Minnesota River Basin: Near Stream Sediment Sources

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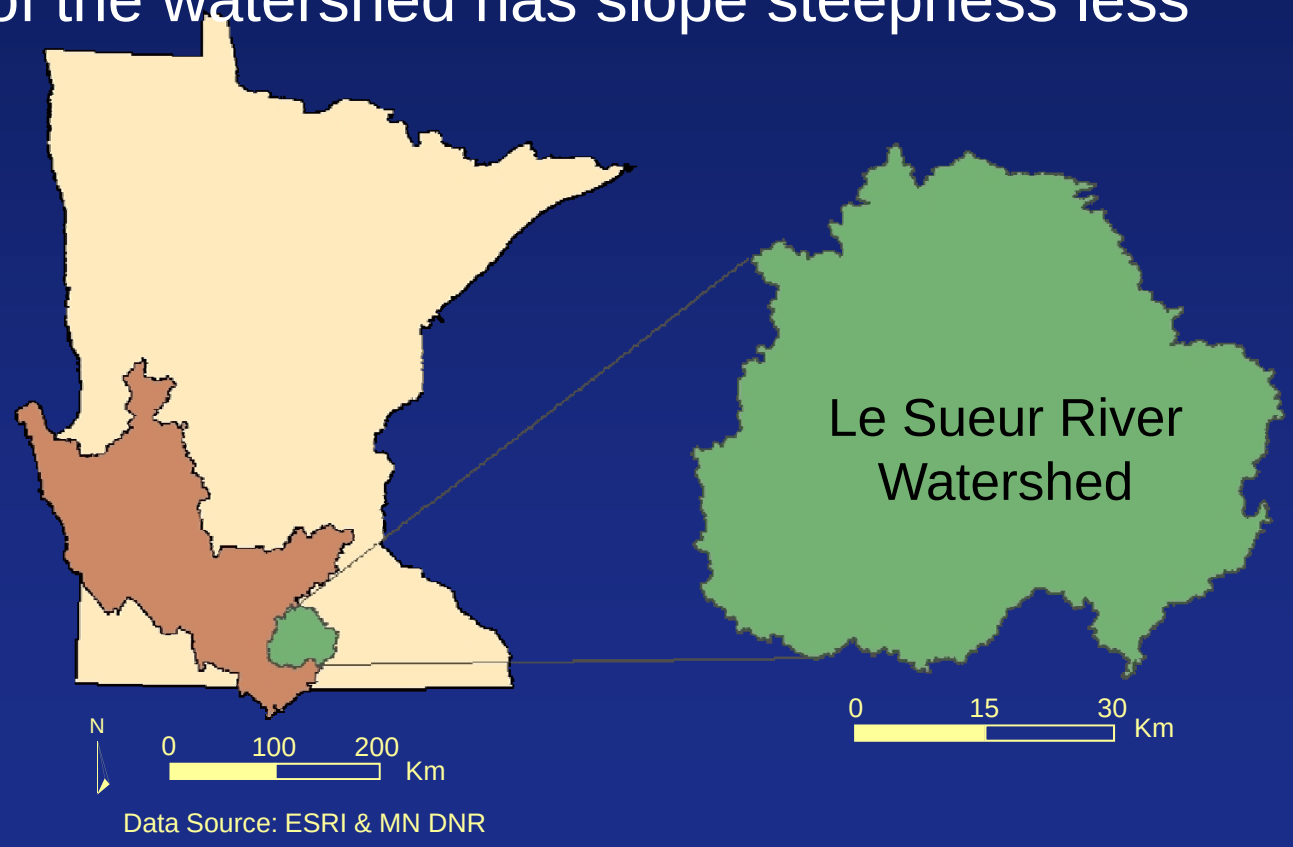
Background

- The Le Sueur contributes a disproportionate amount of sediment pollution to the Minnesota River and Lake Pepin
  - Only comprises 7% of the basin land surface area
  - A majority of the watershed has slope steepness less than 2%
  - 53% TSS
- Why?



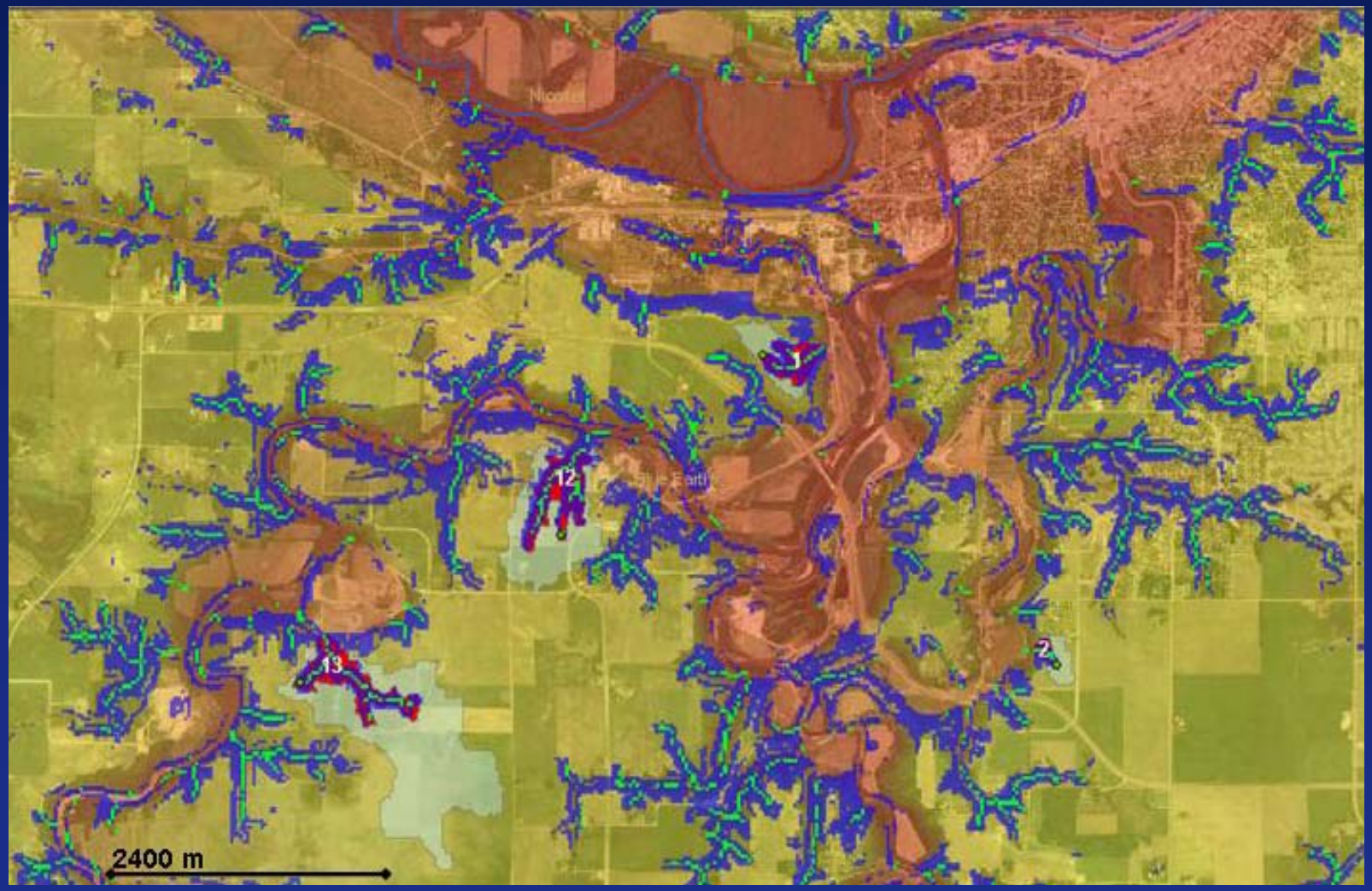
Sources of Sediment

- Gully and ravine erosion
- Stream bank and bluff erosion
- Upland sheet and rill erosion

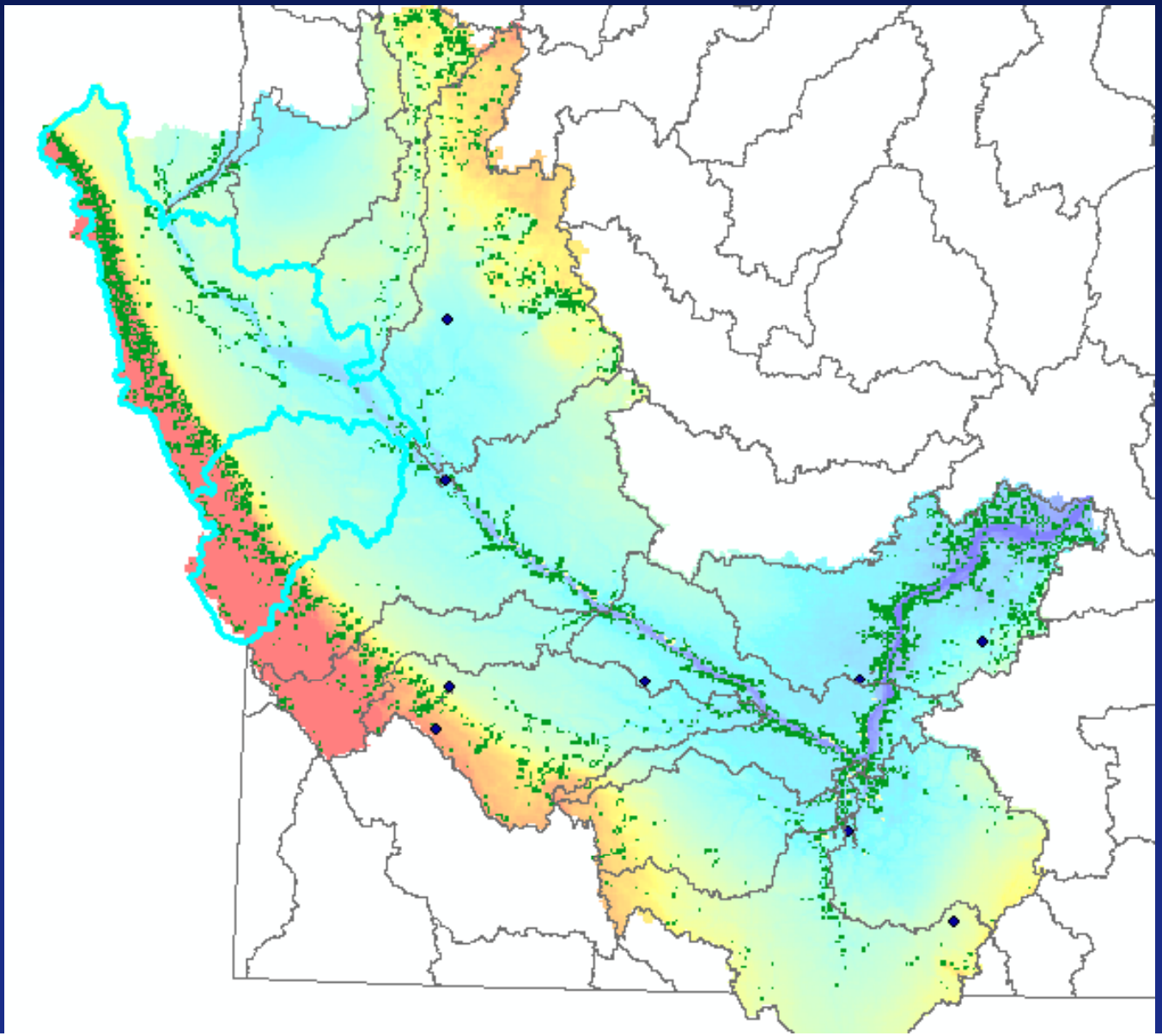
- Where are these sources located?
- What are the relative influences of changes in climate and land use/land management?

Ravines

Ravines

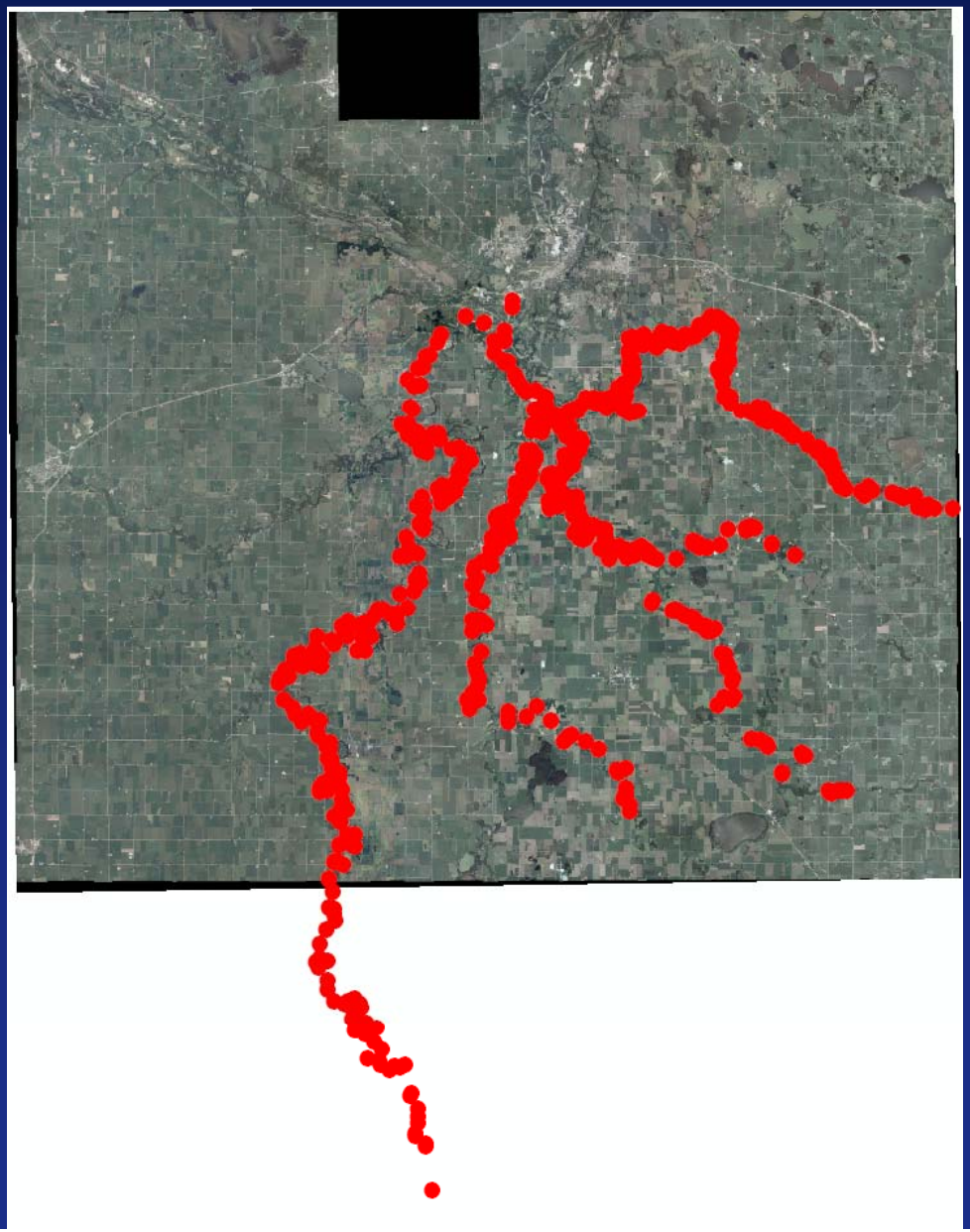


Minnesota River Basin Ravines



Slumping River Bluffs

Blue Earth and Le Sueur River Watersheds



Locations of Slumping Bluffs

Sekely, A. C., D. J. Mulla, and D. W. Bauer. 2002. Streambank slumping and its contribution to the phosphorus and suspended sediment loads of the Blue Earth River, Minnesota. J. Soil Water Conservation. 57(5):243-250.

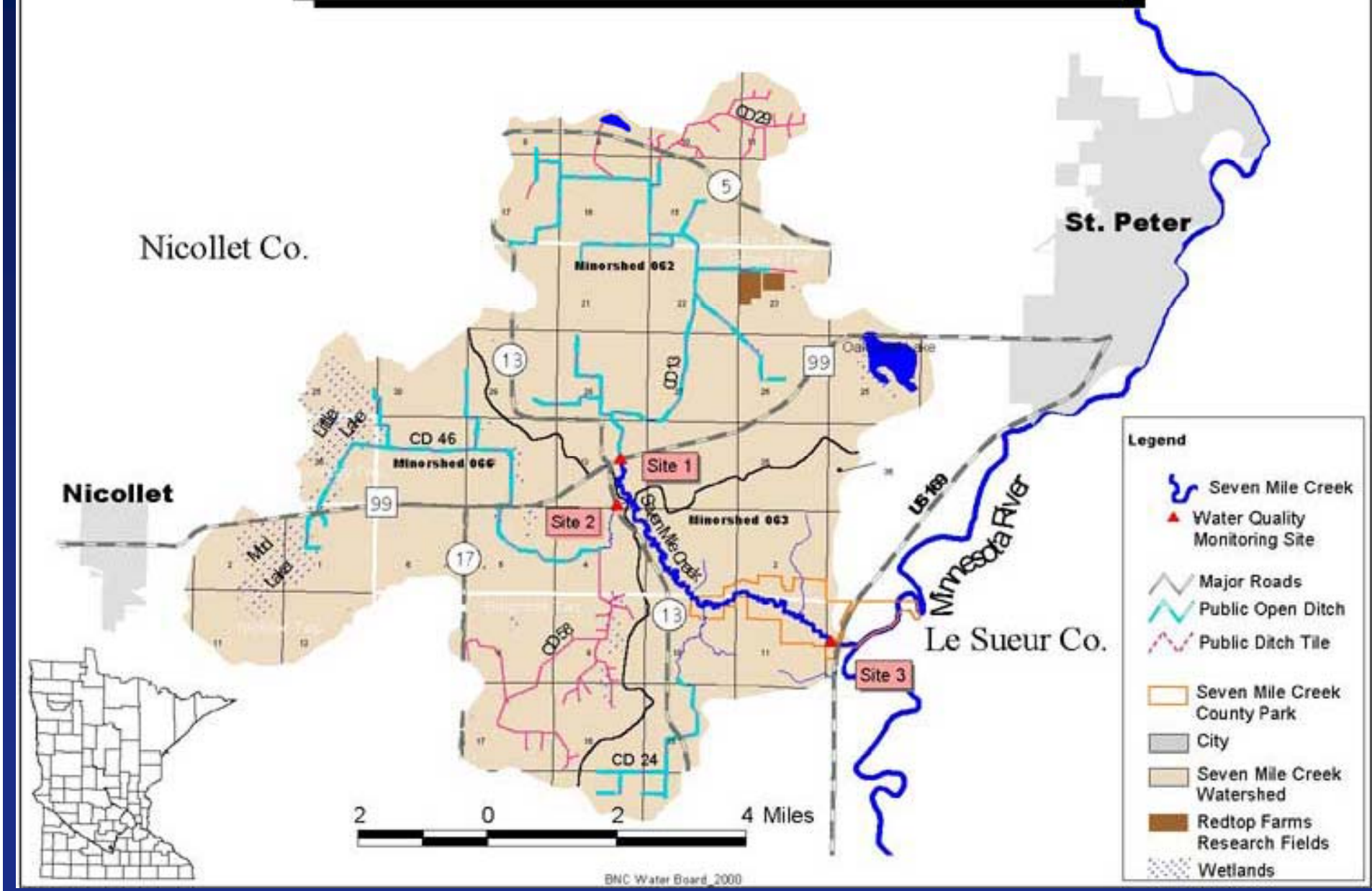
Slumping River Bluffs

Minnesota River Ravines and Bluffs

Watershed	Area (ac)	Ravines (ac)	Bluffs (ac)
Le Sueur	711,607	1354	245
Blue Earth	991,705	1,657	156
Cottonwood	839,800	2,727	52
Watonwan	561,431	598	27
Chippewa	1,326,637	2,401	2.5
Redwood	451,267	971	4.9
Hawk-Yellow	1,327,131	3,463	37
Lac Qui Parle	701,727	2,584	32
Lower	1,164,358	10,601	19.8
Middle	862,030	6,657	9.9
Upper	1,319,227	13,259 (small)	0

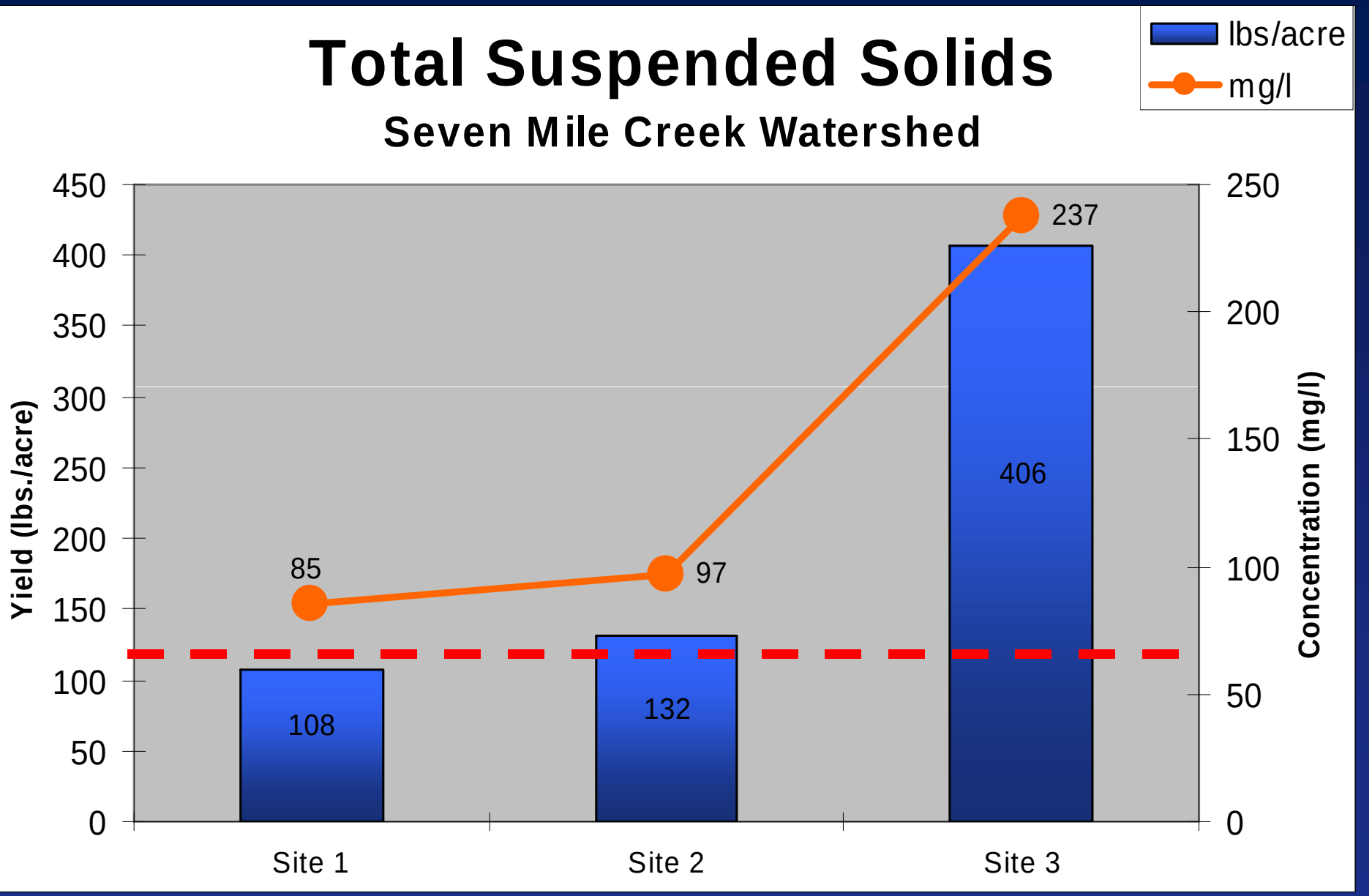
Seven Mile Creek Watershed

Nicollet County, Minnesota

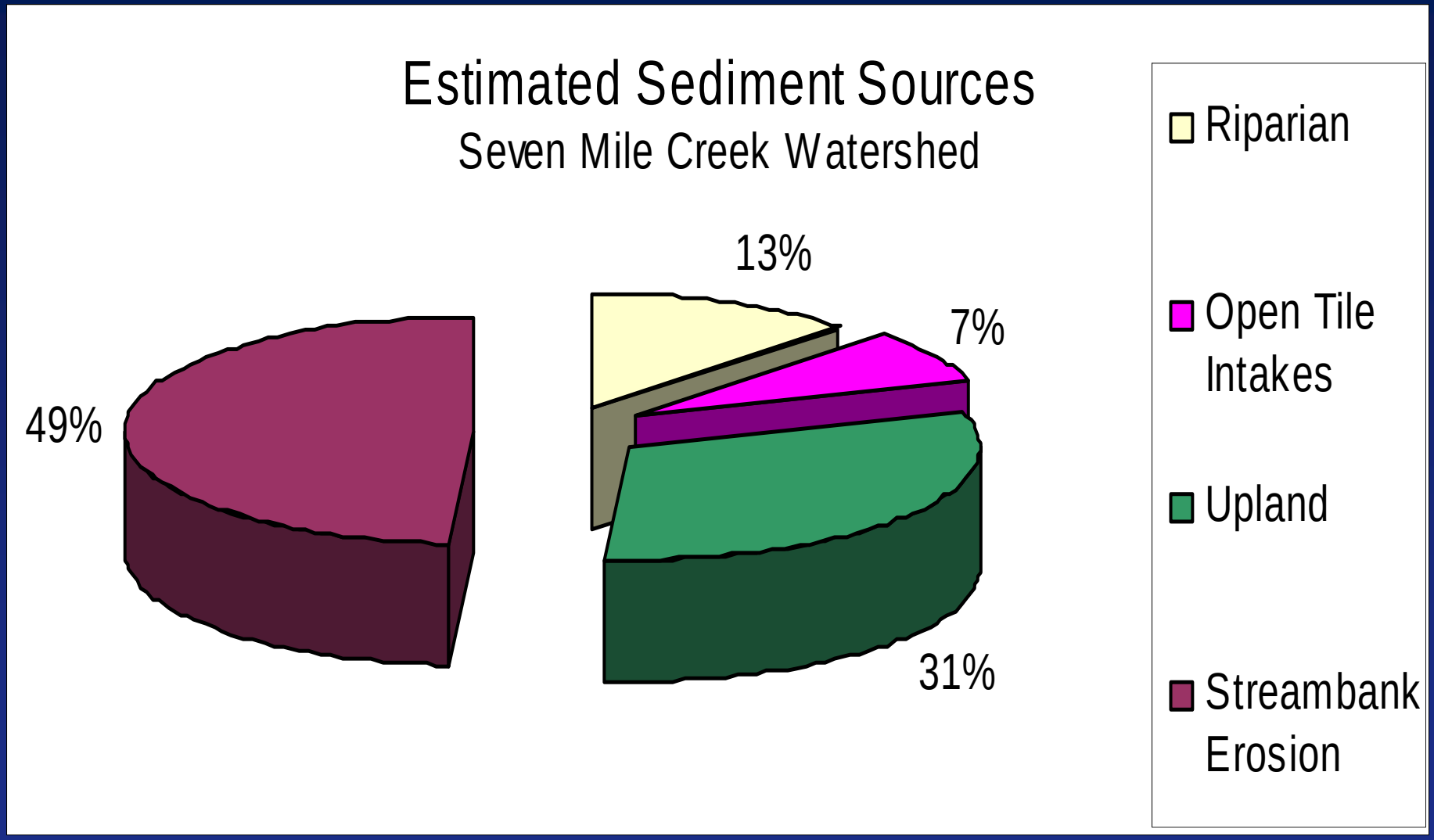


Total Suspended Solids

Seven Mile Creek Watershed



*Four Year Flow Weighted Average, 2000-2003


Estimated Sediment Sources
Seven Mile Creek Watershed
13%
7%
49%
31%
Riparian
Open Tile Intakes
Upland
Streambank Erosion

SWAT Modeling

- SWAT stands for SOIL and Water Assessment Tool
- SWAT model was developed by the USDA-ARS Laboratory in Temple, Texas.

- Why the SWAT Model?
  - User friendly and uses readily available input data
  - Computationally efficient : reasonable time
  - Accepted by the scientific and regulatory agencies

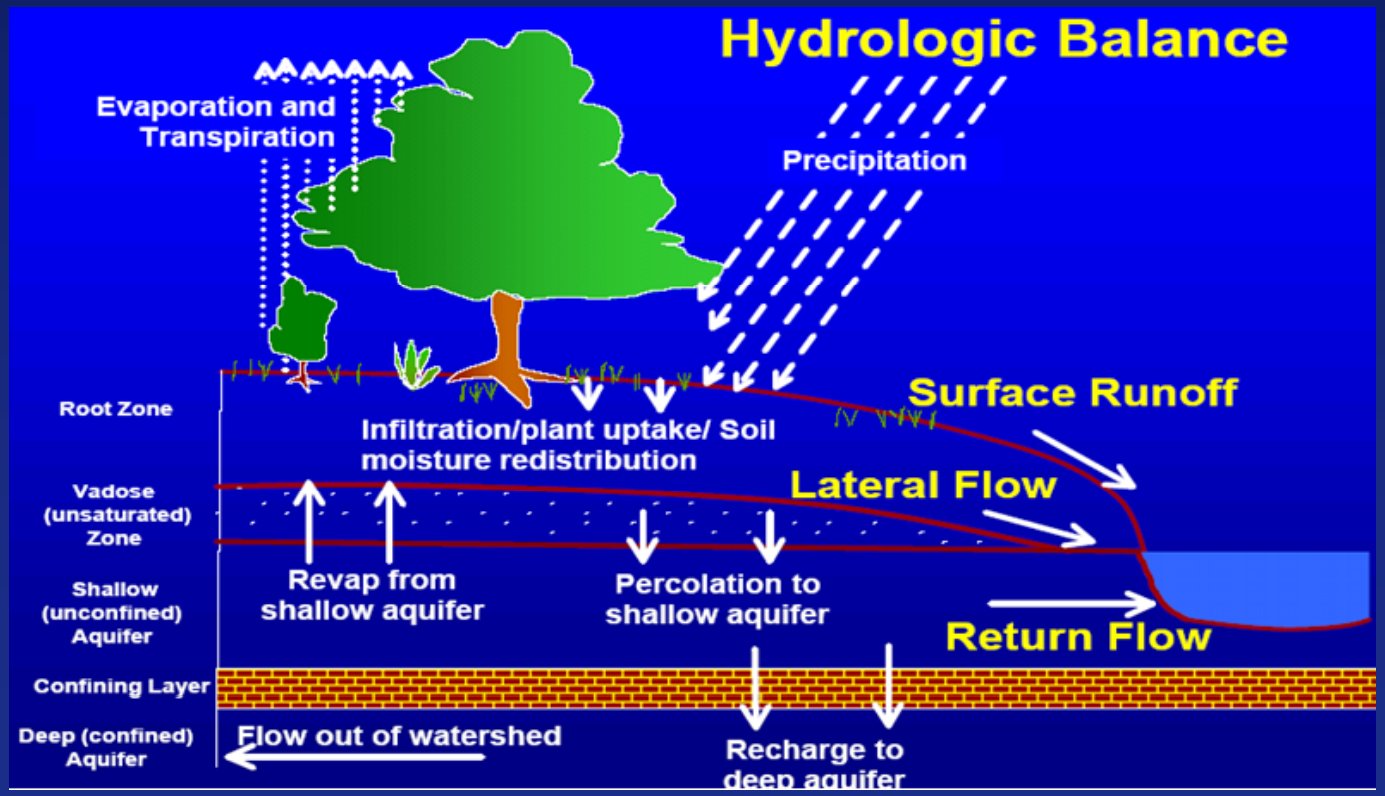
SWAT Modeling

- Developed to predict impacts of land management practices on watershed hydrology and water quality
- Deterministic physically based and spatially distributed continuous watershed scale model
  - Models known upland physical processes
  - Channel sources can be estimated by difference

Processes Modeled by SWAT

<u>Upland Landscape Processes</u>:

Weather, Hydrology, Plant growth, Erosion, Nutrients (N, P), Ag Management



Source: SWAT Model Theoretical Document, 2000

Beauford SWAT Model

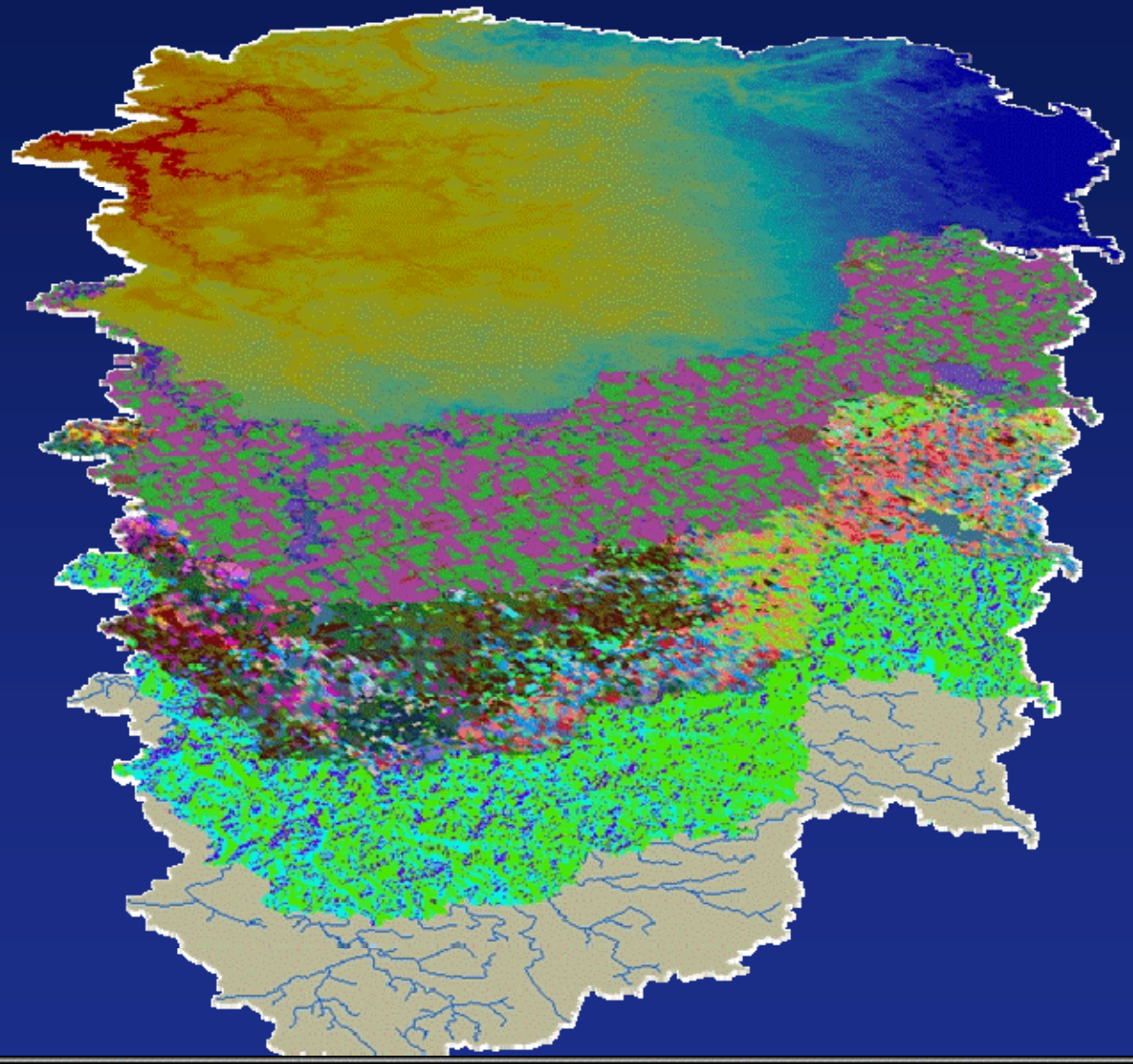
DEM

Land Use

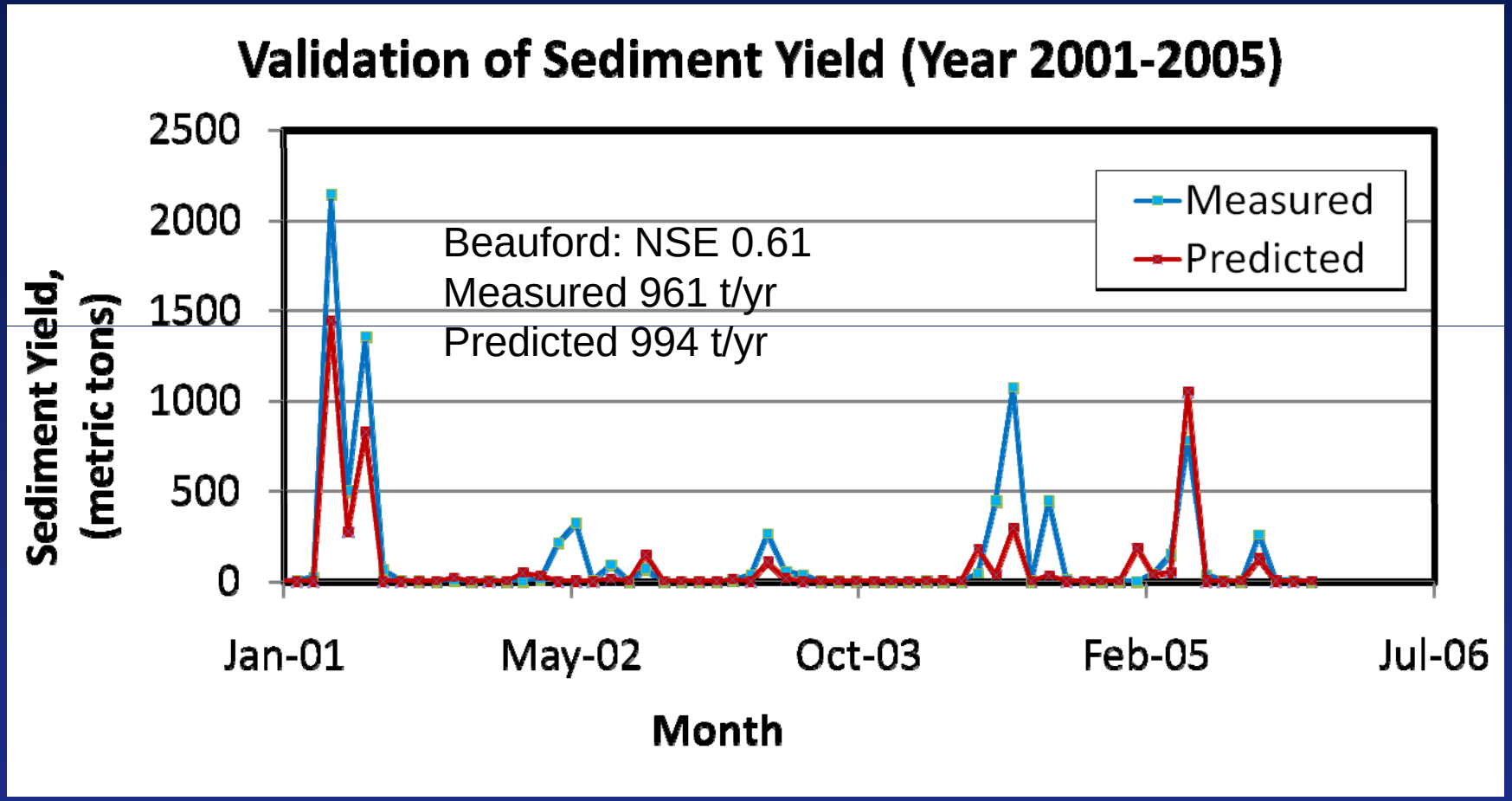
SSURGO Soils

Slope

NHD

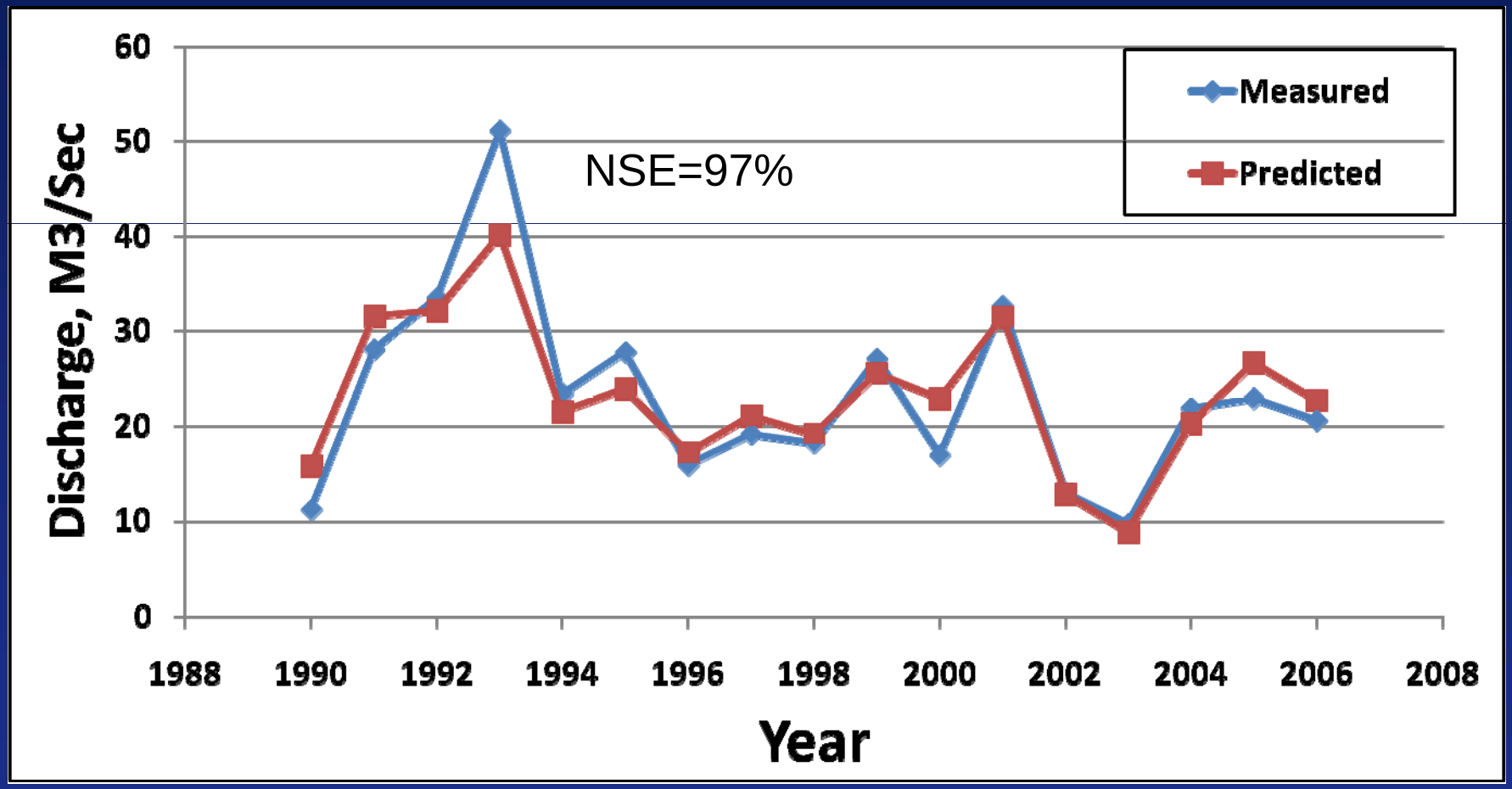


Beauford minor watershed SWAT model



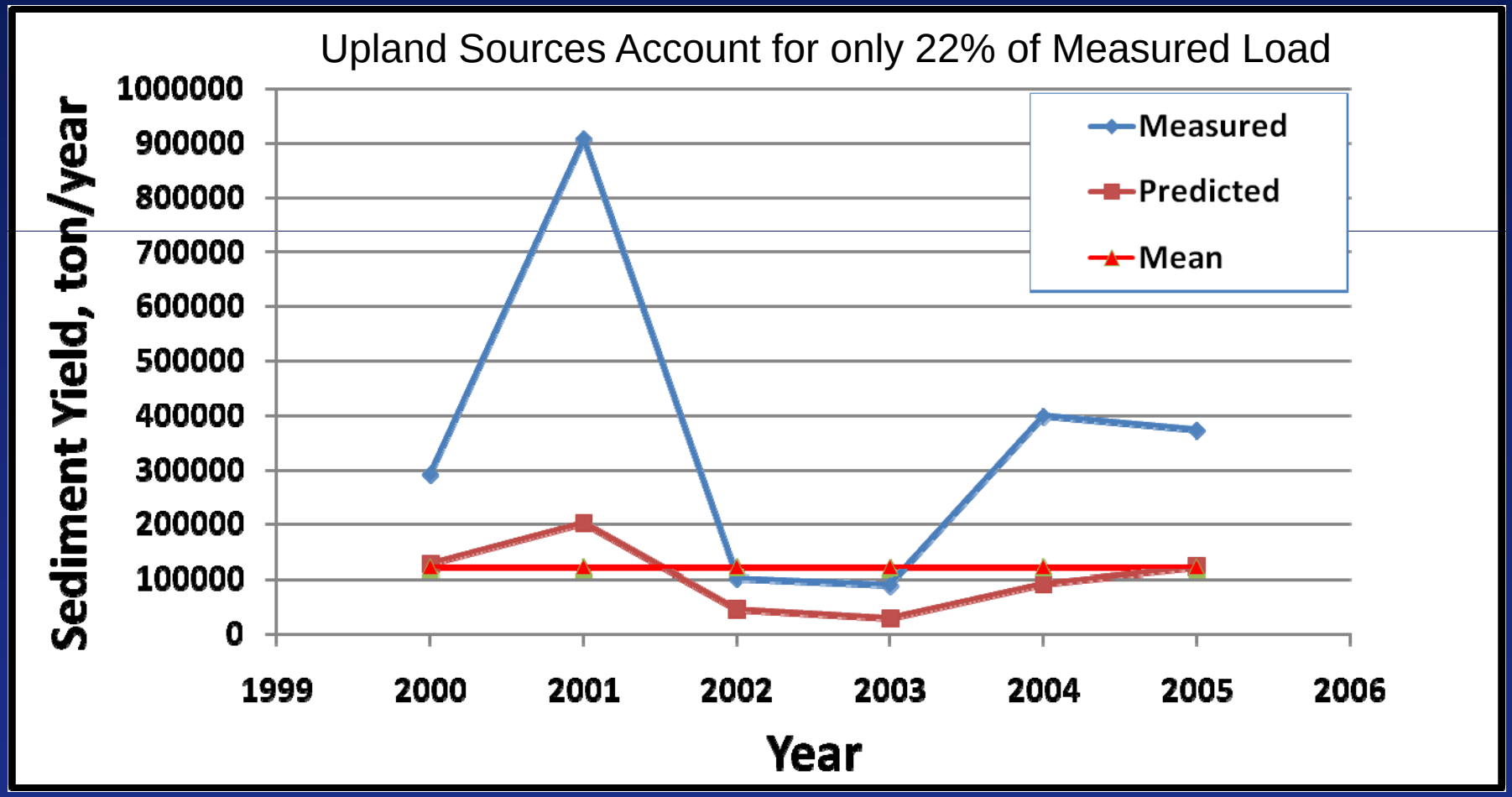
SWAT model accurately predicts upland sediment

Measured and SWAT Predicted Annual Water Yield: Le Sueur River Watershed (1990-2006)



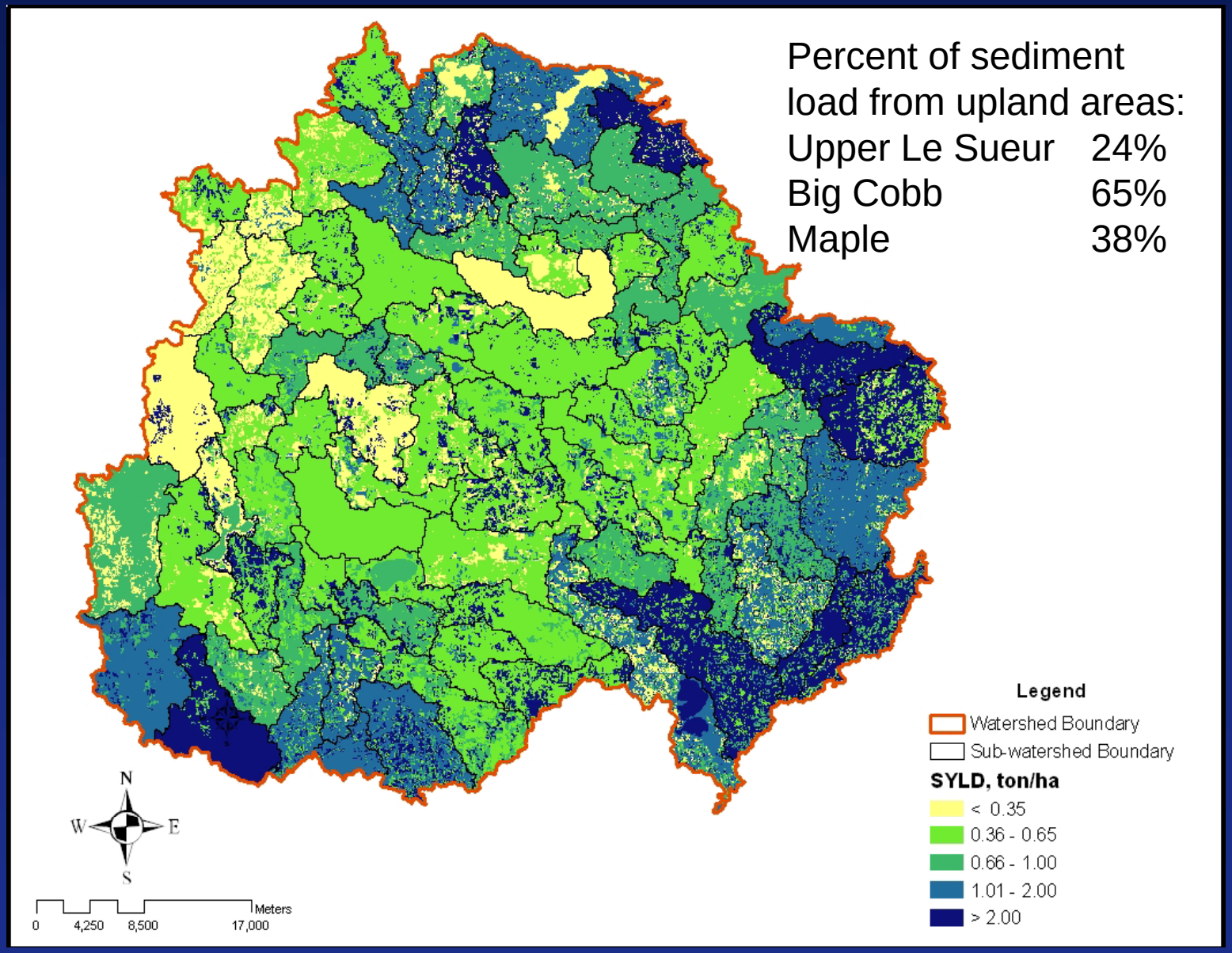
SWAT model accurately predicts Le Sueur watershed discharge

Measured and SWAT Predicted Annual Sediment Yields: Le Sueur River Watershed Mouth 2000-2005



SWAT model fails to predict channel sources of sediment

SWAT Upland Sediment Yields



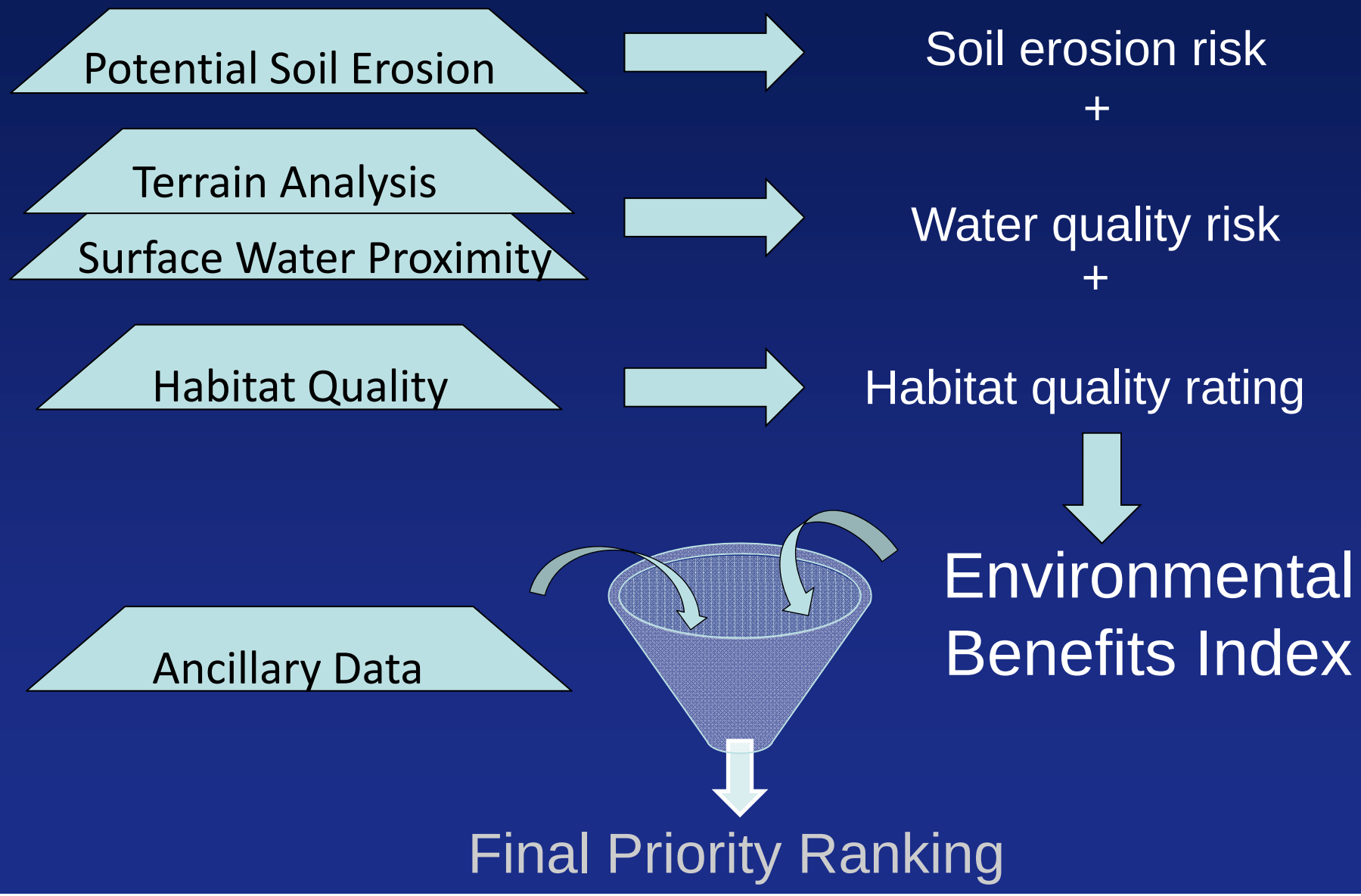
Percent of sediment load from upland areas:

Upper Le Sueur	24%
Big Cobb	65%
Maple	38%

Ecological Ranking Project

- To more effectively target conservation programs to CRP lands and other critical upland regions such as
  - Marginally productive croplands
  - Surface water protection areas
  - Important habitat areas

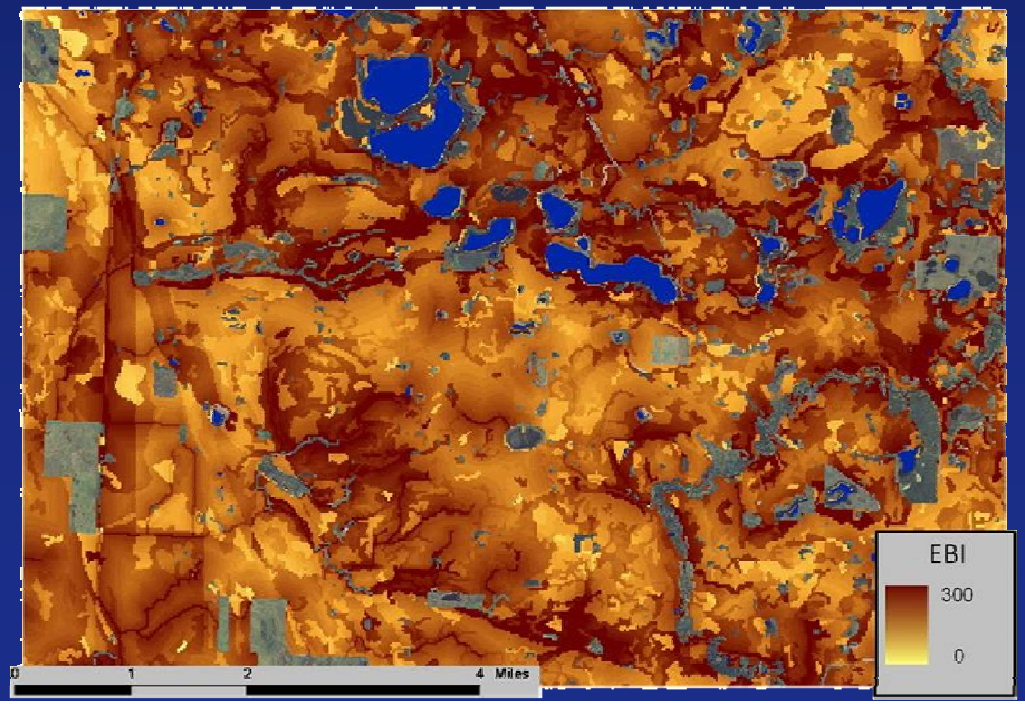
Data layers for ecological ranking



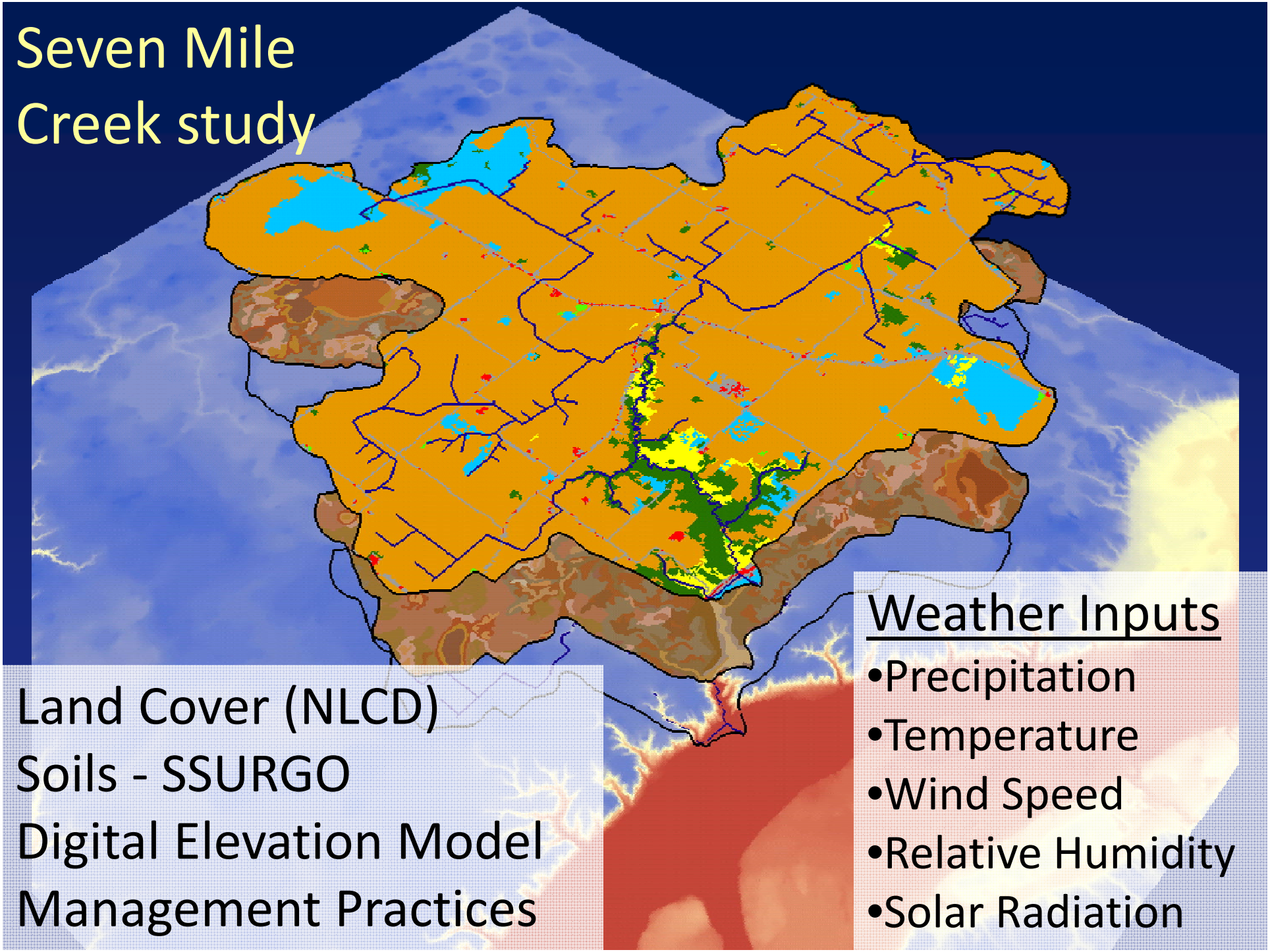
Environmental Benefits Index (EBI)

http://www.bwsr.state.mn.us/ecological_ranking/

- High EBI means:
  - high risk (e.g. water erosion)
  - high quality (e.g. habitat)
  - high value for conservation



Seven Mile Creek study

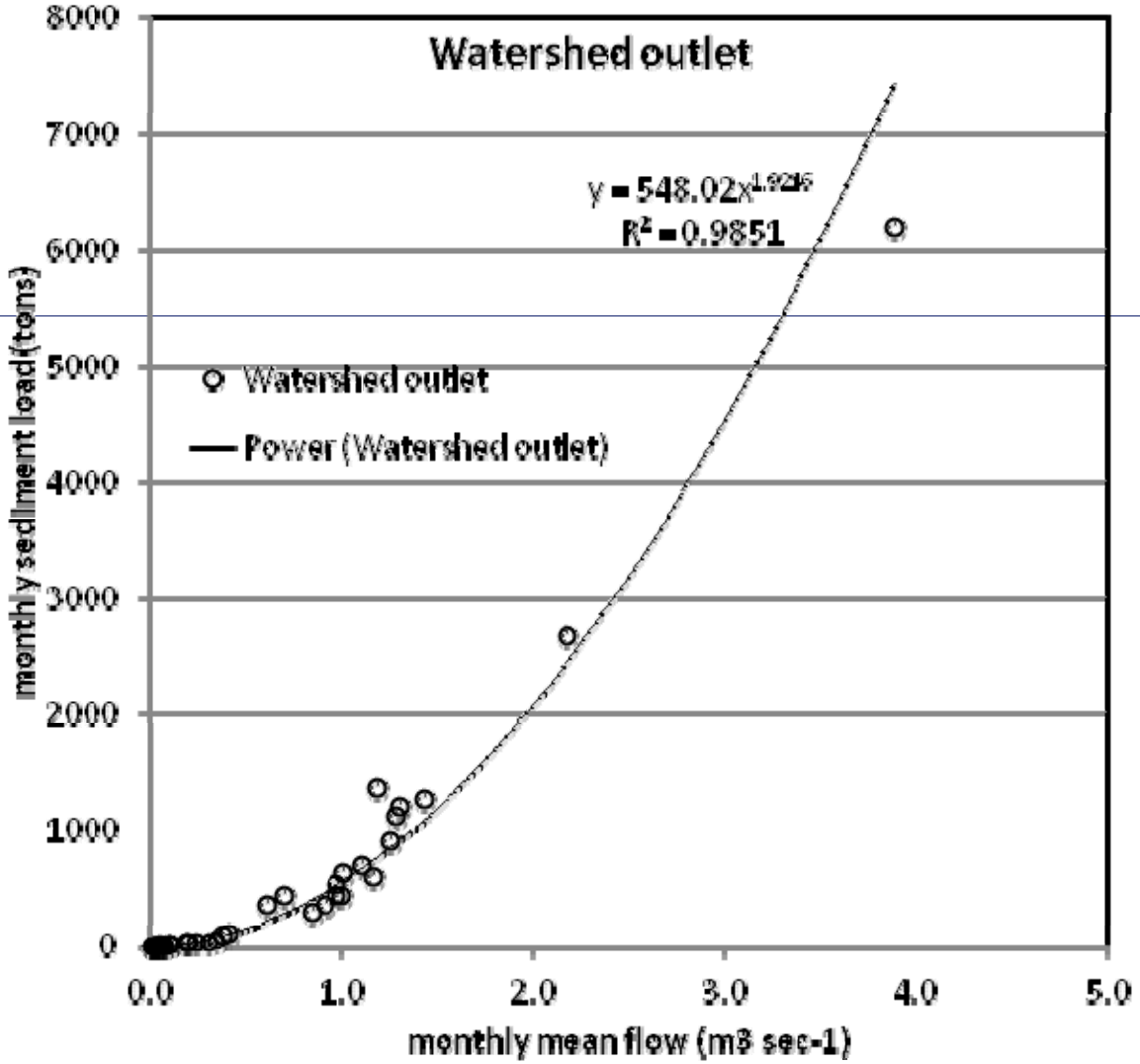


Land Cover (NLCD)
Soils - SSURGO
Digital Elevation Model
Management Practices

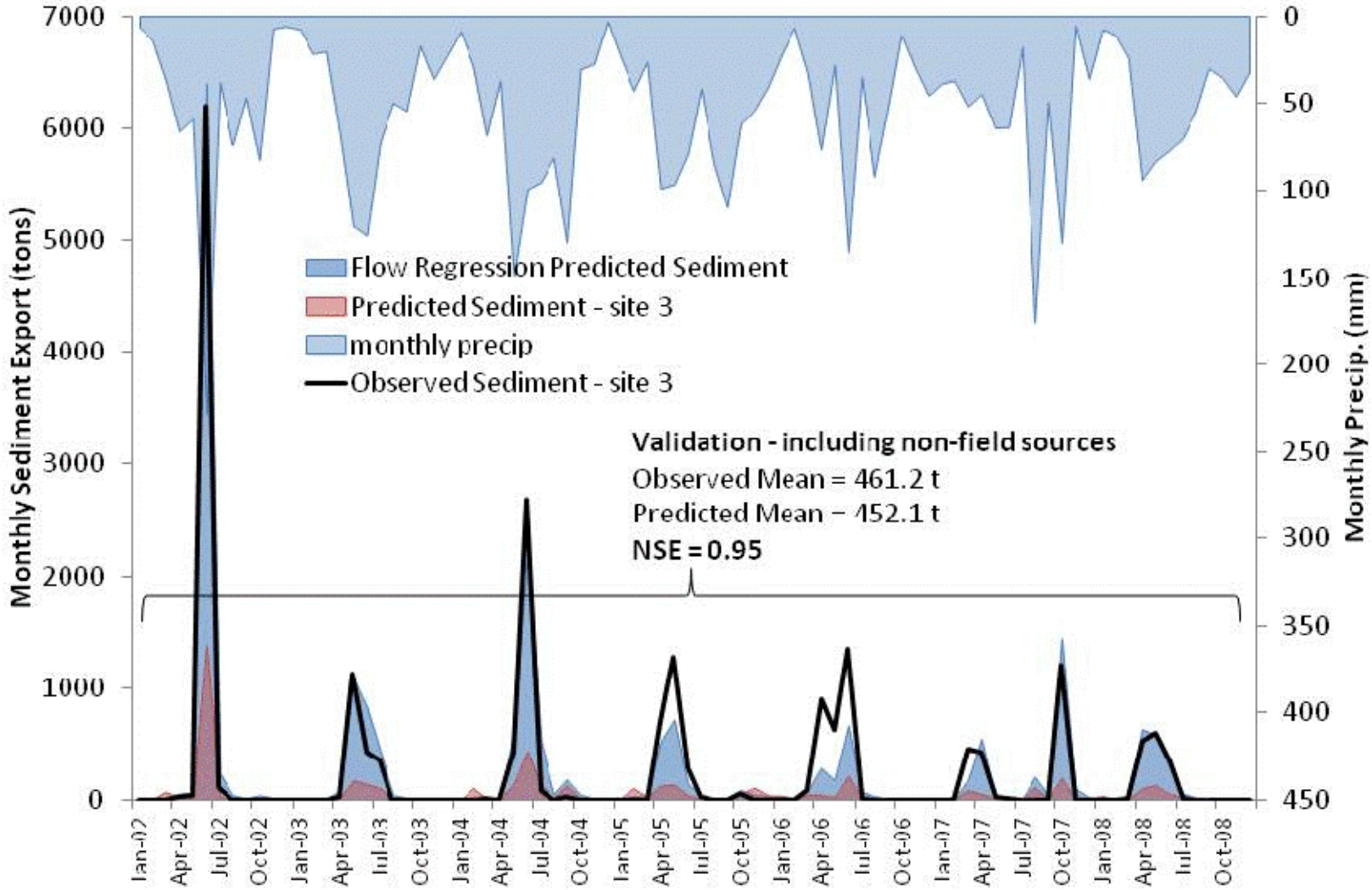
Weather Inputs

- Precipitation
- Temperature
- Wind Speed
- Relative Humidity
- Solar Radiation

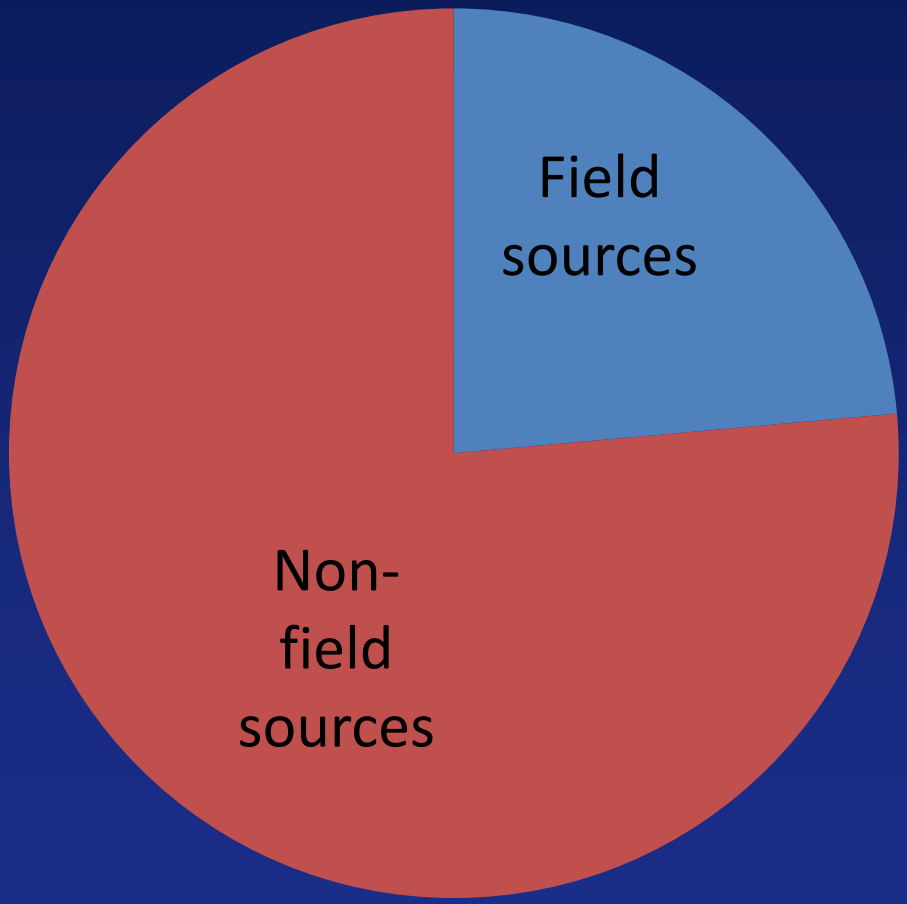
Flow-Sediment relationship at watershed outlet



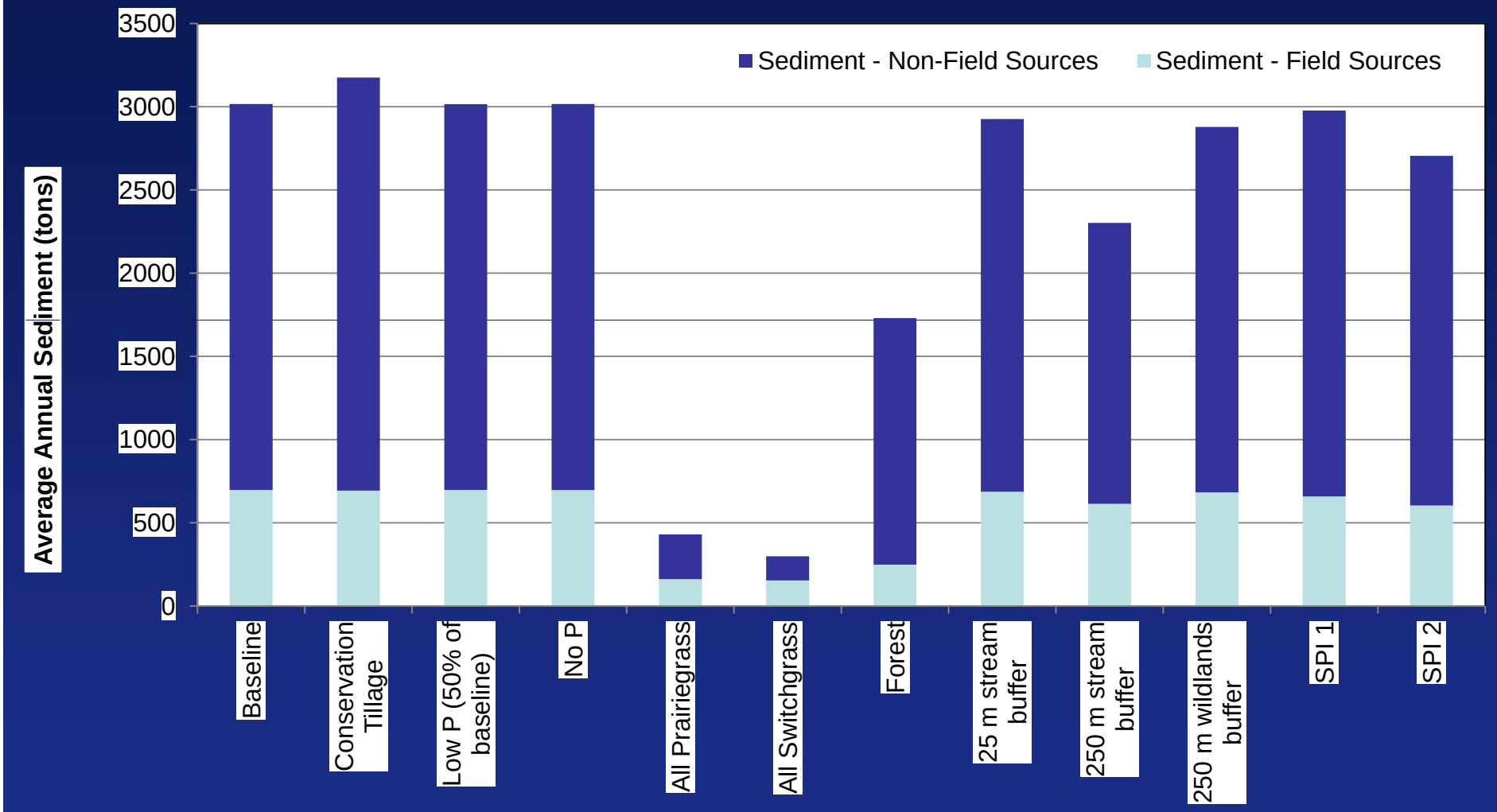
Model performance – including non-field sources



Seven Mile Creek: Sediment sources

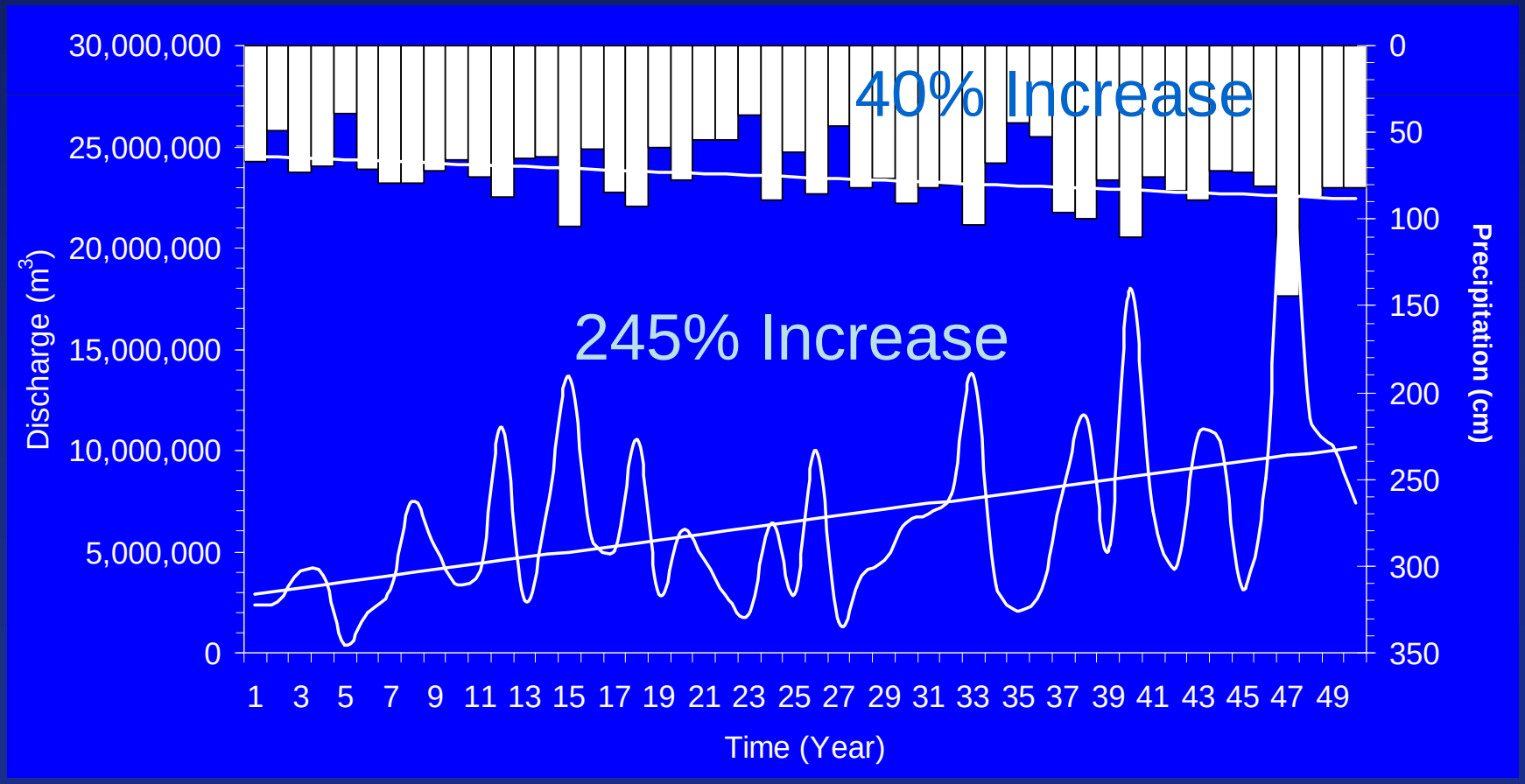


Alternative Landscape Results – Sediment



Effects of Climatic Variability on Seven Mile Creek Discharges

Nangia, V., D. J. Mulla and P. H. Gowda. 2010. Precipitation changes impact stream discharge, nitrate-nitrogen load more than agricultural management changes. J. Environ. Qual. 39:2063-2071.



Seven Mile Creek Land Management Changes Simulated

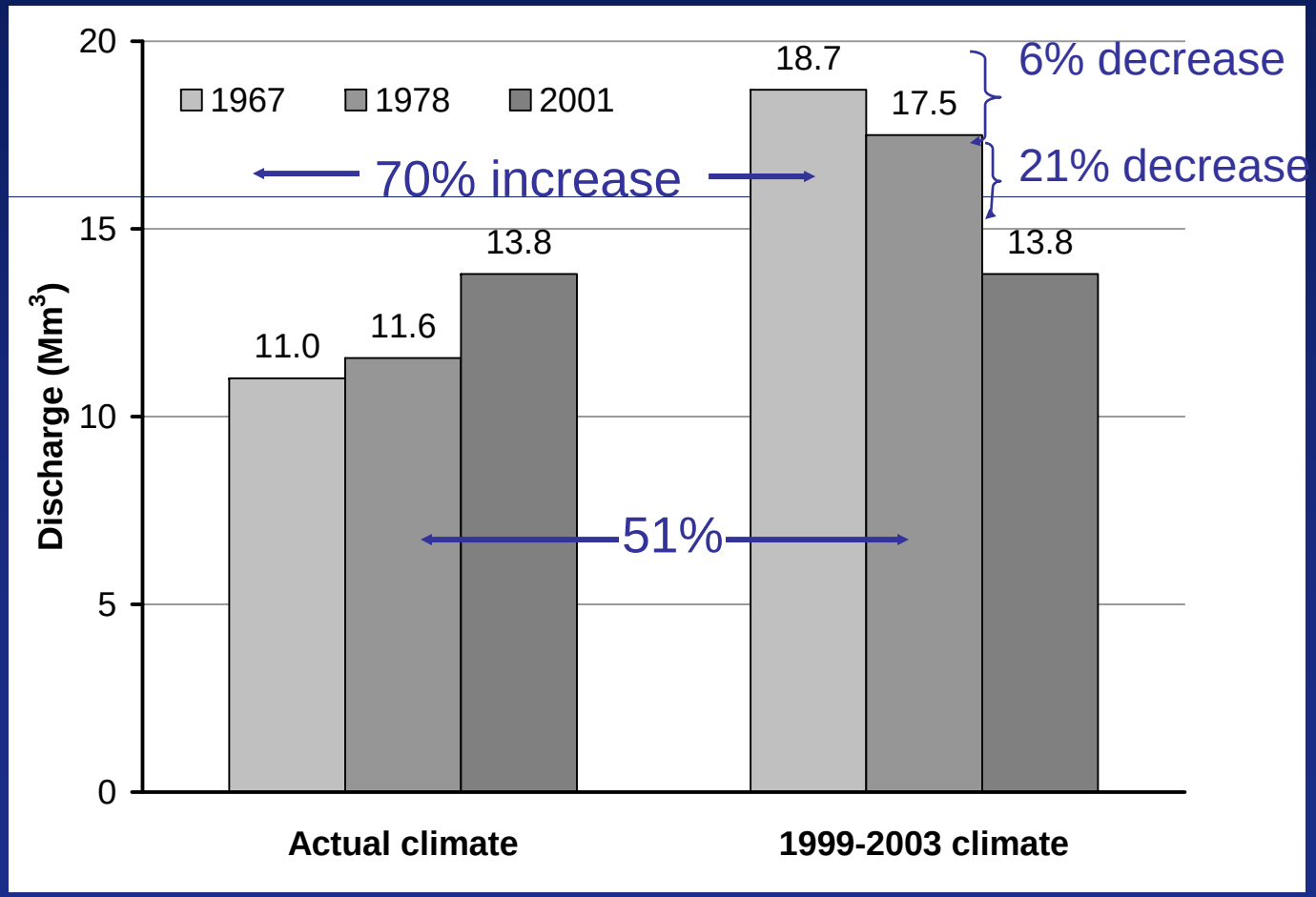
- Area in agricultural production increases
- Cropping system changes (soybeans replaces alfalfa and small grains)
- Crop yield increases
- N fertilizer application rates, forms and timing
- Adoption of conservation tillage increases
- Tile drain spacing decreases (area tile drained increases)

Simulated Climate Scenarios

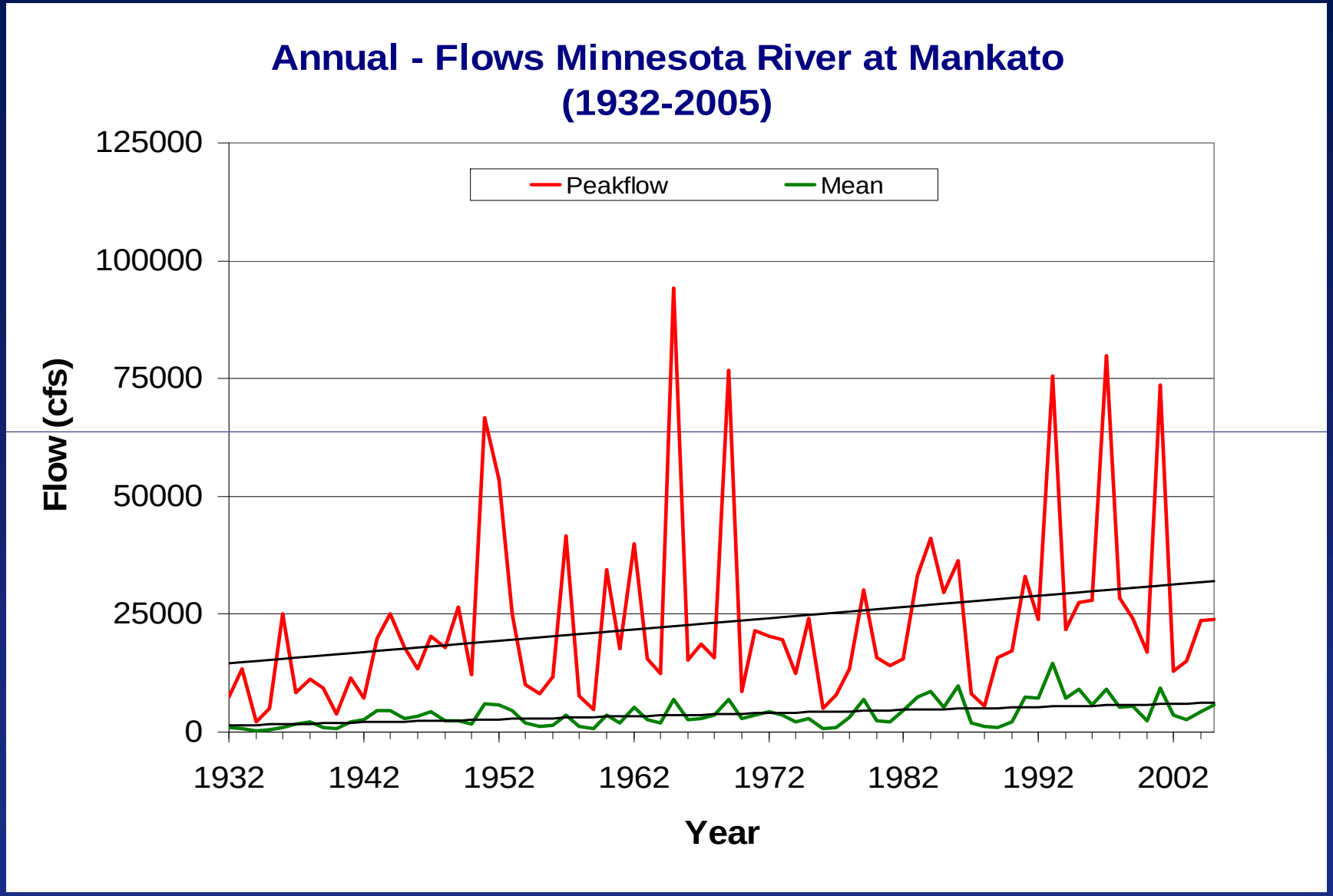
- 5 year continuous measured climate record centered around 1967, 1978 and 2001 with actual landuse and management information
- 5 year continuous measured climate record from 1999-2003 with actual landuse and management information from 1967, 1978 and 2001

Discharge Trends With and Without Climatic Variability

(Horizontal % changes due to effect of climate, Vertical % changes due to effects of management)



Influence of Changing Climate on Flows in the Minnesota River at Mankato

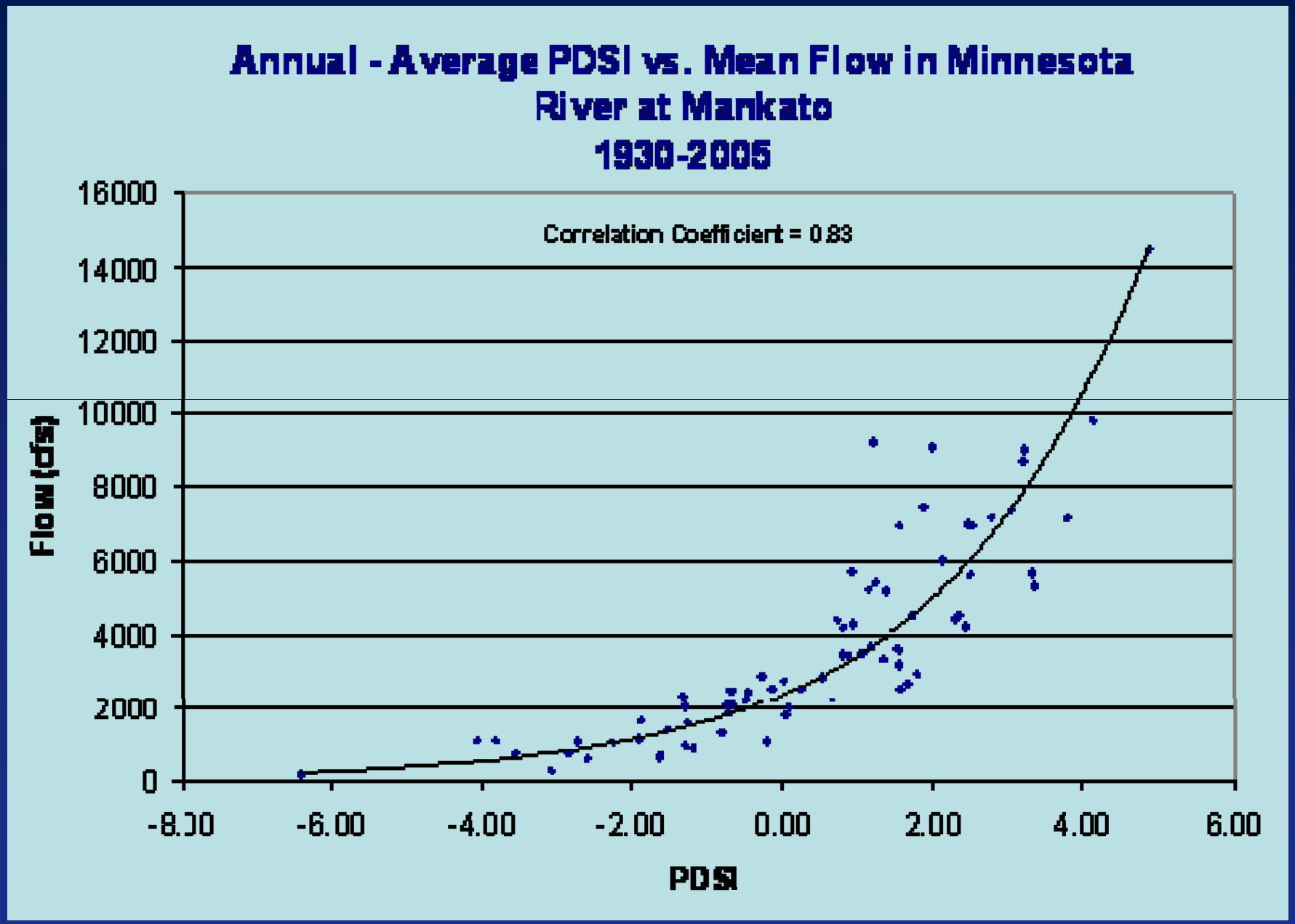


Peakflow trend 240 cfs/yr, p-value = .0016

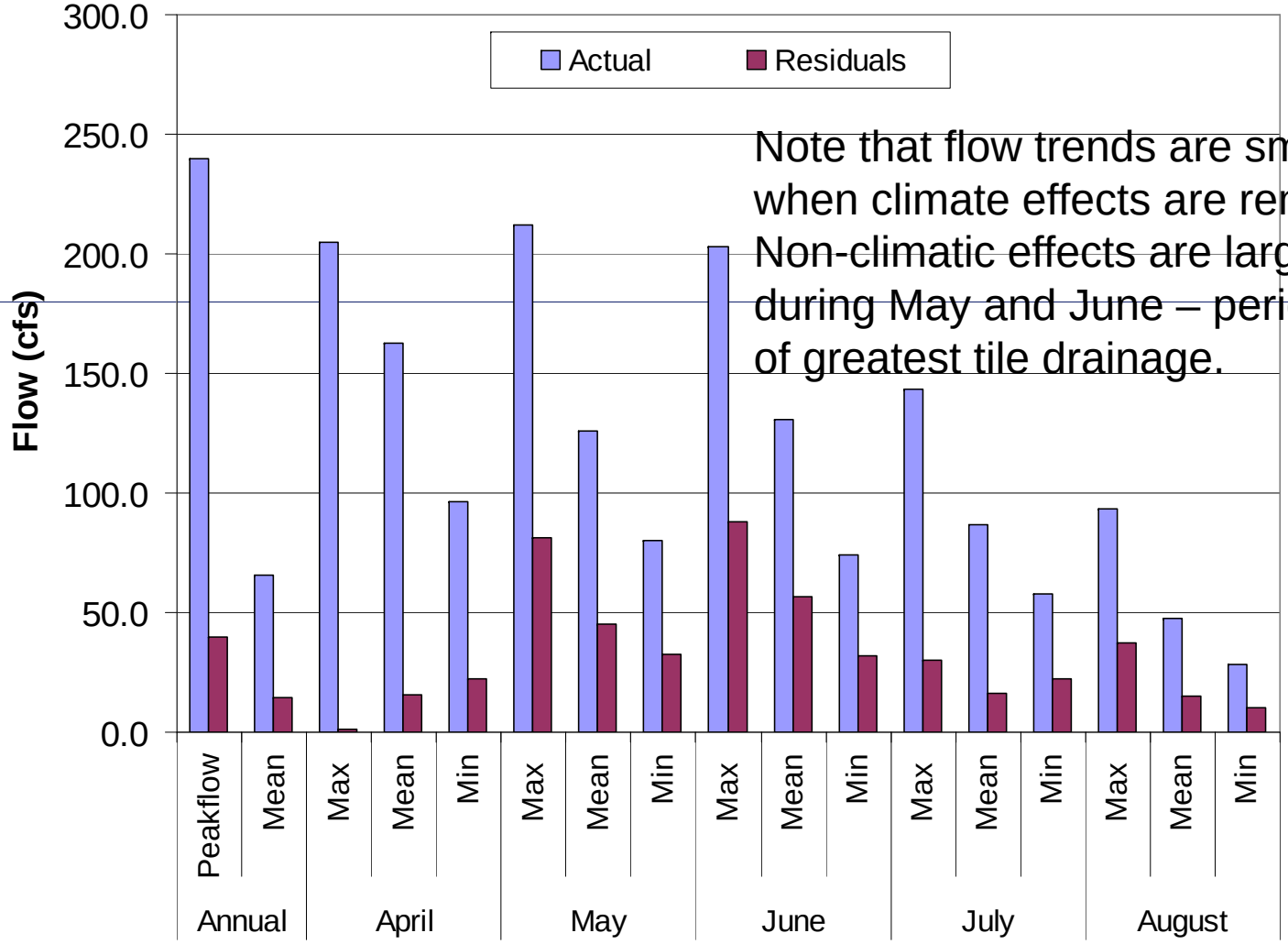
Mean Flow trend 66 cfs/yr, p-value = .000003

PDSI as a Metric for Climate

- **Palmer Drought Severity Index (PDSI)**
- **Accounts for precipitation, temperature, AWC, and latitude**
- **Range of values from (+8 - -8) comparable across regions and time scales**
- **PDSI is calculated independent of actual stream discharge or runoff**

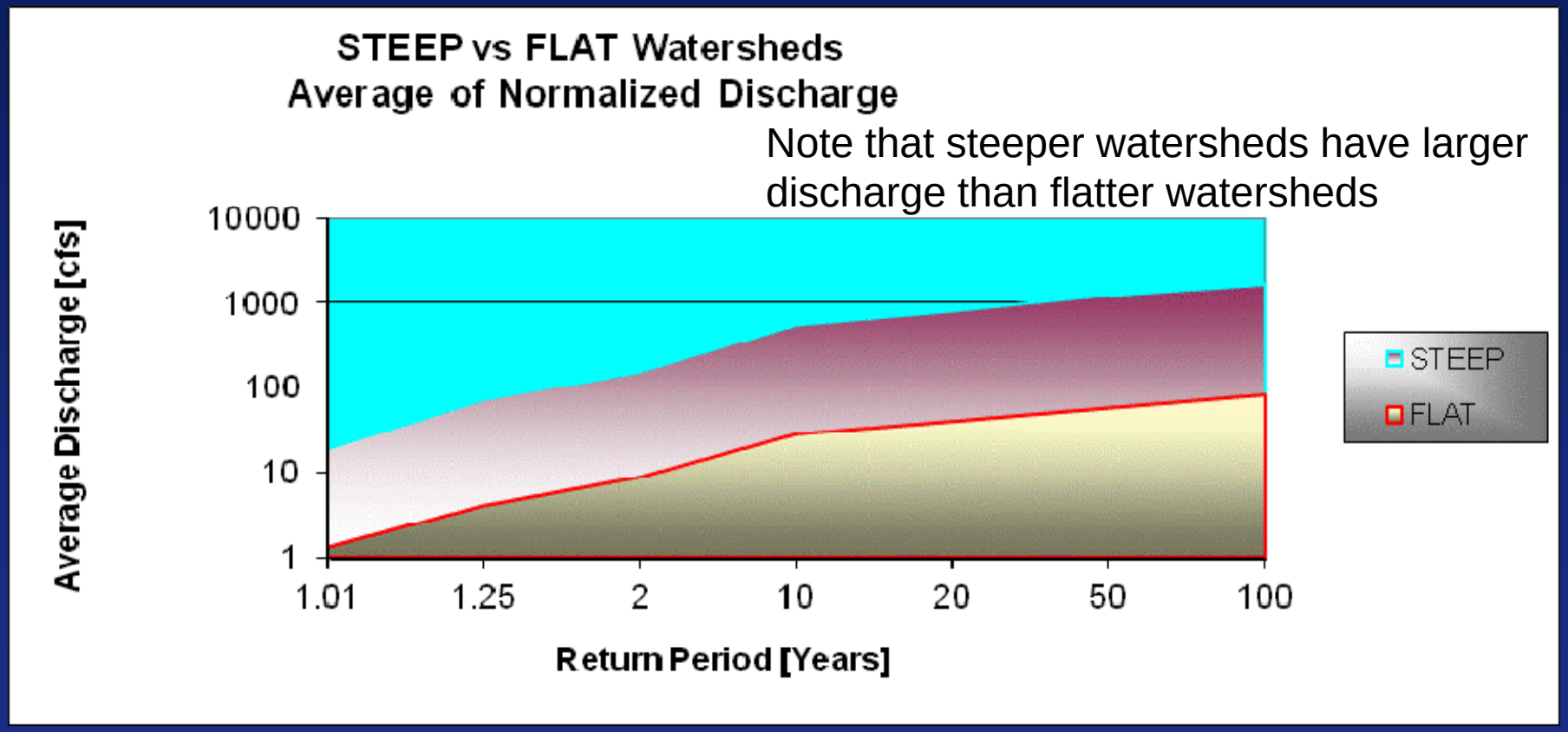

Annual - Average PDSI vs. Mean Flow in Minnesota River at Mankato
1930-2005
Correlation Coefficient = 0.83
Flow (cfs)
16000
14000
12000
10000
8000
6000
4000
2000
0
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
PDSI

Yearly Change in Flow on the Minnesota River at Mankato with and without the Effects of Climate Change

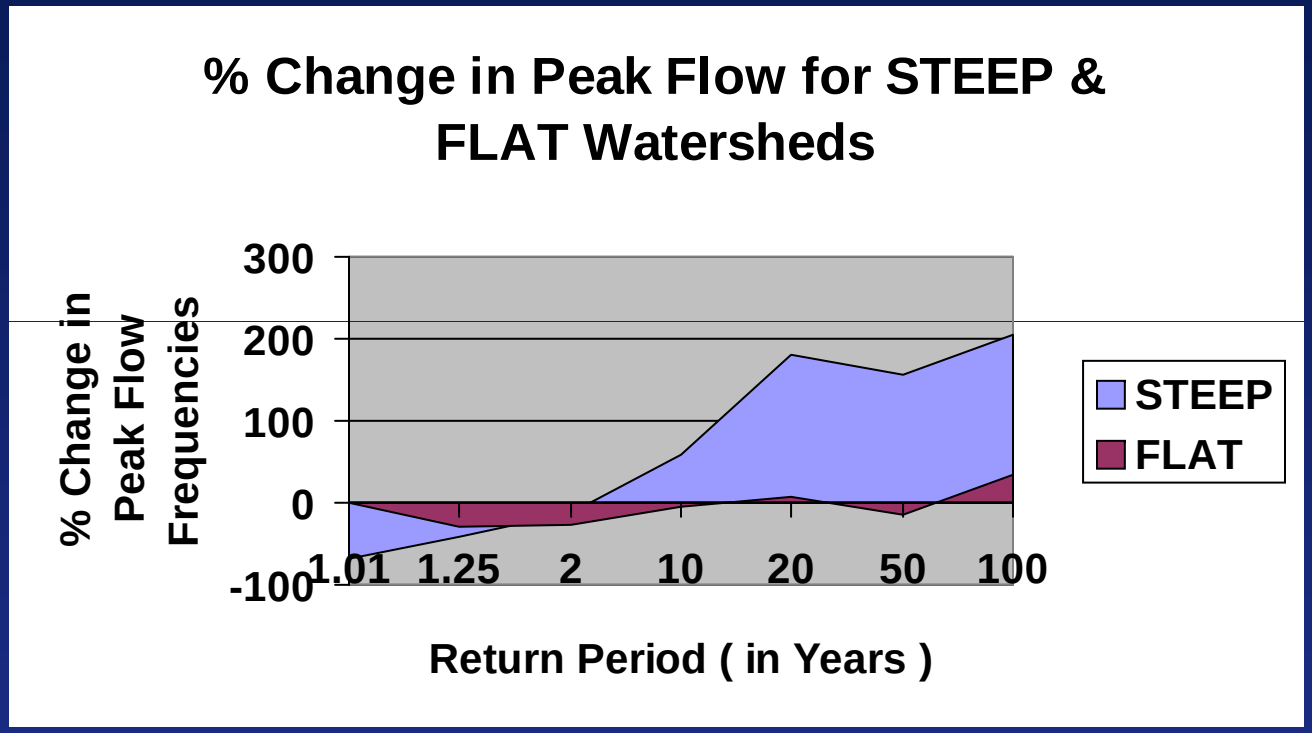


Note that flow trends are smaller when climate effects are removed. Non-climatic effects are largest during May and June – periods of greatest tile drainage.

Comparing Area Normalized Discharge: 16 Small Minnesota River Basin Watersheds Forty Year Discharge Data Records



Changes in Normalized Discharge (16 small watersheds before and after 1979)



Flatter watersheds reduce impacts of climate change on peak flow more than steeper watersheds with less tile drainage.

Conclusions

- Slumping river bluffs are a major source of sediment, particularly in the Le Sueur and Blue Earth watersheds
- Ravines are locally important sources of sediment, particularly along the Minnesota River Valley bluff and the Coteau bluff
- Upland agricultural sources of sediment are generally smaller than river bluffs, but larger than ravines
- Streambank erosion is locally important, but of variable magnitude

Conclusions

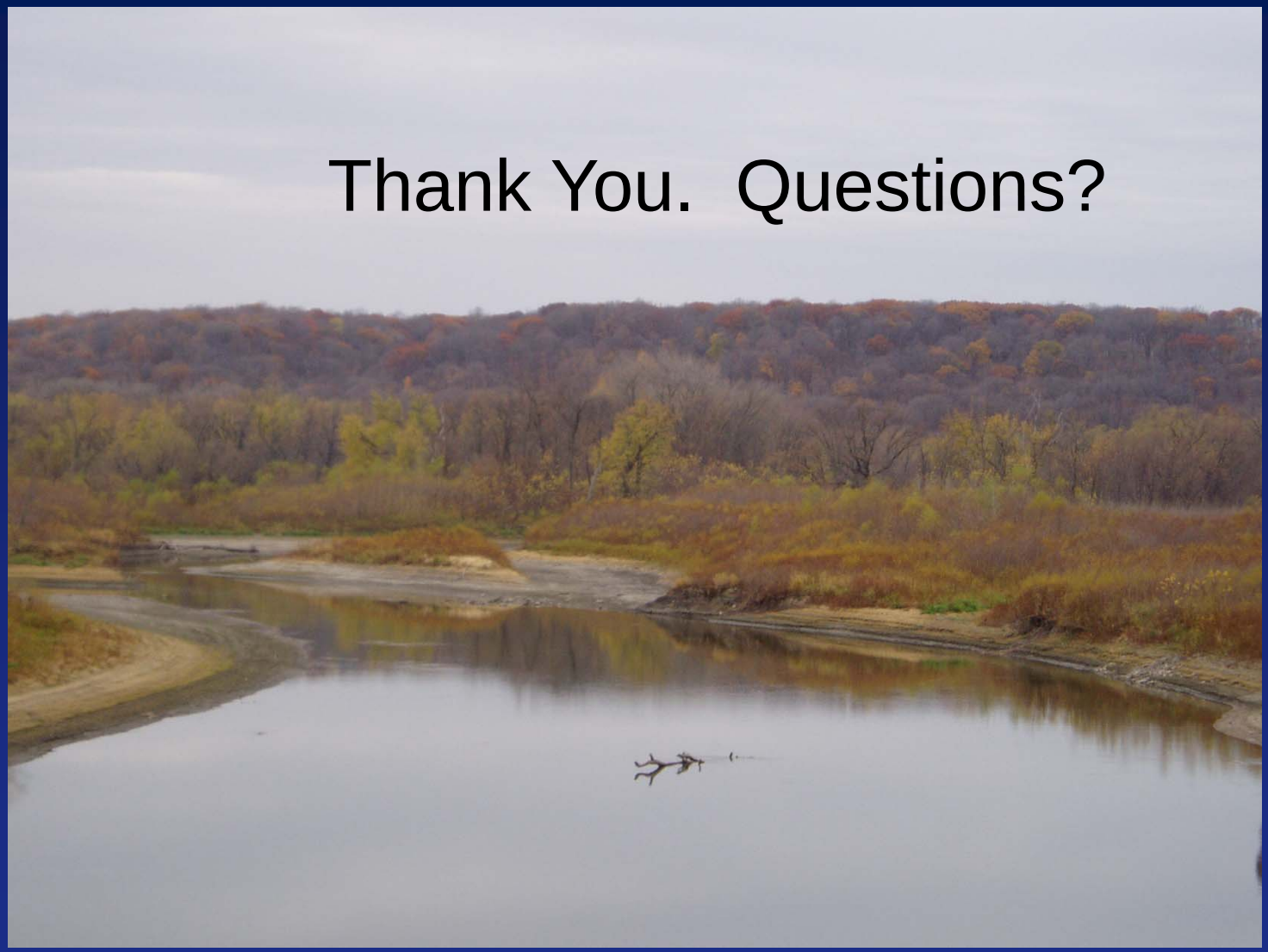
- Minnesota River mainstem discharge at Mankato has increased 66 cfs/yr since 1932, while peak flow has increased 240 cfs/yr
- An increasingly wetter climate during this same period was strongly correlated with increased Minnesota River discharge
- After removing effects on discharge of an increasingly wetter climate, non-climatic factors were also found to increase discharge, particularly during May and June

Conclusions

- Increased discharge in Seven Mile Creek is strongly correlated with increased streambank erosion
- Discharge in Seven Mile Creek has increased significantly since 1967 due to an increasingly wetter climate
- If climate were constant, changes in land management and cropping systems during the same period would have reduced discharge by 29%, despite increases in tile drainage
- Increased biomass and ET of corn helps reduce river discharge and channel sediment loss

Conclusions

- Steeper watersheds with less tile drainage have greater mean discharge at all return periods than flatter watersheds with more tile drainage
- An increasingly wetter climate has increased peak discharge significantly in steeper watersheds, but not in flatter watersheds
- Climate change effects are a more important driver of increased river discharge than increased tile drainage


Thank You. Questions?