Development of the Soil and Water Assessment Tool (SWAT) to Evaluate Water Quality in the Red River of the North Watershed

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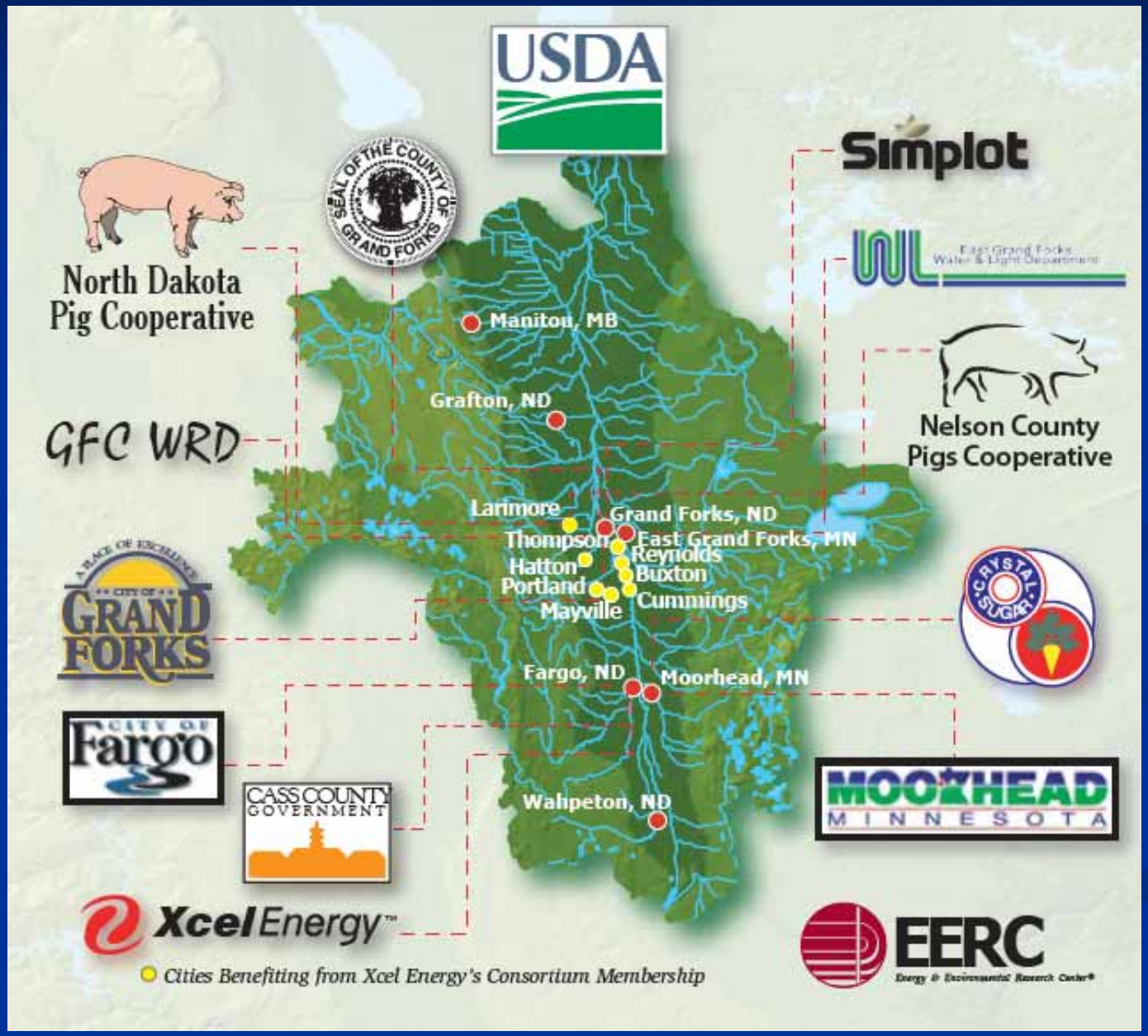
USDA

Minnesota Pollution Control Agency

Red River Water Management Consortium (RRWMC®)

- A partnership, established in 1996, between the EERC, the U.S. Department of Agriculture (USDA), and key stakeholders in the Red River of the North Basin.
- The overall goal of the RRWMC is to provide practical, stakeholder-driven technical input for the development of a long-term watershed management strategy focusing on water quantity and quality to ensure continued economic development of the area.

RRWMC Members



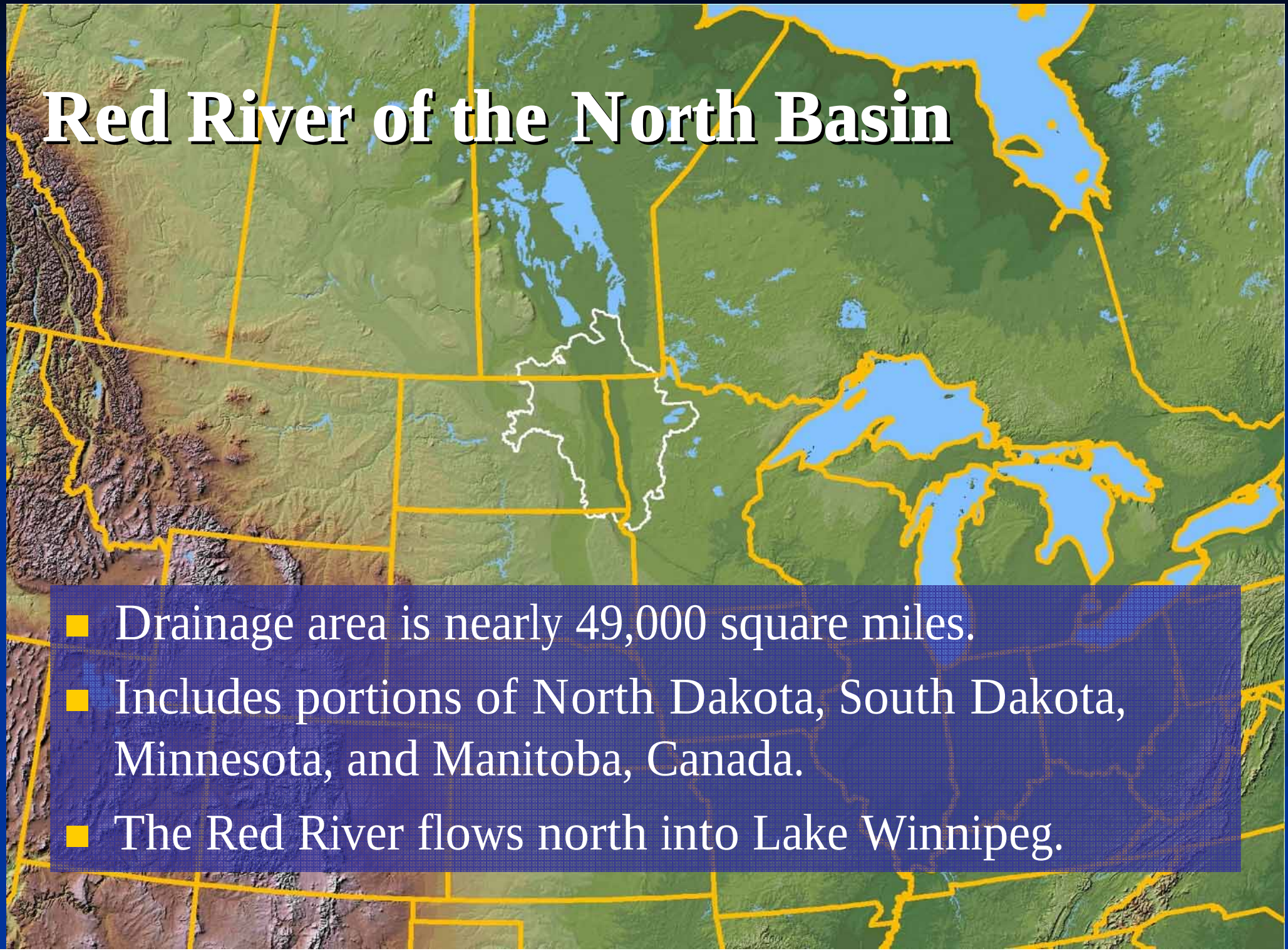
RRWMC Advisory Board

Minnesota Pollution Control Agency

ND State Water Commission

Manitoba Water Stewardship

Red River of the North Basin



- Drainage area is nearly 49,000 square miles.
- Includes portions of North Dakota, South Dakota, Minnesota, and Manitoba, Canada.
- The Red River flows north into Lake Winnipeg.

Water Management Issues

- Intensive surface drainage from agricultural land and widespread stream channelization.
- Multiple impaired waterways due to high sediment and nutrient loading.
- Severe eutrophication of Lake Winnipeg.
- Frequent flooding and drought.
- Potential future water supply shortages.

Water Quality Modeling

- Funded by USDA and the Minnesota Pollution Control Agency (MPCA).
- Water quality models have been developed for several watersheds using SWAT.
- Goal is to assess water quality within each watershed and evaluate the impact of beneficial management practice (BMP) implementation on water quality as well as aid in total maximum daily load (TMDL) development.

SWAT Overview

- Soil and Water Assessment Tool.
- Watershed-scale hydrologic model developed by USDA's Agricultural Research Service (ARS).
- Compiled from several existing USDA-ARS water quality and hydrologic models.
- Available for free from Texas A&M at: www.brc.tamus.edu/swat/arcswat.html

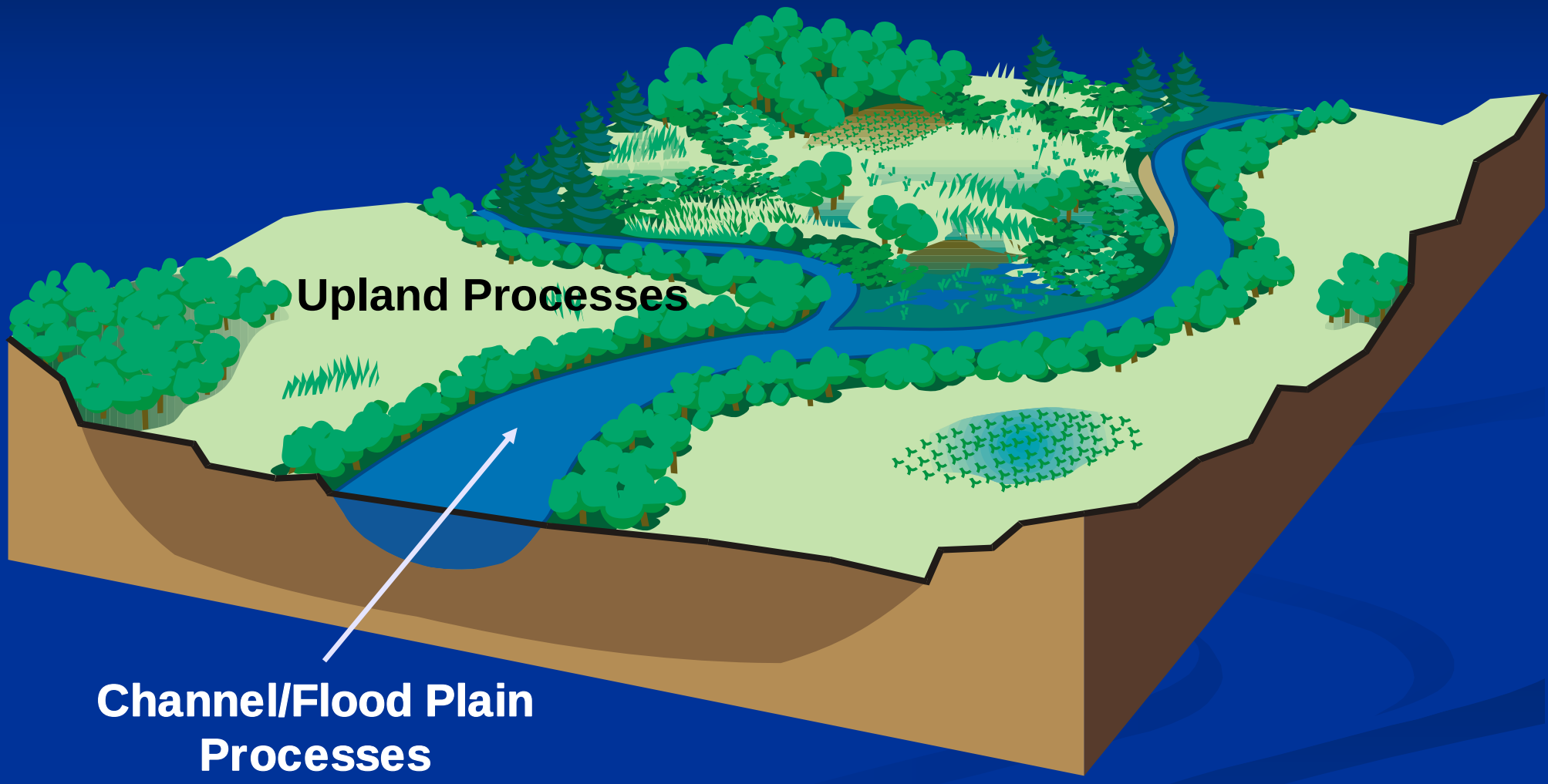
Source: Neitsch et al., 2002, ftp://ftp.brc.tamus.edu/pub/swat/doc/swat2000theory.pdf

SWAT Overview

- Uses physically based input such as soils, weather, land use, and topographic data.
- Predicts the impact of land management practices on water, sediment, and agricultural chemical yields.
- Conducts long-term simulations (up to 100 years) on a daily, monthly, or yearly time-step.

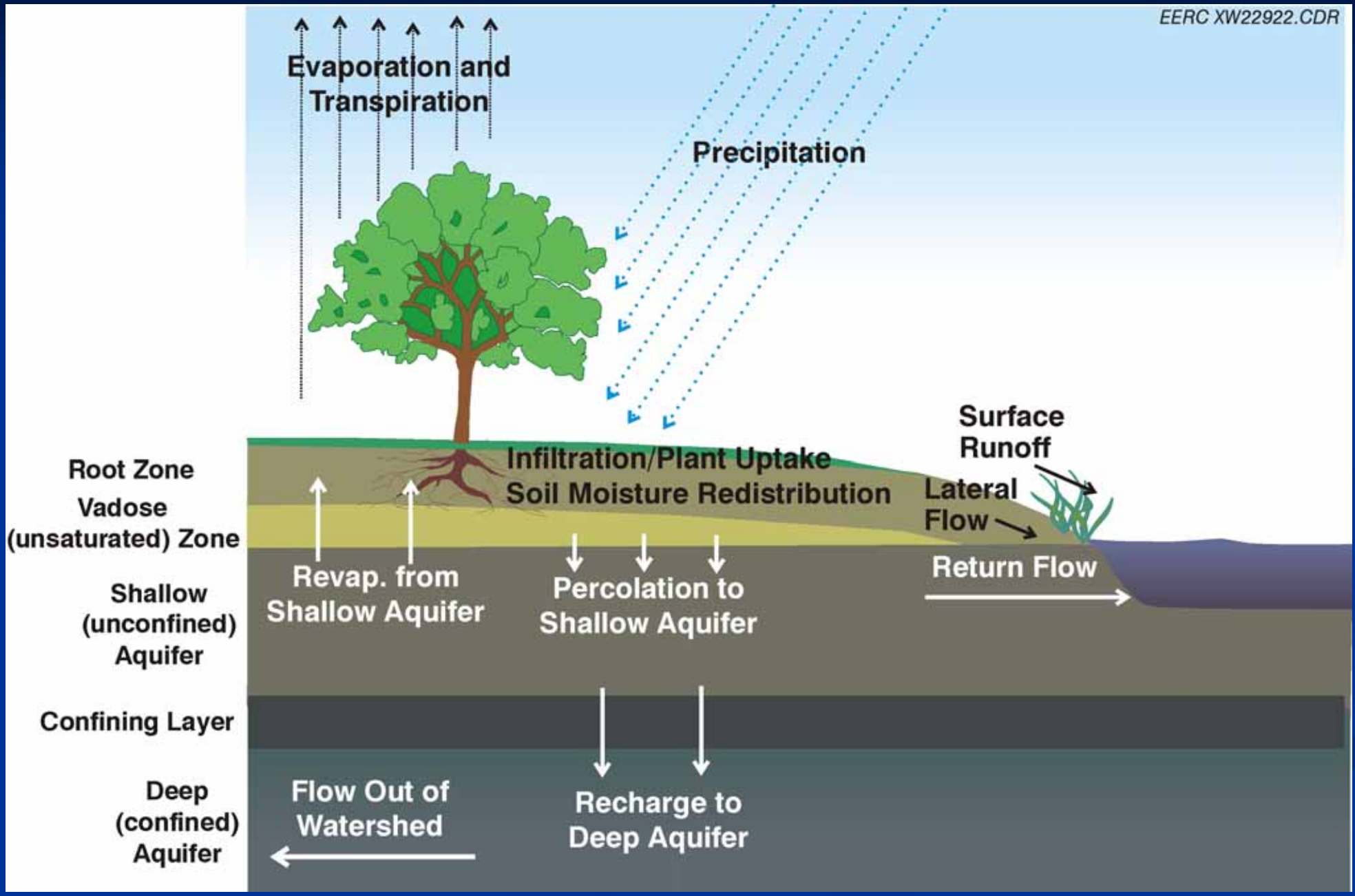
Source: Neitsch et al., 2002, ftp://ftp.brc.tamus.edu/pub/swat/doc/swat2000theory.pdf

SWAT Watershed System



Slide credit: Jeff Arnold, USDA-ARS

Land Phase



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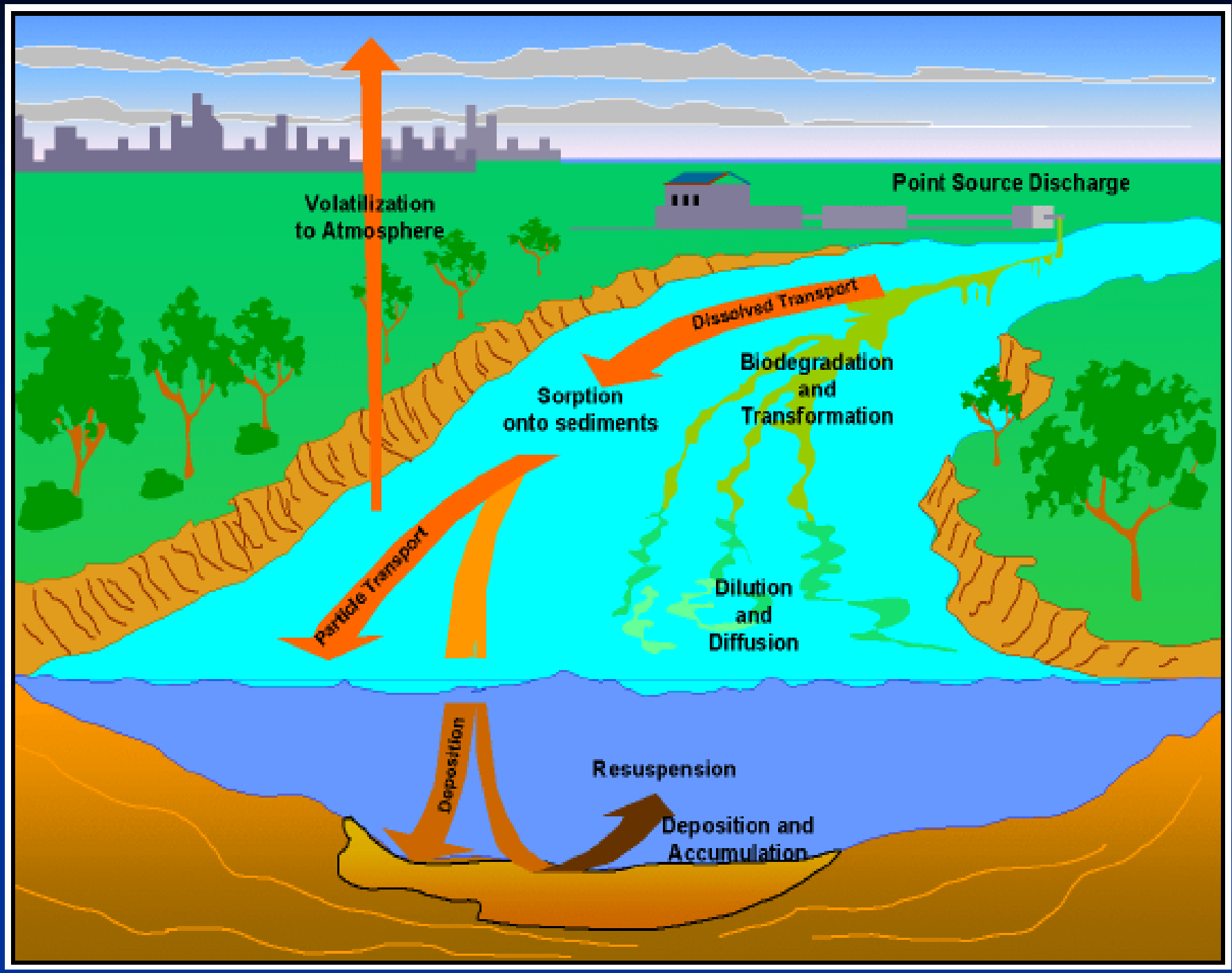

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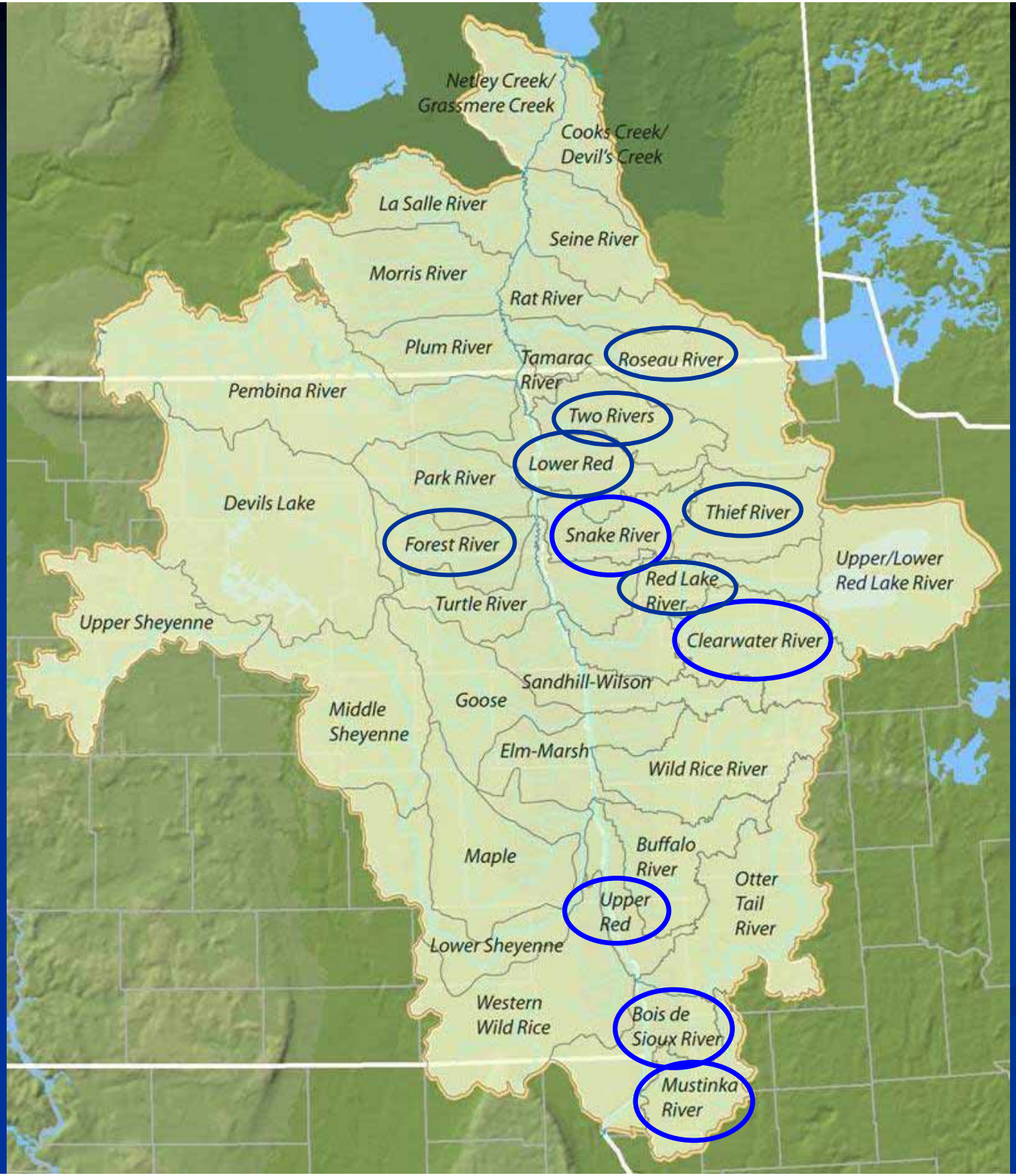
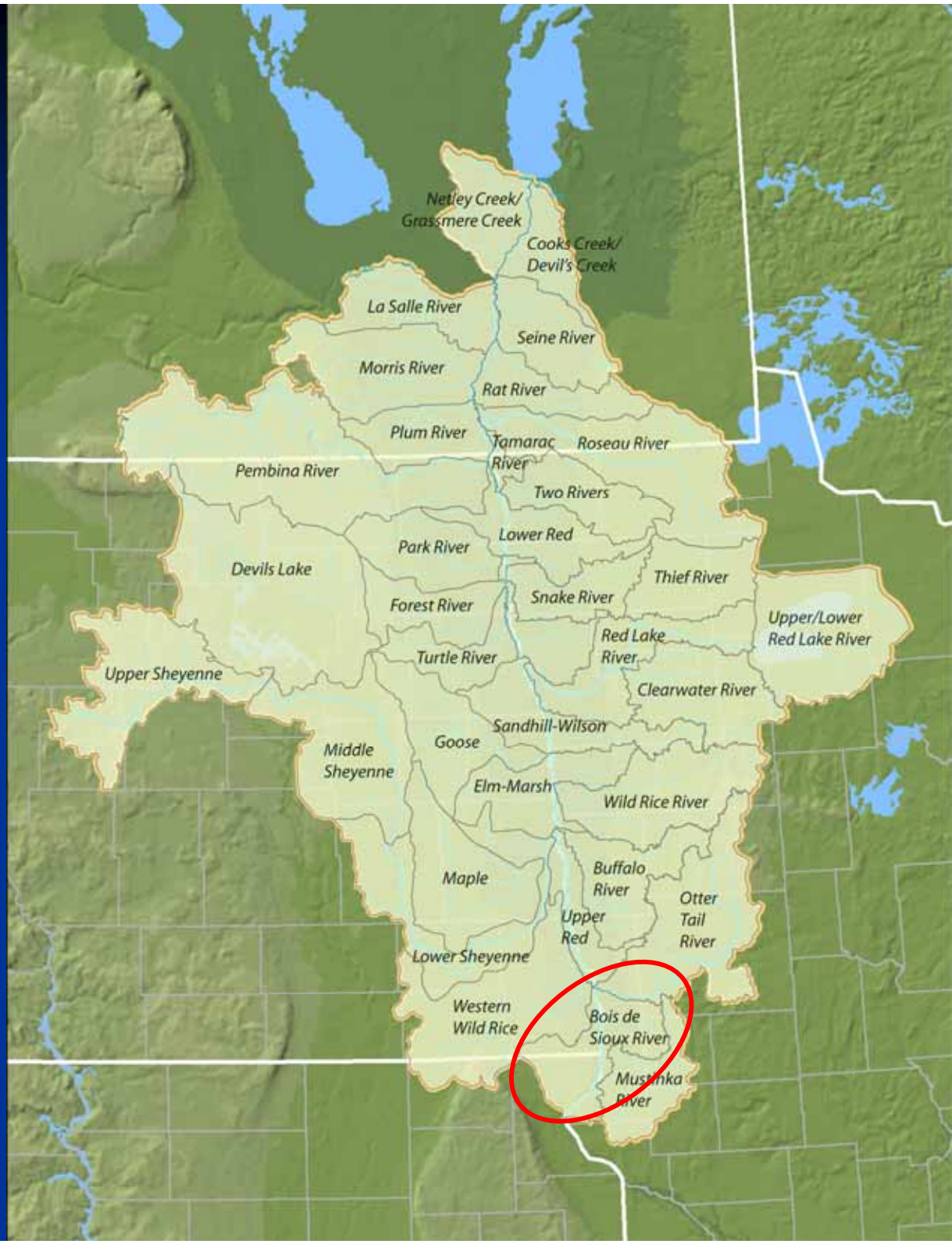

Netley Creek/
Grassmere Creek
Cooks Creek/
Devil's Creek
La Salle River
Seine River
Morris River
Rat River
Plum River
Tamarac
River
Roseau River
Pembina River
Two Rivers
Lower Red
Park River
Devils Lake
Thief River
Snake River
Forest River
Upper/Lower
Red Lake River
Red Lake
River
Turtle River
Upper Sheyenne
Clearwater River
Sandhill-Wilson
Goose
Middle
Sheyenne
Elm-Marsh
Wild Rice River
Buffalo
River
Maple
Otter
Tail
River
Upper
Red
Lower Sheyenne
Western
Wild Rice
Bois de
Sioux River
Mustinka
River

Example Application: Bois de Sioux River Watershed

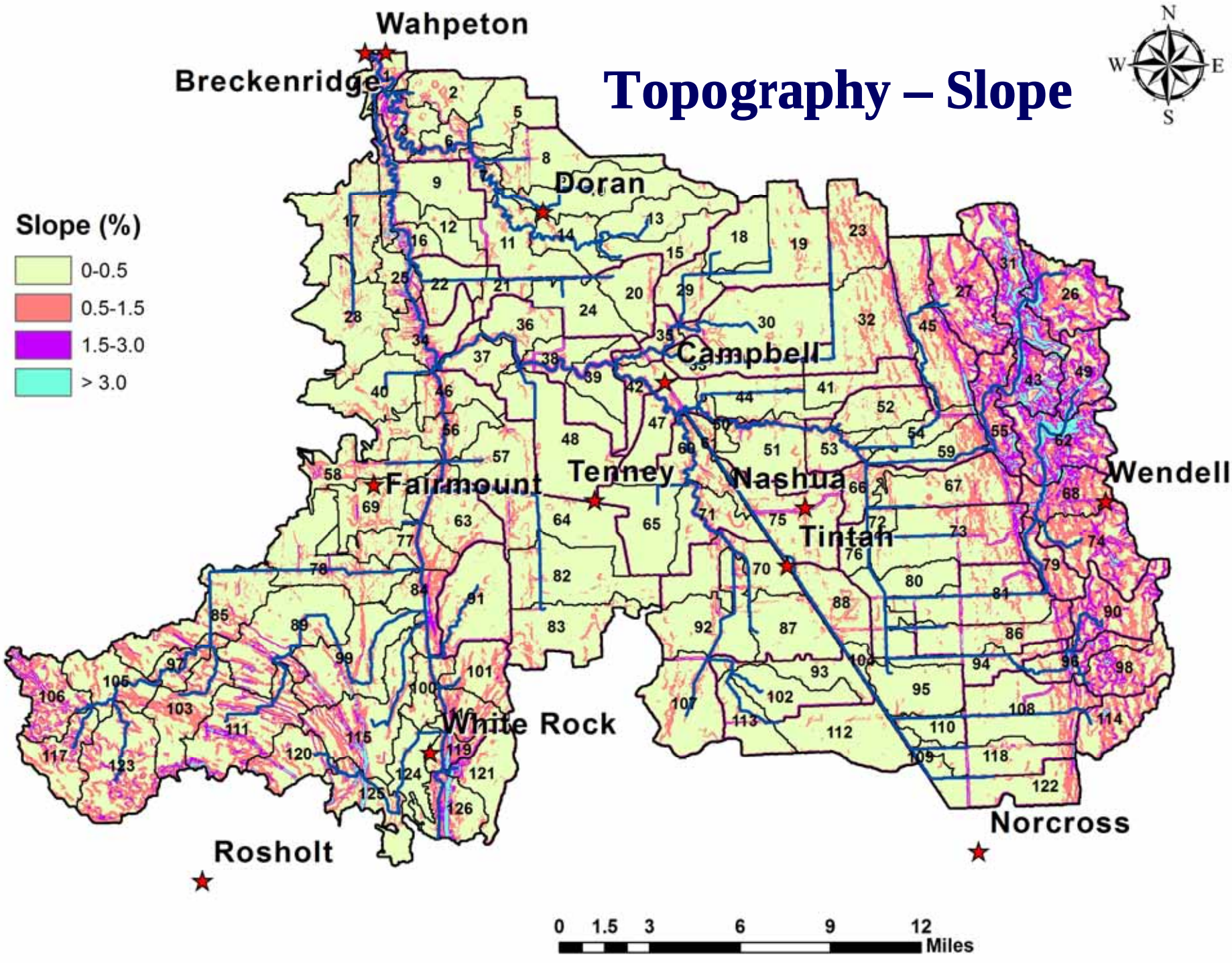
- Drainage area: 590 square miles.
- Land use is primarily agriculture (corn, soybeans, and wheat).
- Very low relief.



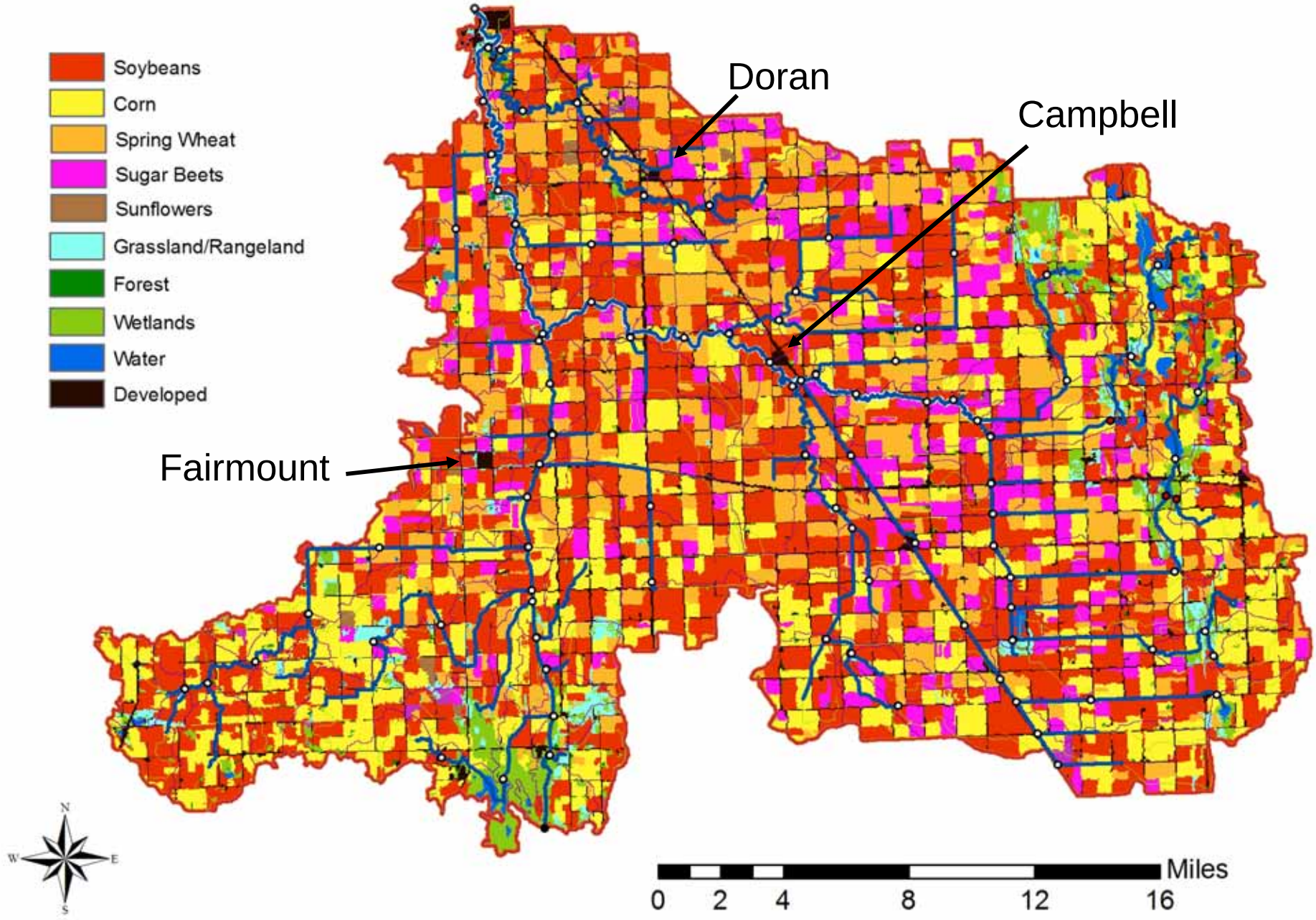
SWAT Model Development

Model development is a process:

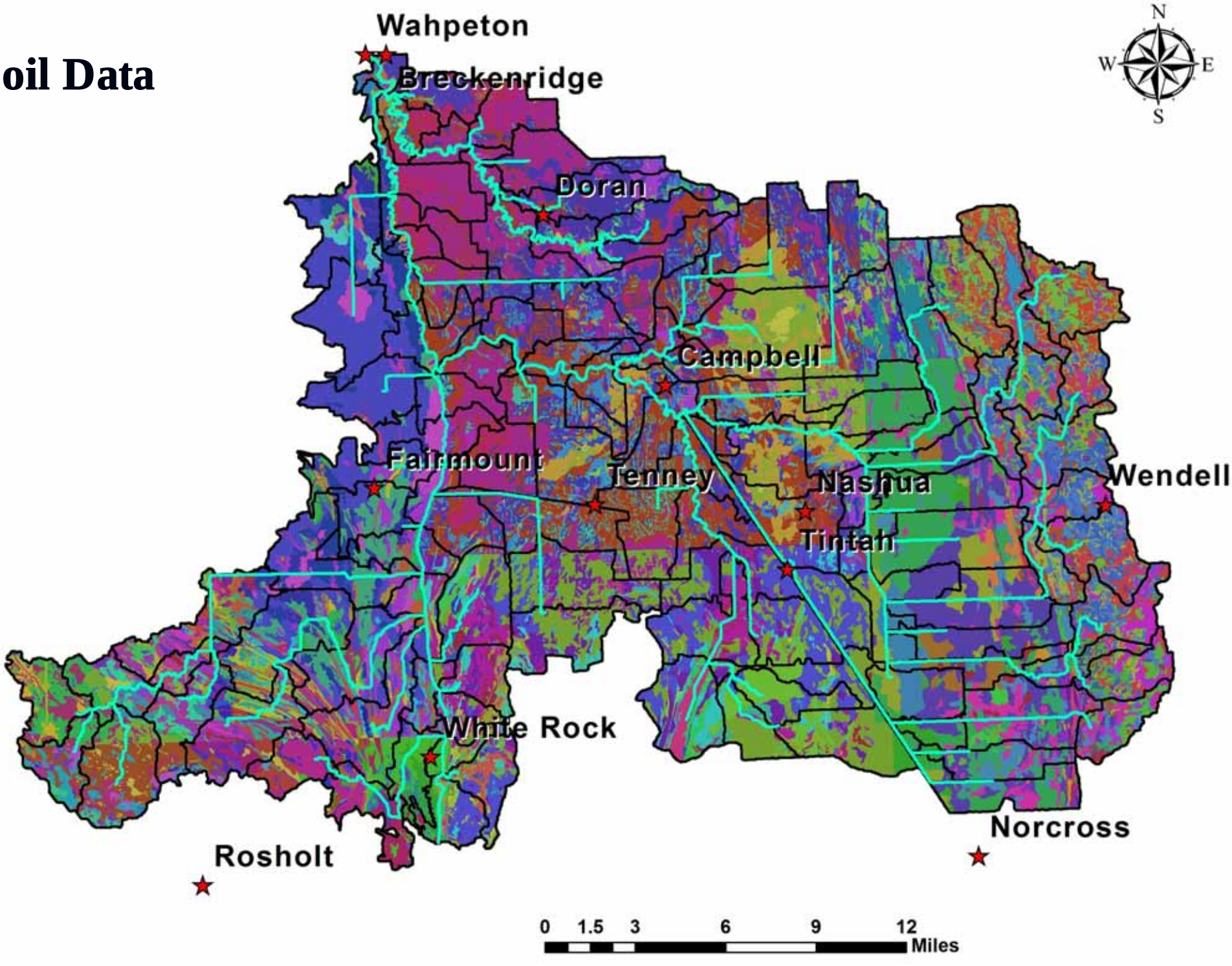
- 1) Determine what needs to be studied
  - Sediment
  - Organic and inorganic nitrogen and phosphorus.
  - Dissolved oxygen.
  - Bacteria (fecal coliform).
  - Algae.
  - Biological oxygen demand.
  - Pesticides.
- 2) Acquire necessary data sets
  - Topography
    - Slope
    - Watershed and subbasin boundaries
  - Hydrography
    - Stream locations
  - Land use/land cover
  - Soils
  - Climate data
- 3) Delineate the watershed
- 4) Calibrate and validate the model
- 5) Simulate BMP scenarios (or climate change, urbanization, etc.)

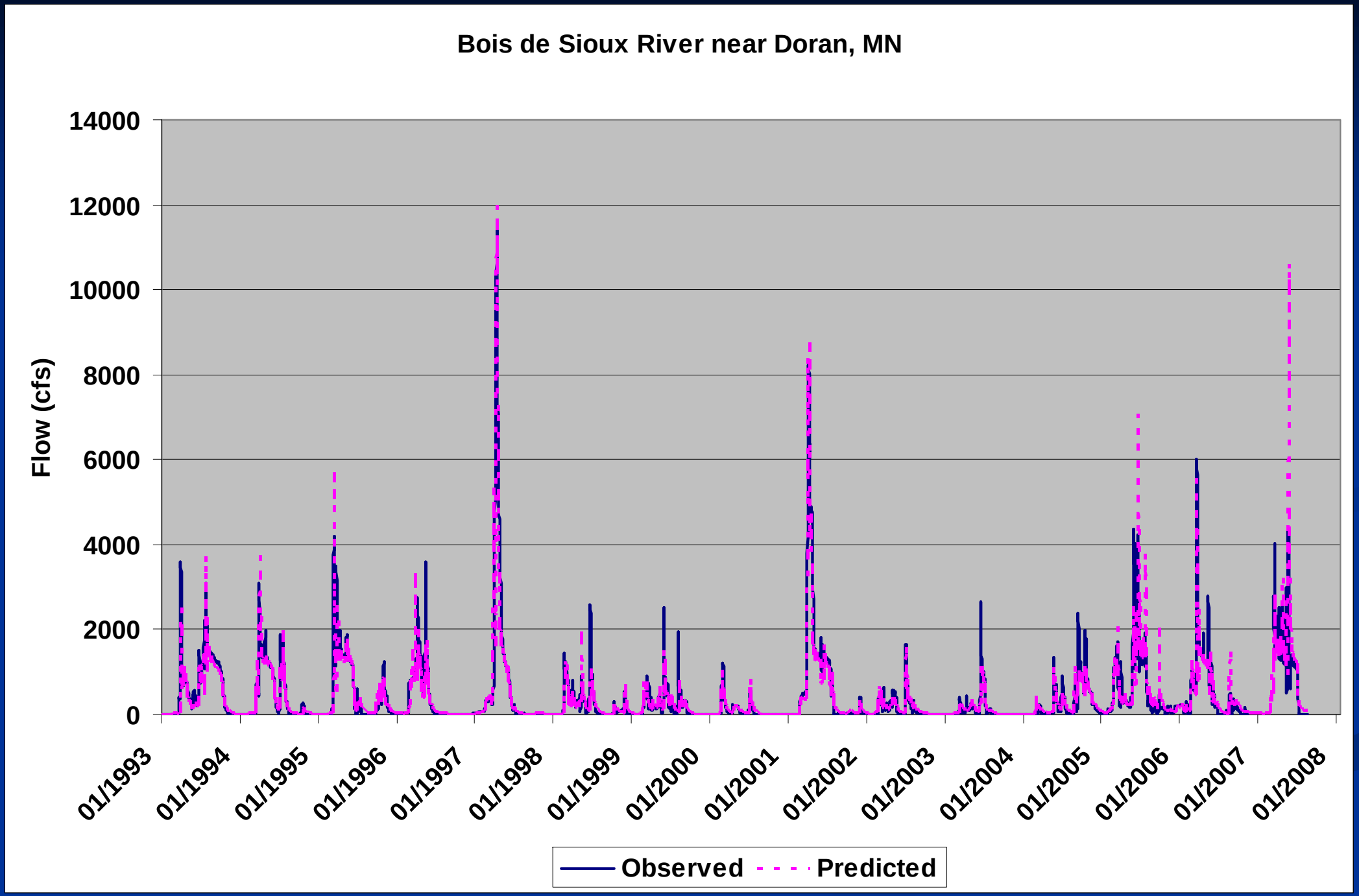

Topography – Slope
N
W
E
S
Slope (%)
0-0.5
0.5-1.5
1.5-3.0
> 3.0
Wahpeton
Breckenridge
Doran
Campbell
Fairmount
Tenney
Nashua
Tintan
Wendell
White Rock
Rosholt
Norcross
0 1.5 3 6 9 12
Miles

Land Use in the Bois de Sioux Watershed



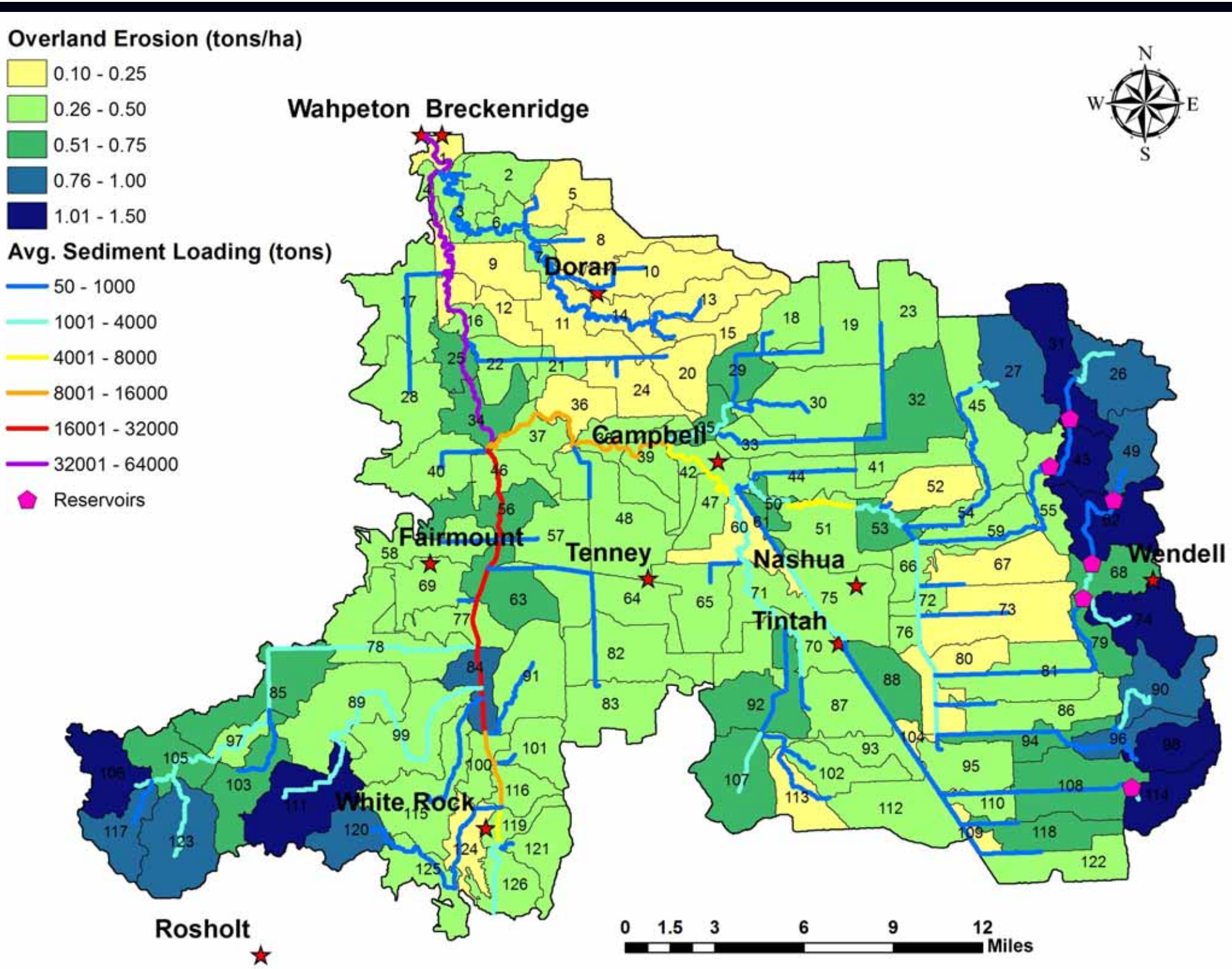
Soil Data

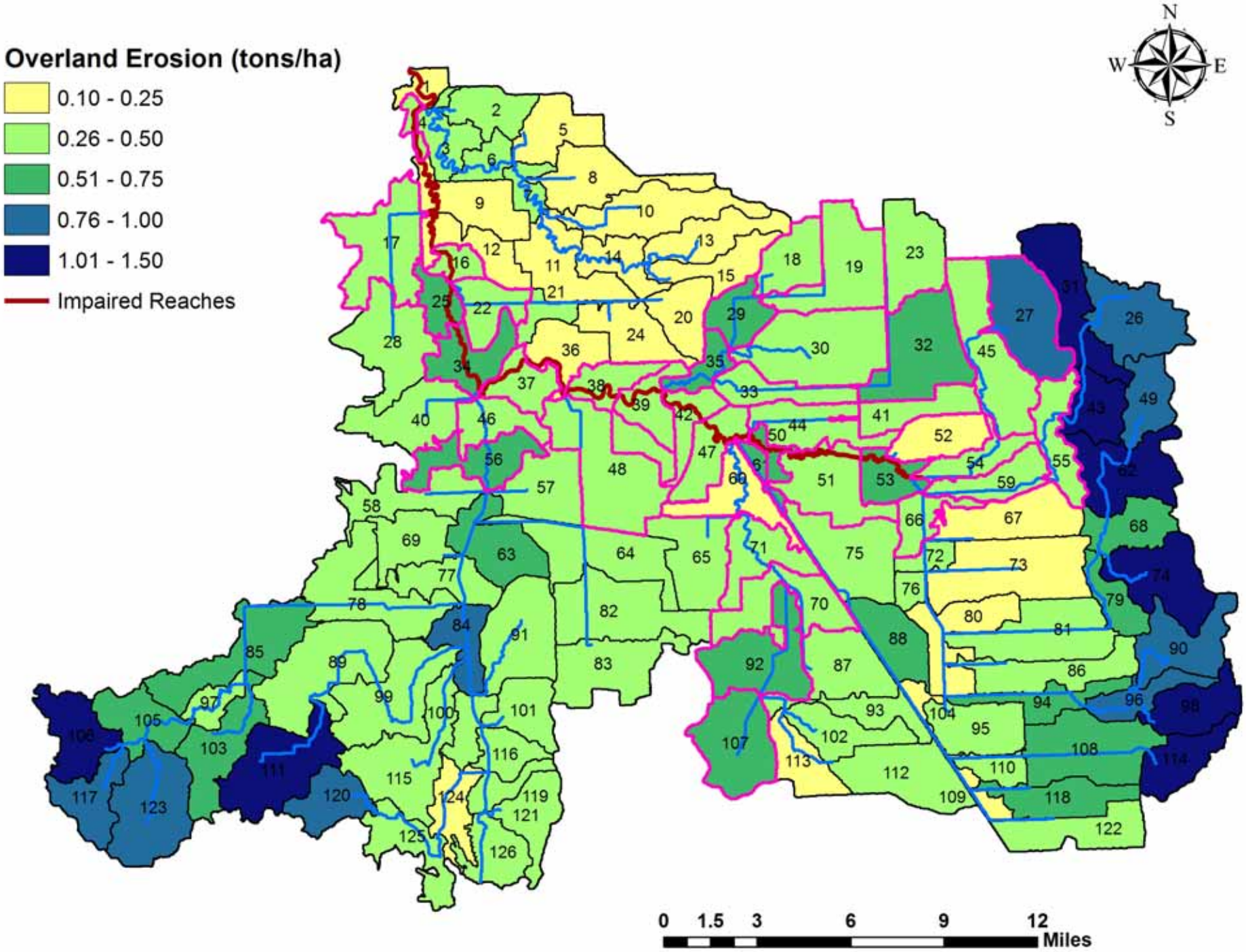

Wahpeton
Breckenridge
Doran
Campbell
Fairmount
Tenney
Nashua
Wendell
Tintah
White Rock
Norcross
Rosholt
N
W
E
S
0 1.5 3 6 9 12
Miles


Bois de Sioux River near Doran, MN
Flow (cfs)
14000
12000
10000
8000
6000
4000
2000
0
01/1993
01/1994
01/1995
01/1996
01/1997
01/1998
01/1999
01/2000
01/2001
01/2002
01/2003
01/2004
01/2005
01/2006
01/2007
01/2008
Observed
Predicted

Bois de Sioux Calibration Results

Year	Nash-Sutcliffe Coefficient (>0.36 is acceptable)	Deviation in Volume, %
1993	0.83	14.0
1994	0.79	1.6
1995	0.64	9.4
1996	0.71	12.8
1997	0.84	9.1
1998	0.61	7.7
1999	0.50	5.5
2000	0.83	-14.5
2001	0.93	11.0
2002	0.80	-11.2
2003	0.69	6.2
2004	0.69	7.7
2005	0.58	-10.1
2006	0.71	8.9


Overland Erosion (tons/ha)
0.10 - 0.25
0.26 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
Avg. Sediment Loading (tons)
50 - 1000
1001 - 4000
4001 - 8000
8001 - 16000
16001 - 32000
32001 - 64000
Reservoirs
N
W
E
S
Wahpeton
Breckenridge
Doran
Campbell
Fairmount
Tenney
Nashua
Tintah
Wendell
White Rock
Rosholt
0 1.5 3 6 9 12
Miles


Overland Erosion (tons/ha)
0.10 - 0.25
0.26 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
Impaired Reaches
N
W
E
S
0 1.5 3 6 9 12
Miles

Example Application: Evaluation of Field Buffer Implementation on Sediment Loading / Erosion

Bois de Sioux River Watershed		
Reach and/or Subbasin	% Reduction in Sediment Loading (river reaches)	% Reduction in Overland Erosion (subbasins)
48	83.16	83.70
107	82.79	82.02
27	82.48	82.70
41	78.97	78.87
30	73.54	73.25
18	66.48	66.54
19	62.59	62.74
44	49.02	71.54
45	46.24	74.38
29	42.16	63.49
22	40.67	75.47
59	39.37	70.97
54	33.80	44.11
35	32.12	3.20
55	30.17	76.94

Water Quality Modeling

- The SWAT models provide us with a comprehensive tool to evaluate the impacts of land management practices throughout the Red River Basin.
- As better data sets become available (i.e., lidar, additional water quality-monitoring data), the models can be improved.

Questions?

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