Watershed-scale sediment budget in the Le Sueur River, Minnesota, for turbidity management and future rehabilitation efforts

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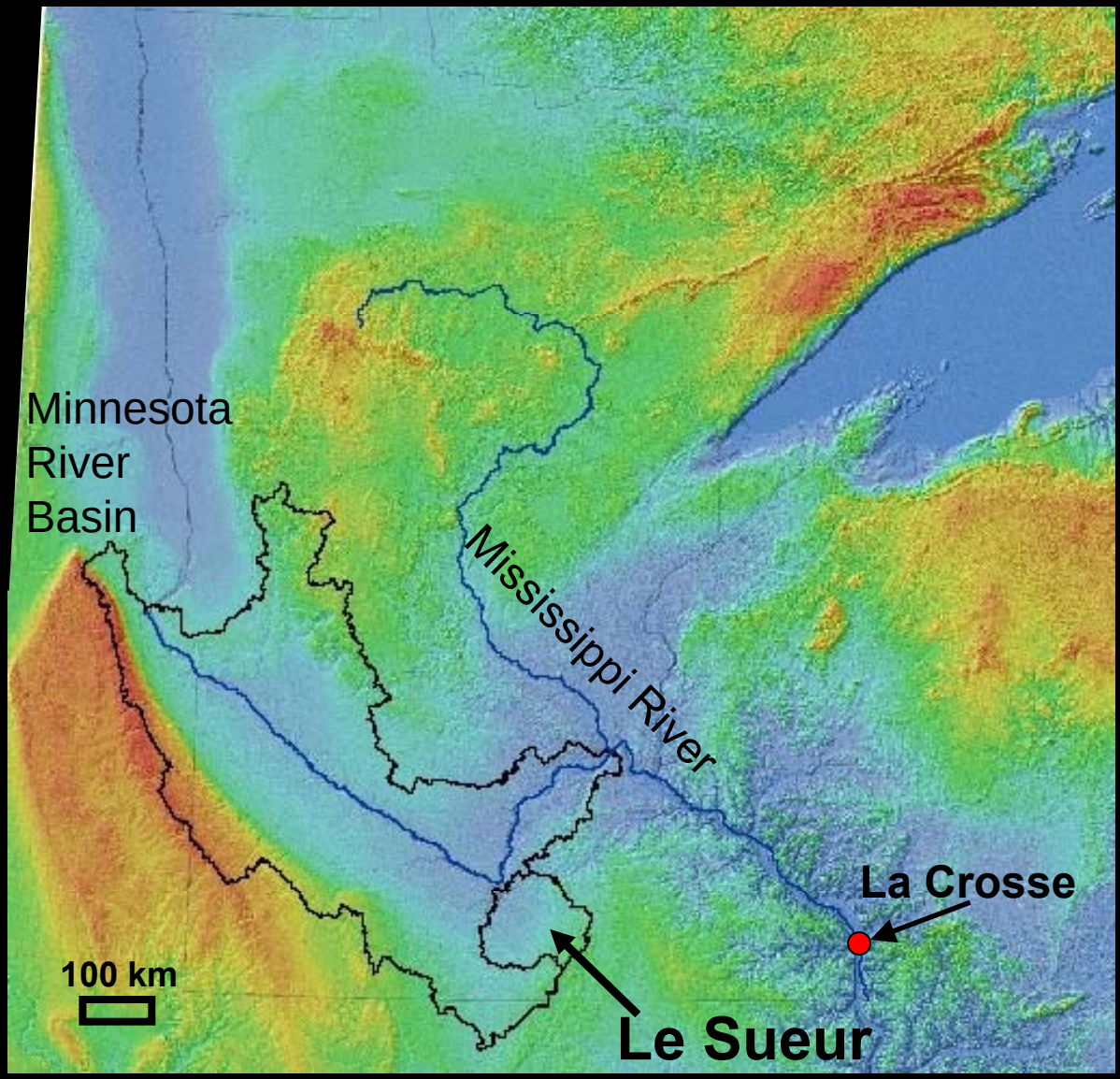
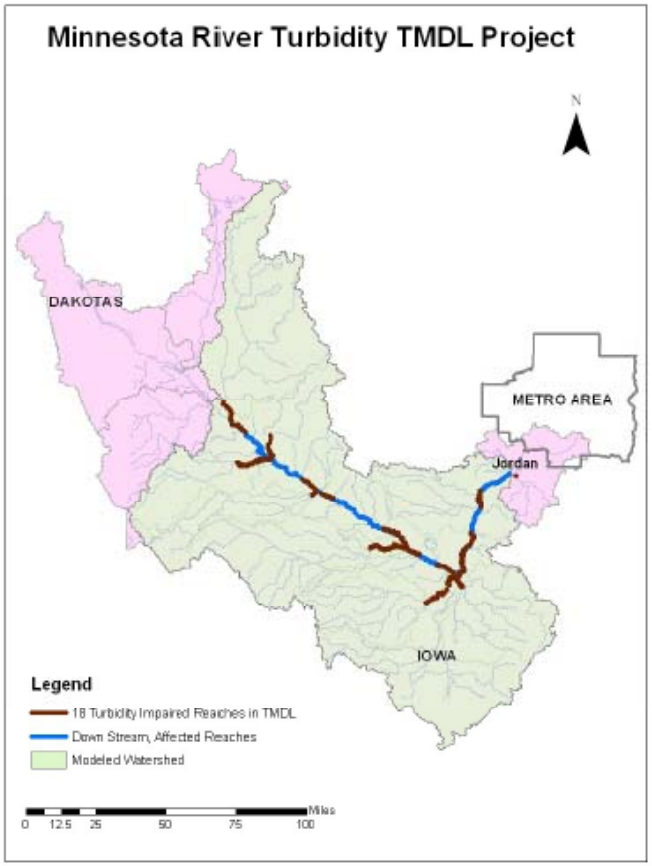
Funded by: NSF

Minnesota Pollution Control Agency


Minnesota
River
Basin
Mississippi River
La Crosse
100 km
Le Sueur

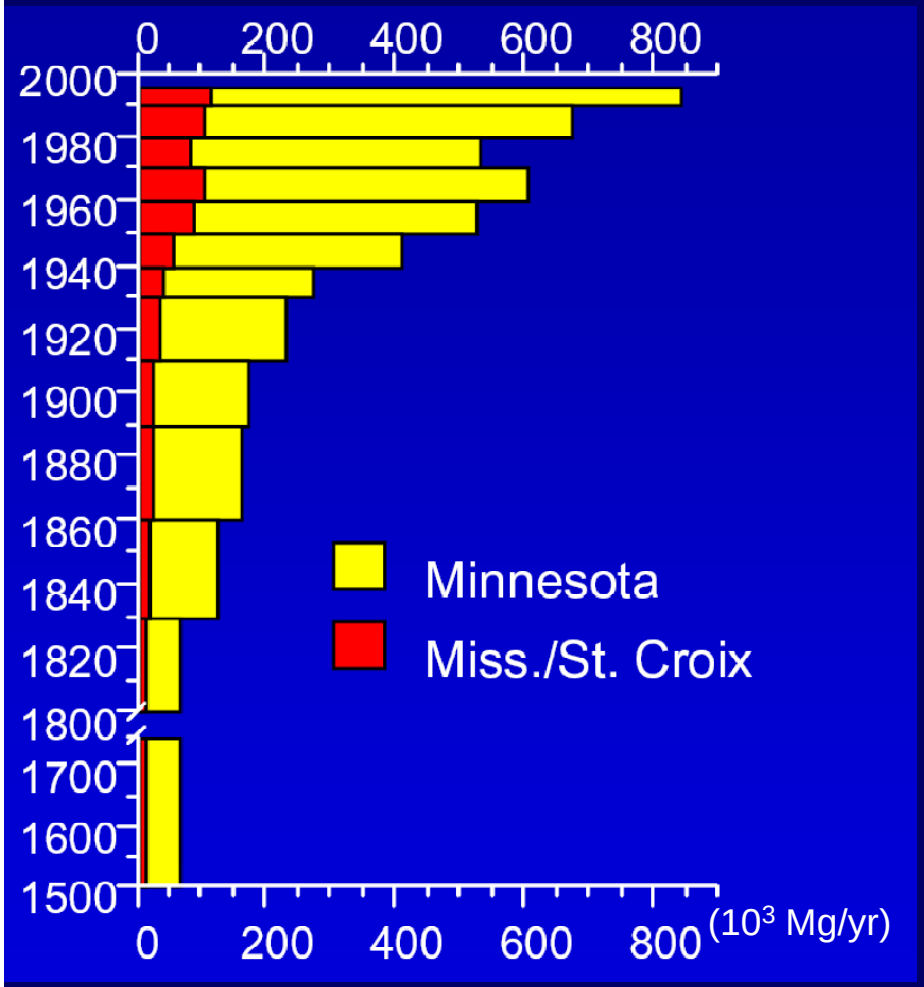
Minnesota Pollution Control Agency
Regional Division, Impaired Waters Program
Water Quality/Basins 3.33, June 2005

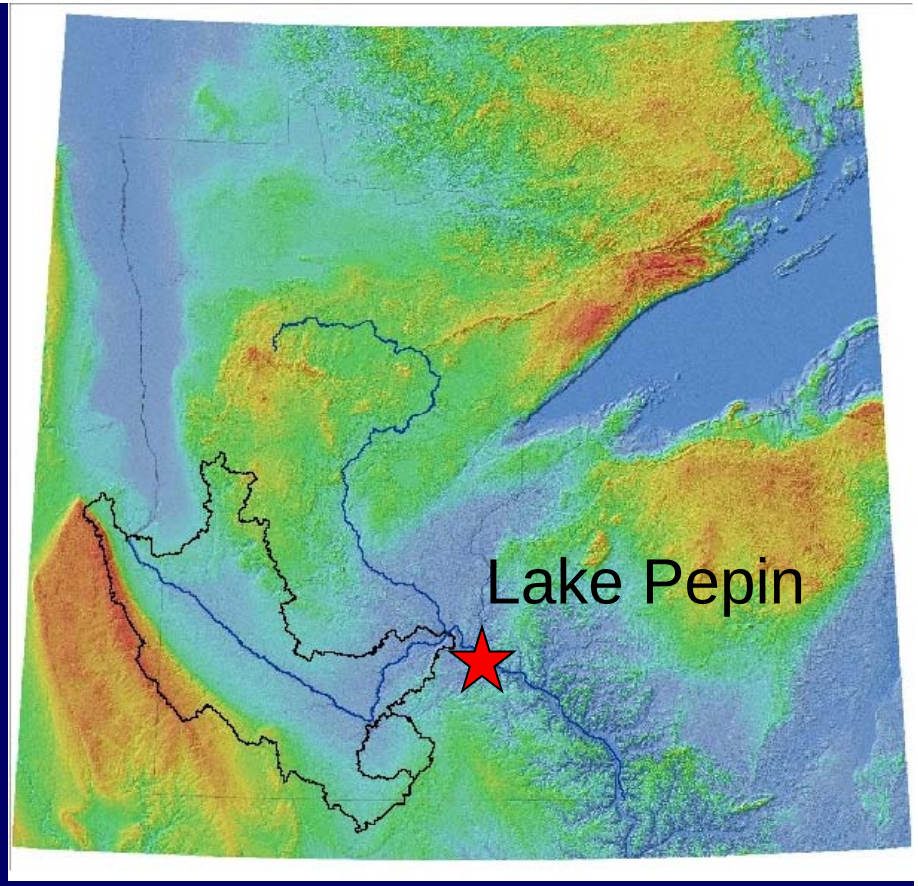


Reducing turbidity through Total Maximum Daily Loads (TMDLs) process

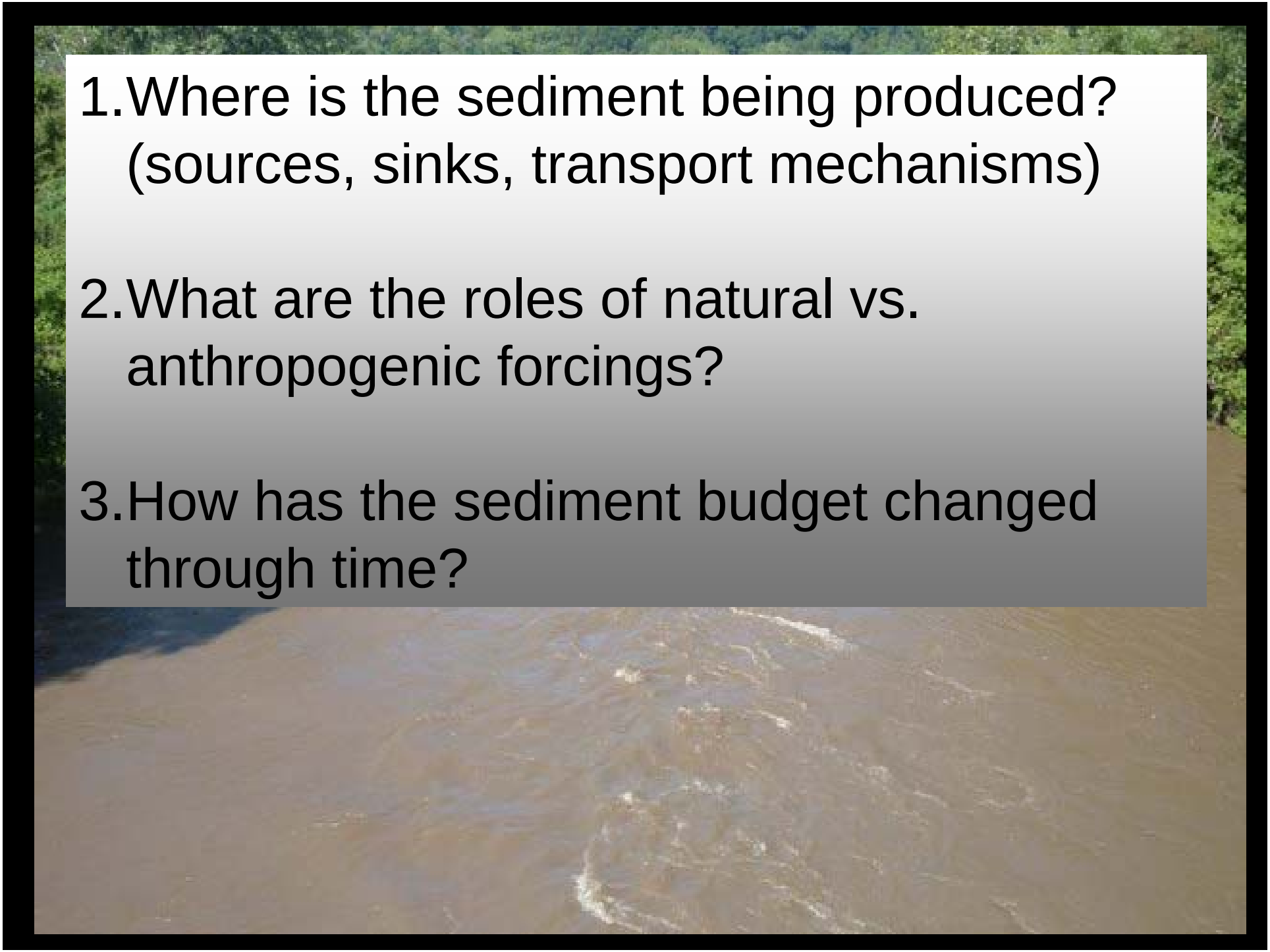
MPCA—Clean Water Act

Sediment flux to Lake Pepin





Kelley & Nater, 2000
Engstrom et al., 2008



1. Where is the sediment being produced? (sources, sinks, transport mechanisms)

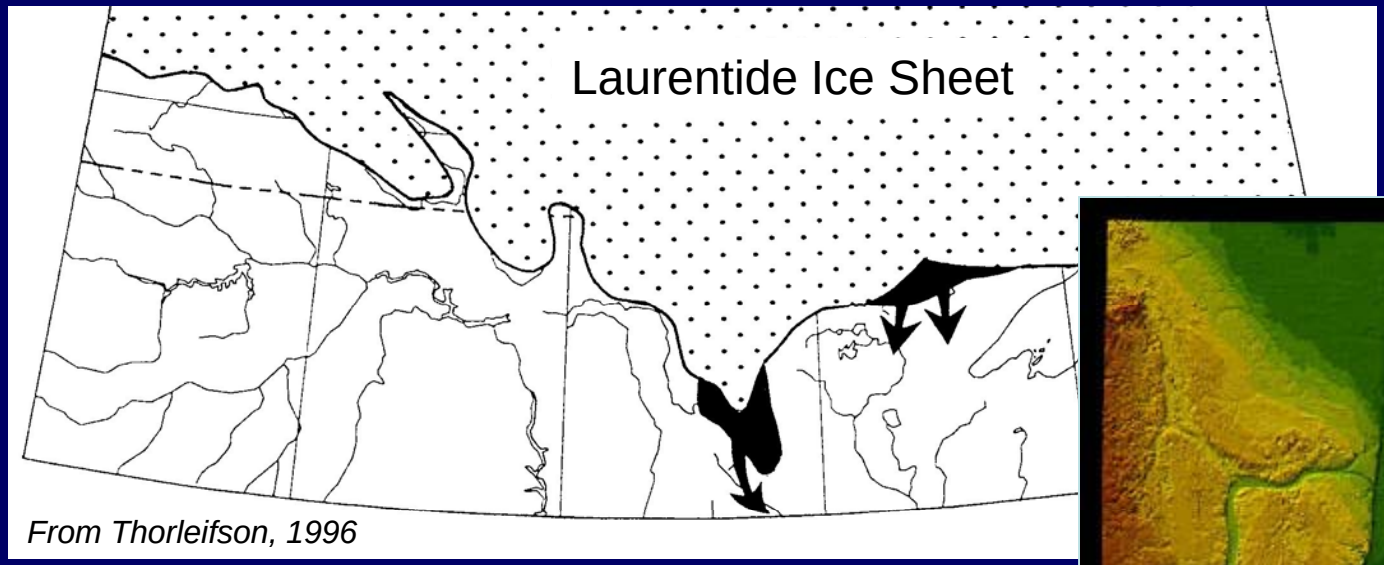
2. What are the roles of natural vs. anthropogenic forcings?

3. How has the sediment budget changed through time?

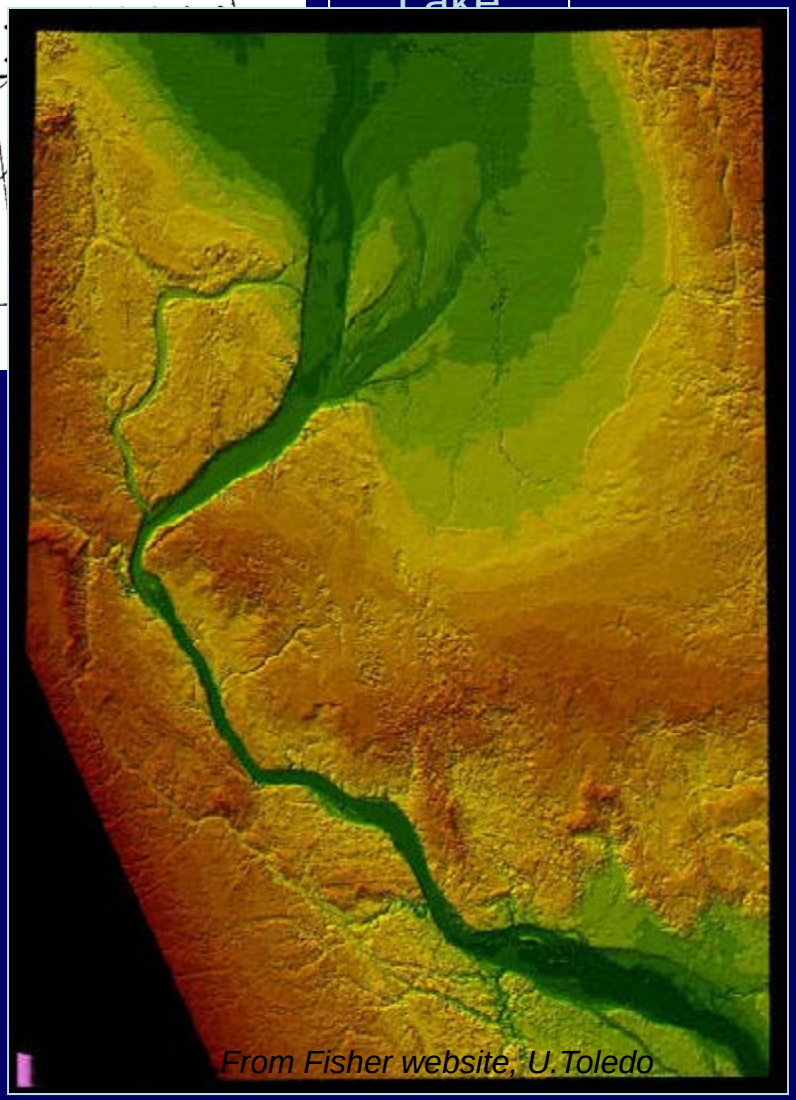
Plan of attack

- Geomorphic background of Le Sueur River
- Current sediment budget (sources, sinks, transport)
  - Bluffs
  - Ravines
  - Uplands
  - Floodplains
- Does it all add up?

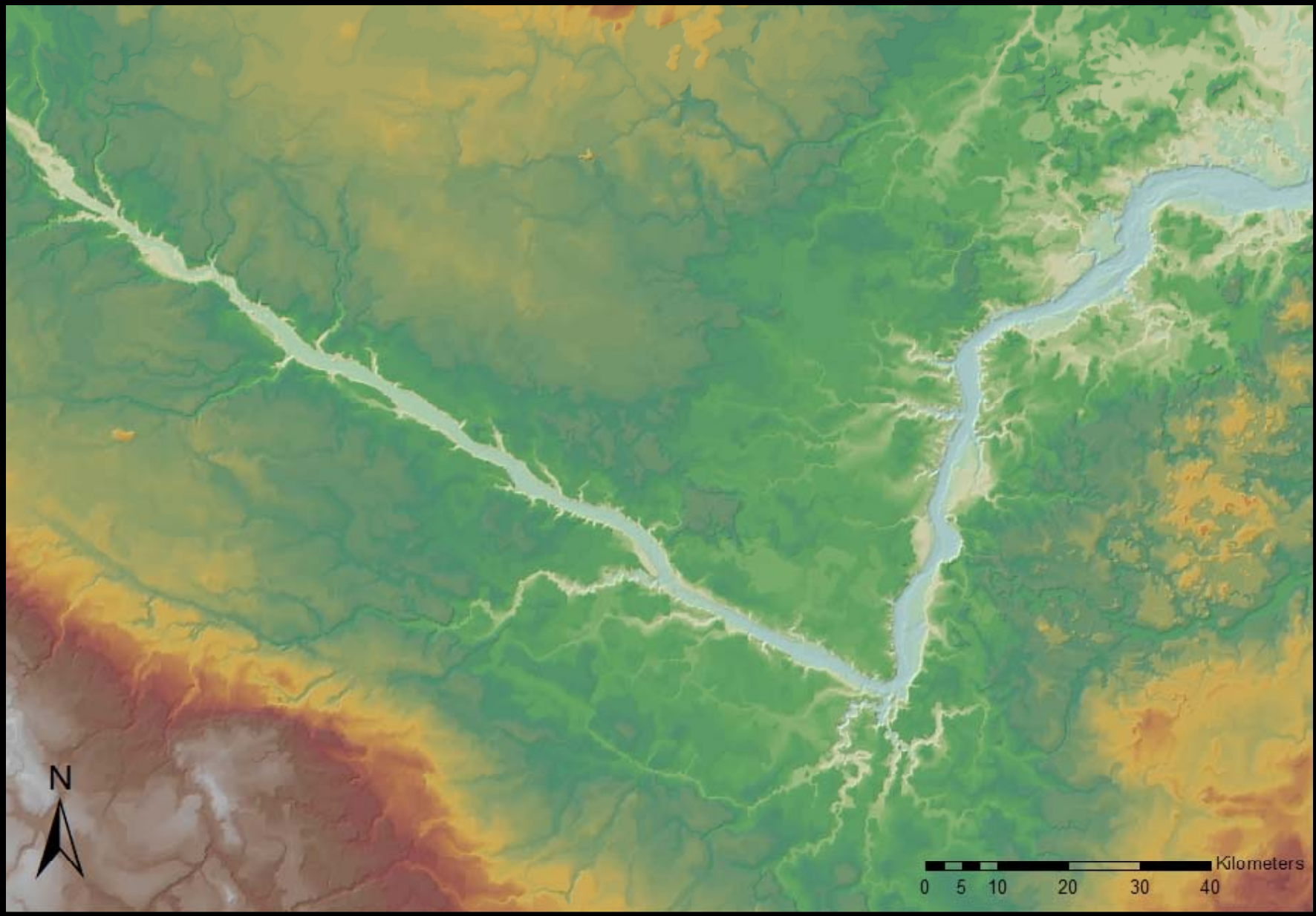
Glacial Lake Agassiz, 11.5ka rc yr BP (13.5ka cal yr BP)

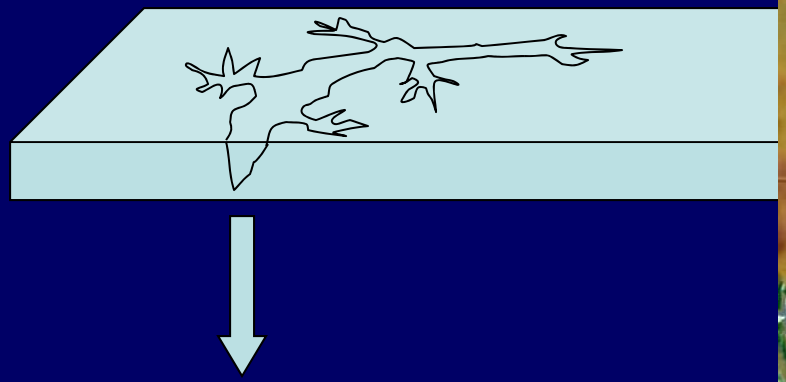


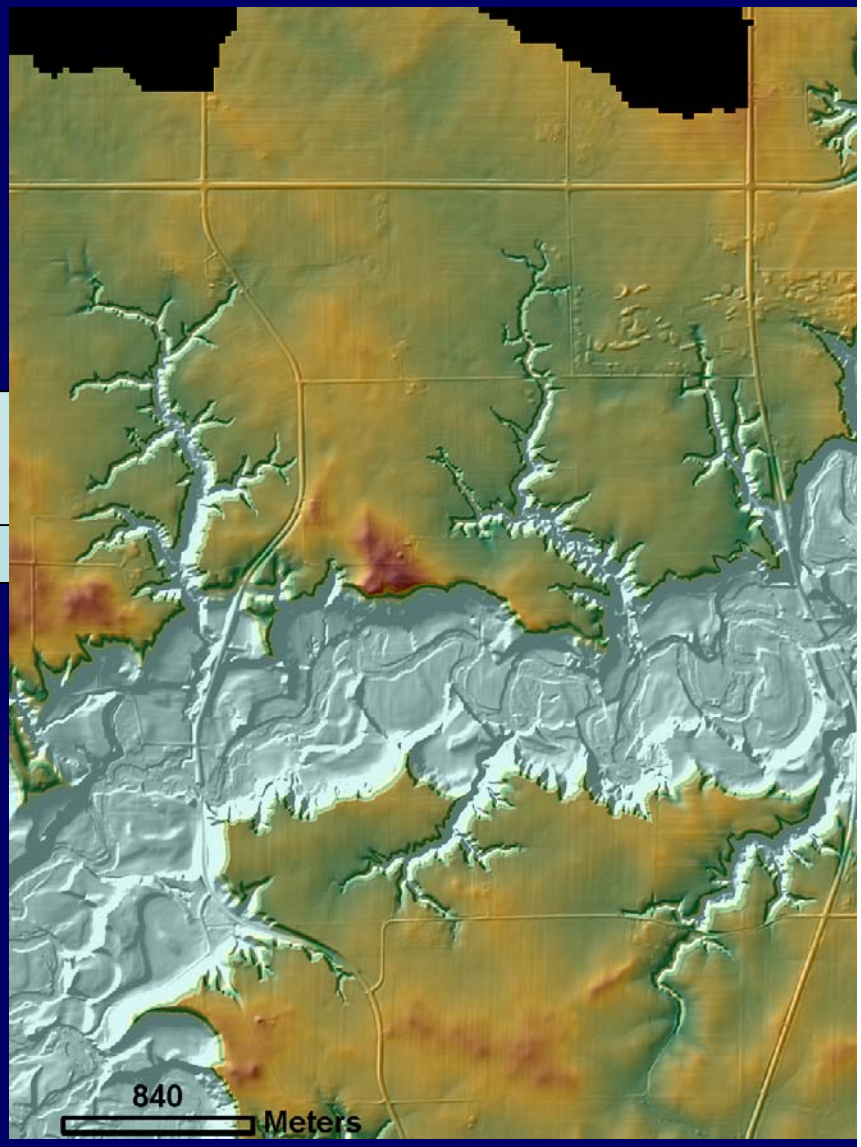
From Thorleifson, 1996



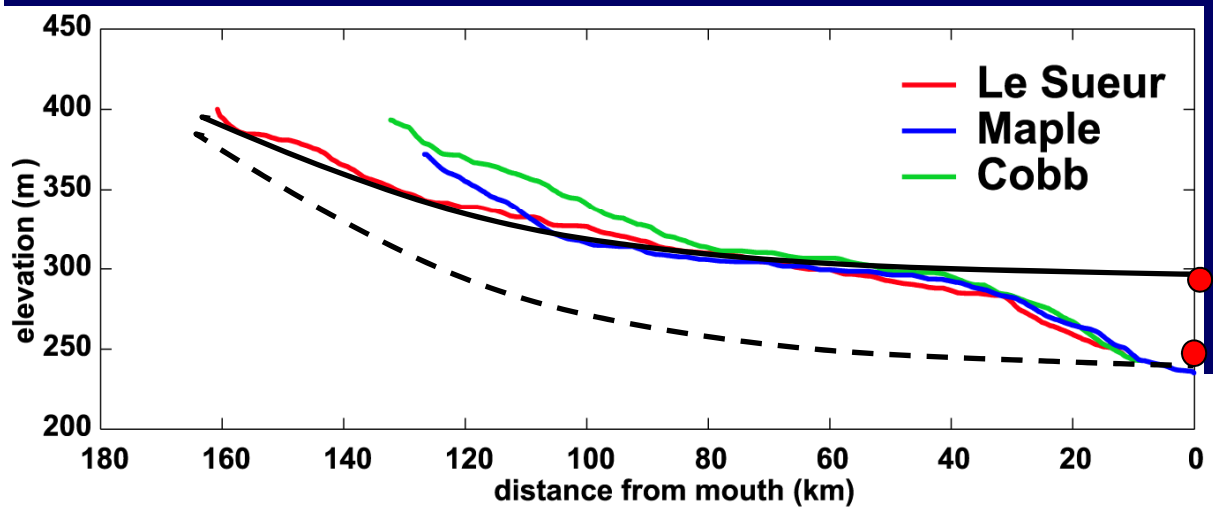
From Fisher website, U.Toledo


N
Kilometers
0 5 10 20 30 40




840
Meters

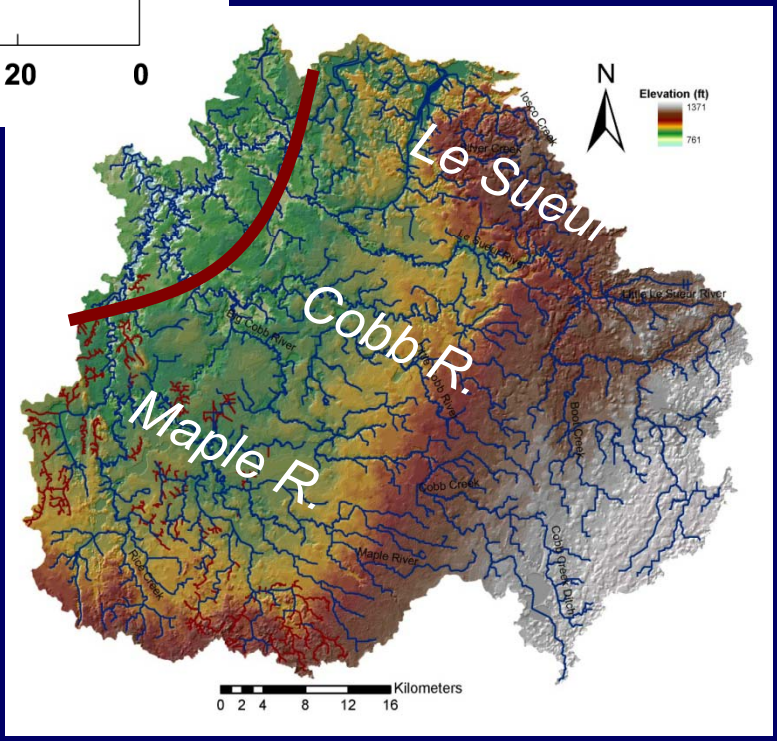
River Longitudinal Profiles



Pre-13.5ka baselevel
Post-13.5ka baselevel

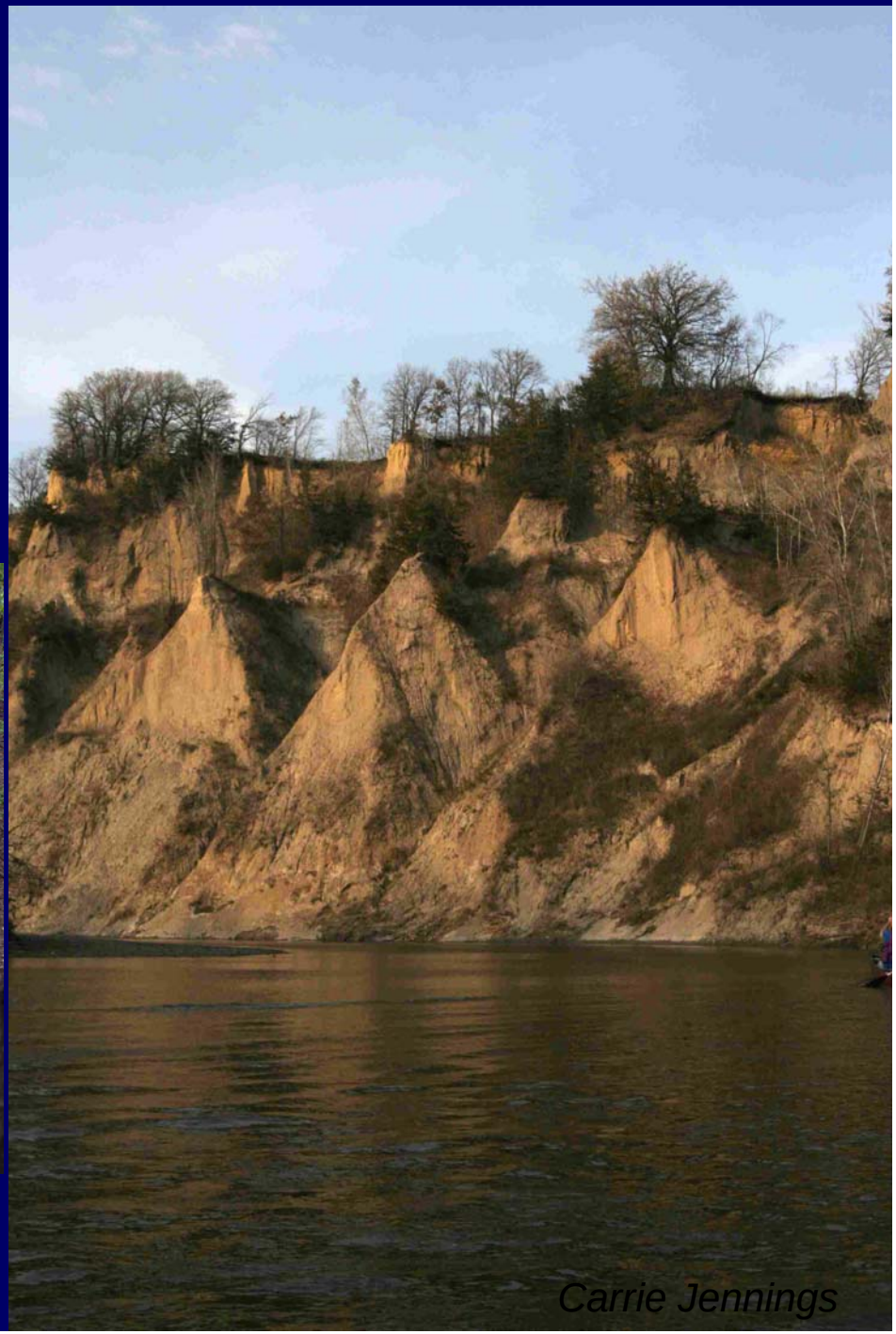
Holocene average
knick migration rate = 3 m/yr

vertical incision rate = 4.5 mm/yr



Above the knick zone

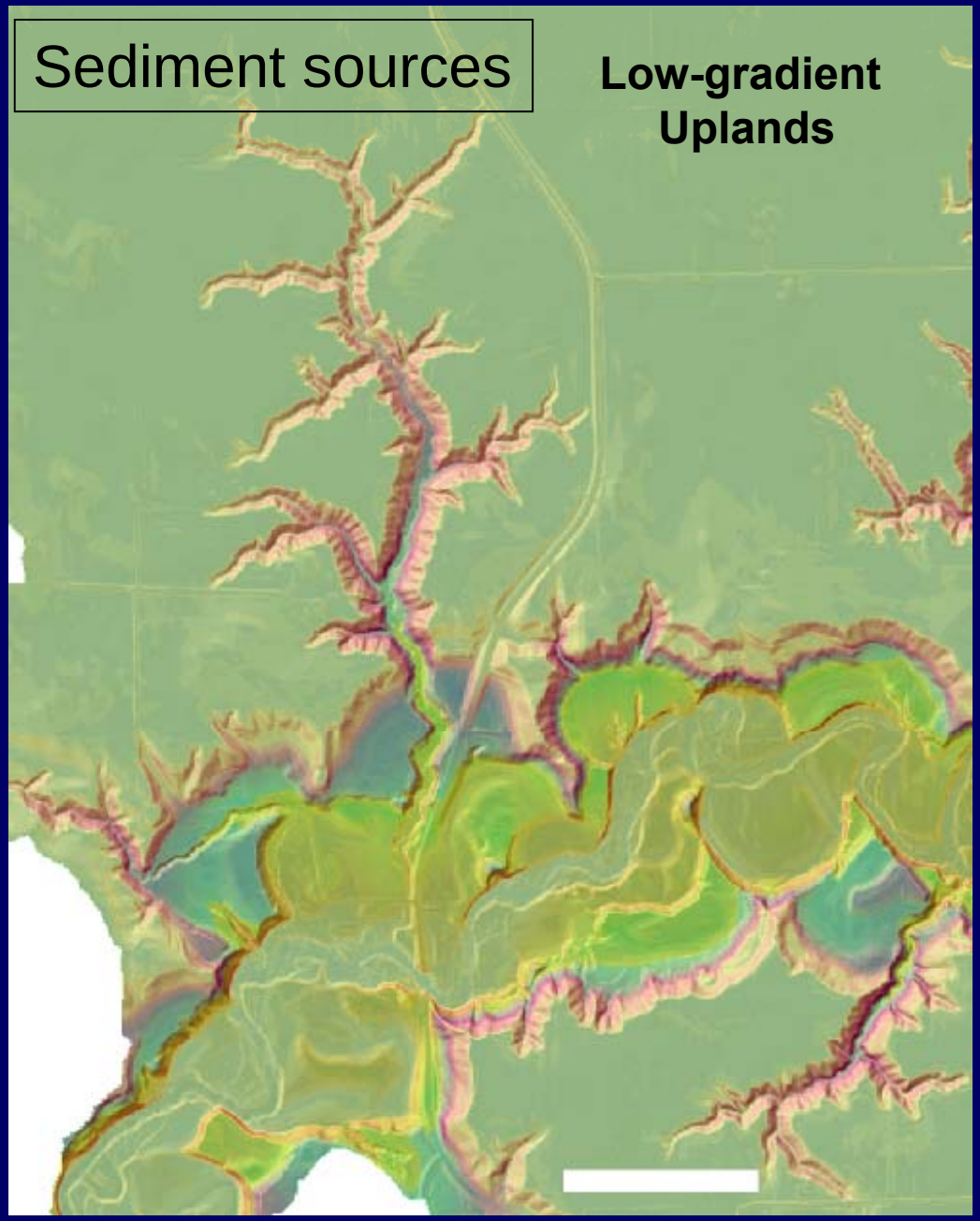
Below the knick zone



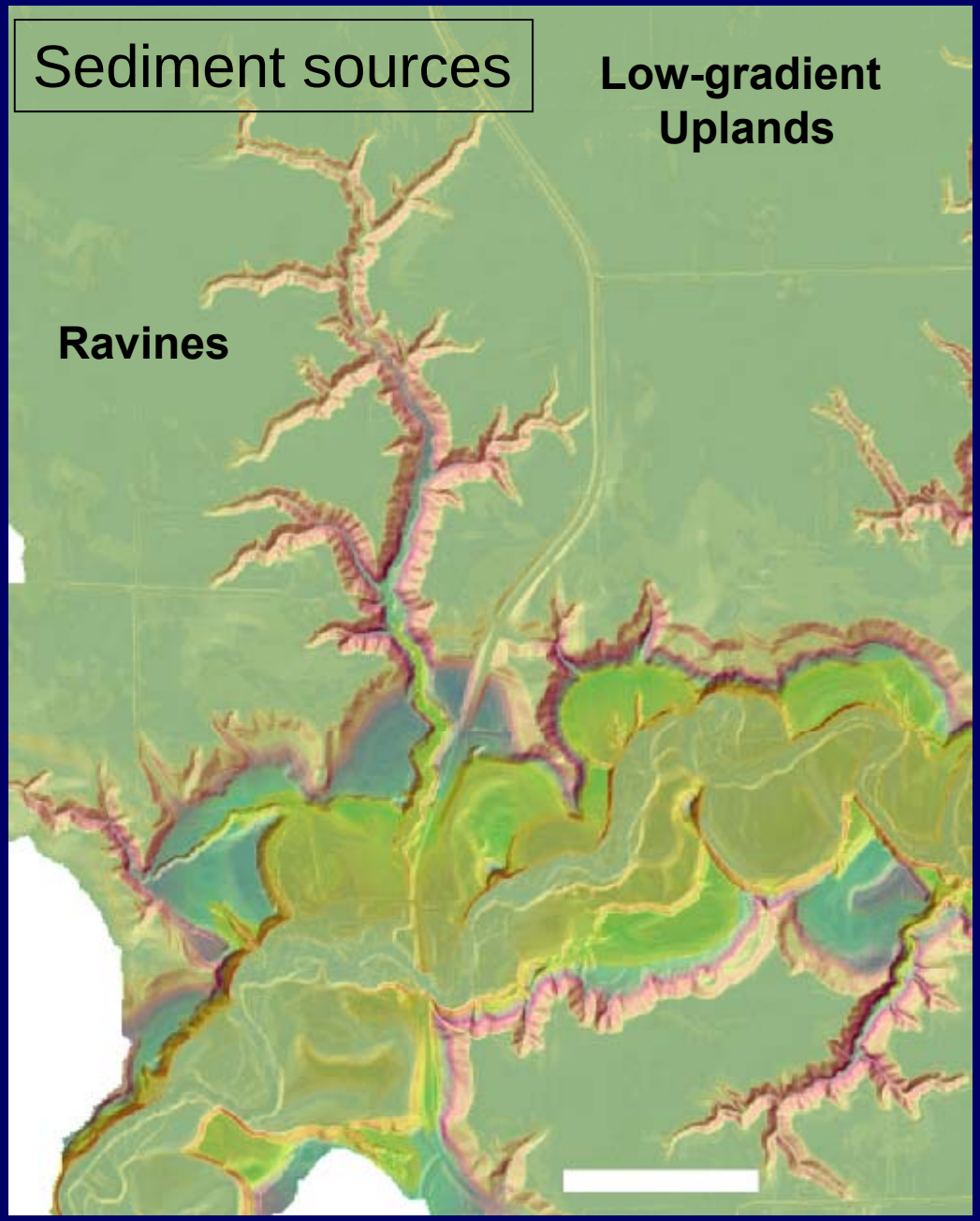
Carrie Jennings

Sediment sources

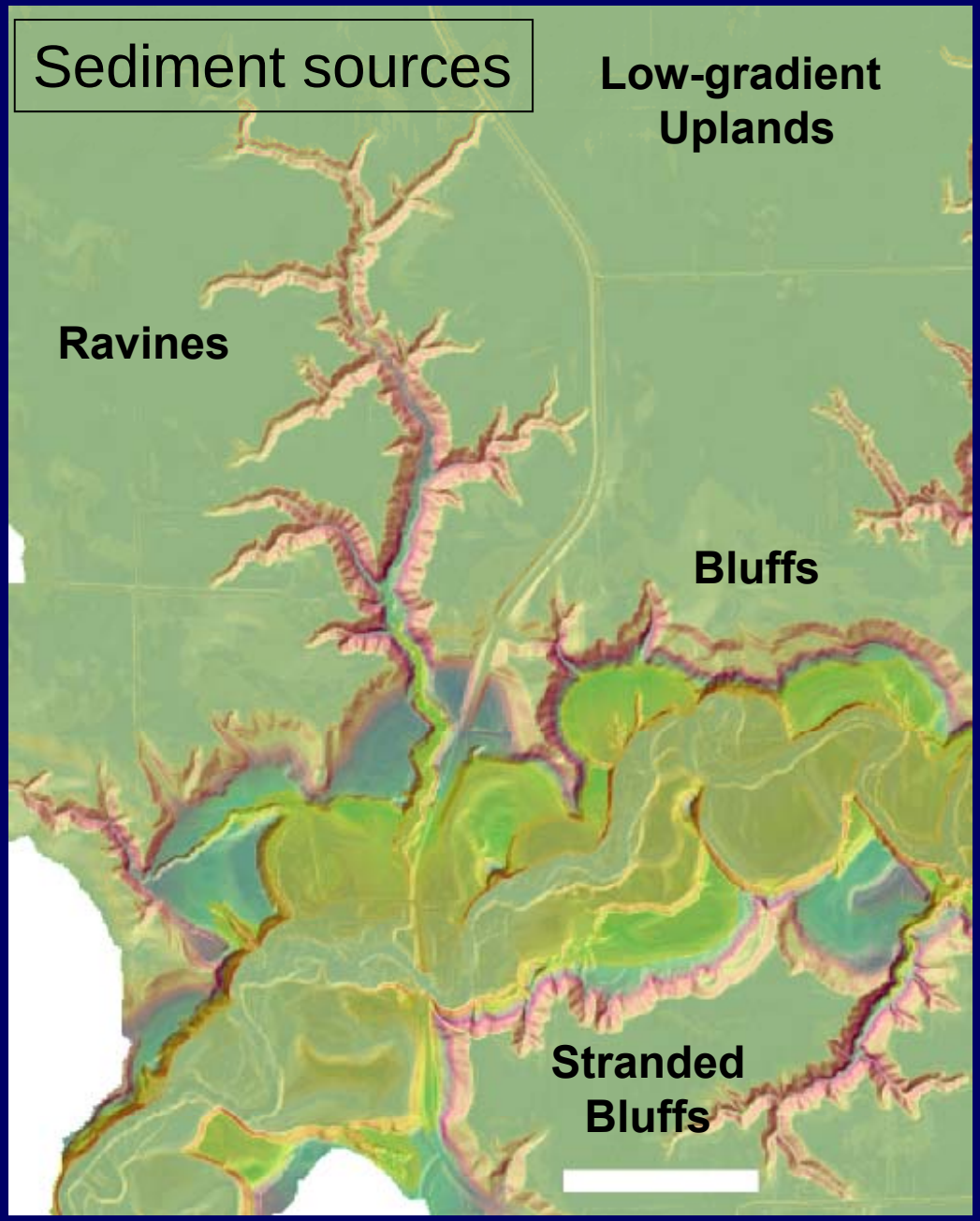
Low-gradient Uplands



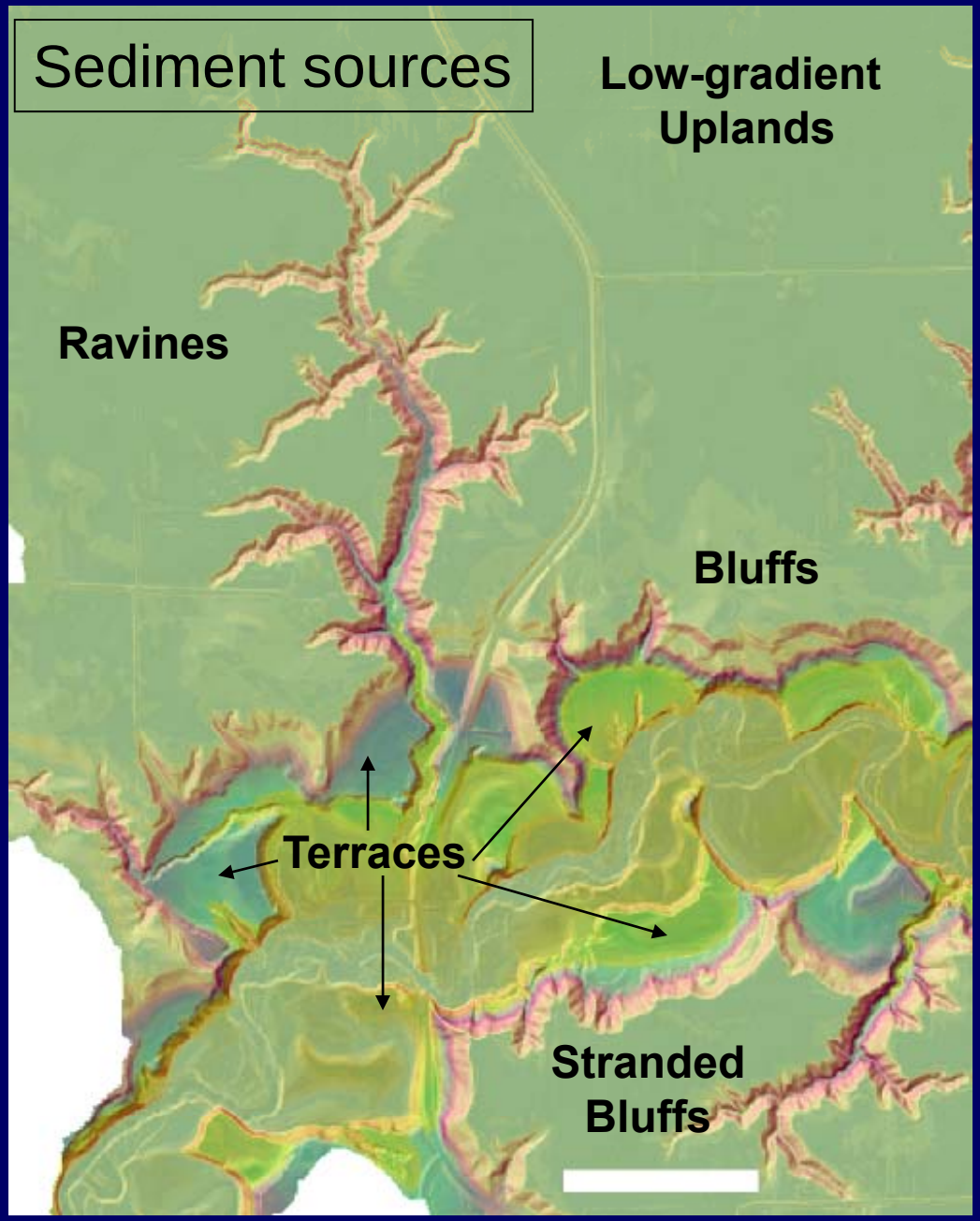
Sediment sources



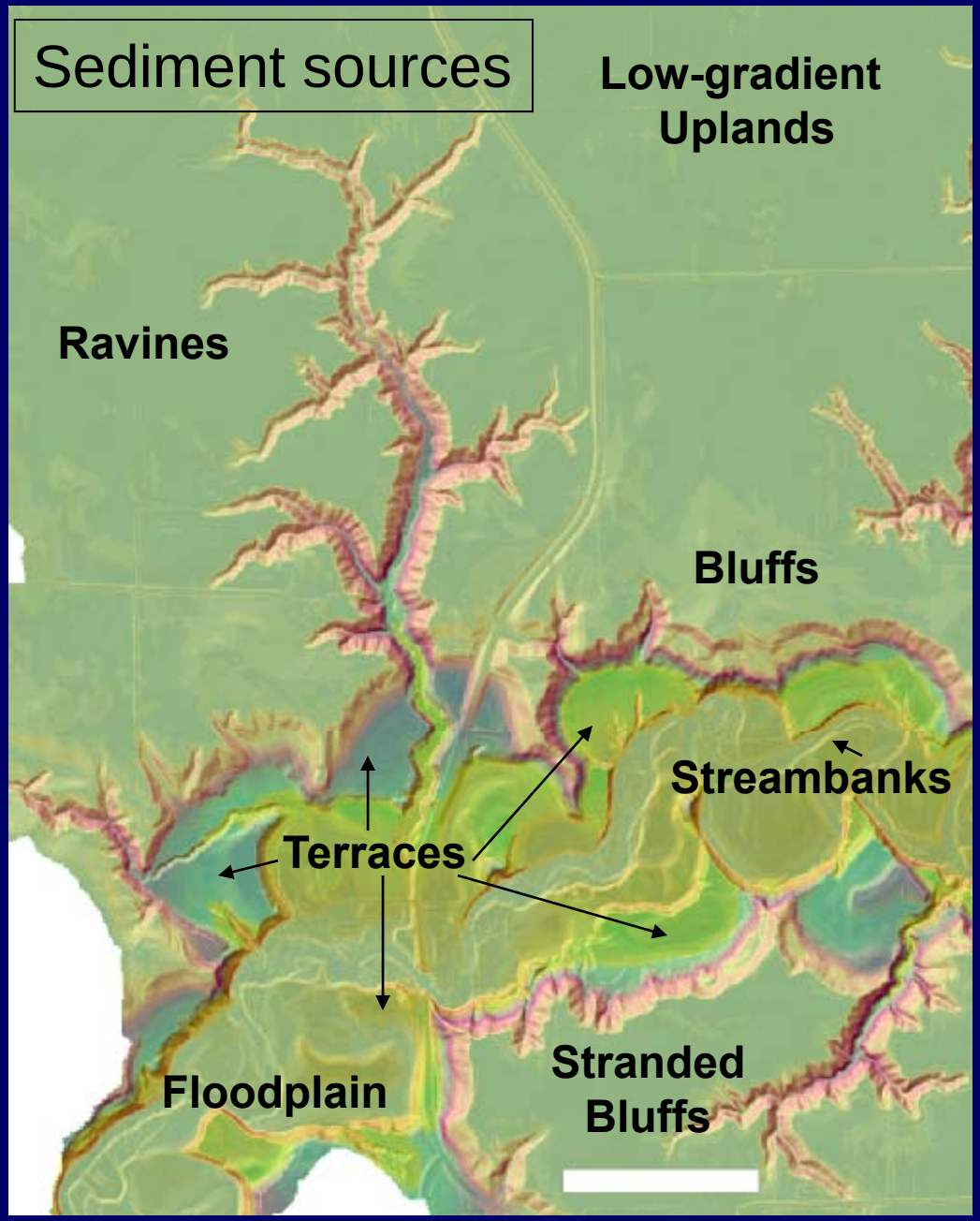
Sediment sources

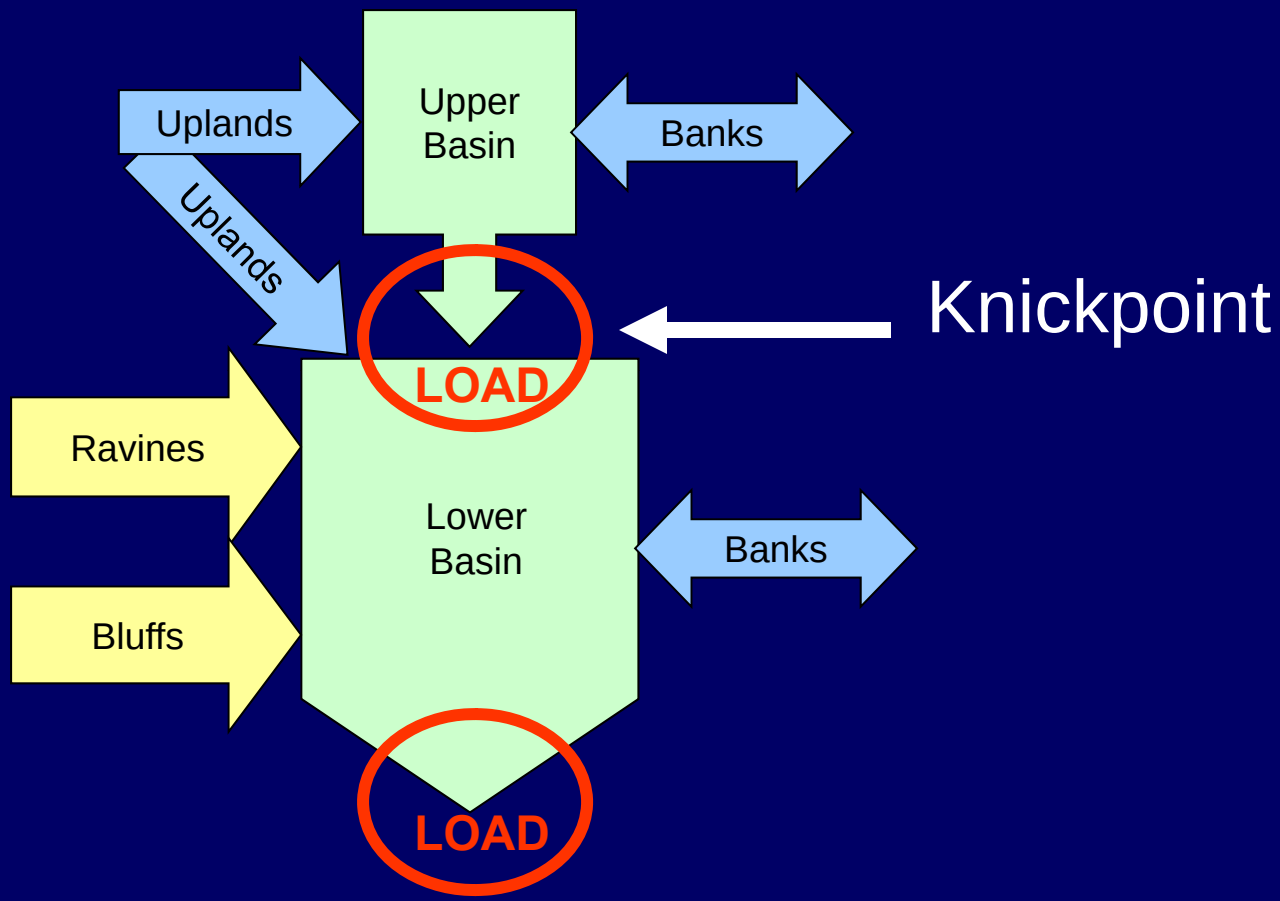


Sediment sources

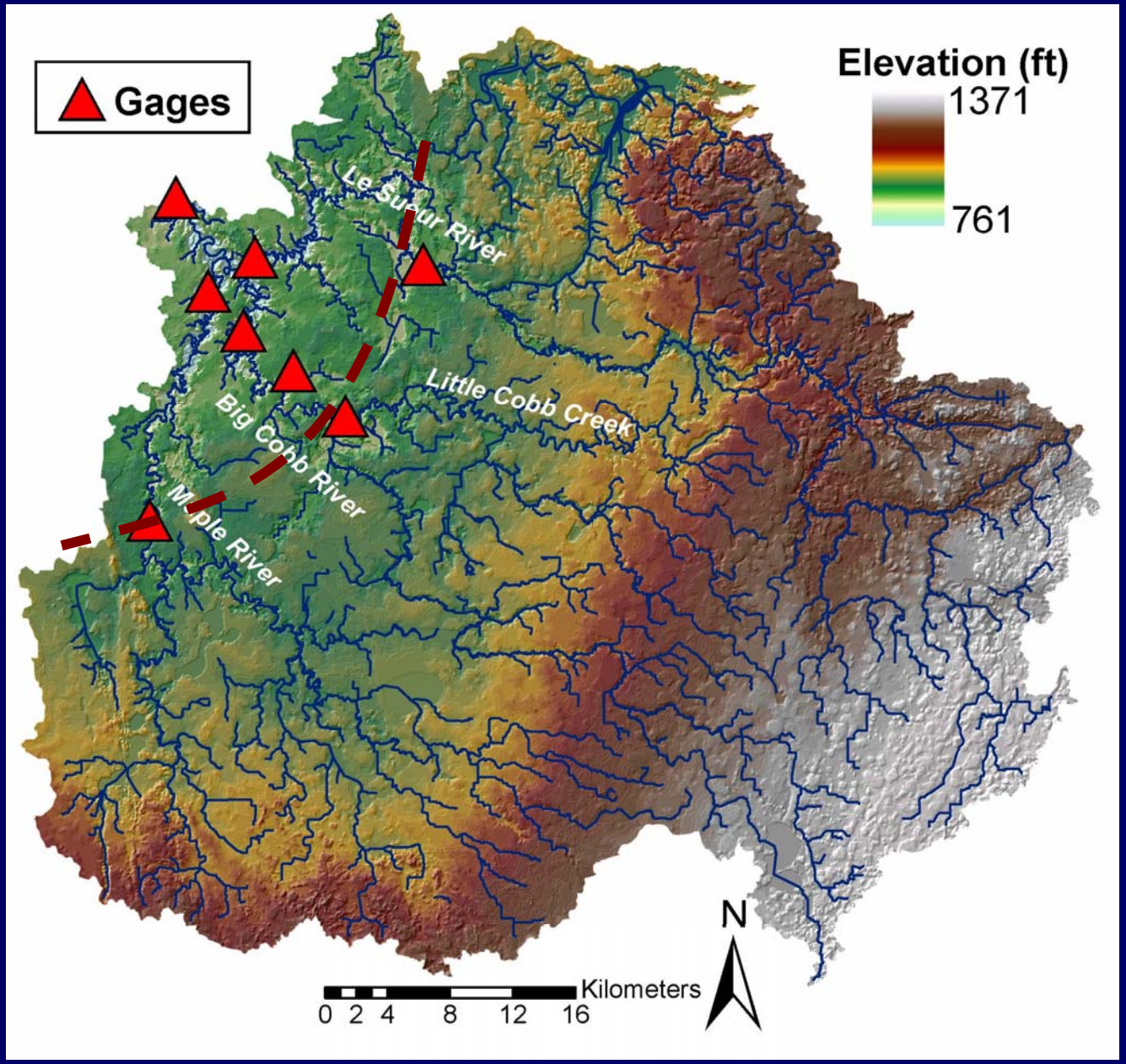


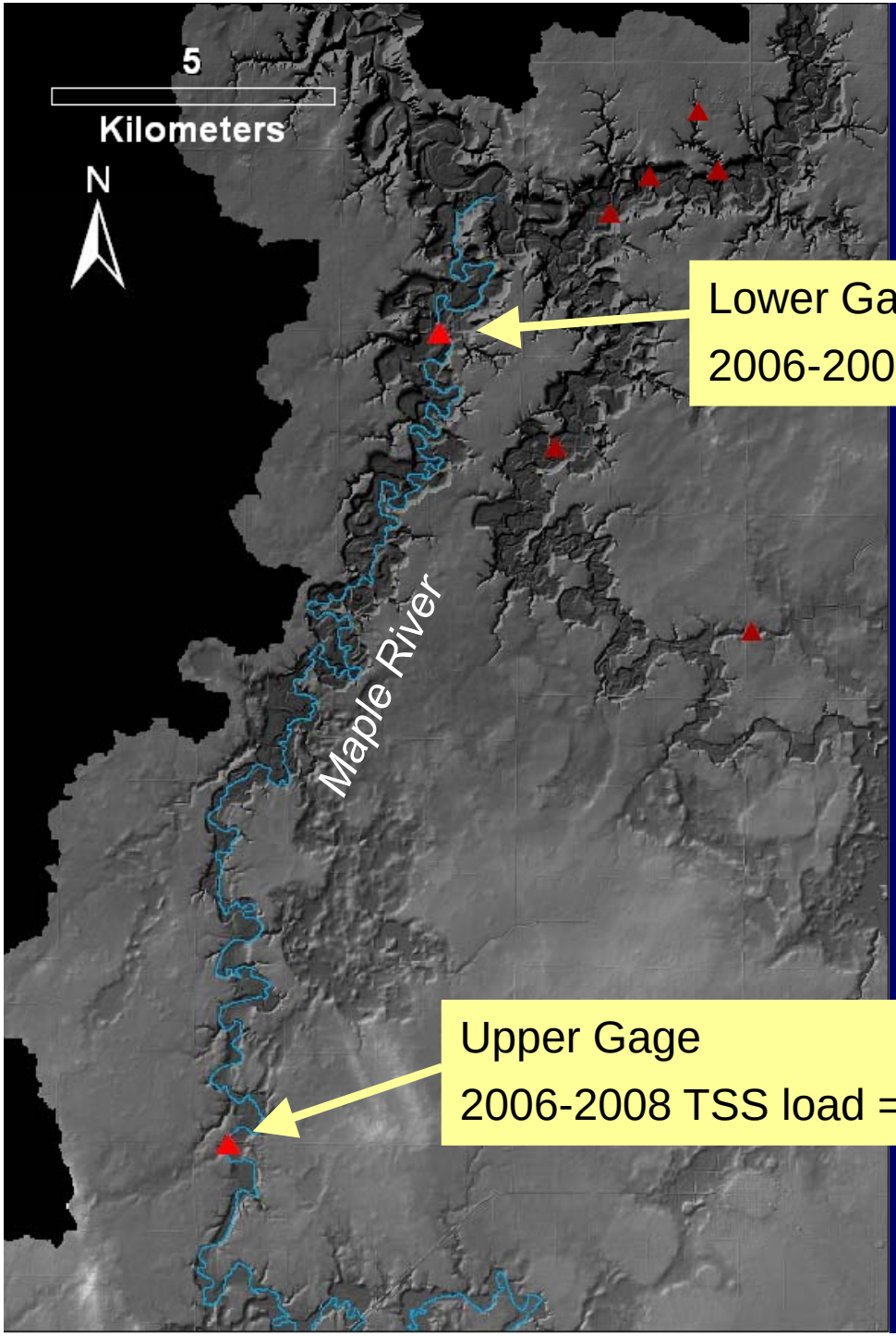
Sediment sources




Uplands
Uplands
Upper
Basin
Banks
Knickpoint
LOAD
Ravines
Bluffs
Lower
Basin
Banks
LOAD

Gage Locations in Le Sueur River watershed



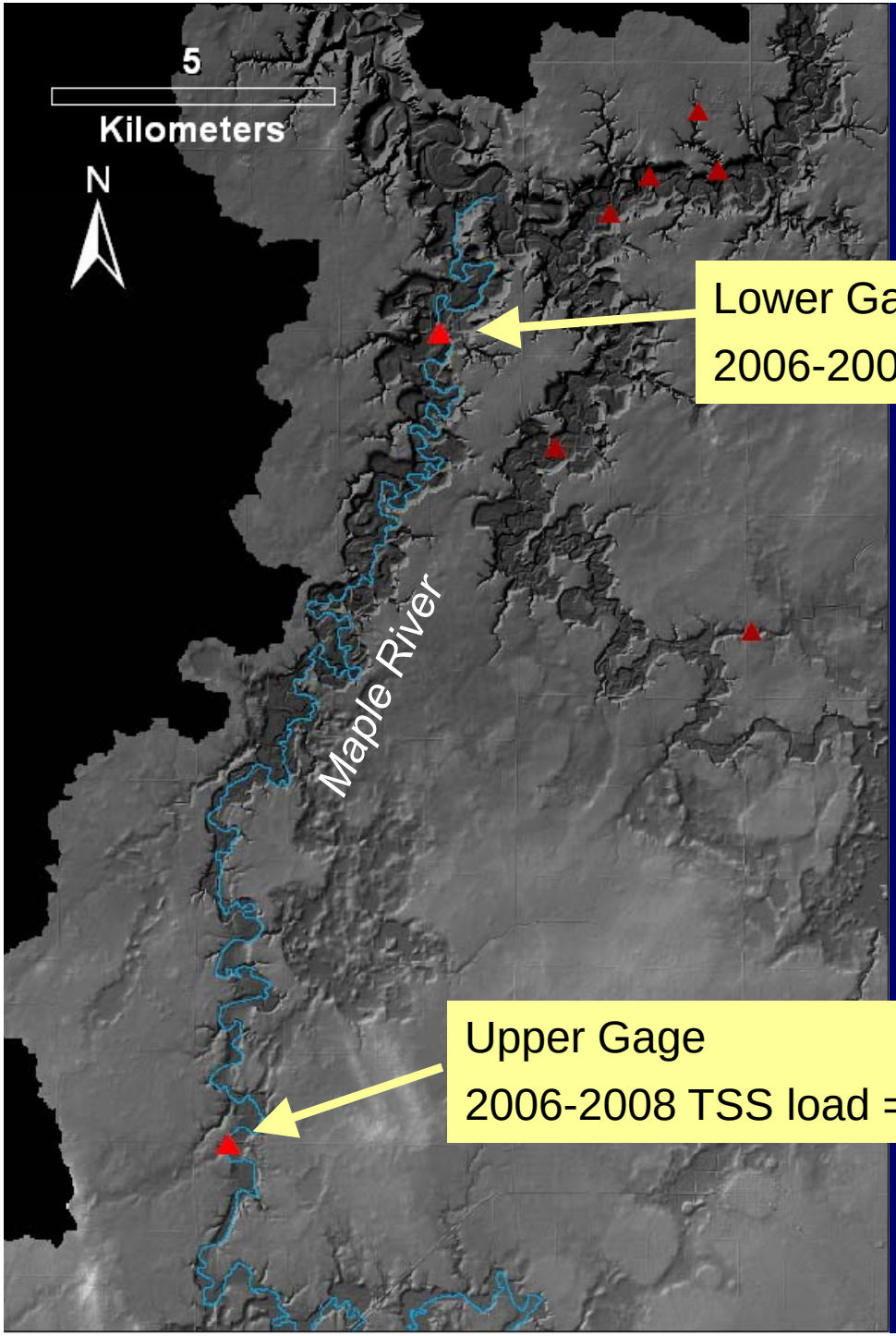


Upper vs. Lower gages Ex. Maple River

Lower Gage
2006-2008 TSS load = **24,000 Mg/yr**

Watershed area increases by only 10% between gages.

Upper Gage
2006-2008 TSS load = **8,000 Mg/yr**



Where is the sediment coming from?

Lower Gage
2006-2008 TSS load = **24,000 Mg/yr**

Uplands:

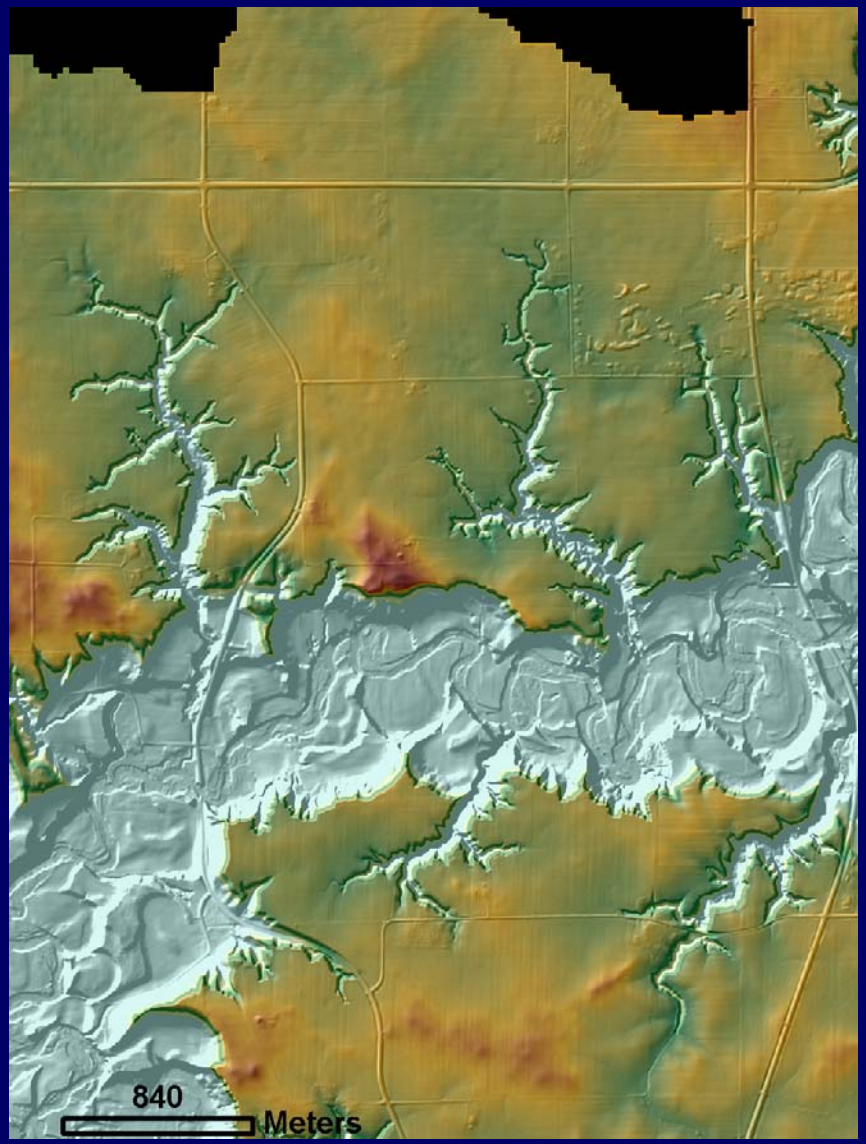
10% increase in area

Max estimate: Assume ALL sediment at upper gage is from uplands
Adjust 2006-08 ratio to 2003-2008 mean: 17 Mg/km^2/yr

3-6% of load increase; <30% total load

Upper Gage
2006-2008 TSS load = **8,000 Mg/yr**

How important are ravines?



Holocene: Volume loss
Decadal: Historical air photos
Annual: Ravine monitoring 2008-09

Decadal-scale ravine change measured from historical air photos.

69 Ravines surveyed

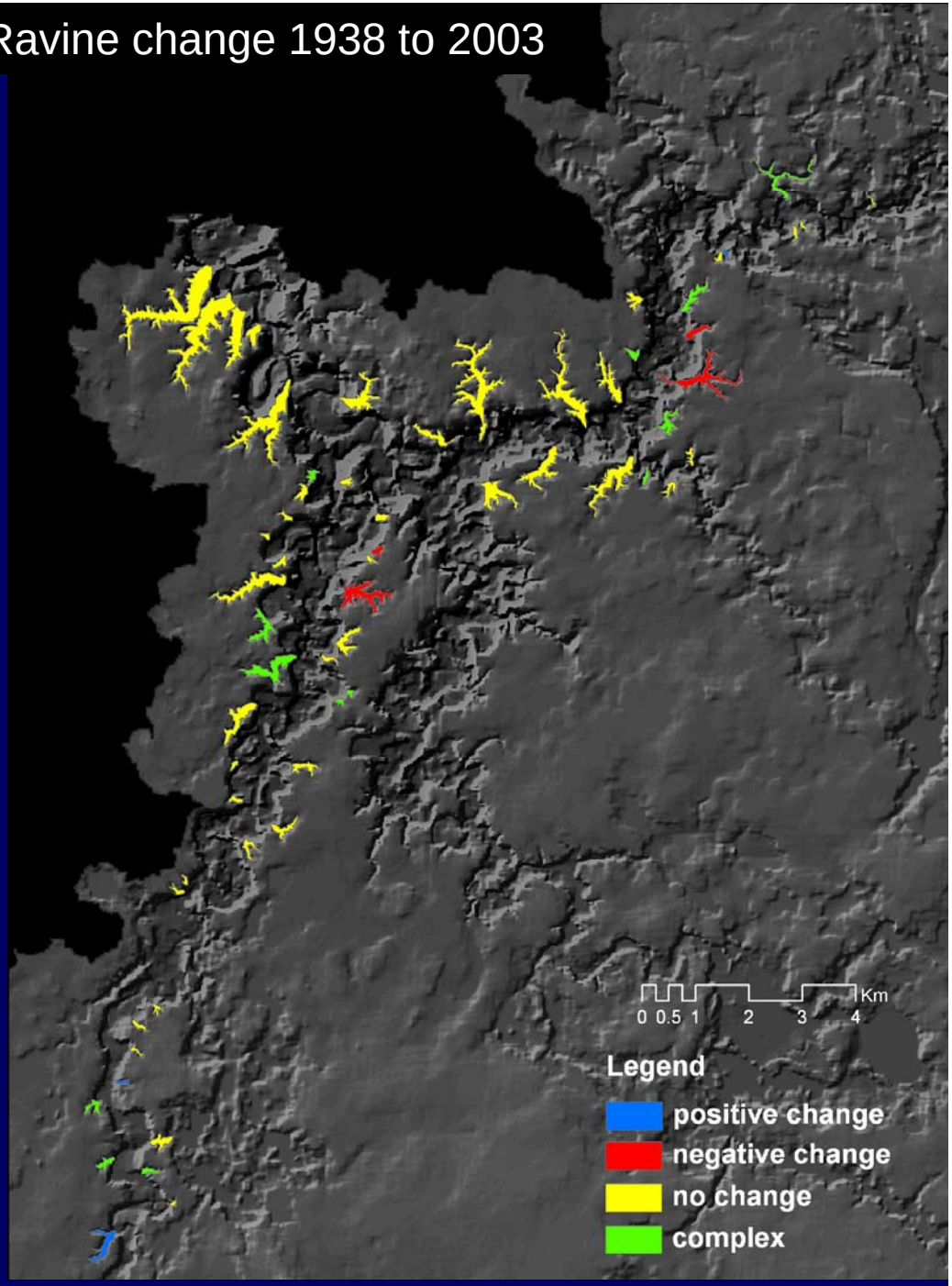
Most (42) show no change

5 show tip growth

4 show tip reduction

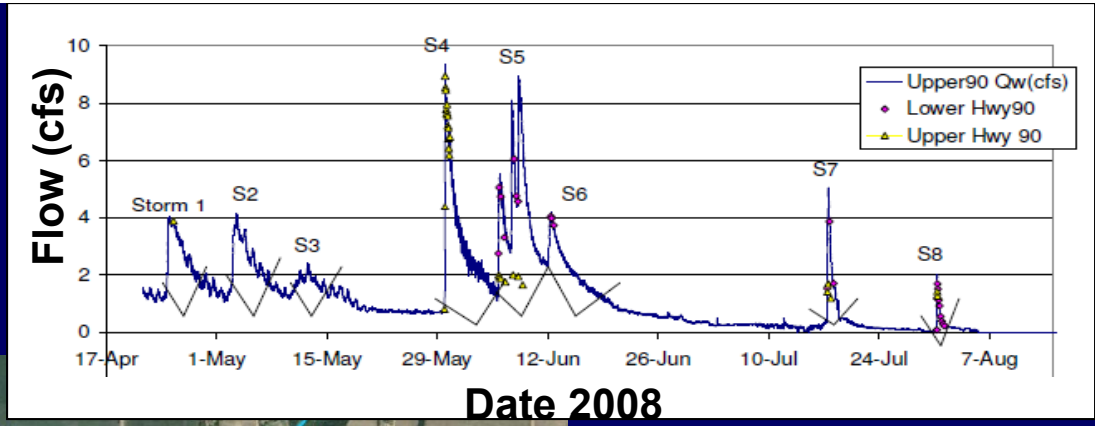
14 show complicated change

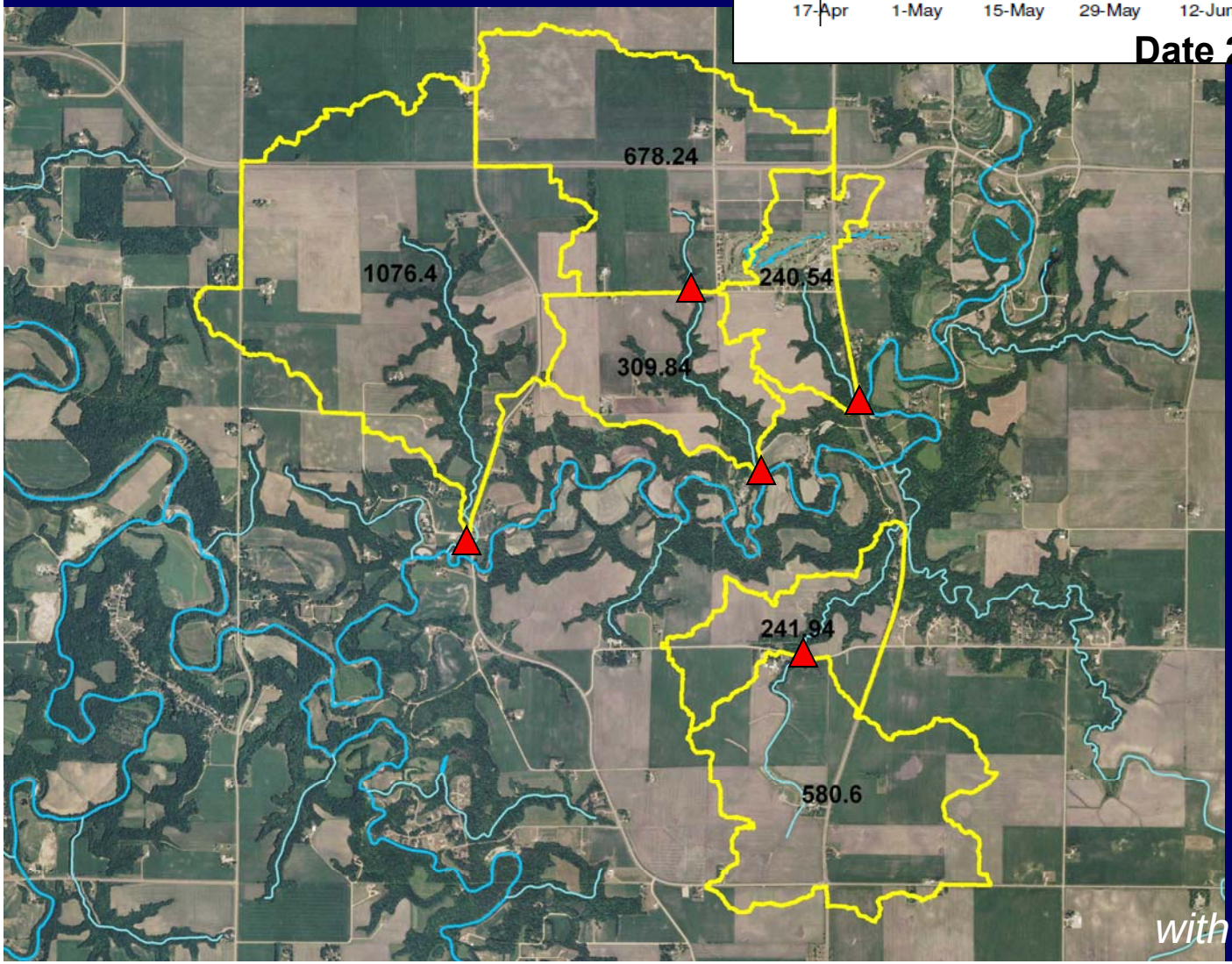
Ravine tip growth only, not widening or incision



completed by S. Day

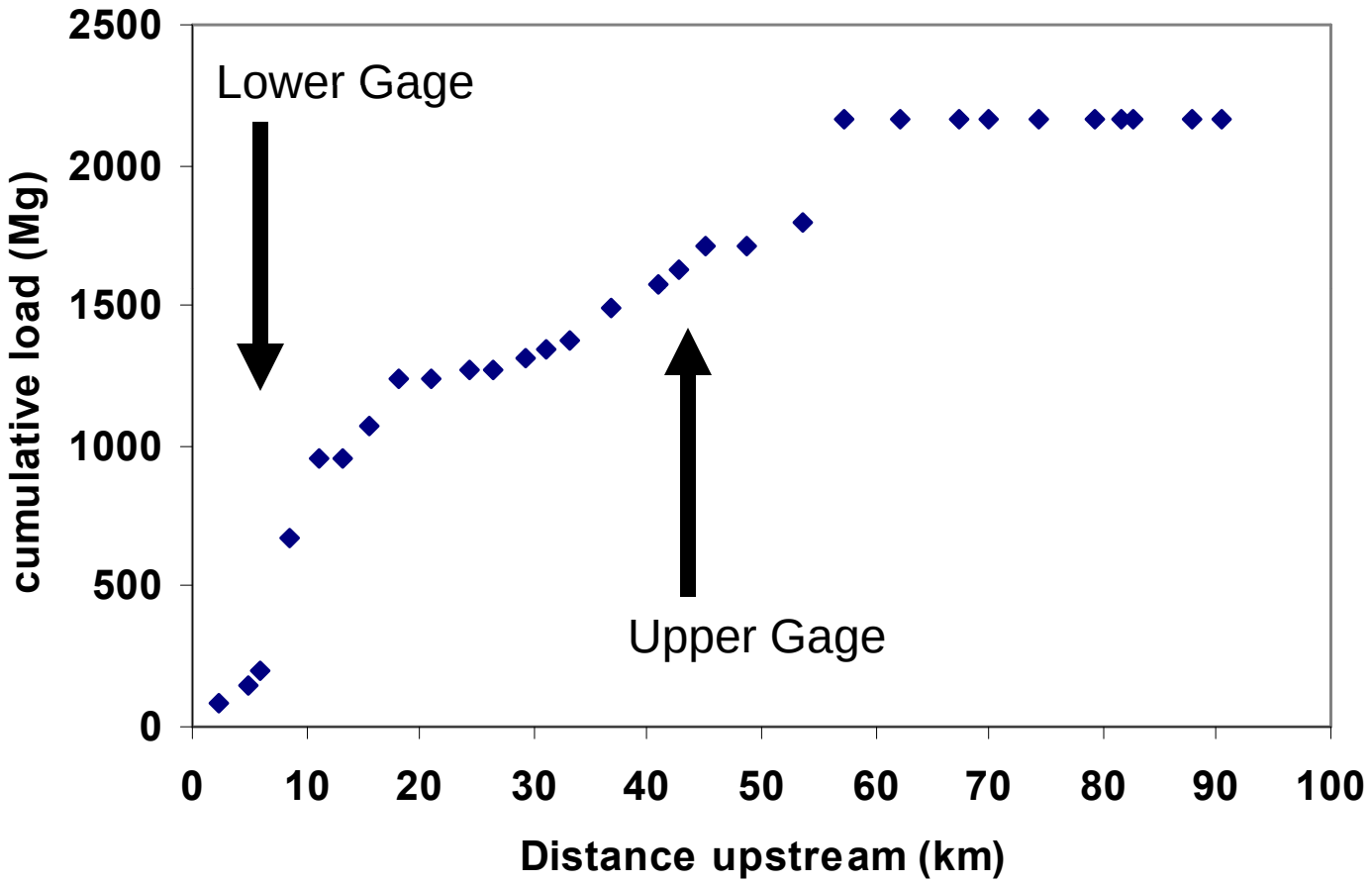
2008-9 Gaging stations

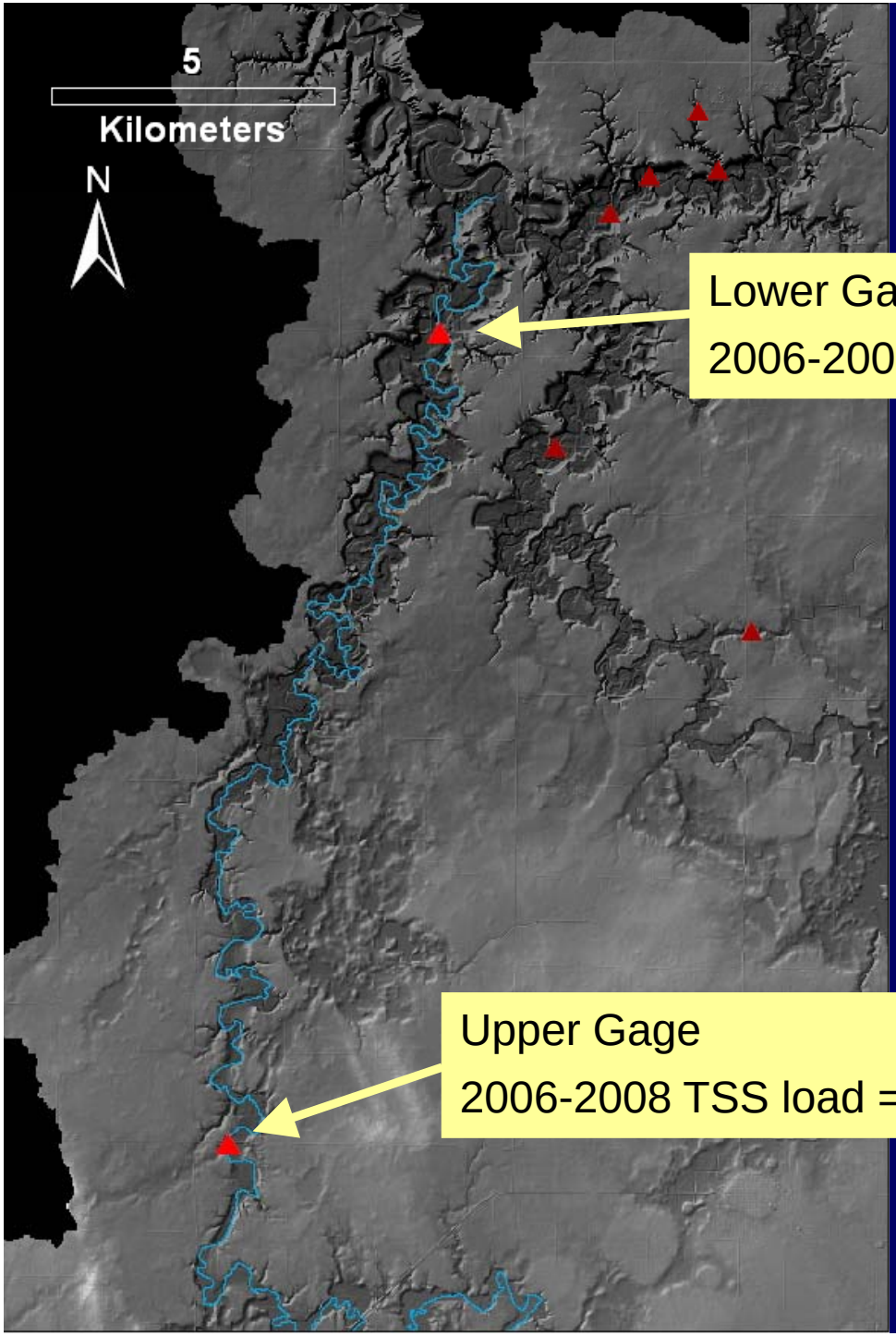




with Scott Matteson, MNSU

Cumulative loading from ravines in Maple River





Where is the sediment coming from?

Lower Gage
2006-2008 TSS load = **24,000 Mg/yr**

Ravines:
~ 1000-1500 Mg/yr → ???

2008: Dry year : 10% of load between gages
2009: Even drier

Upper Gage
2006-2008 TSS load = **8,000 Mg/yr**

Bluffs

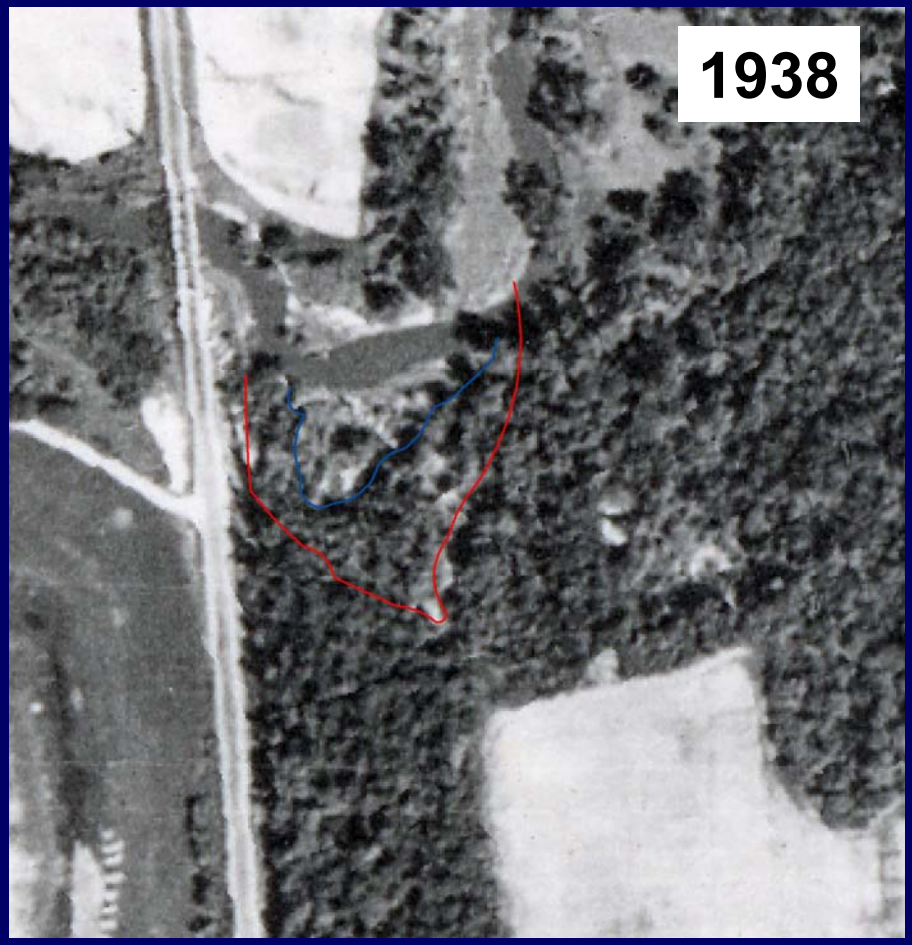
1

Kilometers

P. Belmont

Historic Air Photo Analysis of Bluff Retreat

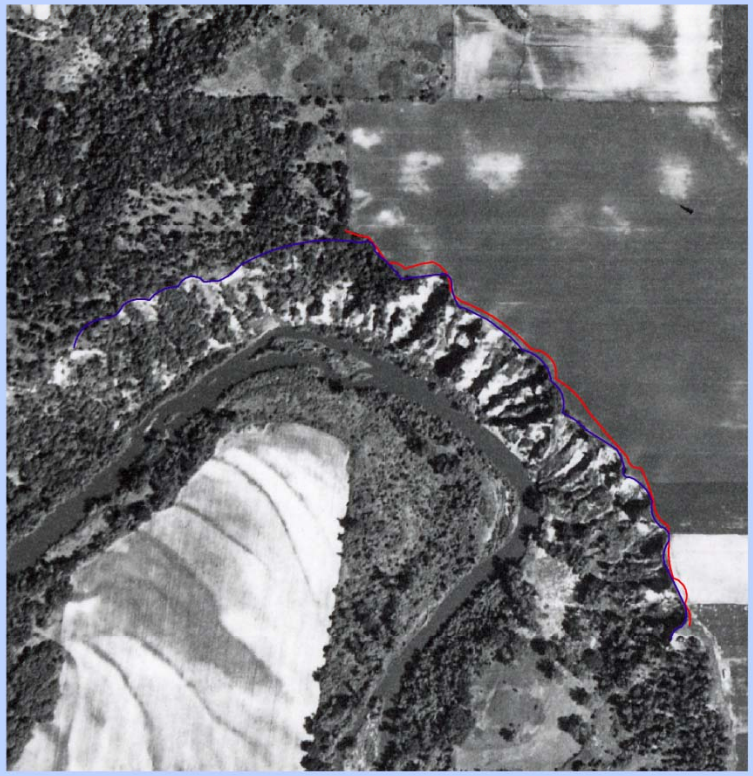
65 year bluff retreat



Bluff retreat is episodic

completed by S. Day

Bluff at intersection of
Jansen Quarry on the LeSueur River



Legend
top_l2_1938_rms2.86
top_l2_2003_rms2.86

0 50 100 200 Meters

N

Bluff at intersection of
Jansen Quarry on the LeSueur River

Legend
top_l2_1938_rms2.86
top_l2_2003_rms2.86

0 50 100 200 Meters

N

Bluff erosion rates converging on 15 ± 6 cm/yr

completed by S. Day

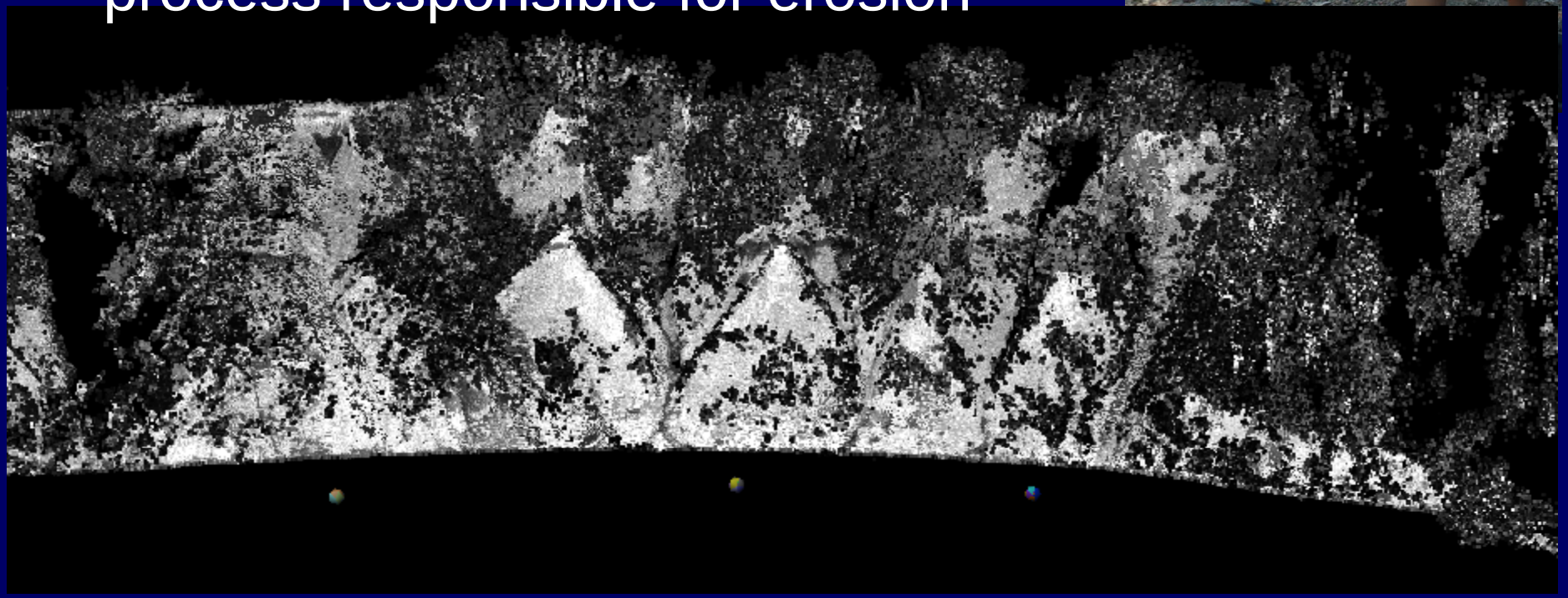
Bluff LiDAR scanning

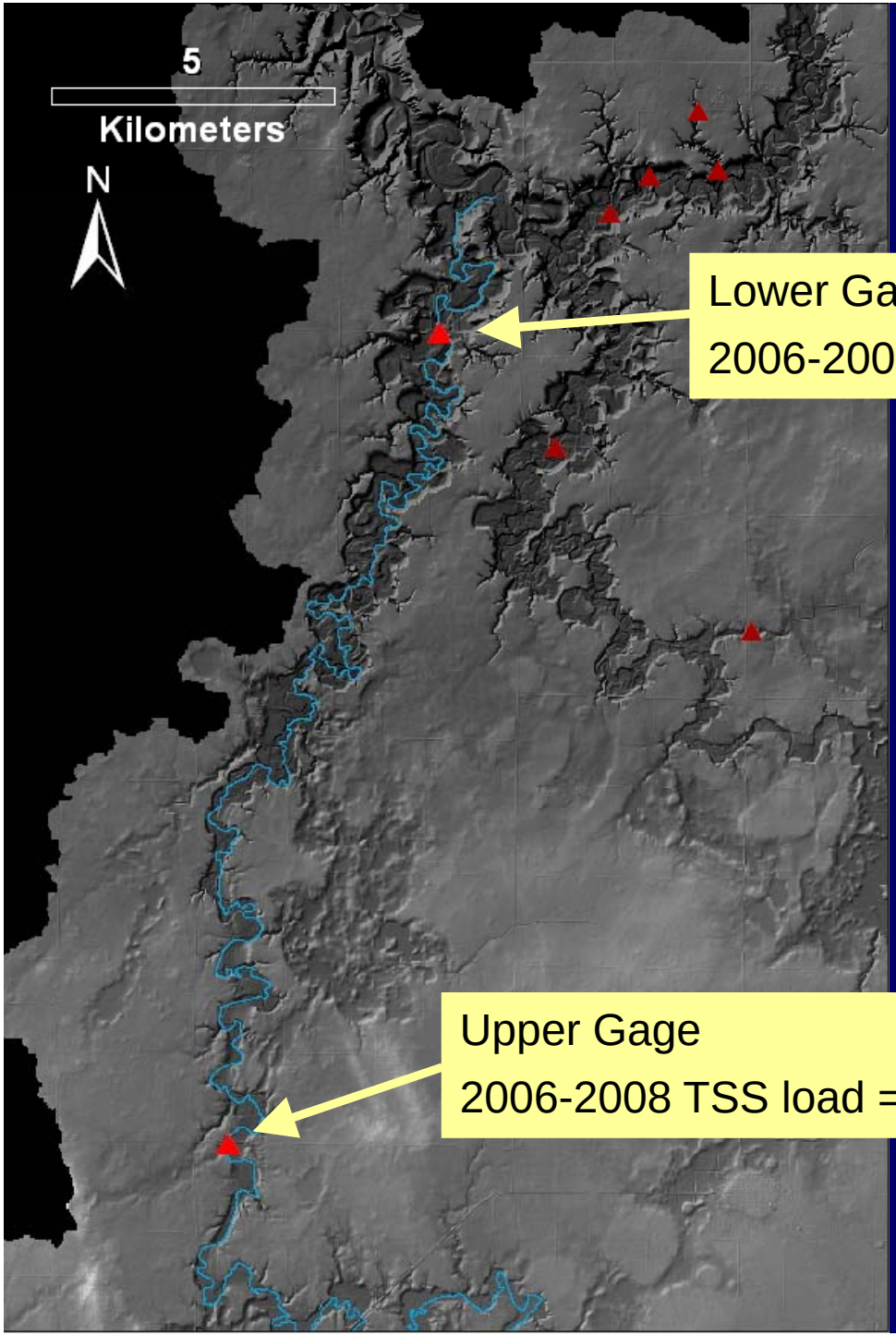
2007 -2010 (planned)

14 sites

completed by S. Day

High-res annual erosion rates & information on location & process responsible for erosion





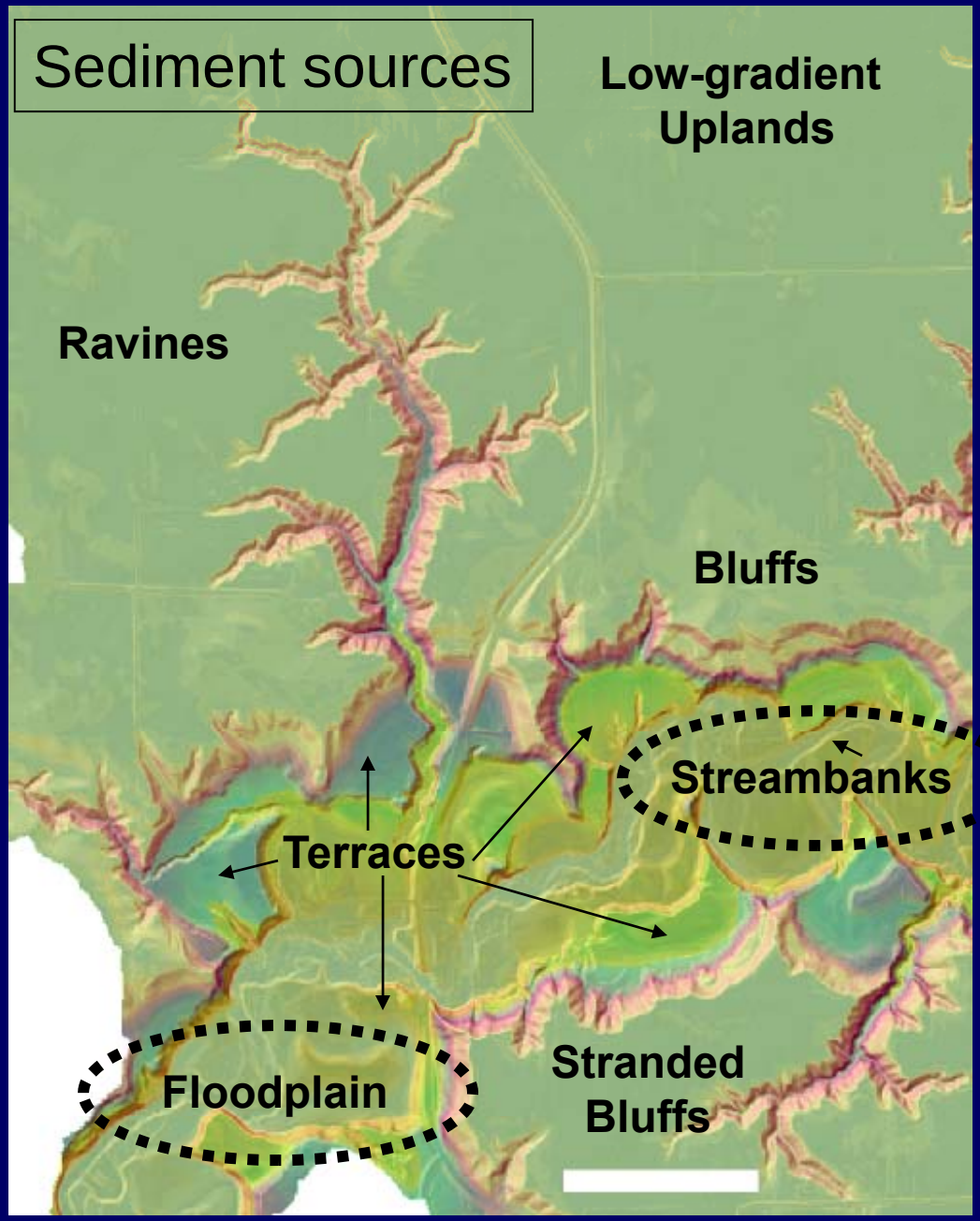
Where is the sediment coming from?

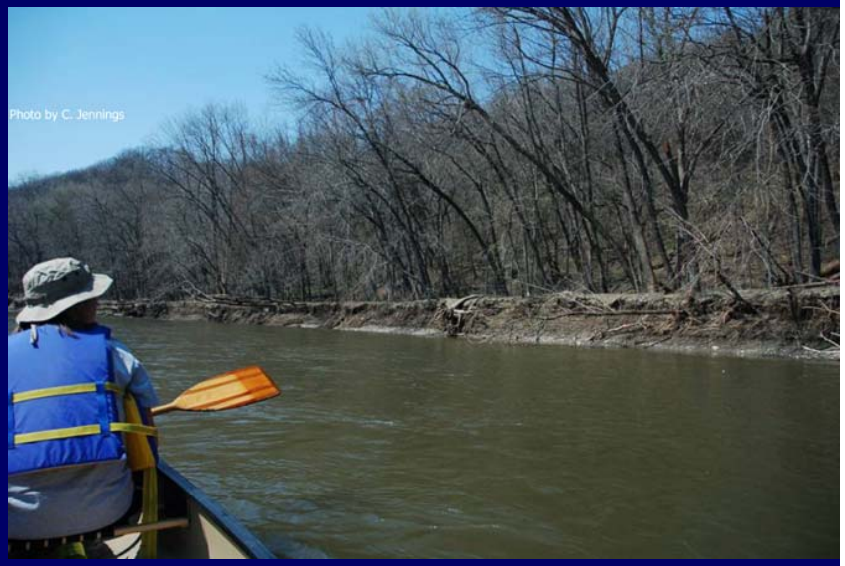
Lower Gage
2006-2008 TSS load = **24,000 Mg/yr**

Bluffs:
~14500 +/- 6000 Mg/yr (65-yr)

Upper Gage
2006-2008 TSS load = **8,000 Mg/yr**

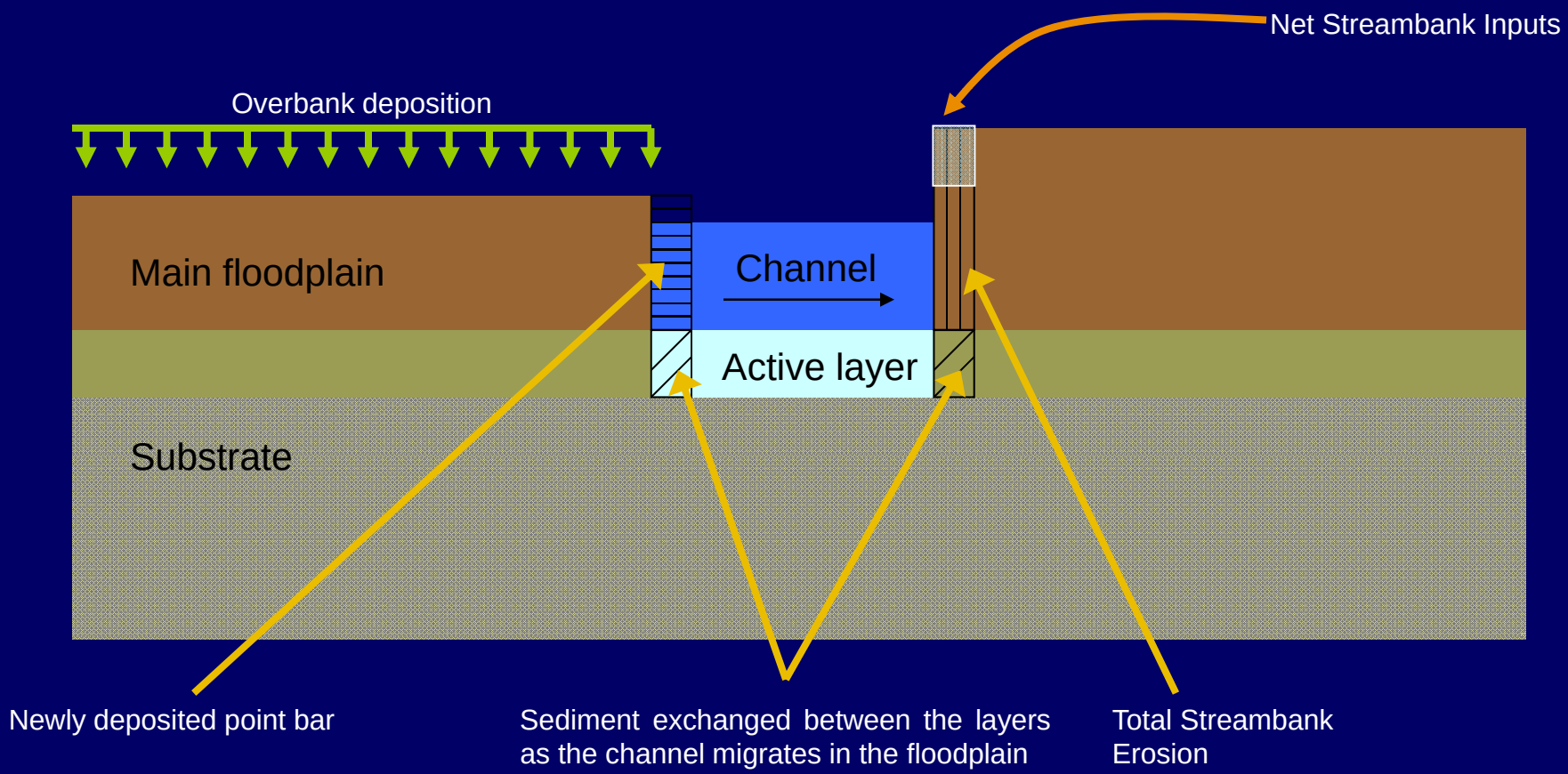
Sediment sources





A floodplain is both a source (streambank) and a sink (overbank/point bar deposition) of sediment.

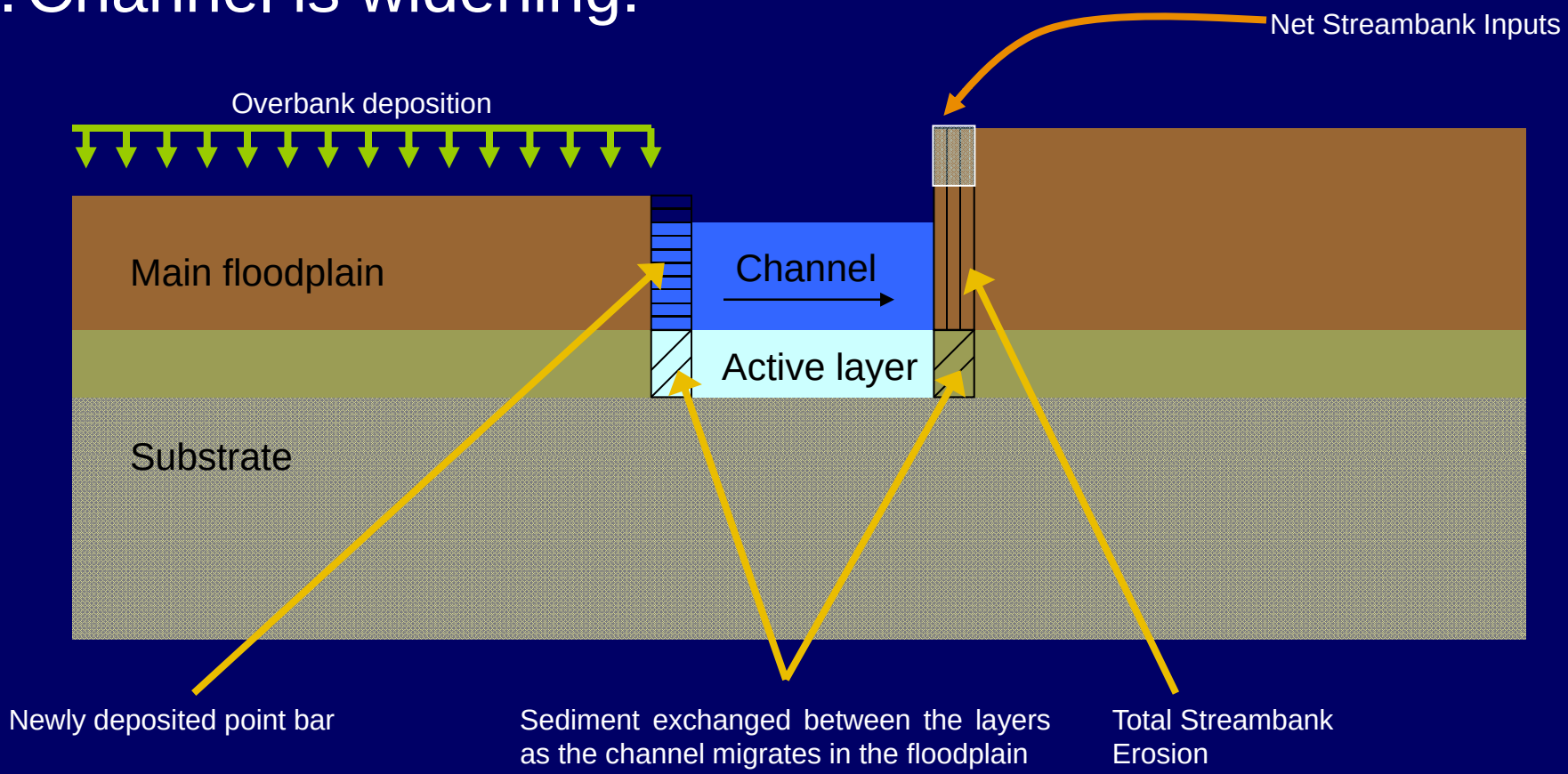
When is the floodplain a net source?



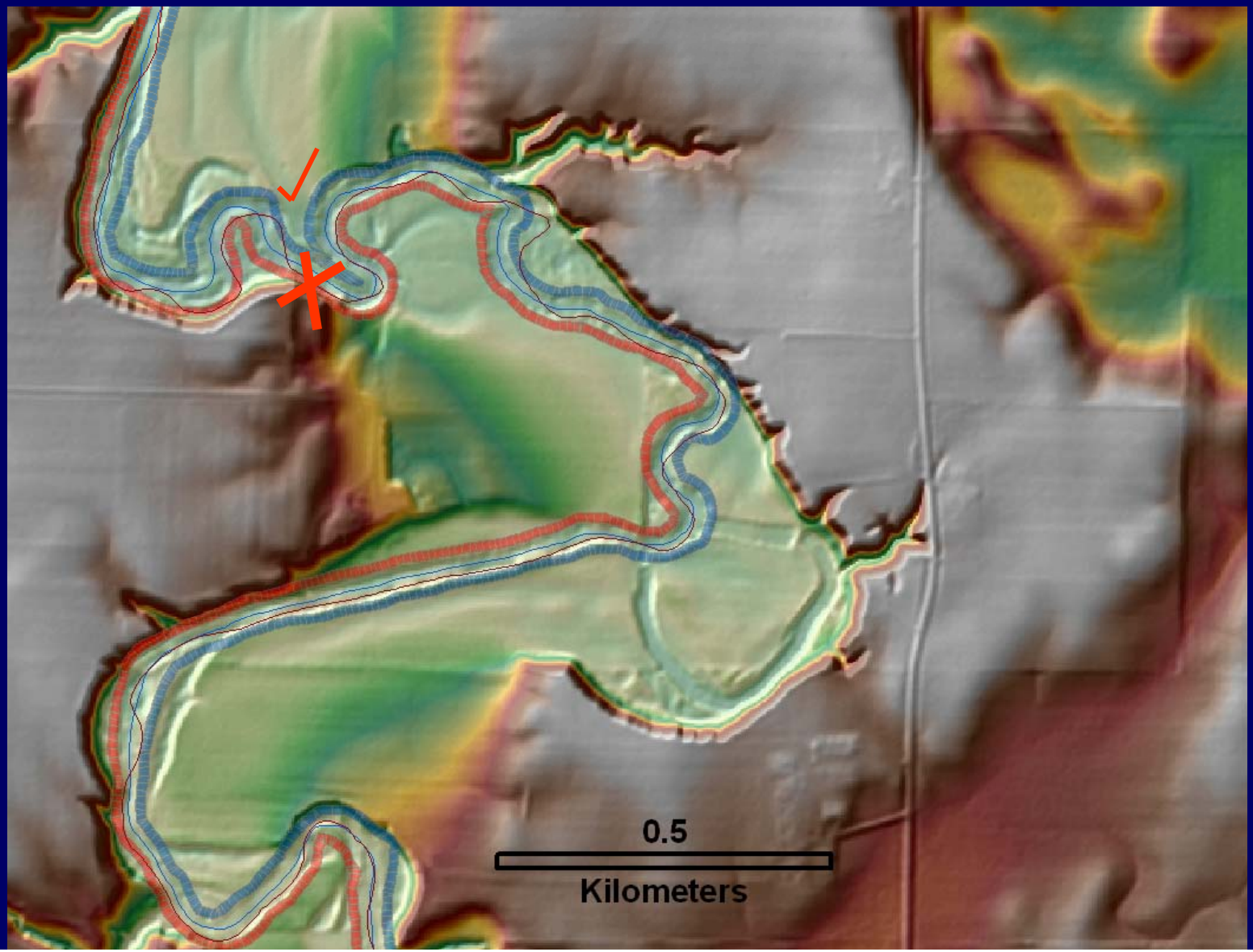
A floodplain is both a source (streambank) and a sink (overbank/point bar deposition) of sediment.

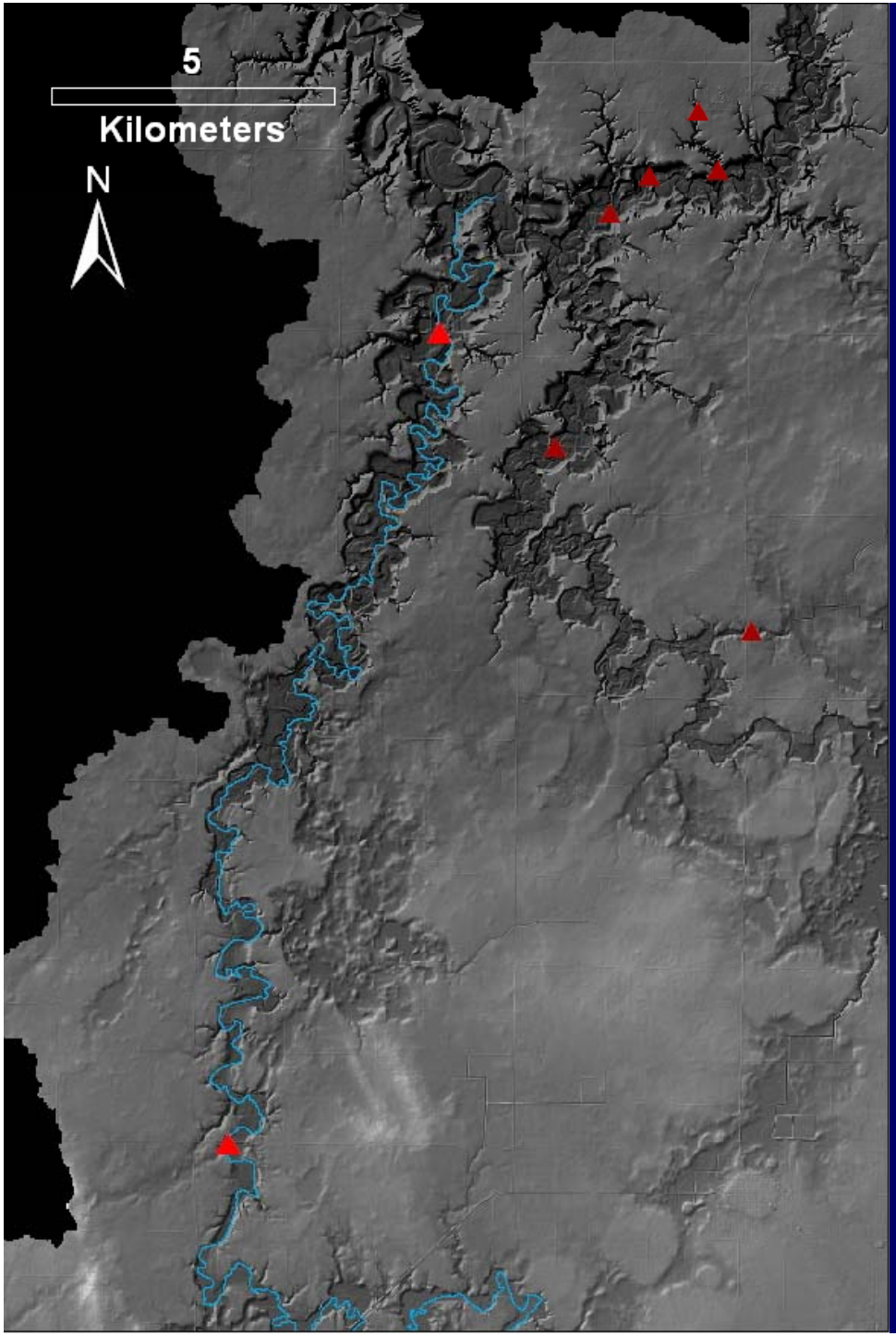
When is the floodplain a net source?

1. Cut bank is higher than depositional side (long-term).
2. Channel is widening.



Buffering 2005 channel banks to measure Δη





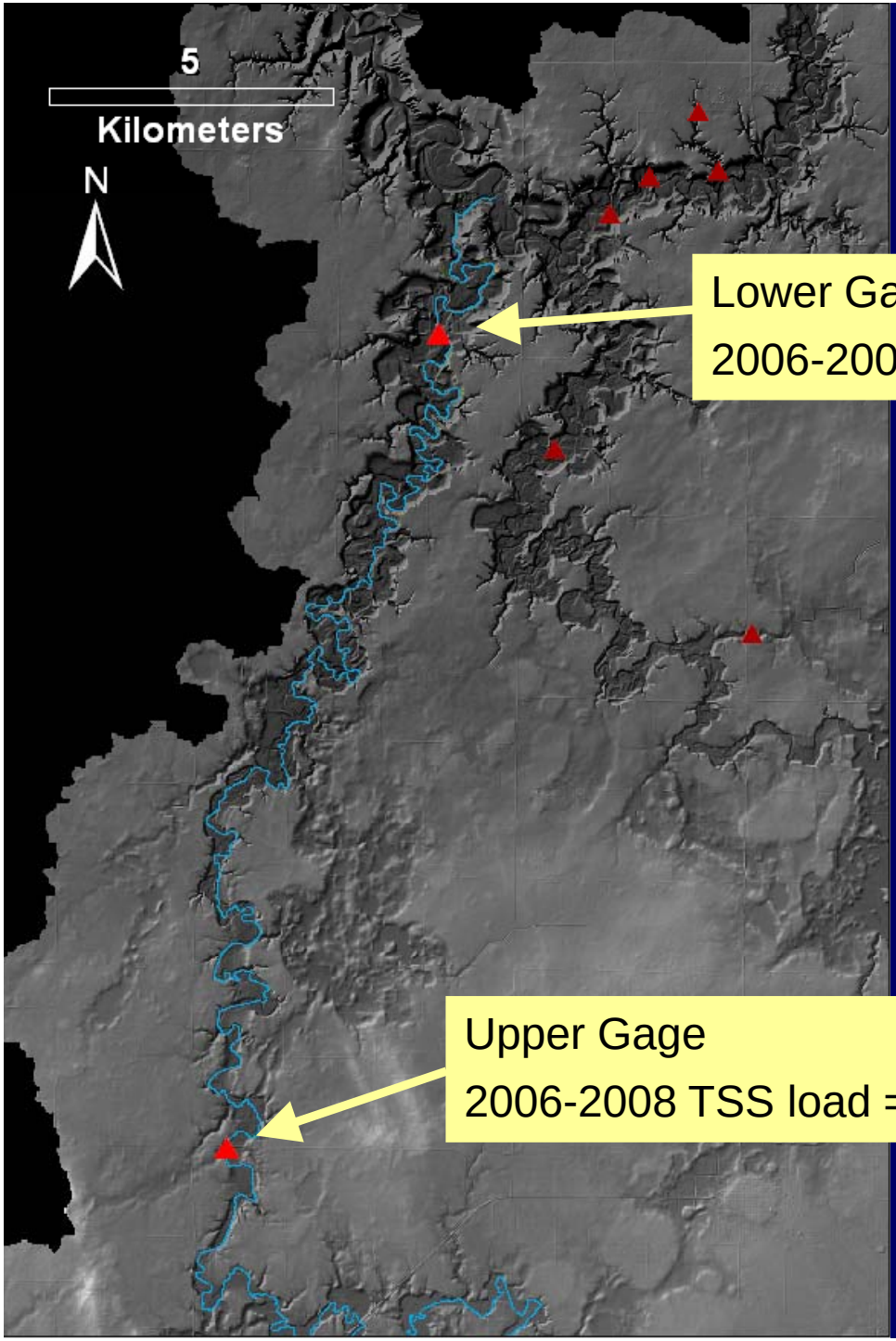
Bank Contributions

Total Load Contributions

	(Mg/yr)
Above upper gage:	2400
Between gages:	5900
Below lower gage:	300

Suspended Load Contributions

	(Mg/yr)
Above upper gage:	1200
Between gages:	2900
Below lower gage:	150



Where is the sediment coming from?

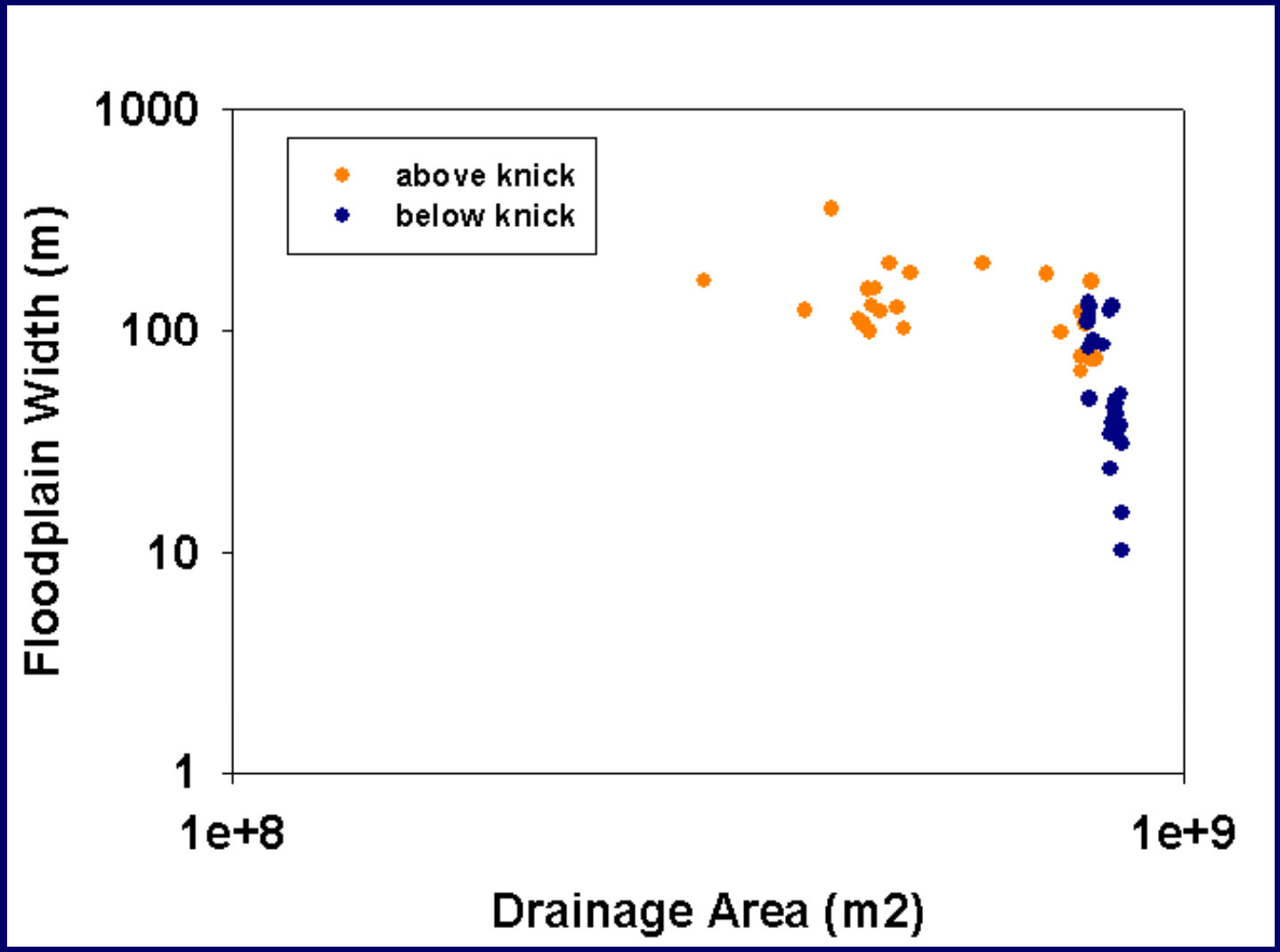
Lower Gage
2006-2008 TSS load = **24,000 Mg/yr**

Erosion: 2900 Mg between gages from floodplain eroded

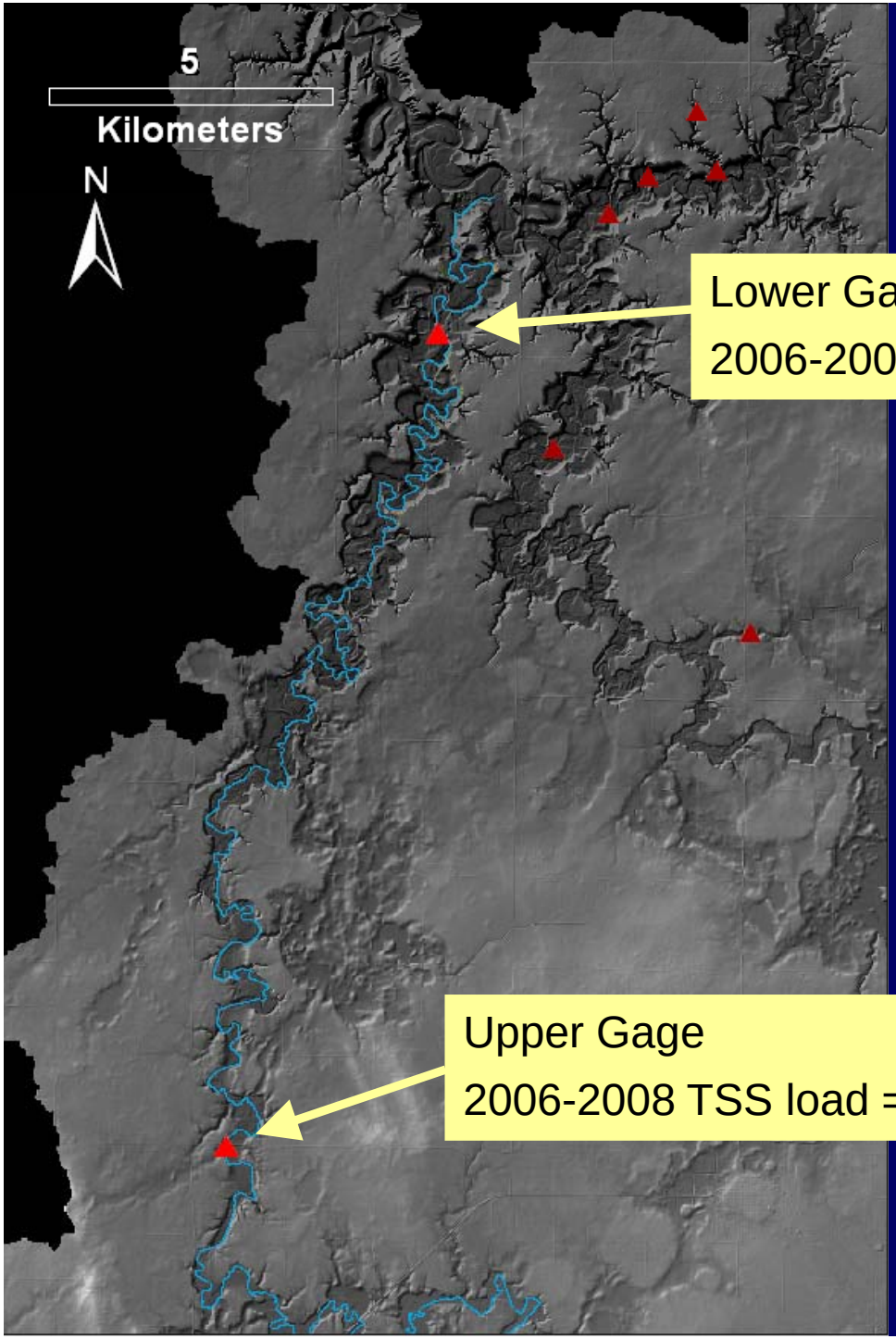
Deposition: estimated based on thickness of overbank deposits on terraces & area of inundation

Upper Gage
2006-2008 TSS load = **8,000 Mg/yr**

Major inflection in Width-Area at knick

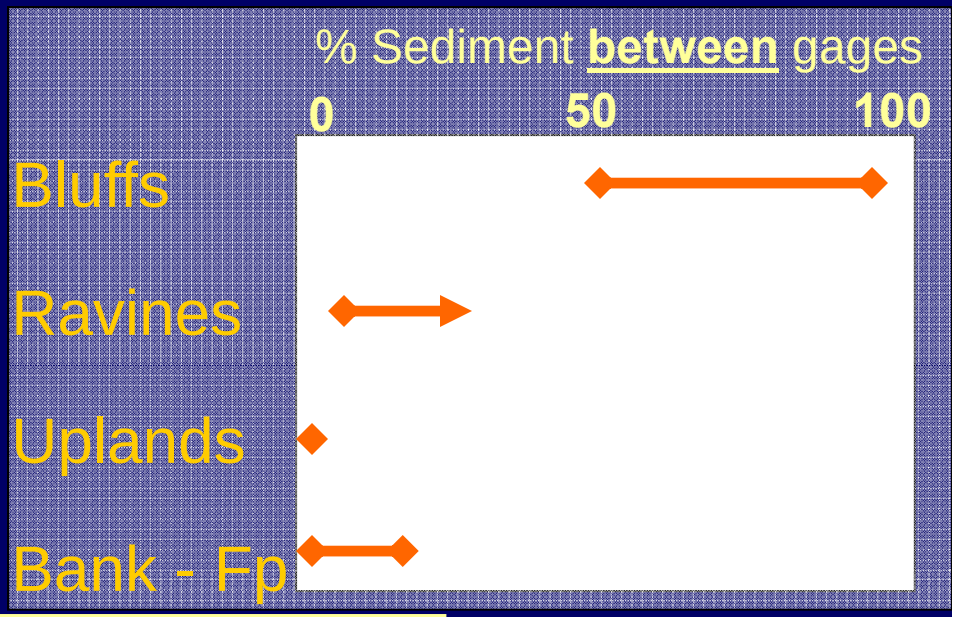


completed by P. Belmont



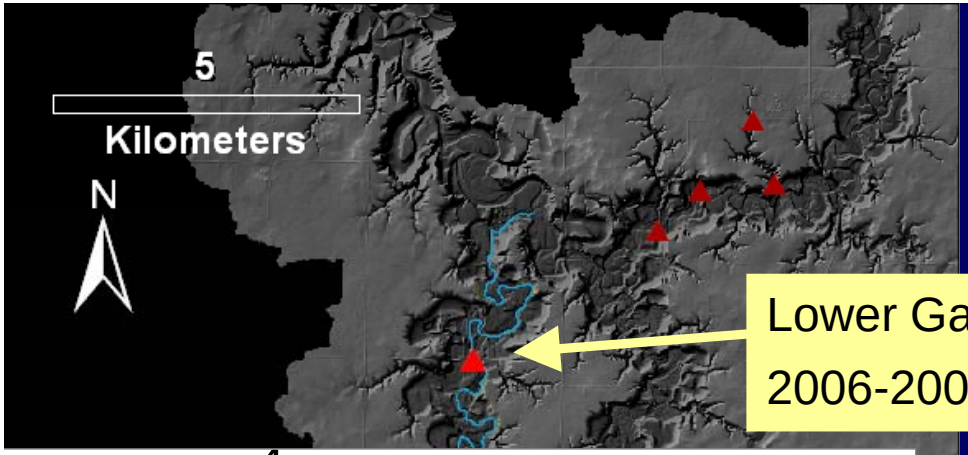
Where is the sediment coming from?

Lower Gage
2006-2008 TSS load = **24,000 Mg/yr**



Upper Gage
2006-2008 TSS load = **8,000 Mg/yr**

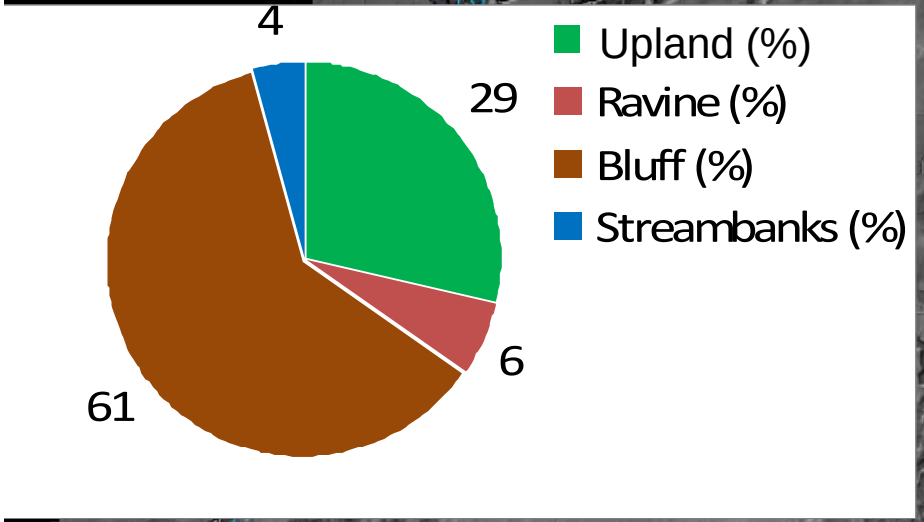
Where is the sediment coming from?

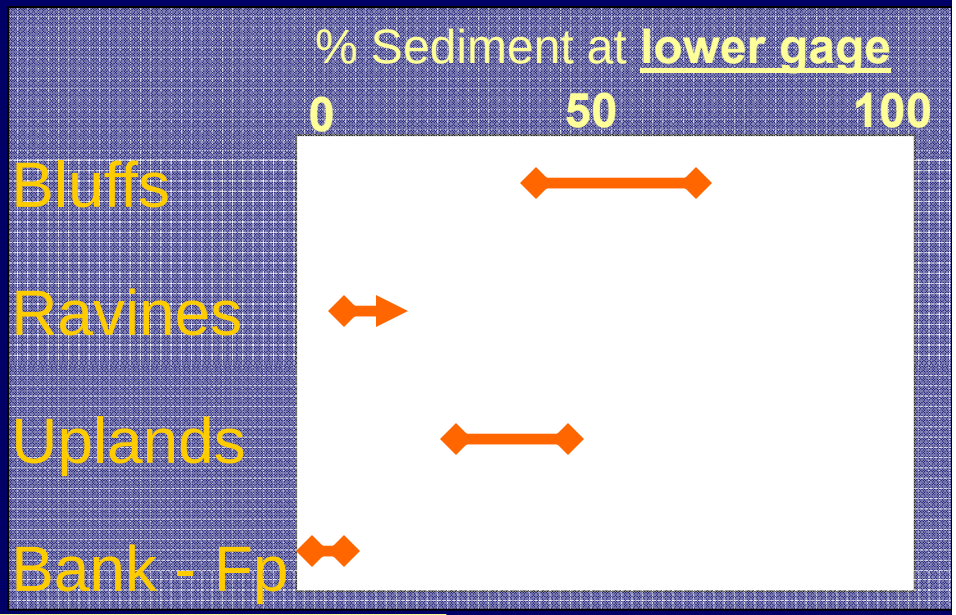


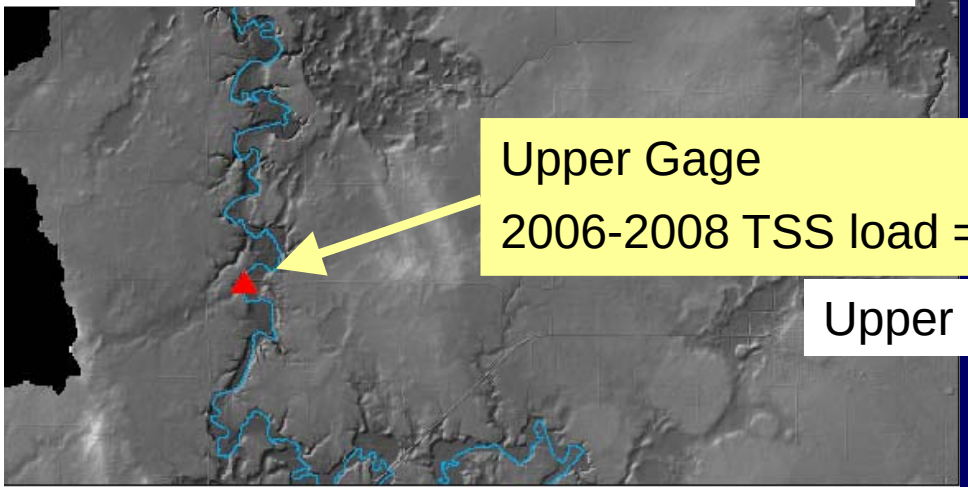
Lower Gage

2006-2008 TSS load = **24,000 Mg/yr**

Lower Gage: 32,400 Mg/yr





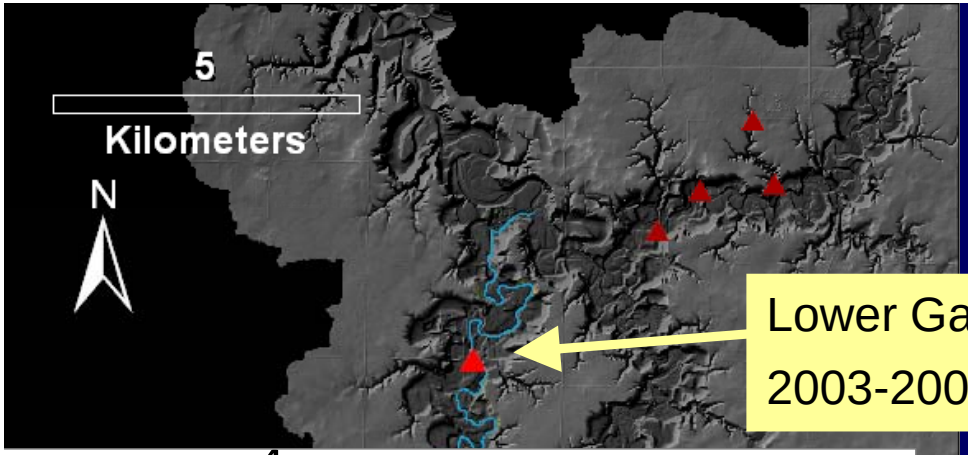


Upper Gage

2006-2008 TSS load = **8,000 Mg/yr**

Upper Gage: 13,600 Mg/yr

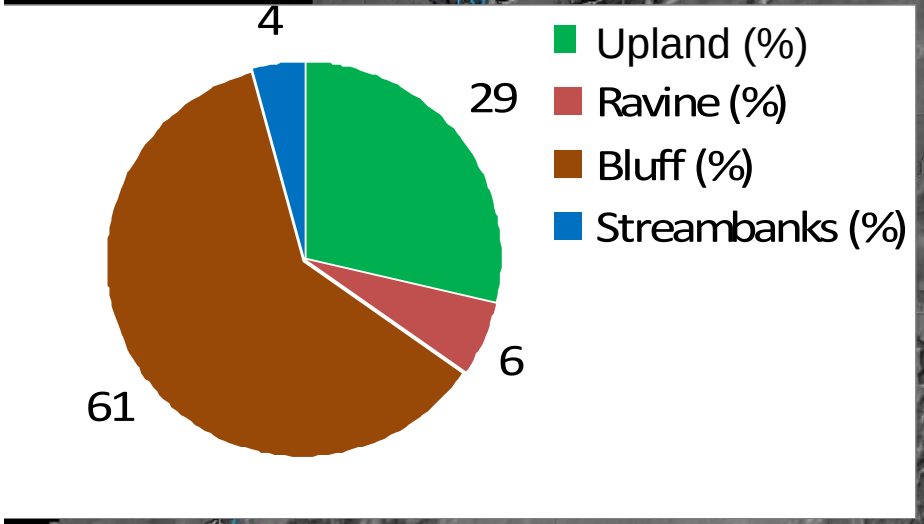
Where is the sediment coming from?

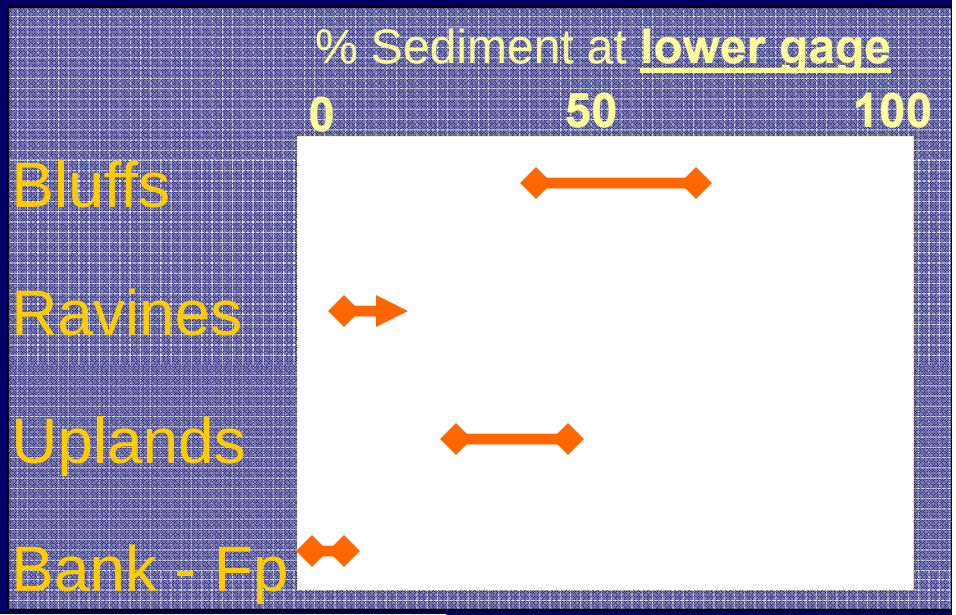


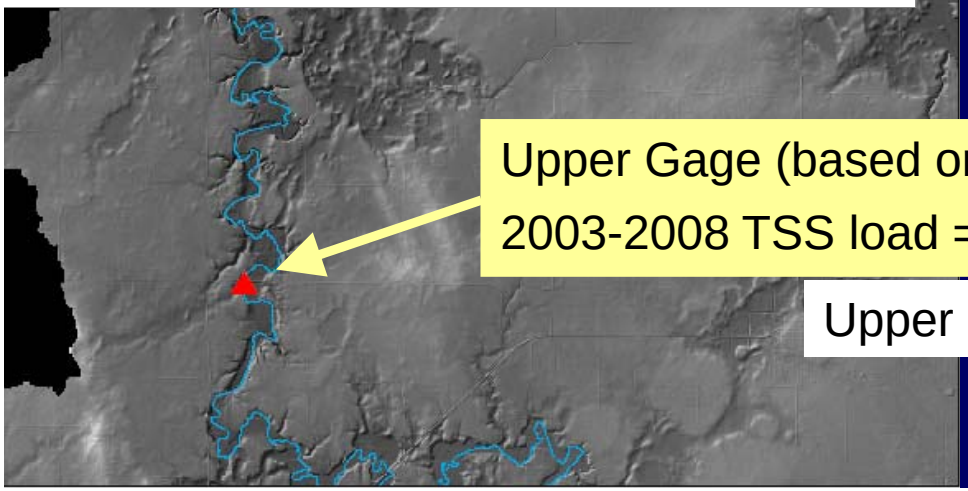
Lower Gage

Lower Gage: 32,400 Mg/yr

2003-2008 TSS load = **41,300 Mg/yr**







Upper Gage (based on ratios '06-'08)

2003-2008 TSS load = **13,000 Mg/yr**

Upper Gage: 13,600 Mg/yr

Adding it up

- Predicted LG:UG ratio is generally lower
- Predicted rates at LG are generally lower
- Must use upper bound rate for bluffs and ravines (including SMC) to match loads

- Do the ratios match fingerprinting?
  - ^{210}Pb (Schottler & Engstrom)
  - Meteoric Cosmogenic ^{10}Be (Belmont & Willenbring)
  - In Situ Cosmogenic ^{10}Be & ^{26}Al

Next step: What to do?