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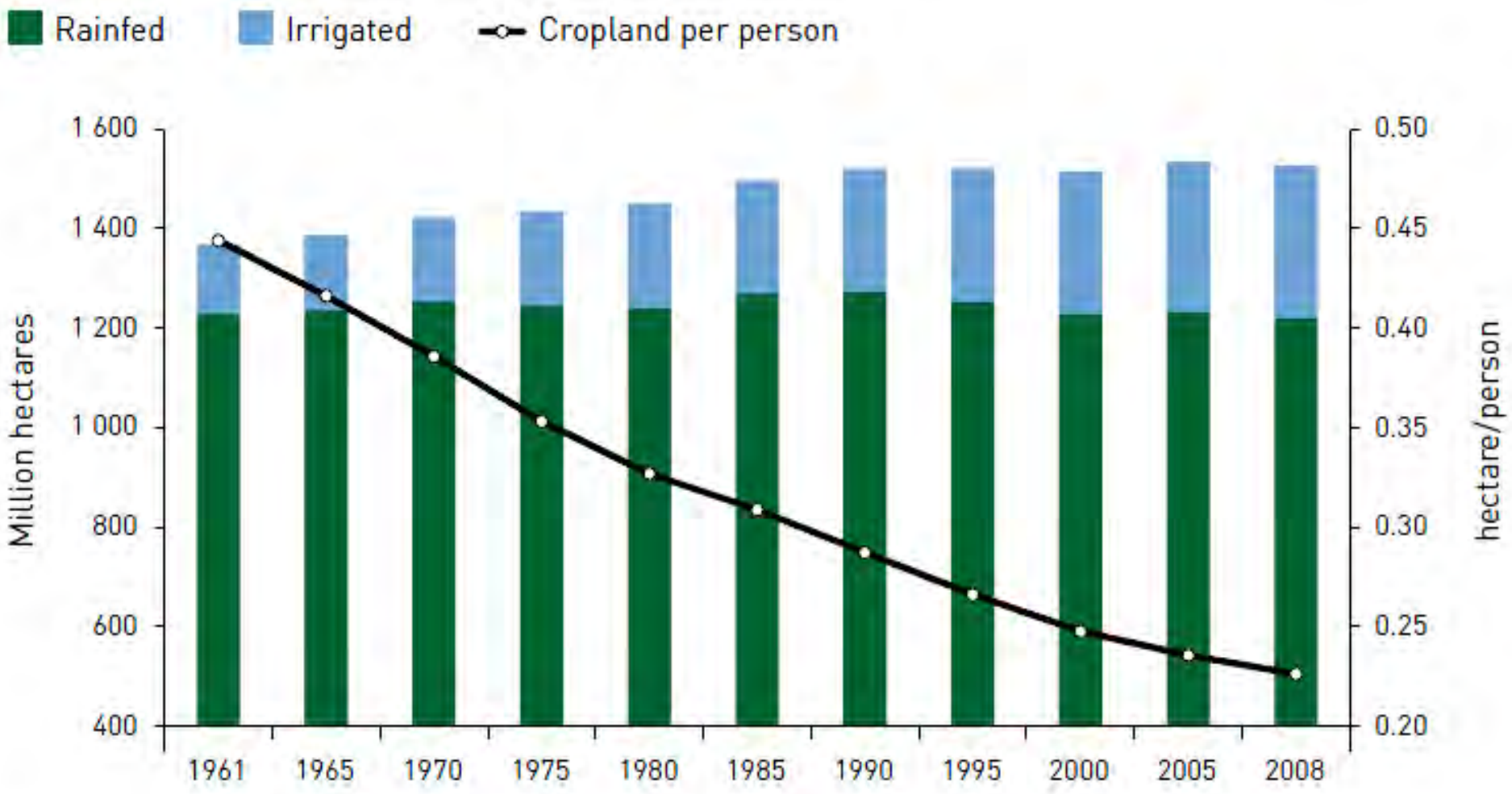
Water, Energy, and Food Production: Observing, Understanding, Forecasting

4th University of Florida Water Institute Symposium
Sustainable Water Resources: Complex Challenges, Integrated Solutions
11 February, 2014
Gainesville, FL

Dr. Jerad Bales
U.S. Geological Survey
Acting Assoc. Director for Water

Feeding the World



Source: FAO (2010b)

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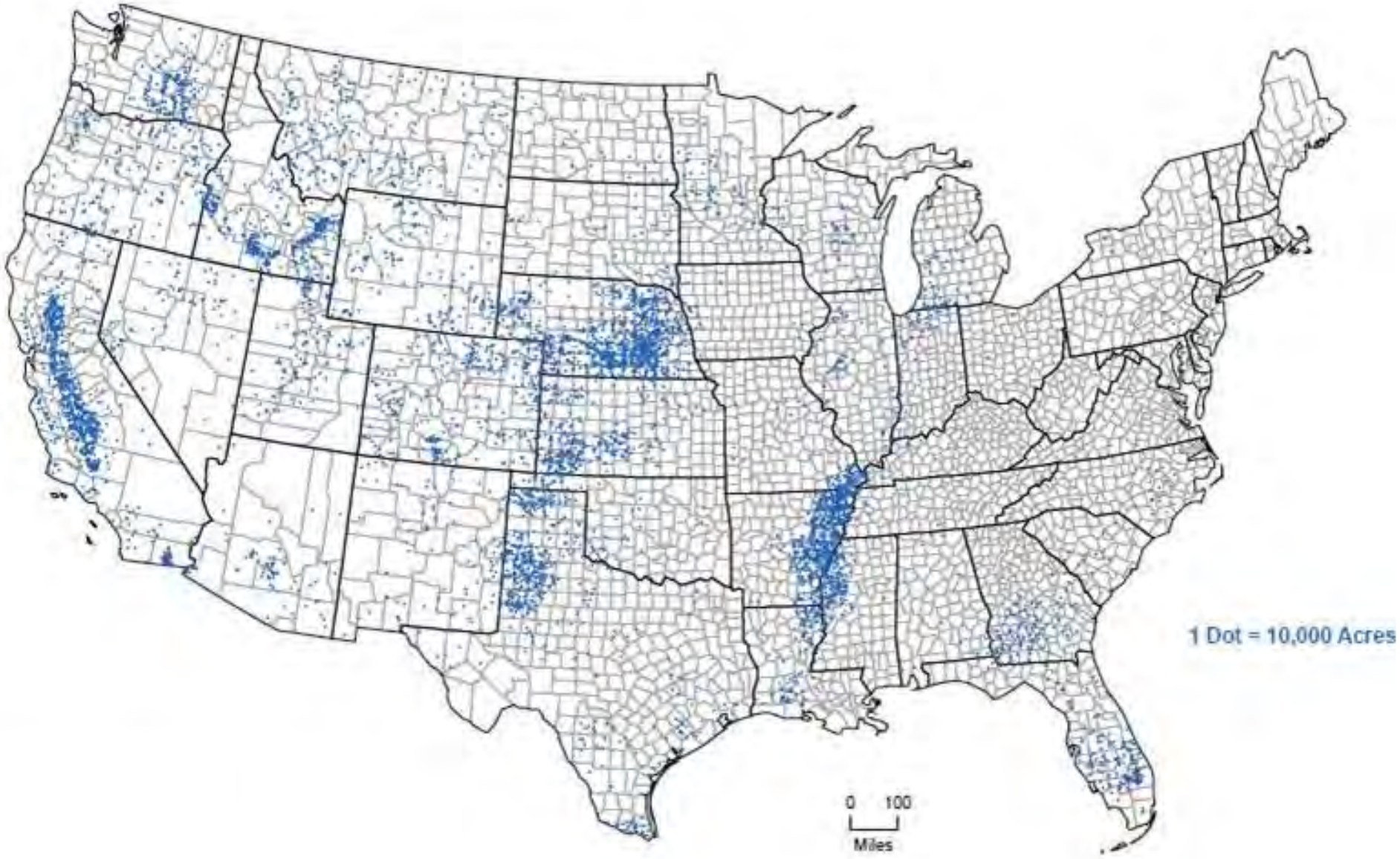
Irrigated Agriculture



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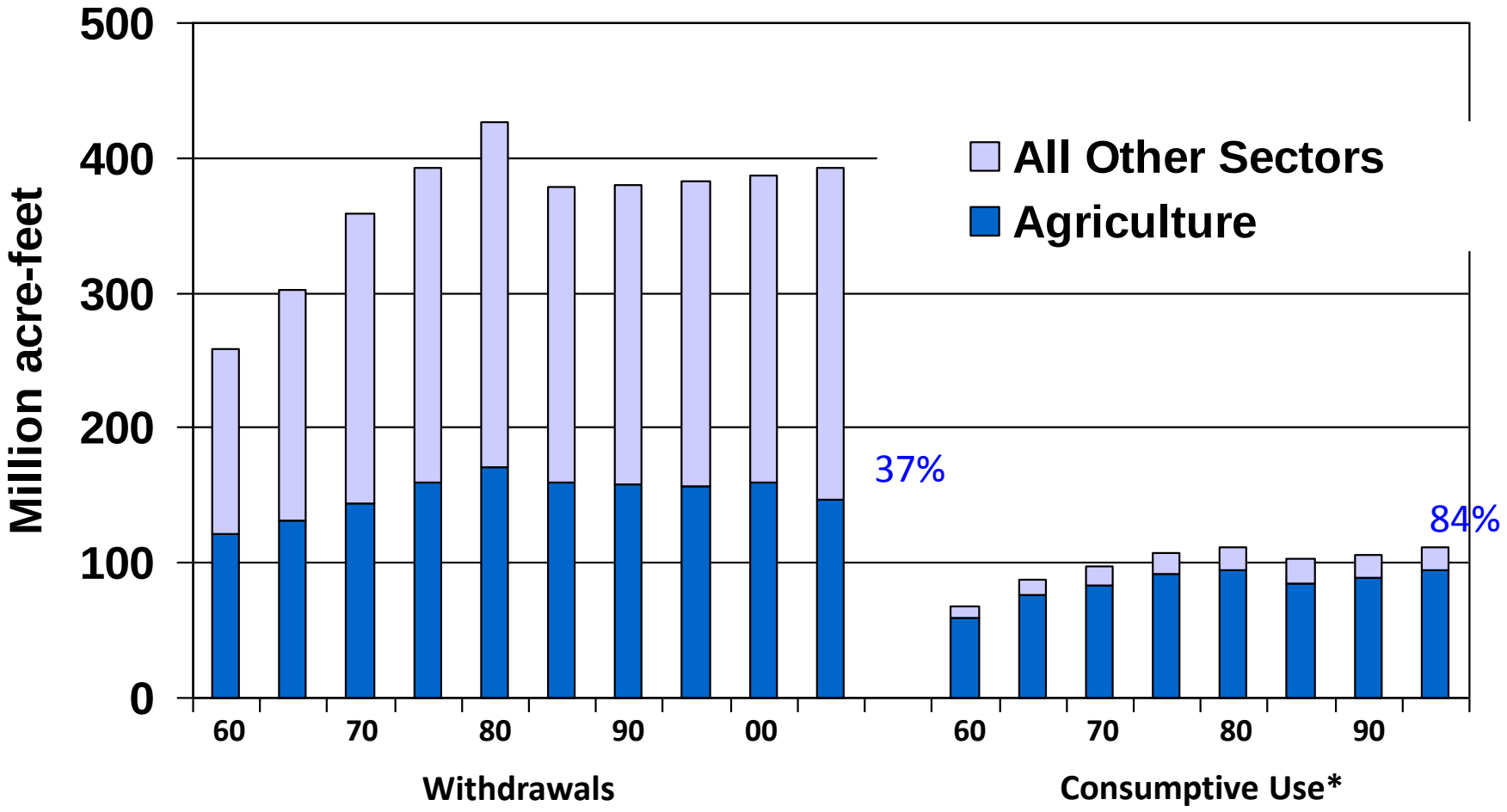
Total and agricultural water withdrawals (1960-2005) and consumptive use estimates (1960-1995)



Source: USDA, NRCS, based on Kenny, et al, 2009

** Data limitations do not allow estimation of consumptive use in 2000.*

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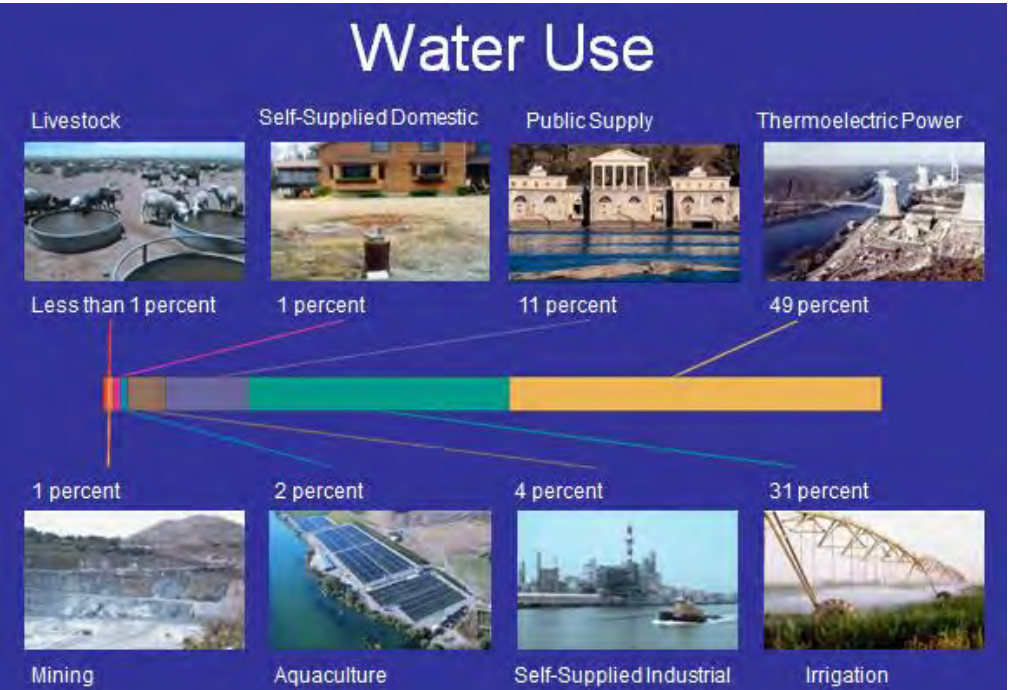
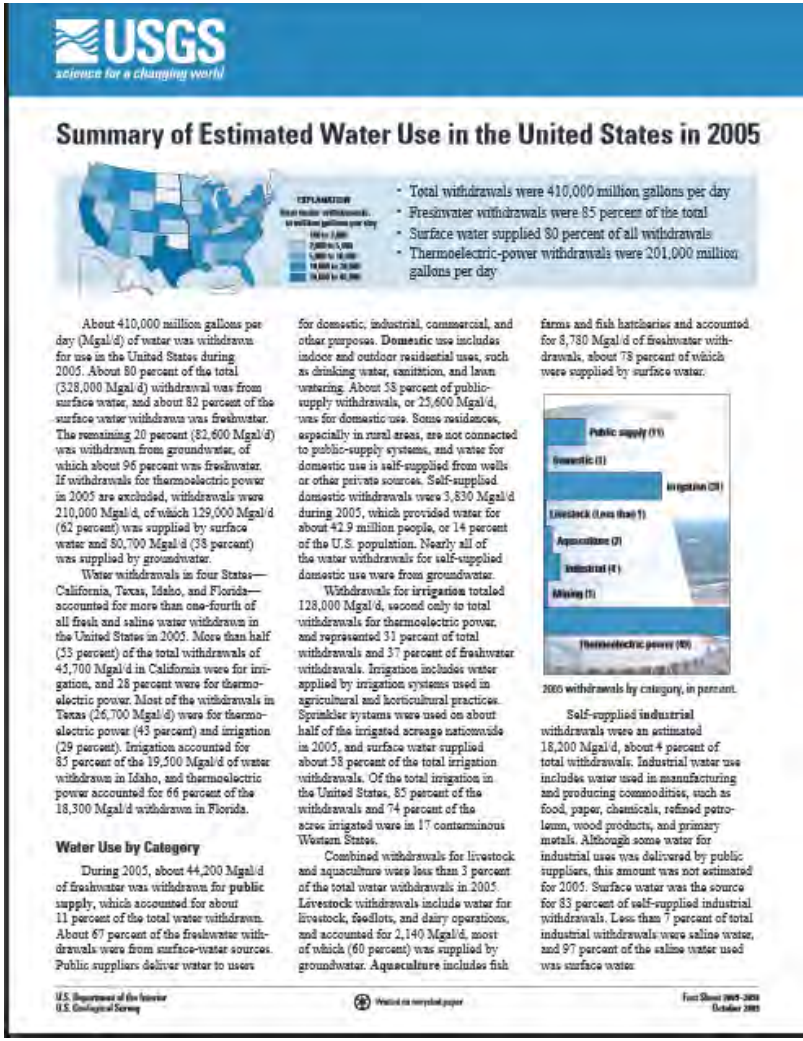
USGS Water-Use Activities

- It's not really water use.
- Information is derived.
- Information is inconsistent.
- Information is incomplete.





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Summary of Estimated Water Use in the United States in 2005

- Total withdrawals were 410,000 million gallons per day
- Freshwater withdrawals were 85 percent of the total
- Surface water supplied 80 percent of all withdrawals
- Thermoelectric-power withdrawals were 201,000 million gallons per day

About 410,000 million gallons per day (Mgal/d) of water was withdrawn for use in the United States during 2005. About 80 percent of the total (328,000 Mgal/d) withdrawal was from surface water, and about 82 percent of the surface water withdrawn was freshwater. The remaining 20 percent (82,600 Mgal/d) was withdrawn from groundwater, of which about 96 percent was freshwater. If withdrawals for thermoelectric power in 2005 are excluded, withdrawals were 210,000 Mgal/d, of which 129,000 Mgal/d (62 percent) was supplied by surface water and 80,700 Mgal/d (38 percent) was supplied by groundwater.

Water withdrawals in four States—California, Texas, Idaho, and Florida—accounted for more than one-fourth of all fresh and saline water withdrawn in the United States in 2005. More than half (53 percent) of the total withdrawals of 45,700 Mgal/d in California were for irrigation, and 28 percent were for thermoelectric power. Most of the withdrawals in Texas (26,700 Mgal/d) were for thermoelectric power (43 percent) and irrigation (29 percent). Irrigation accounted for 85 percent of the 19,500 Mgal/d of water withdrawn in Idaho, and thermoelectric power accounted for 66 percent of the 18,300 Mgal/d withdrawn in Florida.

Water Use by Category

During 2005, about 44,200 Mgal/d of freshwater was withdrawn for **public supply**, which accounted for about 11 percent of the total water withdrawn. About 67 percent of the freshwater withdrawals were from surface-water sources. Public suppliers deliver water to users for domestic, industrial, commercial, and other purposes. **Domestic** use includes indoor and outdoor residential uses, such as drinking water, sanitation, and lawn watering. About 53 percent of public-supply withdrawals, or 25,600 Mgal/d, was for domestic use. Some residences, especially in rural areas, are not connected to public-supply systems, and water for domestic use is self-supplied from wells or other private sources. Self-supplied domestic withdrawals were 3,830 Mgal/d during 2005, which provided water for about 42.9 million people, or 14 percent of the U.S. population. Nearly all of the water withdrawals for self-supplied domestic use were from groundwater.

Withdrawals for **irrigation** totaled 128,000 Mgal/d, second only to total withdrawals for thermoelectric power, and represented 31 percent of total withdrawals and 37 percent of freshwater withdrawals. Irrigation includes water applied by irrigation systems used in agricultural and horticultural practices. Sprinkler systems were used on about half of the irrigated acreage nationwide in 2005, and surface water supplied about 58 percent of the total irrigation withdrawals. Of the total irrigation in the United States, 85 percent of the withdrawals and 74 percent of the acres irrigated were in 17 conterminous Western States.

Combined withdrawals for livestock and aquaculture were less than 3 percent of the total water withdrawals in 2005. **Livestock** withdrawals include water for livestock, feedlots, and dairy operations, and accounted for 2,140 Mgal/d, most of which (60 percent) was supplied by groundwater. **Aquaculture** includes fish farms and fish hatcheries and accounted for 8,780 Mgal/d of freshwater withdrawals, about 78 percent of which were supplied by surface water.

2005 withdrawals by category, in percent.

Self-supplied industrial withdrawals were an estimated 18,200 Mgal/d, about 4 percent of total withdrawals. Industrial water use includes water used in manufacturing and producing commodities, such as food, paper, chemicals, refined petroleum, wood products, and primary metals. Although some water for industrial uses was delivered by public suppliers, this amount was not estimated for 2005. Surface water was the source for 83 percent of self-supplied industrial withdrawals. Less than 7 percent of total industrial withdrawals were saline water, and 97 percent of the saline water used was surface water.

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

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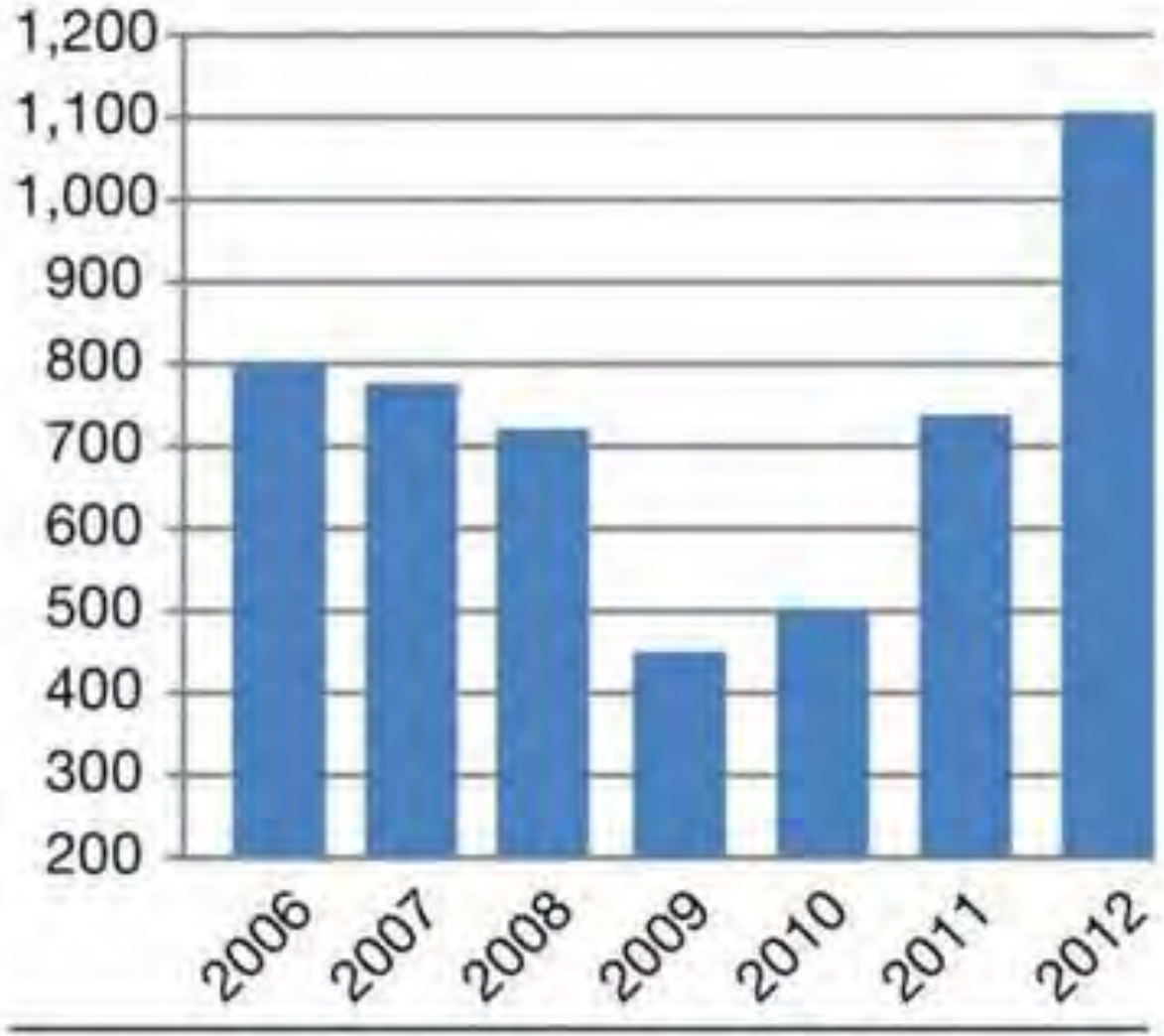
Fact Sheet 2009–3098
October 2009

Drought and Water Use



Source: Nebraska Department of Natural Resources
MARK ANDERSEN/Lincoln Journal Star

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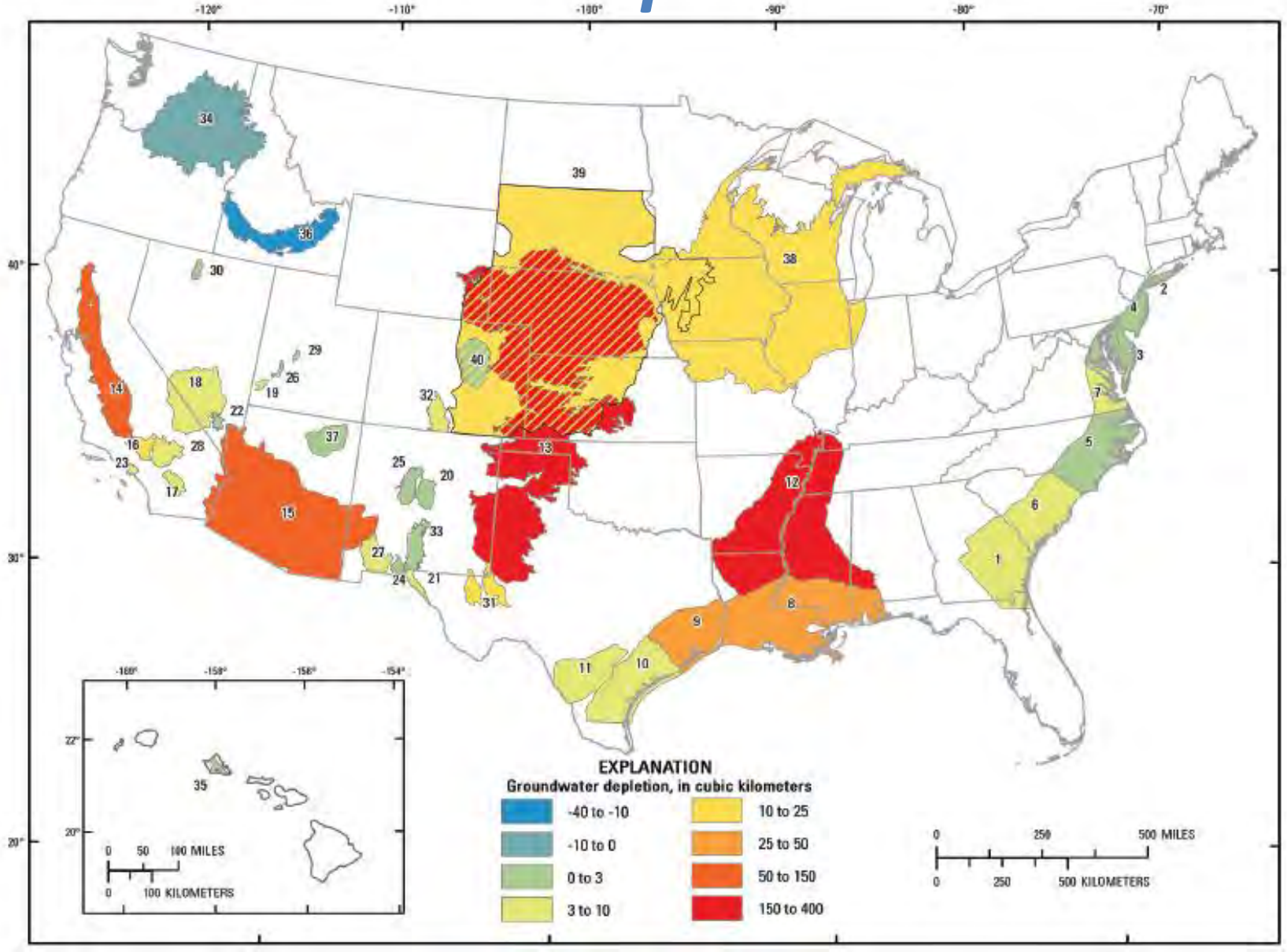
Groundwater Depletion in the U.S.



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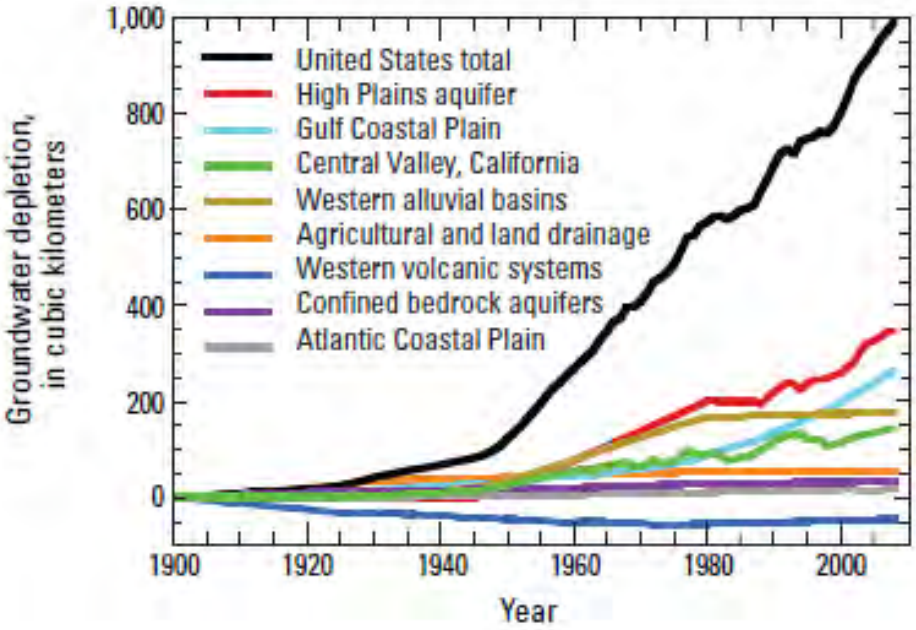
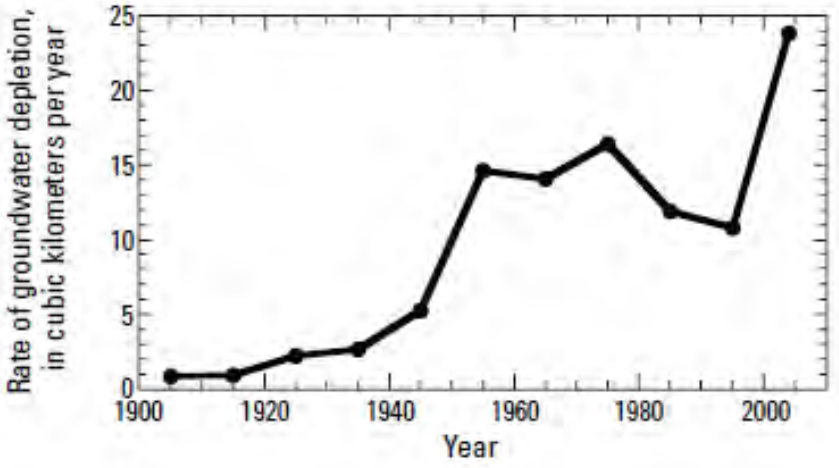
Konikow, 2013

Groundwater Depletion in the U.S.

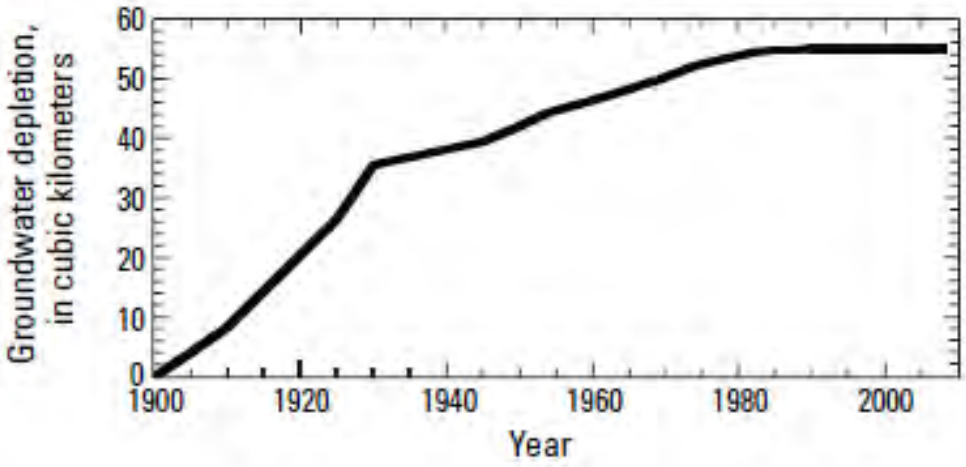


Depletion by Aquifer



Cumulative Depletion

Konikow, 2013



Depletion from Drainage

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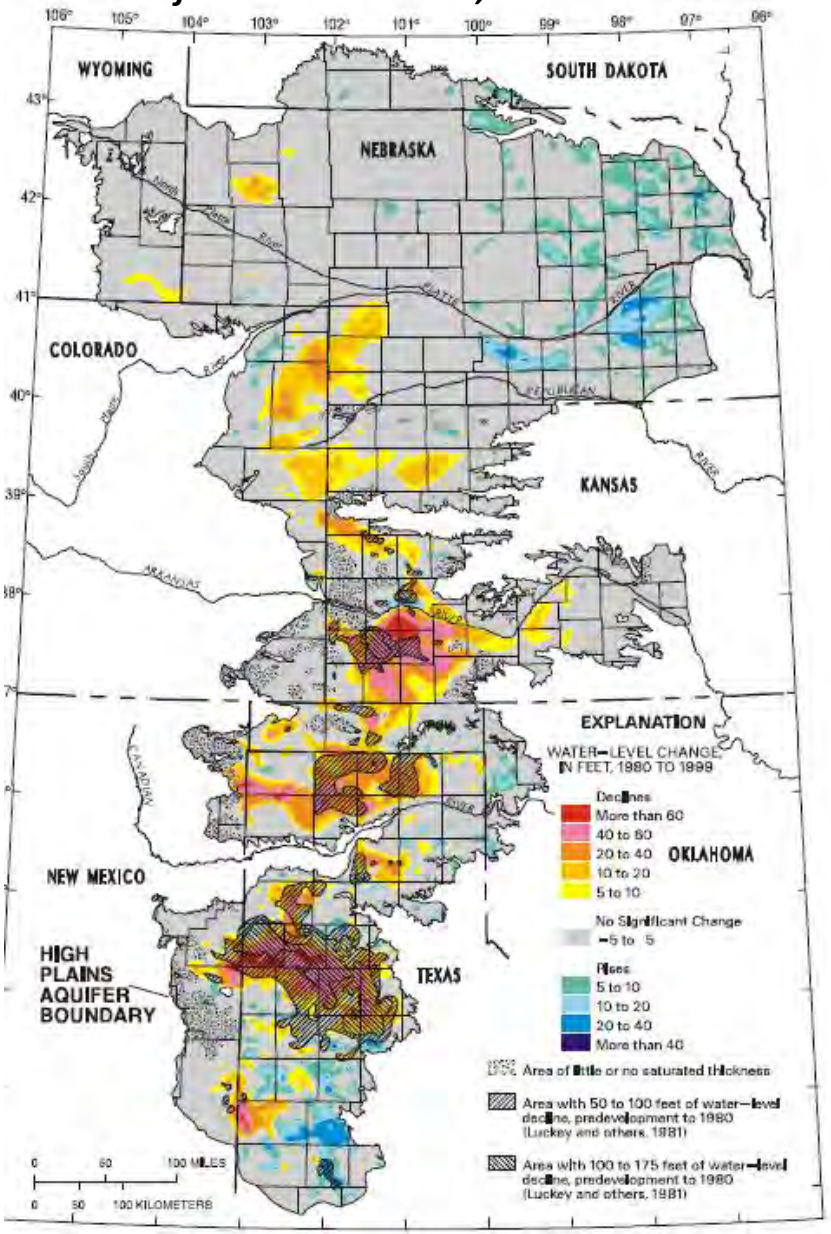
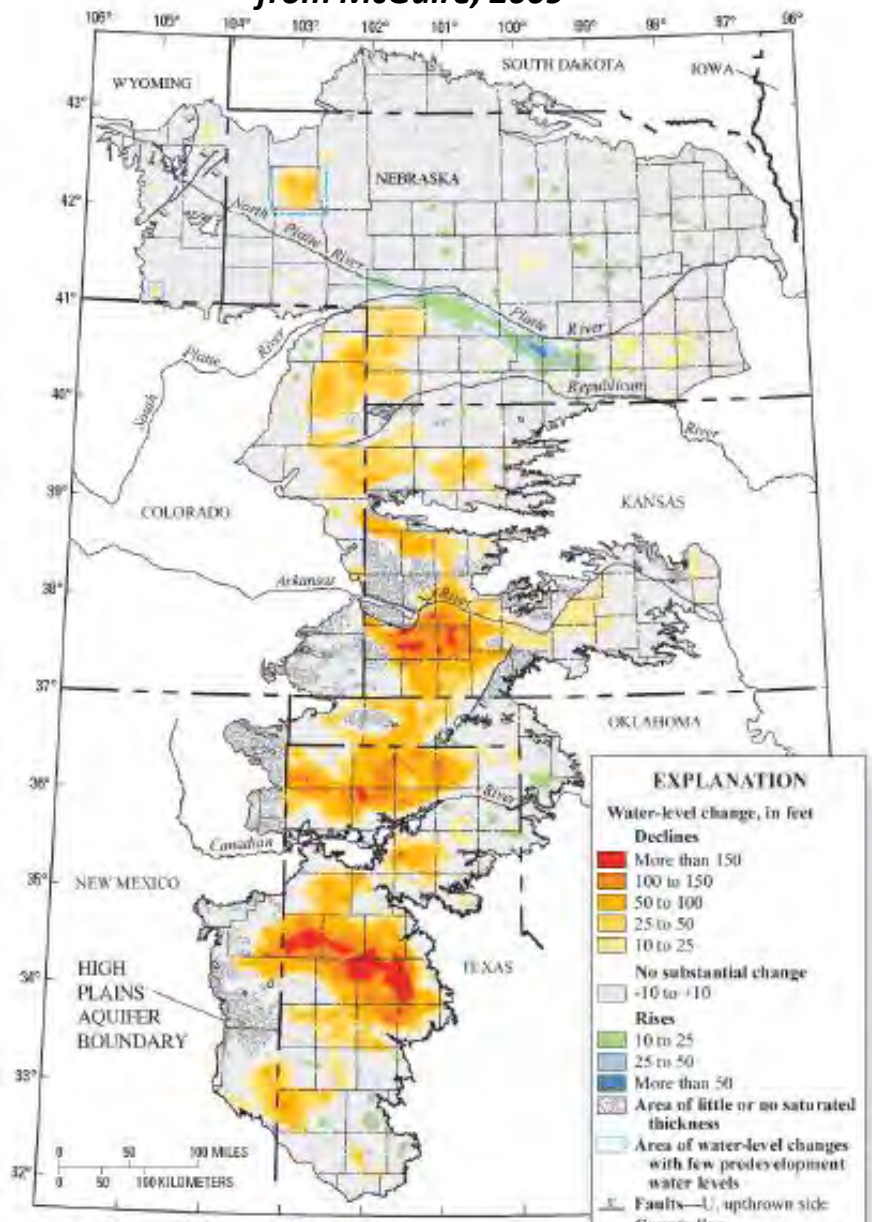
1980 – 1998
red: 40 – 60 ft

from McGuire et al., 2001

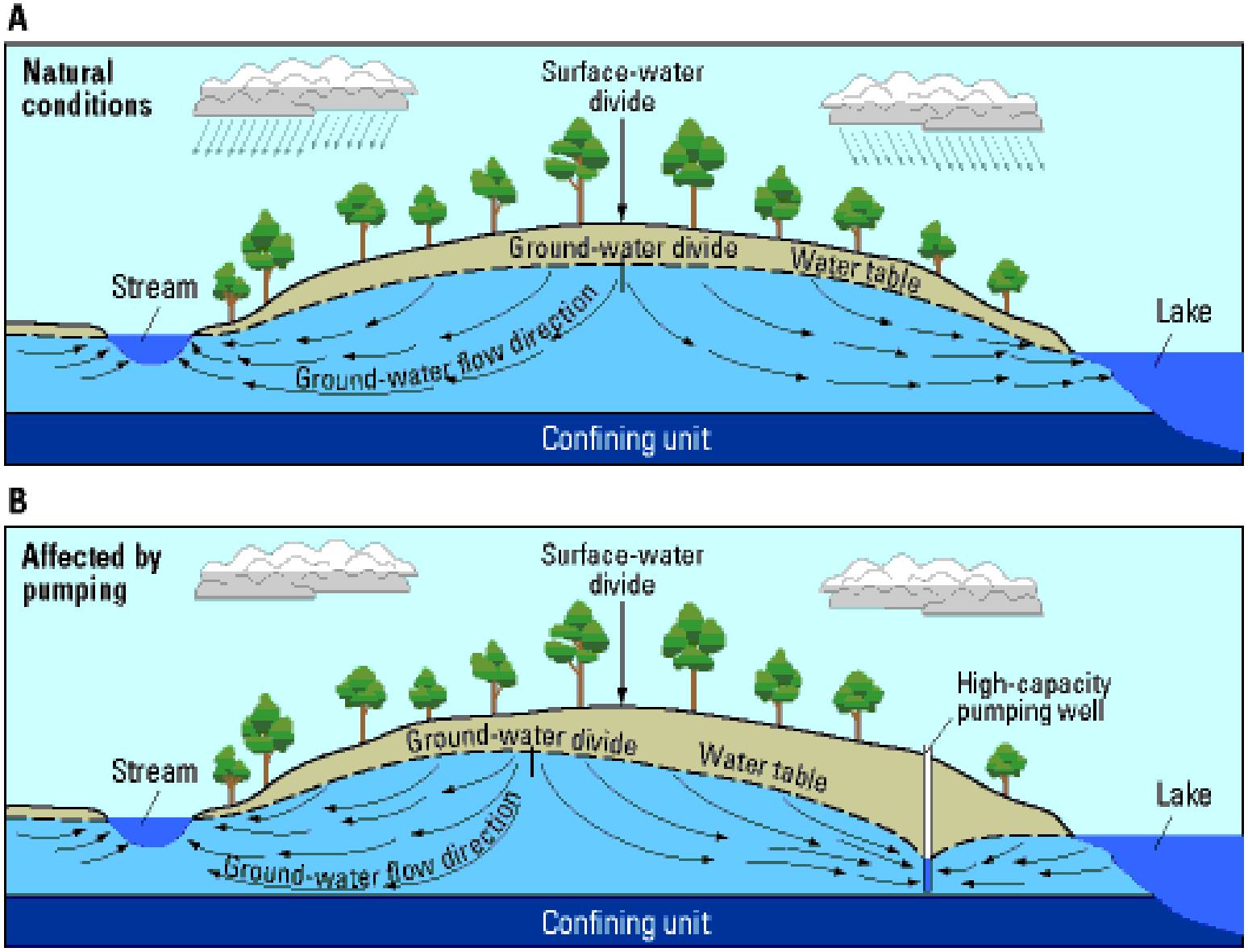


Through 2007
red: >150 ft; orange 100 – 150 ft

from McGuire, 2009



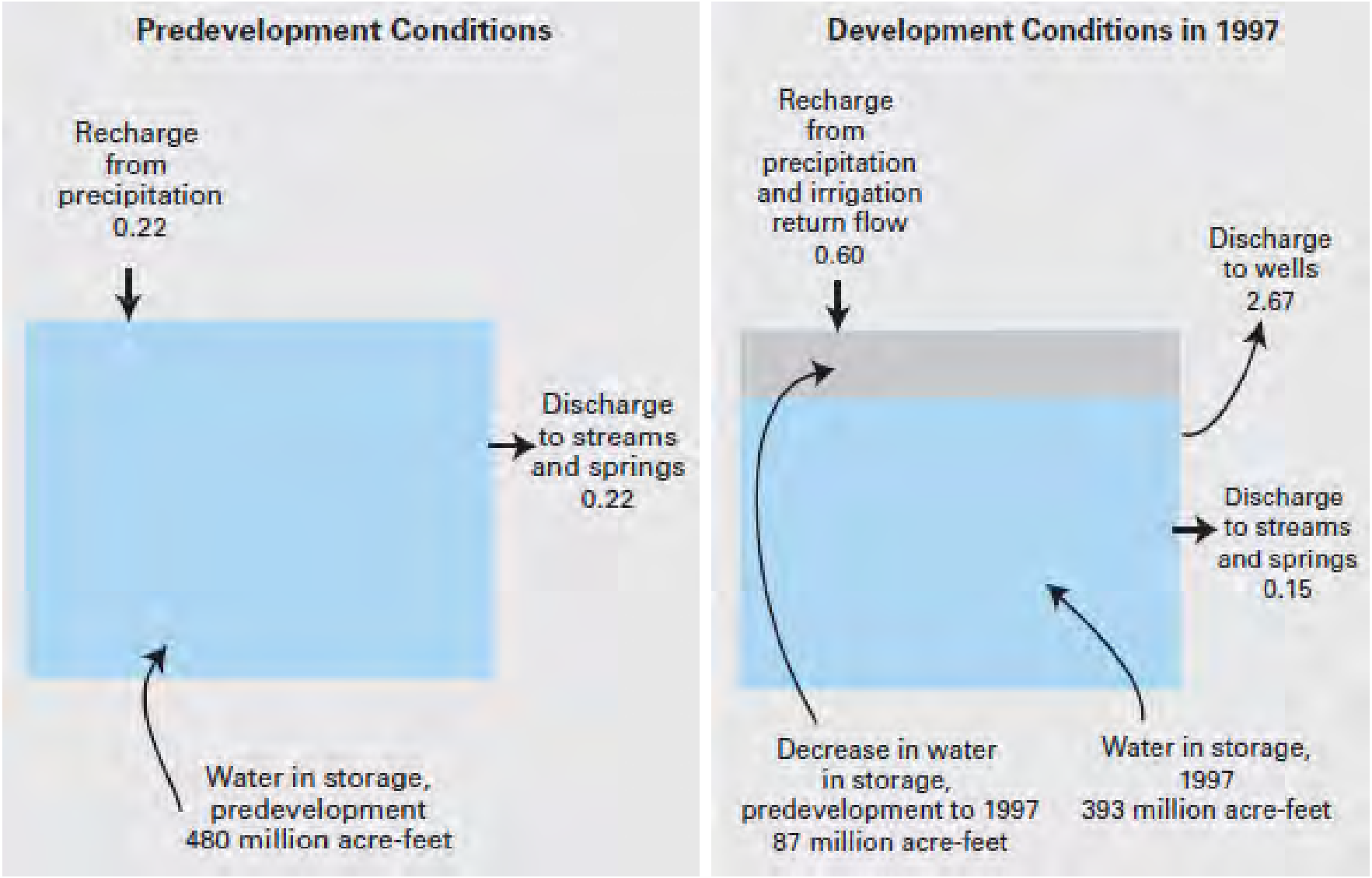
Groundwater Withdrawals



USGS

from Granneman et al., 2010

Example Change to Water Budget



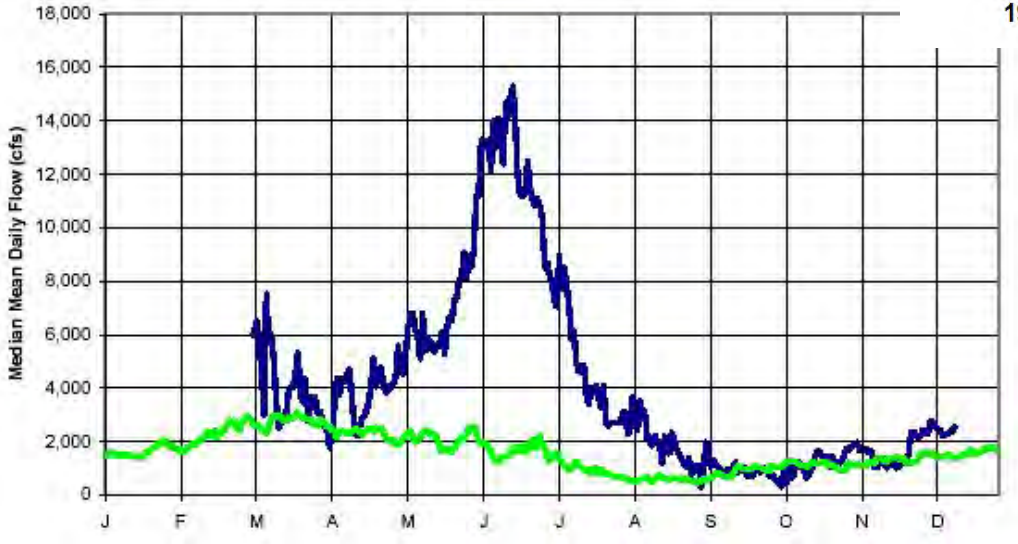
South Central High Plains; values in million acre-ft/yr

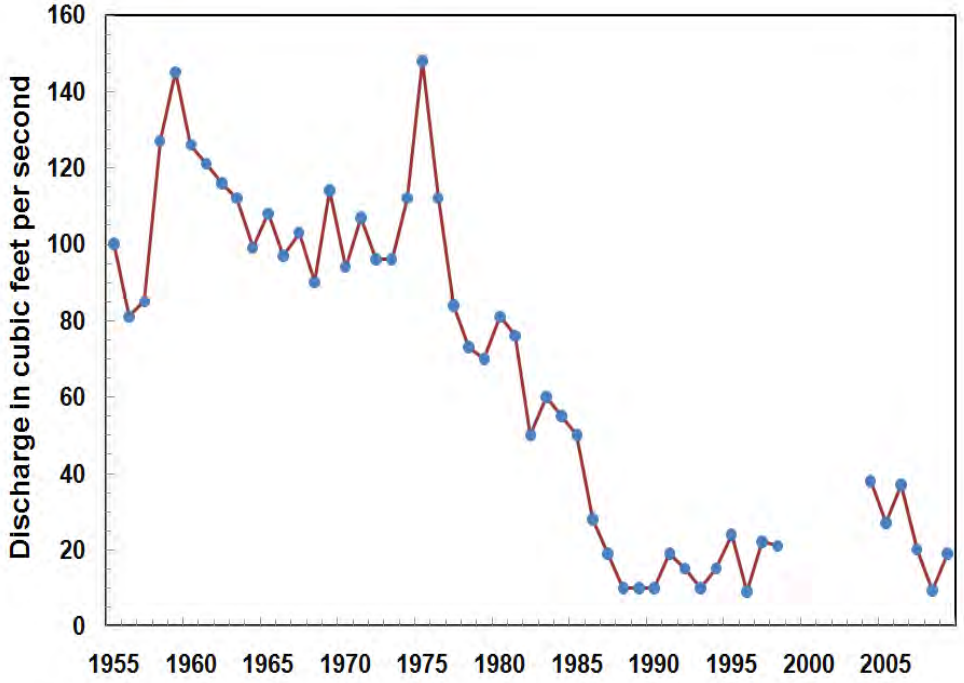
USGS

From McGuire et al, 2001

Groundwater Pumping and Streamflow

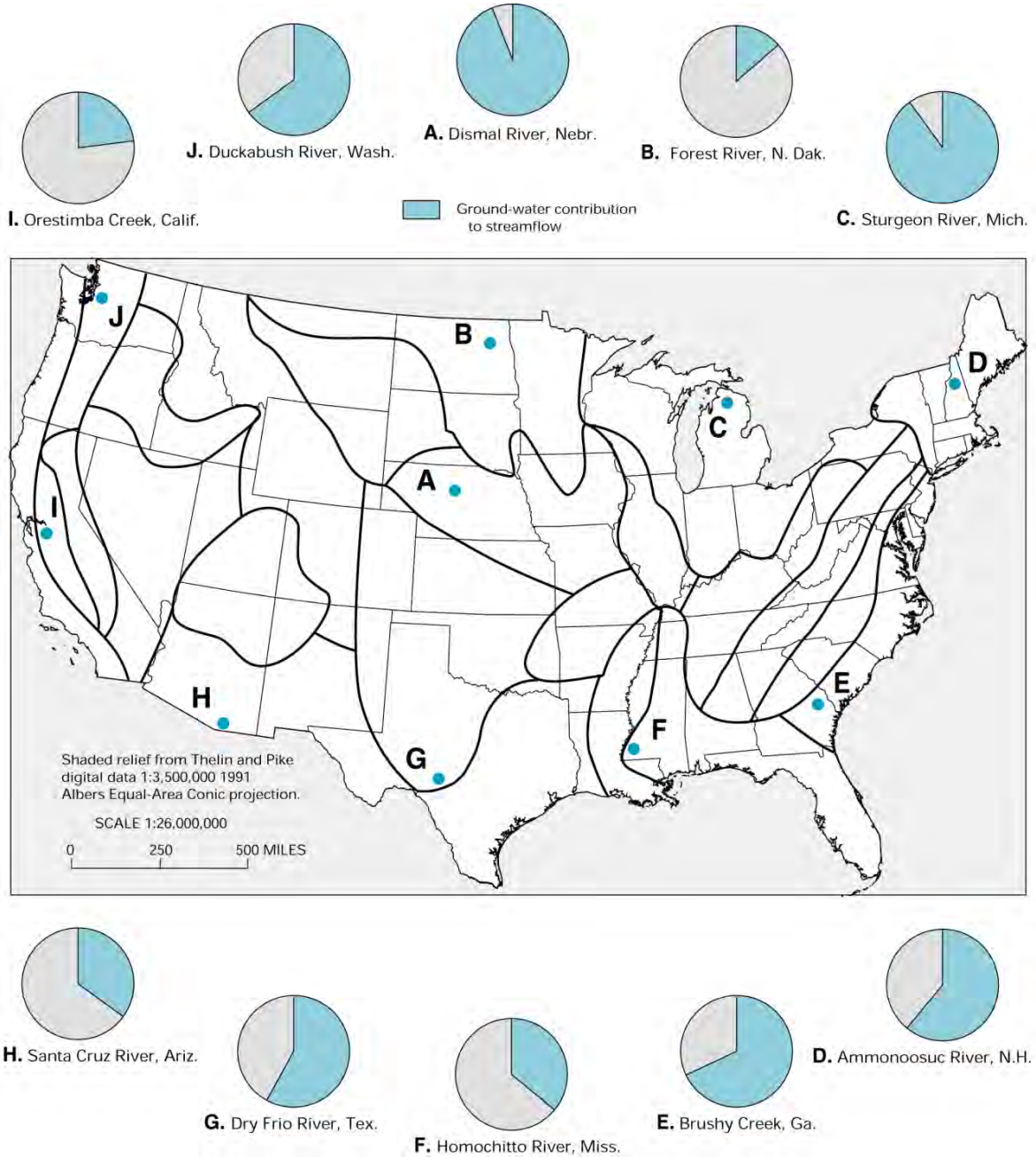
Median daily flow
Platte River near Duncan, NE
Blue = 1895 – 1909
Green = 1975 – 1998





Minimum annual streamflow for the Sunflower River, MS showing effects of withdrawals from the Mississippi River Valley alluvial aquifer on streamflow.
(Welch et al., 2010)

Groundwater Contributions to Streamflow



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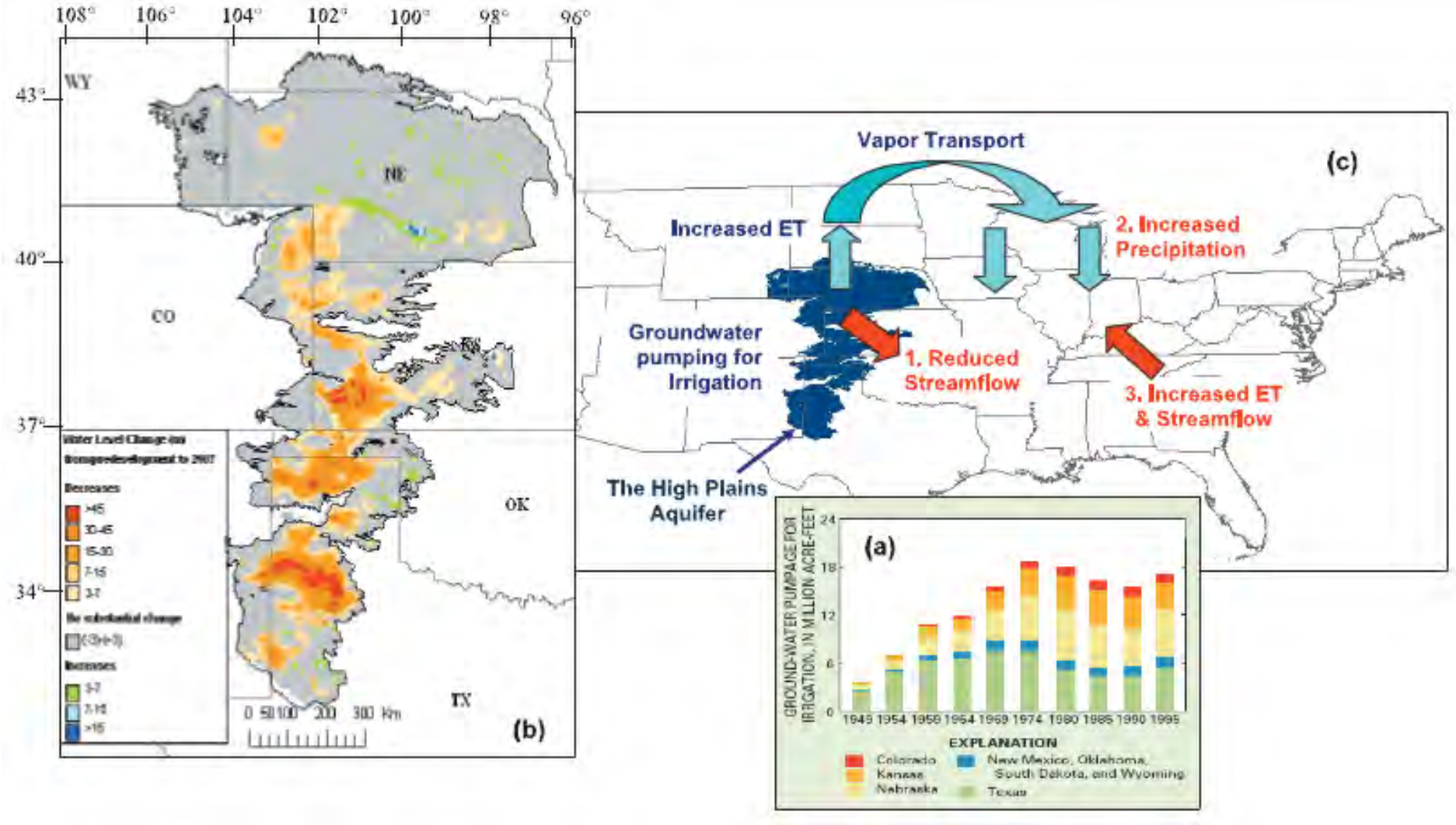
(Winter, et al., 1998)

Groundwater Pumping and Weather



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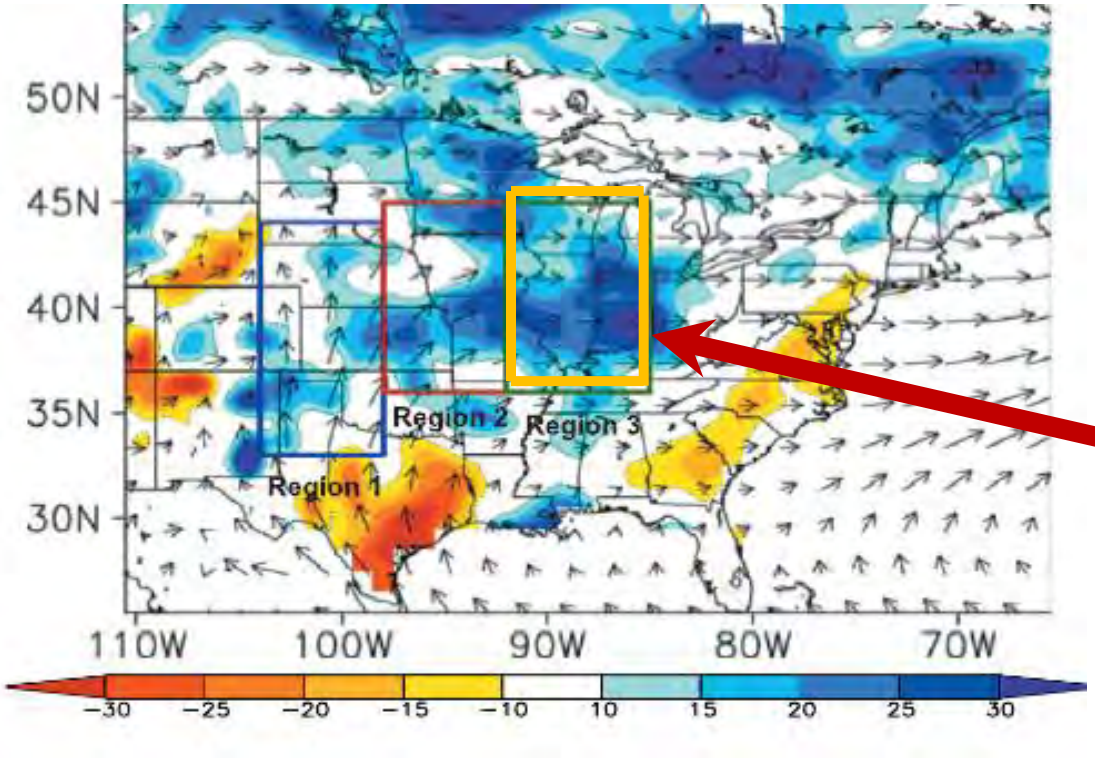
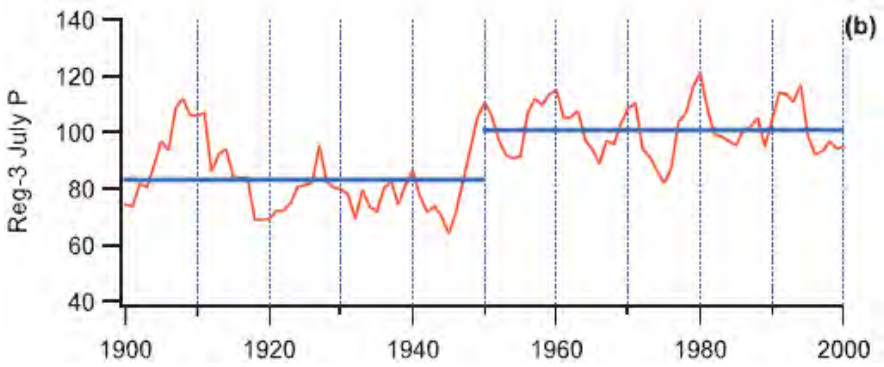
Kustu, et al., 2011, Water Resour. Res., 47, W03522, doi:10.1029/2010WR010046.

Groundwater Pumping and Weather



Percent difference in mean July precipitation, 1900 – 1950 vs. 1951 - 2000

16-station, 5-year moving average July precipitation for area shown



Kustu et al., WRR, 2011

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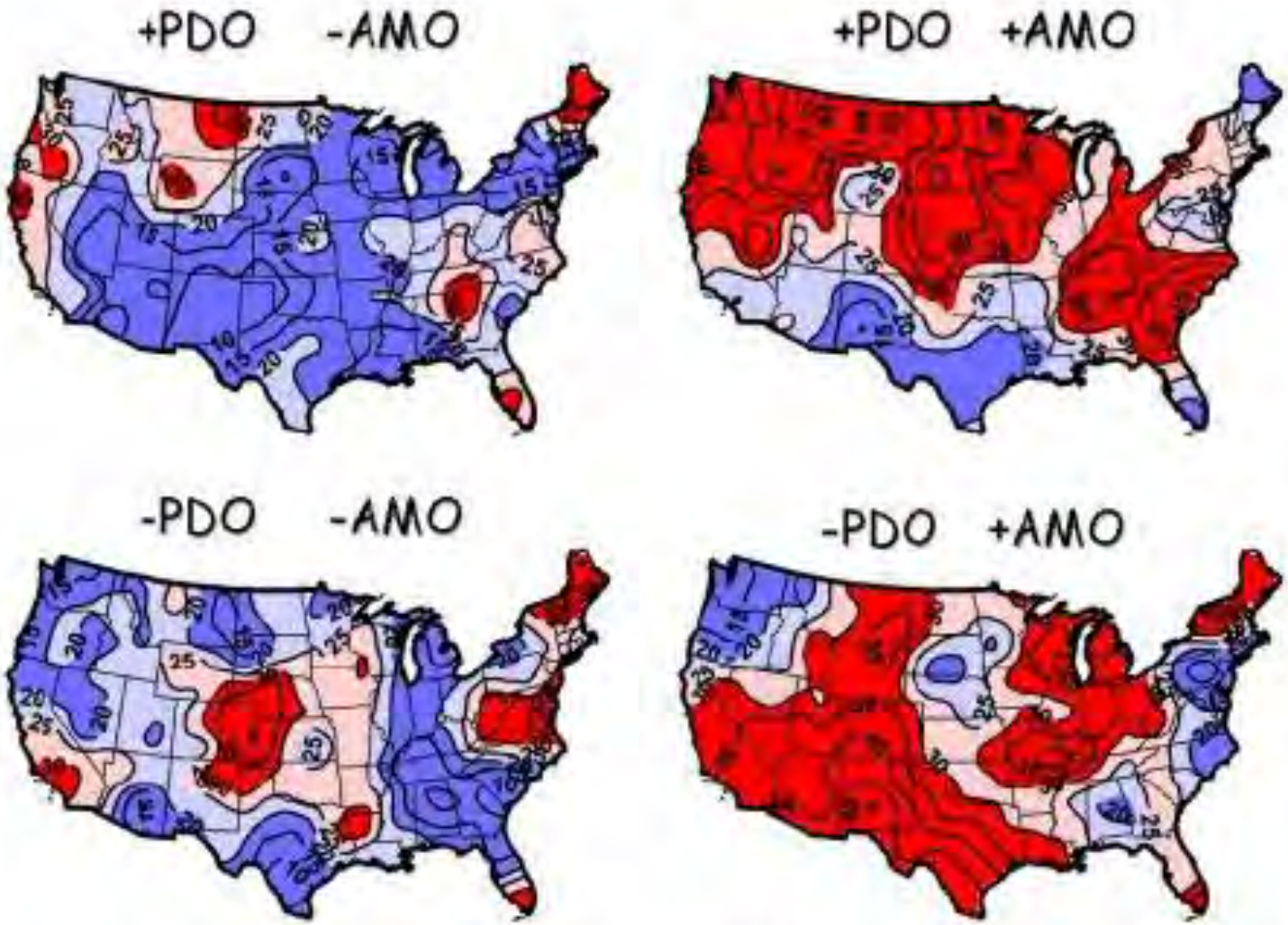
Drought Frequency and Ocean State



25% = normal drought frequency

Red = more frequent drought

Blue = less frequent drought

McCabe et al., 2004

Energy and Water Use

- **9 – 11 percent of purchased agricultural input is for energy.**
- **Disconnect between energy costs and water use:**
  - **Not all irrigation requires energy**
  - **Irrigation may lead to a more profitable crop**
  - **Water prices not set in market and do not reflect scarcity.**

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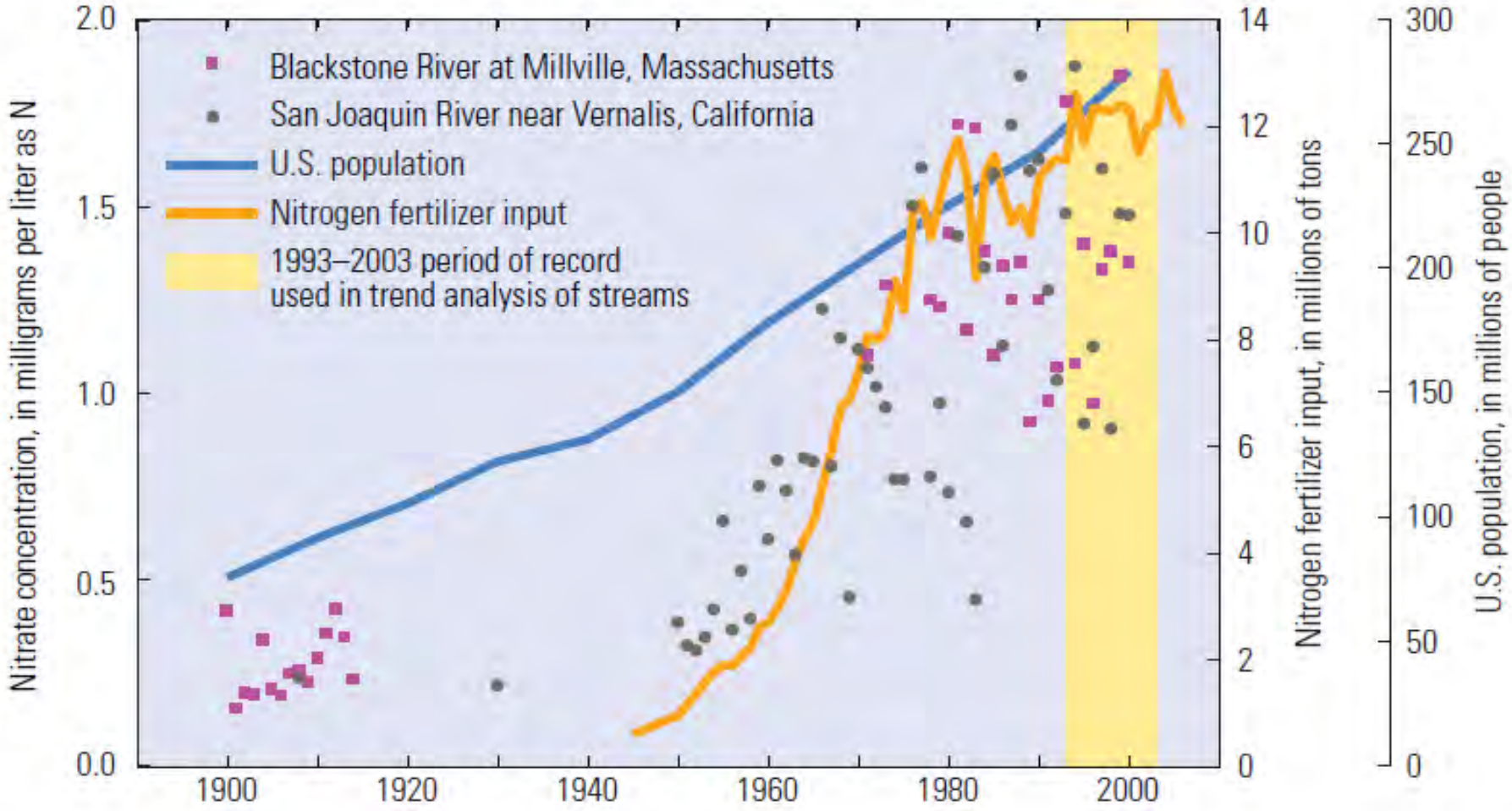
Nitrogen in Streams



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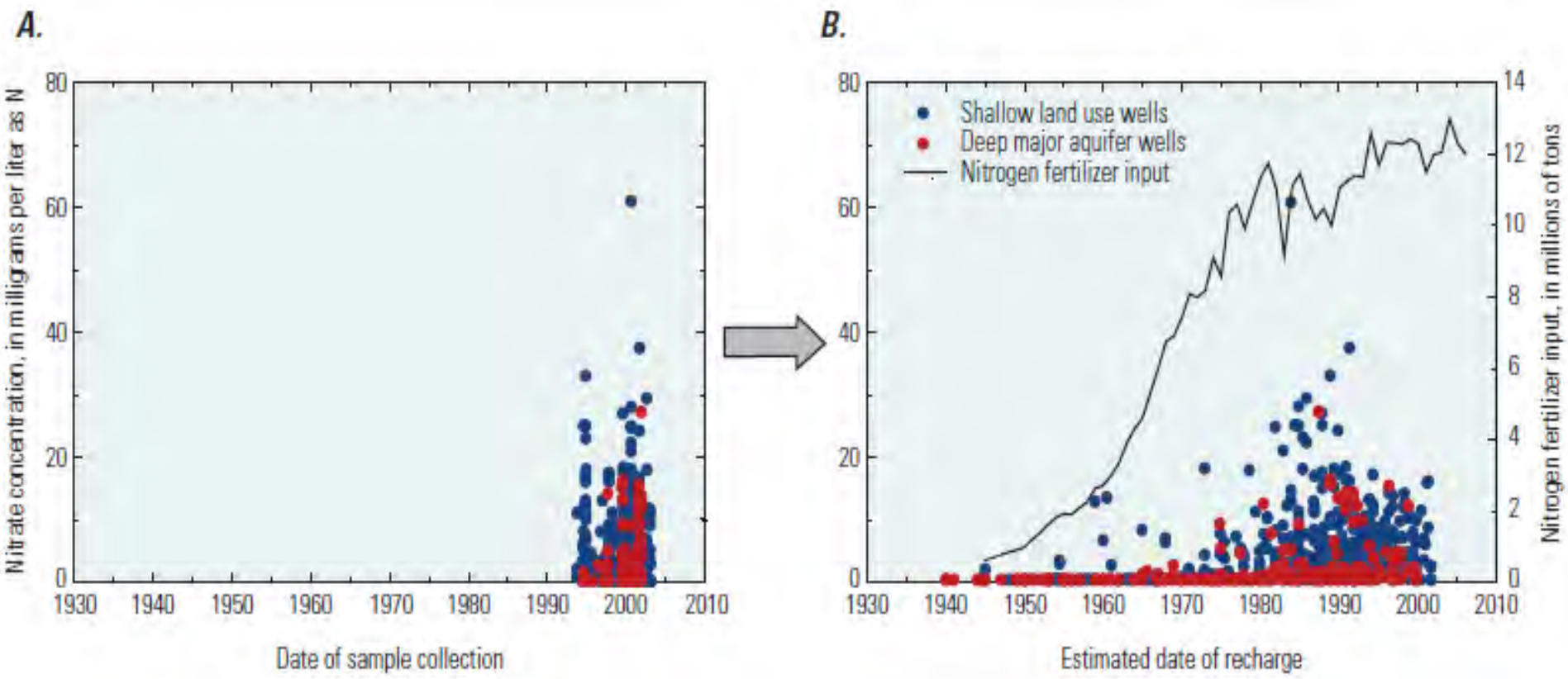
Dubrovsky, et al., 2010

Persistence of NO3 in Groundwater



Measured nitrate concentration in shallow groundwater and deep aquifers by (A) date of sample collection and (B) estimated date when the groundwater was recharged

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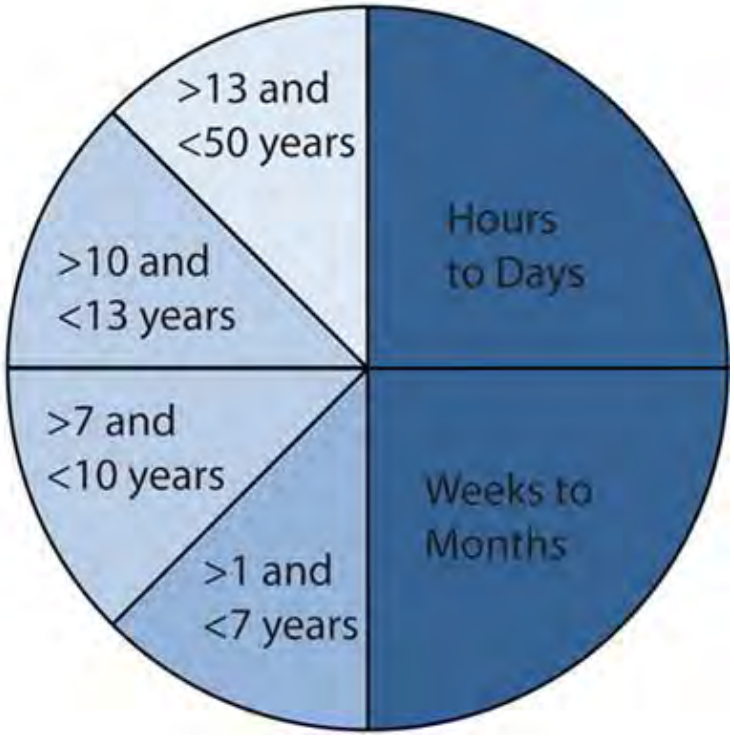
Dubrovsky, et al., 2010)

Contributions of Groundwater Nitrate Depend on Hydrogeologic Setting

Chesapeake Bay Watershed:
The Coastal Plain Province
on the Delmarva Peninsula,
this study

Chesapeake Bay Watershed:
The Piedmont and
Valley and Ridge Provinces,
previous study



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Water and Climate

- **Effects of climate change on agriculture, ecosystems, and energy are mediated by water.**
- **Unambiguous increase in air temperature.**
- **Stationarity can no longer be assumed.**
- **Direct effects on water resources are more difficult to detect.**

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What is the cause?

- **Non-climatic**
  - **Water management**
    - **Reservoirs**
    - **Consumptive use**
    - **GW declines**
  - **Land management**
    - **Tile drains**
    - **Changing land use**
- **Natural variability**
- **New measurement techniques**
- **Greenhouse-driven climate disruption.**

North America during most recent glacial maximum ~20,000 years ago.

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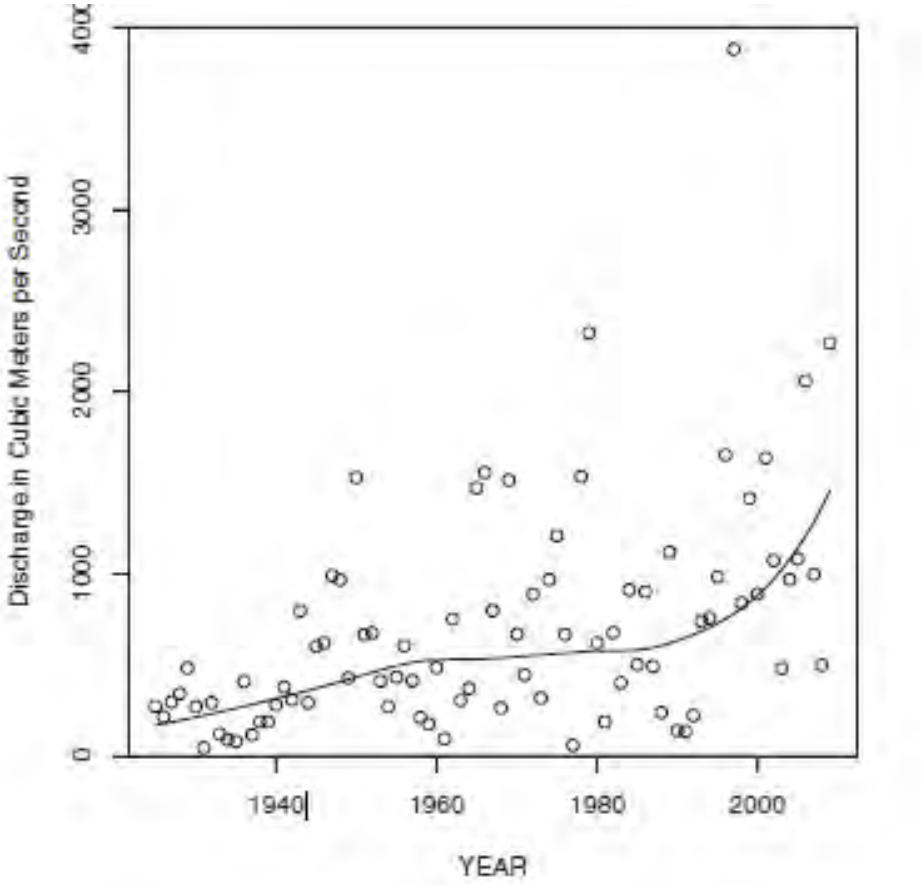
Importance of Long Records



Annual flood peak, Red River of the North at Fargo, ND

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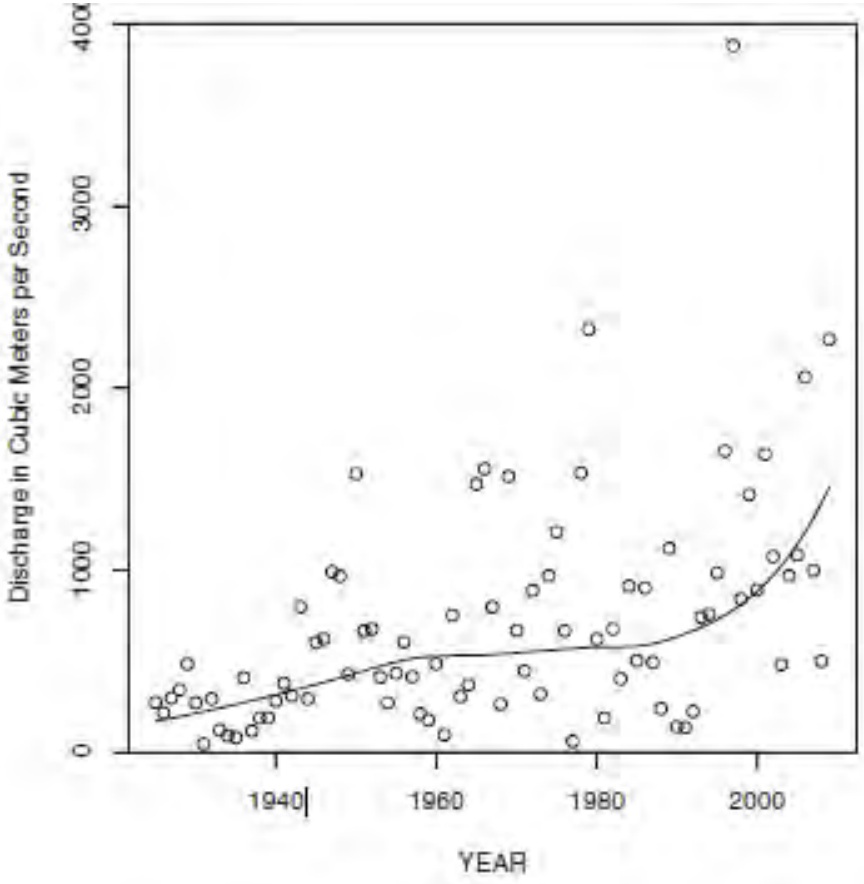
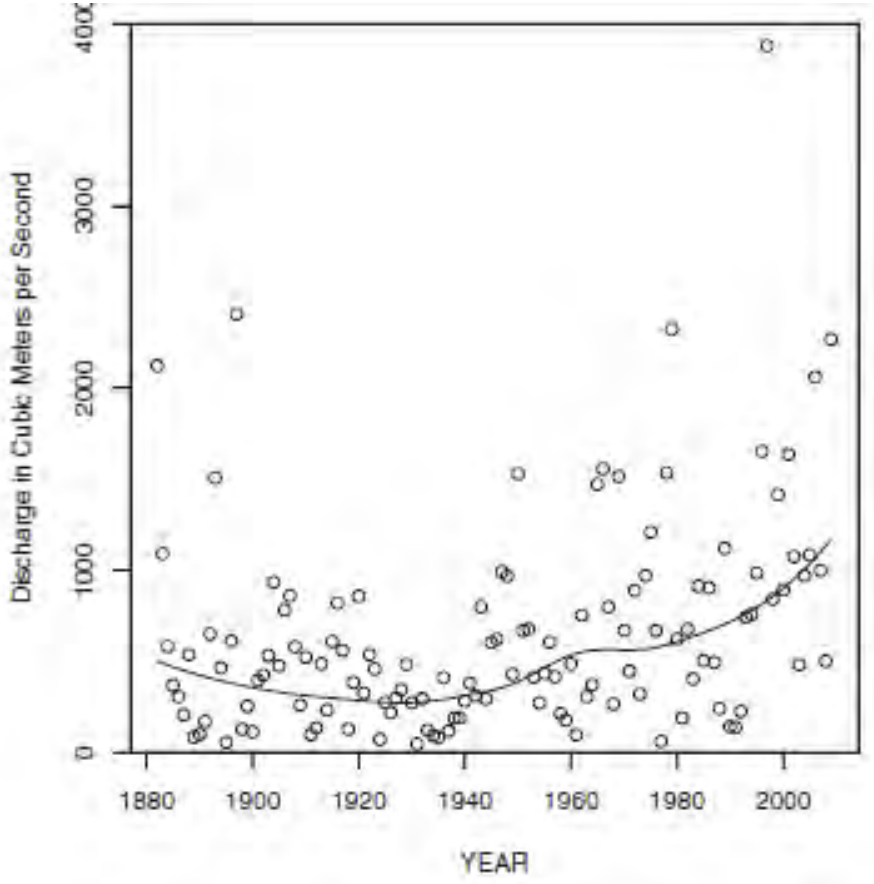
Importance of Long Records





Annual flood peak, Red River of the North at Fargo, ND

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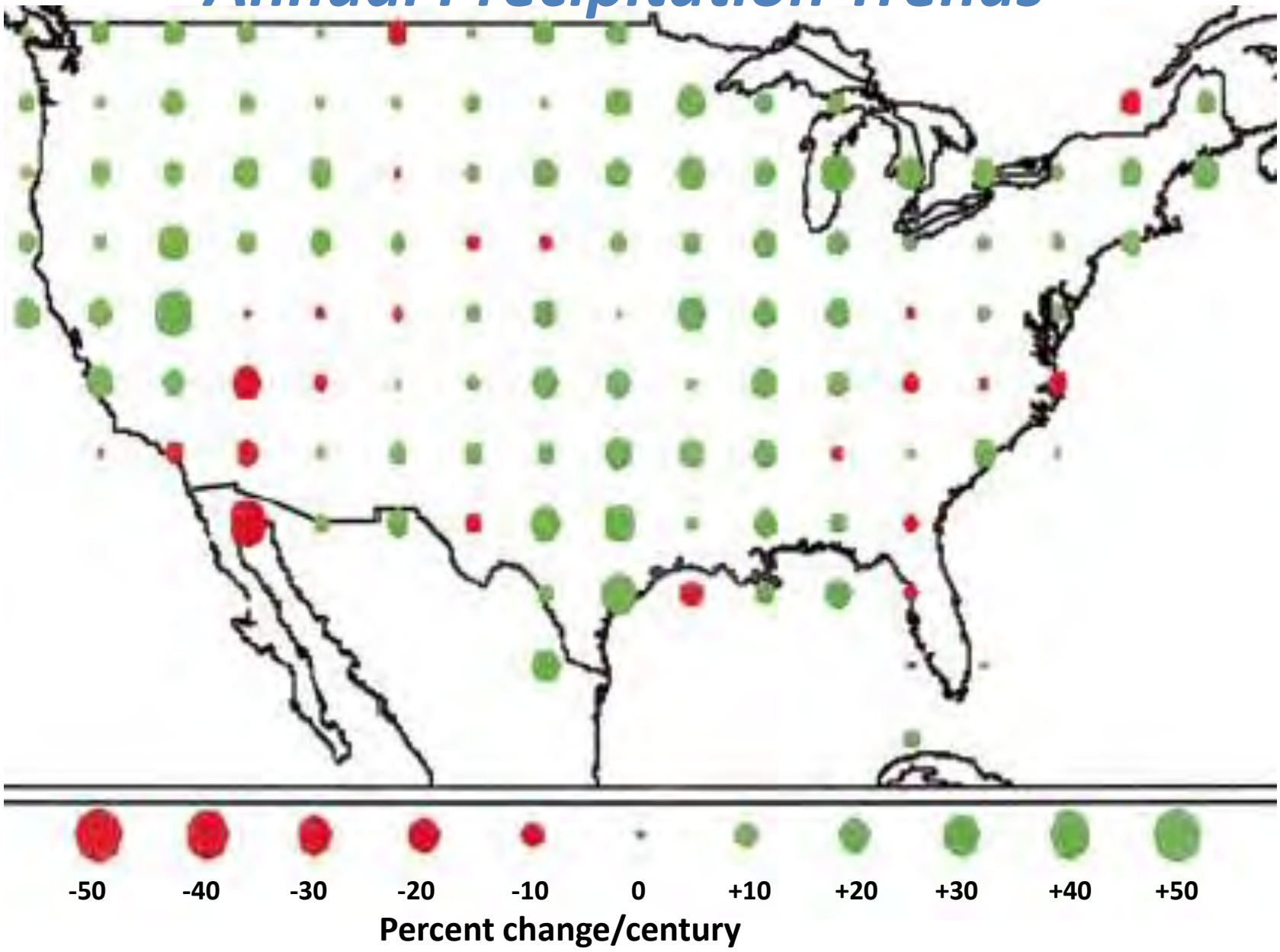
Annual Precipitation Trends



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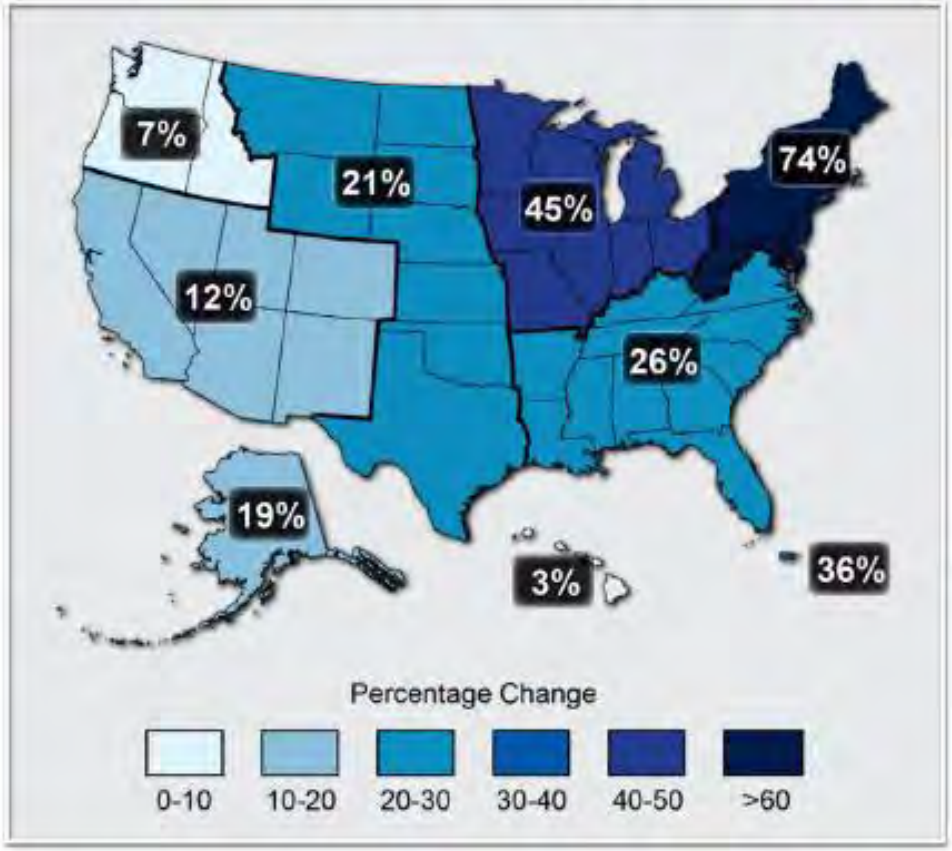
Groisman, et a;., 2004: Journal of Hydrometeorology, 5(1), p. 64-85.

Changes in Precipitation Intensity

Percent increases in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events) from 1958 to 2011.



There are clear trends toward a greater amount of very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest.

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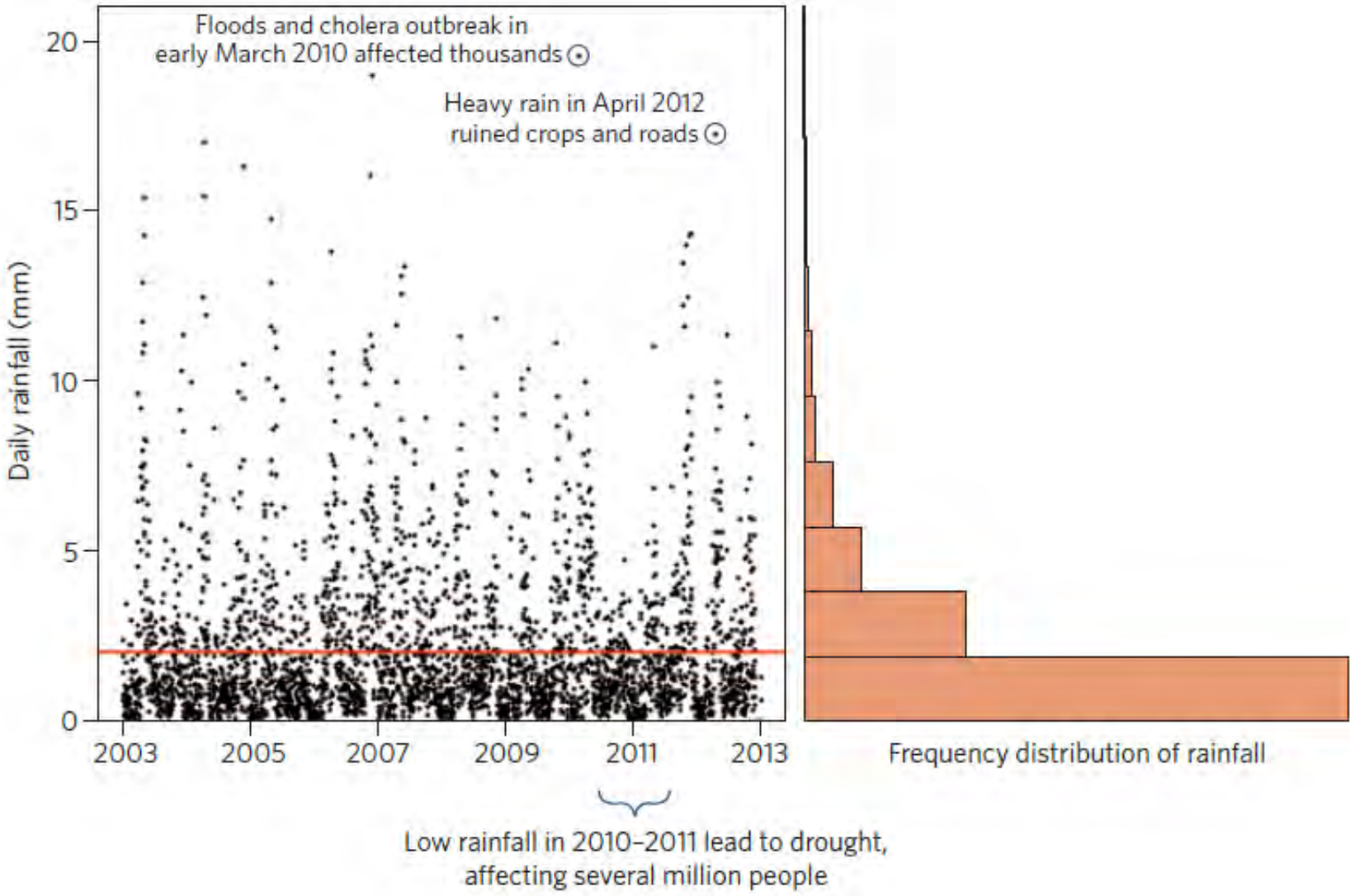
Source: http://ncadac.globalchange.gov/download/NCAJan11-2013-publicreviewdraft-chap2-climate.pdf

Extremes are Important but Changes are Difficult to Detect



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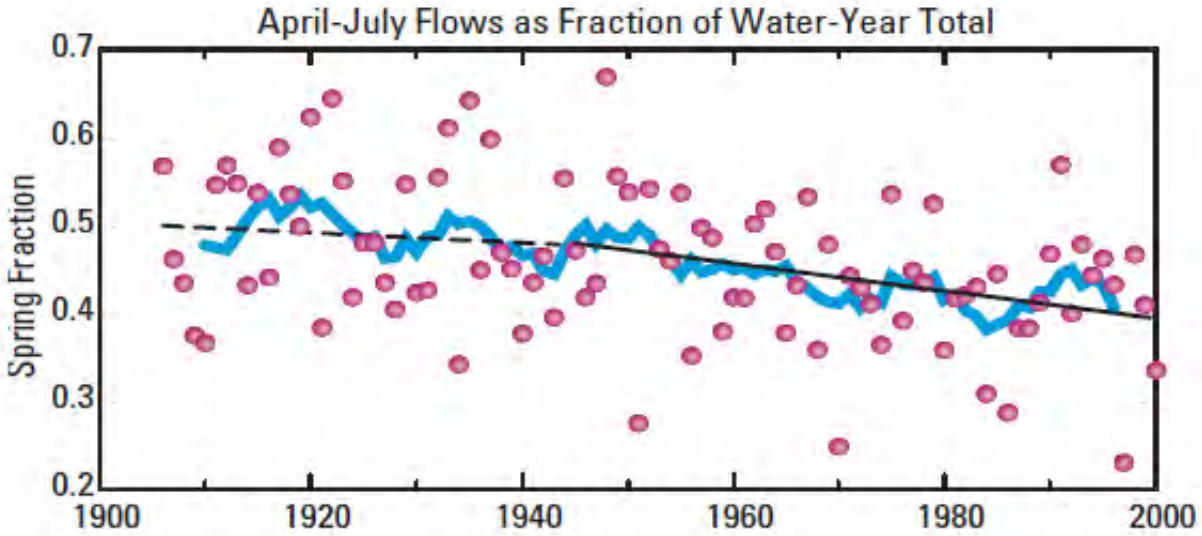
de Perez et al., 2014, Nature Geoscience, 7:78-79

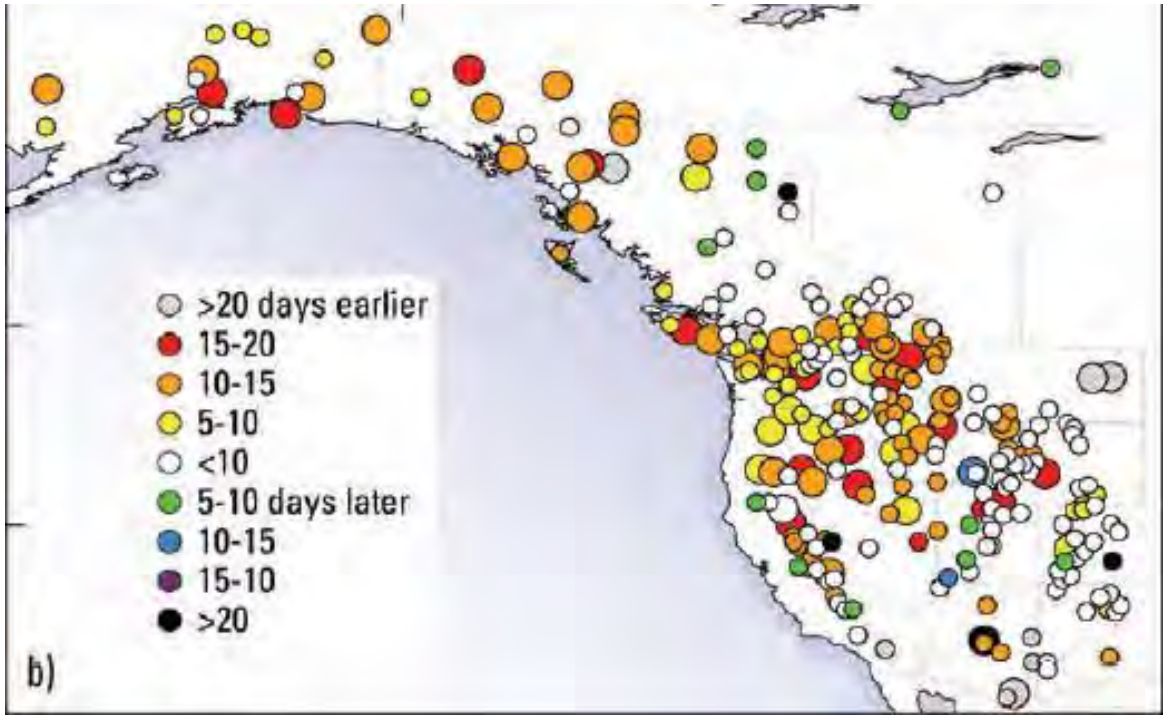
Temporal Redistribution of Streamflow

April – July flow as a fraction of annual flow for 9 western Sierra Nevada rivers. Blue line is 9-yr moving average.



As much as 75% of western water supplies are derived from snowmelt runoff

Trends in center mass of yearly streamflow, 1945 – 2000 (*Dettinger, 2005.)*



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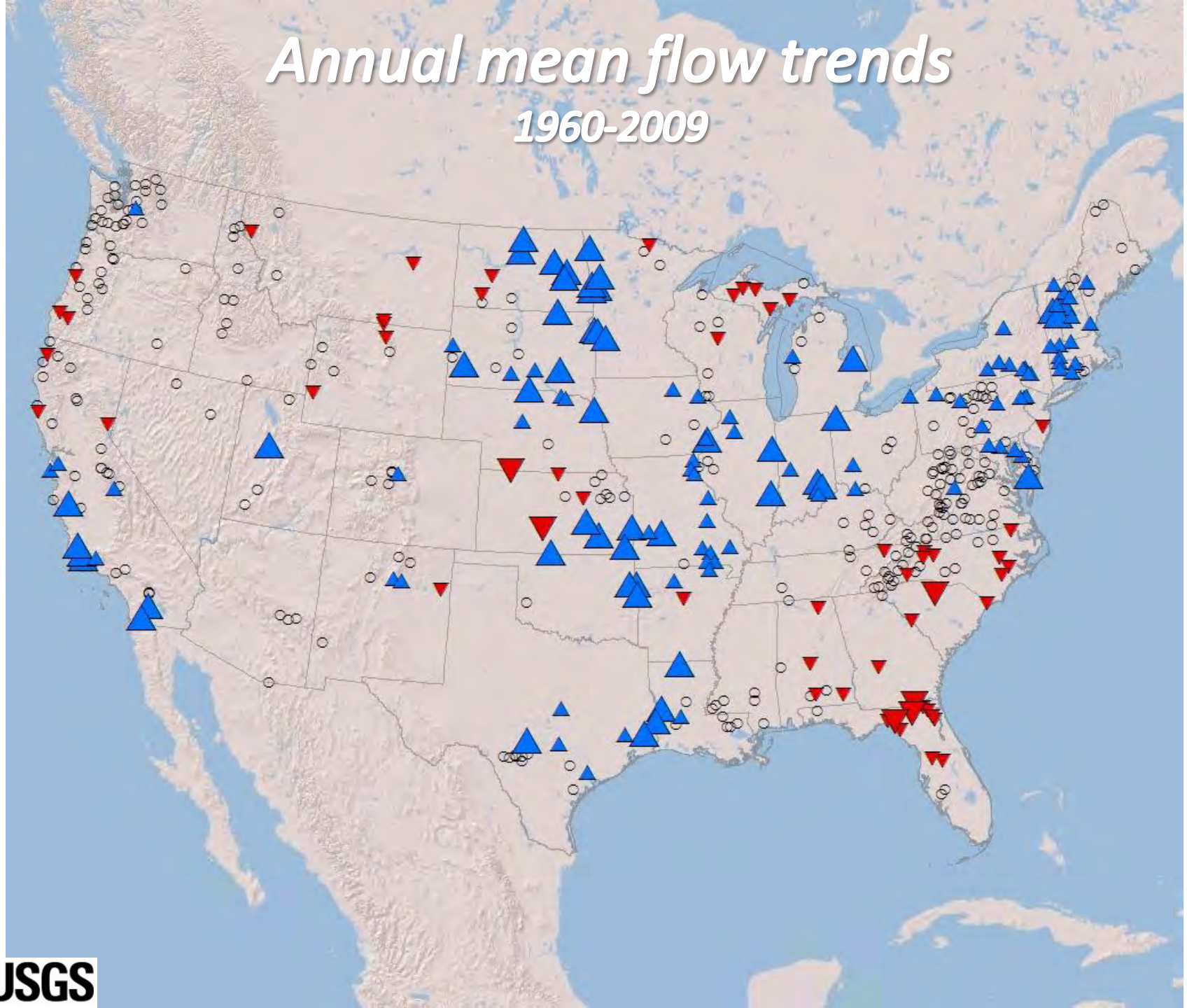
Annual mean flow trends

1960-2009



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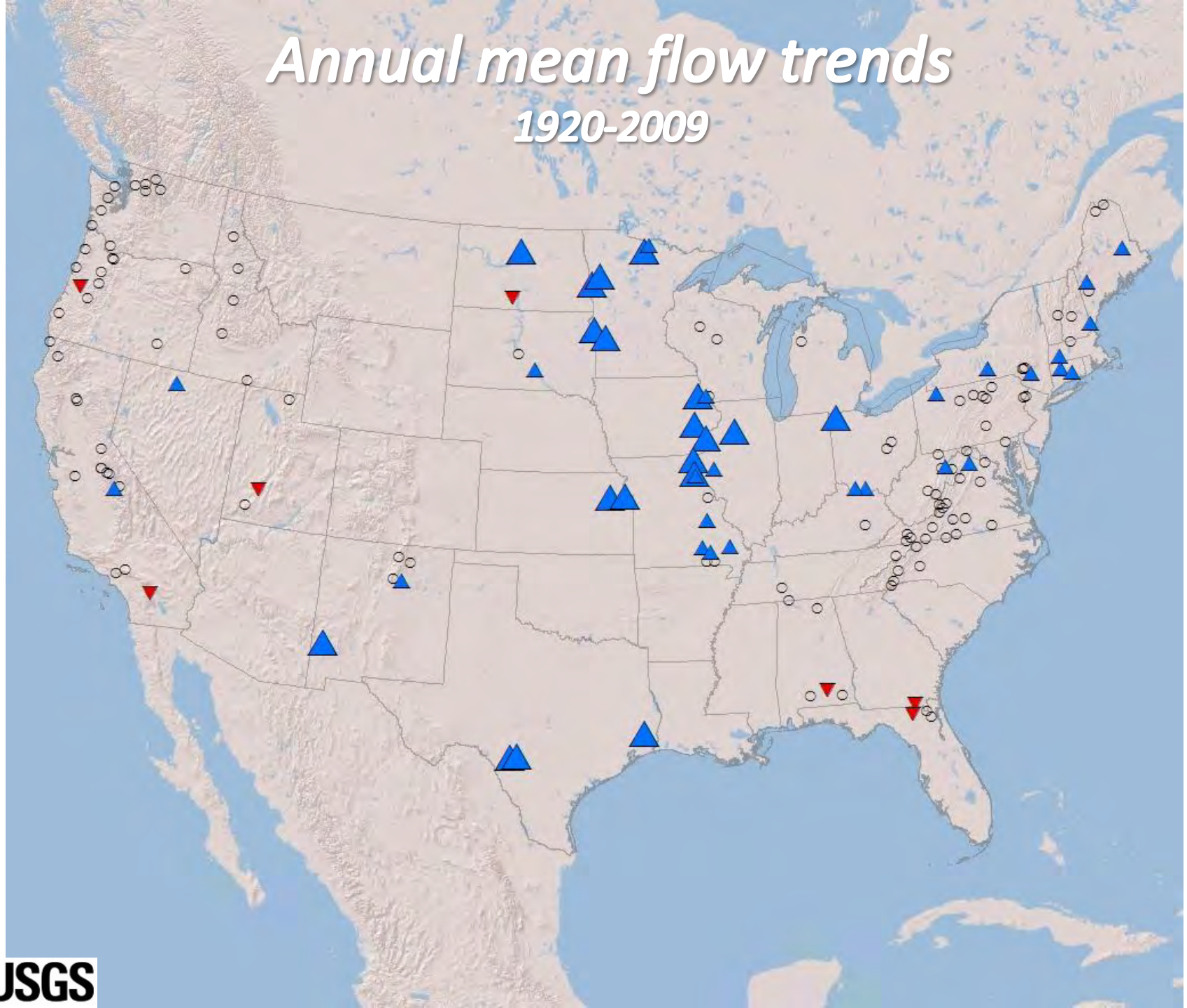
Annual mean flow trends

1920-2009



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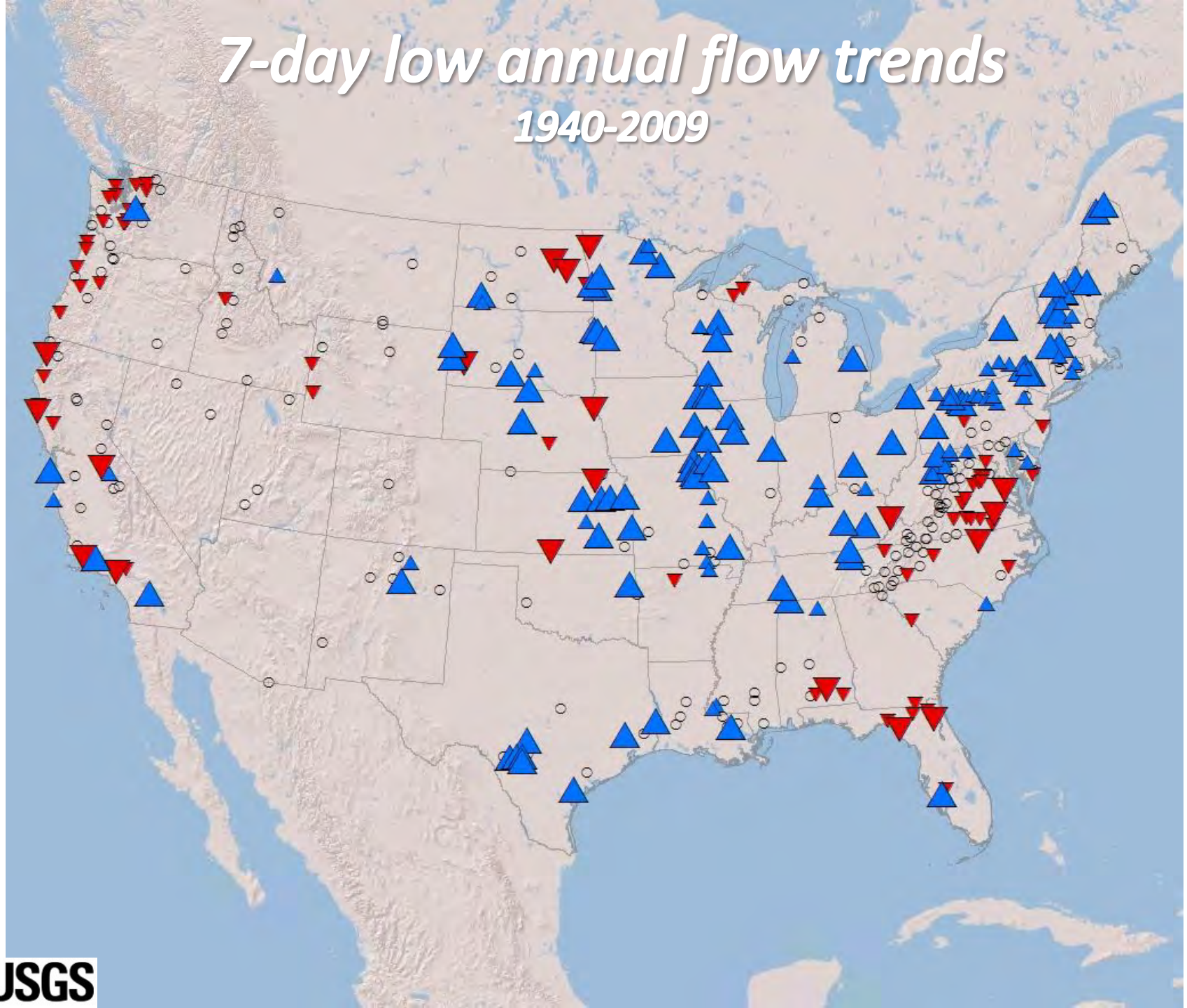
7-day low annual flow trends

1940-2009



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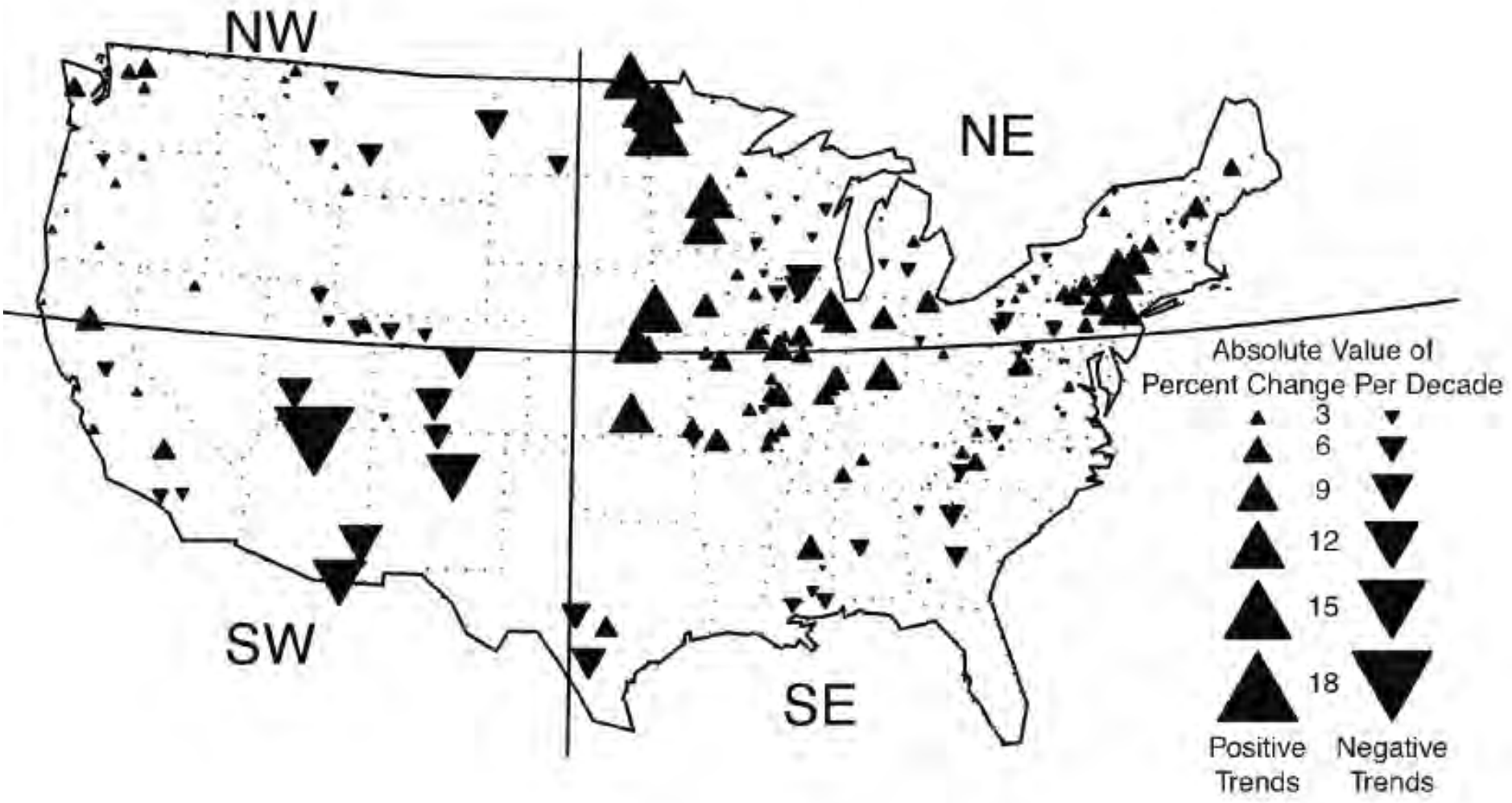
Redistribution of Floods?



Trend in annual flood peaks for stations having 85 – 127 years of record (*Hirsch, JAWRA, 2011*)

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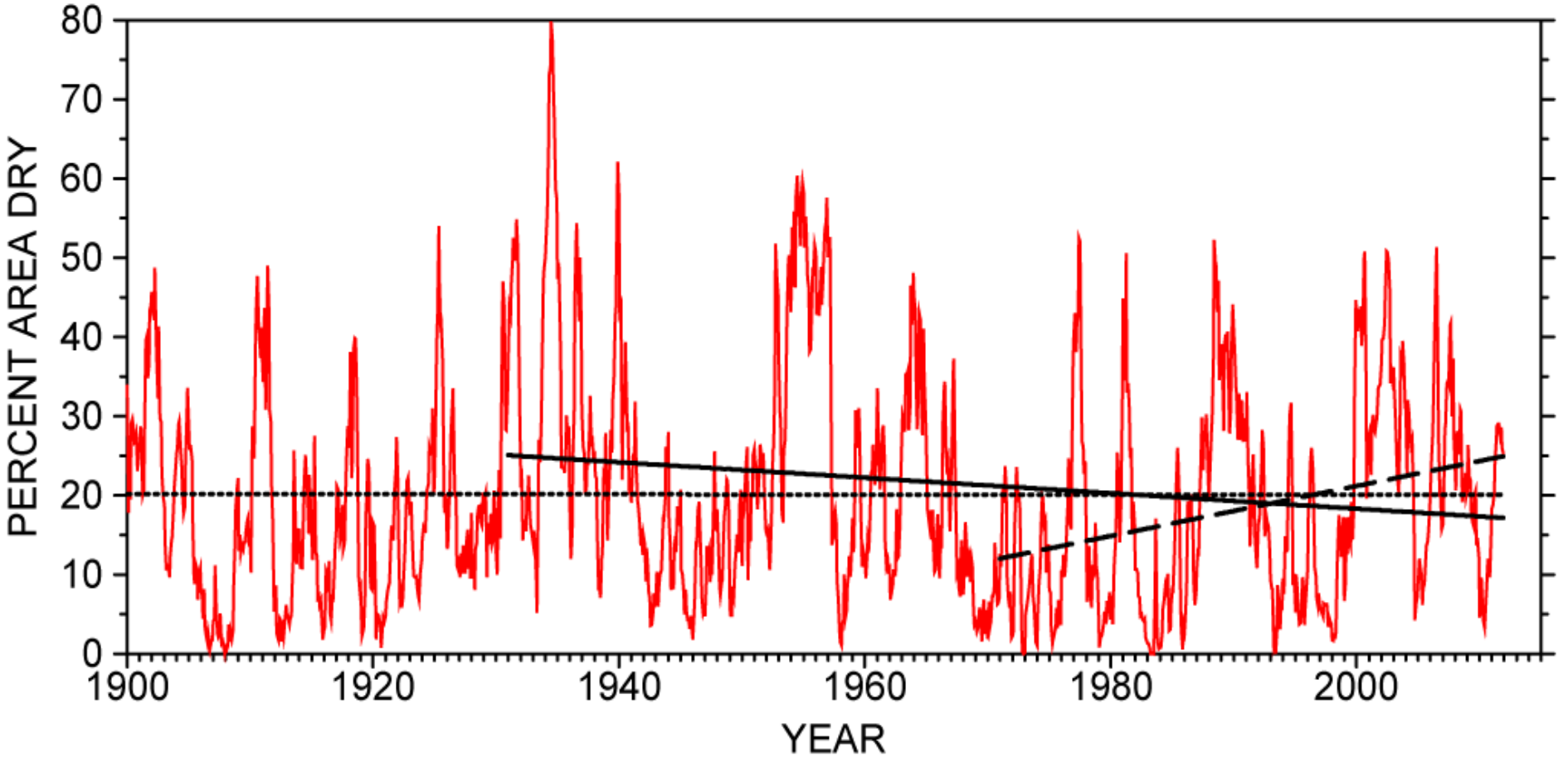
Redistribution of Water Resources



Dotted line = long-term trend

Solid line = 1931 – 2011

Dashed line = 1971 - 2011

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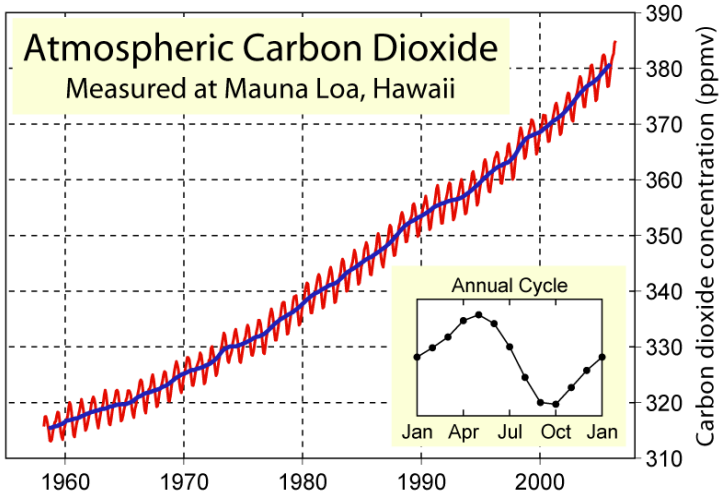
Challenging Times for Earth Science



Science, 2008, p. 1771-1772, Ralph F. Keeling

- **A continuing challenge to long-term Earth observations is the prejudice against science that is not directly aimed at hypothesis testing…We cannot afford such a rigid view of the scientific enterprise.**
- **The only way to figure out what is happening to our planet is to measure it, and this means tracking changes decade after decade and poring over the records.**

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Thank you

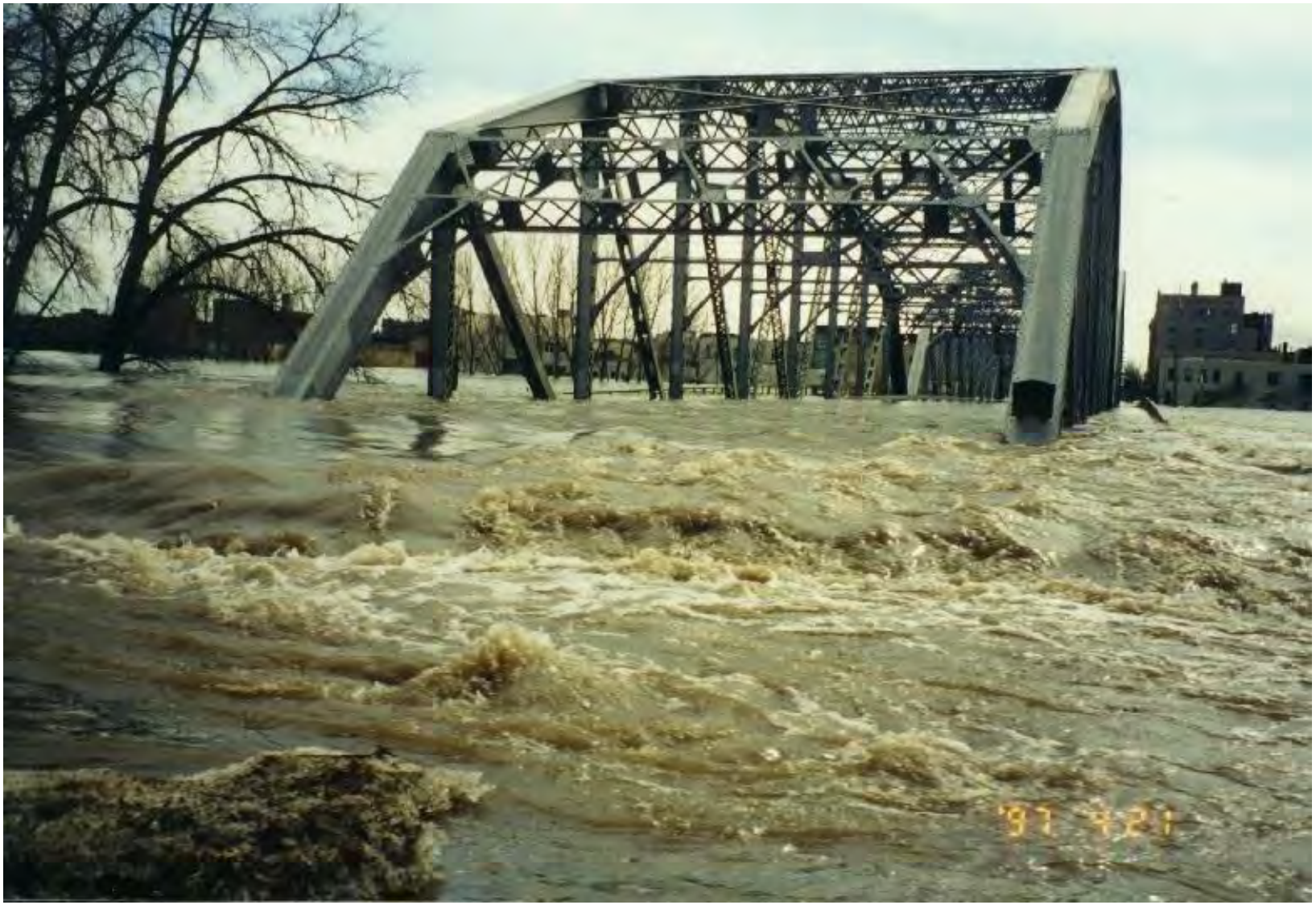

Photo credit: Steve Norbeck, April 21, 1997, Red River of the North at Grand Forks, ND