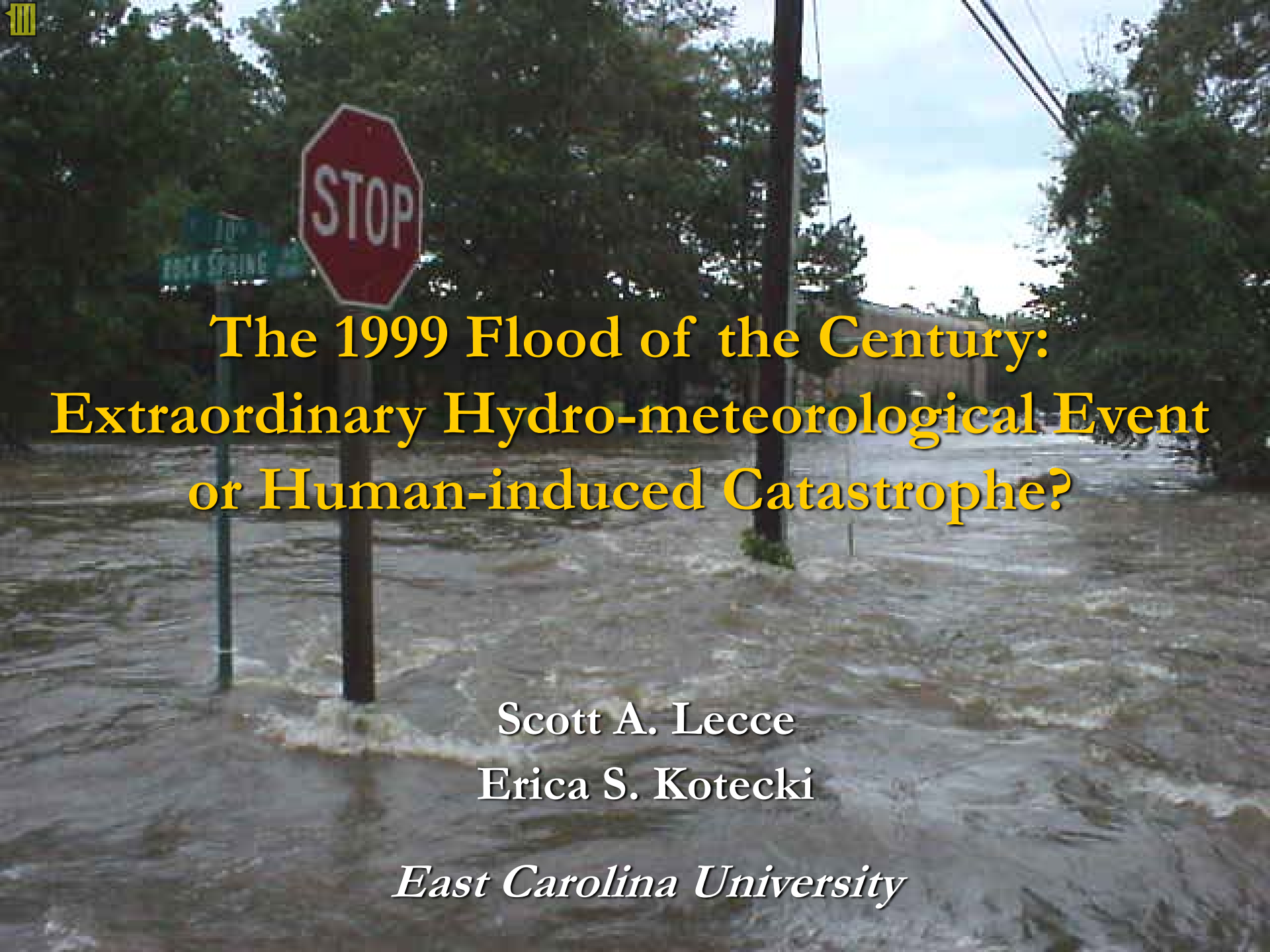

The 1999 Flood of the Century: Extraordinary Hydro-meteorological Event or Human-induced Catastrophe?

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Erica S. Kotecki

East Carolina University

- Question: Was this simply an extraordinary natural event, or a 'human disaster' intensified by human modifications of natural systems

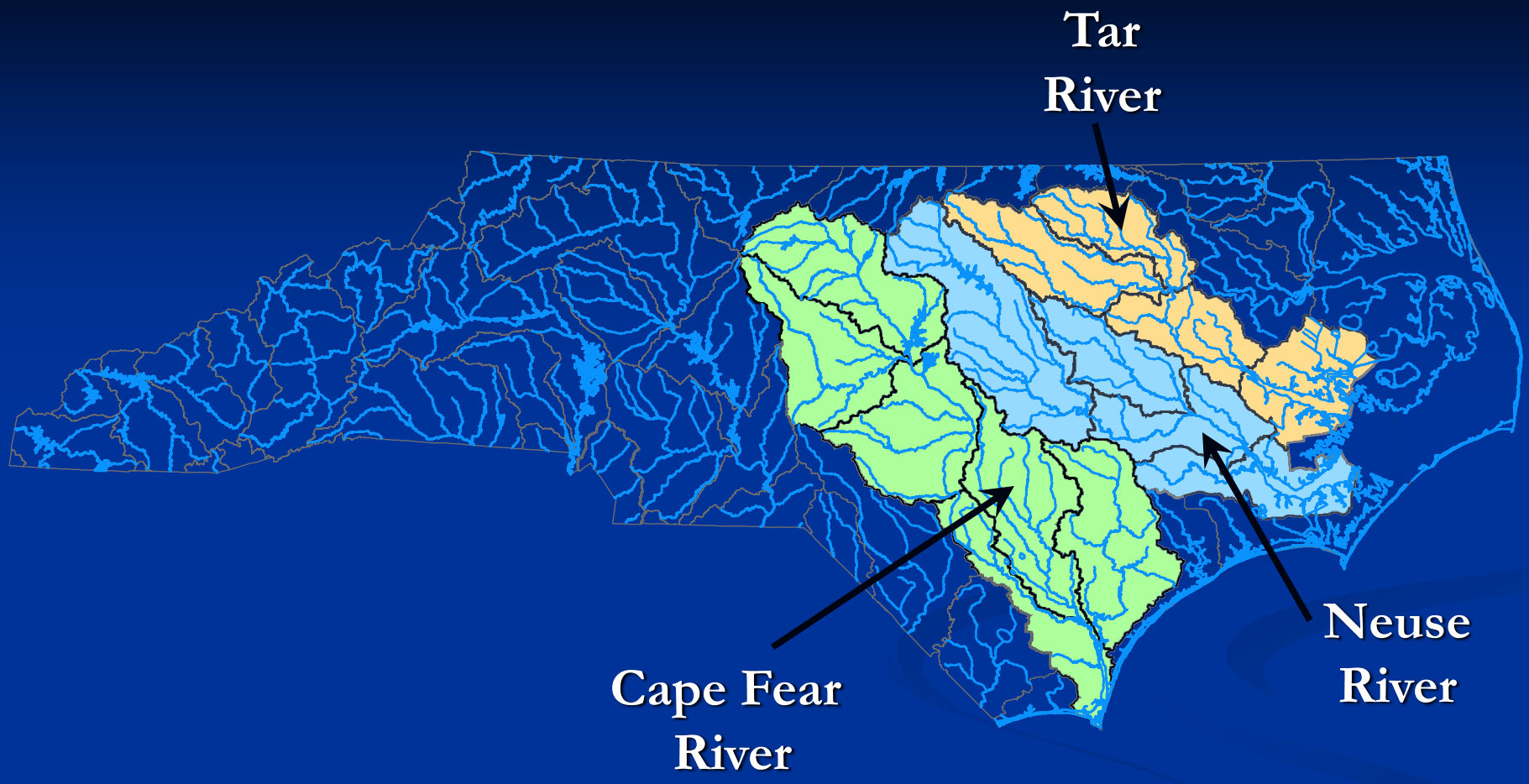
- Our approach was:

  - First, to assess the magnitude-frequency characteristics of the rainfall during the 1999 flood

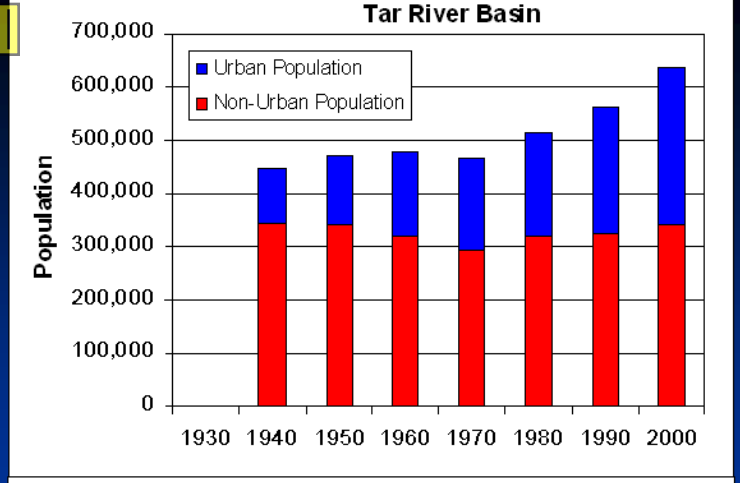
  - Second, to look for trends in hydrological variables that can be influenced by human activities, and might provide evidence for the 'human disaster' perspective

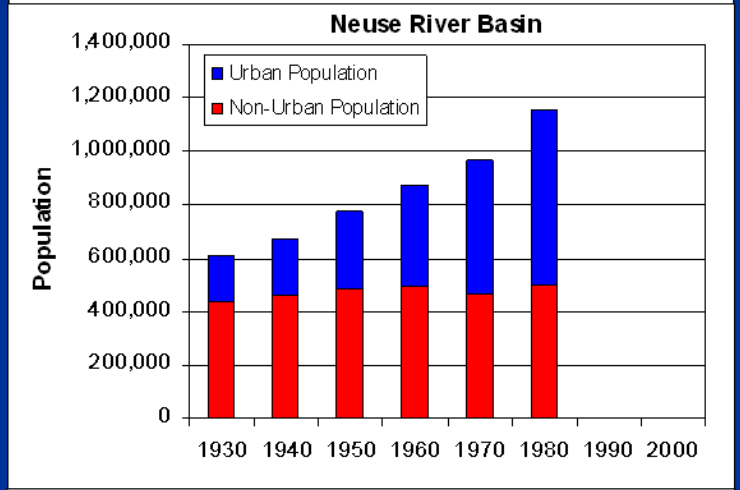

ECU
Downtown
Greenville
Tar River

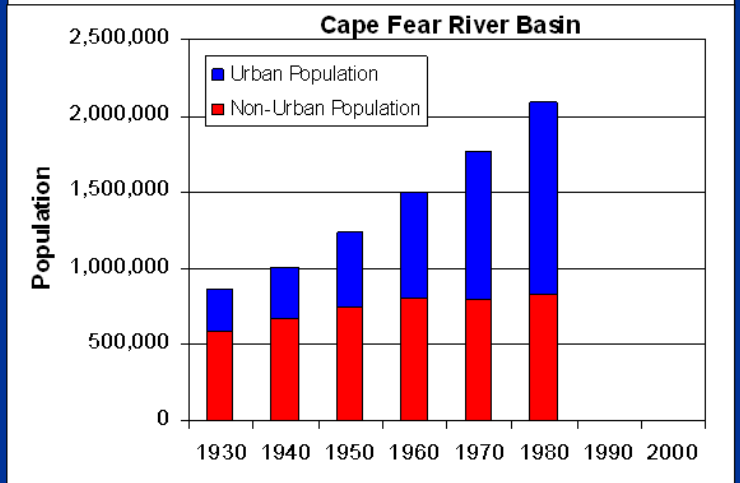

June 21, 2006 stage = 18.4 ft
Normal stage = 8 ft
Floyd = 29.7 ft


Tar
River
Neuse
River
Cape Fear
River

Land Use Change



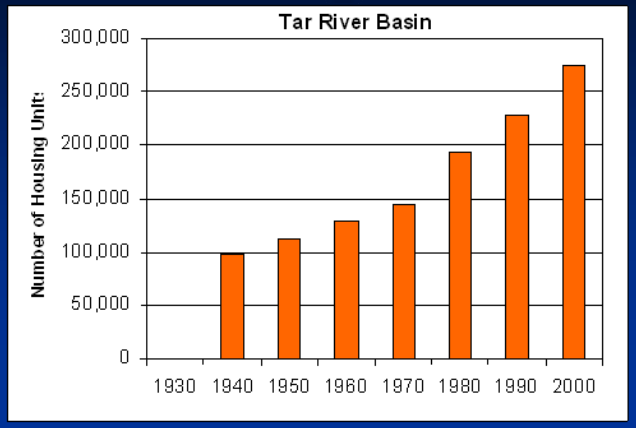


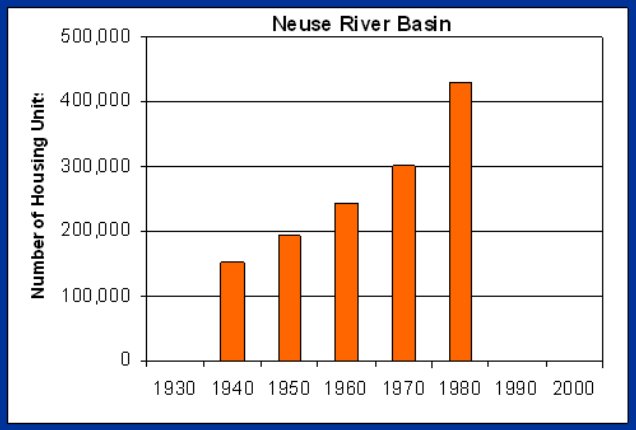


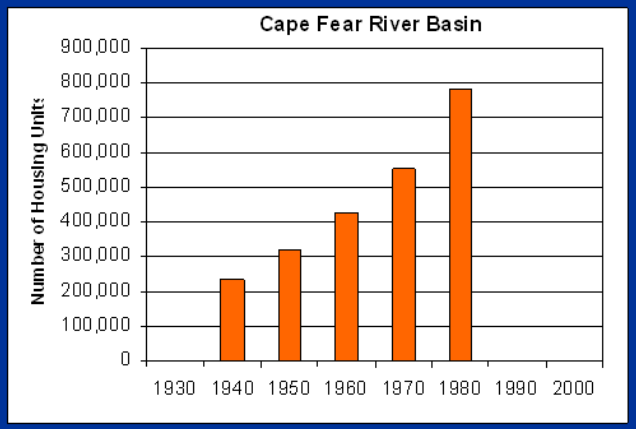
- The argument that human modifications increased the severity of the flood rests largely on the assumption that land use patterns have changed in a way that would increase surface runoff
- Urban population increased 3-4 times
- Rural population remained relatively steady

Source: U.S. Census Bureau

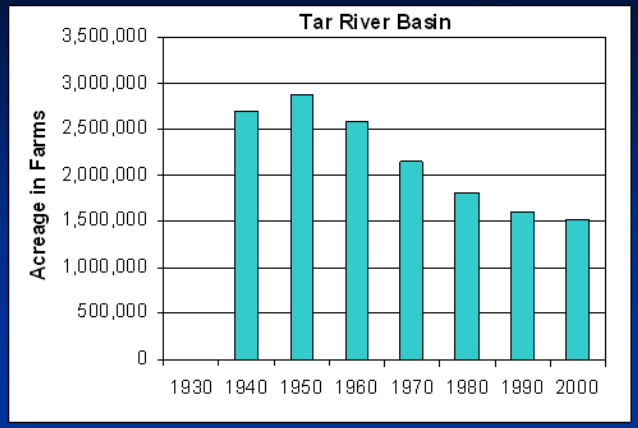
Housing Units

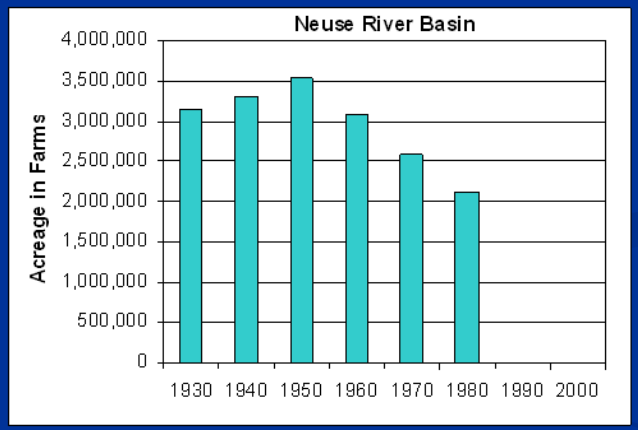


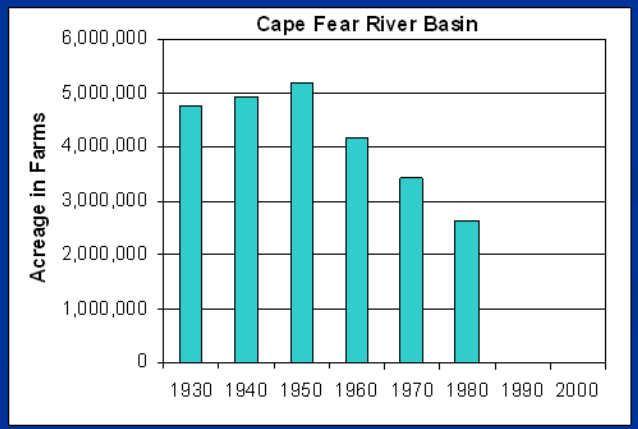




Farm Acreage







- Housing units increased by a factor of 2-3
- Farm acreage was reduced by half

Source: U.S. Census Bureau

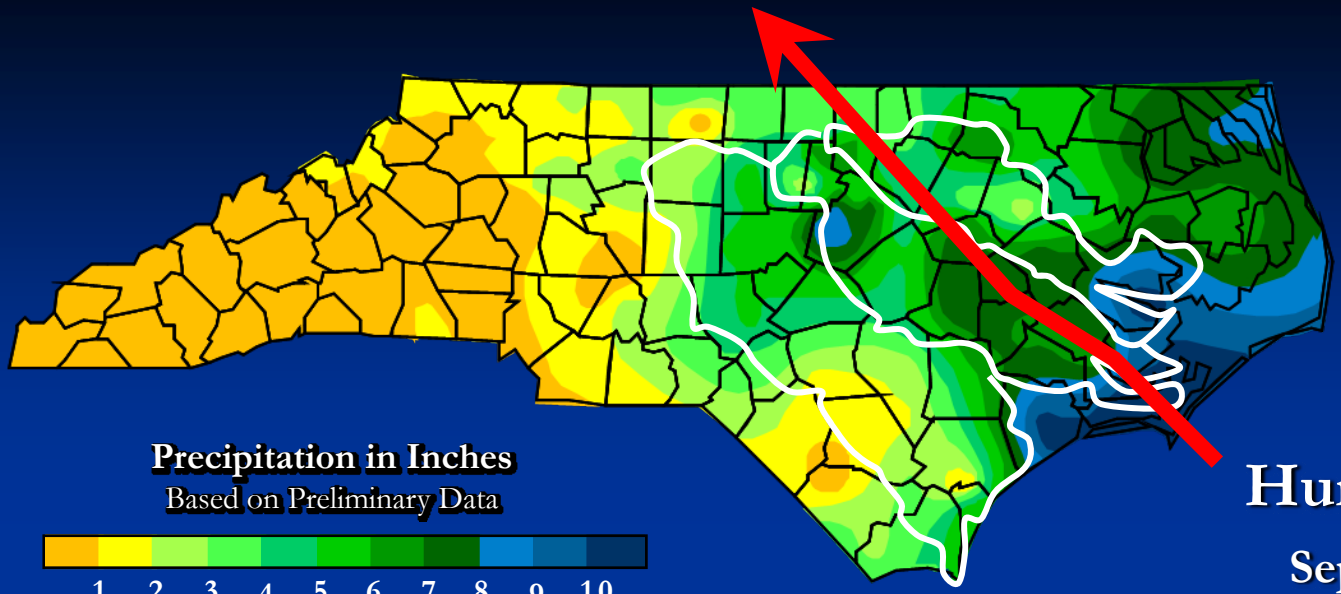
Hydrologic Data

- Rainfall
  - 21 stations for the 1999 event from the National Climatic Data Center and NOAA Atlas 14 partial duration time-series data
- Streamflow
  - 7 USGS gauging stations with daily records
  - Annual flood peak, 3-day flood volume, annual mean flow, annual 7-day low flow

USGS Gauging Stations.

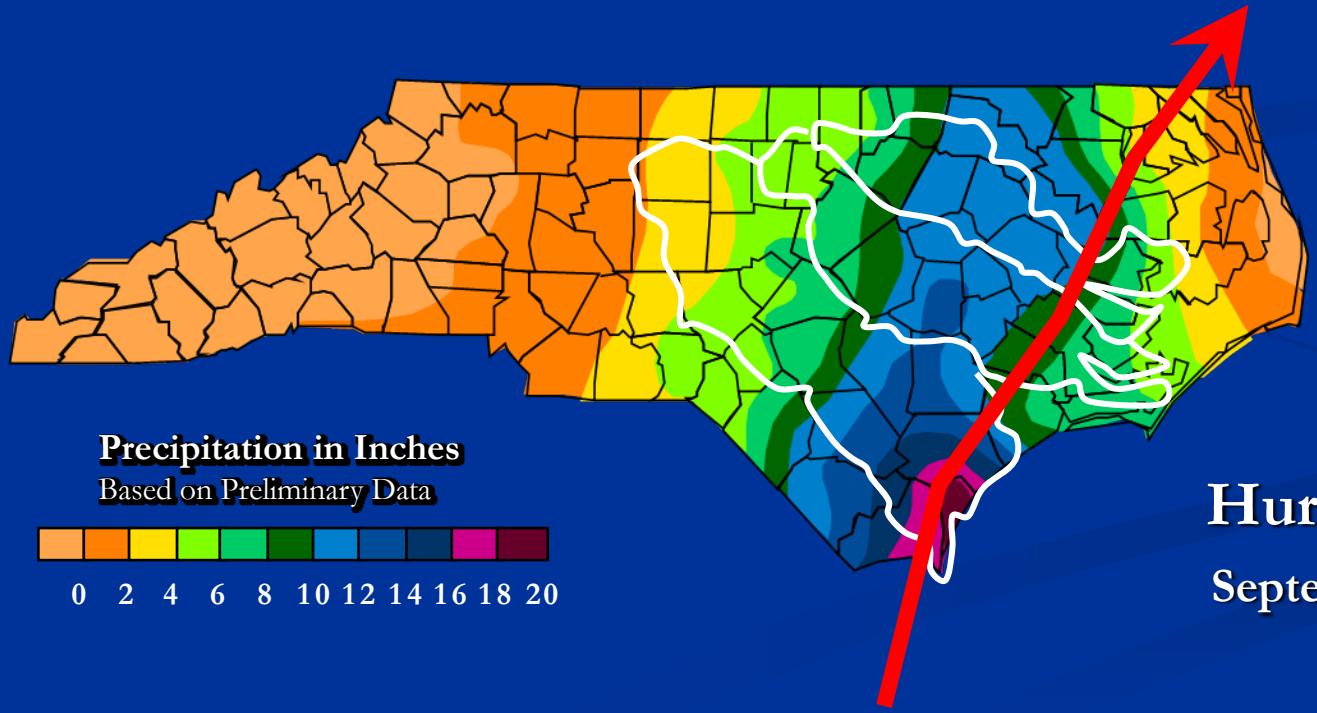
Basin	Station	Station ID	Drainage Area (km^2)	Period of Record[a]
Tar				
	Tar River near Tar River	02081500	433	1940-2004
	Tar River at Tarboro	02083500	5,654	1897-2004
Neuse				
	Neuse River near Clayton	02087500	2,979	1928-1980
	Neuse River near Goldsboro	02089000	6,213	1931-1990
	Neuse River at Kinston	02089500	6,967	1931-1994
Cape Fear				
	Cape Fear River at Lillington	02102500	8,972	1924-1981
	Cape Fear River near Tarheel	02105500	12,567	1941-1980

[a] Historical peaks and flows affected by regulation or diversion were deleted.



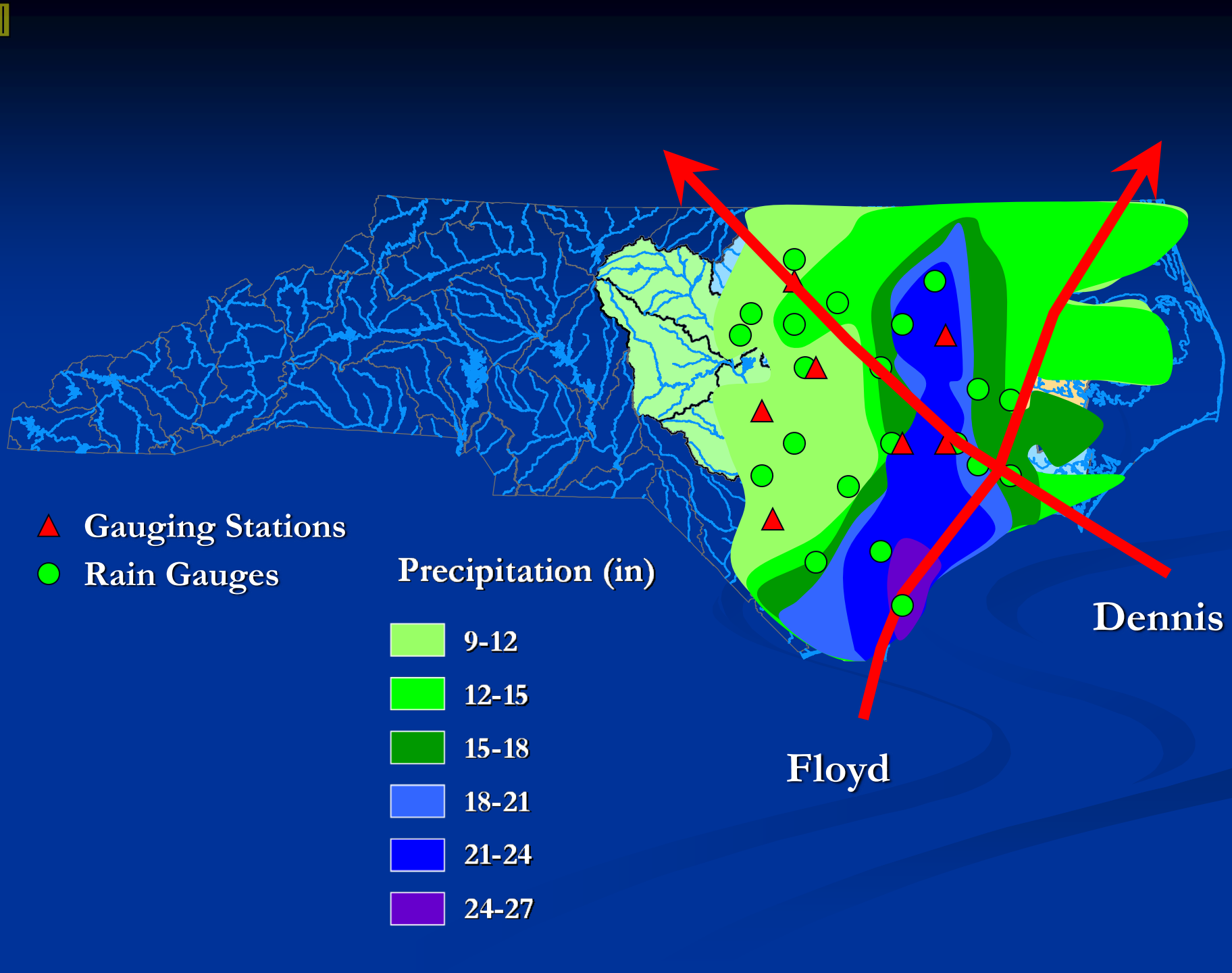
Hurricane Dennis

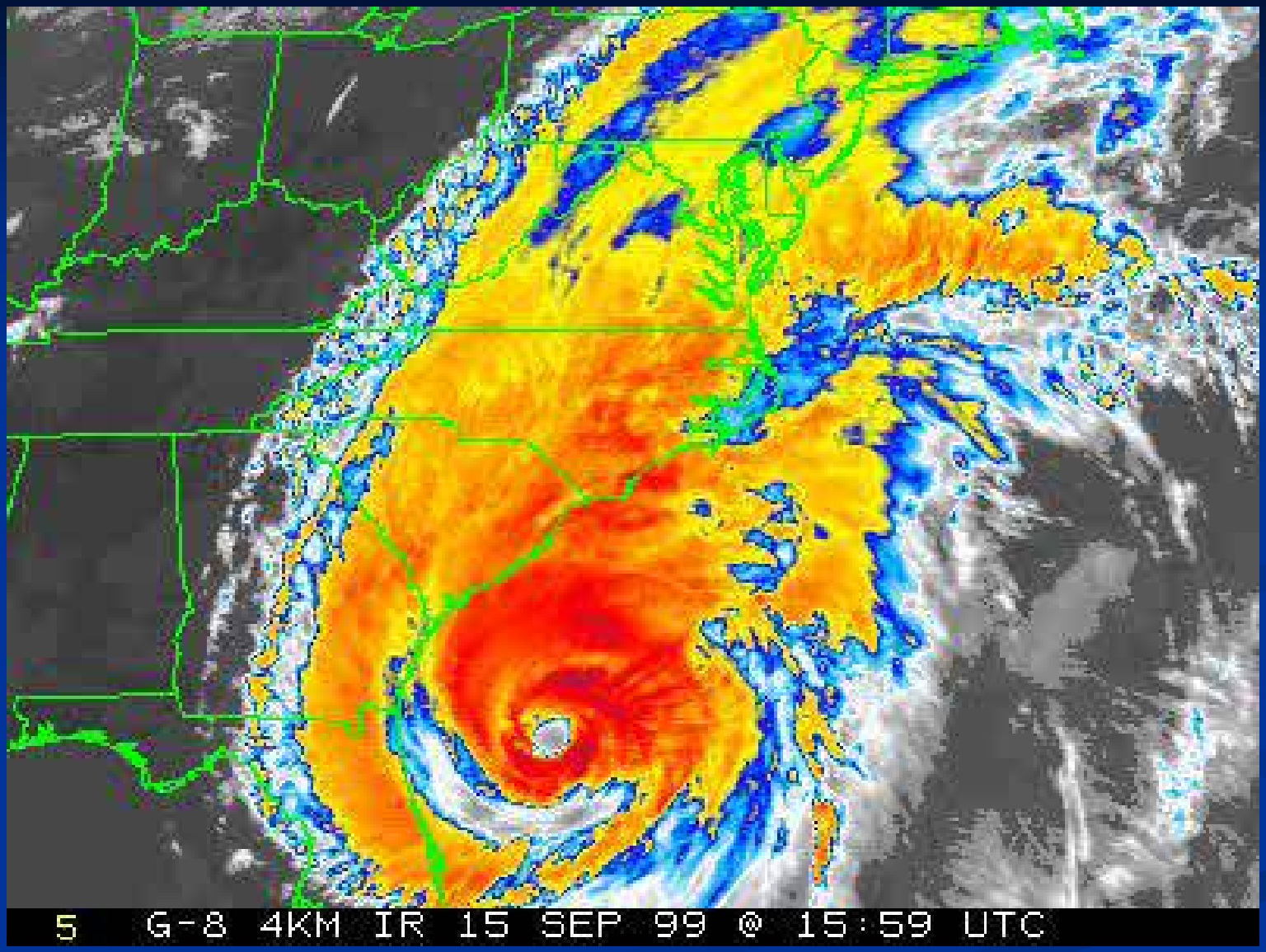
September 4-5, 1999



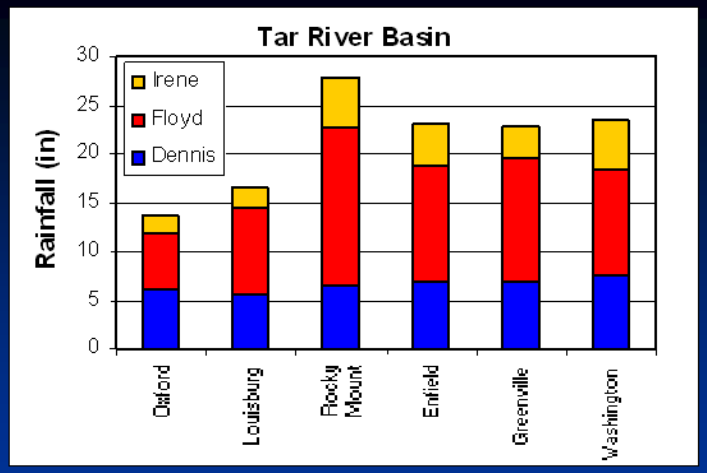
Hurricane Floyd

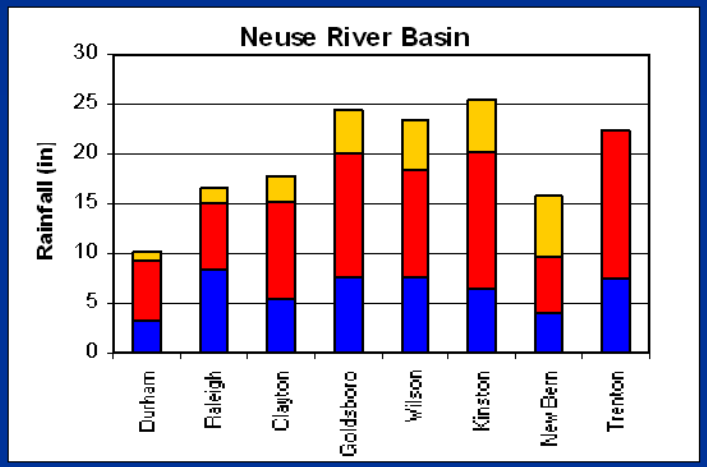
September 15-16, 1999

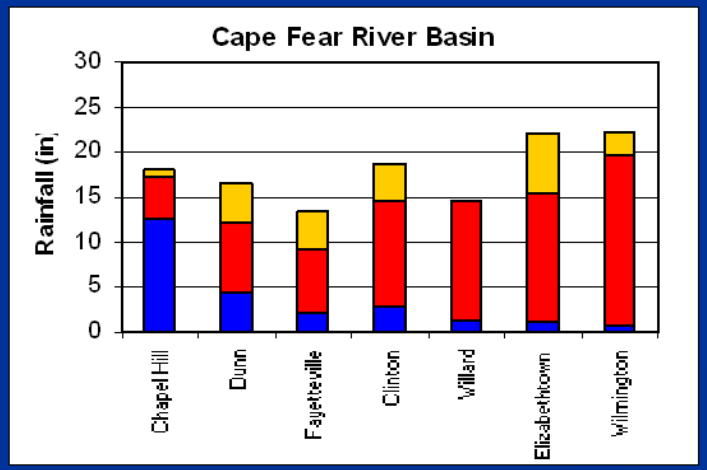

Gauging Stations
Rain Gauges
Precipitation (in)
9-12
12-15
15-18
18-21
21-24
24-27
Floyd
Dennis


5 G-8 4KM IR 15 SEP 99 @ 15:59 UTC

How extreme was the rainfall?



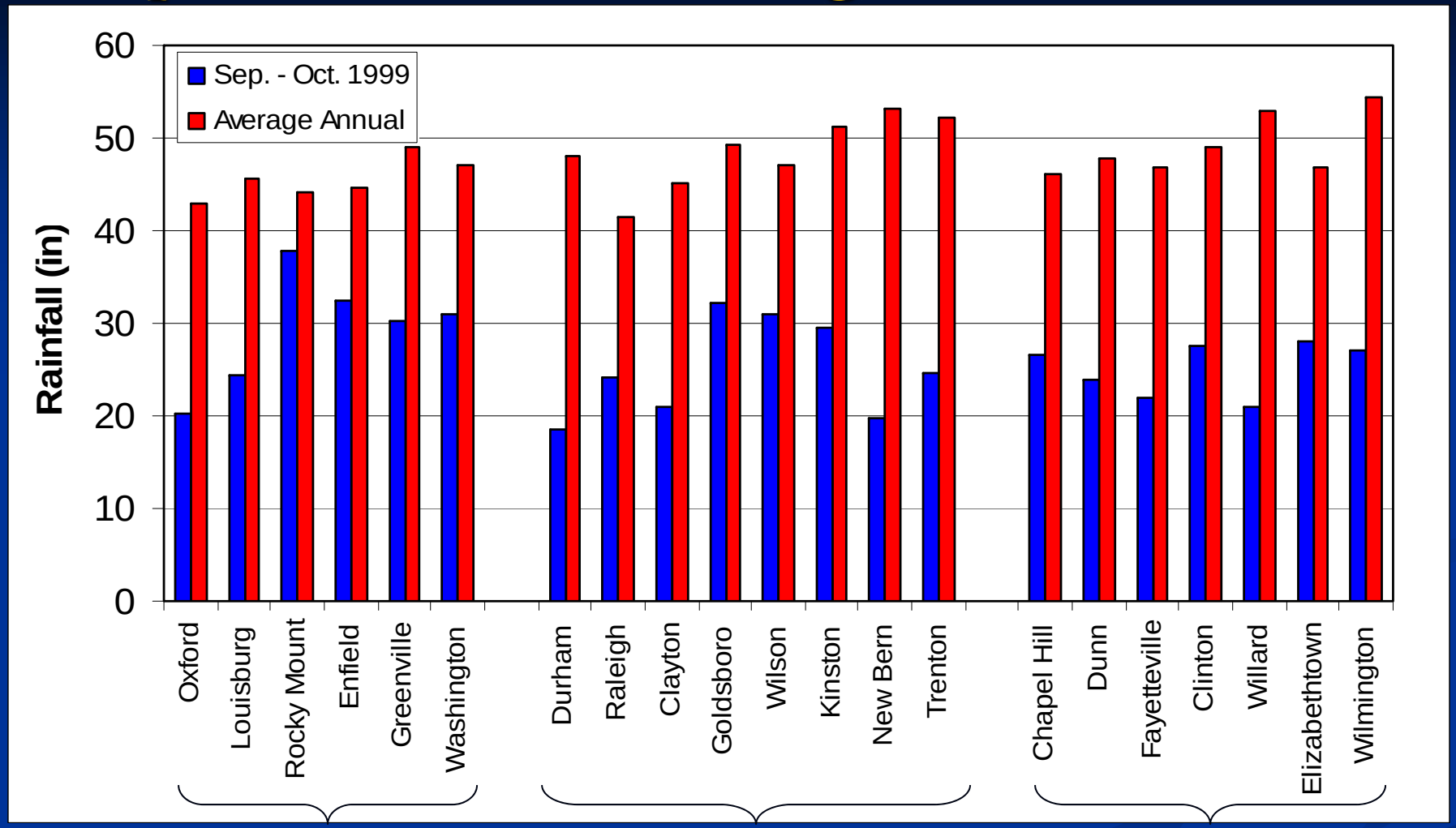




- Floyd
  - Mean = 11 in
  - Range = 5-19 in
- Dennis & Floyd
  - Mean = 16 in
  - Range = 9-23 in

Source: Bales et al. (2000)

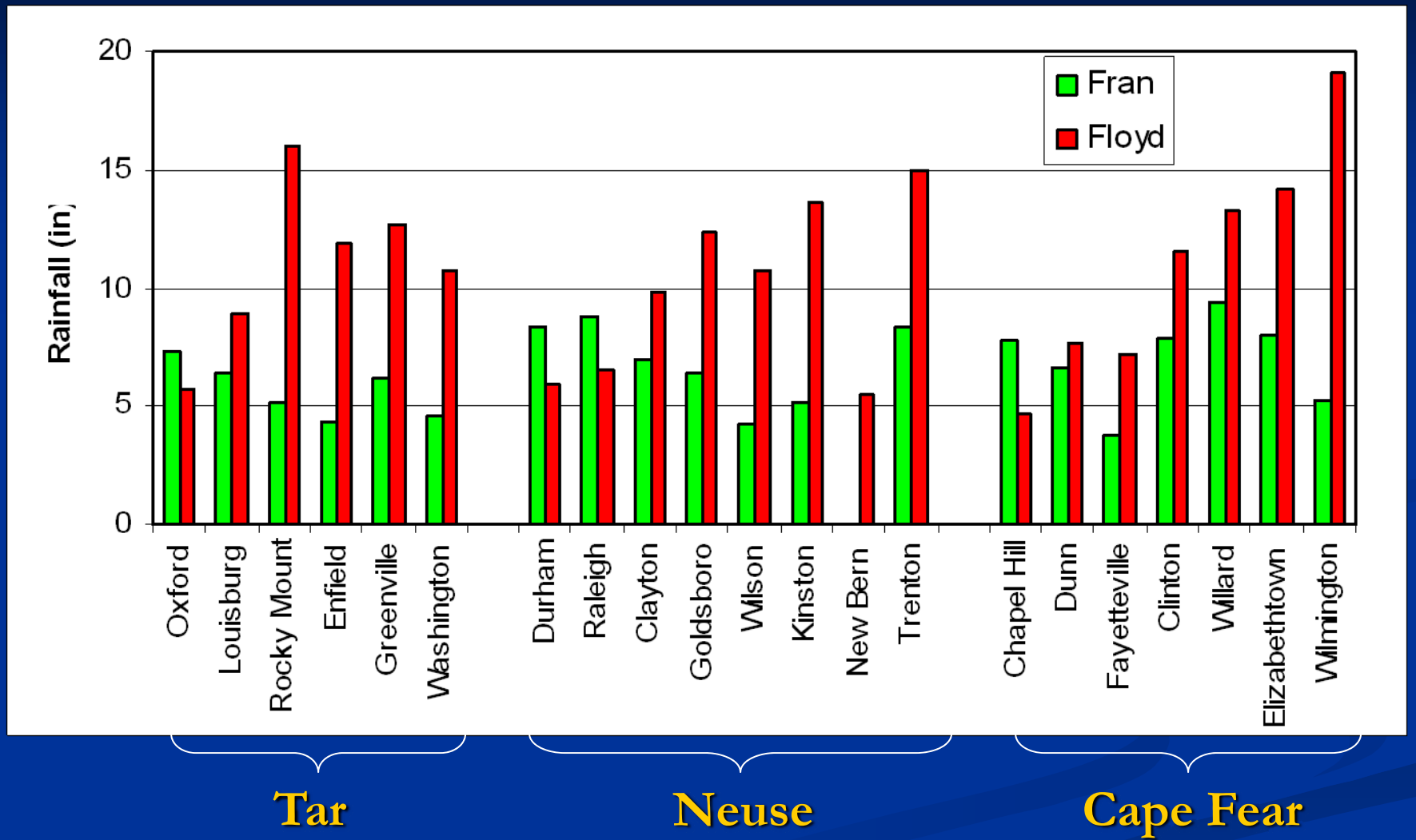
Sep. – Oct. 1999 vs. Average Annual Rainfall



- Mean = 55%
- Range = 40-85%

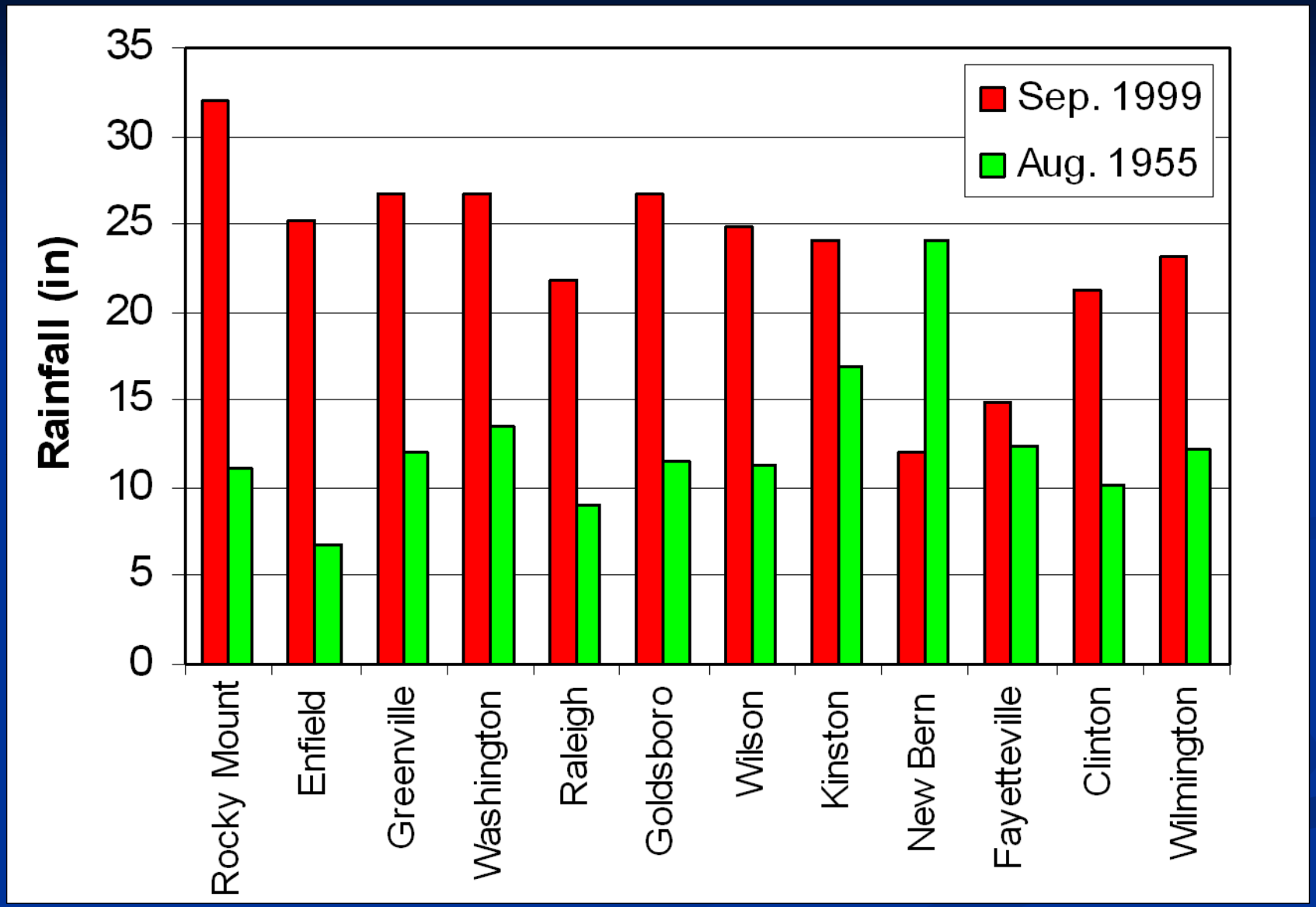
Source: Bales et al. (2000)

Floyd vs. Fran



Source: Bales et al. (2000)

1955 vs. 1999



Aug. 1955: Hurricanes Connie and Diane

Source: Bales et al. (2000)

Rainfall Frequency Estimates.

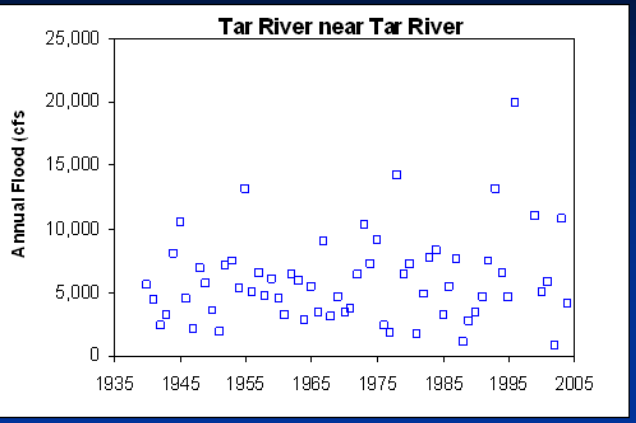
Station	Measured 24-hr Precipitation Maxima (in)	Estimated Recurrence Interval (yr)[a]
Elizabethtown Lock 2	13.60	200
Wilmington WSO Airport	15.04	200
Rocky Mount	14.73[b]	500
Kinston	12.54[b]	200

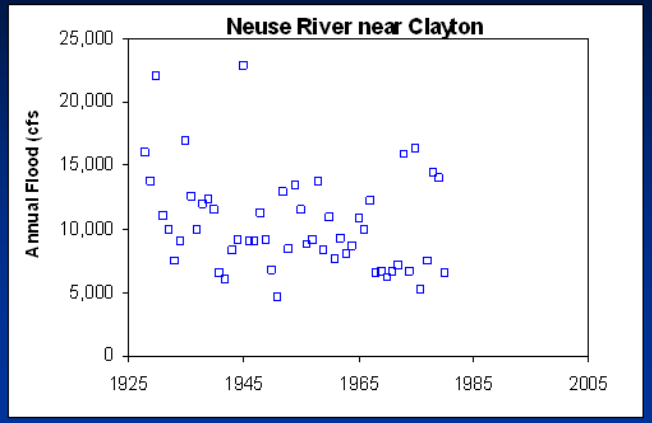
[a]from Hershfield (1961) (100-yr, 24-hr = 8-9 in) and NOAA's Precipitation Frequency Data Server.

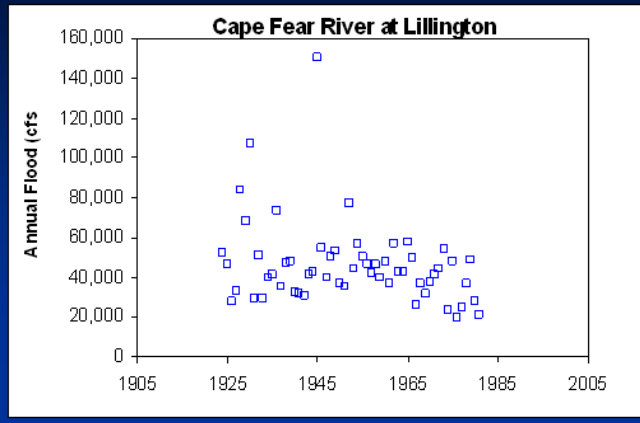
[b]from Bales et al. (2000).

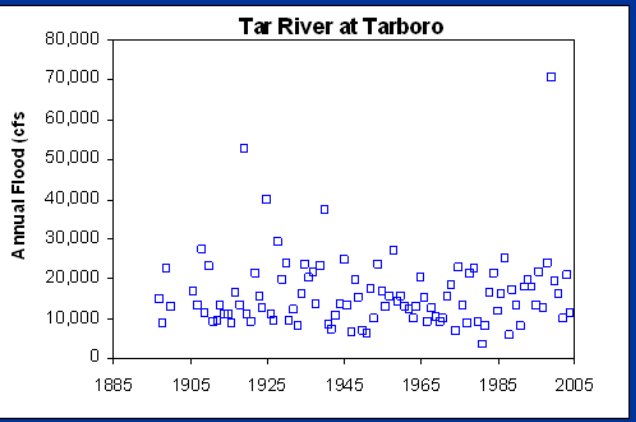
Streamflow Trends

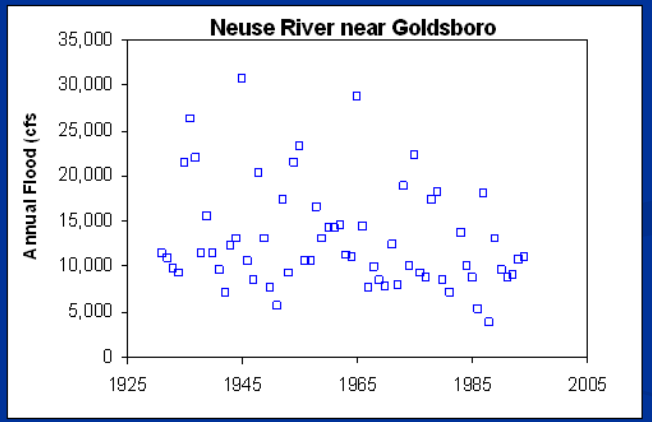
Annual Flood

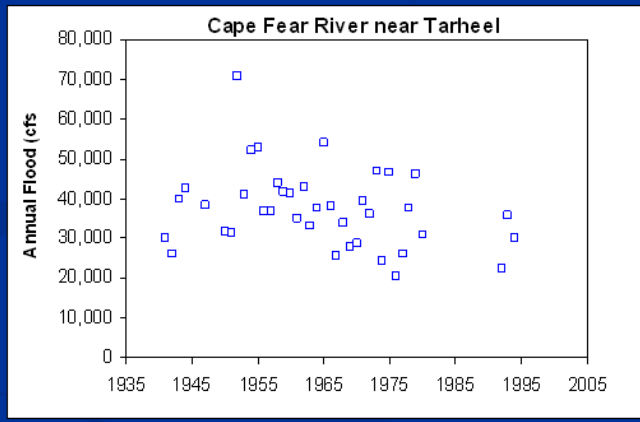


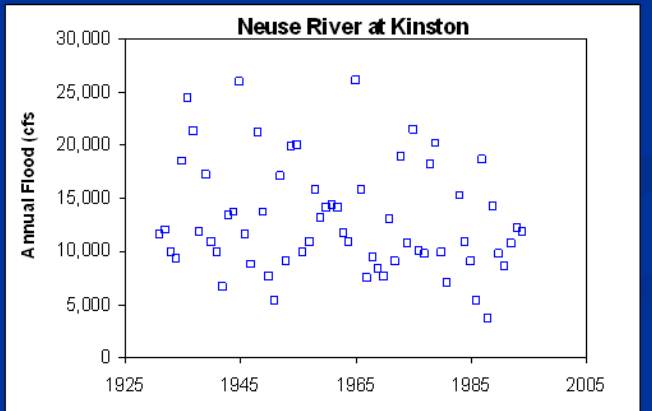






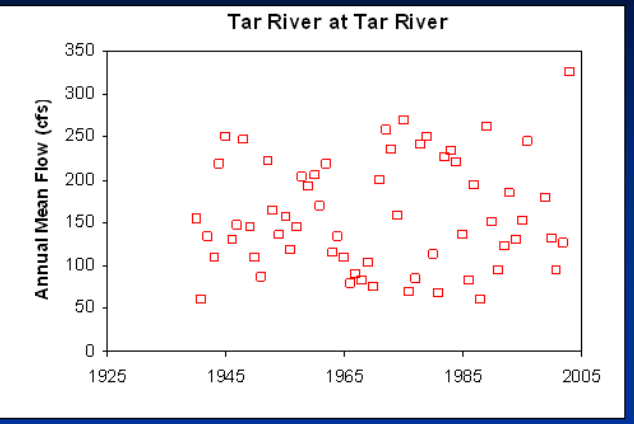


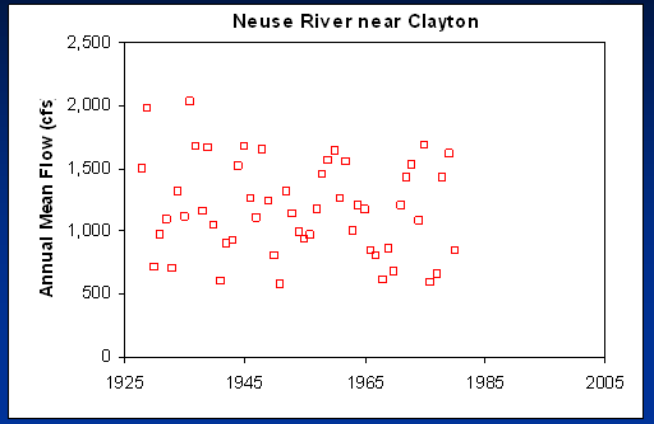


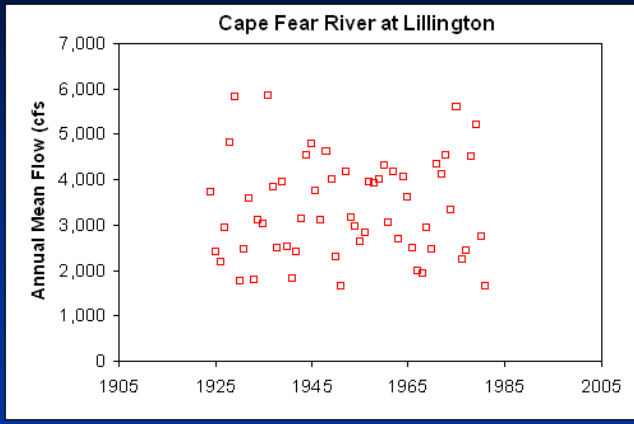


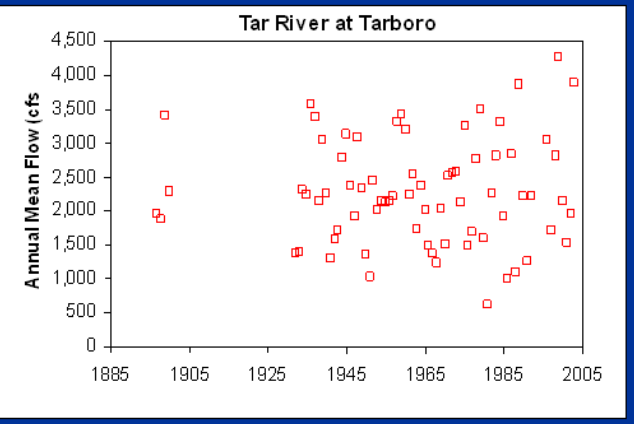
Streamflow Trends

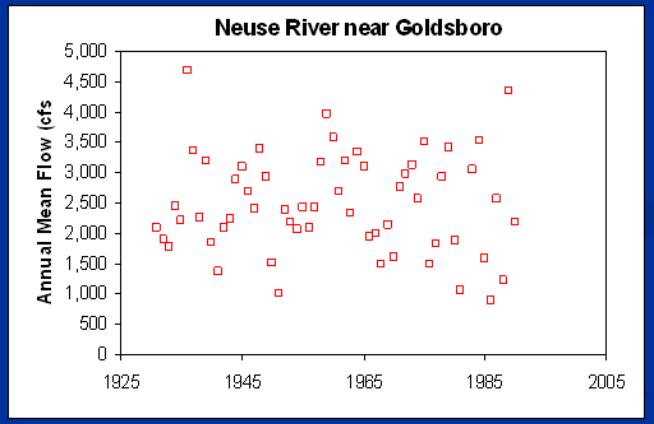
Annual Mean Discharge

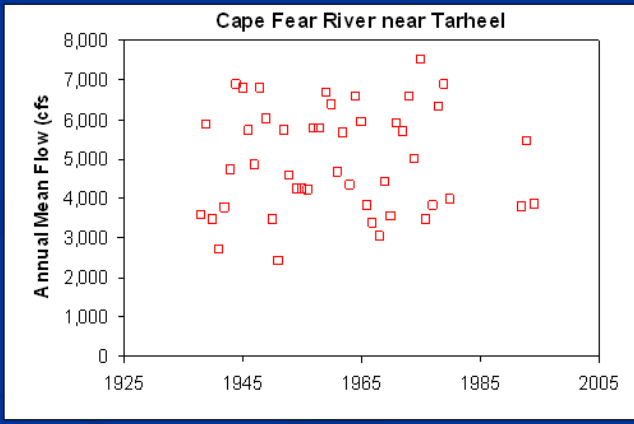


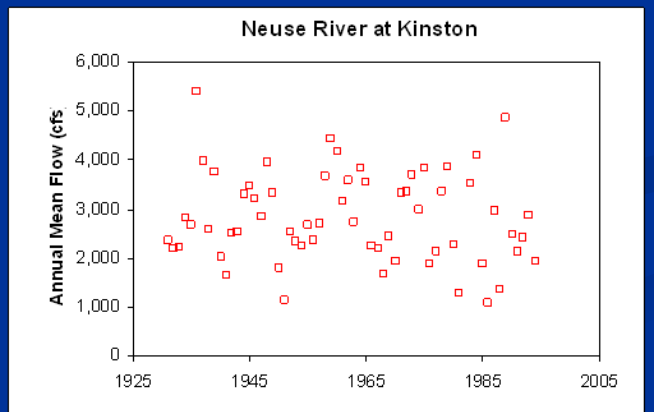






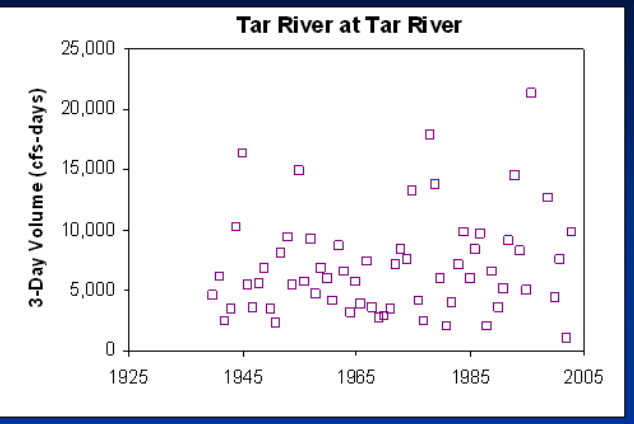


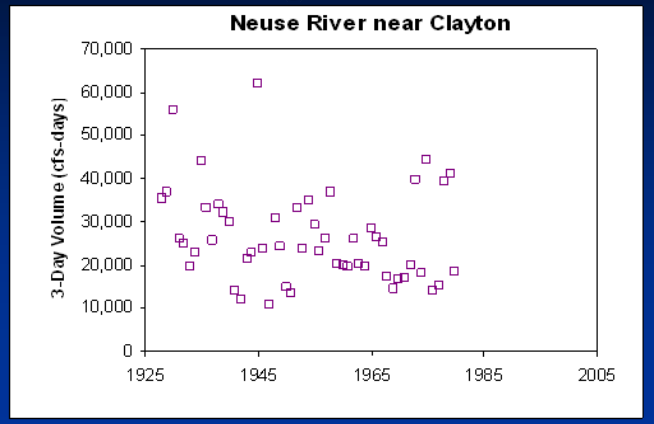


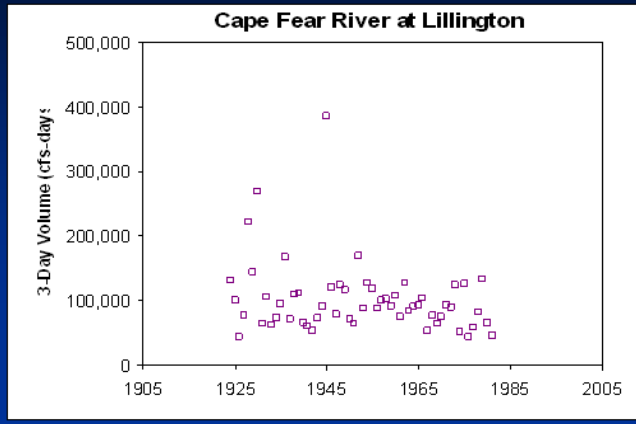


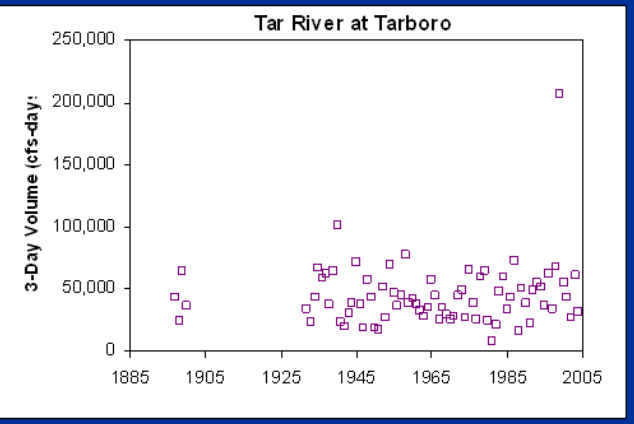
Streamflow Trends

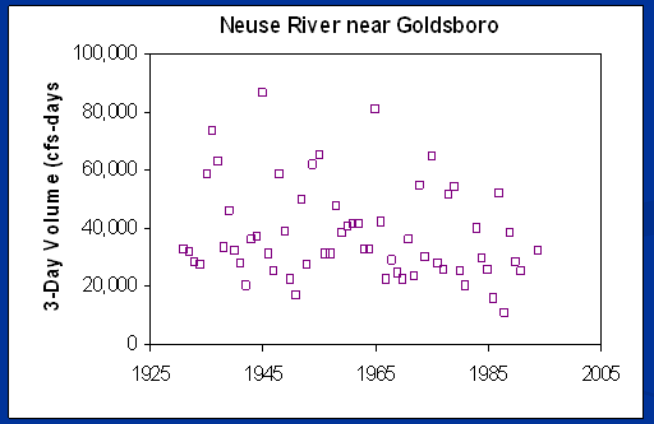
Annual 3-Day Flood Volume

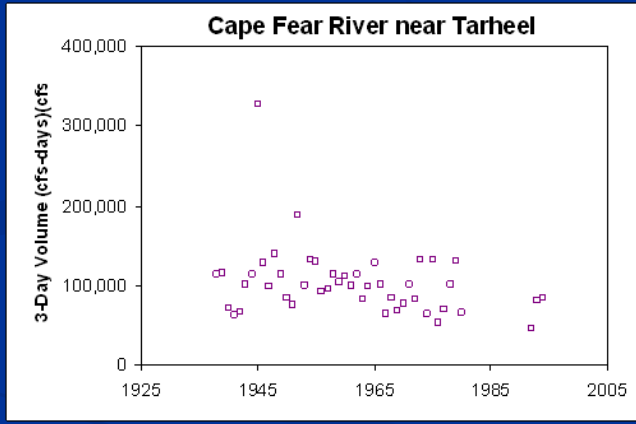


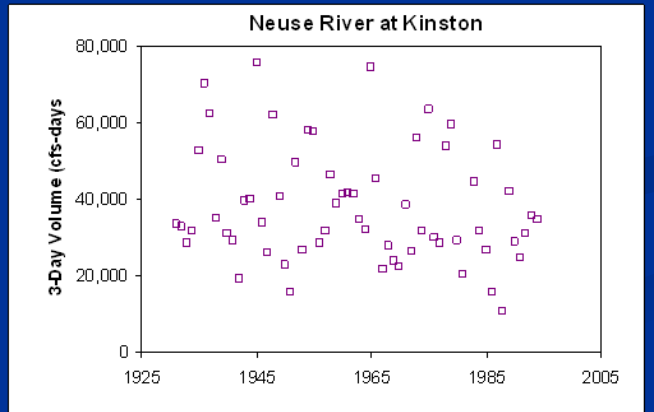






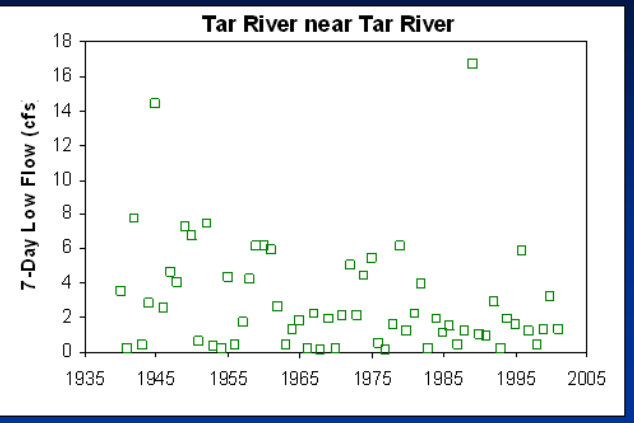


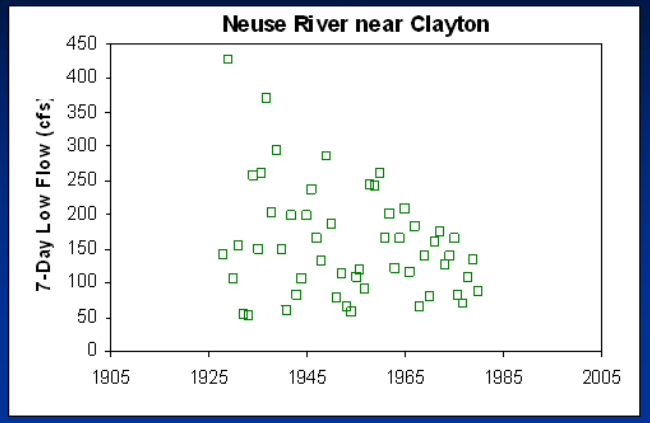


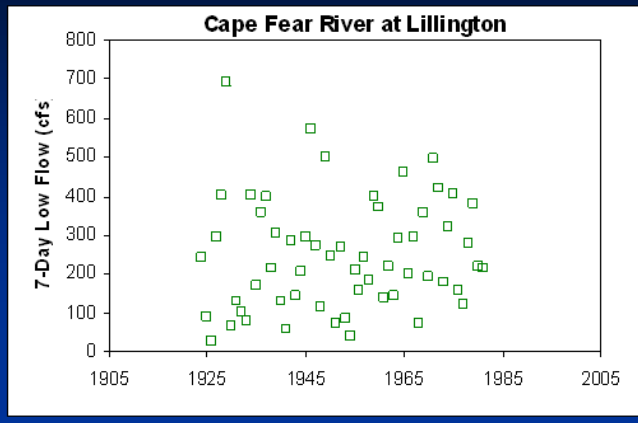


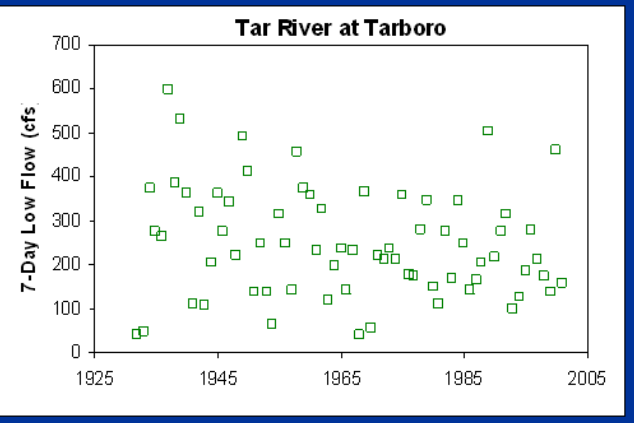
Streamflow Trends

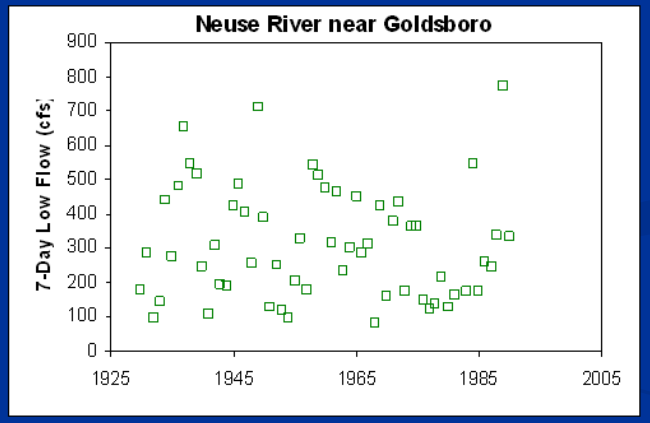
Annual 7-Day Low Flow

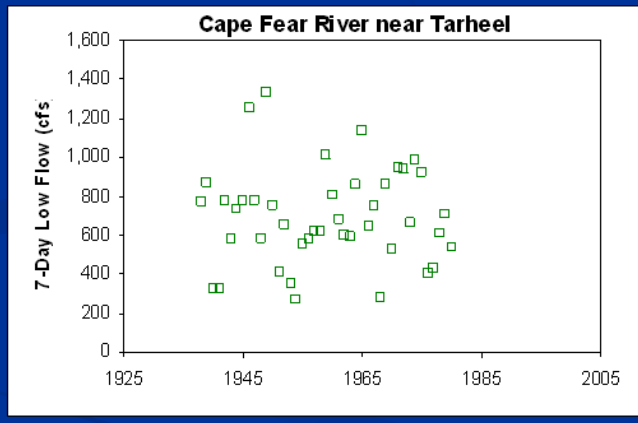


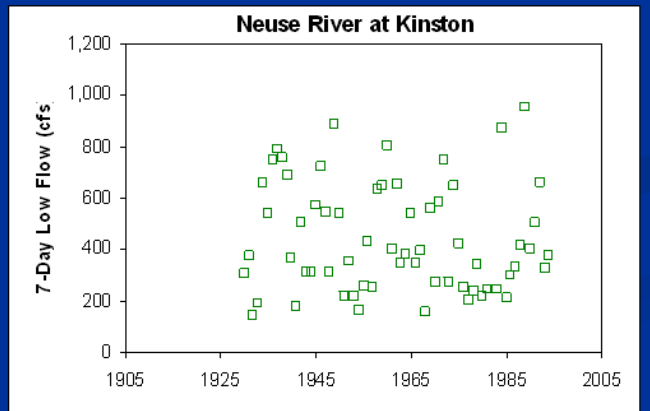




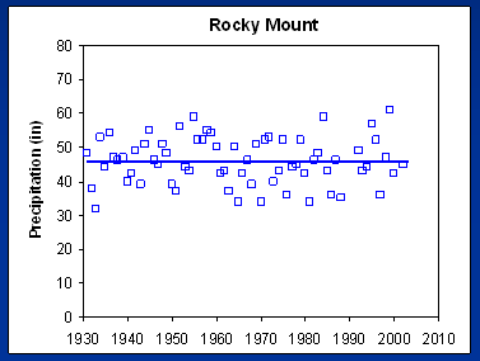


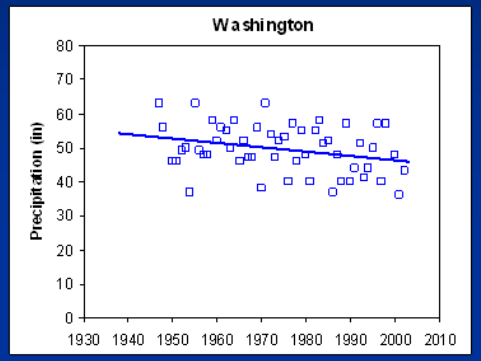


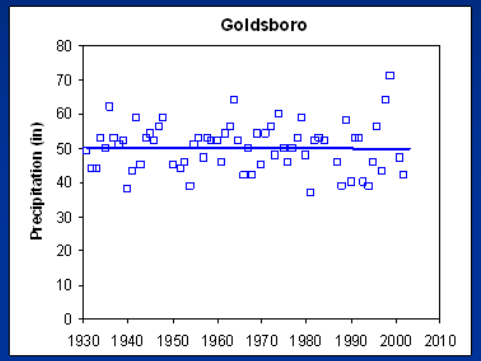


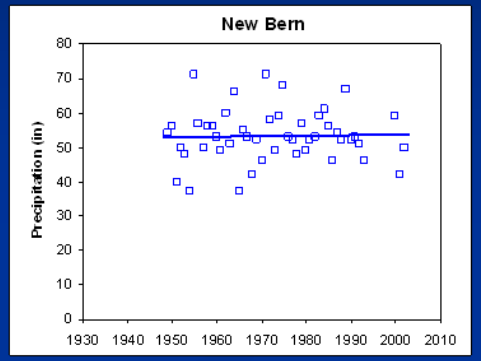


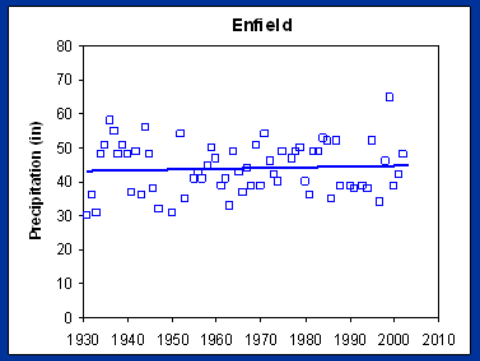
Trends in Annual Precipitation

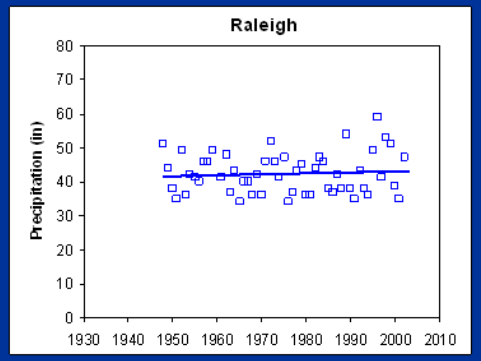


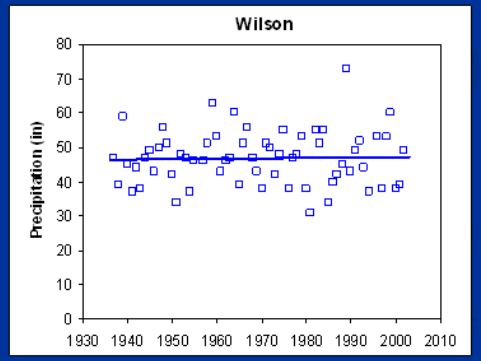


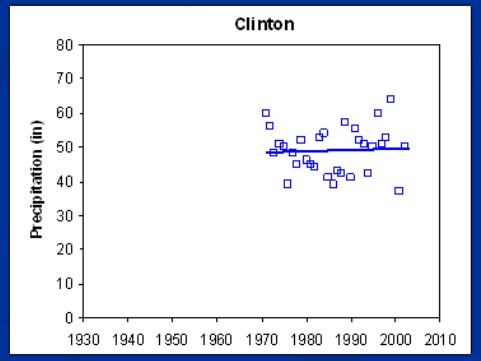


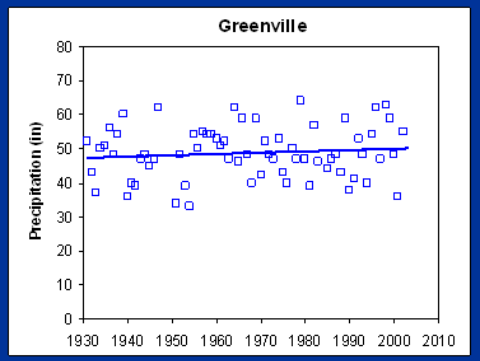


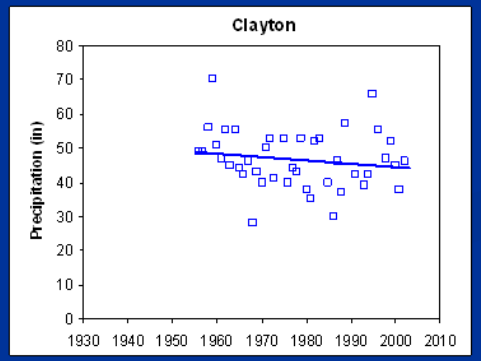


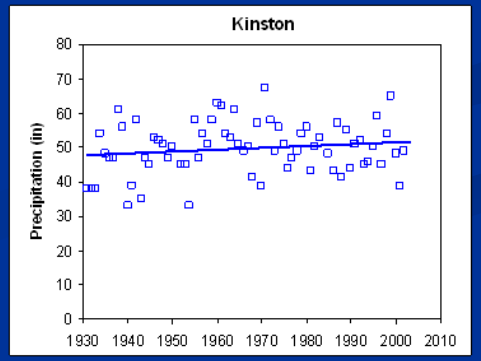


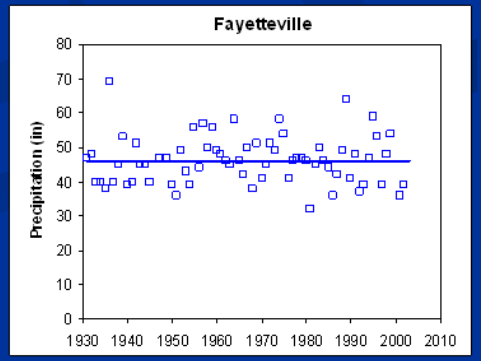




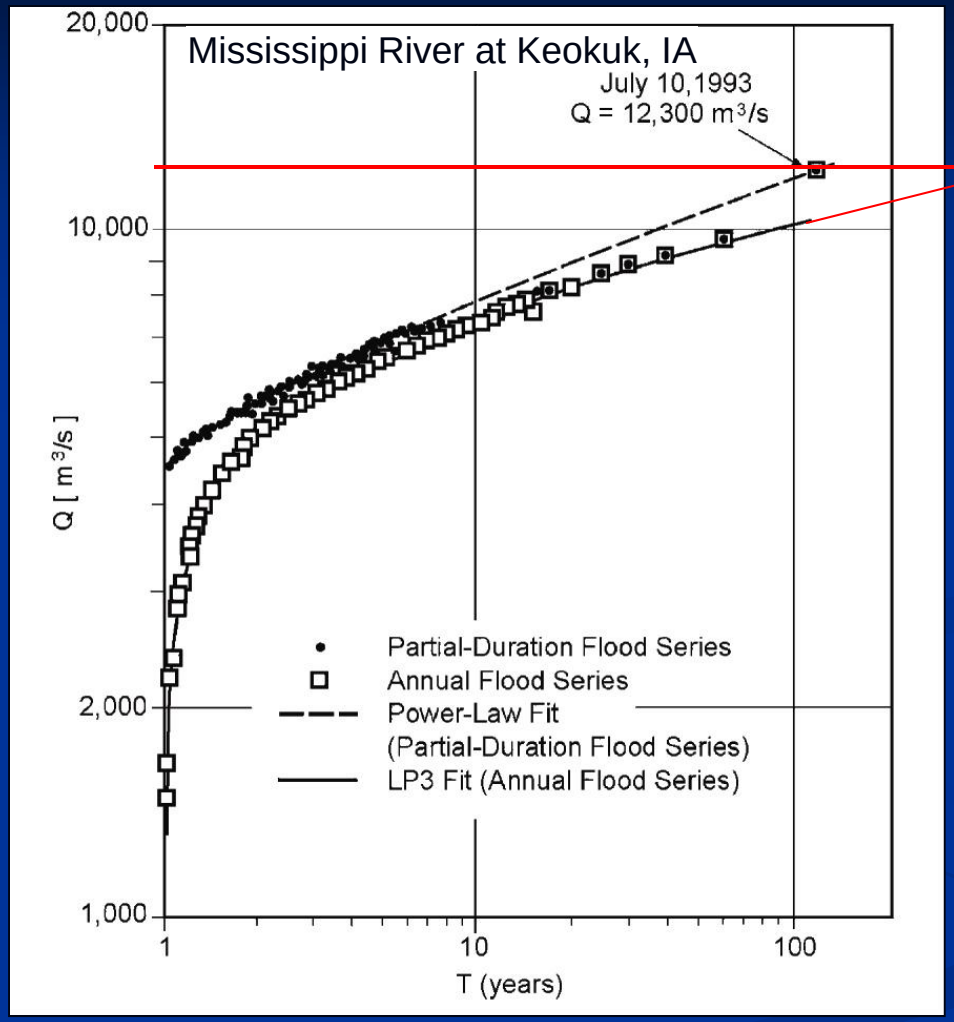






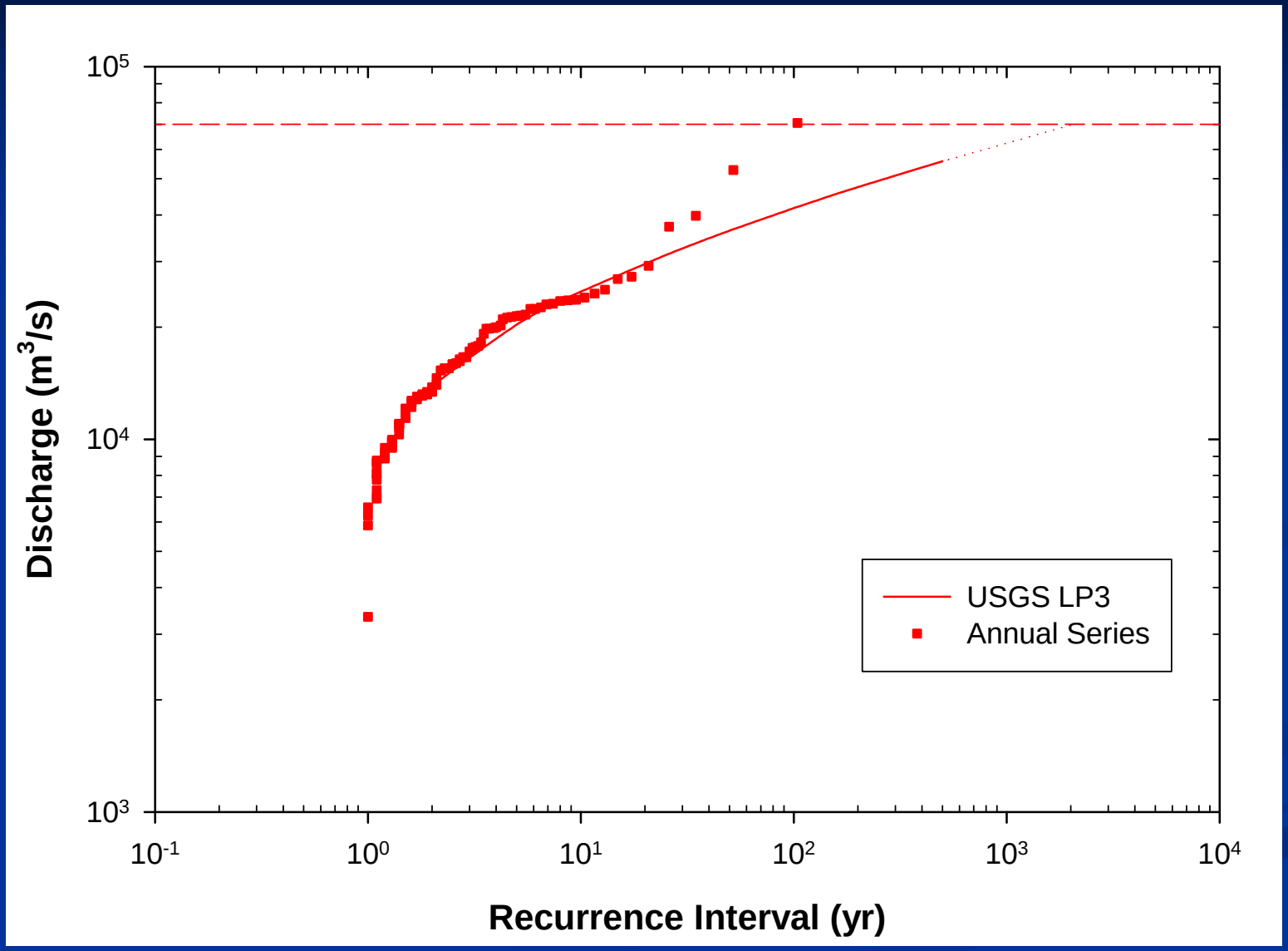


Self-similarity of Flood Behavior?

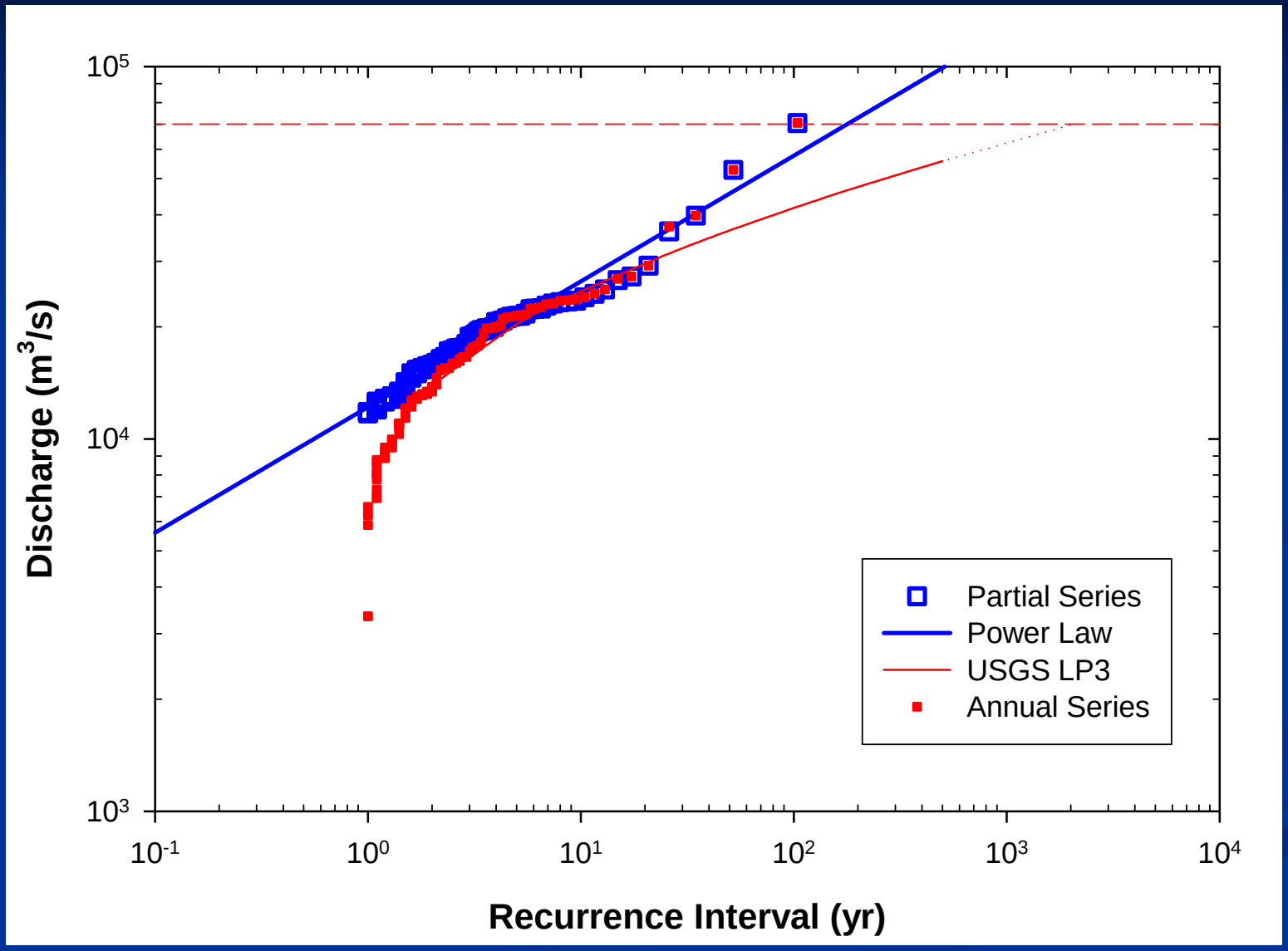


Source: Malamud, B.D., Turcotte, D.L., Barton, C.C. 1996. The 1993 Mississippi River Flood: A One Hundred or a One Thousand Year Event? *Environmental & Engineering Geoscience* 2: 479-486.

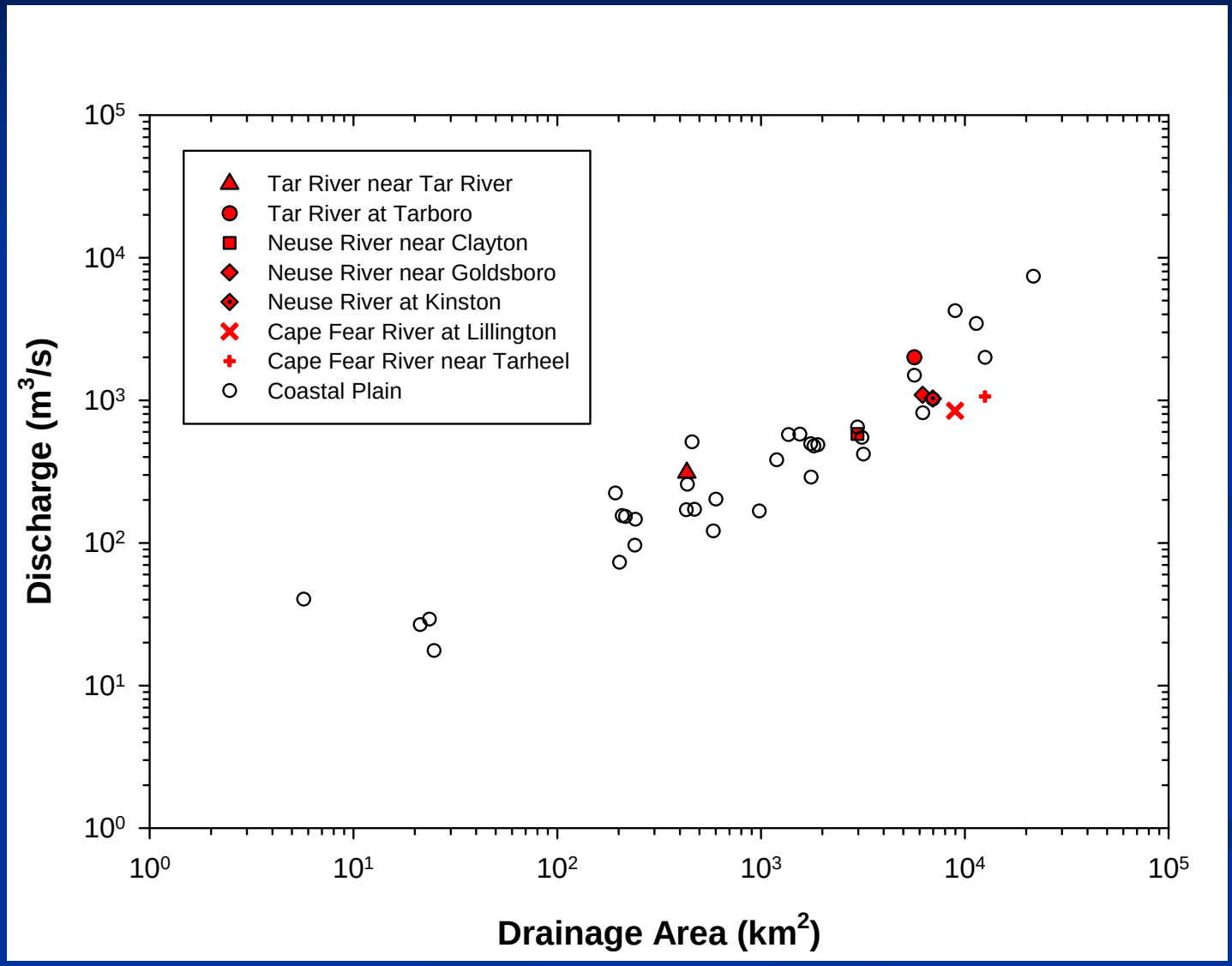
Tar River at Tarboro (1897-2004)



Tar River at Tarboro (1897-2004)



1999 Peak Flows vs. Maximum Discharges in NC Coastal Plain Rivers



Conclusions

- So, if this region is becoming more urbanized, why is there no corresponding hydrological response?
  - Wetlands have a limited storage capacity, which is more likely to be exceeded during big events
  - Scale matters…it is well-documented that the largest events drown out human effects
    - all surfaces become saturated and act as impervious surfaces
  - Event-sequencing
    - Floyd followed Dennis

Conclusions

- Because we only have hydrologic data back to the early 1900s, we cannot say that human agency has not had hydrologic effects since European settlement, although we can speculate that the conversion of forests for agricultural uses produced significant changes

- What we can say, however, is that during a period of rapid urbanization in eastern North Carolina, there has been little change in stream flow at the scale of the watersheds investigated

- That, coupled with the extreme nature of the precipitation and the sequencing of two major hurricanes with 10 days of one another, makes it seem unlikely that human activities made the 1999 flood more severe

"Why was the September 1999 event considered to be the "flood of the century"? Several factors led to the extreme damage resulting from this event. First and foremost, a tremendous volume of water fell in five specific rain events that included two back-to-back hurricanes. Second, and of equal importance, portions of eastern North Carolina have recently experienced tremendous growth and development. During the period from the mid-1990s, the central coastal plain region experienced incredibly high levels of development and very few, minor hurricanes. This rapid growth and development led to modifications of coastal plain drainage systems, including channelization and wetland destruction, floodplain dams, and urbanization" (Riggs 2001, 37).

"Society contributed significantly to the 1999 flood crisis through modification of drainage systems that resulted in major land-use changes and subsequent encroachment into marginal wetlands by agribusiness, forestry, industry, and urbanization. Modification of the drainage system and encroachment into marginal land has major impacts on both the flow dynamics and flooding response" (Riggs 2001, 45).

Riggs, S.R. 2001. Anatomy of a flood. In: *Facing our Future: Hurricane Floyd and Recovery in the Coastal Plain*, Maiolo, et al. (eds.), Coastal Carolina Press, Wilmington, NC, 29-45.

"Thus, the "flood of the century" was first and foremost the product of two months of severe rainfall in the North Carolina coastal plain." (Riggs 2001, 30).

"The "flood of the century" was not a natural disaster…This was a human catastrophe." (Riggs 2001, 45).

Channelization

"But severe drainage system modification really began in response to the late-twentieth century growth boom. Tens of thousands of miles of ditches drained vast acres of the marginal wetlands into adjacent tributaries…Channelization changed the tributary streams into pipe-like ditches for the sole purpose of getting more water off the land faster." (Riggs 2001, 38).

Floodplain dams

"However, the slow discharge of floodwaters from the trunk rivers was also due to two other factors. First, there is an extensive network of road dams across the trunk river floodplains. …Second, the gradient, or river slope, decreases to zero as the lower stretches of the river approach sea level. (Riggs, 2001, 39-40).