Metal Fate and Transport Simulation Using SWAT in the Tri-State Mining District

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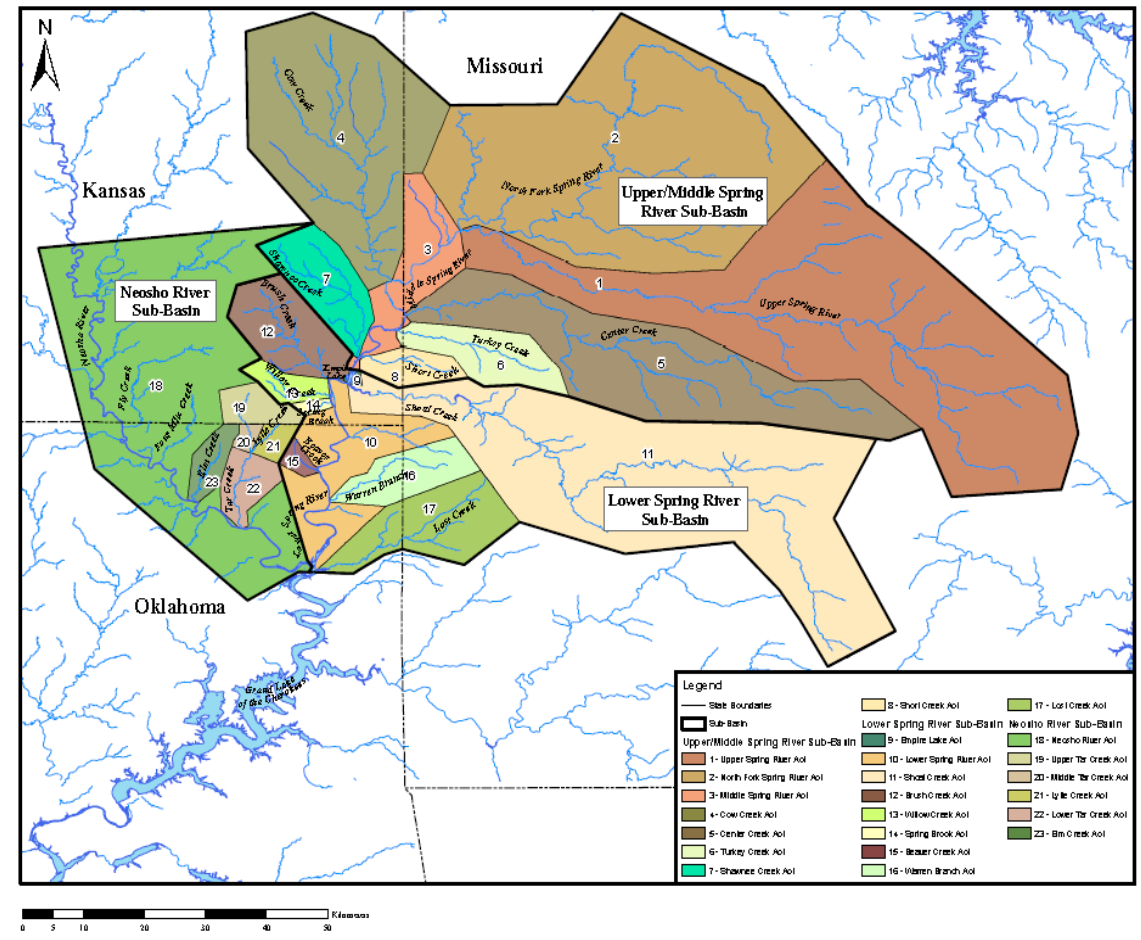
Overview

- **Problem Description**
- **Model Selection**
- **Conceptual Model Framework**
- **Watershed Characterization (Upper-Spring River)**
- **Data Analysis**
  - **Geospatial Analysis**
  - **SWAT (Soil and Water Assessment Tool) Set-up**
- **Results**
- **Next Steps**

Problem Description

- Tri-State Mining District (TSMD): 2,500 mi^2 in southeastern Kansas, southwestern Missouri, and northeastern Oklahoma
- >100+ years of lead and zinc mining
- Piles of mine tailing containing lead, zinc, and cadmium that run-off into nearby streams
- In a 1992-3 survey of 189 children from the TSMD, 35% exceeded a blood lead level (BLL) of 10µg/dL (EPA 1997). Health problems in children from elevated BLL are hearing deficit, learning & reading.
- Clean-up of these sites and their watersheds falls under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)



Model Selection

Step 1

- **EPA Region 7 Raised 16 Management Questions on How to Remediate Spring River Watershed**

Step 2

- **EPA-ORD-NRMRL Conducted Extensive Model Selection Decision Support Process on Watershed-Scale & In-stream Models**

Step 3

- **Two widely used models: SWAT and EFDC (Environmental Fluid Dynamics Code) were Selected to Utilize as a Tool to Support the Best Remediation Alternatives**

Conceptual Model Framework

Geospatial Database

Establish GIS database

Water quality/quantity data assessment

Sampling Plan

Watershed model sampling

Waterbody model sampling

SWAT Model Development

Model set up

Running model

Model calibration & validation

Hot-Spot Identification

EFDC Model Development

Model set up

Running model

Model calibration & validation

Yearly sediment/metal mass flux

Environmental Decision Support System for Evaluating Remediation Scenarios

Conceptual Model Framework

Geospatial Database

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Sampling Plan

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SWAT Model Development

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EFDC Model Development

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Environmental Decision Support System for Evaluating Remediation Scenarios

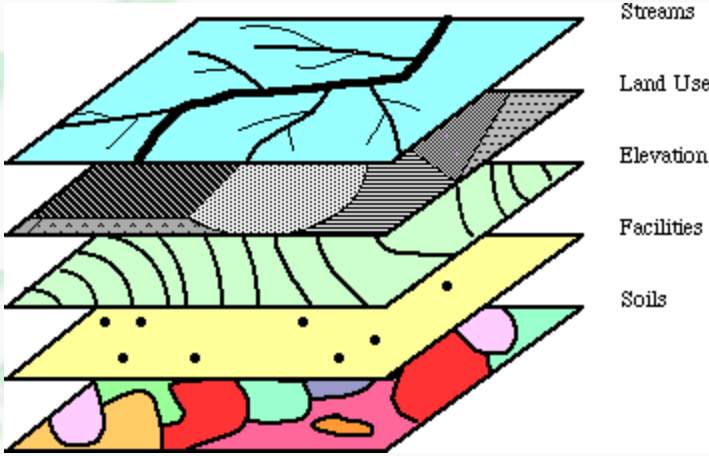
- In-situ Capping
- Hybrid Approach
- In-situ Treatment
- Excavation
- Reactive Caps
- Natural Recovery
- Additive Biodegradation
- Institutional Control
- Dredging

Watershed Characterization

Spring River Geospatial Database:

>100 thematic maps with extensive database was built for quarry and modeling purposes:

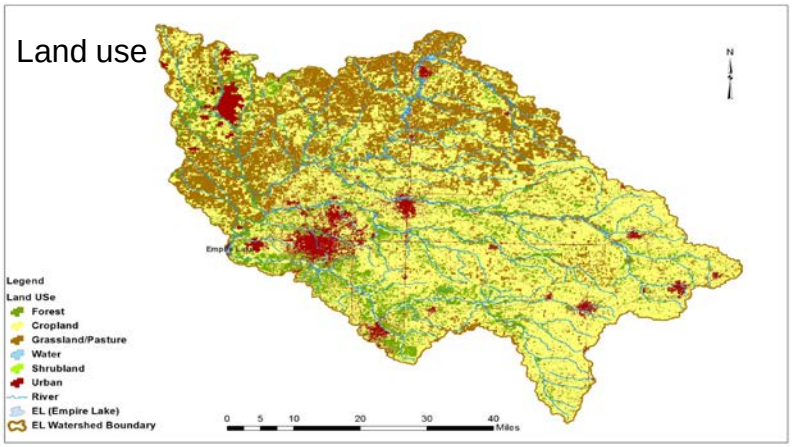
- **Administrative Layers (road, county,..)**
- **Natural (stream, lake, soil, ..)**
- **Human (land use, impaired river, mine distribution,..)**



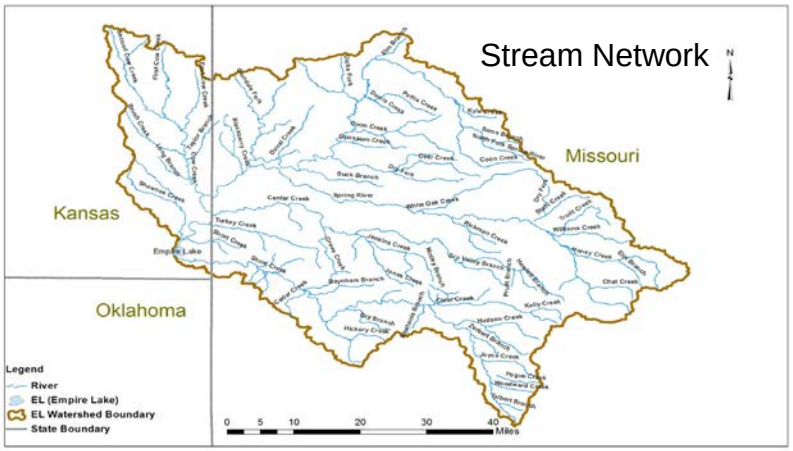
Ref.:http://www.inforain.org/coquille_atlas

Watershed Characterization

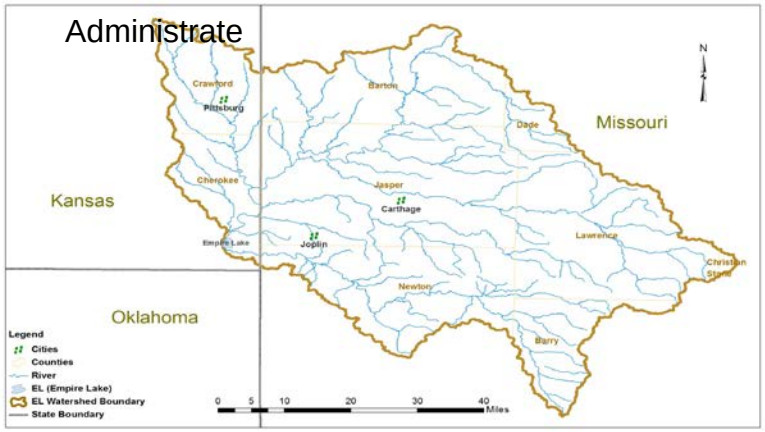
Land use



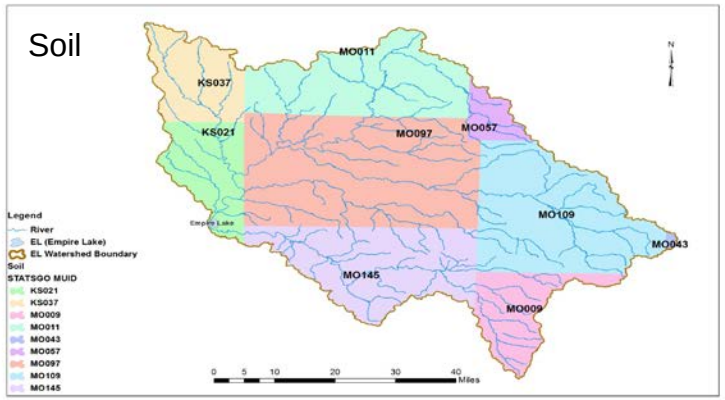
Stream Network



Administrate

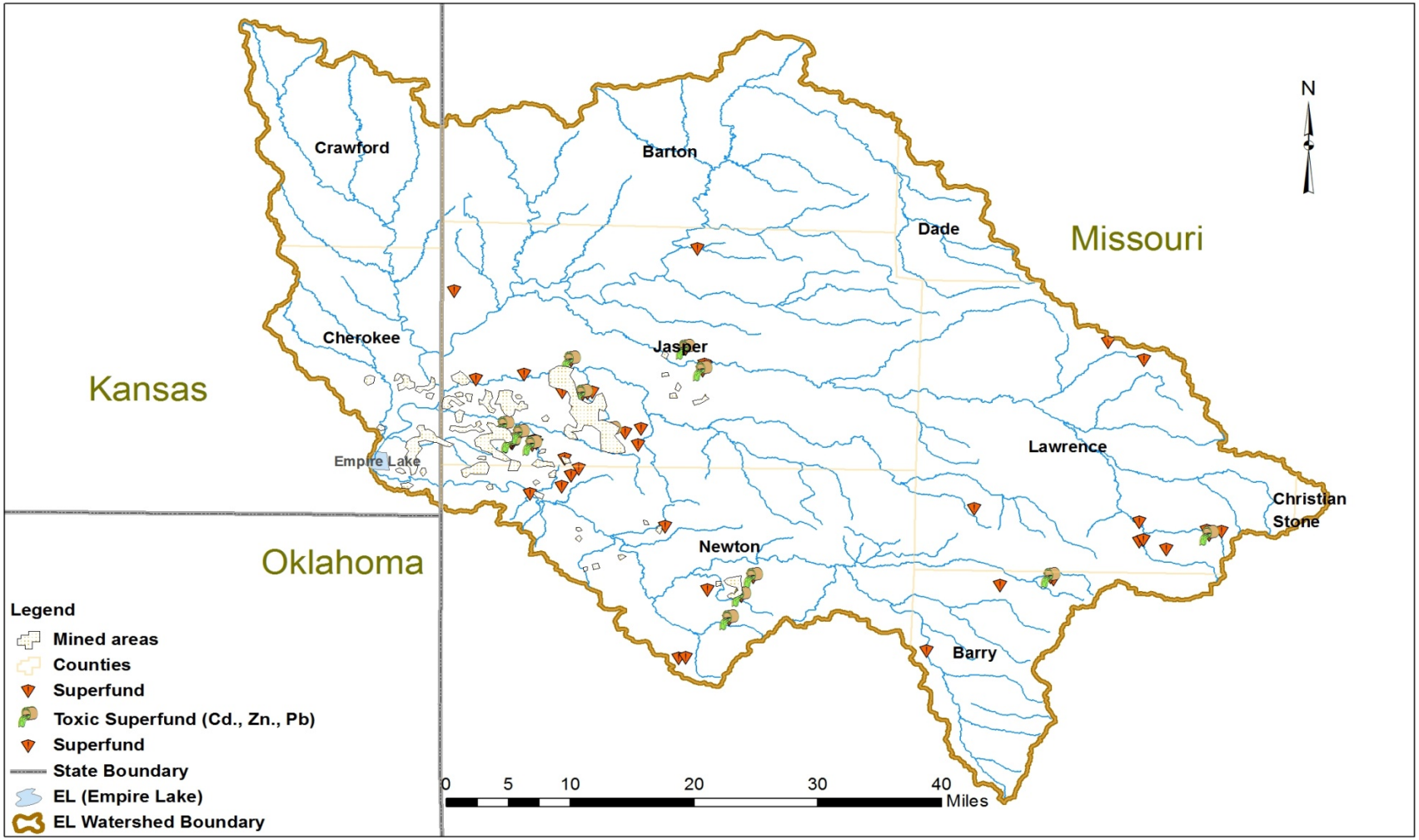


Soil



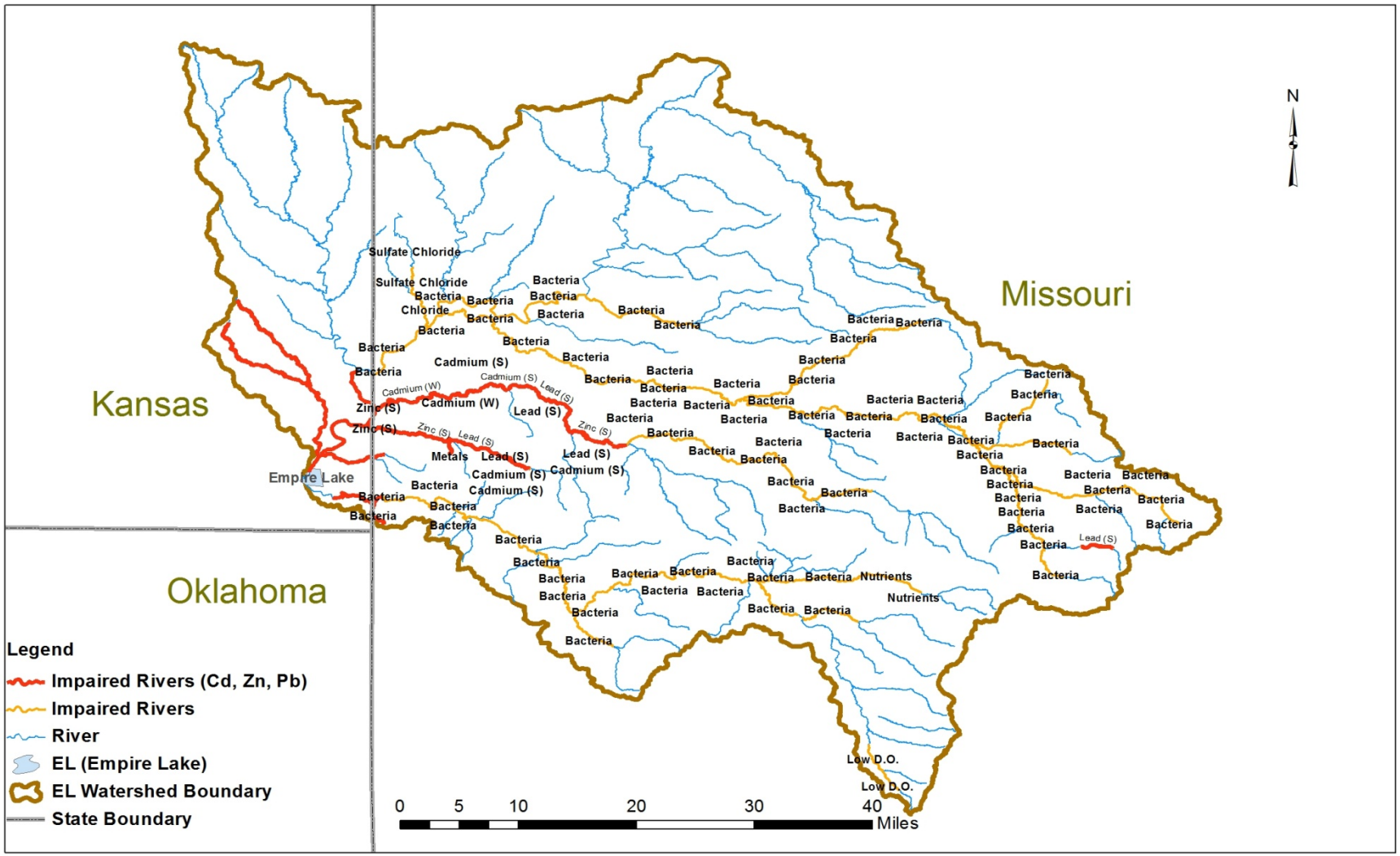
Reference: http://msdisweb-nn.col.missouri.edu & www.kansasgis.org/catalog

Mined Areas vs. Toxic Superfund



Reference: http://msdisweb-nn.col.missouri.edu & www.kansasgis.org/catalog

Impaired Rivers (TMDL Report)

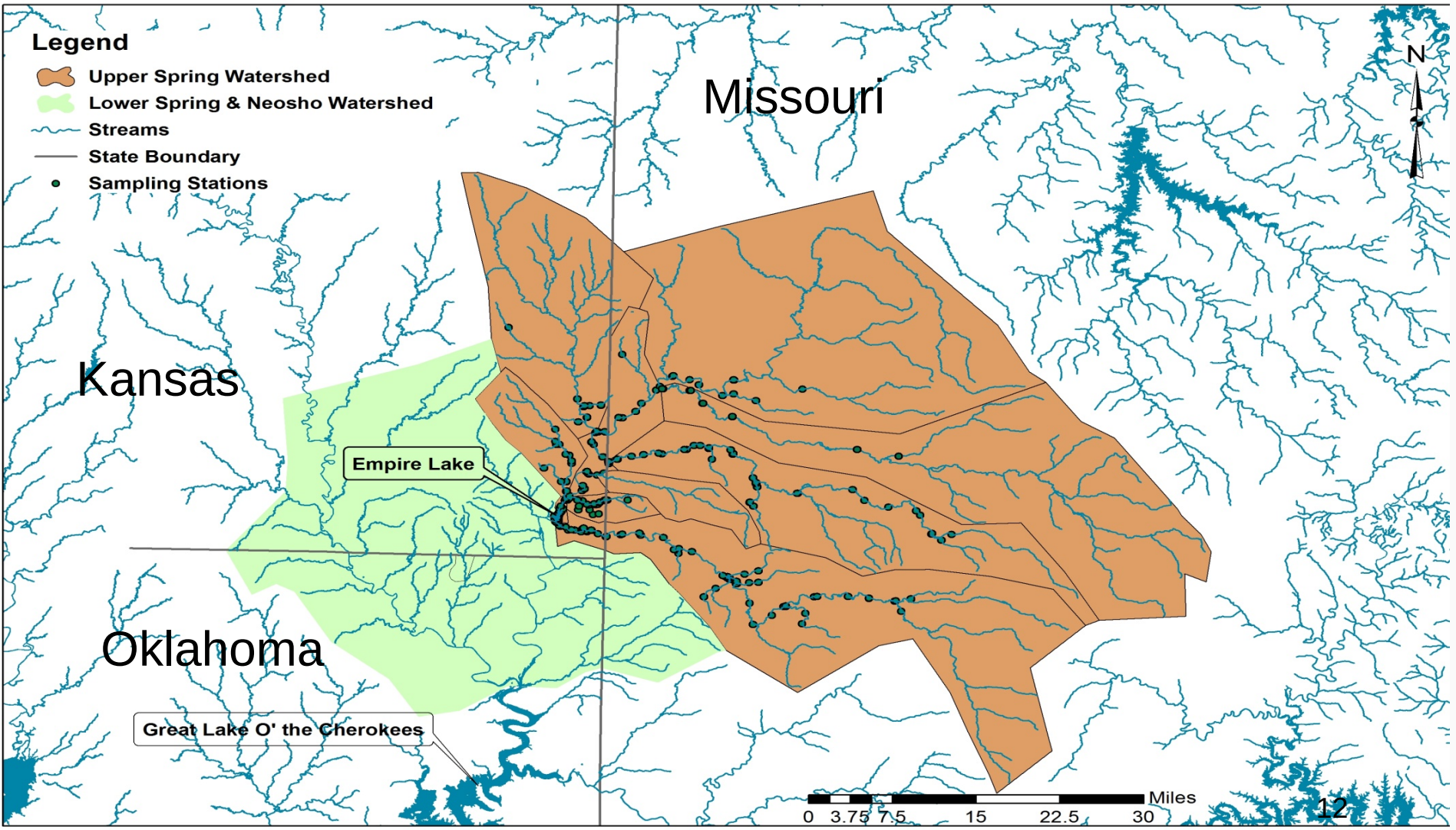


Reference: http://msdisweb-nn.col.missouri.edu & www.kansasgis.org/catalog

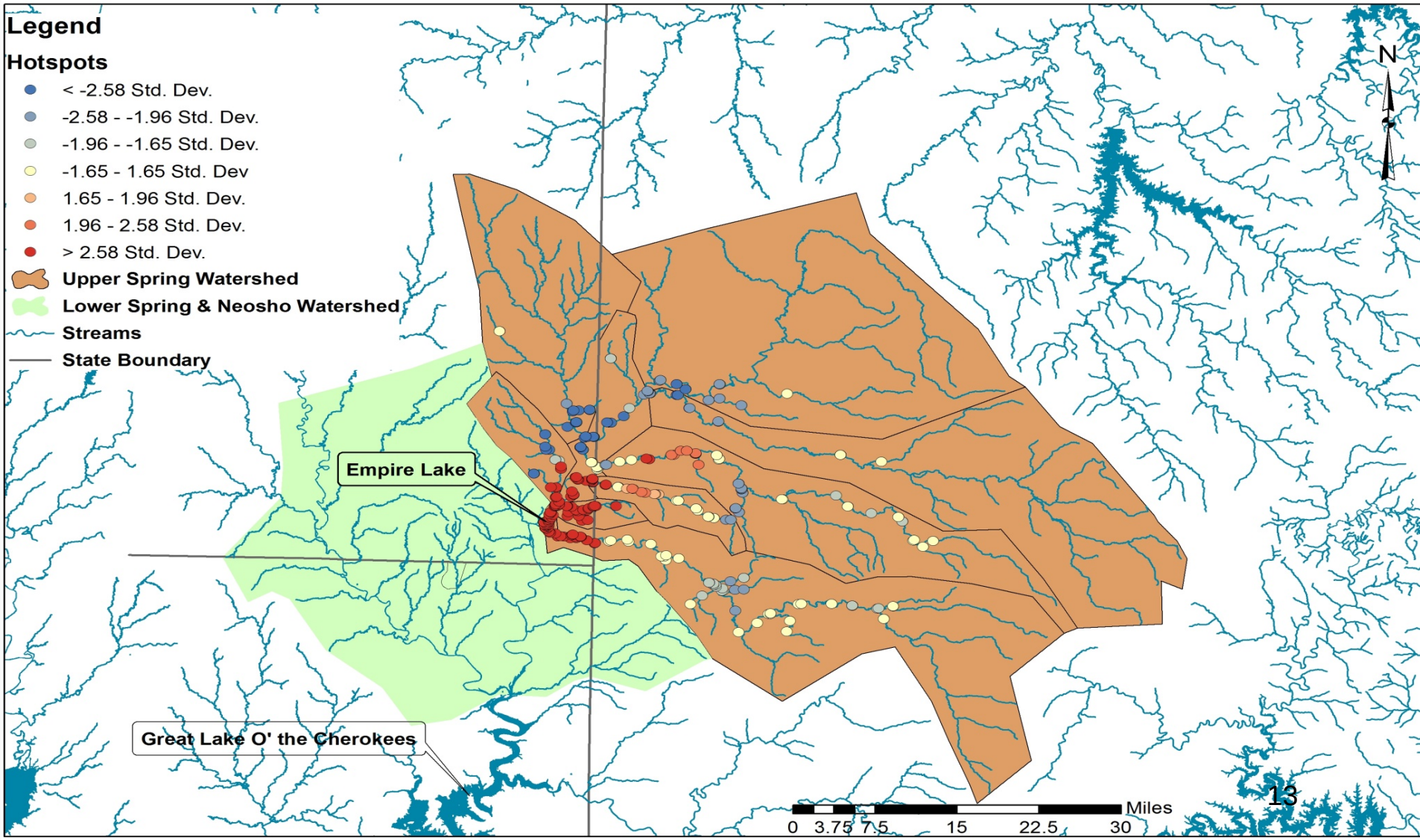
Data Analysis

- Geospatial Statistical Analysis
  - Hot Spot Analysis: Ecological Risk Assessment (ERA) on Aquatic Organisms
- Watershed-Scale Physical Model
  - Applying SWAT Model

> 500 Sampling Stations
ERA on Aquatic Organisms



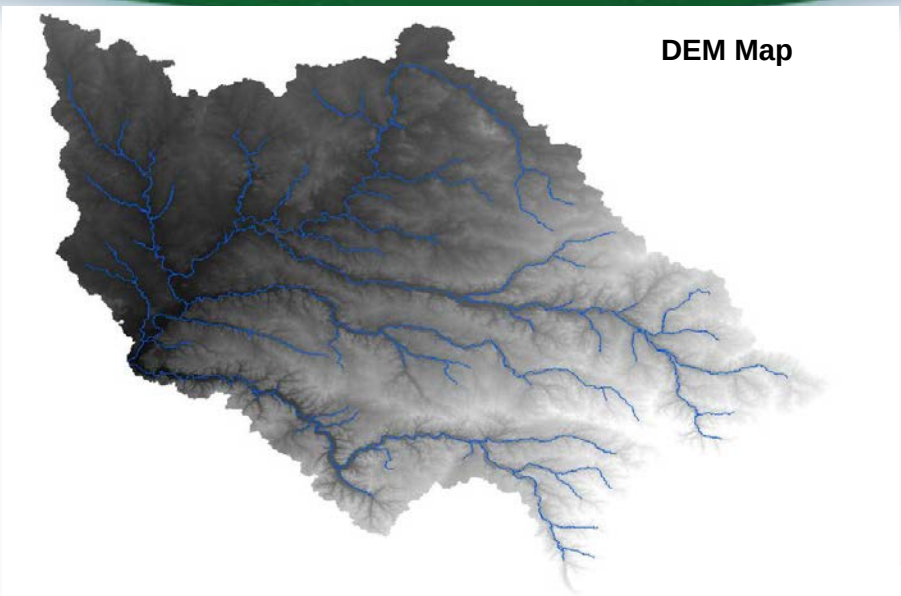
Hotspot on ERA for Aquatic Organisms at Spring River



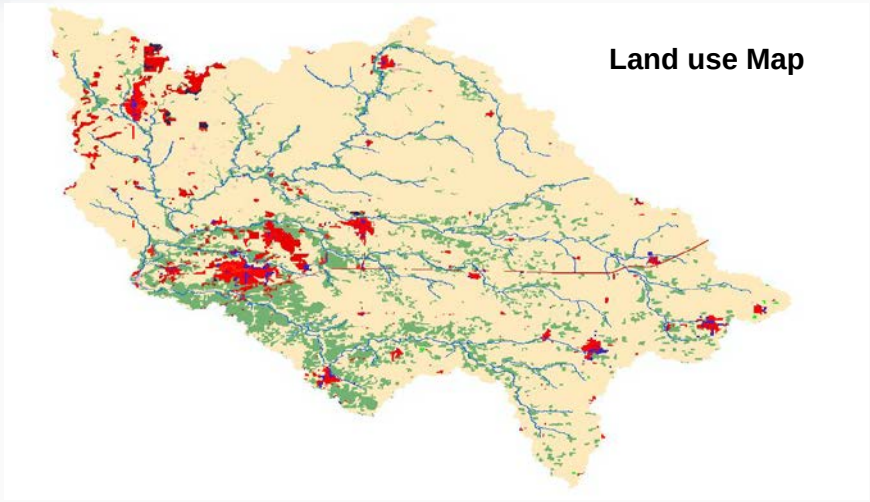
GIS Layers for SWAT Model Set-up

- Stream Network
- Watershed Boundary
- DEM (Digital Elevation Model) 30 meters
- Soils (SSURGO)
- Land Use
- Point Source Locations
- Sampling Points
- Weather Stations
- USGS Stations

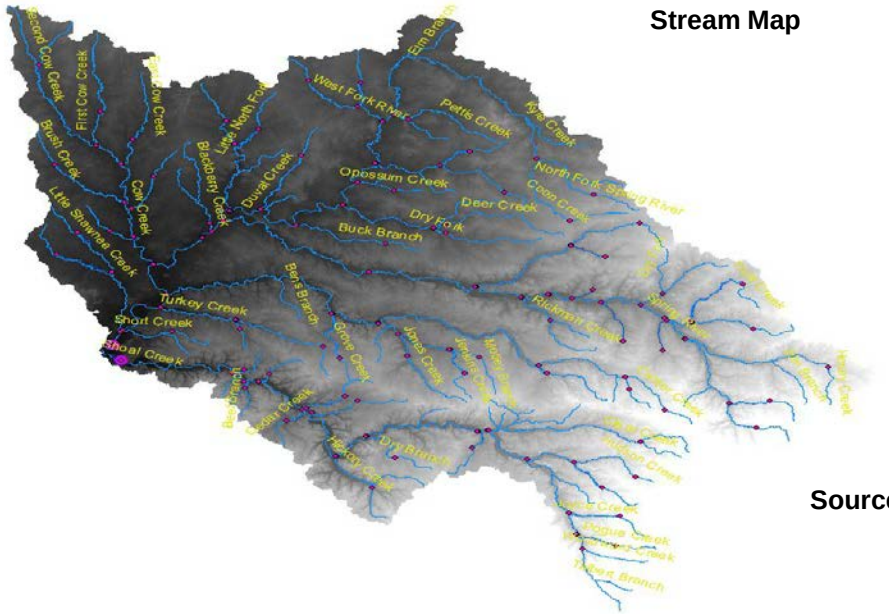
GIS Layers for SWAT Model Set-up



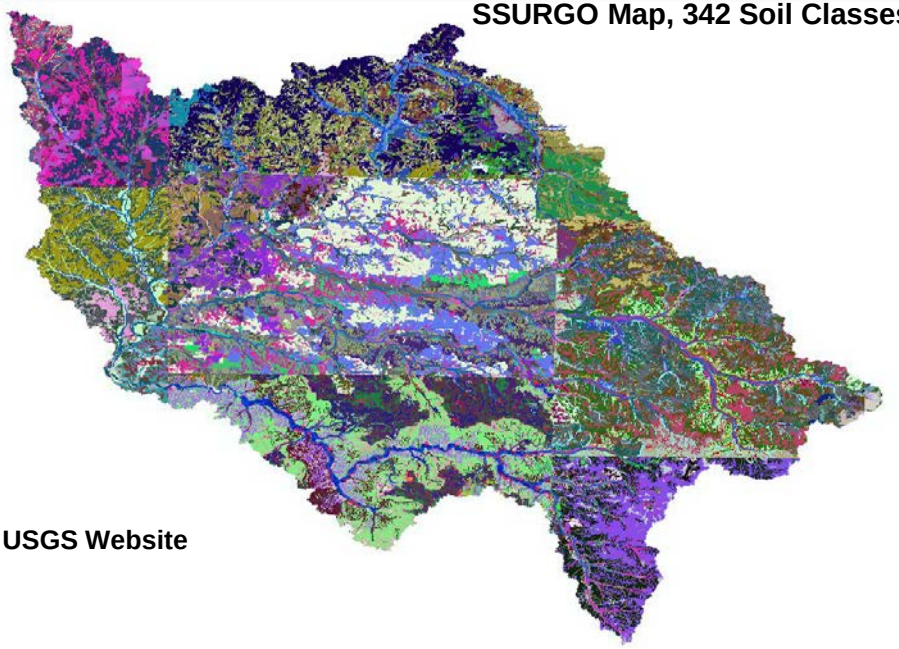
DEM Map



Land use Map



Stream Map



SSURGO Map, 342 Soil Classes

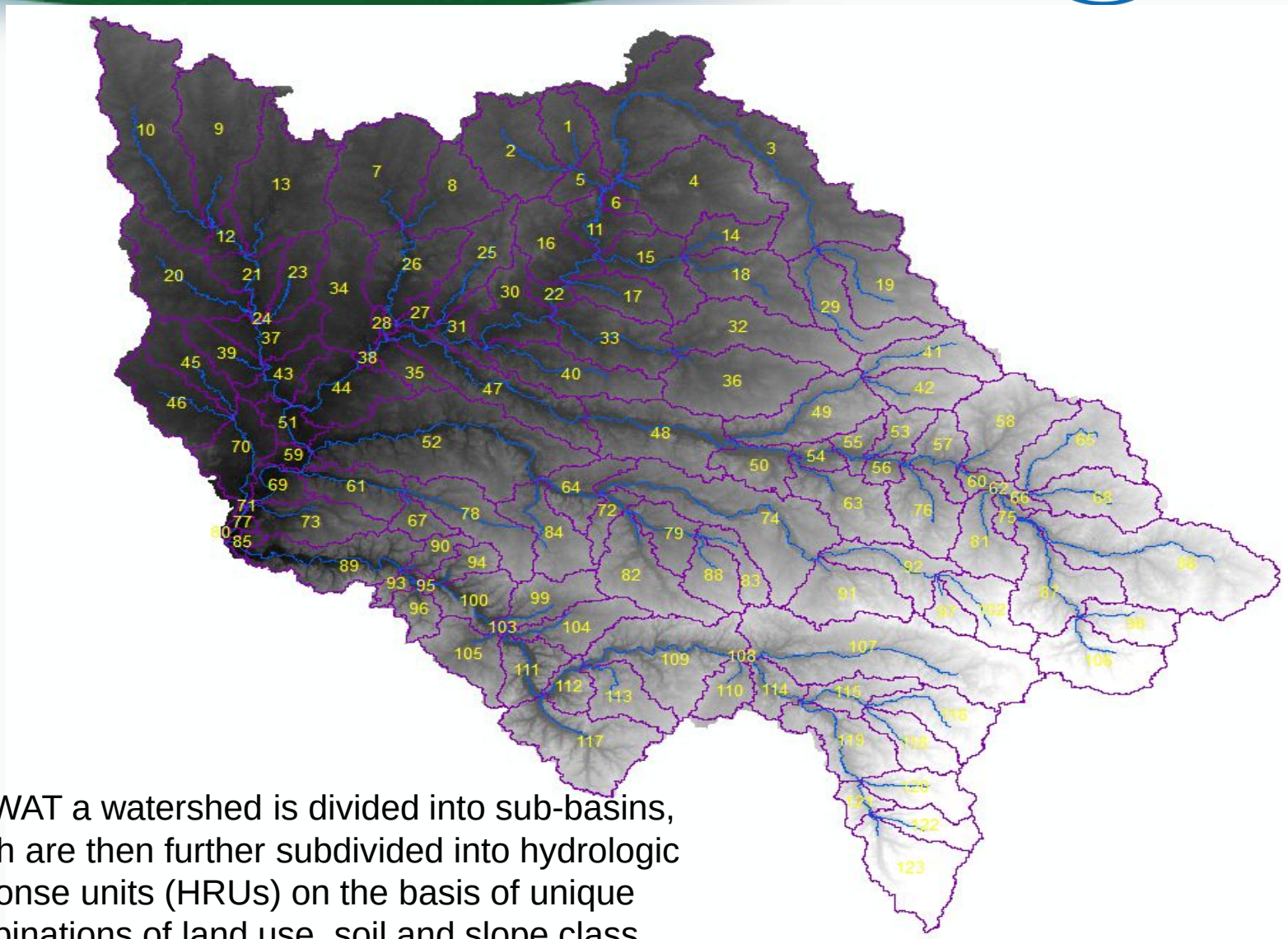
Source: USGS Website

Weather Data

Six weather stations were selected within and around the watershed (2000 to 2010)

- **Max and Min Temperature**
- **Precipitation**
- **Relative Humidity**
- **Solar Radiation**
- **Wind**

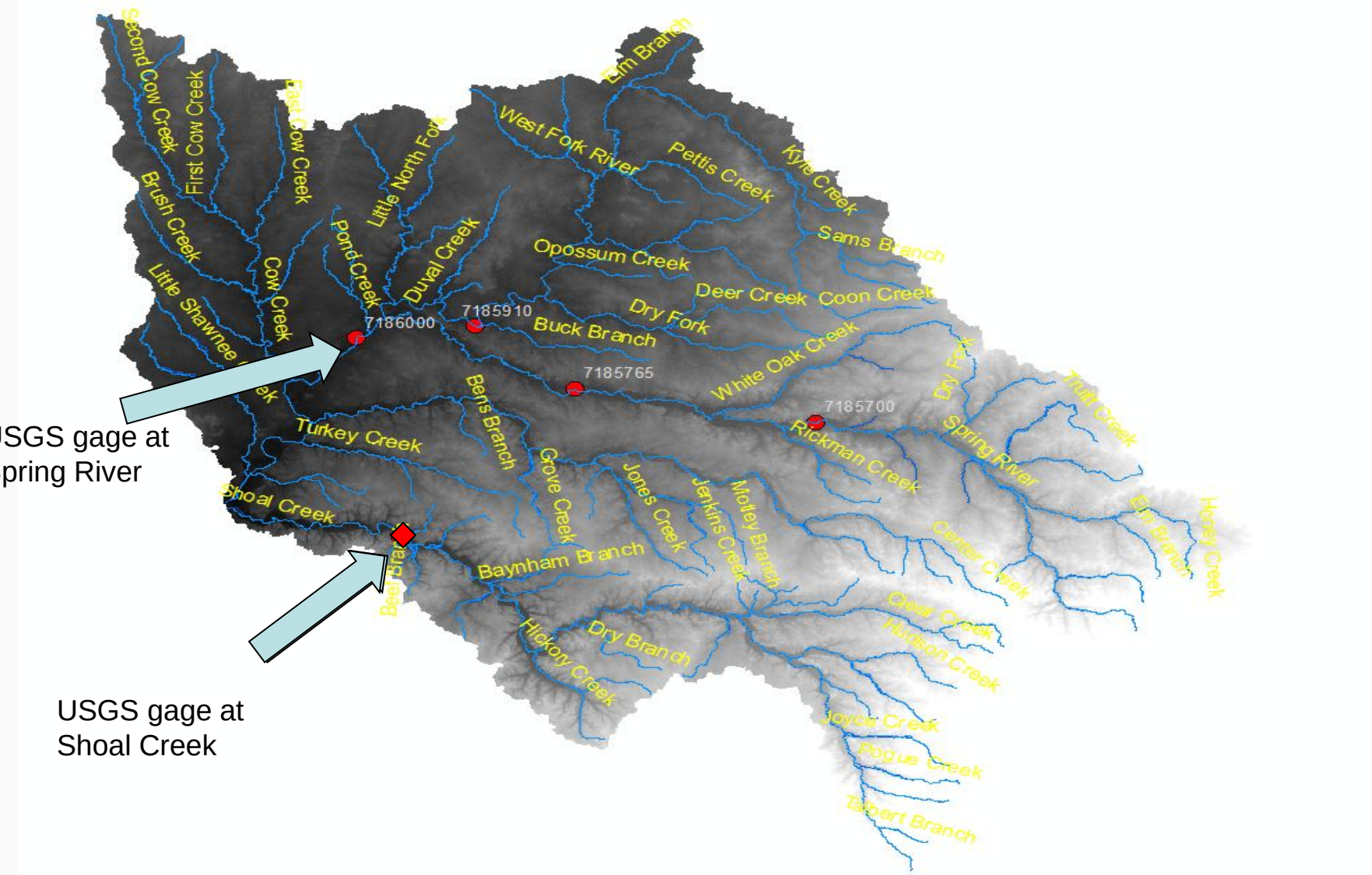
Sub-basin Map



In SWAT a watershed is divided into sub-basins, which are then further subdivided into hydrologic response units (HRUs) on the basis of unique combinations of land use, soil and slope class.

The Spring River watershed: 123 Sub-basins and 470 HRUs

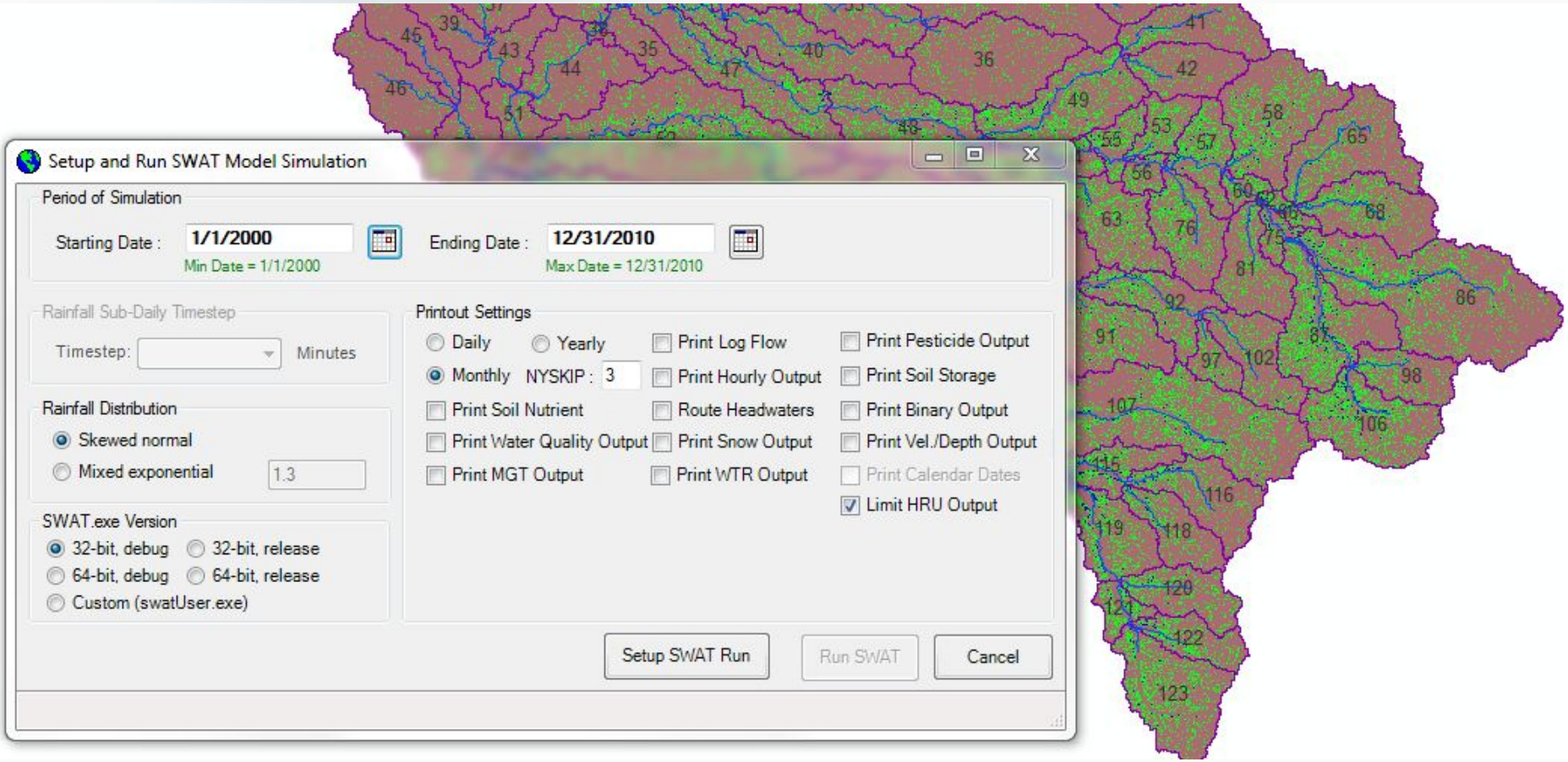
Two out of Five USGS Gages Were Chosen for Model Calibration



USGS gage at Spring River

USGS gage at Shoal Creek

Running SWAT Model

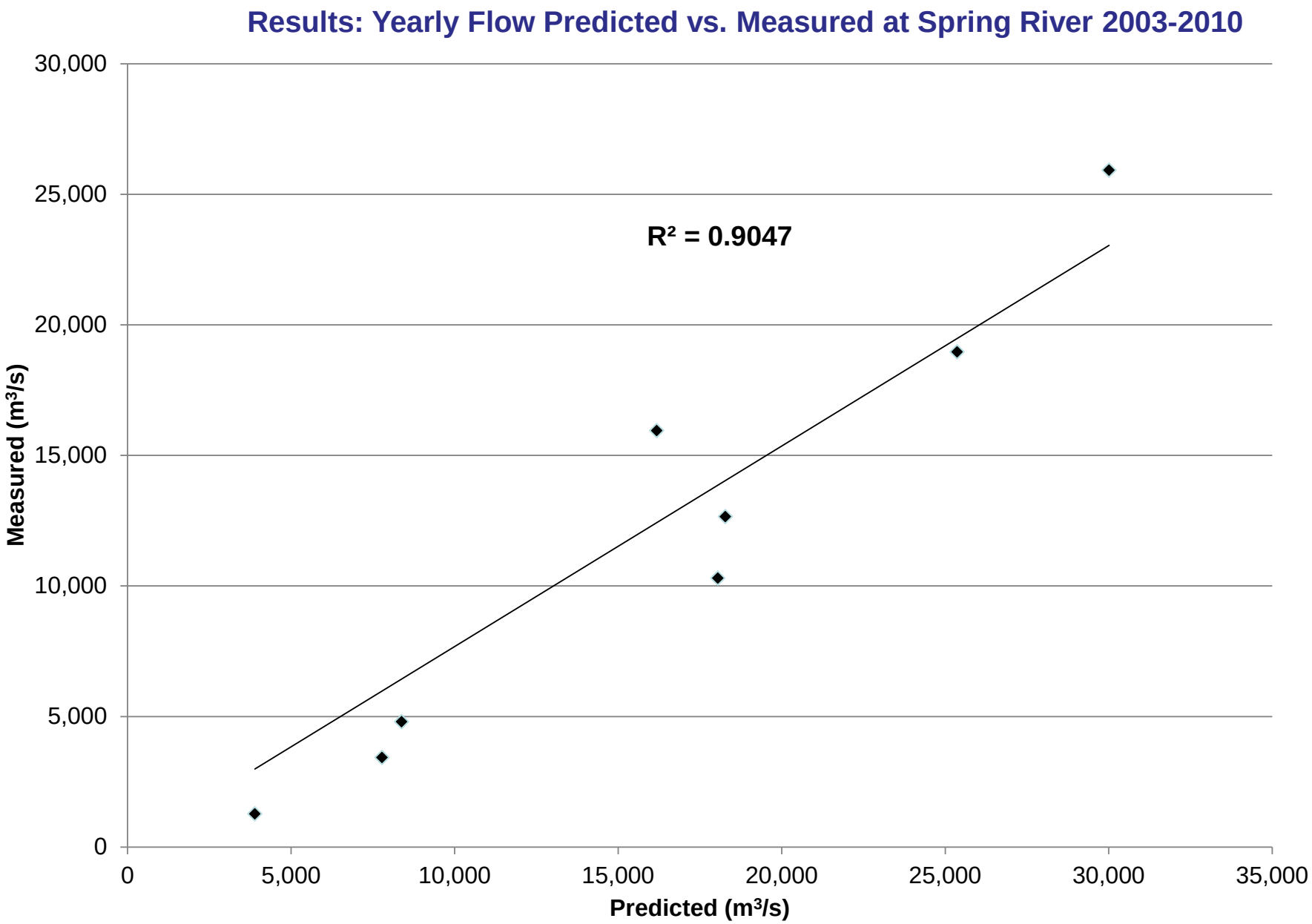


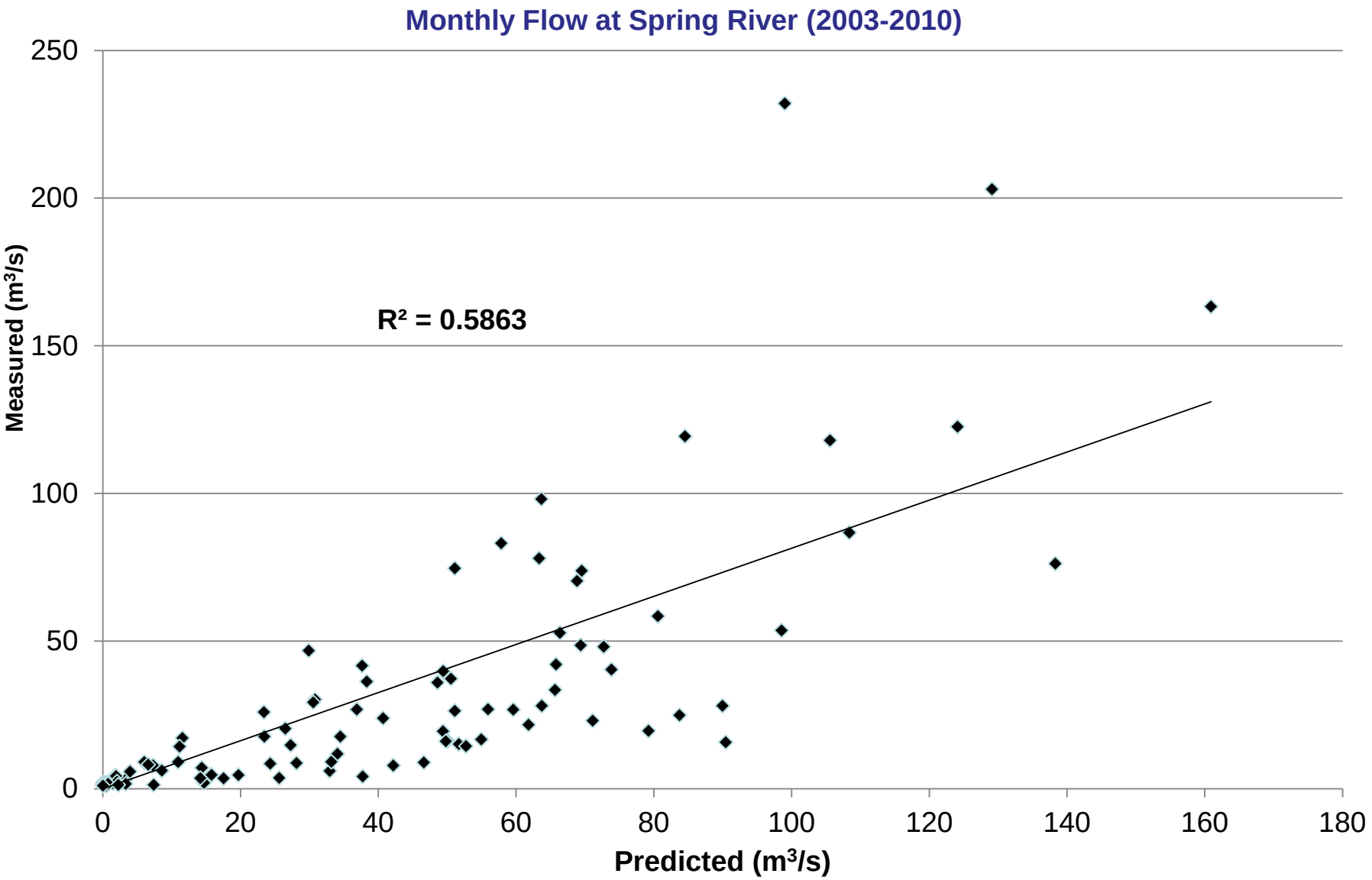
8 yrs simulation, after 3 yrs warm-up

Total time ~5 min.

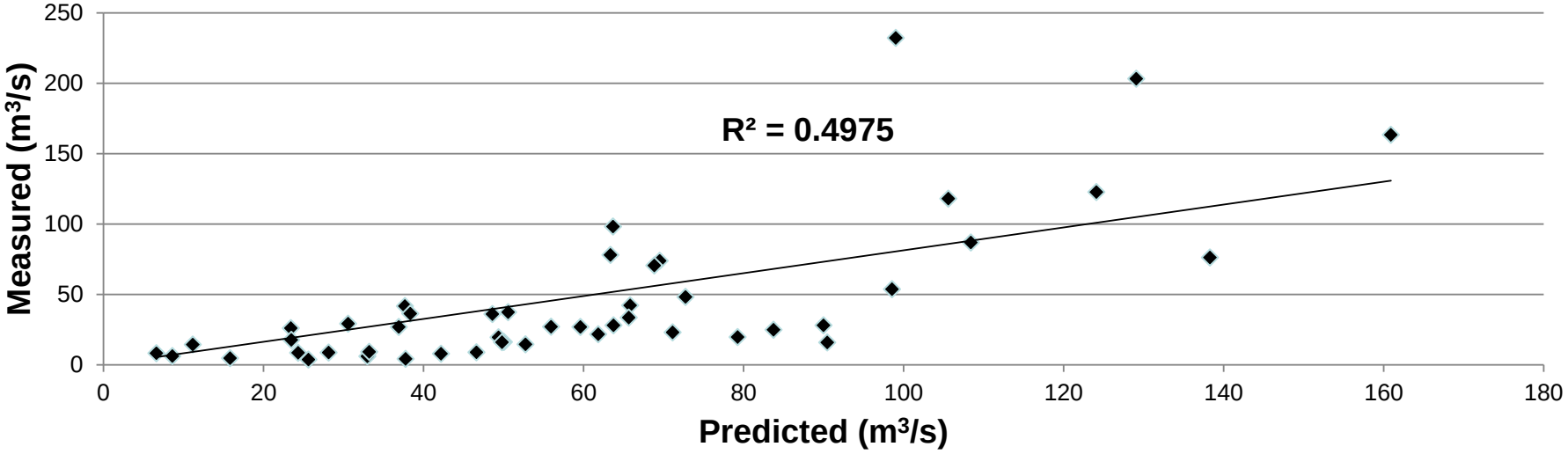
Dry and Wet Years

Year	Precipitation (mm)	Status
2003	872	Dry
2004	1045	Dry
2005	627	Dry
2006	880	Dry
2007	1370	Wet
2008	1425	Wet
2009	1161	Wet
2010	1071	Wet
Average	1060	------

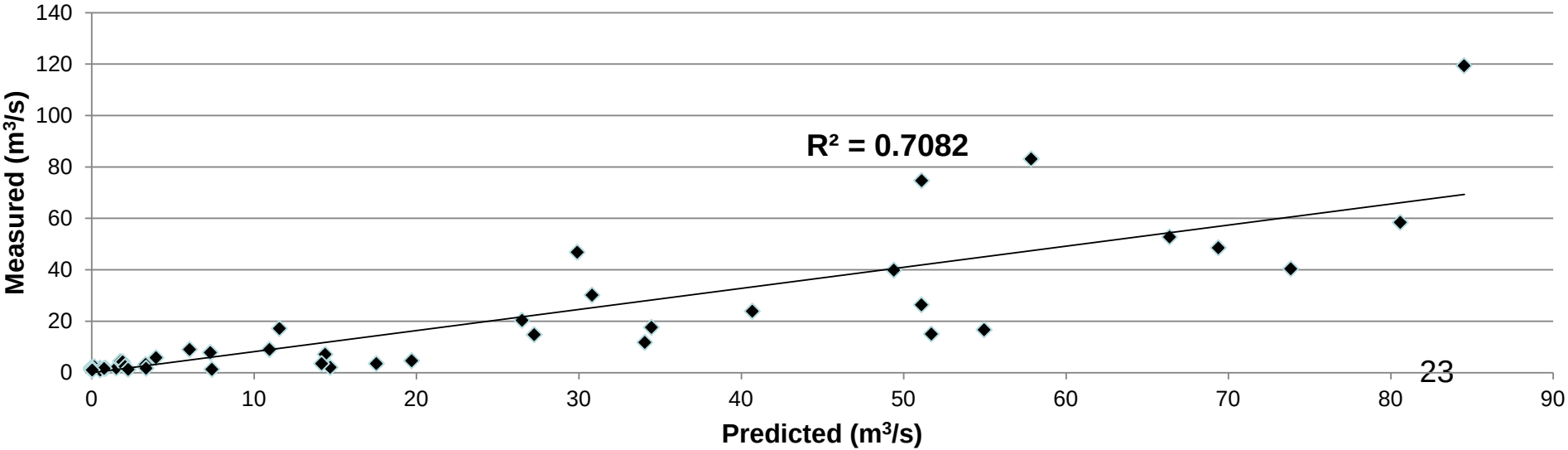

Results: Yearly Flow Predicted vs. Measured at Spring River 2003-2010
R² = 0.9047
Measured (m³/s)
Predicted (m³/s)
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000

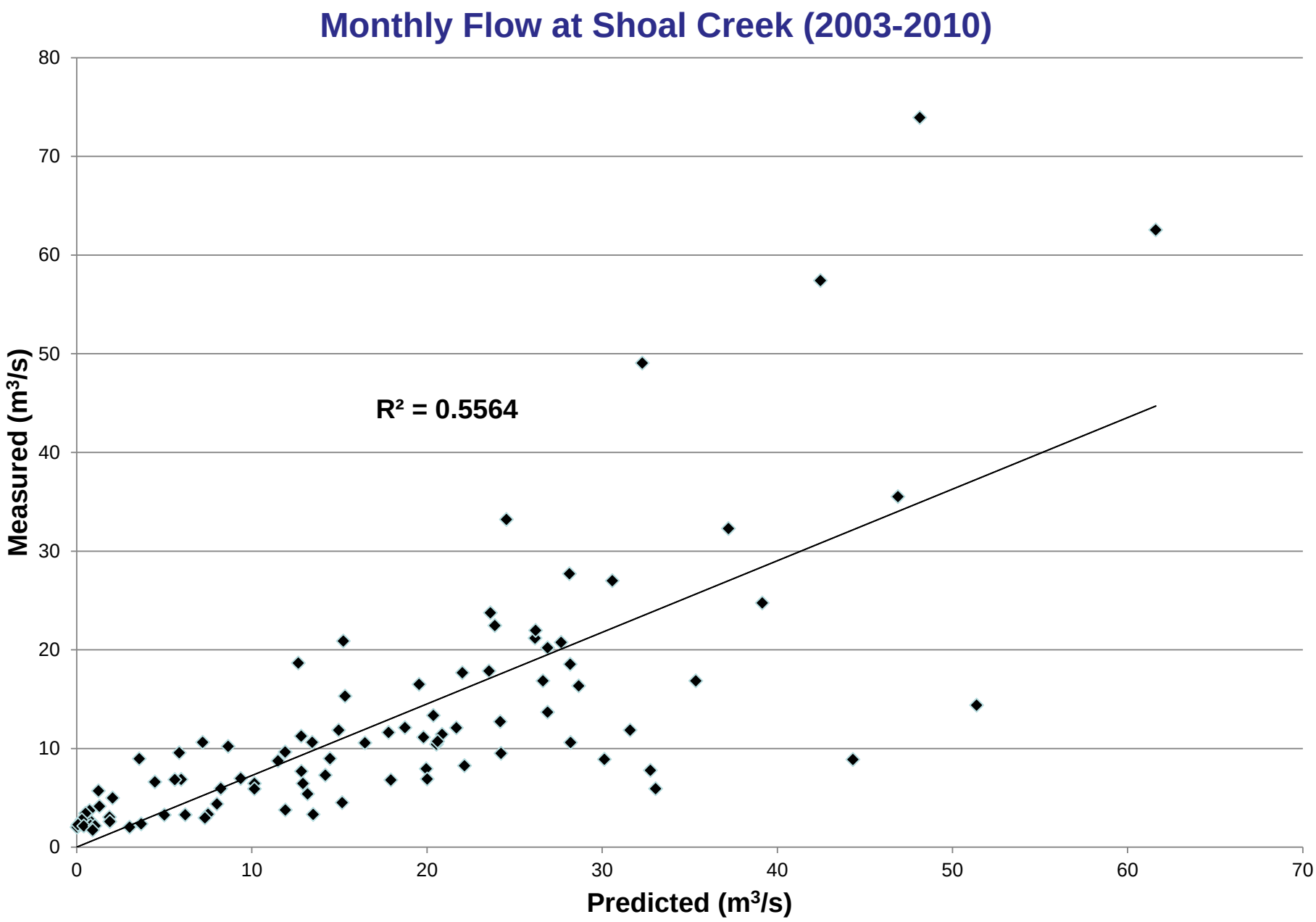

Monthly Flow at Spring River (2003-2010)
250
200
150
100
50
0
Measured (m³/s)
R² = 0.5863
0
20
40
60
80
100
120
140
160
180
Predicted (m³/s)

Monthly Flow for Wet Years (2007-2010) at Spring River

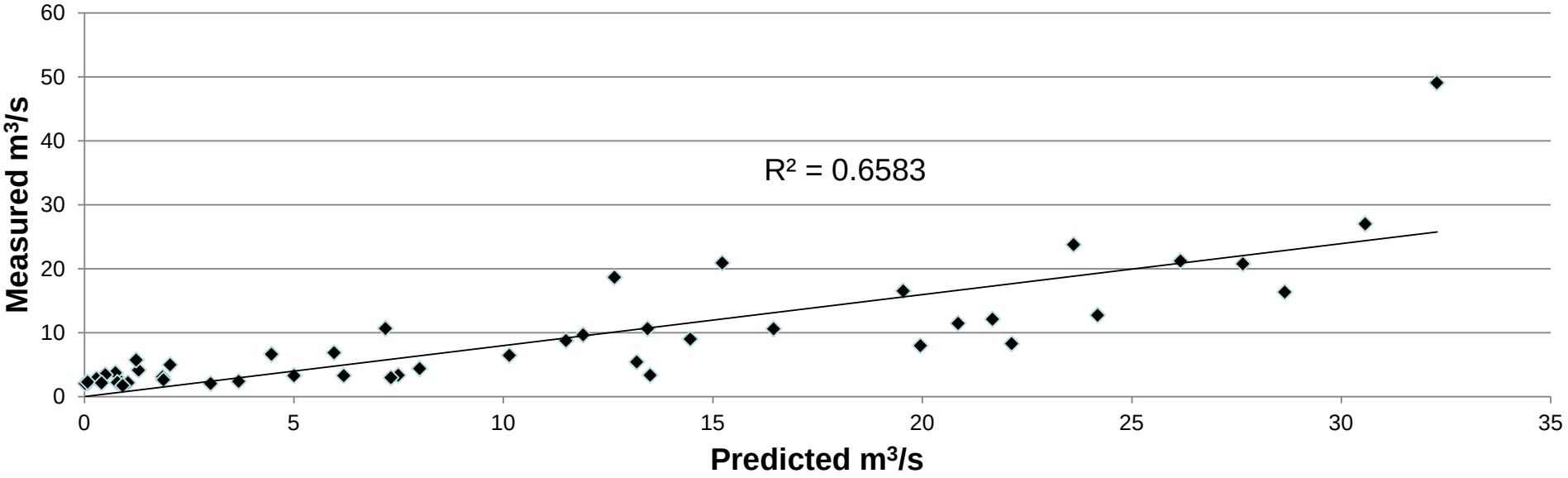


Monthly Flow for Dry Years (2003-2006) at Spring River

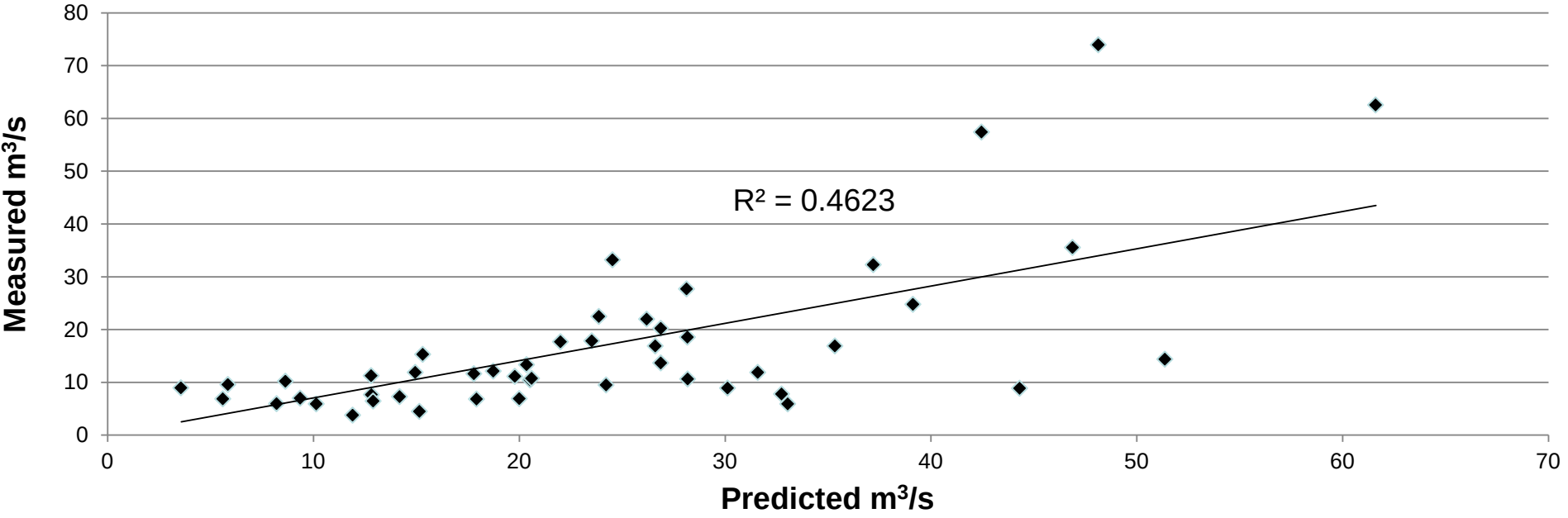



Monthly Flow at Shoal Creek (2003-2010)
Measured (m³/s)
Predicted (m³/s)
R² = 0.5564
0
10
20
30
40
50
60
70
80

Monthly Flow for Dry Years (2003-2006) at Shoal Creek



Monthly Flow for the Wet Years (2007-2010) at Shoal Creek



Flow Calibration Current Status & Future Targets

River	Current R^2	Target Manual Calibration
Spring	Dry = 0.71	Dry = 0.80
	Wet = 0.50	Wet = 0.70
Shoal	Dry = 0.66	Dry = 0.75
	Wet = 0.46	Wet = 0.70

Next Steps

- Sediment Calibration & Validation (2013-14)
- Sensitivity Analysis (2013-14)
- Metal (Cd, Zn, & Pb) Calibration (2014)
- Uncertainty Analysis (2014-15)
- Field Sampling and Lab Analysis (Jan. 2014)
- SWAT Model Validation for Flow, Sediment & Metal (2014)
- Model Set-up for EFDC (2015)
- EFDC Calibration and Validation for Flow, Sediment & Metal (2015-16)
- Developing Decision Support System for Remediation Scenarios (2017)

Acknowledgment

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- Dr. Brian Dyson; EPA-ORD-NRMRL
- Ken Bailey; EPA-ORD-OSP

Questions?

and thank you for attending the talk ☺

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