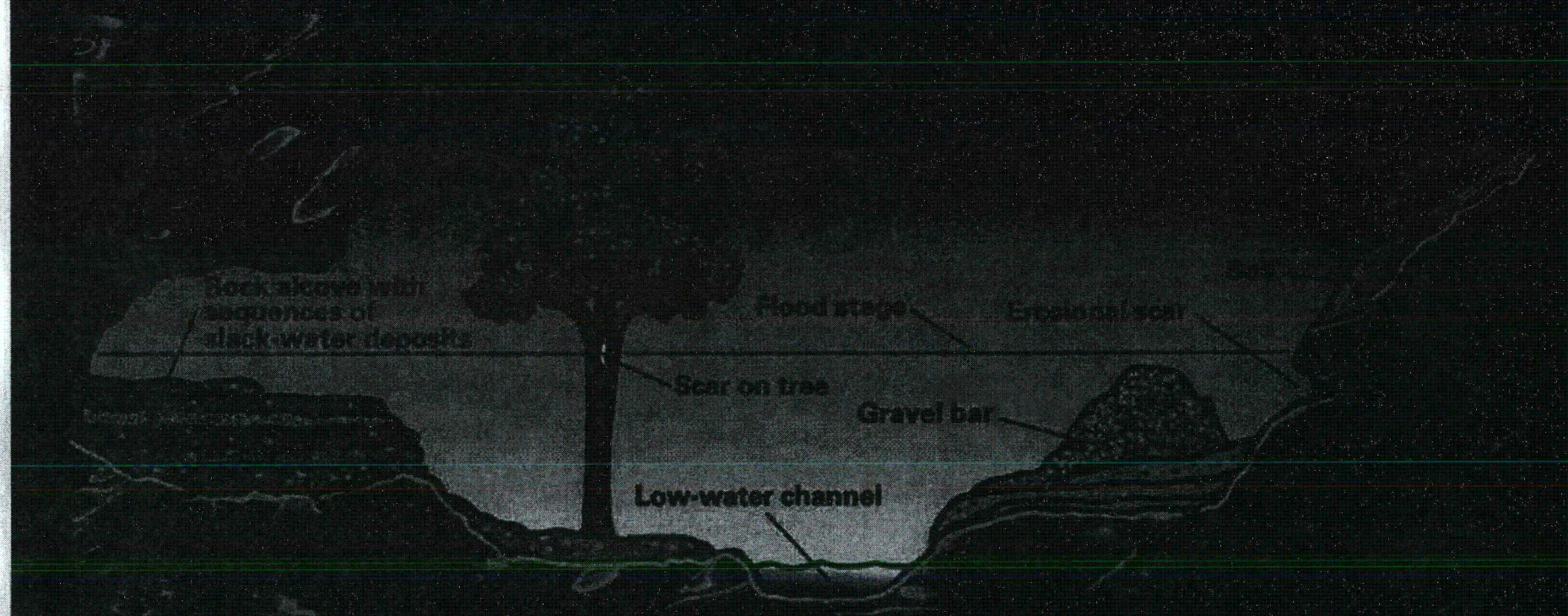


Earthquakes ★ Floods ★ Hurricanes ★ Landslides ★ Tsunamis ★ Volcanoes ★ Wildfires

Paleofloods -Paleostage indicators (PSIs)



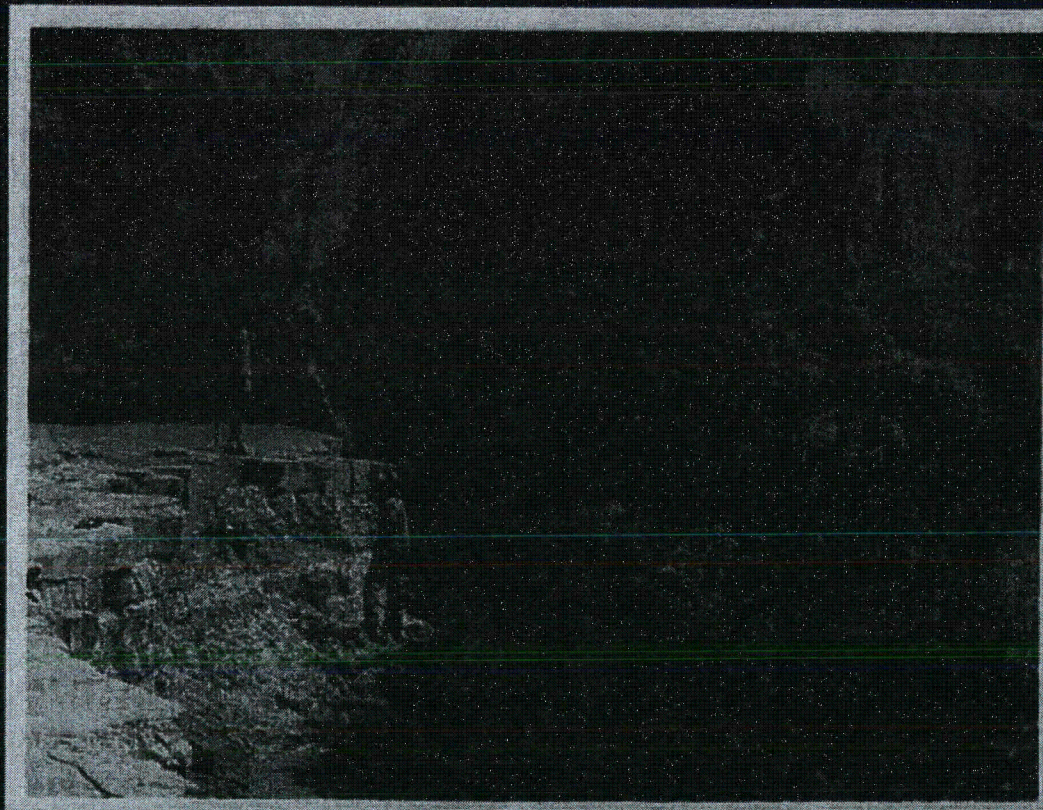
Jarrett (1991) USGS Water-Supply Paper 2375

House et al. (2002) AGU Paleoflood Monograph



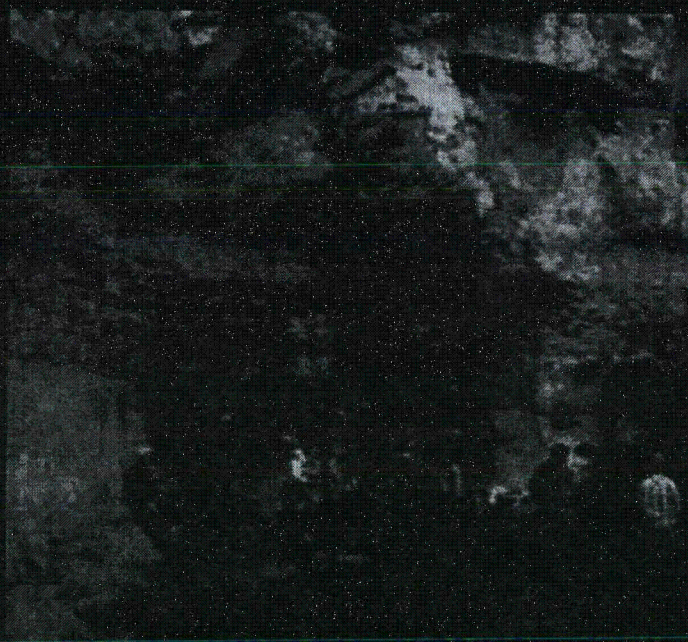
Earthquakes ★ Floods ★ Hurricanes ★ Landslides ★ Tsunamis ★ Volcanoes ★ Wildfires

Slackwater Deposits

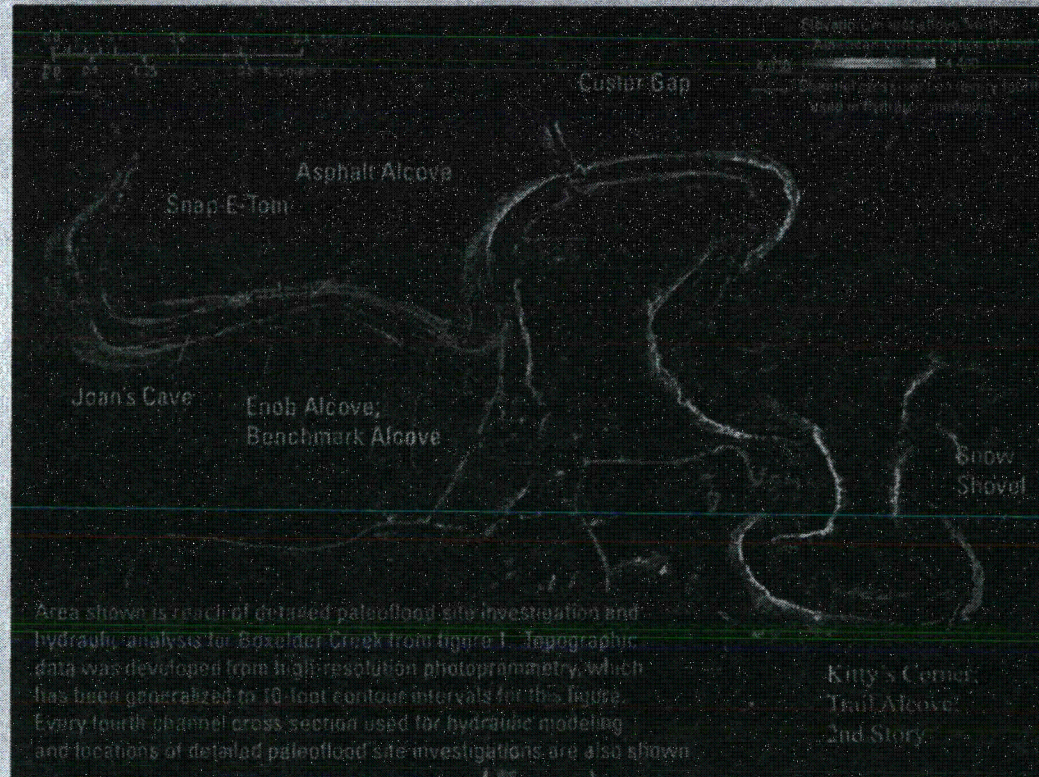
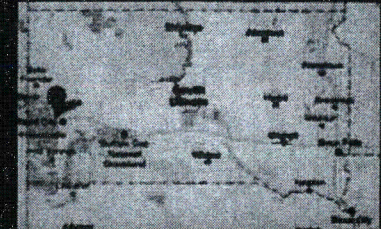


Earthquakes ★ Floods ★ Hurricanes ★ Landslides ★ Tsunamis ★ Volcanoes ★ Wildfires

Searching for Paleoflood Evidence



Paleoflood Sites



Base modified from E87N digital data. Projection: Lambert Conformal Conic, State Plane, South Dakota.
North American Datum 1983, 12,500, False easting = 1969500, False northing = 0.



Figure Boxelder Reach. Topographic information and selected details of hydraulic analysis for Boxelder Creek reach.

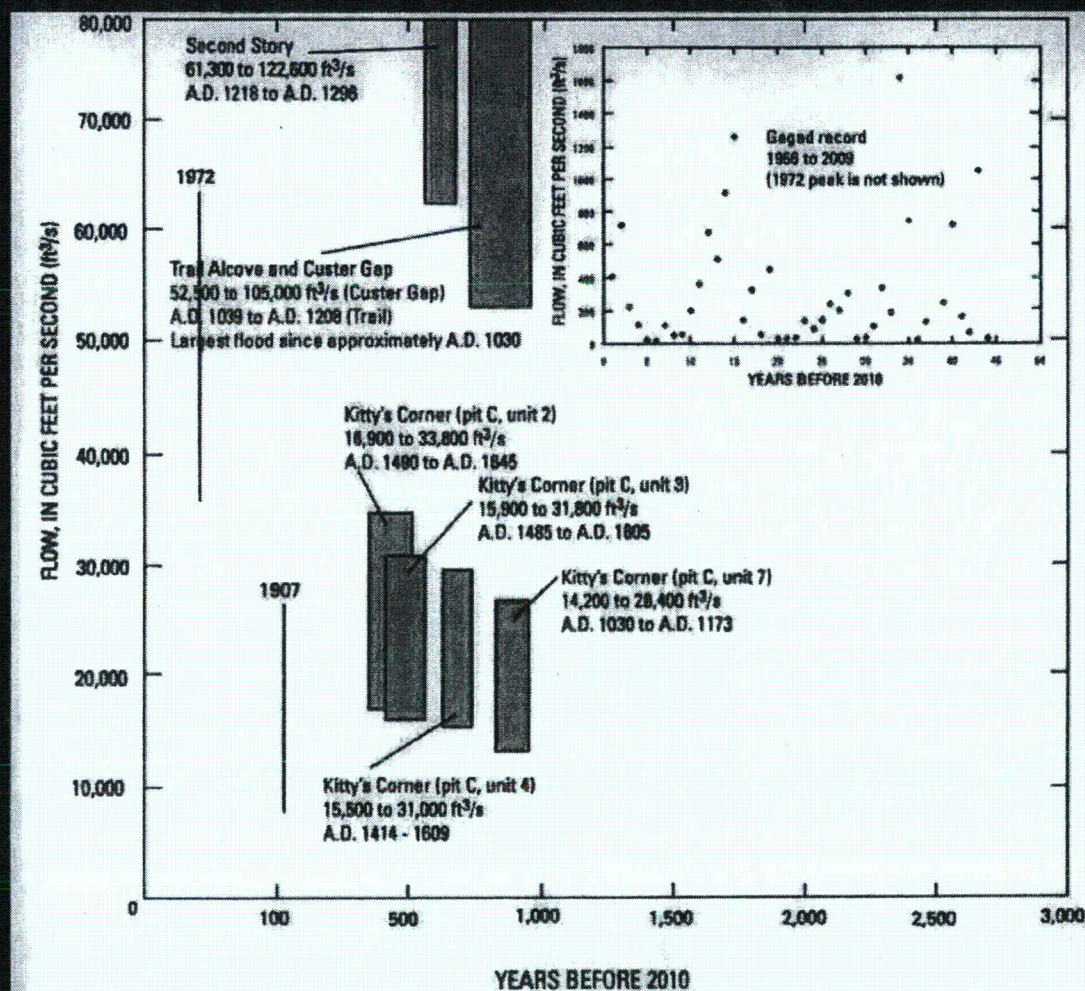
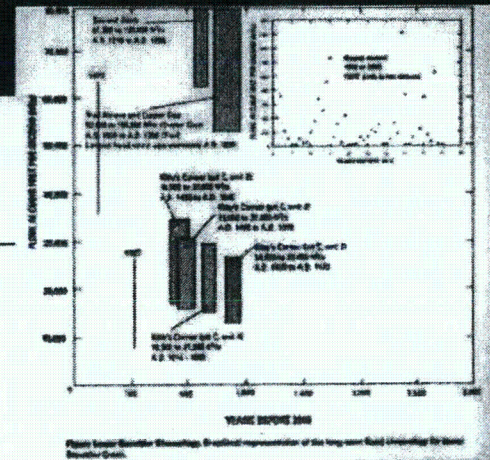
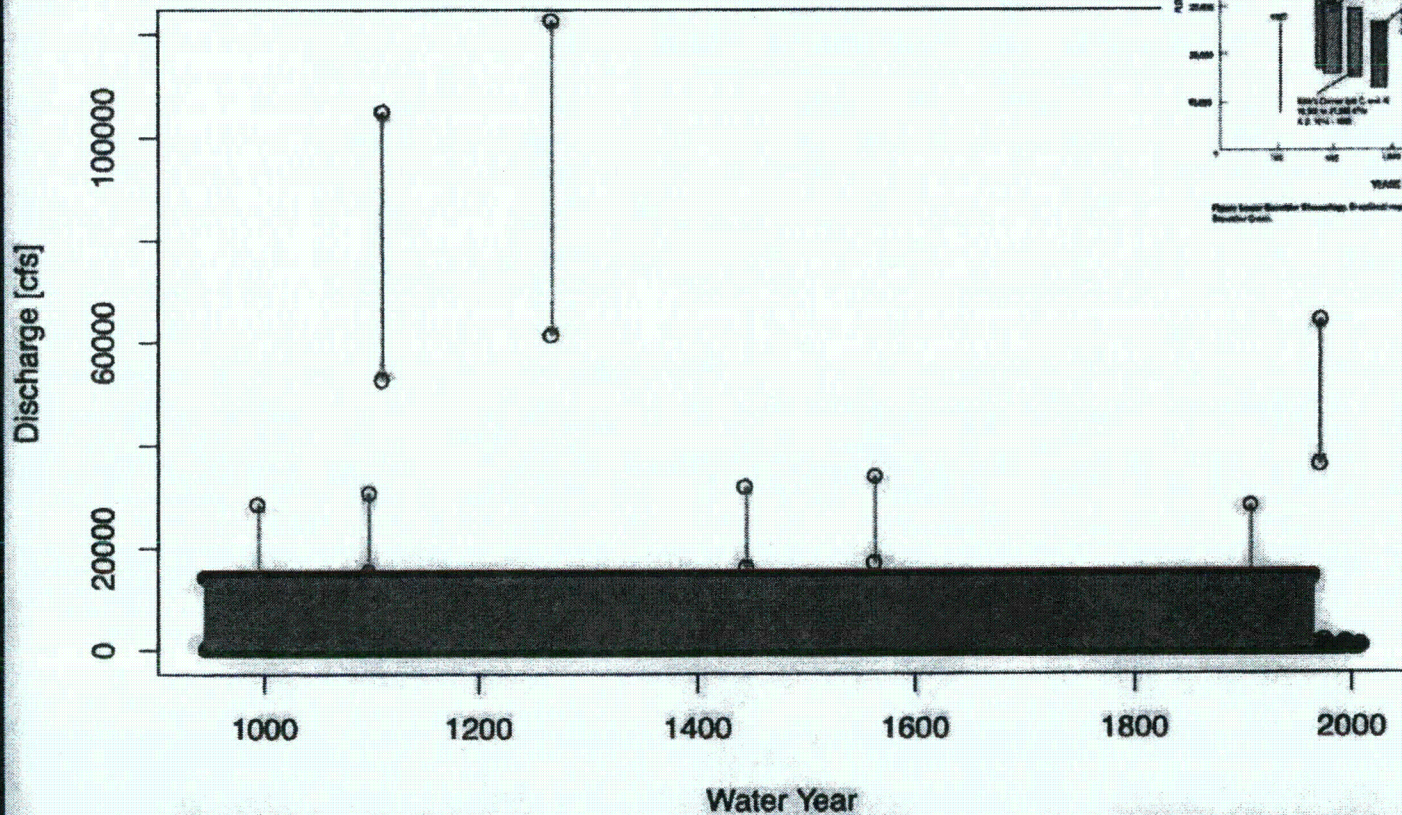
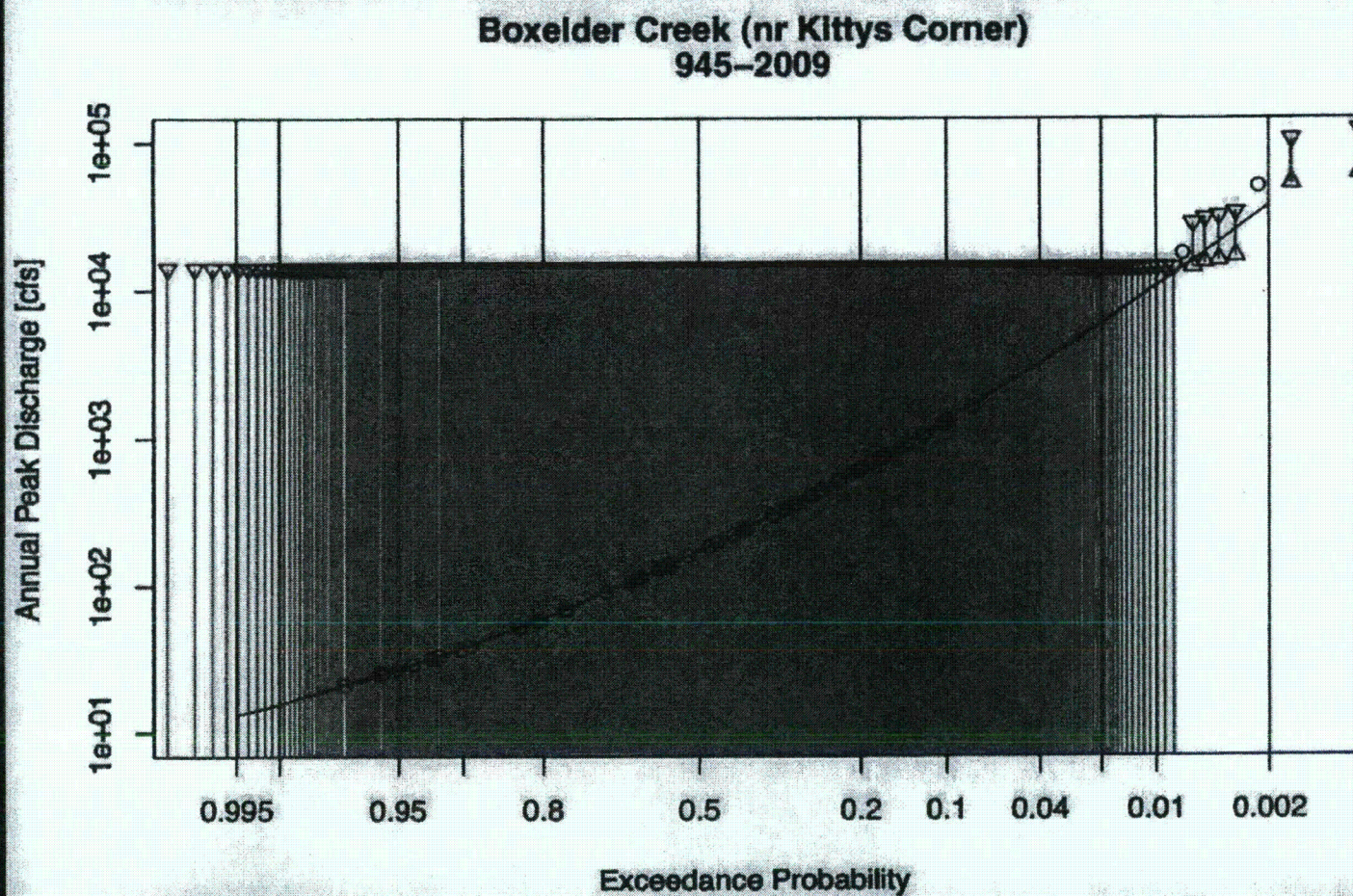


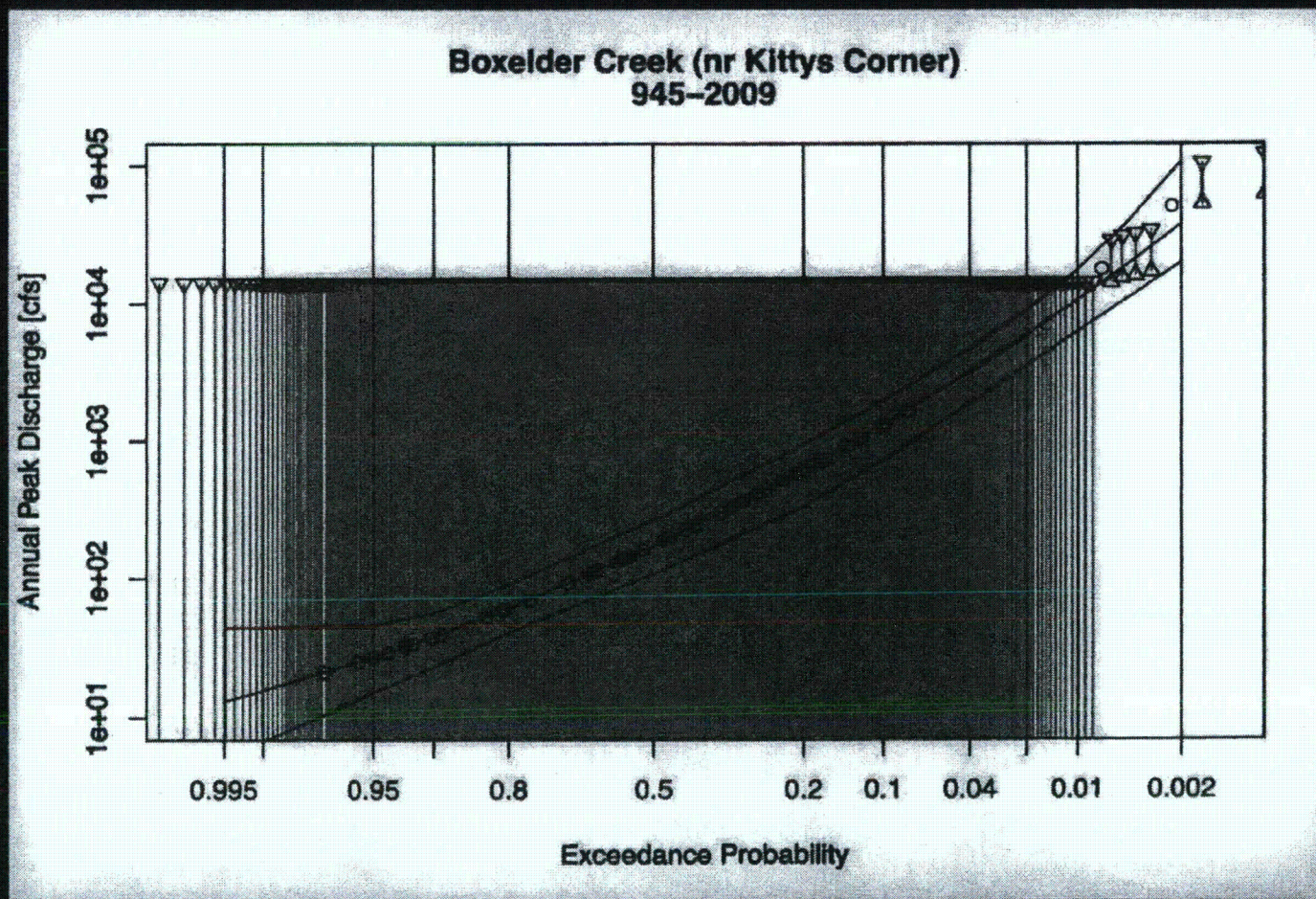
Figure Lower Boxelder Chronology. Graphical representation of the long-term flood chronology for lower Boxelder Creek.

Boxelder Creek (nr Kittys Corner) Annual Peak Flows 945–2009





Uncertainty and Confidence Intervals



Quantile Estimates and Confidence Intervals for 1% Flood

Period of Record	$Q_{0.99}$	95% Confidence Interval	
1966-2009	18,800	4,800	4,640,000
1946-2009	14,100	4,300	820,000
1904-2009	15,300	5,200	273,000
945-2009	10,600	6,300	18,100
1966-2009*	2,760	1,390	19,100

* 1972 flood omitted

Quantile Estimates and Confidence Intervals for 0.2% Flood

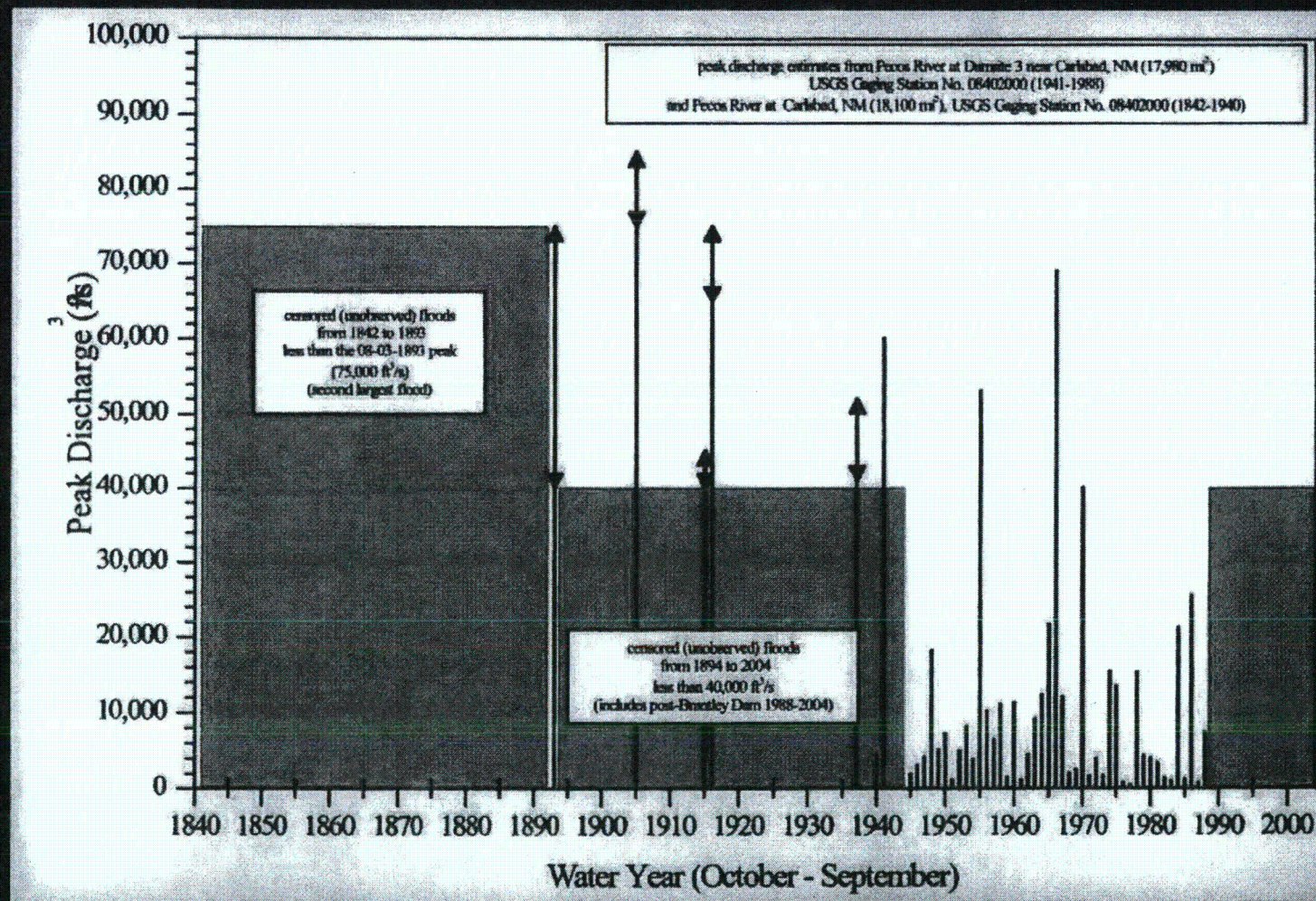
Period of Record	$Q_{0.99}$	95% Confidence Interval	
1966-2009	104,000	15,100	429,000,000
1946-2009	63,400	12,100	28,100,000
1904-2009	64,500	14,800	7,320,000
945-2009	37,400	19,800	108,000
1966-2009*	5,460	2,150	91,400

* 1972 flood omitted

Why Paleoflood Data Are Useful

- Reveal character of right-hand tail of flood frequency distribution
- Inexpensive
- Available now (maybe)

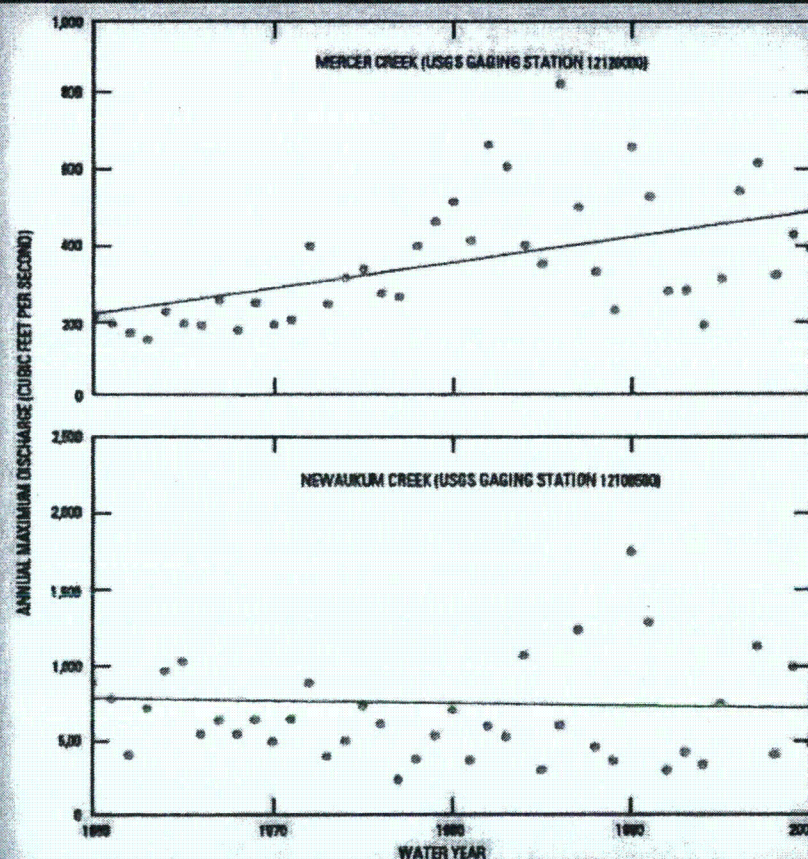
Pecos River near Carlsbad (Brantley Dam), NM



...But There Are Some Issues:

- Dependence on site characteristics
- QA/QC of data
 - Indirect measurements
 - Reconstructing channel geometry and hydraulic conditions
- Nonstationarity
 - Changes in land use in basin
 - Regulation such as dams and levees
 - Climate change

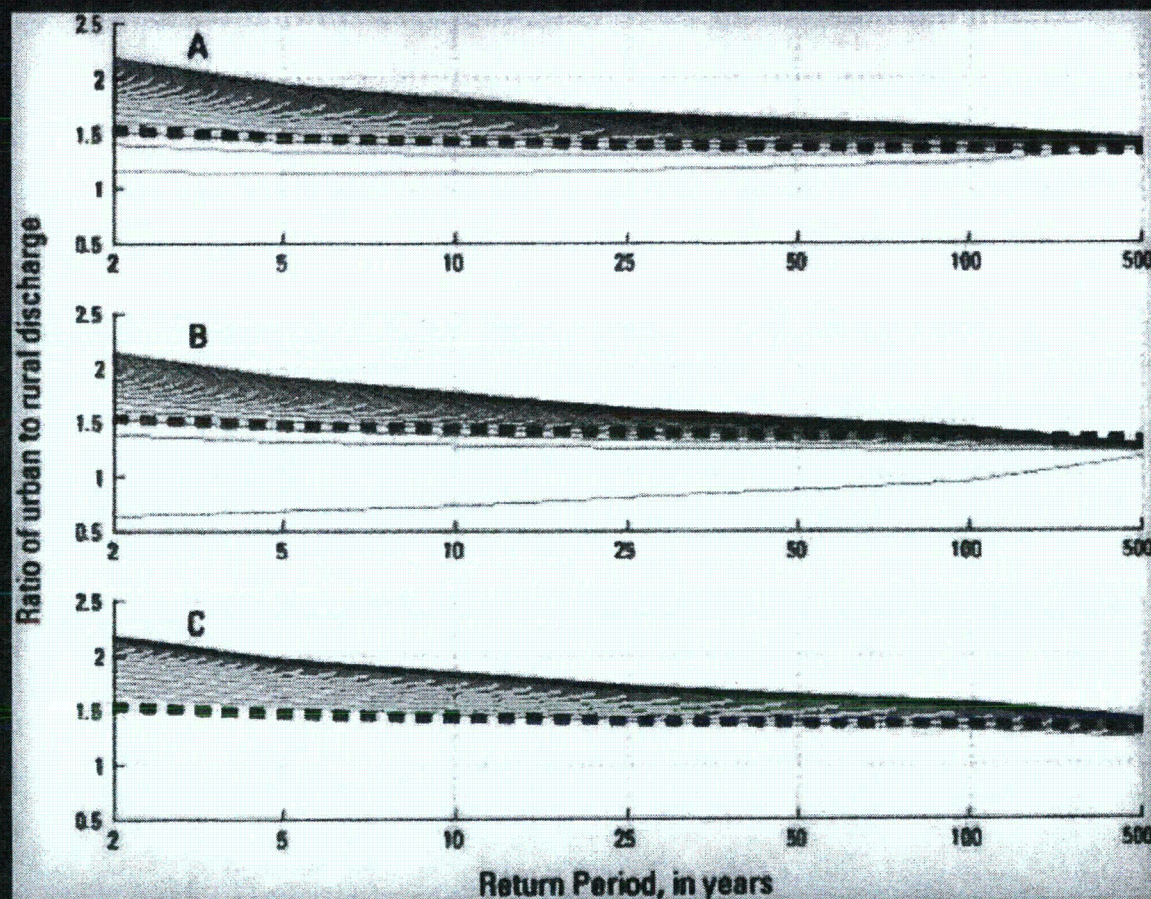
Impact of Development



Annual maximum discharge increased with urban development in Mercer Creek from 1960 to 2000, but remained essentially the same in nearby rural Newaukum Creek during that period.

Ratio of Urban to Rural Discharge

West Branch Herring Run at Idlewylde, MD (01585200)



Stationarity of Climate

IV. Data Assumptions

Necessary assumptions for a statistical analysis are that the array of flood information is a reliable and representative time sample of random homogeneous events. Assessment of the adequacy and applicability of flood records is therefore a necessary first step in flood frequency analysis. This section discusses the effect of climatic trends, randomness of events, watershed changes, mixed populations, and reliability of flow estimates on flood frequency analysis.

A. Climatic Trends

There is much speculation about climatic changes. Available evidence indicates that major changes occur in time scales involving thousands of years. In hydrologic analysis it is conventional to assume flood flows are not affected by climatic trends or cycles. Climatic time invariance was assumed when developing this guide.

Milly et al. [2008]

POLICYEDRUM

CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

R. C. B. MEYER,¹* Julia Botsman,¹ Maja Füllmann,² Robert M. Strack,³ Zoltan W. Erdemovic,⁴ David P. Littman,⁵ David A. Smith⁶

Systems for the management of water resources in the developed world have been designed and expanded under the assumption of stationarity. Stationarity—the idea that natural systems fluctuate within an unchanging envelope of variability—is a foundational concept that permeates training and practice in water resource engineering. It implies that any variable in a natural system (or natural flow peak) has a normal distribution (let *x* = water particles) probability density function that is stationary in time. The distribution is created from the mean and standard deviation. Under stationarity, self-estimation errors are acknowledged, but have been assumed to be reducible by additional observations, among efficient estimation, or regional or hydrologic modeling. The profit, in turn, are used to evaluate and manage risks to water supplies, operations, and floodplains, among global water issues in water resource water science.

[illegible]

Die wesentlichen Daten des Unternehmens werden planmässig

In view of the magnitude and ubiquity of the hydroclimatic change apparently underway, however, we assert that atmospheric fluxes should be larger, more as a corollary default assumption to water-scarcity risk assessment and planning. Finding a suitable evidence is critical for human adaptation in changing climate.

flow, and consequently the "Starkness" of the flow increases substantially. Anthropogenic changes of Earth's climate is altering the volume and character of precipitation, evaporation, and rates of discharge of rivers (15). (See Figure 10 below). Warming of the oceans, atmospheric humidity and water transport. This increases precipitation, and possibly flood risk. Water spreading about the globe, water vapor, has a capacity (16). Warmer sea level induces gradually heightening risk of transgression of coastal lands, water supplies. Global sea surface temperature is increasing very noticeably, but glaciers and shore-based liners diminish actual sea level and submerge entire nations (17).

Amphipods: climate warming appears to be driving a poleward expansion of the subtropical dry zone (if, strictly reducing rainfall in some regions). Together, caveolae, and thermodynamic response largely explain the picture of regional changes in measures of moisture frequency available

Climate Change influences a host of variables that ultimately has facilitated management of water supplies, demands, and risks.

Why not? That anthropogenic climate change affects the water cycle (7) and water supply (10) is a new finding. Hydroclimatologists are often accused for discounting anthropogenic factors. For a time, hydroclimatology had not convincingly stated the effects of initial variability and/or the collective impact of optimally operated infrastructure (11, 12). According to the industrial uncertainties of climate parameters estimated from observations (7), effectively budgeting against such climate changes. Additionally, climate projection was not considered such (13, 14).

Because of the emphasis on basic life support, the opinion that the thesis has come to new heights beyond the well-used risk approach. Projections of *rural* changes are influenced by increasingly data-oriented, interactive sets of climate models. The global pattern of climate change is being described in terms of the greenhouse effect, but the regional pattern is still uncertain. The impact of human activities on the atmosphere has been established—unequivocally and is consistent with traditional research in climate forcing (1,2). Paleoclimatologists' studies suggest that small changes in mean climate might produce large changes in extremes (10), although the magnitude of the extremes is still uncertain. Frequency analysis has been applied (11–13). Projections changes in *rural* during the twentieth century of climate of major urban centers are available (14). The impact of climate change on the structure patterns happen now are large enough to push hydroclimatology beyond the range of climate variability (15). Some of the most likely adverse impacts will be the impacts of climate change on the

Statements cannot be derived. Even with aggressive mitigation, continued warming is very likely, given the resilience time of atmospheric CO₂ and the thermal inertia of the Earth system (p. 20).

A perspective We need to find ways to identify unnecessary prohibitions, models of relevant environmental variables and to use them to guide to optimize water systems. The challenge is daunting. Patterns of change are complex, uncertainties are large and the knowledge base changes rapidly.

Under the rational planning framework advanced by the Harvard Water Program (21, 22), the estimation of sustainability was

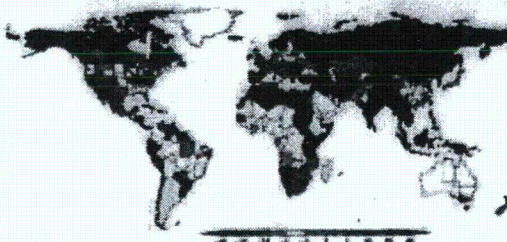
POLICYFORUM

continued with operations research, statistics, and culture economics to formulate design problems as trade-offs of price, risk, and benefit dependent on variables such as resource volume. These trade-offs were evaluated by optimization or simulation using either long historical procedures (time series or stochastic simulations) or simulation based on properties of the temporal time series.

This framework can be adapted to changing climate. Nonstationary hydrologic variables can be modeled stochastically to describe the temporal evolution of their paths, with estimates of their estimating model developed to combine hydrologic measurements of multiple climate variables (e.g., stream flow, snow cover, and soil moisture) to

Rapid flow of such climate-change information from the scientific realm to water managers will be critical for planning, because the information base is likely to change rapidly as climate science advances during the coming decades. Optimal use of available climate information will require extensive training of fluid current and future hydrologists, engineers, and managers in uncertainty and uncertainty. Rapid-growing development of hydrologic very regions focused, interdisciplinary efforts in the spirit of the Harvard Water Program.

A sub-national platform for climate negotiations and climate action delivery may help (23). Higher-resolution simulations of the physics of the global land-atmosphere system that focus on the next 25 to 50 years are crucial. Water managers who are developing plans for their local communities to adapt to climate changes will not be best served by a model whose horizon and grain divisions measured in hundreds of kilometers. To facilitate widespread transfer to local decision-makers, climate scientists need to develop, test, and validate models that can be used to make timely, explicit and faithful representation of surface- and ground-water processes, water infrastructure, and human water, land, and the agricultural and society sectors.



Human Influences. Dramatic changes to rainfall volume from less than used are projected in many parts of the world by the middle of the 21st century, linked to historical conditions from the 1950 to 1970 period. Color denotes percentage change from 1950 to 2050. From 11 climate models. When a country or smaller political unit is colored, it is more of 11 models agreed on the direction of change. Areas outlined of model 11 colors, with the International Geosphere and Biosphere (IGBP) 1994 1/2° resolution of climate.

11. J. A. J. Hargreaves, *et al.*, *Journal of Applied Ecology*, **19**, 1982, 103-114.
12. J. A. J. Hargreaves, *et al.*, *Journal of Applied Ecology*, **19**, 1982, 115-124.
13. J. A. J. Hargreaves, *et al.*, *Journal of Applied Ecology*, **19**, 1982, 125-134.
14. J. A. J. Hargreaves, *et al.*, *Journal of Applied Ecology*, **19**, 1982, 135-144.
15. J. A. J. Hargreaves, *et al.*, *Journal of Applied Ecology*, **19**, 1982, 145-154.
16. J. A. J. Hargreaves, *et al.*, *Journal of Applied Ecology*, **19**, 1982, 155-164.
17. J. A. J. Hargreaves, *et al.*, *Journal of Applied Ecology*, **19**, 1982, 165-174.
18. J. A. J. Hargreaves, *et al.*, *Journal of Applied Ecology*, **19**, 1982, 175-184.
19. J. A. J. Hargreaves, *et al.*, *Journal of Applied Ecology*, **19**, 1982, 185-194.
20. J. A. J. Hargreaves, *et al.*, *Journal of Applied Ecology*, **19**, 1982, 195-204.

blending science and art to synthesize observations, it can have useful both. Assuming climate adversity, anthropologists have paradoxically reviewed ancient texts (24) that they could acquire some perspectives on what was thought to be a fairly constant picture in a nontransmutably more contemporary observations is critical.

The world today faces the increasing and challenging task of ensuring an adequate water infrastructure (25) and building new water infrastructure (26). Now is an opportune moment to update the analytic strategies used for planning such grand investments under an uncertain and changing climate.

[illegible][illegible]

Amphipods possess a variety of sensory appendages that are used for feeding, locomotion, and reproduction. The antennae are the most important sensory appendages and are used for feeding, locomotion, and reproduction. The antennae are the most important sensory appendages and are used for feeding, locomotion, and reproduction.

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In order to adapt to climate change, we will not be held
accountable by a model whose horizontal grid has
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To facilitate information transfer in both
directions between climate science and water
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of surface- and ground-water processes,
water infrastructure, and water uses, including
the agricultural and energy sectors.

[illegible]

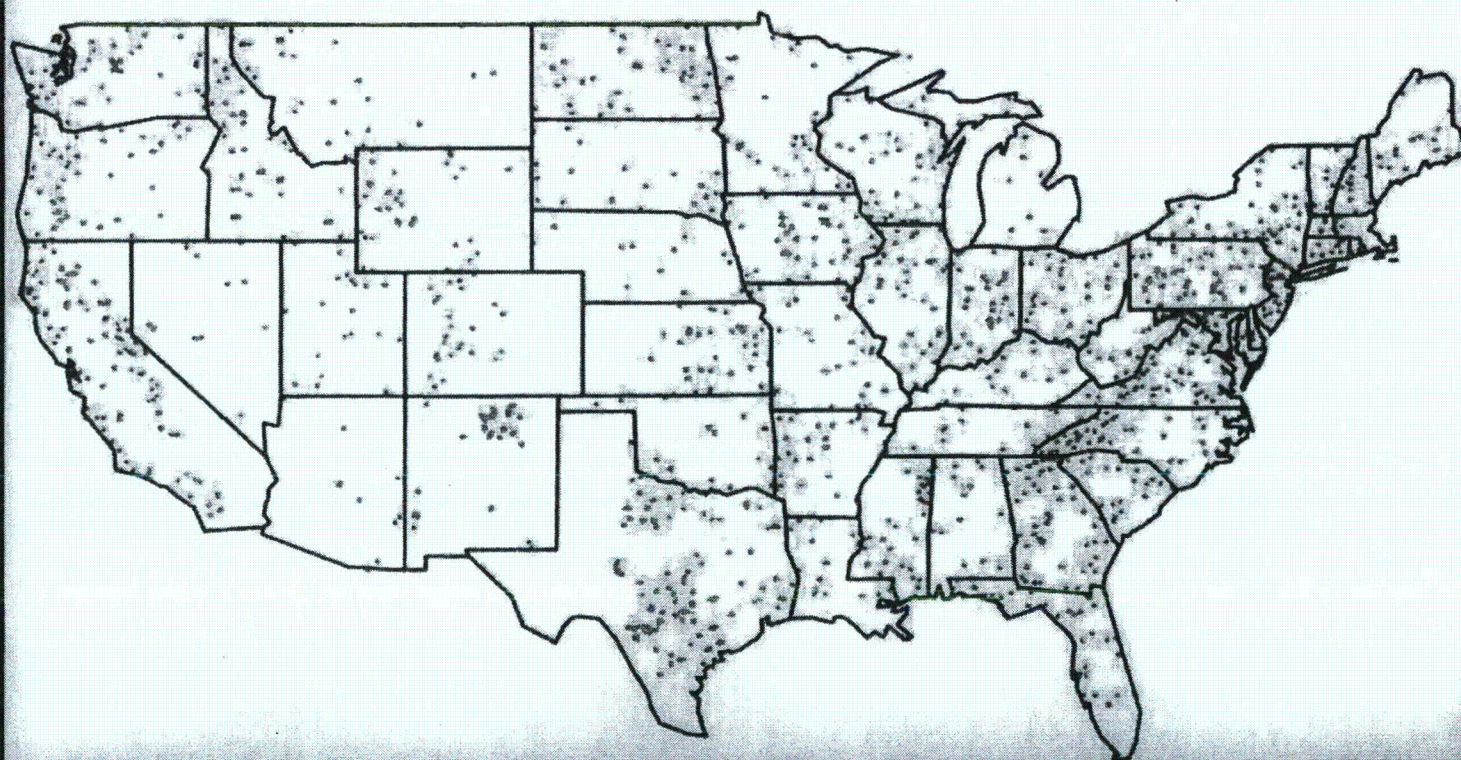
Climate Change and Stationarity of Floods

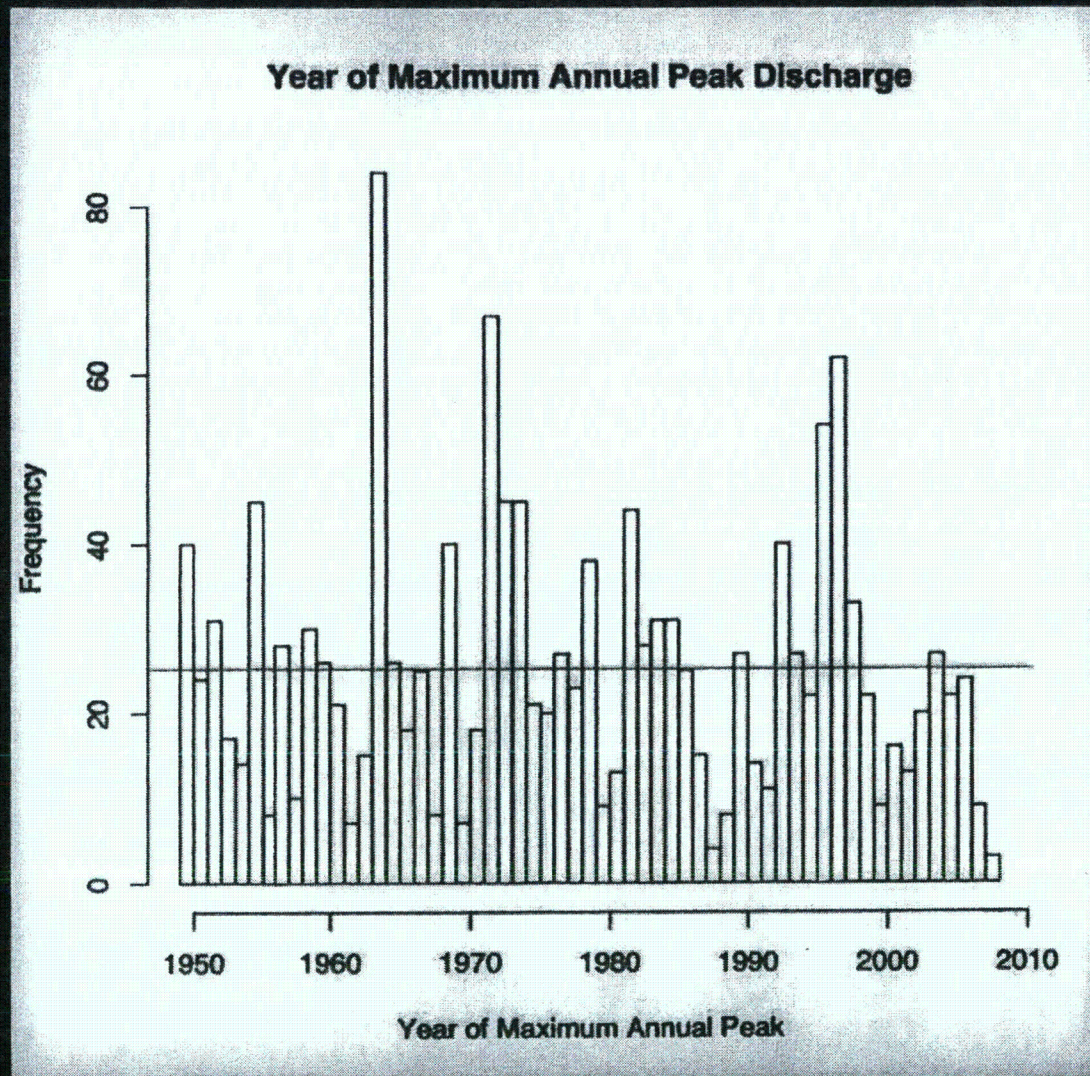
- What data show now
- What models predict

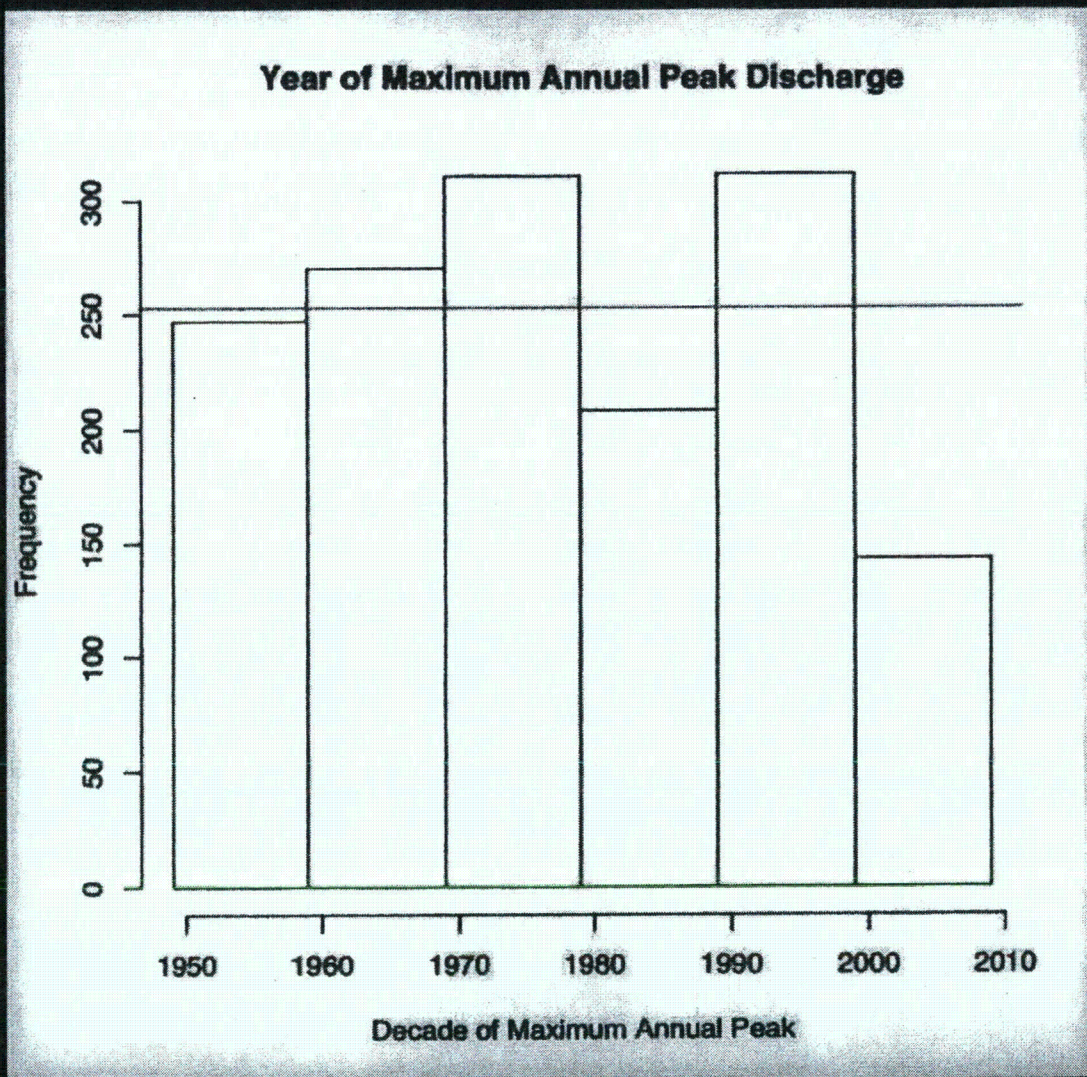
Earthquakes ★ Floods ★ Hurricanes ★ Landslides ★ Tsunamis ★ Volcanoes ★ Wildfires

HCDN Sites

Locations of 1491 HCDN Stations

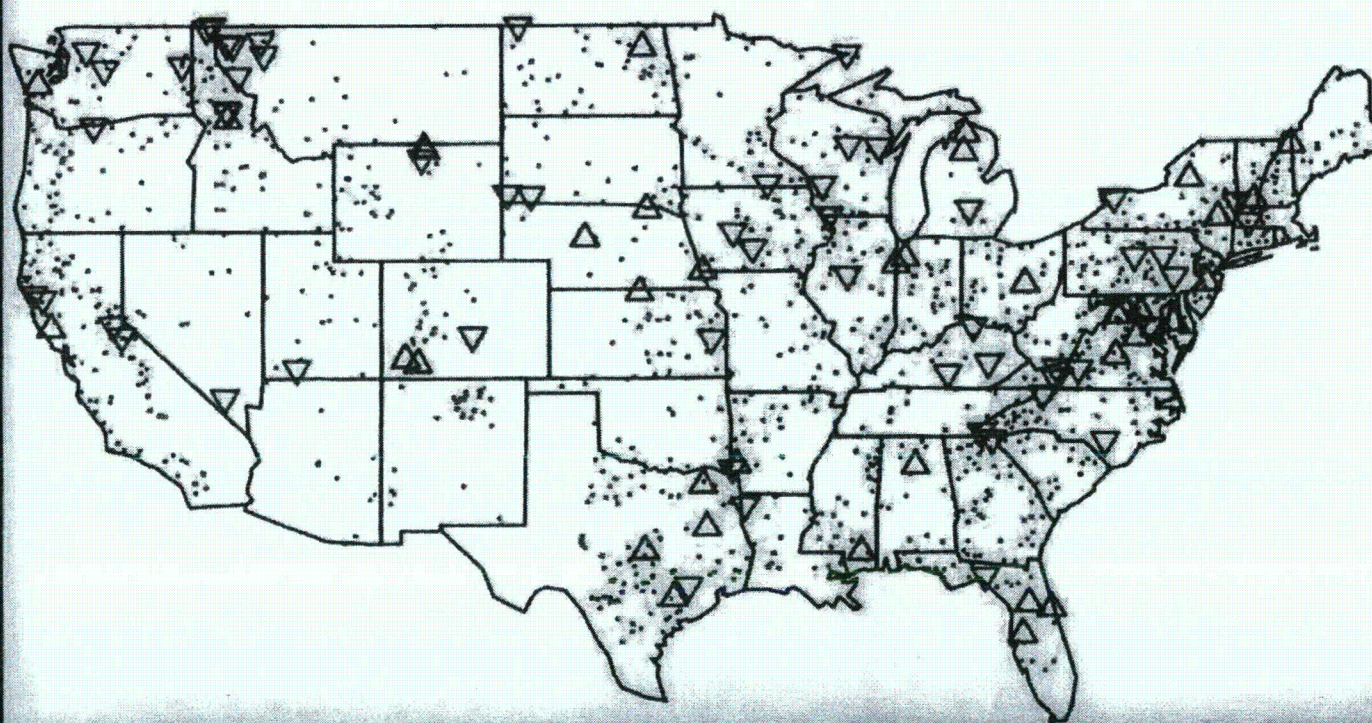




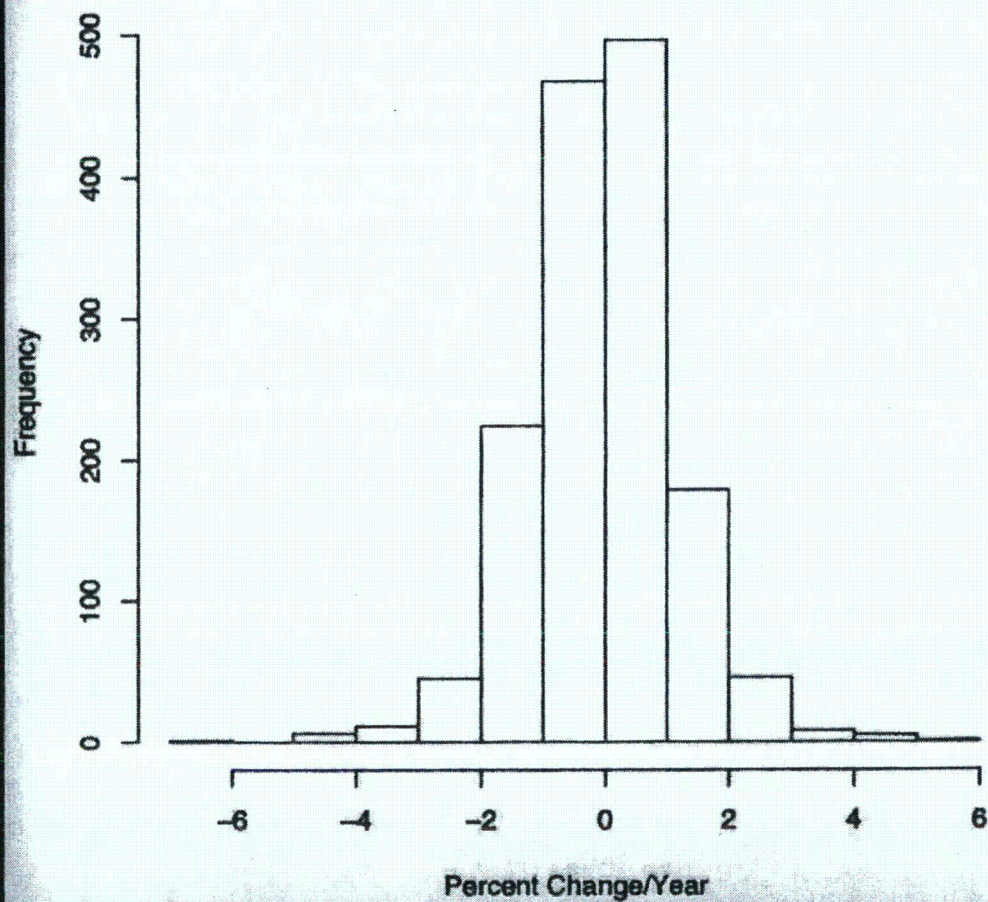


Earthquakes ★ Floods ★ Hurricanes ★ Landslides ★ Tsunamis ★ Volcanoes ★ Wildfires

Trends Observed in Annual Peak Flows (1948–2007)
1491 HCDN Stations, 5% ALRT Test



Histogram of Observed Trend Magnitudes



p-values Corresponding to Upward Trends

