Using cottonwoods to reconstruct river flows and assess the condition of modern riparian ecosystems

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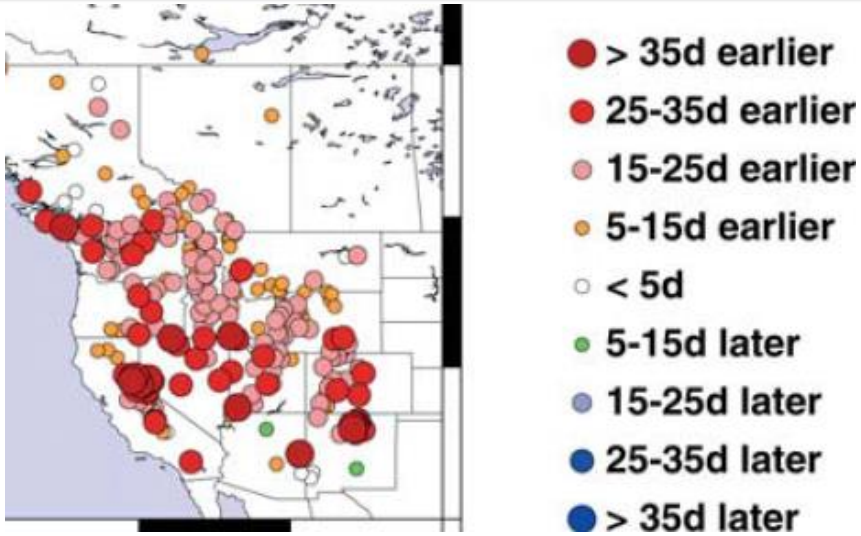
The Setting: western rivers

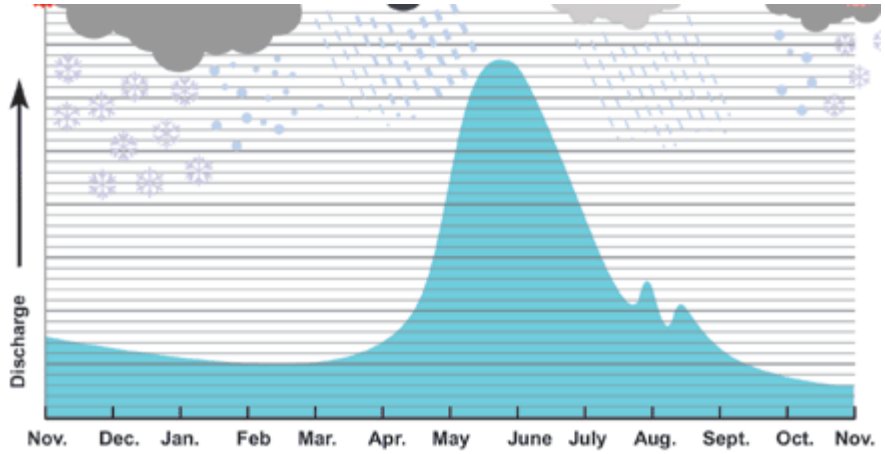
- Ecosystems dependent on dynamic flows
- Valuable: Structural and biological diversity
- Water supply
- Floodplain development
- Shifts in river flow
  - Direct
  - Climate change
- Vulnerable

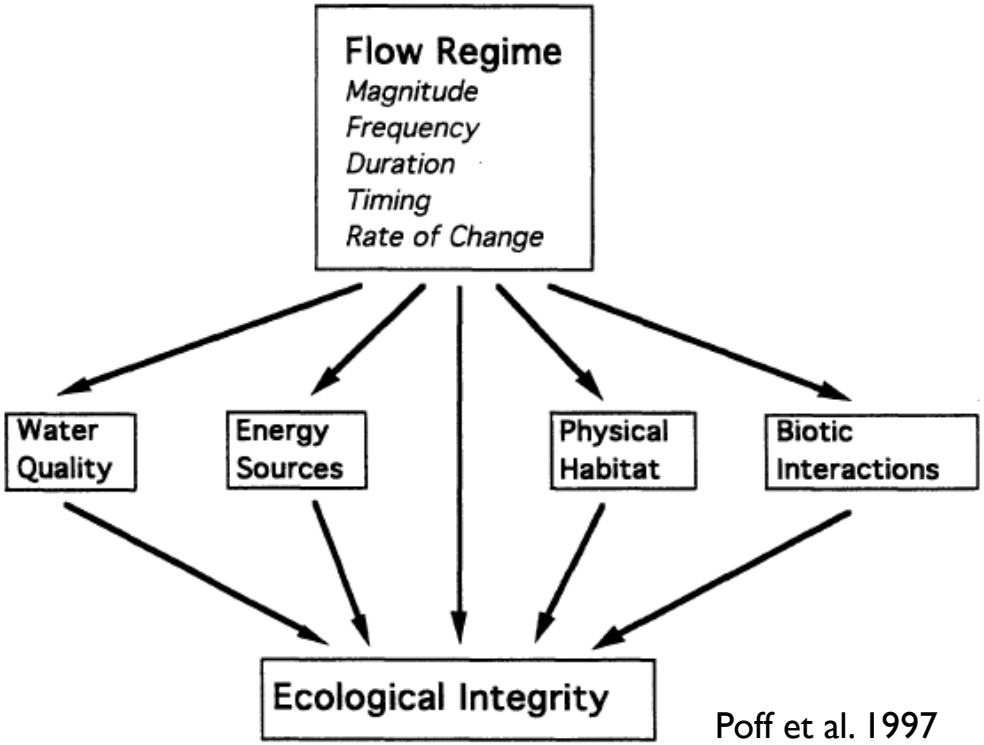


2080-2099 Predictions
(Stewart et al. 2004)

Flow Regimes

- Natural Flow Regime (Poff et al. 1997)
- Natural Sediment Regime (Wohl et al. 2015)





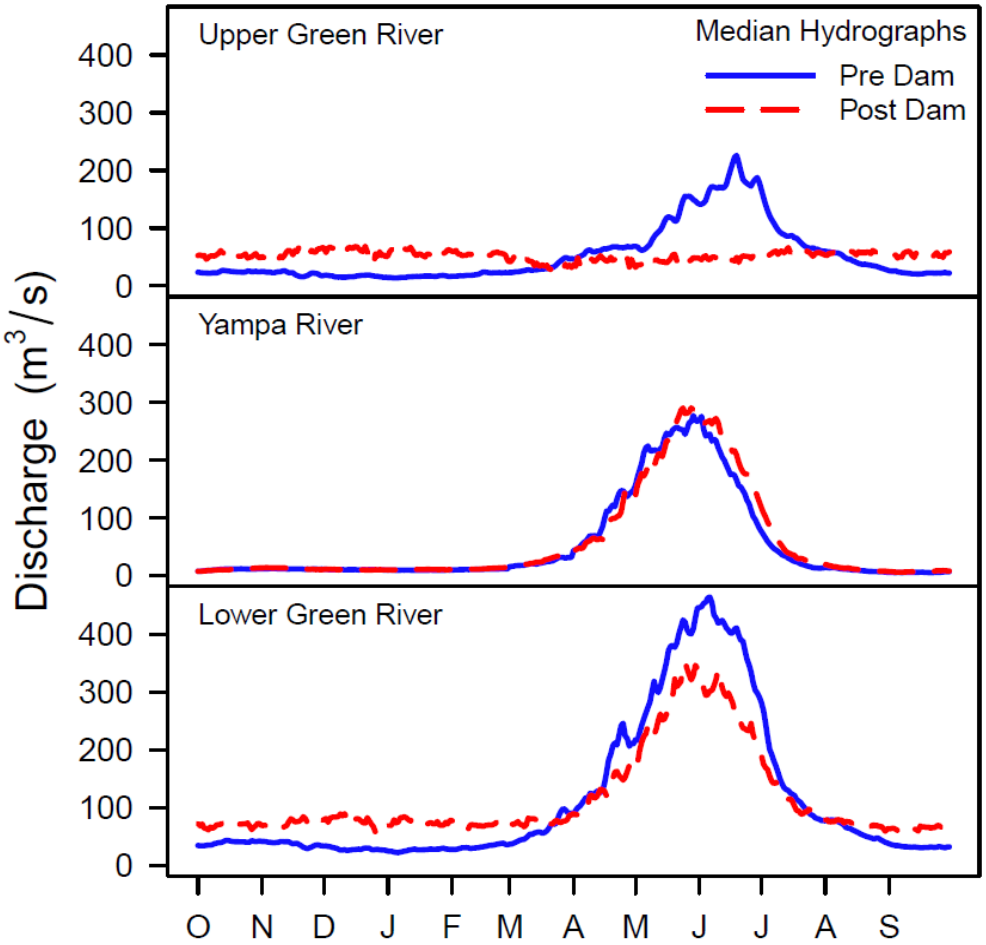
Poff et al. 1997

Geomorphic processes

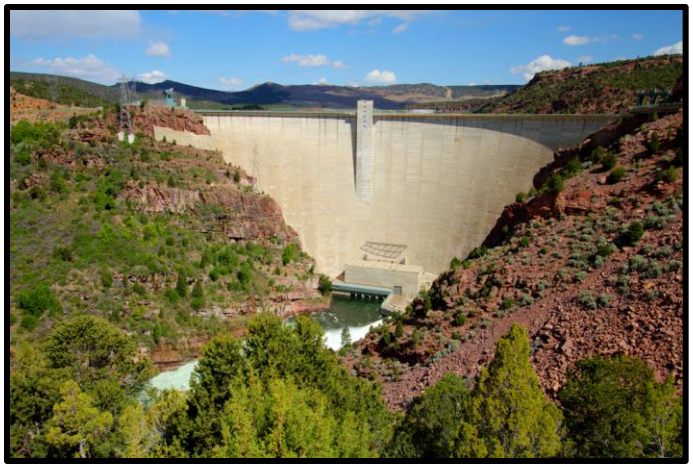
- Shaped by flow regime and properties
- Sediment processes
  - Sediment transport
  - Bank erosion
- Channel migration
  - Habitat destruction and creation
  - Habitat mosaics

Geomorphic processes: channel migration

Flow Regulation:
example hydrographs from the Green River



Schook, Carlson, Sholtes, and Cooper, *in review*



Floodplain Ecosystems: evolution after river regulation

time

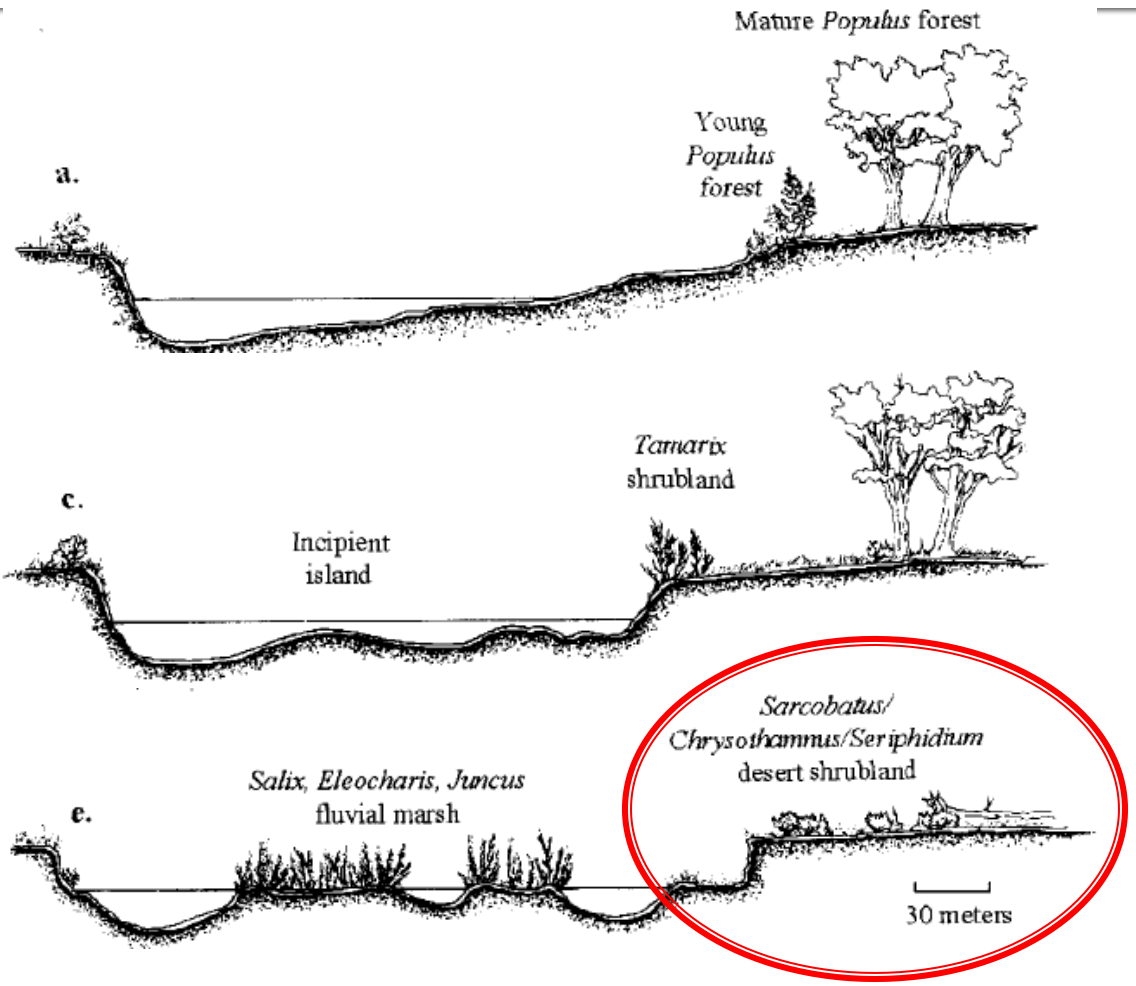
Forms and Processes

Dynamic channel, mosaic of riparian species and habitats

Dam

Banks stabilize, *Populus* forests age

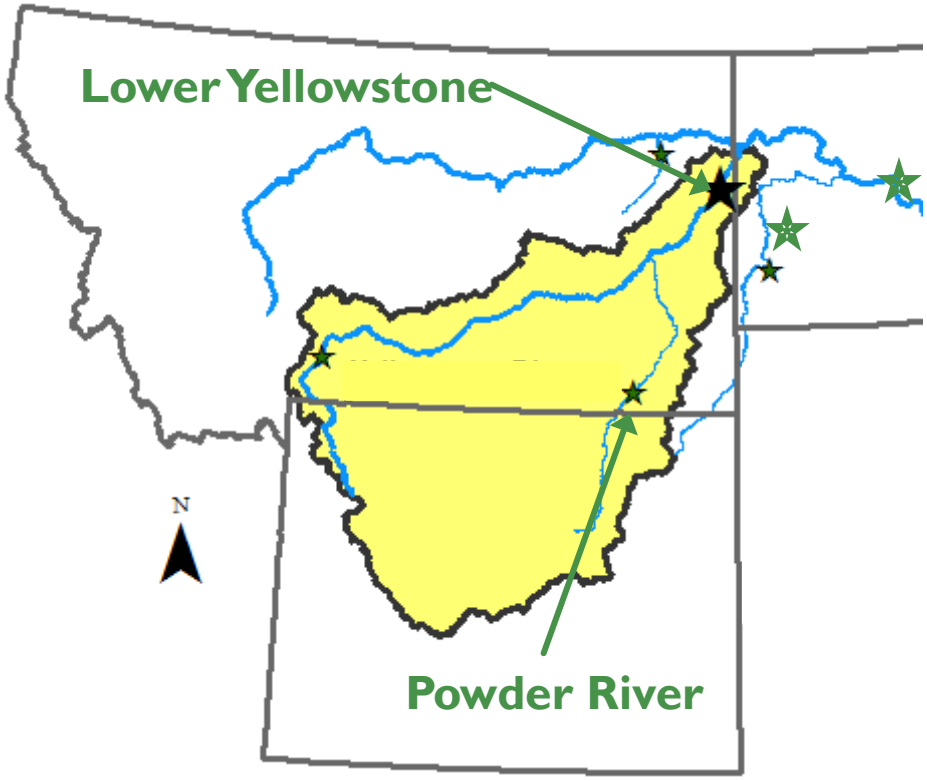
Channel form changes, xerification and community shift in floodplain



Merritt and Cooper 2000

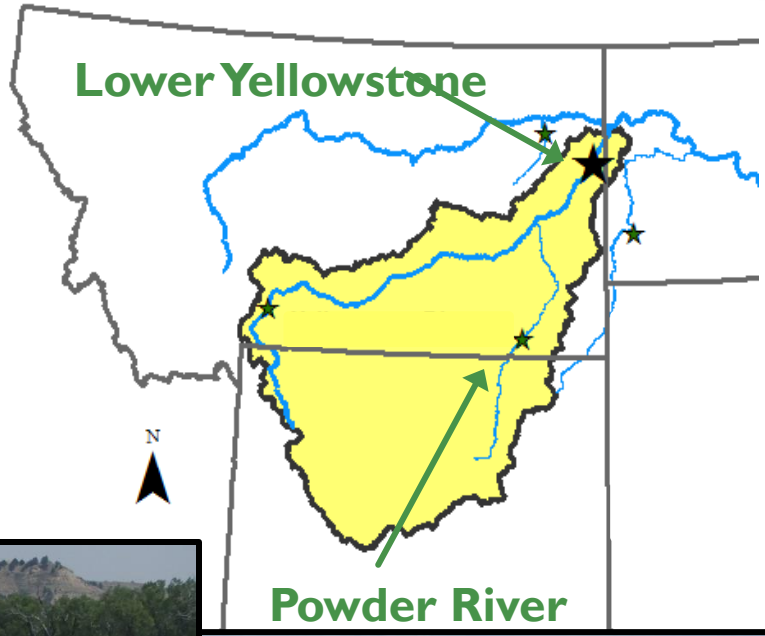
Project scope

- Flow characterization
  - Flow reconstruction
- Channel migration and floodplain turnover
- Regional controls on cottonwood growth
- Future of riparian ecosystems
  - Cottonwood regeneration



Yellowstone and Powder Rivers

- Yellowstone River:
  - 1100 km
  - MAF: 14,000 cfs (400 cms)
- Powder River
  - 600 km
  - MAF: 560 cfs (16 cms)
- **"Natural" flow regimes**



Cottonwood ecology

- Abundant riparian tree
- Establishment and maturation requirements:
  - 1. Abundant moisture
  - 2. Abundant light
  - 3. Safety from future disturbance

Cottonwood ecology

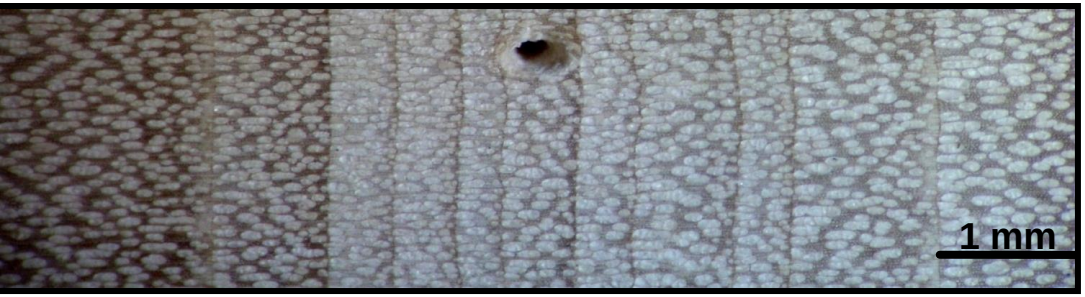
Establishment and survival are both controlled by flow.

Therefore:

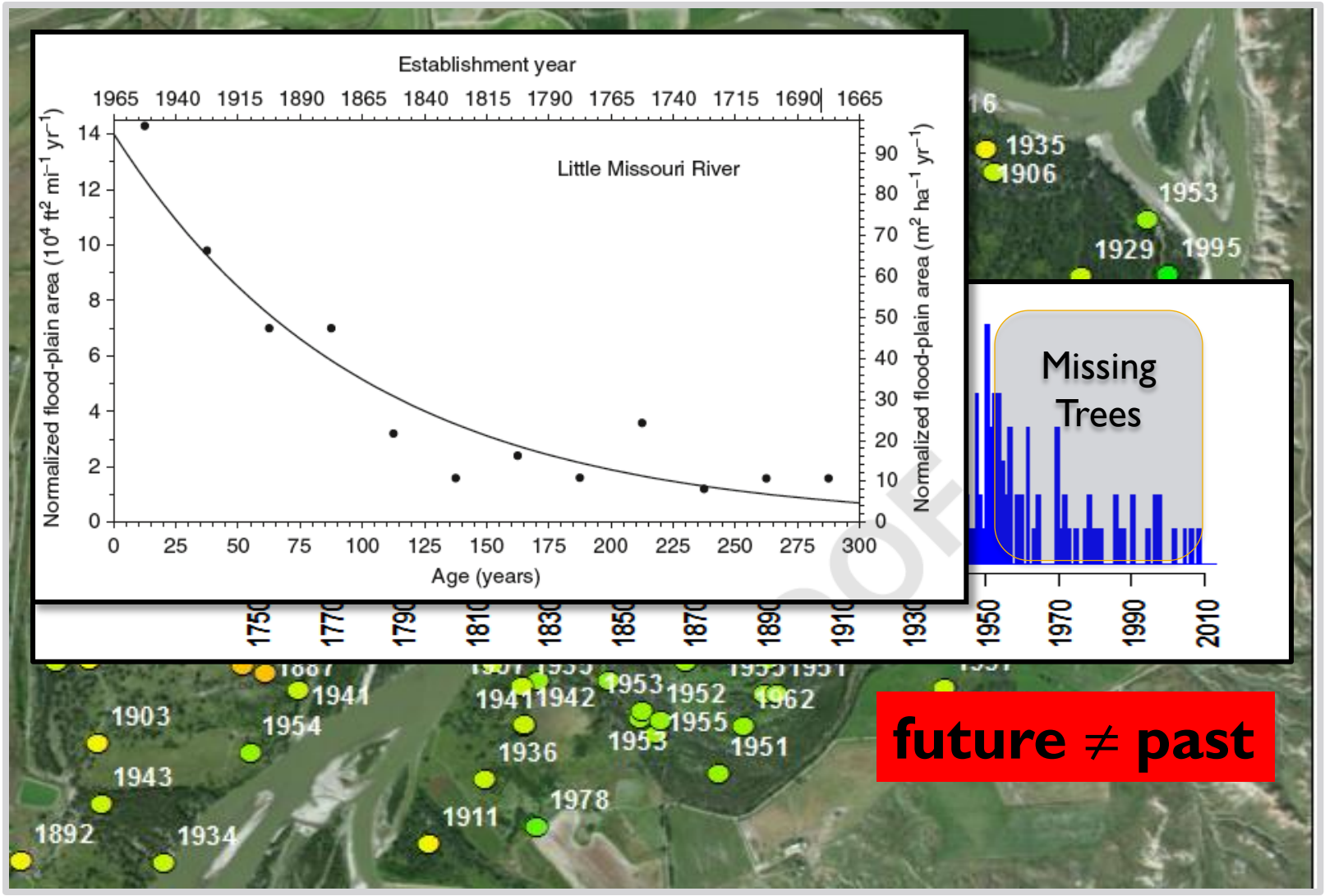
1. Tree ages indicate fluvial processes
2. Annual growth provides a record of past flow

Methods and data

- Dendrochronology
- 240 trees (480 cores) sampled from each:
  - Lower Yellowstone: (Method 1)
  - Powder River (Method 2)
- Measure ring width
- Age trees
- Create models and reconstruct flow

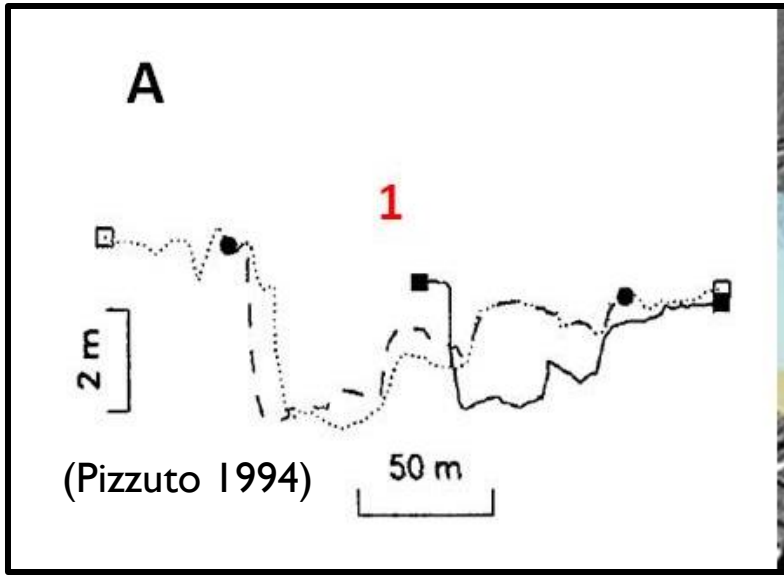


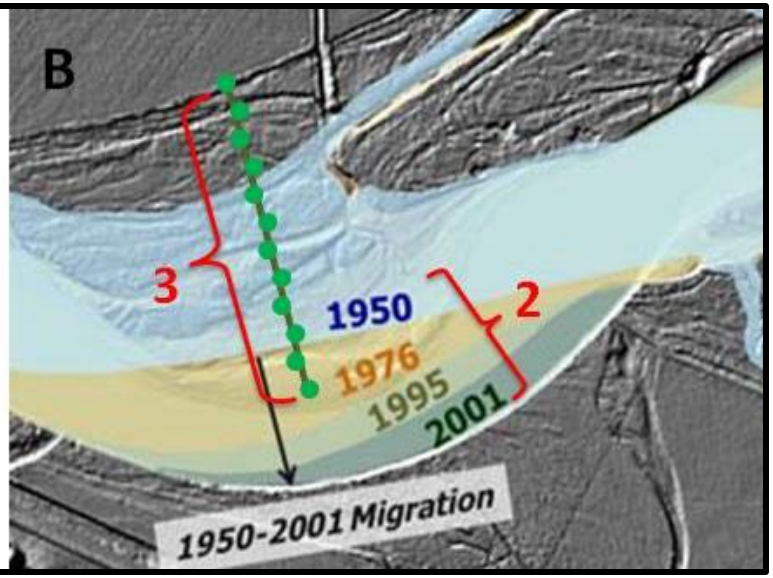
Channel Migration/Cottonwood age distribution: Lower Yellowstone River



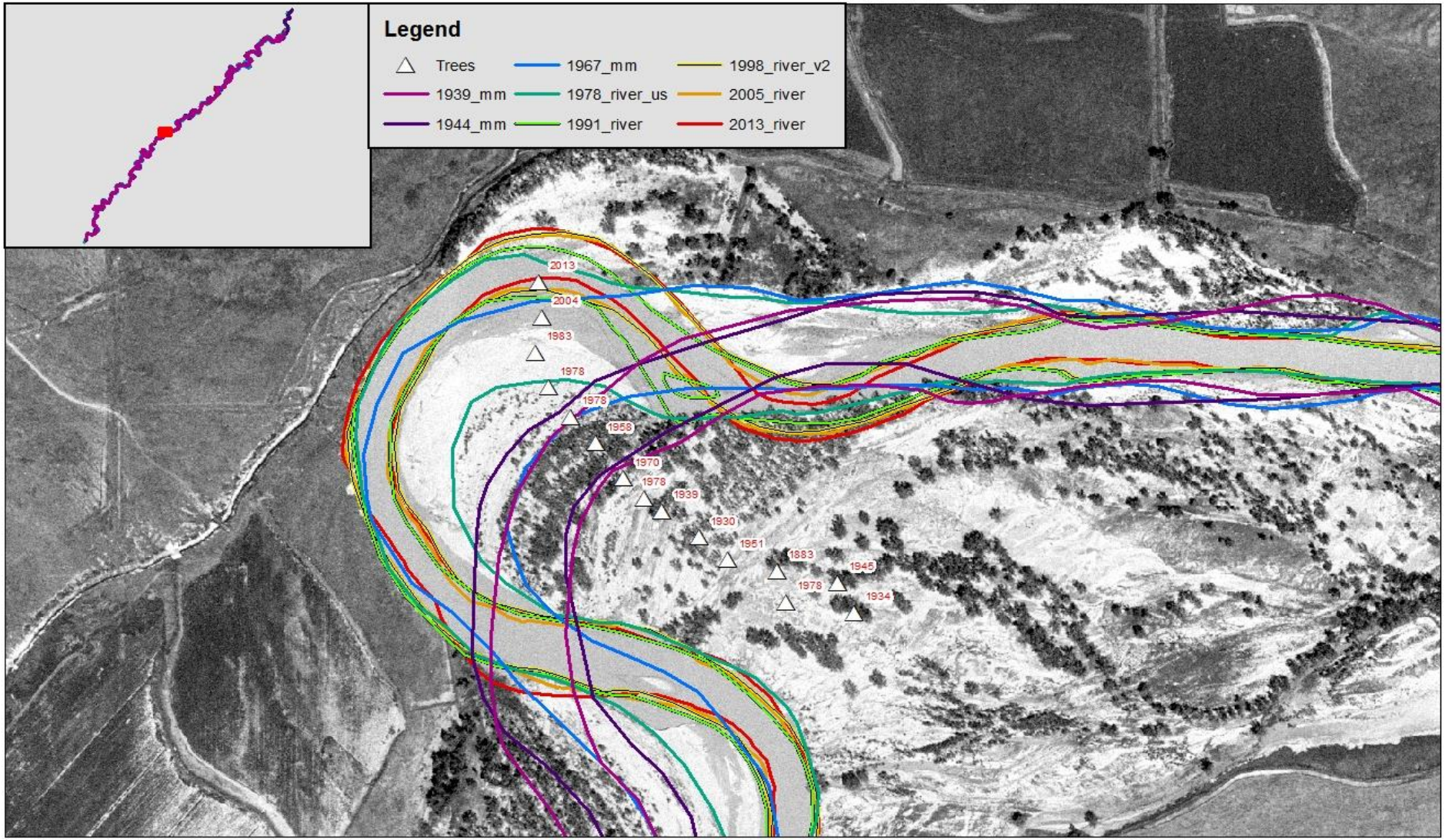
Channel Migration: integrating methods on the Powder River

- Research began in 1975 (Meade and Moody)
- Combine:
  - 1) Topographic cross-sections
  - 2) Air photos
  - 3) Cottonwood transects

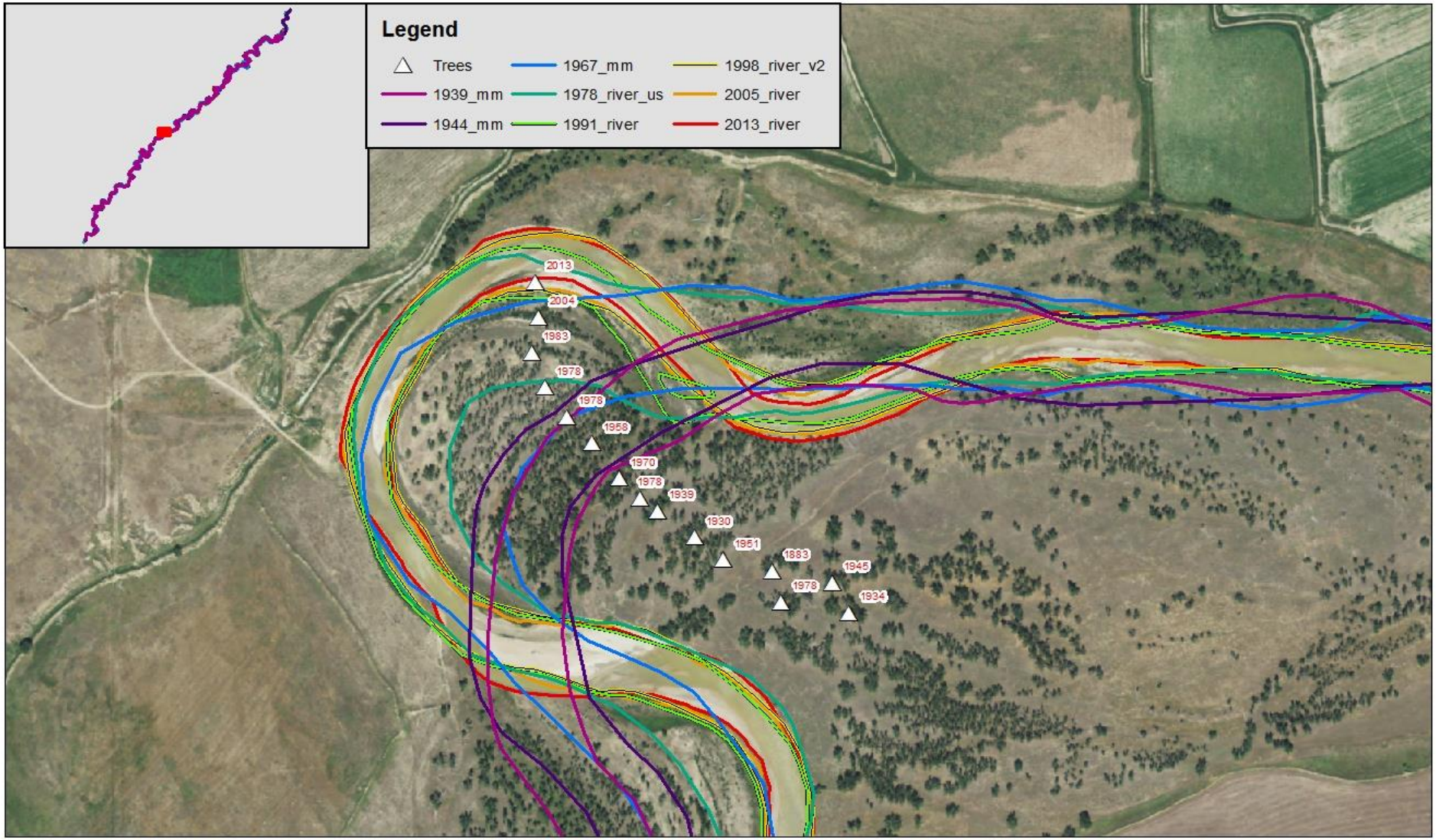




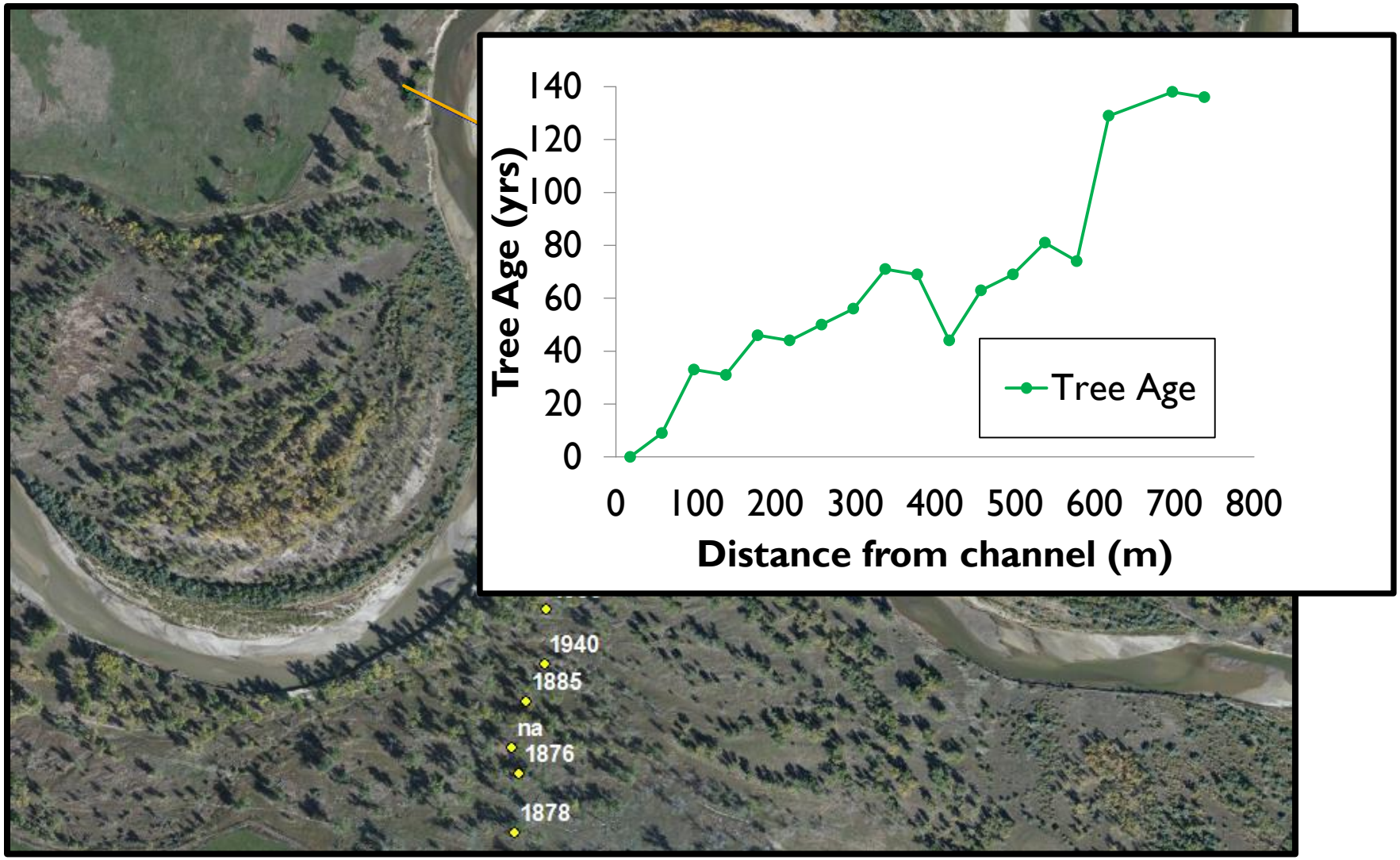
Channel Migration: air photo interpretation



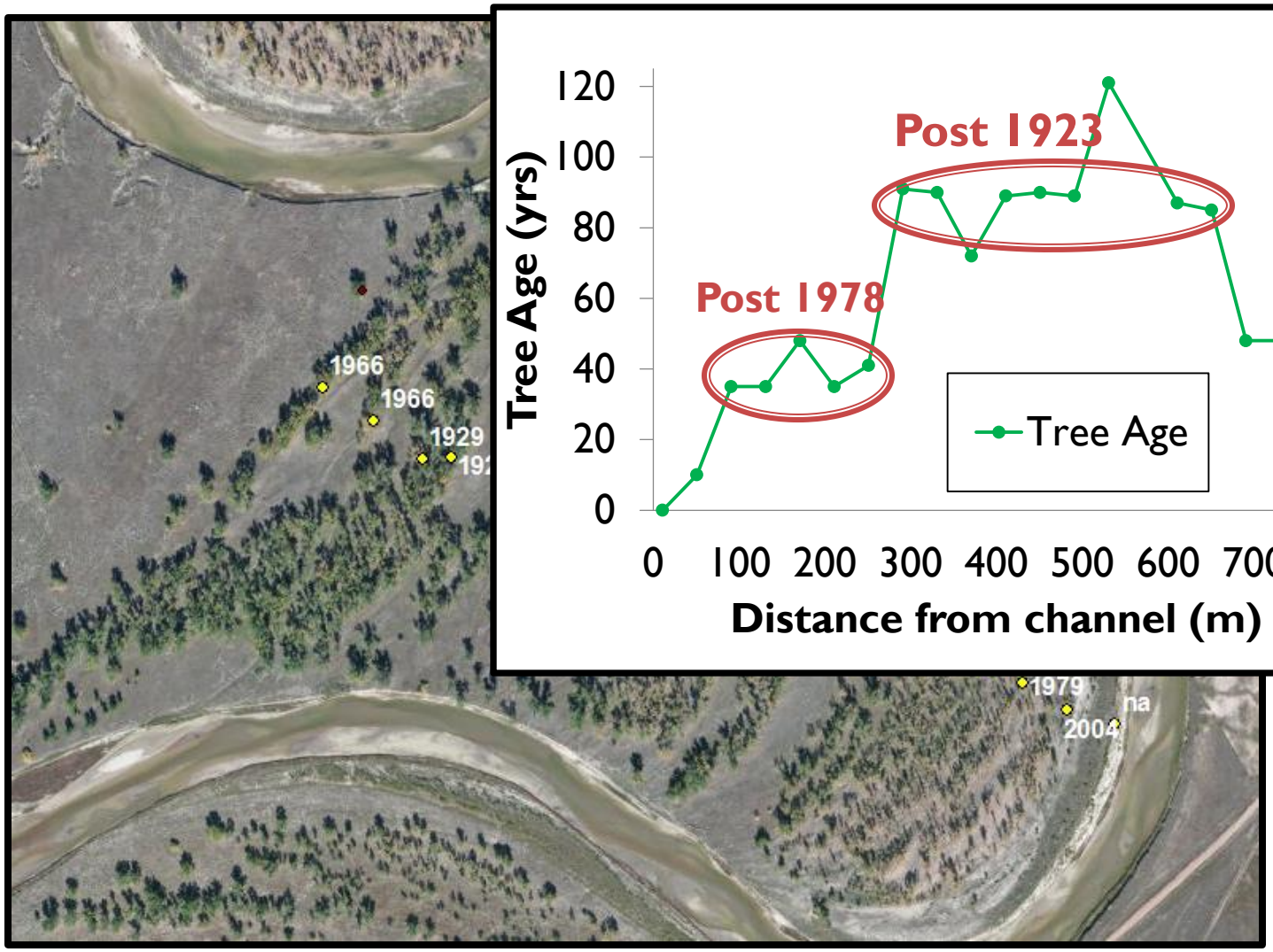
Channel Migration: air photo interpretation



Channel Migration: Powder River

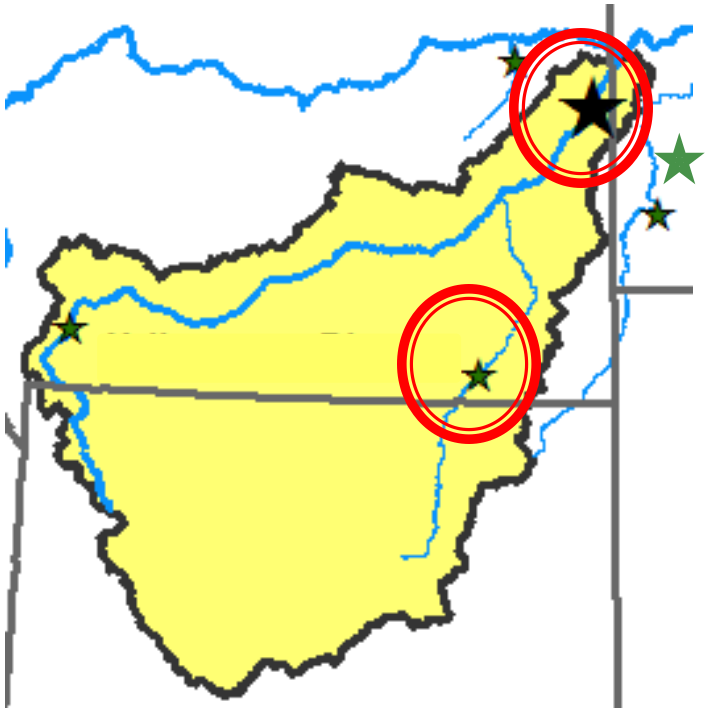


Channel Migration: Powder River



Flow Reconstructions

- How have flows varied for hundreds of years?

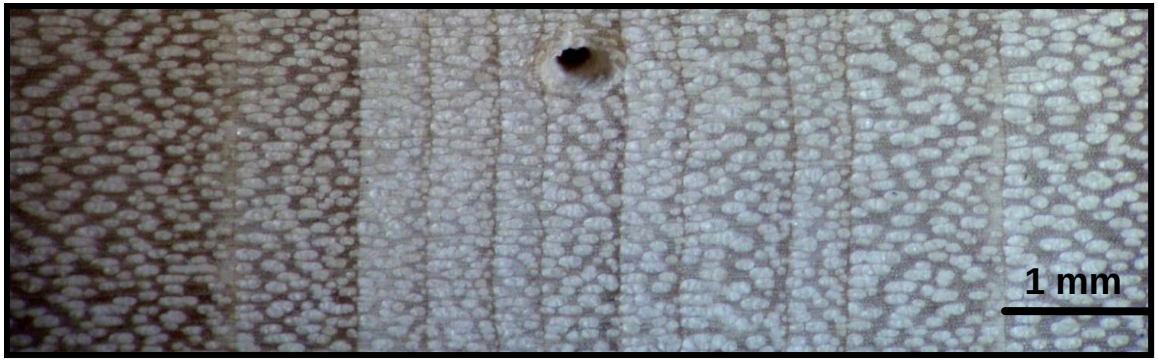


Yellowstone River
near Sidney, MT

Powder River
at Moorhead, MT

Flow Reconstruction: cottonwoods

- Cottonwoods provide special opportunities
  - They feel *actual* flows
  - Forests contain trees of many ages



Flow Reconstruction: old cottonwoods

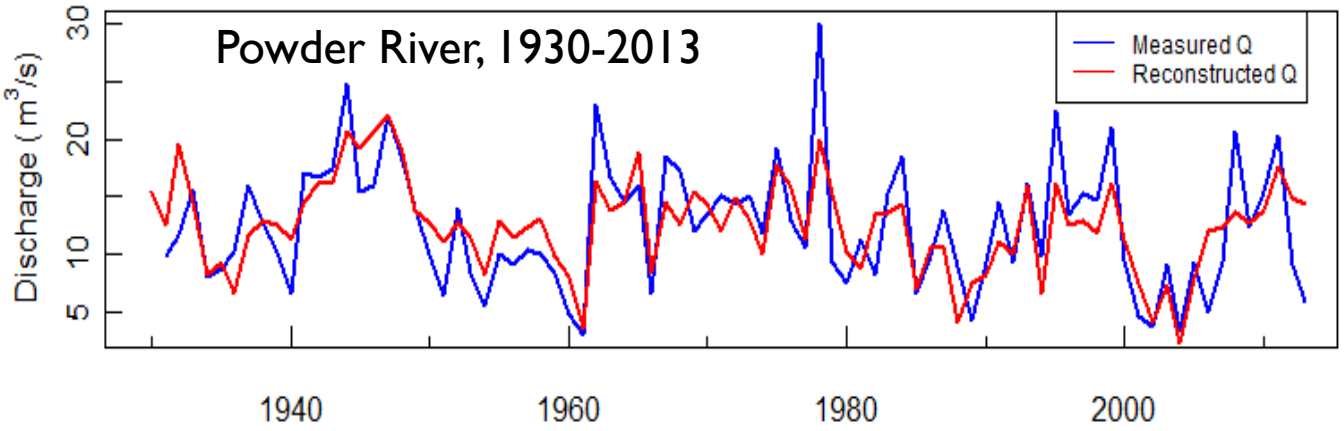
1744

1766

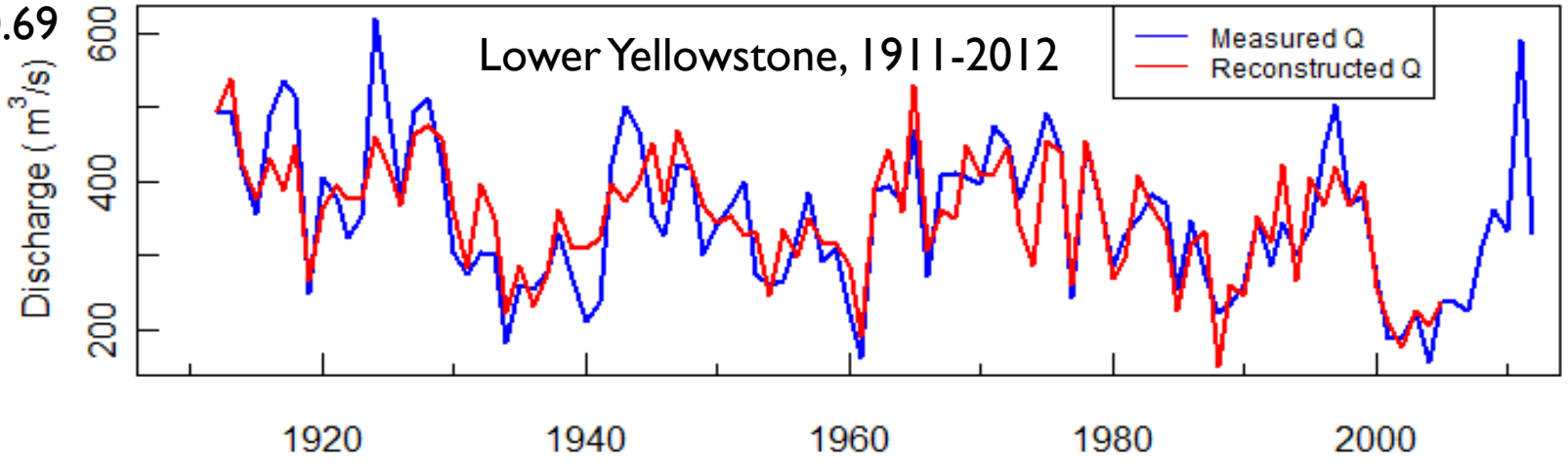
1749

Flow Reconstruction: period of overlap

$R^2 = 0.60$



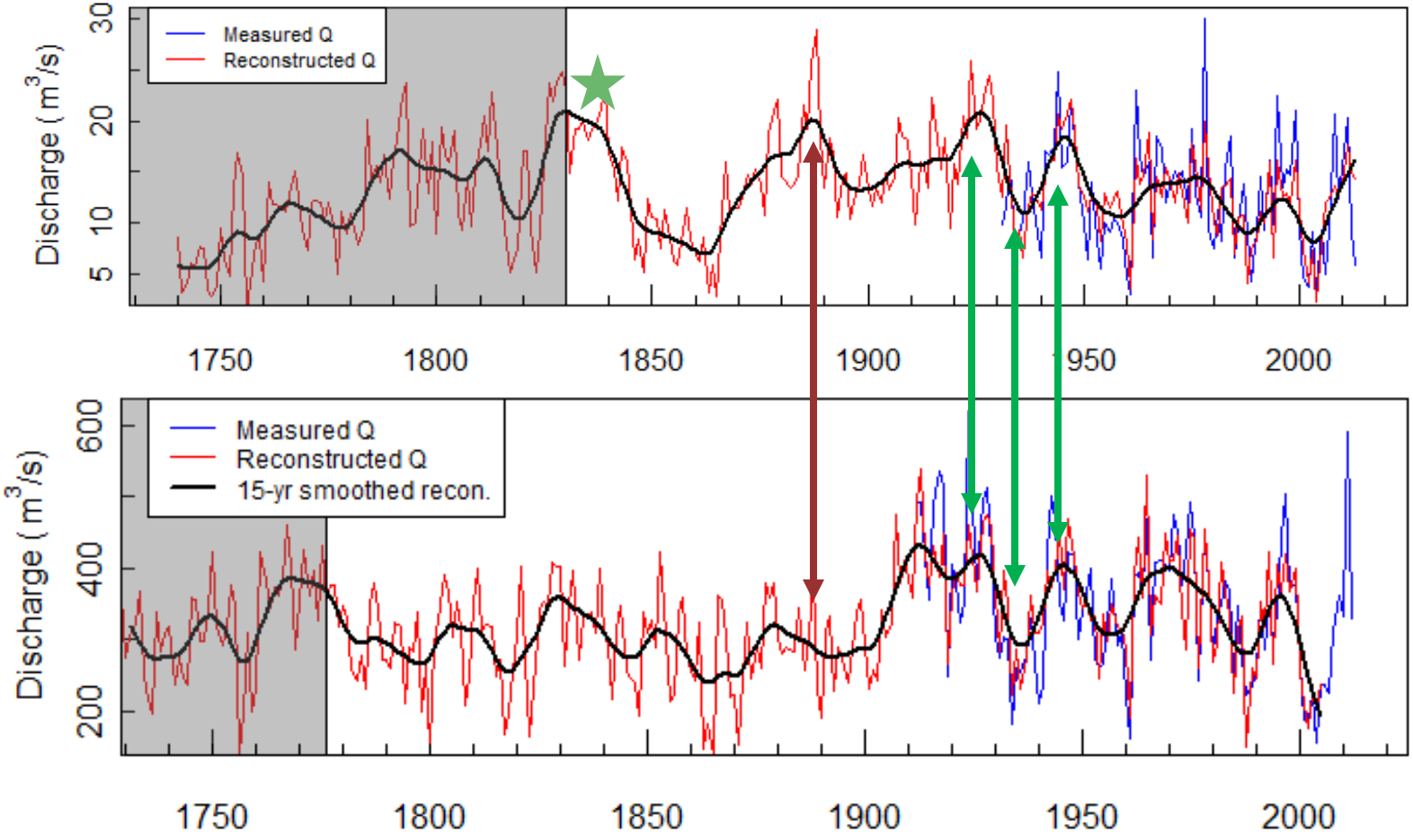
$R^2 = 0.69$



Flow Reconstruction: extending the record

Powder River

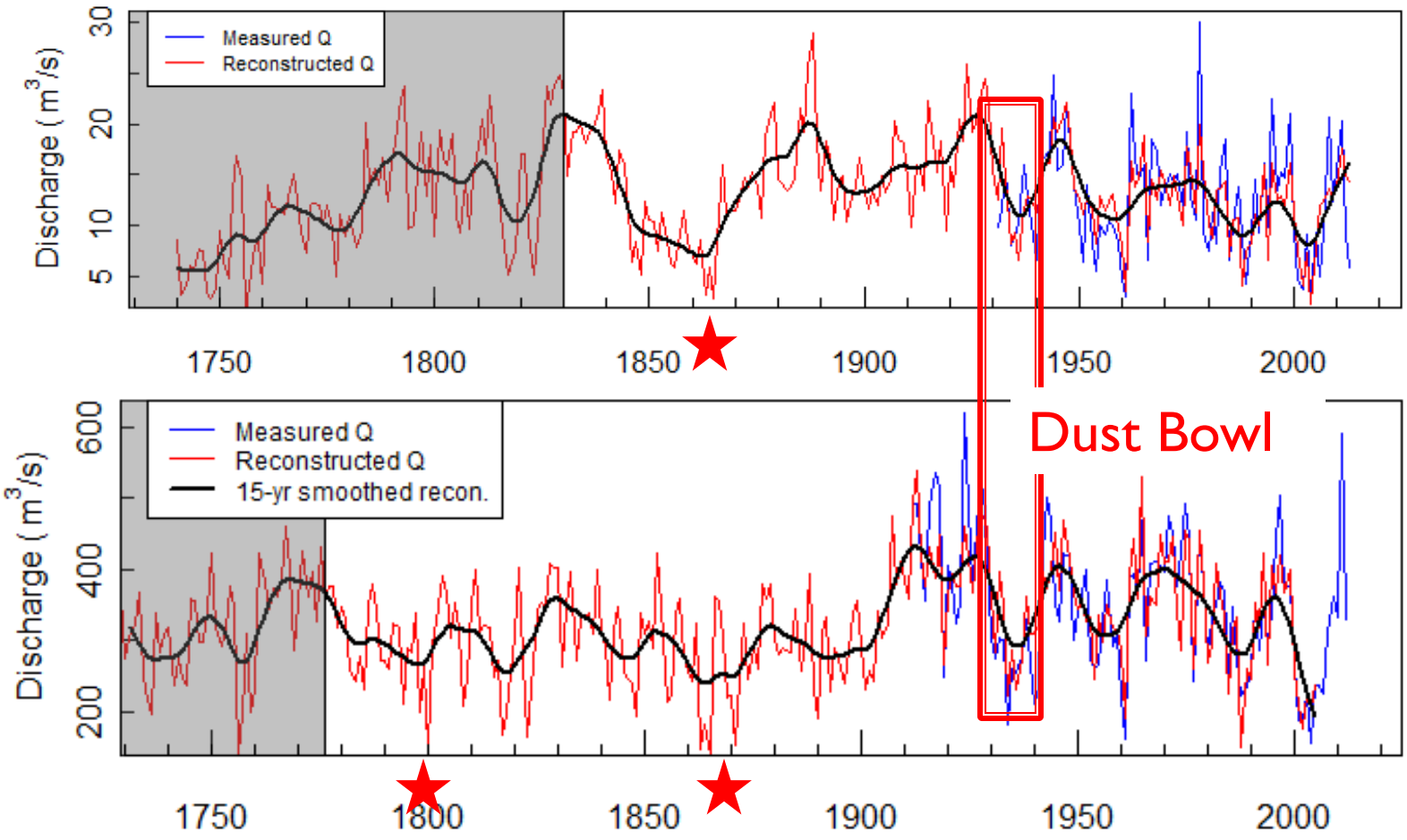
Lower Yellowstone



Flow Reconstruction: extending the record

Powder River

Lower Yellowstone



Floodplain management: process-based restoration

- Re-establish processes that maintain and create habitat
  - Fluxes of water, sediment, wood, energy, nutrients, organic matter.
    - In space and time
  - Channel migration and dynamics, disturbance regime.
- This is difficult!
  - Good science must be conducted
  - Identifying processes and patterns: past, present, and future

Summary

- Cottonwood age distribution informs us of:
  - Physical processes
  - Future floodplain composition
- Cottonwood dendrochronology provides new insights
- Channel migration rates have declined on two "natural rivers"

Big Picture

- We are affecting all western rivers
- Ecosystems transition when channel migration is lost
- Trees preserve history
- Reconstructions better indicate range of variation and extremes
- Watershed perspectives and process-based management will promote success in the long haul

Acknowledgements

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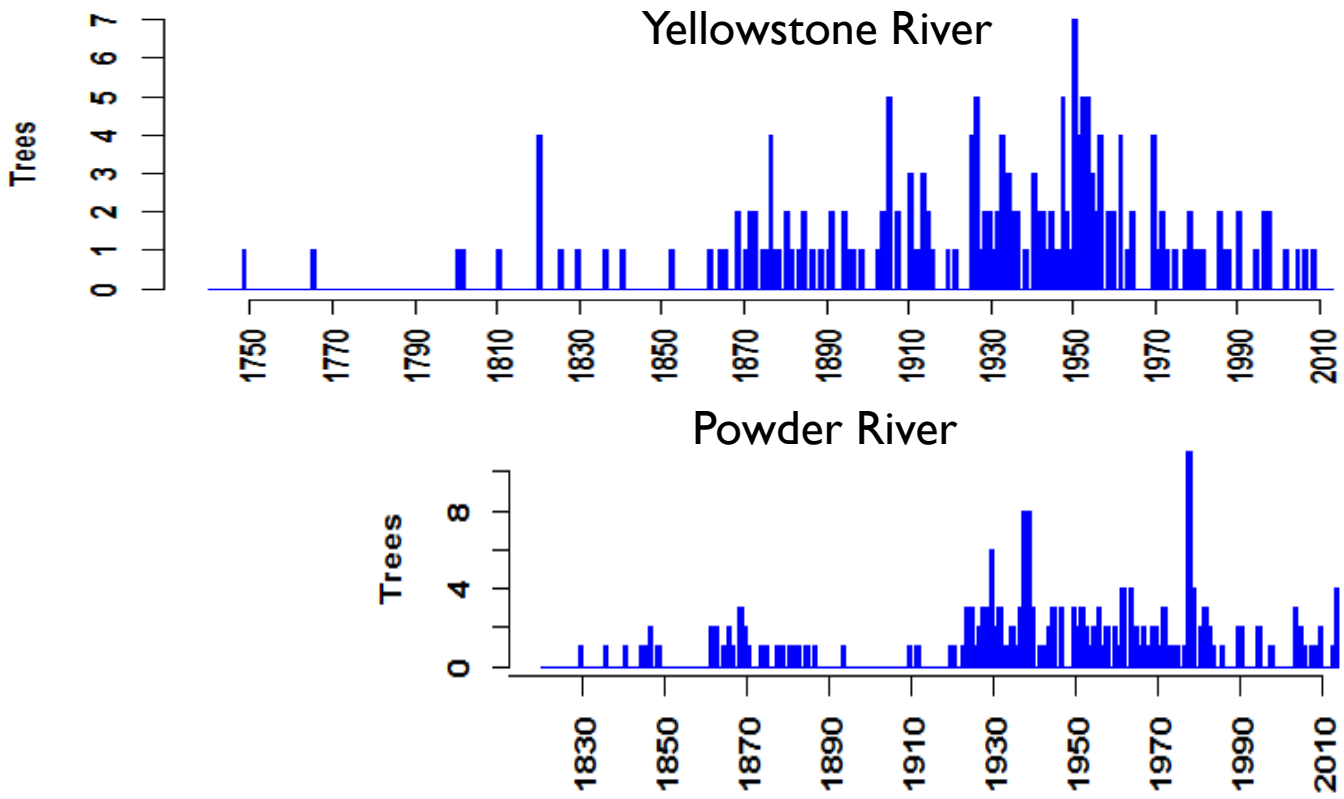
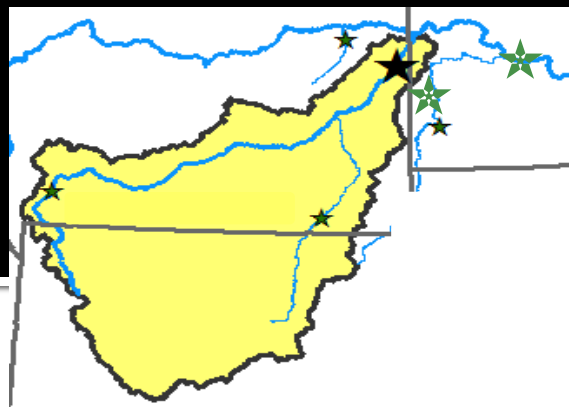
Cottonwood age distributions



Age distribution tells about:

1. Regeneration
2. Discharge
3. Water management
4. Future conditions

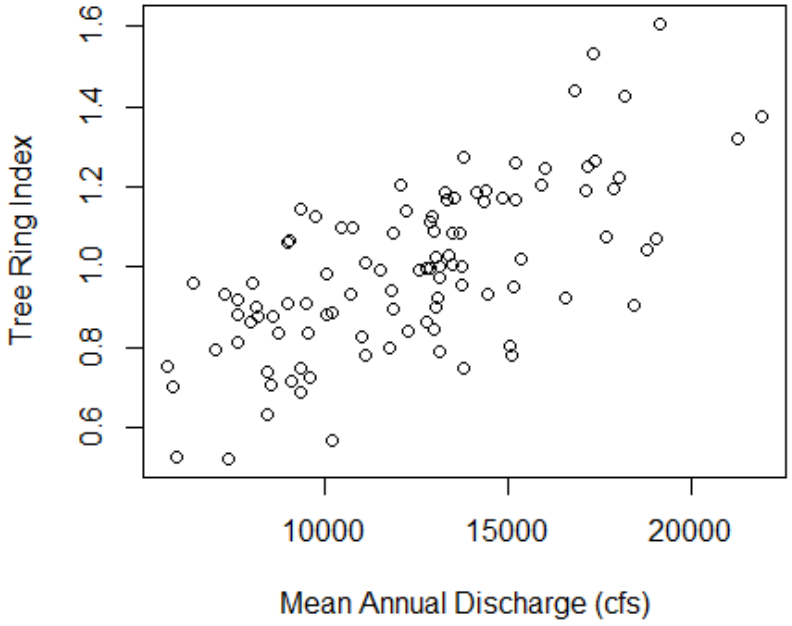
Dendro sample data



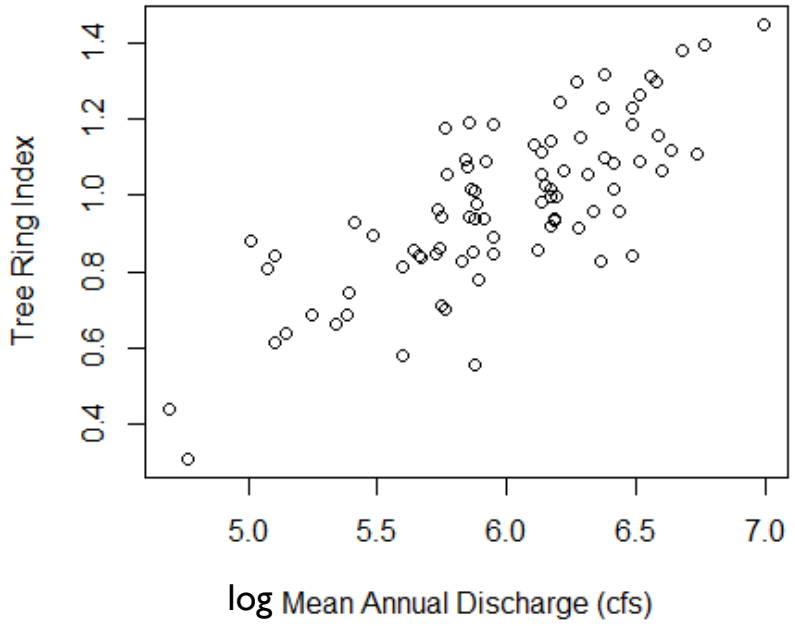
Site	Location	Species	N Trees	Dated Series	Dates	Series intercorrel-ation	Mean Sensitivity
Lower Yellowstone	Sidney, MT	PODE	~215	393	1729-2014	0.58	0.34
Powder River	Broadus, MT	PODE	~220	413	1740-2014	0.60	0.32
Upper Yellowstone	Livingston, MT	POAN	~40	63	1757-2013	0.4*	0.27
Redwater River	Vida, MT	PODE	23	43	1767-2014	0.73	0.38
Burning Coal Vein	Medora, ND	PIPO	14	26	1715-2013	0.8	0.48
Missouri River	Bismarck, ND	PODE	16	na	1865-2014**	na	na
Total digitized			~500	938		* *not all Cofecha flags have been addressed*	
Total collected (could digitize)			~700	~1300		** *preliminary age estimates*	

Ring-width vs. water year discharge

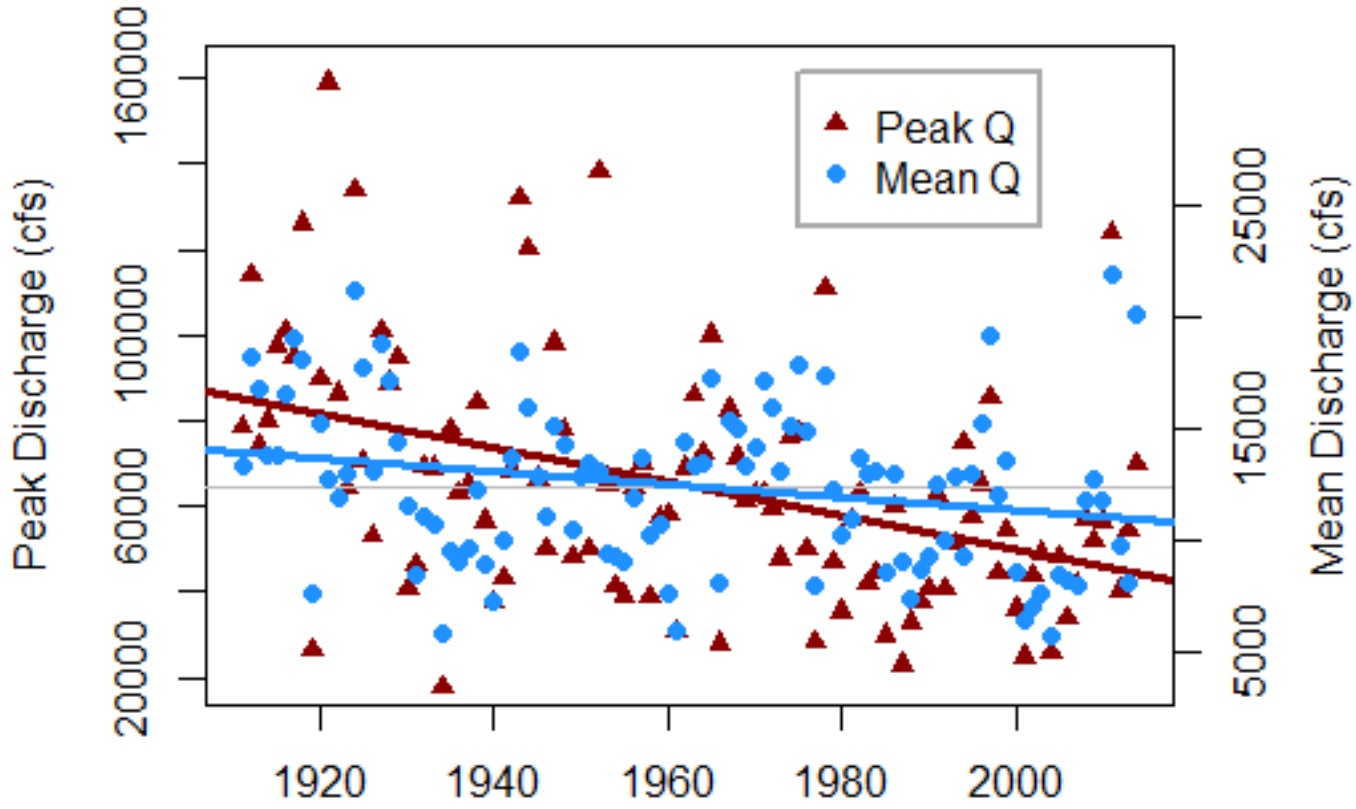
Yellowstone River



Powder River

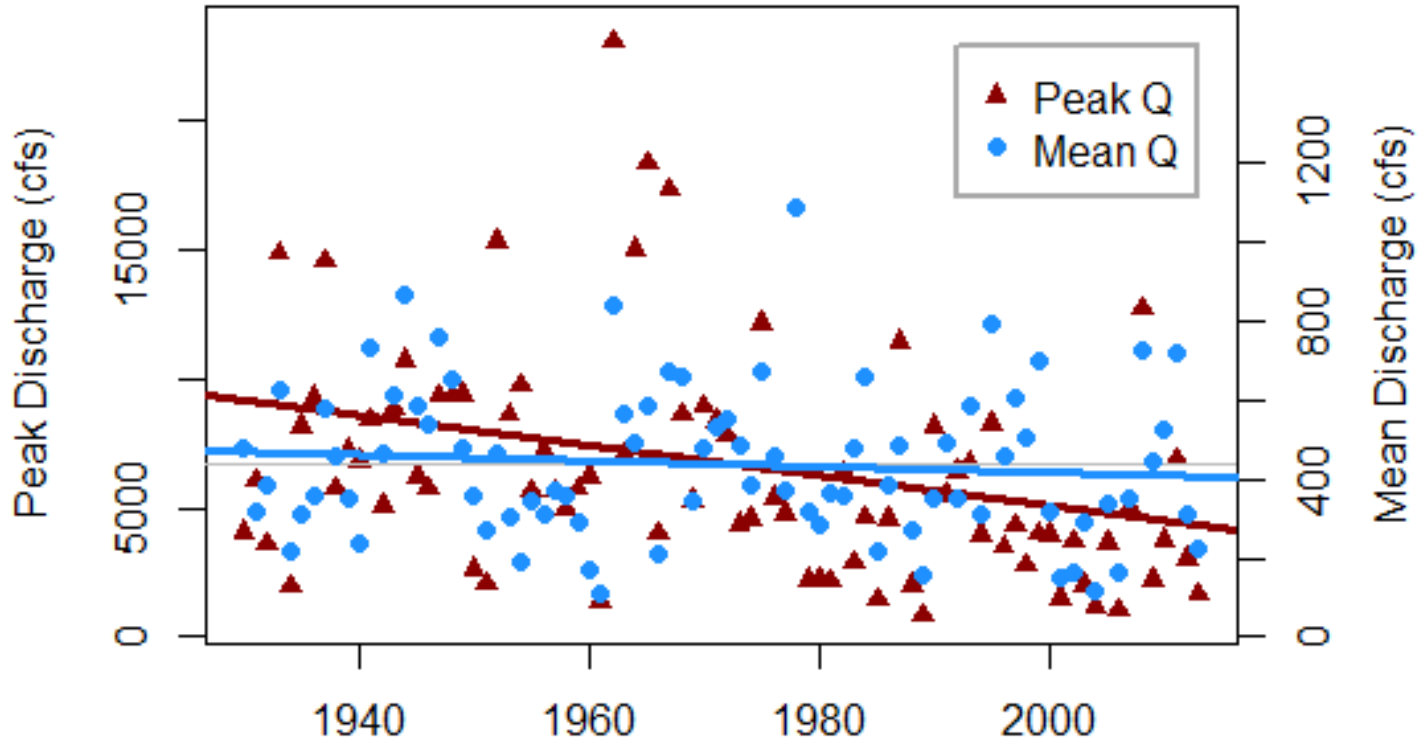


Yellowstone River Discharge,
Sidney, MT



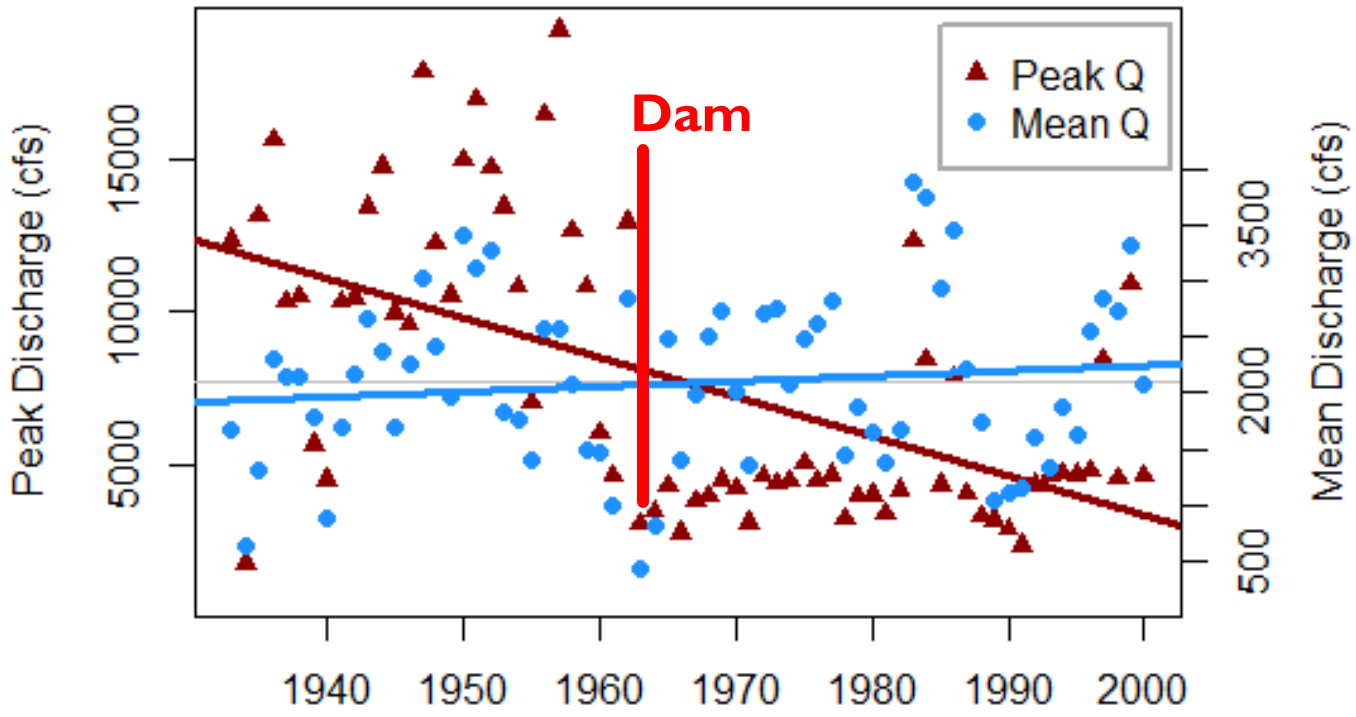
- Both significant declines
- Peak flows reduced more

Power River Discharge,
Moorhead, MT



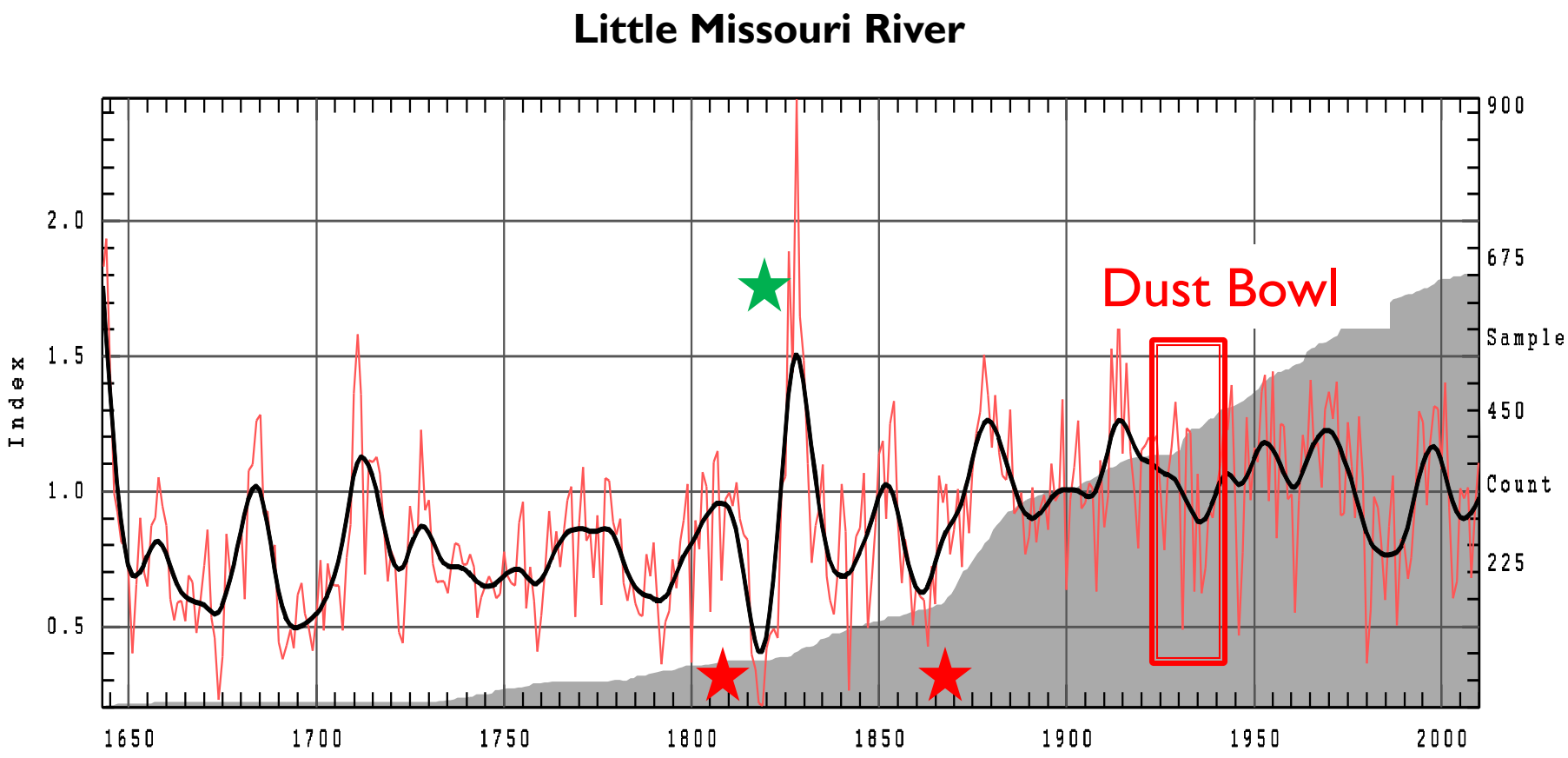
- Peak Q significantly declines
- Difficult to track extractions

Green River Discharge,
Greendale, UT

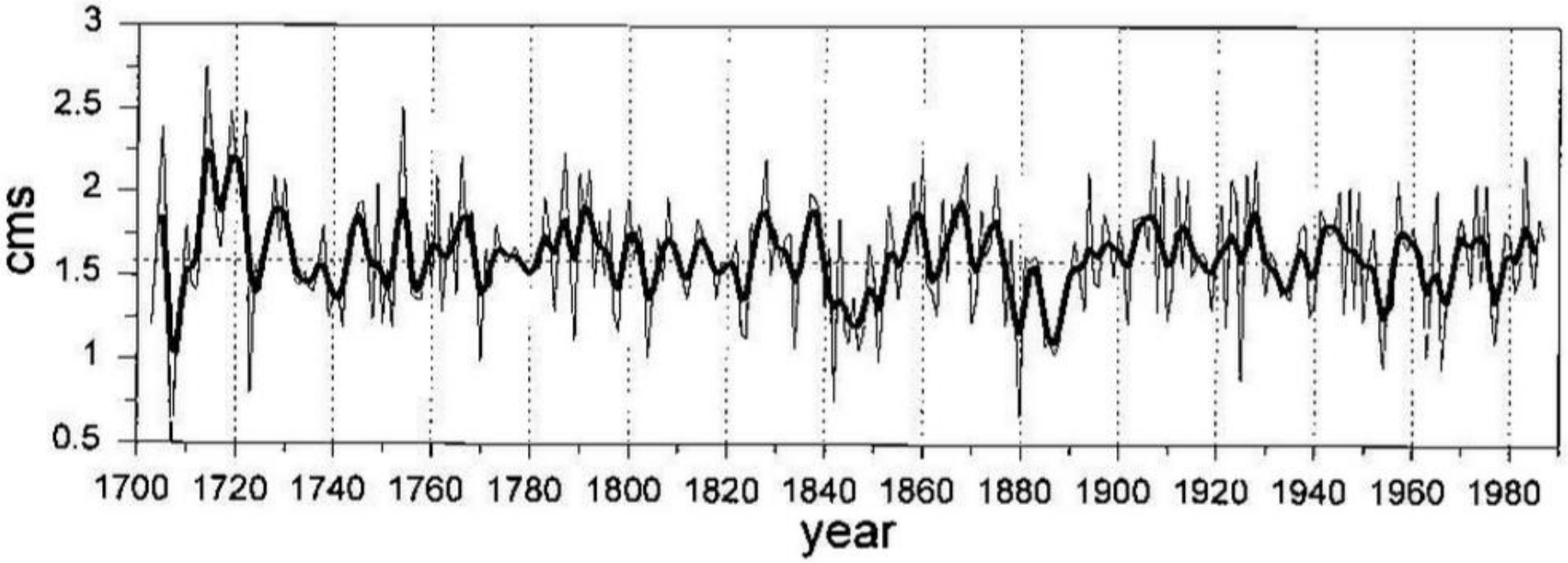


- Peak Q significantly declines
- Linear trendline is inappropriate

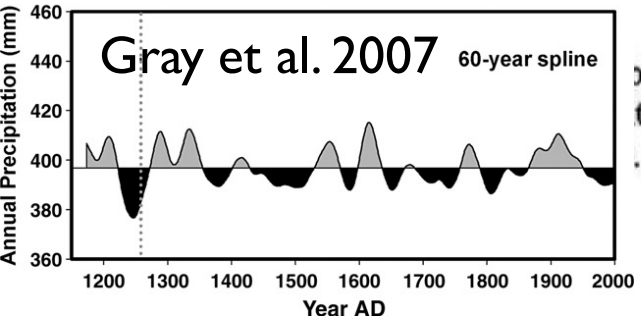
Flow Reconstruction: extending the record



Dendrochronology and unchanging means through time



Woodhouse et al. 2001



ɔulder Creek Mean Annual Flow Reconstruction, 1703-1987.
t line) have been smoothed with a five-weight binomial filter
. Dotted horizontal line represents long-term mean.