Hydrologic Change, and the Geomorphic Transformation of the Little Colorado River: Implications for Sediment Delivery to the Grand Canyon

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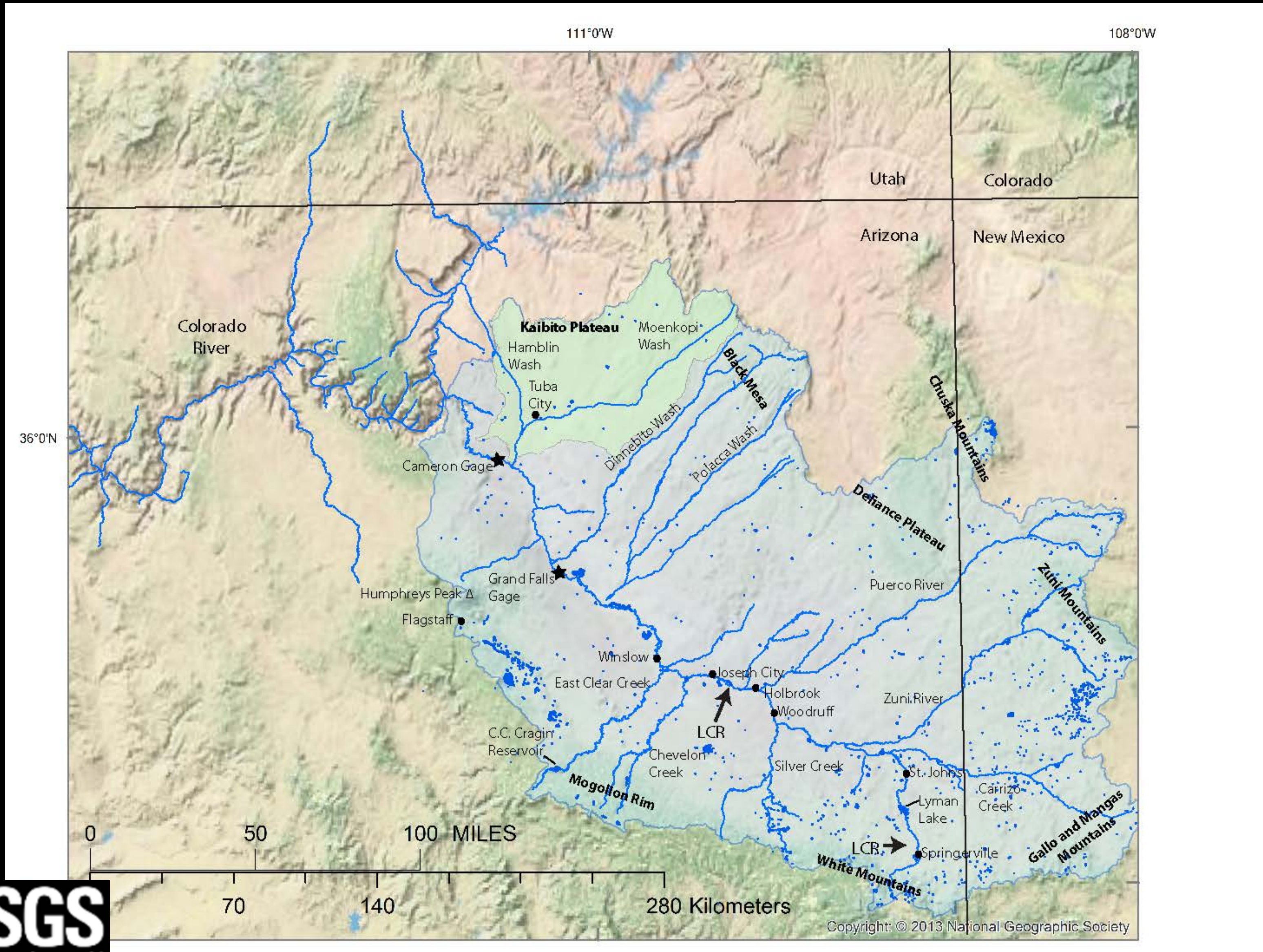
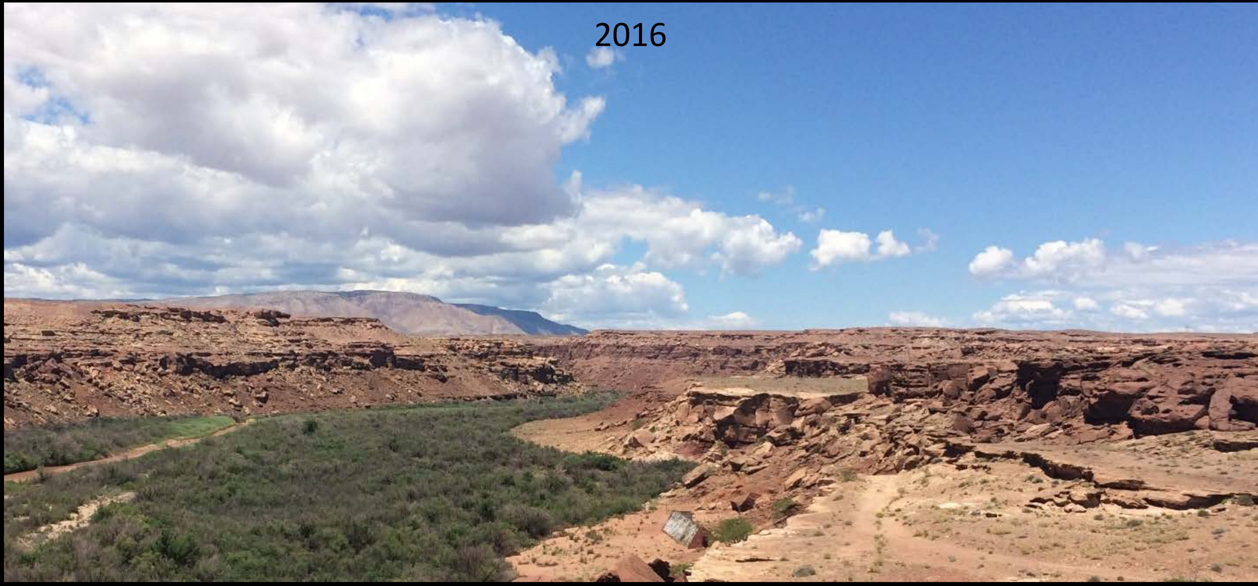
The LCR Basin



The Little Colorado River: 100 Years of Change

A formerly braided river – now single-threaded

The former channel devoid of riparian vegetation – now dense floodplain forests



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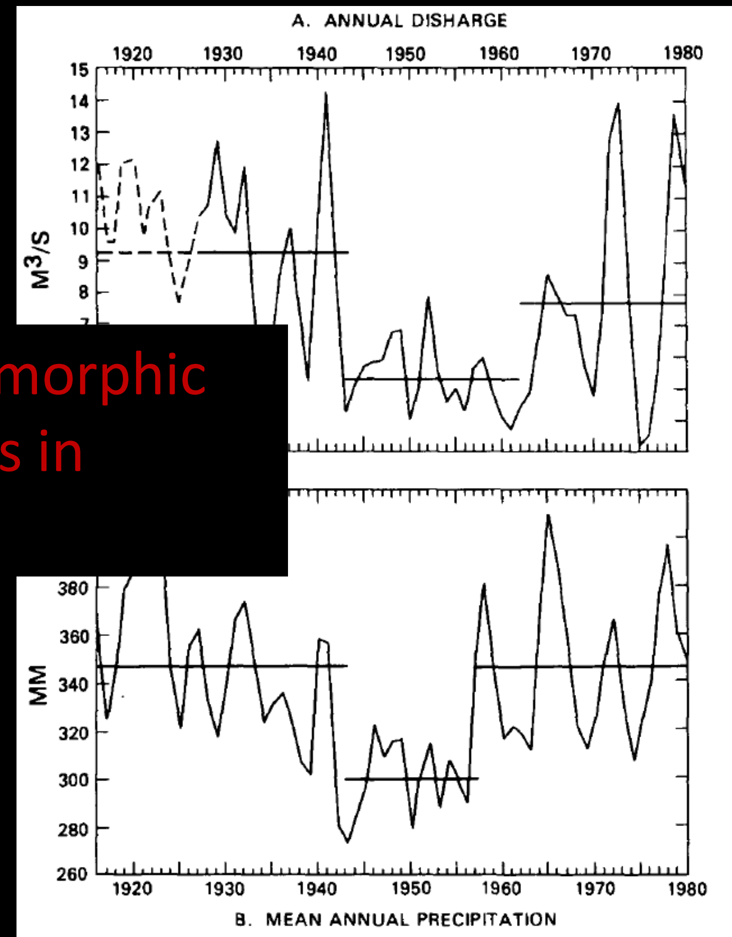
Previous Work on the LCR:

Between the early 1900s and the 1980s:

- Three alternating periods of erosion and deposition
  - 1900-1940s – frequent large floods, high annual dischar
  - 1940s-1 decrea floodplains developed – salt cedar (*Tamarisk* spp.) became widely established on these floodplains
  - 1950/60s-1980s – precipitation and discharge increased – the largest floods during this period caused continued overbank deposition and vertical accretion.

Conclusion: hydrologic and geomorphic changes were driven by changes in climate.



Hereford, 1984

Historical Land Use and Human Development within the LCR Basin

- In the 1870s, Mormon settlers began building diversion dams and irrigation networks.

- Completion of the railroad in the 1880s brought ranchers and their large herds of sheep and cattle (150,000 head of cattle, 120,000 head of sheep).

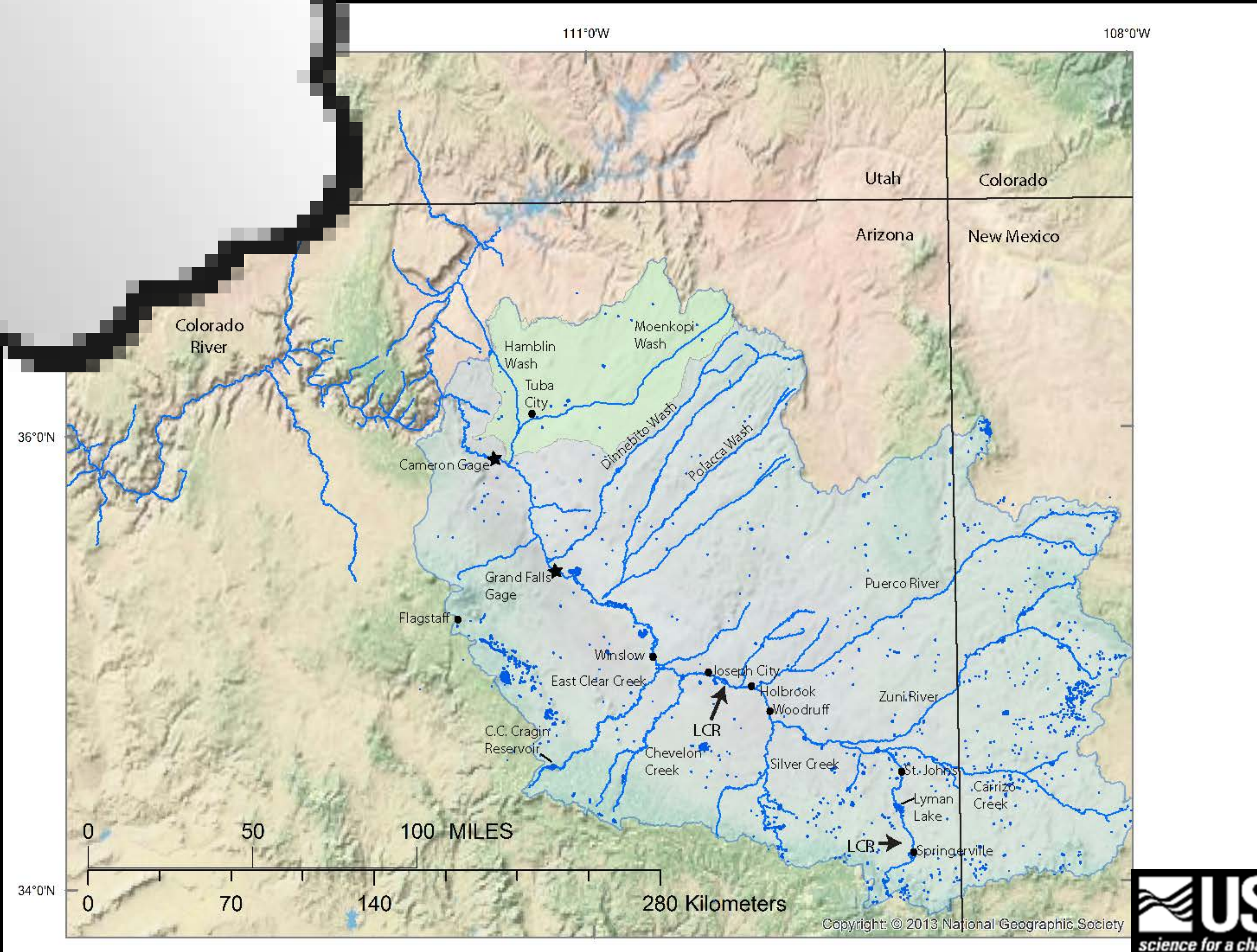
- Widespread denudation of the LCR ranges had occurred by the 1890s = gullying and erosion occurred throughout the LCR drainage network.

- Although grazing likely had some impact on erosion, the primary cause of erosion is believed to be above average rainfall.

- Prior to the start of stream gaging in 1926, substantial changes to LCR hydrology/geomorphology had already occurred

- Today, there are nearly 100 reservoirs within the basin, and over 3,700 stock ponds

ology – Winter/Spring



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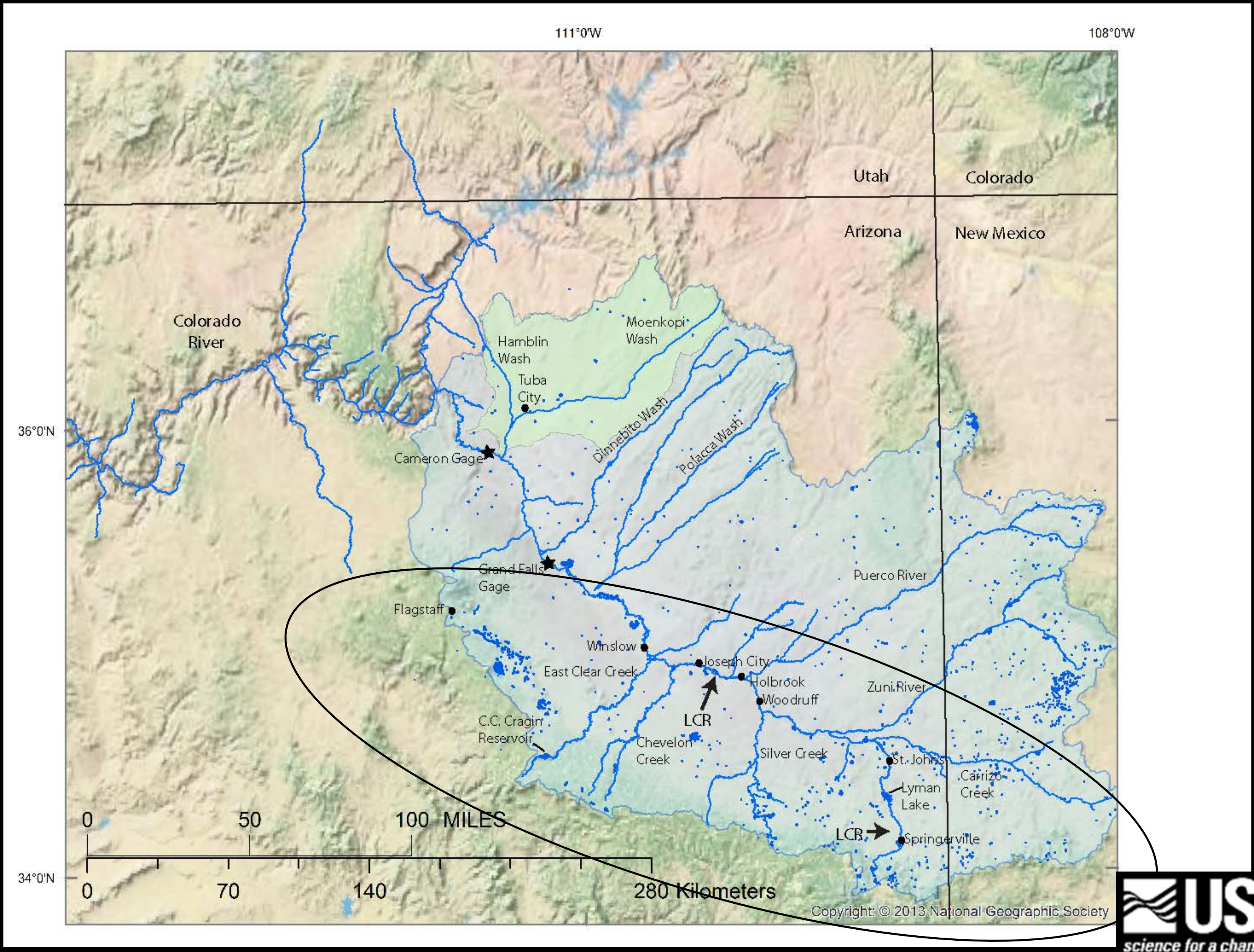
Hydrology – Winter/Spring



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Hydrology – Winter/Spring

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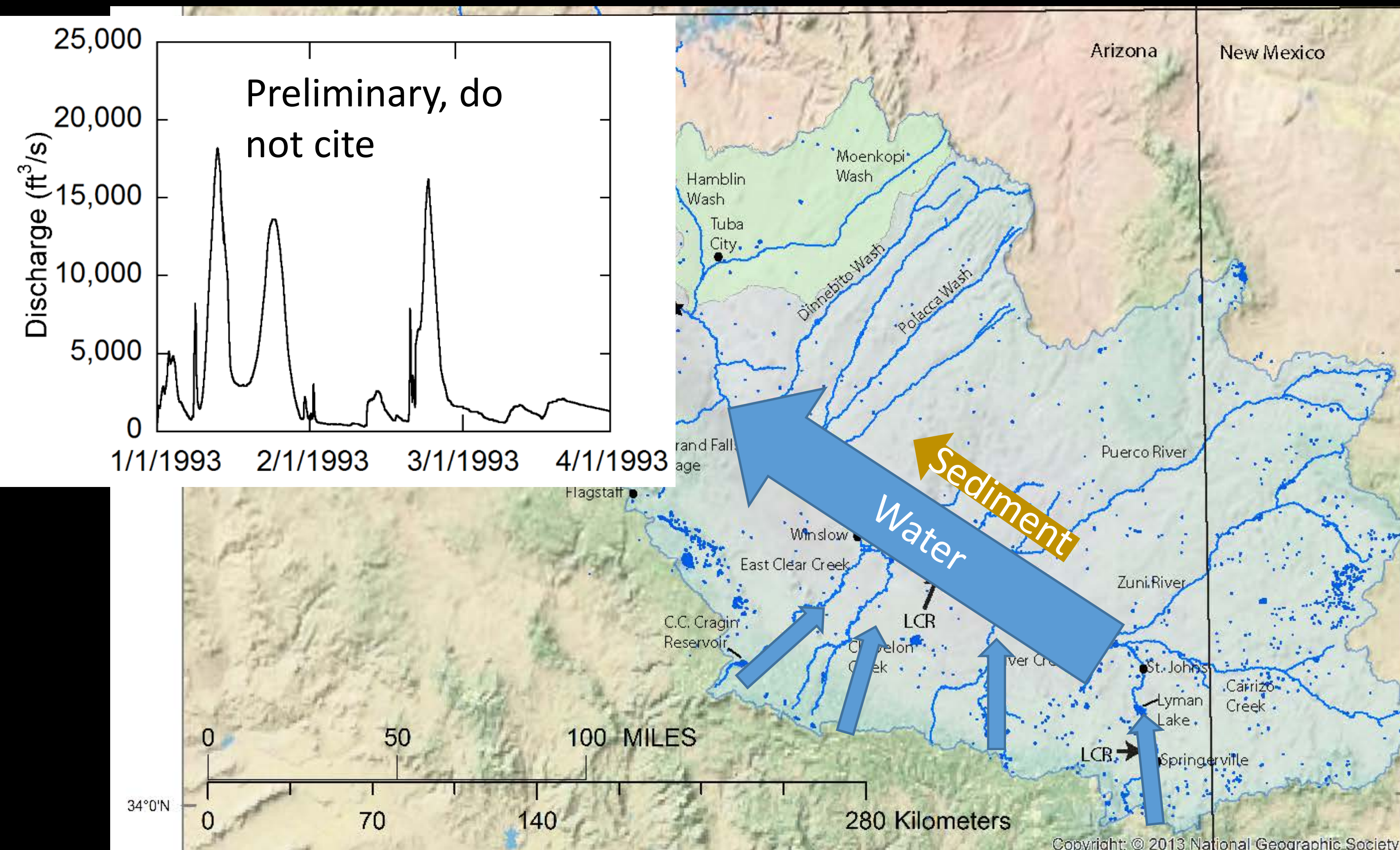
- Long-duration winter/spring runoff driven by large frontal storms.
- Floods can be large, but sediment loads are generally small



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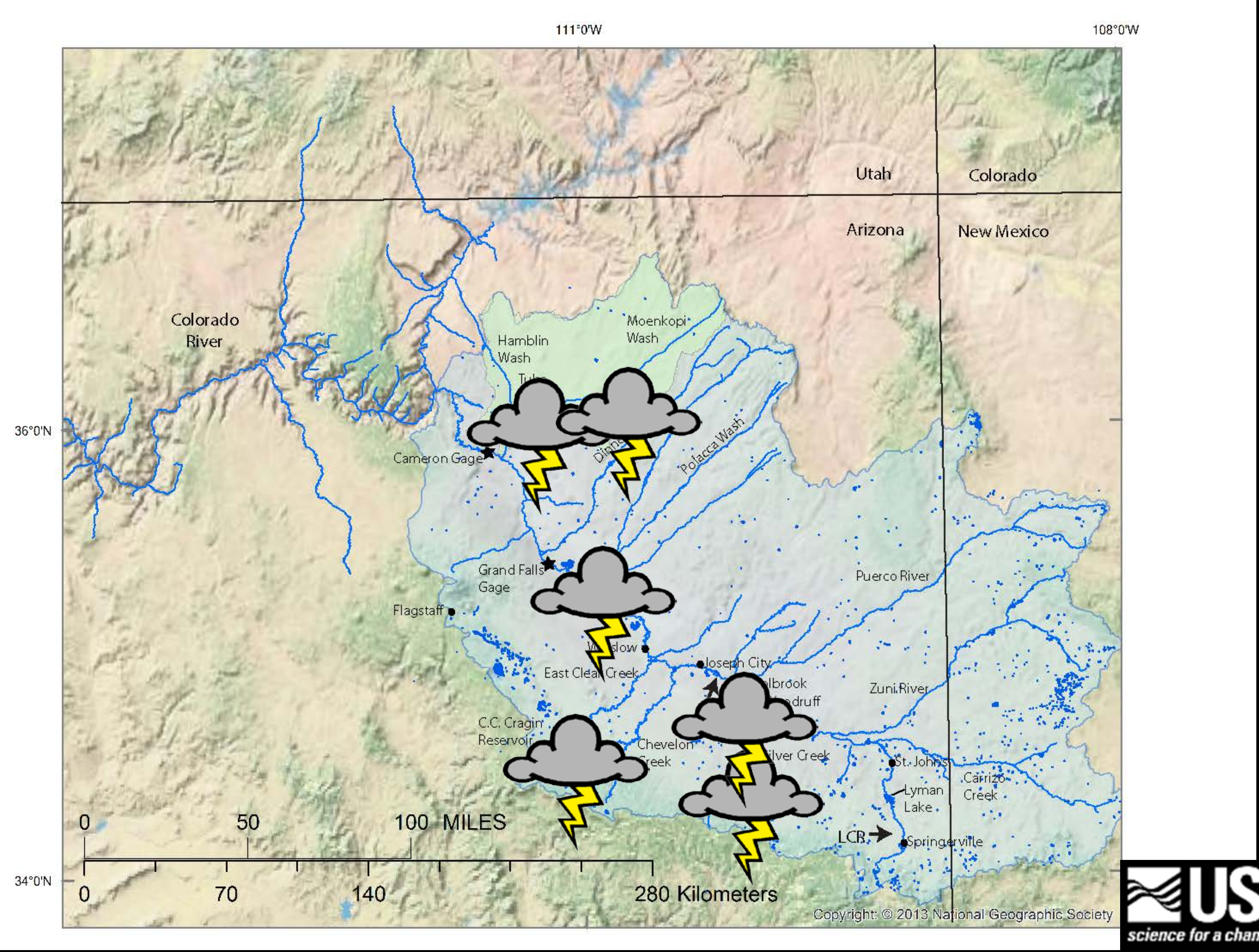
Hydrology – Summer/Fall



Hydrology – Summer/Fall

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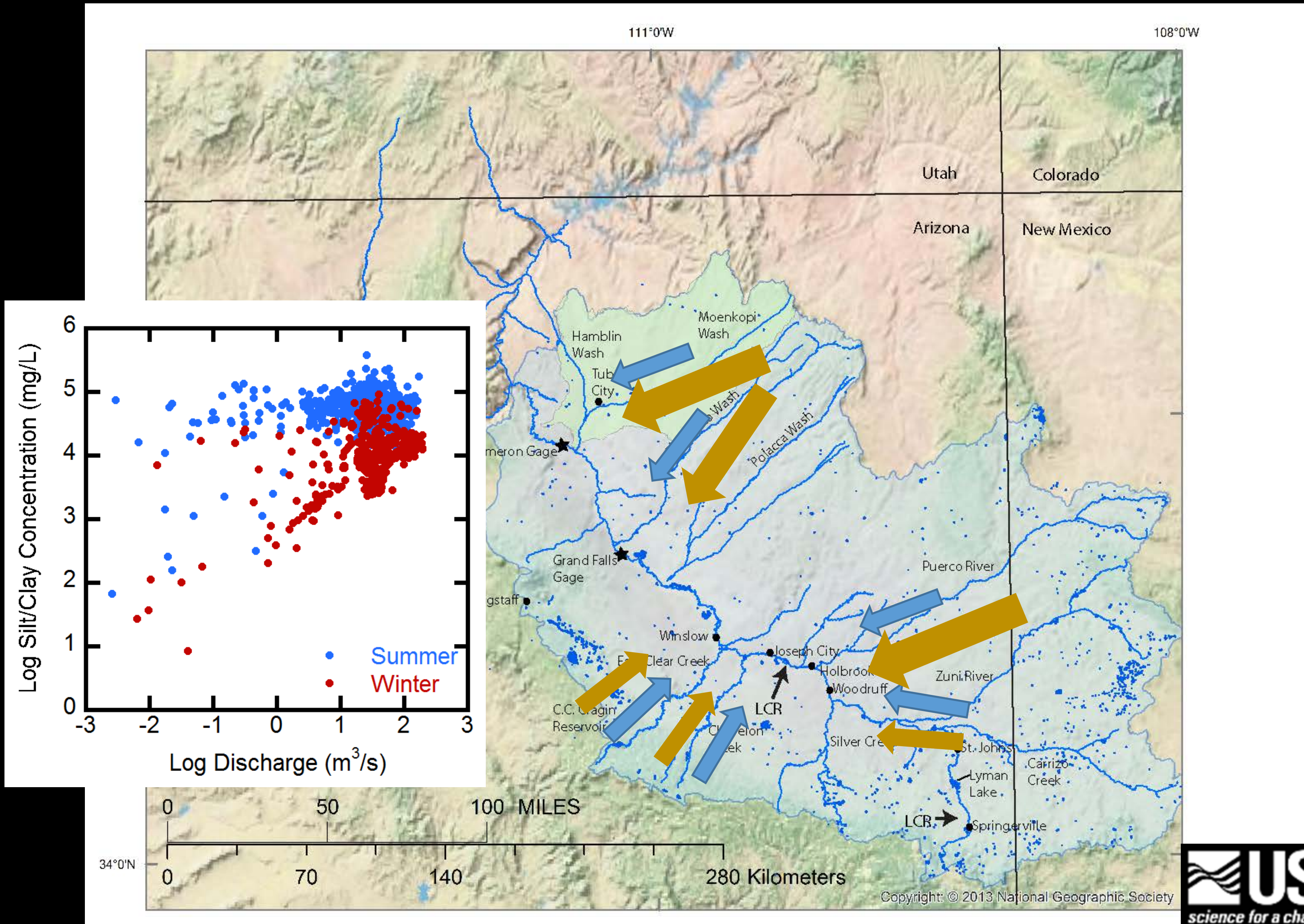

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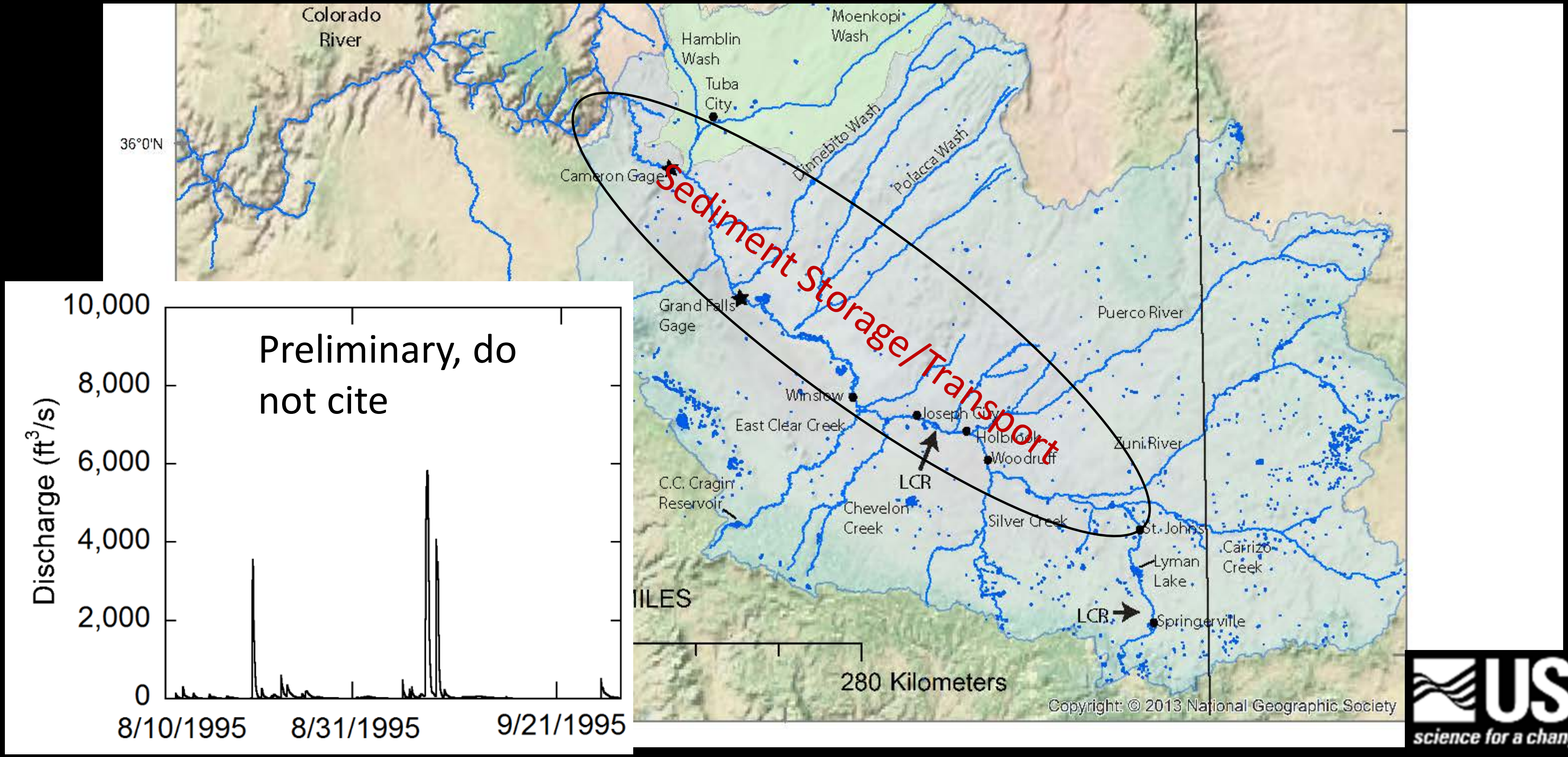
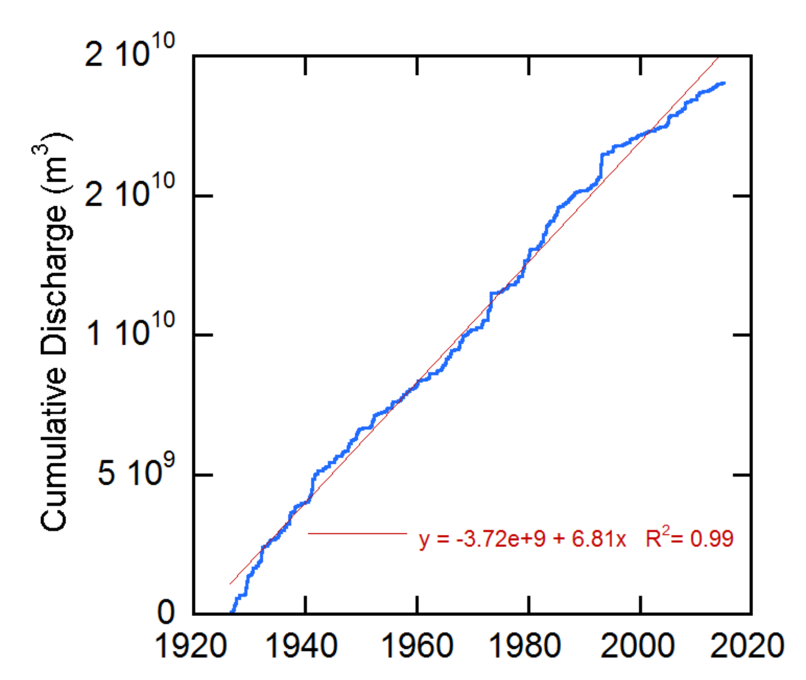
Hydrology – Summer/Fall

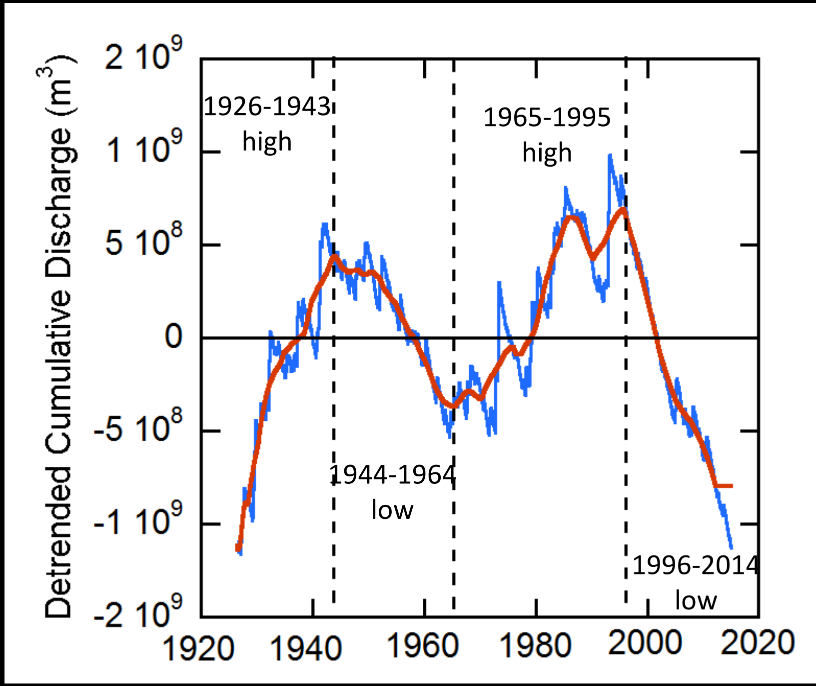
- Short-duration, high-intensity, summer/fall floods driven by convective thunderstorms
- Floods can be large, and sediment loads can be huge. Sediment can be deposited within/on LCR channel and floodplain, or delivered to the Colorado River.



Determining the Timing of Historical Hydrologic Changes

- We created a cumulative discharge curve of LCR stream flow data
- We fit a line to the data, and detrended the data to determine periods of high and low stream flow.





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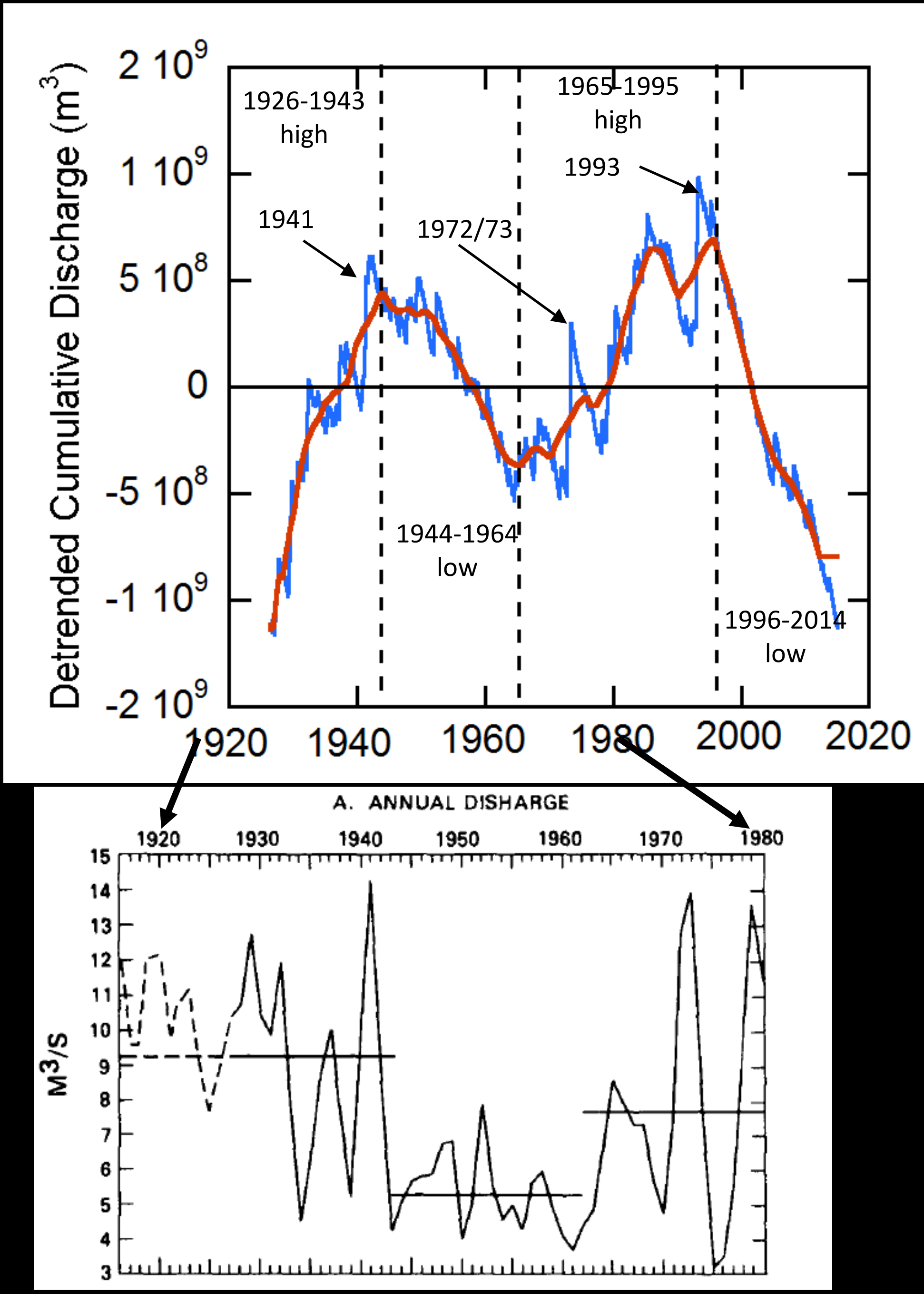
Determining the Timing of Historical Hydrologic Changes

- Our findings concerning timing of change are consistent with Hereford's (1984)
- The most recent low-flow period has had the lowest flow over the entire period of record.



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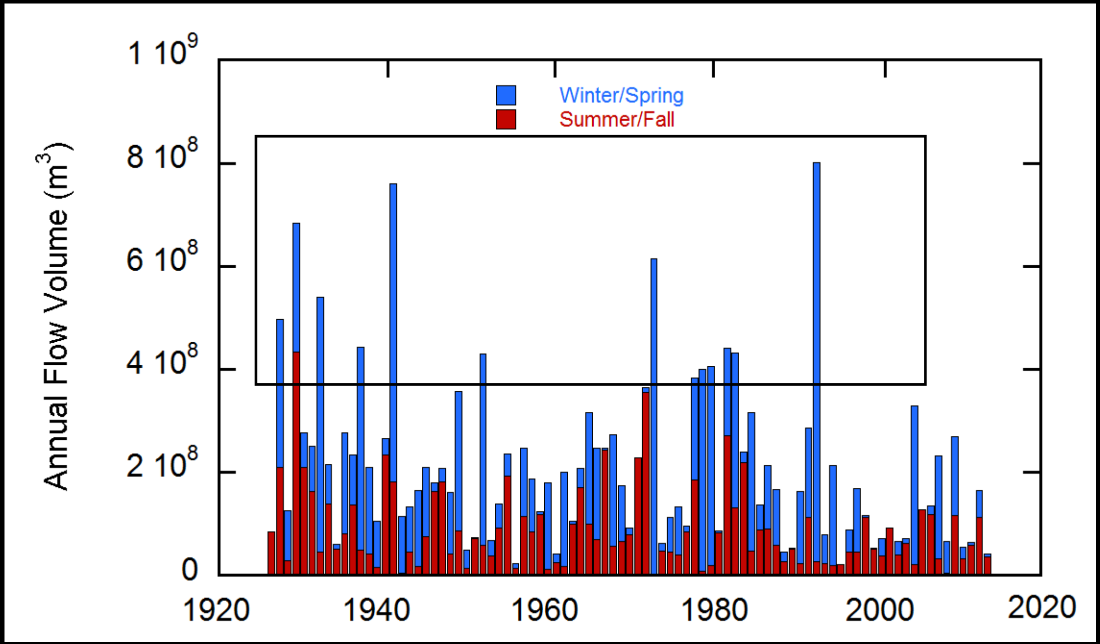
Temporal Changes in Annual Flow Volume



The years with the largest flow volumes are also years dominated by winter/spring flow

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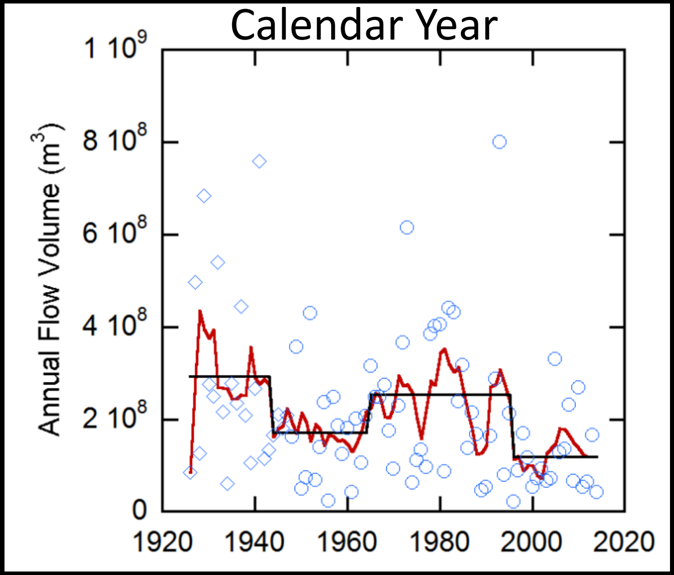
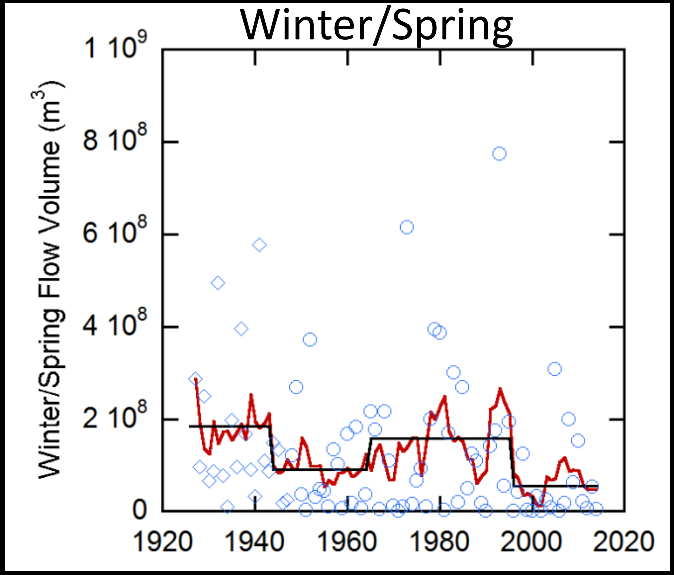
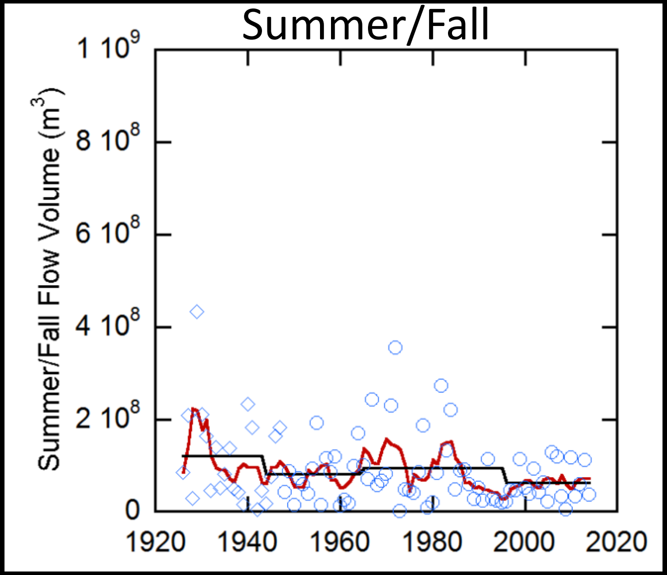
Temporal Changes in Annual Flow Volume





Winter/Spring flow volume mirrors trends in flow volume for calendar year

Summer/fall trends are similar, but much more muted than winter/spring



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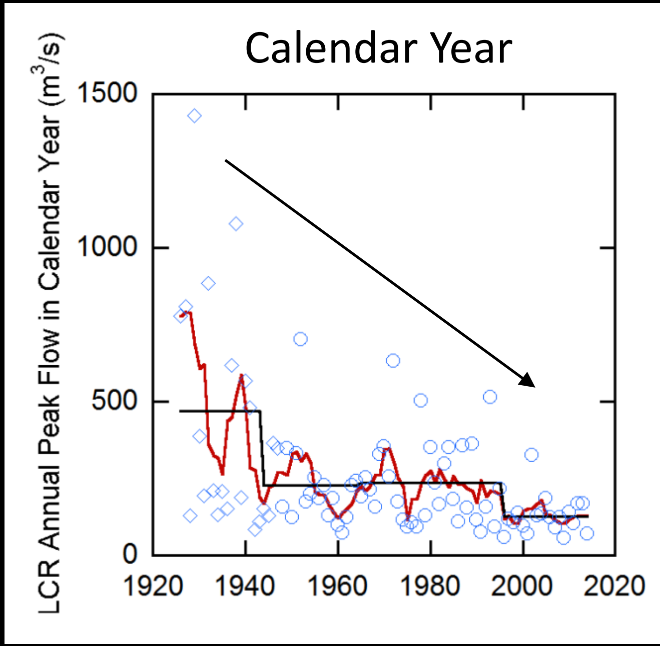
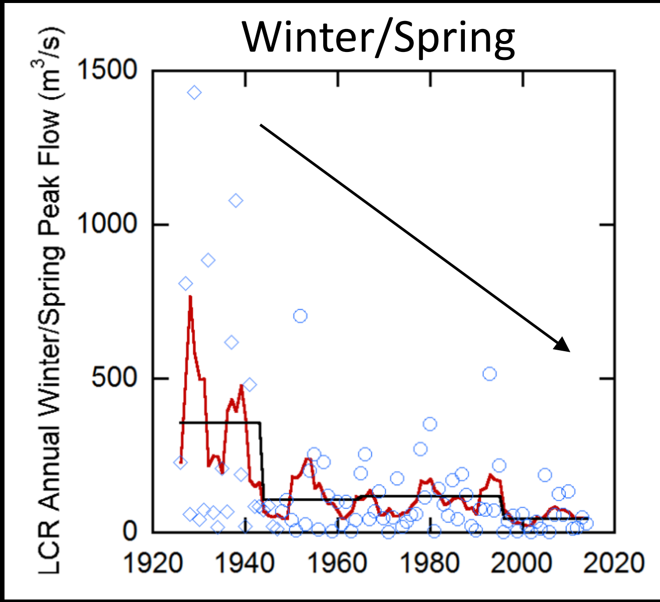
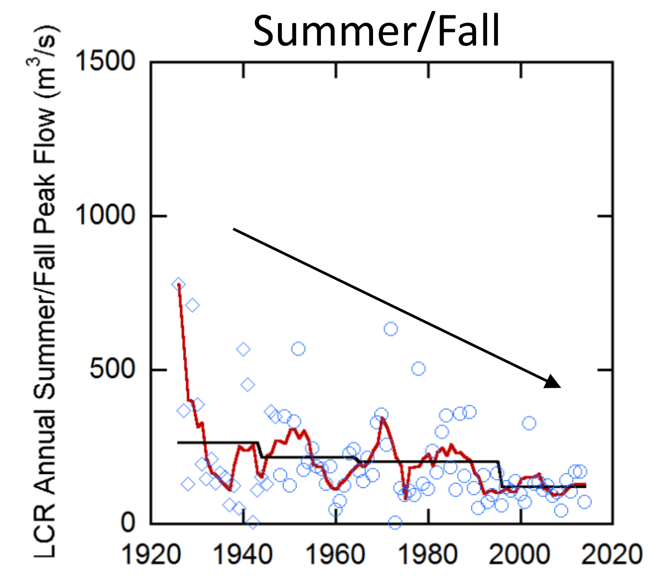
Temporal Changes in Peak Flow





Regardless of increases and decreases in total flow, peak flows have continuously declined over the period of record.



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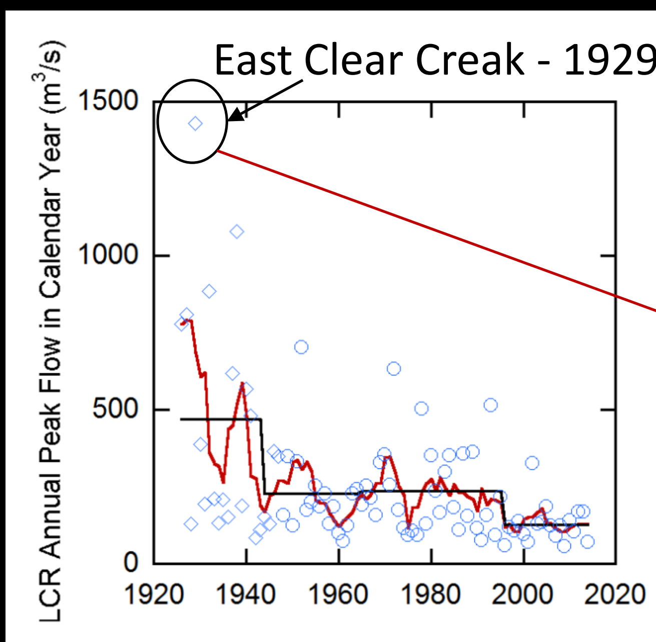
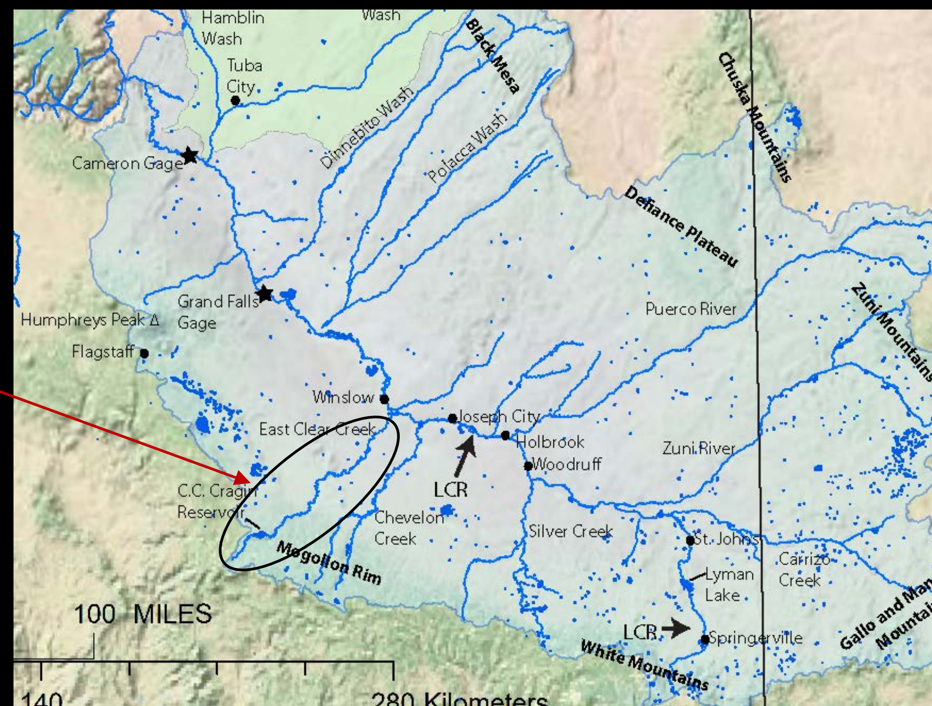
Reasons for Hydrologic Change

Why have peak flows declined even though total flow has not?

Hypothesis 1: Water development and reservoir construction/management have captured floodwater, and have contributed to reduction in flood magnitude





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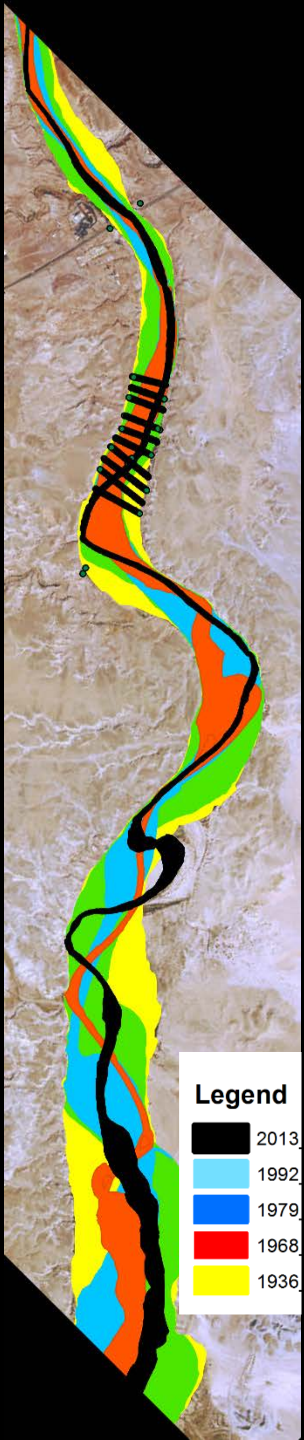
Reasons for Hydrologic Change

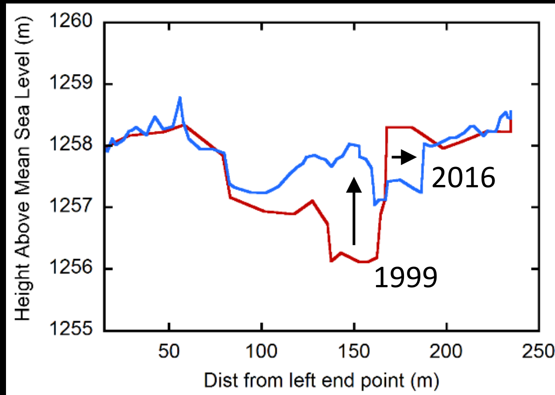
Why have peak flows declined even though there has not been a progressive decline in total flow?

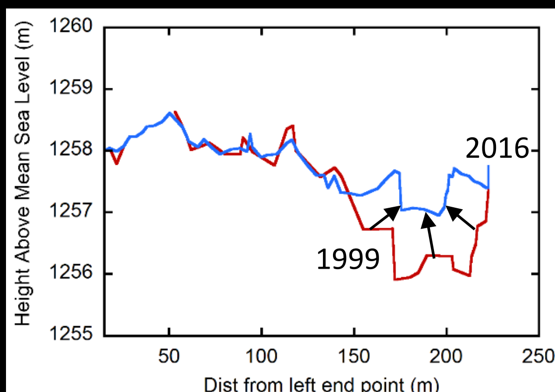
Hypothesis 2: Geomorphic change (channel narrowing, floodplain development) has affected floodwave propagation, and causes flood attenuation.

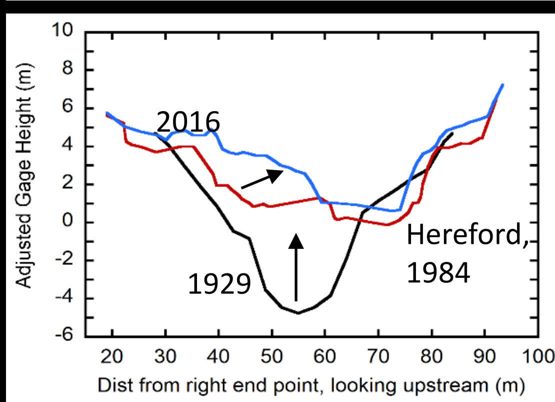
- Large floods inundate floodplains
- Floodplains vegetation provides drag which slows flow velocities and disrupts conveyance.

Continued Geomorphic Change and Changes in Sediment Transport









The channel continues to fill with sediment! Change is ongoing.

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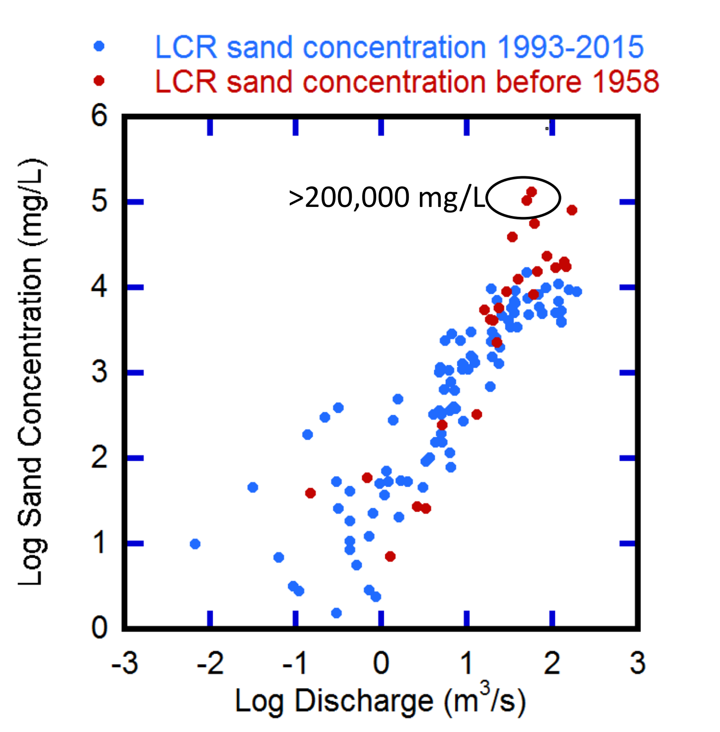

Sediment transport concentrations over last 23 years have only been ¼ of historic measurements. Partly controlled by Moenkopi Wash.

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Conclusions

- Fluctuations in total flow have occurred
- Peak flows have progressively declined, mostly in winter/spring.
- Declines in peak flow = sediment accumulation within LCR channel
- Peak flow declines driven by: 1) human water use and development, 2) geomorphic changes of the river.

Next Steps

- Manuscript on hydrologic change (LCR and Moenkopi Wash) – to be submitted within a month
- Analyses of geomorphic changes (LCR and Moenkopi Wash) to be submitted by the end of year.
- Future manuscript linking hydrology/geomorphic change with sediment transport modeling = determine historic changes to sediment contributed to Colorado River. Implications for endangered fish habitat.

Questions.