Calibration and Validation of AnnAGNPS and SWAT Models in Agricultural Watersheds in CEAP South-central Kansas

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Introduction

Watershed Quality Assessment and Modeling

- Current water quality assess. techniques
  - Water quality monitoring
  - Water quality modeling
- Modeling can save time, cost, and allow for testing management alternatives (Shirmohammadi et al., 2006)
- Watershed modeling approach
  - Quantify pollutants loads
  - Identify critical areas for BMPs implement.
  - Evaluate/compare BMPs effectiveness
- Selection of appropriate models
  - Understand models algorithms
  - Calibration and validation against historical data

Source: Dept. of Agronomy, 2007

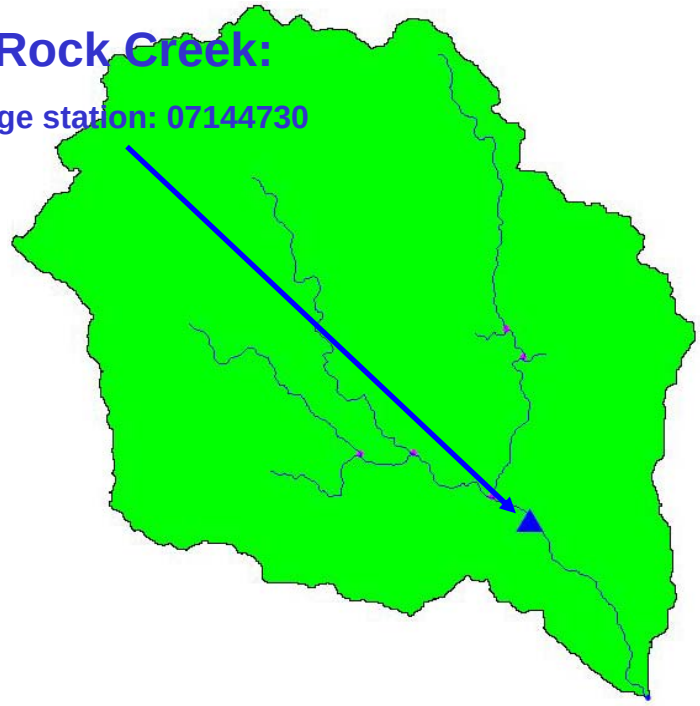
Source: USDA / ARS, NSL, 2007

Objectives

- Calibrate and validate **AnnAGNPS** and **SWAT** models using forty-five months (January, 1997 to September, 2000) of USGS measured data for:
  - Flow
  - Sediment yield
  - Total Phosphorus
- Compare models performances to choose appropriate model
- Establish plans to evaluate conservation practices
- **Unique thing about this study:** calibration and validation study in two separate but similar watersheds

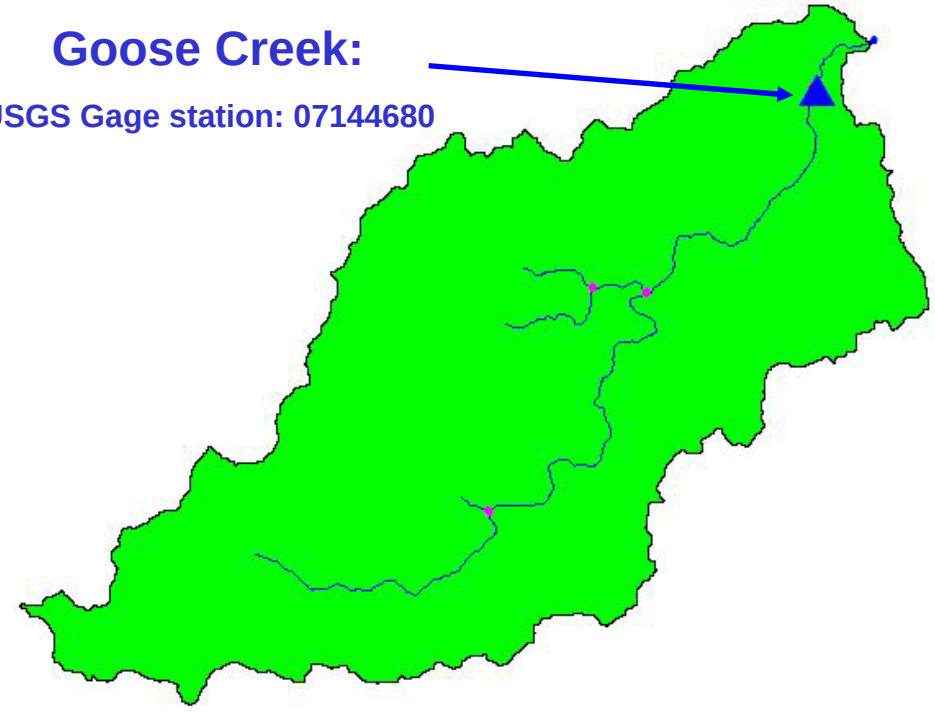
Red Rock Creek:

USGS Gage station: 07144730



Goose Creek:

USGS Gage station: 07144680



Materials and Methods

Model Description

Description	AnnAGNPS	SWAT
Model capabilities Borah and Bera, 2003	**Hydrology, sediment yield, nutrients, pesticides**	**Hydrology, sediment yield, nutrients, pesticides, pathogen transport,**
Time scale	**Long-term, daily, sub-daily**	**Long-term, daily, sub-daily**
Watershed	**Homogeneous cells/reaches**	**Sub-basins, HRU**
PET method Migliaccio et al., 2007	**Penman** (Jenson et al., 1990)	**Penman-Monteith, Priestly-Taylor, Hargreaves** (Monteith, 1965; Allen, 1986; Allen et al., 1989; Priestley and Taylor, 1972; Hargreaves et al., 1985)

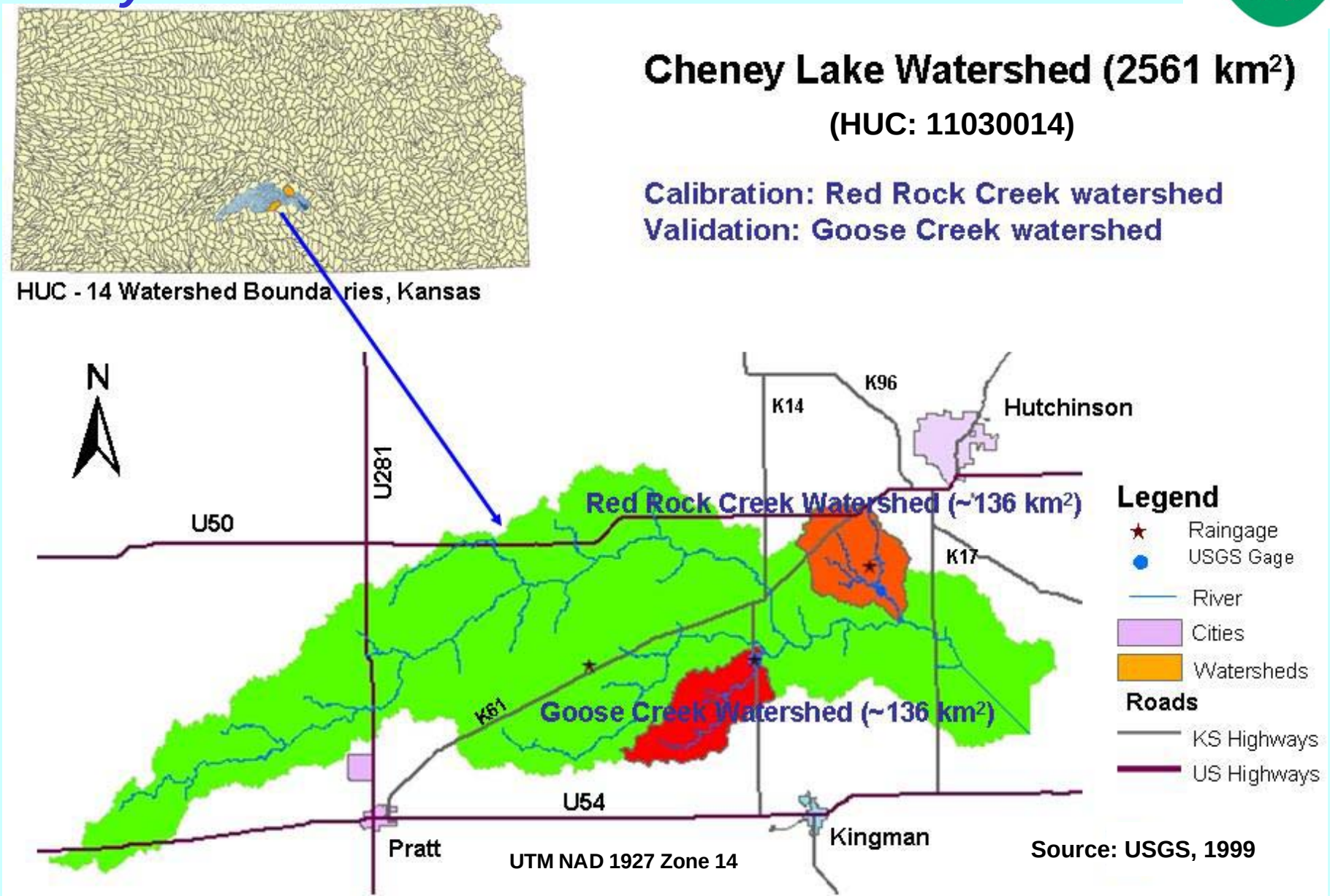
Materials and Methods

Model Description

Description	AnnAGNPS	SWAT
Infiltration/runoff King et al., 1999	**Modified SCS CN2**	**Modified SCS CN2** **Green-Ampt** (Mein and Larson, 1973)
Sediment Yield **Overland** Borah and Bera, 2003	**HUSLE** (Theurer and Clarke, 1991) **Particle size distb.** (Young et al., 1987) **EGEM** (Gordon et al., 2007)	**MUSLE** (Neitsch et al., 2005)
BMPs Borah and Bera, 2003	**VFS, terracing, tillage operation, cover crops, crop rotations** (Yuan et al., 2001; Yuan et al., 2006 Yuan et al., 2007)	**VFS, grasswater way, terracing tillage operation, grade stab. structure, cover crops, crop rotations, grazing operations, nutrient mgmt** (Saleh et al., 2000; Gitau et al., 2003; Bosch et al., 2005; Chu et al., 2005; Bockhold et al., 2006; Bracmort et al., 2006; Gitau et al., 2007; Parajuli, 2007)

Materials and Methods

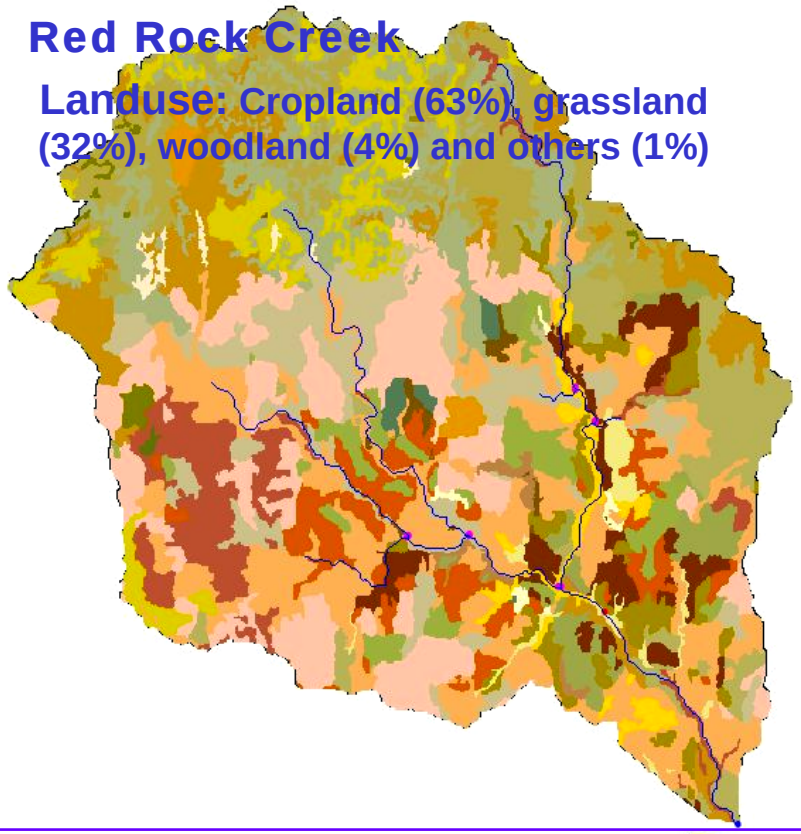
Study area

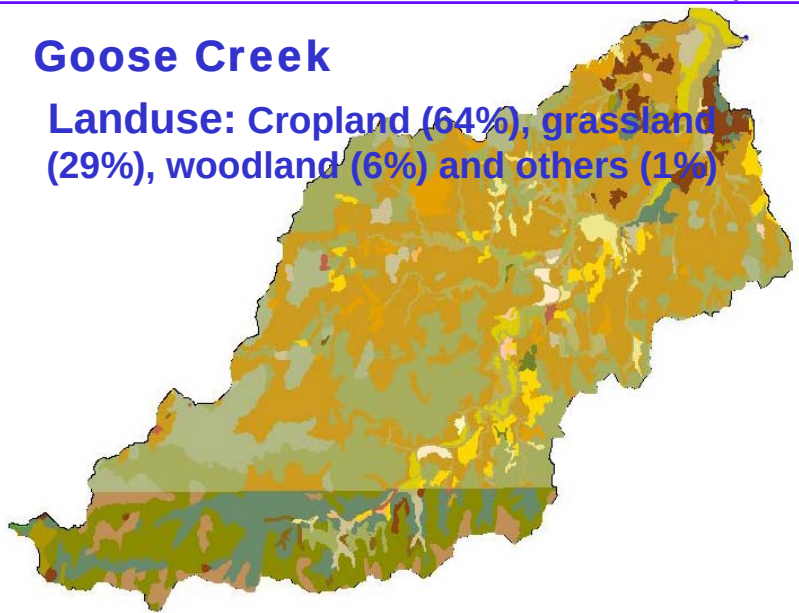


Materials and Method

Data Input

- DEM (30 m x 30 m grid) (USGS, 1999)
- SSURGO (USDA, 2005)
- Landuse (USDA/NRCS/KS, 2002)
  - Reclassified (24) based on field-verified landuse conditions (Lyle Frees, 2007)
    - Landsat 5 satellite imagery data
    - Farm Service Agency records
    - ArcView image analysis
- Weather (NCDC, 2007; USGS/Lyle, 2007)
  - Hutchinson South for Red Rock Creek watershed
  - Turon and USGS gage 3 for Goose Creek watershed

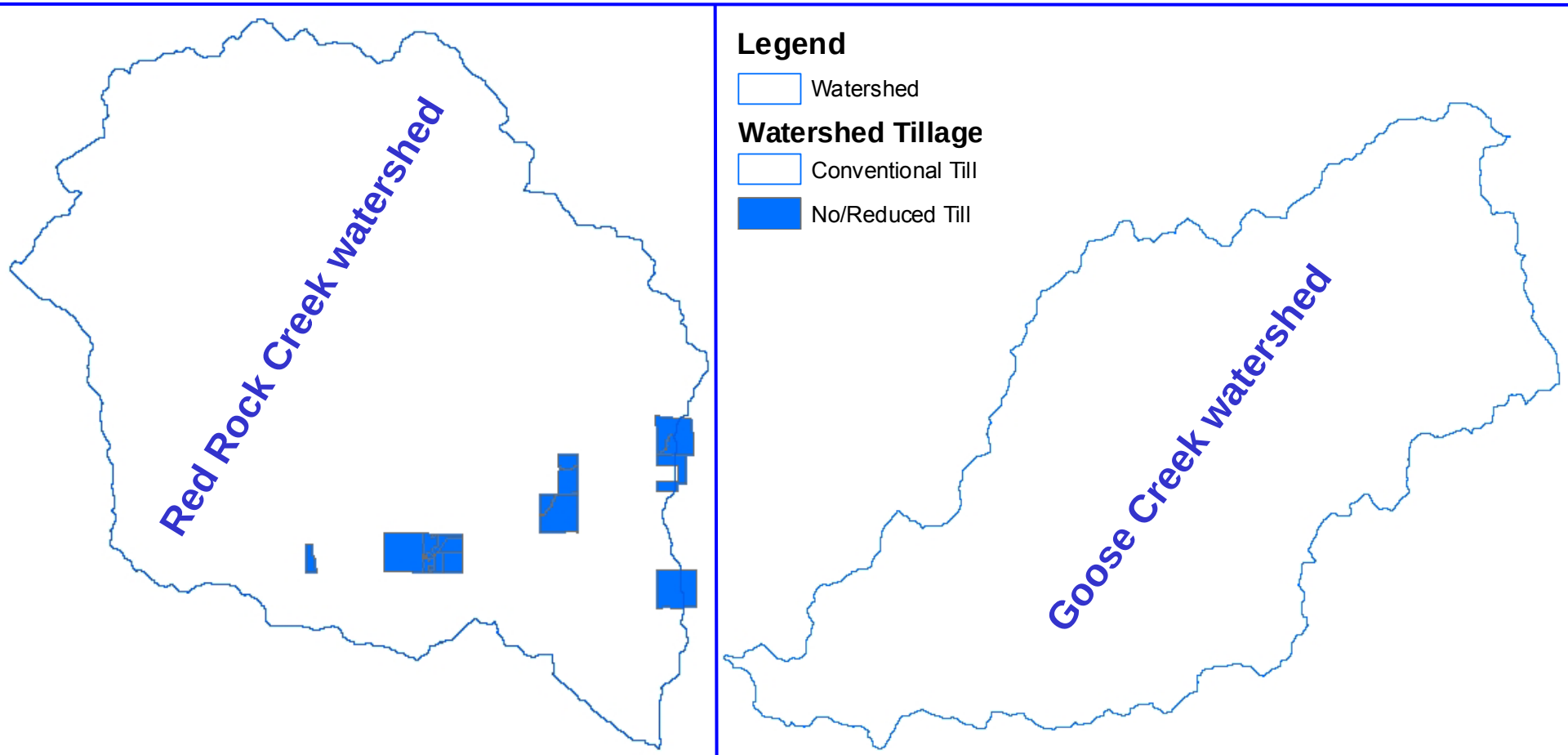




Materials and Methods

Watershed Management - Tillage

- Tillage: Conventional Tillage in both watersheds except some No/Reduced Till conversions in 1995 and 1997 (Lisa French, 2007)



Materials and Methods

Calibration and Validation Procedure

Table 1. Models parameters test and adjustment during calibration

Parameters		Default value	Test range value	Final value
Flow:				
Curve Number (CN) in		73 - 83	73 - 83	77 - 79
AnnAGNPS and SWAT	Cropland	83	74 - 83	78
	Grassland	79	75 - 82	79
	Woodland	73	73 - 80	77
Sediment:				
USLE cover and management		0.03 - 0.20	0.03 - 0.50	0.03 - 0.20
factor (C) in SWAT		Winter wheat	0.03 - 0.30	0.03
		Grain Sorghum	0.20 - 0.50	0.2
		Soybean	0.20 - 0.50	0.2
		Corn	0.20 - 0.50	0.2
Manning's n EGs[1] in AnnAGNPS		0.04	0.04 - 1.00	0.04

[1]Ephemeral Gully

- Phosphorus: No calibrating parameters used

Materials and Methods

Statistical Analysis

- Compare **measured** vs. **models simulated: monthly**
  - **Flow**
  - **Sediment yield**
  - **Total phosphorus**

- Coefficient of Determination (R^2)
  - How consistently do **measured** vs. **predicted** values follow a best-fit line

- Nash-Sutcliffe Efficiency Index (NSE) (Nash and Sutcliffe, 1970)
  - How consistently do **measured** values match **predicted** values (follow 1:1 line)

Classification of Model Efficiencies

R^2 or NSE range	Class
≥ 0.90	Excellent
≥ 0.75 to ≤ 0.89	Very Good
≥ 0.50 to ≤ 0.74	Good
≥ 0.25 to ≤ 0.49	Fair
≥ 0.00 to ≤ 0.24	Poor
< 0.00	Unsatisfactory

(Moriasi et al., 2007; Parajuli, 2007)

Results and Discussion

Monthly Flow

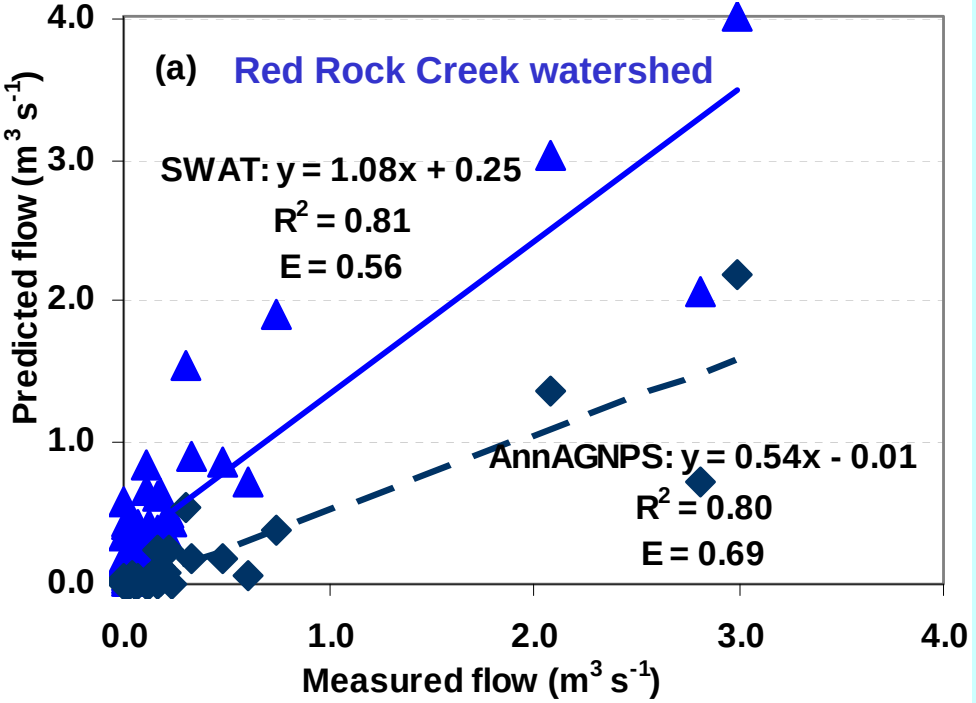
Calibration watershed

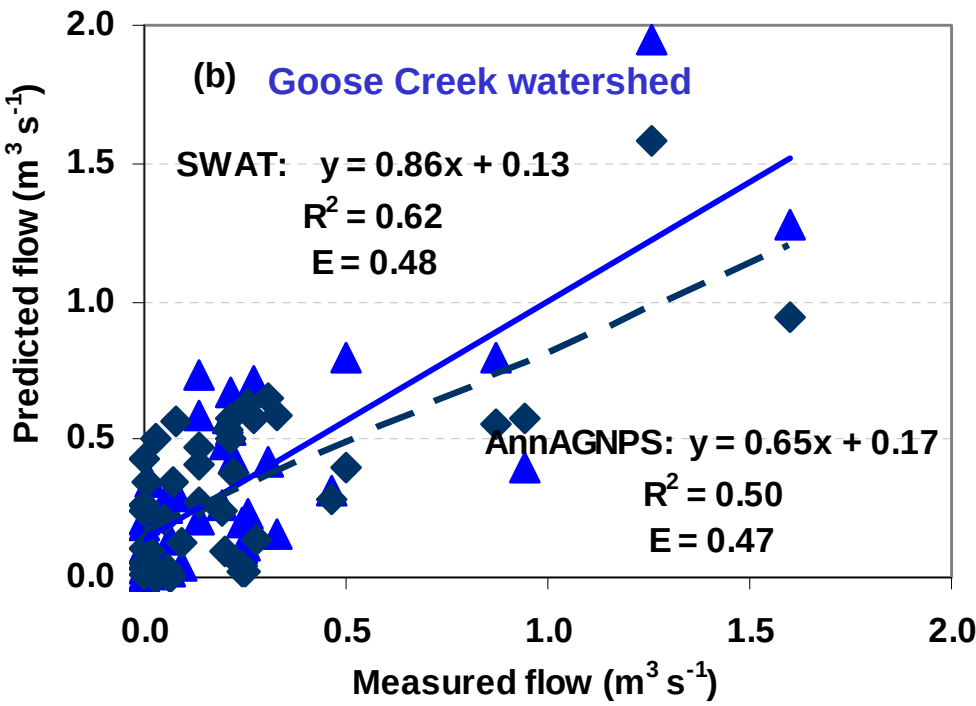
- AnnAGNPS and SWAT determined:
  - **Correlation** - very good
  - **Agreement** - good

Validation watershed

- AnnAGNPS and SWAT showed:
  - **Correlation** - good
  - **Agreement** - fair

- **Other studies determined similar results:**
  (Spruill et al., 2000; Van Liew et al., 2003; Sadeghi et al., 2007)





Results and Discussion

Monthly Sediment Yield

Calibration watershed

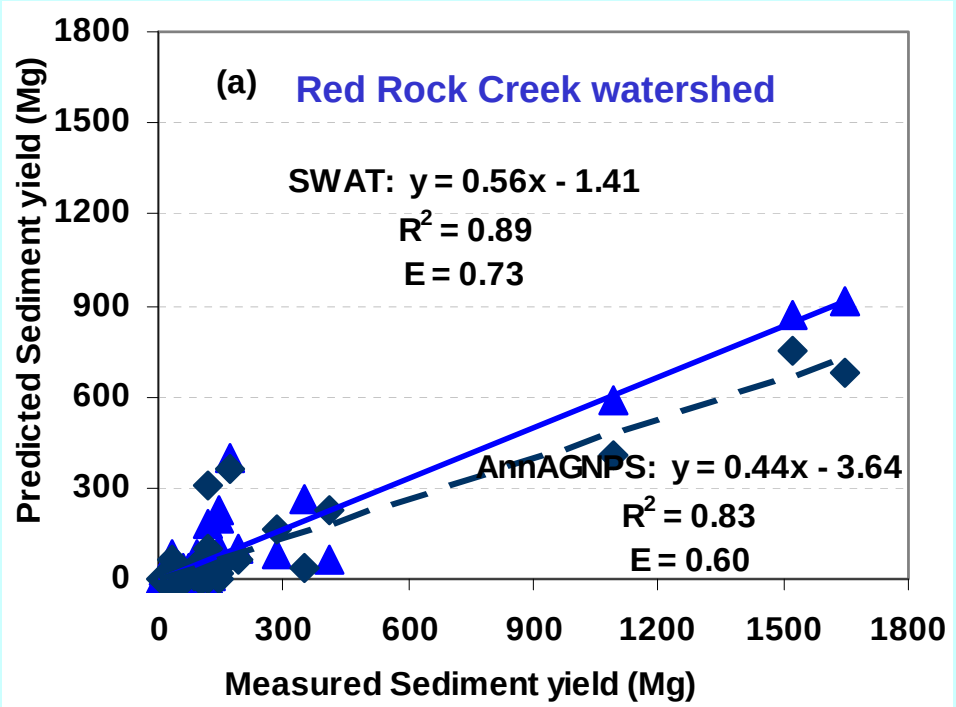
- AnnAGNPS and SWAT predicted:
  - **Correlation** - very good
  - **Agreement** - good

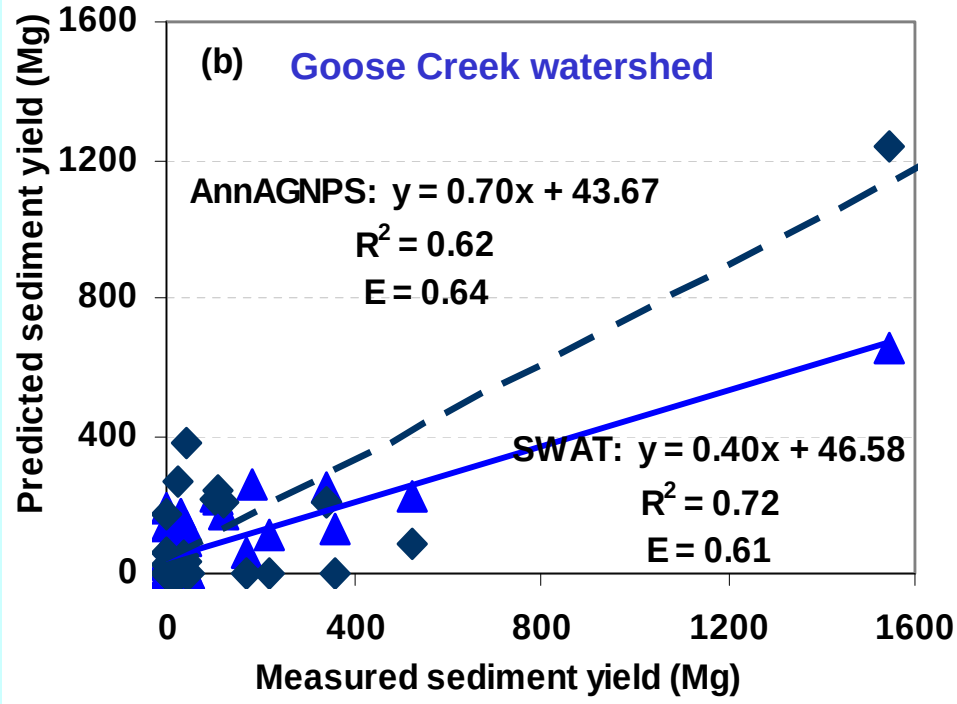
Validation watershed

- AnnAGNPS and SWAT showed:
  - **Correlation** - good
  - **Agreement** - good

- **Other studies showed similar results:**

  (Yuan et al. 2001; Santhi et al., 2001; Kirsch et al., 2002; Das et al., 2007; Jha et al., 2007)





Results and Discussion

Monthly Total Phosphorus

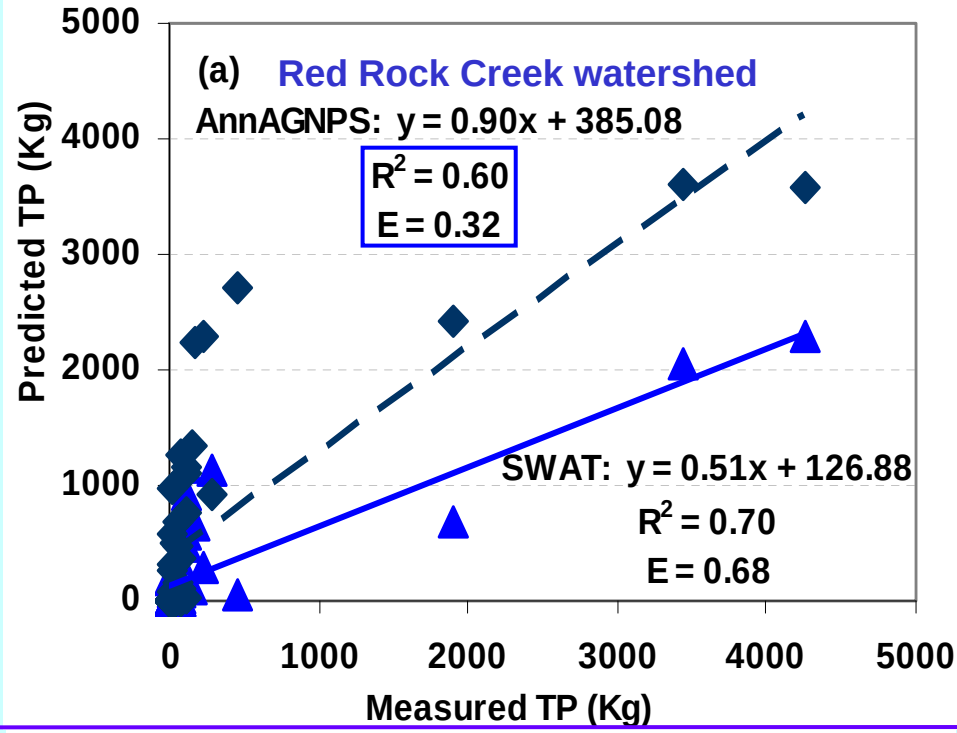
Calibration watershed

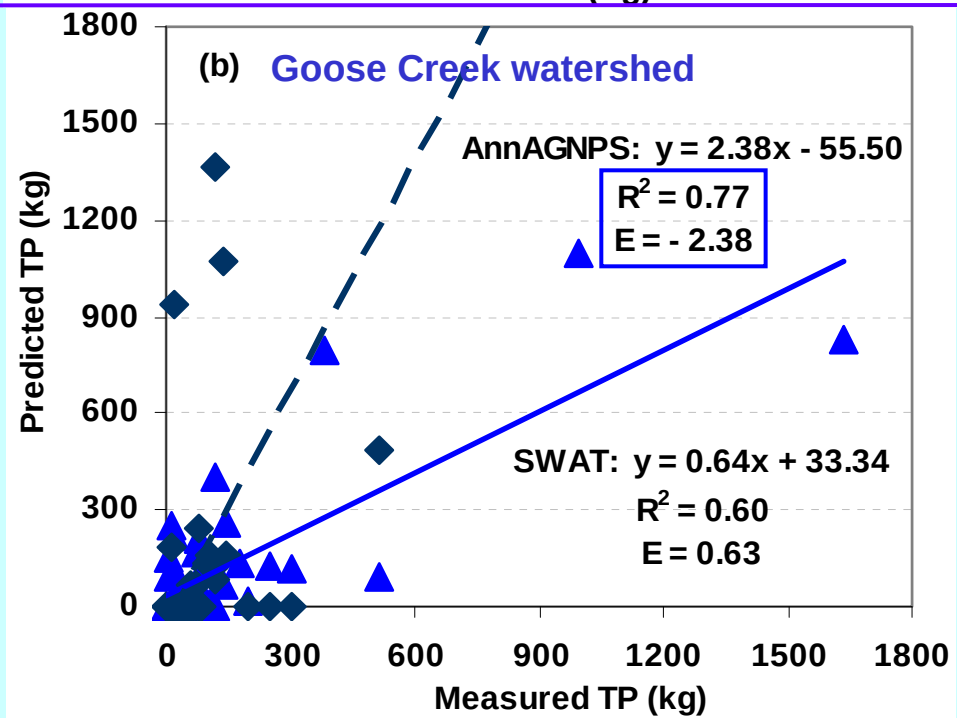
- AnnAGNPS and SWAT estimated:
  - **Correlation** - good
  - **Agreement:**
    - **AnnAGNPS** - fair
    - **SWAT** - good

Validation watershed

- AnnAGNPS and SWAT showed:
  - **Correlation:**
    - **AnnAGNPS** - very good
    - **SWAT** - good
  - **Agreement:**
    - **AnnAGNPS** - unsatisfactory
    - **SWAT** - good

- **Other studies found similar results:** (Baginska et al., 2003; Yuan et al., 2005; Das et al., 2007)



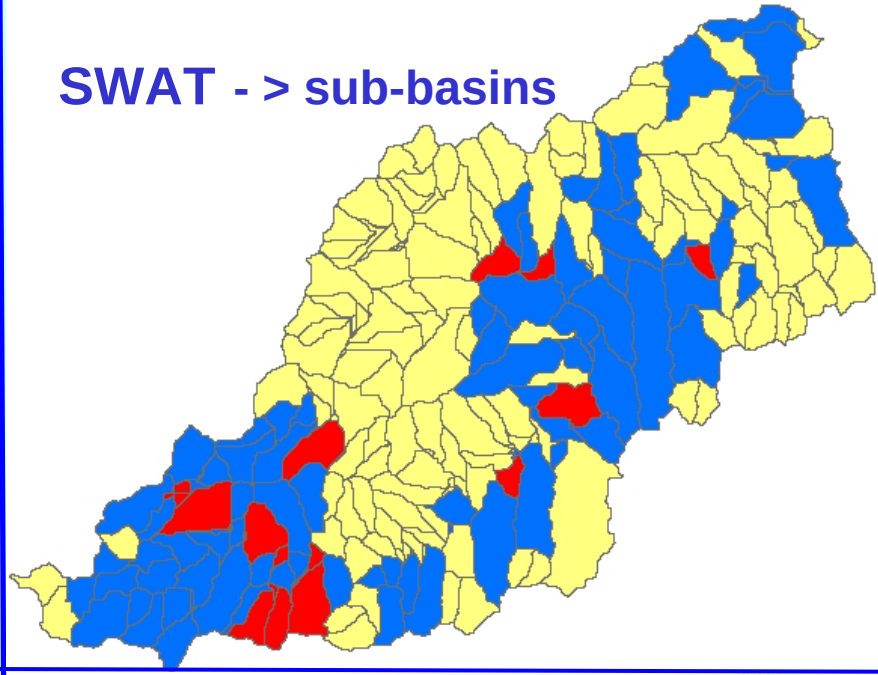


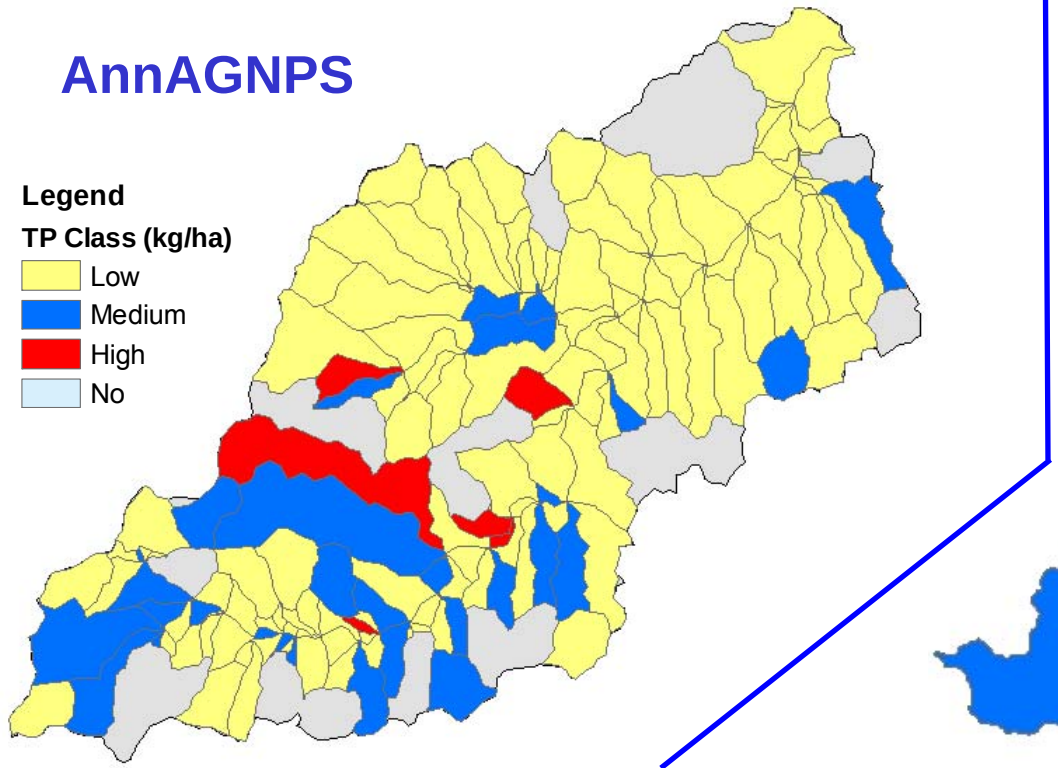
Identifying Critical Areas ?

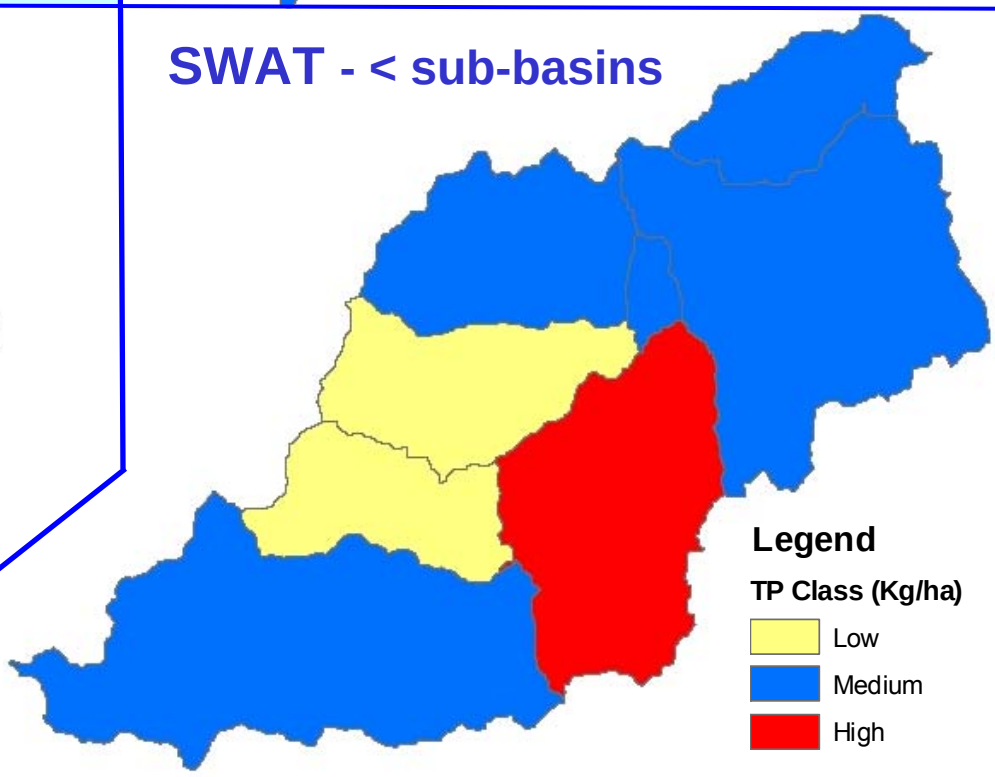
Phosphorus Yields – Goose Creek

Lowest spatial unit:

- AnnAGNPS - cell based prediction
- SWAT - HRU based prediction
- BMPs implementation - HRU based







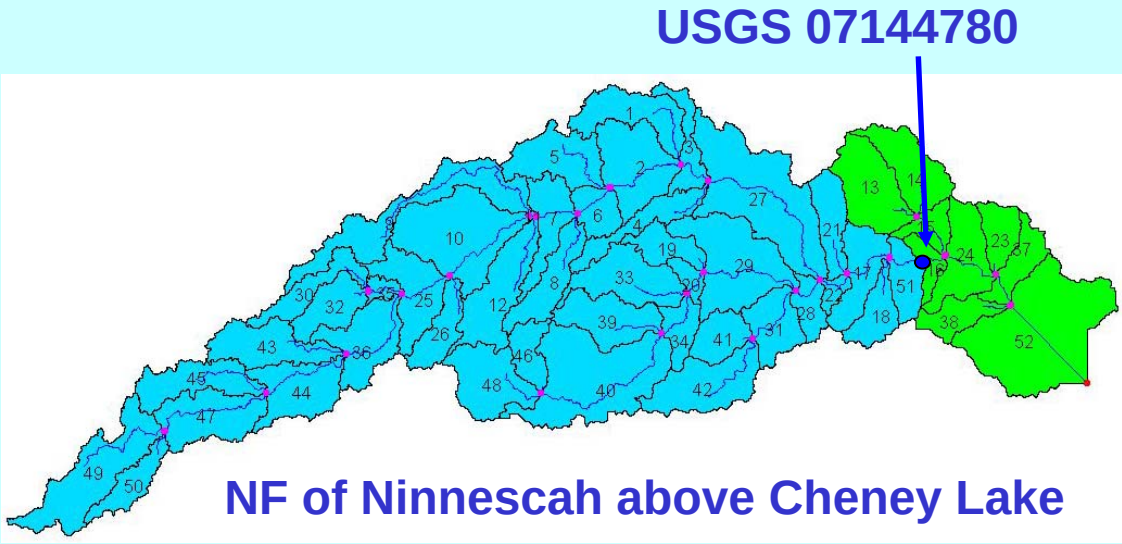
Summary and Conclusions

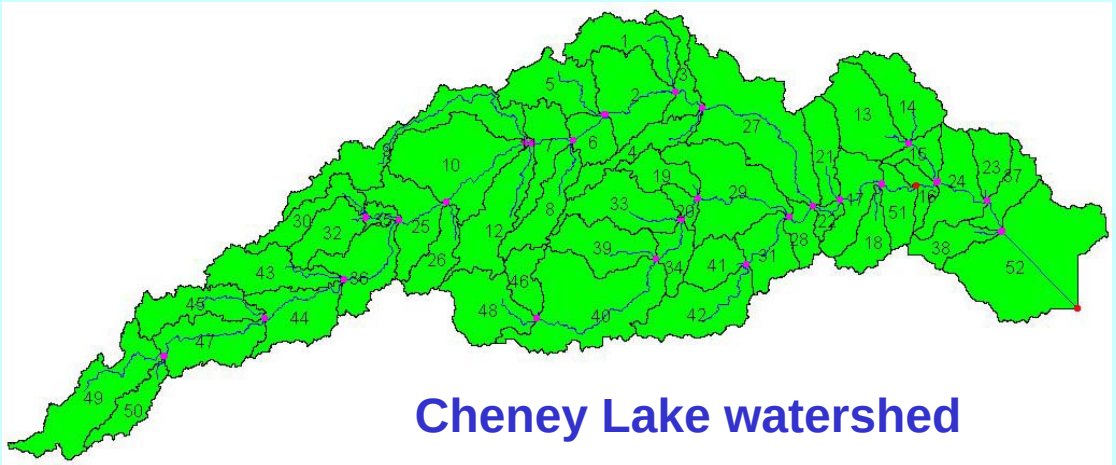
- **Calibration and validation:**
  - AnnAGNPS and SWAT models calibrated and validated using forty-five months of measured flow, sediment yield, and total phosphorus
  - Demonstrated calibration and validation of models in ***two separate but similar*** watersheds
  - Calibration and validation results help to ***choose appropriate model*** for BMPs evaluation and targeting **(SWAT)**
- **Preliminary models performance:**
  - **AnnAGNPS** and **SWAT** models demonstrated equally good performance for predicting **monthly flow** and **sediment yield**
  - **SWAT** found consistently robust to predict **total phosphorus**

Plans for BMPs Evaluation

Evaluate BMPs in the Cheney Lake watershed (SWAT)

- Verify model at North Fork of Ninnescah above Cheney Lake
- Evaluate effectiveness of the conservation practices (95-06)
- Identify critical areas (sub-basins) in the watershed (water yield, sediment yield, and TP)
- Rank sub-watersheds
- Select/apply/evaluate BMPs
- Recommend BMPs





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Dr. Daniel L. Devlin, Professor,
Dr. Michael Langemeier, Professor, at Kansas State University

Thank you very much!
?

AnnAGNPS (HUSLE) (Theurer and Clarke, 1991):

$$Sy = \boxed{0.22 * Q^{0.68} * qp^{0.95}} * KLSCP$$

Where,
Sy = sediment yield (Mg/ha),
Q = surface runoff volume (mm),
qp = peak rate of surface runoff (mm/s),
K,L,S,C,P are RUSLE factors.
(All three variables (Sy, Q, and qp) are based on unit area; i.e., divided by their drainage areas

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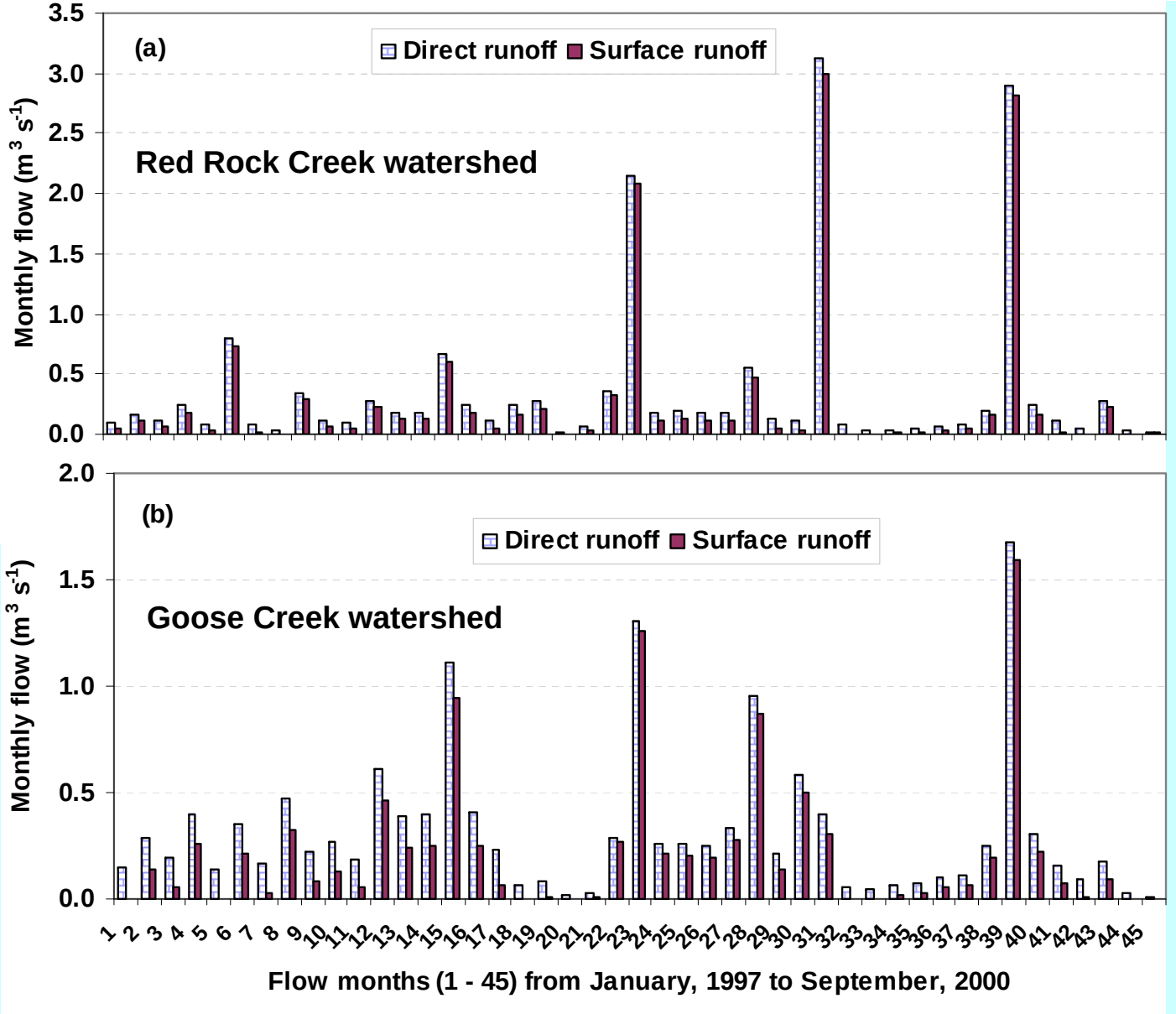
SWAT (MUSLE) (Williams, 1995):

$$sed = \boxed{11.8 \cdot \left(Q_{surf} \cdot q_{peak} \cdot area_{hru}\right)^{0.56}} \cdot K_{USLE} \cdot C_{USLE} \cdot P_{USLE} \cdot LS_{USLE} \cdot CFRG$$

where,
sed = sediment yield on a given day (metric tons),
Q_{surf} = surface runoff volume (mm/ha),
q_{peak} = peak runoff rate (m^3/s),
$area_{hru}$ = area of the HRU (ha),
K_{USLE} = soil erodibility factor,
C_{USLE} = is the USLE cover and management factor,
P_{USLE} = USLE support practice factor,
LS_{USLE} = USLE topographic factor
CFRG = coarse fragment factor

Table 2. Weather data input requirement by different PET methods

Method	Weather data input required
Penman	Air temp. (max and min), dew point temp., sky cover, wind speed, wind direction, and solar radiation
Penman - Monteith	Air temp. (max and min), wind speed, relative humidity, and solar radiation
Priestley-Taylor	Air temp. (max and min), humidity, and solar radiation
Hargreaves	Air temp. (max, min, and average)

Base Flow Separation

- Used web-based hydrograph analysis tool (Kyoung et al., 2005)
- Selected Recursive Digital Filter Method
- Base flow accounts up to 1.2% of (weighted average) of direct flow