



Estimating Nitrate Transport in Surface-Subsurface Hydrologic Systems by the linked SWAT- MODFLOW-RT3D Model

Xiaolu Wei
Ryan Bailey
Rosemary Records
Mazdak Arabi
Tyler Wible



Outline

- Model Overview
- Model Linkage
- Applications: Klamath Basin, OR

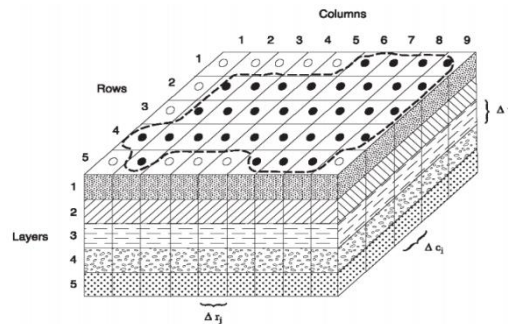
Overview

Method: Link SWAT with physically-based, spatially-distributed groundwater models.

SWAT

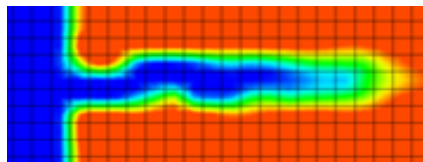


MODFLOW



- Groundwater model
- 3D finite difference

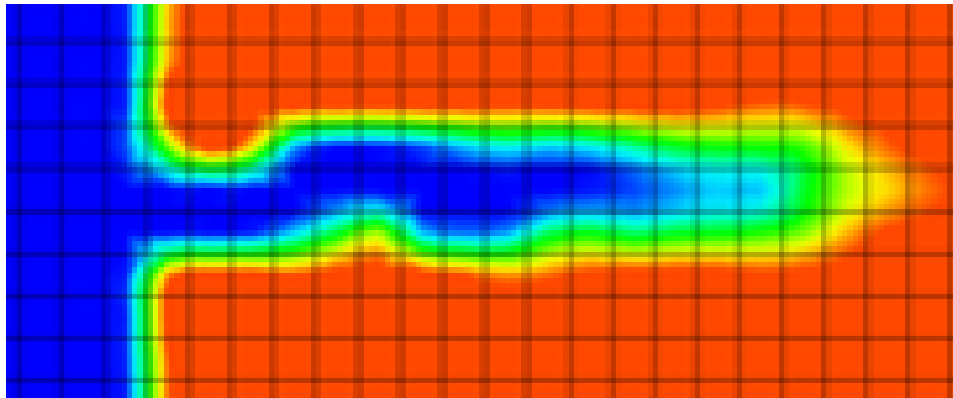
RT3D



- Reactive transport
- 3D finite difference

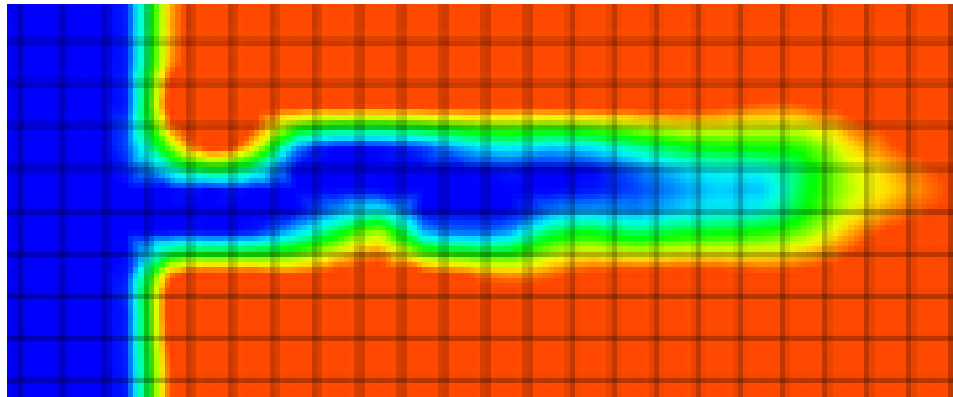
RT3D Introduction

Reactive Transport in 3 Dimensions



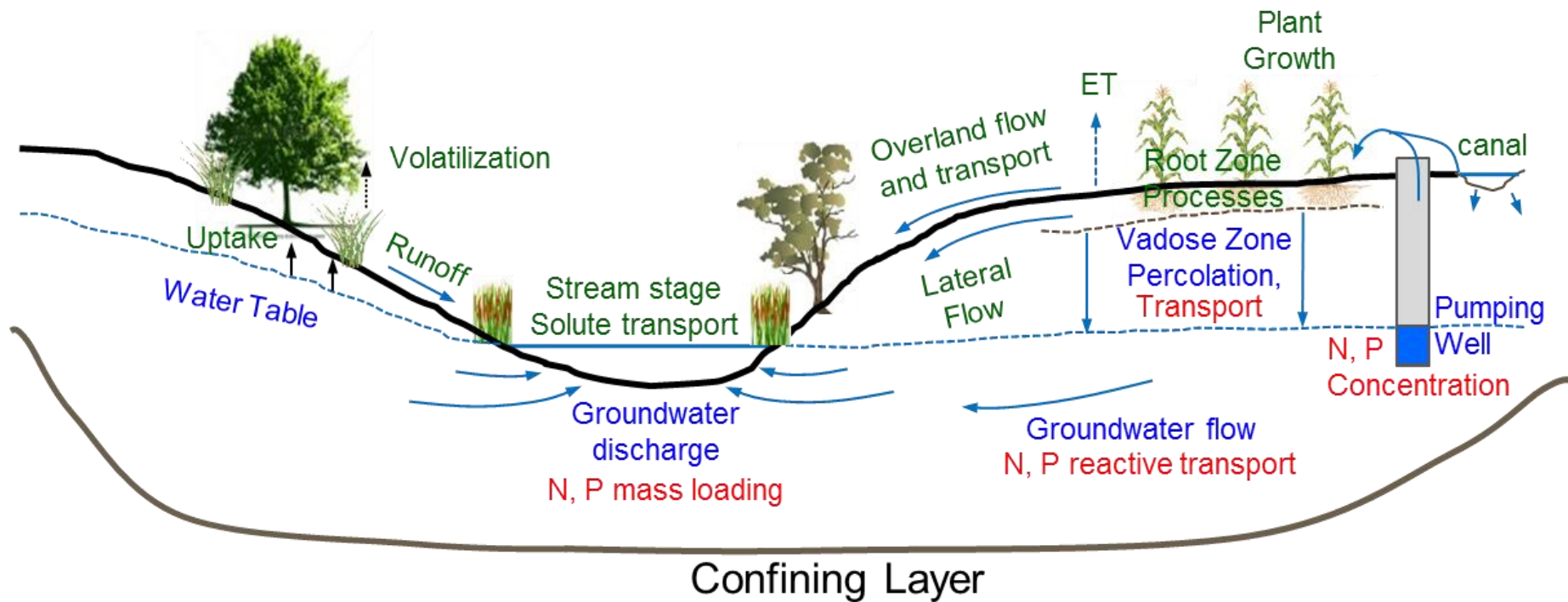
$$\frac{\partial C_k}{\partial t} = \underbrace{\frac{\partial}{\partial x_i} \left(D_{ij} \frac{\partial C_k}{\partial x_j} \right)}_{\text{Dispersion}} - \underbrace{\frac{\partial}{\partial x_i} (v_i C_k)}_{\text{Advection}} + \underbrace{\frac{q_s}{\phi} C_{s_k}}_{\text{Sources and Sinks}} + \underbrace{r_c}_{\text{Reactions (first-order kinetics)}}, \text{ where } k = 1, 2, \dots, m$$

Reactive Transport in 3 Dimensions



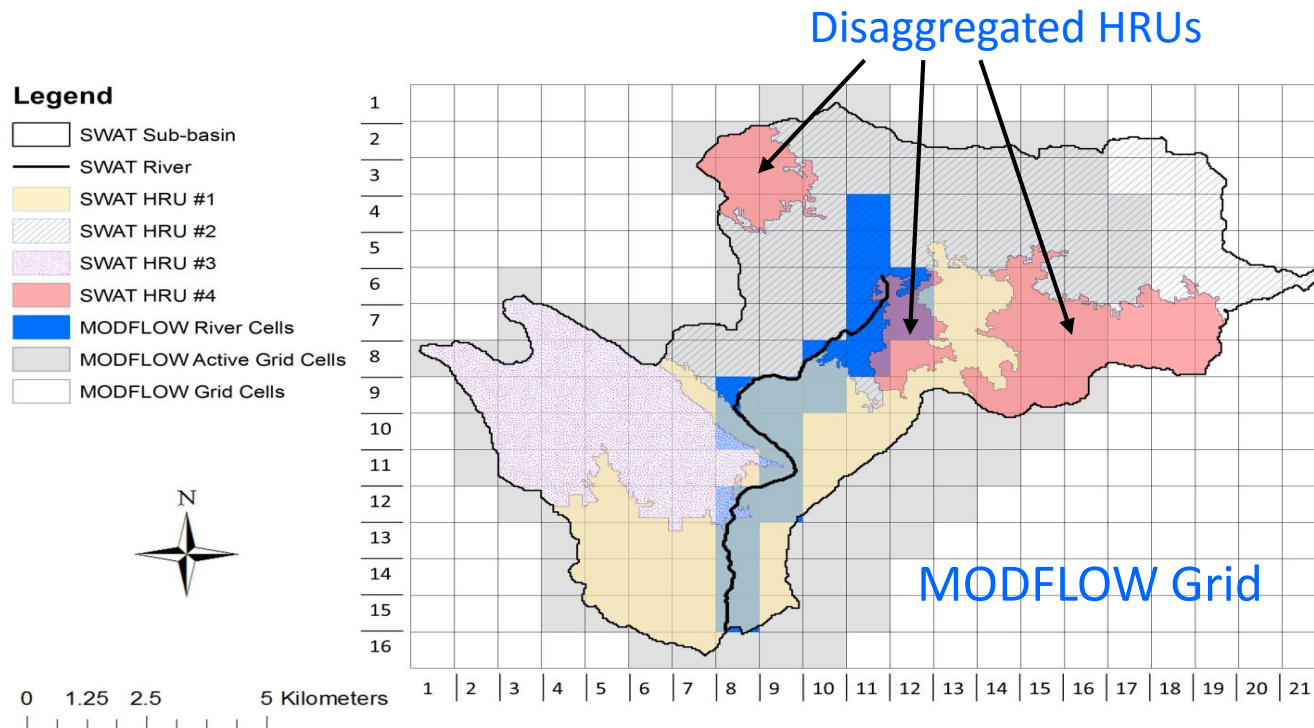
- Finite Difference Method
- Same grid as MODFLOW
- Flows/SS from MODFLOW

Overview



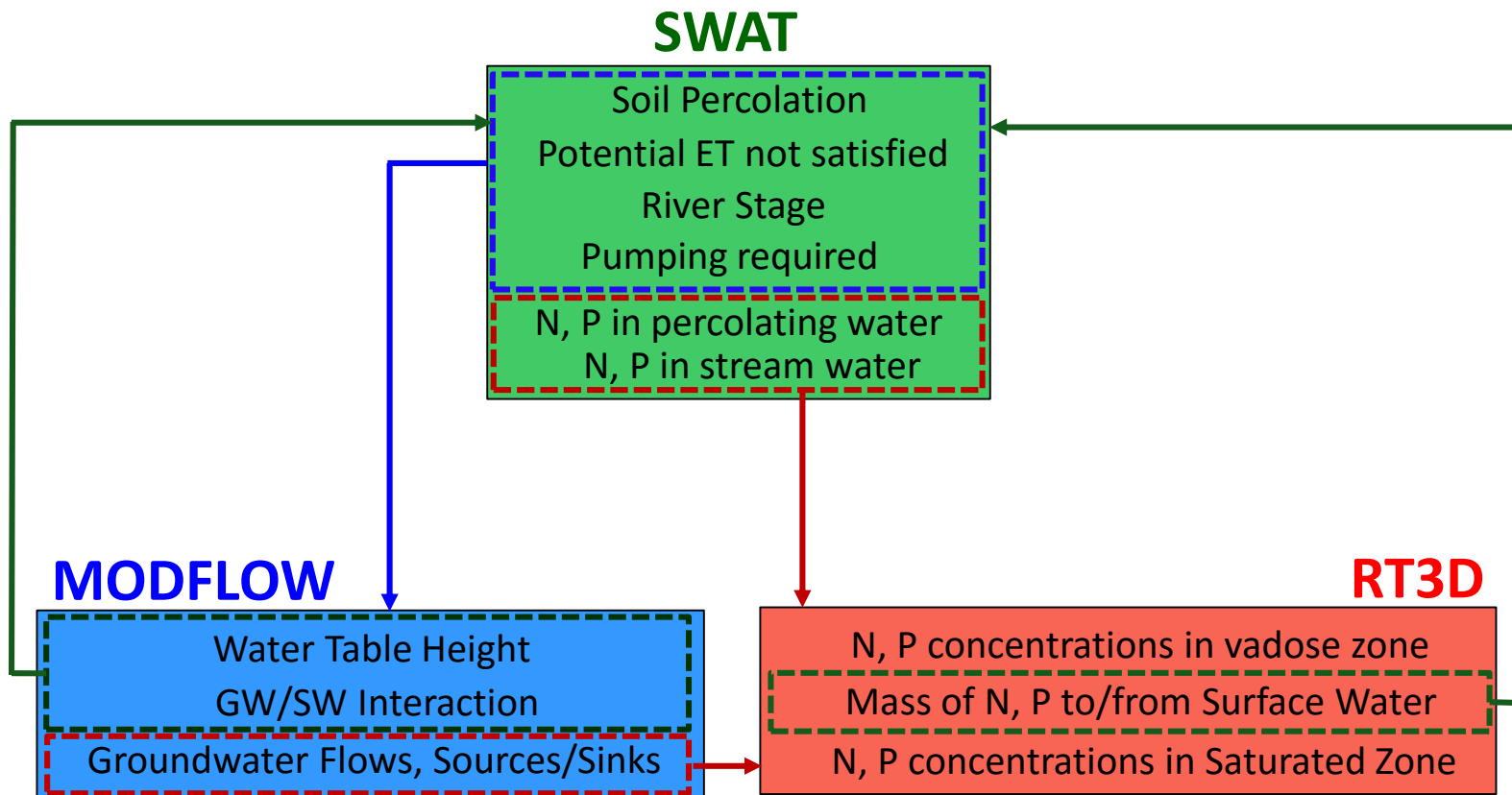
SWAT-MODFLOW

1. HRU → Grid Recharge
2. River Cells → Subbasin GW Discharge
(Pre-processing tools)

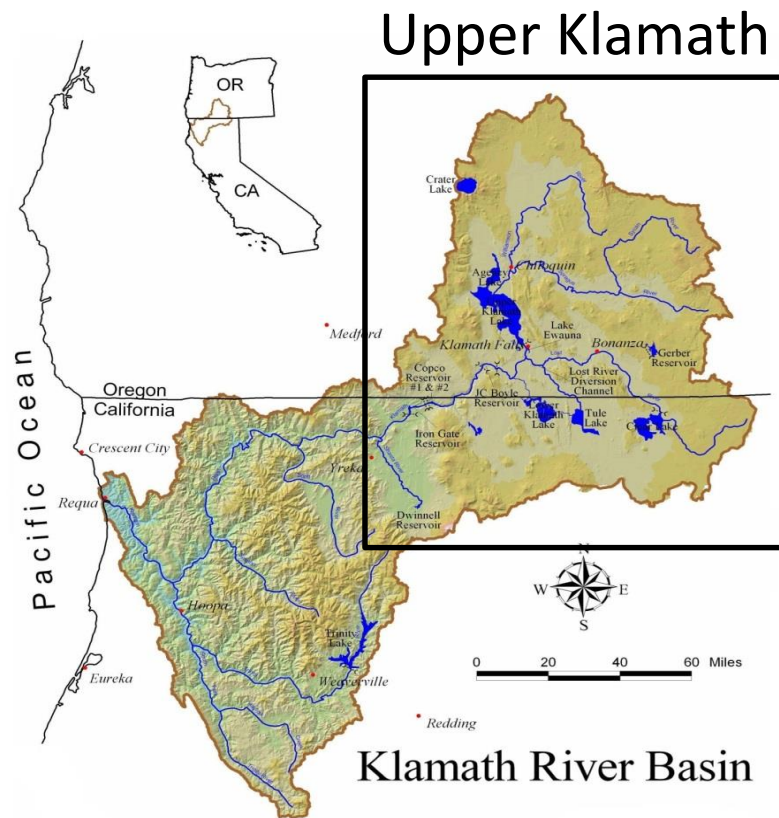


Linking Three Models

Daily Interactions



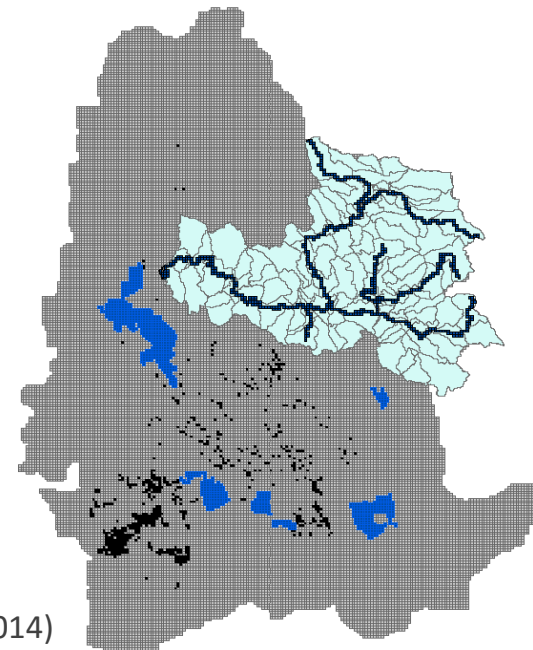
Klamath Basin, Oregon



MODFLOW Model

- USGS (2012)
- 1970-2004
- 100,000 grid cells

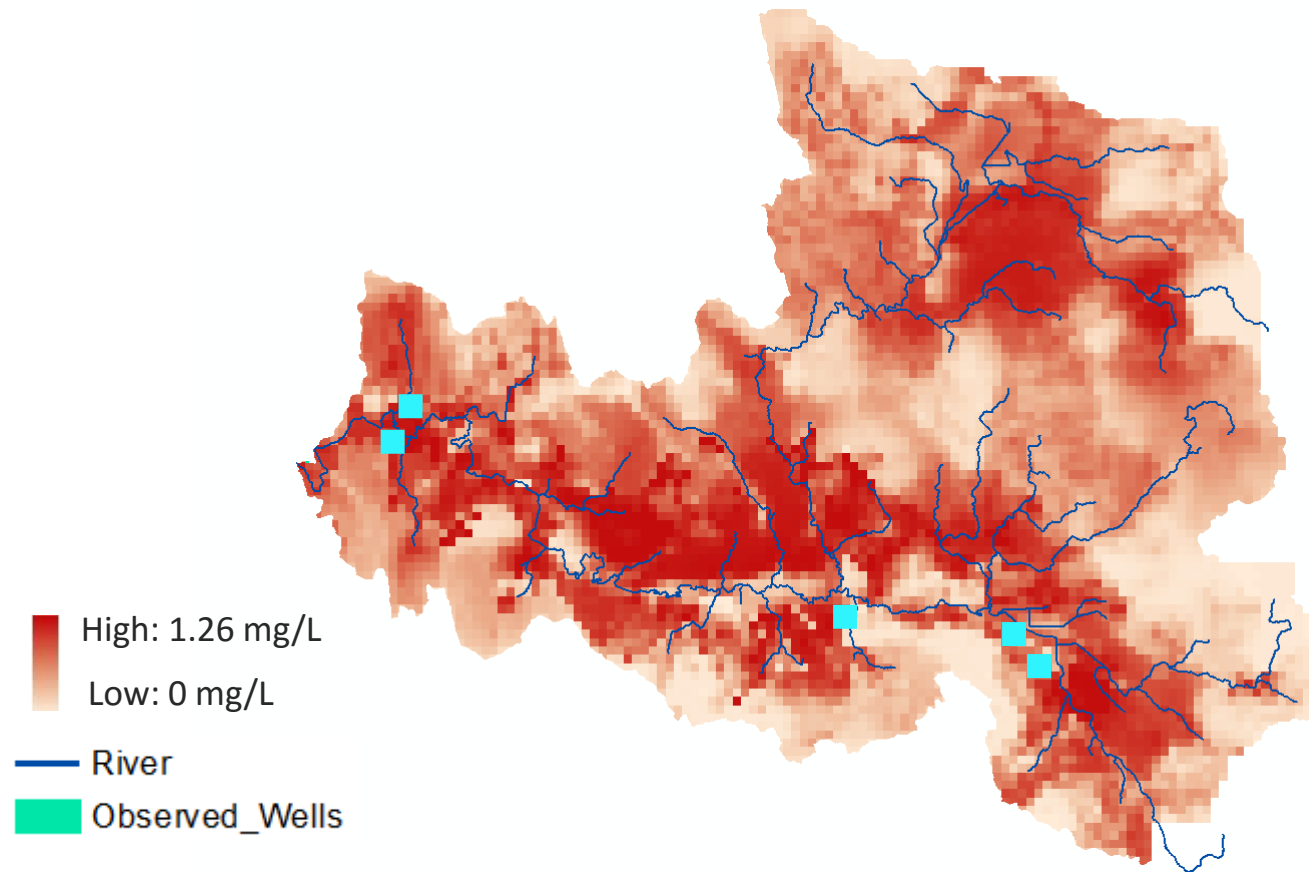
SWAT Model



Records et al (2014)
Hydrol. Earth Syst. Sci. 18: 4509–4527

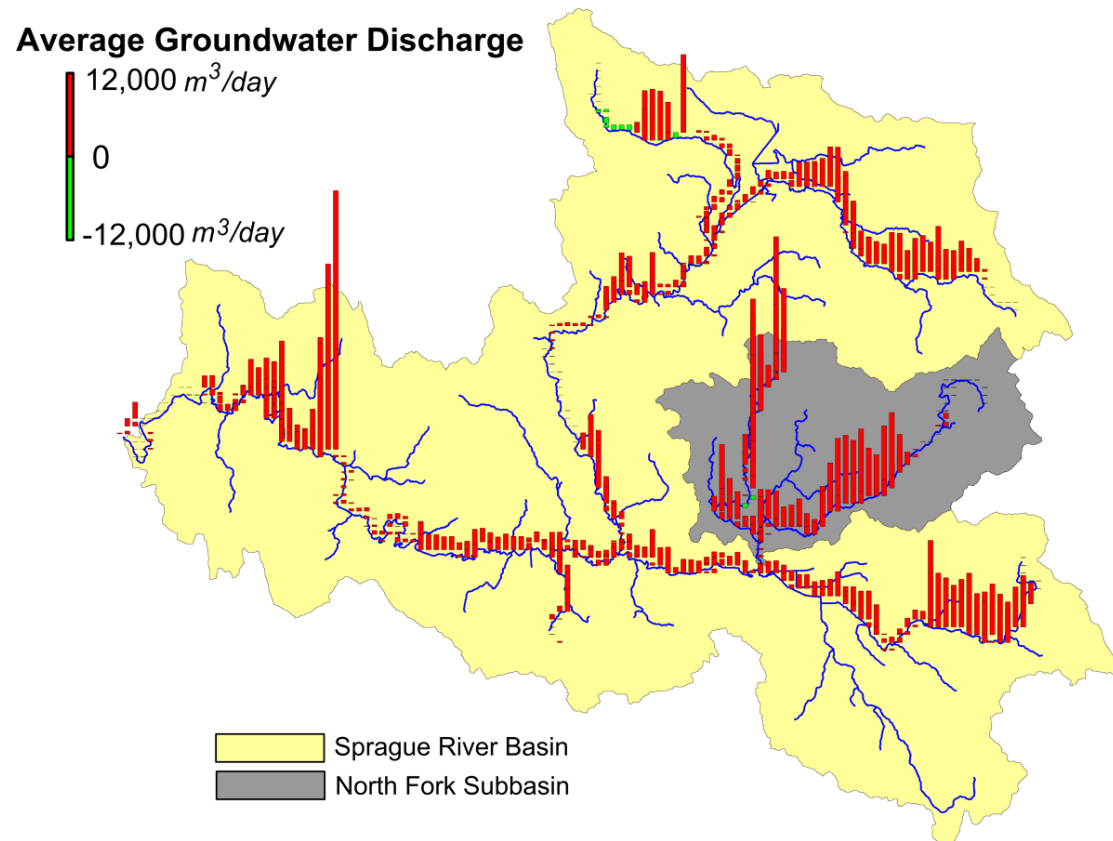
Simulation Results

Nitrate Concentration in Groundwater



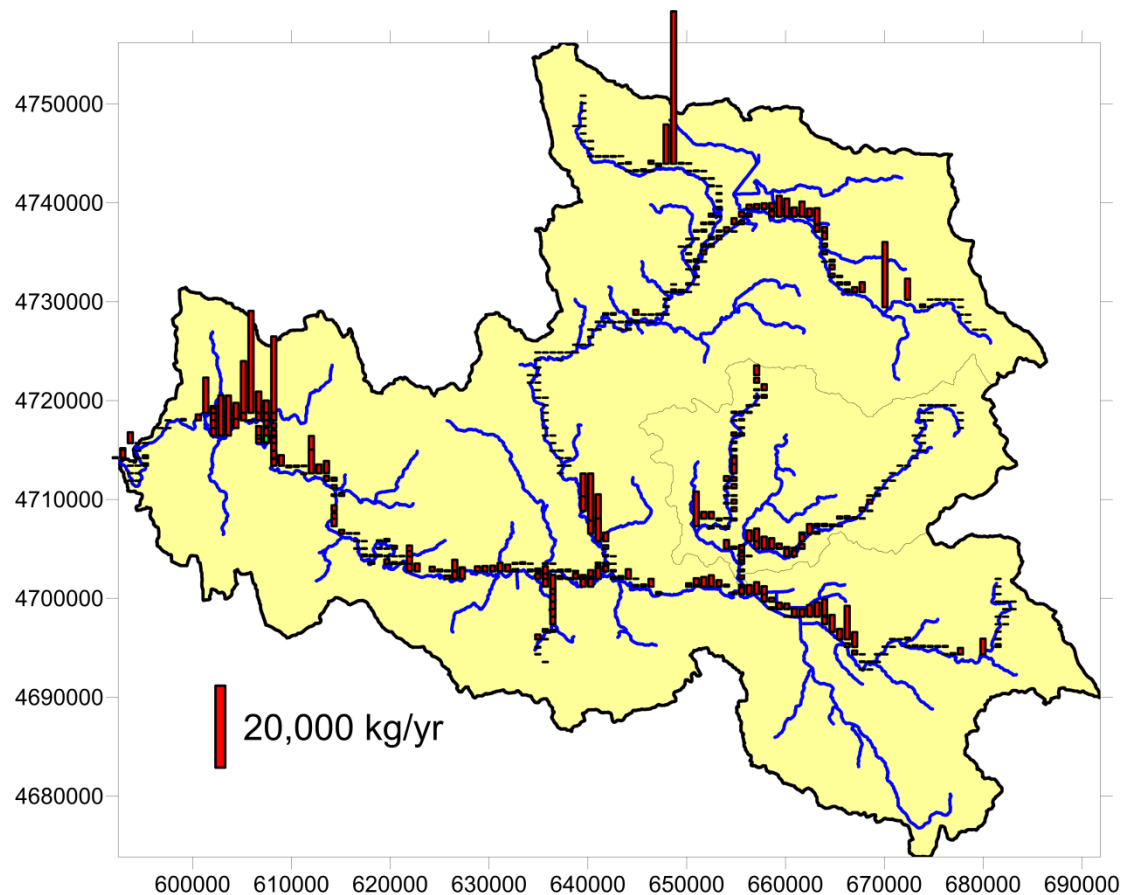
Simulation Results

Groundwater Discharge to Streams



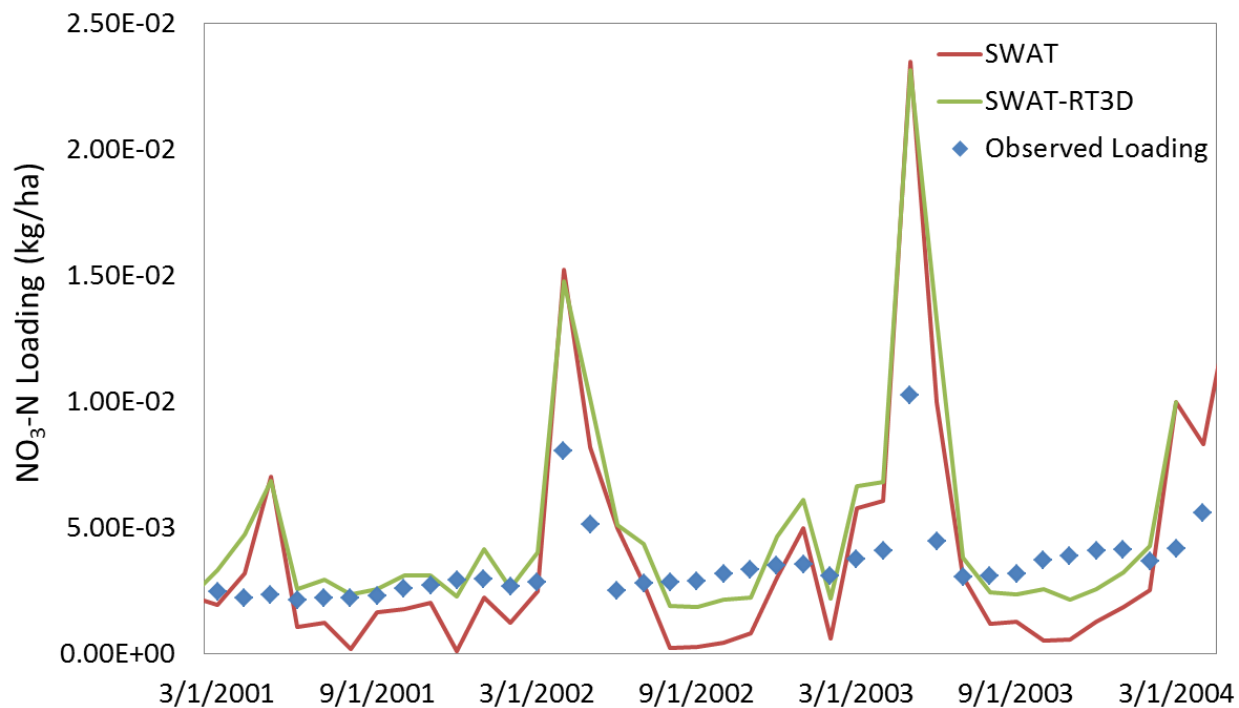
Simulation Results

Groundwater Nitrate Loading to Streams



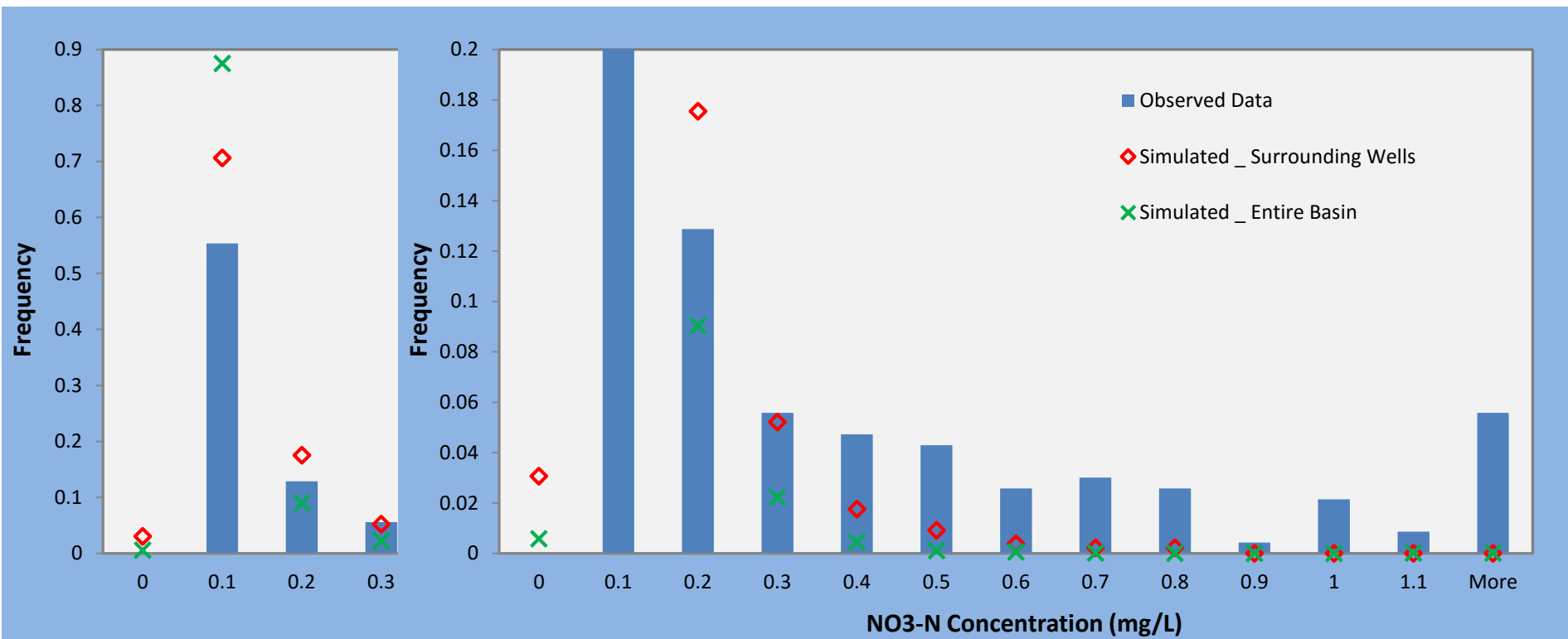
Simulation Results

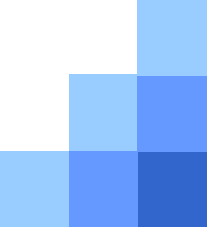
Stream loading comparison



Simulation Results

Frequency Plot





Future work

- Keep increasing N leaching from SWAT
- Balance stream flow, stream loading, and leaching
- Applied to Arkansas River Basin
- Developing: ArcGIS interface

Funding

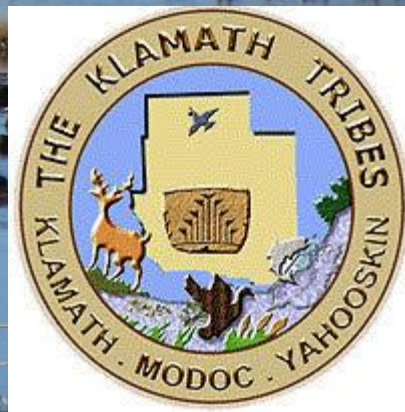


United States Department of Agriculture
National Institute of Food and Agriculture

Acknowledgements

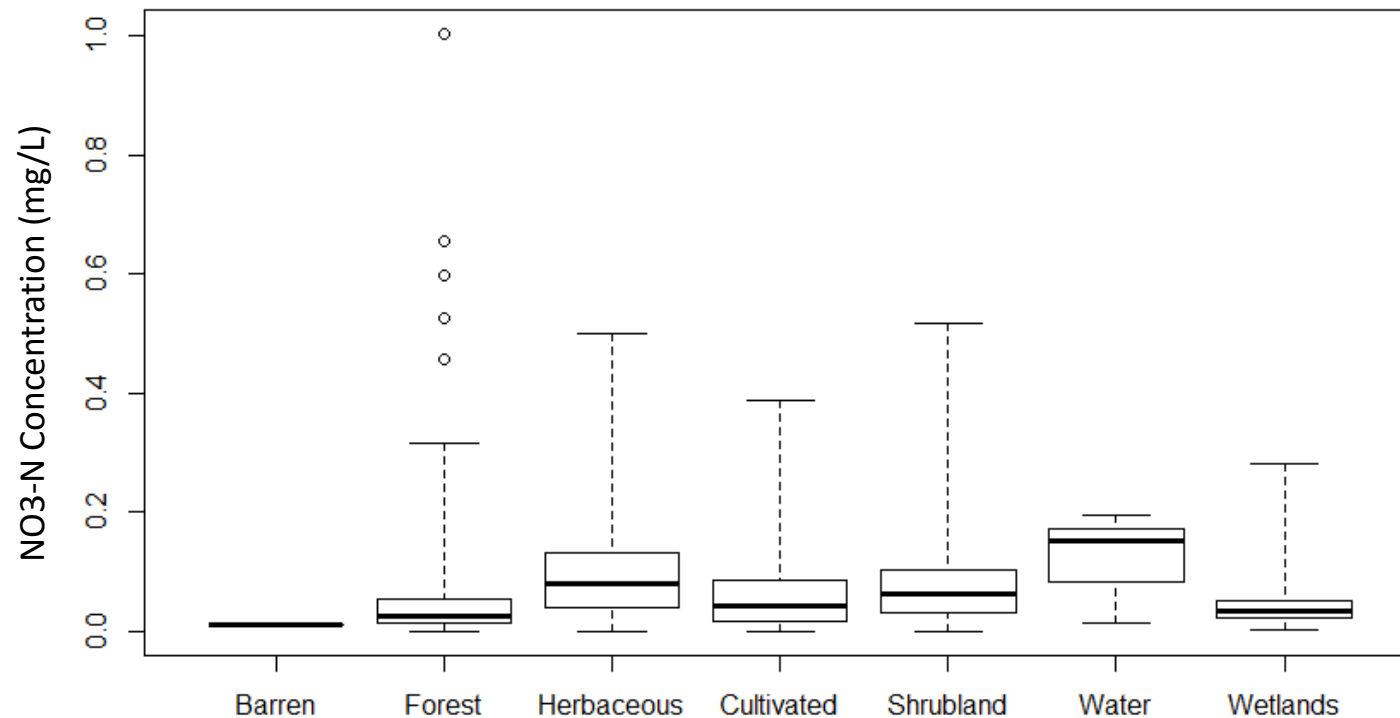


**CALIFORNIA
COOPERATIVE
FISH & WILDLIFE
RESEARCH UNIT**



Simulation Results

Box Plot for different Land Use



Code Structure

Read/Allocate arrays MODFLOW / RT3D

simulate

Years

Days

command

Surface

1: subbasin (hru calculations)

Aquifer

19: MODFLOW / RT3D

Map SWAT → Grid

HRU values → disaggregated HRUs (DHRUs)

DHRUs → Grid cells

River stage → MODFLOW River cells

NO₃ in percolation

NO₃ in river water

Run MODFLOW

Run RT3D Denitrification

Map Grid → SWAT

GW Discharge → Subbasin streams

NO₃ loading → Subbasin streams

Routine

2: Route