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The Effect of Urbanization on Peak Streamflows in Northeastern Illinois

Thomas Over and David Soong, US Geological Survey, Urbana, Illinois

T.Y. Su, US Army Corps of Engineers, Chicago

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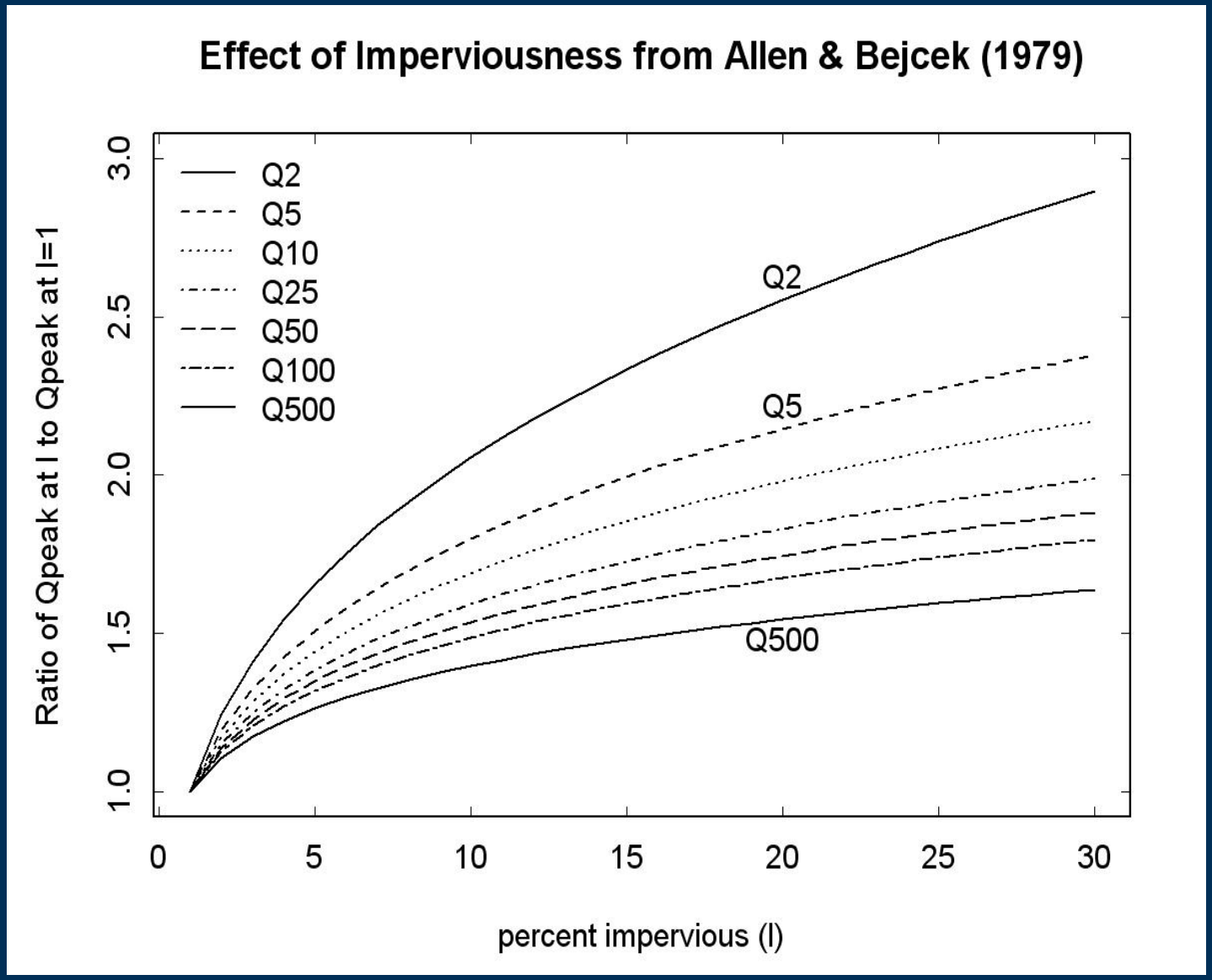
U.S. Department of the Interior
U.S. Geological Survey

Practical Goal: Update 1979 Illinois regional flood frequency equation study



Causes of changes in flood peak distributions in urban watersheds

- Urbanizing land use, w/ and w/o detention
- Construction of reservoirs and other large-scale flood control facilities
- Climatic variation

Approaches to analysis of urban watersheds with changing conditions

- Usual approach:
  - ***Truncate*** record to most convenient quasi-stationary condition (usually most recent)
- Alternative approach:
  - ***Adjust*** record to some reference condition
- Advantages of adjustment approach:
  - Uses complete record
  - Obtain estimates of effects of causal factors
  - Adjusted record available for at-site analyses

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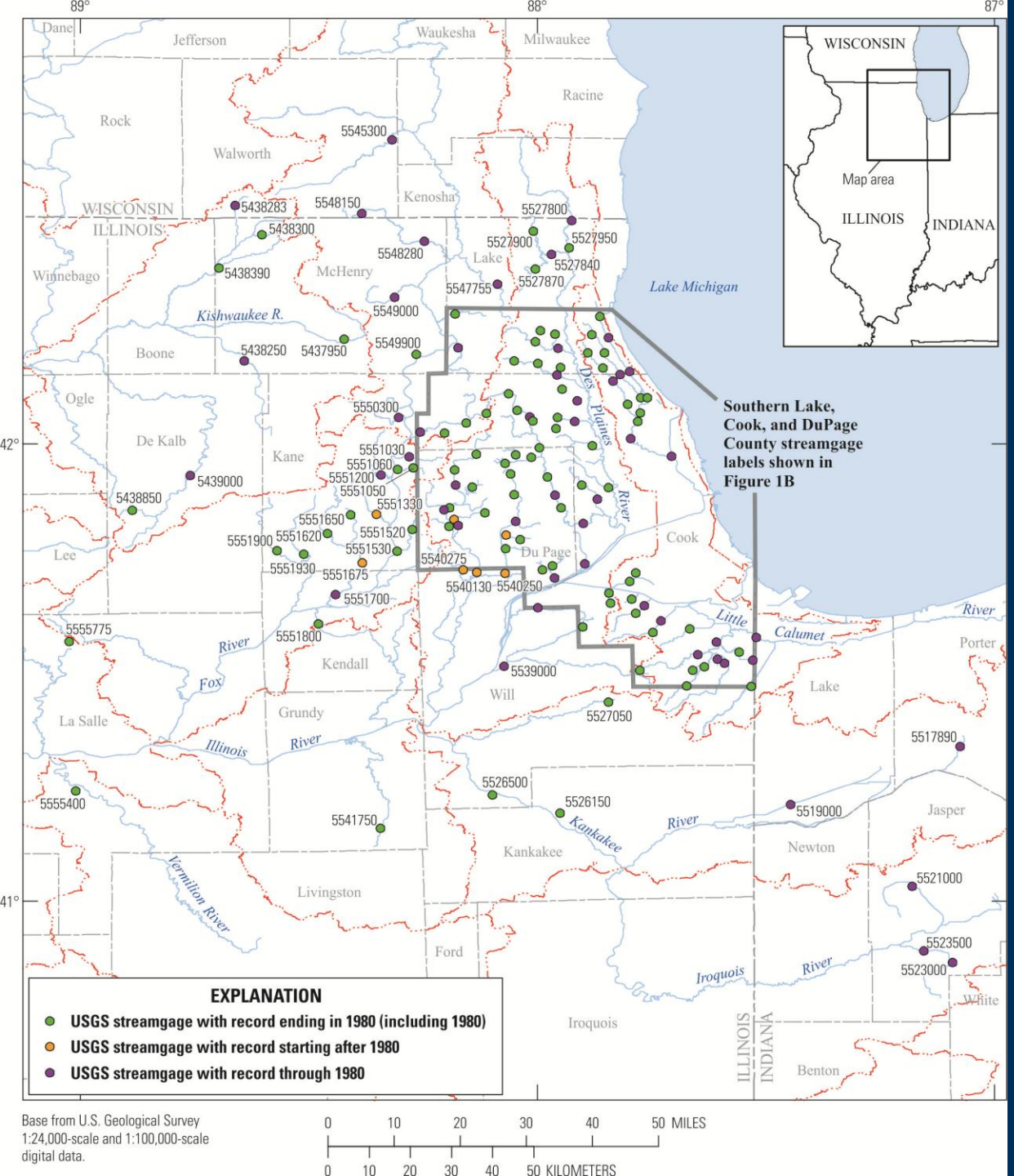
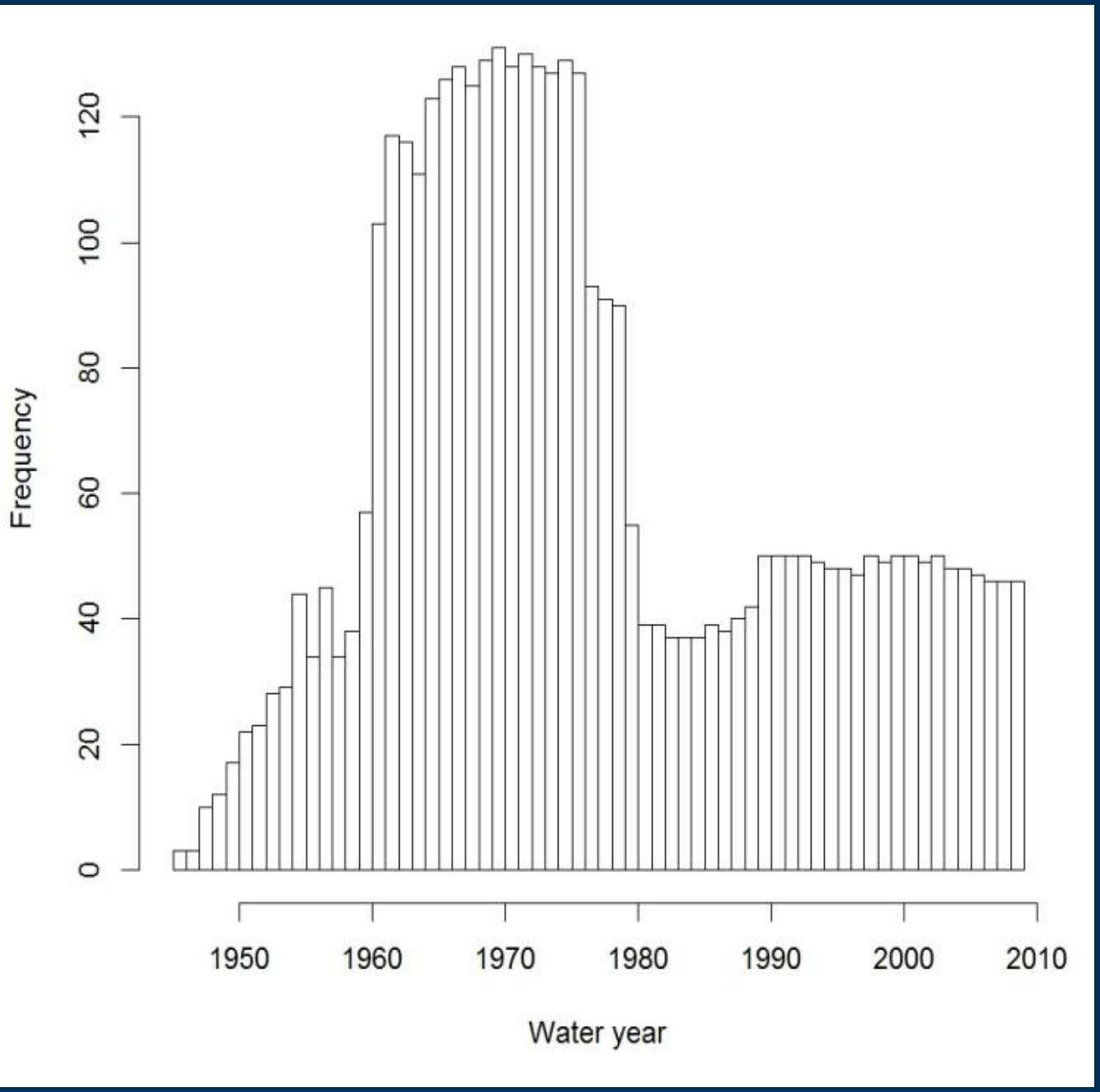
Overview of analysis and adjustment methodology

- Select stations
- Obtain historical information on land use, reservoir construction, precipitation
- Split records into segments at times of reservoir construction
- Fit linear regression equation to record segments
- Adjust to present (2010) land use and reservoirs only: changes in precipitation considered too uncertain to adjust for.

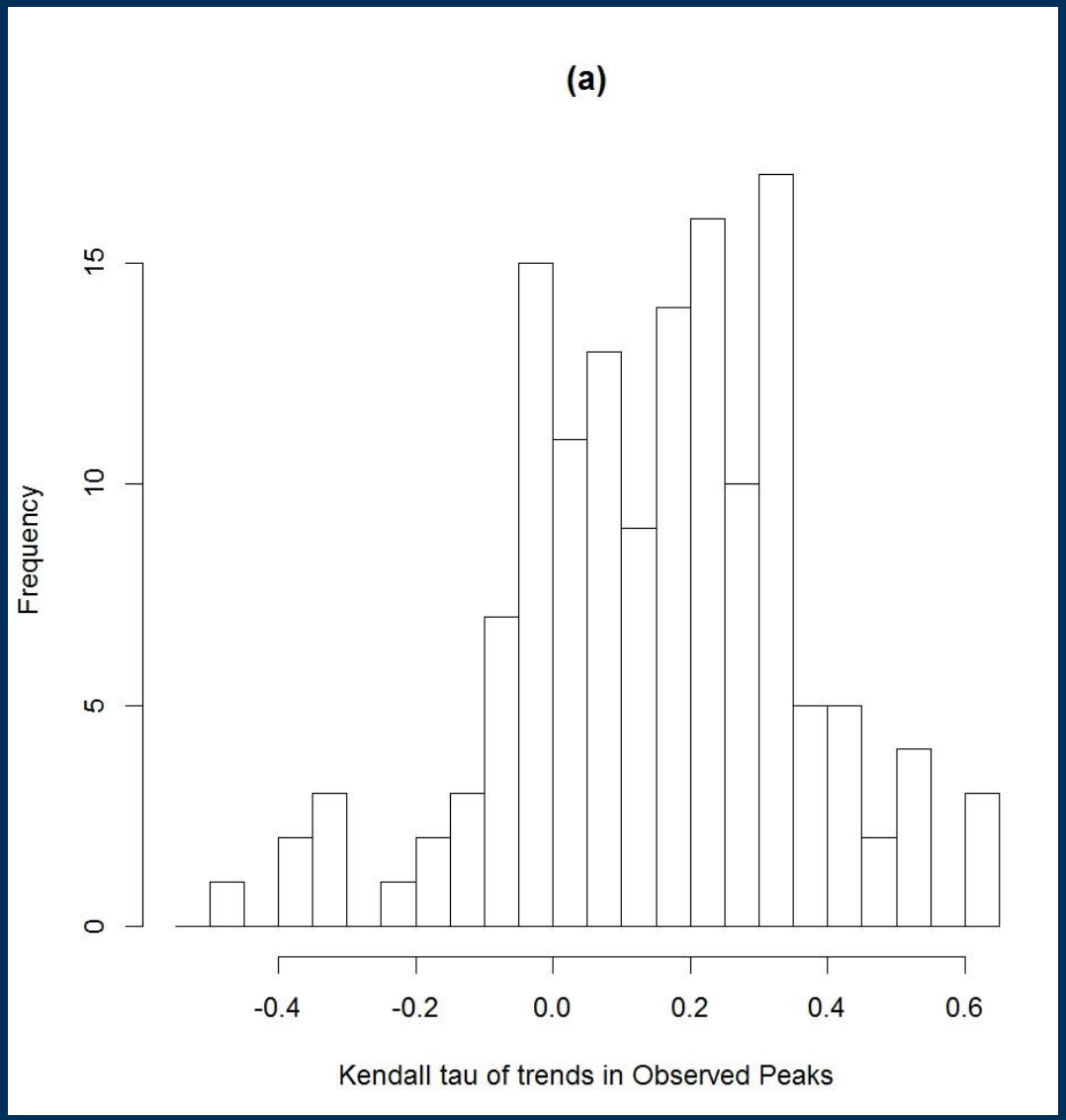


Stations used in study

- Stations with
  - > 10 years of record
  - DA < 200 sq. mi.
- 143 stations
- 83 station records ended by 1979; of these, 82 were CSGs
- Peaks from 1945-2009



Number of stations available each year of study



Histogram of trends in peak flow in selected stations

How much caused by

- land use change,
- climate variation,
- large-scale construction (reservoirs, channelization)?

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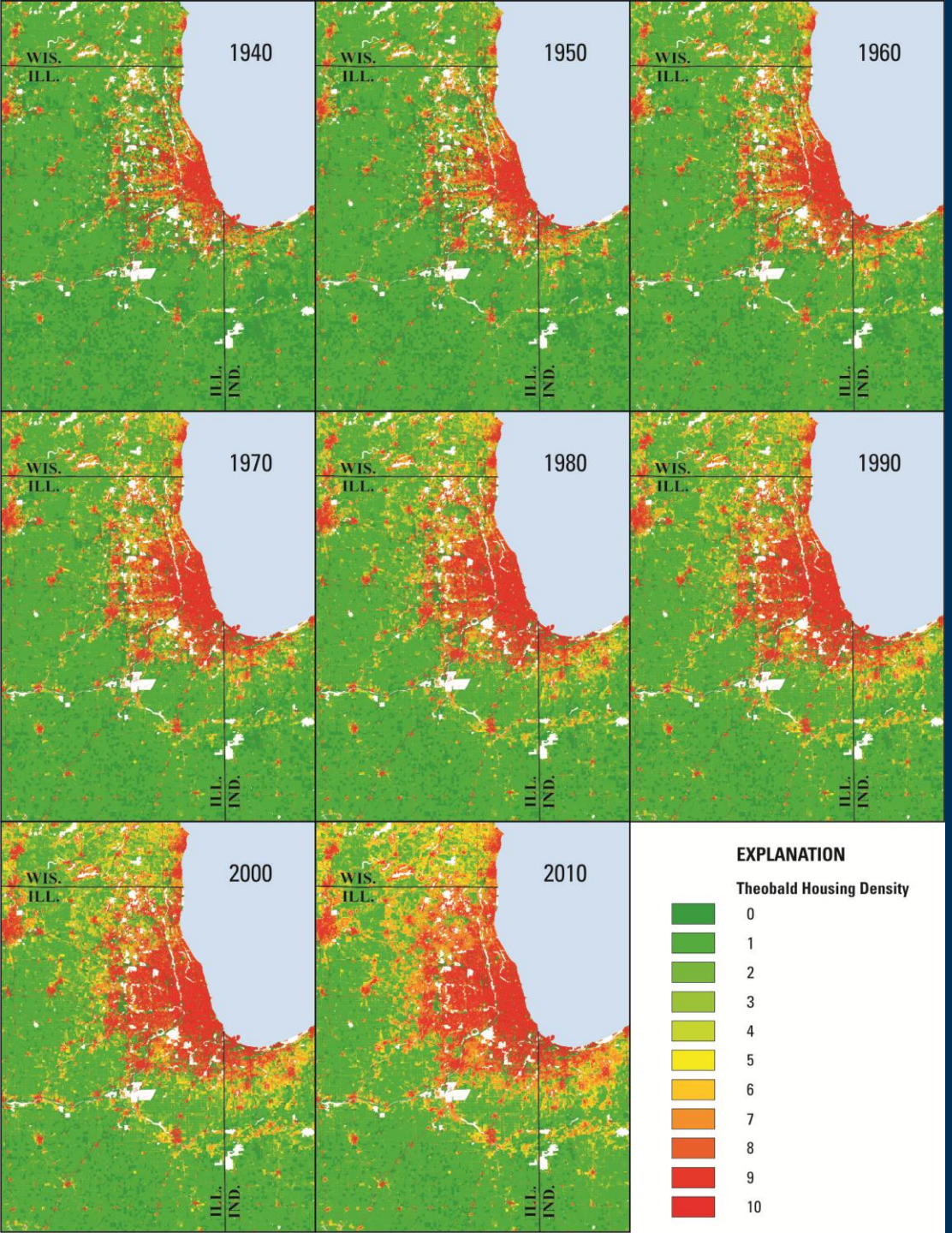
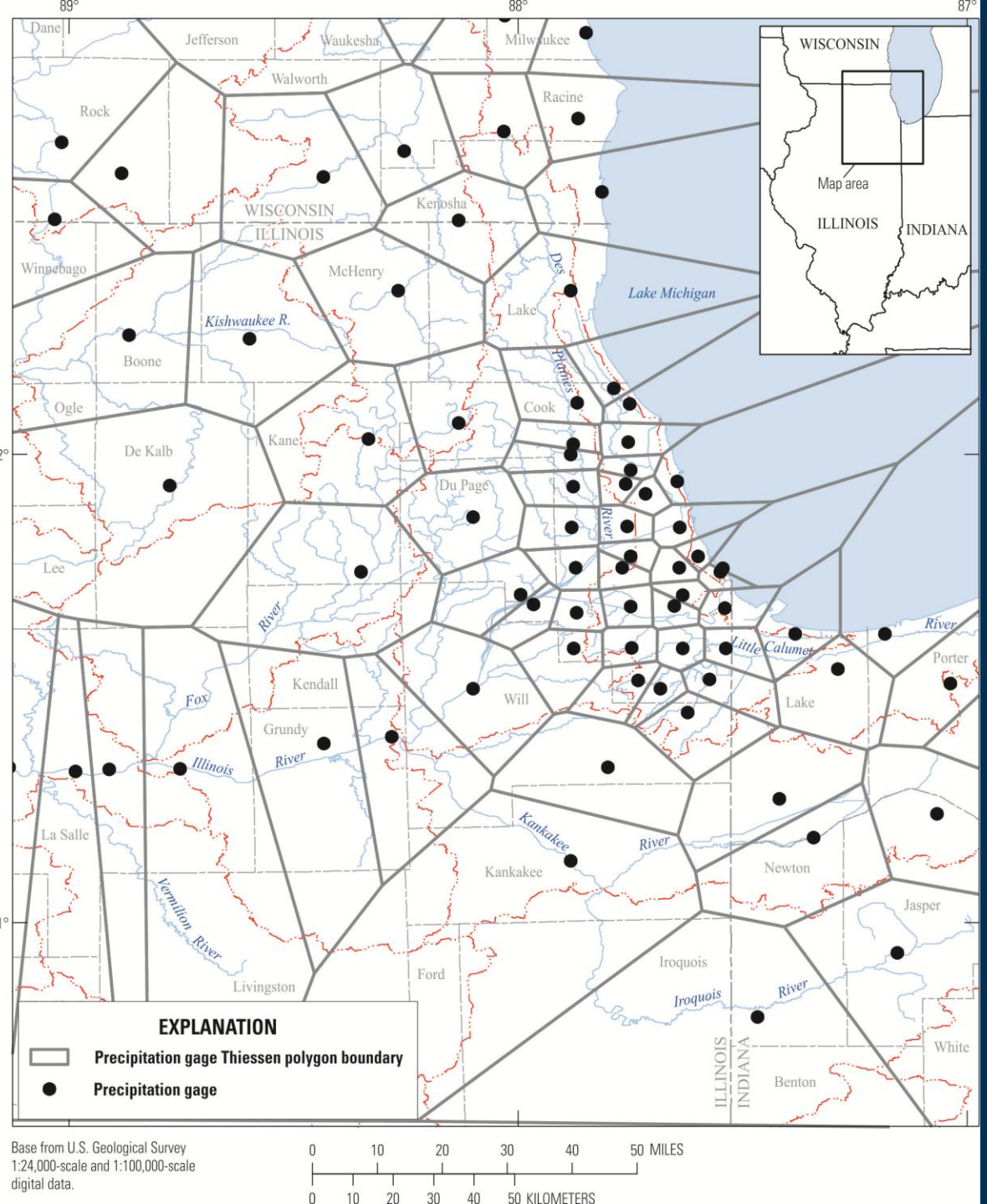


Land use data

- Census-based housing density data from Theobald (2005), classes 7-10:
- < 10 acre lots plus commercial / industrial / transportation.

Reservoir information

- Locations, date of construction, capacity obtain from National Inventory of Dams and other sources.
- IDNR, MWRDGC, and County staff assisted in verifying / correcting information.
- Records broken into segments at years when reservoirs of significant capacity and drainage area were built in watershed.



Precipitation data

- Daily time step (more stations)
- Distributed with Thiessen polygons
- Used maximum value from 3 days before to 1 day after date of peak.

Fitted regression model

For each segment *i* and year *t*,

$\log_{10}Q_p(i,t) = a(i) + 0.5117U(i,t) + 0.0846P(i,t) + e(i,t)$,

where

- Q_p = annual maximum flood peak
- a = intercept: one per segment
- U = urbanized fraction of watershed
- P = maximum daily precipitation
- e = error term

Notice *U* and *P* coefficients are assumed to apply to all segments (station records)

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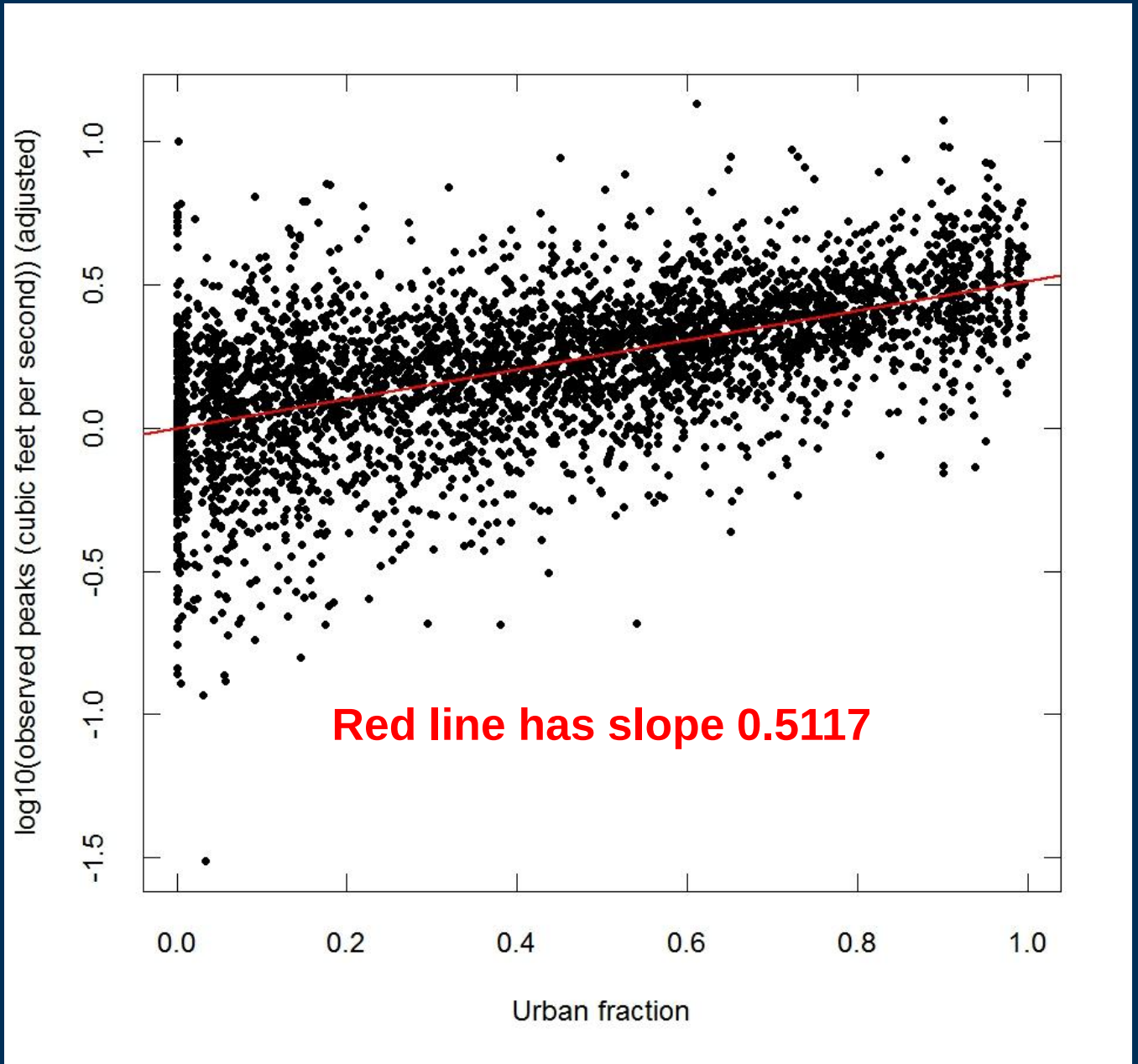
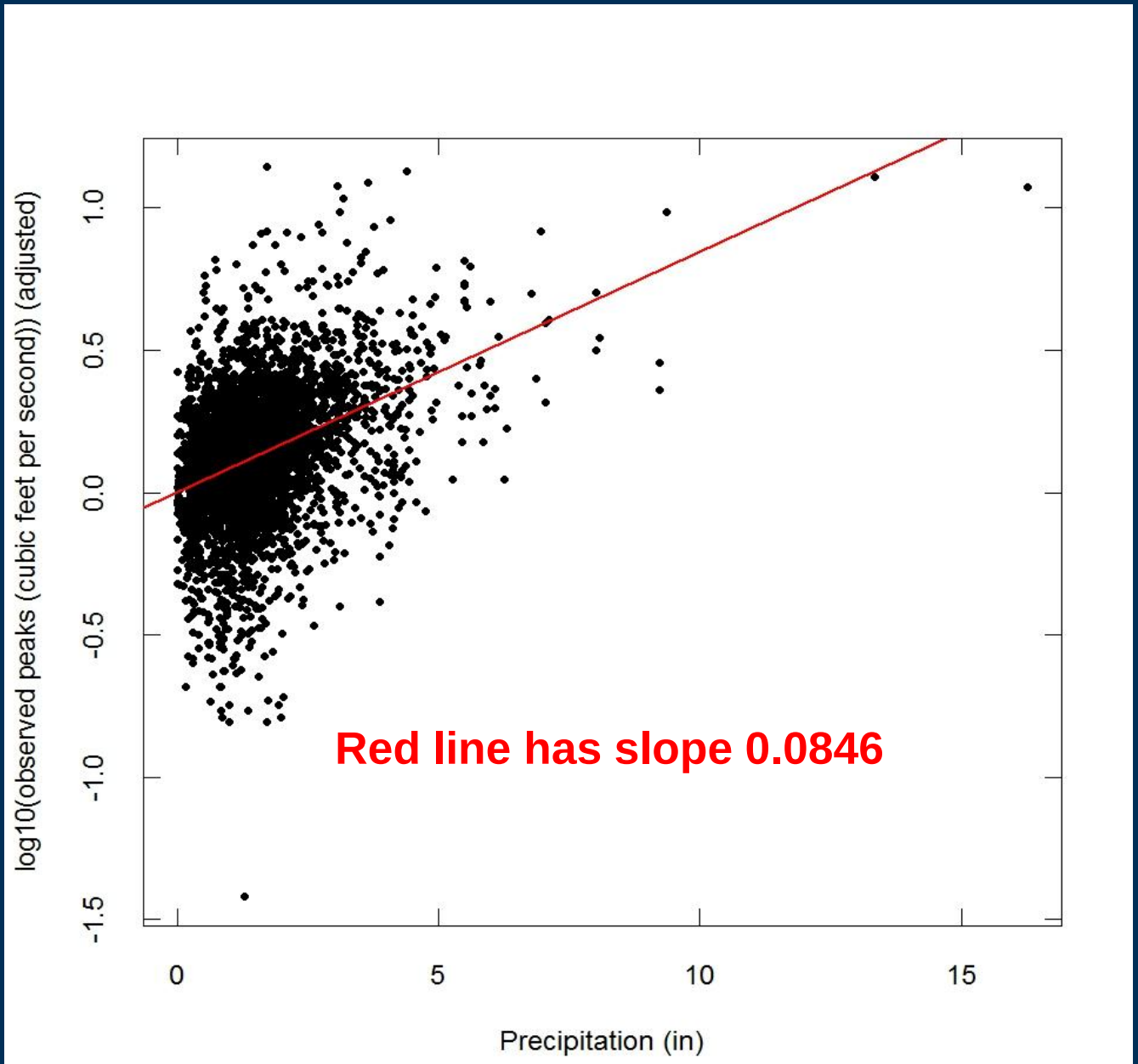
Dependence of logQ_p on urbanization



Dependence of logQ_p on precipitation



Adjustment of peak flows

Fitted model was:

$\log_{10}Q_p(i,t) = a(i) + 0.5117U(i,t) + 0.0846P(i,t) + e(i,t)$.

To adjust to year 2010 urbanization:

$\log_{10}Q_{p,2000}(i,t) = \log_{10}Q_p(i,t) + 0.5117[U(i,2010) - U(i,t)]$

Examples:

- If U increases 10%,

  Q_p increases $10^{0.1*0.5117} = 1.125 = 12.5\%$

- If U increases 100%,

  Q_p increases $10^{1.0*0.5517} = 3.249 = 225\%$

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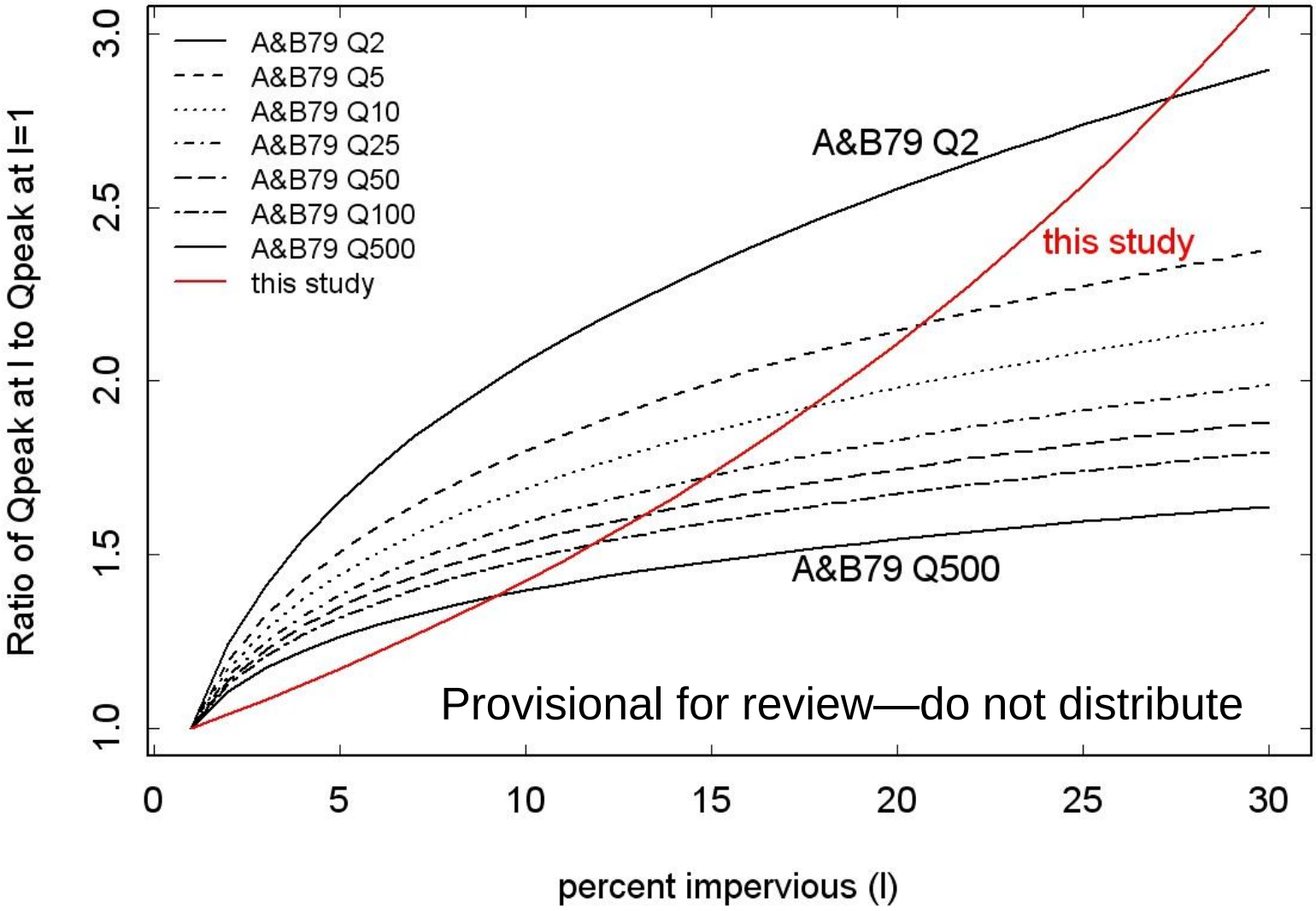
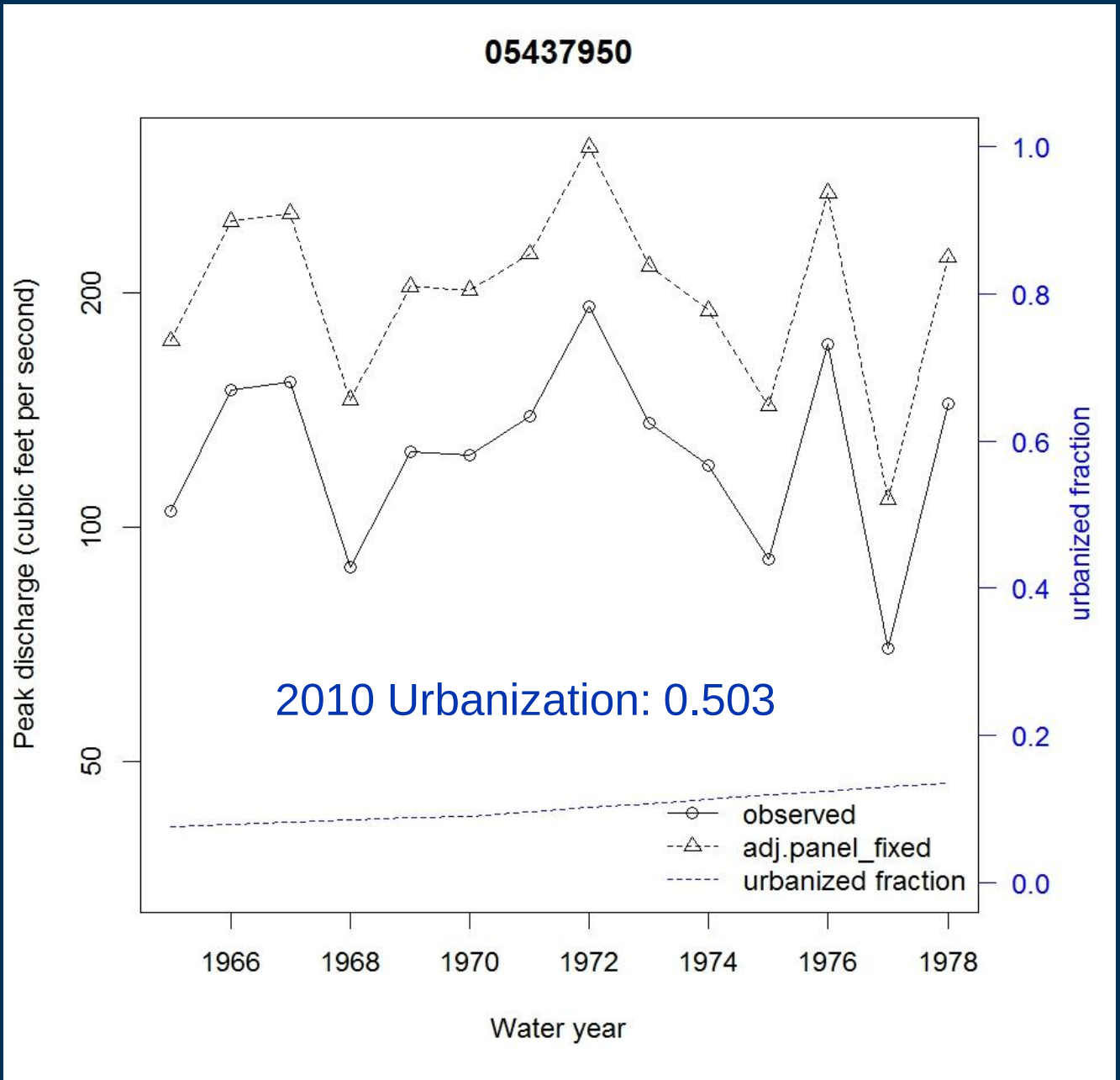
Comparison with Allen & Bejcek (1979)

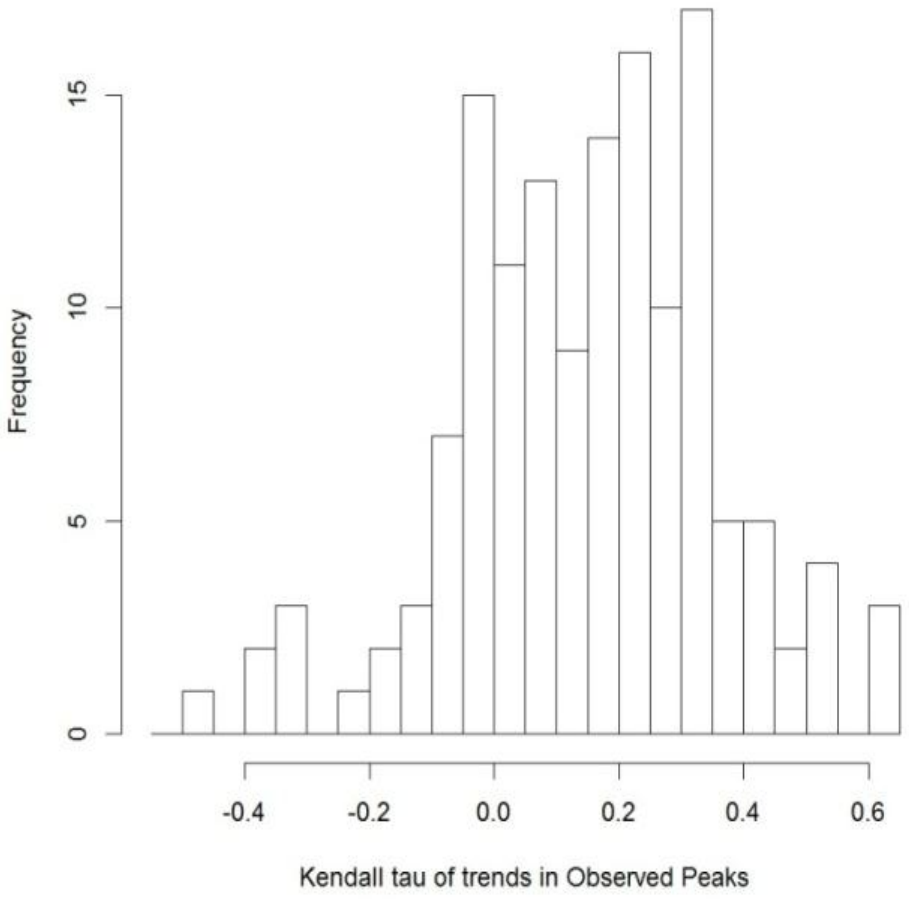


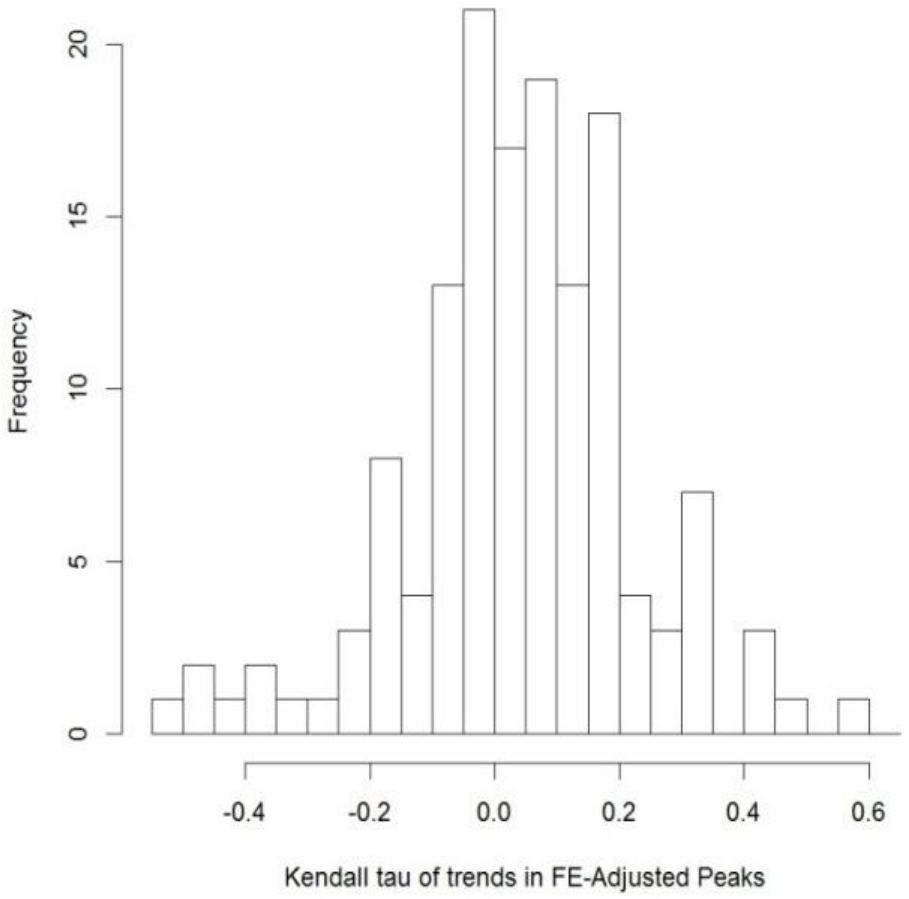
Example of Adjusted Record

Provisional for review—do not distribute



Effect of adjustments on trends





Trends of adjusted peak series are similar to precipitation series trends (not shown)

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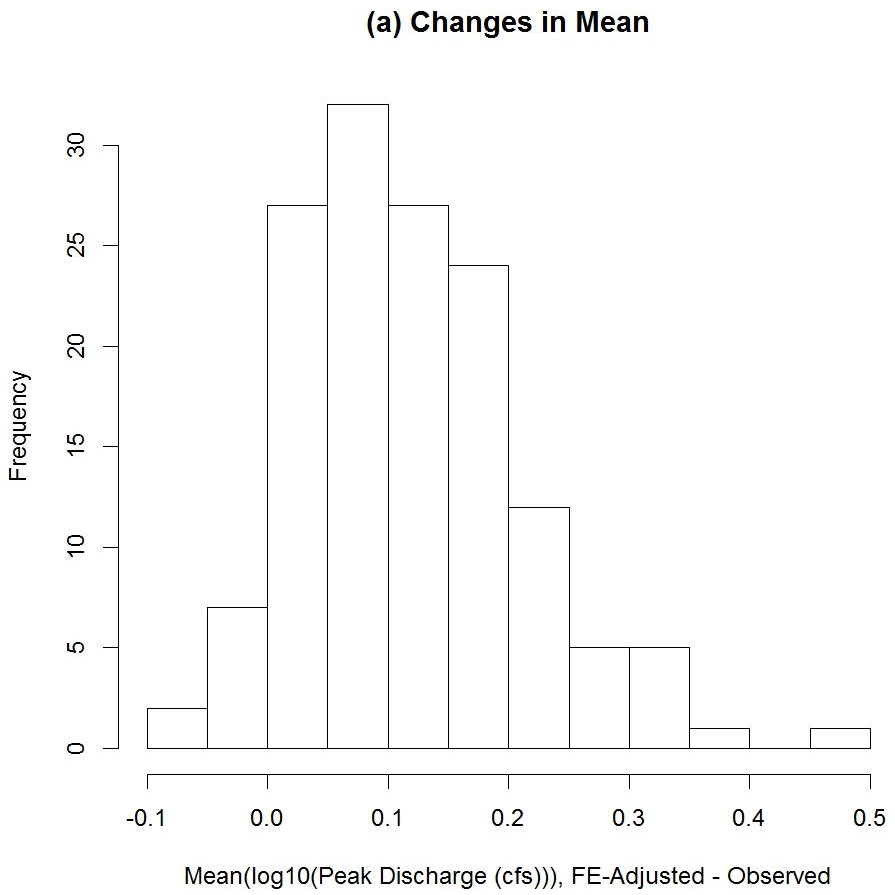
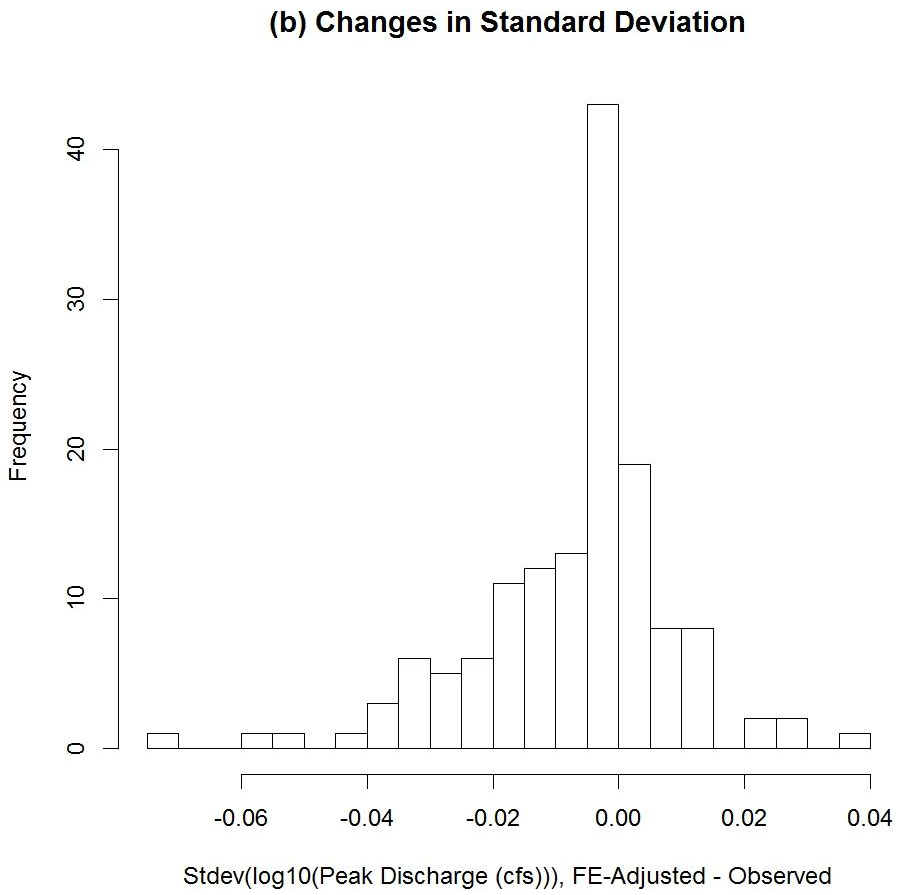
Effect of adjustments on $log_{10}Q$ moments





Effect on Skewness is similar to Standard Deviation: little change on average

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Provisional for review—do not distribute

Conclusions

- Peak flow adjustment method has been fitted and applied to 143 NE IL stations; report is undergoing review.
- Method accounts for changes in urbanized land use, precipitation, and reservoir construction
- Peak flows adjusted to fraction urbanized in 2010.
- Dependence of peaks on urbanization similar in magnitude to Q2 from 1979 regional study.
- Adjustment reduces prevalence of positive trends.
- Next step: Use adjusted flows to update 1979 regional study and make available on-line as part of Illinois StreamStats at http://streamstats.usgs.gov/illinois.html

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