Status of the Hydrologic Frequency Analysis Work Group (HFAWG)

Report to the Subcommittee on Hydrology

August 19, 2013

Will Thomas

Chair of the HFAWG

Baker

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Objectives of Presentation

- Provide a brief history of the HFAWG and how we got to this point
- Discuss why new statistical procedures, like the Expected Moments Algorithm (EMA), are needed in Bulletin 17B
- Discuss the recommended changes in Bulletin 17B as proposed by the HFAWG
- Note the major points of the Minority Report
- Provide some comparison of results for EMA and Bulletin 17B
- Path forward – draft Bulletin 17C

Hydrologic Frequency Analysis WG

- Established December 1999 under the Subcommittee on Hydrology of the Advisory Committee on Water Information
- First meeting in January 2000
- Representatives from Federal agencies, private consultants, academia, water management agencies

- http://acwi.gov/hydrology/Frequency/
- http://water.usgs.gov/osw/bulletin17b/bulletin_17B.html

HFAWG Membership, from Web Site

Name	Organization
Siamak Esfandiary	Federal Emergency Management Agency
Don Woodward	Global Ecosystems Center
Martin Becker	
Will Thomas	Michael Baker, Jr. (Chair)
Zhida Song-James	Michael Baker, Jr.
Tim Cohn	U.S. Geological Survey
Beth Faber	U.S. Army Corps of Engineers
John England	U.S. Bureau of Reclamation
Jerry Coffey	
Joe Krolak	Federal Highway Administration
William Merkel	Natural Resources Conservation Service
Sanja Perica	National Weather Service
Jery Stedinger	Cornell University
Thomas Nicholson	Nuclear Regulatory Commission
Samuel Lin	Federal Energy Regulatory Commission
Rocky Durrans	University of Alabama
Mike Eiffe	Tennessee Valley Authority

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Hydrologic Frequency Analysis WG

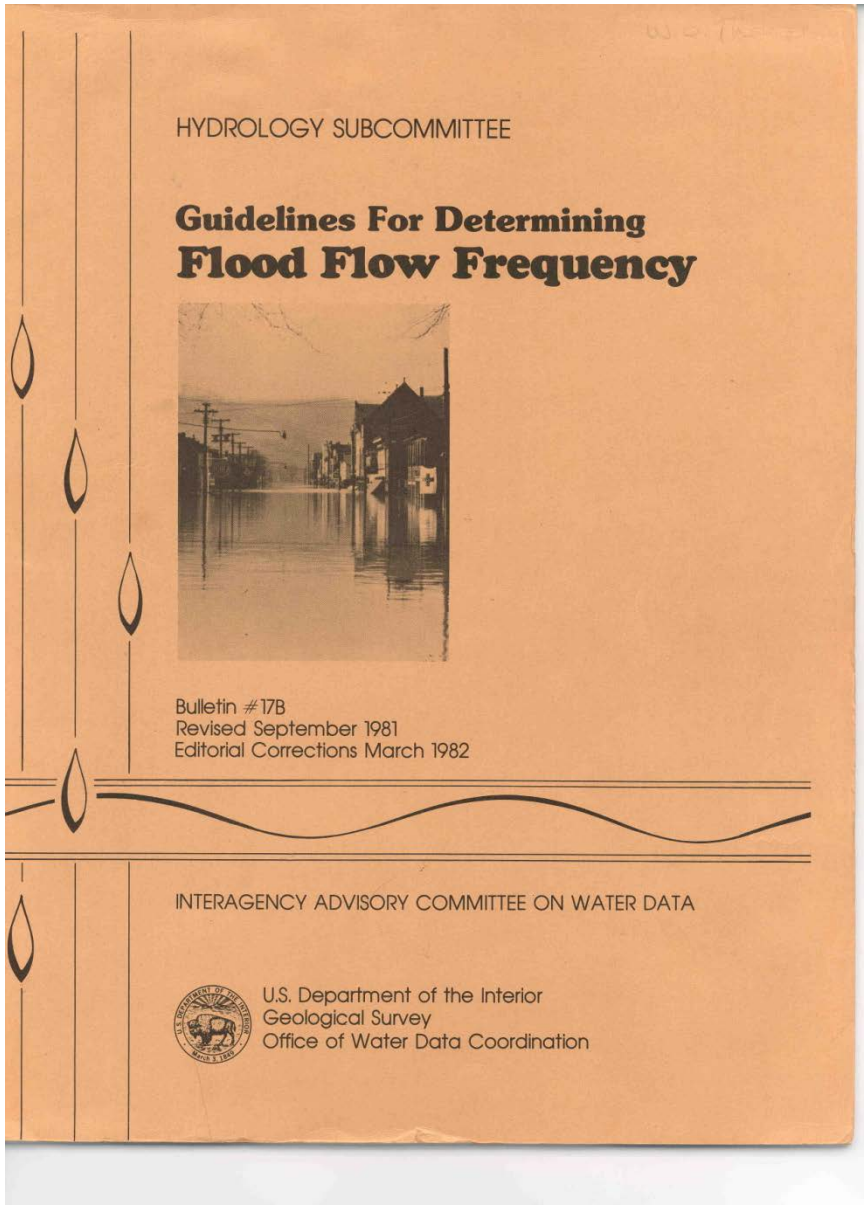
Purpose: **"The overall goal of the Hydrologic Frequency Analysis Work Group (HFAWG) is to recommend procedures to increase the usefulness of the current guidelines for Hydrologic Frequency Analysis computations (e.g. Bulletin 17B) and to evaluate other procedures for frequency analysis of hydrologic phenomena."**

http://acwi.gov/hydrology/FA_terms.html

Existing Bulletin 17B Guidelines

Published in March 1982, based on research from 1960s and 1970s:

- Fitting Pearson Type III distribution to logs of annual peak flows
- Estimating generalized skew
- Weighting generalized skew with station skew
- Low- and high-outlier detection tests
- Conditional probability adjustment for low outliers
- Adjustments for historical flood information



Possible Improvements to Bulletin 17B

- In November 2005, the HFAWG identified possible improvements in Bulletin 17B (continue use of log-Pearson Type III distribtion)
- The four major improvements are related to:
  - Improved procedures for analyzing historical floods and paleoflood data
  - Improved procedures for analyzing low outliers and zero flow data
  - Improved procedures for estimating generalized/regional skew
  - Improved procedures for estimating confidence intervals

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Improved Procedures

- A major effort of the HFAWG was the testing and evaluation of a new technique for estimating the parameters of the Pearson Type III distribution – Expected Moments Algorithm (EMA) (Cohn et al., 1997), and
- A new Multiple Grubbs-Beck (MGB) test for identifying potentially influential low flows
- Why is EMA/MGB needed in the Bulletin 17B flood frequency analysis?

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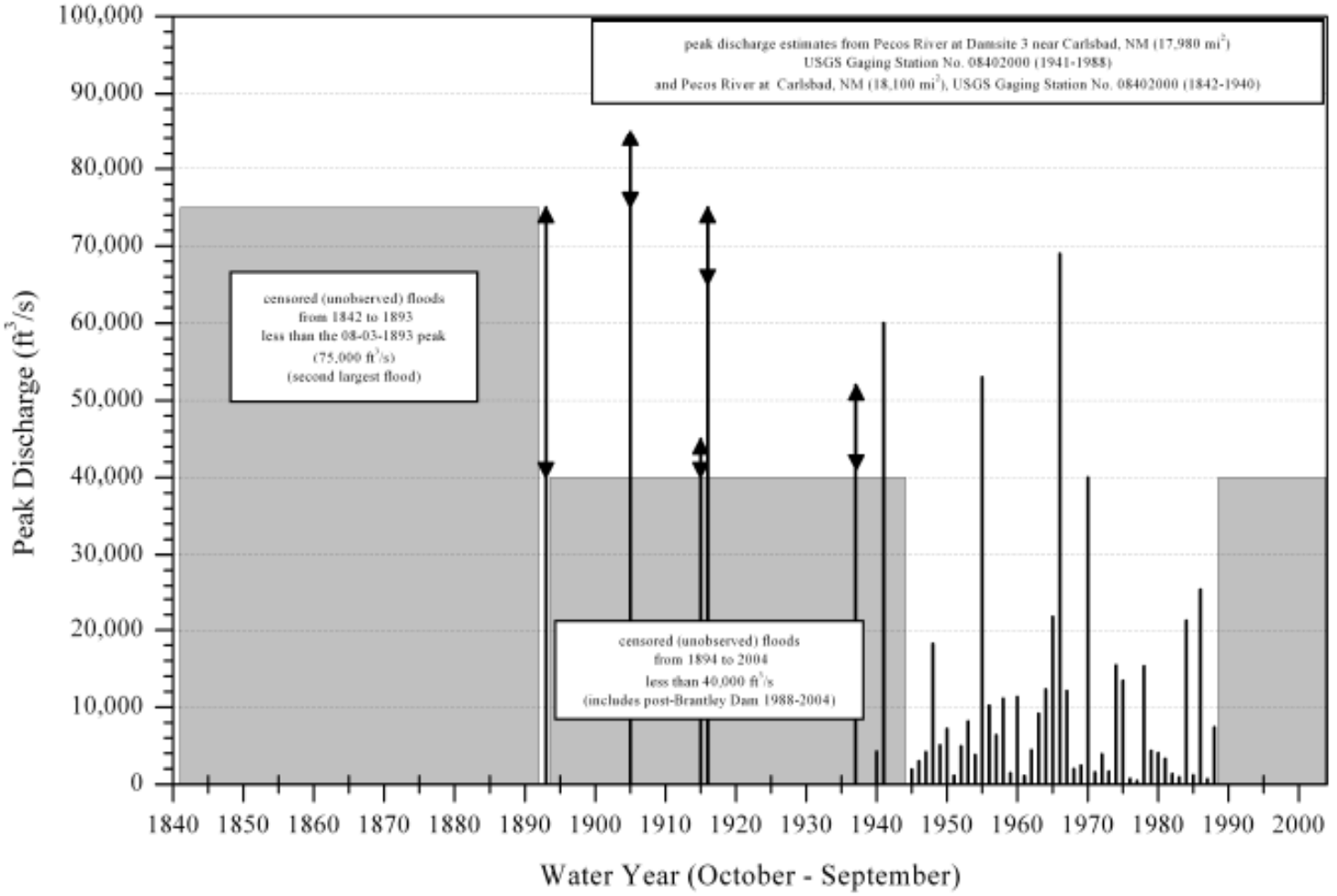
Research Conclusions

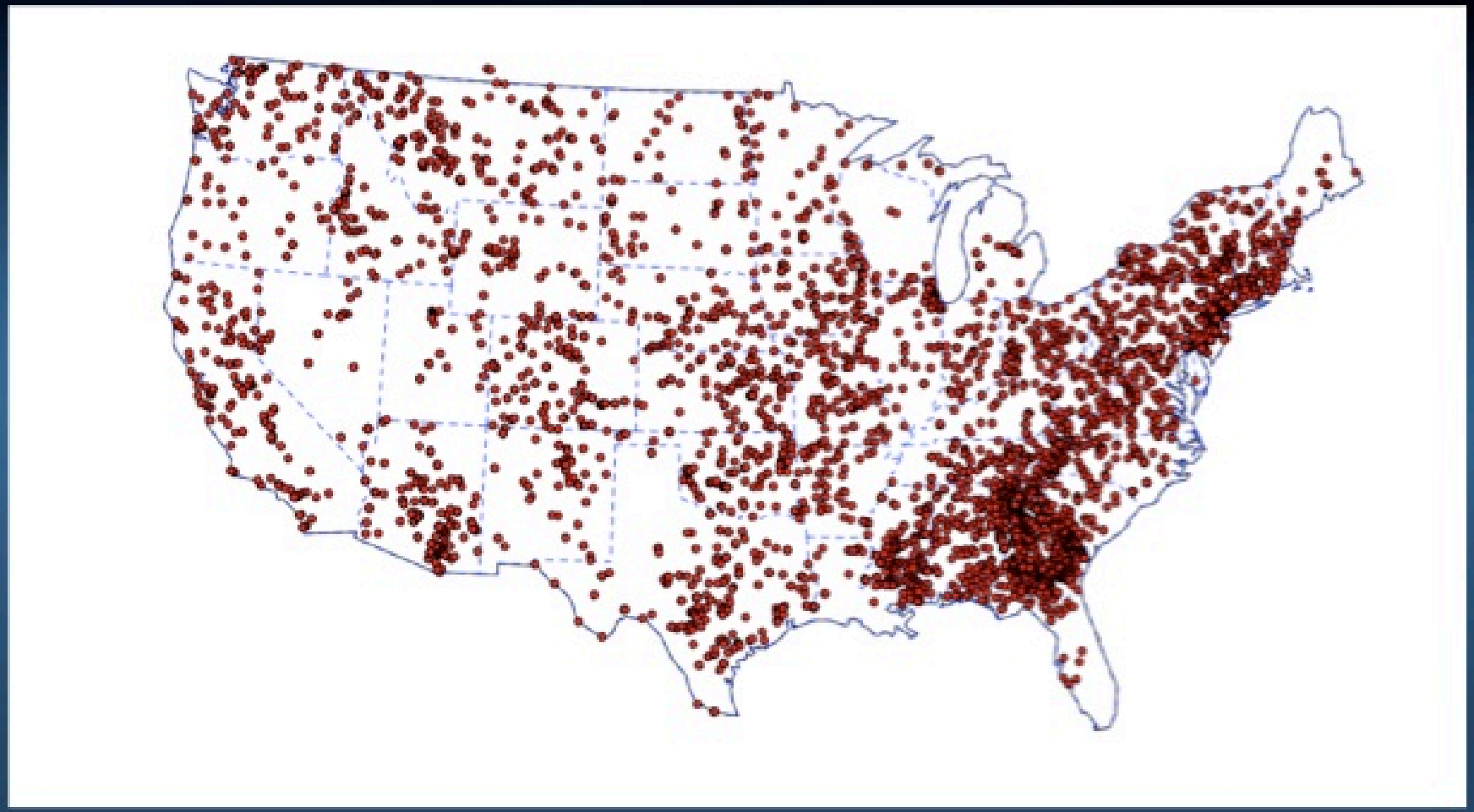
Between 1982-2012, analytical and simulation studies have been conducted suggesting that:

- **B17B, as usually employed, is *not efficient* with respect to**
  - **Historical information**
  - **Regional (skew) information**
- **B17B does not deal with interval data or multiple thresholds**
- **B17B confidence limits are inaccurate**
- **"Relatively modest changes" would make B17B competitive with best alternatives**

Multiple thresholds and interval data



Sites with “Historic” Data



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Treatments for Data Problems

Problem	Remarks	B17B	Proposed
No Data?	Regional equations and models; 2-station comparison, etc.		
Zeros, Below Base Q's	5% of sites overall 20 typical for SW	Conditional Probability Adjustment (CPA)	New Multiple LO test and Interval Data
Low outliers	20-30% of sites, more in West	Grubbs-Beck, CPA	Interval Data
Historic Data	20-30% of sites	Historic Adjustment	Interval Data
Data Inaccuracies	Currently report on point data	???	Interval Data
Parameter instabilities	Mainly short records with HO	Regional Skew Map	New Skew Map New SD relations

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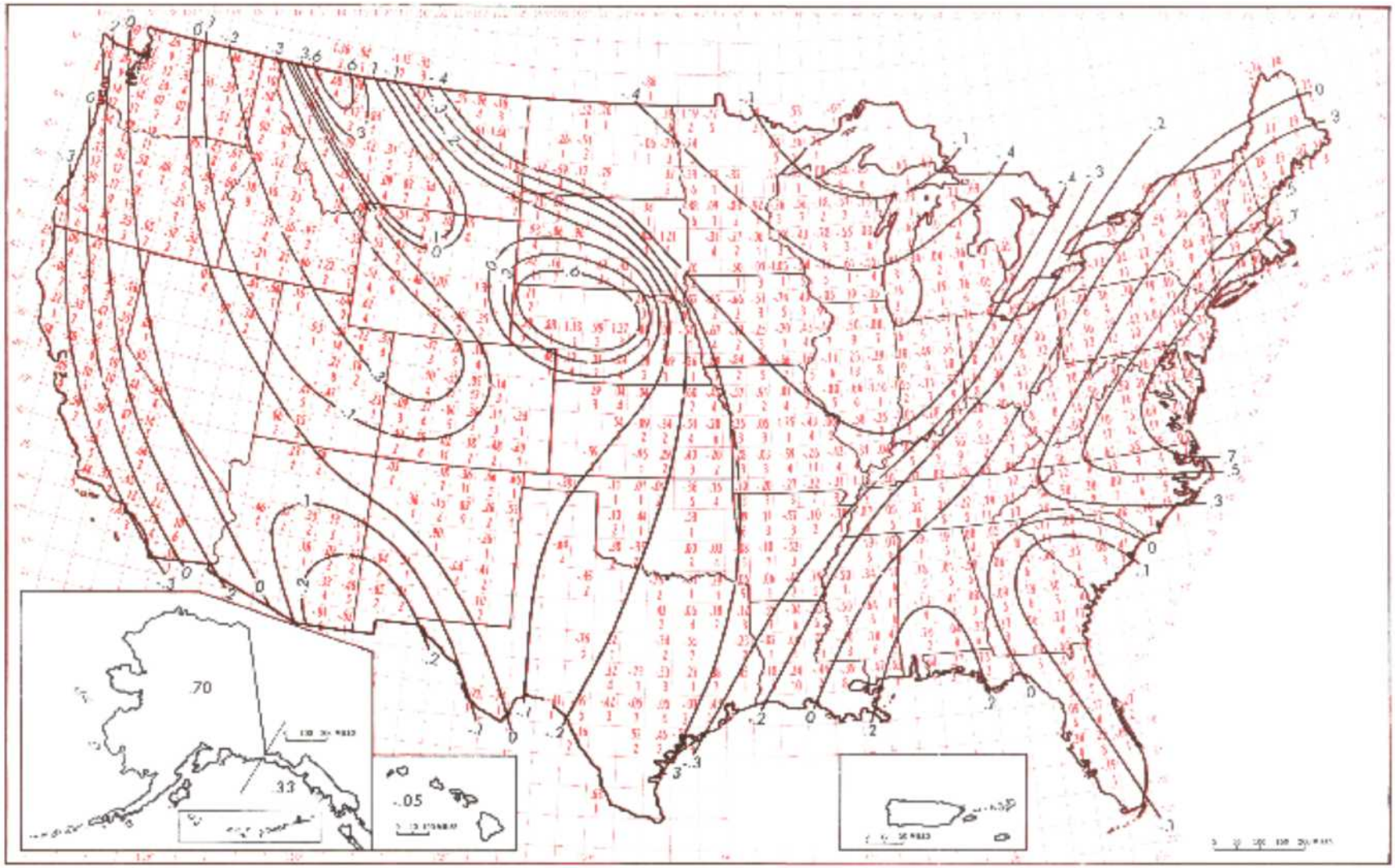
Regional Skew - B17B Skew Map



GENERALIZED SKEW COEFFICIENTS OF LOGARITHMS OF ANNUAL MAXIMUM STREAMFLOW

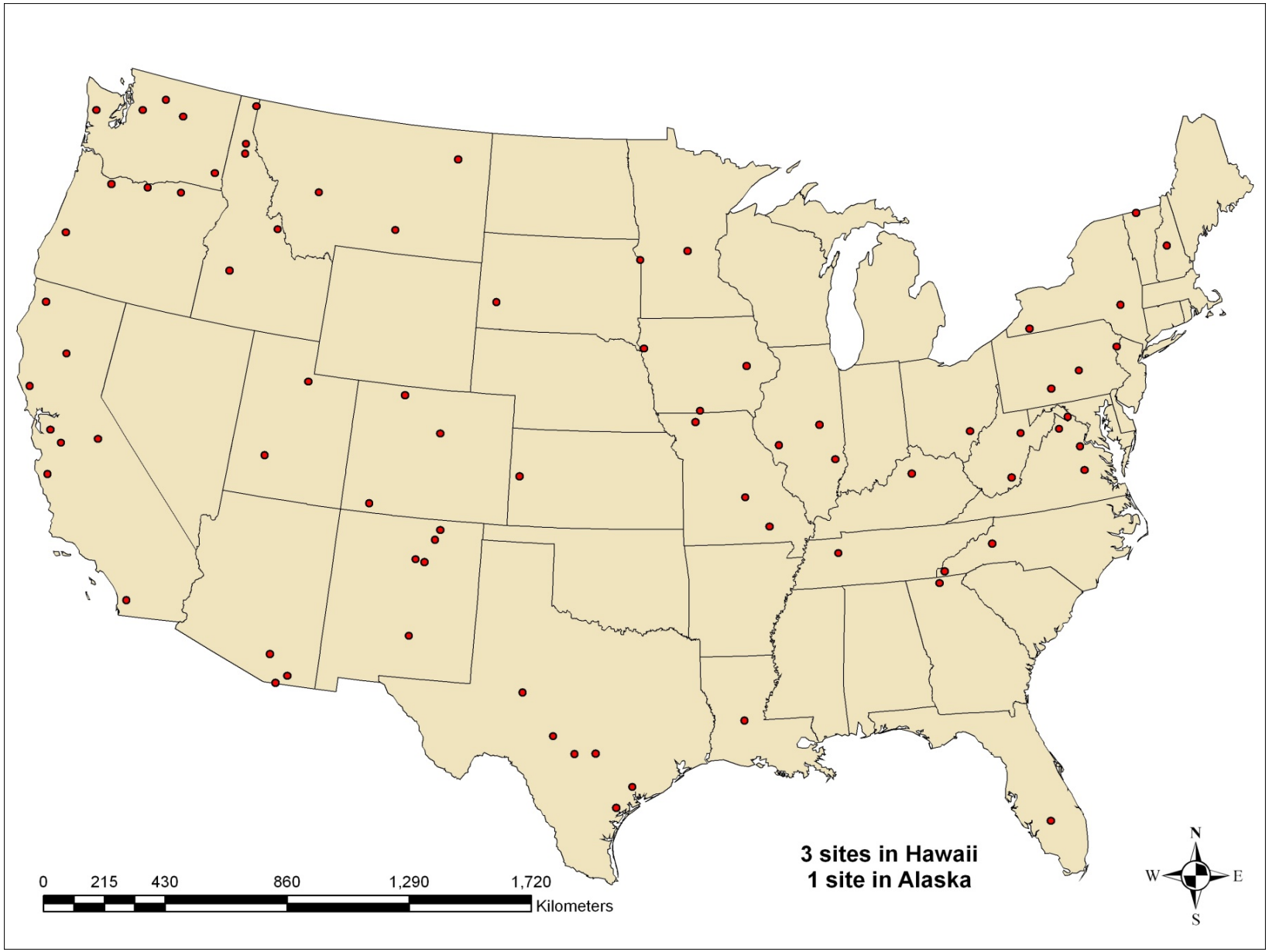
AVERAGE SKEW COEFFICIENT BY ONE DEGREE QUADRANGLES

Lower number in each quadrangle is number of stream gaging stations for which the average shown above it was computed

HFAWG Testing Approach

- In August 2007, a plan for testing EMA was finalized by the Data Group and included two approaches:
  - Observed data – analysis of 82 long-term gaging stations with historic peaks, high and low outliers
  - Monte Carlo simulation – simulate data from assumed frequency distributions (LP III with negative and positive skews, mixed distributions, etc.)
- The USGS and USBR took the lead in testing EMA and comparing to Bulletin 17B techniques

Location of 82 Long-Term Gaging Stations



HFAWG Progress and Meetings

- HFAWG meeting in November 2009 discussed test results on observed data at the 82 gaging stations
- In the Fall of 2011, Testing Group (USGS, USBR, USACE, Cornell University) completed testing on simulated and (updated) observed data (82 stations)
- HFAWG meeting in March 2012 discussed test results for both simulated and observed data that were documented in a March 8, 2012 report – Updating Bulletin B17B for the 21st Century (on HFAWG web site)

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HFAWG Progress and Meetings

- March 2012 test results based on MGB test for identifying low flows – some felt the MGB test identified too many low flows
- HFAWG meeting in September 2012 discussed a new MGB test suggested by Cornell University that identified fewer low flows
- Action items from September 2012 meeting were to:
  - Rerun the test results with the new MGB test
  - Update the March 8, 2012 Testing Report

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Change in Approach

- **Bulletin 17B defined outliers as**
  - **"Data points which depart significantly from the trend of the remaining data."**

- **The new approach is to identify low flows that have high leverage (influence) on the upper end of the frequency curve – Potentially Influential Low Flows (PILFs)**

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HFAWG Progress and Meetings

- April 19, 2013 – new testing results documented in a report to HFAWG, review comments requested
- June 10, 2013 – responses to review comments sent to HFAWG
- June 12, 2013 – HFAWG meeting discussed the testing results, the comments on the April 19 report and the recommended changes to Bulletin 17B
- July 29, 2013 – Recommendations Memorandum and revised Testing Report (renamed Evaluation of Recommended Revisions to Bulletin 17B) was provided to SOH members

HFAWG Progress and Meetings

- At the June 12, 2013, HFAWG adopted the recommended changes (to be discussed) for Bulletin 17B by 12 to 1 vote
  - 13 of 16 voting members were in attendance
  - 13 members represent 8 Federal agencies and 5 non Federal members
  - Vote was 12 to 1 in favor of adopting the recommended changes (Jerry Coffey only No vote)
- Jerry Coffey submitted a Minority Report that was provided to SOH members on July 29, 2013

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Other Progress and Improvements

- USGS developed PeakFQ 7.0 program that implements EMA/MGB
- Software available from John England's ftp site (ftp://ftp.usbr.gov/england/HFAWG/software)
- USGS conducted two webinars on PeakFQ 7.0 on April 25 and May 1, 2013
- Paper on MGB test accepted by Water Resources Research, available from the web but not published yet

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Proposed Changes to Bulletin 17B

1. Replace Historical-Weighted-Moments and Conditional-Probability-Adjustment (CPA) with Expected-Moments-Algorithm (EMA)

2. Generalize Grubbs-Beck (GB) test to new Multiple Grubbs-Beck (MGB) test

3. Replace confidence interval formulas that do not consider the uncertainty in skew with EMA computations based on weighted skew and its uncertainty.

4. Revise guidelines for estimation of generalized (regional) skew estimators

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Proposed Changes to Bulletin 17B

5. Replace single-threshold plotting position with multiple-threshold plotting position (Hirsch and Stedinger, 1987)

6. Replace outdated statements on "Climate Trends" with a revised statement reflecting current understanding of climate change

7. Remove discussion of "Expected Probability" since it is no longer used

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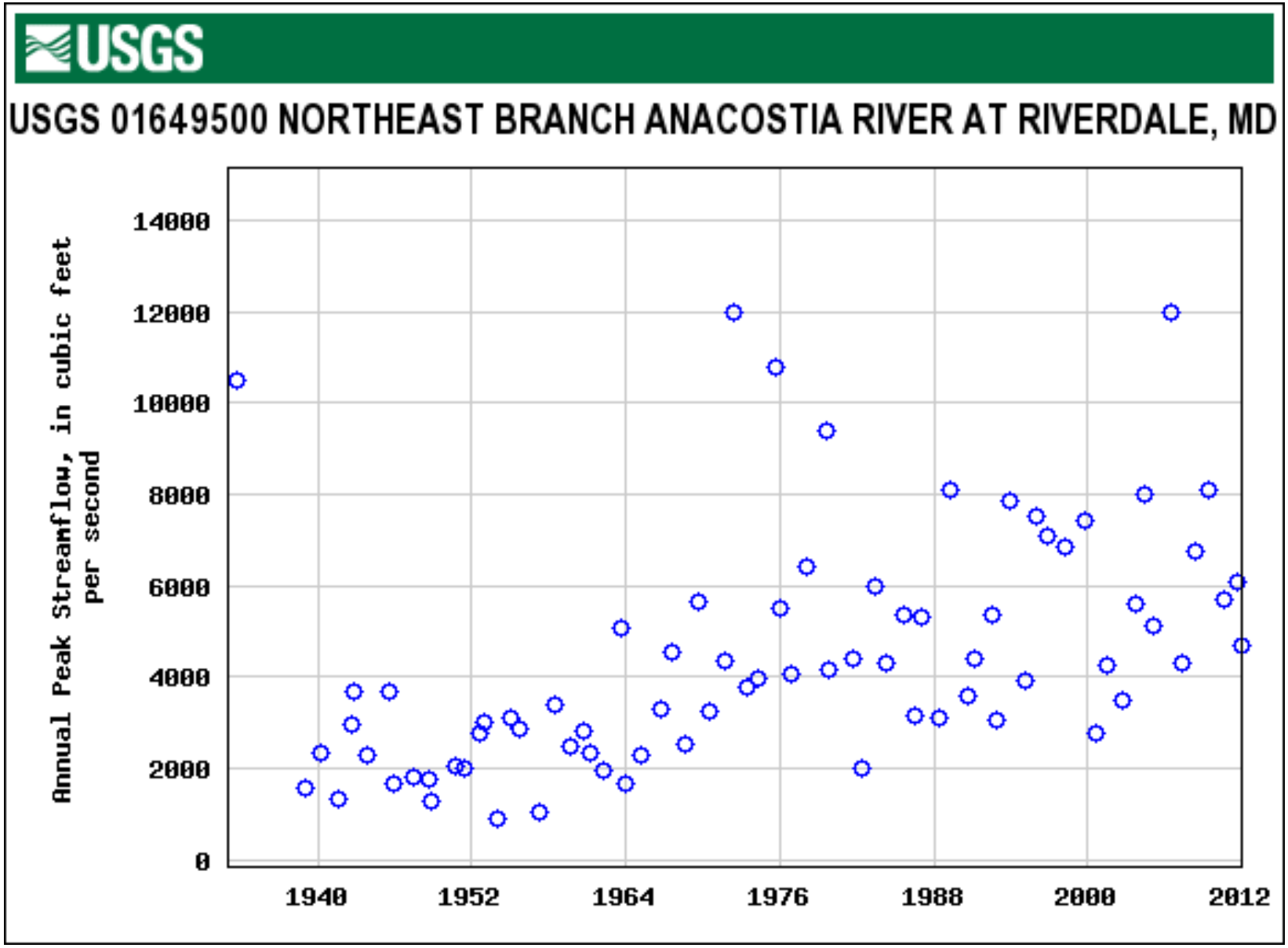
Proposed Statement on Climate Change

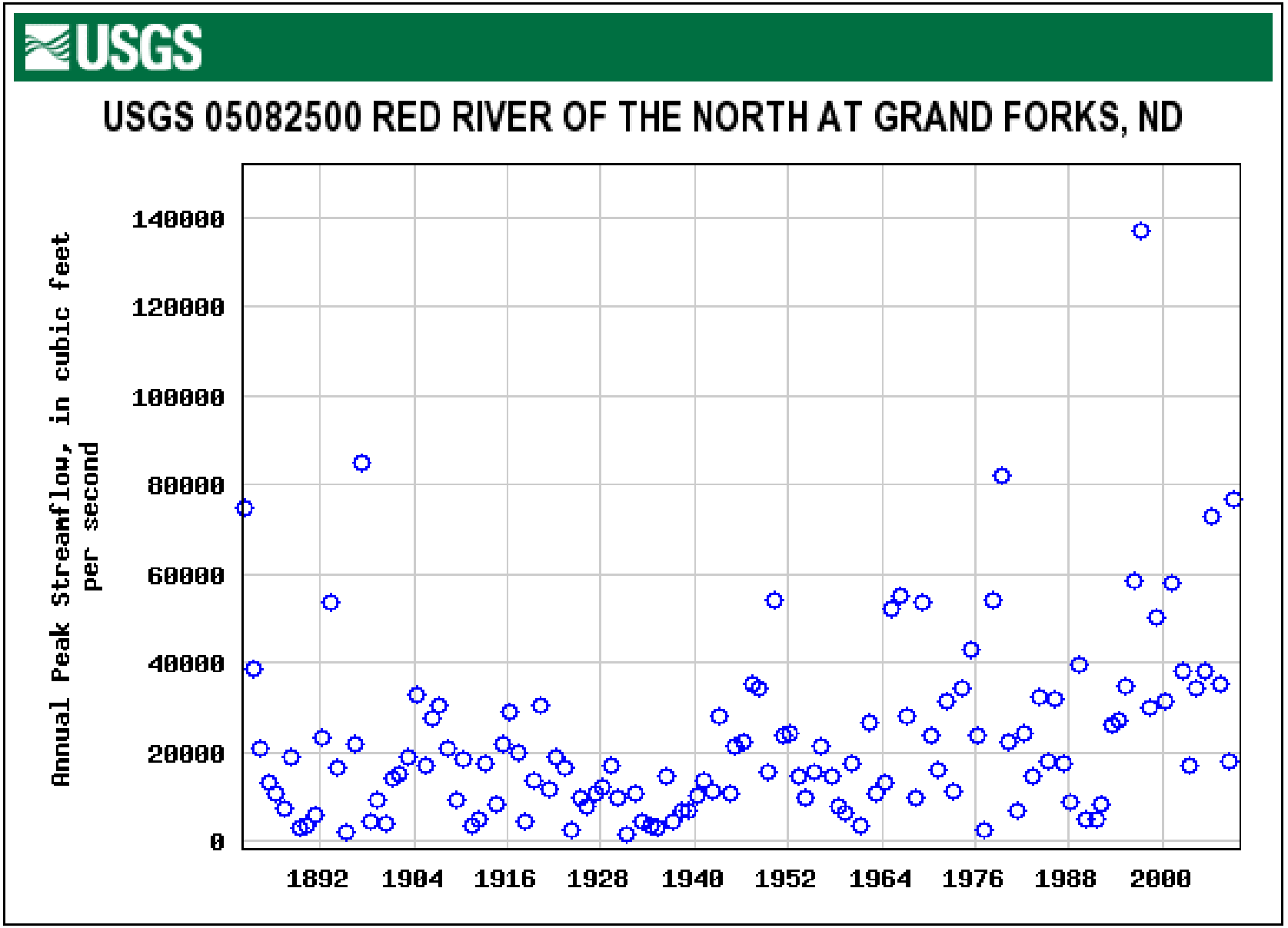
Climate Change

There is much concern about changes in flood risk associated with climate variability and long-term climate change. Time invariance was assumed in development of this guide. In those situations where there is sufficient scientific evidence to facilitate quantification of the impact of climate variability or change on flood risk, this knowledge should be incorporated in flood frequency analysis by employing time-varying parameters or other appropriate techniques. All such methods need to be thoroughly documented and justified.

Non stationarity Due to Land Use Change



Climatic Variability or Climate Change??



Minority Report by Jerry Coffey

- Three major issues in Jerry's Minority Report are Stationarity, Variance and Mixtures – responses are from the Chair, HFAWG
- Stationarity Issues – responses follow
  - Is a relevant issue but equally affects Bulletin 17B and EMA
  - Will be addressed in future technical guidance
  - Cyclic patterns in flood data are a result of climatic variability (wet and dry periods)

Minority Report by Jerry Coffey

- Variance Issues – responses follow
  - Variance of the slope of the frequency curve has been accounted for
  - Uncertainty in systematic and historical floods can be accounted for through EMA
  - Censoring of multiple low peaks has not increased the variance of the flood estimates (see next slide from presentation by Jery Stedinger)

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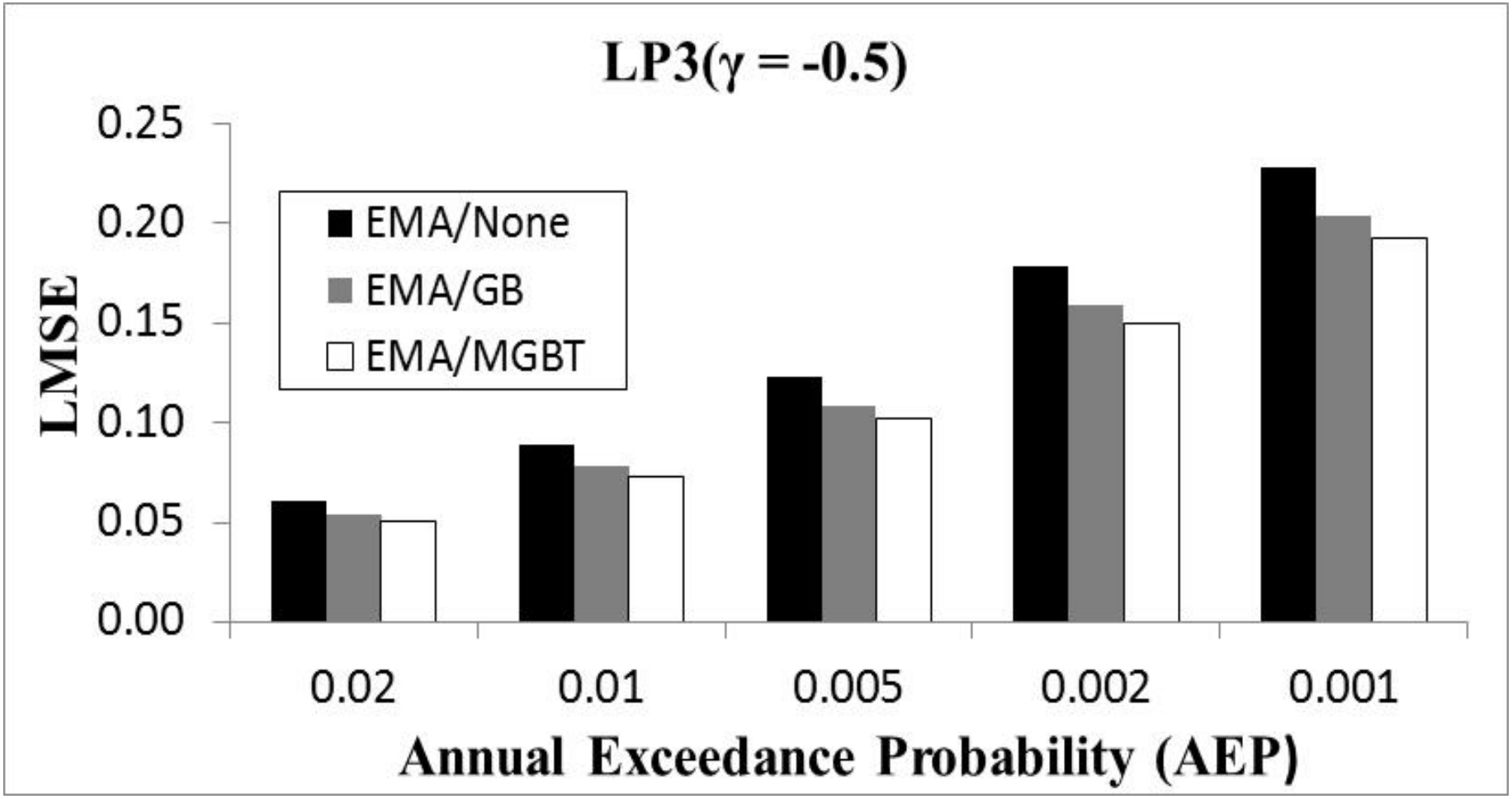
Monte Carlo Analysis of MSE($\hat{Q}_t$) LP3(γ = -0.5)



Minority Report by Jerry Coffey

- **Mixtures Issues – responses follow**
  - **Mixtures of flood data from different meteorological events are real**
  - **Mixed populations are addressed in Bulletin 17B and will be addressed in Bulletin 17C**
  - **Solution is to fit different distributions to the mixed populations and then combine them**

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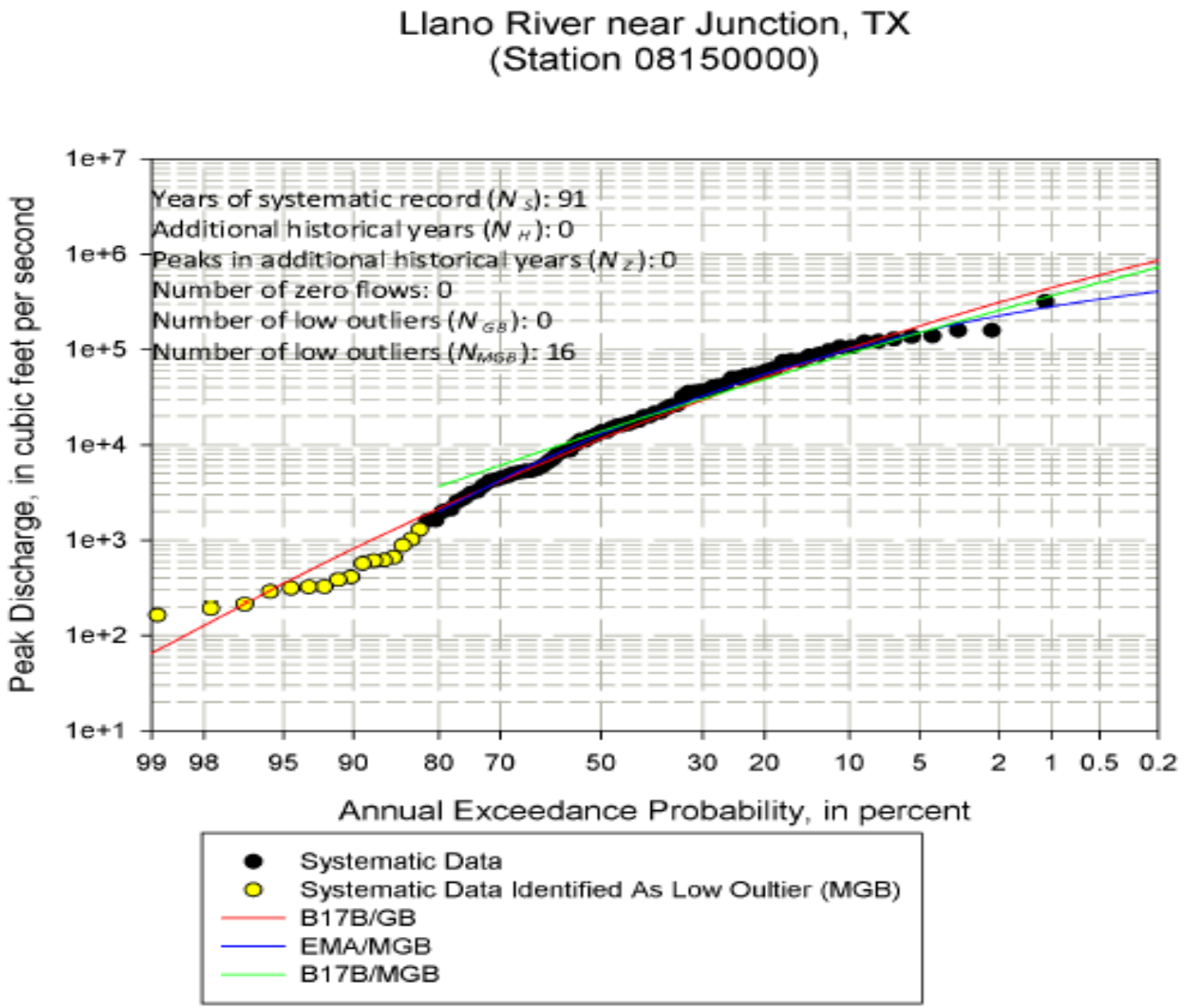
Discussion of some testing results

- **Next few slides discuss results comparing Bulleting 17B to EMA for**
  - **Observed flood data: two sites in Texas that are included in the 82 long-term stations**
  - **Simulated data: log-Pearson Type III distribution with skew of -0.5 and a combination of two GEV distributions**

Llano River near Junction, TX

- Llano River near Junction, TX (08150000)
  - 1,854 square miles, 91 years of record
  - Peak of record = 319,000 cfs, second largest peak = 158,000 cfs
  - No zero flows or historical data
  - GB identifies zero low peaks, MGB identifies 16 low peaks
  - EMA 1-percent chance discharge is 36.4 percent less than B17B estimate

Llano River near Junction, Texas (08150000)

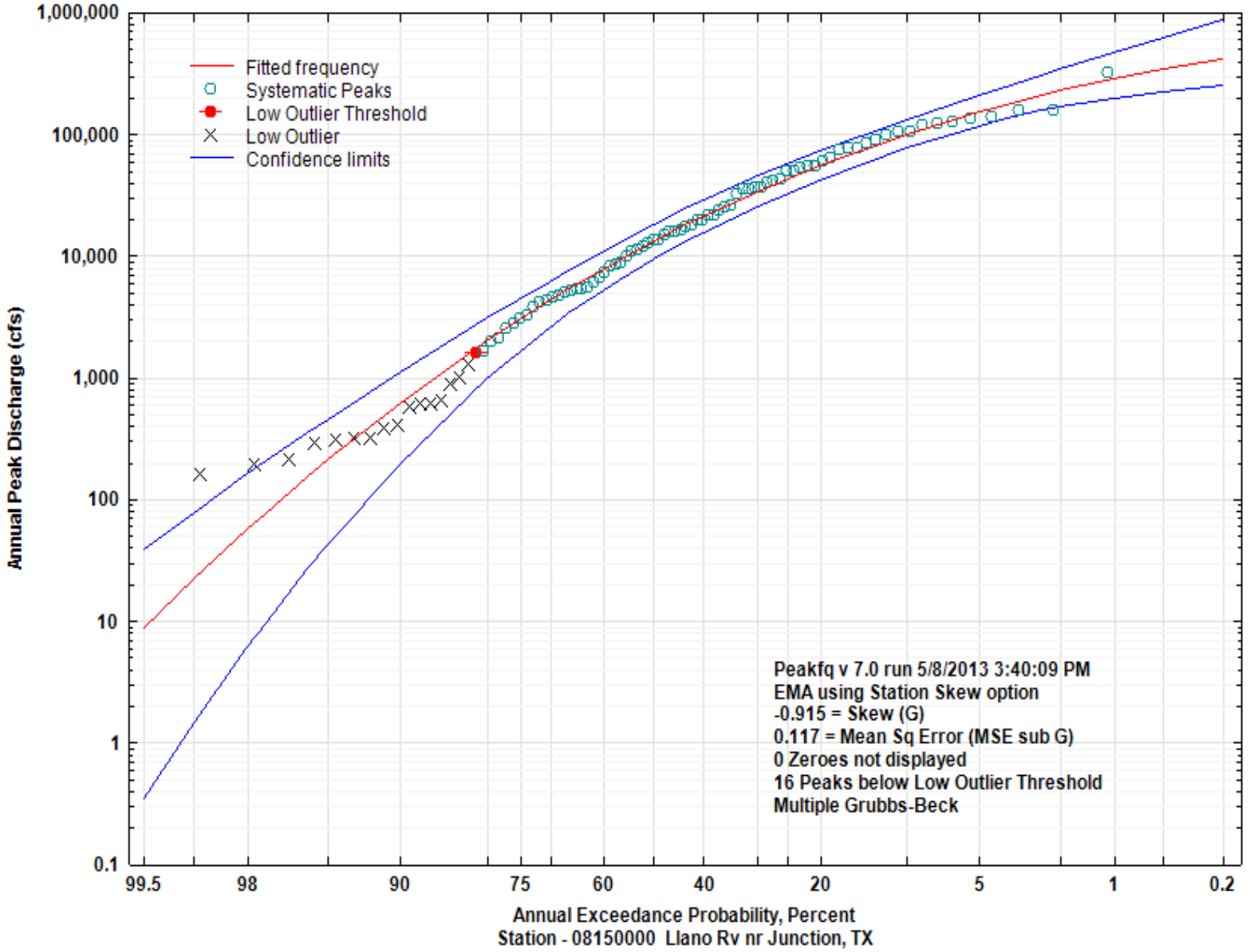


Llano River near Junction, Texas (08150000)

+ Default computations – GB test identified no low peaks, MGB test identified 16 low peaks

# of peaks censored	B17B/GB 1-percent Q (cfs)	B17B/GB Std Dev (log units)	B17B/GB Skew	EMA/MGB 1-percent Q (cfs)	EMA/MGB Std Dev (log units)	EMA/MGB Skew
0	445,100+	0.8267	-0.452	445,100	0.8265	-0.452
4	406,500	0.7879	-0.435	351,500	0.8708	-0.720
8	381,900	0.7506	-0.400	256,400	0.9442	-1.071
12	370,300	0.7105	-0.328	210,700	1.0052	-1.295
16	366,900	0.6716	-0.232	283,100+	0.8905	-0.915

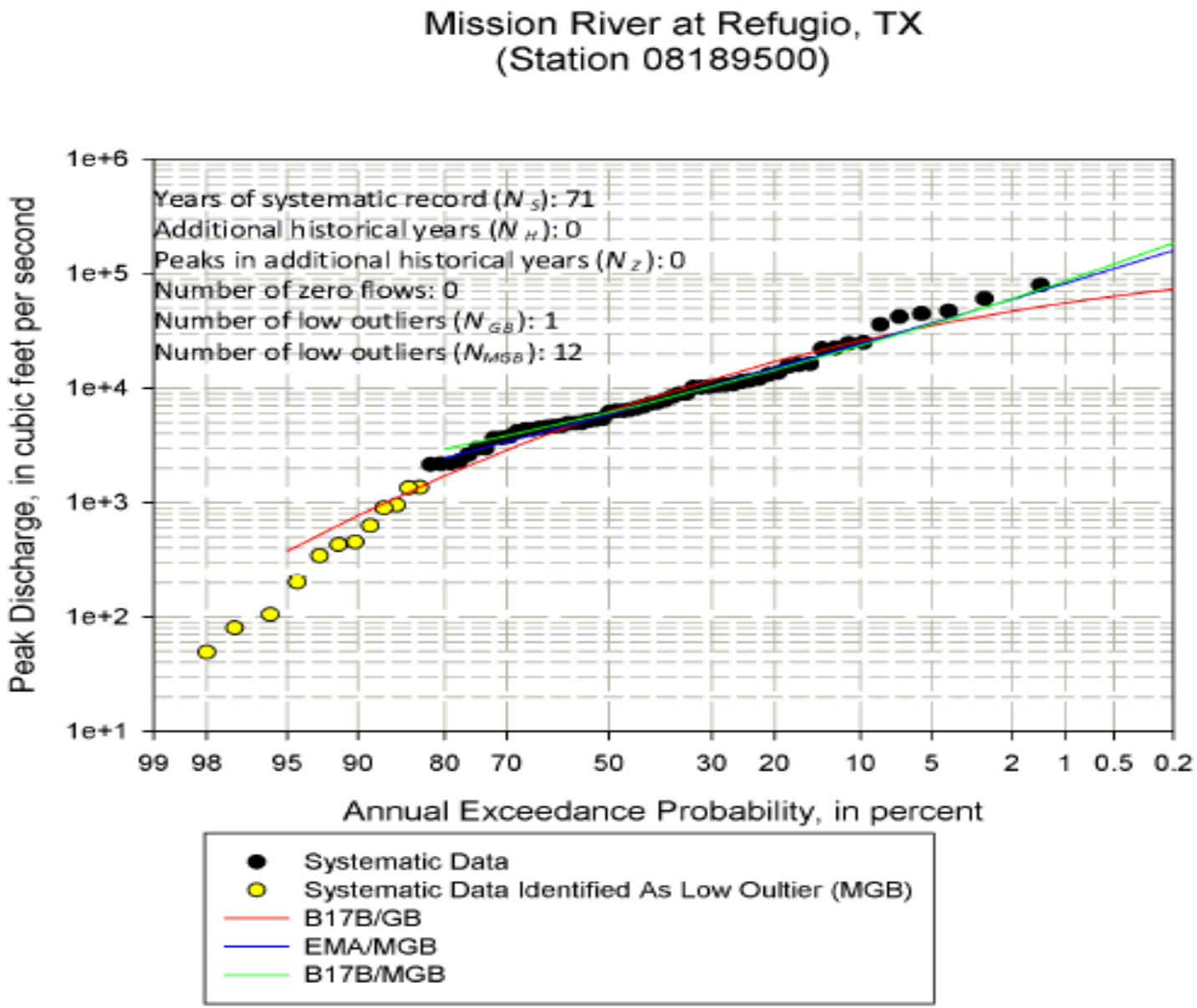
Llano River near Junction, Texas (08150000)



Mission River at Refugio, TX

- Mission River at Refugio, TX (08189500)
  - 690 square miles, 71 years of record
  - Peak of record = 79,000 cfs, second largest peak = 60,200 cfs
  - No zero flows or historical data
  - GB identifies 1 low peak, MGB identifies 12 low peaks
  - EMA 1-percent discharge is 48.0 percent larger than B17B estimate

Mission River at Refugio, TX (08189500)



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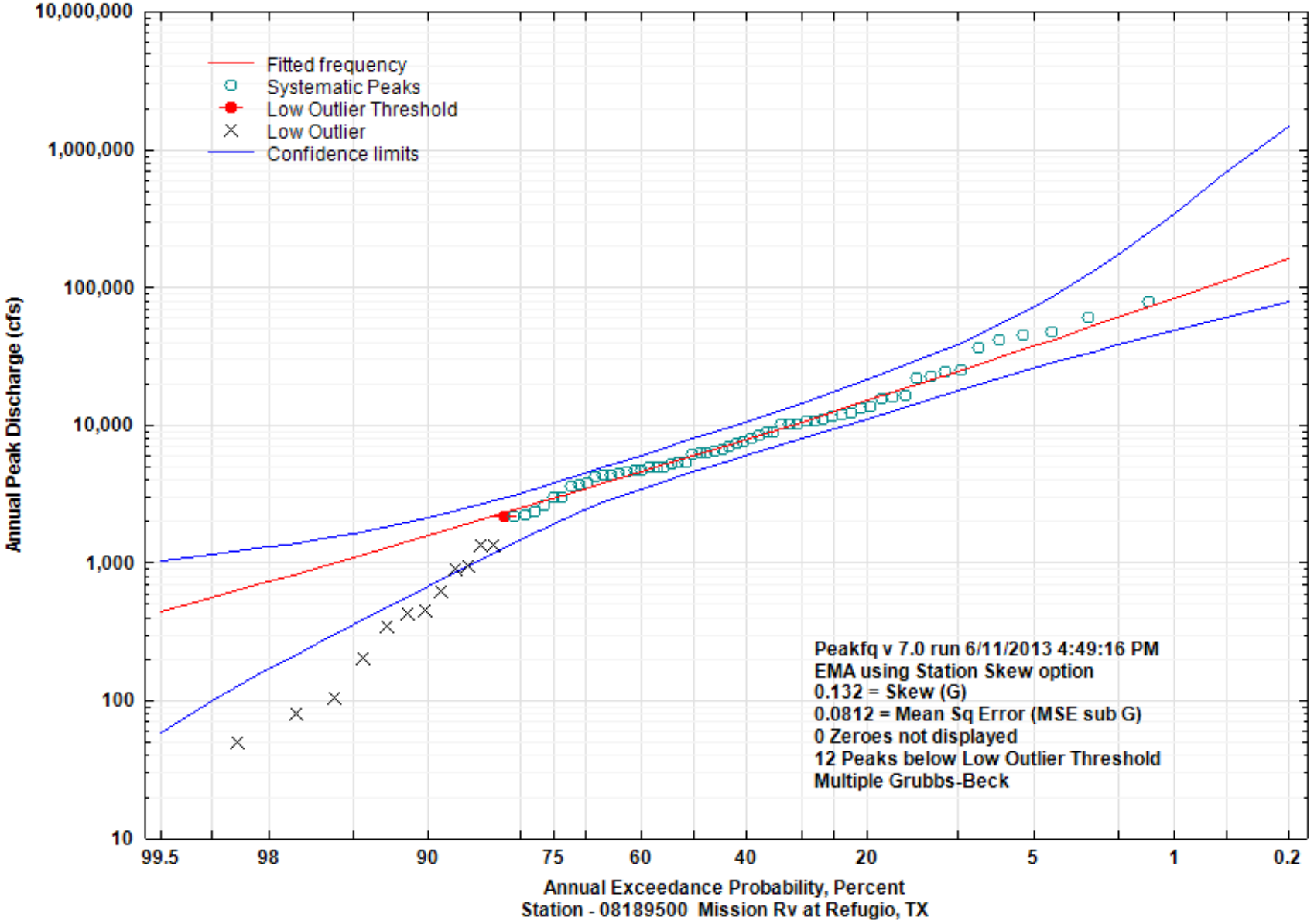
Mission River at Refugio, TX (08189500)

# of peaks censored	B17B/GB 1-percent Q (cfs)	B17B/GB Std Dev (log units)	B17B/GB Skew	EMA/MGB 1-percent Q (cfs)	EMA/MGB Std Dev (log units)	EMA/MGB Skew
1	55,390+	0.6134	-0.859	43,880	0.6651	-1.217
4	68,490	0.5255	-0.352	40,760	0.6718	-1.307
8	79,510	0.4571	0.136	46,810	0.6427	-1.100
12	86,040	0.4140	0.504	81,990+	0.4671	0.132

Mission River at Refugio, TX (08189500)



Subjective Evaluation of Observed Data

- Jerry Coffey performed a visual inspection of the frequency curves for the 82 gaging stations
  - Group I of 38 stations where B17B had a good fit
  - Group II of 11 stations where B17B fit better for 7 stations and EMA fit better for 4 stations
  - Group III of 33 stations where B17B fit not good, no implication that EMA fit was better

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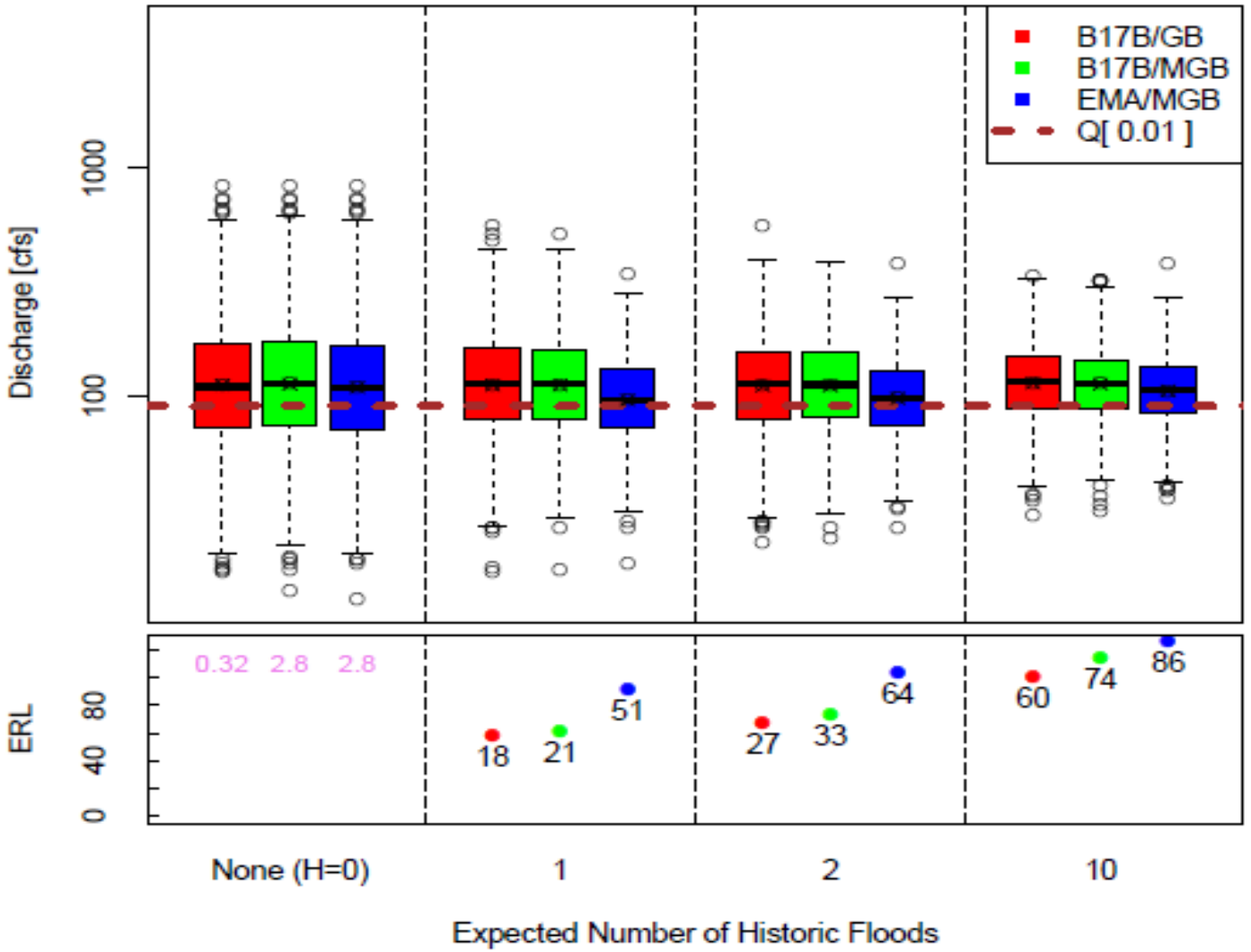
Subjective Evaluation of Observed Data

- Will Thomas evaluated the reasonableness of the 1-percent chance flood for the 21 stations with differences of 9 percent or more
  - EMA estimate better for 14 stations, B17B better for 6 stations and 1 station a tie
- Nancy Barth did a visual evaluation for same 21 stations for the 1-percent chance discharge
  - EMA estimate better for 14 stations, 7 ties
- Conclusion: Subjective evaluations give different results as to best results and not that reliable

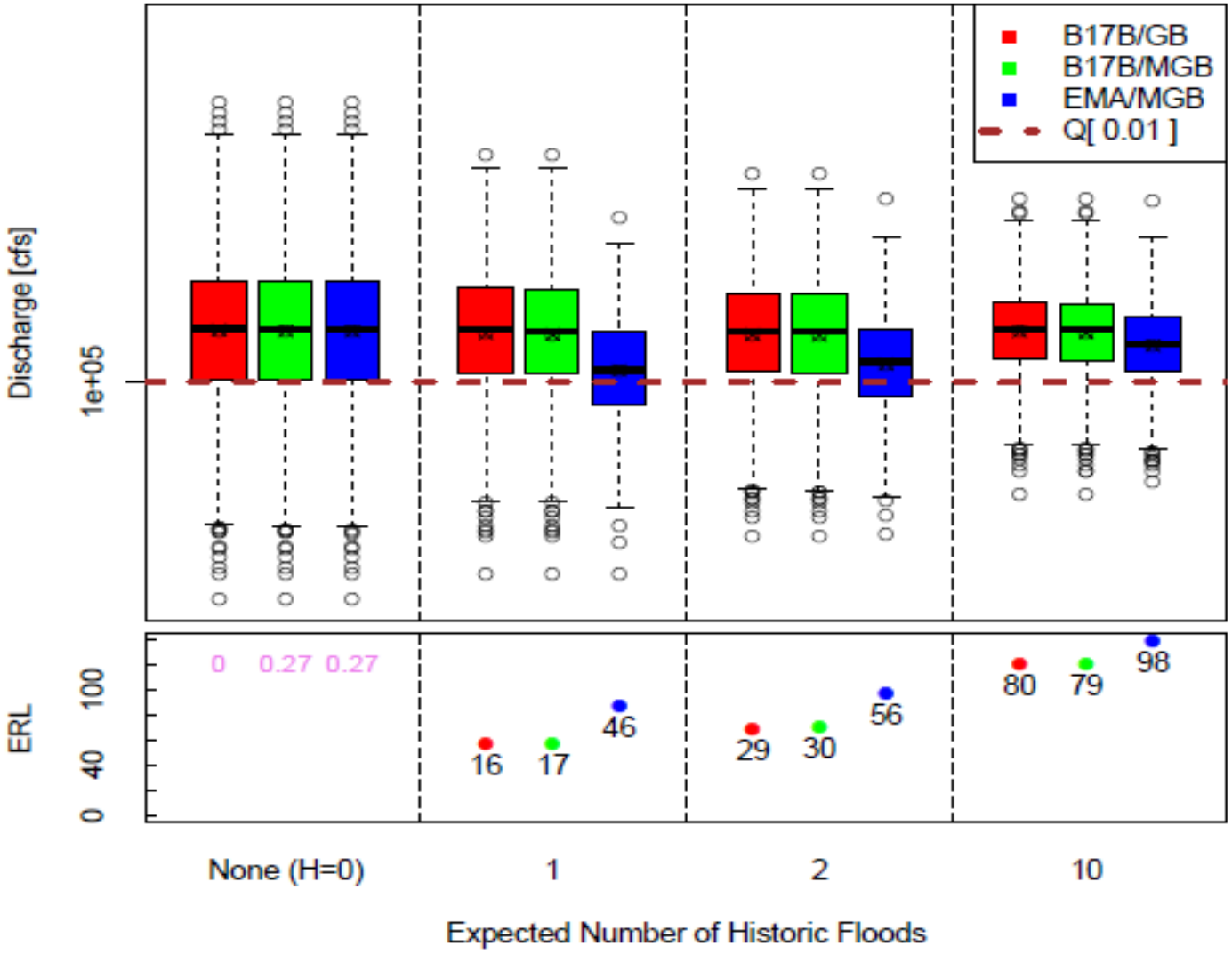
Simulated Data Test Results

Figure 3: Monte Carlo results based on 10000 replicate samples of size $N_S = 40$ and $N_H = 100$ drawn from a Log-Pearson Type 3 distribution with skew $\gamma = -0.5$.



Simulated Data Test Results

Figure 8: Monte Carlo results based on 10000 replicate samples of size $N_S = 40$ and $N_H = 100$ drawn from robustness test curve 6.



HFAWG Plans For Moving Forward

- Develop Bulletin 17C based on recommendations discussed earlier
  - Develop an outline and draft of document
  - Define review, comment and approval process
- Develop supporting material for Bulletin 17C
  - Web site for FAQs, references, software links
  - Prepare conference papers and journal articles

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HFAWG Plans For Moving Forward

- Develop software for Bulletin 17C
  - USGS has a beta version of PeakFQ 7.0 that implements EMA/MGB
  - Provide application examples with software
  - Develop documentation
- Conduct outreach and training on Bulletin 17C
  - Present update plans at conferences
  - Develop training materials and classes