Overview of Precision Conservation: Tools and Strategies for Effectively Targeting Conservation Practices and Resources

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MDA and MPCA

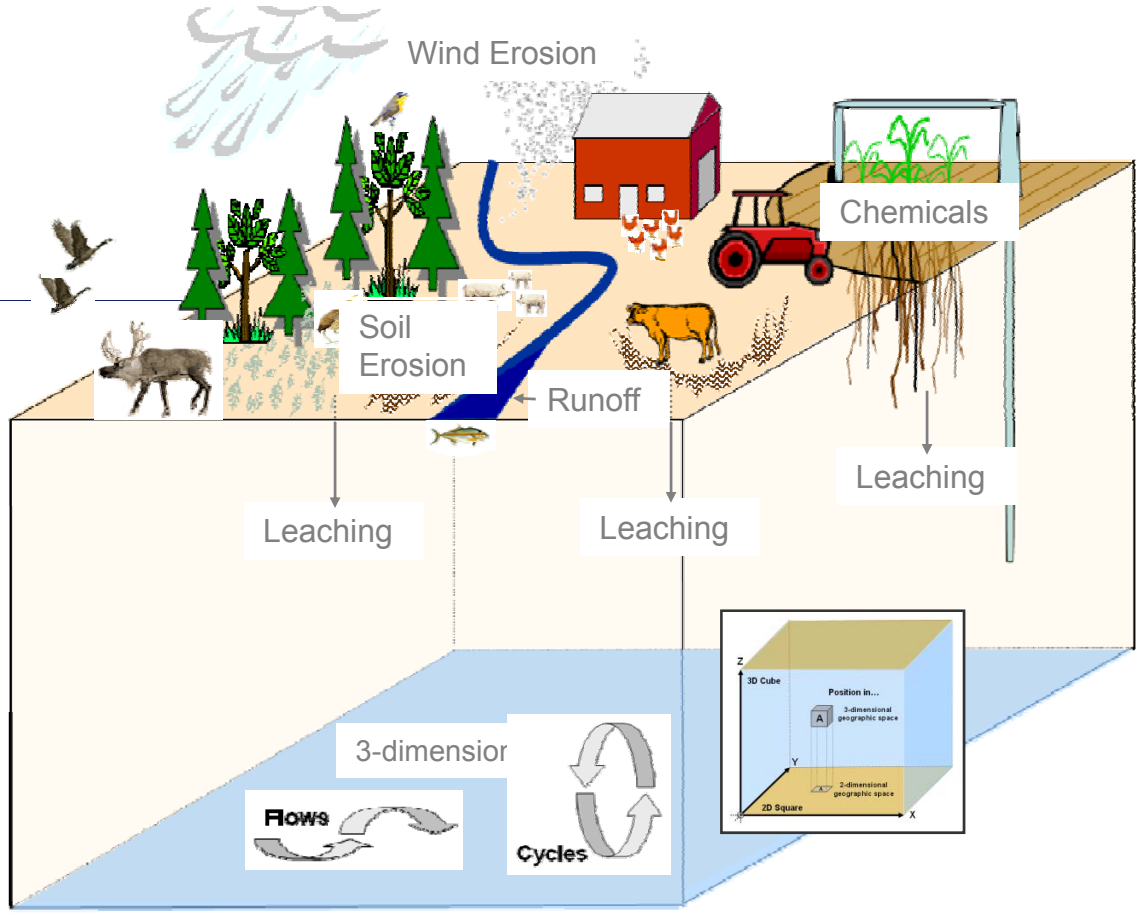
Precision Conservation

- Precision Conservation allows small portions of the landscape that have a disproportionate effect on water quality or wildlife habitat to be targeted with Best Management Practices (BMPs)
- Best Management Practices placed on critical landscapes can help treat small areas that produce disproportionate amounts of pollution
- Identifying critical landscape areas can best be achieved using high resolution digital elevation and remote sensing data, although information about existing management practices is also important

Precision Conservation *(compared to Precision Ag)*

Precision Conservation

(Farm, Watershed,… Focus)

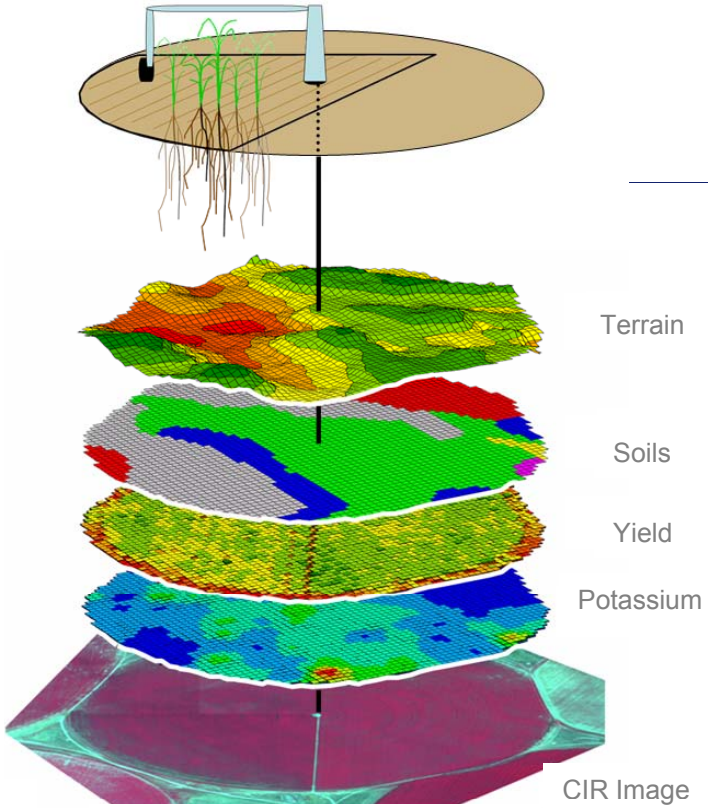


Interconnected Perspective

(Stewardship Focus)

Precision Ag

(Individual Field Focus)

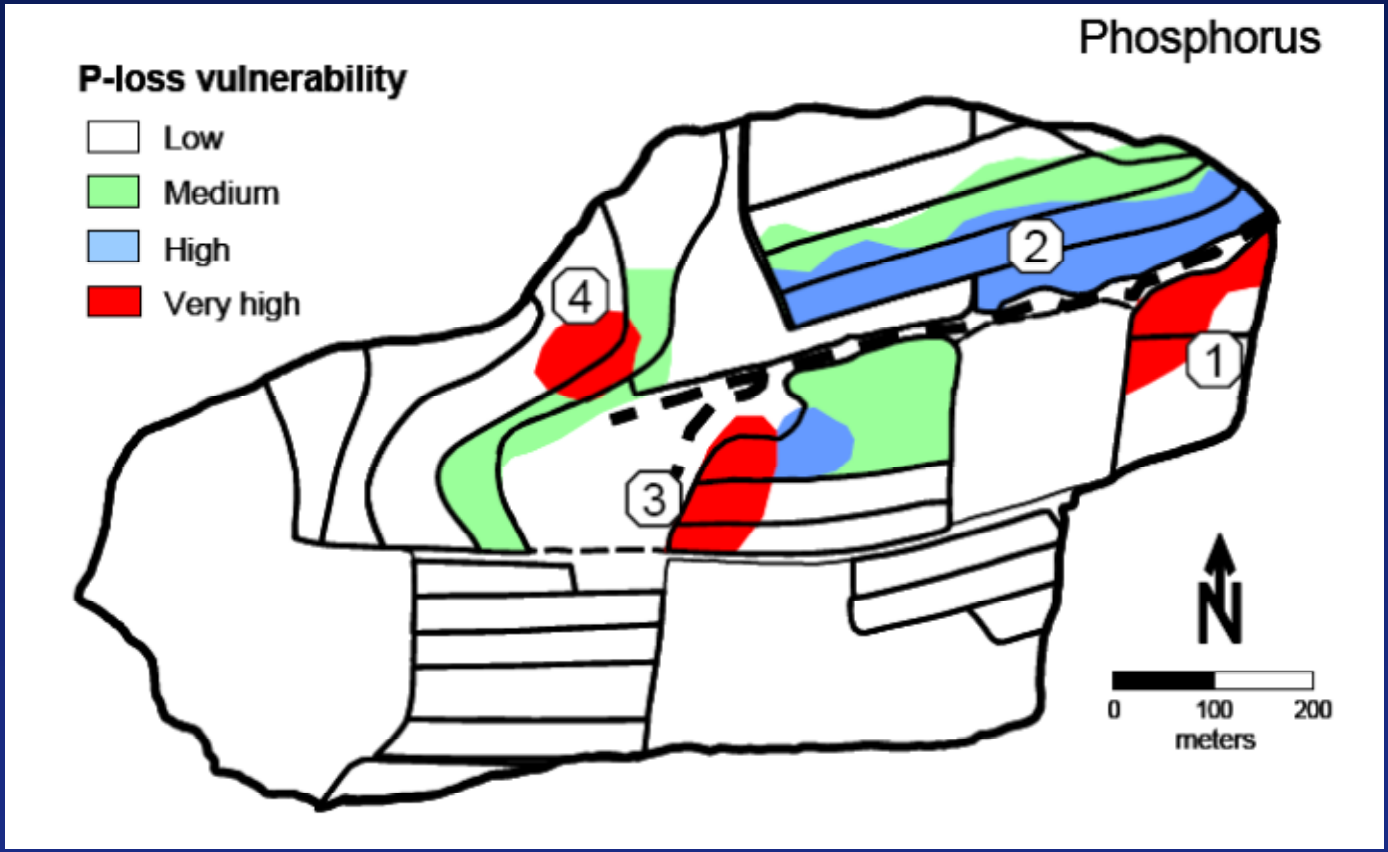


Isolated Perspective

(Production Focus)

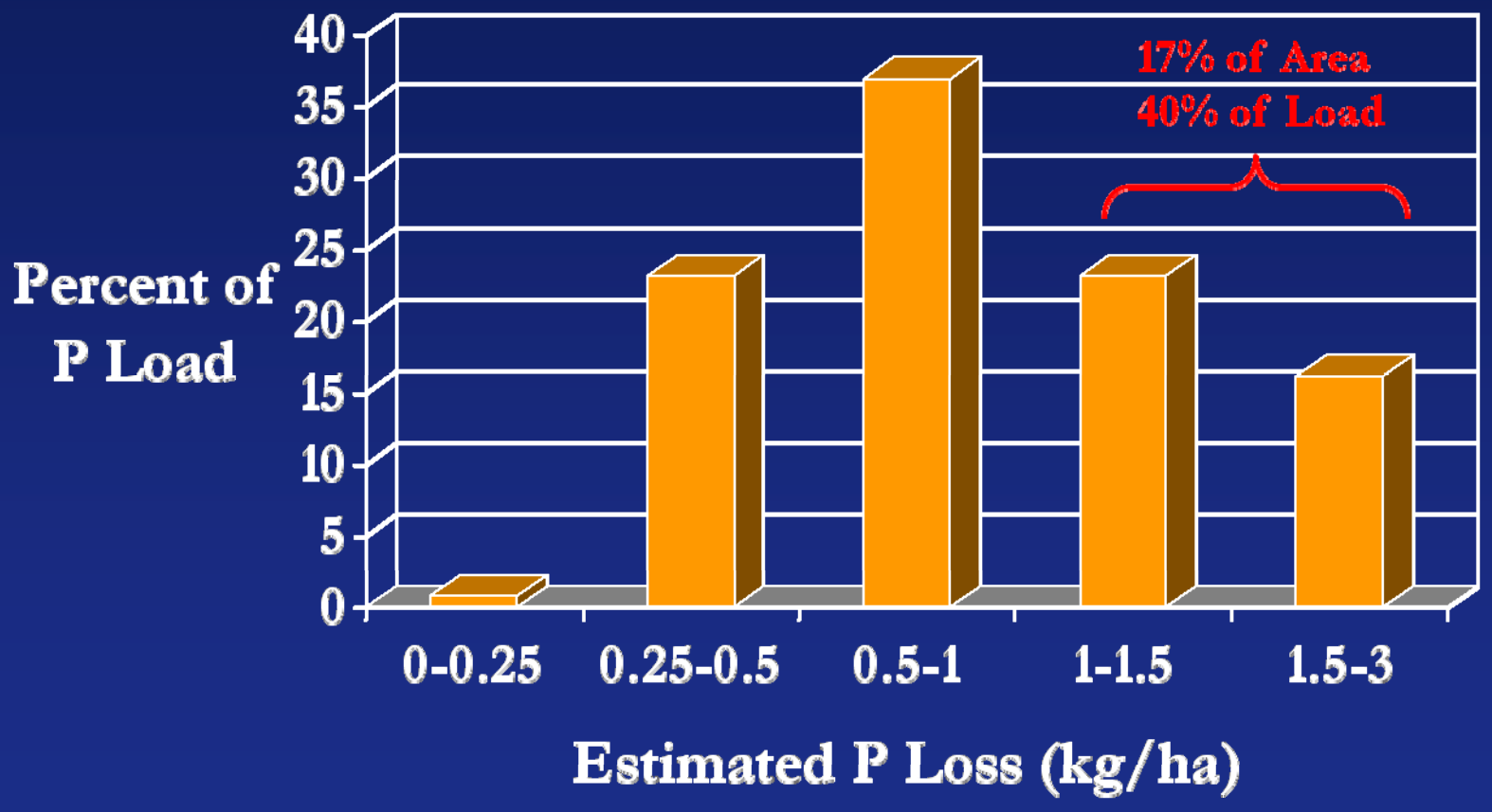
(From *Berry, 2008*)

Precision Conservation Example

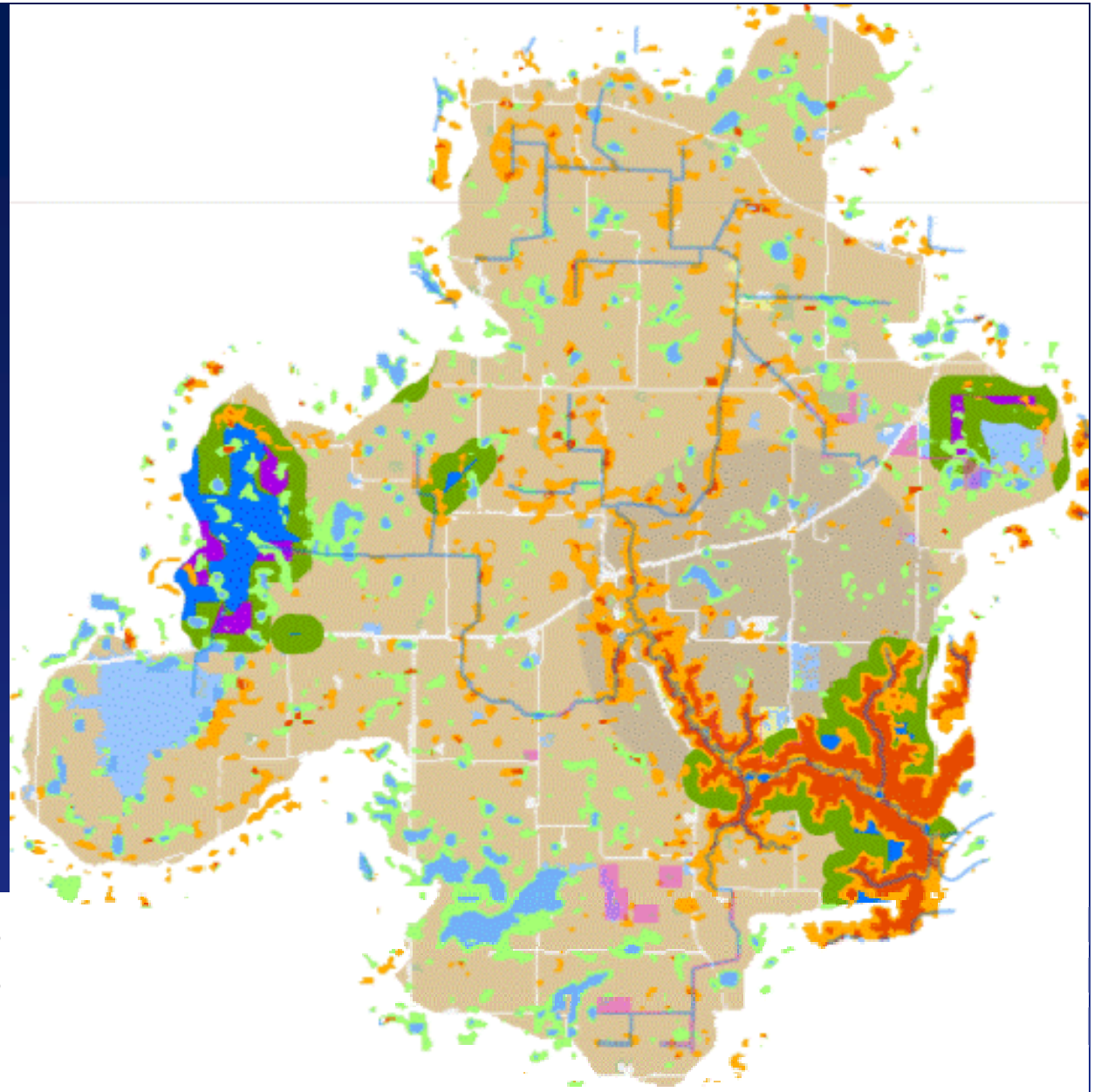


Source: Sharpley et al. 2006. Nutrient Management Practices. In Environmental Benefits of Conservation on Cropland: The Status of Our Knowledge. Schnepf and Cox (eds). Soil and Water Conservation Society, Ankeny Iowa.

Disproportionalities in P Loss at Watershed Scale



Precision Conservation Example

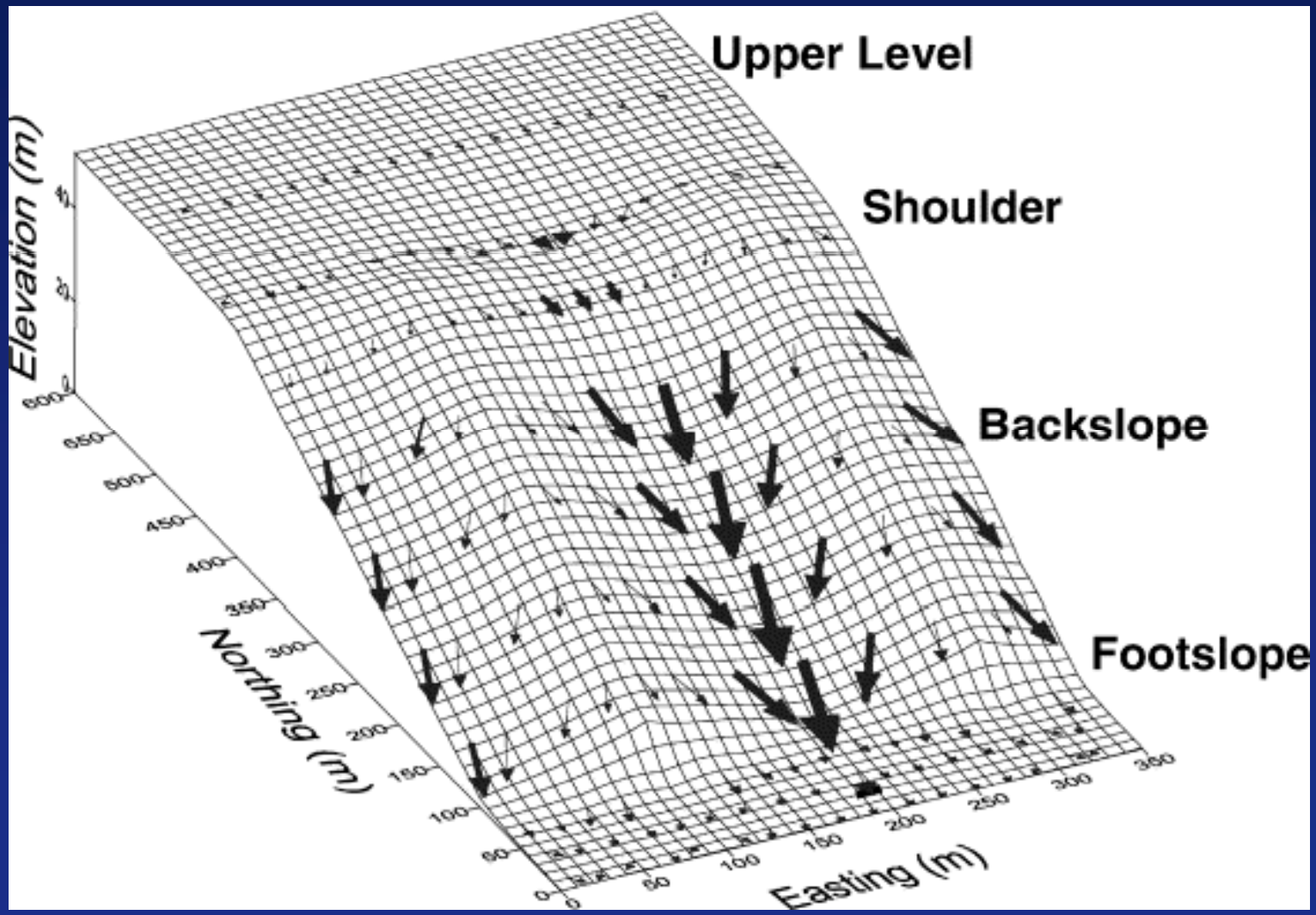


- Wetland Planting Option 1
- Wetland Planting Option 2
- Marginal Land Retirement
- Sediment Source Planting
- Biodiversity Habitat Planting
- Wildlife Habitat Planting
- Riparian Planting

Critical Source Areas (CSAs)

- Studies suggest that small areas of the agricultural landscape (5-25%) generate a disproportionately large amount of runoff, erosion or phosphorus
- The reduction of nonpoint source pollution loads at the outlet of agricultural watersheds is dependent on the implementation of best management practices (BMPs) in critical source areas
- Defining critical source areas is a challenge, but terrain analysis using LiDAR based digital elevation models (DEMs) is promising

Converging/Diverging Flows



Critical Source Areas

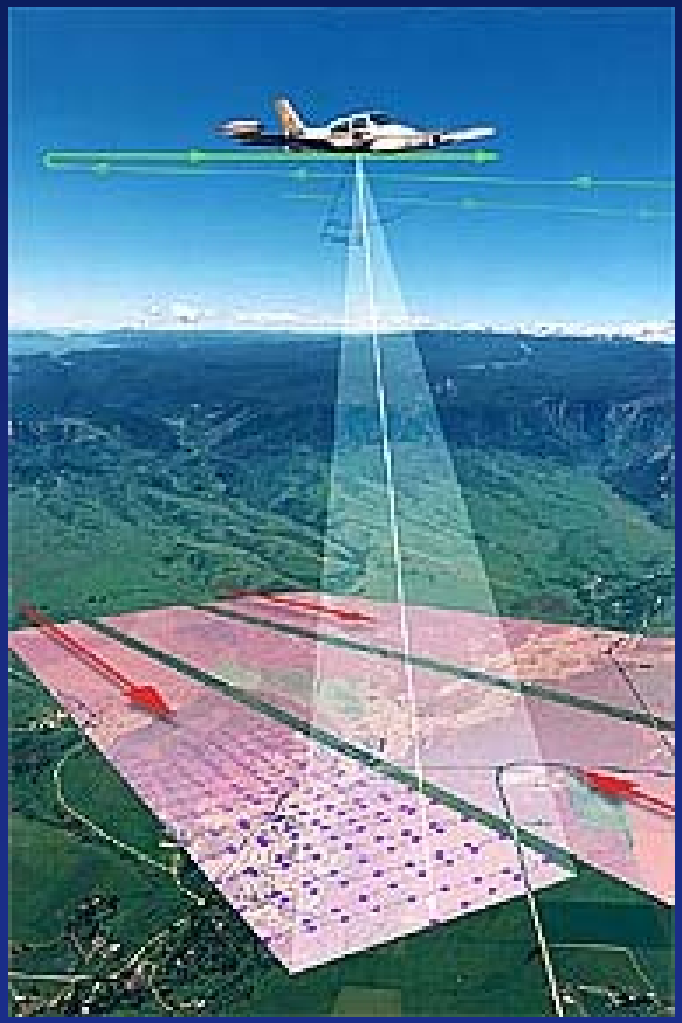
- Critical source areas can include upland depressions, riparian areas, open culverts and tile outlets, gullies, ravines, eroding stream banks and slumping stream bluffs

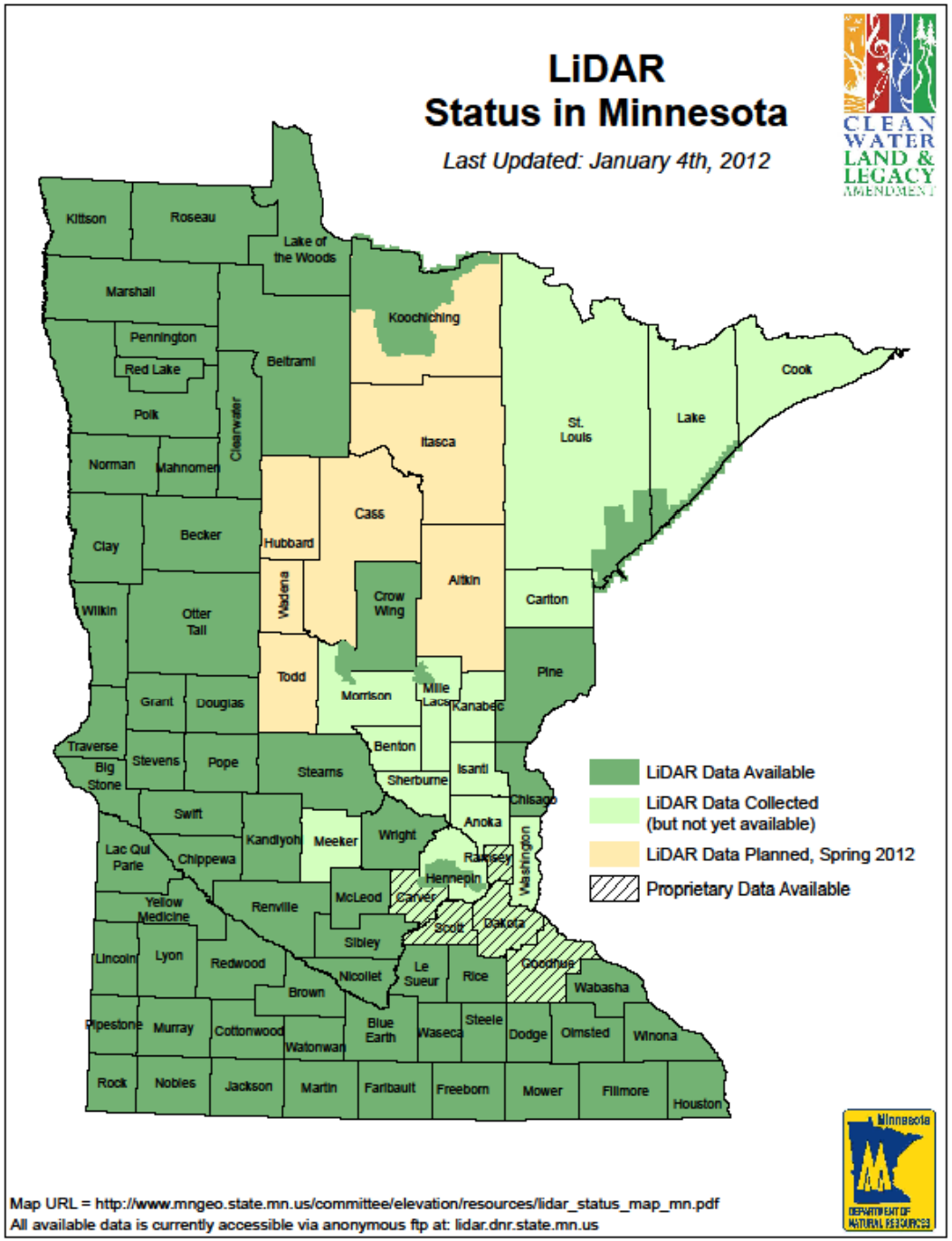
LiDAR
Light Detection and Ranging

Laser scan of earth's surface

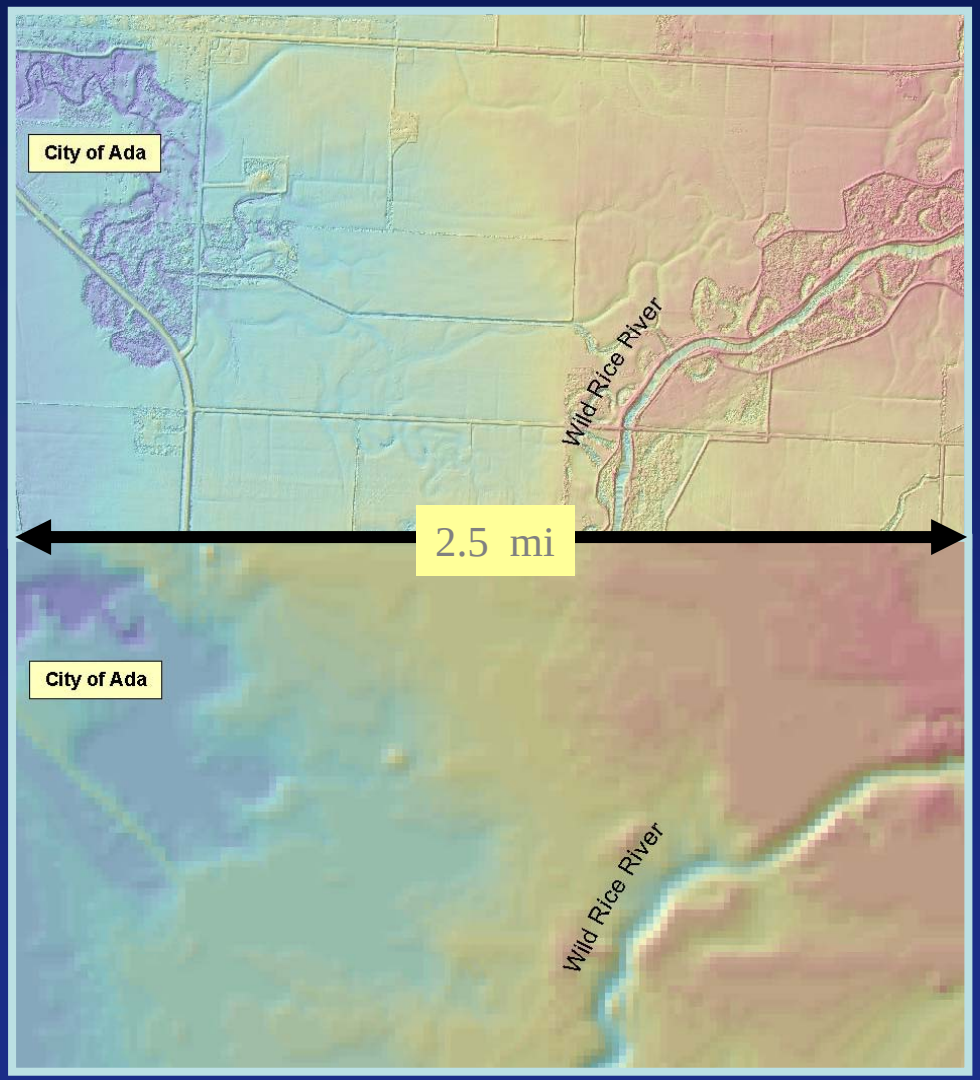
Products:

- Elevation for each reflecting point ("point cloud")
- Digital Elevation Models (DEM) (grid elevation)
- Contour lines
- Hillshade images
- Many others




LiDAR
Status in Minnesota
Last Updated: January 4th, 2012
CLEAN WATER LAND & LEGACY AMENDMENT
Kittson
Roseau
Lake of the Woods
Marshall
Koochiching
Pennington
Red Lake
Beltrami
Polk
Clearwater
Itasca
St. Louis
Lake
Cook
Norman
Mahnomen
Cass
Clay
Becker
Hubbard
Wadena
Crow Wing
Aitkin
Carlton
Wilkin
Otter Tail
Todd
Pine
Morrison
Mille Lacs
Kanabec
Grant
Douglas
Traverse
Big Stone
Stevens
Pope
Stearns
Benton
Sherburne
Isanti
Chisago
Swift
Kandiyohi
Meeker
Wright
Anoka
Lac Qui Parle
Chippewa
Ramsey
Hennepin
Washington
Yellow Medicine
Renville
McLeod
Carver
Scott
Dakota
Sibley
Lincoln
Lyon
Redwood
Nicollet
Le Sueur
Rice
Goodhue
Wabasha
Brown
Pipestone
Murray
Cottonwood
Watonwan
Blue Earth
Waseca
Steele
Dodge
Olmsted
Winona
Rock
Nobles
Jackson
Martin
Faribault
Freeborn
Mower
Fillmore
Houston
LiDAR Data Available
LiDAR Data Collected (but not yet available)
LiDAR Data Planned, Spring 2012
Proprietary Data Available
Minnesota
DEPARTMENT OF NATURAL RESOURCES
Map URL = http://www.mngeo.state.mn.us/committee/elevation/resources/lidar_status_map_mn.pdf
All available data is currently accessible via anonymous ftp at: lidar.dnr.state.mn.us

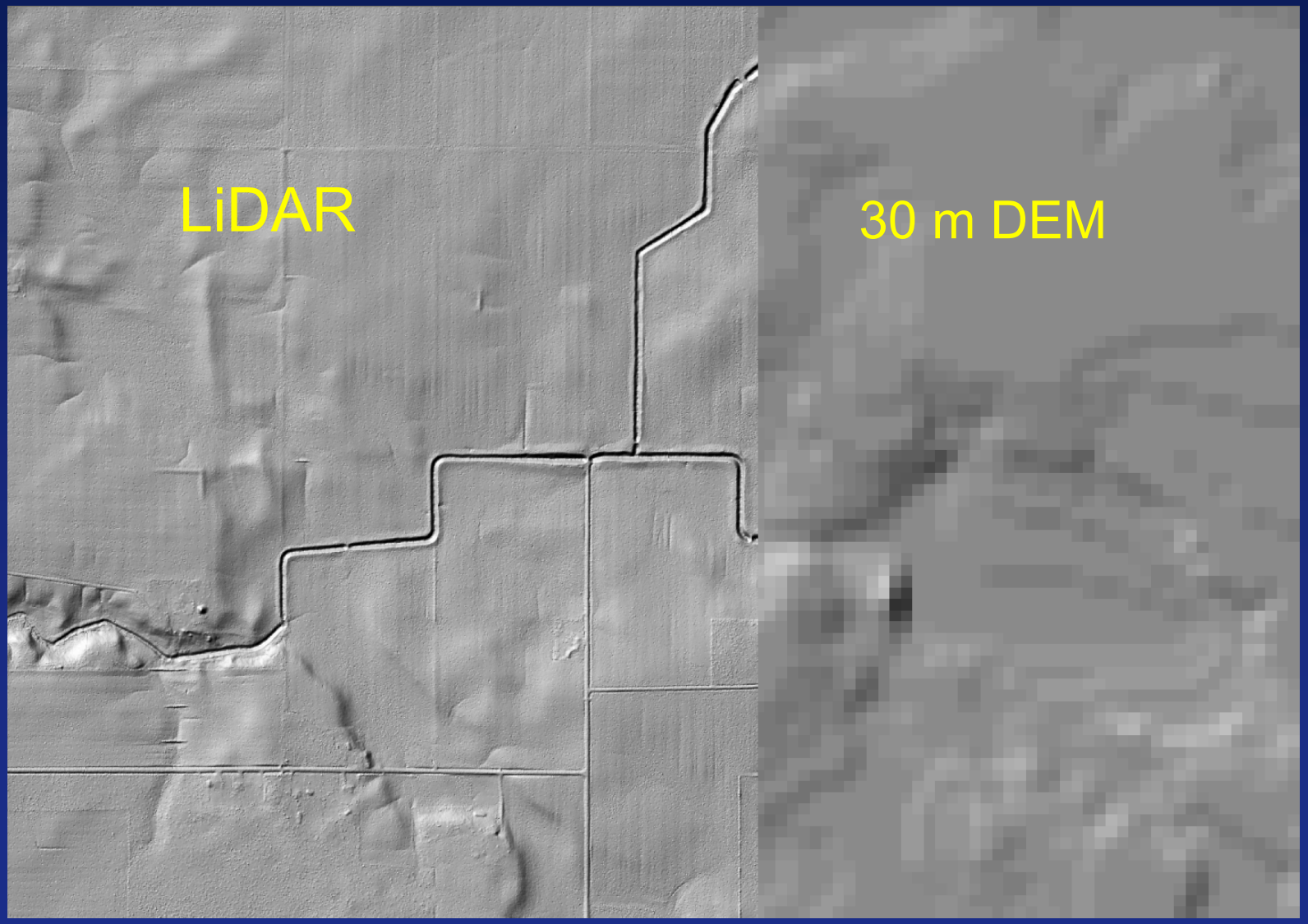
Elevation Resolution



LiDAR Derived DEM
1 meter grid

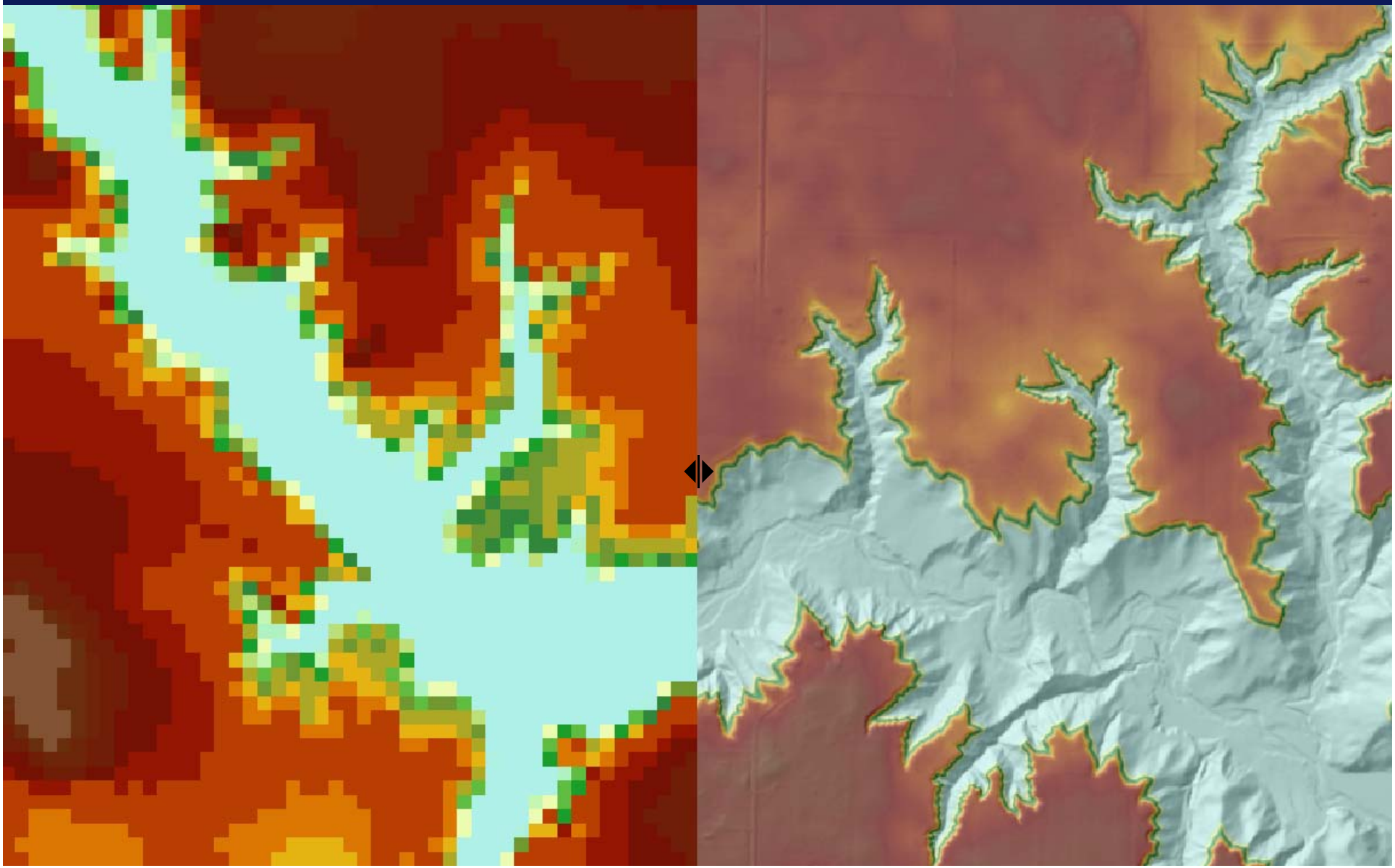
USGS Standard DEM
30 meter grid

Comparison Between LiDAR and 30 m DEMs



30 m DEM

3 m LiDAR DEM



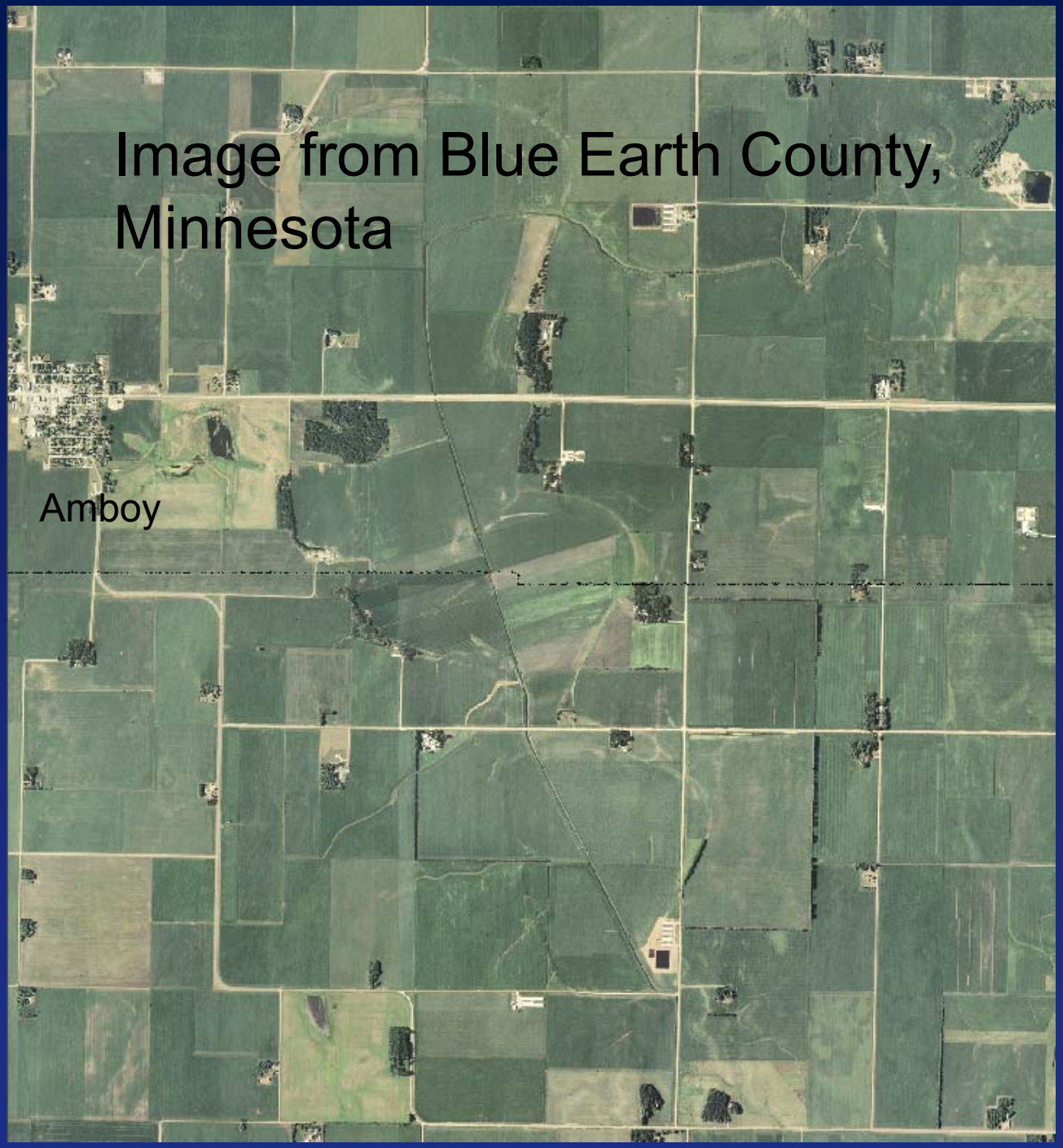
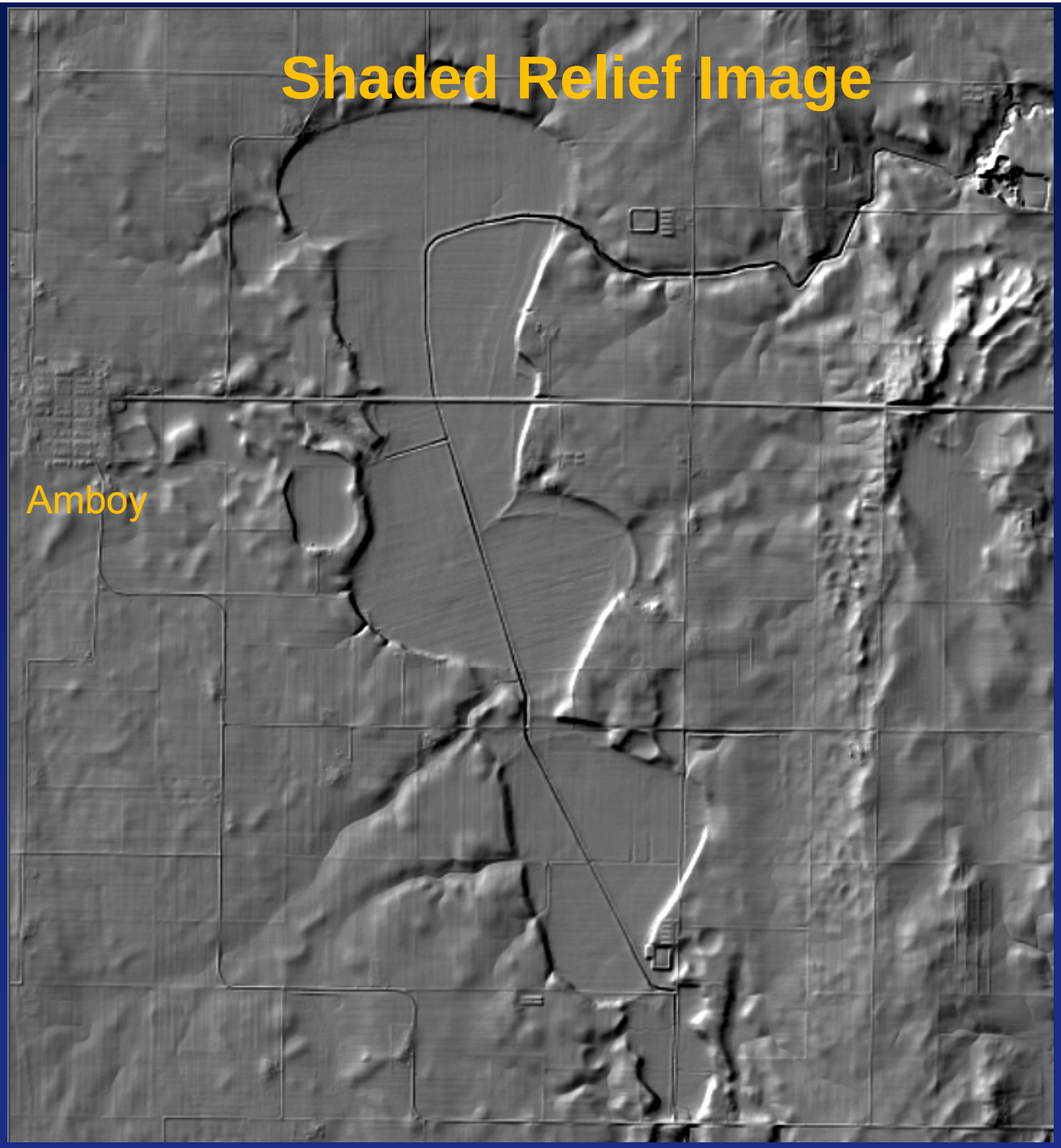


Image from Blue Earth County, Minnesota
Amboy

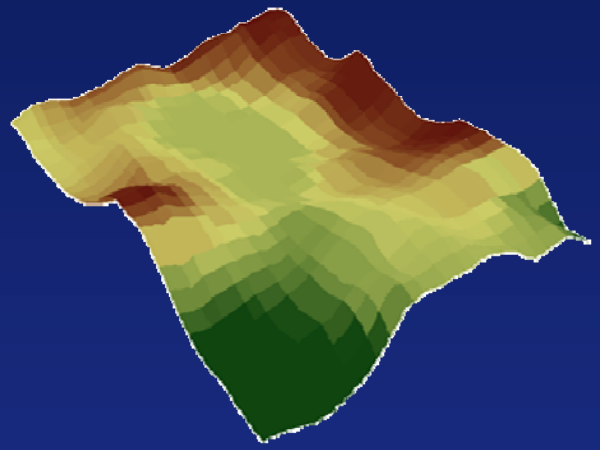
Shaded Relief Image



Terrain Attributes for Precision Conservation

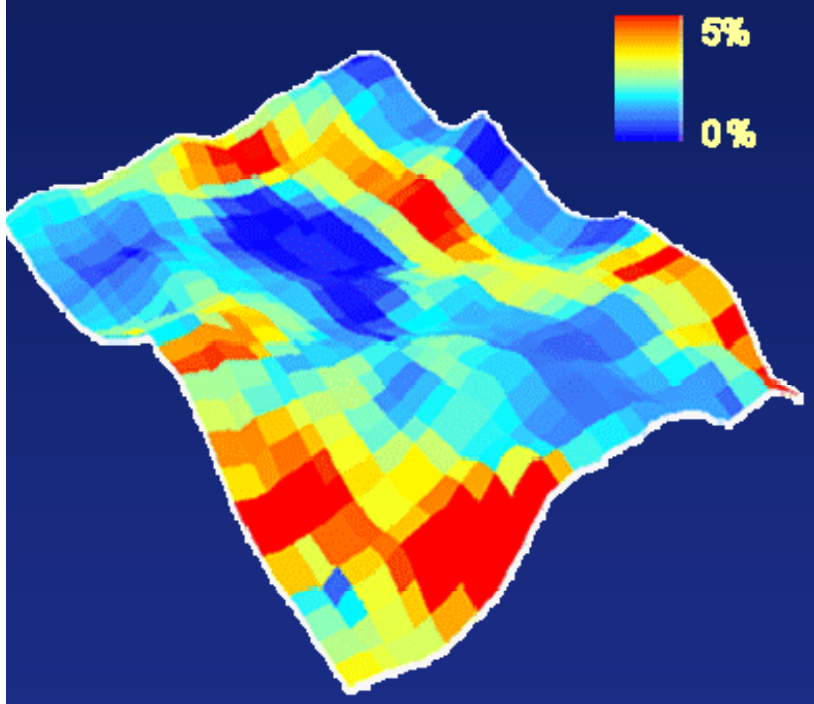
- Terrain attributes can be derived from DEMs using…
  - ESRI's AcrGIS v. 10
  - TAUDEM v. 3.1 (Tarboton, 2005)
    - D∞ method of flow routing

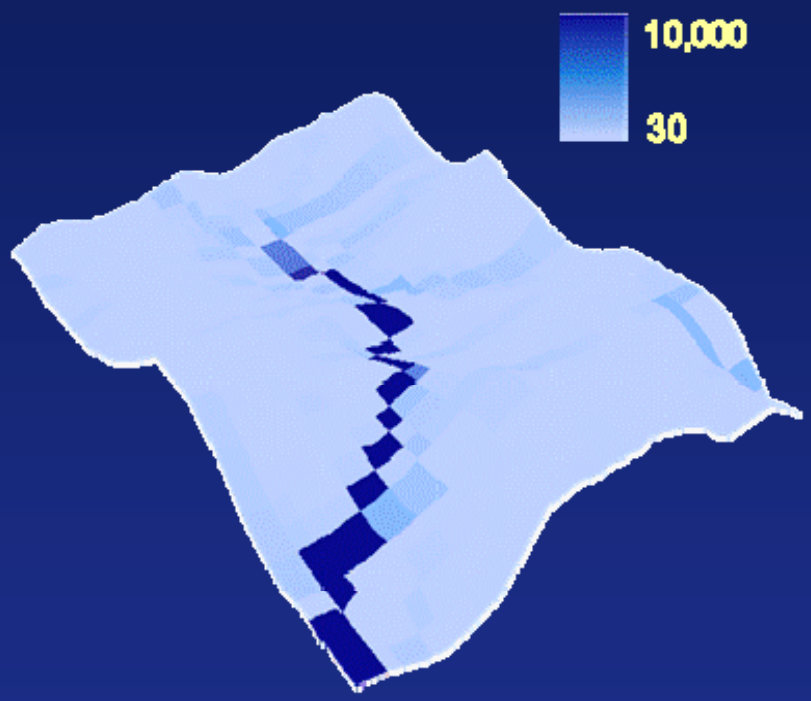
      (Tarboten, 1997)

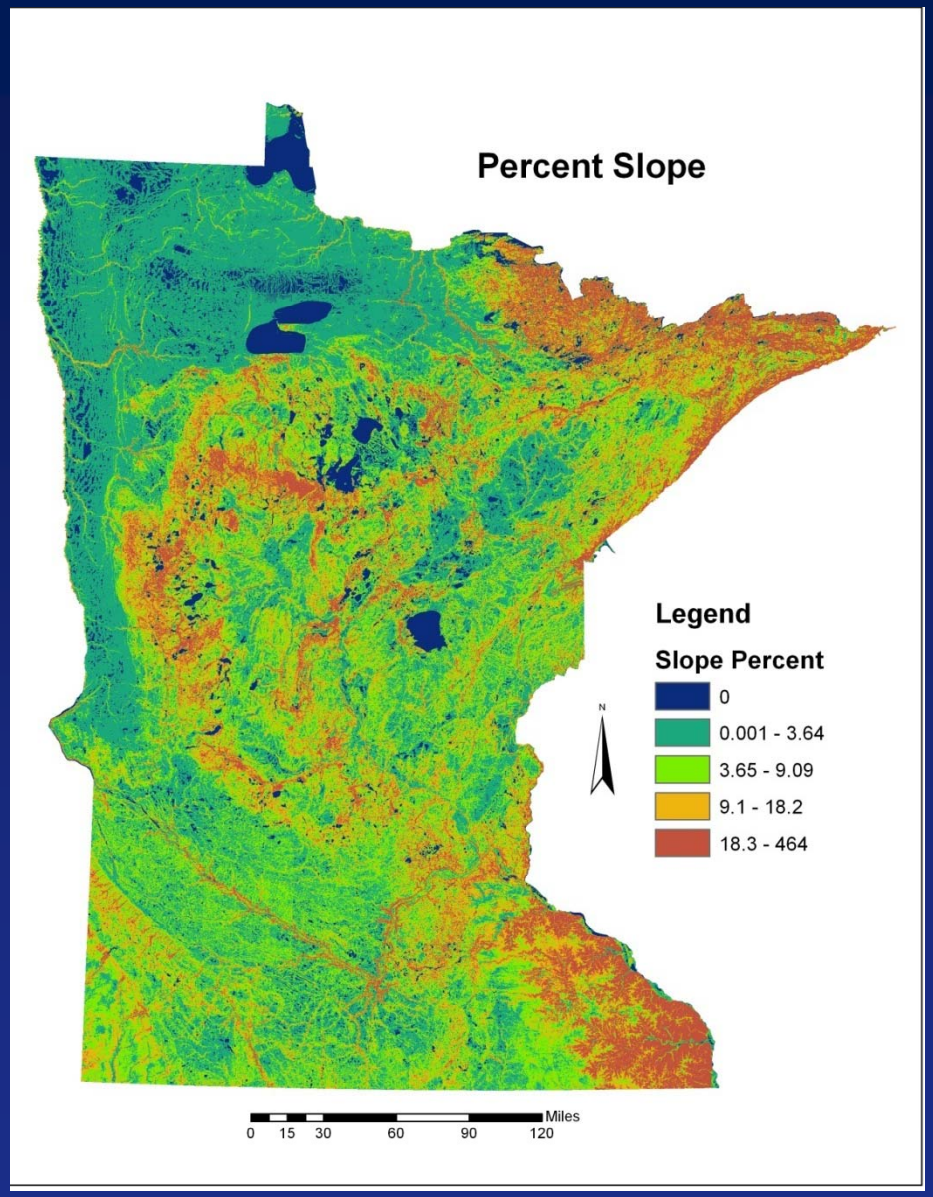


- Critical source area data layers can be created by combining…
  - Different thresholds applied to terrain attributes
  - Ancillary GIS data (Soils drainage, Land use/Land cover)

Slope and Specific Catchment Area



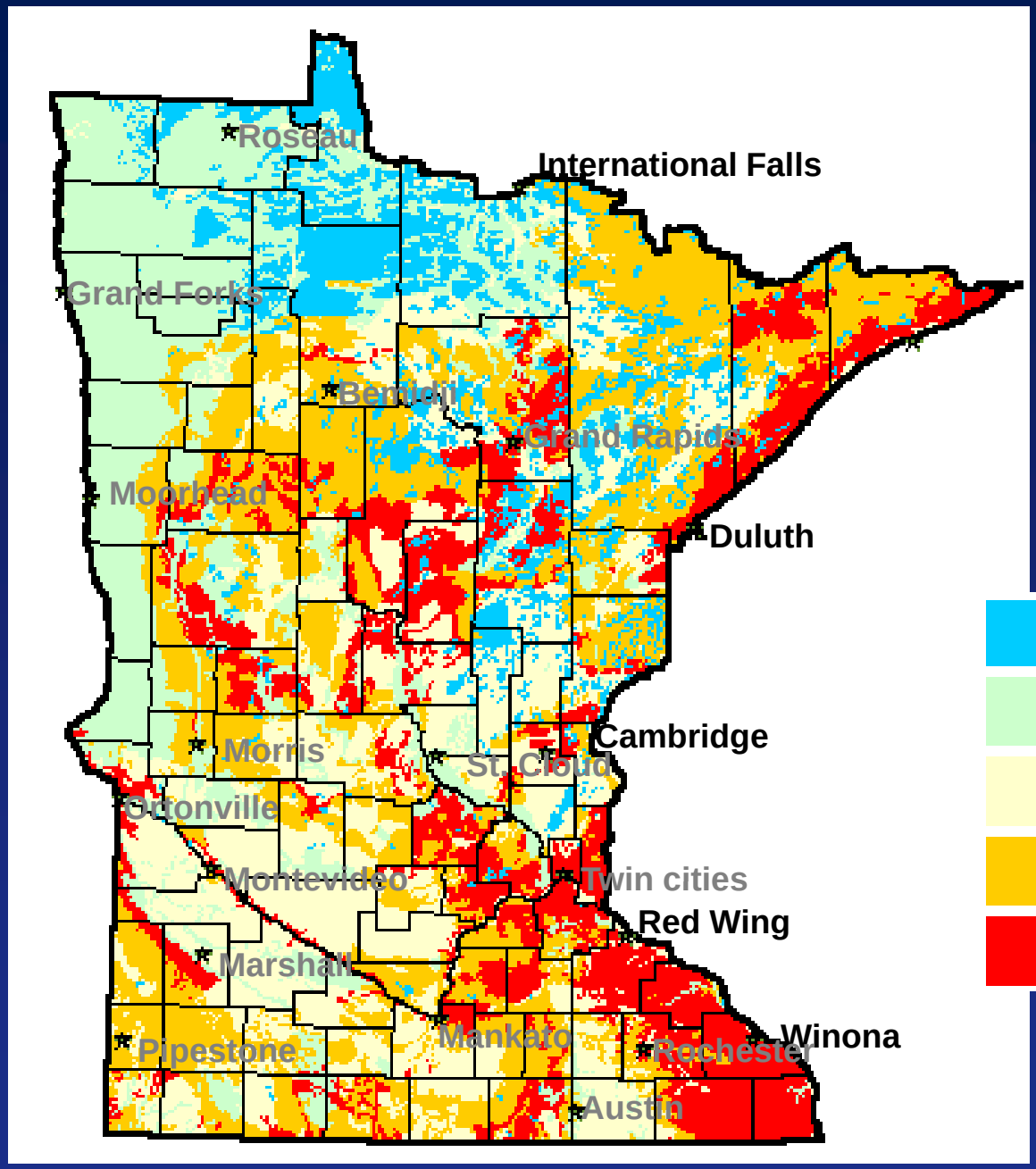




Landscape slope

Affects overland flow and erosion potential

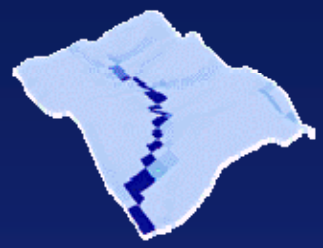
Sheet & Rill Water Erosion Potential



- Low
- Medium
- High
- Very High
- Extreme

Compound Topographic Index

CTI = Ln (SCA / S)



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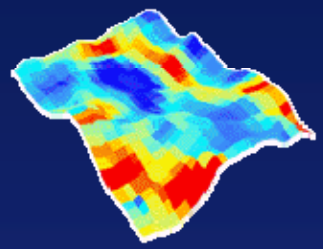

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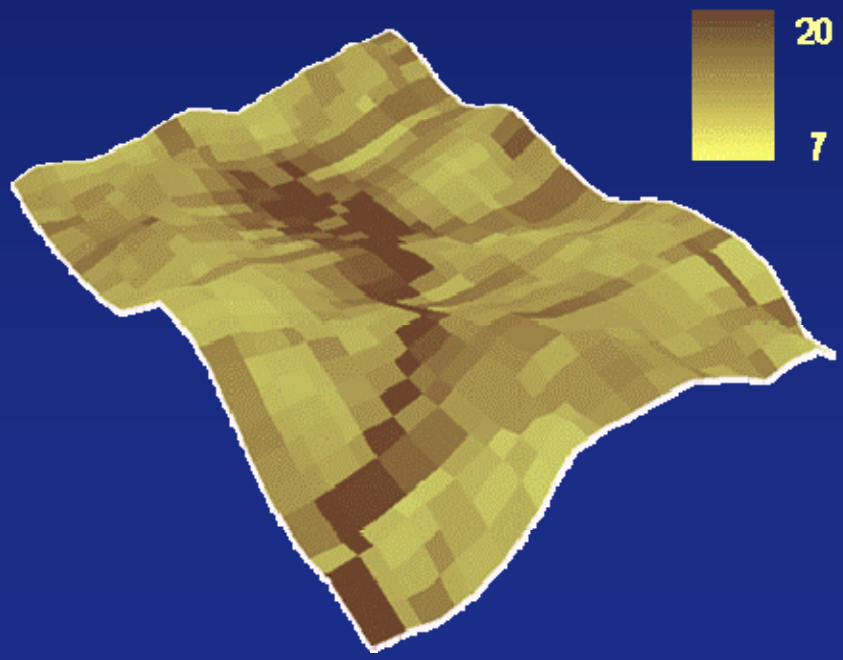
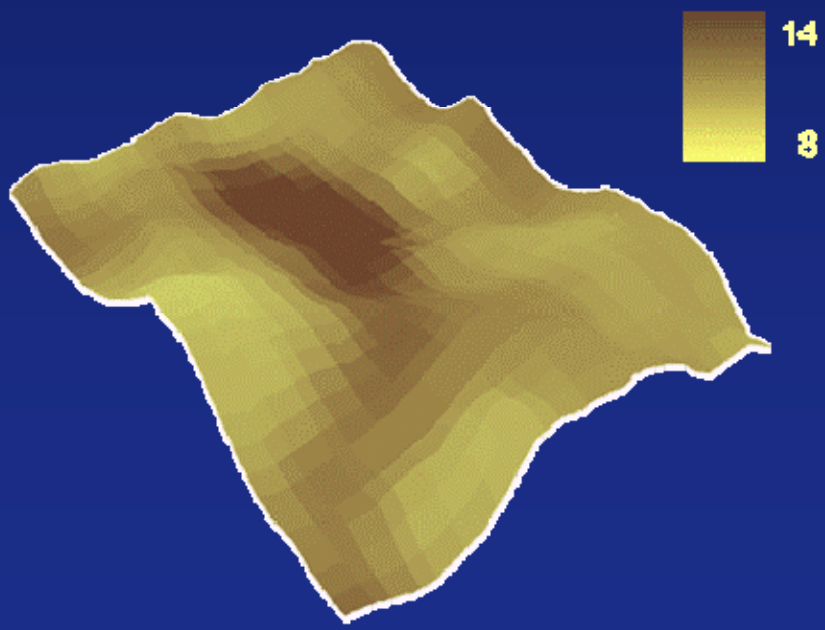
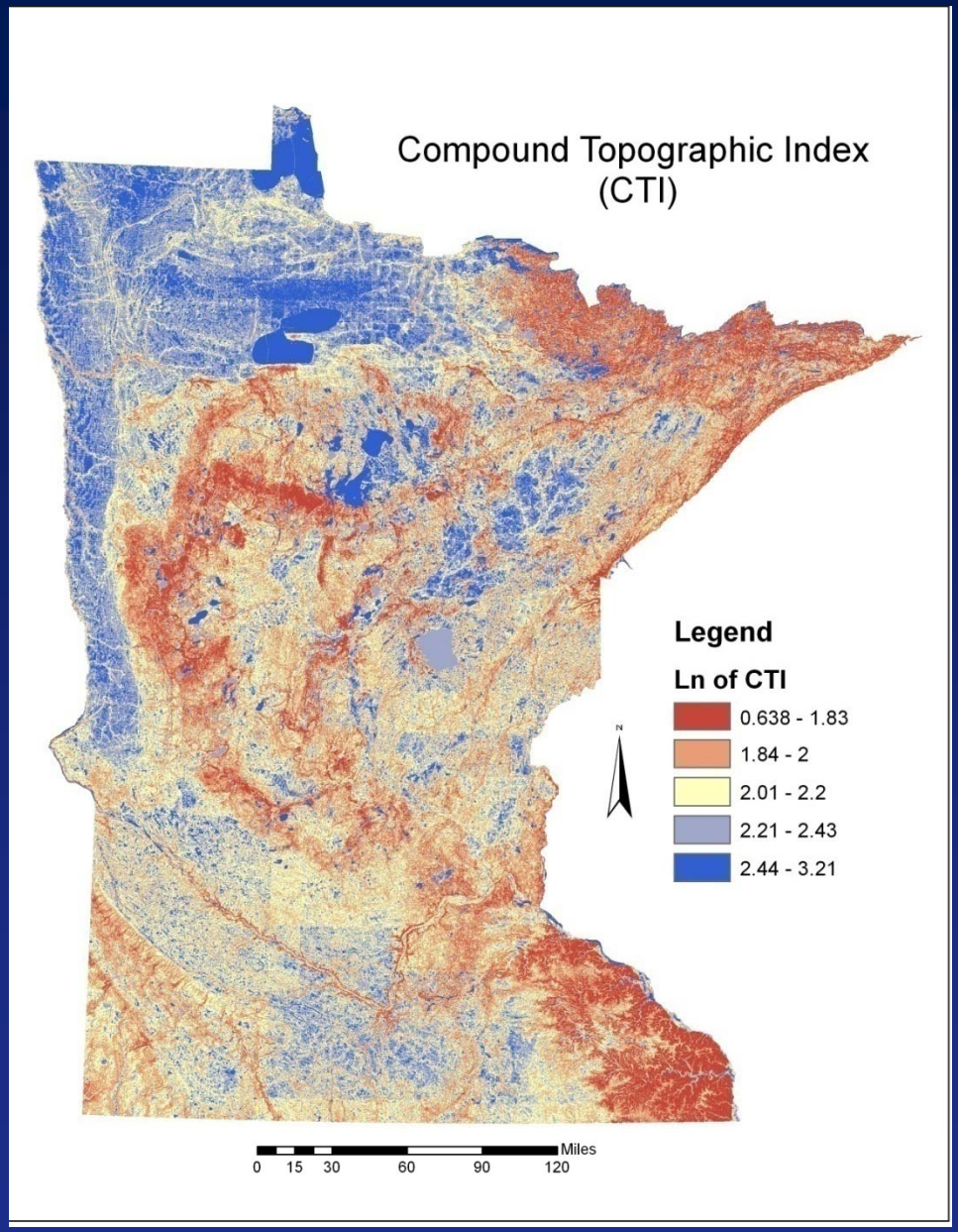
CTI Values



Smoothed CTI





Compound Topographic Index

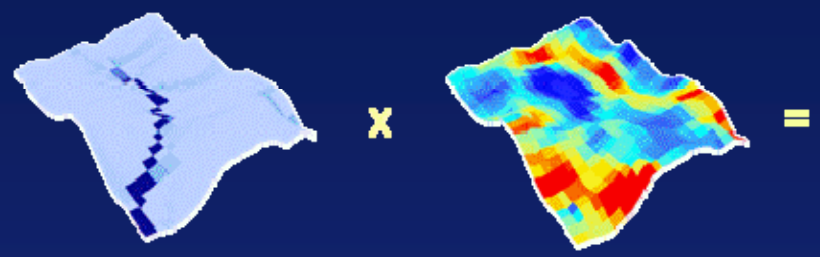
$CTI = \ln(A_s/\tan S)$

A_s is specific catchment
S is slope

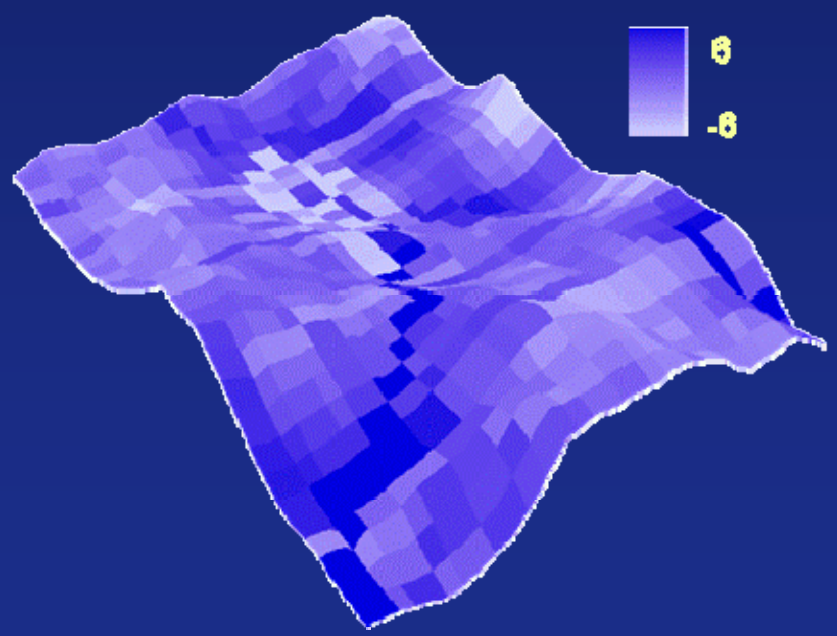
Characterizes soil water content and surface saturation zones

Terrain Indices: Stream Power Index

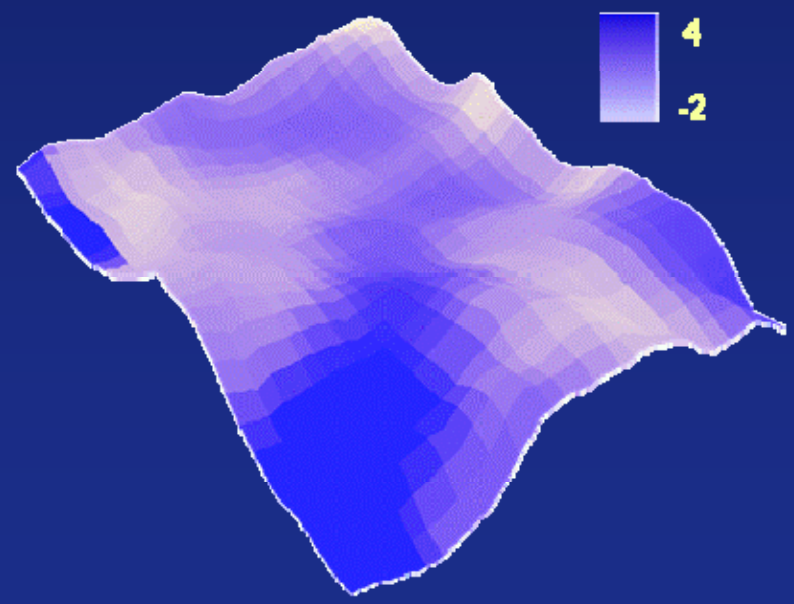
SPI = SCA x S

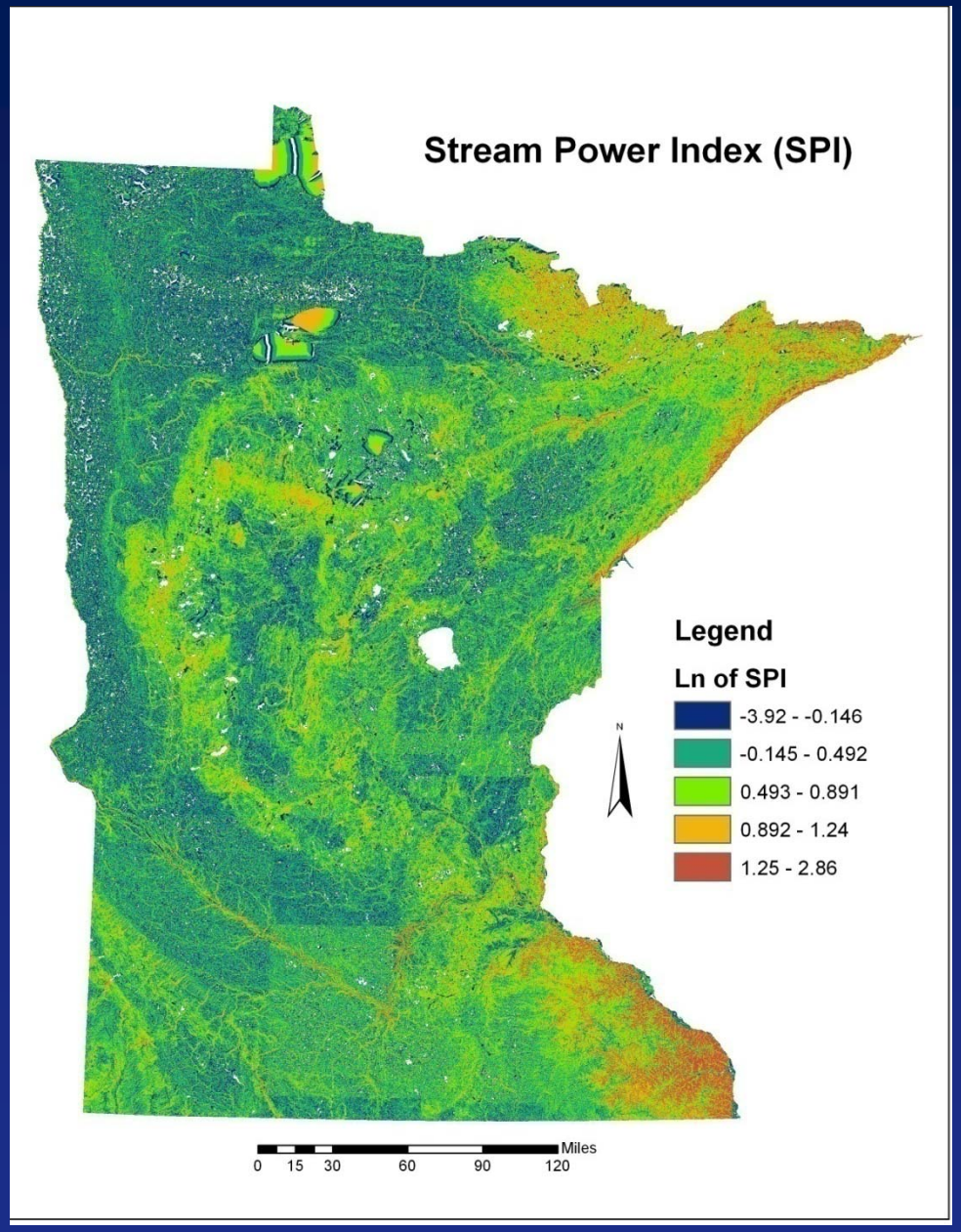


Ln (SPI Values)



Smoothed Ln (SPI)





Stream Power Index

$$SPI = A_s \tan S$$

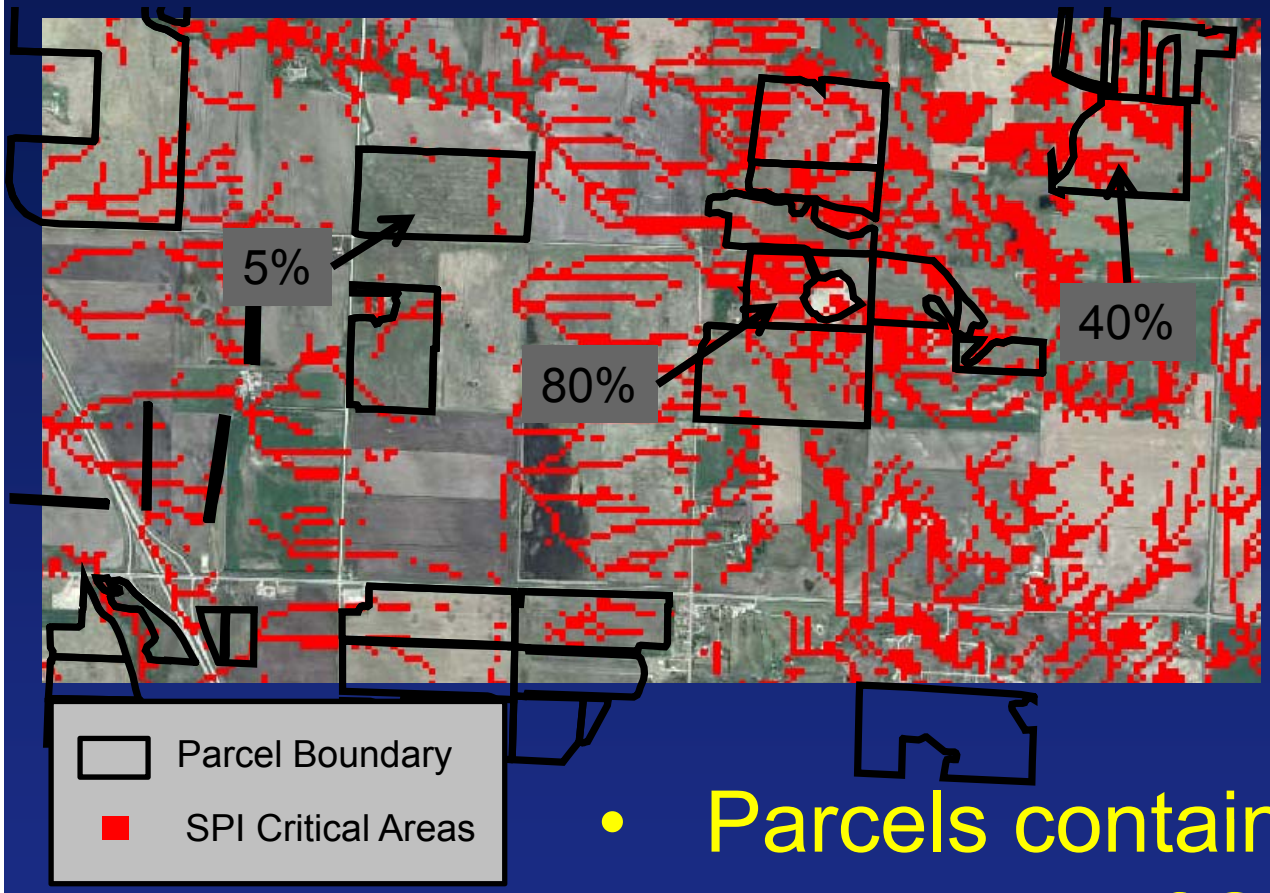
A_s is specific catchment area, S is slope

Measures erosive power of overland flow

Critical Areas

- Two criteria:
- Accumulation of surface flow
- Hydrologic connection to surface waters

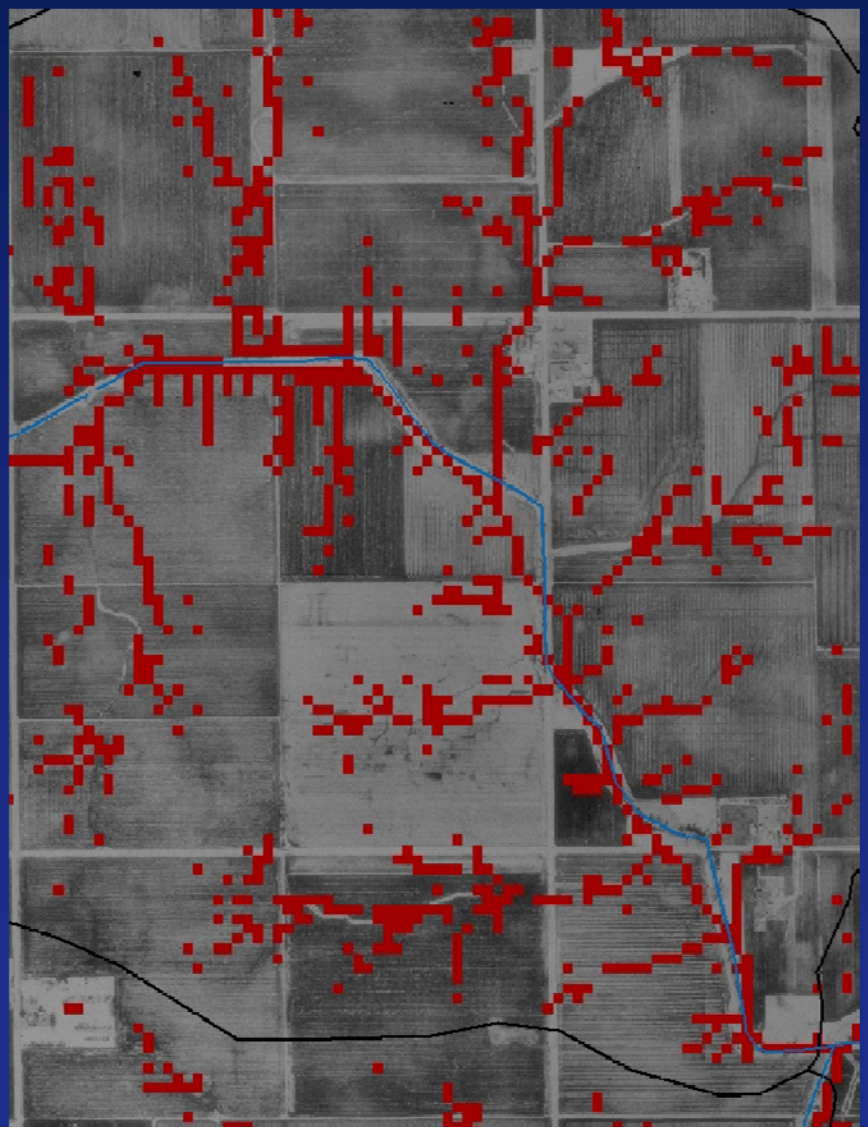
Stream Power Index Critical Areas



High SPI areas can be identified and represent likely overland flow paths

- Parcels containing a higher proportion of SPI critical areas have a higher overland erosion risk score

Comparison of SPI signatures for 3m LiDAR vs 30m DEMs



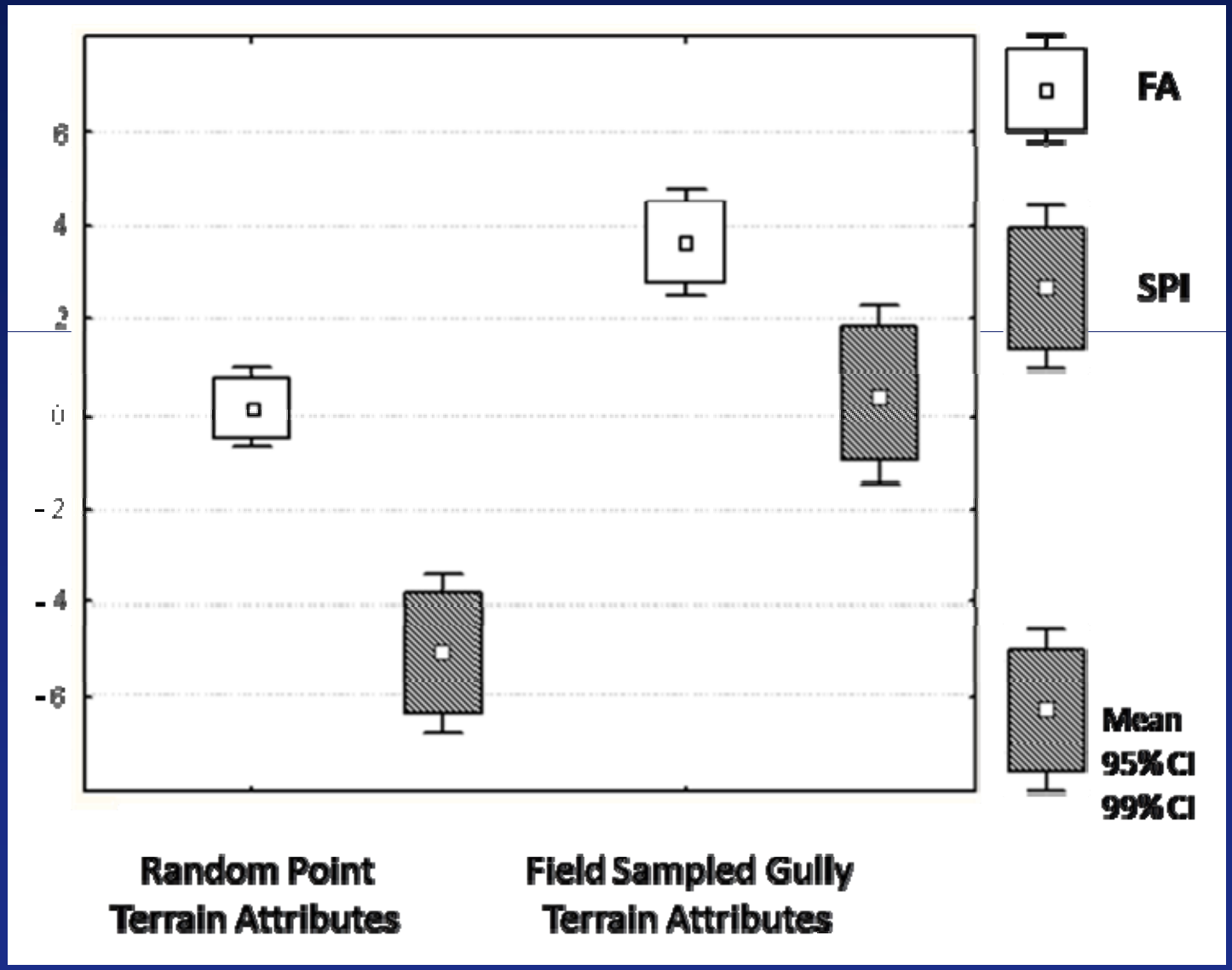
Validation of Terrain Analysis Method

- Field surveys conducted along stream corridor to identify locations with a high potential for erosion (gullies, side inlets)

Results of research published in special issue of J. Soil Water Conserv. dealing with Precision Conservation

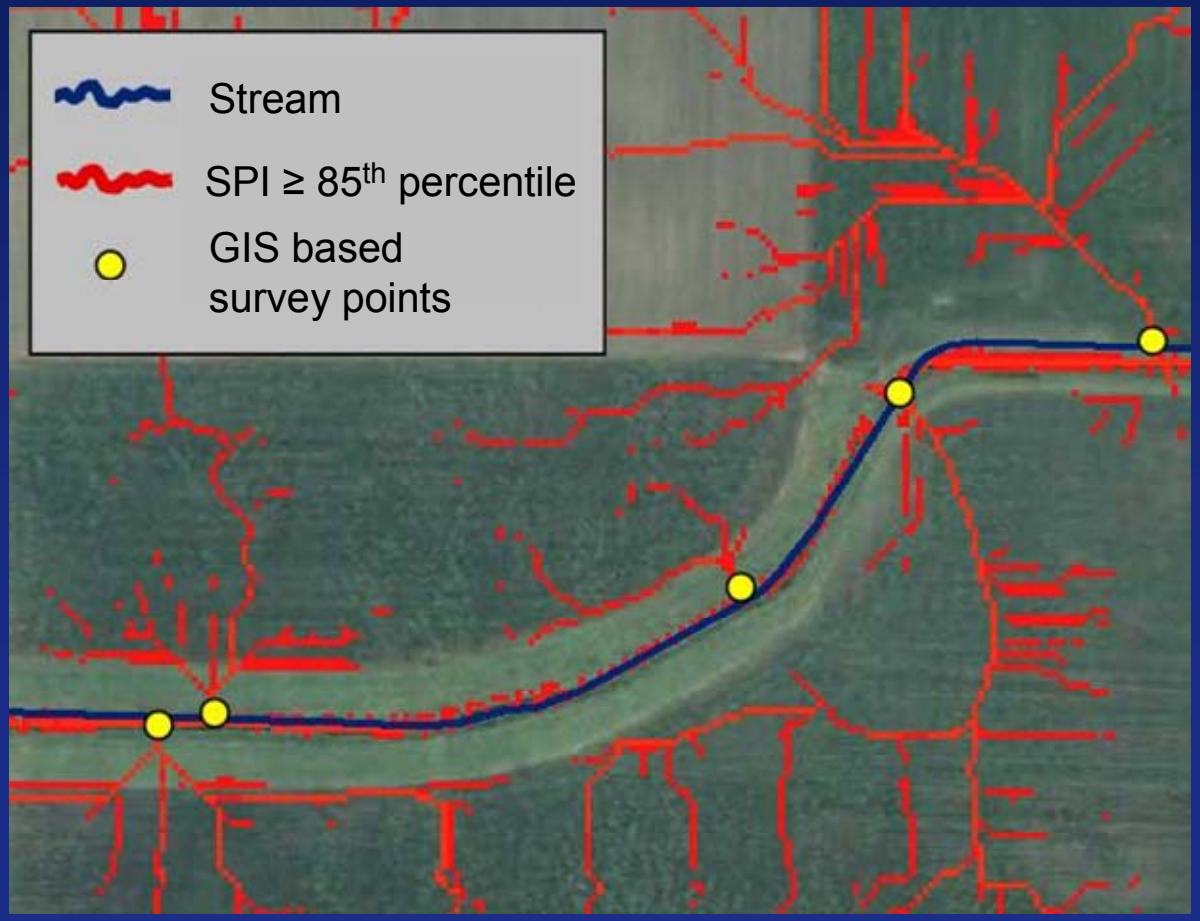
- Galzki, J., A. S. Birr and D. J. Mulla. 2011. Identifying critical agricultural areas with 3-meter LiDAR elevation data for precision conservation. J. Soil Water Conserv. 66:423-430.

Seven Mile Creek Gullies

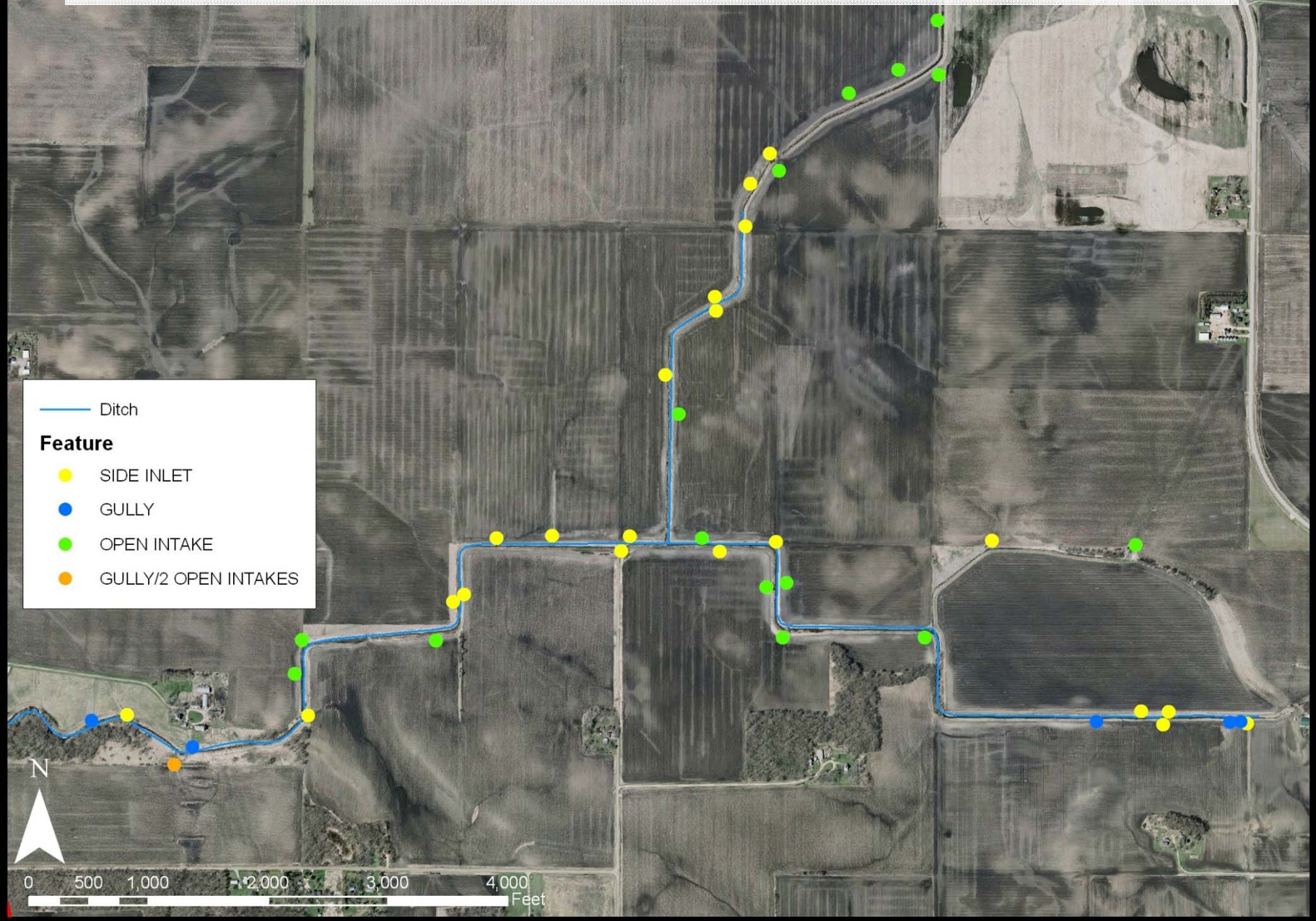


Validation Set

- GIS based survey was completed in Seven Mile Creek Watershed
- Points were created wherever an SPI signature intersected the stream corridor (78% accuracy)

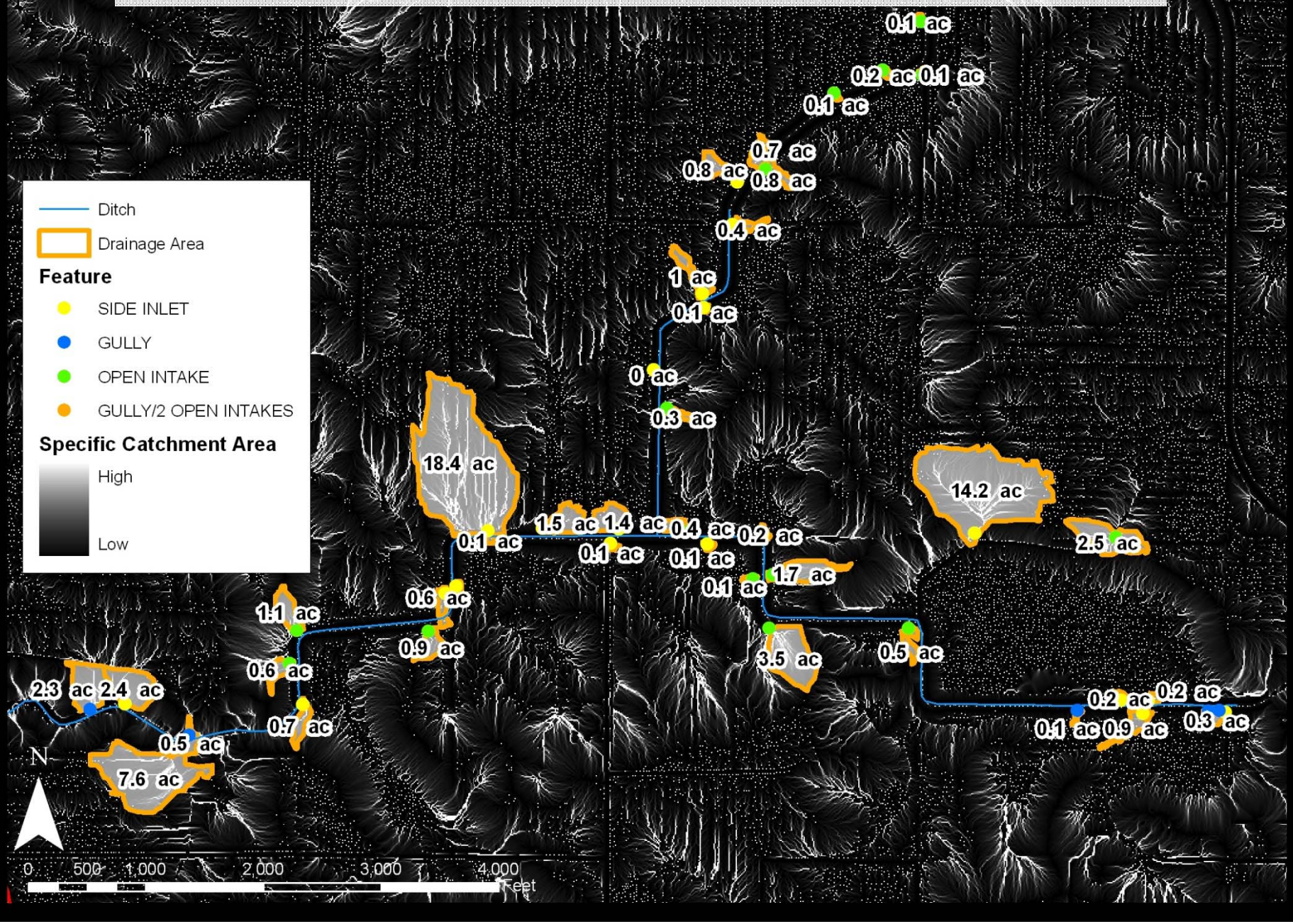


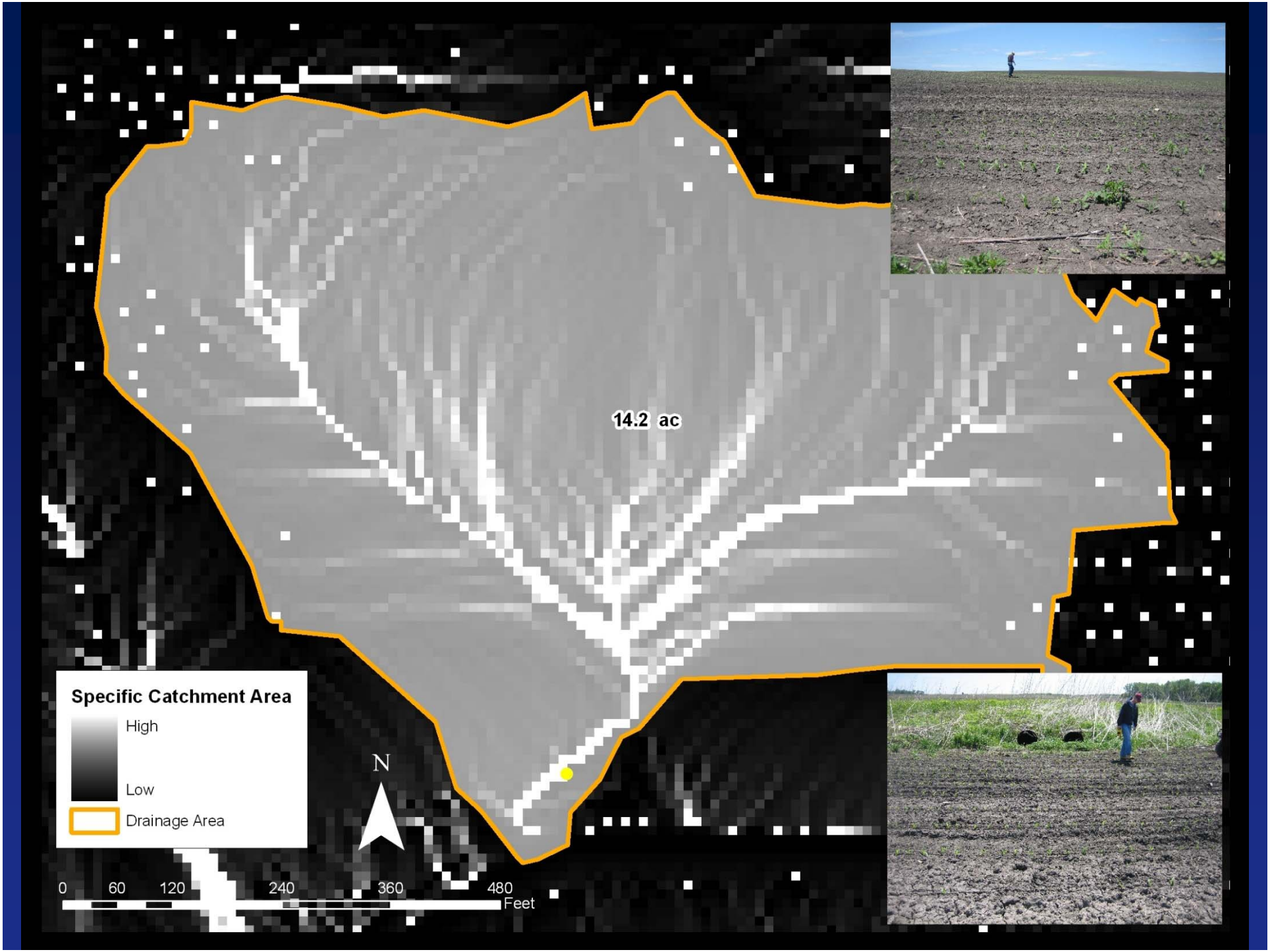
Specific Catchment Area used to Identify Critical Source Areas
Beauford Watershed (Blue Earth County)



Critical Source Areas Ranked by Upland Catchment Size

Beauford Watershed (Blue Earth County)




14.2 ac
Specific Catchment Area
High
Low
Drainage Area
N
0
60
120
240
360
480
Feet

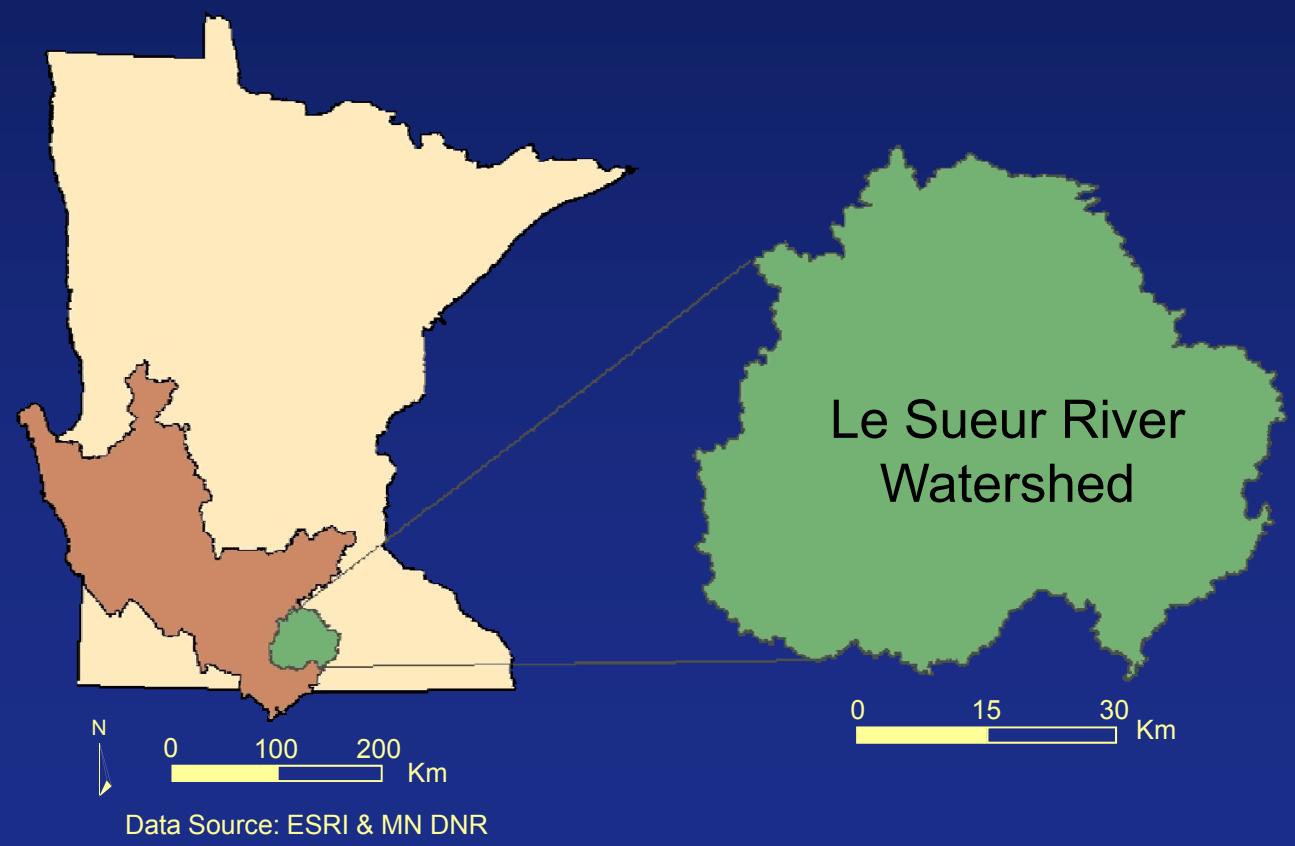
Cost Benefits of Terrain Analysis
Seven Mile Creek Watershed

- Walking survey took 10 days and about 300 labor hours with 3 people
- Equip. and mileage cost= $2,500
- Labor cost = $7,000
- Total cost = $9,500 or about $413/ditch mile
- It is estimated that it would take about 10-12 years at a cost of about $100,000-$120,000 in labor to conduct the same survey for the rest of the County
- Source: Brown Nicollet Cottonwood Water Quality Board

Disproportionalities

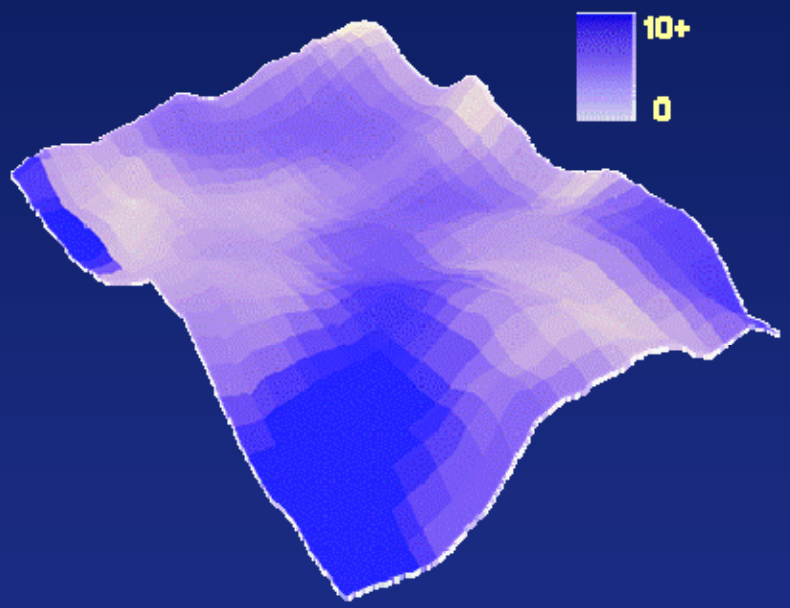
- The Le Sueur contributes a disproportionate amount of non-point source pollution to the Minnesota River
  - Only comprises 7% of the basin land surface area
  - 53% TSS
  - 31% Total P
  - 20% NO_3-N

(MRBDC, 2005)

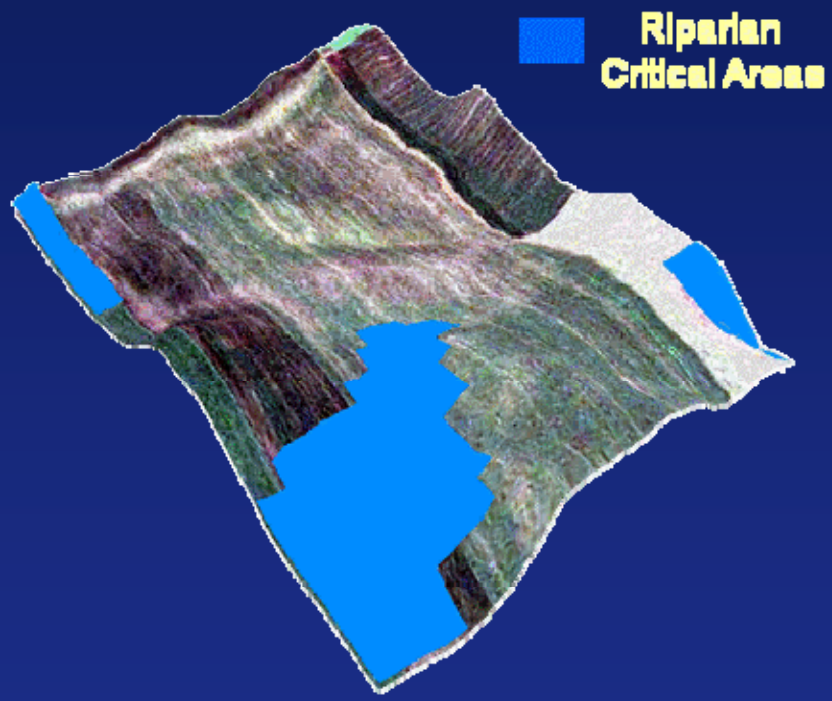


Riparian Critical Areas Delineation

Smoothed SPI > 10

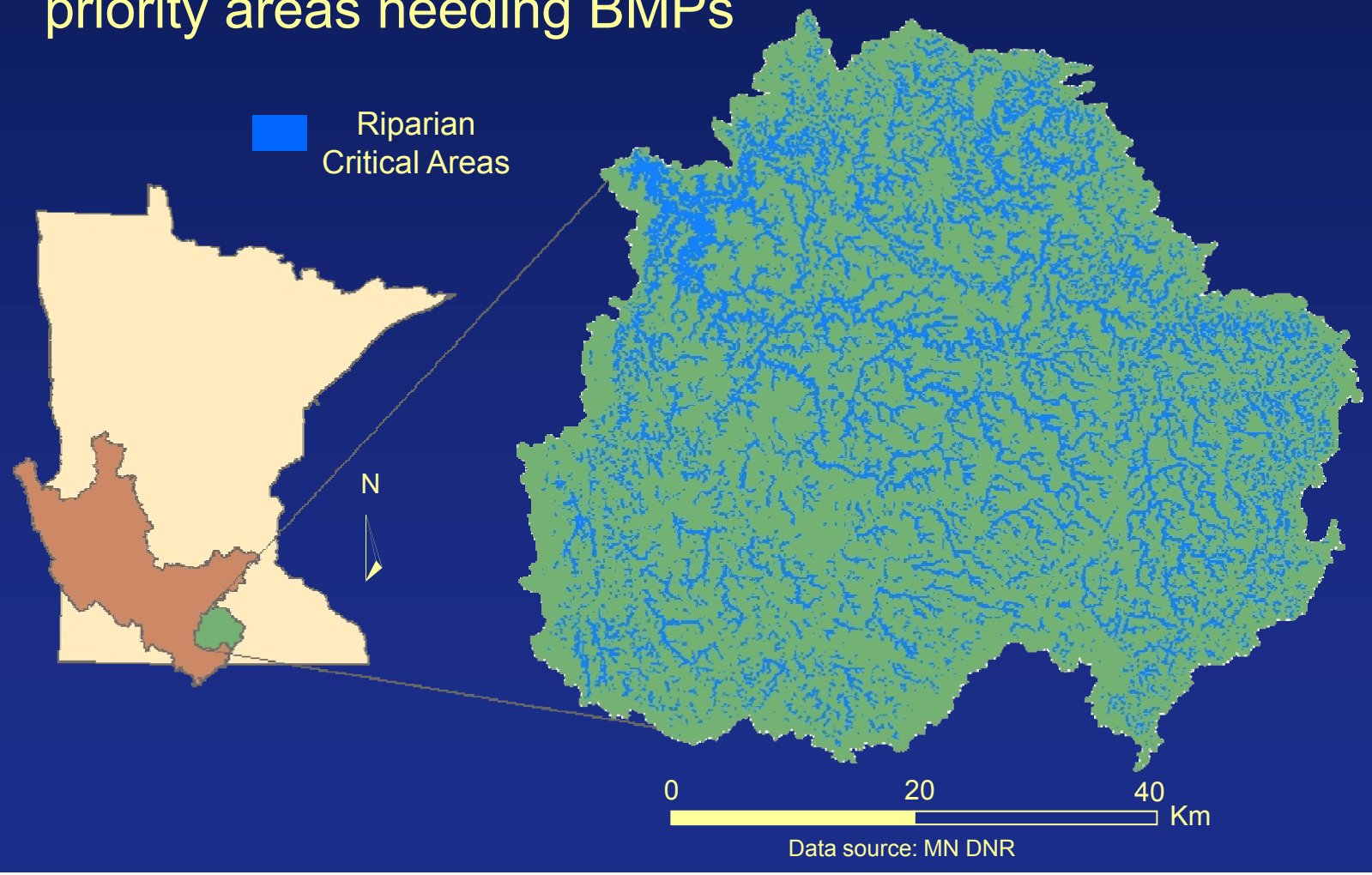


= Riparian areas



Critical Riparian Areas

- Covers over 25% of the watershed (~74,000ha)
- 59% of riparian critical areas are in ag production
- When combined with erosion potential, gives high priority areas needing BMPs



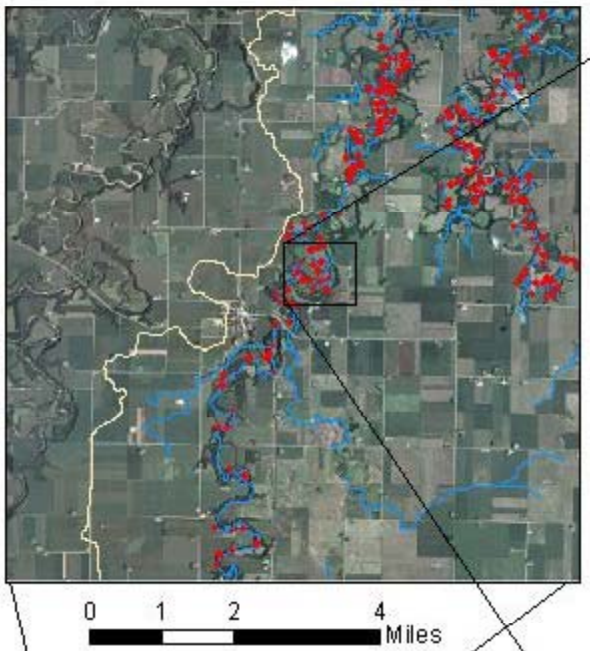
Eroding Stream Bank

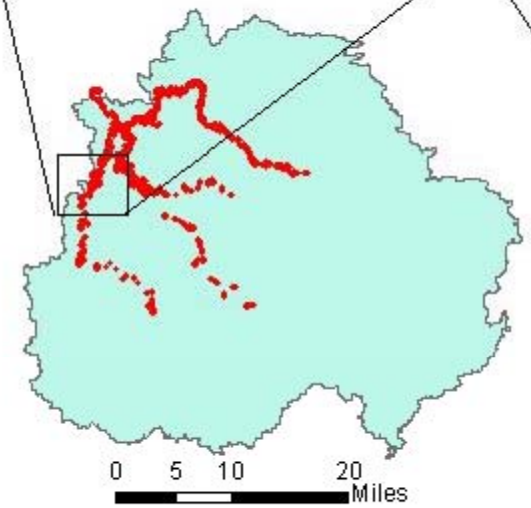
Stream Bluff Erosion

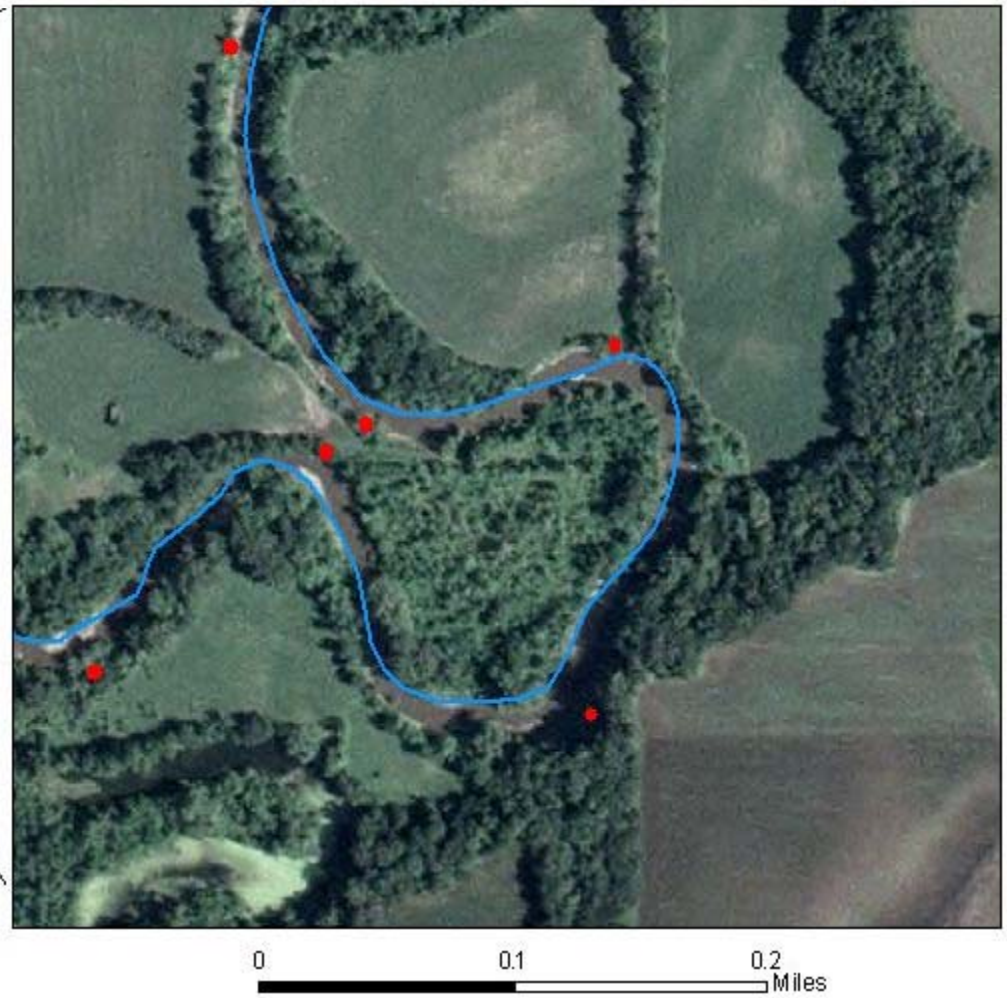
Cobb River Slumping Bluff

Appendix D

Le Sueur Watershed Bluffs





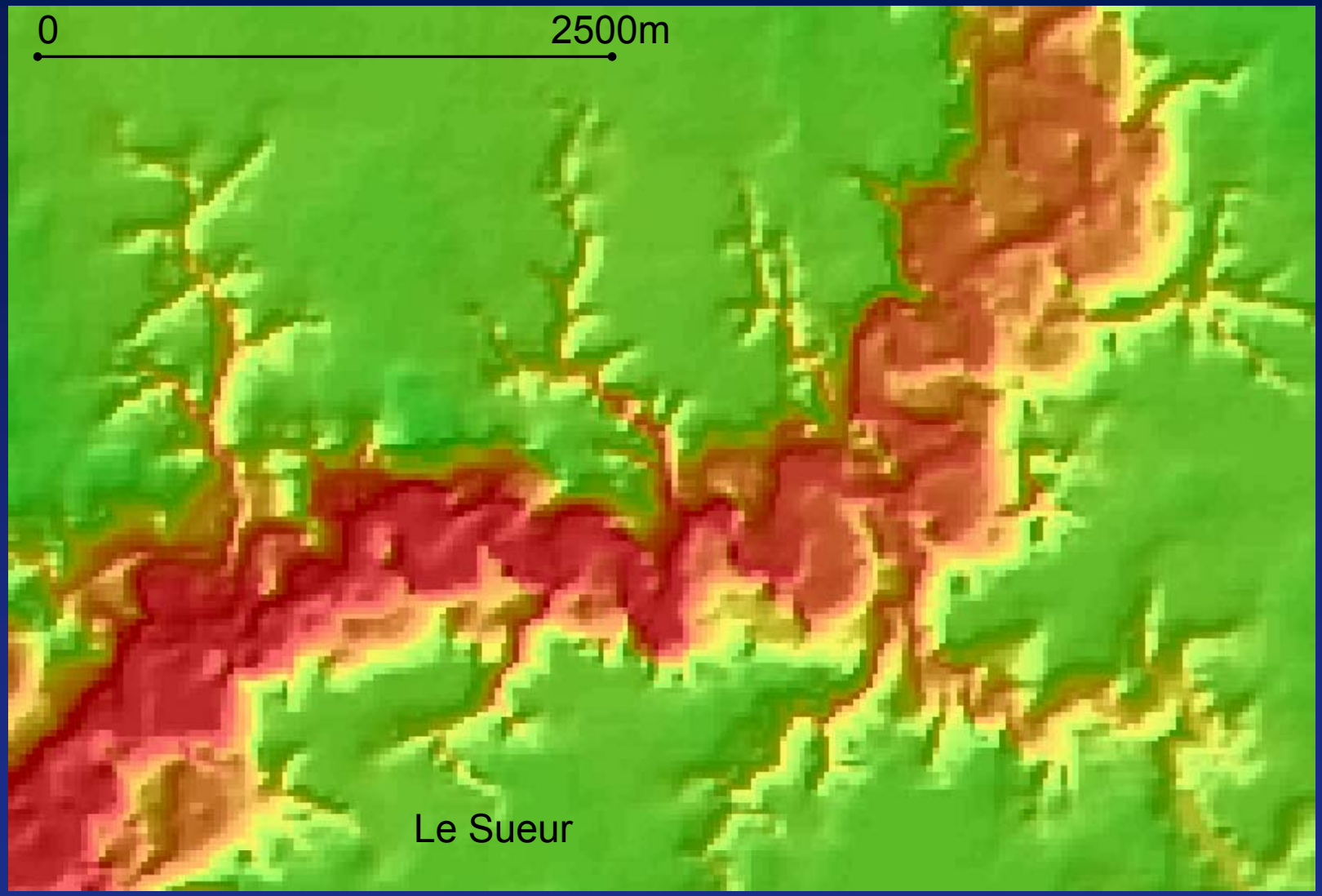


The Bluffs layer identifies areas with high potential for stream bank erosion. These points were digitized from 1 meter resolution orthophotography.

Data Source: MN DNR & The
Land Management Infromation Center
Cartography by: Joel Nelson & Jake Galzki

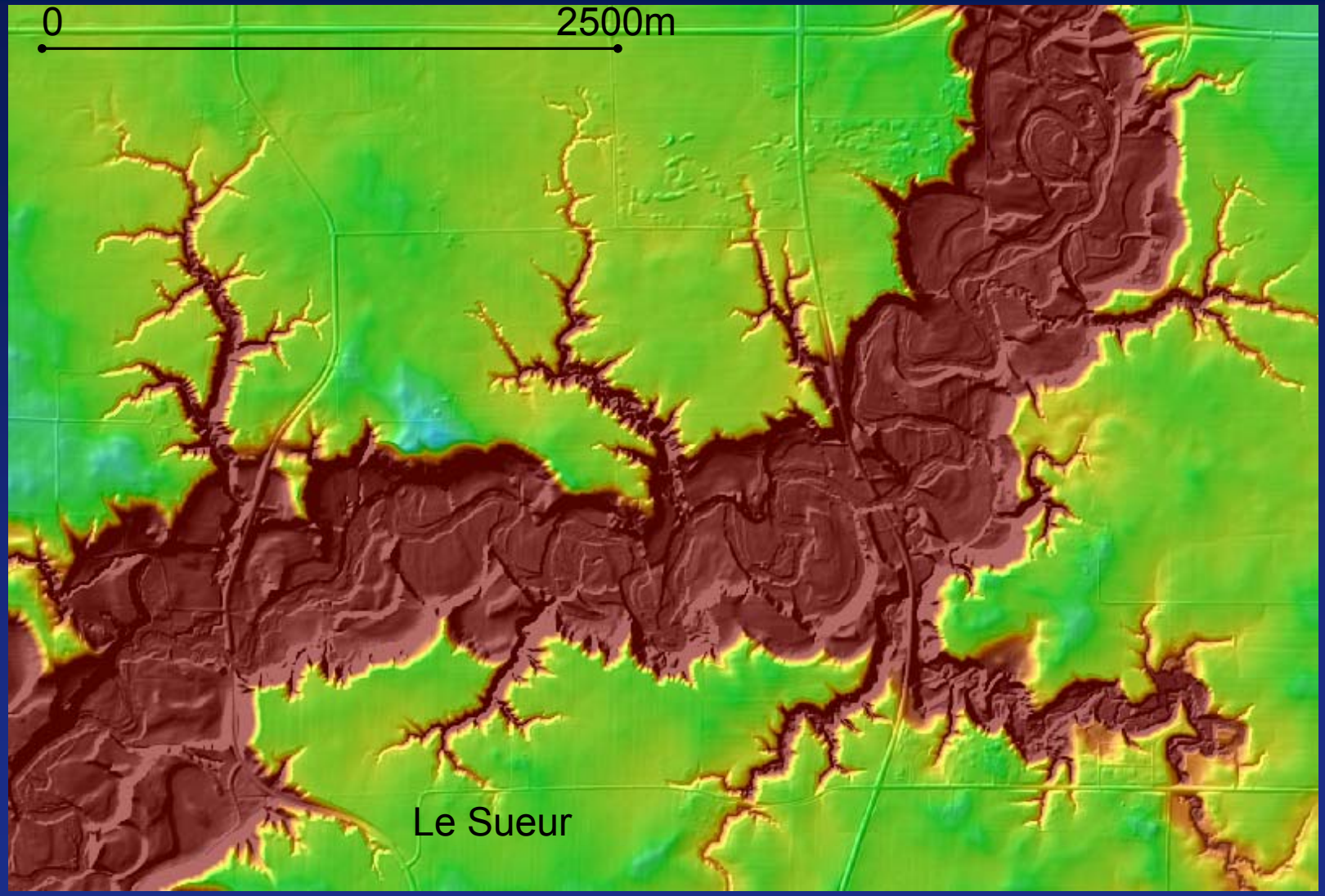
Ravine Erosion

Ravines in Blue Earth county



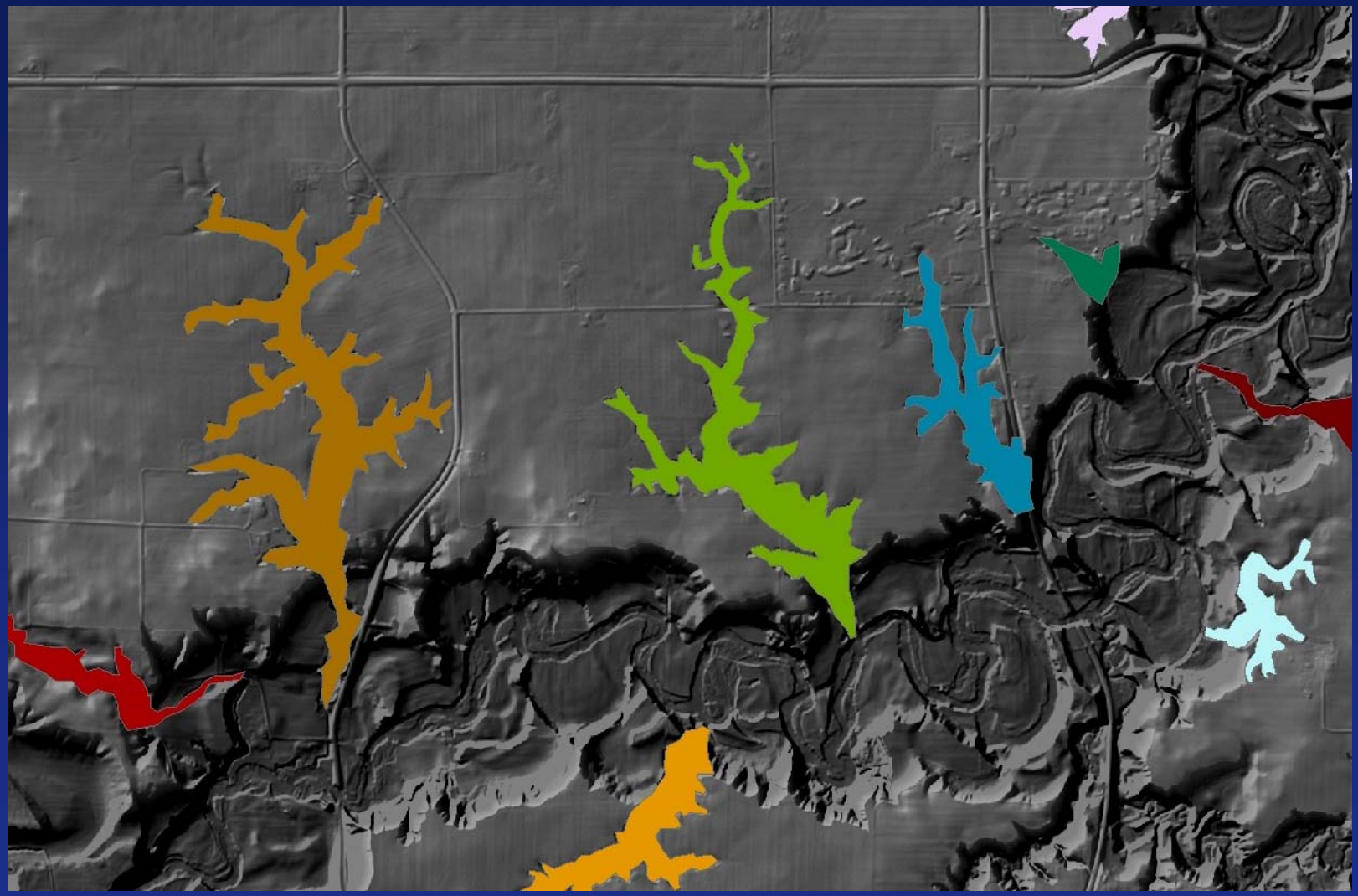
30 m DEM

Ravines in Blue Earth county



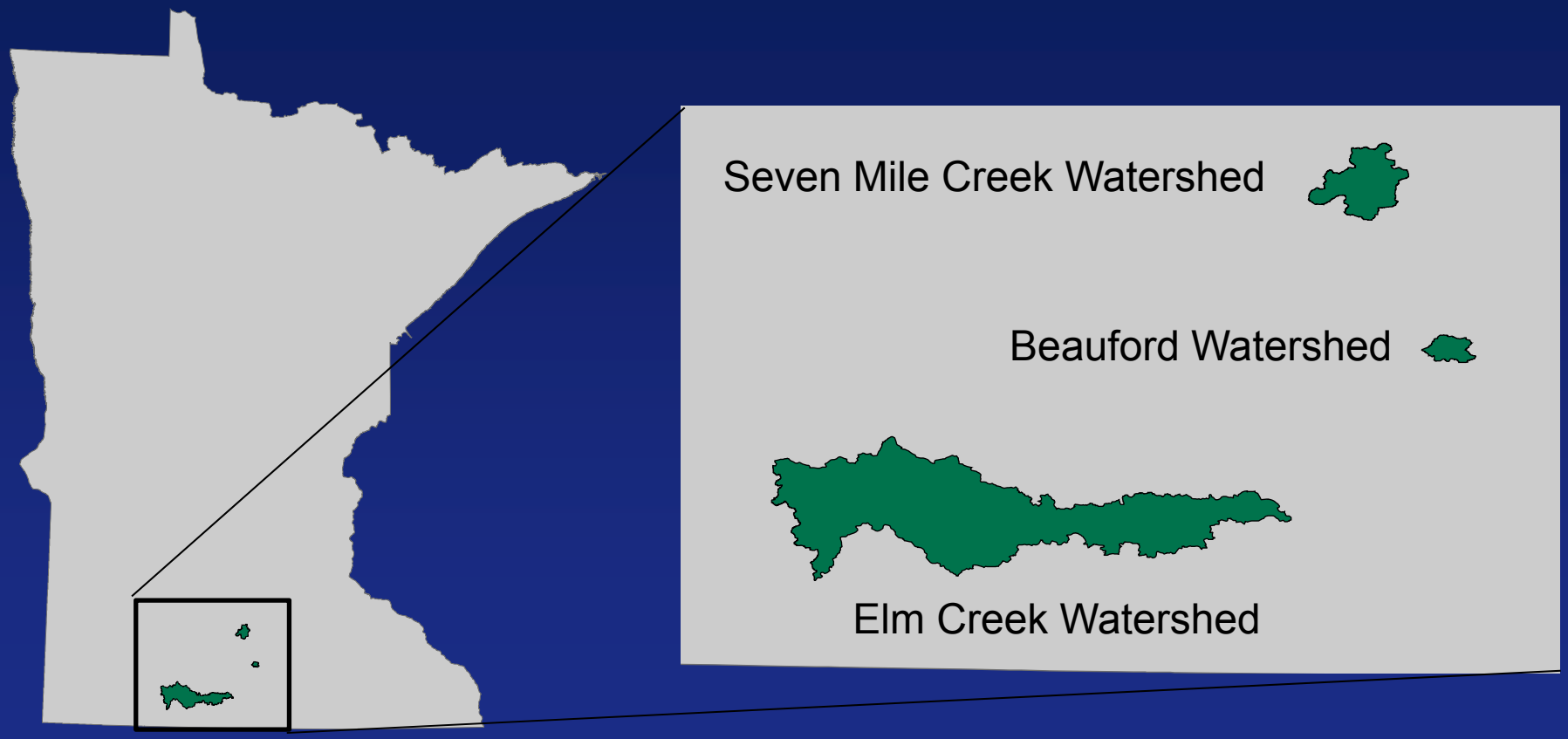
3 m LiDAR

Ravine Sediment Sources



Digitized from Blue Earth county Lidar by Patrick Belmont - NCED

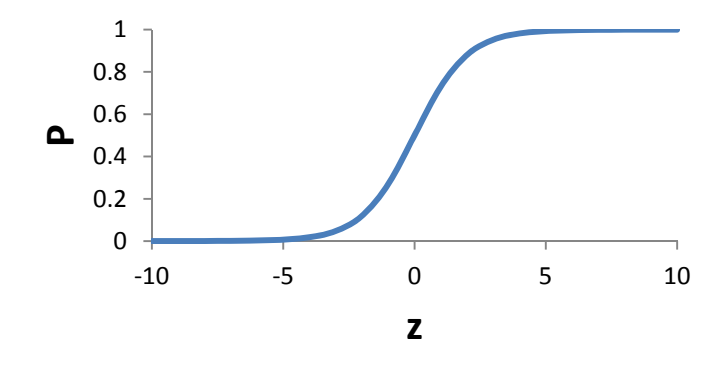
Wetland Restoration Potential



Logistic Regression Model

- Use wetland/upland points for calibration
- Reserve points for validation
- Nominal logistic model (wetland/upland)

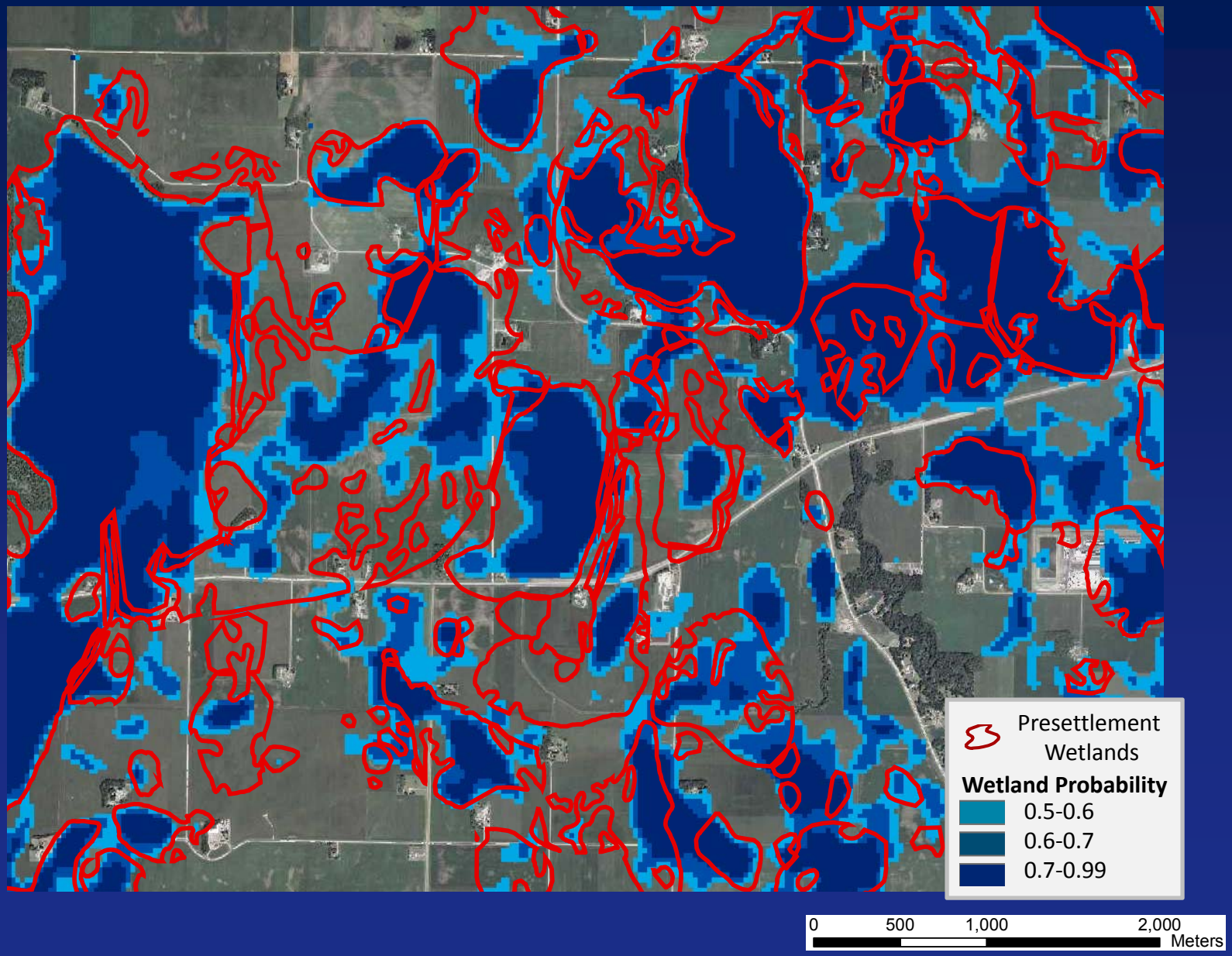
$$P = \frac{1}{1+e^{-z}}$$



P = probability that a point on the landscape is upland (not wetland)

$$z = \beta_0 + \beta_1(CTI_u) + \beta_2(hydric\%) + \beta_3(slope) + \beta_4(curve_{prfl}) + \beta_5(fslope_{480m})$$

Seven Mile Creek Restorable Wetlands



Accuracy – Seven Mile Creek

		Reference Class			
		Upland	Wetland	Total	Commission
Mapped Class	Upland	185	62	247	25%
	Wetland	90	163	253	36%
	Total	275	225	348	
	Omission	33%	28%		**70%**

Statewide Ecological Benefits Index for Minnesota Land Parcels

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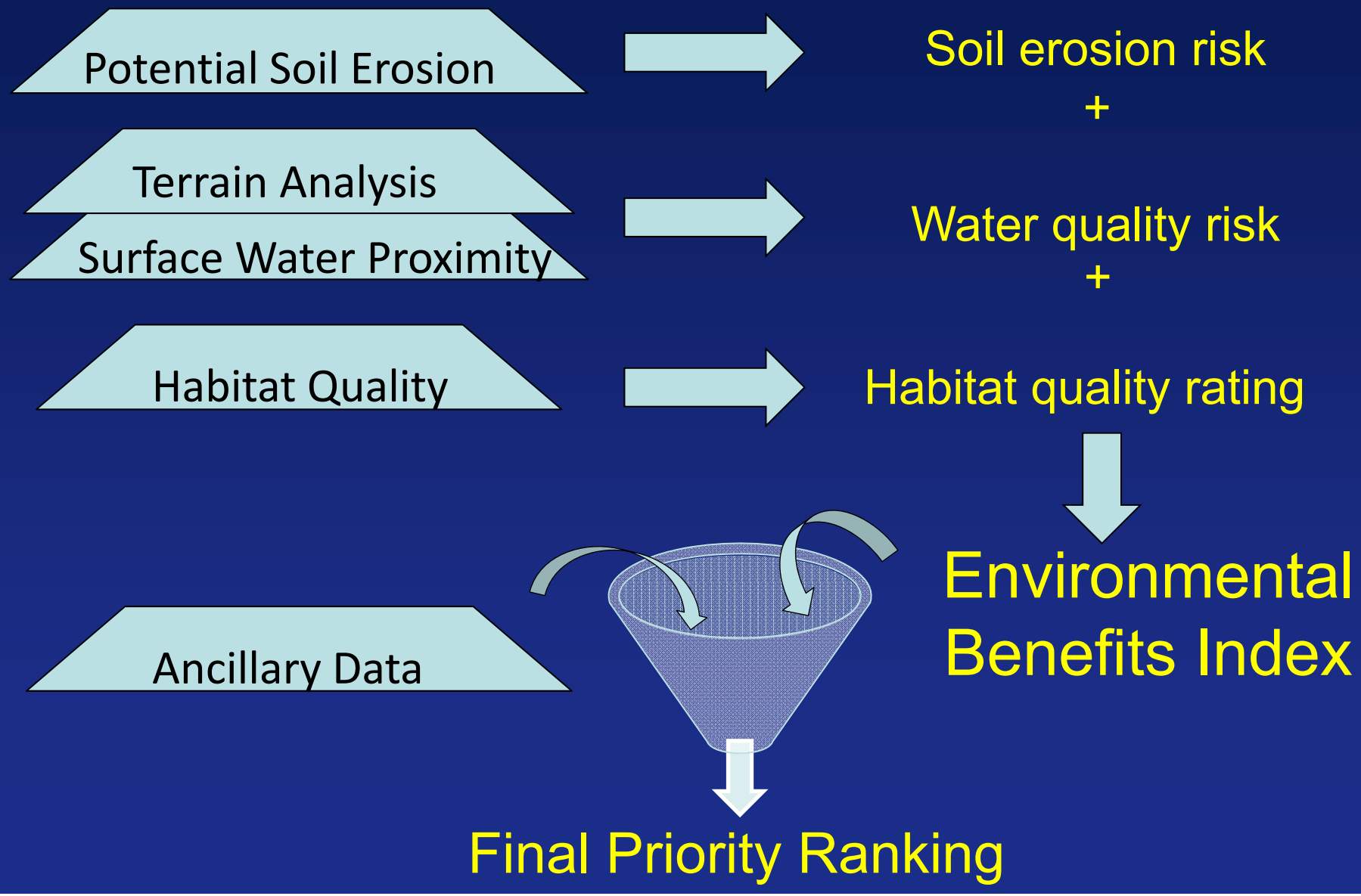
Goal of the Ecological Ranking Project

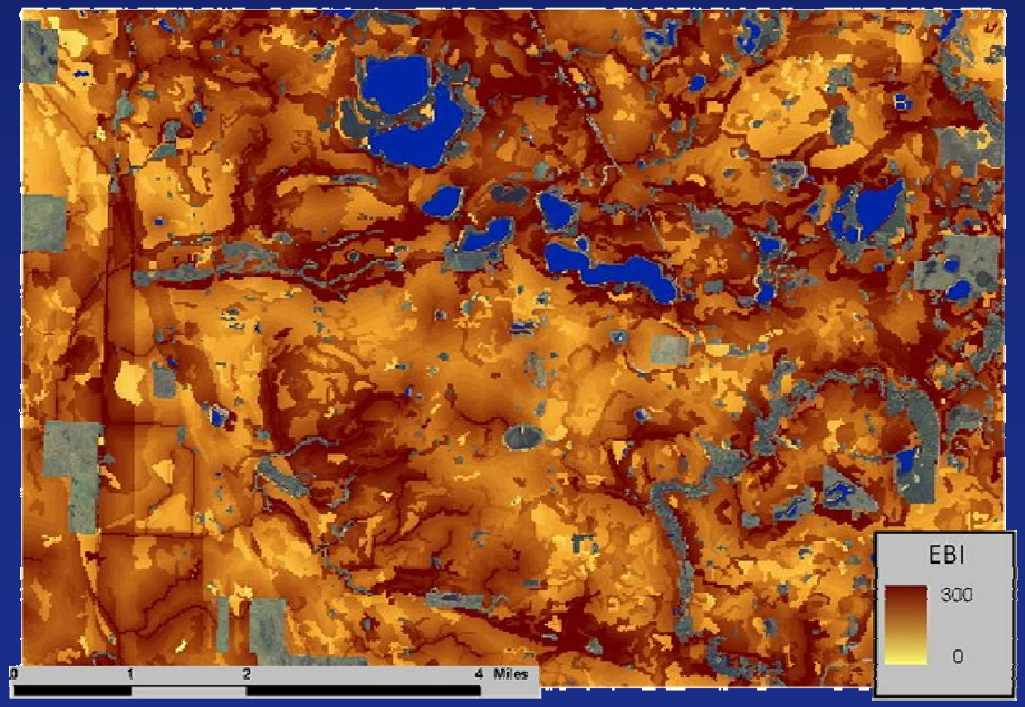
- To more effectively target conservation programs to CRP lands and other critical lands such as
  - Marginally productive croplands
  - Surface water protection areas
  - Important habitat areas

Data layers for ecological ranking

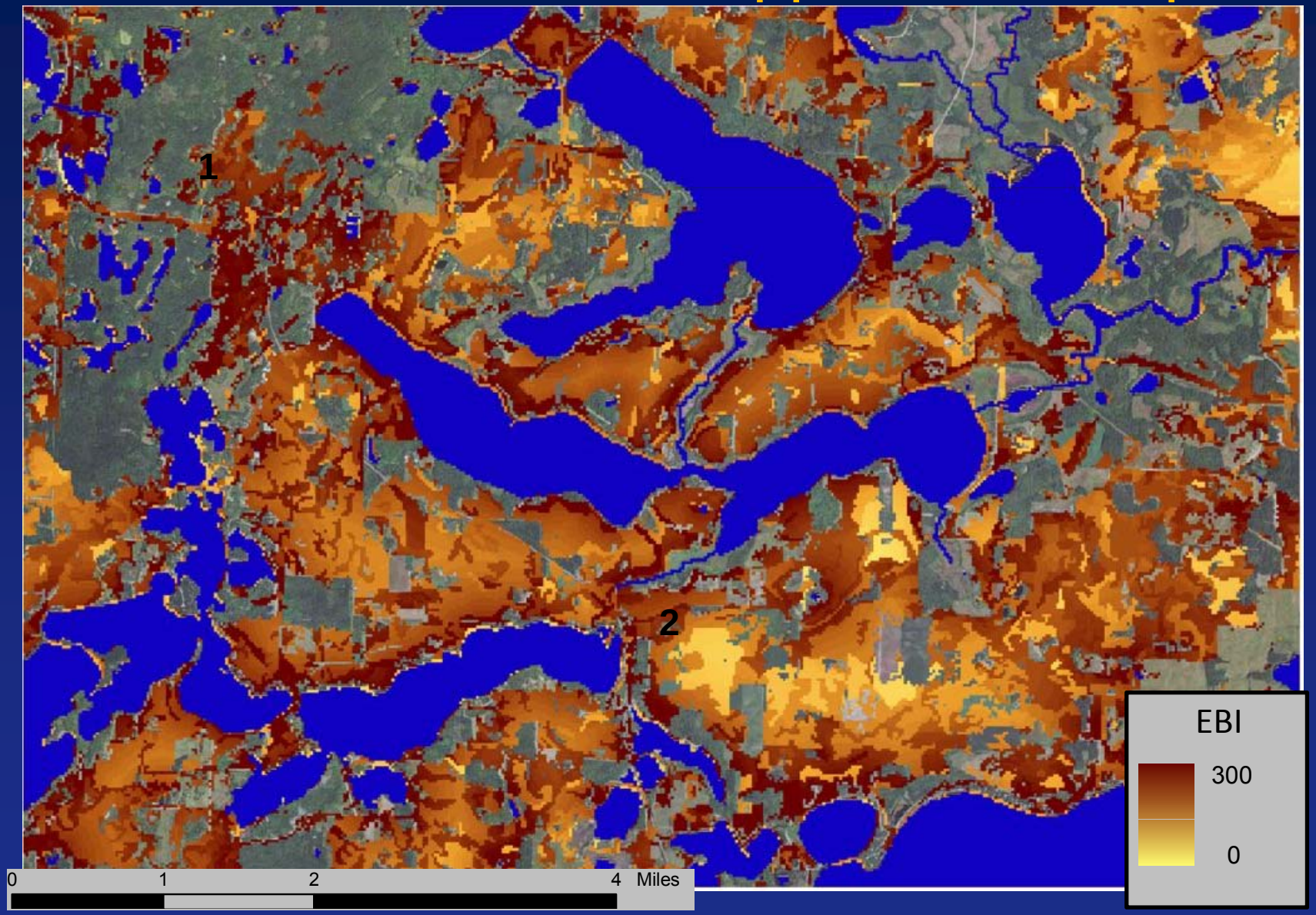


Environmental Benefits Index (EBI)

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

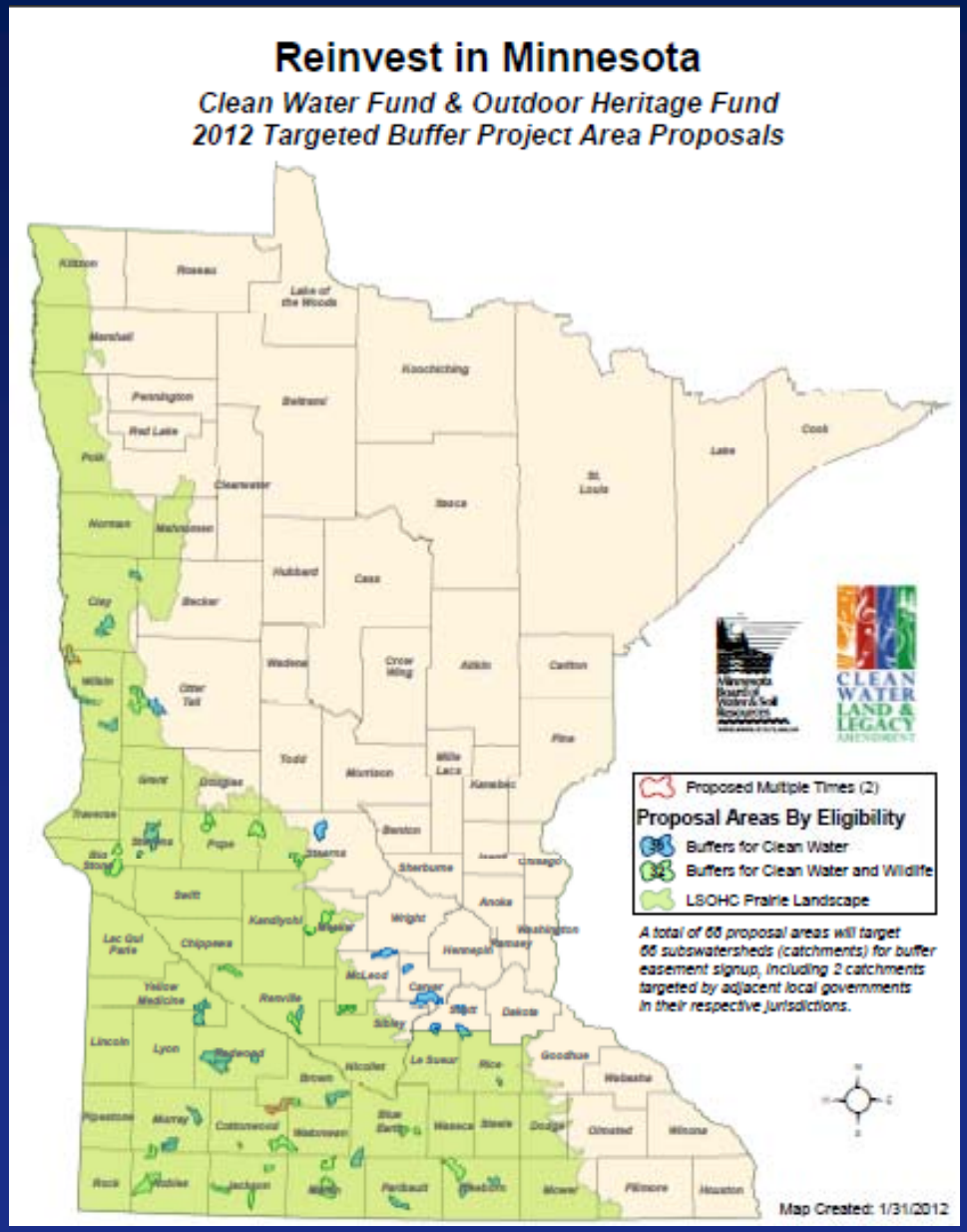


Central Lakes EBI – Cropped Landscapes



BWSR Targeted RIM Buffer Program

- RIM program initially involved 203,000 acres enrolled in 5,300 conservation easements
- Program was heavily focused on Minnesota River Basin riparian areas and wetlands
- Has been extended geographically



BWSR Ecological Ranking Tool Website

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

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Ecological Ranking Tool

Targeting conservation solutions to address landscape needs

The statewide ecological ranking tool makes it possible to identify areas on the landscape that are at risk for soil erosion, at risk for contributing sediment to surface waters, or are of high habitat quality. When used in combination with other tools and resources, local conservation staff can develop and establish conservation practices that address the site's specific needs and in turn achieve the greatest environmental benefits.

Identifying potential costs and benefits of conservation practices requires accurate information about a site's soils, terrain, and proximity to water bodies.

This new tool helps local soil and water conservation district staff prioritize tracts of land to be targeted for conservation easements or other conservation practices. The tool consists of three spatial data layers:

- Erosion potential of soils
- Terrain analysis and surface water proximity to determine critical overland flow areas
- Habitat quality

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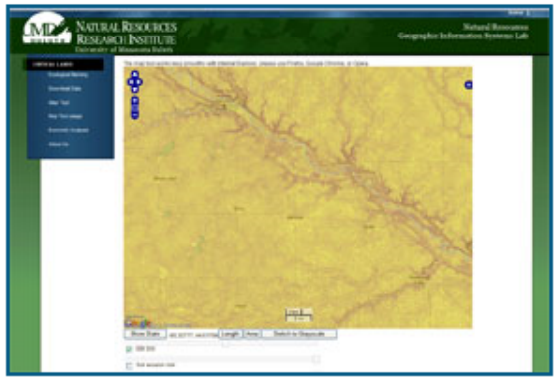
Maps & GIS Data

Interactive Map

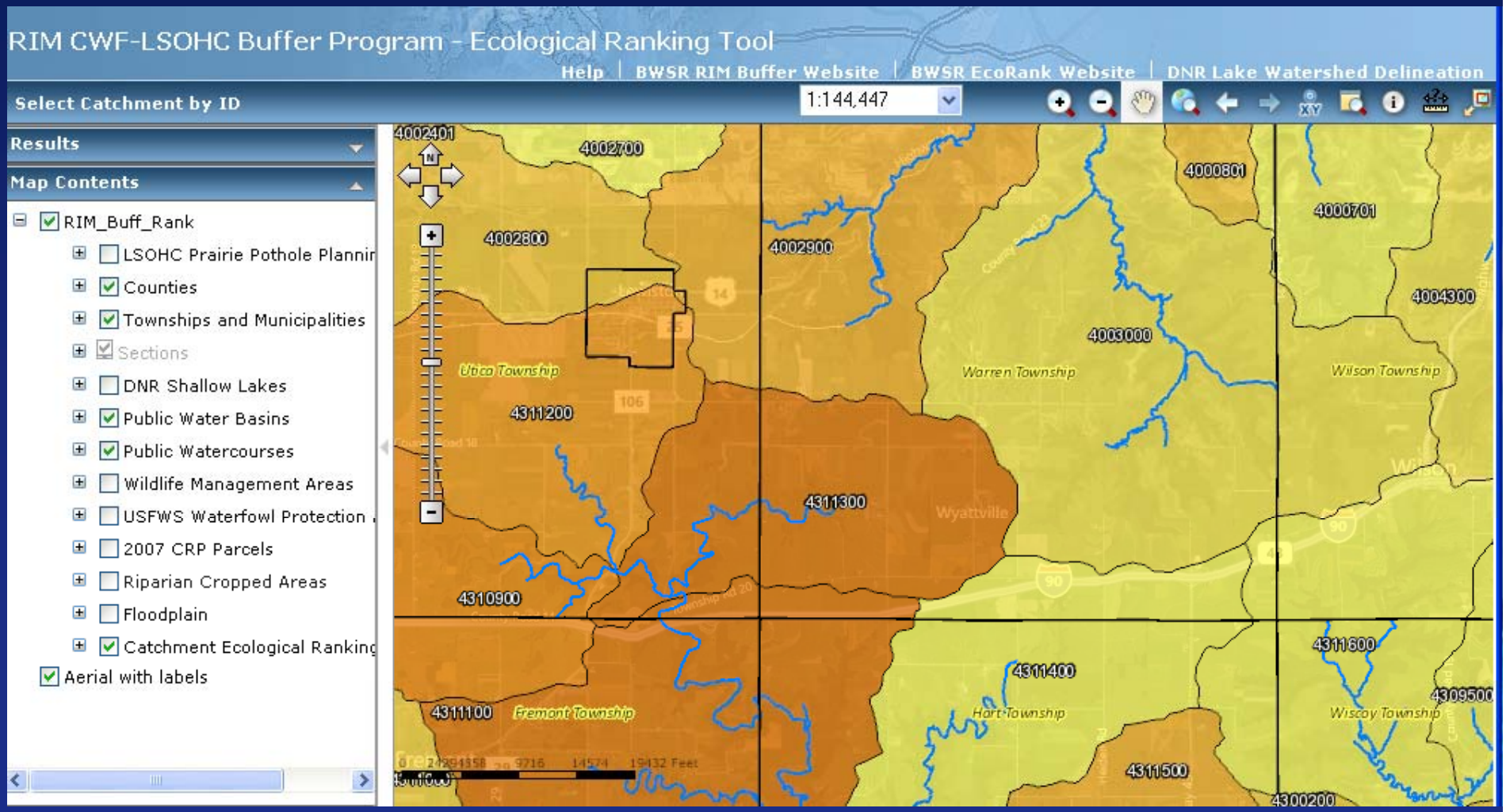


Launch interactive web map

Download data layers

RIM Watershed Ecological Ranking

Use this interactive mapping tool to locate the highest priority project areas (catchments) in your county and determine catchment IDs for inclusion in your RFP



SWAT
(biophysical model)

Field Sources of:
- Sediment
- Phosphorus
- Water

Non-Field Sources of:
- Sediment
- Phosphorus

Biophysical estimates
- Yield by crop type

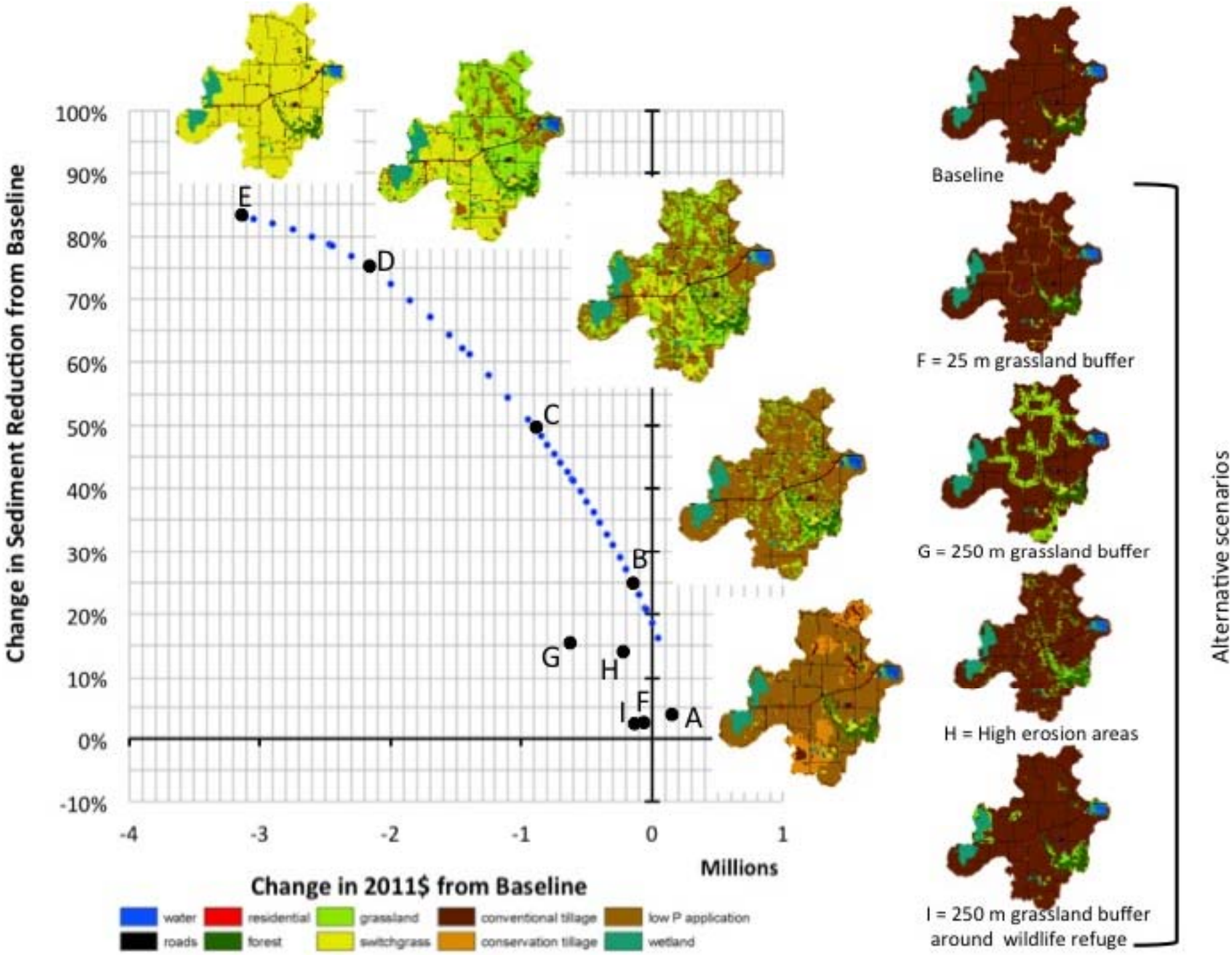
InVEST
(biophysical and valuation model)

Biophysical estimate
- Carbon Sequestration

Market valuation:
- Agriculture production

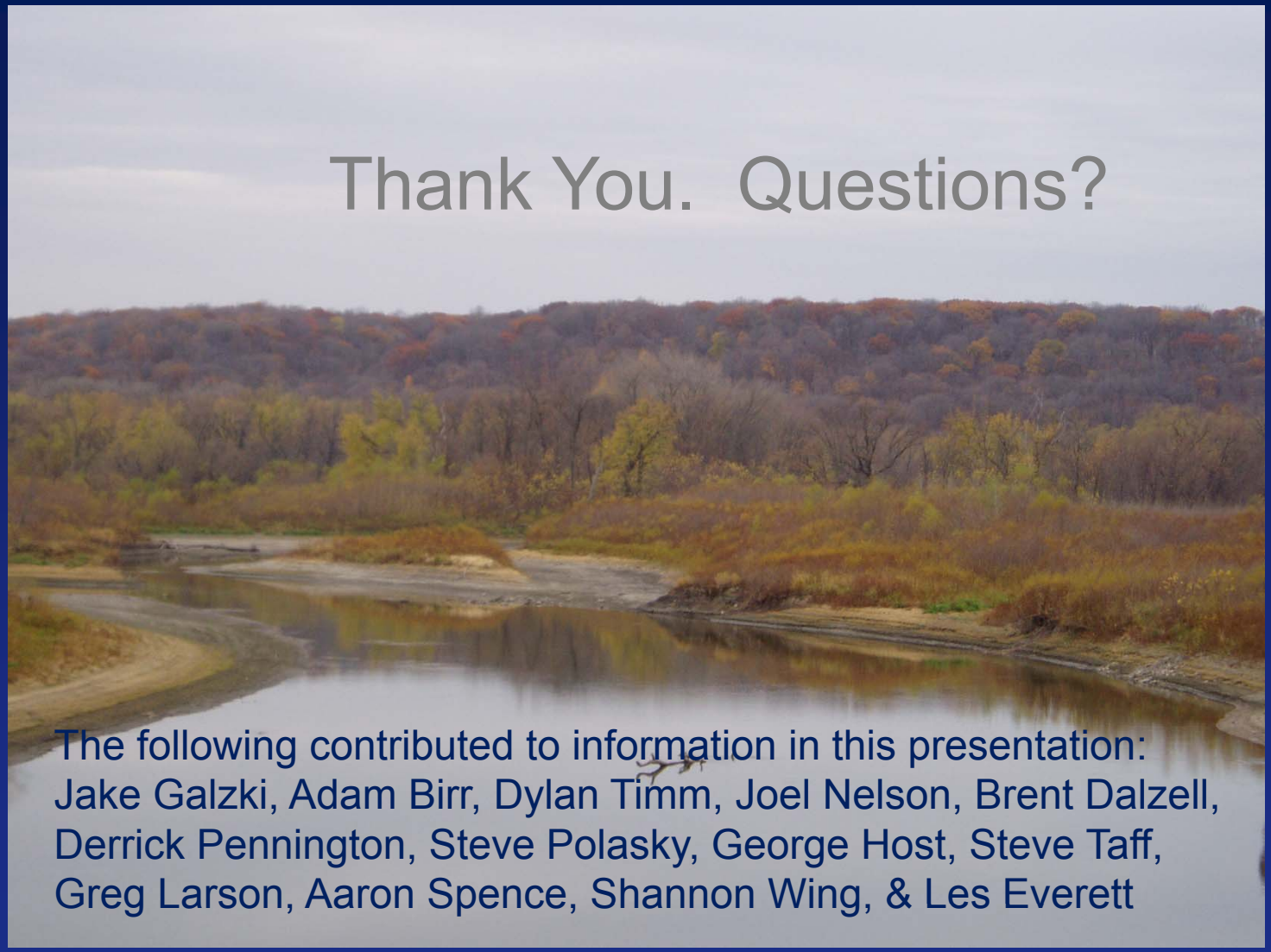
Non-market valuation:
- Sediment
- Phosphorus
- Carbon Sequestration

Integrate outputs into an optimization routine


Change in Sediment Reduction from Baseline
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-4
-3
-2
-1
0
1
Millions
Change in 2011$ from Baseline
E
D
C
B
G
H
I
F
A
water
residential
grassland
conventional tillage
low P application
roads
forest
switchgrass
conservation tillage
wetland
Baseline
F = 25 m grassland buffer
G = 250 m grassland buffer
H = High erosion areas
I = 250 m grassland buffer around wildlife refuge
Alternative scenarios

Conclusions

- Conservation practice implementation is neither economically nor environmentally efficient when done uniformly across the landscape
- Disproportionate amounts of sediment and phosphorus are generated from small areas of the watershed
- The effectiveness of BMPs depends on placing them in vulnerable portions of the landscape
- Precision conservation strategies involving LiDAR based DEM terrain analysis may prove very helpful in the future to guide conservation efforts tailored to specific landscapes and to maximize their placement in critical source areas
- Tools for analyzing LiDAR based DEMs need to be developed and integrated with existing conservation planning tools such as MN P-Index, RUSLE2, SWAT, etc.



Thank You. Questions?

The following contributed to information in this presentation:
Jake Galzki, Adam Birr, Dylan Timm, Joel Nelson, Brent Dalzell, Derrick Pennington, Steve Polasky, George Host, Steve Taff, Greg Larson, Aaron Spence, Shannon Wing, & Les Everett

Web Resources

- Ecological Ranking Tool
  http://www.bwsr.state.mn.us/ecological_ranking/
- BWSR Riparian Buffer Conservation Easements
  http://www.bwsr.state.mn.us/easements/buffers/index.html
- Basic LiDAR Tutorial Videos
  http://wrc.umn.edu/randpe/agandwq/tsp/lidar/trainingvideos/index.htm
- MN Dept. of Ag. Precision Conservation Initiative
  http://www.mda.state.mn.us/protecting/cleanwaterfund/toolstechnology/precisionconsinit.aspx
- Conservation Applications of LiDAR
  http://wrc.umn.edu/randpe/agandwq/tsp/lidar/