Session B3

Wednesday, 24 June:

BMPs

"Best Management Practices"

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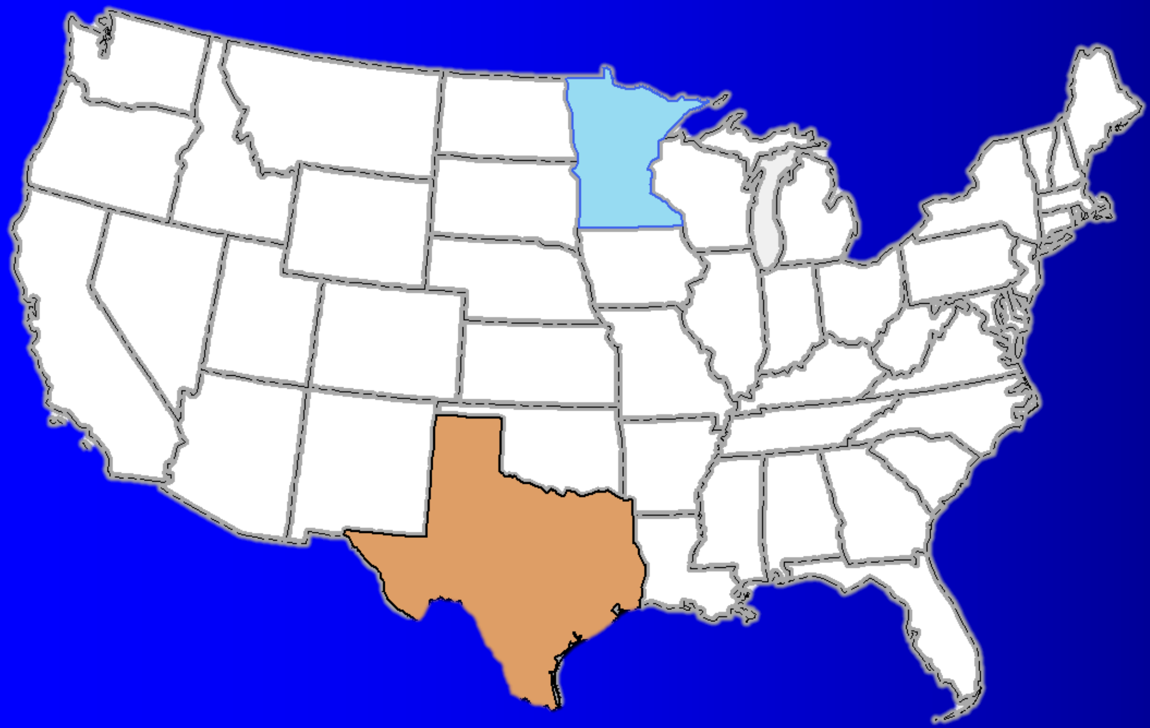
WMPs
"Worst Management Practices"

- Really not a good idea...
- Funding for WMP projects is almost impossible

Other MPs

- Minnesota (humble)
  - *Not Too Bad Management Practices*
  - *Could Be Worse Management Practices*
  - *OK Management Practices*
  - *Better Than I Thought Management Practices*



- Texas (bold)
  - *Best Management Practices*

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Session B3 speakers:

1) Jim Almendinger
Science Museum of Minnesota

2) Nicola Fohrer
Christian Albrechts University

3) Olga Vigiak
European Commission - Joint Research Center

4) Raghavan Srinivasan (Srini)
Texas A&M University

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Phosphorus Load Reductions due to Agricultural "Best" (Not Too Bad) Management Practices *and* Spatial Scaling of Phosphorus Export Coefficients

St. Croix Watershed Research Station

James E. Almendinger
St. Croix Watershed Research Station, Science Museum of Minnesota

Jason Ulrich
Dept. of Bioproducts and Biosystems Engineering, University of Minnesota

Funding and data provided by:

Minnesota Pollution Control Agency

National Park Service

Data provided by:

Chisago SWCD

US Army Corps of Engineers St. Paul District

Minnesota Department of Natural Resources

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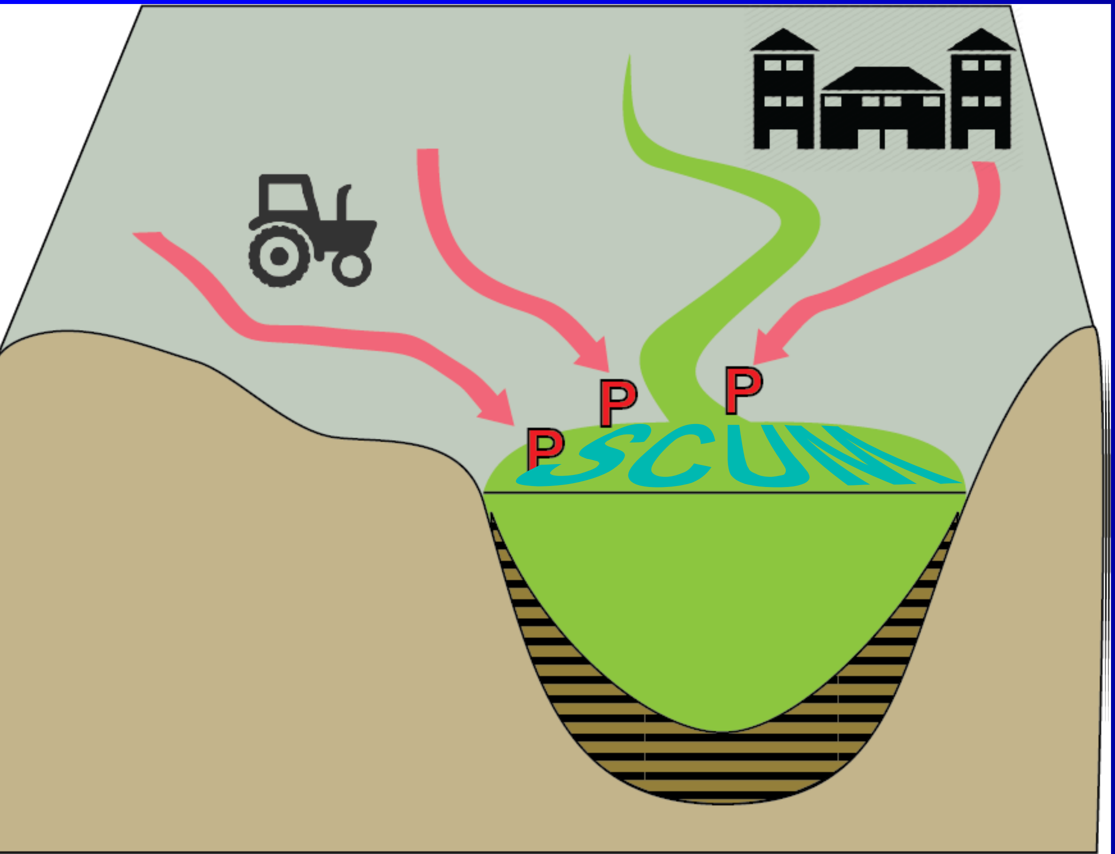
Issue of Concern:

- Excess P loads from the watershed cause eutrophication = excessive algal growth in lakes and rivers.



Purpose:

- To use SWAT to estimate the reduction in ***phosphorus loads*** in our study watershed by applying best management practices (BMPs)
  - Load = kg/yr
  - BMPs = Filter strips, grassed waterways, no-till, etc.
- To quantify how ***phosphorus yields*** for agricultural land change with spatial scale
  - Yield = kg/ha/yr
  - Net TP yield at different spatial scales = “Total Phosphorus Export Coefficient” (TPEC)
  - Scales: from local (~0.5 km^2) up to basin (1000s of km^2)

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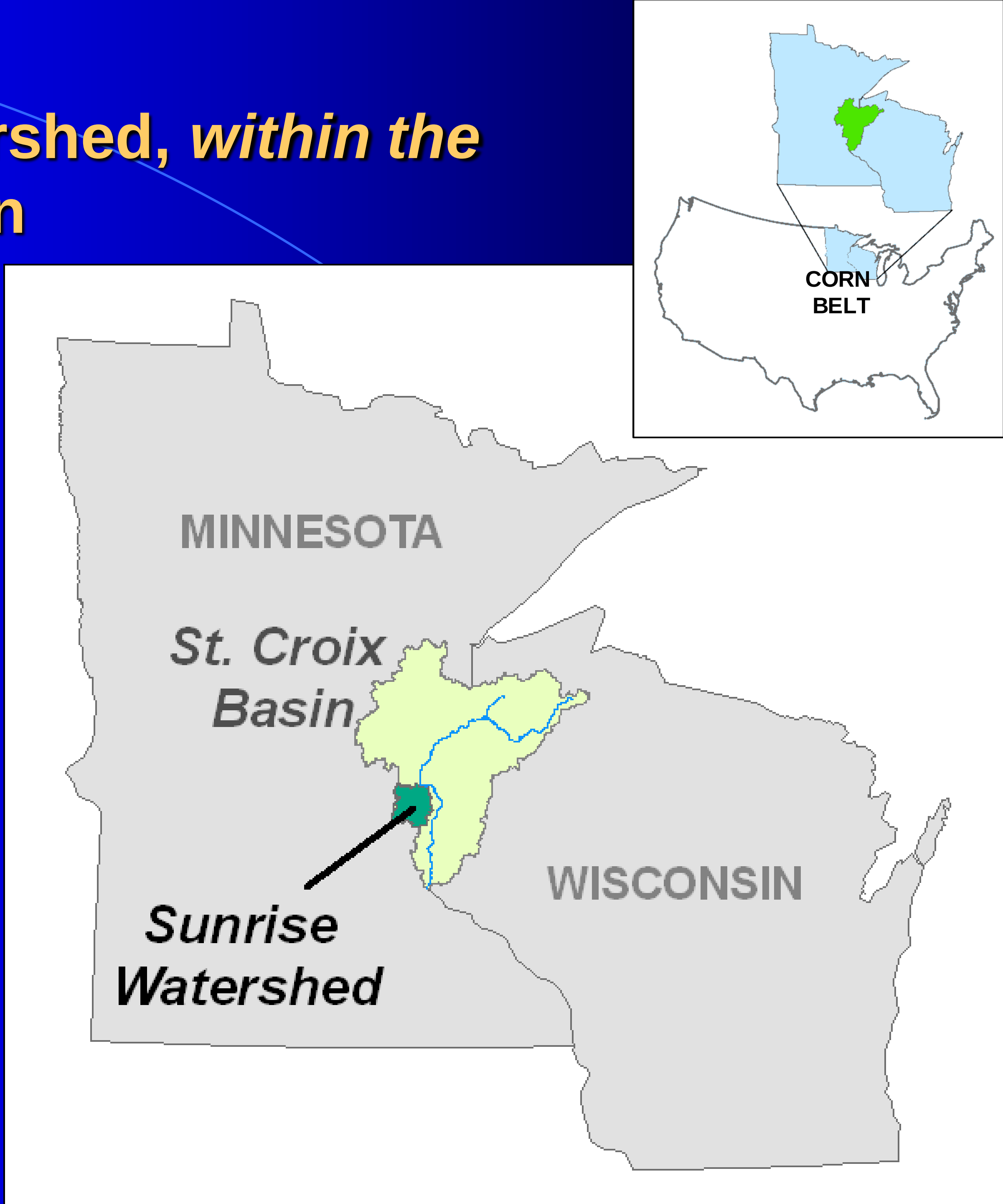
Study Area

Sunrise River Watershed, *within the* St. Croix River basin

- Many lakes and rivers impaired by excess phosphorus
- Goal is to reduce P loads by 20%
- SWAT2009 model complete for Sunrise
- SWAT2012 nearly completed for St. Croix



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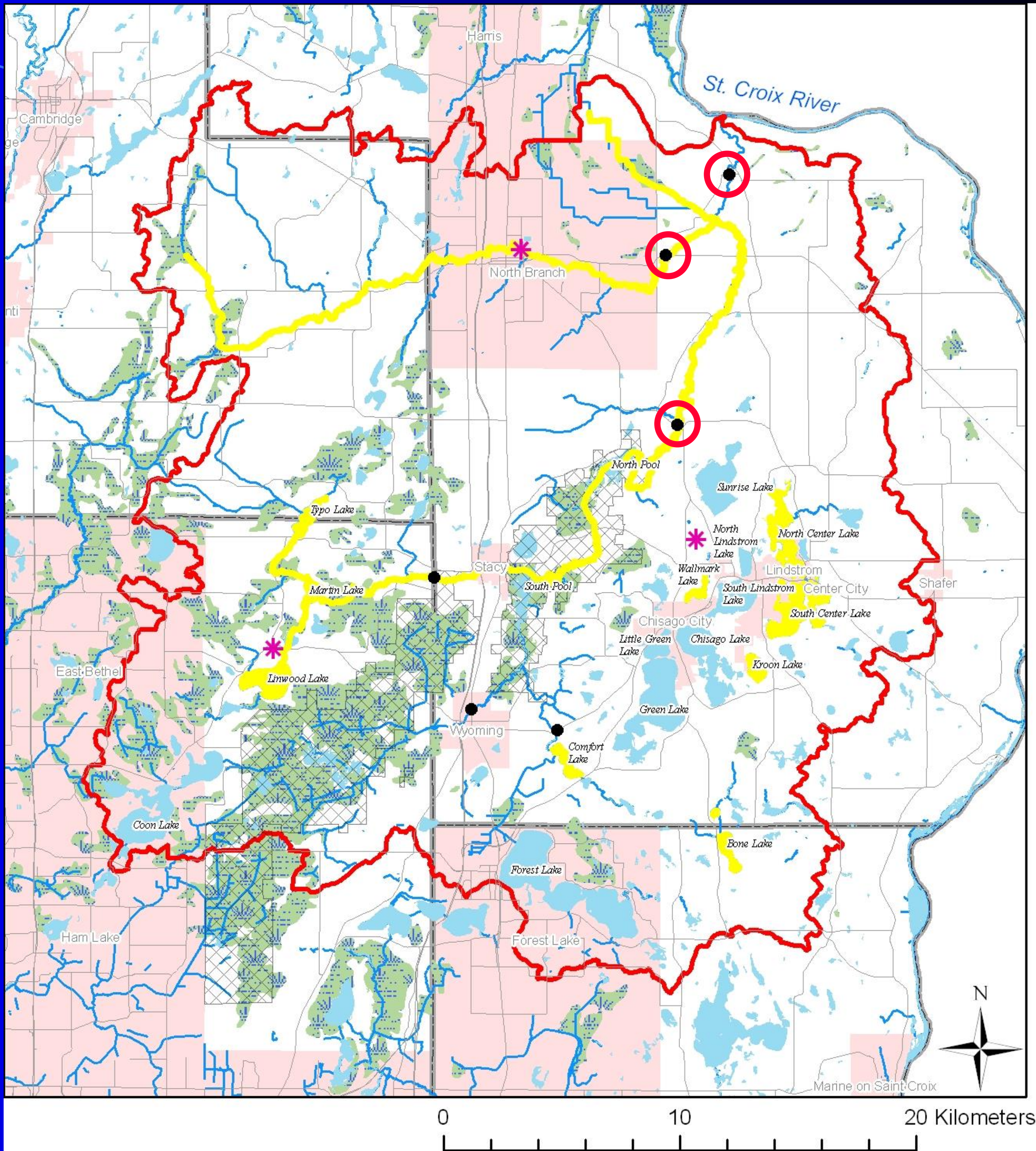
Sunrise River Watershed

- **Land use**
  - Agricultural in the north
  - Many lakes and large wetlands in the south
  - Urban areas around some lakes.
- **Impaired waters**
  - 4 River reaches
  - 10 Lakes
- **Monitoring stations : 3**



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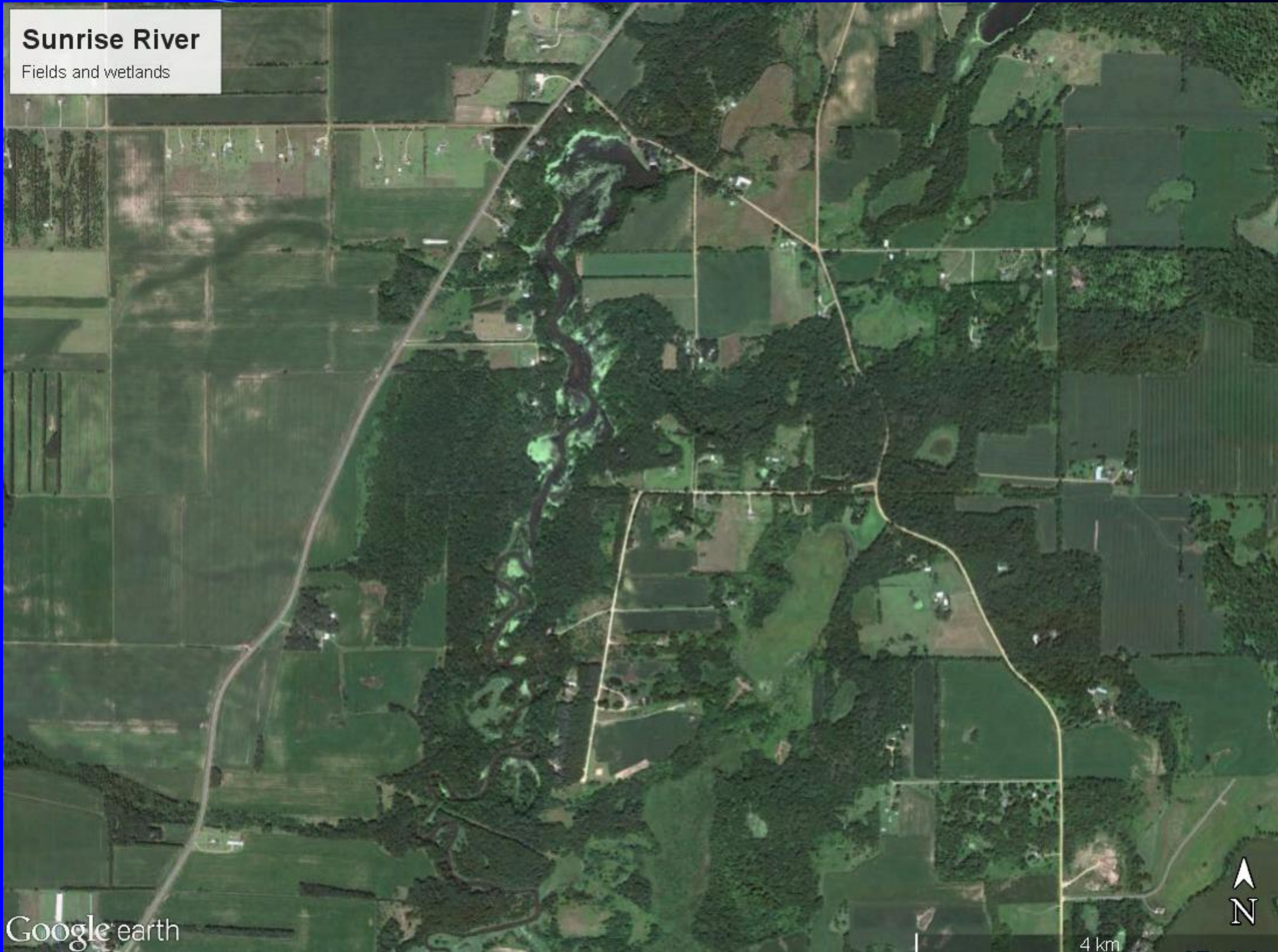
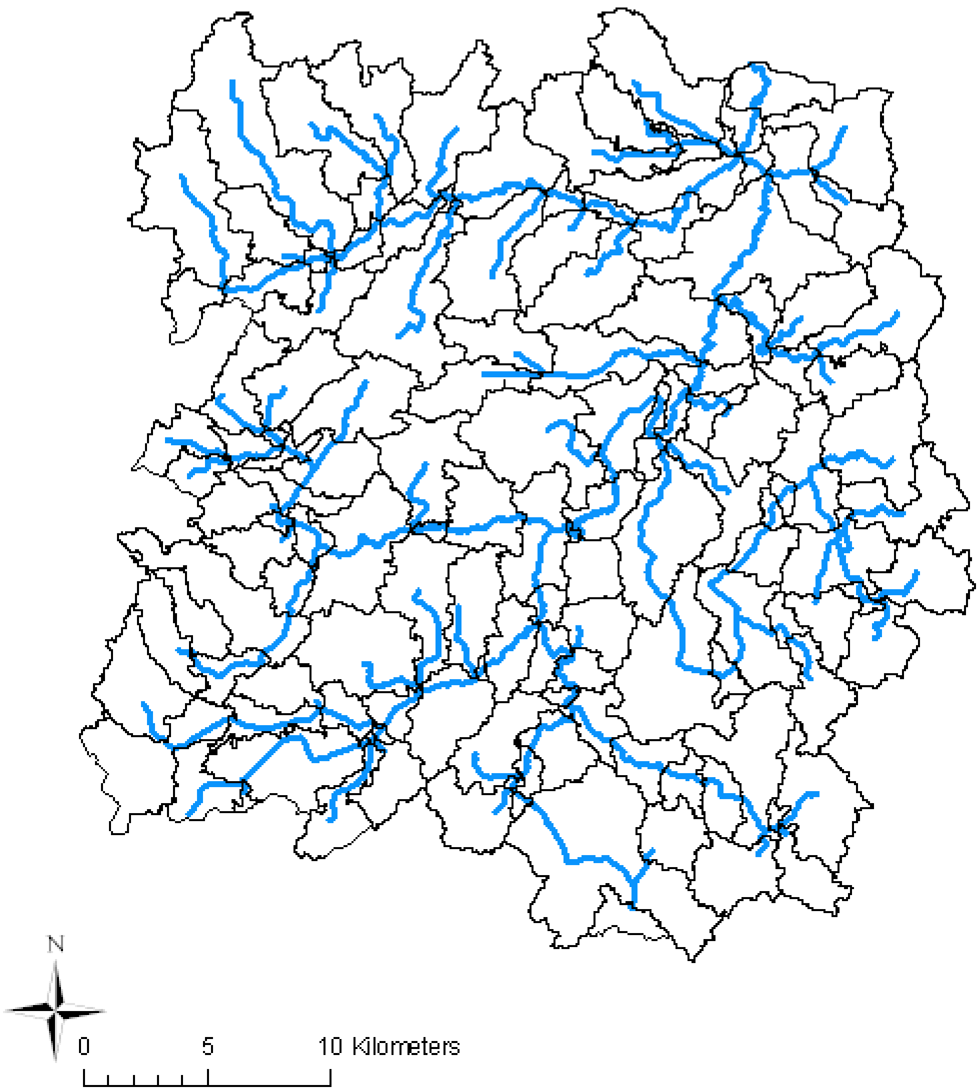

Sunrise River
Fields and wetlands
Google earth
4 km
N

Building the SWAT model: 142 subbasins

The fundamental spatial framework of SWAT:

-- Channel network ("reaches" in SWAT)
-- Subbasin polygons
-- Topographic and hydrographic statistics (slope, reach lengths, etc.)
-- Subbasin polygons key in clipping soils and land use



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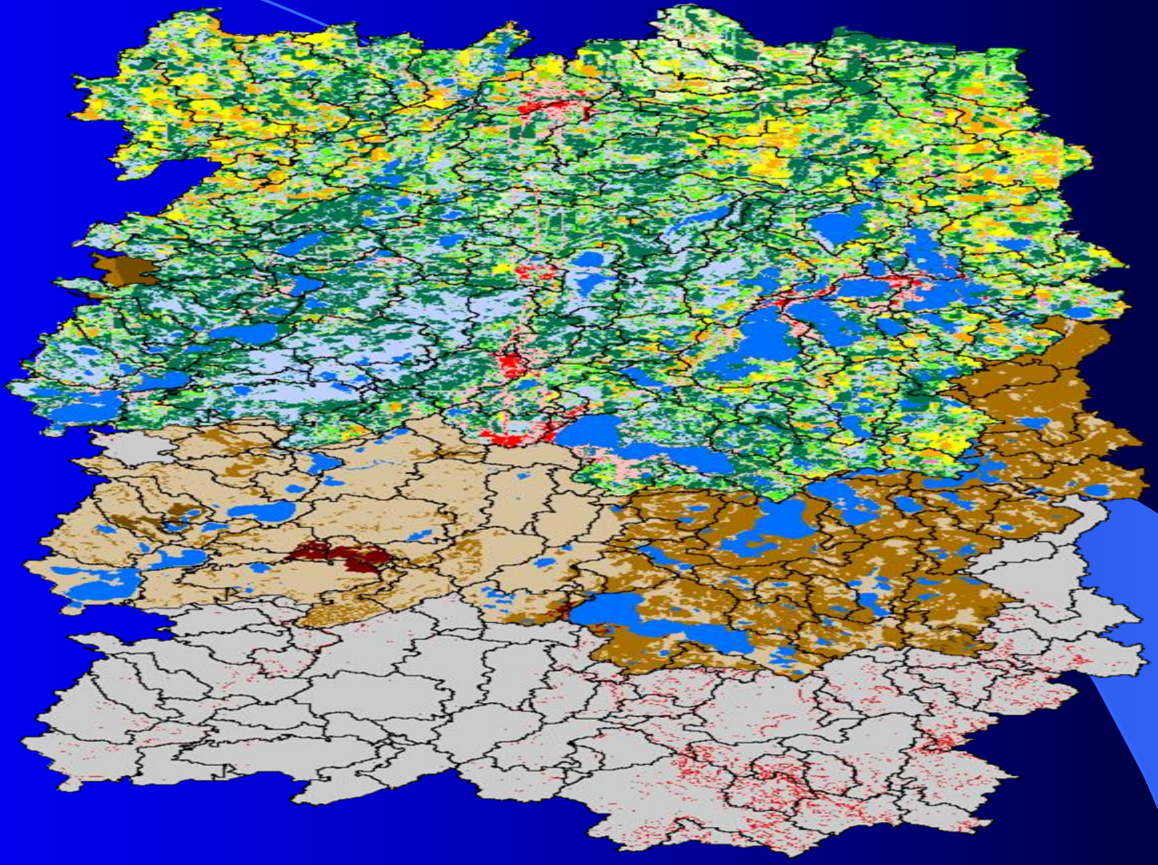
Building the SWAT model: 1,643 HRUs

Land Cover

Soil Type

Slope Class



Land-Cover X Soil-Type X Slope Class Combos in each subbasin = 1,643 HRUs

-- E.g.: Corn/Soil-A/Slope1, Corn/Soil-B/Slope2, Beans/Soil-A/Slope2, Beans/Soil-B/Slope1, etc.

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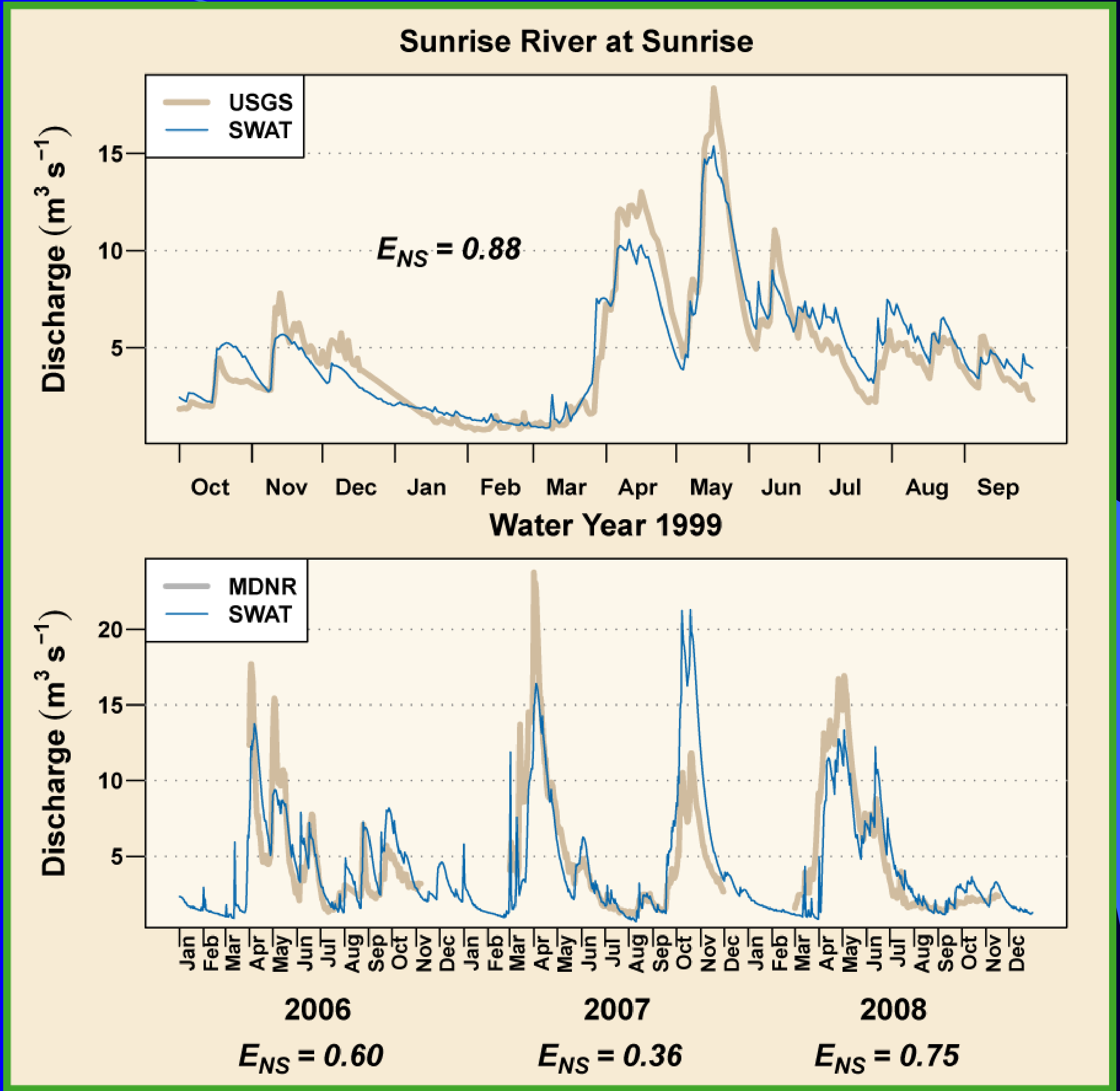
Model calibration: Flow



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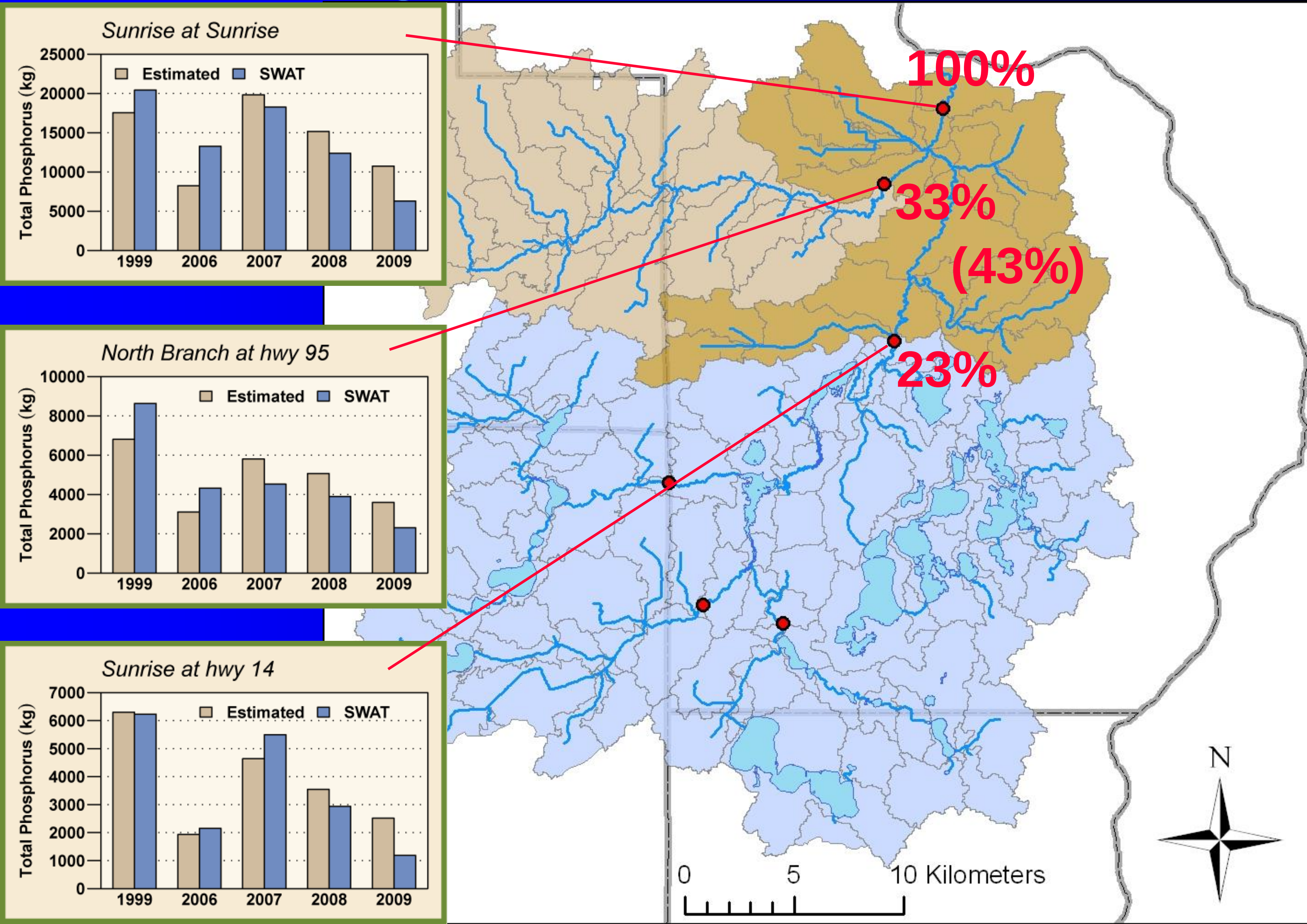
Model calibration: Phosphorus



Subbasin-wide phosphorus yields

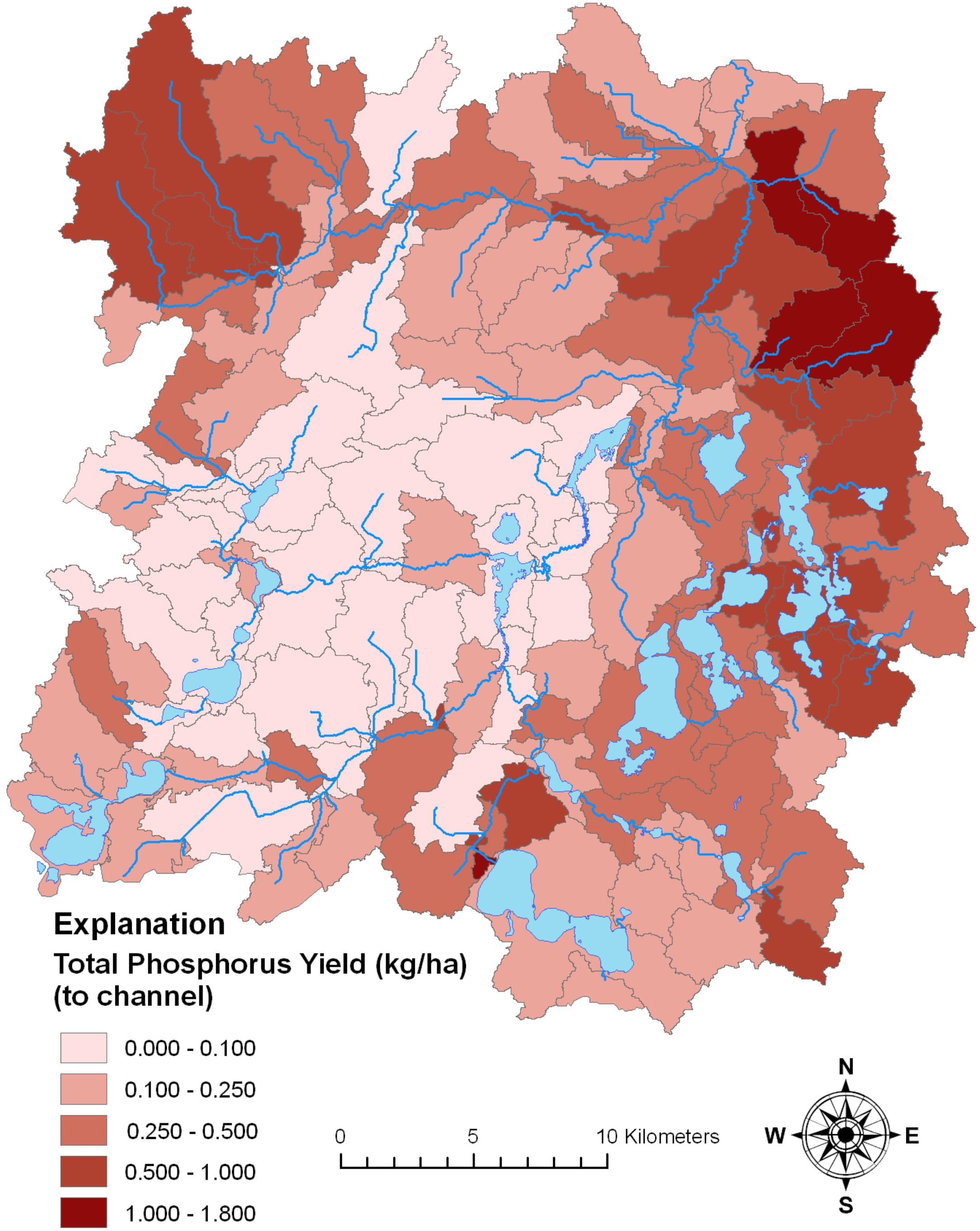
Phosphorus yields to channel are highest where:

-- Soils are less sandy

-- Slopes are steeper

-- Land use = agriculture or urban

-- Less runoff captured by ponds and wetlands



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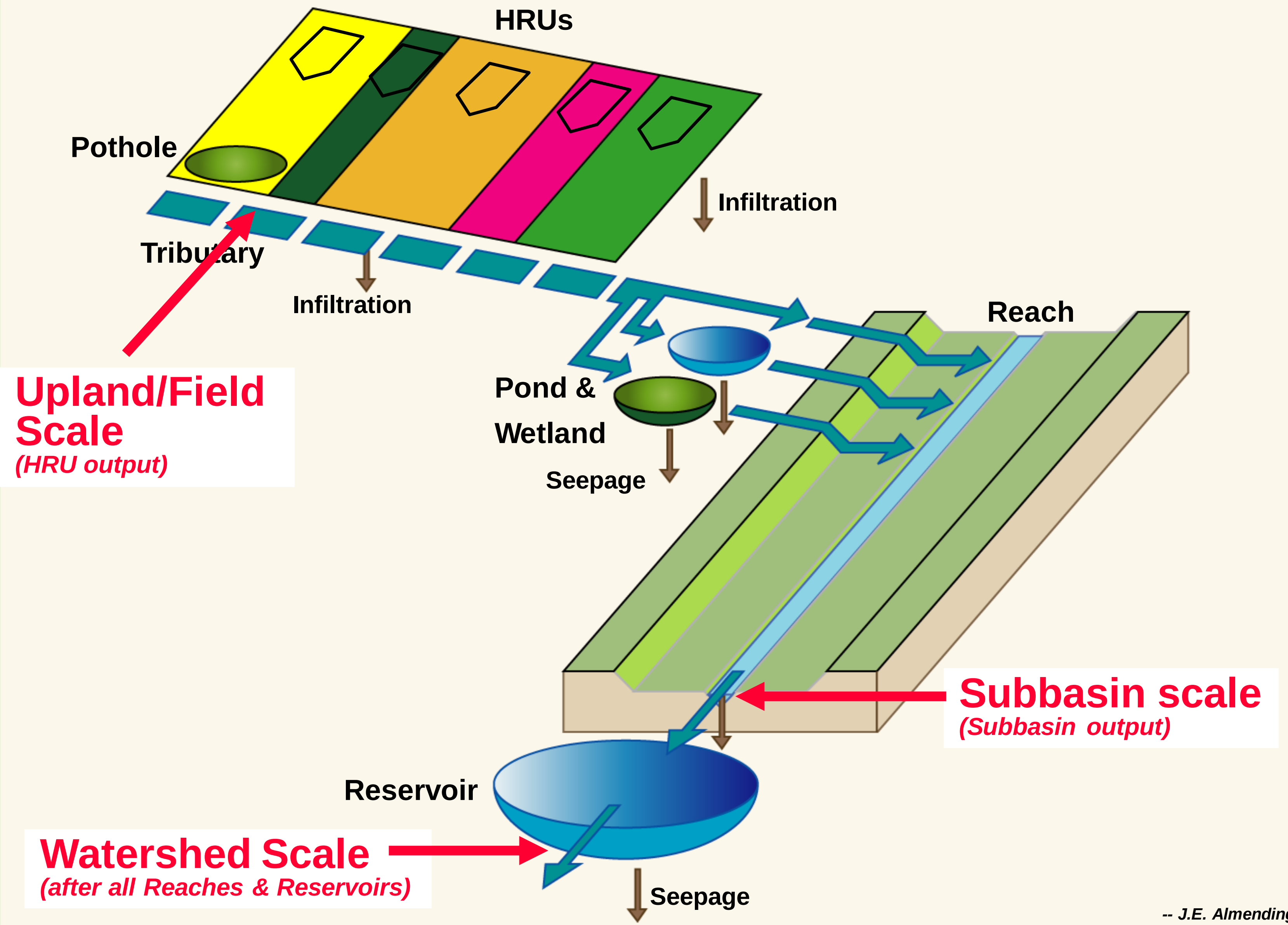
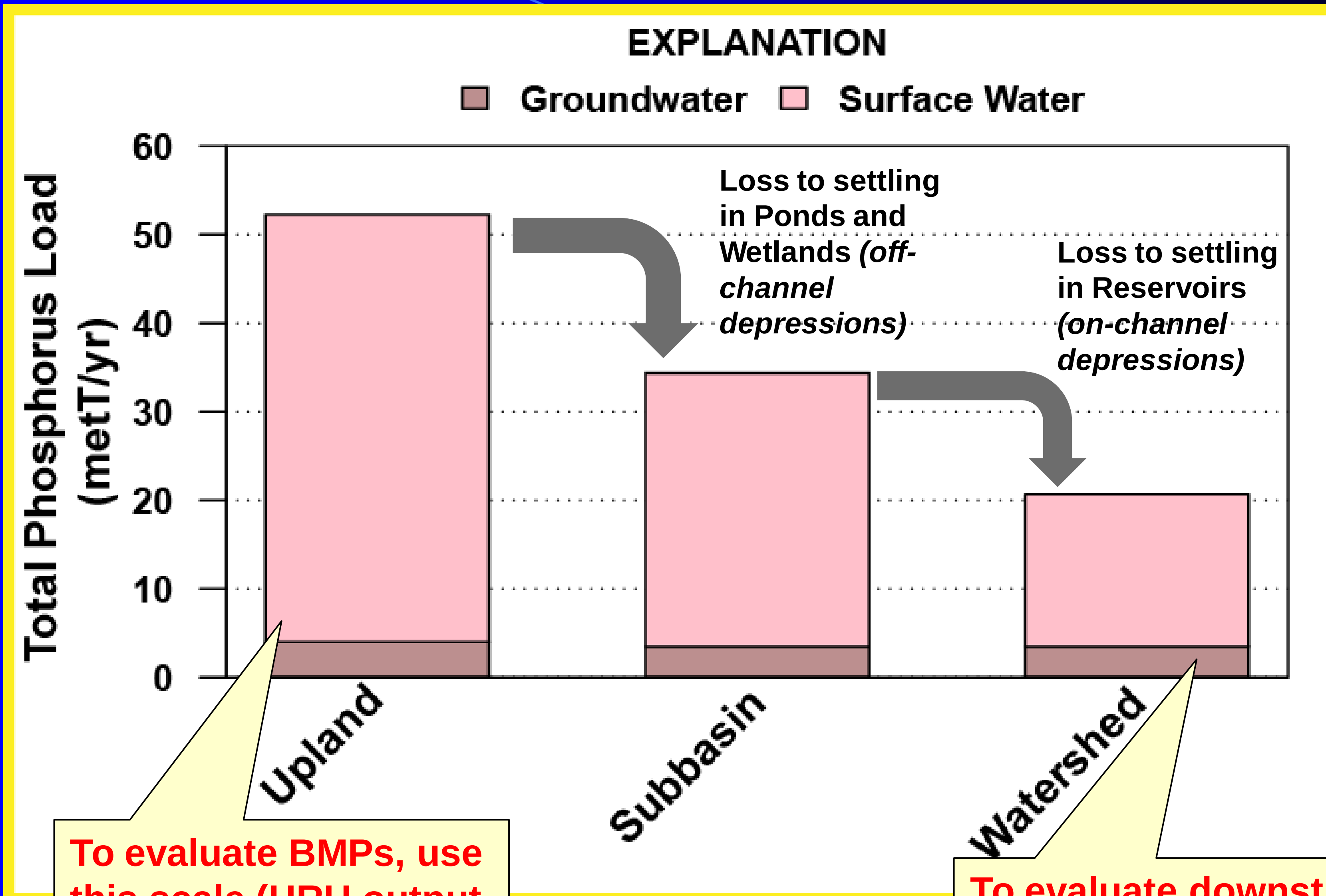
SWAT schematic view -- HRU / subbasin / reservoir:



-- J.E. Almendinger, St. Croix Watershed Research Station, 2011 --

Loads at different spatial scales



To evaluate BMPs, use this scale (HRU output, with Ponds removed)

To evaluate downstream impacts, use this scale (watershed output)

TP Load Reductions from Agricultural BMPs in the Sunrise

Agricultural Areas and TP Loads in the Sunrise

Land Use	Area (%)	TP load (%)
Agriculture	21%	55%
CS rotation	*11%*	*44%*
CA rotation	*2%*	*7%*
Hay, Pasture	*8%*	*4%*
Developed	16%	27%
Other	63%	17%

NOTES: TP, total phosphorus; CS, grain corn-soybean rotation; CA, silage corn-alfalfa rotation.

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Agricultural BMPs in SWAT

-- No-Till agriculture

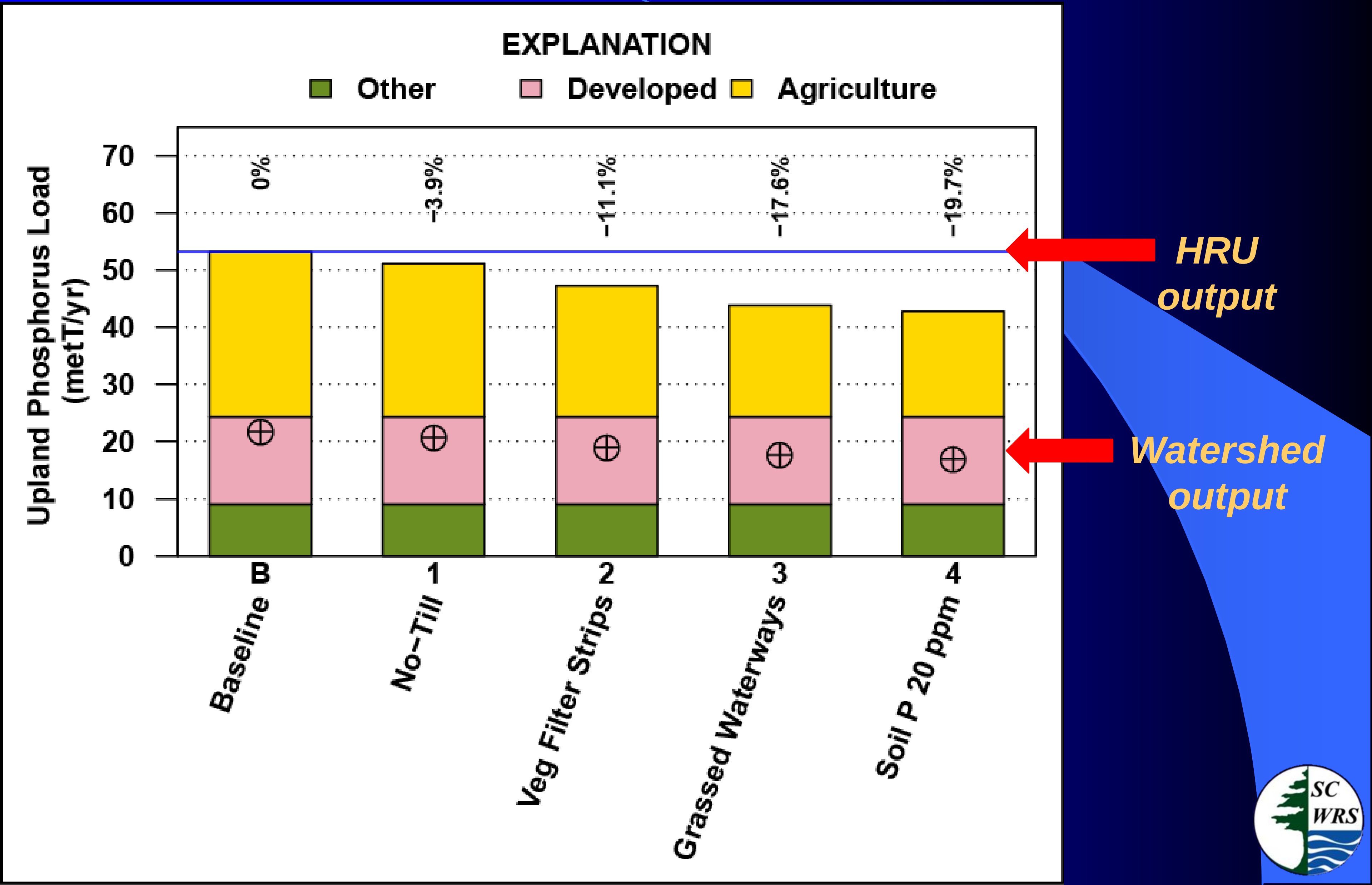
-- Filter strips

-- Grassed waterways

-- Reduction of soil phosphorus

Agricultural BMPs: What works?

-- a little of everything



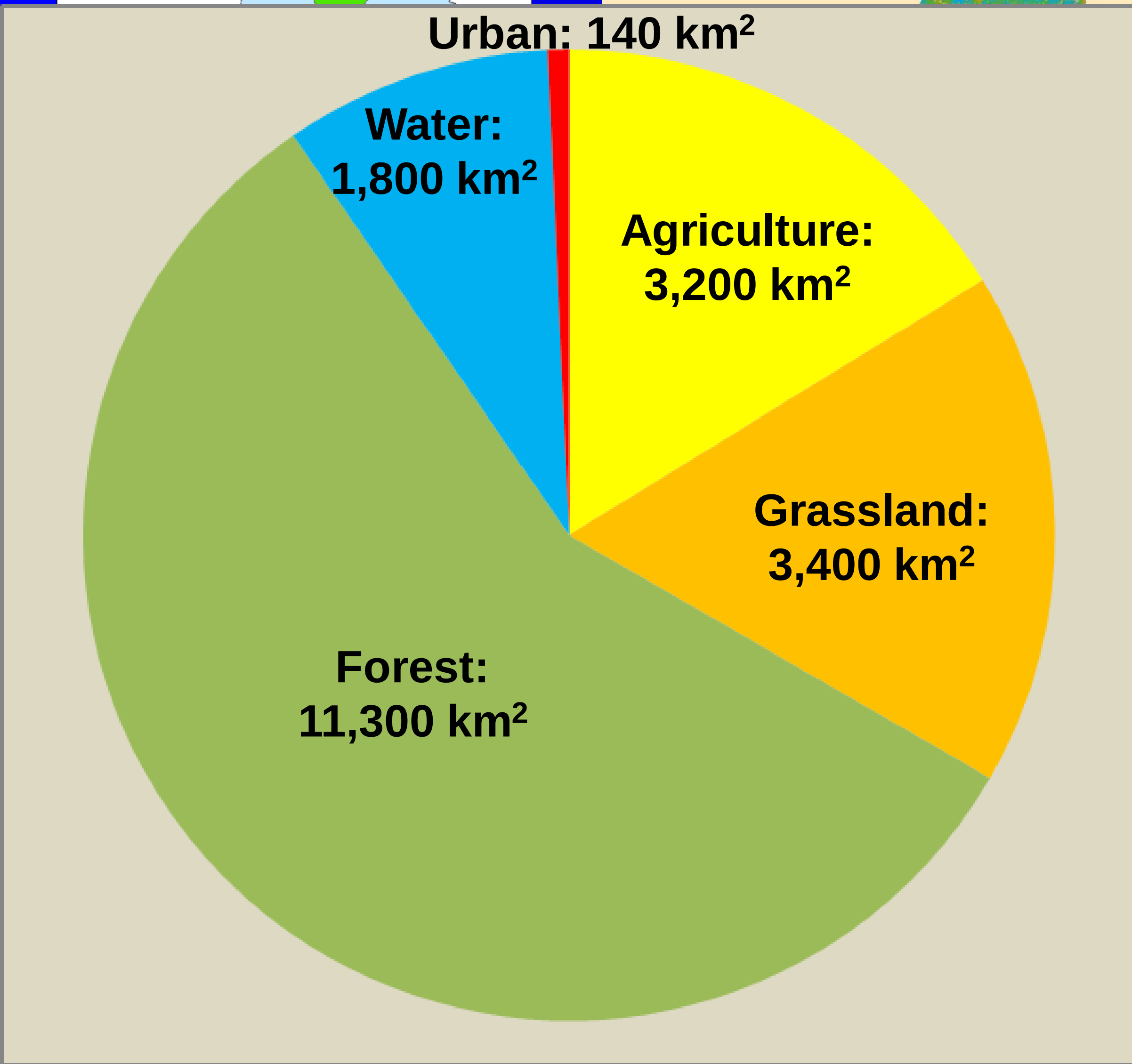
How phosphorus yield changes with scale

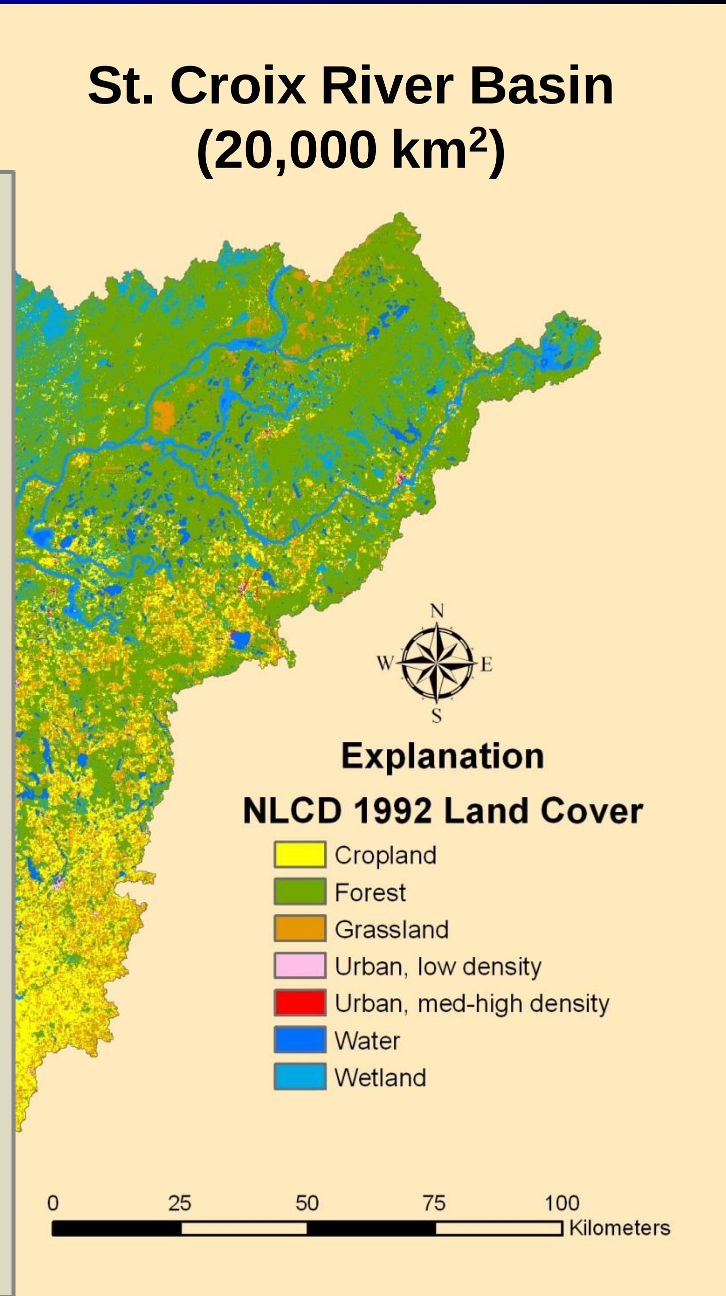
Why should I care?

Because phosphorus yields for selected land uses -- "Total Phosphorus Export Coefficients" (TPECs) – are used to estimate loads of phosphorus to streams and lakes.

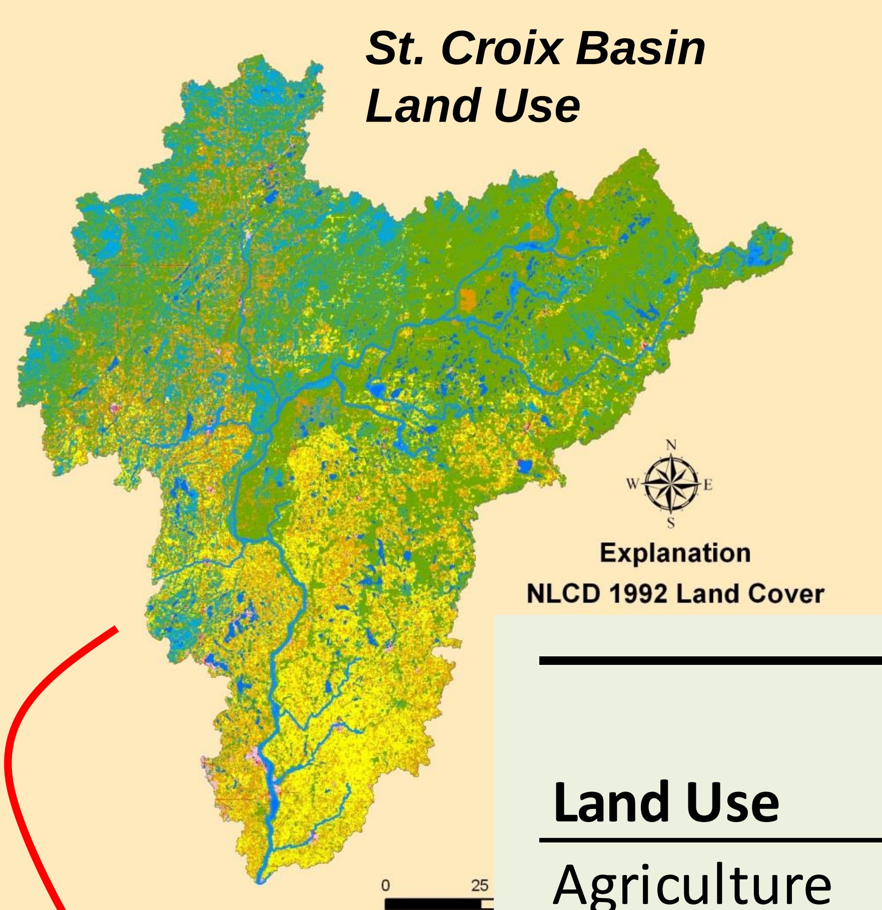
Scale effects need to be quantified!

Simple P Loads = TPEC * Land-Use Area

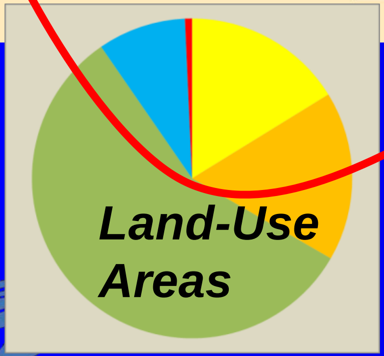




Simple P Loads = Land-Use Area * TPEC



- These TPEC values are surely not constant everywhere in the basin.
- ***How do they change with scale?***
  - From local scales (< 1 km^2) to regional scales (1000s km^2)



Land Use	Area (km^2)		TPEC (kg/ha/yr)		Load (t/yr)
Agriculture	3,200	x	0.63	=	202
Grassland	3,400	x	0.22	=	75
Forest	11,300	x	0.10	=	113
Urban	140	x	0.63	=	9
Total	*(converting km^2 to ha, and kg to tons)*				*398*

Why export coeffients change with scale

Because some P is trapped (lost) during transport

Start with gross P yield (e.g. 5 kg/ha/yr)

1a. In-field loss (slope change, residue): 25%?

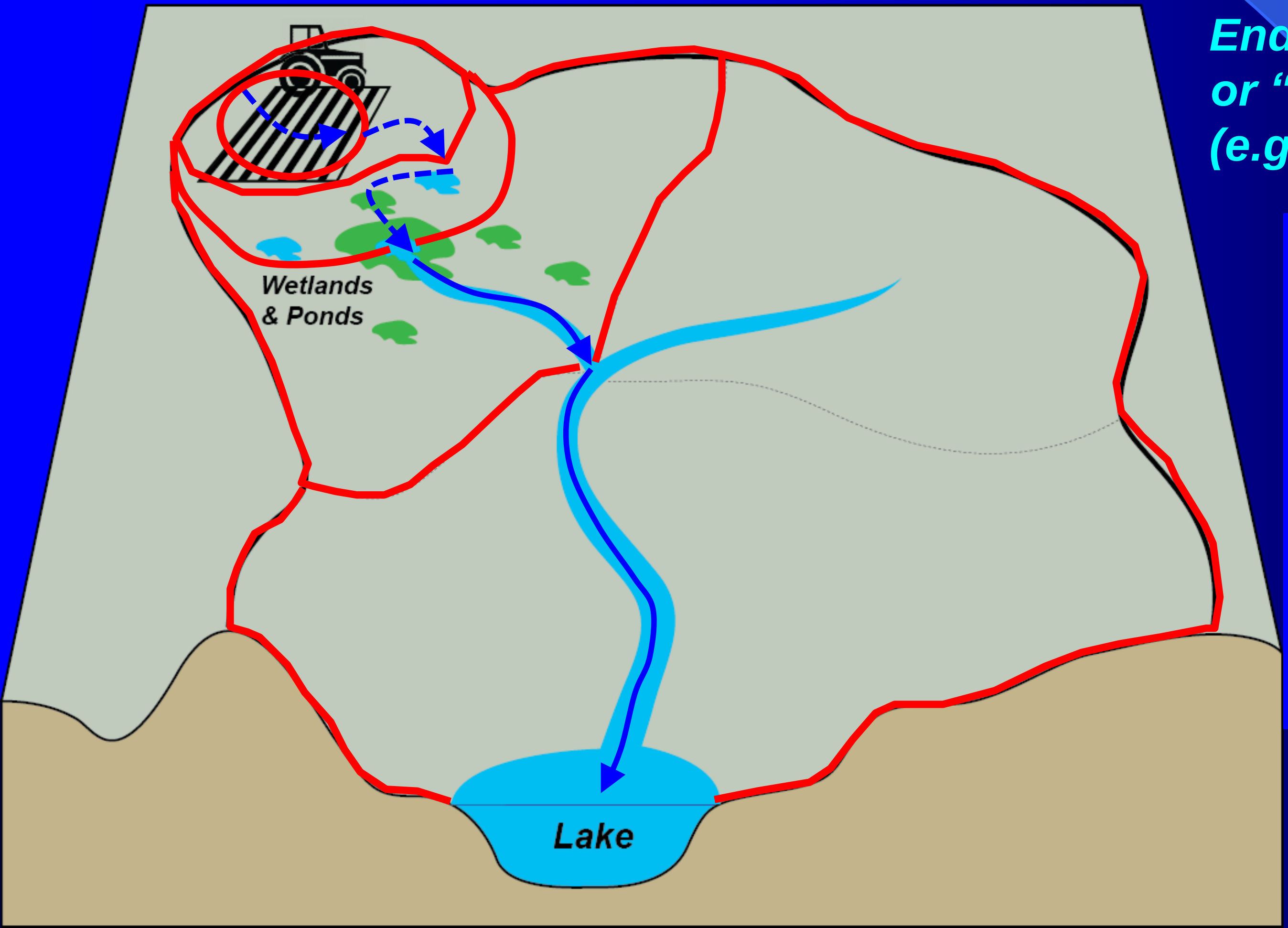
1b. Overland flow loss: 20%?

2a. Lowland loss: 20%?

2b. Subbasin channel loss: 5%?

3. Watershed loss (lakes and floodplains): 10%?

End with apparent P yield, or "export coefficient" (e.g. 1 kg/ha/yr)



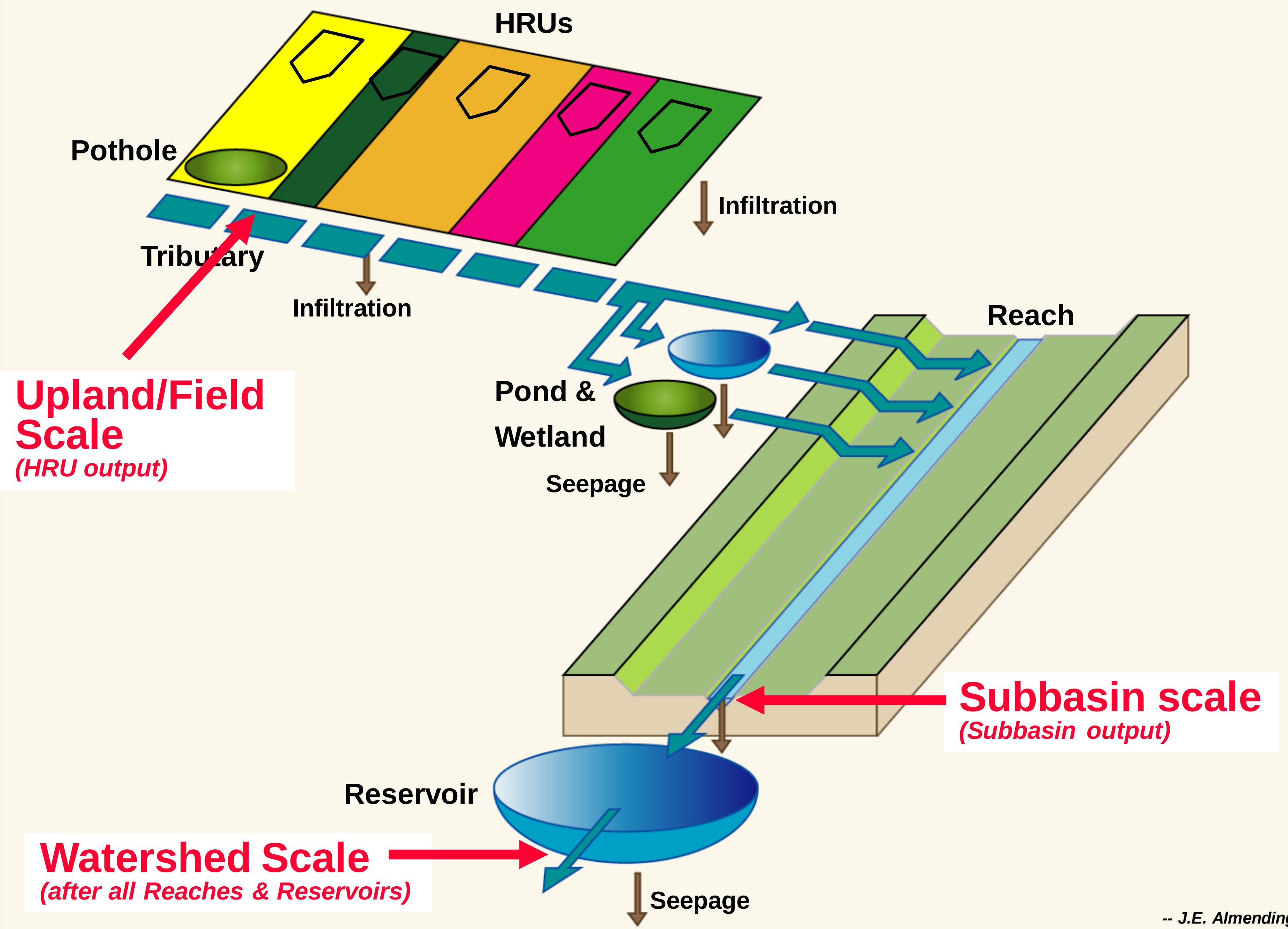
SWAT can help quantify "scale appropriate" export coefficients:

1 = HRU output

2 = Subbasin output

3 = Watershed output

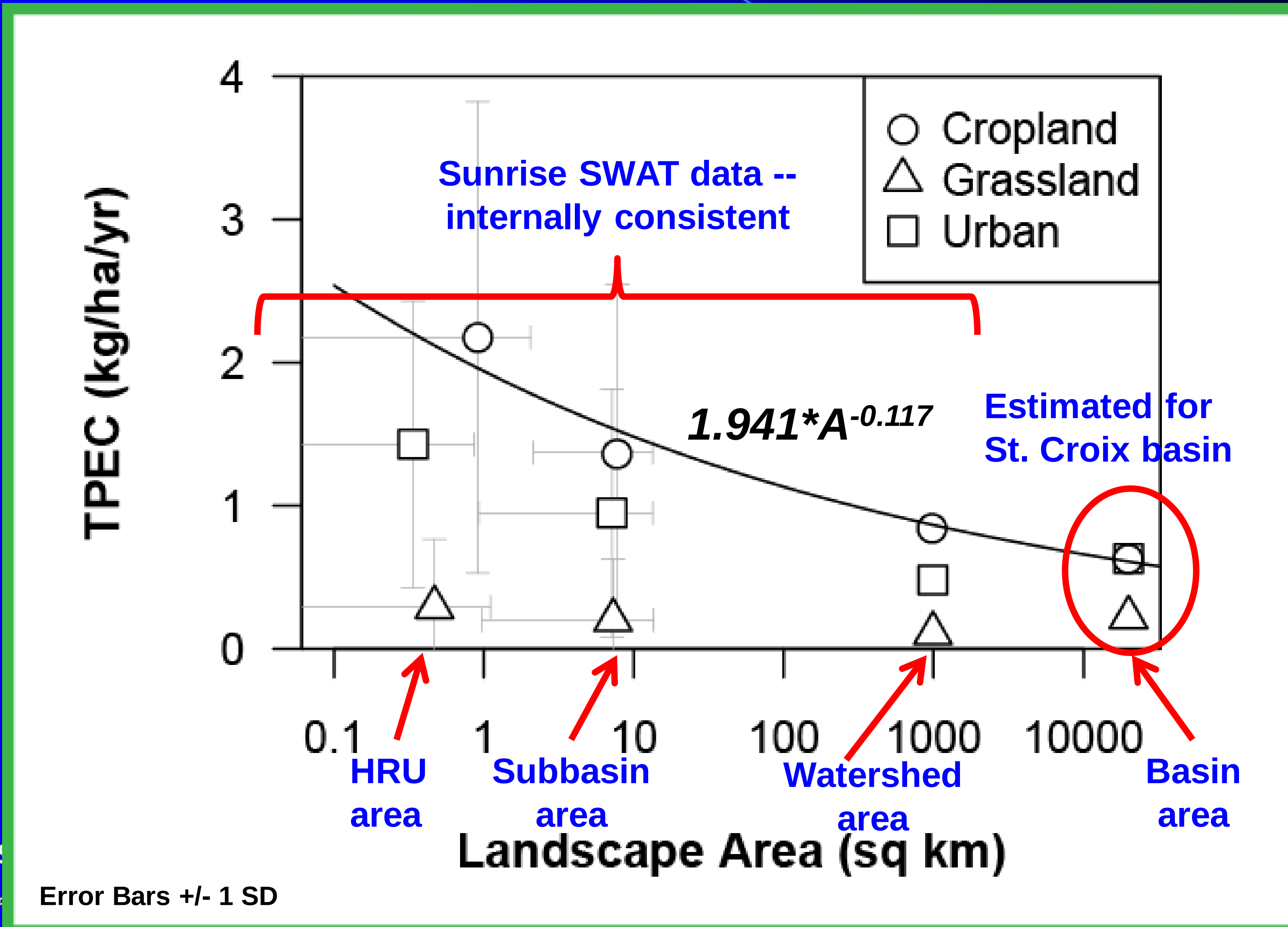
SWAT schematic view -- HRU / subbasin / reservoir:



-- J.E. Almendinger, St. Croix Watershed Research Station, 2011 --

Apparent yields (TPECs) at different spatial scales

Which of these values should be used as a TPEC depends on the scale of application.



Summary & Conclusions:

In the Sunrise Watershed and St. Croix Basin:

- **Agricultural BMPs could reduce TP loads by:**
  - 4% from No-Till
  - 11% from filter strips
  - 18% from grassed waterways
  - 20% for reducing soil phosphorus (P)
- **Total Phosphorus Export Coefficients (TPECs) for cropland depend on spatial scale:**
  - Negative power relationship: $TPEC = a * Area^{-b}$
  - Upland field scale (0.6 km^2): 2.12 kg/ha/yr
  - Subbasin scale (7 km^2): 1.39 kg/ha/yr
  - Watershed scale (991 km^2): 0.85 kg/ha/yr
  - River basin scale (20,000 km^2): 0.63 kg/ha/yr

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Questions?

I envy this kid... He really, really knows the right answer!

When was the last time that you really, really knew the right answer?

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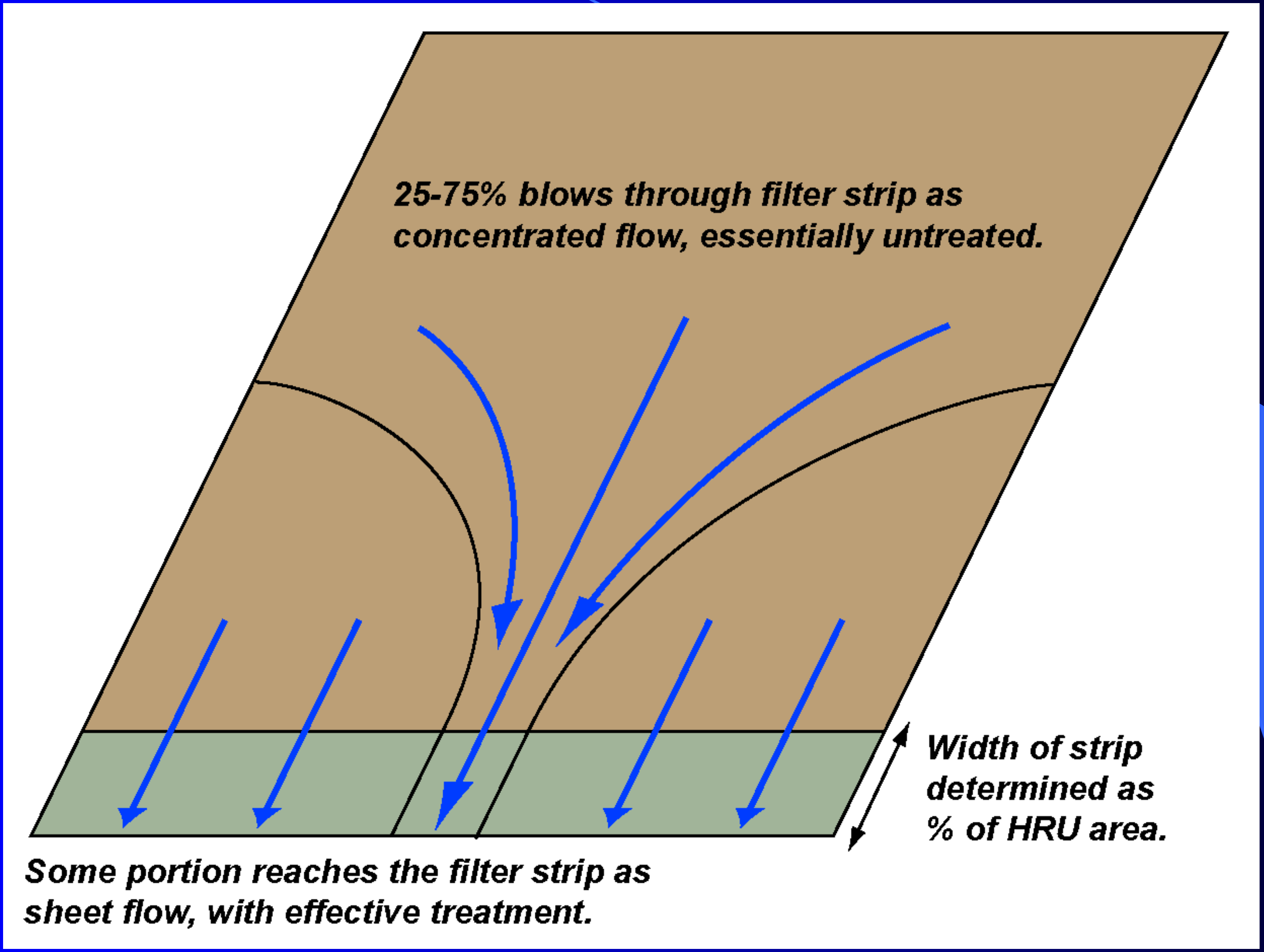
(Misc. further slides / extras)

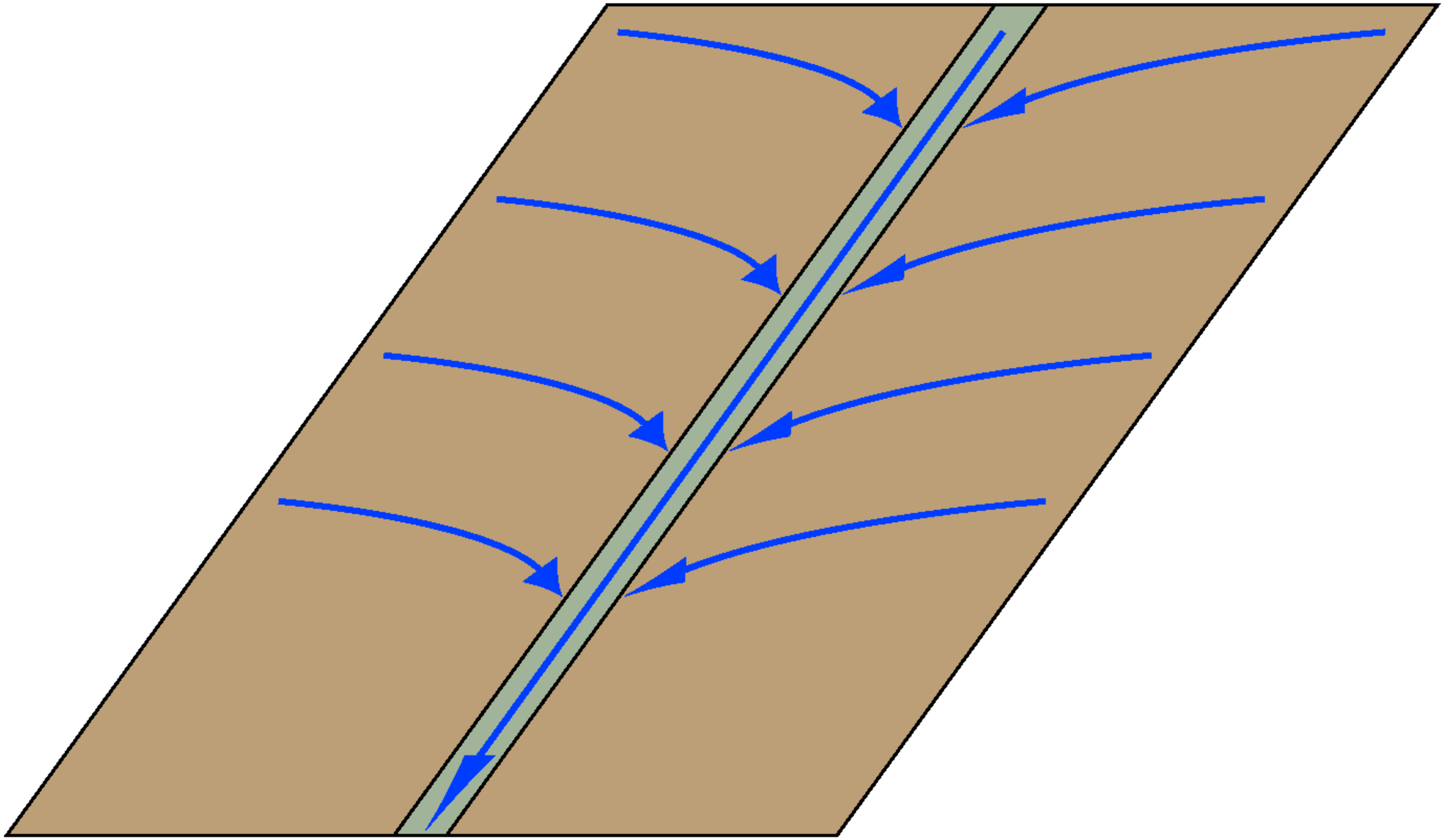
Agricultural BMPs: What is a SWAT filter strip?

A strip along the bottom of an HRU – not necessarily along a stream



Agricultural BMPs: What is a SWAT grassed waterway?

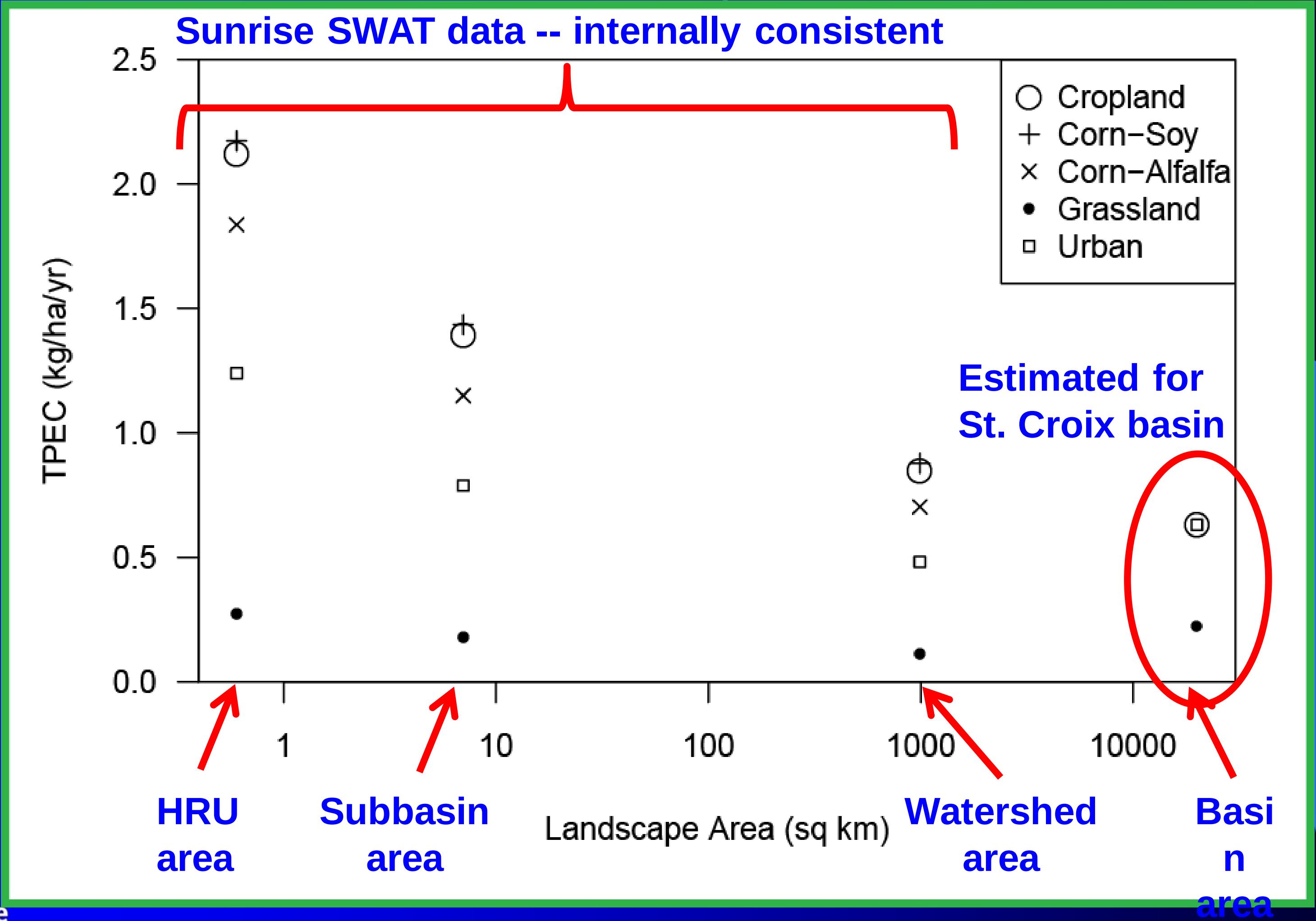
A strip down the middle of an HRU (I think)



Grassed waterway length set to square root of HRU area (by default). Should act as filter strip from both sides, plus slowing longitudinal flow, plus armoring channel from gullying.

Apparent yields (TPECs) at different spatial scales

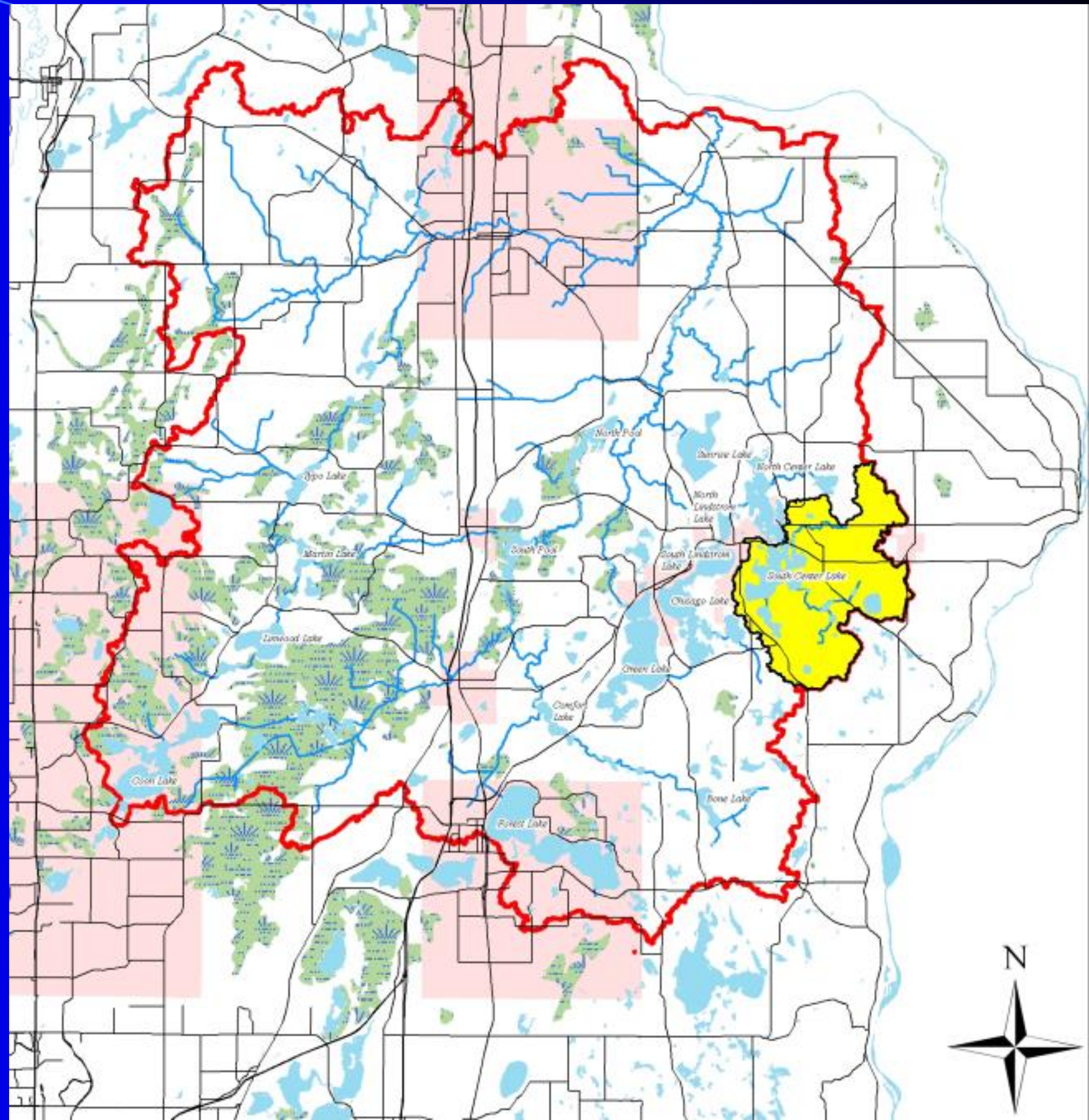
Which of these values should be used as a TPEC depends on the scale of application.



What about South Center Lake ? (one of our Sentinels)

Legend

- Roads
- South Center Lake Watershed
- Sunrise River Watershed
- Wetlands
- Cities



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- # South Center Lake phosphorus loads
  - How much is coming in (input load)?
  - How much is being trapped?

(1) Input Load (kg/yr)

a. By land use TPEC *(Total P Export Coefficient)*

Land Use	Area		St. Croix Basin-Scale	
			TPEC	TP Load
2013	(km²)	(%)	(kg/ha/yr)	(kg/yr)
Urban	3.64	8%	0.63	229
Agriculture	11.76	27%	0.63	739
Grassland	6.97	16%	0.22	154
Forest	8.91	20%	0.10	88
Shrubland	0.03	0%	0.10	0
Water	12.18	28%	0.01	9
Total	**43.49**	**100%**		**1,218**

b. By SWAT:

-- For 2000s: 1,875 kg/yr

(2) Trapped in lake (kg/yr)

a. By SWAT:

-- For 2000s: 1,795 kg/yr (96% -- too high?)

b. By lake-sediment analysis (Mark's work):

-- For 2000s: 3,023 kg/yr (too high)

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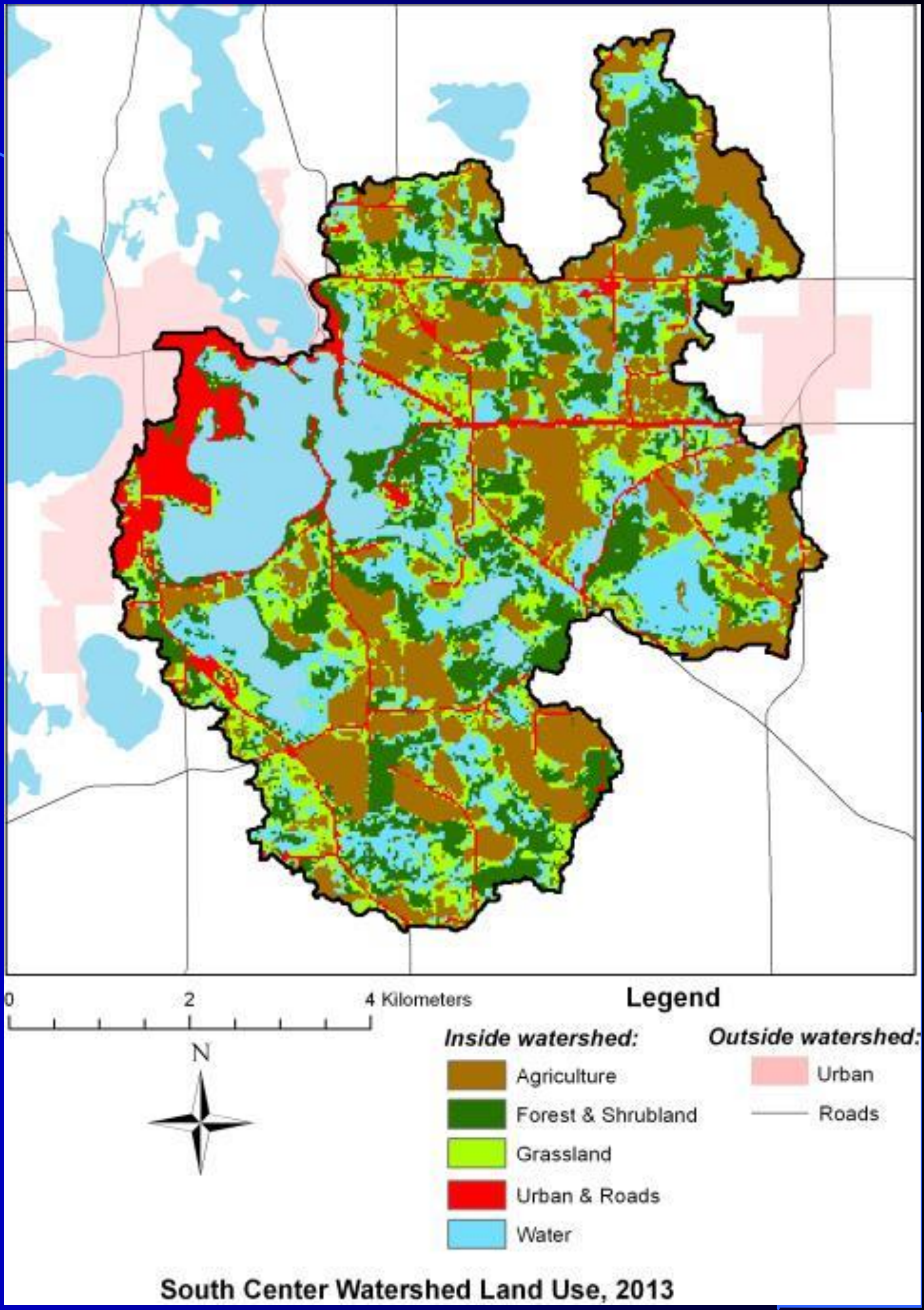

Watershed-wide export coefficient will be average of all subbasins