WSC Cat 3: Watershed Integrated System Dynamics Modeling: An example of linking a coupled Earth System model and System Dynamics in a sub-basin of the Columbia River

Introduction

The **Columbia River Basin** covers a total drainage area of about 670,000 km^2 of the Pacific Northwest and is managed to satisfy multiple human objectives. The availability of surface water for irrigation in the basin is expected to be negatively impacted by climate change. Previous climate change studies in the region suggest a likelihood of increasing temperatures and a shift in precipitation patterns, with precipitation higher in the winter and lower in the summer. For better management and decision making in the face of climate change, earth system models must explicitly account for natural resource and agricultural management activities.

Our *approach* is to construct linked models to study interactions between water use decisions and climate change-driven watershed processes, and then to explore how participant / stakeholder involvement in the modeling could both improve understanding of the systems and lay the groundwork for adaptive changes in institutional arrangements. The inclusion of stakeholder-driven collaborative modeling will occur in two of four sub-basins including Spokane River Basin in northern Washington State and northwestern Idaho State.

Objective

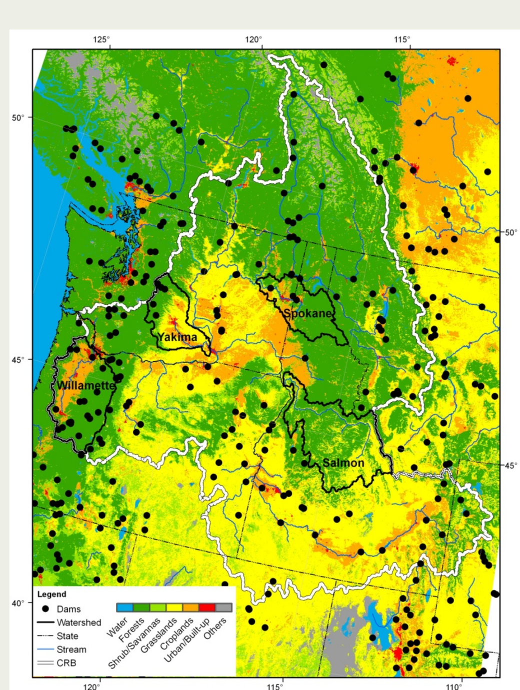
Our **goal** is to study the impacts of climate change on CRB water availability at multiple scales and how stakeholders will respond to these changes in an altered climate. Towards this goal, it is essential that we have process-based knowledge of biophysical and biogeochemical systems and the future responses of these systems to change. Furthermore, assessment of water-system vulnerability requires directly modeling human and environmental system feedbacks, and interactions between economic and social entities heterogeneously across space. Only then will it be possible to model how changing incentives faced by individuals alter decisions, preferences, and beliefs that aggregate to affect institutional change.

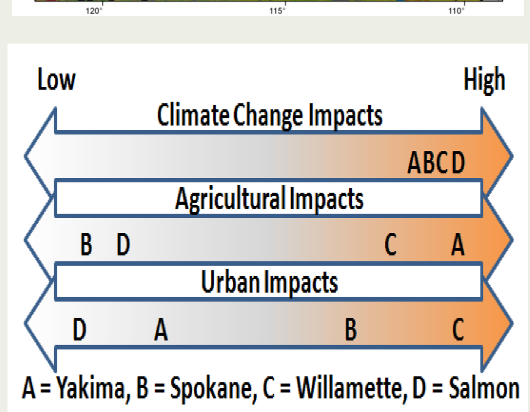
Basin Description

▪The Spokane River basin (SRB) is one of the four sub basins chosen as focal points of the WISDM project to represent the existing range of agricultural and urban impacts.

▪The Spokane Valley-Rathdrum Prairie Aquifer (SVRP) connected to the SRB is the sole-source aquifer for 500,000 people. It is highly connected to the Spokane River and response rapidly to perturbation.

▪Discussion of management options for water quality regulation (TMDL) have been complicated by uncertainty about projected low-flow discharge and the role groundwater plays in maintaining base flow in drought years.





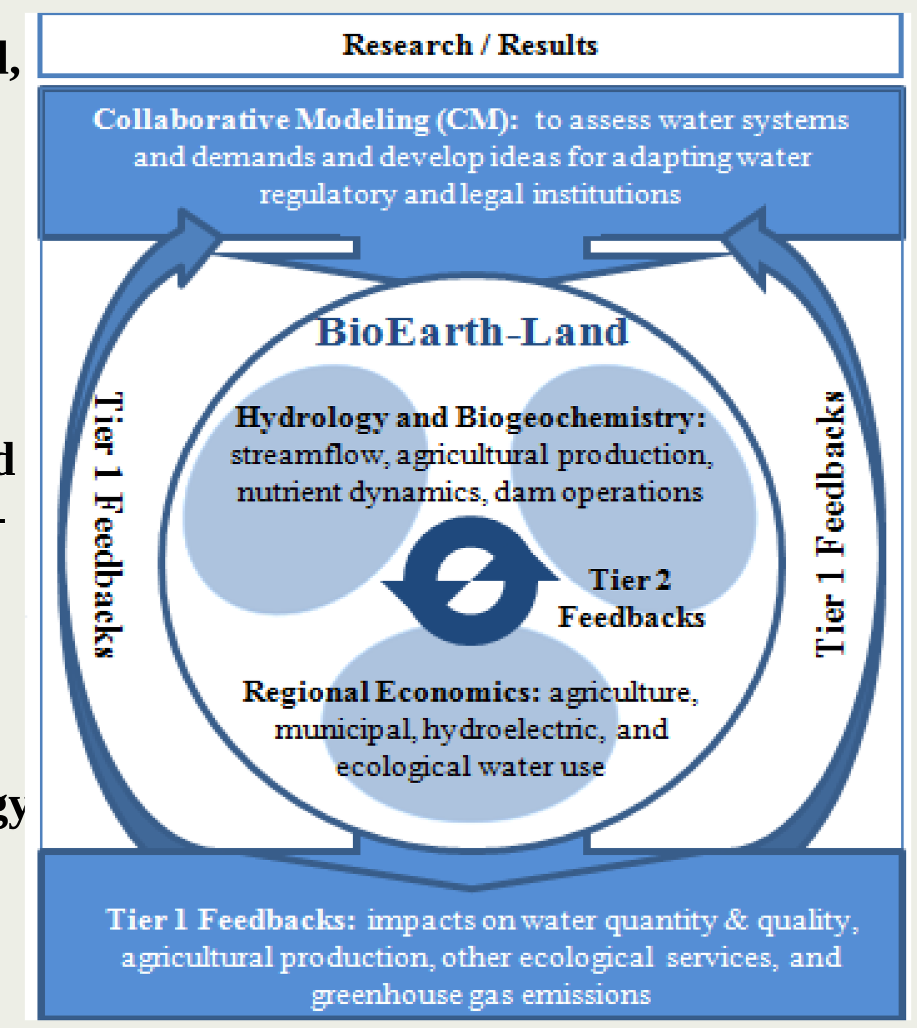
WISDM Modeling Approach

Linking Collaborative modeling and BioEarth Land

BioEarth Land is a regional, Biosphere relevant Earth System model developed through a USDA EaSM project.

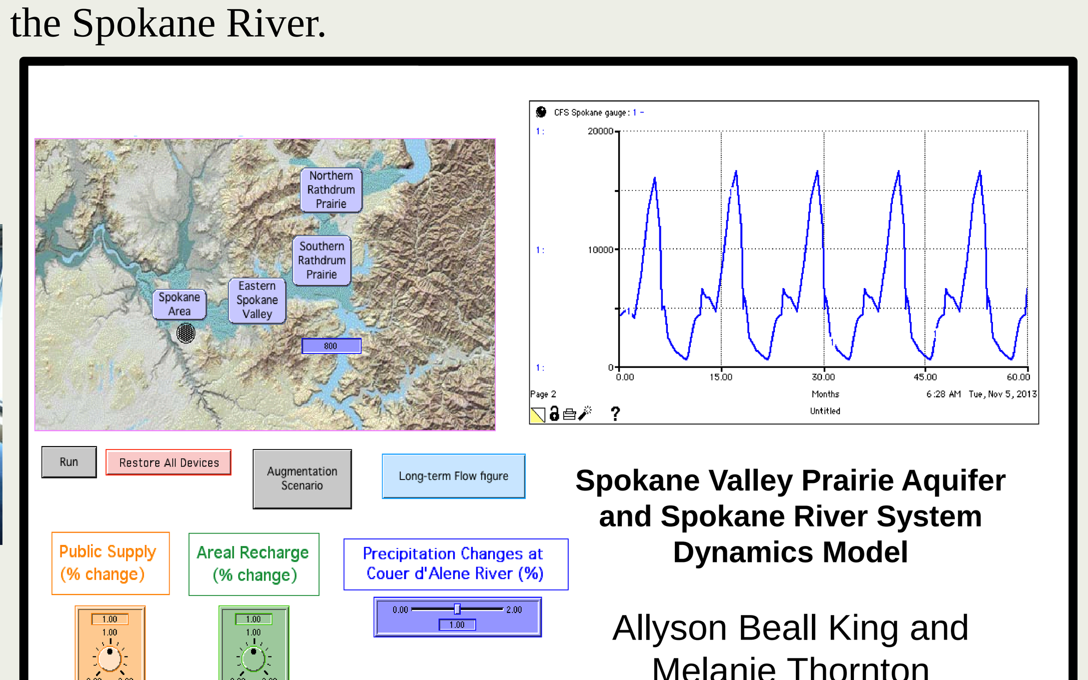
Tier 1 feedbacks occur between the BioEarth-Land Scenarios and stakeholder-driven Collaborative modeling

Tier 2 feedbacks occur between the linked Hydrology Biogeochemistry and Economic models within BioEarth Land



Collaborative Modeling

Collaborative modeling involves building and running a system dynamics (SD) model with stakeholders in real time, allowing them to drive inputs and scenarios for the SD model, and developing an understanding as to what changes in the biophysical system will cause them to promote a change in policy and what that policy will look like. For the SRB stakeholders are concerned with low flows, phosphorous and DO and toxics such as PCBs. The SD model will include information from BioEarth and GSFLOW to initialize the hydrology, additional models will assist with P,N,DO, etc. Stakeholders decide upon policy options that can be used to simulate preferred futures in the SD model such as the one below simulating discharge in the Spokane River.

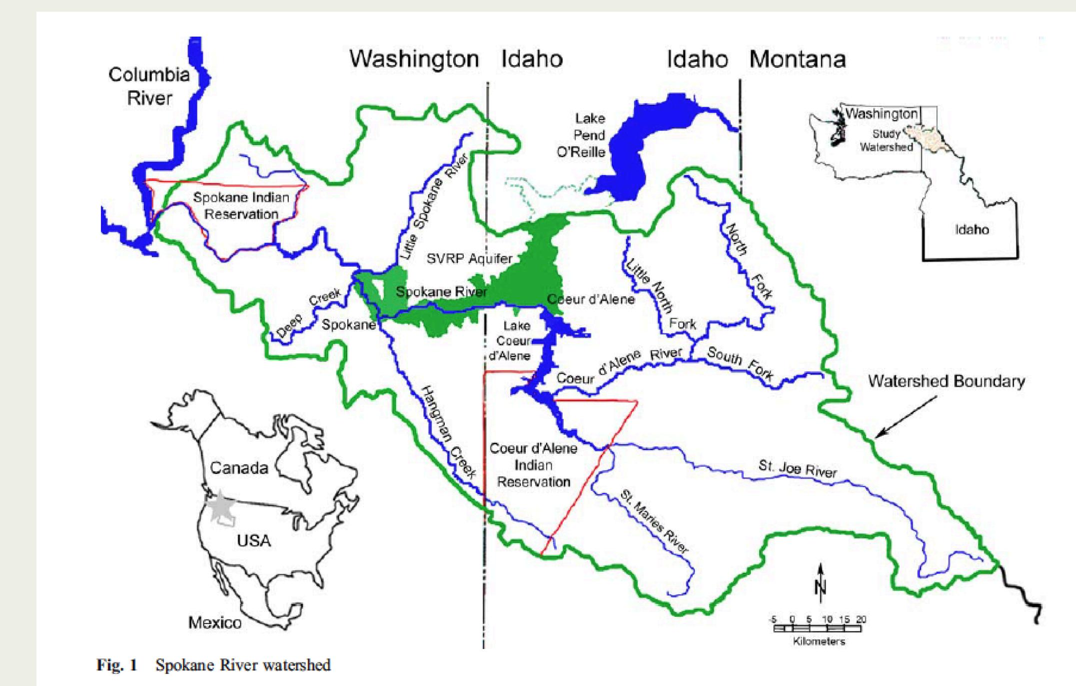


Water management in 2063?

	Responses	
	Percent	Count
a. Managed as a basin	43.64%	48
b. Increased conflict	40%	44
c. Business-as-usual	16.36%	18
Totals	100%	110

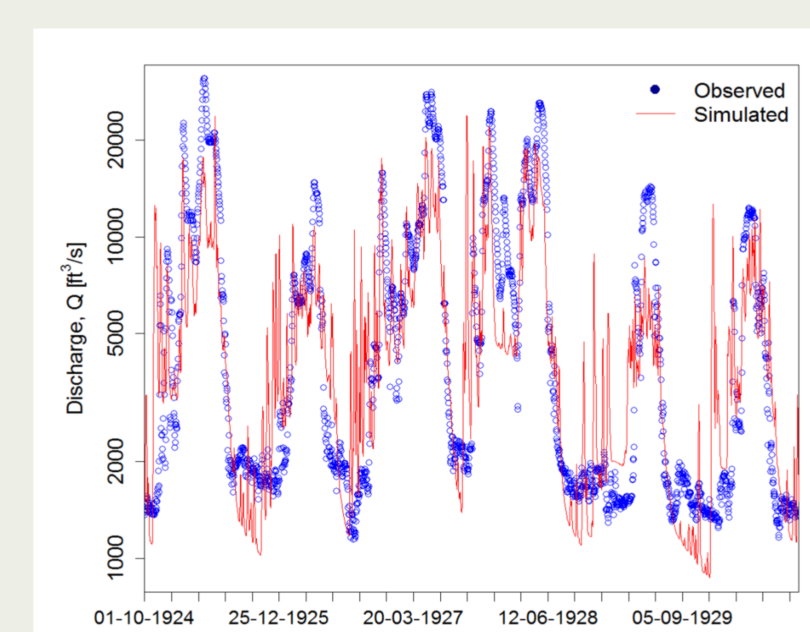
Spokane Valley-Rathdrum Prairie Aquifer

Groundwater storage, recharge and discharge play important roles in land-atmosphere studies because of their impacts on surface energy and water exchange with the atmosphere. The dynamics of groundwater table control runoff generation processes, soil moisture in the root zone and evapotranspiration rate. Inclusion or exclusion of groundwater – surface water interactions in future climate change impact studies can lead to different estimations of surface water availability and dilution capacity – an essential input into CM efforts to manage river solute concentrations and meet TMDL targets.

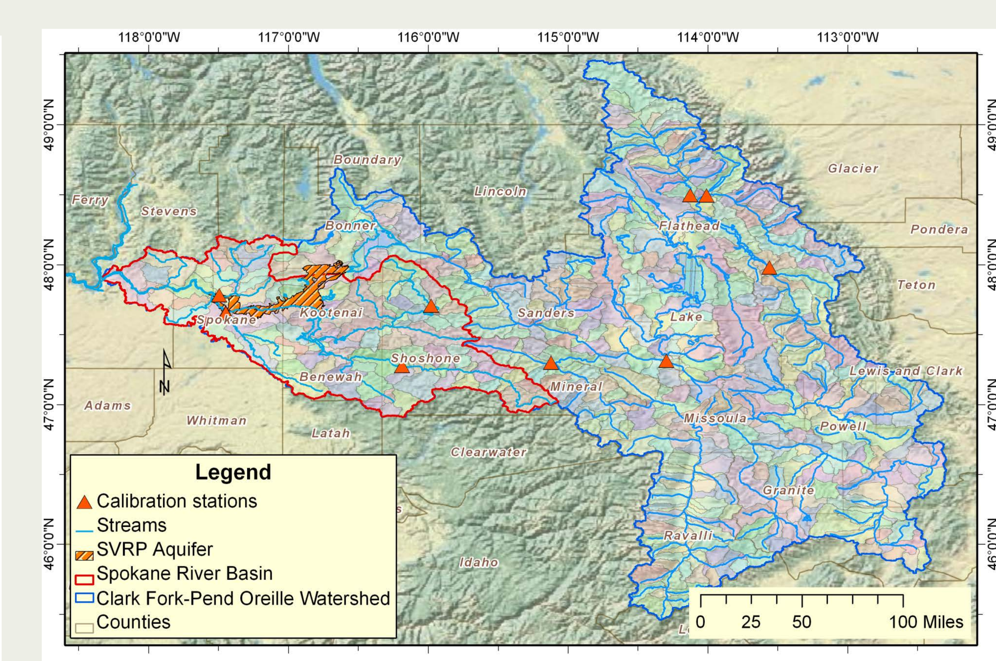


Surface water – Groundwater modeling

1. Previous hydrological modeling efforts (e.g. the Variable Infiltration Capacity Model – VIC) have failed to represent the dynamics of strong groundwater – surface water interactions in the SVRP aquifer especially in summer (see figure below)
2. We use a coupled Groundwater and Surface-water FLOW model (GSFLOW) which consists of a physically-based hydrological model – the USGS Precipitation-Runoff Modeling System (PRMS) and the Modular Ground Water Flow Model (MODFLOW-2005) (Markstrom et al., 2008)
3. The model can account for climatic conditions, flow across the land surface, saturated subsurface flow and storage, plus connection among streams, lakes and groundwater (Huntington and Niswonger, 2012). It is based on a well-calibrated MODFLOW model for the SVRP aquifer developed by Hsieh et al. (2007)



VIC simulation result at the Spokane River at Spokane station from 10/1924 – 9/1930



The SRB and the SVRP Aquifer modeled in the GSFLOW

More information:

WISDM: USDA 2012-67003-19805

http://www.cereo.wsu.edu/WISDM

BioEarth: USDA 2011-67003-30346

http://www.cereo.wsu.edu/bioearth/