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Linking Sediment Transport, Channel Stability, and Mussel Habitat: Implications for Restoration and Management

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NRDAR Science Webinar – January 2017

U.S. Department of the Interior
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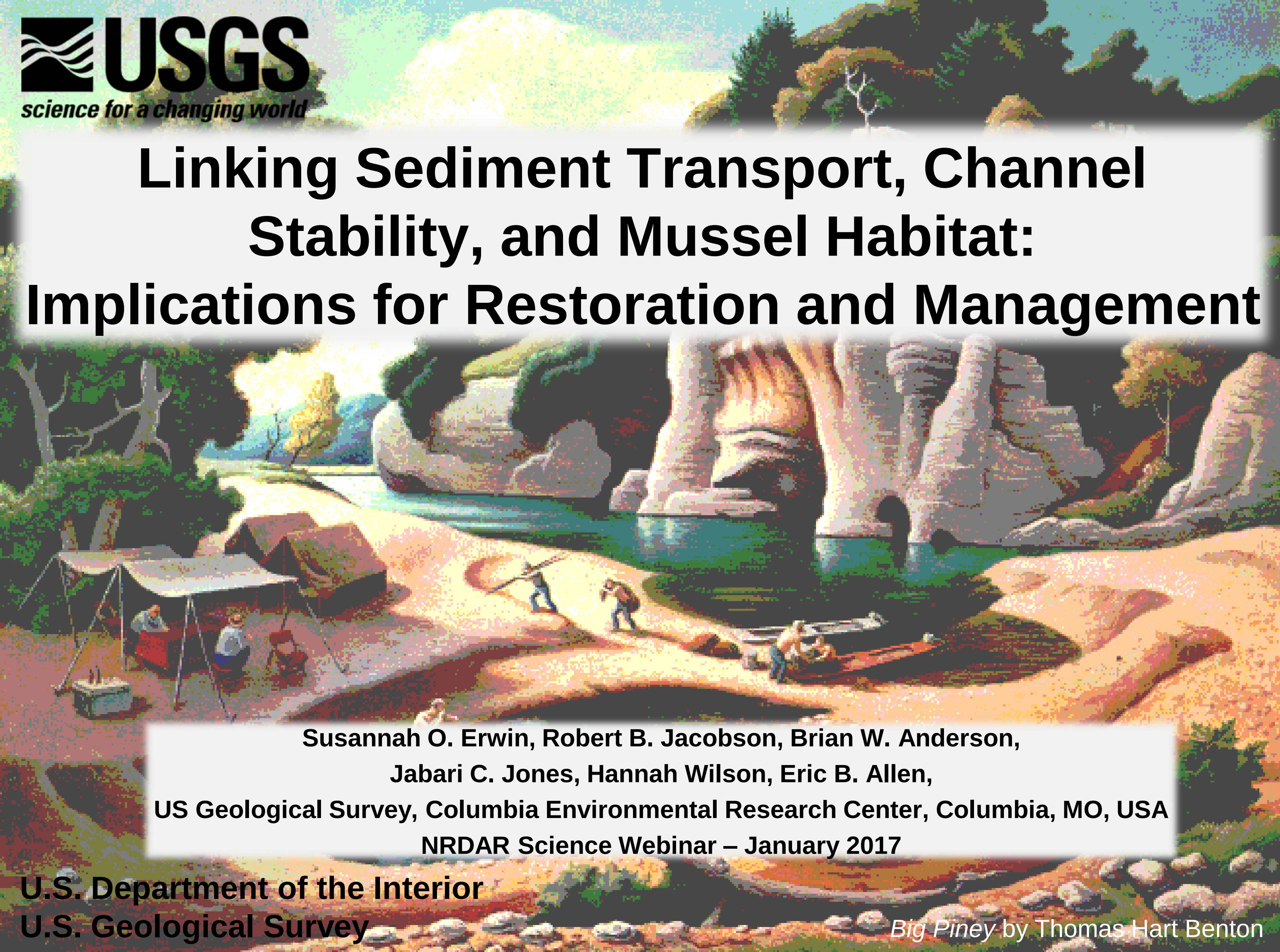

Big Piney by Thomas Hart Benton

Defining river restoration

- ***"Returning a site to a condition similar to one that existed before it was altered, along with its pre-disturbance functions and related physical, chemical and biological characteristics"***

Fischenich, 2003

- **Actions that support rehabilitation or repair of physical and ecological processes, or species recovery**

Restoration? Rehabilitation? Repair?

- **Wide range of activities conducted in name of physical habitat restoration, e.g.:**
  - **Instream habitat improvement (e.g. in-channel structures)**
  - **Restored floodplain connectivity**
  - **Riparian rehabilitation**
  - **Bank stabilization**
  - **Fencing (grazing exclusion)**
  - **Channel reconfiguration**
  - **Dam removal/retrofit**
  - **Flow modification**

Provo River Restoration Project, UT

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Factors determining physical habitat

Watershed characteristics
- Lithology of rocks
- Tectonics
- Climate
- Vegetation
- Water production from hill slopes
- Sediment production from hill slopes
- Drainage network

- **Stream flow**
  - Amount
  - Timing
- **Sediment**
  - Amount
  - Size

Cross-section

Bed material

Planform

Slope

Stream channel and floodplain form

Geomorphology of Ozark Streams

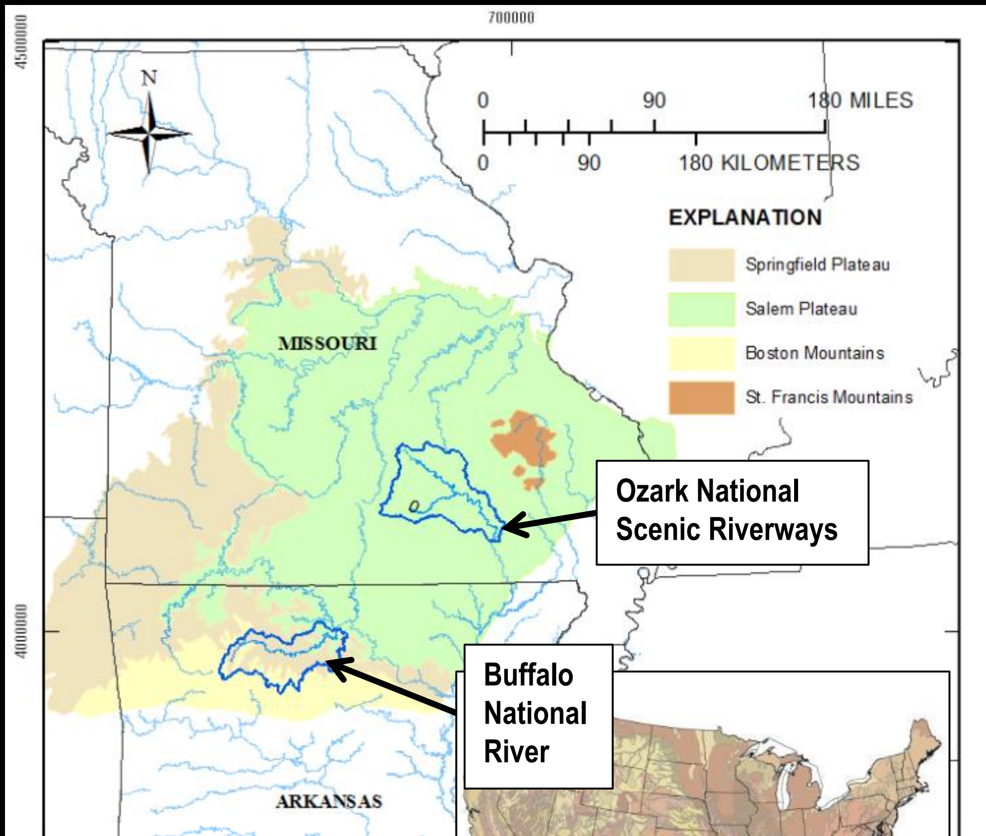
Observation: Ozarks streams are characterized by large accumulations of chert gravel, lots of channel instability.

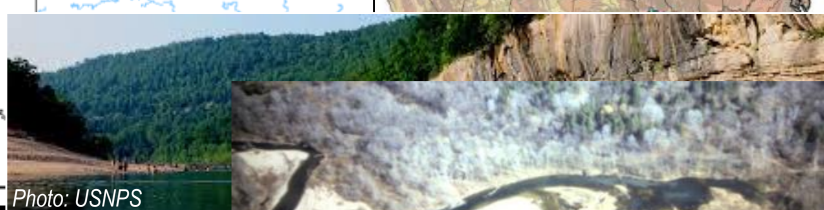
- **Eroding banks and gravel bars are natural ecological processes** ***(Florsheim et al., 2008)***
- **Have human land use activities altered delivery of gravel and channel stability in Ozark streams?**
- **Does excess gravel compromise distribution and quality of aquatic habitat?**

Ongoing study: USGS-NPS Natural Resource Preservation Program (NRPP)

Ozark Plateaus of Central US

- Elevation range: 150-720 m
- Mean annual precip: 1000-1200 mm
- Mean annual temps: 15-18 ˚C
- Predominantly Paleozoic sedimentary rock; abundant chert
- Karst drainage system
- Two national parks
- Historic land-use practices accelerated delivery of coarse sediment to river networks





Historical disturbance and sediment routing

- **Perturbations to sediment regimes due to anthropogenic activities may have long lasting effects.**
- **In systems dominated by coarse sediment travel times are relatively long.**
- **Effectively evaluating management alternatives requires understanding the future trajectory of river response at both the river network and reach scales.**


Photo: G. Parham, USFWS


Photo: C. Barnhart, MSU

Native freshwater mussels

- **North American mussel fauna:**
  - **Highest diversity of mussels in world**
  - **Most imperiled group of animals in NA – declining nation wide**
  - **Numerous ecological benefits**
  - **Key indicator of ecosystem health**

- **Mussel habitat paradox:**
  require ‘stable’ habitat
  - **Traditional microhabitat variables (e.g. depth, velocity, grain size) are poor predictors of the occurrence of mussel aggregations**
  - **Meaningful functional characteristic of habitat: measures of bed stability**

Morales et al., 2006; Strayer, 2008; Haag, 2012

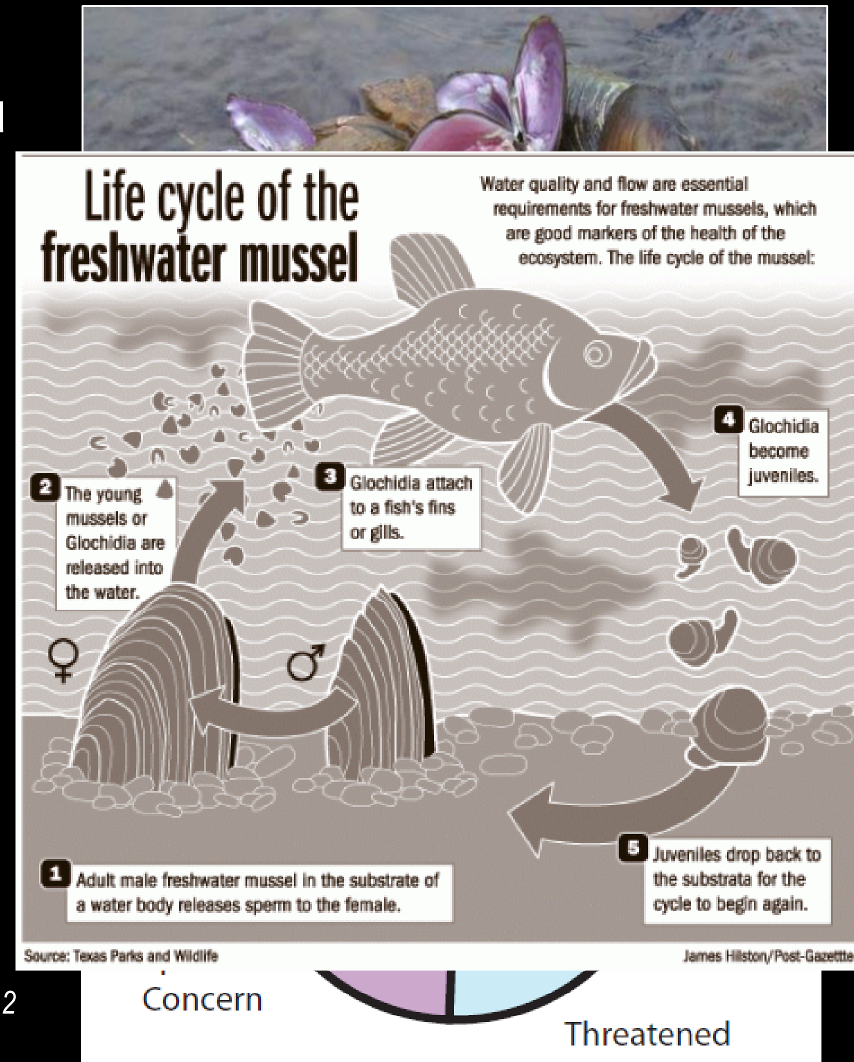


Figure: USGS – UMESC

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Sedimentation and freshwater mussel habitat

"Apart from direct habitat destruction, sedimentation is the most widely invoked explanation for mussel declines and is mentioned in nearly every study on the topic"

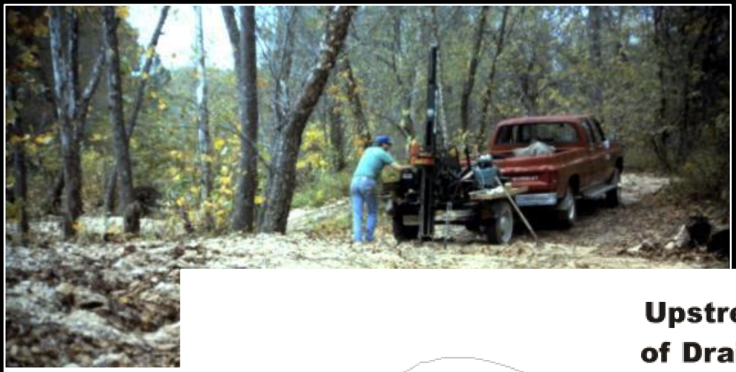
Hagg, 2012, p. 359

Sedimentation often equated with deposition of fine sediment → presumably filling interstitial spaces, and smothering or interfering with filter feeding

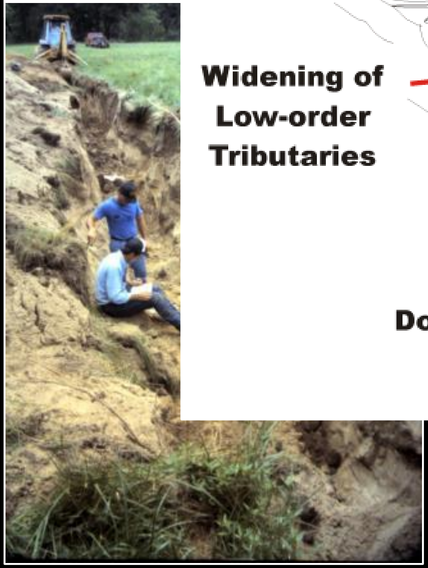
Ozarks sedimentation concerns: coarse sediment (i.e. gravel) → channel instability

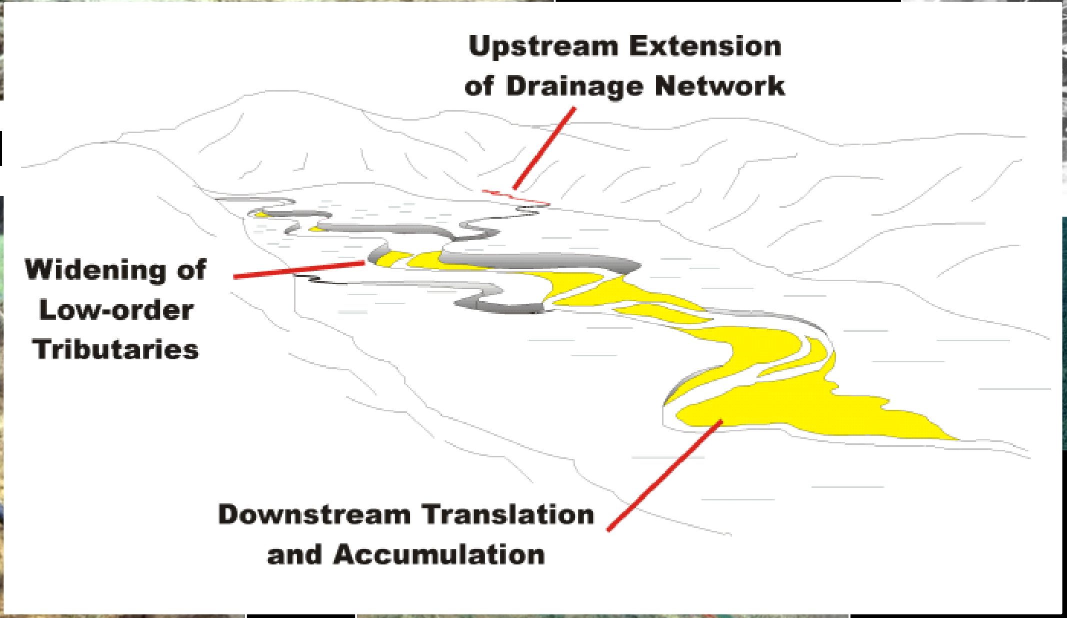
Current River - Waymeyer

Prior geomorphic studies: *Jacobson, et al.*



Floodpl





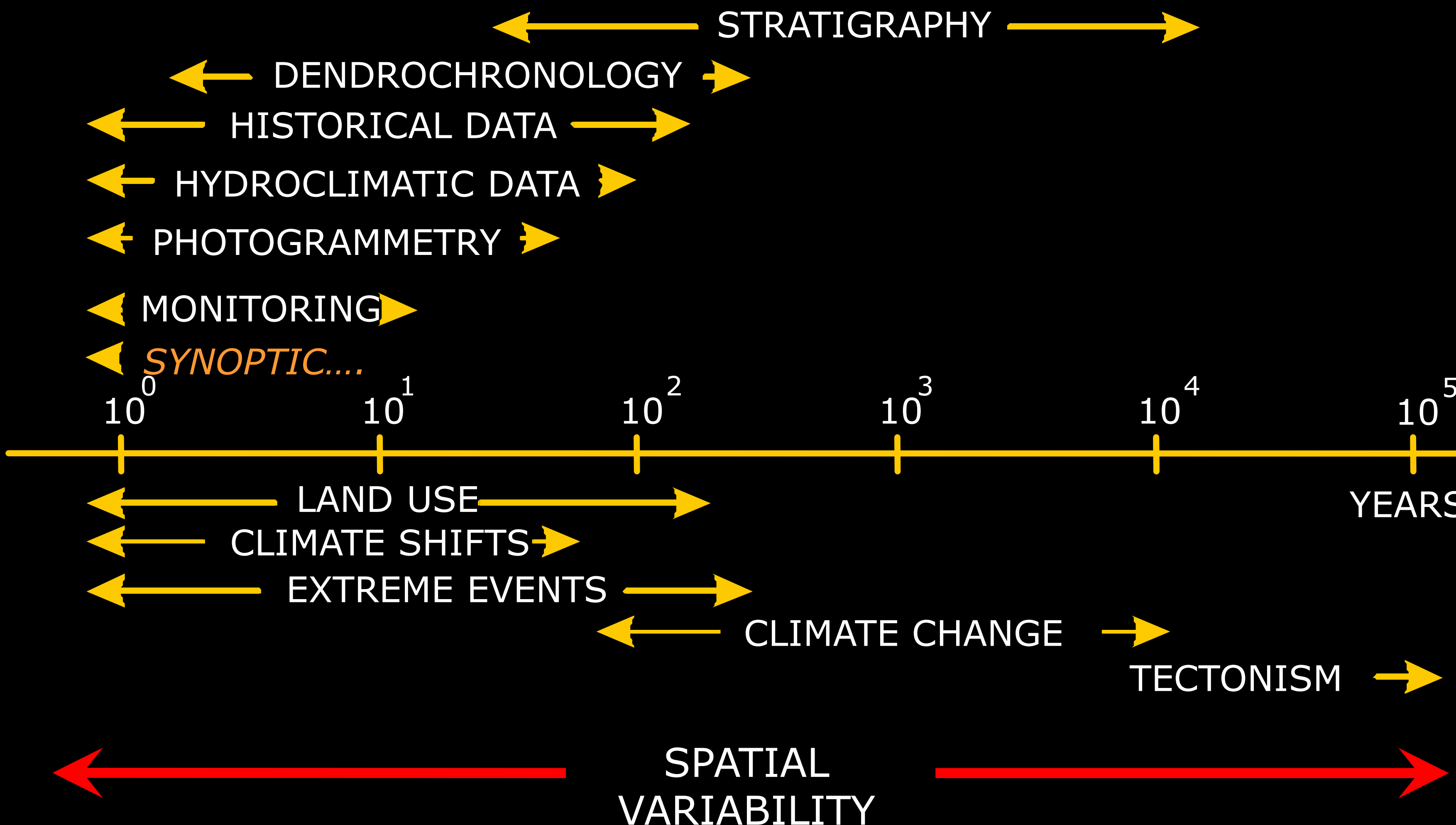
Historical data

Synthesis:

Recent increase in gravel deposition,

in rivers that have always been gravel rich

Data sources and potential disturbances



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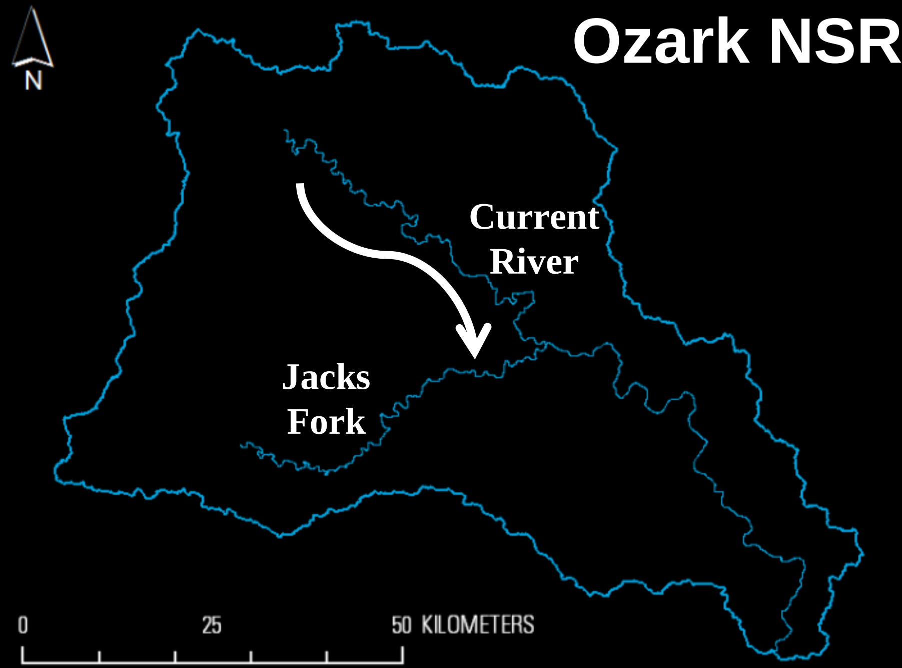
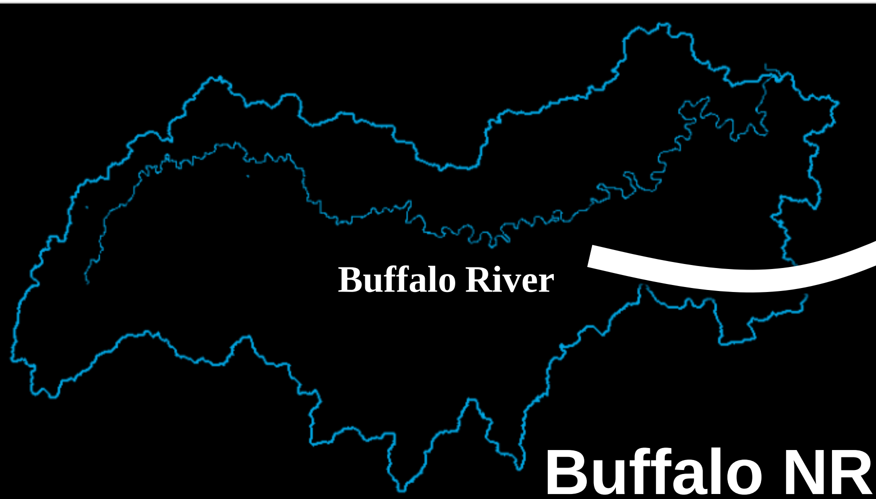
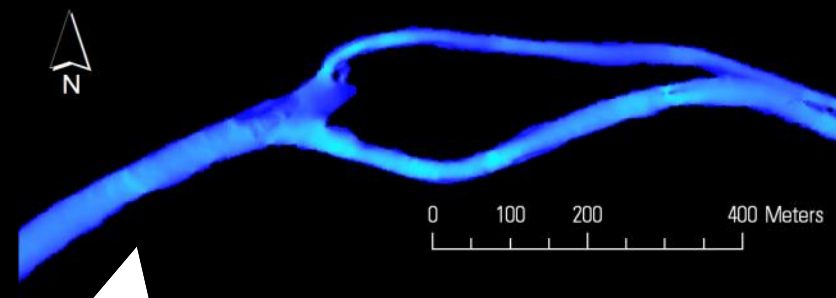
Evaluating sediment routing and restoration potential:

basin, reach, and patch scales



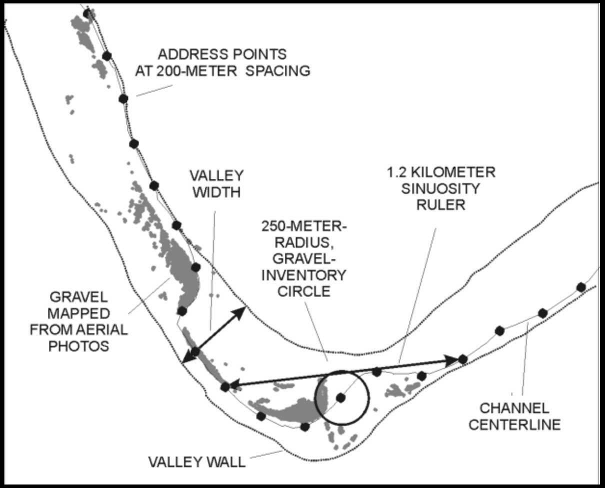


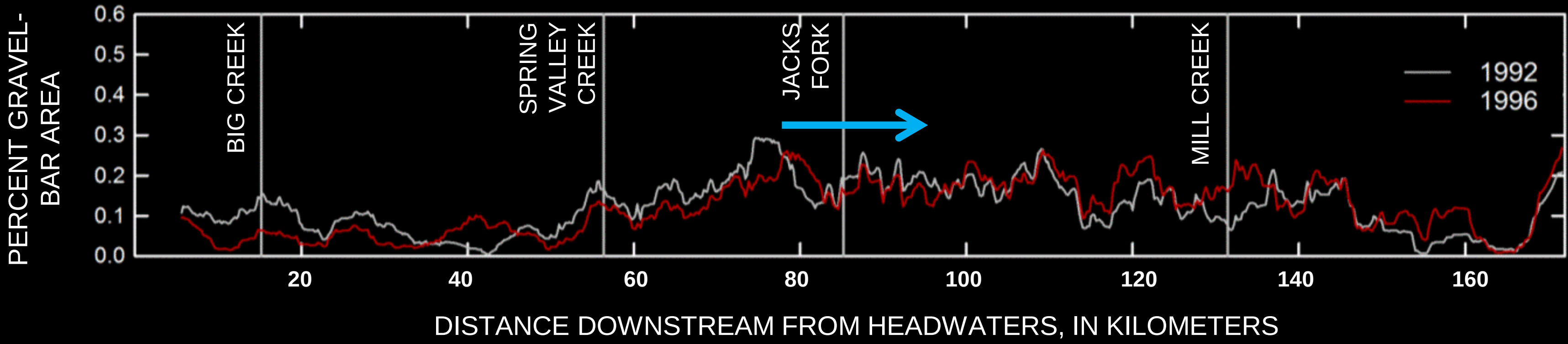


- What are the patterns of stability occurring across a range of spatial and temporal scales?
- How do geomorphic patterns and sediment routing impact management alternatives?

Basin-scale: Current River gravel-bar inventory

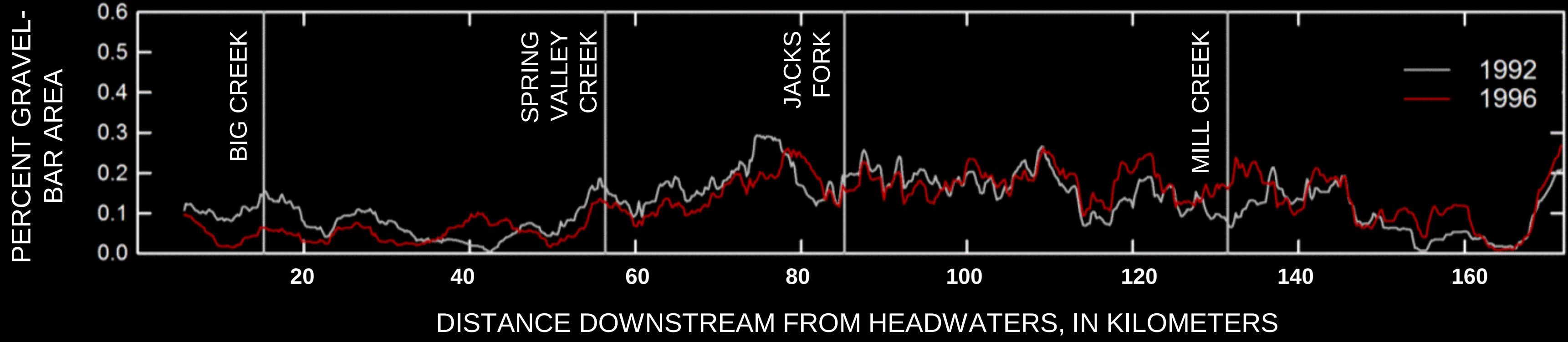
- Bar area quantified at 200-m address points
- Low, steady flows for each time series
- Normalized by total area to account for variable discharge
- Bars delineated manually and via supervised classification





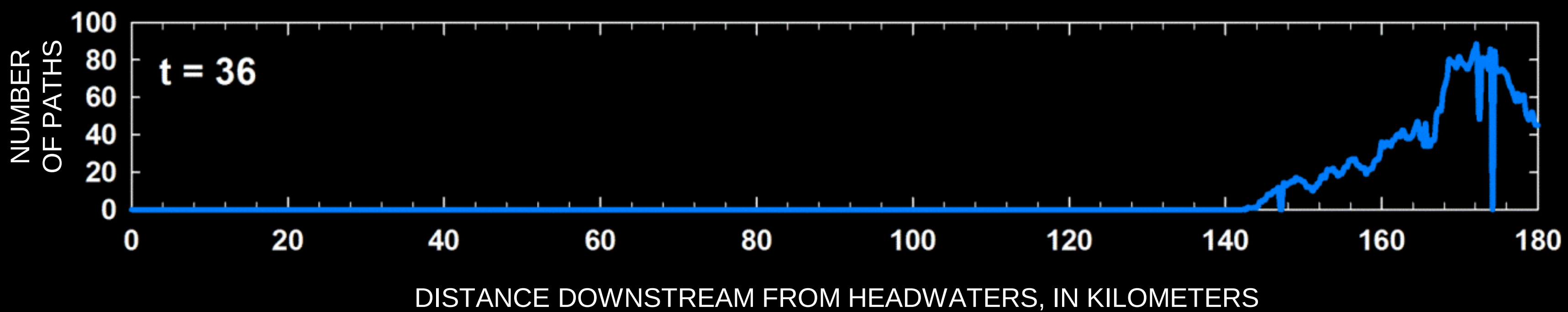
Jacobson and Gran, 1999
Panfil and Jacobson, 2001

Basin-scale: sediment routing model



Simple routing model:

- **Travel time proportional to path length**



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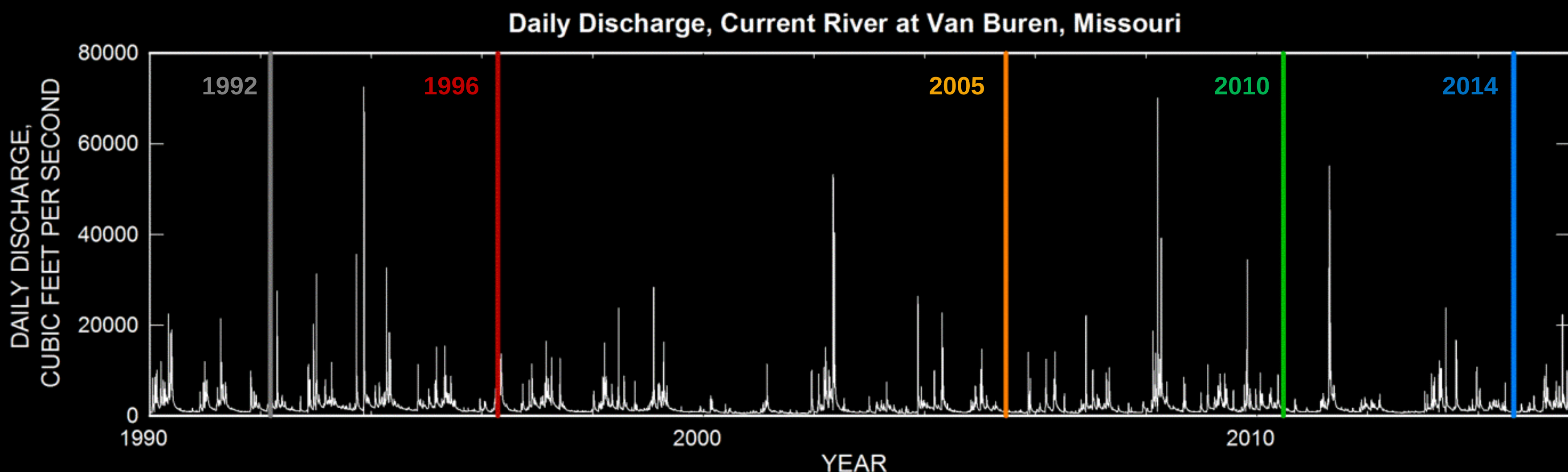
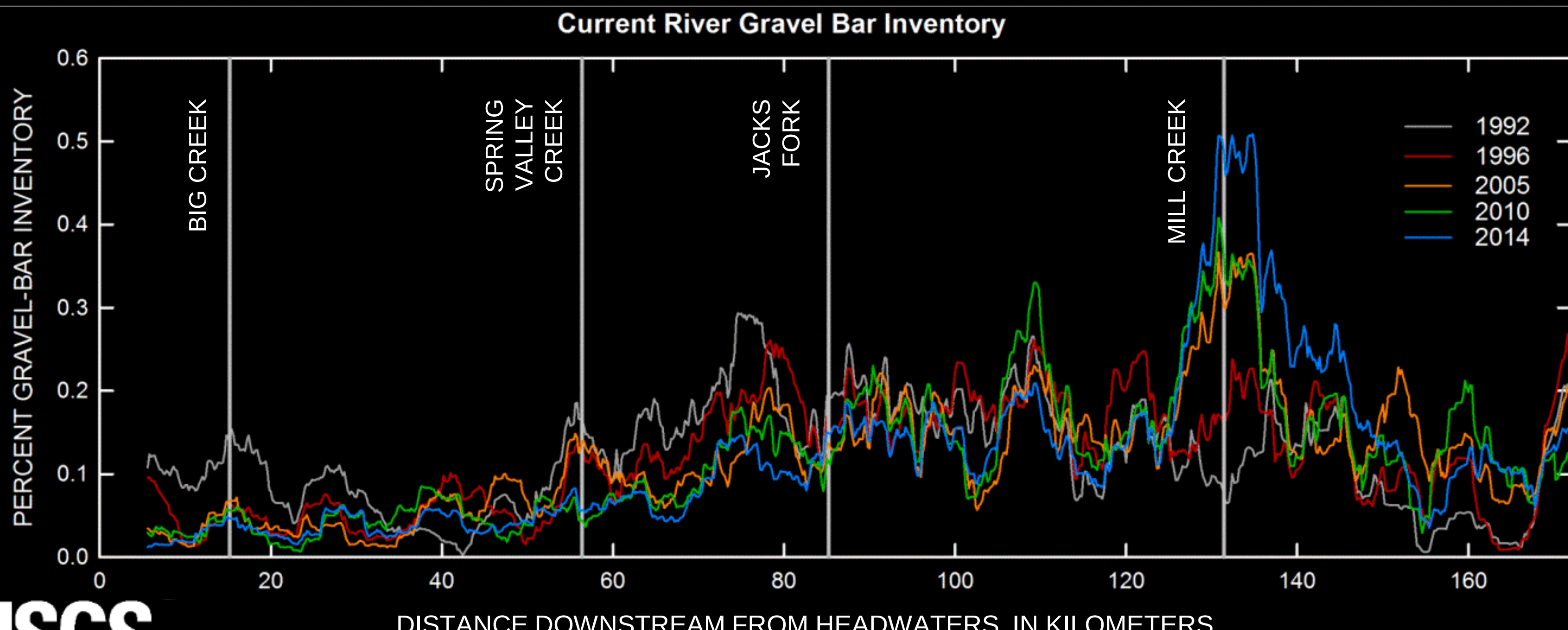
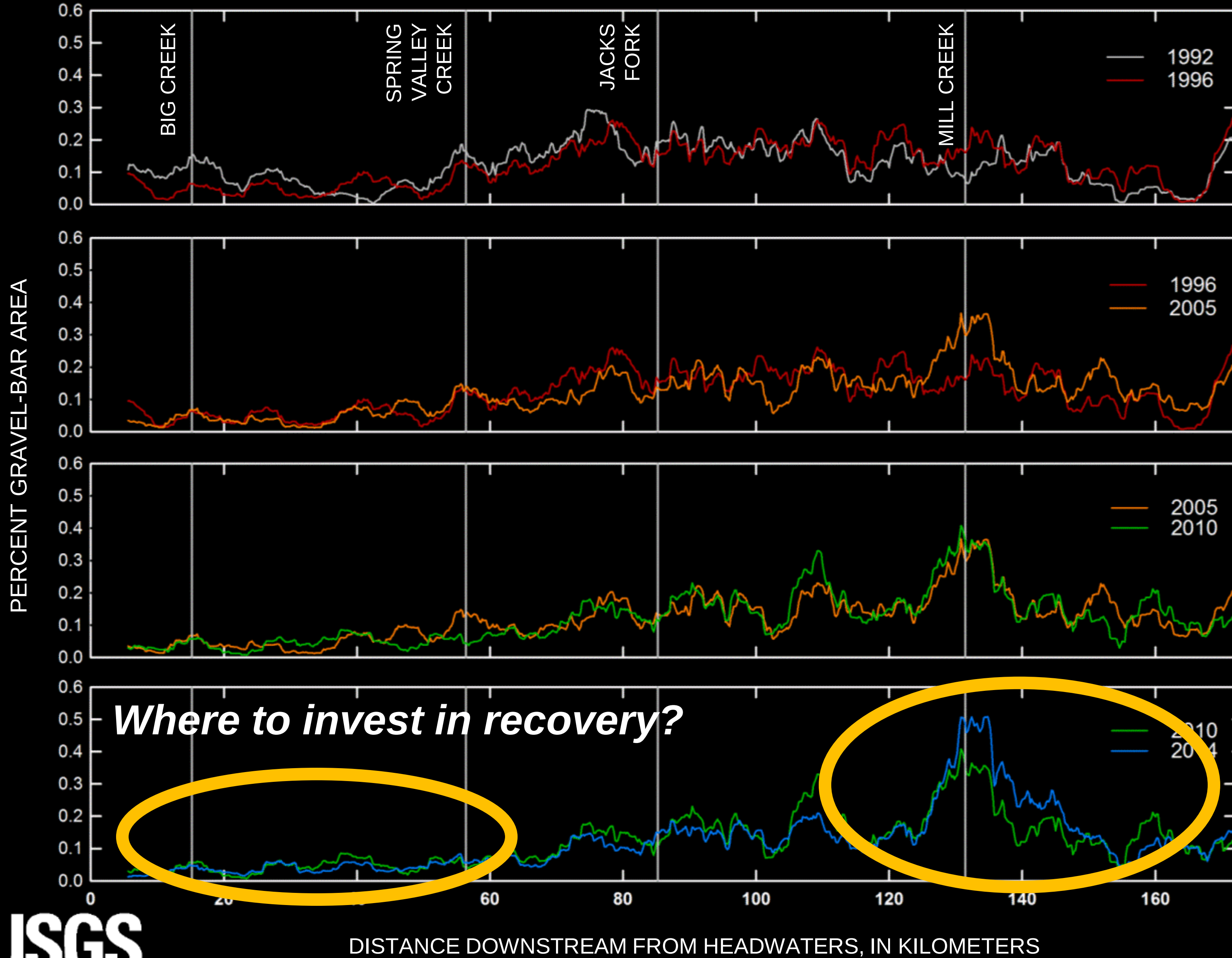
Jacobson and Gran, 1999
Panfil and Jacobson, 2001

Basin-scale: Current River gravel-bar inventory





Basin-scale: Current River gravel-bar inventory



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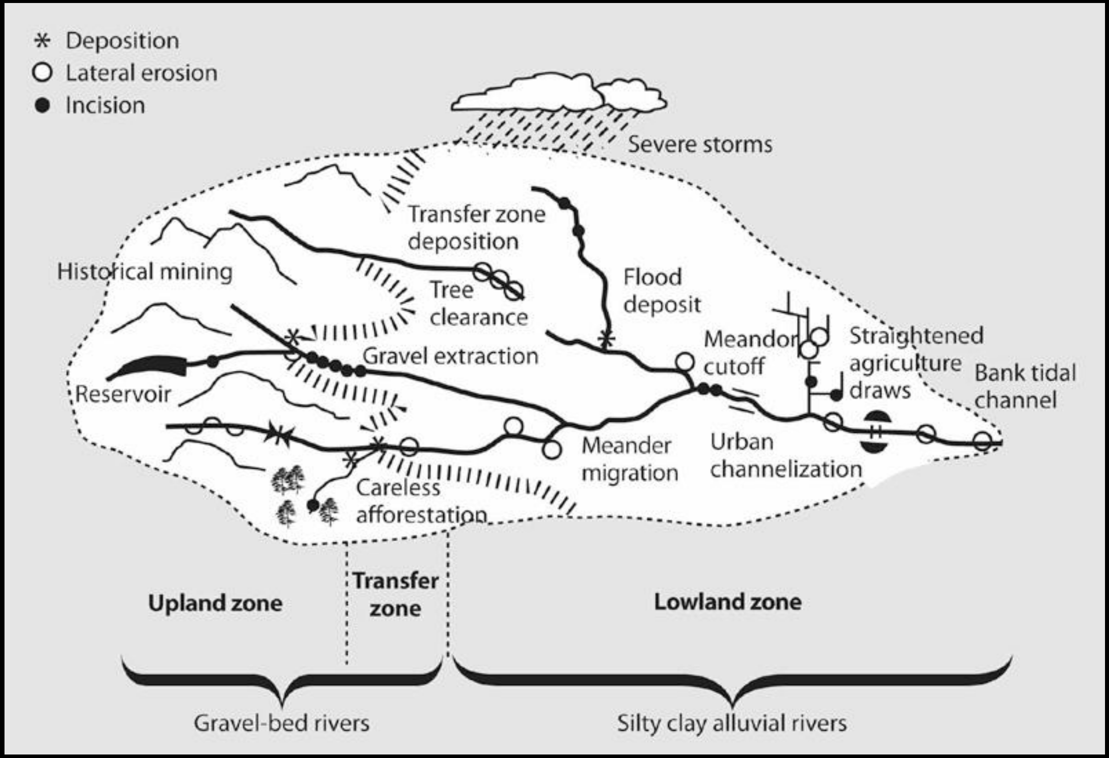
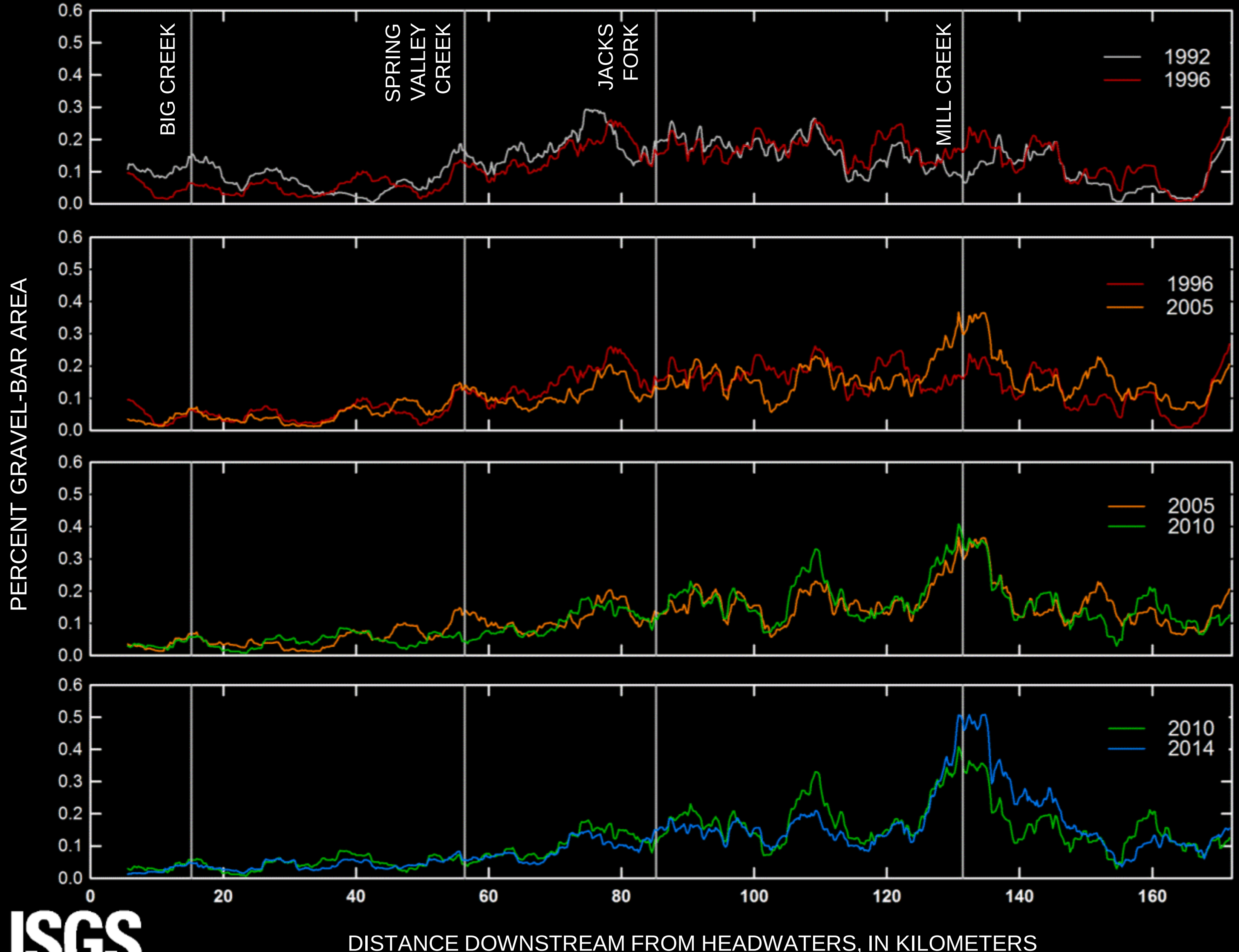
Understanding watershed context

Natural and anthropogenic processes affecting sediment sources

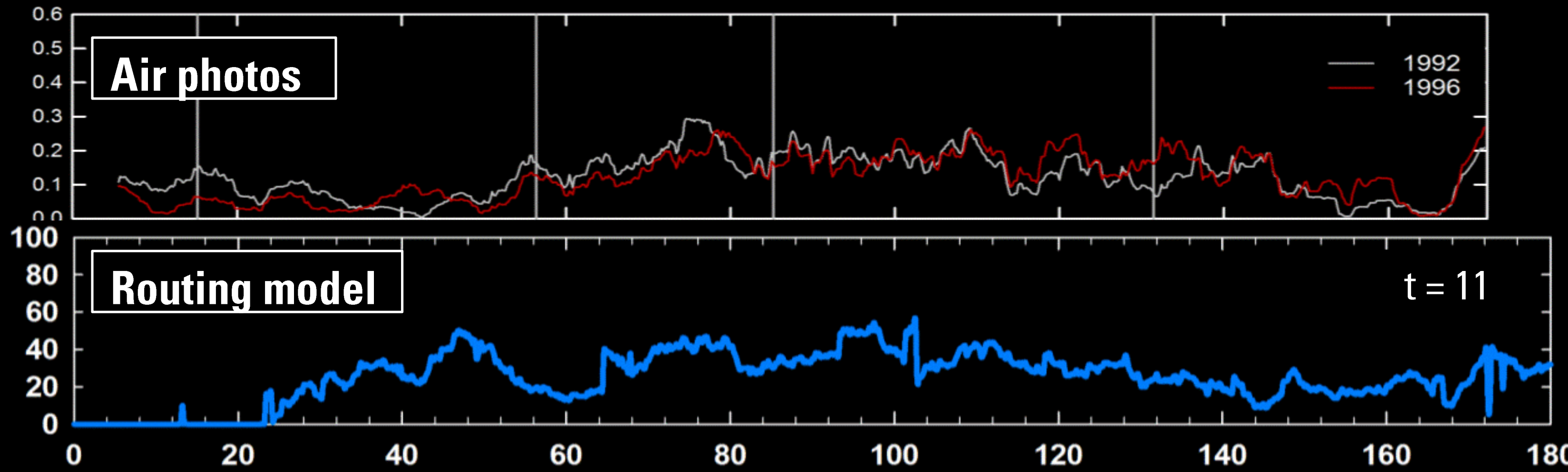


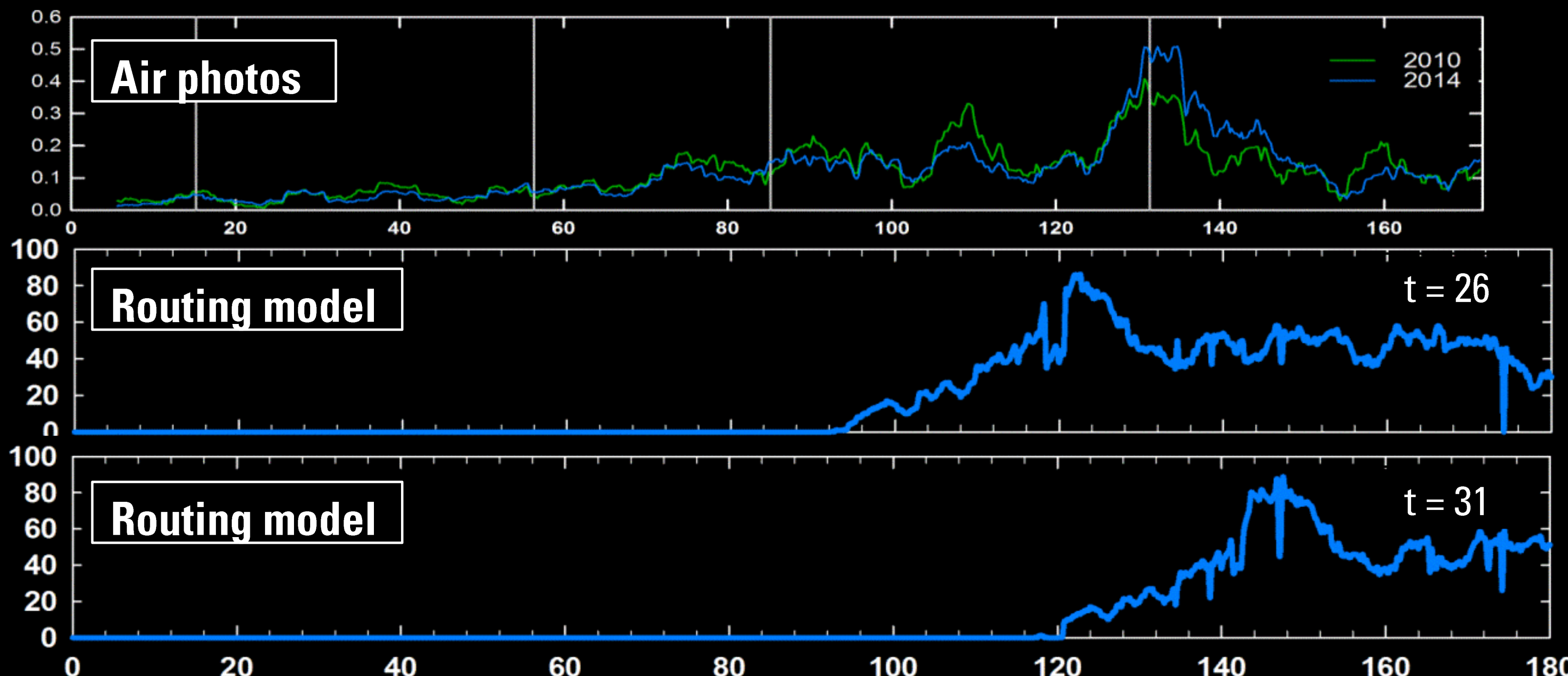
Skidmore et al., 2011 (adapted from Sear et al., 2003)

Basin-scale: Current River gravel-bar inventory

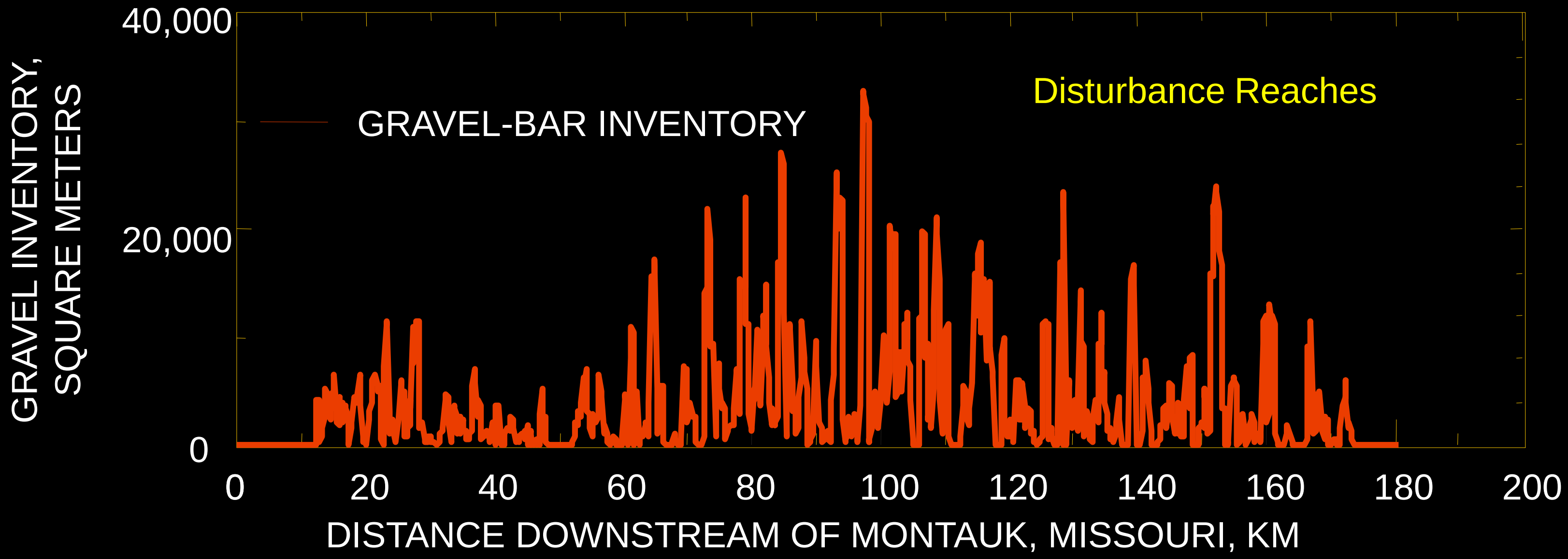


Basin-scale: Current River inventory vs model



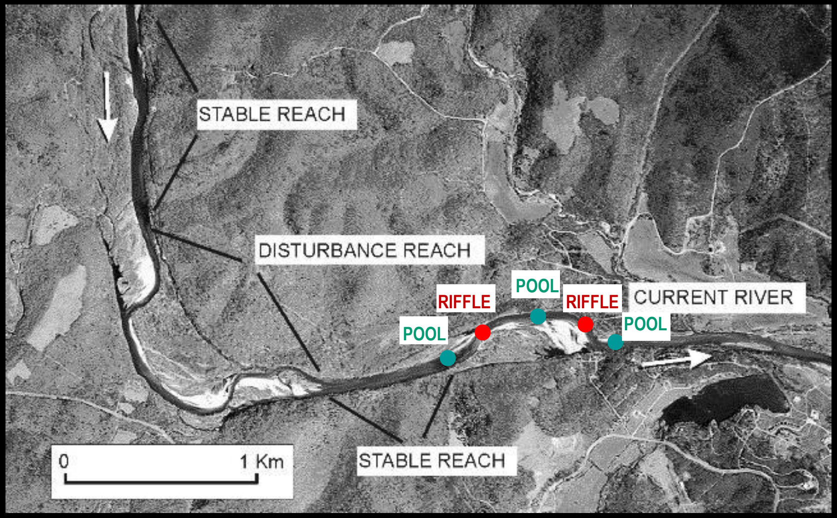


Reach-scale: planform change and habitat stability



- **Wandering planform: alternating stable and disturbance reaches**

- **~~Disturbance~~ *Dynamic* reaches provide benefits and challenges to ecology and management**



Jacobson and Gran, 1999

Patterns of (in)stability occur at multiple scales

1. **River basin – sediment waves**
2. **Reach – ‘stable’ and ‘disturbance’ reaches**
3. **Habitat unit, patch – distribution of velocity and bed stress**



Prior Ozark river studies have described disturbance and instability from a planform perspective, largely focused on decadal time-scales

What’s happening on the bed of the river during a typical flood?

Gravel-bed rivers are naturally dynamic: sediment moves

Most of the time	Sometimes (2-6 weeks per year)	Only briefly (0-3 weeks per year)	Rarely (every decade or two)
Base flows; Minimal or no bed material transport	Moderately high flows; some transport of fines (sand) over immobile coarse bed	High flows; moving larger grains making up bed framework	Huge floods; bed fully mobile
Not much happens	Sand may collect into pools, infiltrate into interstices	Bed scour and aggradation, bar building and migration, bank erosion, & other geomorphic action; disturbance of benthos, flushing of substrate	Reset the channel bed and, often, its geometry

Modified from P. Wilcock

In a typical year, most (but not all) of the material in the bed is mobilized

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Bed mobilization is not spatially uniform

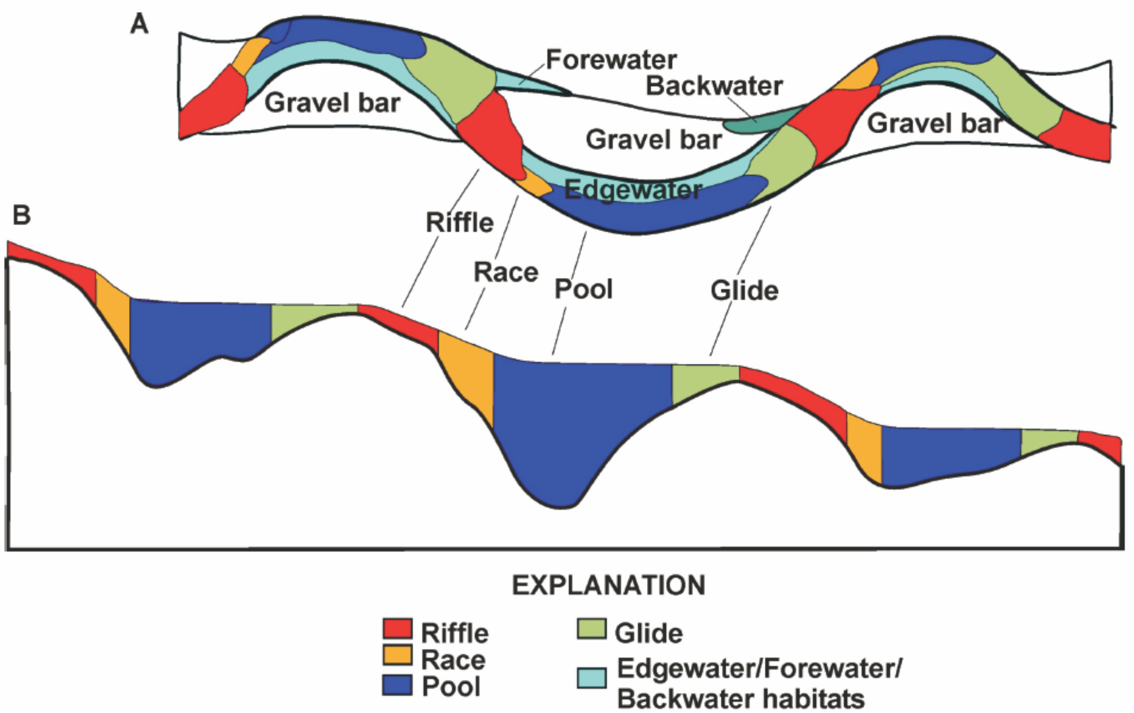


Figure 3. Typical arrangement of physical stream habitat units in Ozarks streams, after McKenney (1997), Panfil and Jacobson (2001). A. Planview showing longitudinal and marginal habitats. B. Longitudinal view along thalweg. See figure 4 for additional descriptions.

From Reuter et al., 2003

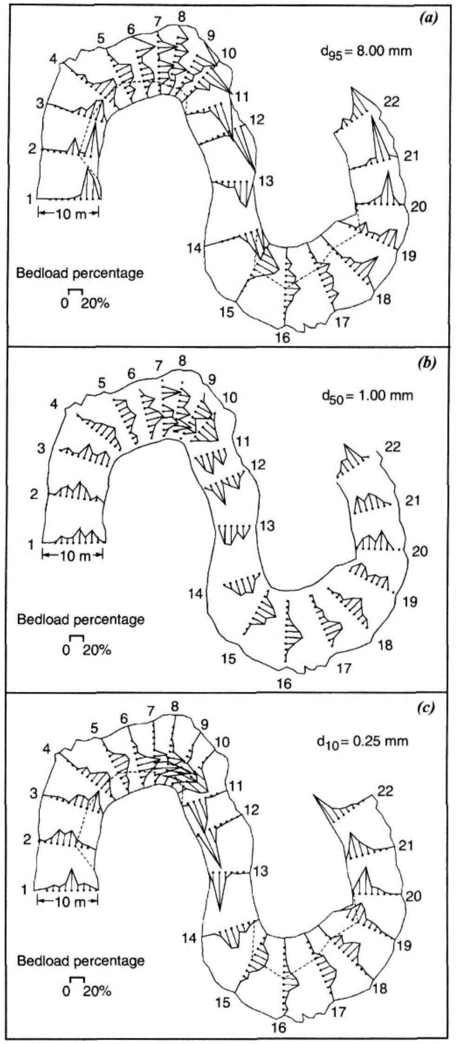


Fig. 4 Percentage of moving bedload at each interval for all channel cross-sections: a) d_{95}=8 mm; b) d_{50}=1.0 mm; and c) d_{10}=0.25 mm

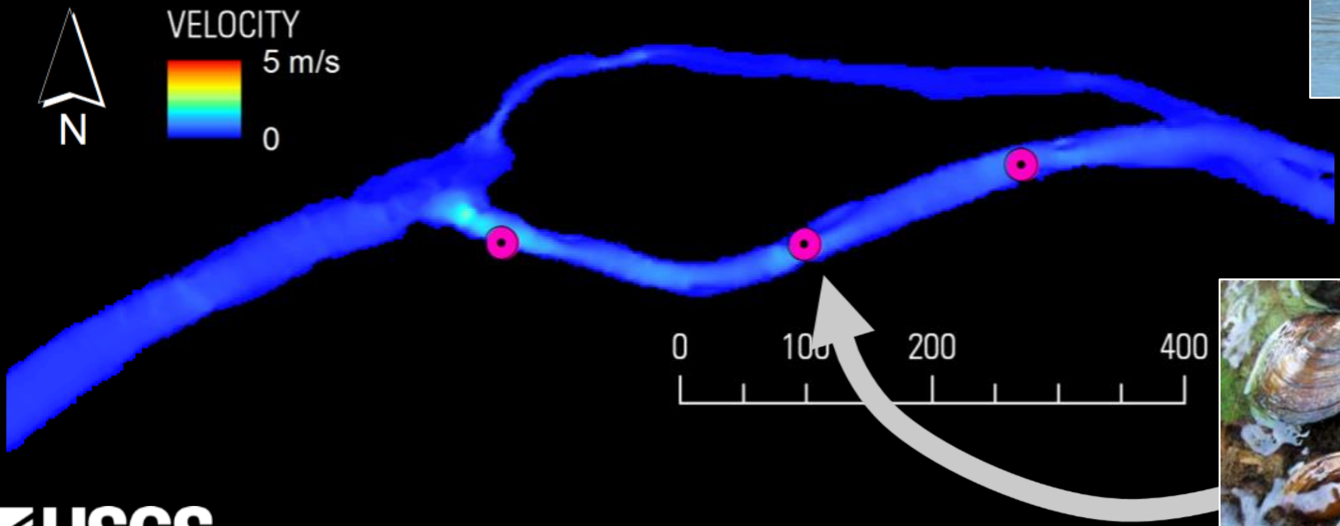
From Julien and Anthony, 2002
Fall River, CO

USGS

NRDAR Science Webinar, January 2017; preliminary data

Reach scale: hydraulic patterns

- Field methods: single beam echosounder, Zboat, rtkGPS
- 2d model: SRH-2D (USBR)
- Multiple sites per park
- Limited calibration datasets



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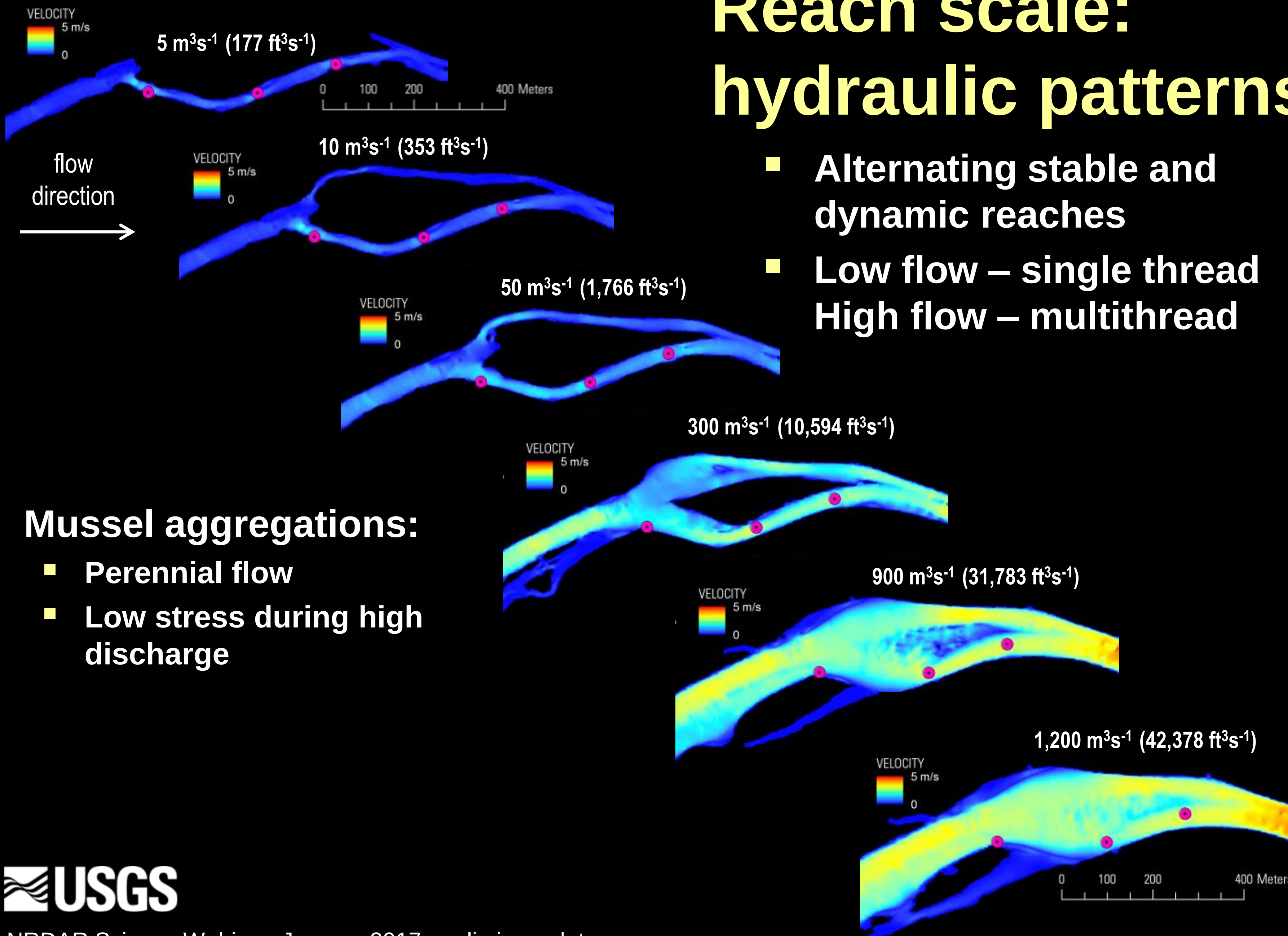
Buffalo River – Site I

Reach scale: hydraulic patterns

- Alternating stable and dynamic reaches
- Low flow – single thread
  High flow – multithread



- **Mussel aggregations:**
  - Perennial flow
  - Low stress during high discharge

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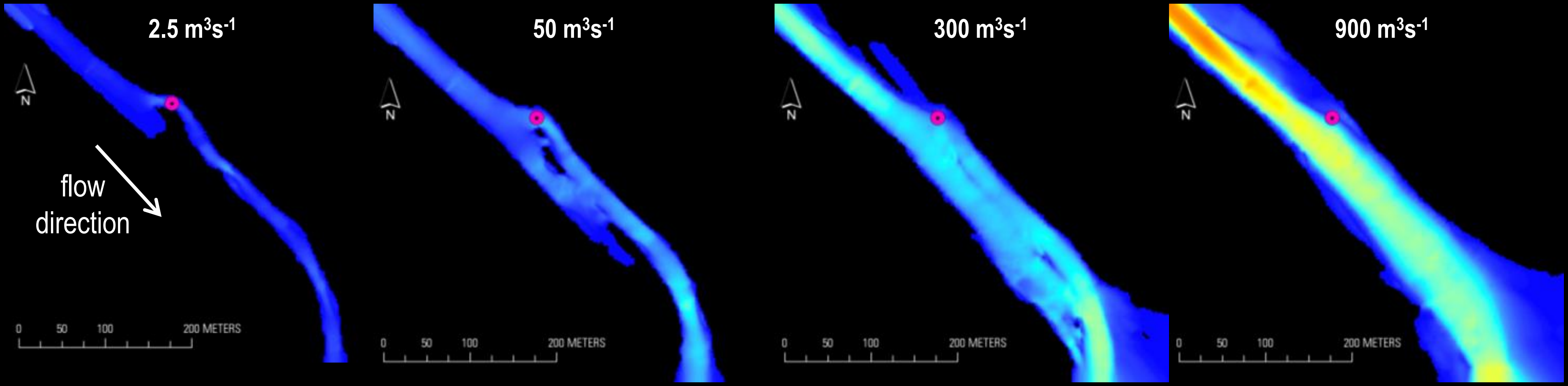
Reach scale: hydraulic patterns

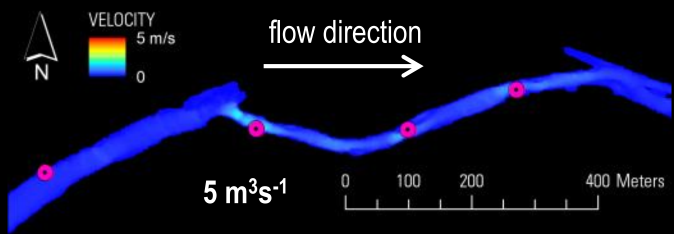
Buffalo River – Site II



- **Further upstream in watershed, similar pattern**

Reach scale: hydraulics and mussel habitat

- **Limited locomotion dictates habitat suitability indices**
- **Temporal component– beds must satisfy all life stage requirements through entire hydrograph**



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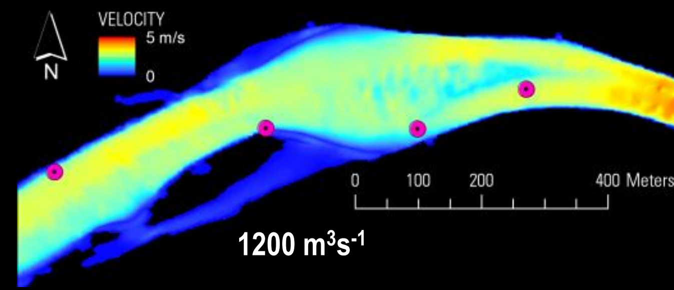

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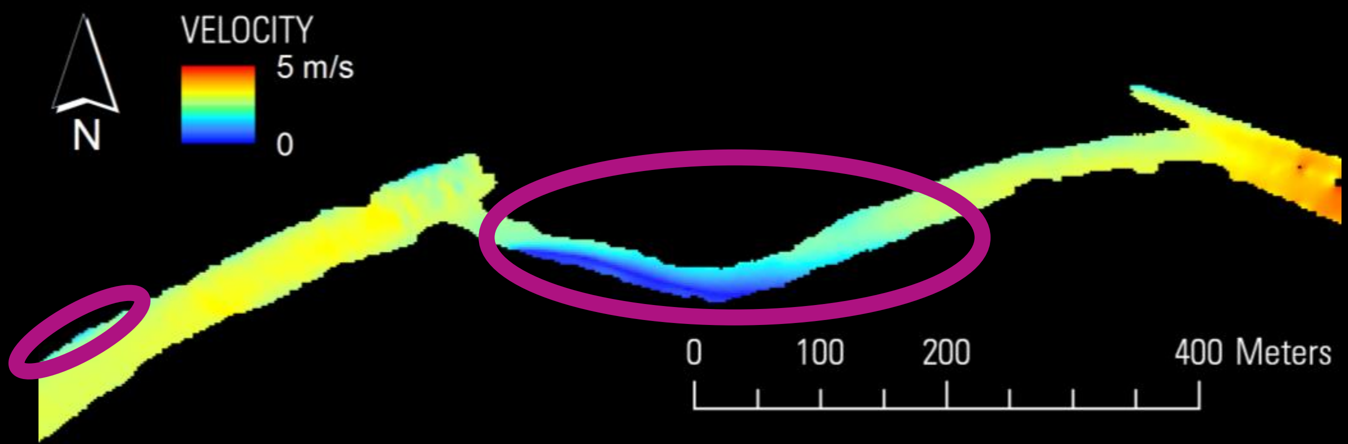

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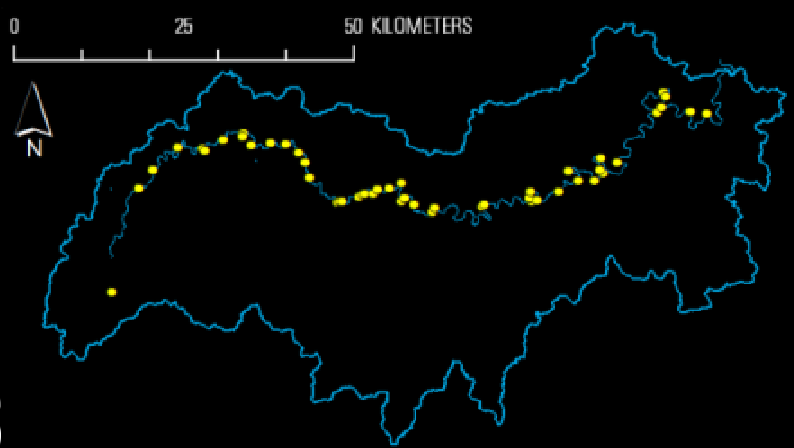
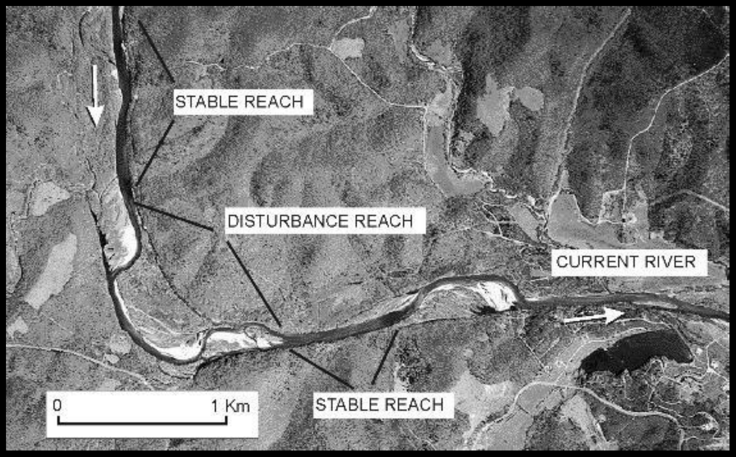
Summary

- **Alternate planform configurations route and store sediment differently → different patterns of bed stability at reach scale → affects the distribution and availability of habitat for native biota**
- **Reaches that have a more dynamic planform may provide more hydraulic refugia and habitat heterogeneity compared to stable, homogeneous reaches**
- **Planform stability ≠ bed stability**
- **Temporal scale of planform adjustment vs bed mobilization**





NRDAR Science Webinar, January 2017; preliminary data

Acknowledgements

- Ozark National Scenic Riverways
  Buffalo National River
- USGS-NPS Natural Resource Preservation Program
- USGS Ecosystems Mission Area

Photo: USNPS

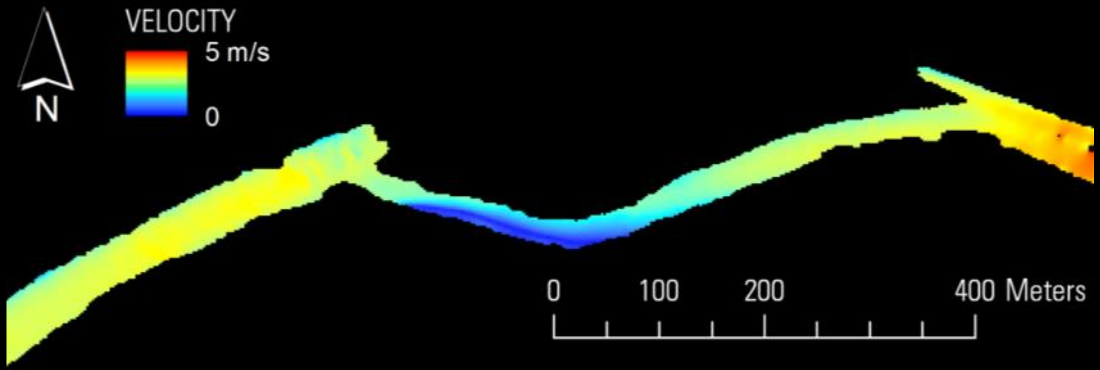


Photo: USNPS

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Questions?