The Spokane River :

Low Flow Trends and Modeling Under A Changing Environment

Tung Nguyen &

Heather Baxter

June 10, 2014

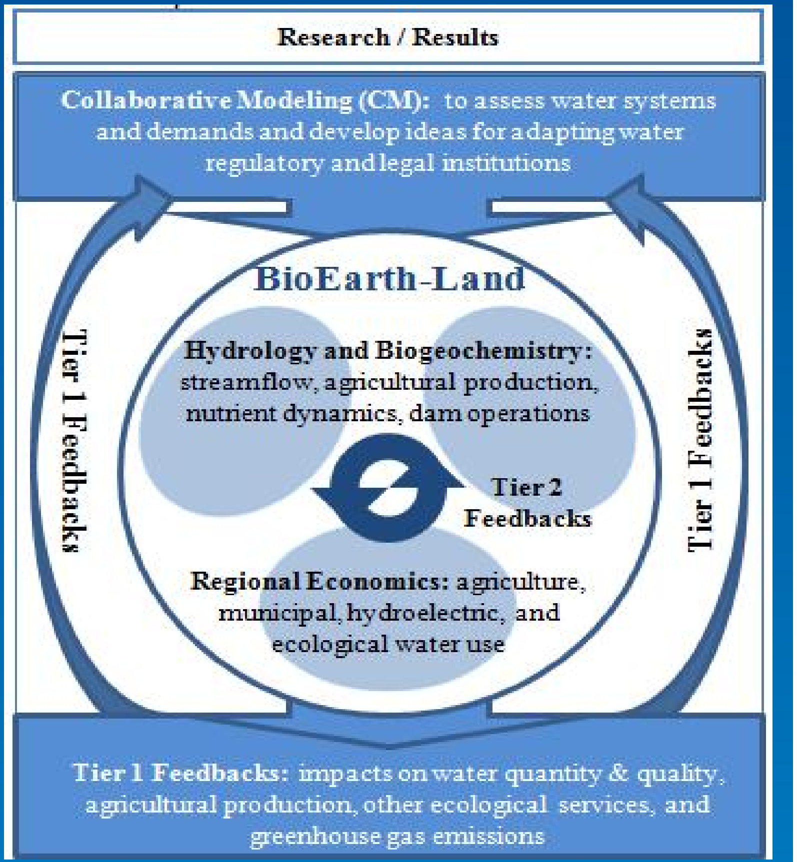
IWAC Meeting

Content

- Introduce WISDM project and our group
- Introduce our research focus
- The USGS MODFLOW model (Hsieh et al., 2007)
- Hydrological Modeling using Precipitation Runoff Modeling System (PRMS) model
- Discussion

The WISDM project

- Watershed Integrated Systems Dynamics Modeling (WISDM)
  - Improve understanding of the interactions between water resources, water quality, climate change, and human behavior in agricultural and urban environments
  - How stakeholder involvement in the modeling could both improve understanding of the systems and lay the groundwork for adaptive changes in institutional arrangements



Multi-Scale Land Surface Hydrology Group

Jennifer Adam, PhD
Associate Professor

Ming-Liang Liu, PhD
Res. Assistant Professor

Kirti Rajagopalan – Agricultural production in the Columbia River basin in an altered climate: crop response and adaptation alternatives

Julian Reyes – Eco-hydrologic modeling of rangelands/grasslands under changing management and climate conditions

Keyvan Malek – Impact of climate change and agricultural water management on interaction between climate, hydrology and agricultural productivity of Yakima River Basin

Tung Nguyen – Role of groundwater in understanding the vulnerability of hydro-ecological system in response to climatic and anthropogenic changes in the Yakima River Basin

Heather Baxter – Impact of climate change and human activities on summer low flow in the Spokane River Basin

Our (individual) research focus

- Low flow trend
  - 1951-2007: –3.3 $ft^3/s/year$
  - Possible causes
    - Climate change
    - Water use patterns change
      - Irrigation canal near Post Falls
    - Municipal pumping increase
    - Reservoir operations (Post Falls Dam)
- Potential impacts of climate and anthropogenic changes in the future

Barber et al. (2009)

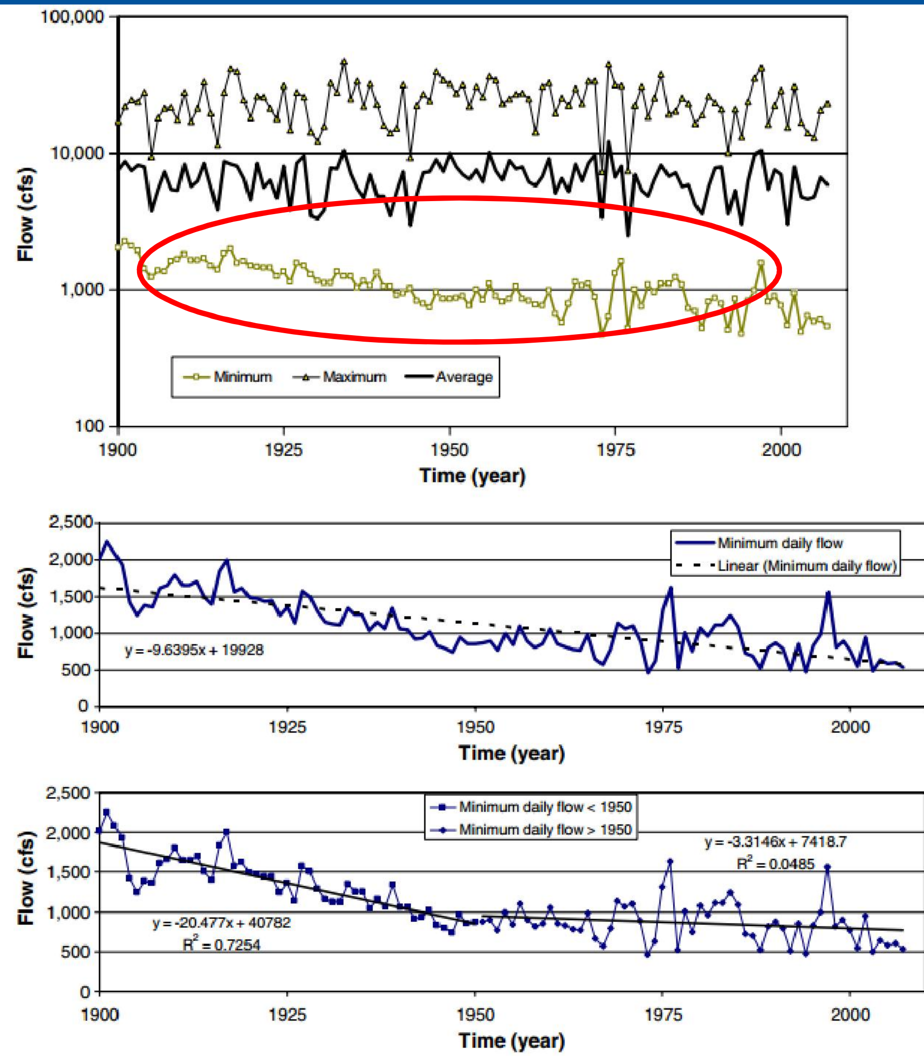


Fig. 6 Long-term daily flow trend for Spokane River at Spokane gage (1 $ft^3/s=0.0283\ m^3/s$)

Research Objectives

- How climatic and anthropogenic changes effect groundwater recharge & surface water/groundwater interaction process in the Spokane River Basin
- Identify the factors influencing the decreasing trend in low flow in the Spokane river

How to meet objectives

- Future simulations (e.g., in an altered climate) require more dynamic modeling approaches
- We are adding Precipitation Runoff Modeling System (PRMS) model to make the current aquifer model more dynamic to changes (climatic and anthropogenic changes)
  - Dynamic response in tributary and river inflows
  - Dynamic response in aquifer recharge
- Incorporation of newly developed Surface Water Routing (SWR1) package to allow for dam/reservoir simulation

Summary: Modeling framework

1. Identify research objectives
2. Develop/refine framework (in progress)
3. Calibrate (next step)
   - Streamflow data
   - Well water level and seepage observation (if any)
4. Evaluate (next step)
5. Apply (next step)
   - Future climate projections
   - Future changes (e.g. land use, water supply)

THE USGS MODFLOW MODEL (HSIEH ET AL., 2007)

Prepared in cooperation with the
IDAHO DEPARTMENT OF WATER RESOURCES
WASHINGTON STATE DEPARTMENT OF ECOLOGY
UNIVERSITY OF IDAHO
WASHINGTON STATE UNIVERSITY

IDWR

WASHINGTON STATE DEPARTMENT OF ECOLOGY

WASHINGTON STATE UNIVERSITY

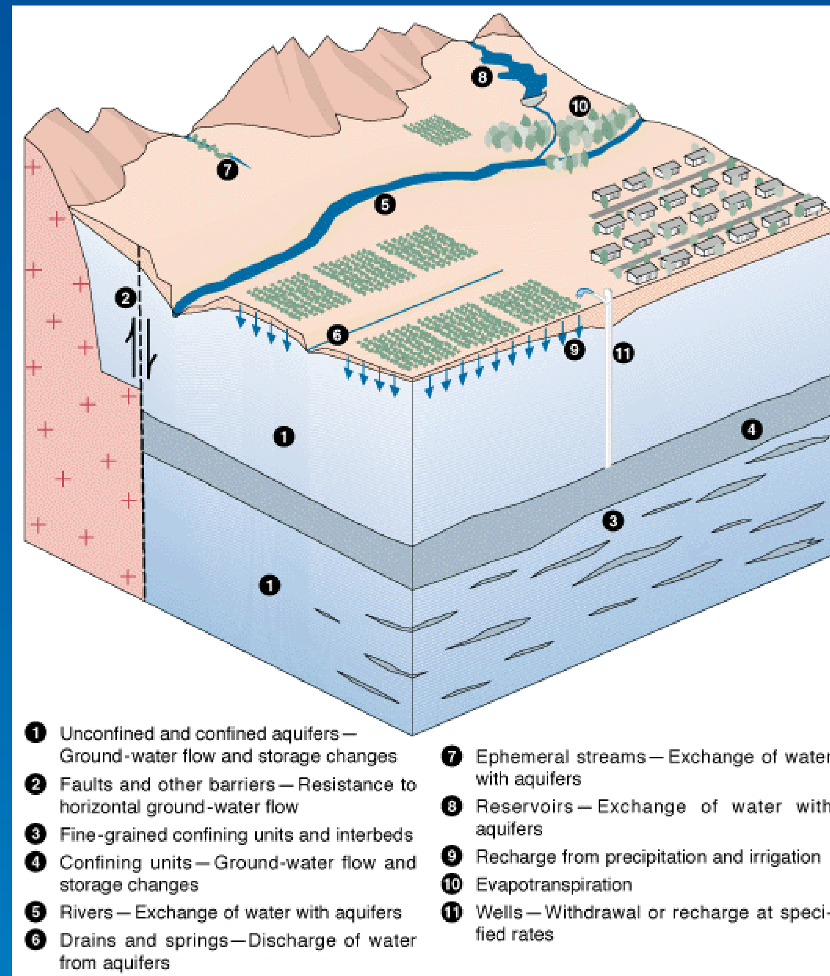
University of Idaho

Ground-Water Flow Model for the Spokane Valley-Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho

Scientific Investigations Report 2007–5044

Current MODFLOW Model

- Model accepts current precipitation and streamflow information
- Relates precipitation to recharge (precipitation transported to aquifer, as opposed to evaporated) using statistical approaches
- Uses gauged streamflow and stage to estimate streamflow-aquifer exchanges



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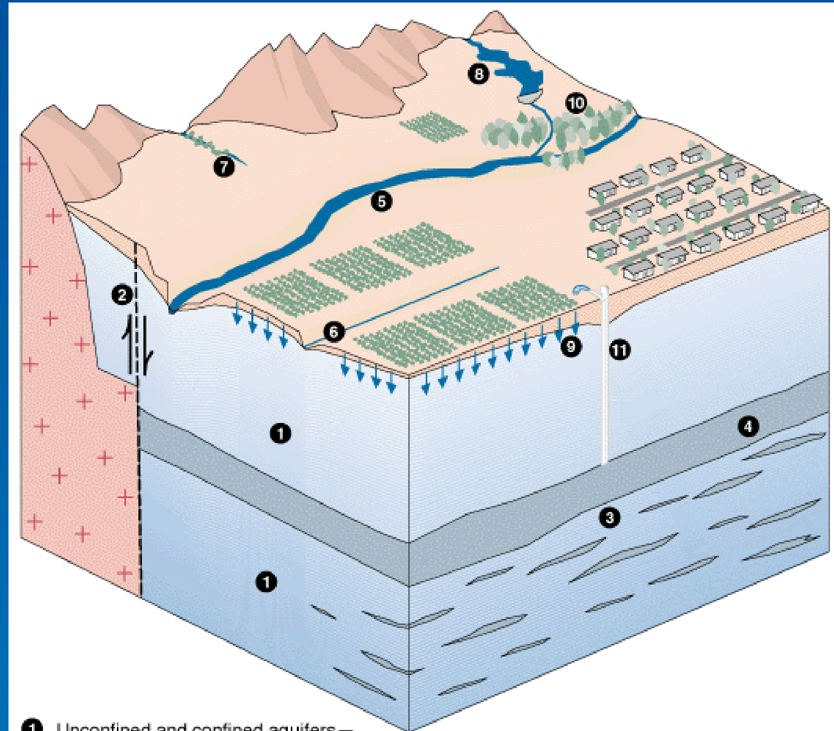
Modifications to MODFLOW Model

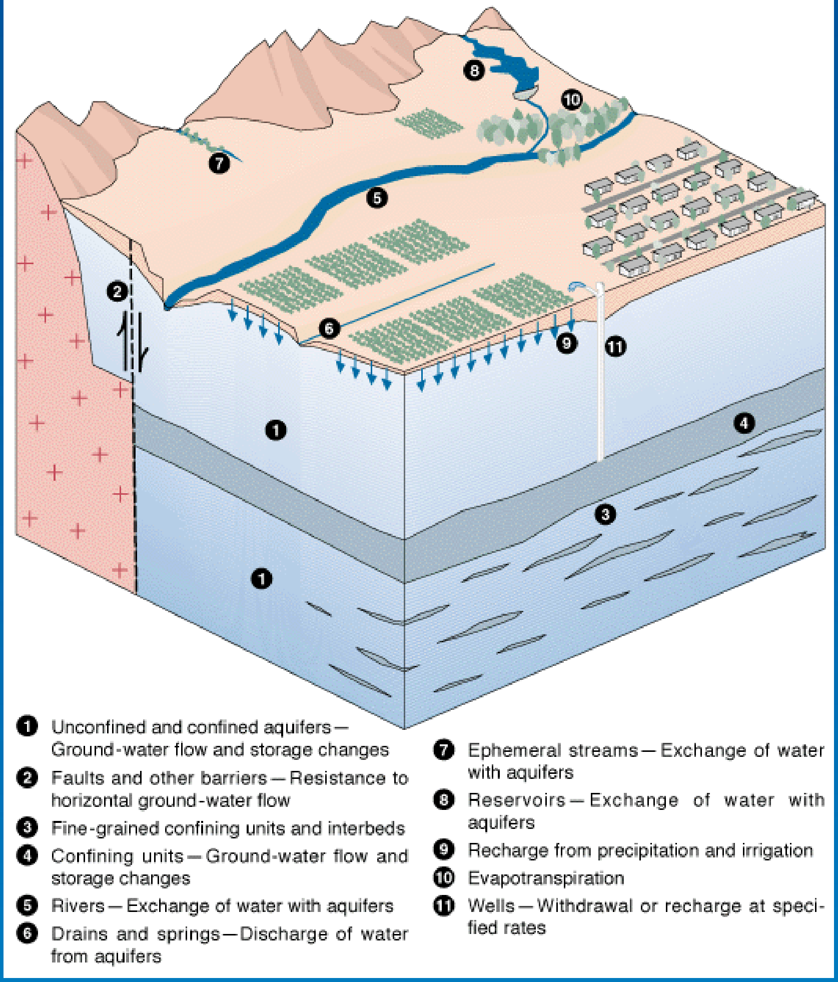
- Model accepts current and projected precipitation
  - Calculate streamflow from current and future climate scenarios
- Estimates aquifer recharge from climatic variables (precipitation, temperature and radiation) and other physical characteristics (soil, vegetation, etc.)
- Uses simulated streamflow and stage to estimate streamflow-aquifer exchanges



1. Unconfined and confined aquifers—Ground-water flow and storage changes
2. Faults and other barriers—Resistance to horizontal ground-water flow
3. Fine-grained confining units and interbeds
4. Confining units—Ground-water flow and storage changes
5. Rivers—Exchange of water with aquifers
6. Drains and springs—Discharge of water from aquifers
7. Ephemeral streams—Exchange of water with aquifers
8. Reservoirs—Exchange of water with aquifers
9. Recharge from precipitation and irrigation
10. Evapotranspiration
11. Wells—Withdrawal or recharge at specified rates

Added Capacities

- Able to simulate recharge and streamflow in response to climate change
- Allows for the attribution of observed trends in streamflow



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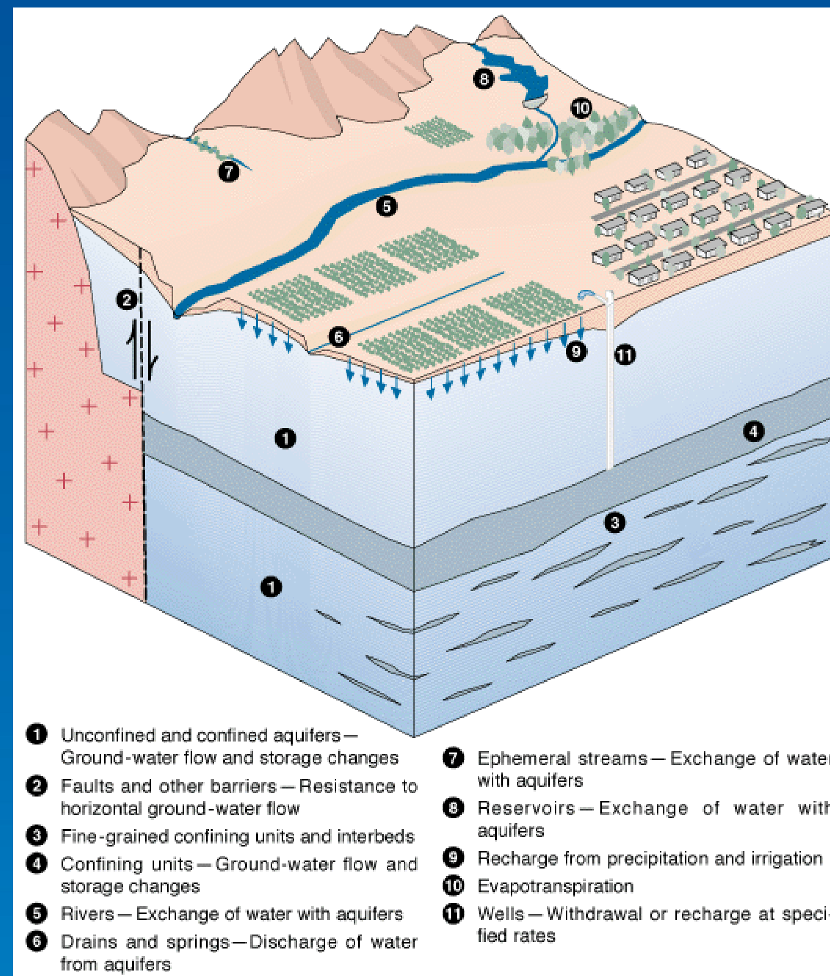
Tools used

- Dynamic recharge will be calculated using PRMS
- Streamflow estimation will be done using either PRMS or Variable Infiltration Capacity (VIC) models
- Might use Surface Water Routing (SWR1) package to take into account the influence of control structures in the river (to be determined)



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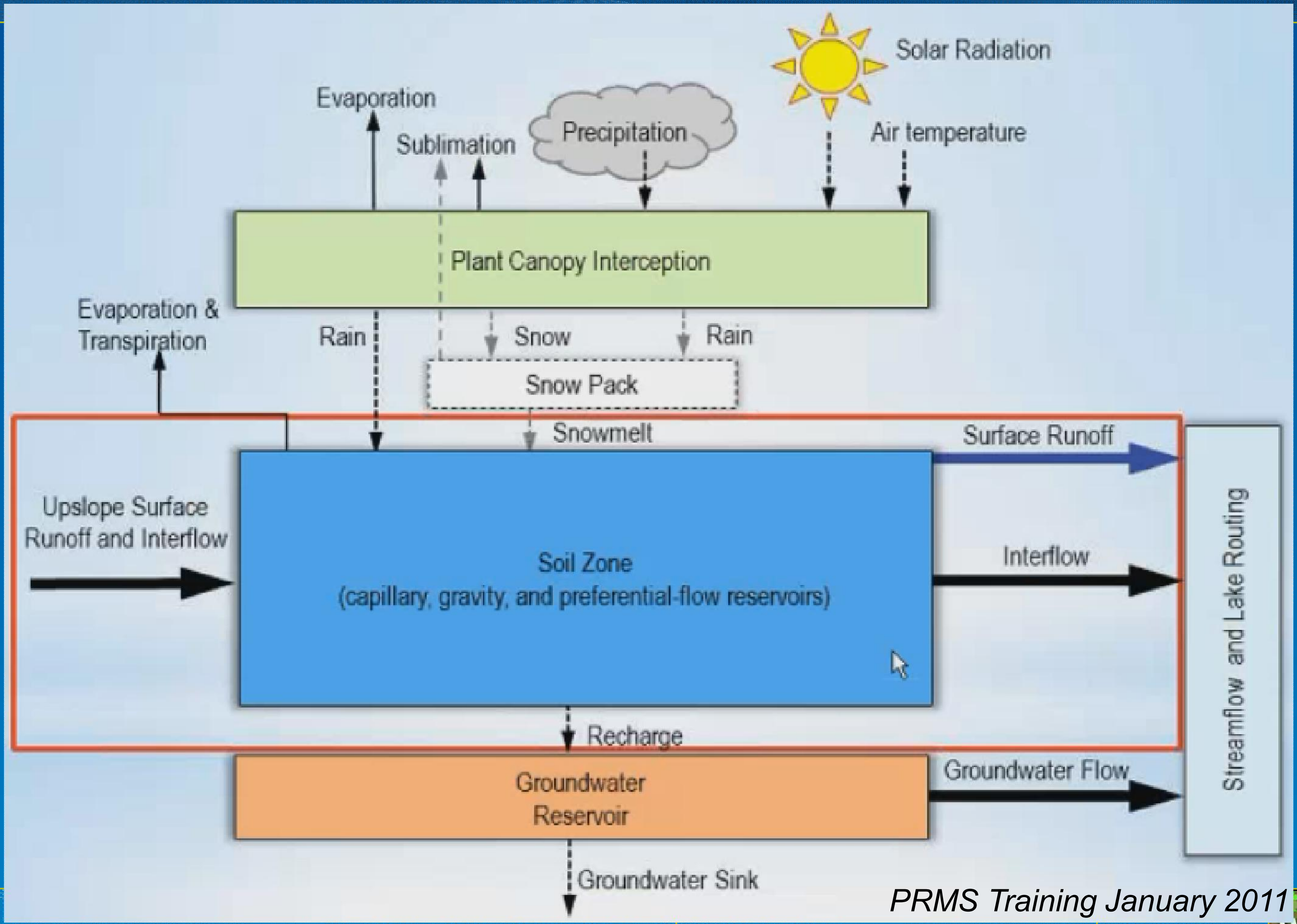
HYDROLOGICAL MODELING USING PRECIPITATION RUNOFF MODELING SYSTEM (PRMS) MODEL

PRMS (1)

- Distributed, physically-based hydrological model
- Spatial scale: 10s to 10,000s km^2 (< 1 km^2 resolution)
- Temporal scale: daily time step (subdaily – storm mode available)

PRMS (2)



PRMS Training January 2011

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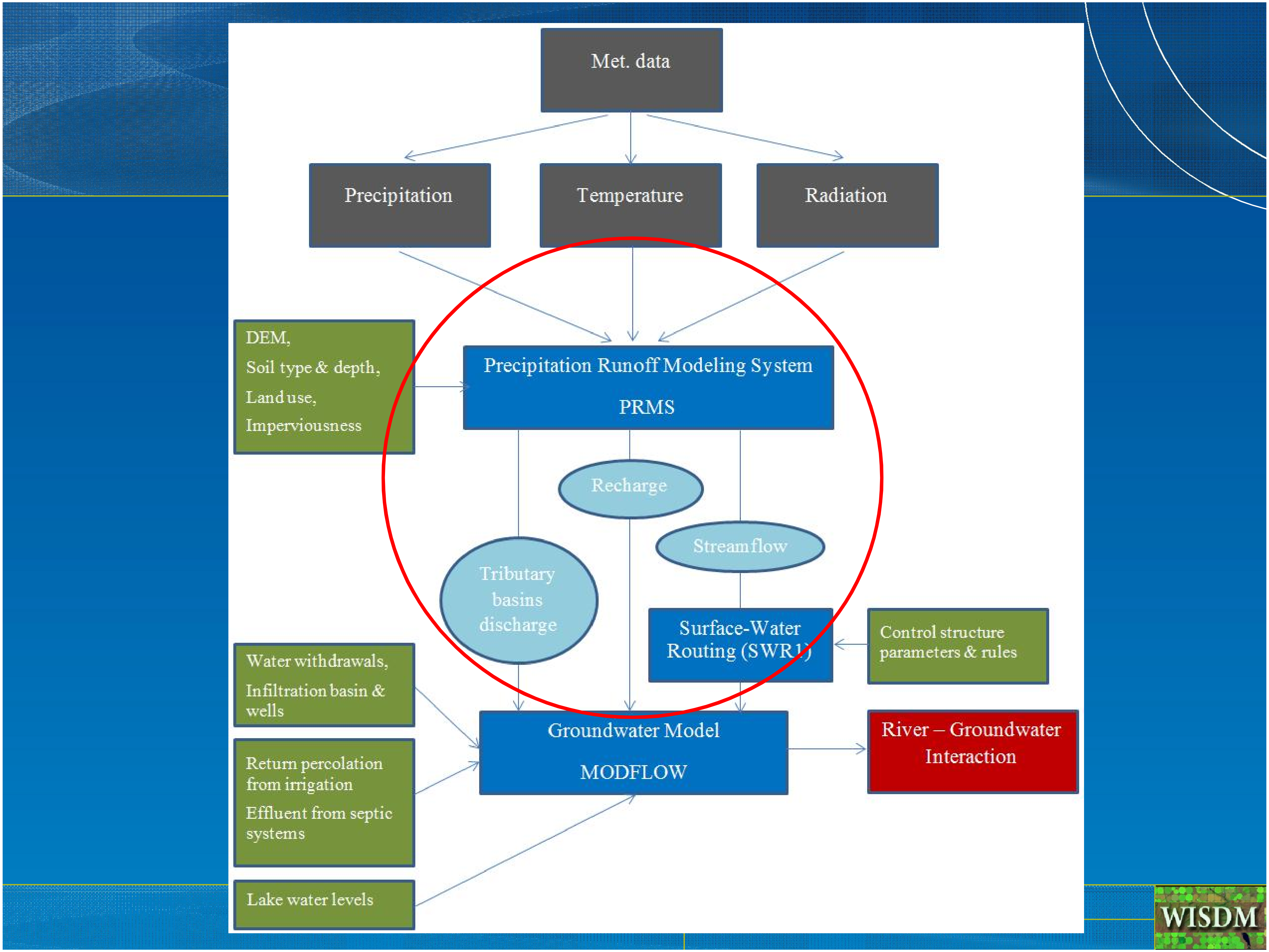
Met. data
Precipitation
Temperature
Radiation
DEM,
Soil type & depth,
Land use,
Imperviousness
Precipitation Runoff Modeling System
PRMS
Recharge
Streamflow
Tributary basins discharge
Surface-Water Routing (SWR1)
Control structure parameters & rules
Water withdrawals,
Infiltration basin & wells
Groundwater Model
MODFLOW
River – Groundwater Interaction
Return percolation from irrigation
Effluent from septic systems
Lake water levels
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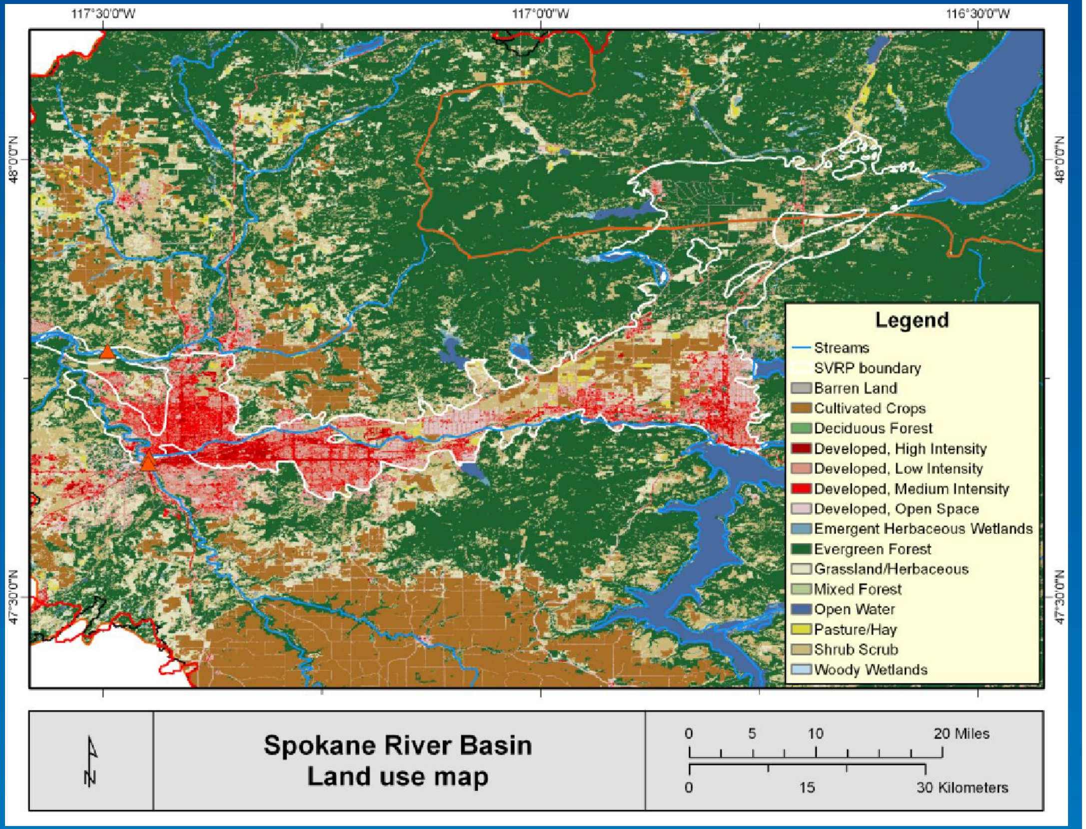
PRMS: Input and Output

- Meteorological data
  - Daily precipitation
  - Max. and min. temperature
  - Solar radiation (optional)
- Streamflow data
- Land-use & Vegetation type
- Soil type & depth
- Output
  - Recharge to MODFLOW
  - Surface runoff

  (current & future climate)



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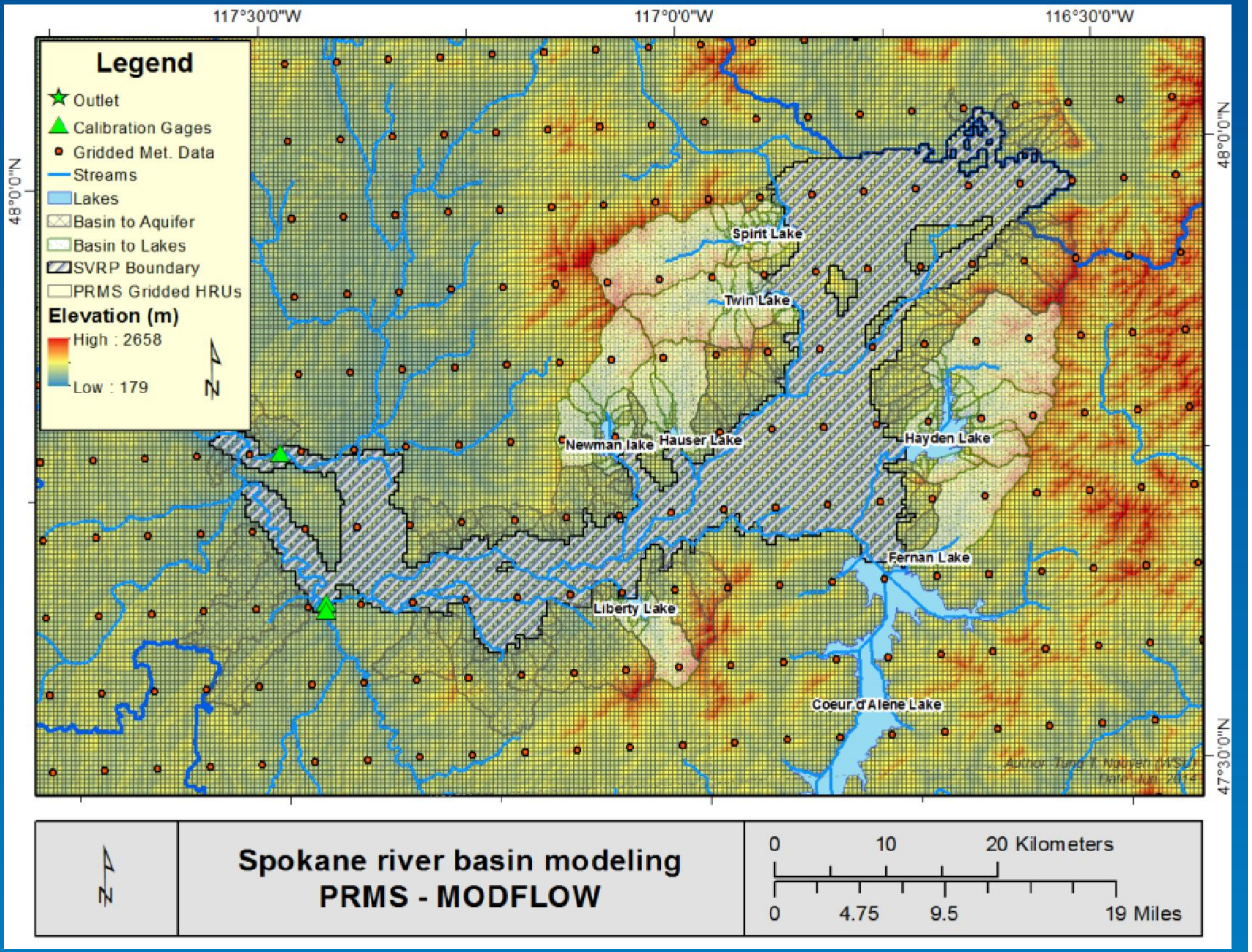
PRMS – MODFLOW

- 189,540 cells
  - 97,416 active
  - 503 lake cells
  - 91,621 inactive
- Cascading flow
  - 253 segments
  - 7,037 reaches
  - 187,452 links



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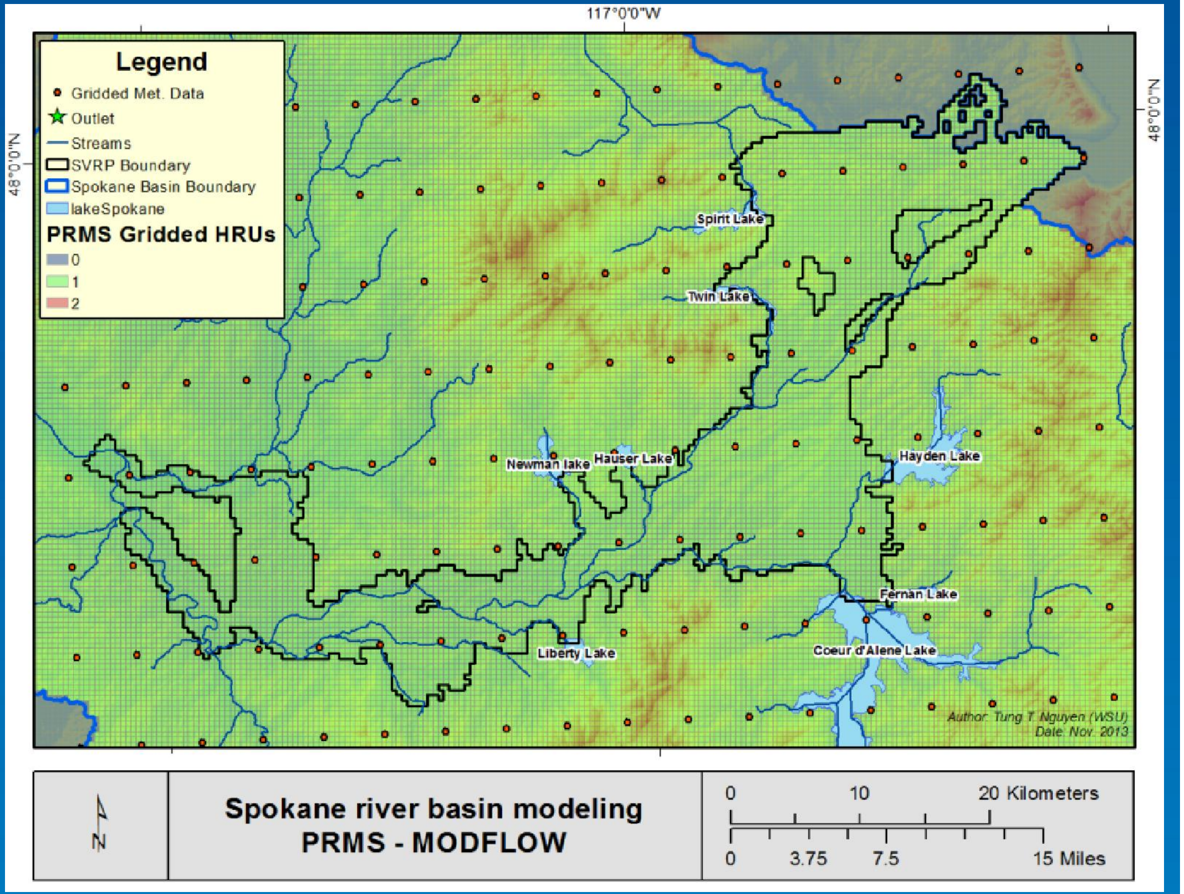
PRMS – MODFLOW

- New met. data: Livneh etal v1.2 at 1/16th degree resolution (~6-7 km, UW, Mar. 2014)
  - 1127 grid points
- Calibration & validation (on-going)



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THANK YOU !

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