Application of Remote Sensing to Watershed Hydrologic/Water Quality Modeling

Remote Sensing Workshop
Norman, Oklahoma
November 12, 2014

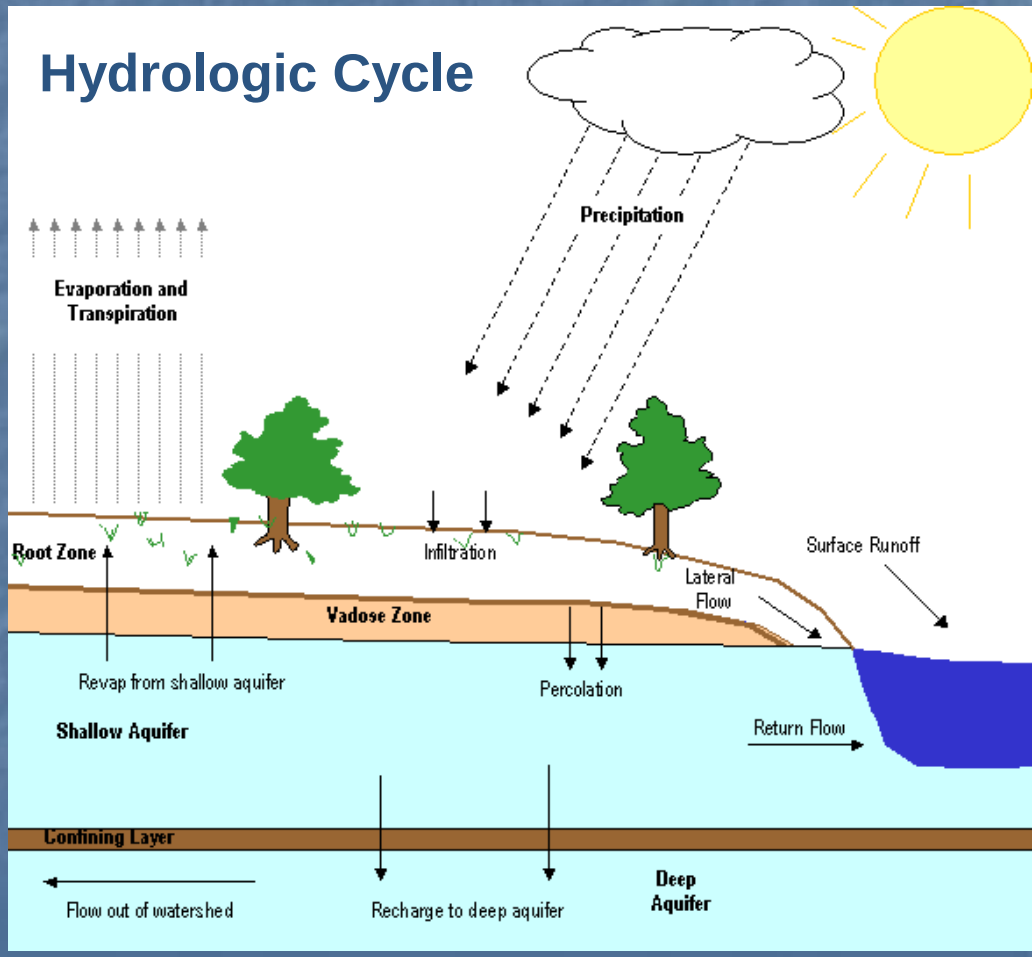
Aaron Mittelstet and Daniel Storm
Department of Biosystems and Agricultural Engineering

Scott Stoodley, Director
Environmental Science Graduate Program

Oklahoma State University

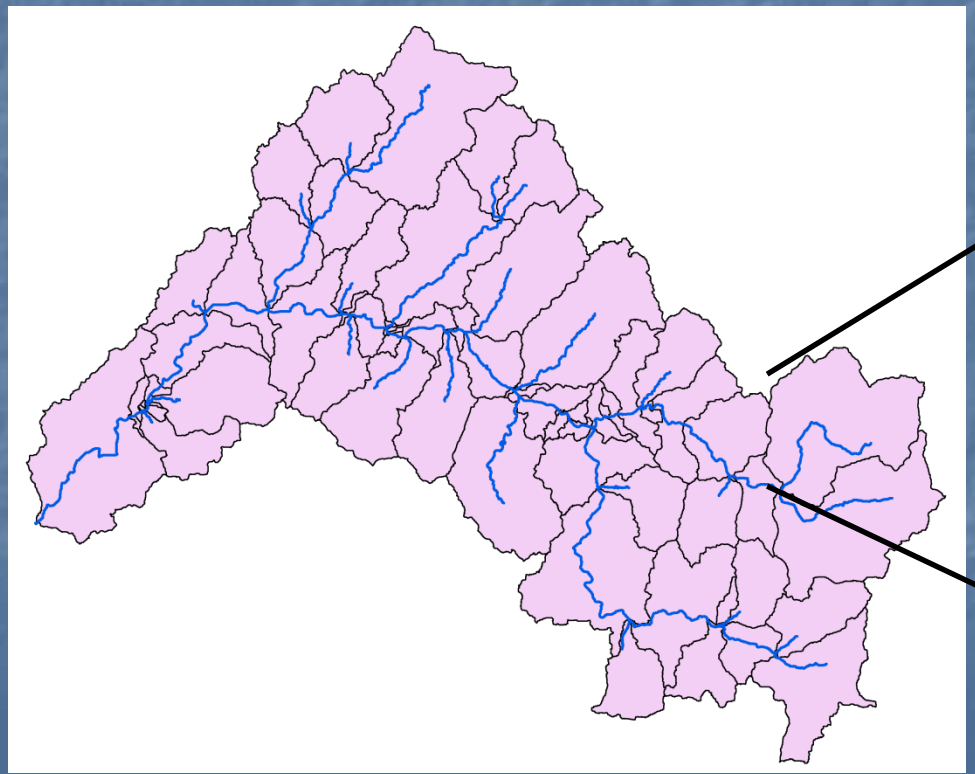
What is a Hydrologic Model?

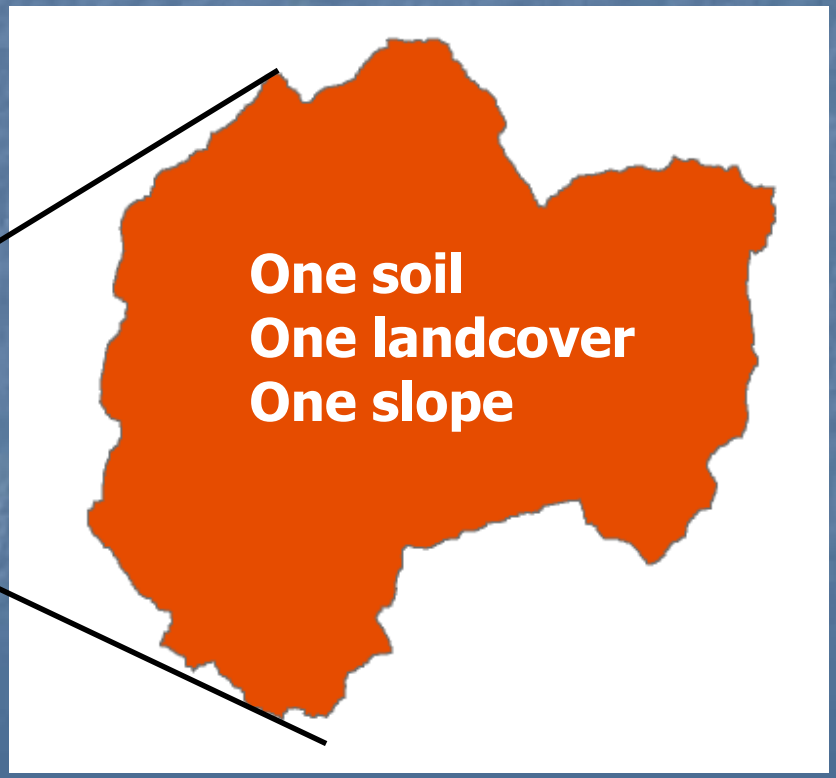
A mathematical representation of the physical, chemical, and biological processes in a watershed.



Hydrologic Model Subdivision

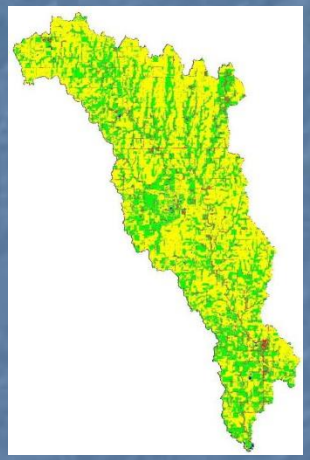
- Watershed delineated into subbasins
- Subbasins divided into Hydrological Response Units (HRUs)



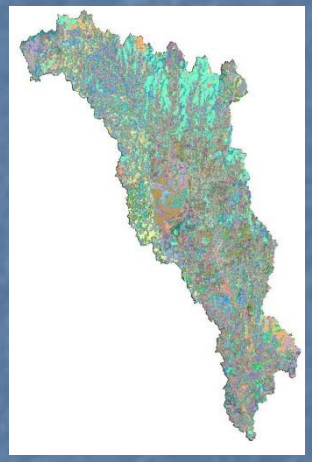


Hydrologic Model Data Requirements

Landcover

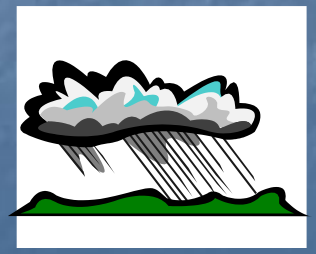


Topography



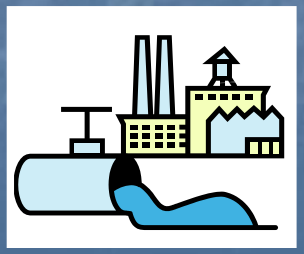
Soils

Weather

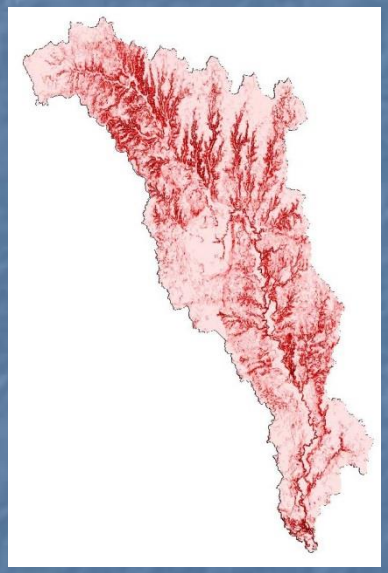


Management

Point Sources

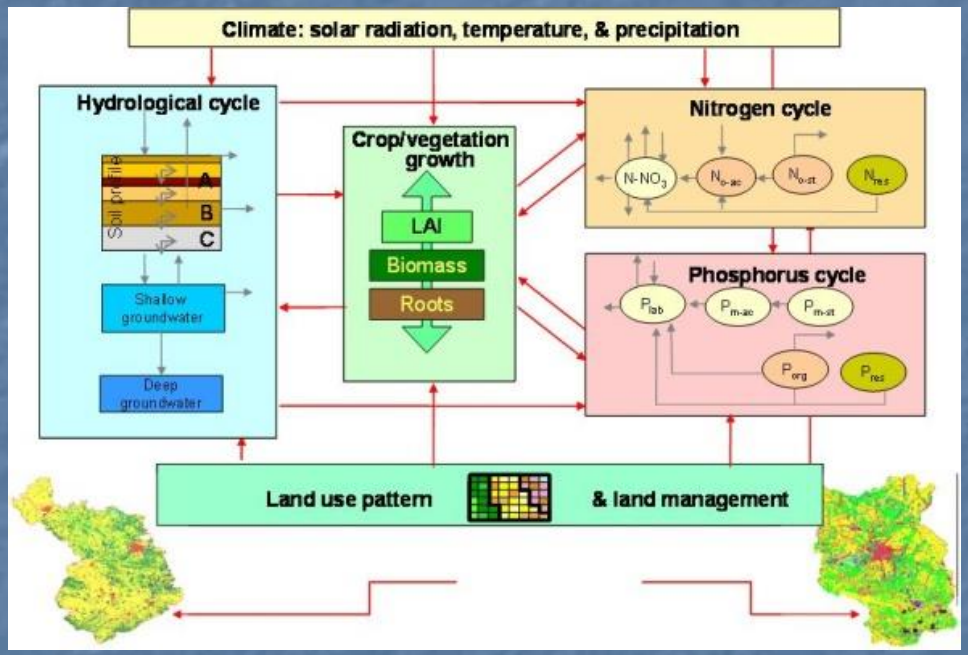


Model Predictions



Soil and Water Assessment Tool (SWAT)

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



Sensors Used in Previous Projects

- Landsat
  - Decades of archived images
  - Free
  - Large coverage
- Other Sensors (IKONOS, QuickBird, SPOT, etc.)
  - Expensive at the watershed scale
- Aerial Photography
  - Requires manual classification

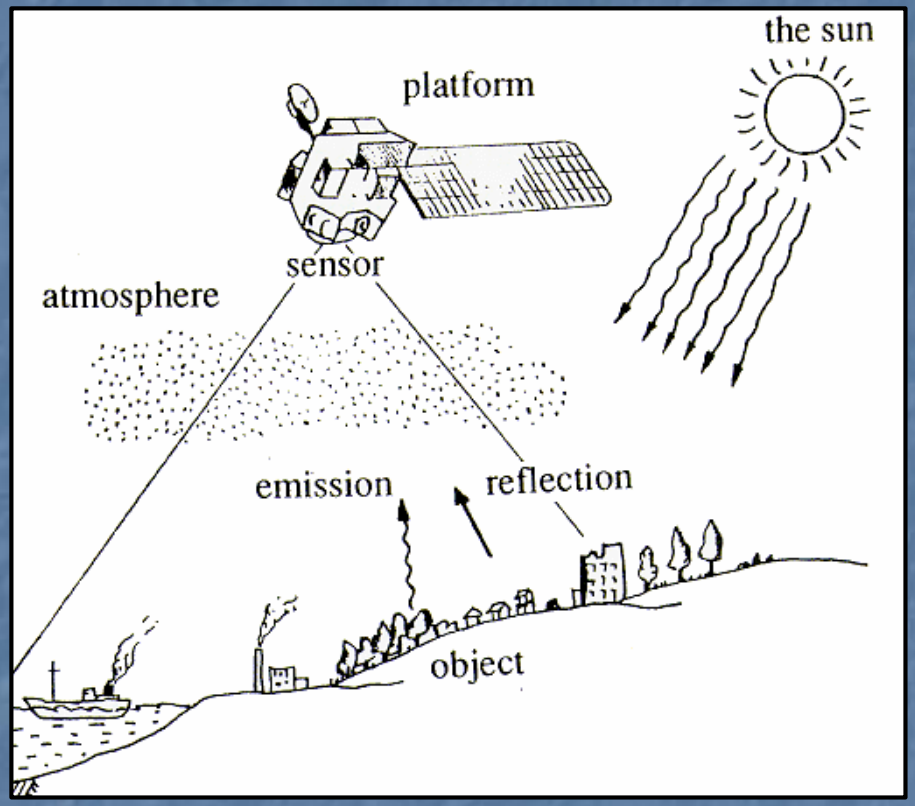


Image Footprint

= Landsat Image

100 mi. x 100 mi.
(Path orientation)

= IKONOS Image

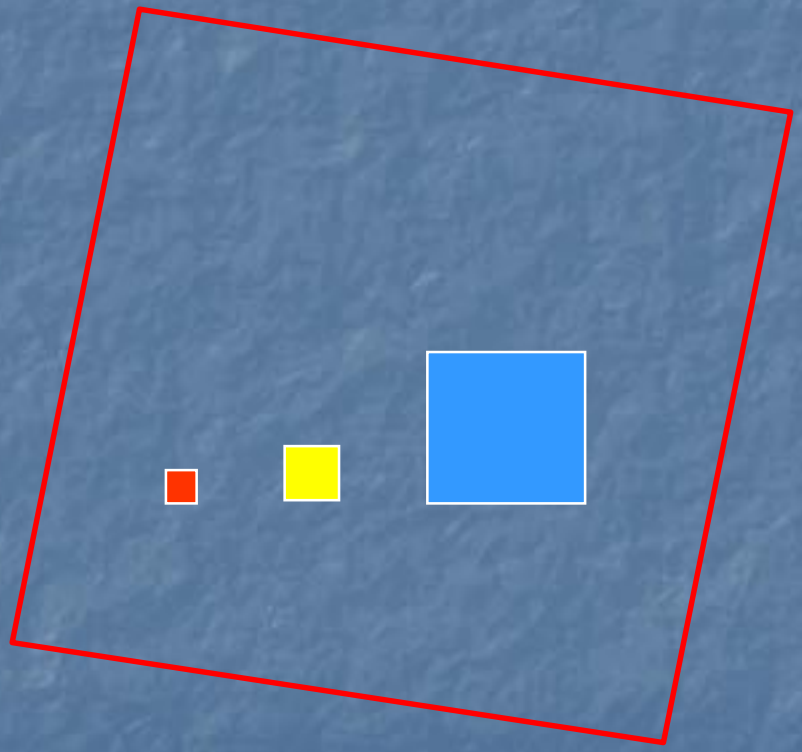
6 mi. x 6 mi.
(Map orientation)

= QuickBird Image

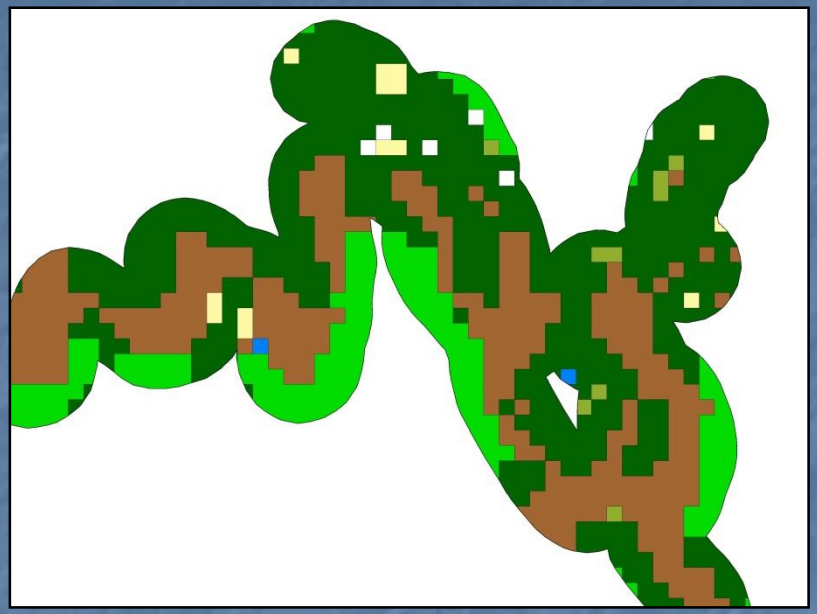
5mi. x 5 mi.
(Map orientation)

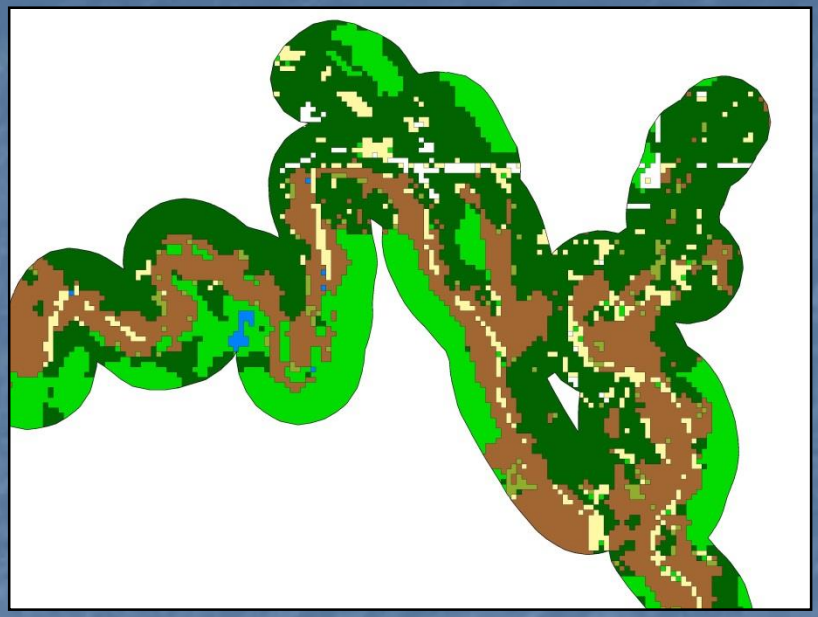
= SPOT 5 Image

36 mi. x 36 mi.
(Map orientation)

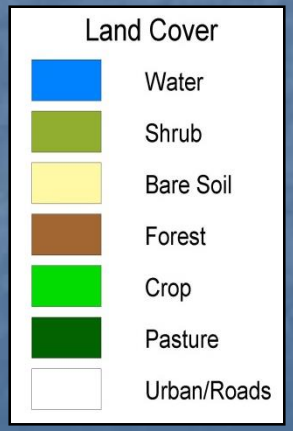


Classified Imagery





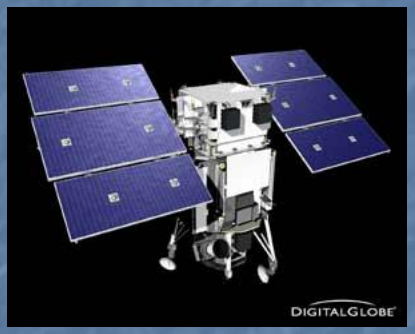
Landsat 7
15-60 m



Spot 5
5-20 m

Newer Data Sources

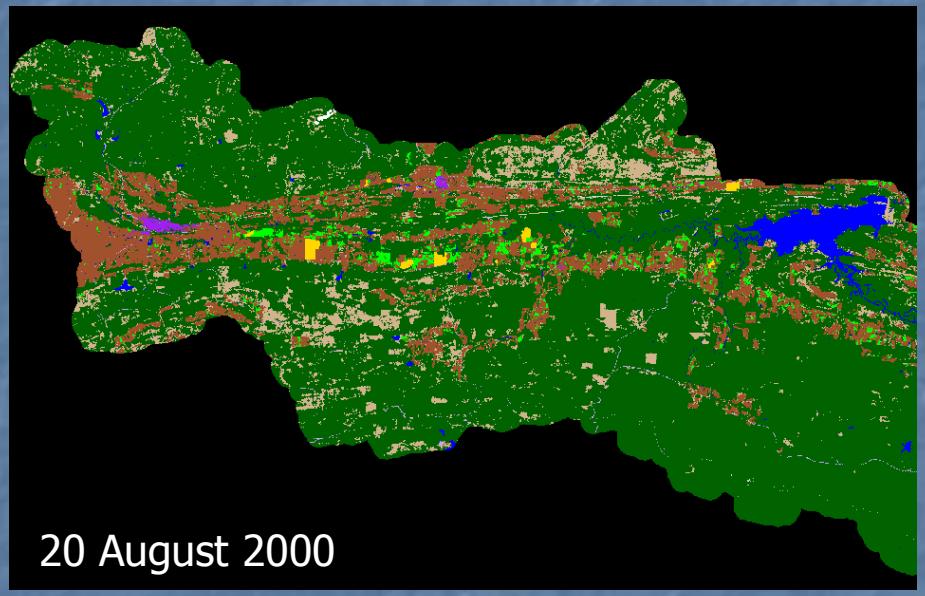
- GeoEye-1
  - Panchromatic (0.41 meter)
  - 4-band multispectral (1.64 meter)
- WorldView II
  - Panchromatic (0.46 meter)
  - 8-band multispectral (1.8 meter)
- WorldView III
  - Panchromatic (0.30 meter)
  - 8-band multispectral (1.24 meter)

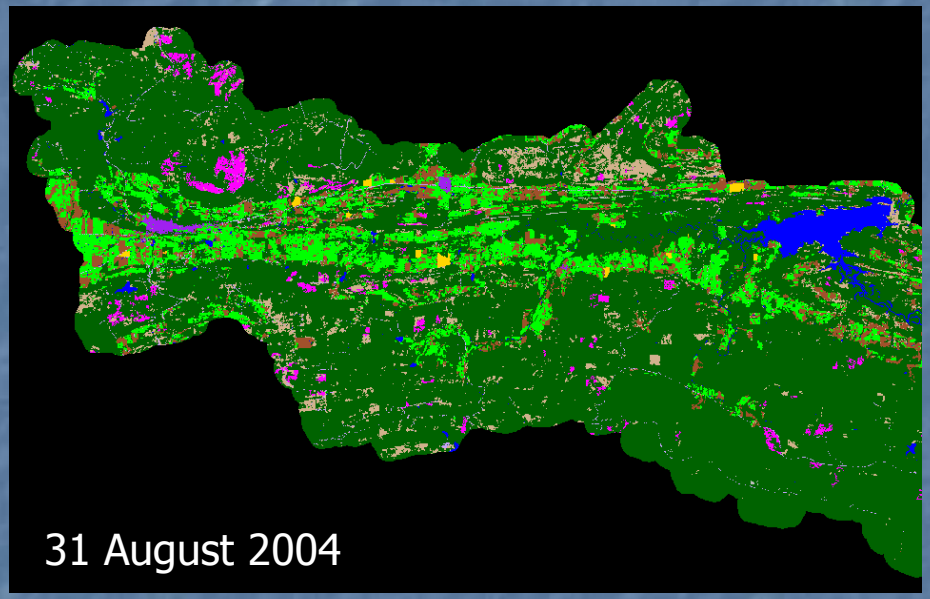


Projects Using SWAT

- **Objectives**
  - Targeting Critical Source Areas of Pollutants
  - Riparian Corridor Targeting
  - Pollutant Source Identification for TMDLs
- **Watersheds**
  - Fort Cobb Reservoir
  - Lakes Eucha/Spavinaw
  - Illinois River
  - Stillwater Creek
  - Turkey Creek
  - Elem Fork/North Fork River
  - Lake Wister
  - North Canadian River
- **Agencies**
  - Oklahoma Conservation Commission
  - Oklahoma Department of Environmental Quality
  - US EPA Region VI
  - USDA-ARS
  - City of Tulsa

Landcover Classification: Lake Wister Watershed, Oklahoma



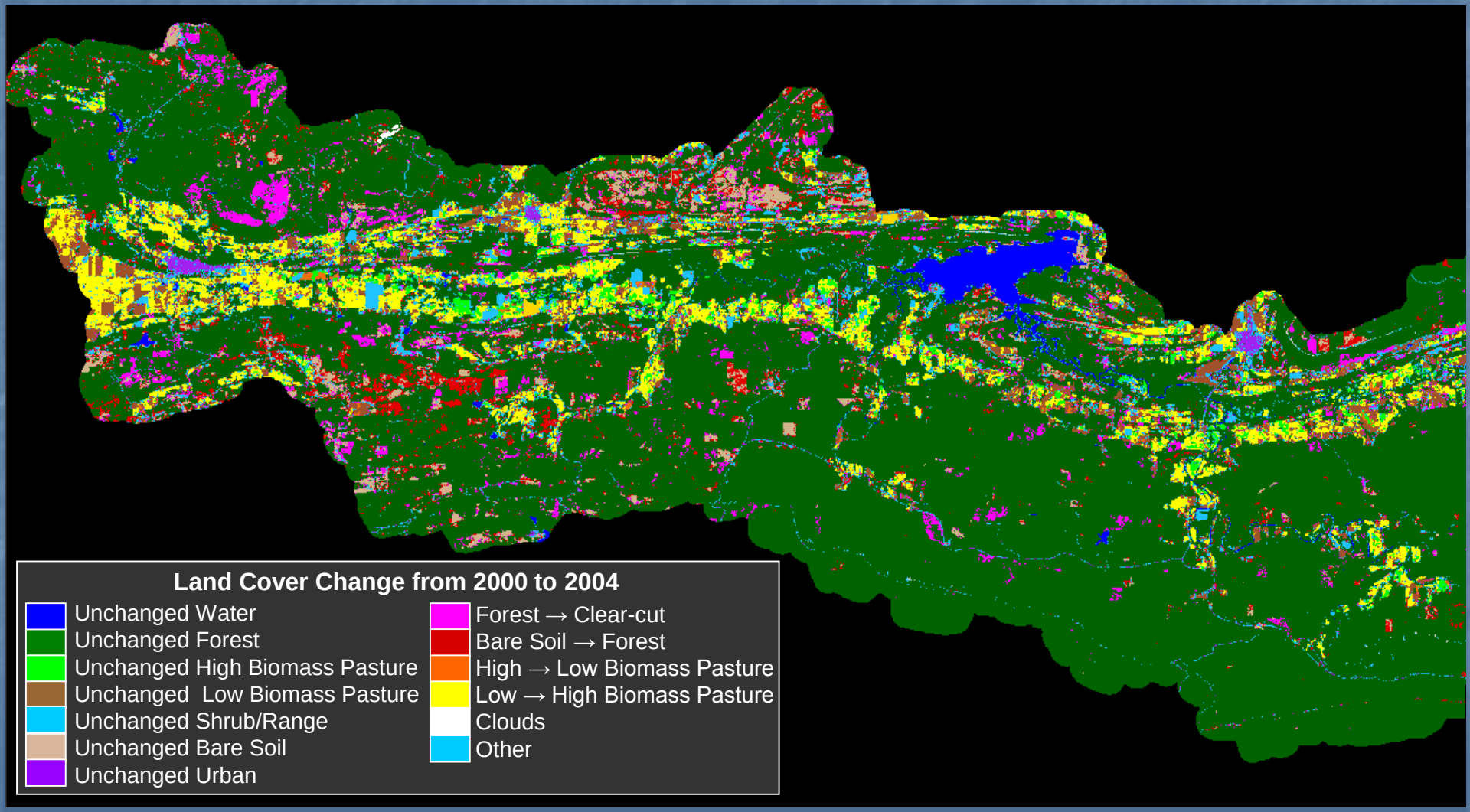


Land Cover Categories

Water	Clear-cut
Forest	Rock Outcropping
High Biomass Pasture	High Density Urban
Low Biomass Pasture	Low Density Urban
Shrub / Range	Mining
Bare Soil	Clouds

- **Landcover data can be useful for a wide variety of applications**
- **In this case, landcover data were used in a SWAT model to identify critical source areas of phosphorus and target BMPs.**

Change Detection:
Lake Wister Watershed, Oklahoma



AMEC Earth & Environmental

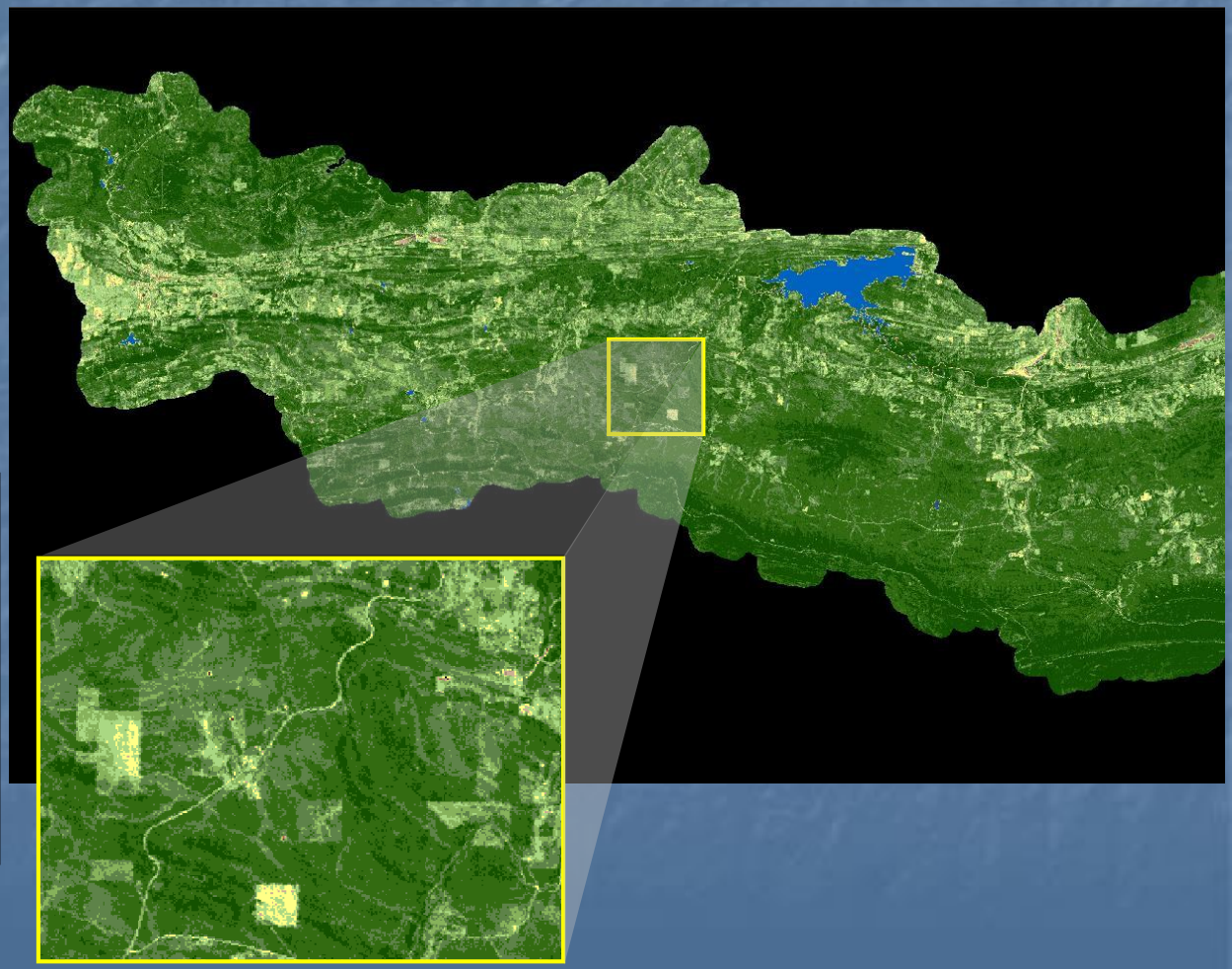
Vegetation Analysis: Lake Wister Watershed, Oklahoma

Normalized Difference Vegetation Index

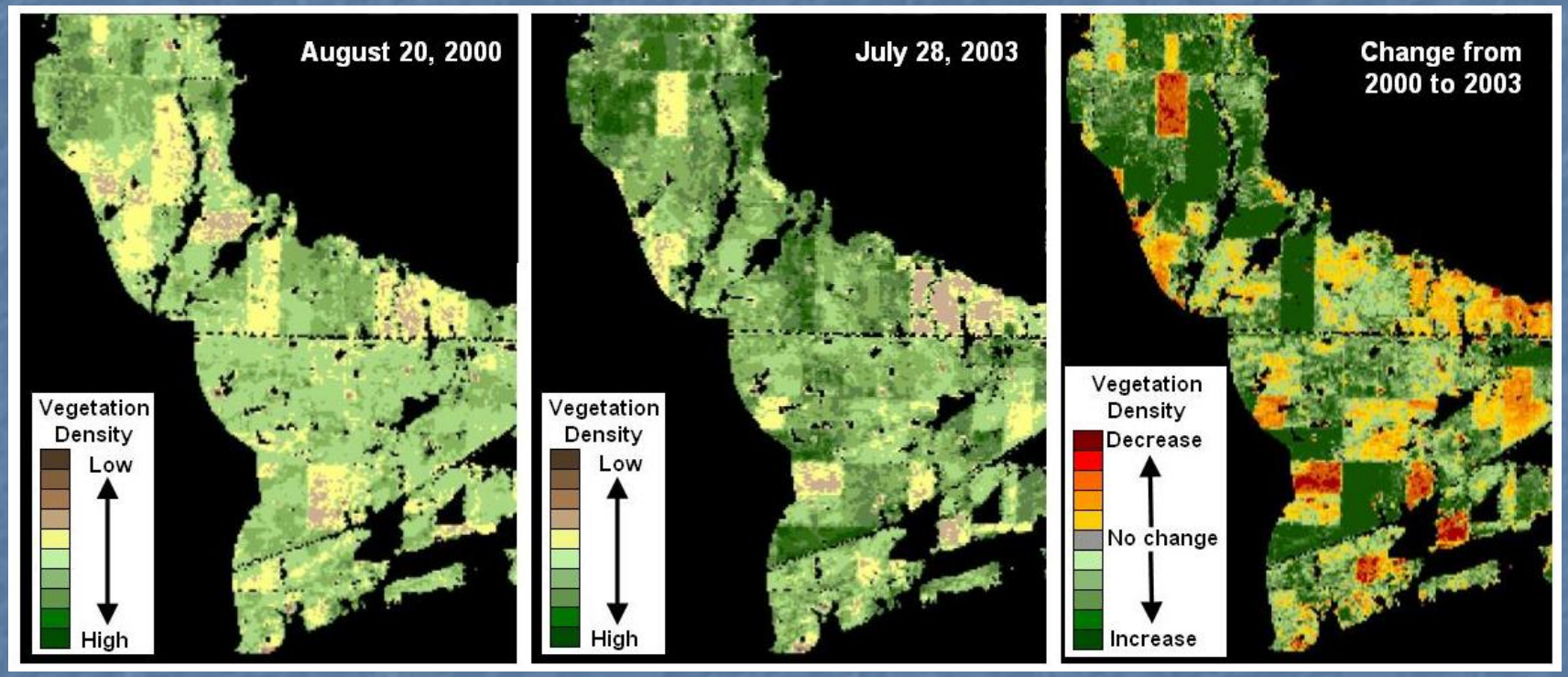
$$NDVI = \frac{(NIR-Red)}{(NIR+Red)}$$

Normalized Difference Senescent Vegetation Index

$$NDSVI = \frac{(SWIR-Red)}{(SWIR+Red)}$$

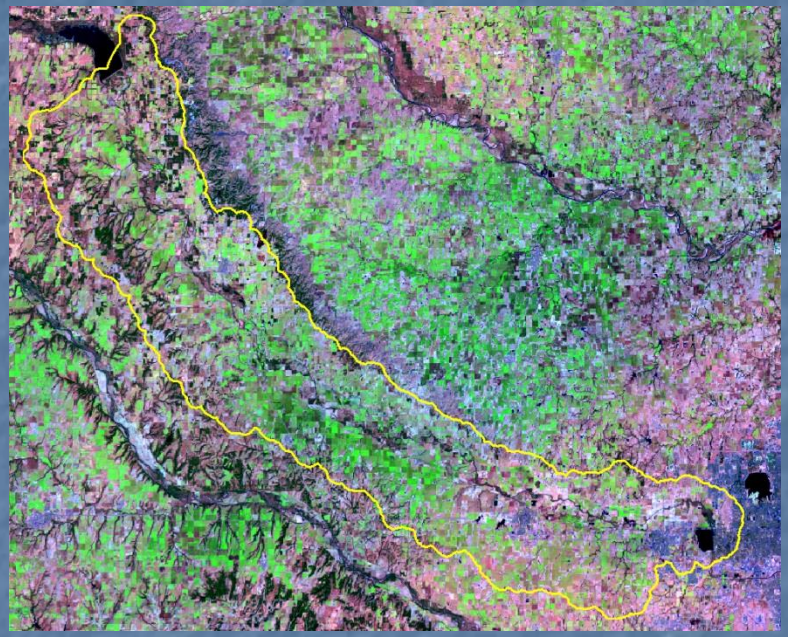


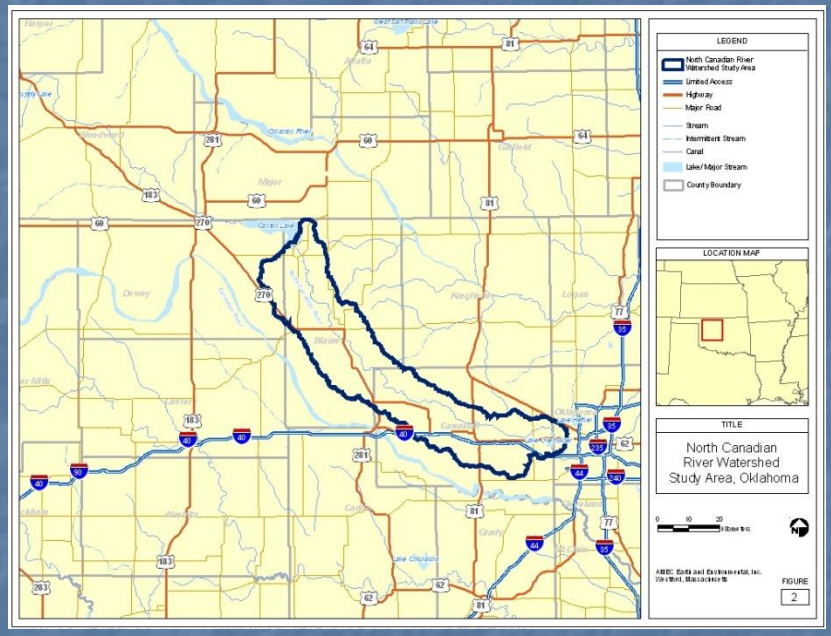
Vegetation Analysis: Lake Wister Watershed, Oklahoma



- Vegetation was analyzed to evaluate the effectiveness of implemented BMPs to reduce runoff from pastures

Landcover Classification: North Canadian River, Oklahoma

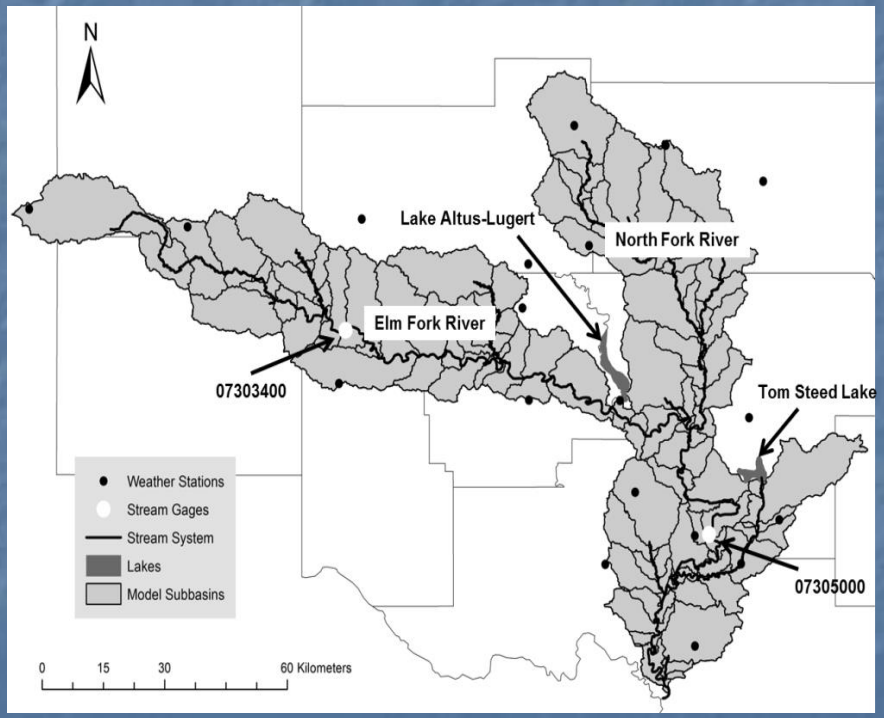


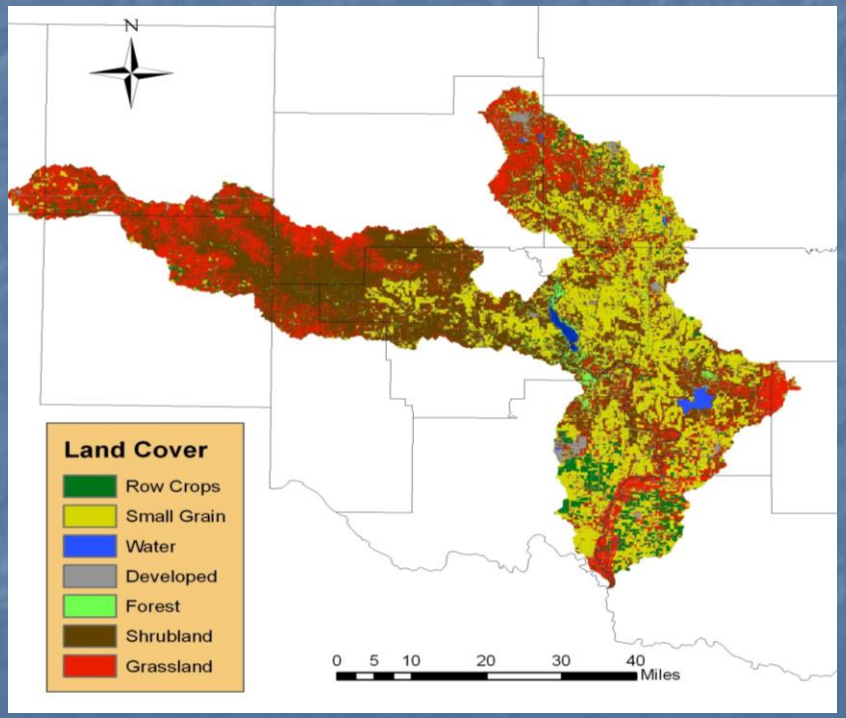


- Satellite remote sensing was used to develop accurate and current landcover data for use as an input to the SWAT model.
- The SWAT model was used to identify critical source areas of nitrogen and phosphorus and determine the endpoint for Lake Overholser necessary to meet Oklahoma WQS.

North Fork River Watershed

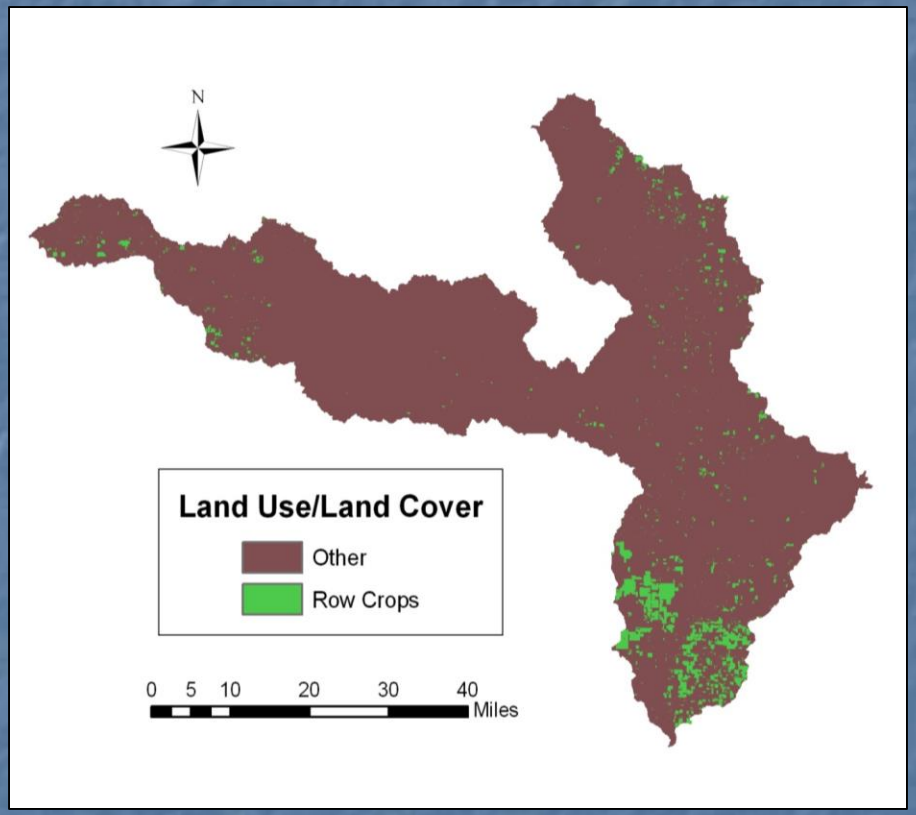
- **Objective: Predict streamflow, salinity and crop yields based on weather variability**





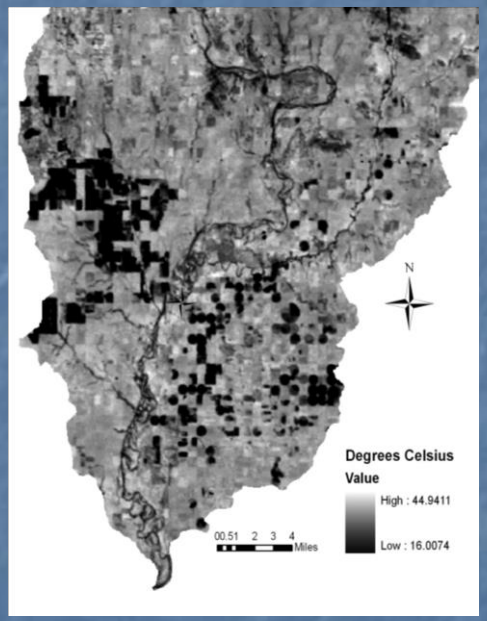
North Fork River Watershed Identification of Irrigated Cotton

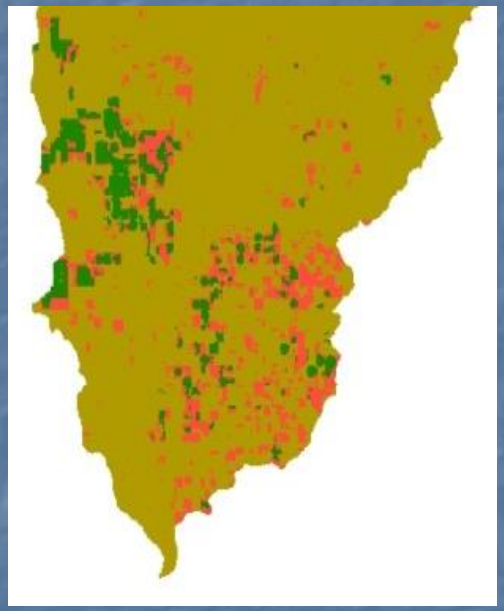
- 21,000 hectares of cotton
- Issue: differentiating dryland from irrigated cotton

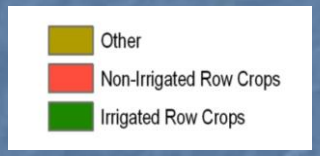


North Fork River Watershed Identification of Irrigated Cotton

- Thermal band six from Landsat 5 utilized
- Cooler areas identified as irrigated cotton



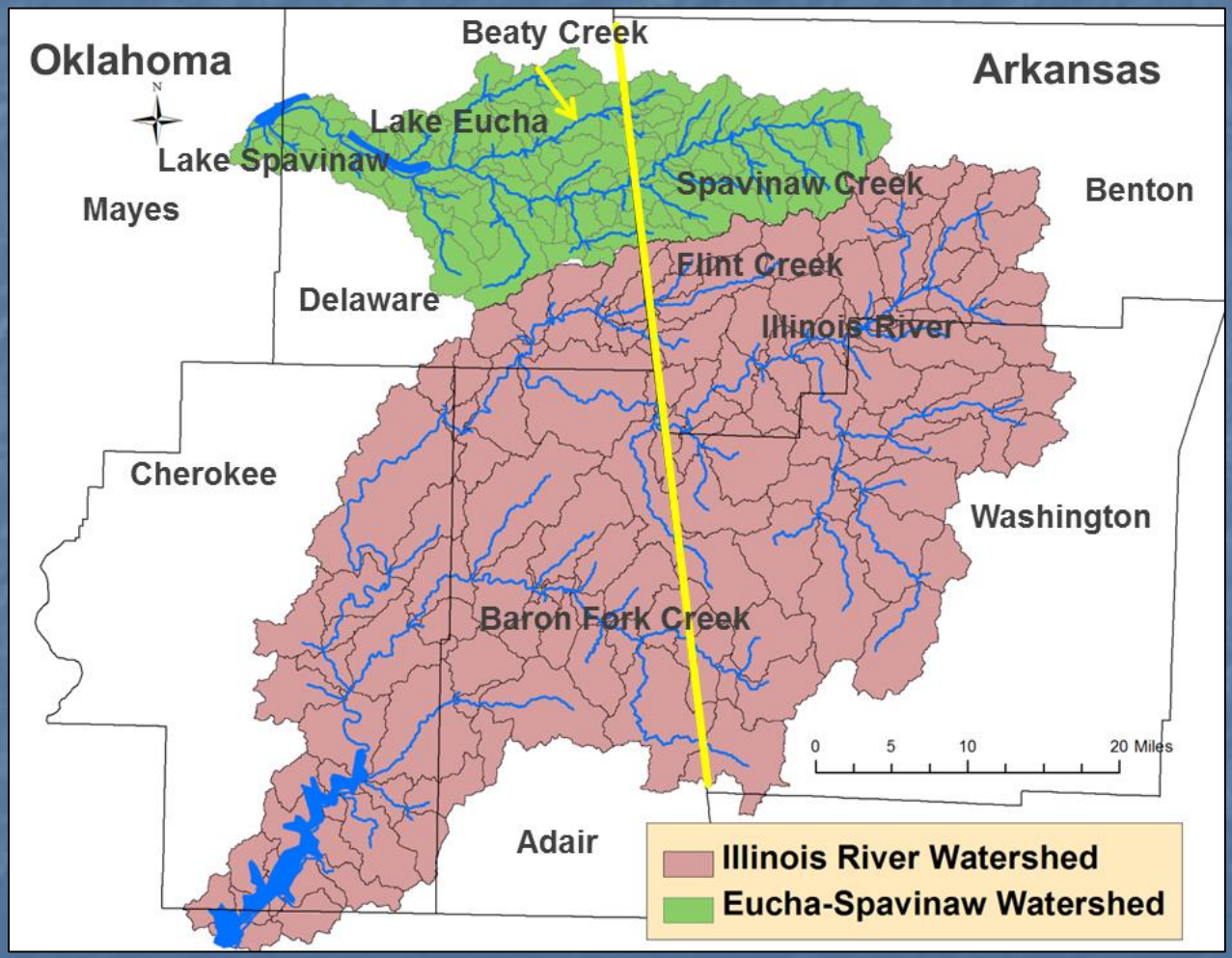




$$T = \frac{K2}{\ln\left(\frac{K1}{L_\lambda} + 1\right)}$$

Land Use	Basin Area	
	Percent	km²
Developed Land	4.5	250
Forest	2.1	120
Grassland	24.4	1360
Row Crops	3.8	210
• Dryland	2.0	110
• Irrigated	1.8	100
Scrubland	37.4	2080
Small Grain Crops	27.1	1510
Water	0.7	390

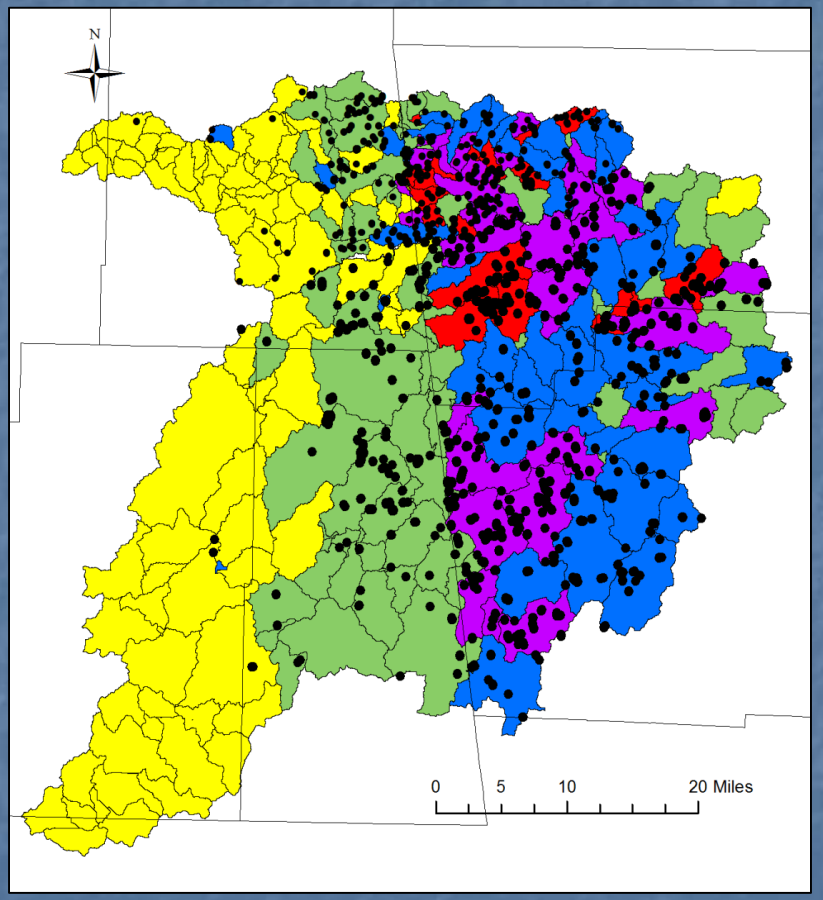
Illinois River and Lakes Eucha-Spavinaw Watersheds



Illinois River/Lakes Eucha-Spavinaw Elevated Phosphorus in Surface Waters

- Sources
  - Poultry
  - Cattle
  - Wastewater treatment plants
  - Other

County	# of Broilers (million)
Benton	120
Washington	115
Delaware	50
Adair	30
Cherokee	2

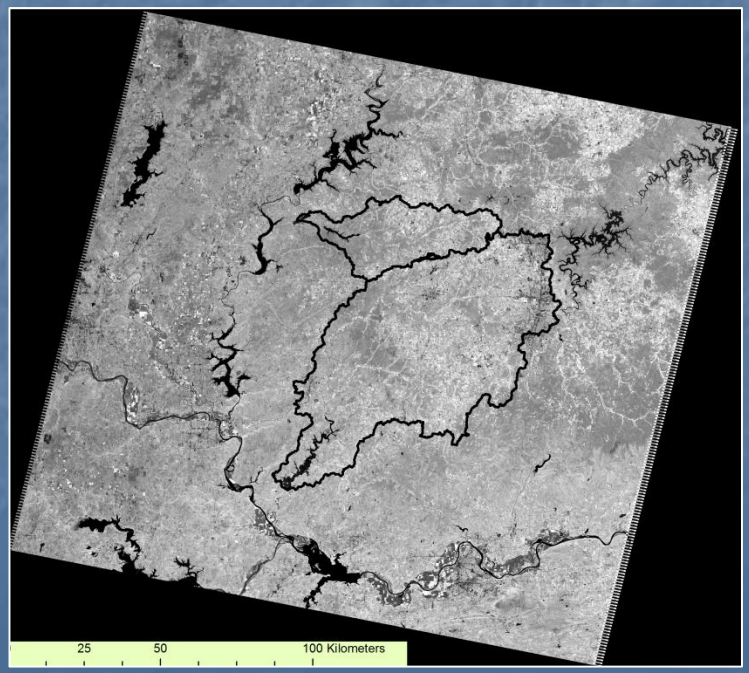


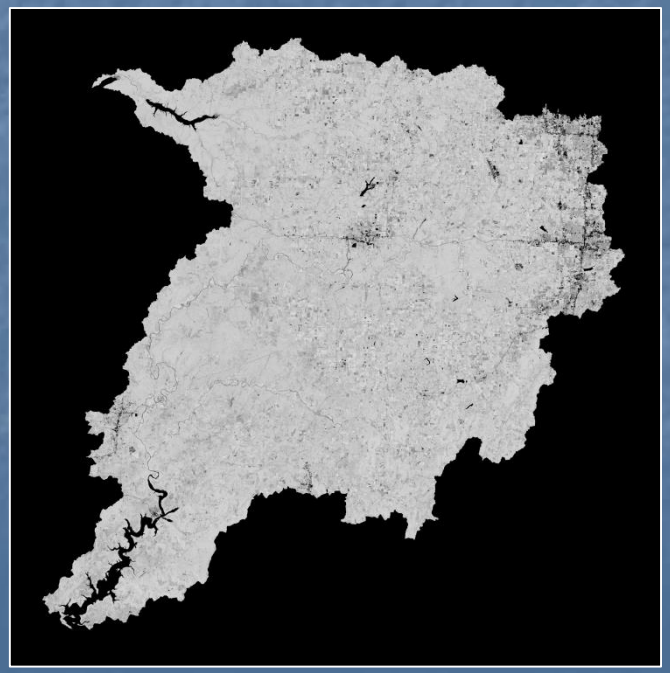
Illinois River/Lakes Eucha-Spavinaw Modeling Objectives

- Quantify sources of P reaching streams and reservoirs
- Identify management practices needed for Oklahoma to meet water quality standards
- Issue: latest available landcover dataset is 2001 NLCD

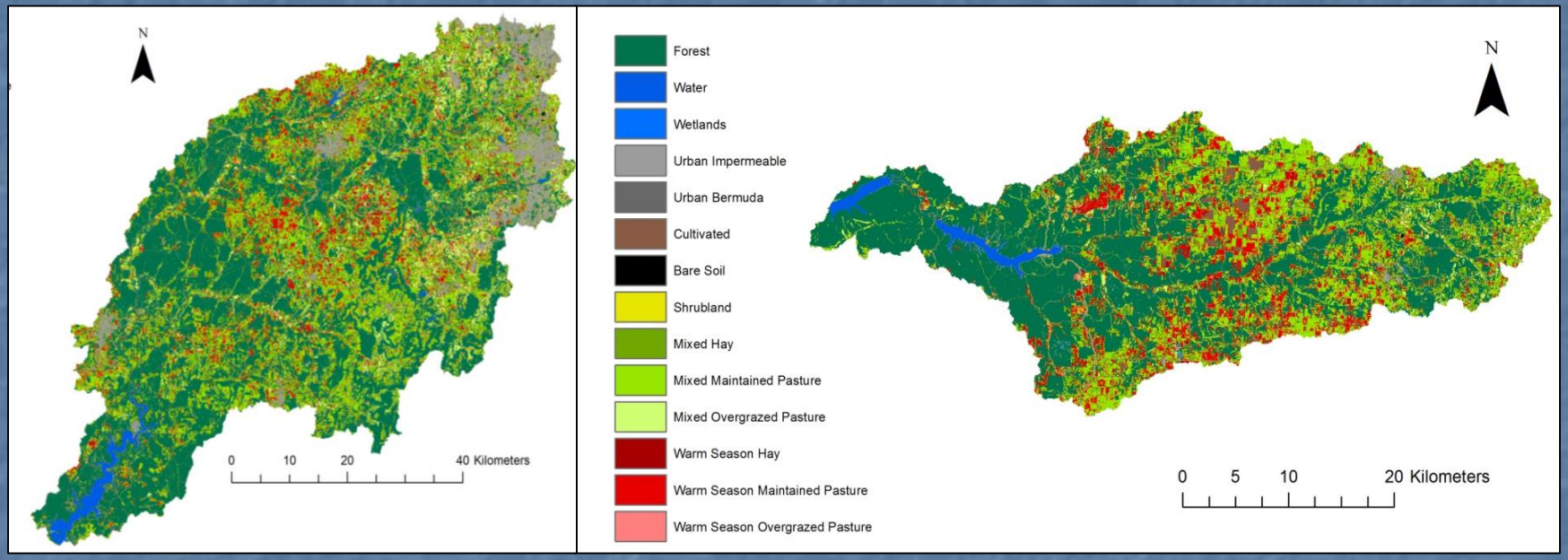
Illinois River/Lakes Eucha-Spavinaw Landcover Generation

- Used ArcGIS 10.0 and Erdas Imagine 9.3
- Utilized Landsat 4-5 TM images from October and December 2010; May and August 2011
- Normalized Difference Vegetation Index (NDVI) calculated





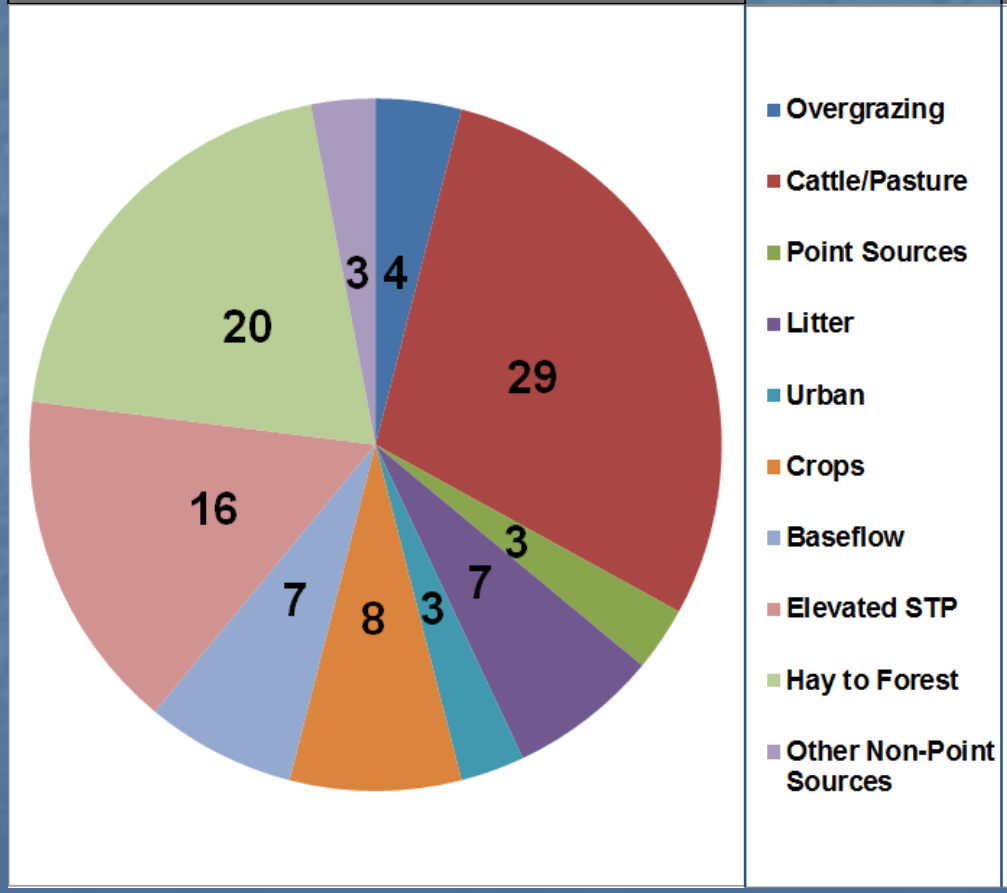
Illinois River/Lakes Eucha-Spavinaw Landcover Generation



Land Use	Illinois River Watershed (%)	Eucha-Spavinaw Watershed (%)
Forest	47.2	48.6
Well-Managed Pasture	19.0	27.0
Overgrazed Pasture	8.3	3.4
Hay	11.9	8.7
Rangeland	3.6	2.6
Row Crops	0.2	1.1
Bare Soil	0.2	0.1
Urban	8.5	2.4
Water	1.3	1.9

Illinois River/Lakes Eucha-Spavinaw Phosphorus Sources By Land Use

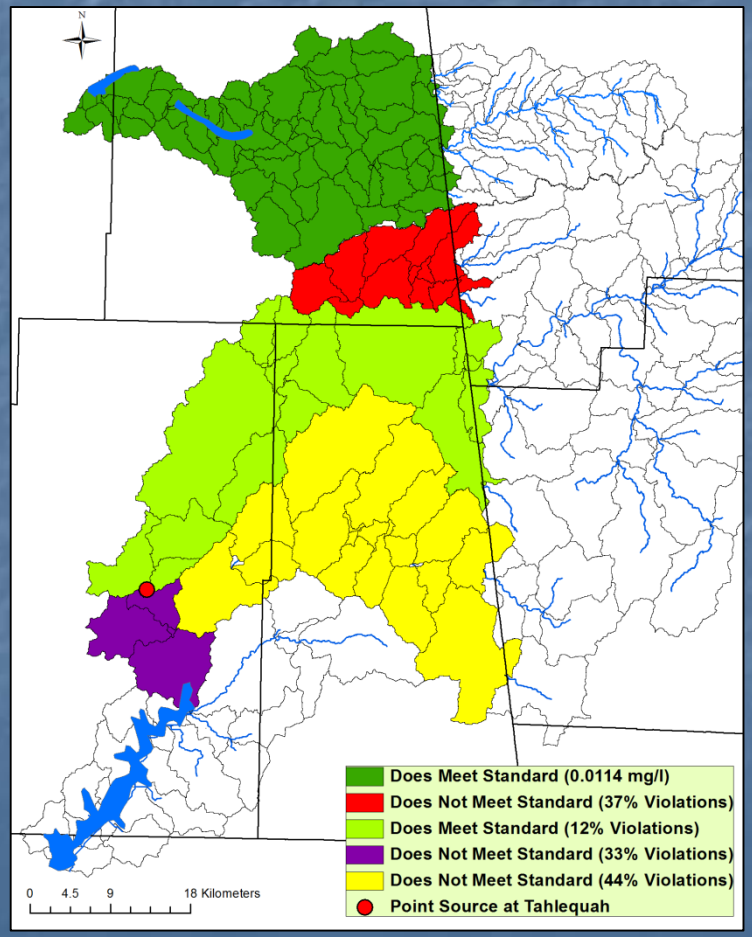
Entering Lake Eucha: 30,000 kg P/yr



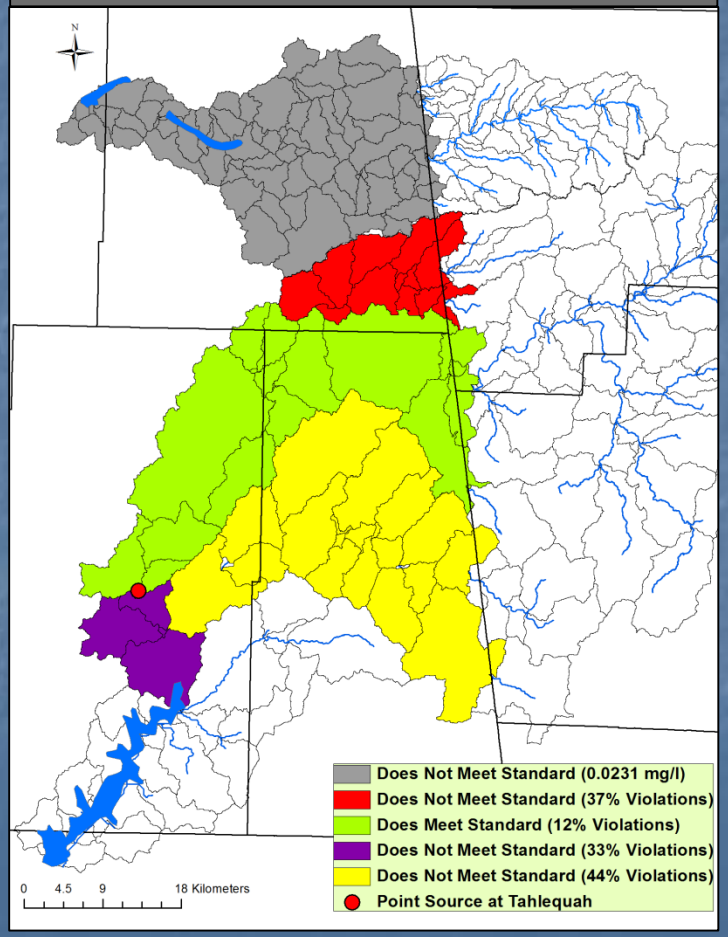
Entering Lake Tenkiller: 190,000 kg P/yr

Current Oklahoma Water Quality Standard Exceedances

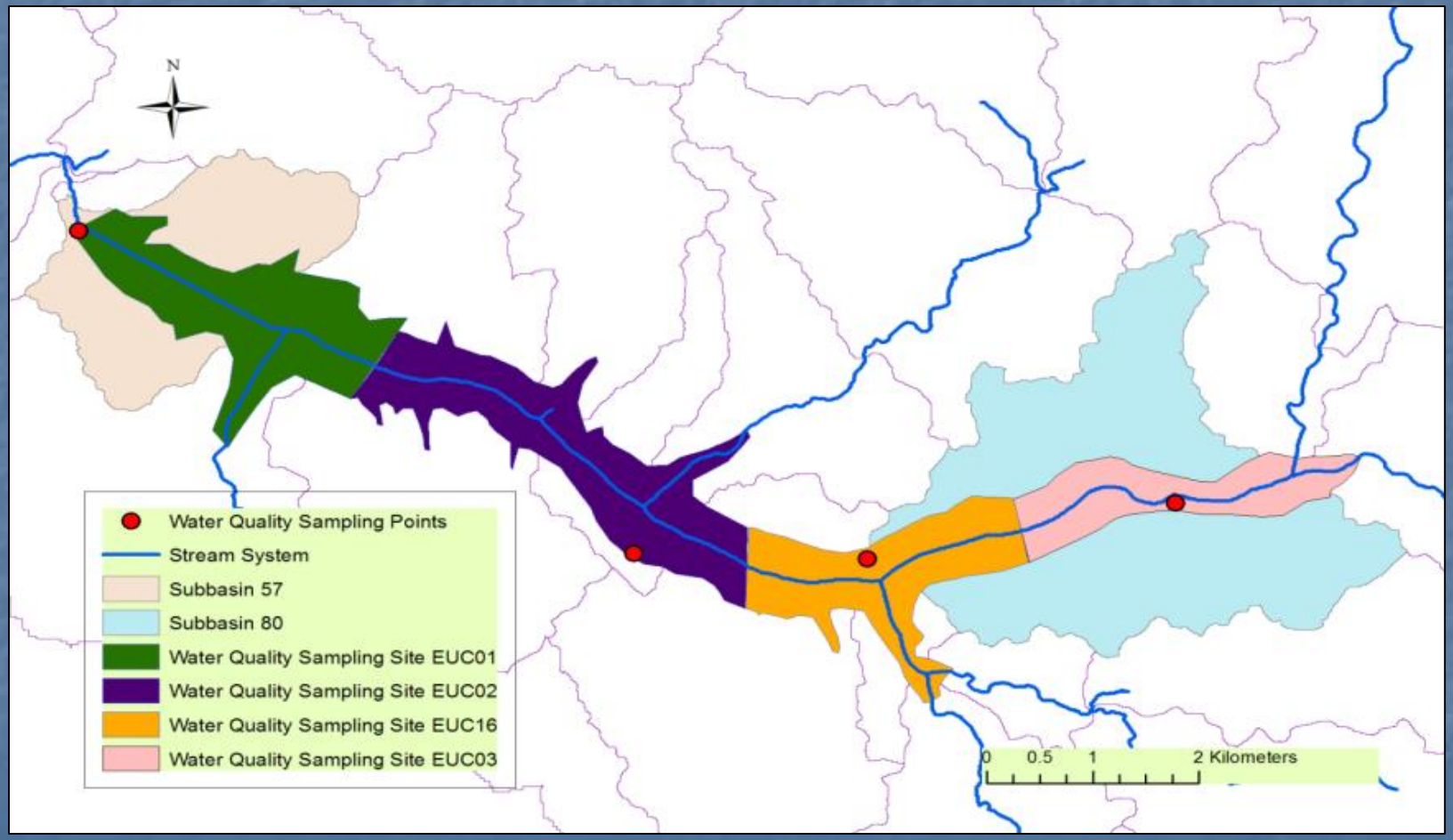
Lake Eucha P concentration from weighted average



Lake Eucha P concentration from upper end of the lake (worst case)



Lake Eucha Weighted Average Phosphorus Concentration



Example Scenarios to Meet OK Water Quality Standards

Illinois River Watershed

- No litter application
- No overgrazing
- 50% pasture to hay
- No urban P fertilizer

Eucha-Spavinaw Watershed

- No Litter Application
- All crops converted to forest

Questions?

Aaron Mittelstet

aaron.mittelstet10@okstate.edu

Dan Storm

dan.storm@okstate.edu

Scott Stoodley

scott.stoodley@okstate.edu