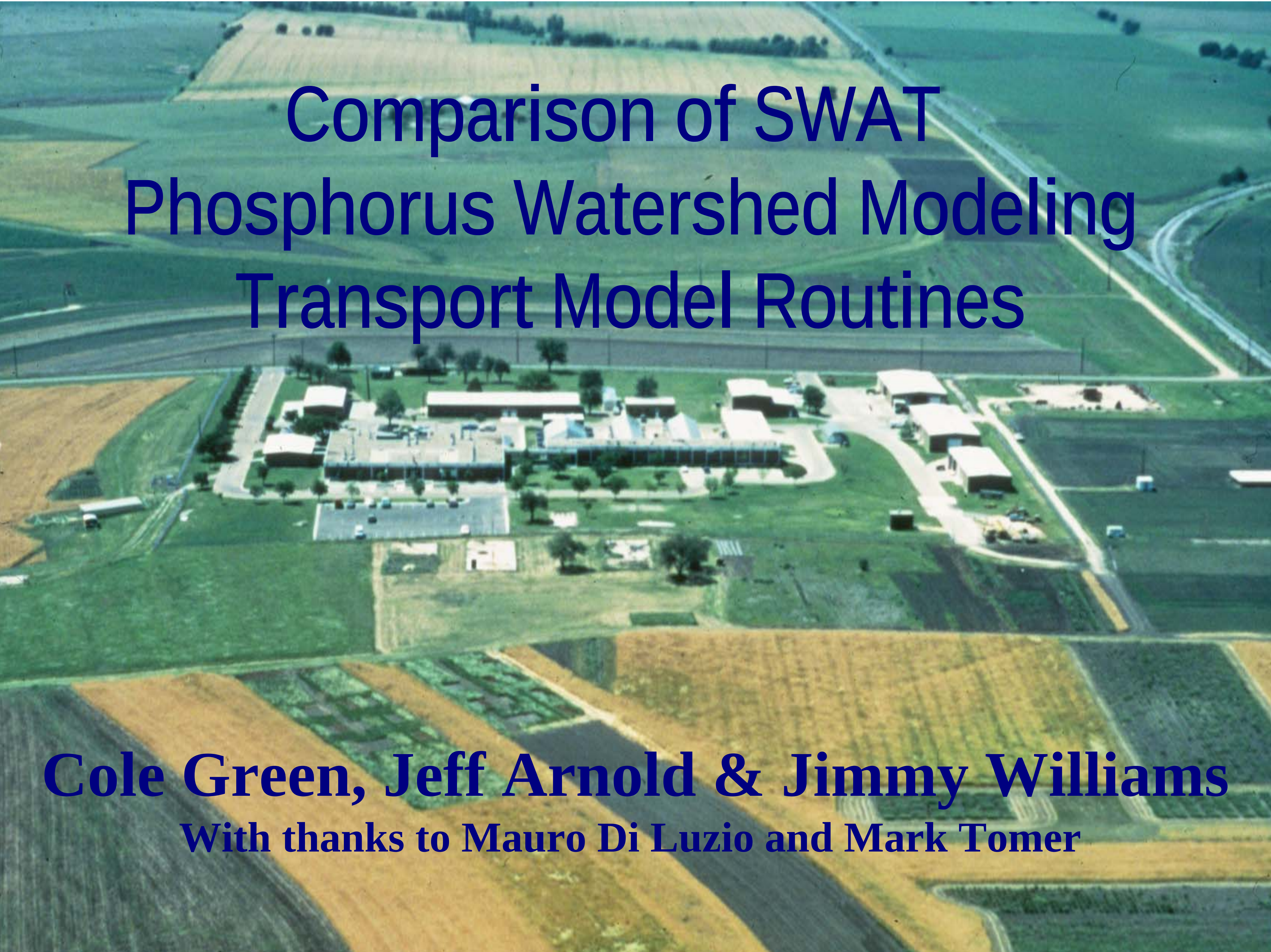
Comparison of SWAT Phosphorus Watershed Modeling Transport Model Routines



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With thanks to Mauro Di Luzio and Mark Tomer

Overview

I. South Fork of the Iowa River, IA, USA

II. Watershed Background (Tile Drains)

III. SWAT P-original

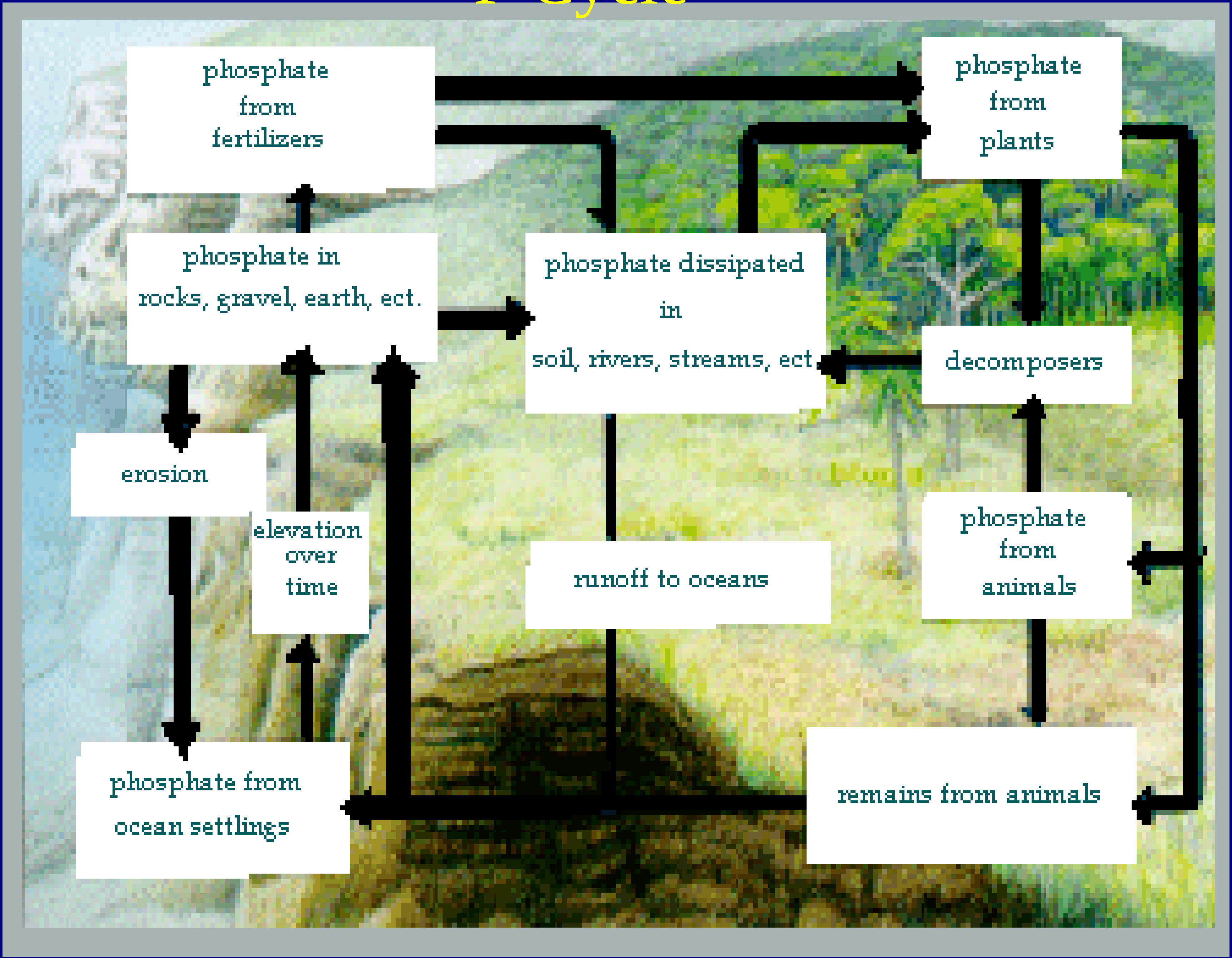
IV. SWAT P-new & P developments (where are we going and how do we get there?)

V. Comparison/Results

VI. Conclusion

VII. Future Work

P Cycle


phosphate from fertilizers
phosphate from plants
phosphate in rocks, gravel, earth, ect.
phosphate dissipated in soil, rivers, streams, ect
decomposers
erosion
elevation over time
runoff to oceans
phosphate from animals
phosphate from ocean settlings
remains from animals

Phosphorus

- Weathering and erosion are two dominant processes that release P which allows for its transport throughout the landscape.
- The ecosystem phase of the P cycle is faster than the sediment phase. All organisms require P for synthesizing phospholipids, ATP, etc.
- Plants absorb P very quickly in the ionic phases.

South Fork Watershed

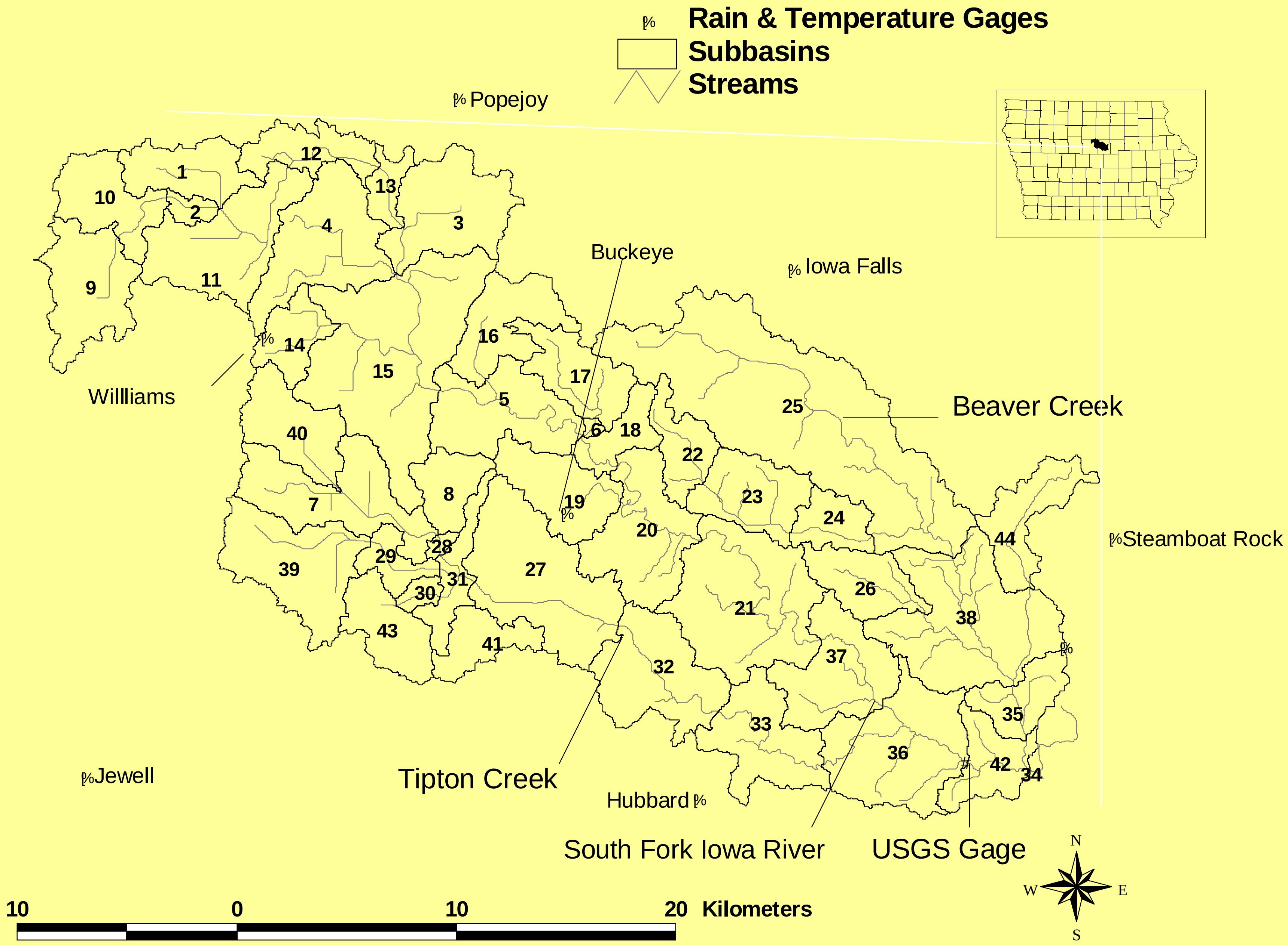
- P is an essential crop nutrient that is simulated in models due to its impact on water quality and crop yield.
- A model's ability to adequately simulate watersheds is dependent on the usage of quality data for calibration purposes.
- While land application of animal manures is generally accepted as a common method of disposal, its impact on environmental quality is not well understood and is reflected in the assumptions of process modeling.
- A watershed in the Midwest was used to illustrate the importance of including the appropriate environmental processes, i.e. tile drainage and soluble P.

South Fork of the Iowa River Watershed

- About 80% of it (775 km^2) is tile drained; subsurface pathways can provide a significant amount of pollution.

- Typifies one of the more intensively managed agricultural areas in the Midwest

- SSURGO soils; 30 m DEM; USGS discharge data at SF450 site; NOAA & NCDC (Nat’l Climate Data Ctr) for precip and temp data; land use: NASS (Nat’l Ag Stat Serv)



Rain & Temperature Gages
Subbasins
Streams
Popejoy
Buckeye
Iowa Falls
Willliams
Beaver Creek
Steamboat Rock
Jewell
Tipton Creek
Hubbard
South Fork Iowa River
USGS Gage
10
0
10
20
Kilometers
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FERTILIZER AND MANURE APPLICATION

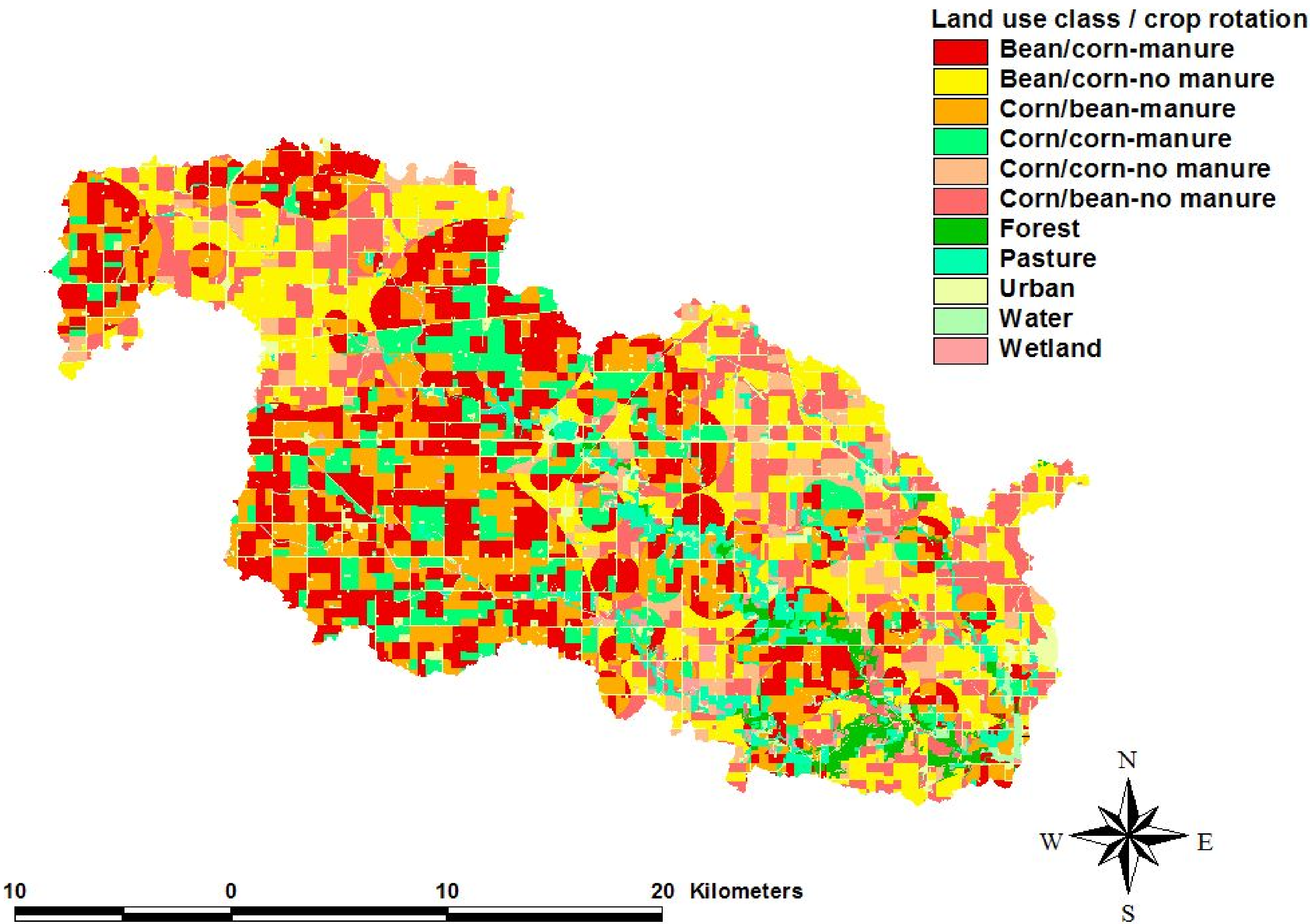
1. Nearly 100 swine CAFOs in two main areas

2. CAFOs were digitized based on rectified mosaic of infrared photographs (Iowa DNR); 1 animal per 0.75 km^2

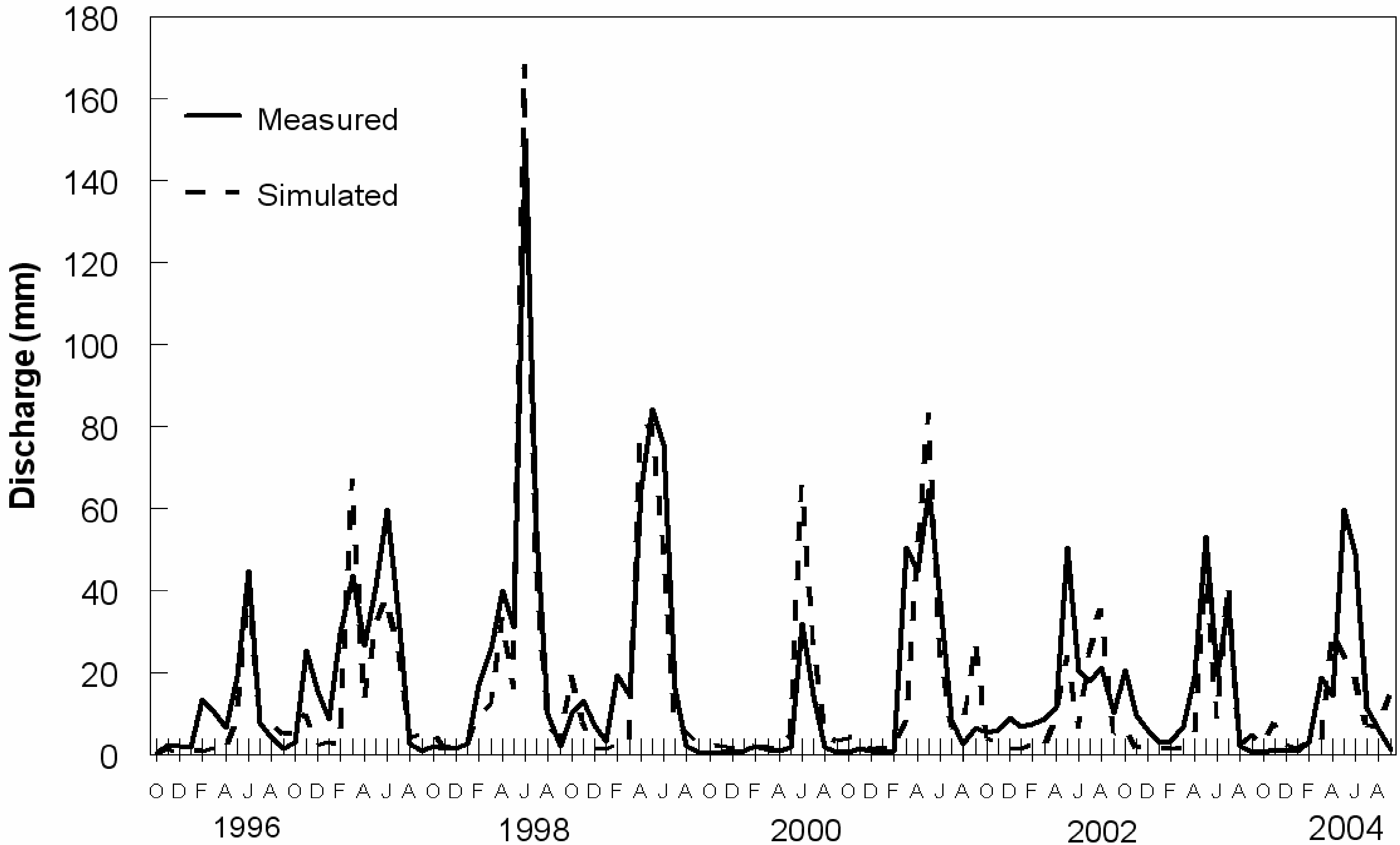
3. Most CAFOs (~60 out of 110) lack external manure storage.

4. Based on animal excretion rates, an N-based manure application of 200 kg N ha^{-1} was applied per year of corn (avg= 100 kg N ha^{-1}).
Scenario used = BmC

5. The locations of manure-applied land were modeled by spreading N from each facility to increasingly sized circles (in 40 m radius increments, without overlap) until the area could accept the N loading from the facility the rate for corn.



Land use class / crop rotation
Bean/corn-manure
Bean/corn-no manure
Corn/bean-manure
Corn/corn-manure
Corn/corn-no manure
Corn/bean-no manure
Forest
Pasture
Urban
Water
Wetland
N
W
E
S
10
0
10
20 Kilometers



180
160
140
120
100
80
60
40
20
0
Discharge (mm)
Measured
Simulated
O D F A J A O D F A J A O D F A J A O D F A J A O D F A J A O D F A J A O D F A J A O D F A J A O D F A J A
1996
1998
2000
2002
2004

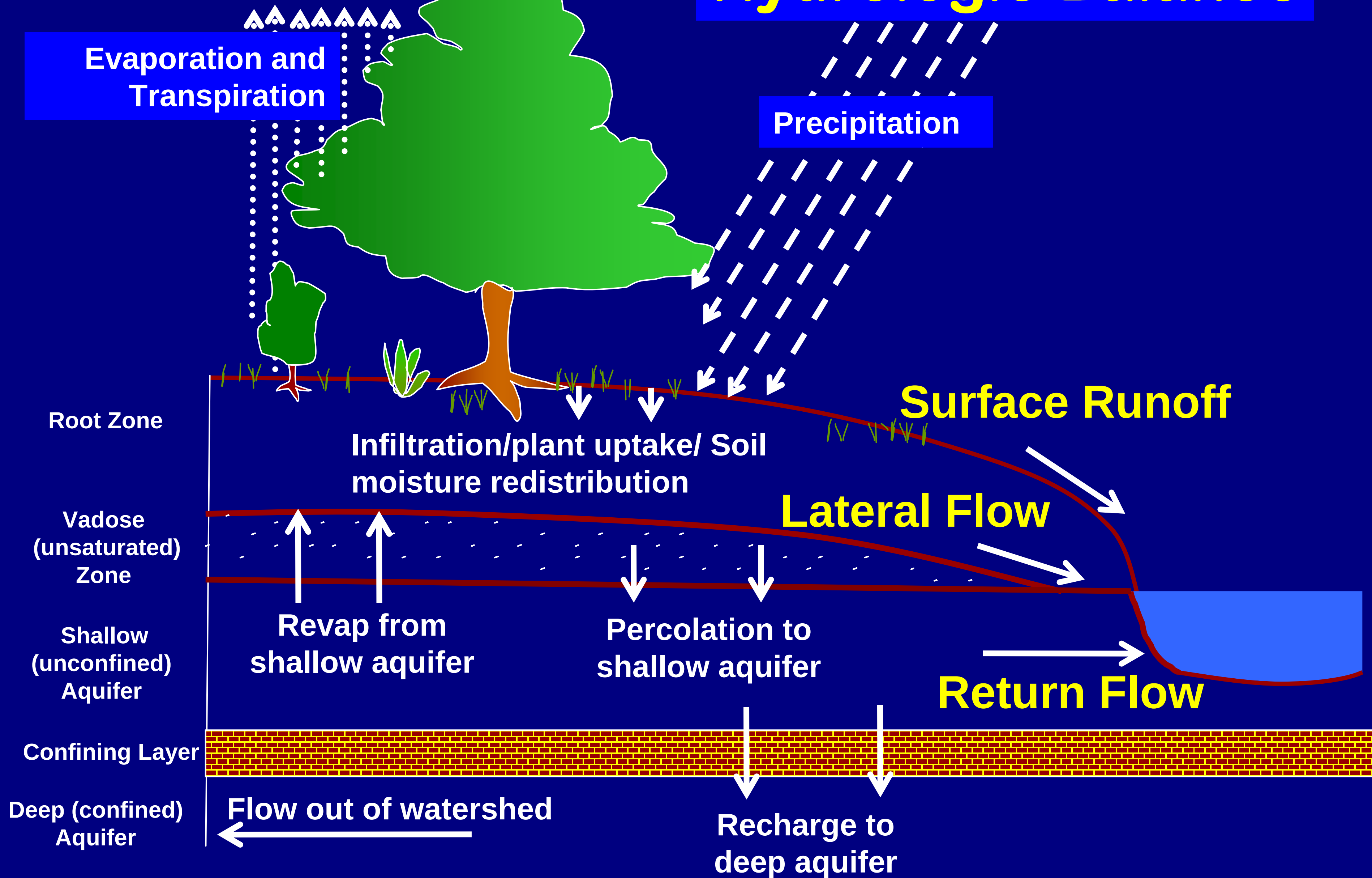
Flow E_{NS}

- E_{NS}: Calibration(95-98) a/m/d: 0.7/0.9/0.7
- E_{NS}: Validation (99-04) a/m/d: 0.6/0.5/0.4

Calibrated values for adj. parameters

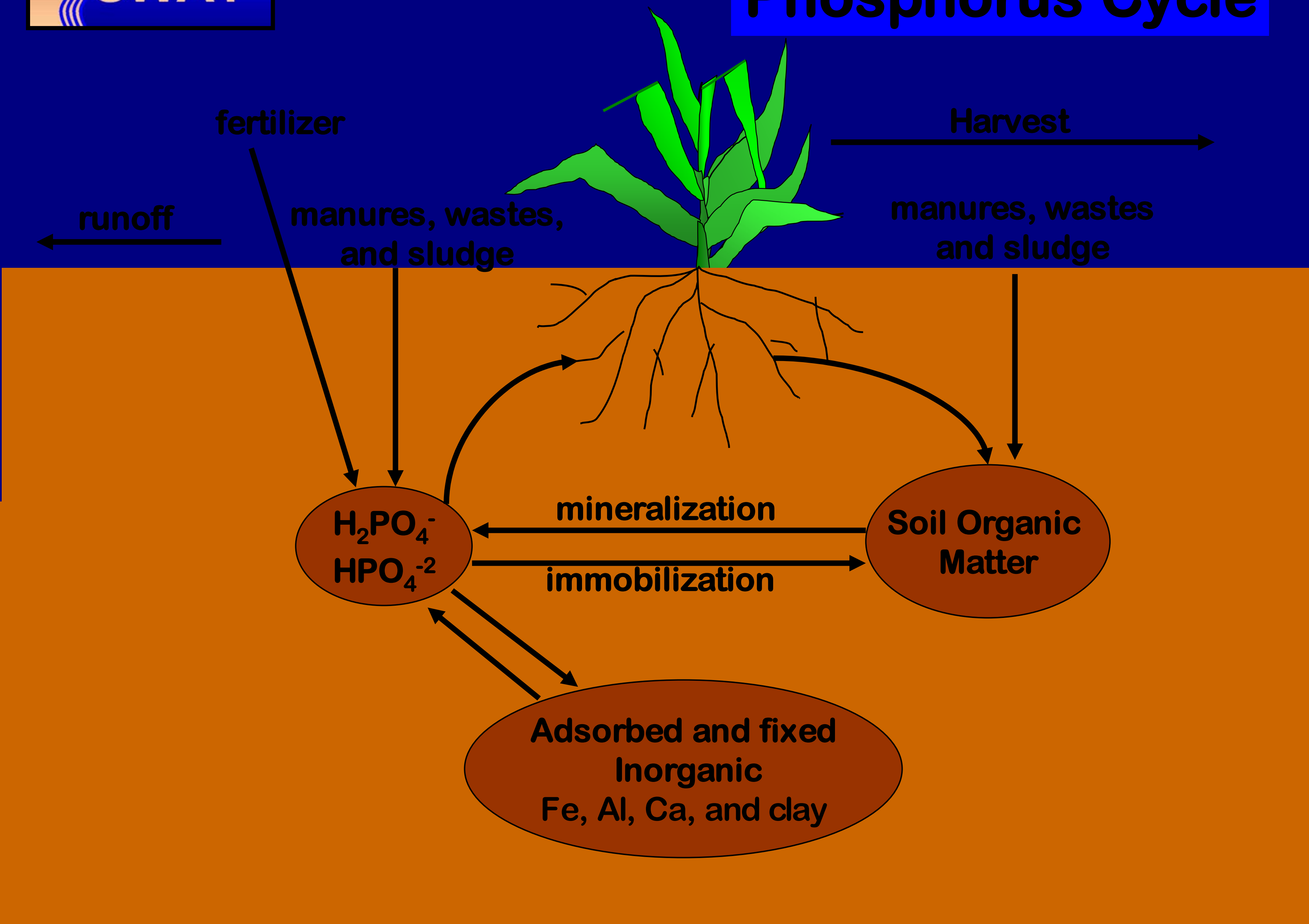
Parameter	Description	Range	Calibrated Value
ESCO	Soil evaporation compensation factor	0.01 to 1.0	0.95
FFCB	Initial soil water expressed as a fraction of Fc water content	0 to 1.0	0.8
Surlag	Surface runoff lag coefficient	0 to 4 (days)	0.2
ICN	Based on SCS runoff CN & a soil moisture accounting technique	0 or 1	1
Cncoeff	CN coefficient	0.5 to 2.0	0.2
CN2	Initial SCS runoff CN to moisture Condition II	20 to 100	66-78
PHU	Potential Heat unit	1000 to 2000	1800

Hydrologic Balance

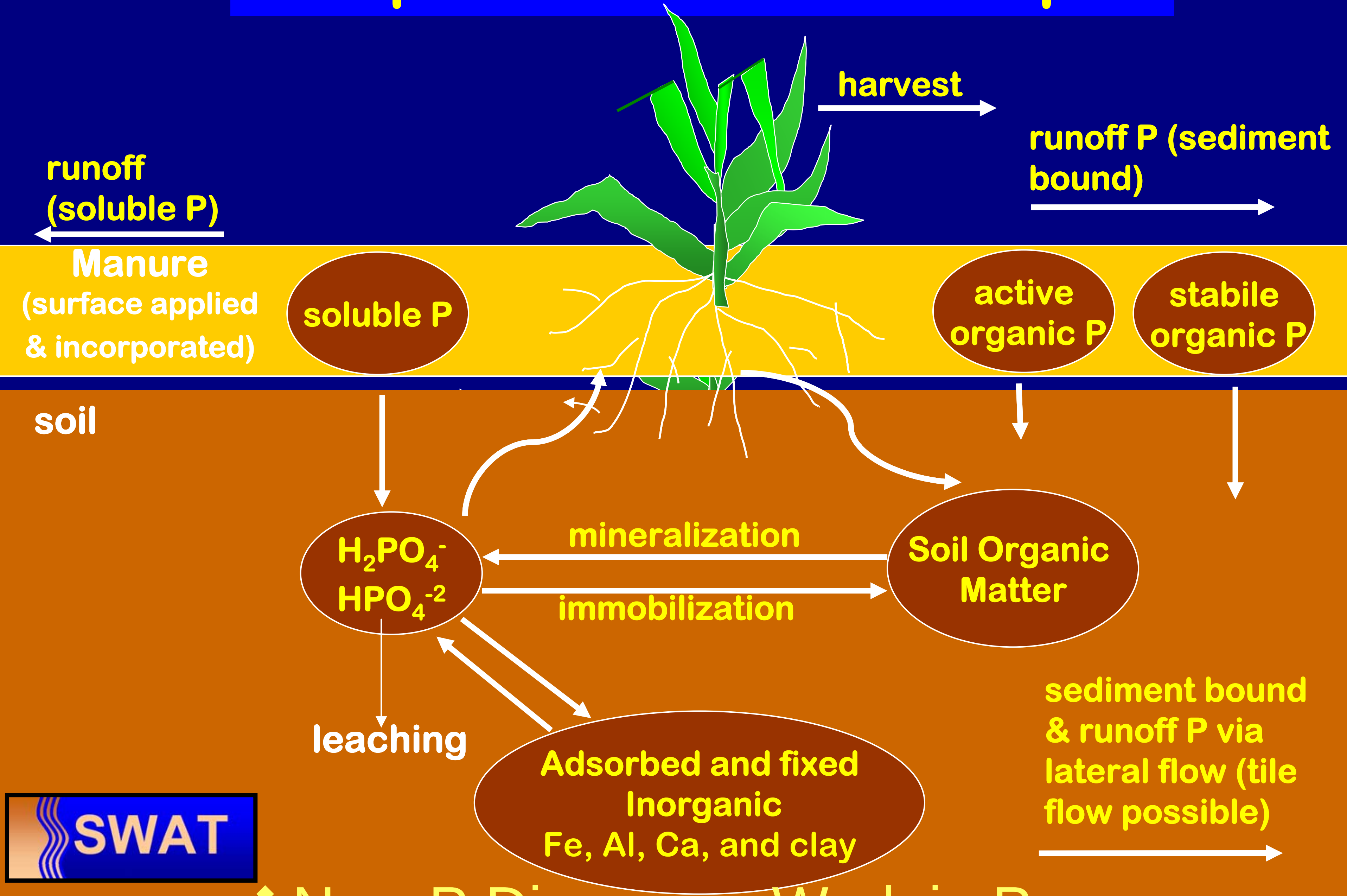


SWAT

Phosphorus Cycle



Phosphorus Forms & Transport



- New P Diagram—Work in Progress

P eqn 1

- The depth of each soil layer and the associated soluble P in each soil layer is calculated as:

$$Psol_{zi} = (sol\_z - sol\_zi)$$

where $Psol_{zi}$ is the soluble P available in the soil layer between sol_z (the soil layer above) and sol_zi, the soil layer beneath.

P eqn 2, etc.

- The soluble phoskd for the subsurface soil layers ($phos_{kdsub}$) are then multiplied by the soil depth and the soil bulk density in order to obtain an intermediate term that can be used in the percolation, lateral flow and tile flow of soluble P accounting.

$$xx = sol\_bd * (sol\_z - sol\_zi) * phos_{kdsub}$$

where *xx* is an intermediate term used in accounting for the bulk density of the soil (*sol_bd*), the difference between the upper (*sol_zi*) and the next lower soil layer (*sol_z*) and the phoskd subsurface phosphorus soil partitioning coefficient ($phos_{kdsub}$).

- The new SWAT P routines *allow* for soluble P movement throughout the soil profile. Soluble P can be distributed with lateral flow, including tile flow, in groundwater, surface flow, and in percolate throughout the soil profile.

Results

Hydrologic Component	With Tile Flow (mm) 1995-2004	Without Tile Flow (mm) 1995-2004	Calibration (mm) 1995-1998	Validation (mm) 1999-2004
Precipitation	770.6	768	787.5	758
Surface runoff	38.1	117.4	44.3	34.3
Lateral flow	5.2	0.4	5.5	5.3
Tile flow	158.79	0	196.55	182
Groundwater flow	0	11.7	0	0
Evapotranspiration	499	638.6	437.6	515
Potential ET	760	1191.6	698.2	775.5
Soluble P in Surface Runoff kg $ha^{-1*(B)}$	0.185	0.259	0.018	0.017
Soluble P in Surface Runoff kg $ha^{-1\dagger(A)}$	0.113	n/a	0.012	0.02
P Leached kg $ha^{-1*(B)}$	0.562	0.104	0.362	0.537
P Leached kg $ha^{-1\dagger(A)}$	0.581	n/a	0.378	0.524
Lateral Soluble P kg $ha^{-1\dagger(A)}$	0.004	n/a	0.004	0.004
Tile Soluble P kg $ha^{-1\dagger(A)}$	0.077	n/a	0.148	0.086

P developments

- Sharpley and Syers (1979): surface runoff is the primary mechanism by which P is exported from most catchments; late 1990s, leachable P past 10 mm is accepted
- SWAT monitors 6 different P pools in the soil {3 organic (active, stable, fresh) & 3 mineral (active, stable, solution)}
- Users can 1) define initial concentrations 2) utilize SWAT initialization of P pools using PAI
- Have 2 sorption coefficients; one for the top 10 mm and one for the layers below (phoskd, phoskdsub)
- P can now be leached through the entire soil profile (crack flow, sandy textures)
- P can now be transported through tile drains
- In-stream P change with addition of sediment classes

How can we improve P process modeling?

- First, we need to identify what our P objectives are: regulatory? risk assessment?
- We need to identify what we know and what we don’t know about P processes—including the assumptions and their validity, i.e. determine if quality data were used to develop equations used in the model.
- Determine what options the model has available, i.e. do we want high user input for greater detail? utilize model initializations? How do we regulate calibration? Autocalibration initial concentrations?
- We need to address variability; a lot of time is spent calibrating the model when measured data variability is unknown. CEAP requires modelers to cite variability.

- ❖ In order to model the P process better; we need to know the timeframe on when P desorbs from translocated soil and becomes available on the soils of interest (those problematic to P release) including bank destabilization.
- ❖ How can we keep the model user-friendly while requiring more inputs?

- Do our extractants adequately represent the P pools? Can we develop a model that exactly represents extractants used for its representative pool? Arkansas case…
- What data from chemical analyses is useful to modelers? Why is there a disparity between the data collected by researchers and the inputs required for the model? Typical analyses include: TP, MRP, WEP, and STP whereas the model requires soil labile P (mg kg^{-1}) concentration, soil organic P (mg kg^{-1}), depth of P leaching, concentration of soluble P in GW contribution to streamflow from subbasin, organic P enrichment ratio, etc.
- Is there a need for P desorption/adsorption to be better connected with clay, Fe and Al content (linear vs. nonlinear Isotherms)?

- Can we specifically target the inorganic and organic P fractions fertilizers and how they degrade? Can we adequately approximate what pools P exists in and at what times (i.e.mineral P is 20-80% of total P)? Or do we use regression equations established from data which represent dominant soils throughout the U.S. but doesn’t address them individually? Would this be an improvement to the model?
- We need more information for the types of manure including its residence time in (incorporated) or on (surface applied) the soil.

Conclusions

- Water yield results were significantly different for the simulations with and without the tile flow component (25.1% and 16.9%, expressed as a percent of precipitation). With the water budget correct, water quality constituents can now be addressed.

- Without the tile drain component inclusion, the surface flow would be overestimated, resulting in a non-representative water balance with erroneous management implications.

- With the new SWAT code adjusted for greater P mobility, the movement of P to the subsurface areas (laterally and via tile flow) were easily discerned and now can be applied to management decisions.

- Multiple applications of manure and the impact of large rain events will be tested next. Currently, percolate P, lateral P and tile P have been validated but groundwater soluble P will be tested with the Bosque watershed data.

Thank you!!