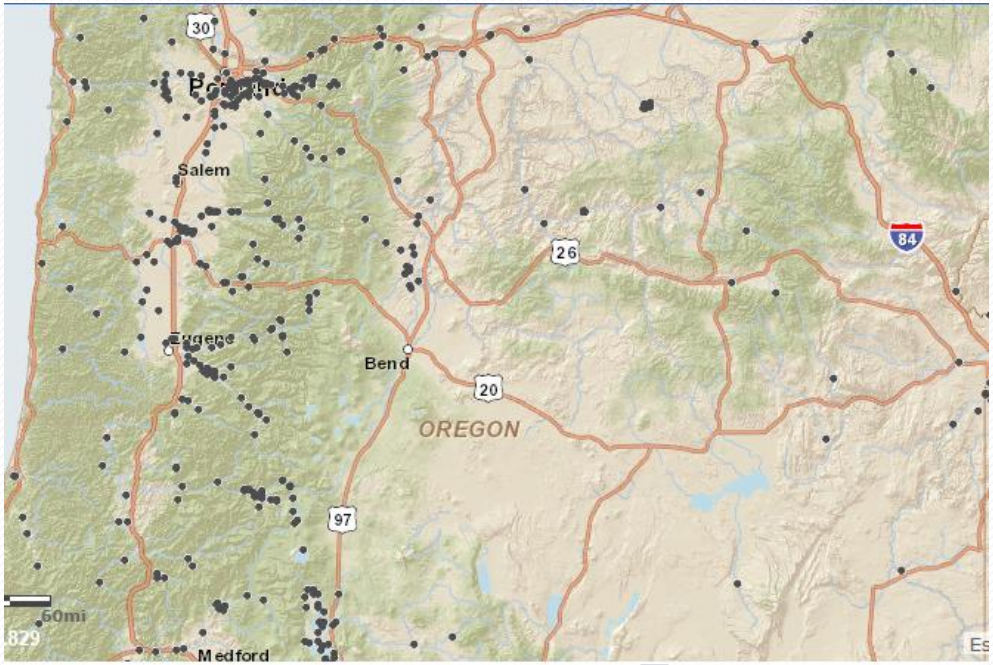
- **Period of Record – Larger Data Set**
  - Provides Better Estimate of Frequency Relationship
  - R



Methodologies for Estimating Extreme Floods

Flood Frequency Analysis Challenges (Continued)

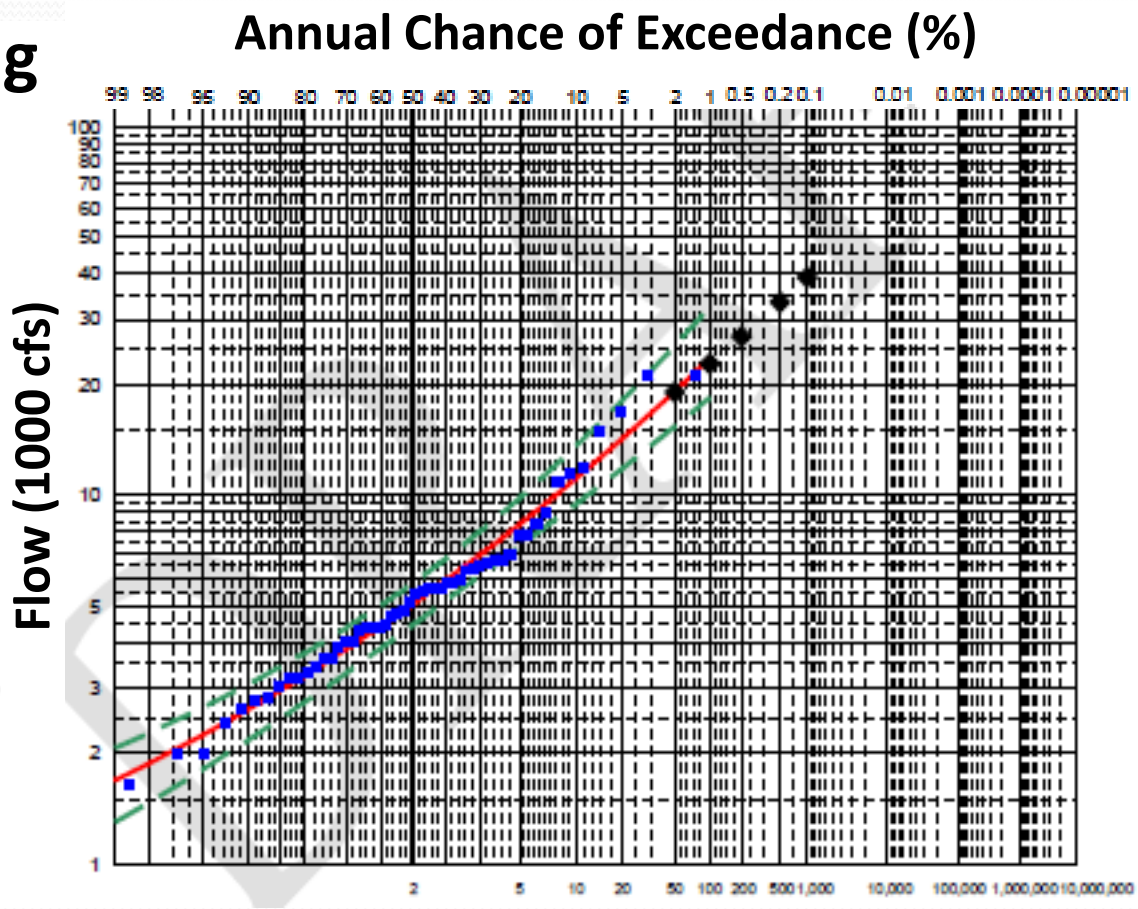
- **Period of Record - Larger Data Set**
  - **Regionalization**
    - Observations from Several Independent Sites with Similar Properties
    - Substitute Space with Time
    - Less Issues with Precipitation than Runoff



Methodologies for Estimating Extreme Floods

Flood Frequency Analysis Challenges (Continued)

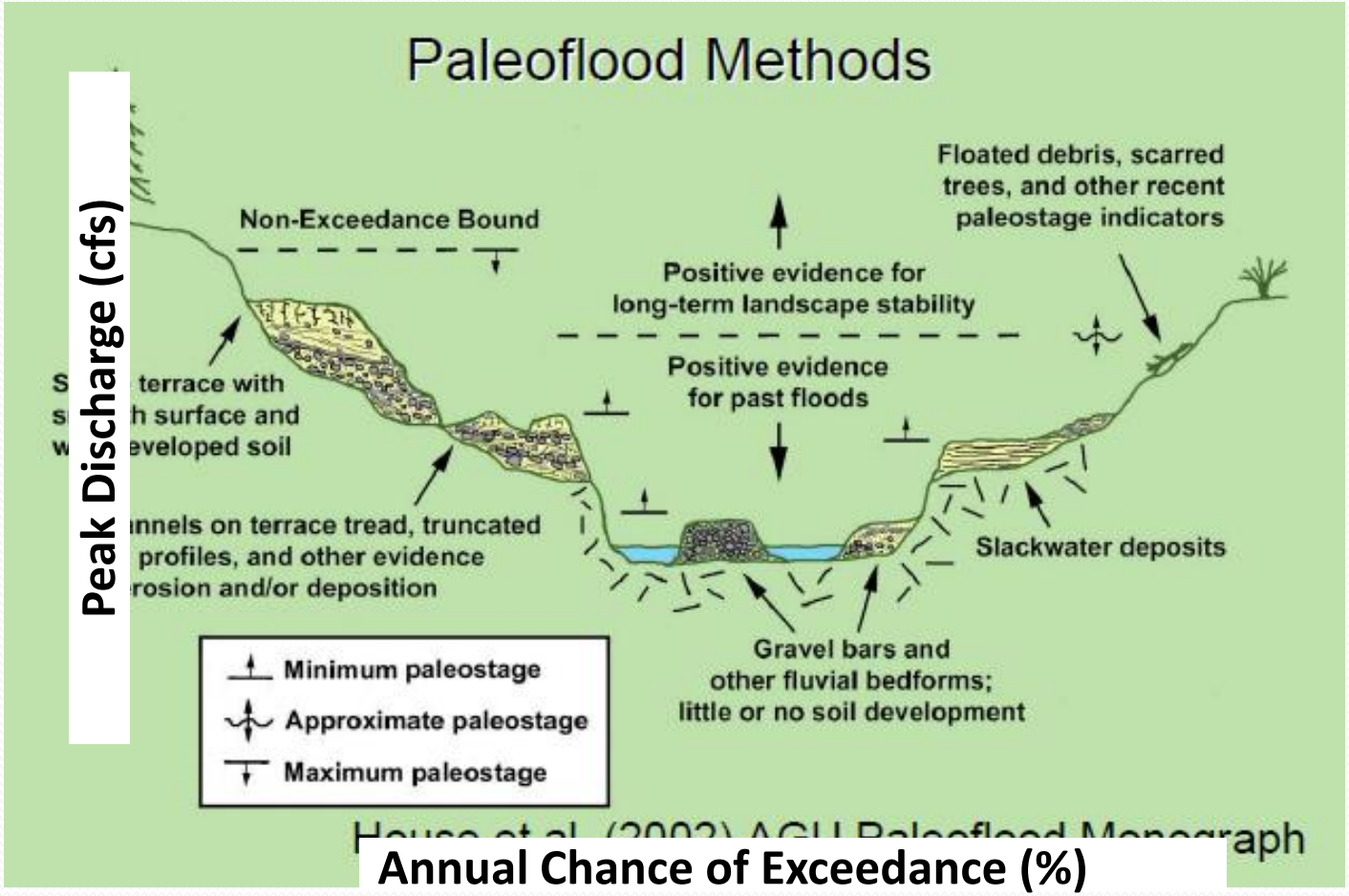
- **Extrapolation**
- **Hydrologic Modeling**
  - Analysis using NOAA Atlas 14



Methodologies for Estimating Extreme Floods

Flood Frequency Analysis Challenges (Continued)

- **Extrapolation**

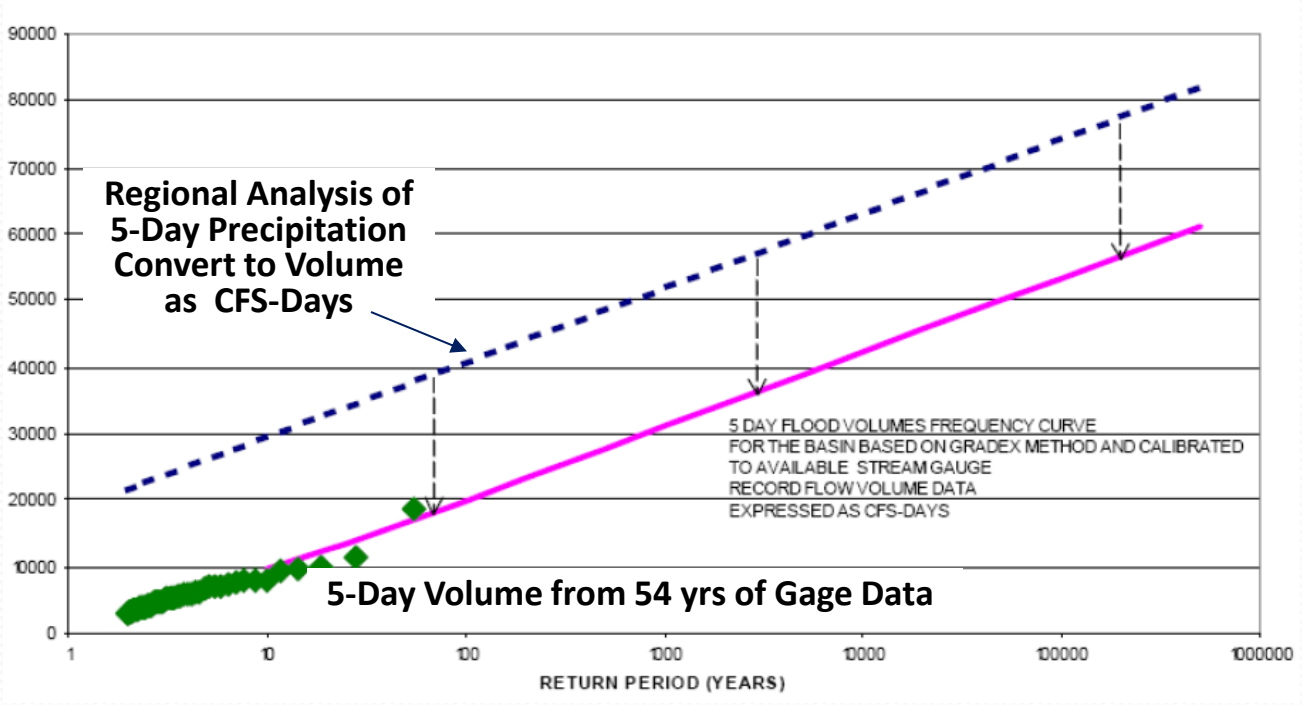


Methodologies for Estimating Extreme Floods

- Regional Regression Equations
- Flood Frequency Analysis
- **Rainfall Statistics**
- Hydrologic Modeling (Rainfall-Runoff Modeling)

Methodologies for Estimating Extreme Floods

- **Rainfall Statistics**
  - GRADEX – GRADient of Extreme values
  - Bureau of Reclamation (USBR)
  - Extrapolation of Flood Volume Frequency Distribution using a Rainfall Series



Methodologies for Estimating Extreme Floods

Rainfall Statistics (Continue)

Challenges

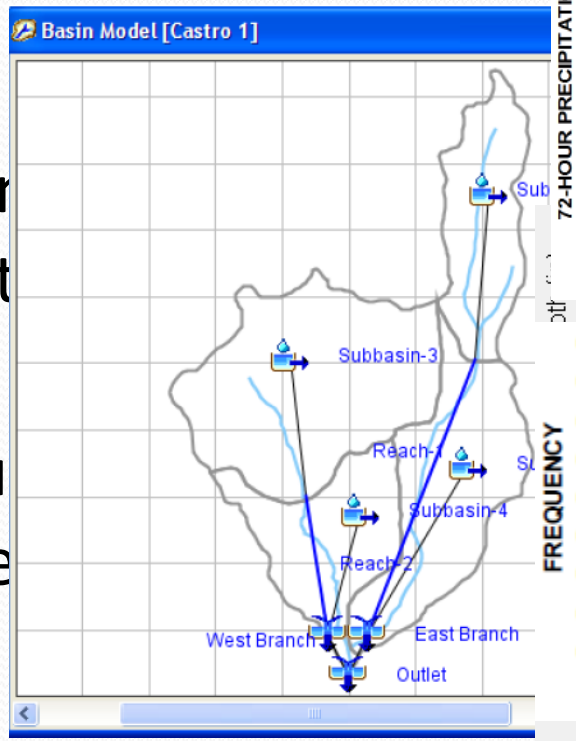
- Estimates only Flood Volumes
- Minimal US Application
- No User Documentation
- Requires Streamflow and Rain Gage Network System

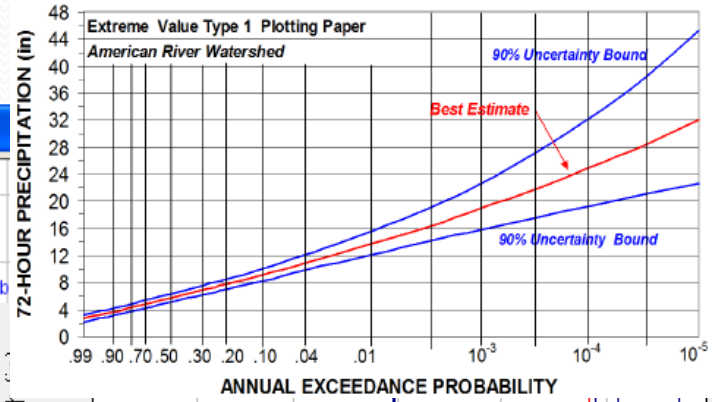
Methodologies for Estimating Extreme Floods

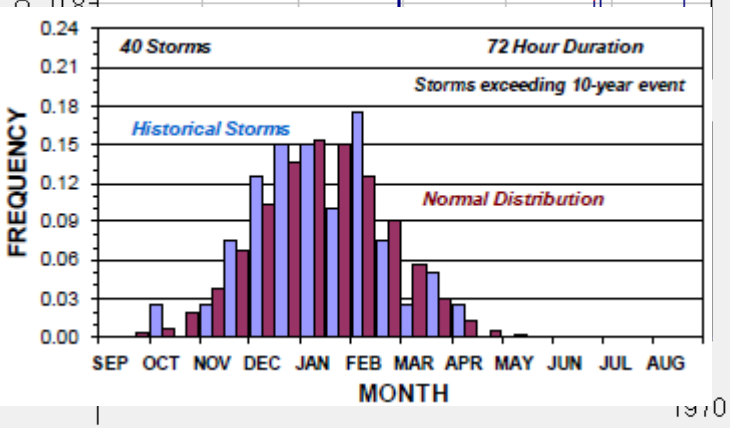
- Regional Regression Equations
- Flood Frequency Analysis
- Rainfall Statistics
- **Hydrologic Modeling (Rainfall-Runoff Modeling)**

Methodologies for Estimating Extreme Floods

- **Hydrologic Modeling (Rainfall-Runoff Modeling)**
  - Utilization of a Hydrologic Model (HEC-HMS or HSPF)
    - Develop or Extend Frequency Curve
    - Estimate PMF Hydrograph
  - Approaches
    - Single Ever
      - Precipit
      - PMP
    - Continuou
      - Long-te
    - Stochastic



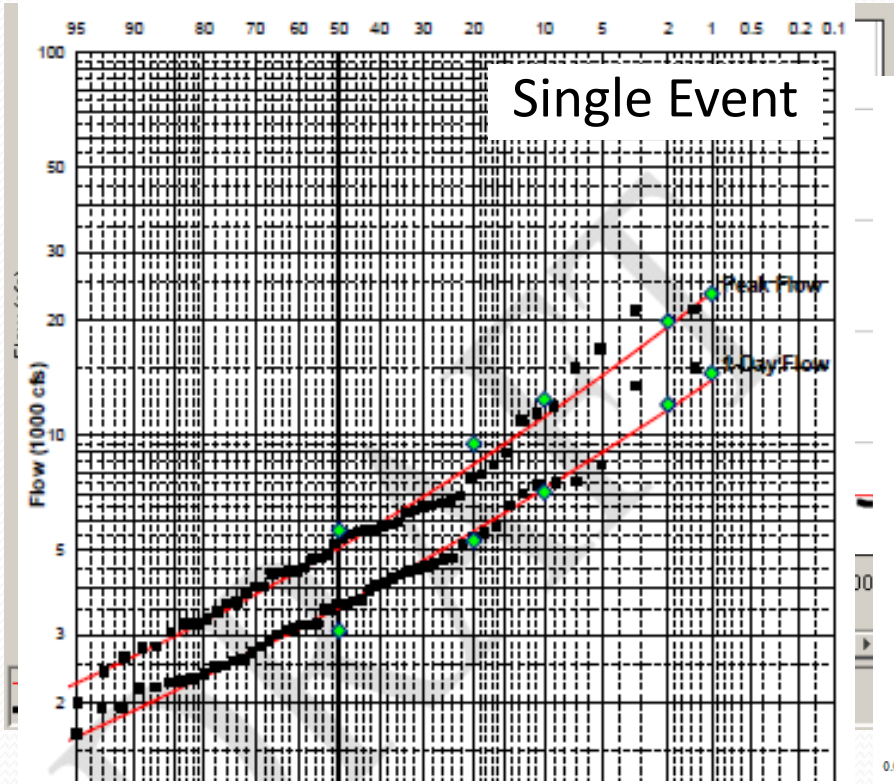




Methodologies for Estimating Extreme Floods

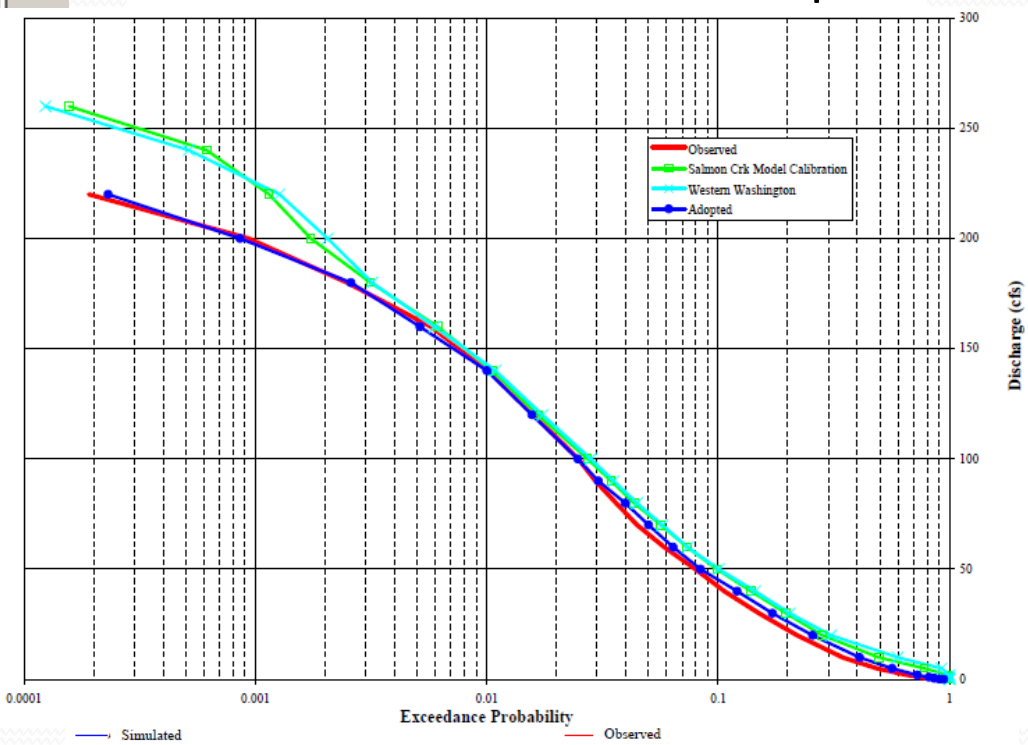
Hydrologic Modeling (Continued)

- Calibration and Verification



Flood Frequency Relationship

Flow Duration Relationship



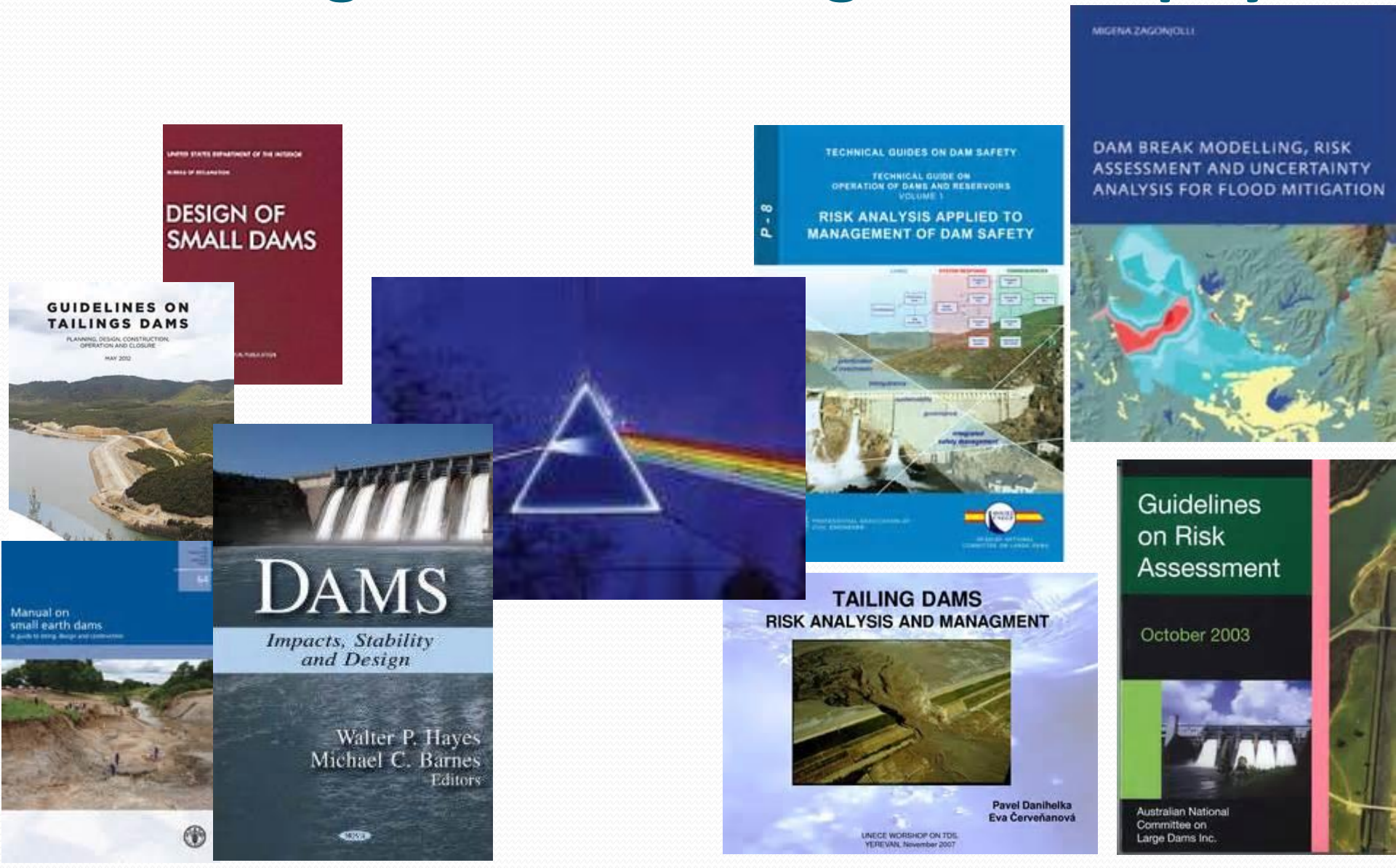
Continuous Simulation

Methodologies for Estimating Extreme Floods

Hydrologic Modeling Challenges

- Runoff Frequency = Precipitation Frequency
  - Antecedent Conditions
    - Soil Moisture
    - Precipitation
    - Snow Pack
- Model Calibrated to More Frequent Event
- Precipitation
  - NOAA Atlas 14 not available for PNW (Event)
  - Long-term Rainfall Gage Network (CS Based)
- Involves Extrapolation

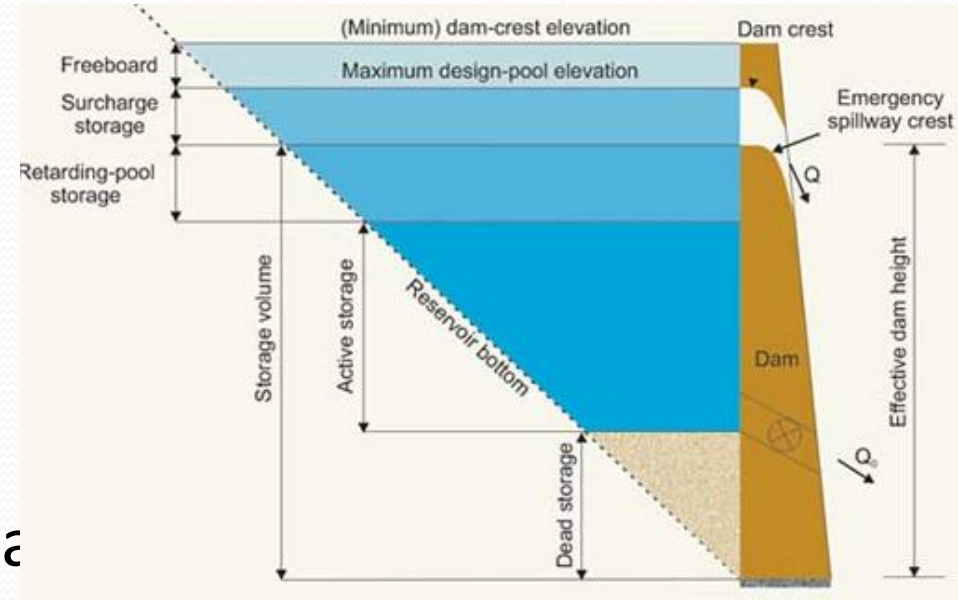
Paradigm Shift in Design Philosophy



Paradigm Shift in Design Philosophy

Current State-of-Practice

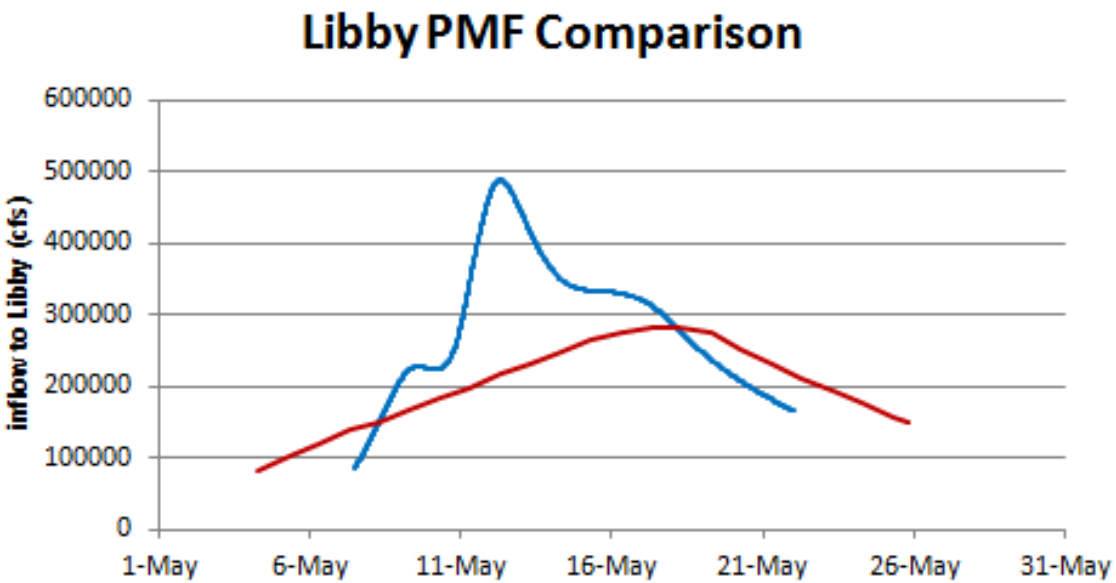
- Deterministic Analysis with Best Guess Relationships
- Design Inflow Hydrograph
  - Low Hazard: ***1% Annual Chance Flood***
  - Significant Hazard: ***0.2% Annual Chance Flood***
  - High Hazard: ***PMF***
- Embankment
  - Maximum Pool Elevation
  - Freeboard
    - Wave Setup and Runup
- Outlet Works\Spillway
  - Maximum Outflow Discha



Paradigm Shift in Design Philosophy

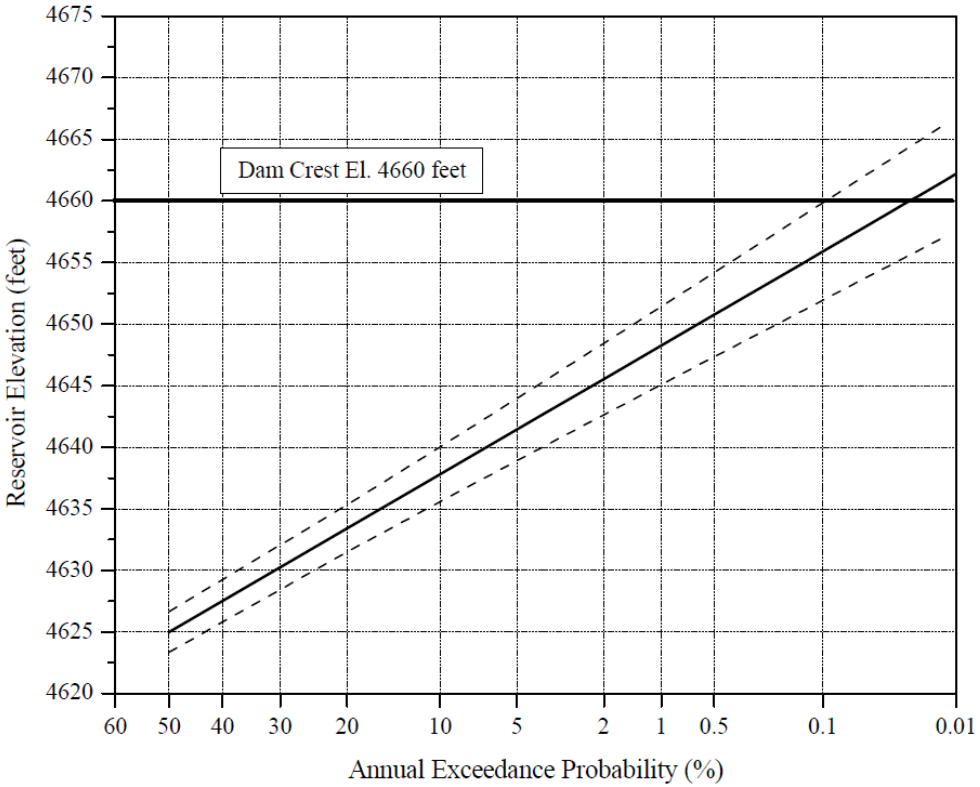
Current State-of-Practice Challenges

- No Communication of Risk and Uncertainty
- Cannot Make Real Risk-Informed Decisions
- Handling of Antecedent Conditions
  - Rain-on-Snow
- PMP (HMR 57)
  - Published in 19
    Methods
- Reservoir Initial P
  - Top of Flood Co
  - Top of Active Co

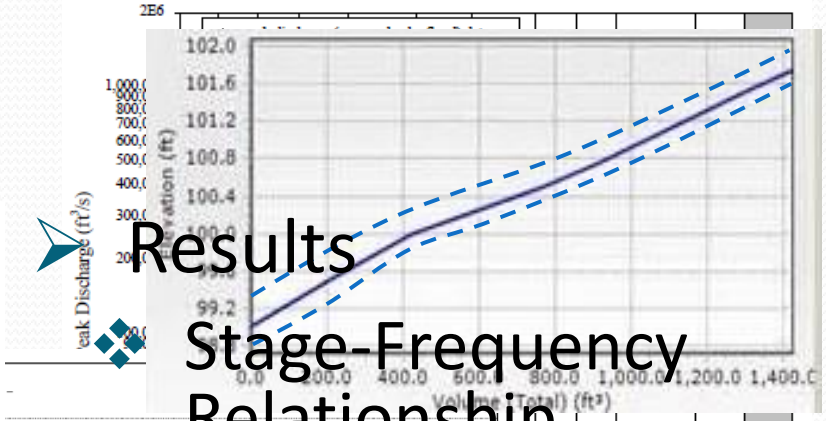


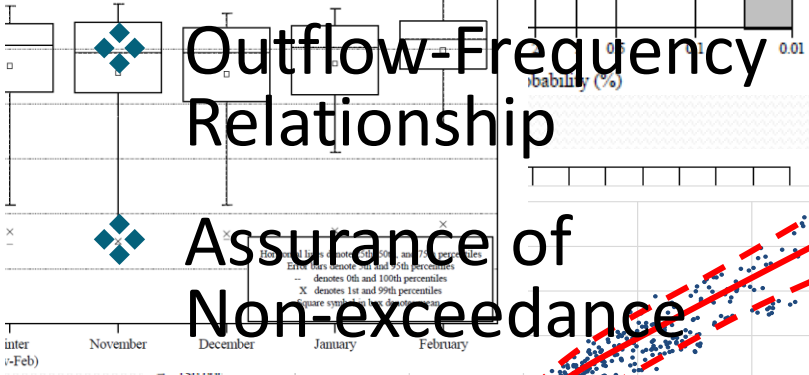
Paradigm Shift in Design Philosophy

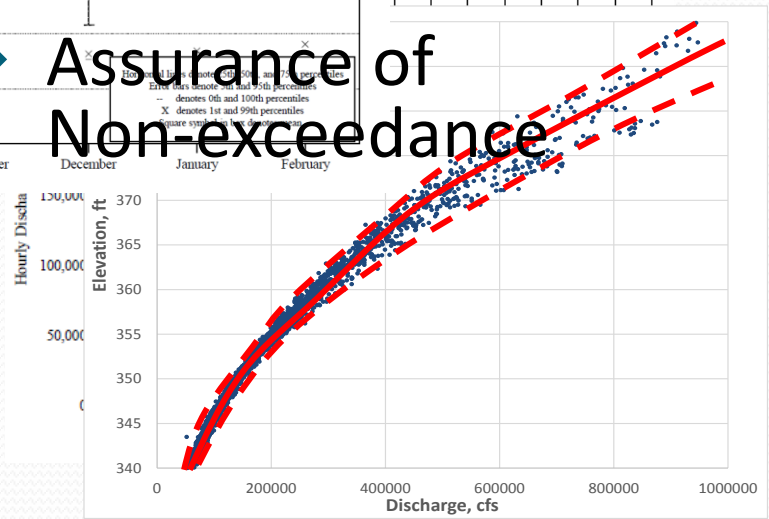
Probabilistic (Risk & Uncertainty)



- Results
  - Stage-Frequency Relationship
  - Outflow-Frequency Relationship
  - Assurance of Non-exceedance







Paradigm Shift in Design Philosophy

Probabilistic Challenges

- Communication of Probability and Statistics
- Resistance to Change
- Time and Cost
- Available Data
- Not Recommended for All Locations
  - Low Hazard Dams

Paradigm Shift in Design Philosophy

Comparison

Site Location	Freeboard (ft)	Return Interval for 90% Assurance
4	**0.8**	**60 YR**
5	2.5	303 YR
6	2.0	35 YR
10	1.9	31 YR
11	2.4	57 YR
13	**4.3**	**16 YR**

Take Home Message

- Various Methods for Estimating Extreme Floods
- Significant Uncertainty in the Estimating Extreme Floods
- Uncertainty Should be Considered in the Design and Analysis of Dam Structures

Thank You!

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