Pitfalls of Risk Analysis in Designing Flood Control Projects

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BIOGRAPHICAL SKETCH

Mr. Countryman worked for the U.S. Army Corps of Engineers from 1966 through 1988 (22 years). His duties included flood control hydrology, hydraulic design, water resources planning, and design of hydraulic structures. In addition, he was involved in the operation of flood control reservoirs in California, and Colorado. In 1988, he joined MBK Engineers and in 1992 became a partner in the firm and is currently the president of MBK Engineers. While at MBK he has worked on a diverse array of flood control projects ranging from reservoir reoperation to the design of flood control facilities. He has also served as an expert witness in numerous flood litigation cases.

EDUCATION:
California State University, San Jose
BS in Civil Engineering, 1966

PROFESSIONAL LICENSES, SOCIETIES AND HONORS:
Registered Civil Engineer, California, 20486
Registered Civil Engineer, Nevada, 8086
Member, American Society of Civil Engineers
Award of Distinction, San Jose State University, College of Engineering

2007 CALIFORNIA EXTREME PRECIPITATION SYMPOSIUM

Pitfalls of Risk Analysis

In Designing Flood Control Projects

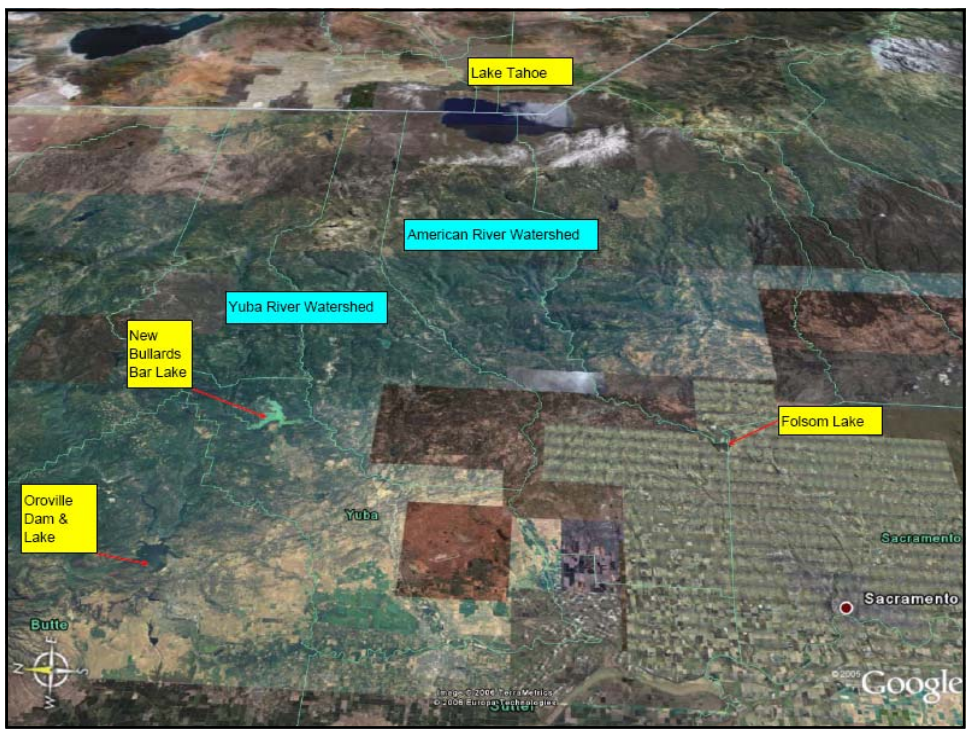
By

Joseph D. Countryman PE, D. WRE

Presented

April 13, 2007

California State University, Sacramento



Risk Analysis

- Account for Uncertainties
- Optimize the Project Net Benefits
- Require Documentation of Safety Factors
- Primarily Used for Economic Evaluation

Design in the Face of Uncertainty

- Uncertainty in Hydrology
- Uncertainty in Hydraulics
- Uncertainty in Maintenance
- Uncertainty in Geotechnical Properties
- Uncertainty in Construction Control
- Uncertainty in Future Economics
- Etc!

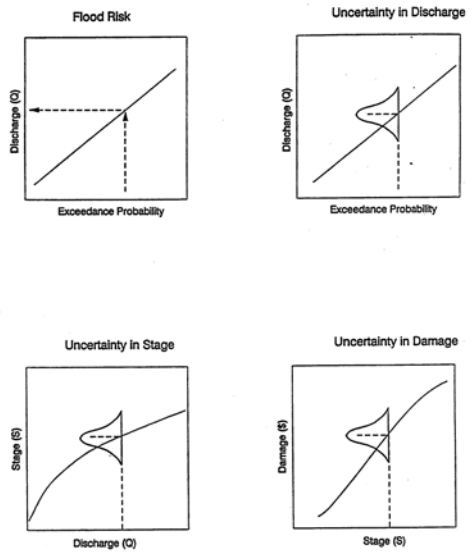


Figure 1. Uncertainity in Discharge, Stage, and Damage

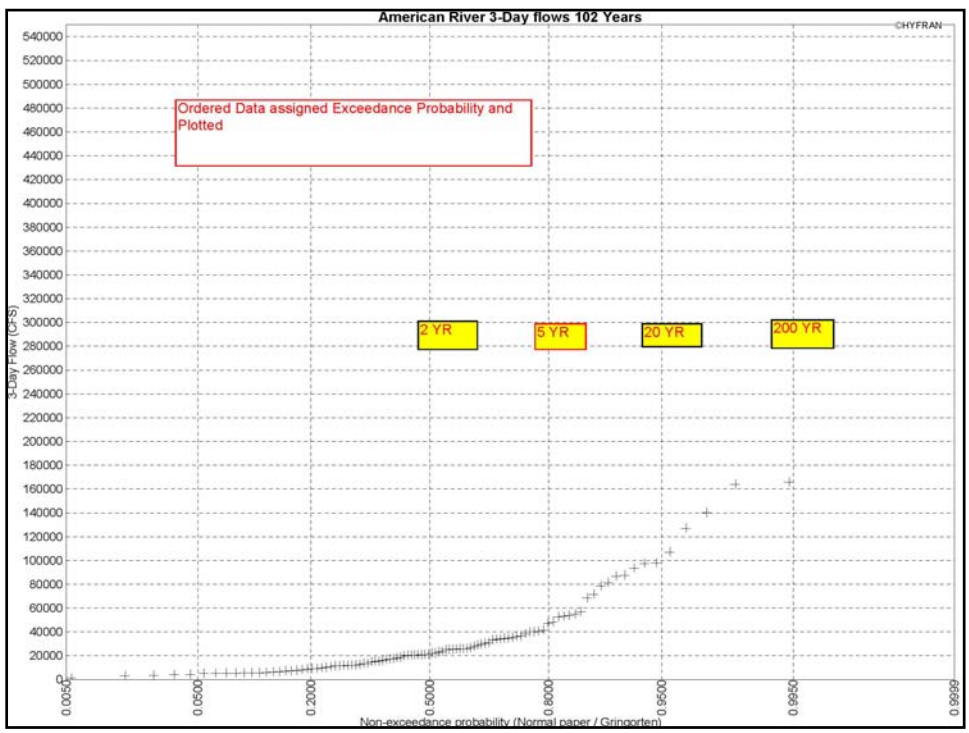
Chart from Corps of Engineers

Hydrology Uncertainty

- Probability Distribution Function
- Extrapolation of Curve Fitting
- Calculation of Uncertainty of the Estimate (Confidence Intervals)

What is a pdf?

- Ordered Data – Assigned Exceedance Probability
- Mathematical Function
  - Curve Fitting of PDF to Data
  - Parameters to adjust PDF
    - Mean
    - Std Dev
    - Skew



Show me a pdf!!!

Log Pearson Type III

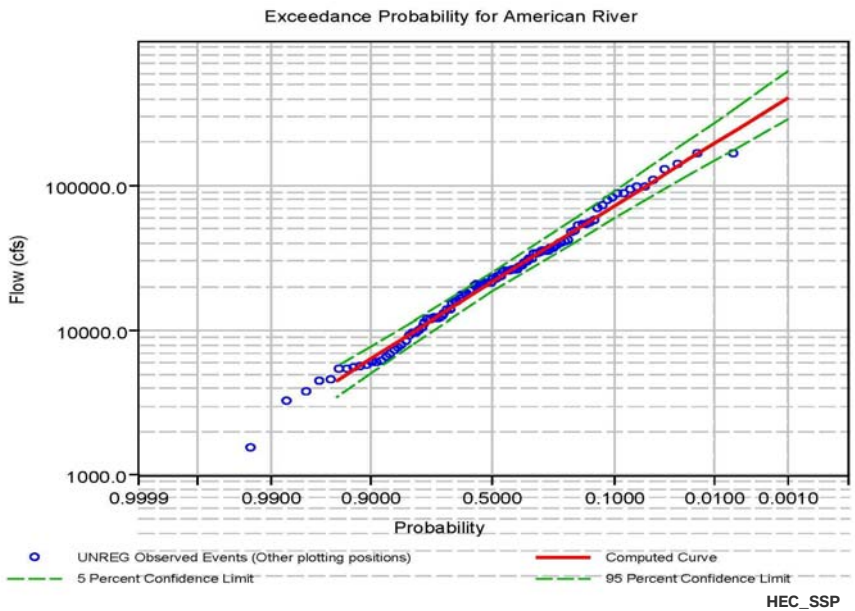
$f_{LP}(u)=k|\alpha|e^{-\alpha(\log_a u-m)}[\alpha(\log_a u-m)]/u\Gamma(\lambda)$; $k=1/\ln a$

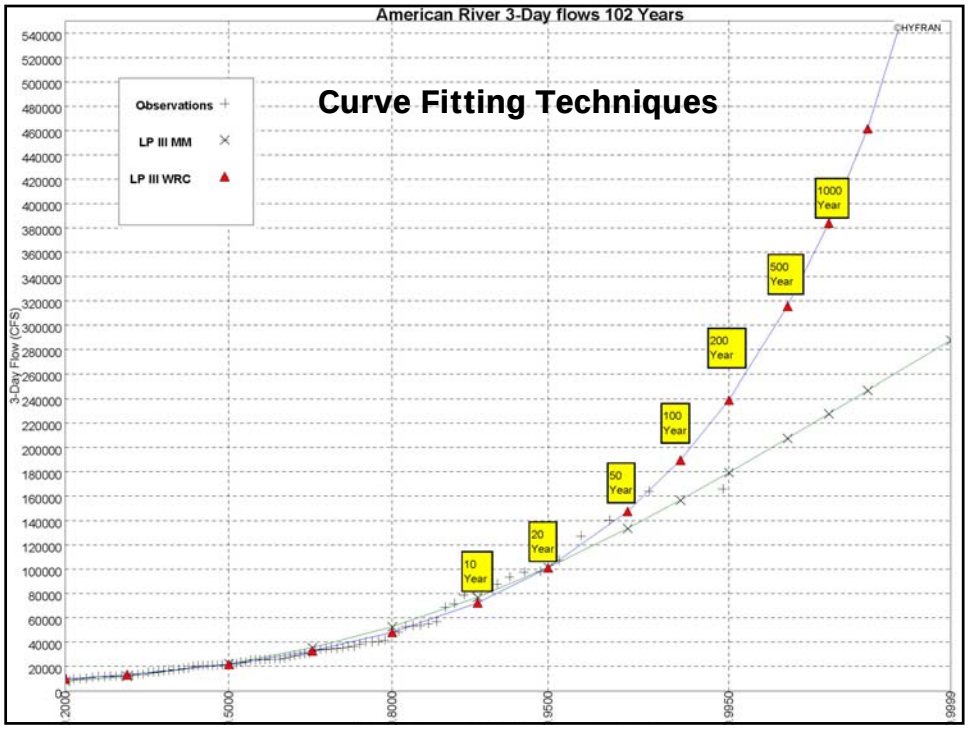
u, α and λ are function parameters that can be used to fit the distribution to the ordered data set

Source: The Gamma Family and Derived Distributions Applied in Hydrology

American River LP III

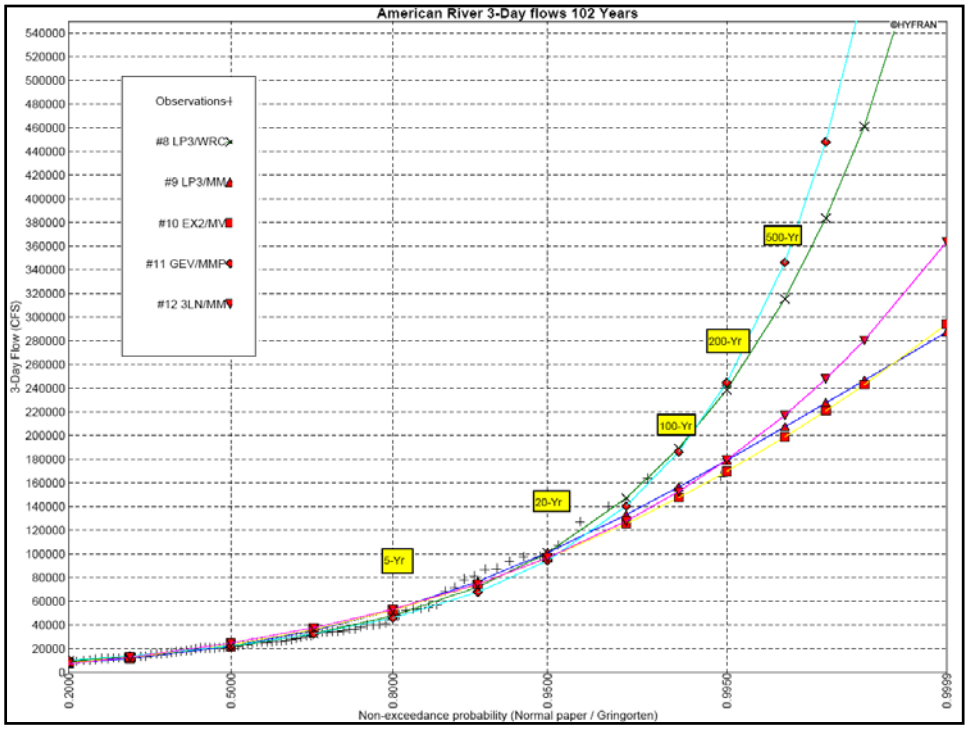
(Log Scale)





Remember This!!!

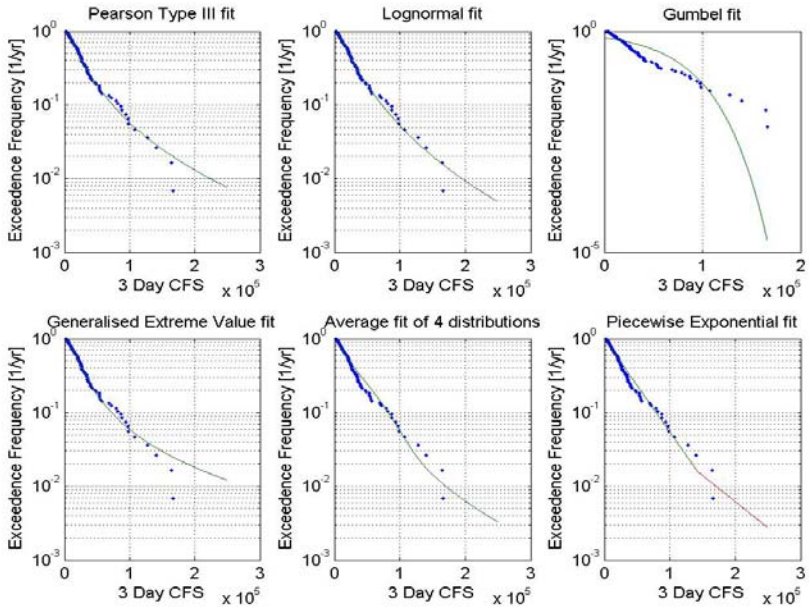
- It is all about curve fitting!!!
- No information about the basic factors of the meteorology or Hydrology of the Watershed is included
- There are many pdfs other than LP III
- Extrapolation of curves is a guess!!!



Approved Procedures

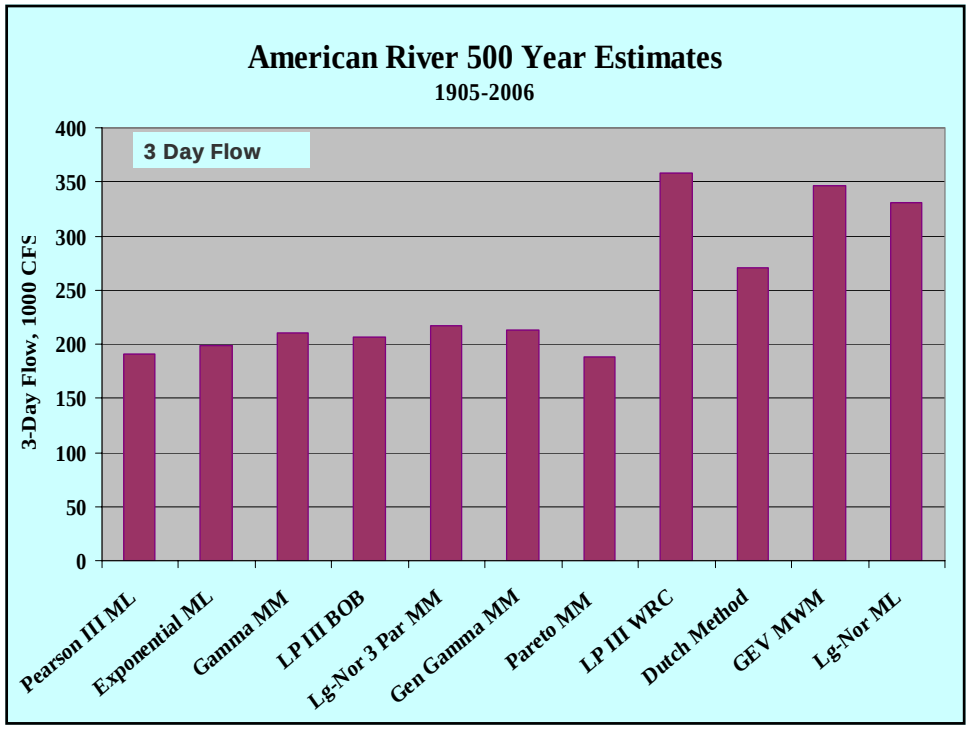
- Bulletin 17B
- Dutch Average 4 pdfs
- Canada has selected another Methodology
- God has not committed on His/Her pdf!!

Dutch Method



What is significance of 500 Year

- ASFPM – Draft Discussion Paper is recommending Replacing the 100-Year FEMA Base Flood with 500-Year Flood
- Congressional Testimony Suggesting Same Change



Vit Klemes

Common Sense and Other Heresies

- " …from a hydrological point of view, very extreme floods and their causes tend to be outliers by definition, i.e., very little, if any, information about their likelihood is contained in the frequencies of relative small floods of which the bulk of a typical flood sample is composed. Extrapolating distribution models fitted to these samples is tantamount to extrapolating the small flood dynamics beyond the range it can physically function."

Bulletin 17B

- "The accuracy of flood probability estimates based upon statistical analysis of flood data deteriorates for probabilities more rare than those directly defined by the period of systematic record. This is partly because of the sampling error of the statistics from the station data and partly because the basic underlying distribution of flood data is not known exactly."
- "All types of analyses should be incorporated when defining flood magnitudes for exceedence probabilities of less than 0.01 (larger than the 100-year)"

Bureau of Reclamation

- "An ultimate goal would be to arrive at a frequency curve that is valid over the entire range of possible flood flows. This of course is not possible because sufficient data do not exist to verify the choice of base distribution. The sample data is only sufficient to provide estimates for the distribution parameters. The errors that are unavoidable in the parameter estimates become intolerable once the frequency curve is extrapolated."

Bureau of Reclamation

- "Practical rule-of-thumb knowledge, which is supported by statistical calculation, indicated that frequency curves are reasonably reliable out to return periods of about the sample record length…"

How does Corps Risk Analysis Deal with pdf Uncertainty

- It doesn't!!!!!
- Corps Risk Analysis assumes Bulletin 17B made this final determination

Remember This!!!

- It is all about curve fitting
- No information about the basic factors of the meteorology or Hydrology of the Watershed is included
- There are many pdfs other than LP III and many different methods of applying these pdfs
- Extrapolations are guesses!!!!!

Confidence Intervals

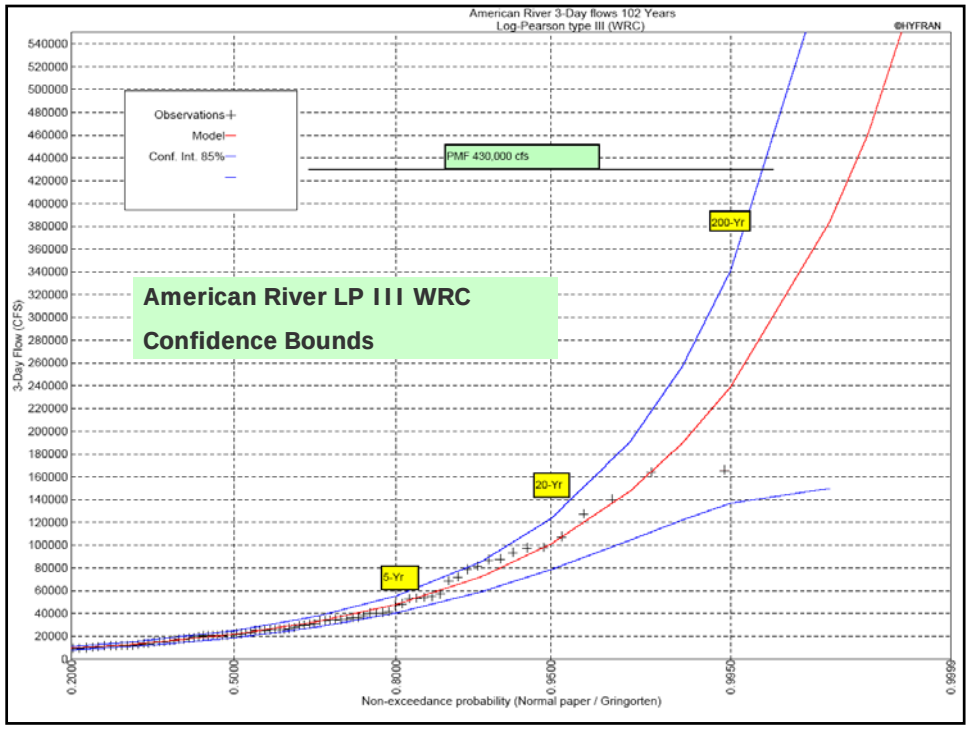
- A way to measure the Uncertainty of the Estimate based on sampling error
- Assumes the pdf chosen is a true representation of the Flood Data population
- Unproven Validity for Real Flood Data

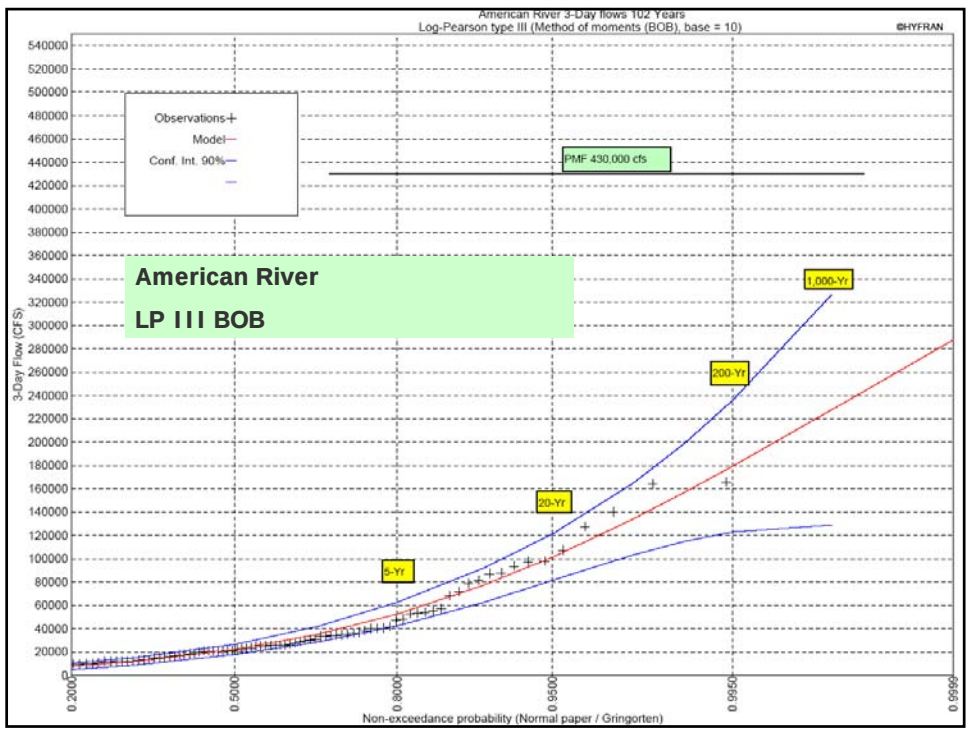
Do You Want to Certify Your Levee Based on 90% Confidence Bounds?

- The Corps has abandoned the use of Best Estimate Water Surface Elevation + Freeboard for levee certification
- They have adopted a 90% Conditional Non-Exceedance Standard (Confidence Intervals)

What do Confidence Bounds Look Like?

- Very Impressive!!!
- Impossible to verify


American River 3-Day flows 102 Years
Log-Pearson type III (WRC)
©HYFRAN
Observations
Model
Conf. Int. 85%
PMF 430,000 cfs
200-Yr
20-Yr
5-Yr
American River LP III WRC
Confidence Bounds
3-Day Flow (CFS)
Non-exceedance probability (Normal paper / Gringorten)


American River 3-Day flows 102 Years
Log-Pearson type III (Method of moments (BOB), base = 10)
©HYFRAN
Observations
Model
Conf. Int. 90%
PMF 430,000 cfs
1,000-Yr
200-Yr
20-Yr
5-Yr
American River
LP III BOB
3-Day Flow (CFS)
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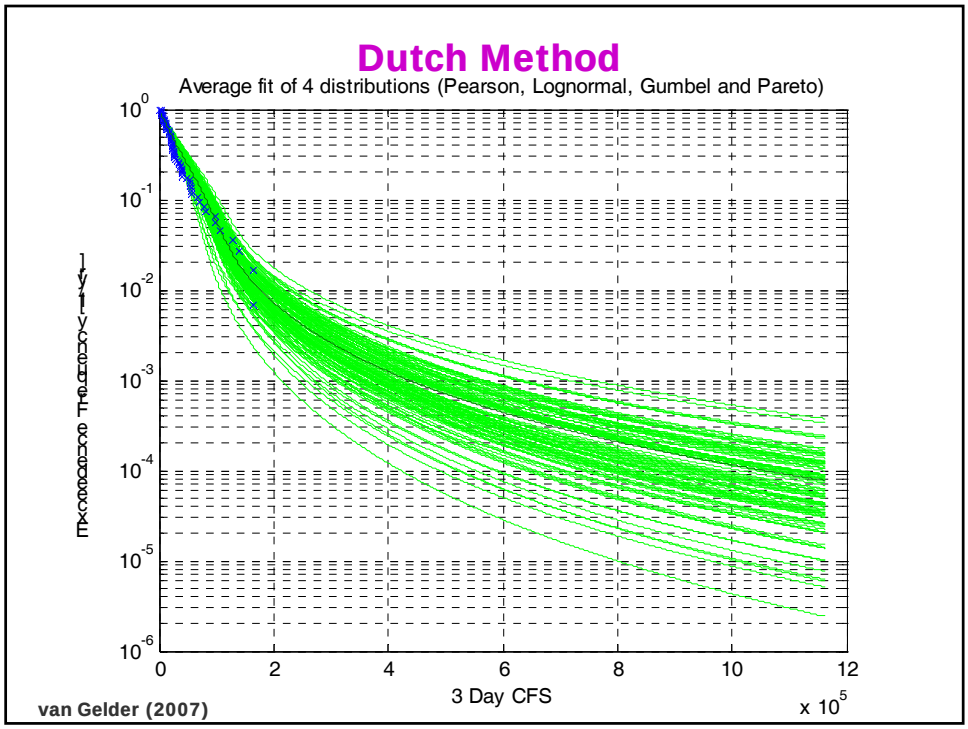
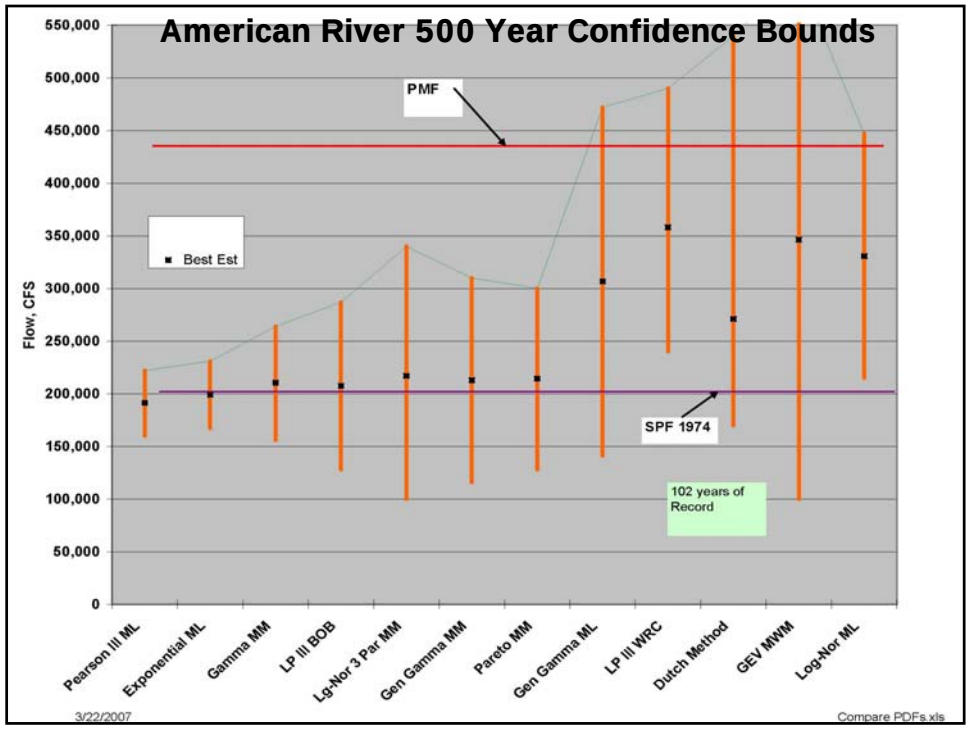
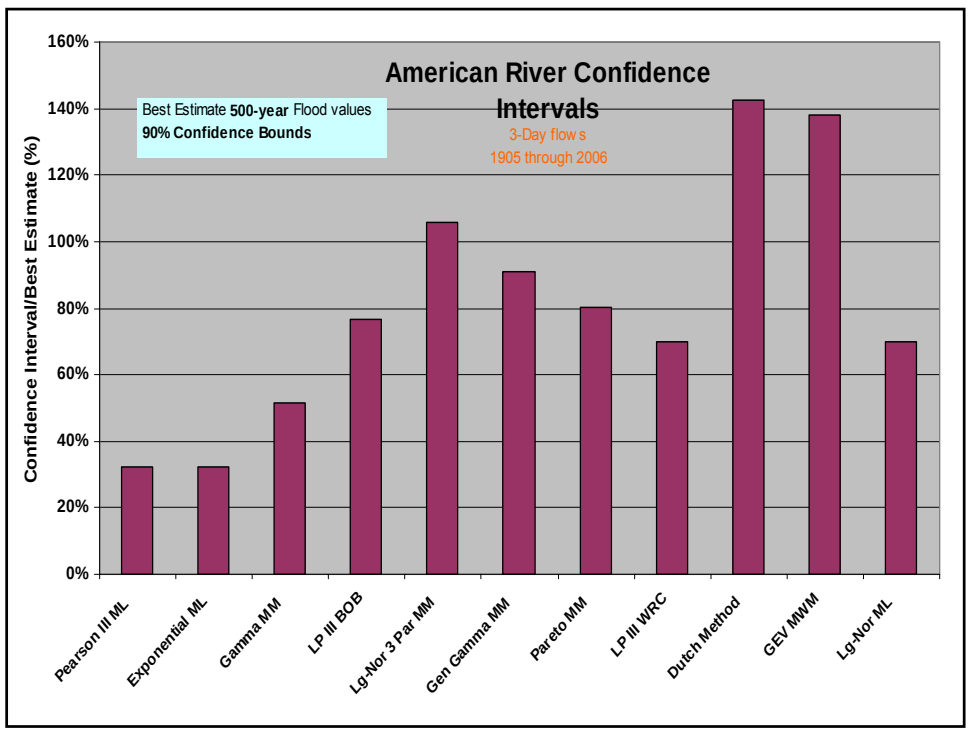


Do You Believe in Confidence Intervals?

- Upon What is your Belief Based?
- If you believe, Shouldn't you Select the pdf that has the least uncertainty (narrowest Confidence Bounds) ?


American River 500 Year Confidence Bounds
PMF
Best Est
SPF 1974
102 years of Record
Flow, CFS
550,000
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Pearson III ML
Exponential ML
Gamma MM
LP III BOB
Lg-Nor 3 Par MM
Gen Gamma MM
Pareto MM
Gen Gamma ML
LP III WRC
Dutch Method
GEV MWM
Log-Nor ML
3/22/2007
Compare PDFs.xls


American River Confidence Intervals
3-Day flows
1905 through 2006
Best Estimate 500-year Flood values
90% Confidence Bounds
Confidence Interval/Best Estimate (%)
160%
140%
120%
100%
80%
60%
40%
20%
0%
Pearson III ML
Exponential ML
Gamma MM
LP III BOB
Lg-Nor 3 Par MM
Gen Gamma MM
Pareto MM
LP III WRC
Dutch Method
GEV MWM
Lg-Nor ML

CAUTION!!!!

- FEMA Levee Certification Based on Confidence Intervals Needs a Great deal of Discussion Before Adoption

Risk Analysis

- Is here to stay!
- Much more research and documentation of Uncertainty Estimates needs to be conducted
- Limit RA to Economic Evaluation
- Do Not Use Confidence Bounds for levee certification until validity of procedure can be documented