Quantifying Streambank Erosion and Phosphorus Load for Watershed Assessment and Planning

Final Report Presentation
2015 OWRRI Research Grant

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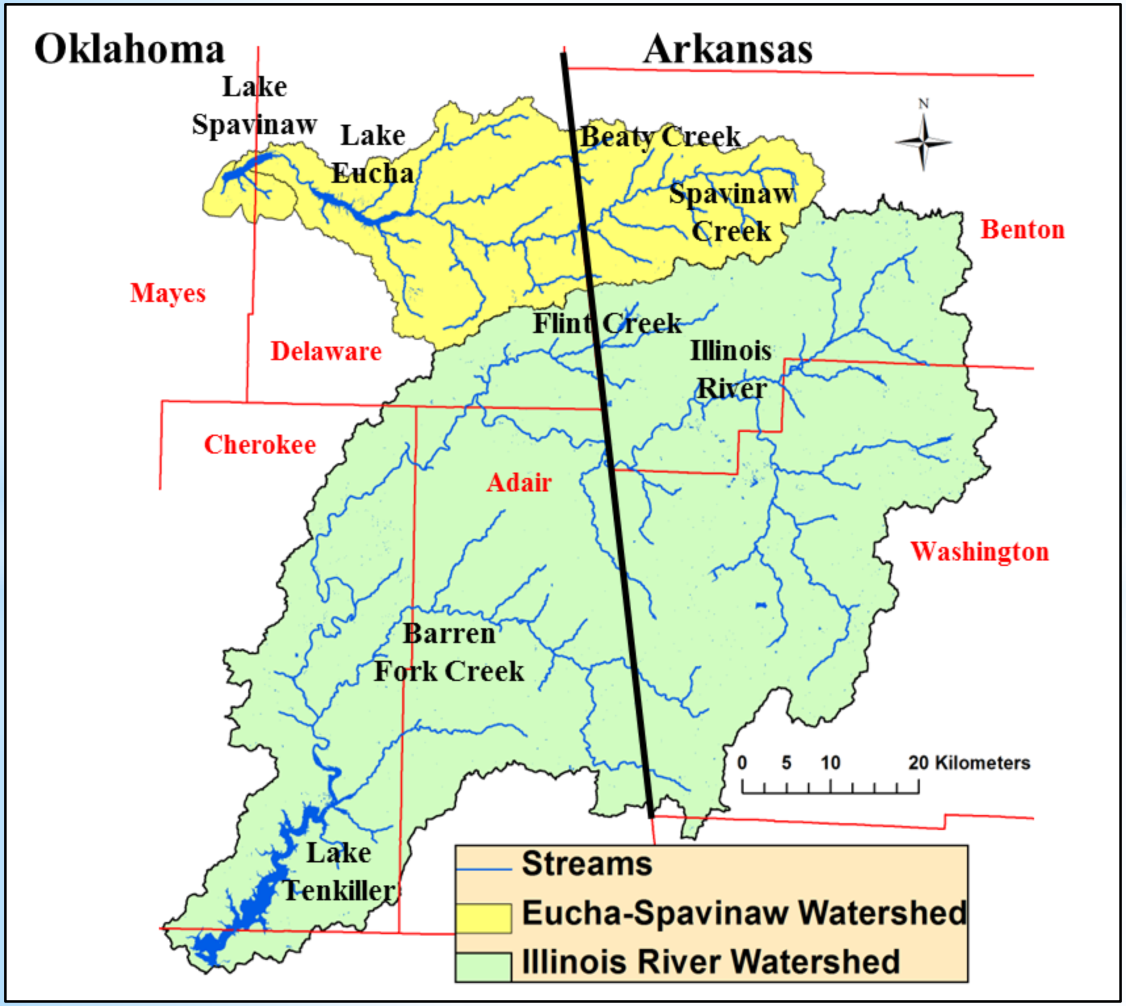
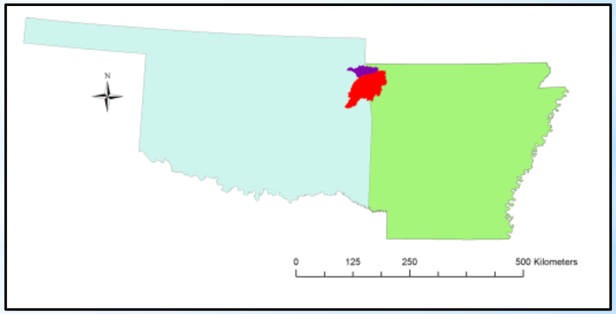
Research Objectives

1. Estimate streambank erosion in Barren Fork Creek watershed
2. Develop and test new streambank erosion model for SWAT
3. Predict streambank erosion and P load for the Barren Fork Creek watershed using the improved SWAT model

Illinois River (IRW) and Eucha-Spavinaw Watersheds (ESW)





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IRW and ESW Water Quality Issues

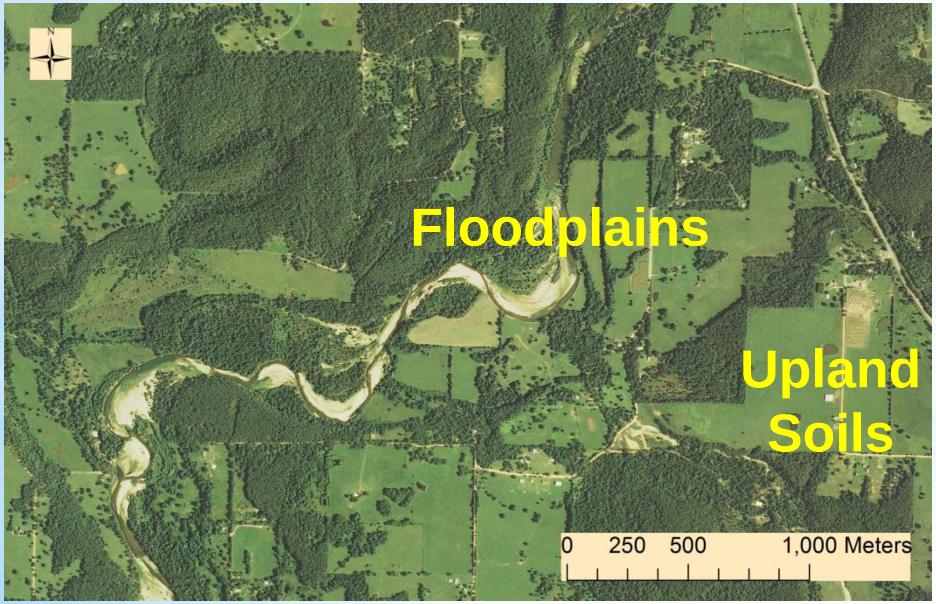
- **Phosphorus**
  - Poultry litter
  - Cattle
  - Point sources
  - Streambank erosion
  - Soil Test P (STP)
  - Urban

- **Sediment**
  - Pasture
  - Urbanization
  - Streambank erosion
  - Crops
  - Roads
  - Construction



Legacy Phosphorus

- Accumulated P in soils and water, which may serve as a long term P source
- May mask or buffer impacts of conservation practices and other water quality improvement practices



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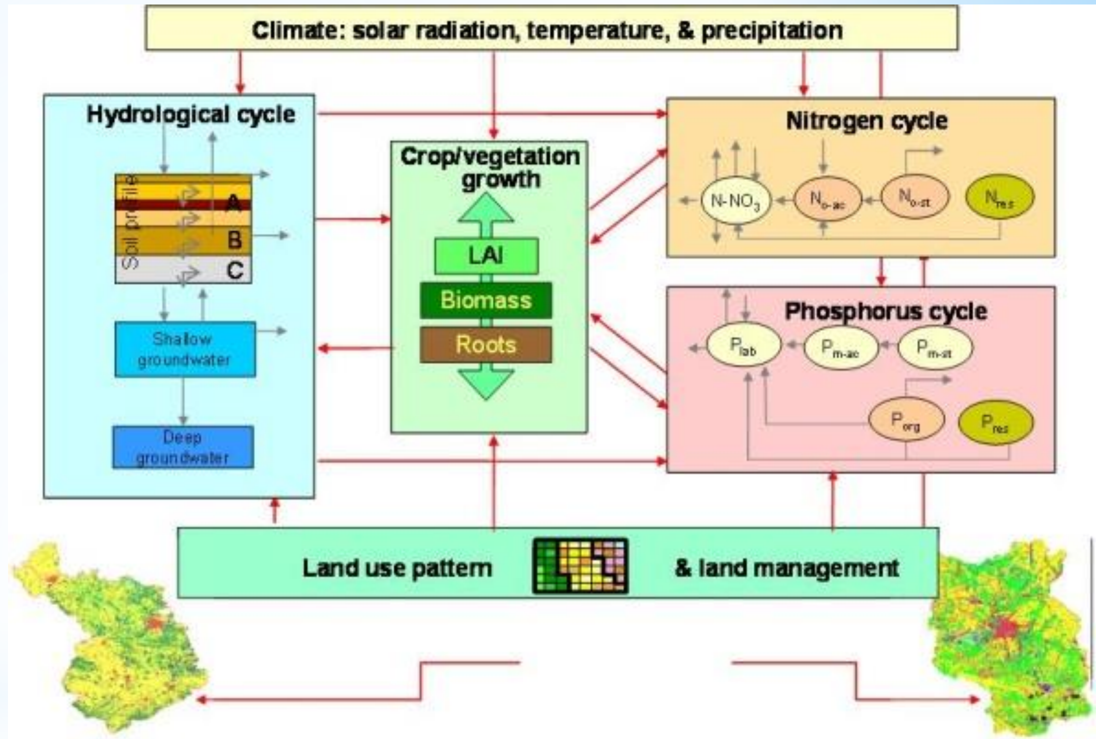
Soil and Water Assessment Tool (SWAT)

- Product USDA Agricultural Research Service
- Used worldwide
- Predicts streamflow, sediment, nitrogen, P, crop yields, etc.
- Evaluates conservation practices
- Pollutant loads for TMDLs



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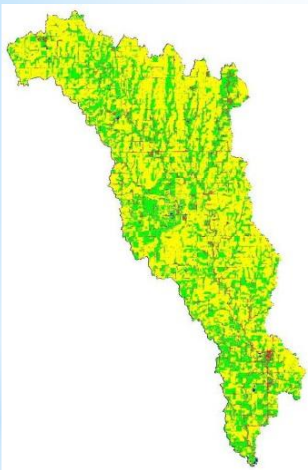
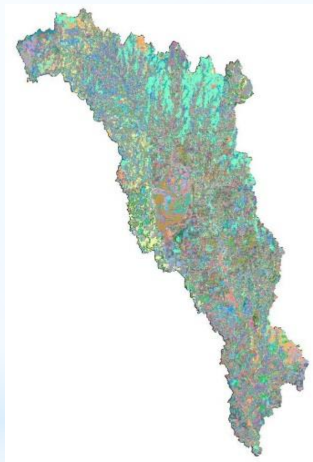
SWAT Model Data Requirements

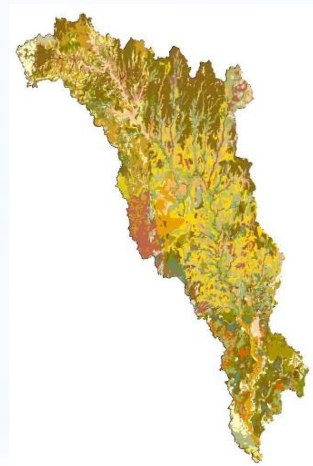
Landcover



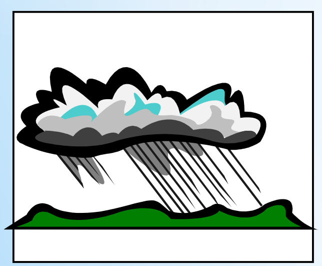
Topography



Soils

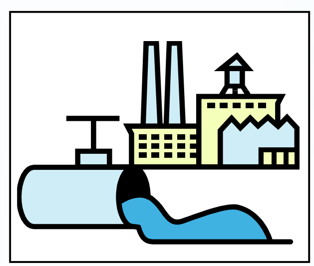


Weather

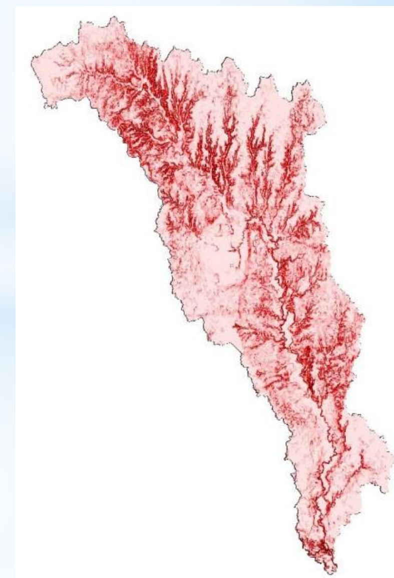


Management

Point Sources



Model Predictions



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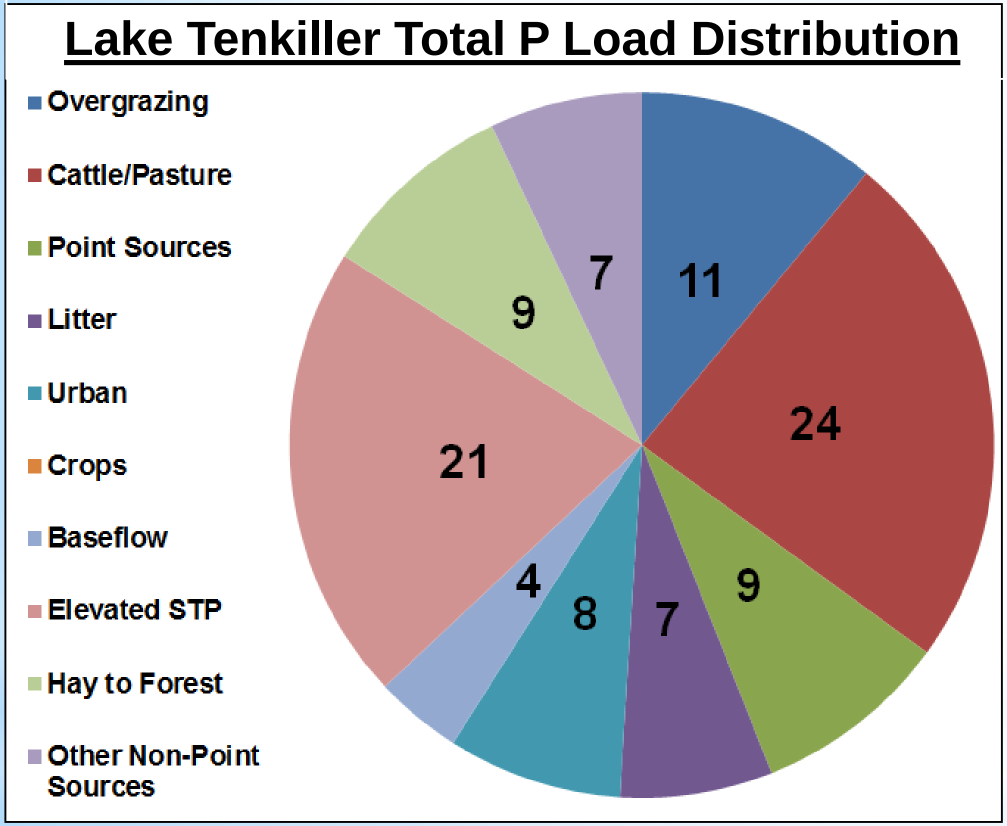
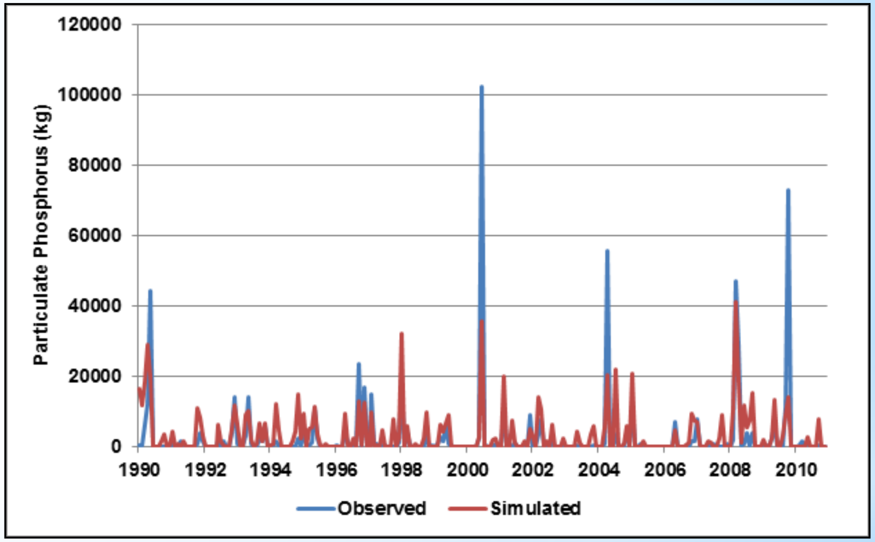
Phosphorus Sources

SWAT Model Predictions 2004-2013



Barren Fork Creek Particulate P Load

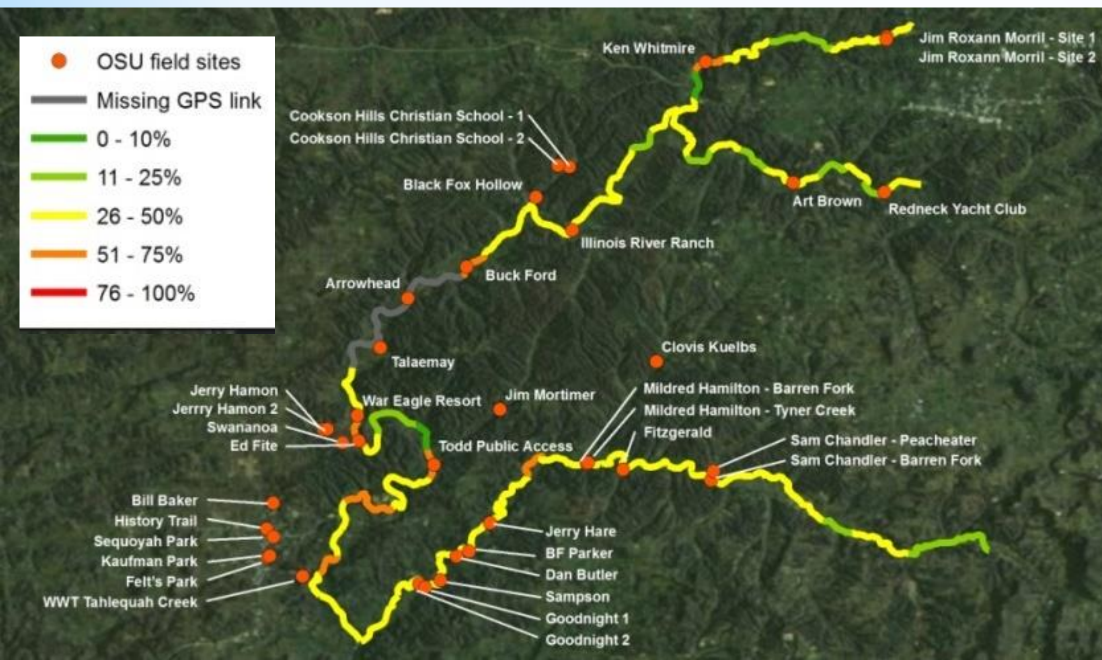


Lake Tenkiller Total P Load 190,00 kg/yr

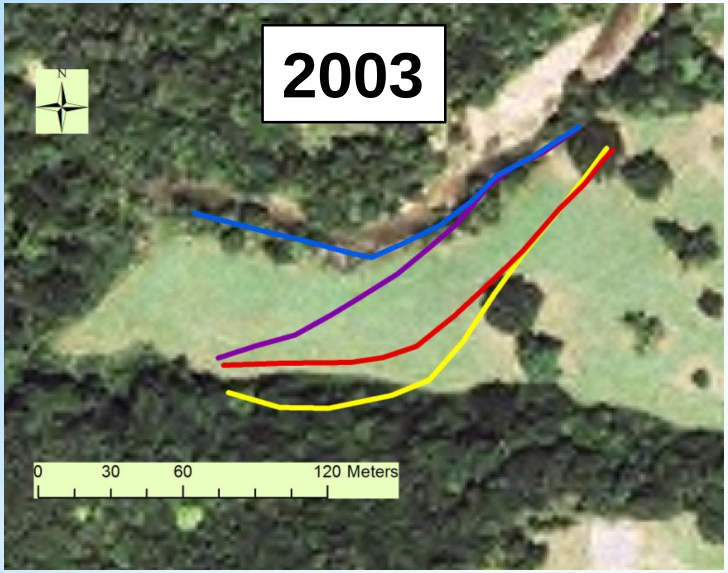
Streambank Erosion is Missing!

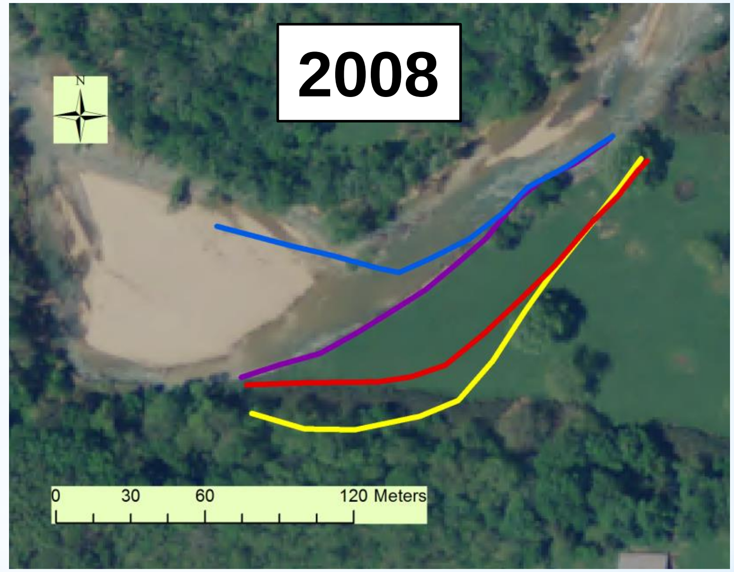
Streambank Erosion

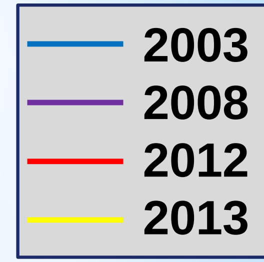
- TMDL being developed for Illinois River watershed not explicitly accounting for P from streambanks
- Barren Fork Creek Watershed - 36% streambanks unstable, estimated erosion 93 Mg TP/yr
- Illinois River Watershed - recent estimates >350 Mg TP/yr from eroded streambanks
- Note: not all streambank erosion & P reaches lake!

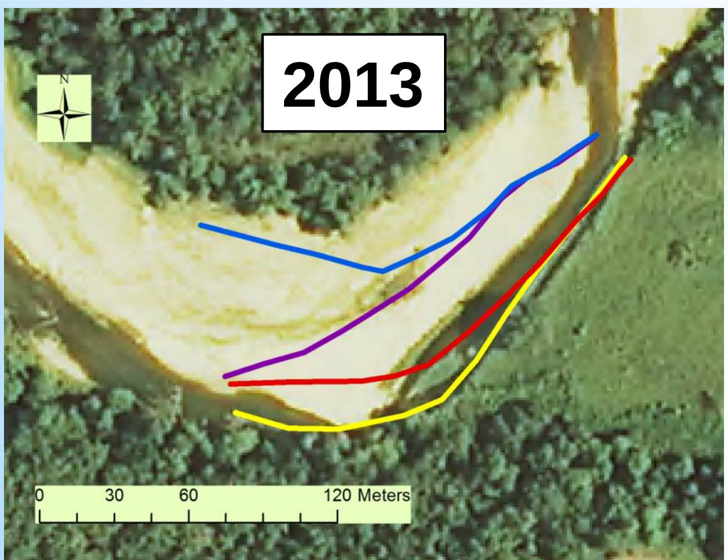


Objective 1: Measuring Streambank Erosion









- Lake Tenkiller Total P load 190,000 kg/yr
- Period 2003-2013
  - Single 190 m reach - 40,000 Mg eroded soil
  - >5,000 kg Total P
  - 26% annual Total P load

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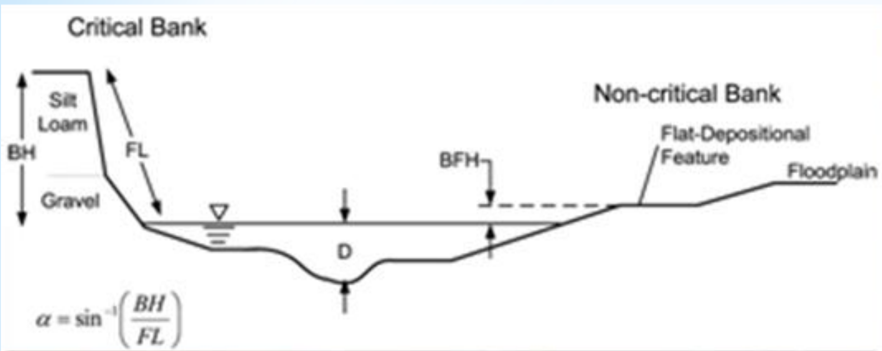
Objective 2

- Modify and test streambank erosion model for SWAT
  - Compare field measured and SWAT default parameter values
  - Analyze SWAT predictions using literature and field-based data
  - Evaluate observed vs SWAT predicted streambank erosion at ten sites
- Develop guidance for watershed modelers and managers on data collection, parameter estimation and use of the new SWAT model

Typical Stream Channel Profile
Barren Fork Creek



SWAT Streambank Erosion

Excess Shear Stress

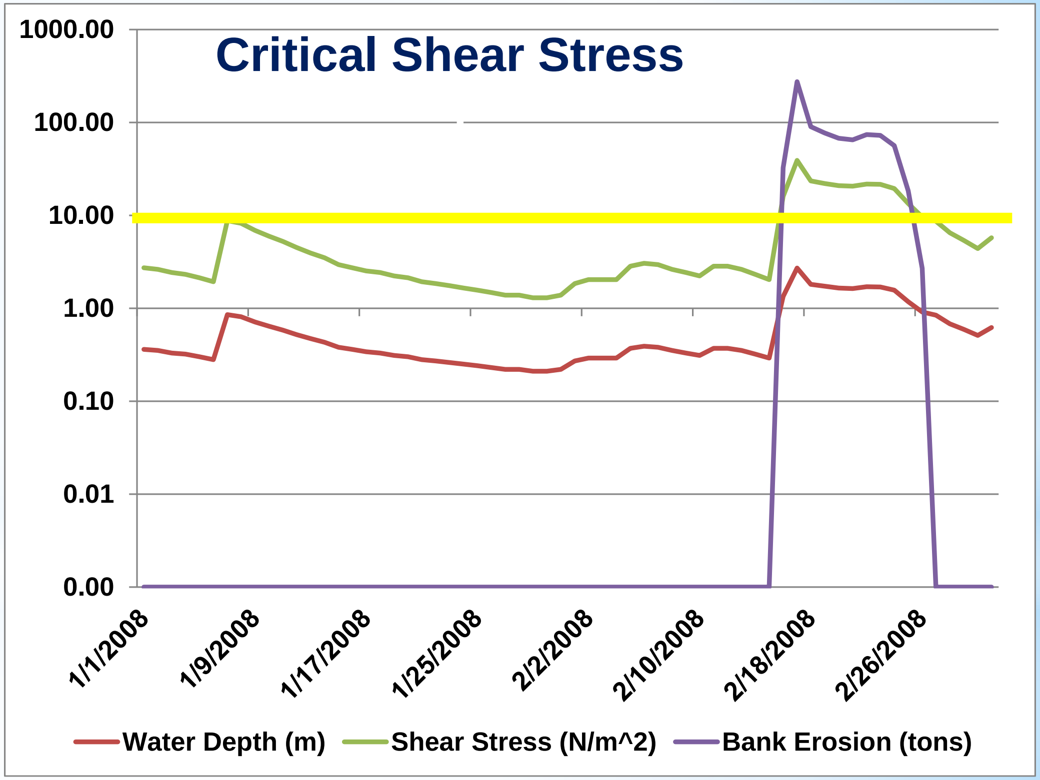
$$\varepsilon_r = k_d(\tau - \tau_c)$$

ε_r = erosion rate (cm s^{-1})

k_d = erodibility coefficient ($cm^3\ N^{-1}\ s^{-1}$)

τ = applied shear stress (Pa)

τ_c = critical shear stress (Pa)



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SWAT Streambank Erosion Modifications

- **Replace empirical applied shear stress equation with process-based**

Empirical

$$\log(SF_{bank}) = -1.4026 * \log\left(\frac{P_{bed}}{P_{bank}} + 1.5\right) + 2.247$$

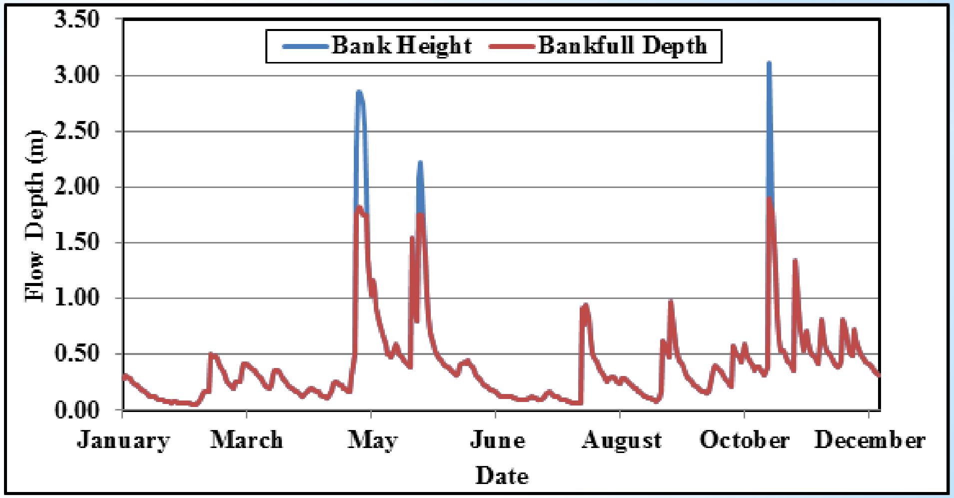
$$\frac{\tau_e}{\gamma * depth * slp_{ch}} = \frac{SF_{bank}}{100}\left(\frac{(W + P_{bed}) * \sin\theta}{4 * d}\right)$$

Process-based

$$\tau = \lambda * R * S_f$$

$$S_f = n^2 * Q^2 / A^2 * R^{\frac{4}{3}}$$

- **Replace bankfull width and depth with top width and bank height**



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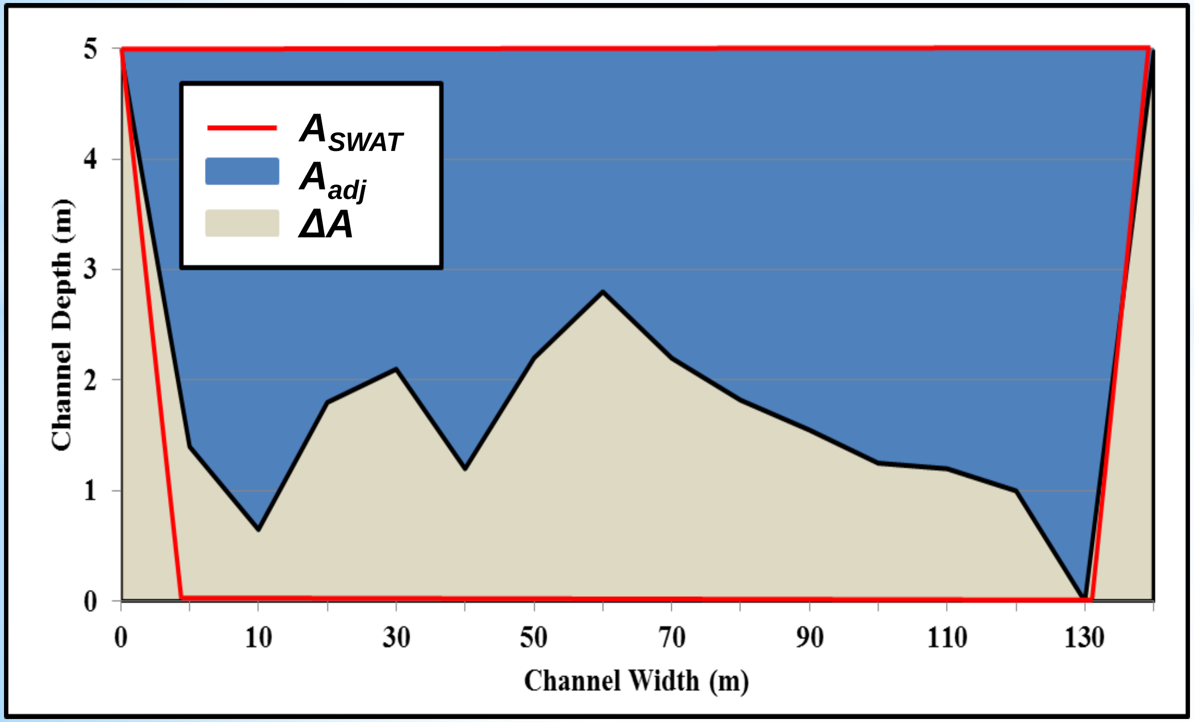
SWAT Streambank Erosion Modifications

- **SWAT assumes 2:1 homogenous trapezoidal cross-section (——)**
- **Area adjustment factor, *a* (≤1):** $A_{adj} = a * A_{SWAT}$



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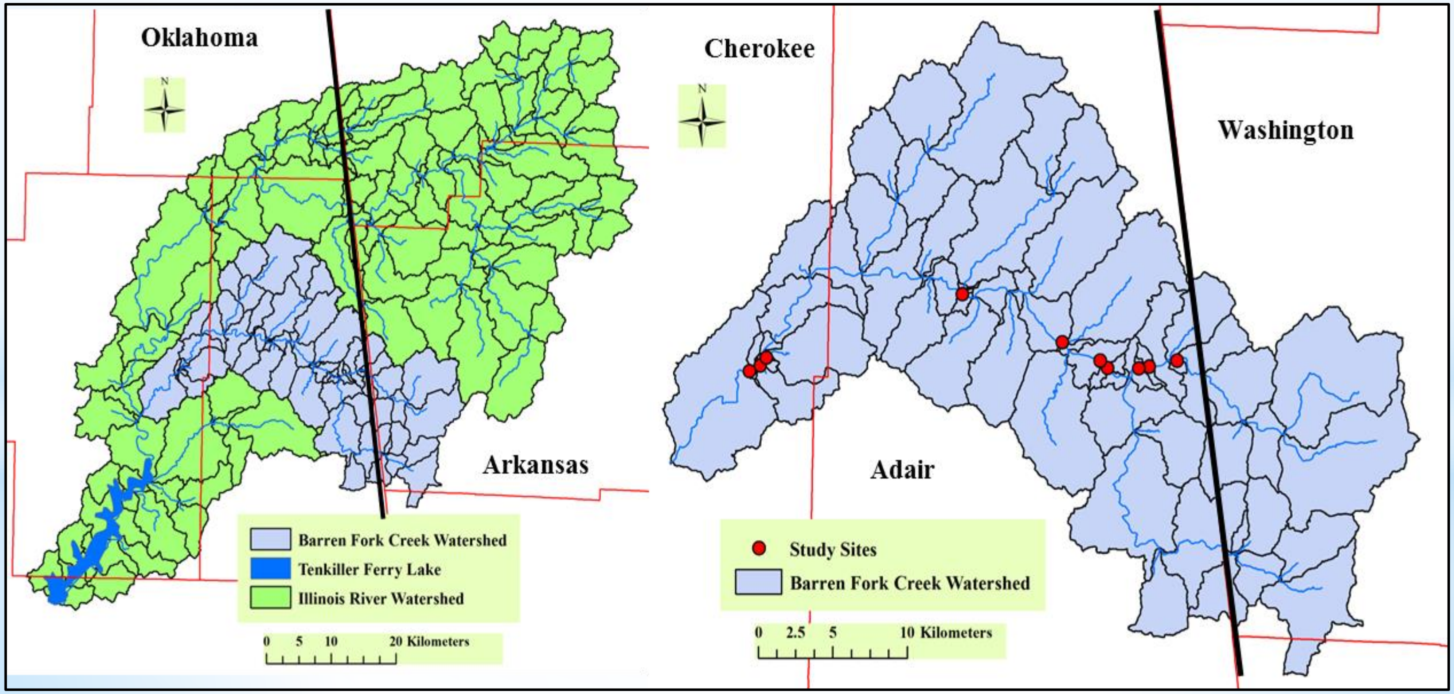
Streambank Data Collection

- Tested new SWAT model on Barren Fork Creek watershed using ten study sites (Miller et al., 2014)
- Characterize stream channel parameters using 28 cross-sectional surveys

Illinois River Watershed   Barren Fork Creek Watershed



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Model Parameter Estimates

- **Literature Based**
  - **Sinuosity**
  - **Radius of curvature**
  - **Bed slope**
- **Field Measured**
  - **Bankfull width and depth**
  - **Bed slope**
  - **Critical shear stress and erodibility coefficient**
  - **Top width and bank height**
  - **Side slope**
  - **Area adjustment factor**

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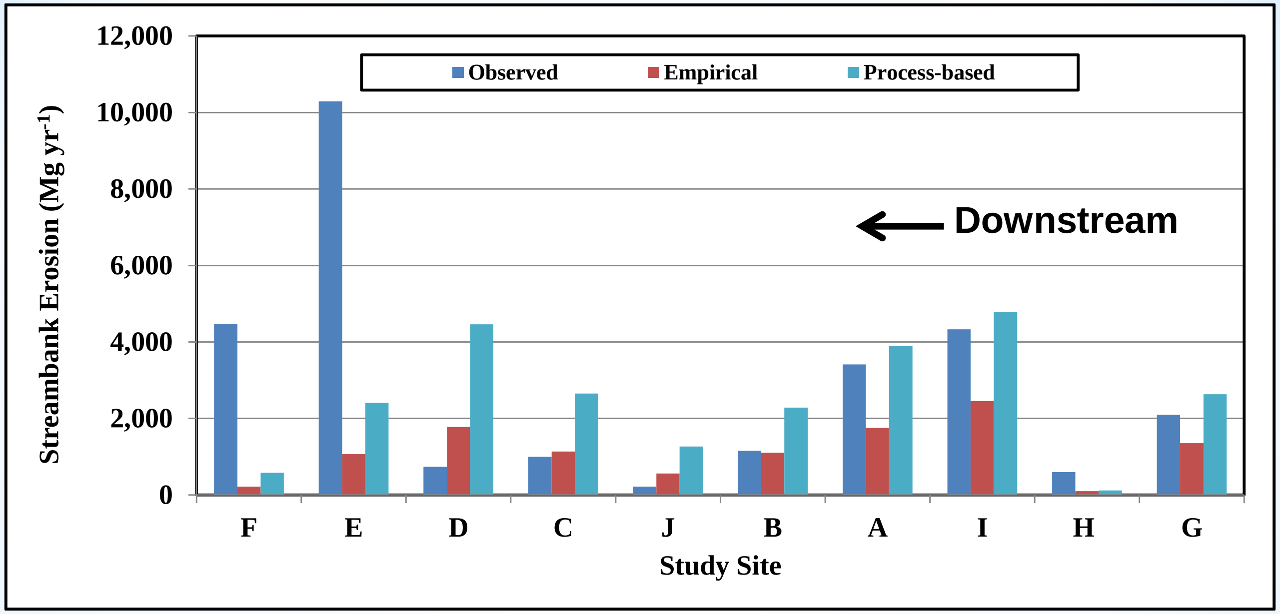
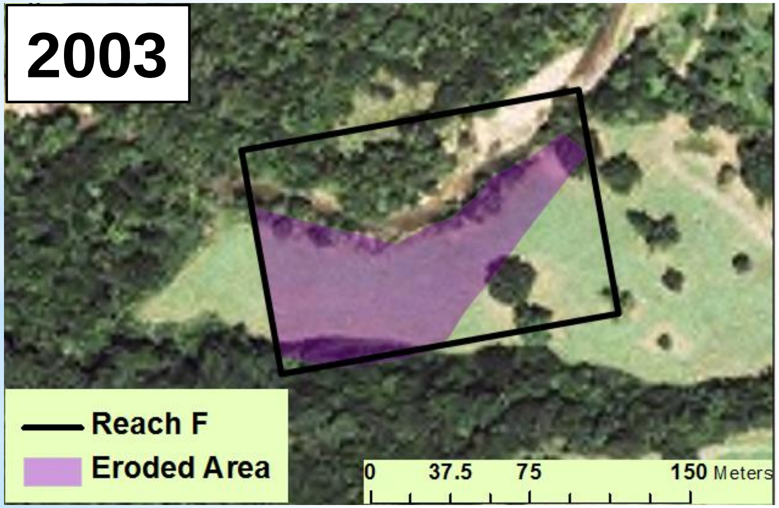
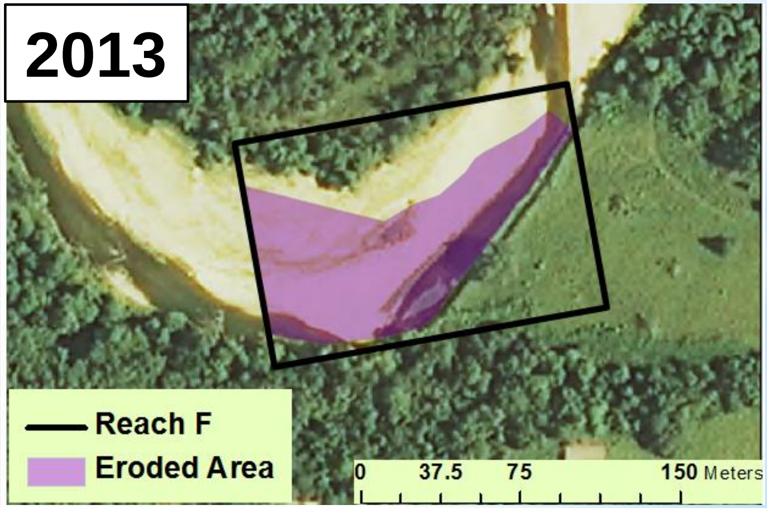
Observed vs Simulated Streambank Erosion







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Observed vs Simulated Streambank Erosion

- **Substantial improvement in model predictions**
  - **SWAT using new streambank erosion model**
  - **Field measurement-based parameter estimates**
- **Observed Streambank Erosion - 2,800 Mg yr^{-1}**

Parameter	Applied Shear Stress Equation					
	Empirical			Process-Based		
	Erosion (Mg yr^{-1})	R^2	NSE	Erosion (Mg yr^{-1})	R^2	NSE
Default	1,150	0.02	-0.33	2,510	0.01	-0.16
Literature based	1,090	0.65	-0.12	2,410	0.65	0.49
Field-based	1,250	0.28	-0.14	2,350	0.46	0.32
Field-based + A_{adj}	2,960	0.34	0.31	3,080	0.47	0.41

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Objective 3

- Predict streambank erosion using SWAT for the Barren Fork Creek watershed with modified streambank erosion routine
- Use SWAT to predict P load in with and without new streambank erosion routine
- Assess significance of streambank as P source

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Extending Field Measurement to Watershed Streambank Parameter Characterization

- **Longitudinal trend**
  - **Bed slope**
  - **Top width**
  - **Streambank total & dissolved P**
  - **Radius of curvature**
- **Average**
  - **Bank height**
  - **Critical shear stress & erodibility coefficient**
  - **Side slope**
  - **Bank composition**
  - **Area adjustment factor**
- **Measured for each reach**
  - **Sinuosity**
  - **Cover factor**

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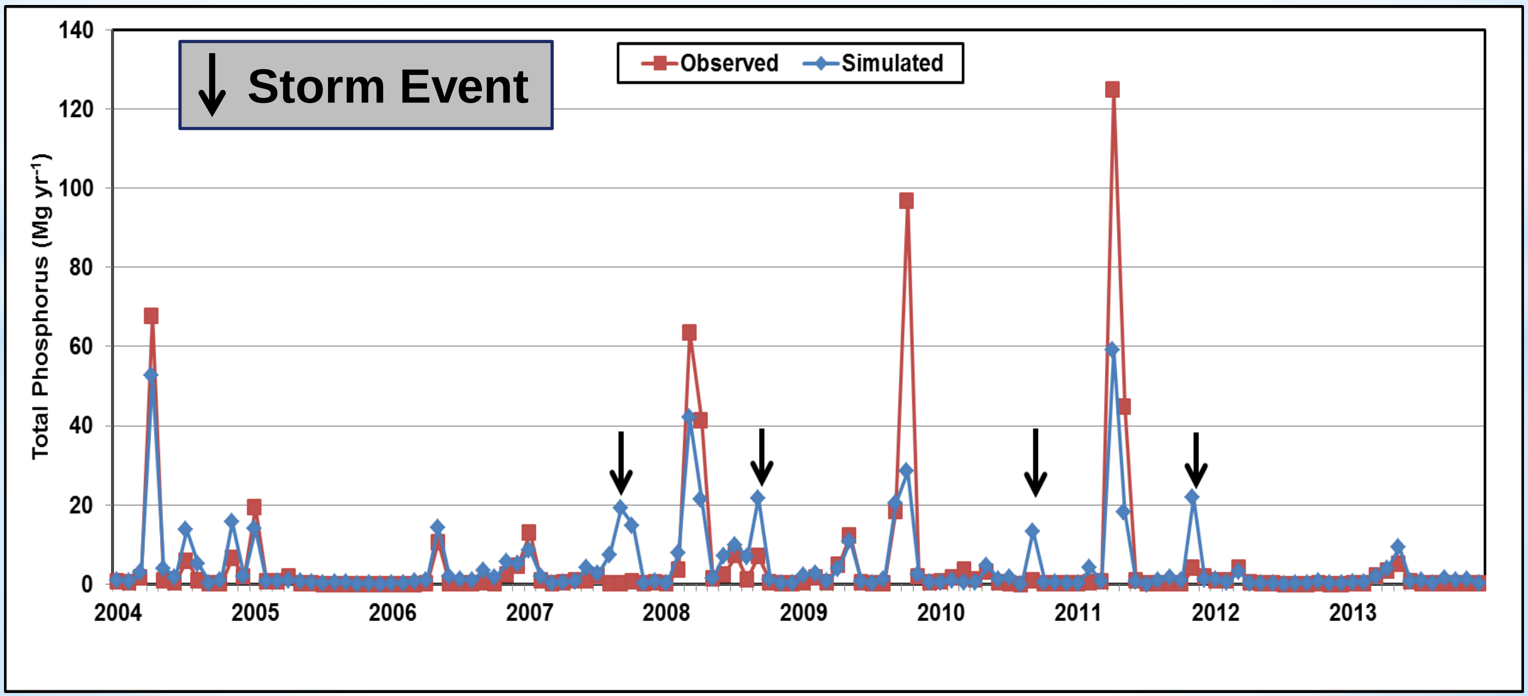
Observed vs Simulated P Without Streambank Erosion

- Under predicts P for large storm events
- Over predicts P for several small events



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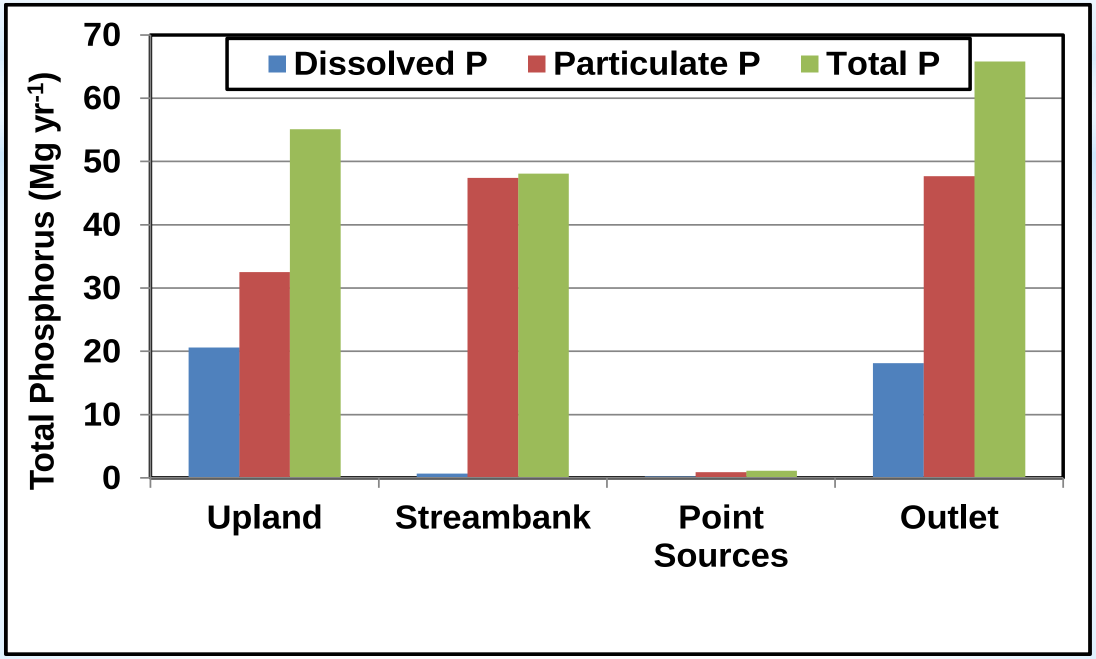
Phosphorus Sources

- >100 Mg yr^{-1} total P load to Barren Fork Creek
- Streambank erosion contributed 47% total P load
- Total P Load
  - 65% leaves watershed
  - 35% remains in watershed (stream, floodplain)



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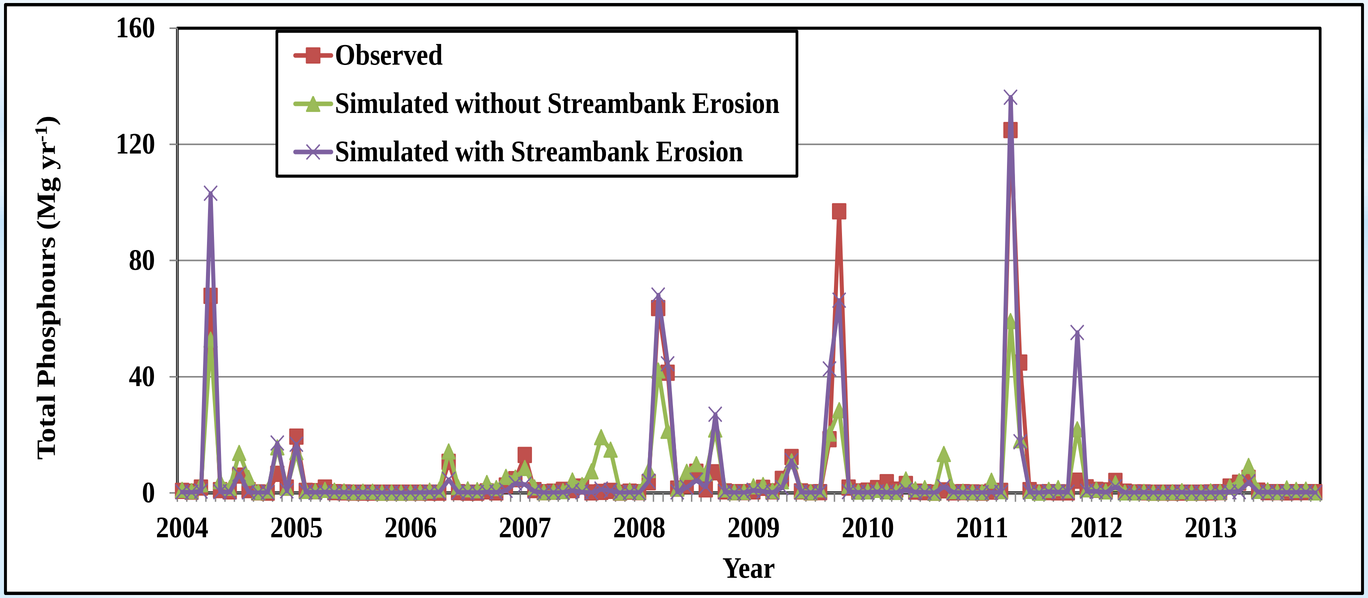
OBSERVED vs SIMULATED P WITH STREAMBANK EROSION

Statistic	Without Streambank Erosion		With Streambank Erosion	
	Calibration	Validation	Calibration	Validation
R^2	0.82	0.80	0.80	0.95
NSE	0.60	0.77	0.78	0.95



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Conclusions

- Modified streambank erosion routine adequately predicted streambank erosion for composite streambanks in Barren Fork Creek watershed
- Process-based applied shear stress equation, area adjustment factor and other changes improved model predictions
- Literature-based stream parameters provided reasonable estimates and predictions

Recommendations

- Watershed-based plans must consider legacy P sources when selecting conservation practices
- Cross-sectional surveys should be conducted when resources permit
- P from streambanks need to be considered, especially for nutrient impacted migrating streams and their receiving waterbodies

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Student Support

- Ph.D. Students: 2
- Undergraduate Student: 1

Questions

?

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Future Work

- Incorporate multiple bank layers and mass wasting into SWAT streambank erosion routine
- Consider incorporating BSTEM or CONCEPTS into SWAT
- Measure P deposition on non-critical bank and floodplain to improve model
- Quantify vegetation and root density effects on streambank erosion
- Test proposed streambank erosion and in-stream P modifications on other watersheds
- Modify SWAT to adjust channel dimensions on a daily time step