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Columbia Environmental Research Center
River Corridor Habitat Dynamics

Exploring Common Ground between Agriculture and Ecological Restoration in Large-River Floodplains

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

Presentation Objectives

- Brief overview of floodplain science needs project
- Explore two examples of floodplain modeling results:
  - Potential benefits of floodplains in providing flood-risk reduction and nutrient processing.
  - Can floodplains be common ground in conservation and agricultural land-use conflicts on large rivers?

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Large-river floodplains are highly dynamic, spatially variable, highly valued for agriculture, development, and – increasingly – conservation.

What information is needed to manage these lands for resiliency, especially given inherent uncertainties and non-stationary conditions?

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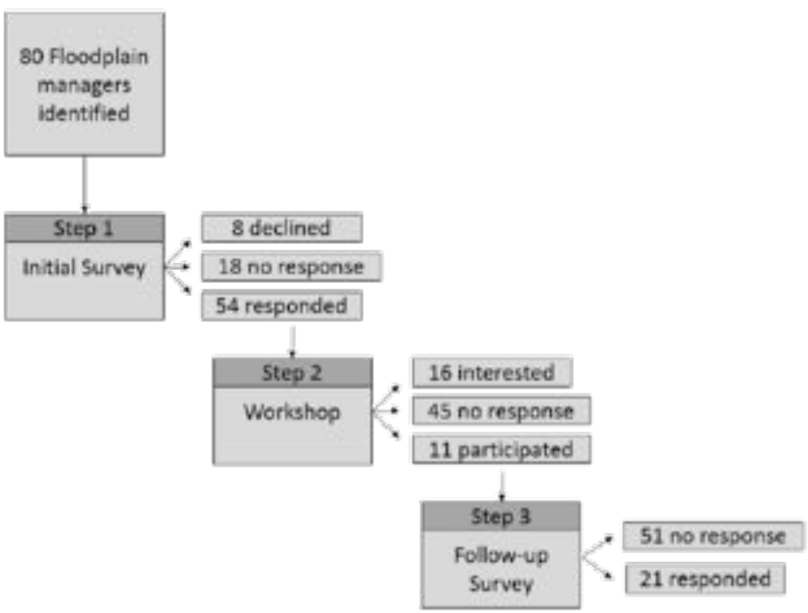
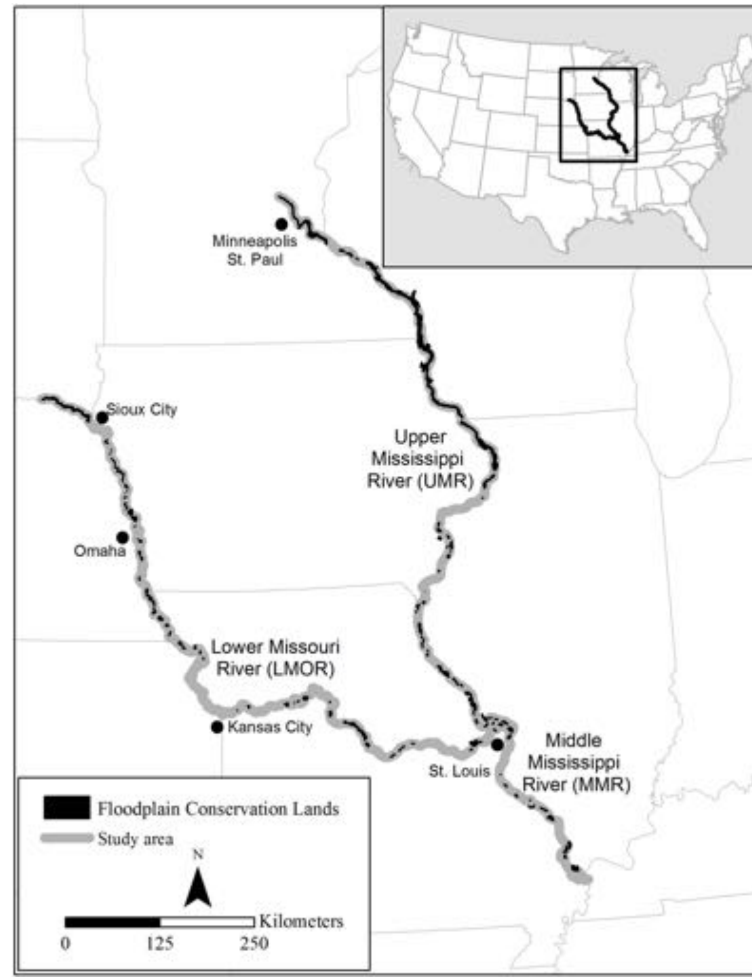
Project Objectives

- Solicit science needs from floodplain conservation land managers.
- Develop data, models, and tools to address those needs.
  - Look at variety of ecological endpoints
  - Evaluate sensitivity to non-stationarity, as caused by climate variation, land-use change, water-use change.

Assessing floodplain science needs

- Surveyed natural resource managers of floodplain conservation lands across UMR, MMR and LMOR





Bouska, Lindner, Paukert & Jacobson, 2016, Stakeholder-led science: engaging resource managers to identify science needs for long-term management of floodplain conservation lands, Ecology and Society 21(3):12

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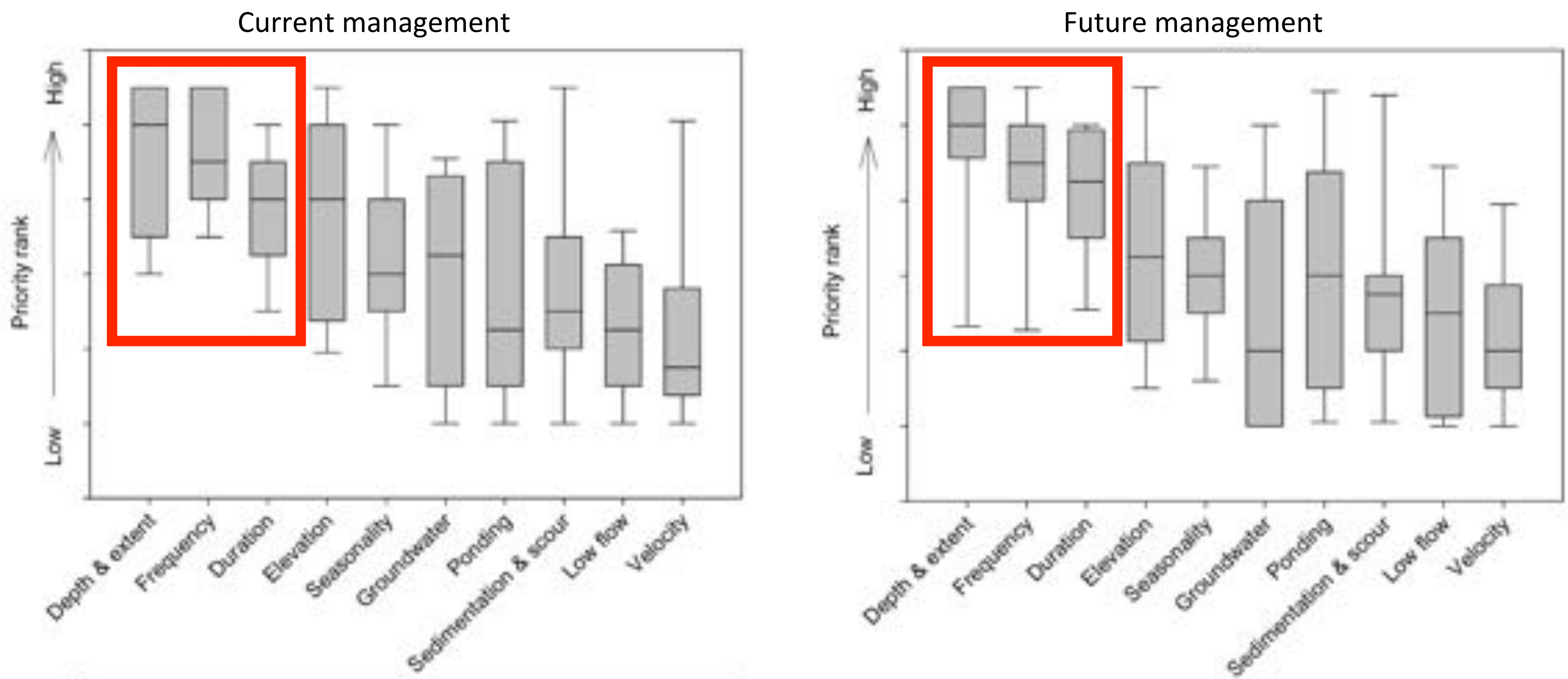
What scientific information is needed to help inform management decisions?



Bouska and others., 2016

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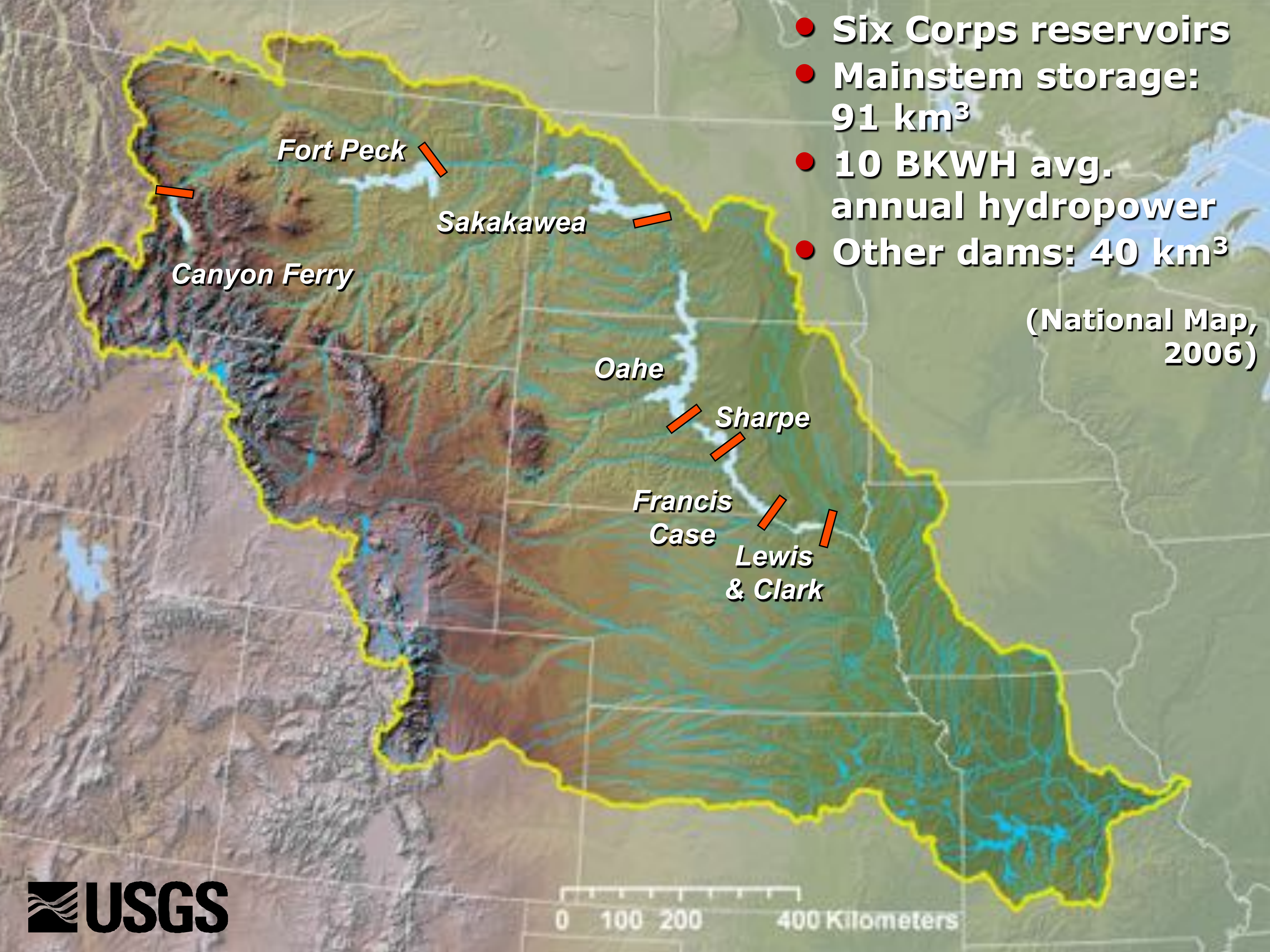
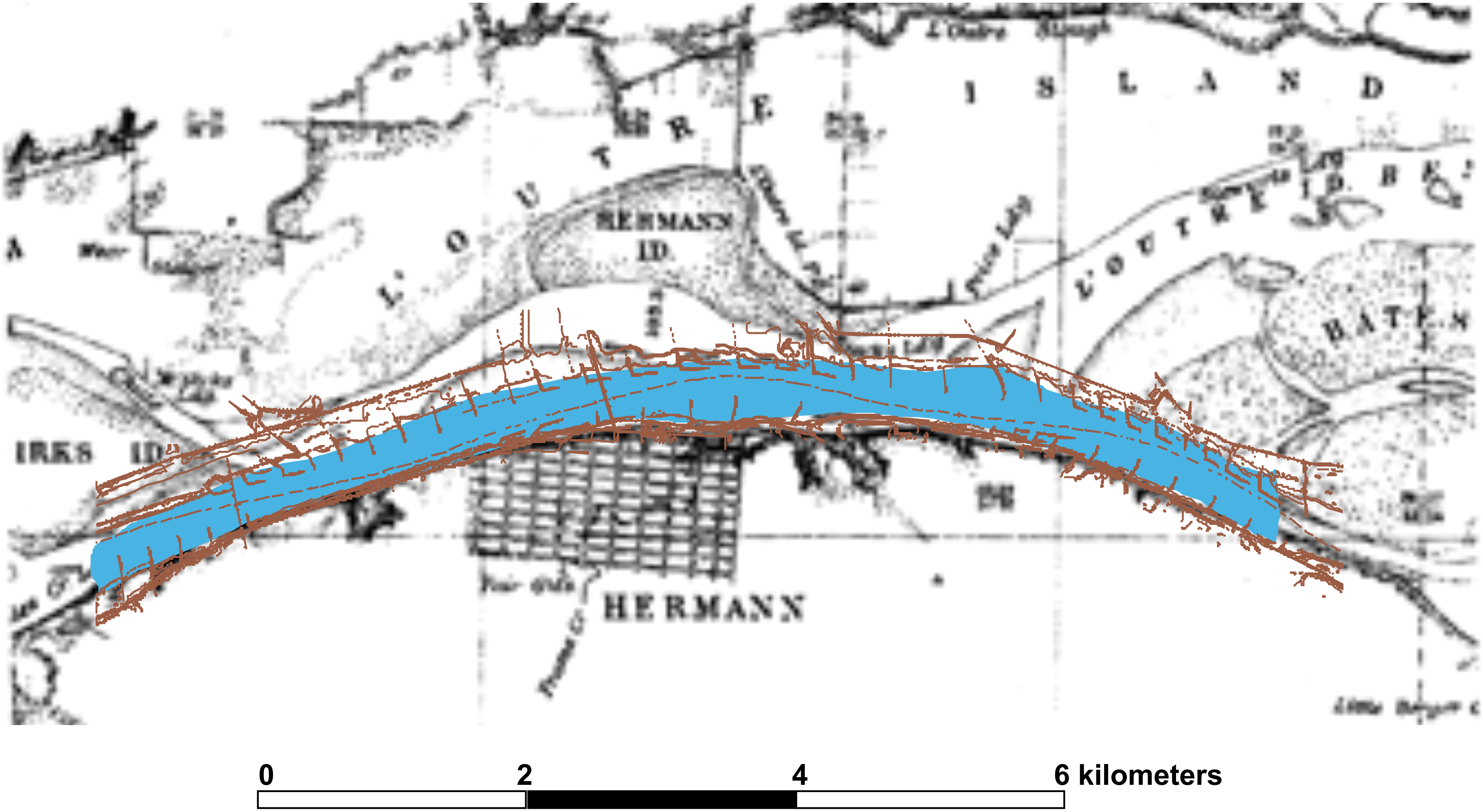

• Six Corps reservoirs
• Mainstem storage: 91 km³
• 10 BKWH avg. annual hydropower
• Other dams: 40 km³
(National Map, 2006)
Fort Peck
Sakakawea
Canyon Ferry
Oahe
Sharpe
Francis Case
Lewis & Clark
0 100 200 400 Kilometers
USGS

Lower Missouri River at Hermann, Missouri
Missouri River Commission Maps - 1894



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Modeling Approach

Hydrologic time series

How much, when

- Historical
- Modeled historical
- Modeled future
  - GCM and scenario
  - Downscale
  - Mitigation scenario
  - ....

82 years of historical inflows with current reservoir management – USACE HEC-ResSim model

Hydraulics

Where water goes

- Floodplain scenarios
- Models:
  - 1-dimensional
  - 2-dimensional
  - Surface + groundwater
  - …

USACE- HEC-RAS

USGS-constructed 2-dimensional model (TuFlow)

Ecological endpoints

- Magnitude, duration, frequency, timing..
- Spatial characteristics
- Habitat availability
- Explicit bioenergetics
- Ecosystem services
- …

Regulating services:

- **Flood-risk reduction**
- **Denitrification**

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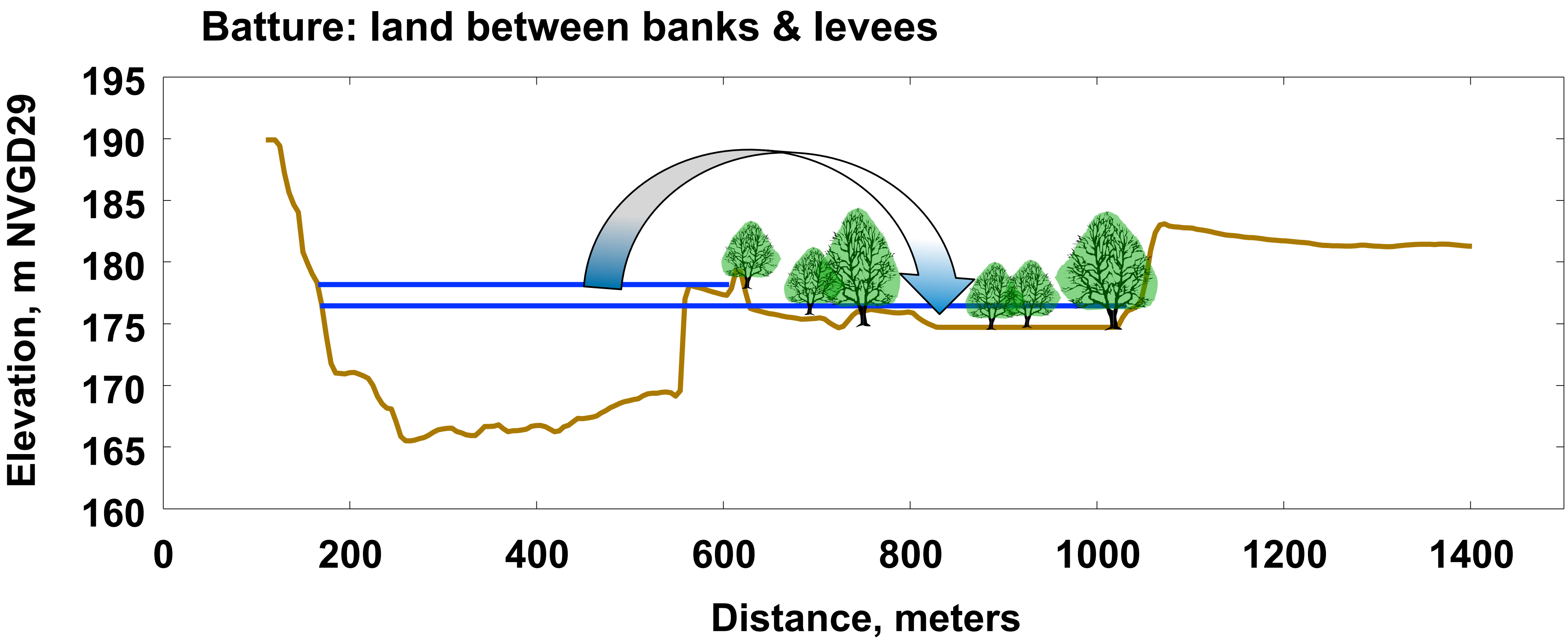
Local Stage Effects, Conversion from Ag to Conservation



Conservation of Mass:

$V =$

Hydraulic roughness – vegetation interaction

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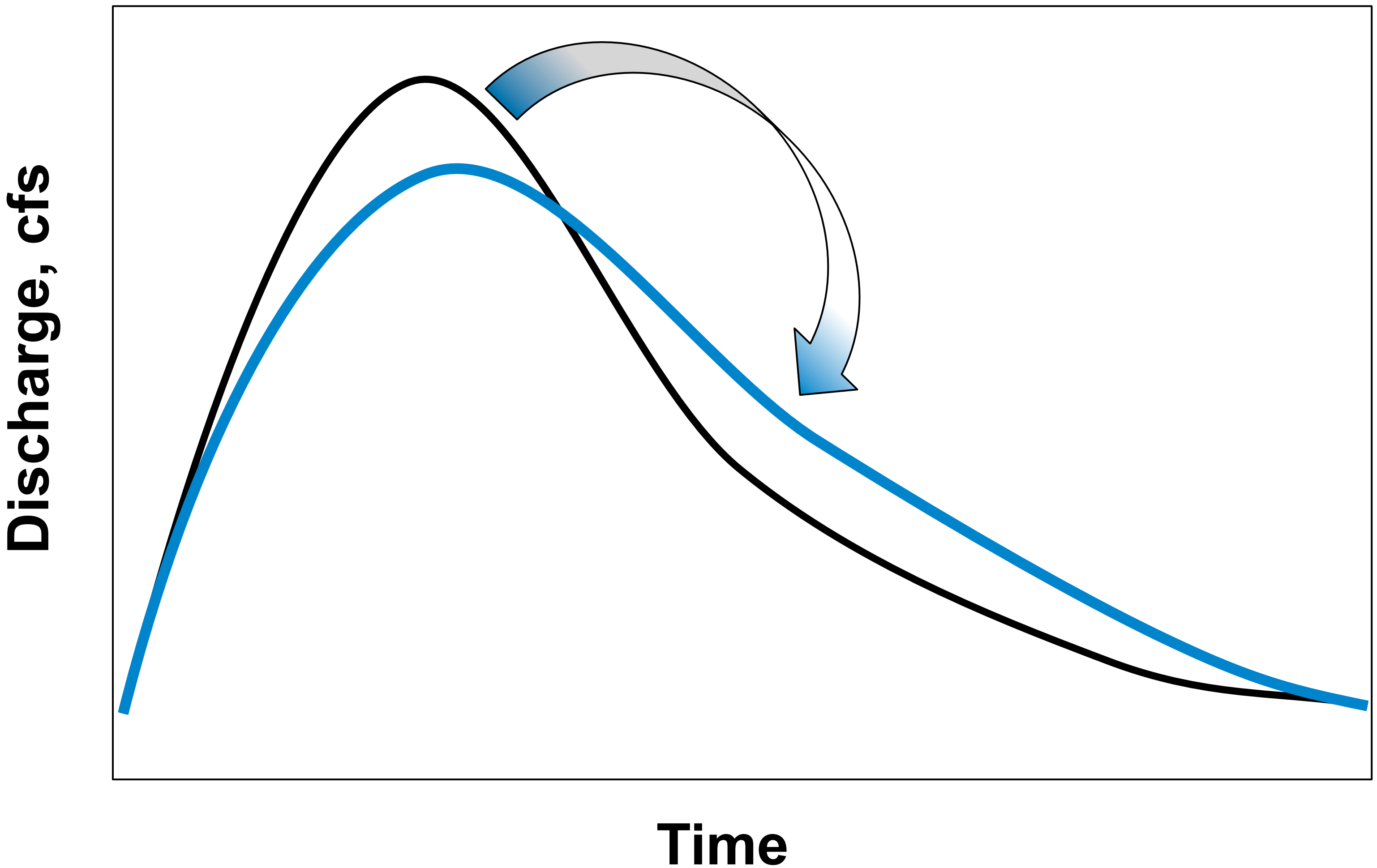
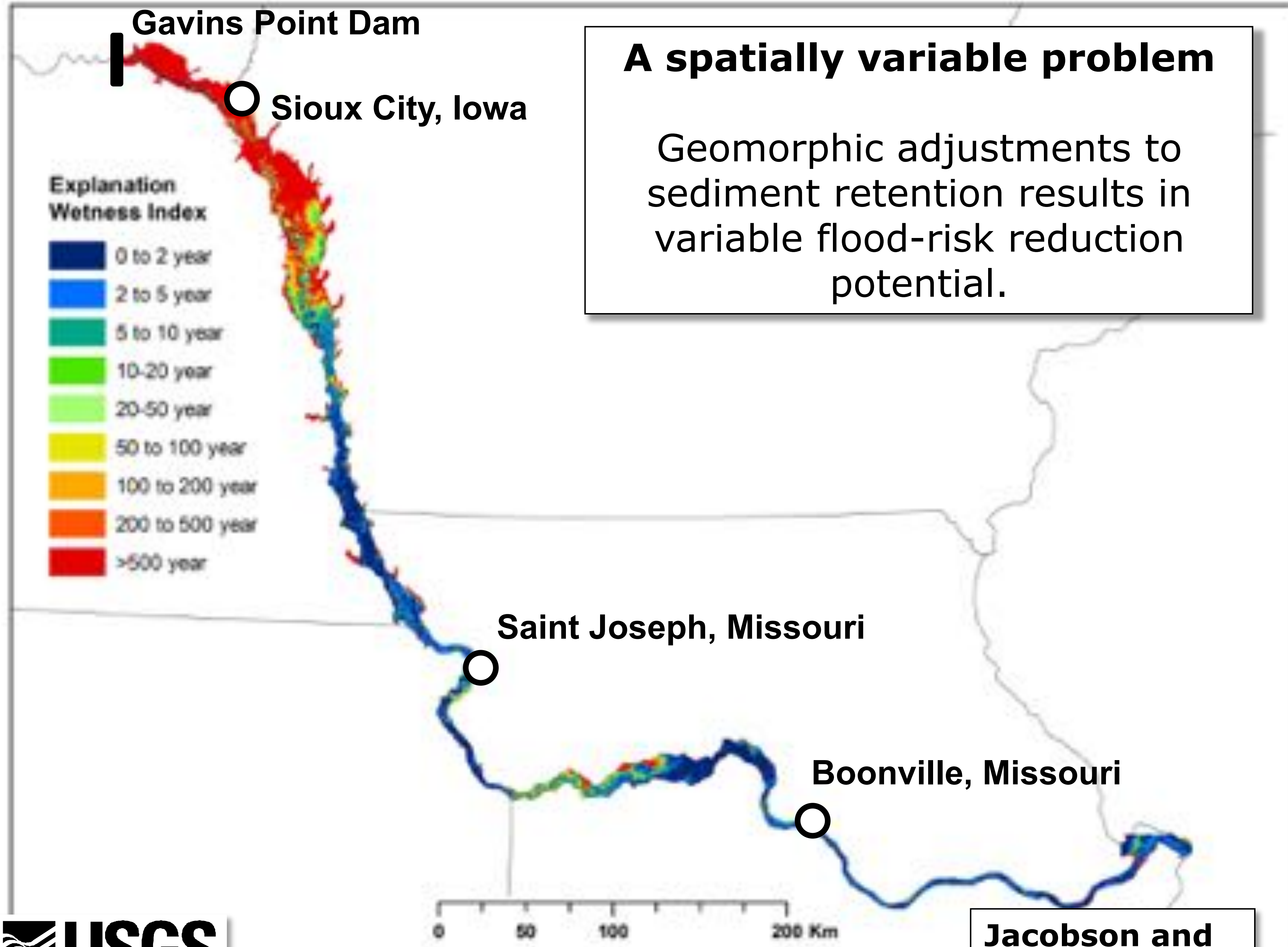
Attenuation Effects, Conversion from Ag to Conservation



A spatially variable problem

Geomorphic adjustments to sediment retention results in variable flood-risk reduction potential.



Jacobson and others, 2011

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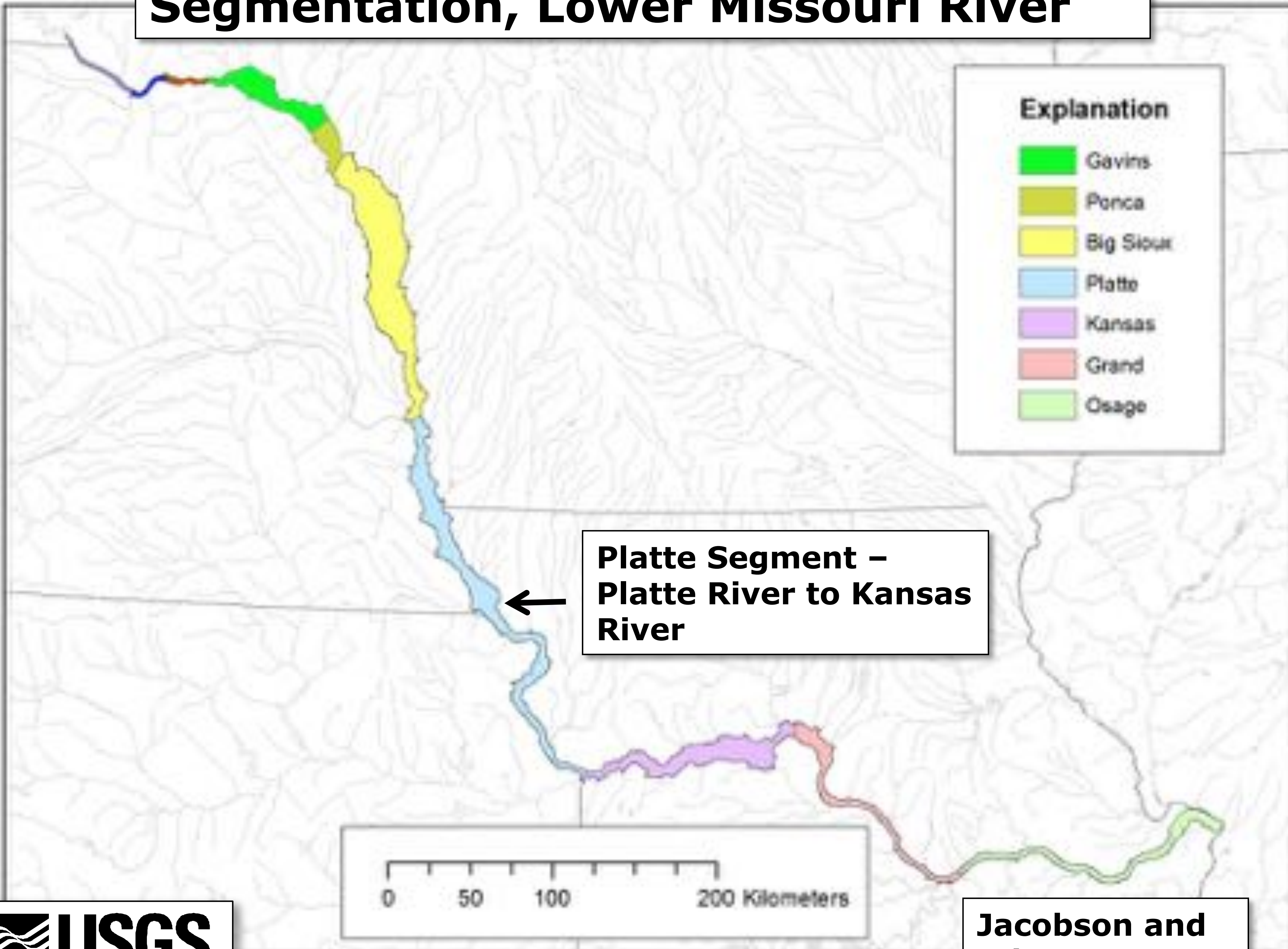
Segmentation, Lower Missouri River



Platte Segment – Platte River to Kansas River

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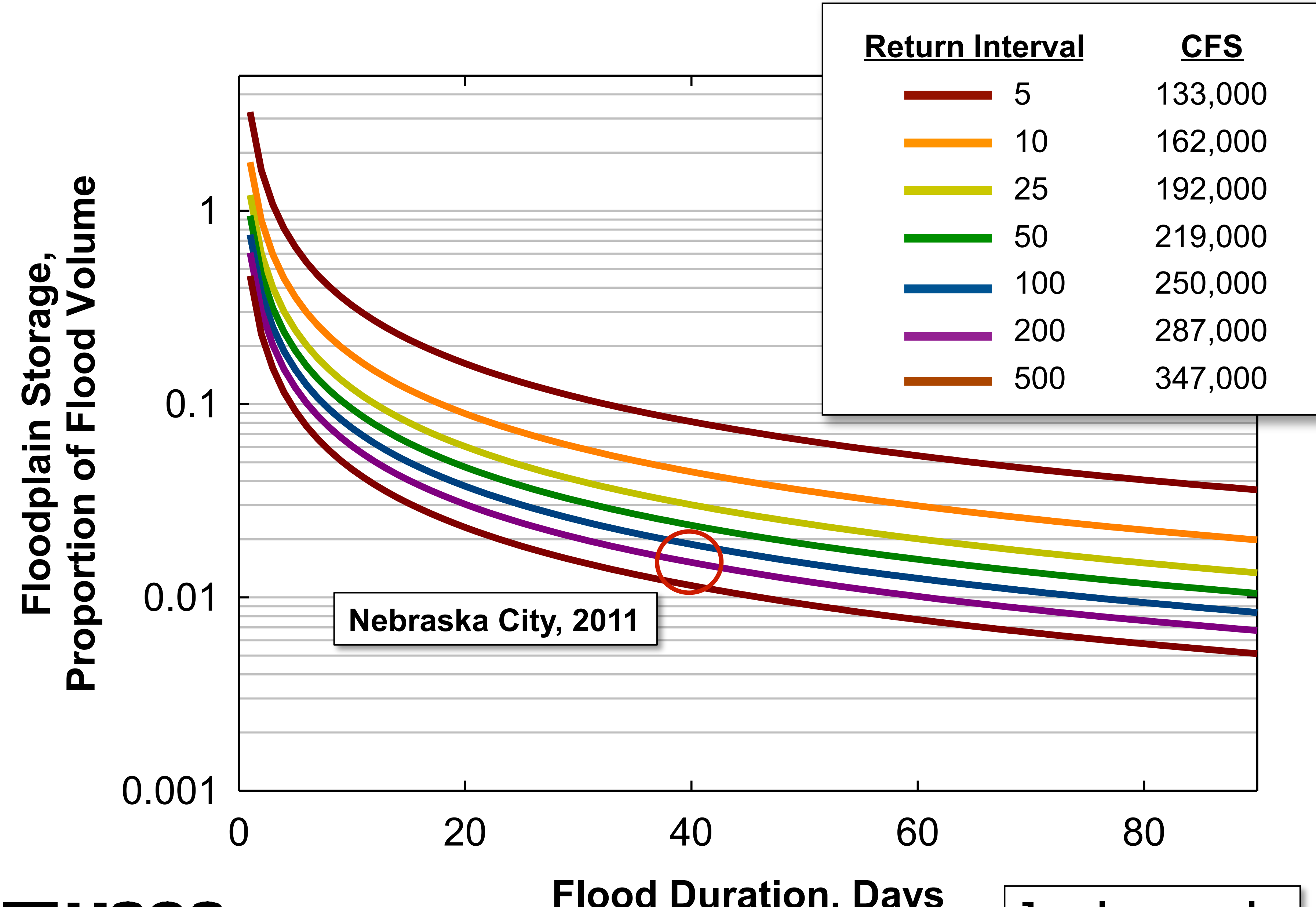
Jacobson and others, 2010

Flood Volume Potential – Platte Segment



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Jacobson and others, 2015

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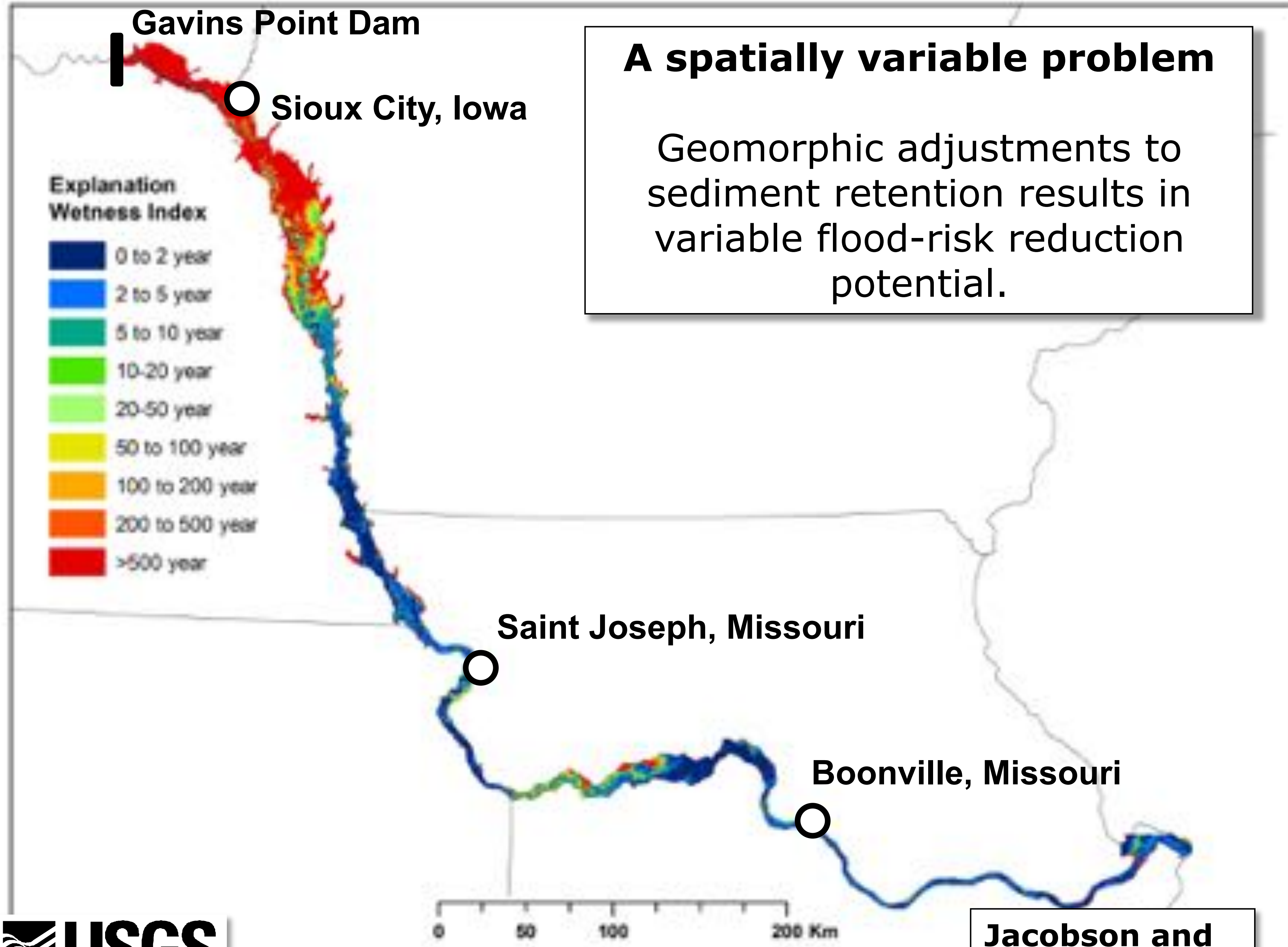
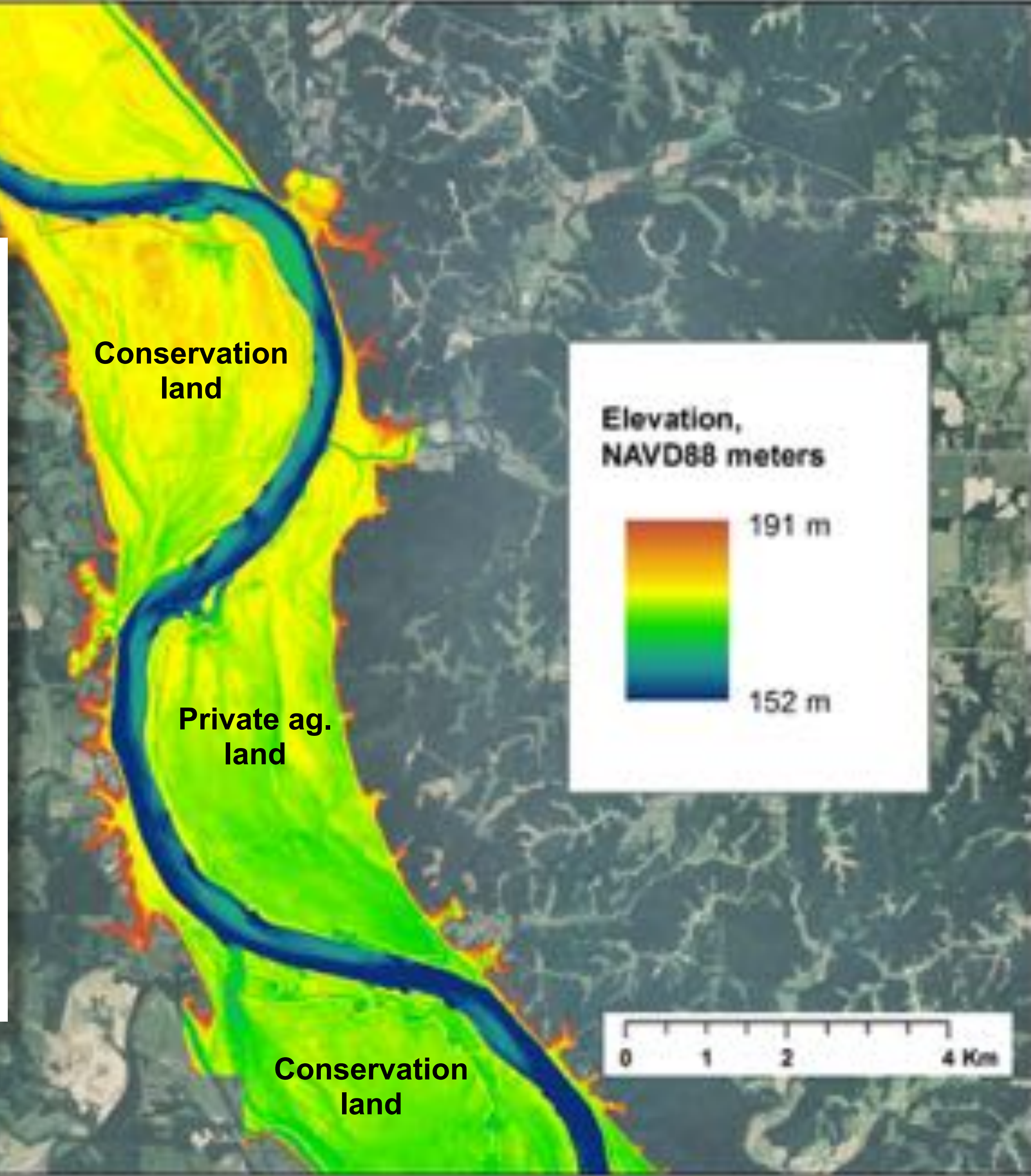


Jacobson and others, 2011

Unsteady 2-dimensional flow model

Used 2007 10-year flood to assess scenarios with variable levee setbacks from present day to no levees.

Jacobson and other (2015)



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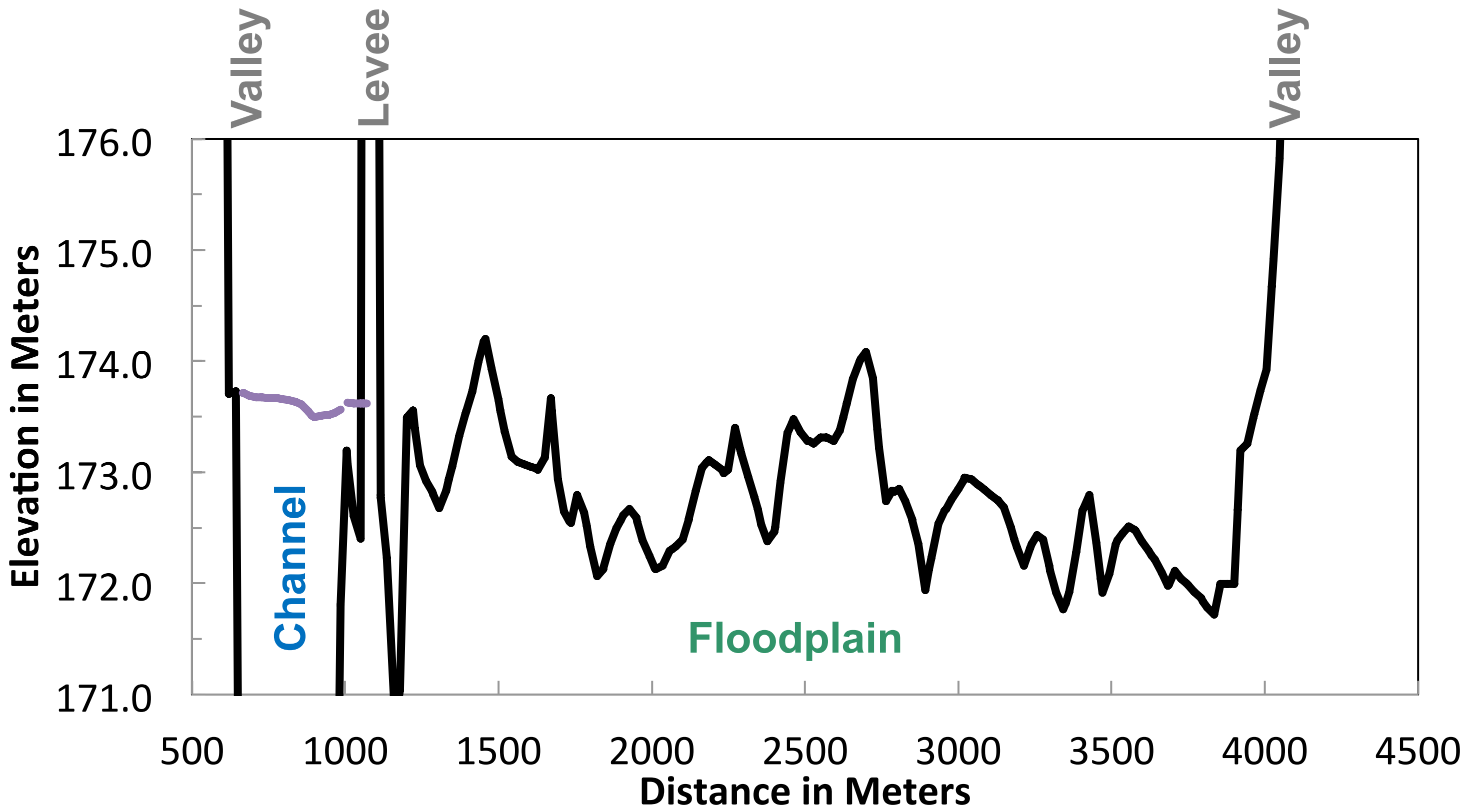
Vertical Cross Section, Looking Downstream
294,000 cfs, Approximately 5-year Return

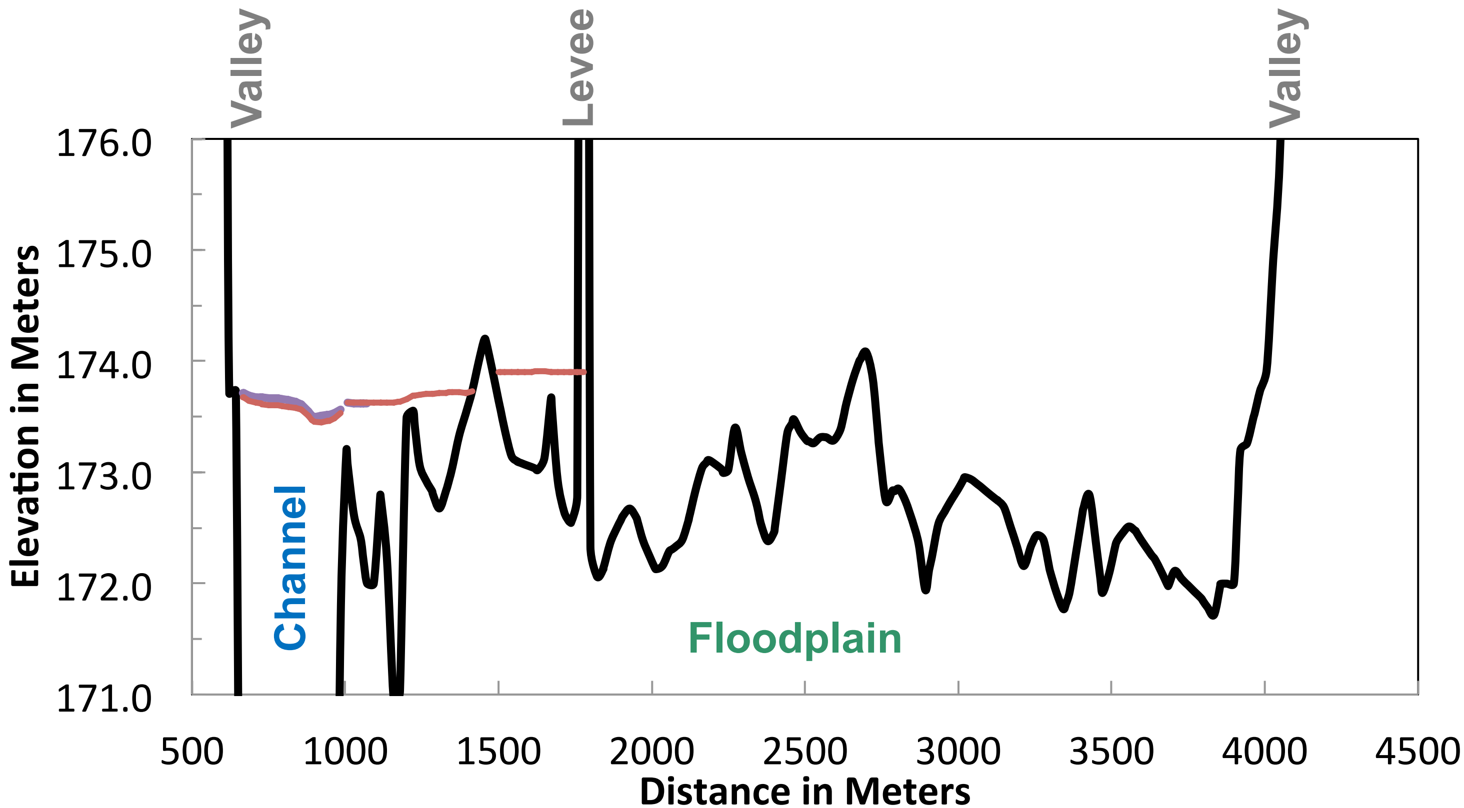


Pre-1993 Levee Alignment
Low Floodplain Roughness
n = 0.05

Jacobson and others, 2015

USGS

Vertical Cross Section, Looking Downstream
294,000 cfs, Approximately 5-year Return

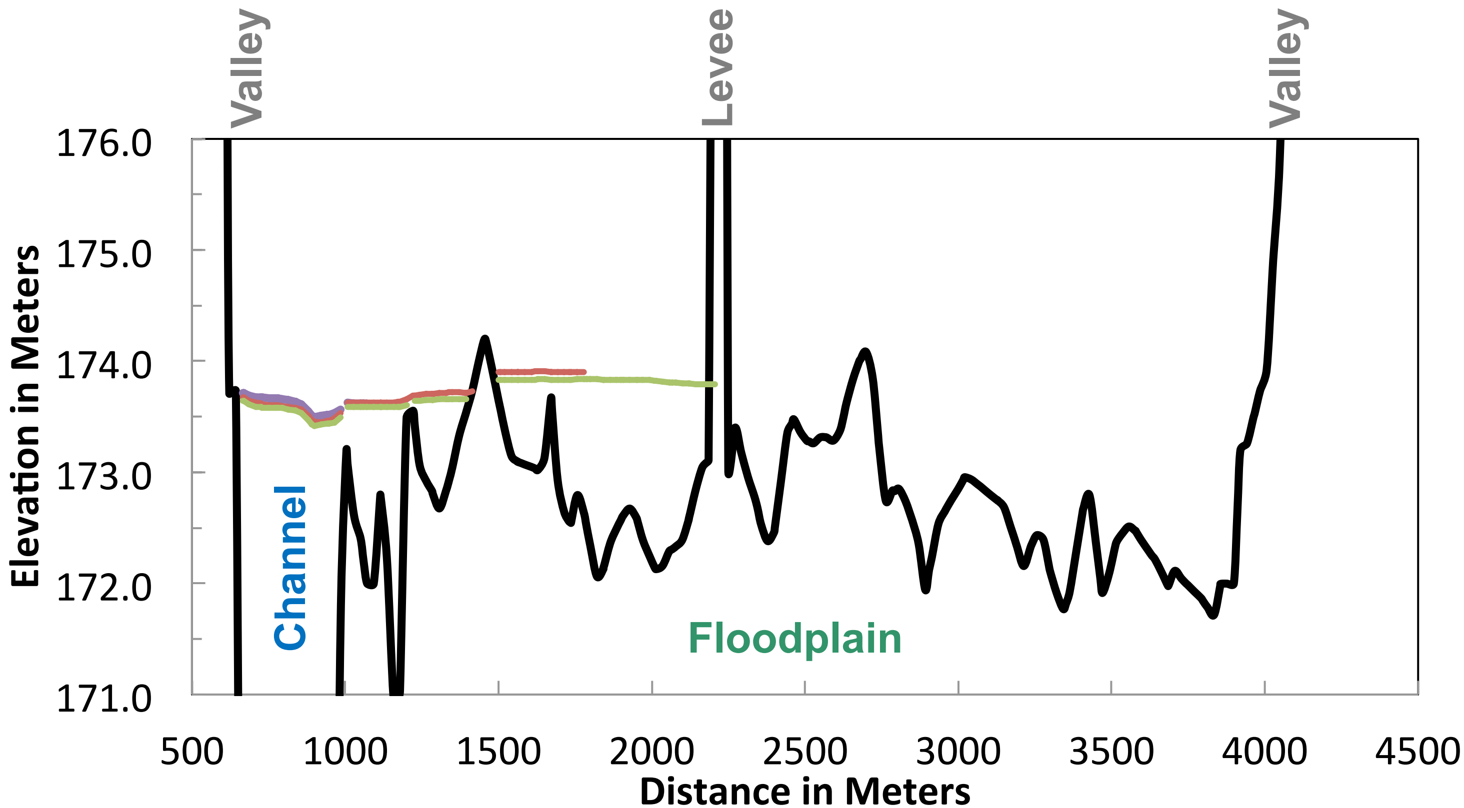


3,750 Ft. Floodway
Low Floodplain Roughness
n = 0.05

Jacobson and others, 2015

USGS

Vertical Cross Section, Looking Downstream
294,000 cfs, Approximately 5-year Return

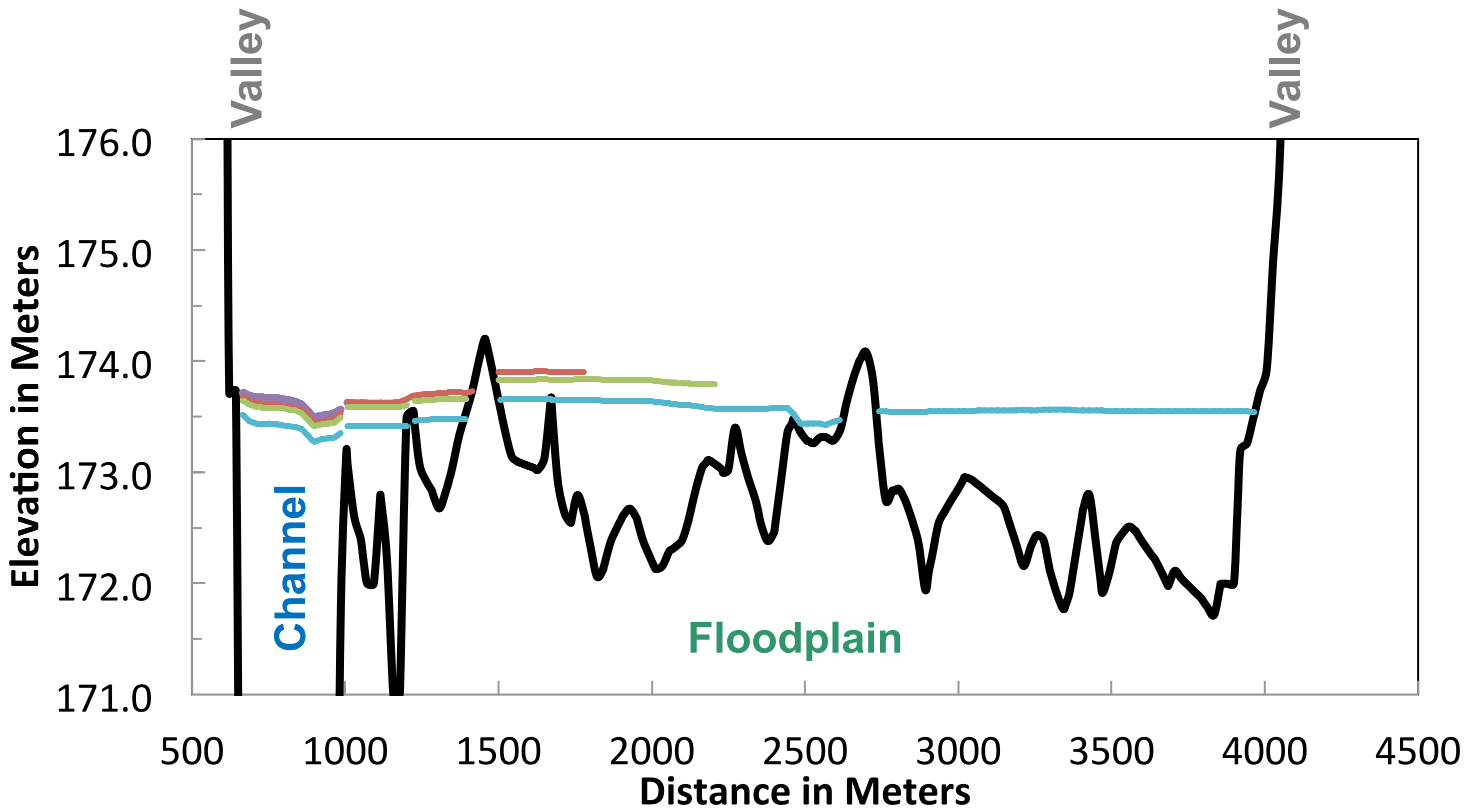


5,000 Ft. Floodway (Pick Plan, 1944)
Low Floodplain Roughness
n = 0.05

Jacobson and others, 2015

USGS

Vertical Cross Section, Looking Downstream
294,000 cfs, Approximately 5-year Return



No Levee Scenario
Low Floodplain Roughness
n = 0.05

Jacobson and others, 2015

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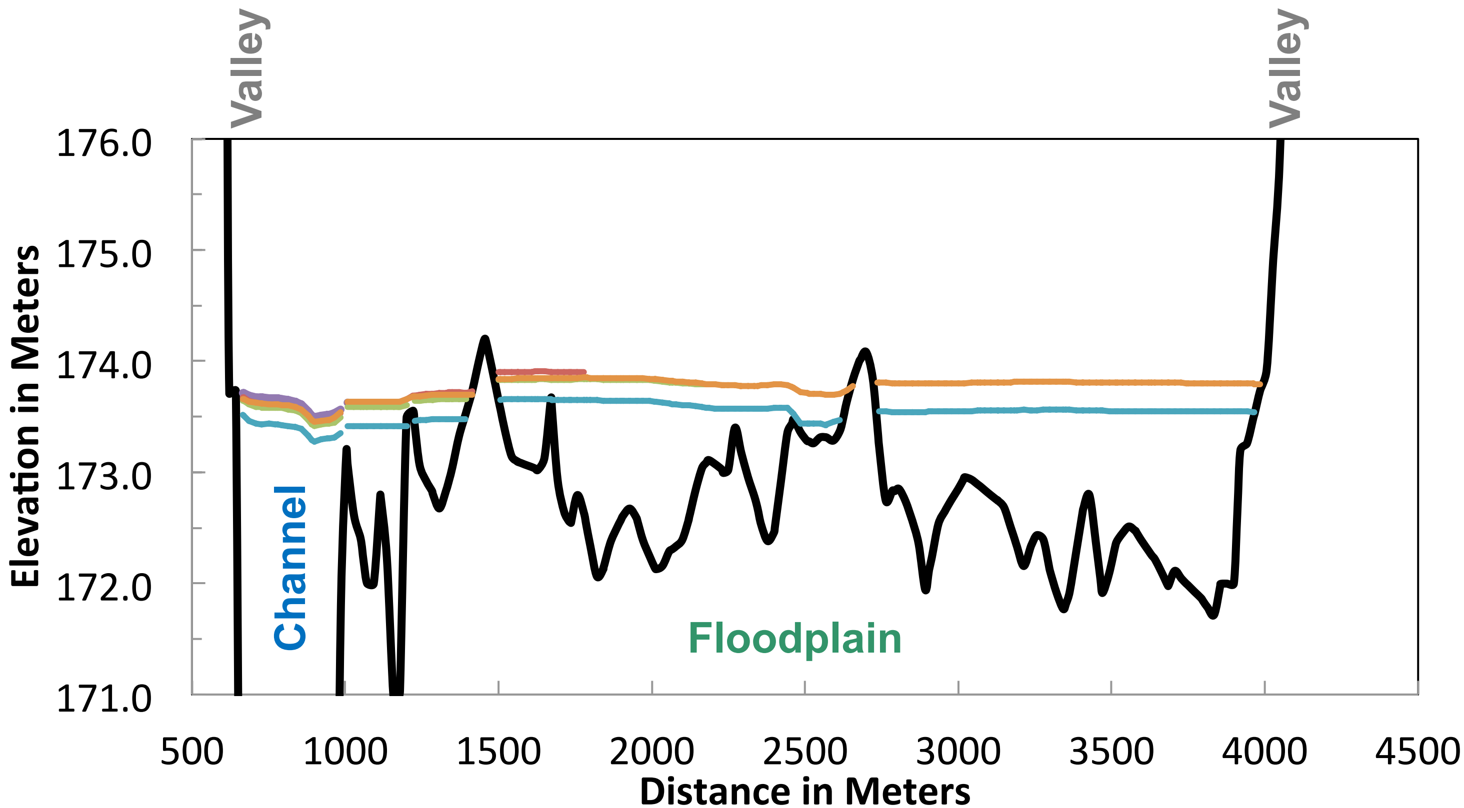
Vertical Cross Section, Looking Downstream
294,000 cfs, Approximately 5-year Return



No Levee Scenario
High Floodplain Roughness
n = 0.20

Jacobson and others, 2015

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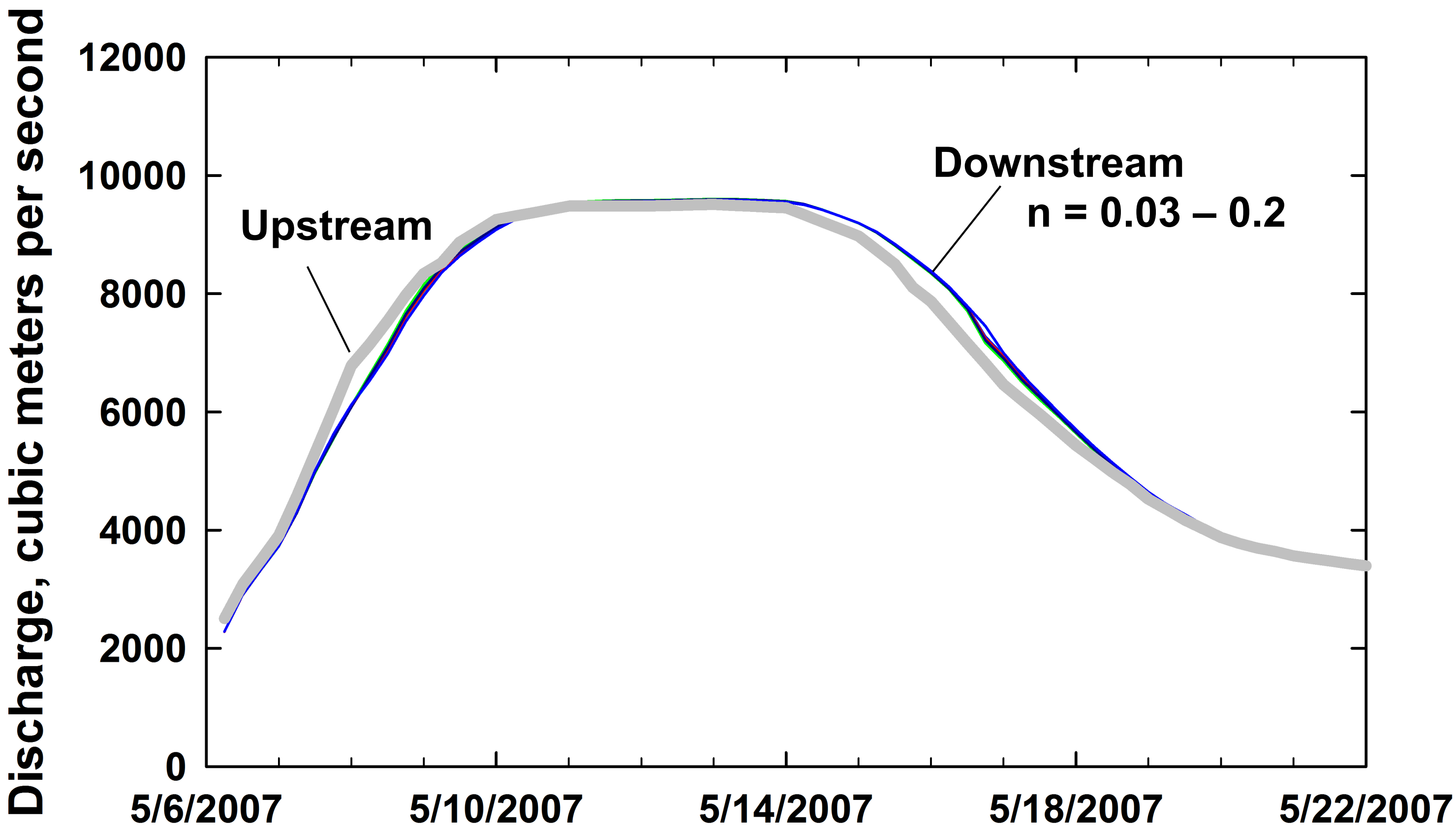
2007 10-year flood routed through no-levee model



- Little attenuation is apparent
- Caveat: modeled area is relatively small, about 13 river miles, 19 square miles of floodplain.
- Deformation of rising limb suggests < 5 year flood affected

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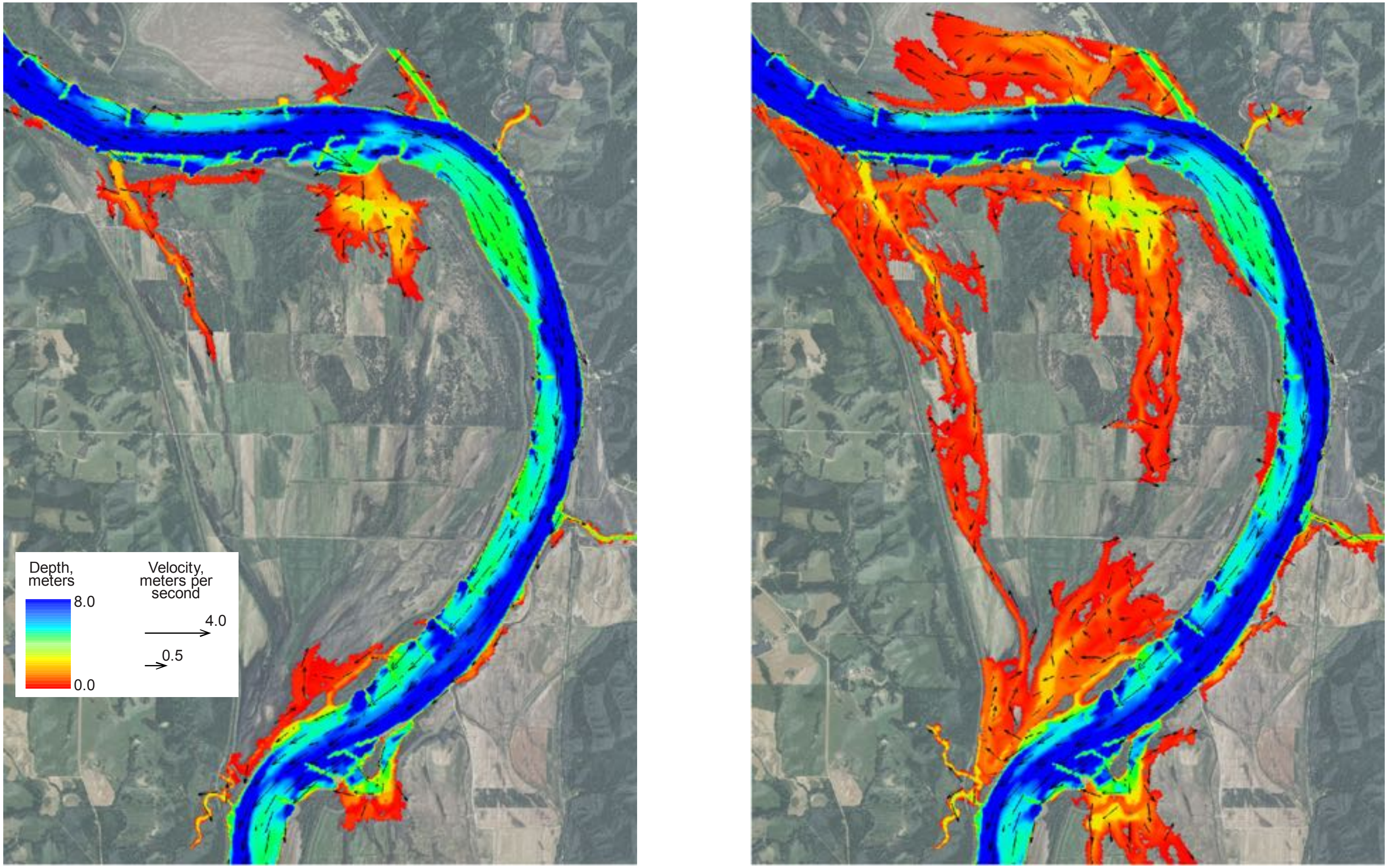
Jacobson and others, 2015

Floodplain Storage in Low-lying Areas, 2-5 Year Frequency Floods
No-Levee Scenario



5/8/2007
12:00 hours
7,754 m^3/s

5/8/2007
18:00 hours
8,165 m^3/s

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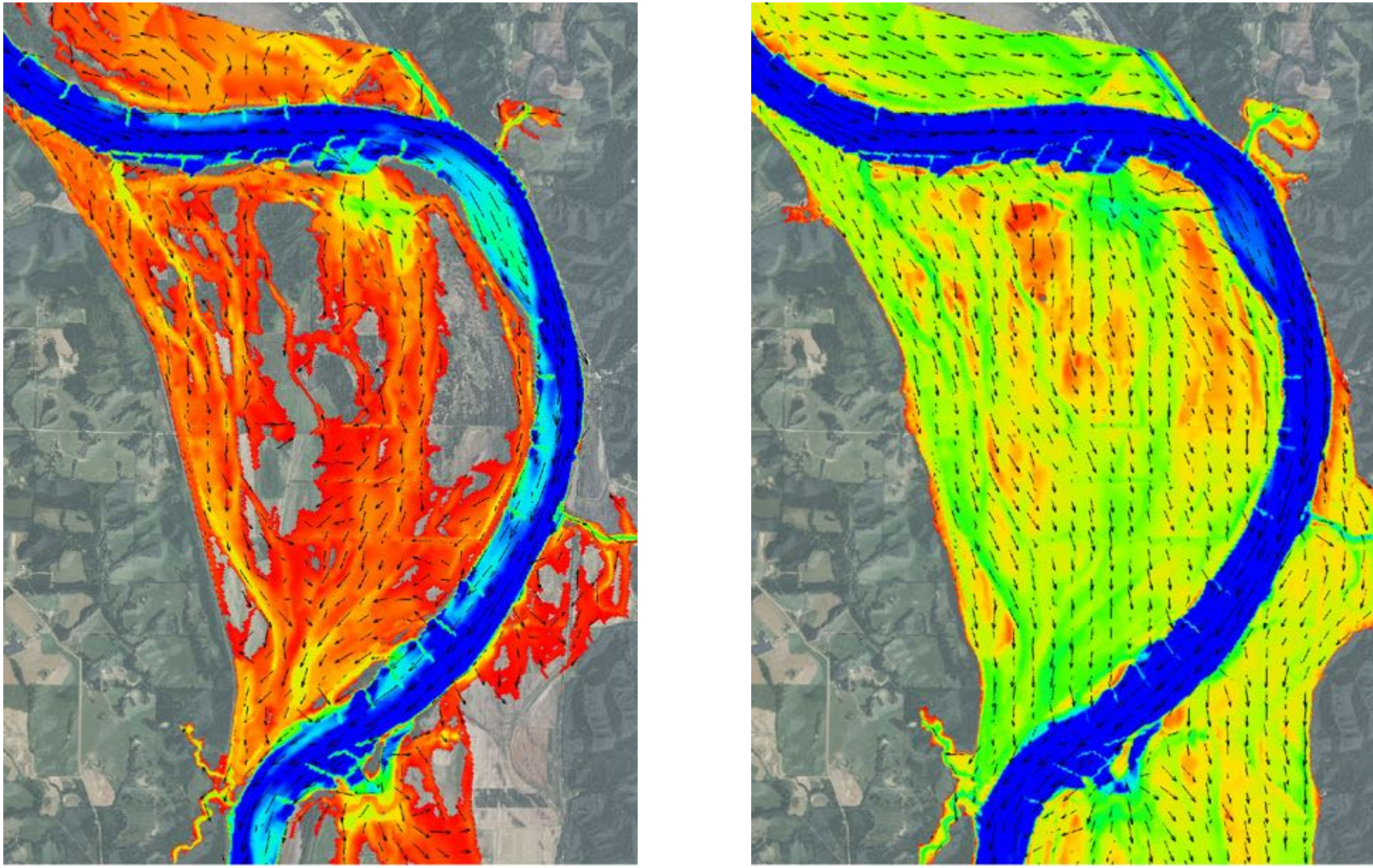
Jacobson and others, 2015

Floodplain Convyance, > 5-Year Frequency Floods
No-Levee Scenario



5/9/2007
0:00 hours
8,575 m3/s

5/11/2007
0:00 hours
9,565 m3/s

Jacobson and others, 2015

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Common ground in flood-risk reduction?

- Local stage effects can be substantial, on the order of a meter, but roughness mediates.
  - What is land cover in set-back area?
- Attenuation can be effective on smaller floods – how big depends on area, storage, conveyance
- Conservation lands avoid flood damages, thereby diminish hazard (=probability x consequence).

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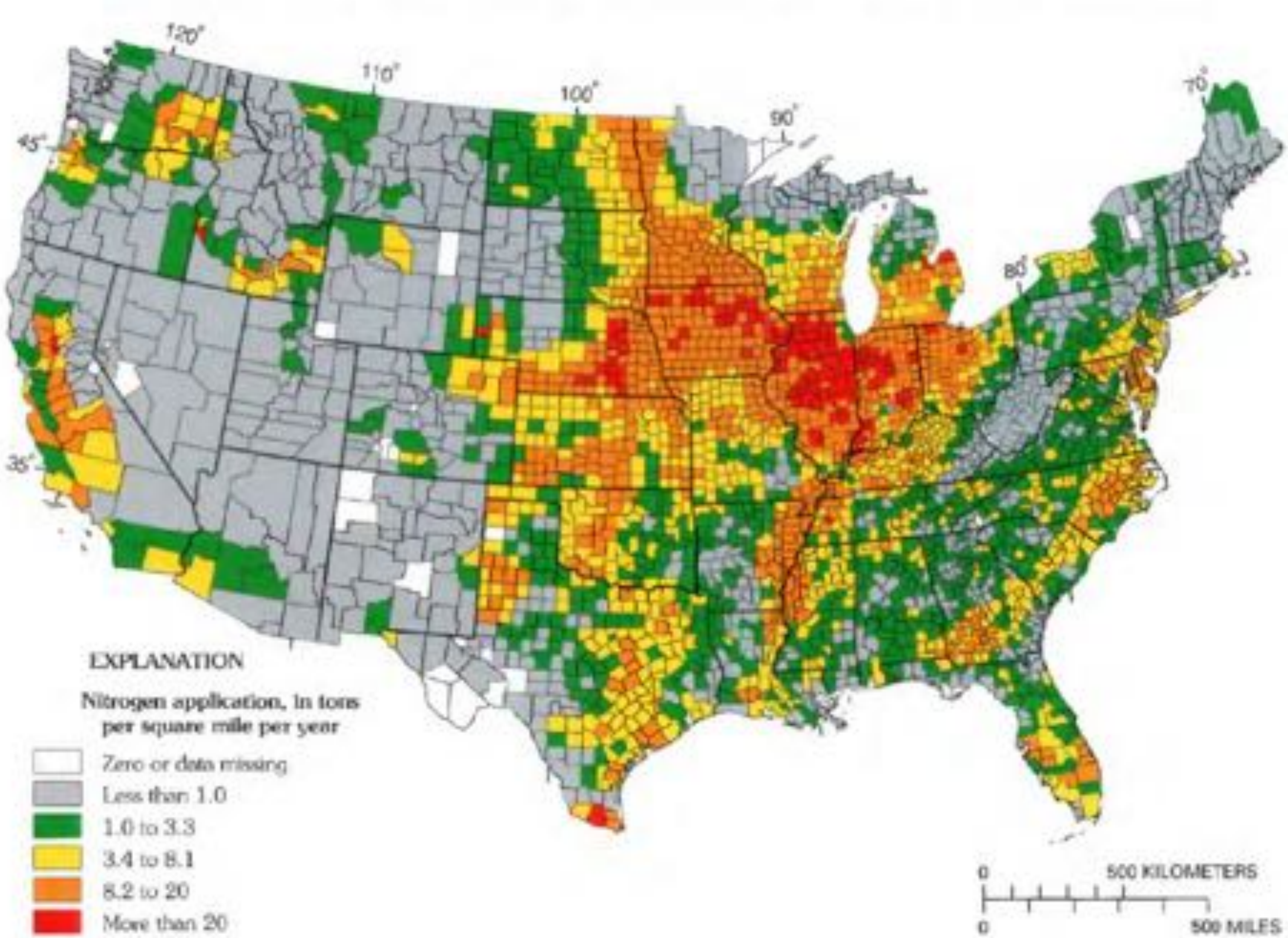
Non-point source agricultural chemicals
Nitrogen Applications, Mississippi Basin

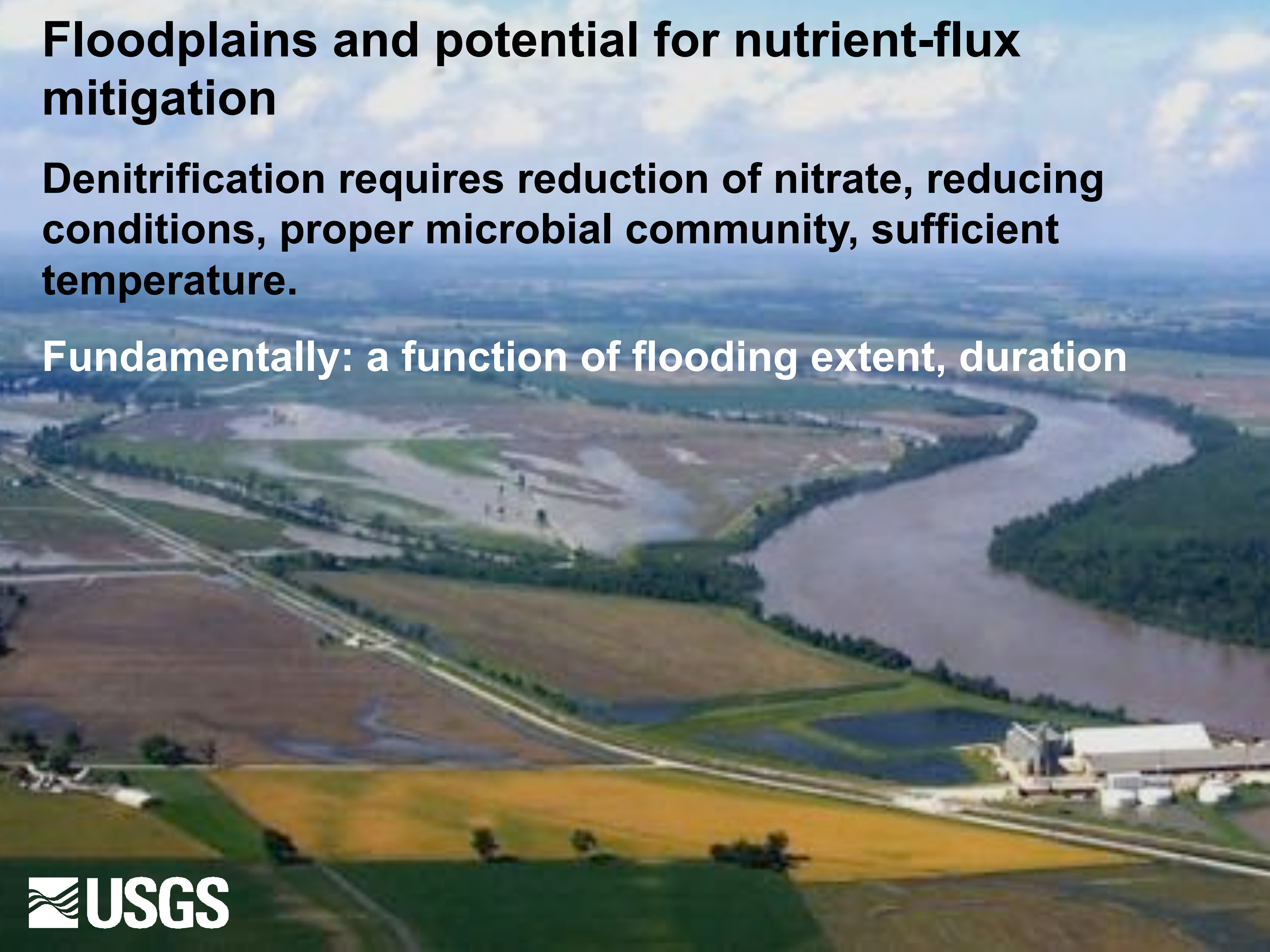


From Meade, R.H., (1995)

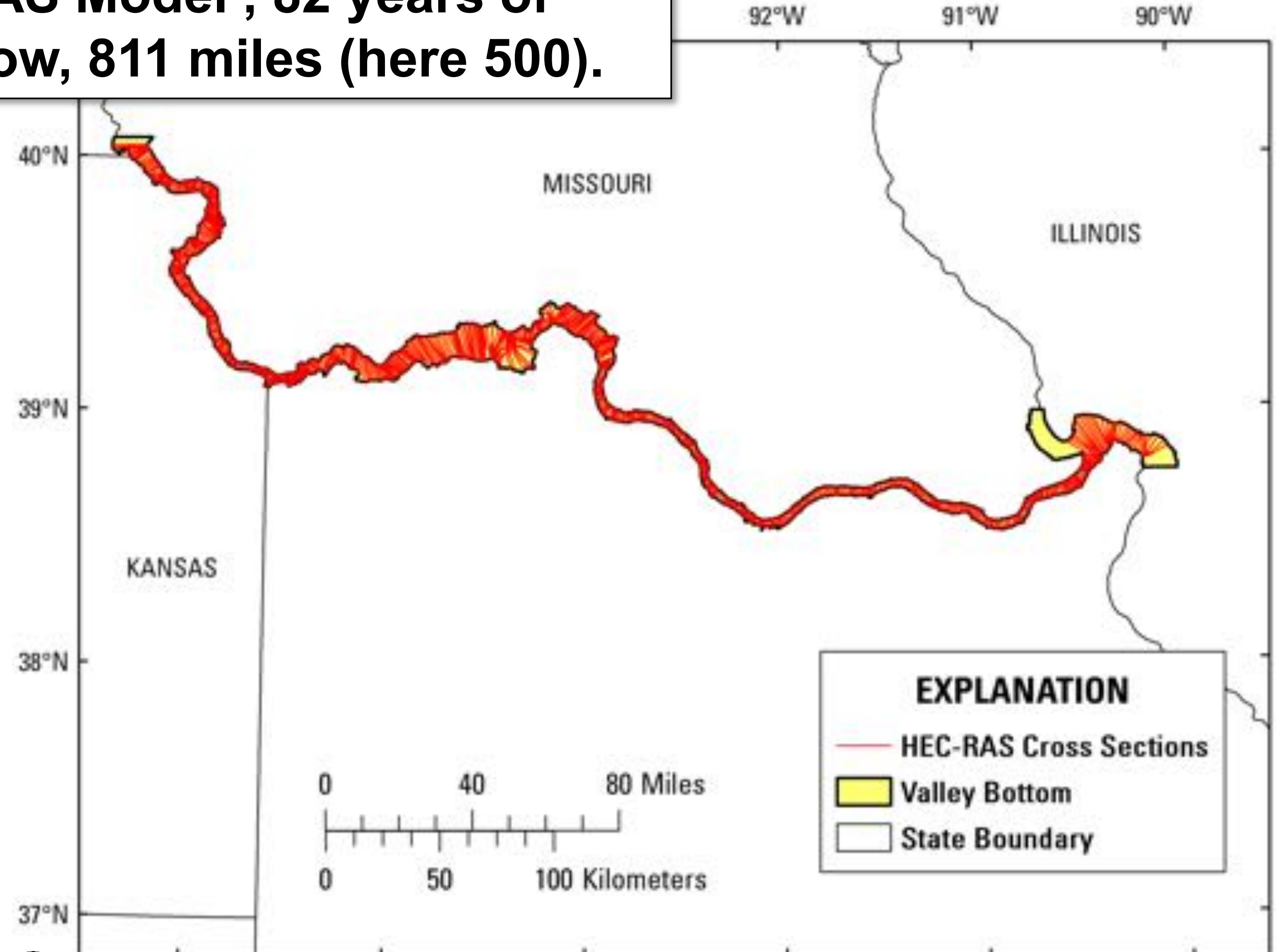
Floodplains and potential for nutrient-flux mitigation

Denitrification requires reduction of nitrate, reducing conditions, proper microbial community, sufficient temperature.

Fundamentally: a function of flooding extent, duration



Inundation based on USACE HEC-RAS Model , 82 years of daily flow, 811 miles (here 500).



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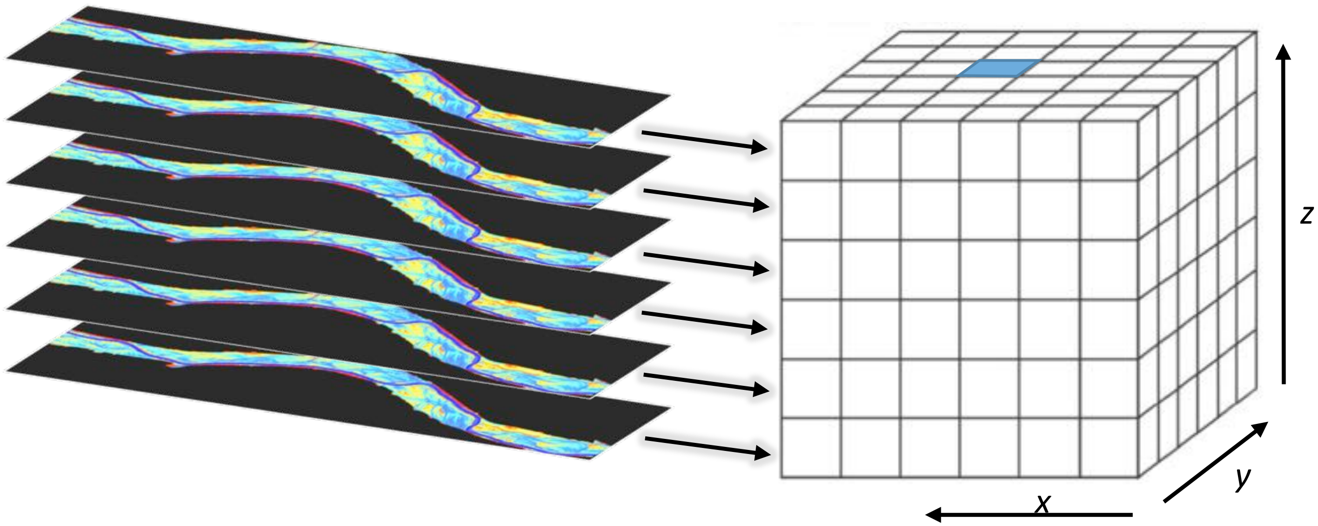
Lindner, Bulliner, in prep.

LMOR HEC-RAS model daily matrices



Structured 3-dimensional matrix of data

x and *y* are geospatial coordinates

z is time coordinate (30,256 days)

Water depth  for each x,y,z

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Lindner, Bulliner, in prep.

- **What are annual totals and averages in square km x days that floodplain is inundated to at least 0.5 m during May – October in this 500-mile segment?**
- **What is resultant potential denitrification? And how does it relate to river N fluxes?**

	Long-term averages			
	Low rate*	High rate**	Low rate*	High rate**
	8 $mg/m^2/d$	300 $mg/m^2/d$	8 $mg/m^2/d$	300 $mg/m^2/d$
	Metric tons/year		Percent measured load	
Batture	96	3,593	0.05%	1.71%
Full floodplain	204	7,656	0.10%	3.64%
Annual N load at Hermann, MO: 210,248 metric tons				

*Hurst and others (2016)
**Blevins (2004)

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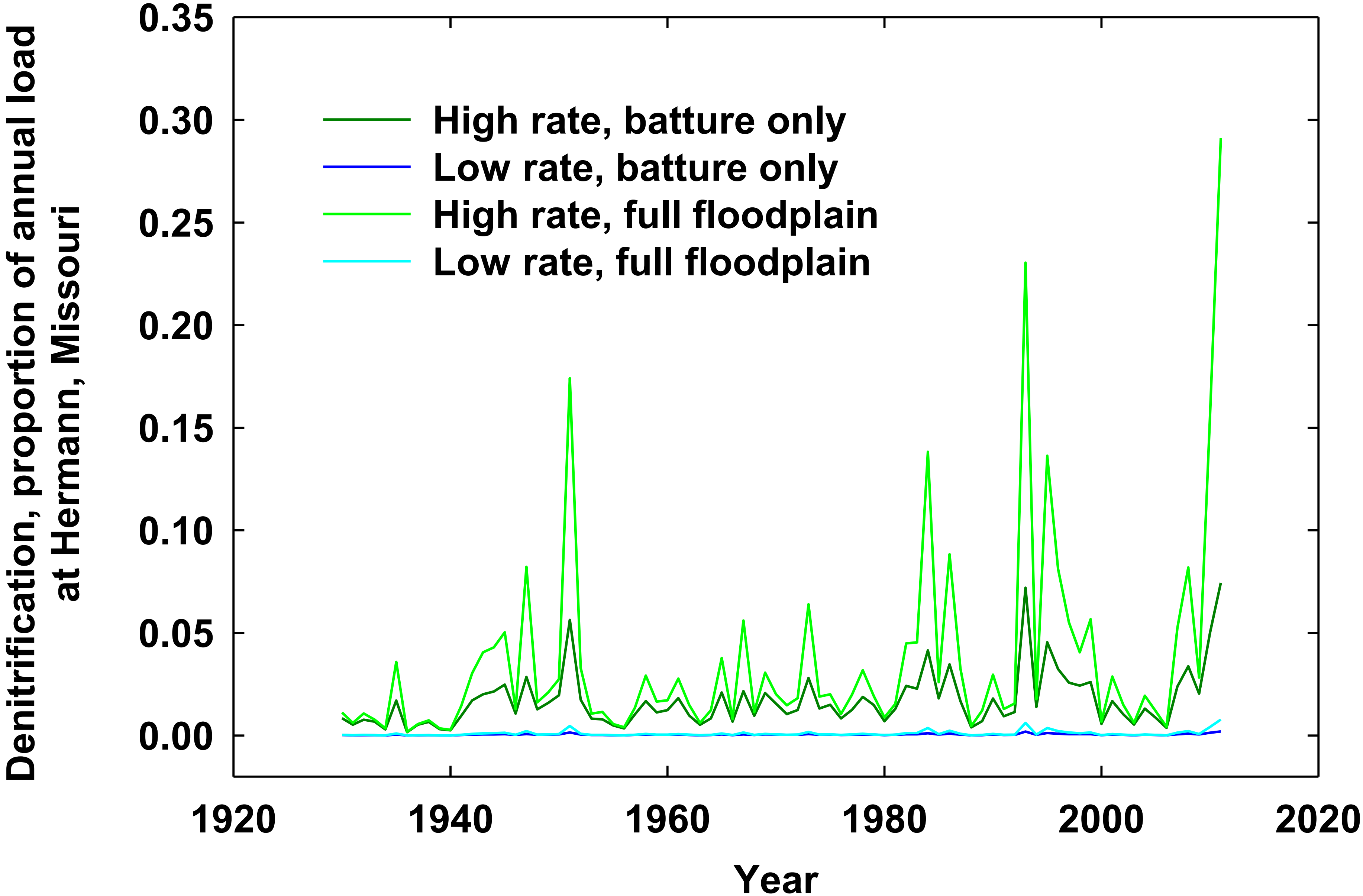

Batture is about 30% of entire floodplain in this segment

Common ground in nutrient mitigation?

- **Big, long floods and complete connectivity can attain appreciable denitrification.**
  - **But in most years the potential is < 4% of background flux under optimal circumstances**
- **Hot spots – oxbows, tributary junctions, some batture wetlands – may achieve higher rates. Little Bean Marsh was NO_3- limited.**
- **Intensive engineering of denitrification may achieve higher intrinsic rates.**
- **Generally indicates limitations of large-river floodplain mitigation and need to address nutrients at the field scale, throughout the watershed.**

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Conclusions

- Ecological restoration and agricultural conflicts are acute in large-river floodplains where objectives are highly divergent.
  - Dynamic and spatially variable systems require high resolution assessments and models.
- Two potential win-win solutions – flood risk reduction and nutrient mitigation – are marginal.
  - Floodplains cannot fully mitigate watershed stressors.
- Common ground between restoration and floodplain agriculture may depend on quantifying and summing a wider range of ecosystem services – hazard mitigation, recreation, alternative crops.

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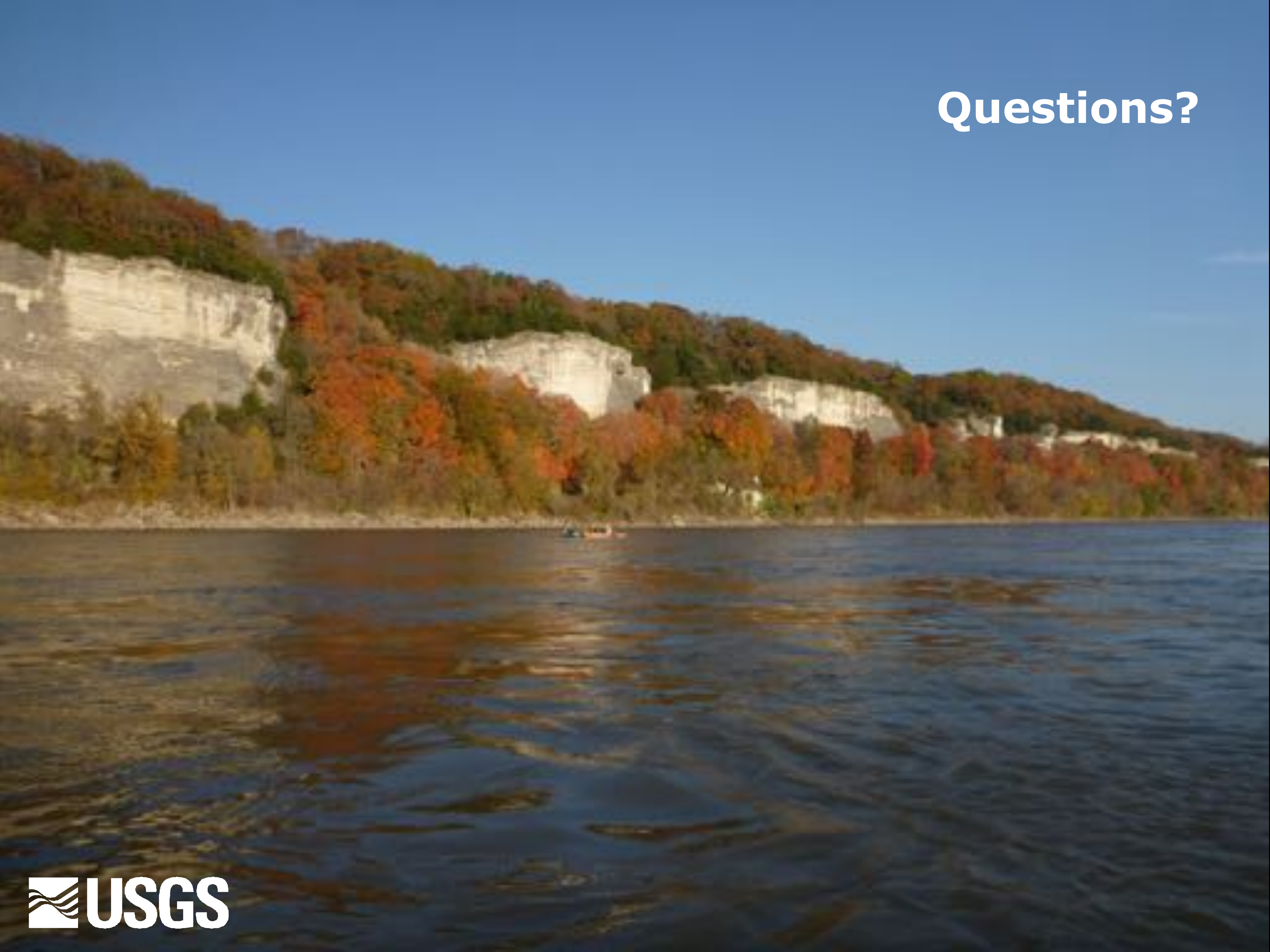
Questions?



Flood risk reduction: Avoiding damages to land and infrastructure

Photo: Lee Valley, Inc.

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ultural Lands

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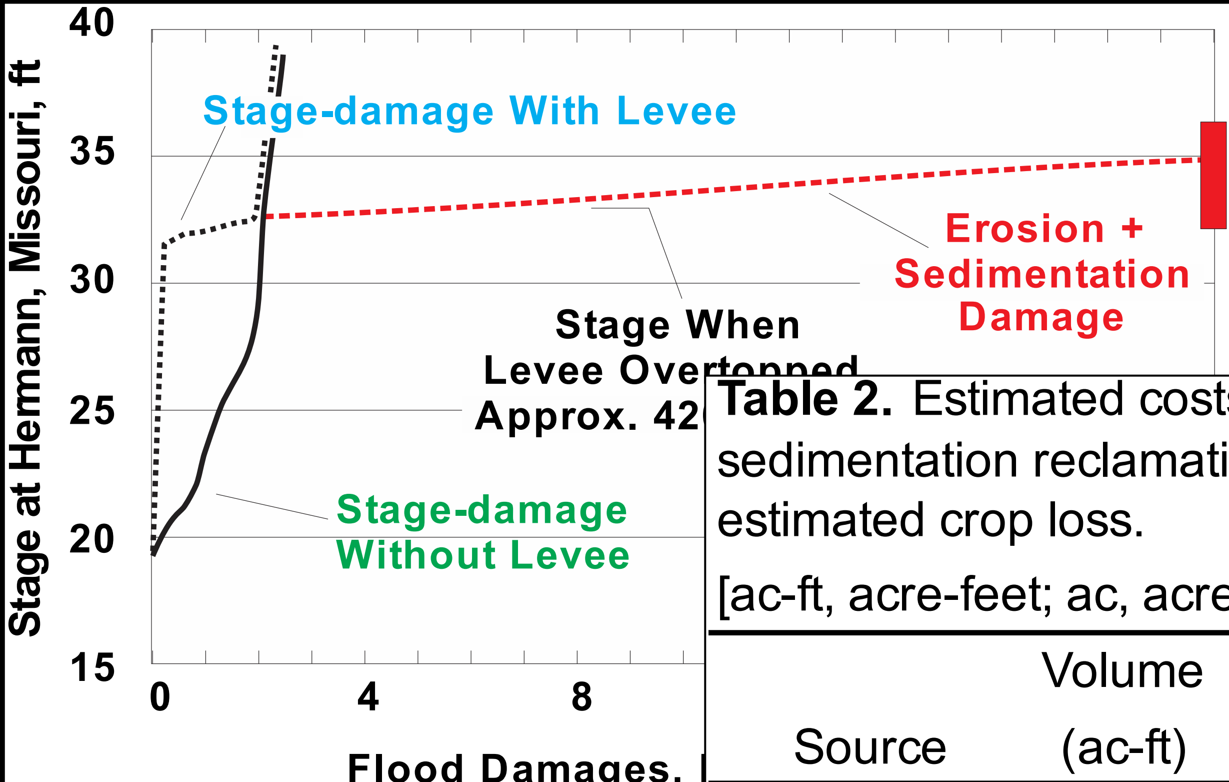

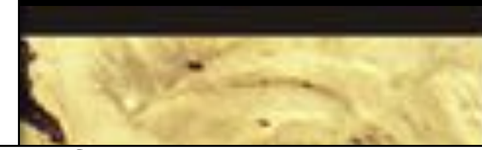

Table 2. Estimated costs of erosion and sedimentation reclamation at Berger Bottoms, and estimated crop loss.

[ac-ft, acre-feet; ac, acre; na, not applicable]

Source	Volume (ac-ft)	Volume (cubic-yards)	Cost (dollars)
Levee	na	424,000	$ 2,600,000
Scour	720	1,161,576	$ 7,000,000
Deposit	2,730		$ 8,800,000
Deep plowing, 6,160 ac @ $190/ac			$ 1,200,000
Total reclamation cost			$19,600,000
Crop damage costs			$ 2,200,000

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Jacobson (2003)

Reistance to Change


Photo: http://floodlist.com


Photo: http://www.talkvietnam.com

Mekong River is an example of a highly productive, relatively natural system.

Debate is about <u>conservation</u> of existing ecological value:

- **3.9 million metric tons of fish harvest**
- **$3.9 – 7.0 billion annual value**
- **Compared to gains in hydropower, sand, flood control**

USGS

Image: Google Earth

Resistance to Change

Missouri River is an example of a river that is already highly altered, highly developed:

- **Management debate is about <u>restoration</u> of some natural ecosystem processes and productivity.**
- **Ecological gains are uncertain and require vision.**
- **Economic losses from restoration -- represented by ~11 million metric tons of corn production-- are perceived as certain; a difficult threshold to cross.**