Groundwater-Surface Water Modeling of the Walla Walla Basin Using IWFM

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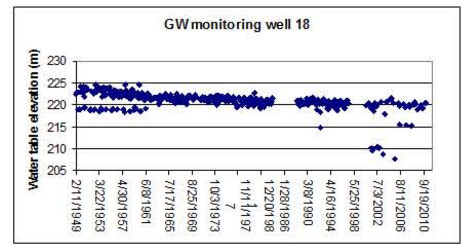
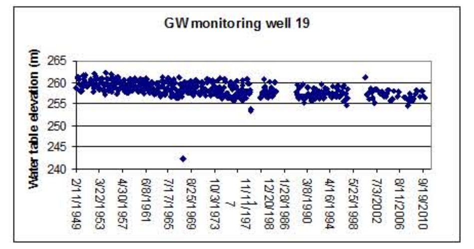
Abstract

The Walla Walla basin lies in an arid region of Eastern Washington and Oregon. A large portion of the area is devoted to **agricultural production**, relying on irrigation water diverted from the Walla Walla River and underlying aquifers occurring within Quaternary alluvial gravel and Miocene to Pliocene conglomerate gravel formations. Heavy water demand over summer months has resulted in a **fully allocated surface water** supply and **significant drawdown in groundwater** levels. Specific questions have emerged regarding regional water supply as stakeholders work towards management strategies that meet water user demands well also addressing concerns related to groundwater depletion and fish habitat. Currently, there are proposals aimed at increasing water use efficiency such as the lining of permeable canal beds and the expansion of a **shallow aquifer recharge program**. Effective implementation of such strategies, in part, relies on understanding the interactions between surface water and groundwater within this region. This project uses the distributed hydrologic model, Integrated Water Flow Model (IWFM), for simulating surface and subsurface flows over a portion of the Walla Walla River basin spanning from Milton-Freewater, Oregon to west of Touchet, Washington. It is being developed as a tool for predicting systemic responses to changes in management practices. **The work is a collaborative effort between a research team from Oregon State University and the Walla Walla Basin Watershed Council (WWBWC).** An initial version of the model was developed by Aristides Petrides-Jimenez (PhD candidate) in 2008 and the current version has been expanded to cover a greater area with a smaller grid size. The model is being developed using data from 2007 through 2009, with 2010 data to be used for validation. Analysis using the **Nash-Sutcliffe method yields a value 0.92 for surface water** based on 30 gauged locations. Simulation results at 96 well locations yield a **Nash-Sutcliffe efficiency of 0.88 for groundwater** with a **standard deviation of 3.0** meters when compared to recorded data.

Current Issues in the Walla Walla basin

- **Aquifer Depletion** and declining spring flows
- ESA listed Bull Trout and Summer Steelhead species
- **Instream flow** requirements (currently a minimum of 0.5 cms must be flowing at Beet road gauge)
- **Irrigation demand** for 3 irrigation districts, serving nearly 5,600 hectares, with diversions totaling 1.7-8.2 cms between March and October.
- Significant **seepage losses** from irrigation canal beds





From WWBWC.org

Modeling Objectives

Compile known information and identify unknown parameters

Assess system hydrology

Simulate flow conditions for groundwater, rivers, canals, and springs

Apply model to **predict systemic responses** to management scenarios including…

- •Current Shallow Aquifer Recharge (SAR) program
- •Site selection and basin configuration for future recharge locations
- •Lining and piping the canal network
- •Predict effects of management on water quality and fisheries
- •Quantifying dynamics of surface water-groundwater interactions for model area

Integrated Water Flow Model (IWFM)

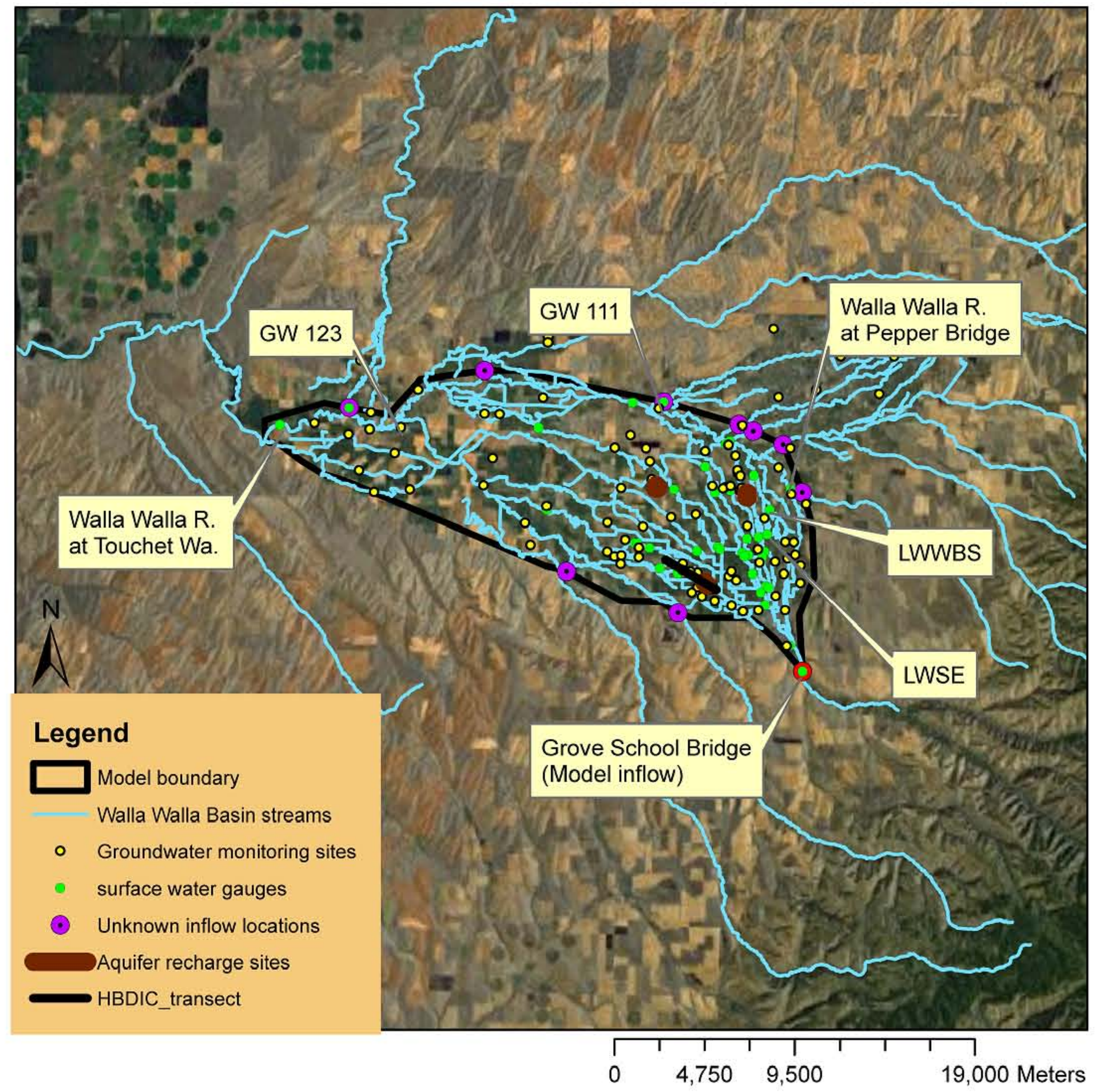
- A distributed, physically based, finite-element model developed by the California Water Resource Board
- Uses FORTRAN based programming .
- This application uses an average grid spacing of 100 meters. A smaller spacing is used near recharge sites for improved resolution at those locations.
- Highlights include detailed budget outputs for groundwater, surface water , and soils as well as computation of agricultural water demand, pumping and diversions based on user inputs.
- **Freely distributed** at http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM

Surface Water

- Model inflow is located at Grove School Bridge in Milton-Freewater, Oregon.
- There are 3 gauged streams and 8 ungauged creeks contributing surface flow in the model area.
- Agricultural diversions are managed by **3 irrigation districts** (Hudson Bay District Improvement Company (HBDIC), Gardena Farms, and Walla Walla River Irrigation district.
- These parties operate under an agreement to leave a **minimum of 0.5 cms** below Gardena Farms Beet rd. diversion facility.

Input Data

- Inflows (gauged or transducer data)
- Precipitation (interpolation between 3 gauges)
- Evapotranspiration (interpolation between 3 gauges)
- Land use and crop distribution(WWBWC surveys)
- Crop demand (FAO 56)
- Urban demand (census data)
- Agricultural diversions (gauge data, ET data, personal communication)
- Soil charecteristics (NRCS)
- Rating tables (USGS, DOE, OWRD, WWBWC, Field measurements)

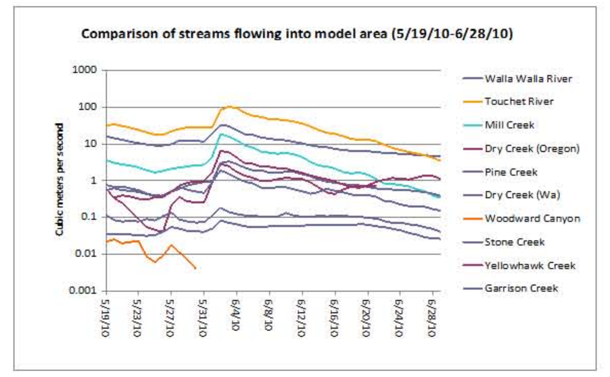


Unknown Inflows

Transducer gauges were installed at 8 locations (see central map)

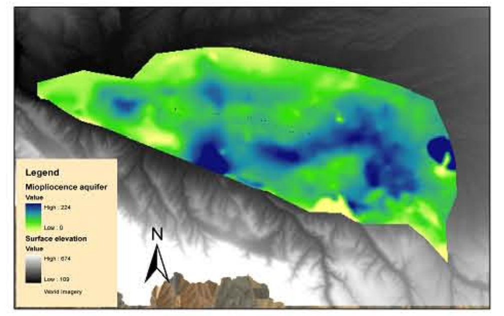
•Field measurements and observations along with the Manning equation were used to develop rating tables.

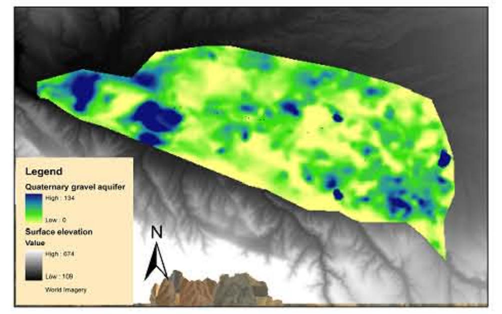
•These were applied to generate flow estimates and compared to gauged flows in the Walla Walla and Touchet rivers to estimate historic flow conditions



Aquifer Thickness

GIS interpolation based on Linsey (2004)





Geology

3 geologic layers are incorporated into the model

1) Touchet Beds (Pleistocene loess, felsic silt and felsic to basaltic fine to medium sand).
2) Young alluvial gravel (Holocene to Pliocene sand and gravel not well constrained).
3) Old gravel (Miocene to Pliocene conglomerate sand, silt and clay).

The Columbia River Basalt formation underlies these layers and is treated as an impermeable boundary for the purposes of this model.

A complete geologic description of the aquifers in this region can be found in Lindsey (2007).

(Petrides-Jimenez, et al. 2010)

Groundwater

- Initial and boundary conditions were determined based on monthly water table elevations over the model area. These water tables were produced by the interpolation of monitoring well data for the simulation period (2007-2009).
- Calibration parameters selected based on a sensitivity analysis. The most sensitive were vertical and horizontal hydraulic conductivity of the Quaternary gravel aquifer.
- To date, the simulation results yield a **standard deviation of 3.0 meters** when compared to observed data.
- The model has a Nash-Sutcliffe efficiency of 0.88

(Petrides-Jimenez, 2010)

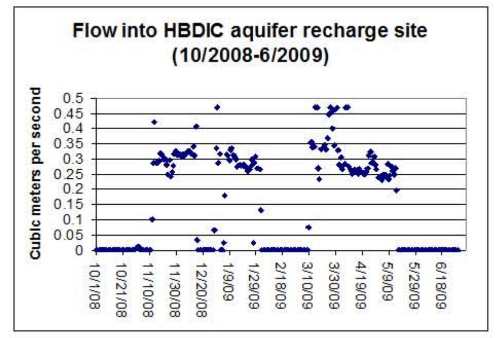
Aquifer Recharge

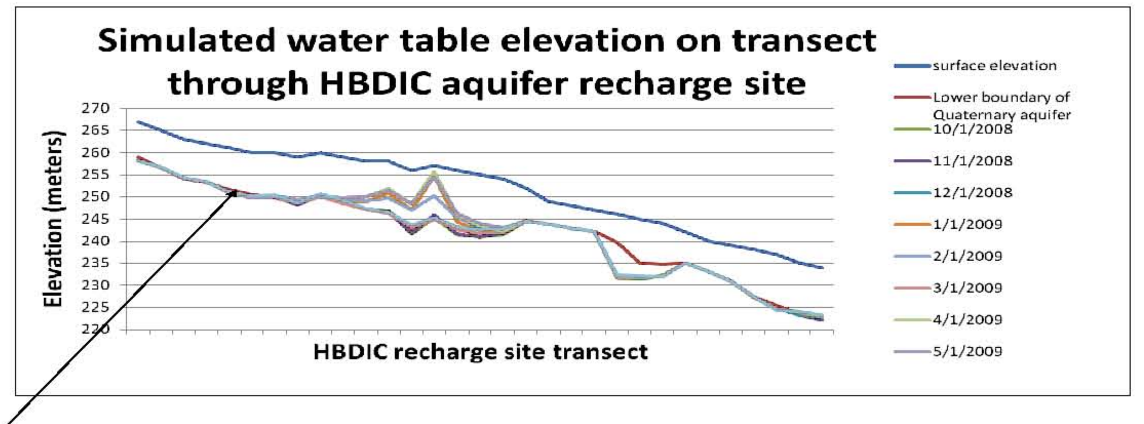
1) Hudson Bay aquifer recharge project, managed by the HBDIC and the WWBWC, diverts water from the White Ditch irrigation canal into rectangular infiltration basins.

2) Locher Road aquifer recharge basin, managed by Gardena Farms Irrigation District, diverts water into an abandoned gravel pit with constructed circular basins.

3) Hall-Wentland aquifer recharge. This project recharges the gravel aquifer by flood irrigation of a 2 hectare pasture. This site does not have constructed infiltrating basins.

(Petrides-Jimenez, et al. 2010)





HBDIC recharge site

HBDIC shallow aquifer recharge site

Locher Road shallow aquifer recharge site

Evaluation of Model Performance

- The following metrics can be applied to evaluate model ouputs in comparison to data
- Root Mean Squared Error $\sqrt{(Q_o - Q_m)^2}$
- Nash-Sutcliffe efficiency: E = 1.00 is a perfect fit while 0.00 implies that the model output is no better than a mean for estimating flow rates

$$E = 1 - \frac{\sum_{t=1}^{T} \left(Q_o^t - Q_m^t\right)^2}{\sum_{t=1}^{T} \left(Q_o^t - \overline{Q_o}\right)^2}$$

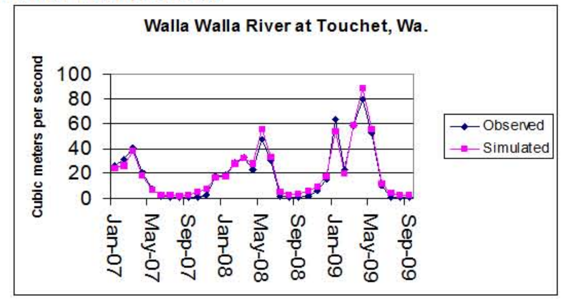
- Q_o = observed discharge or head
- Q_m = modeled discharge or head
- Q_o^t = observed discharge at time t

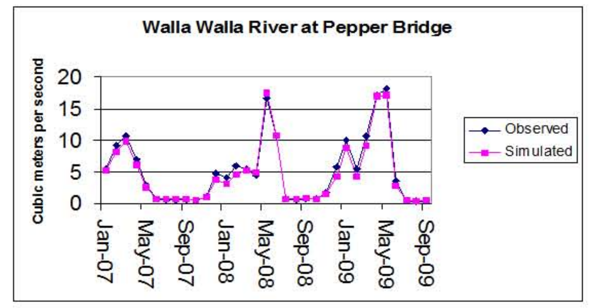
Error estimations have been determined based on and evaluation of gauge types, dynamic conditions , and assumptions entailed in the modeling process.

Nash, Sutcliffe (1970)

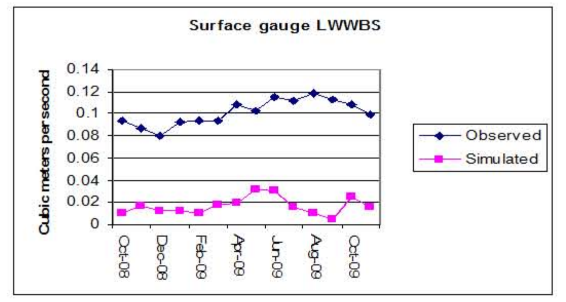
Results (see map for locations)

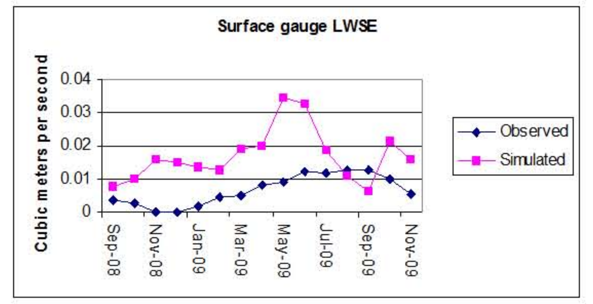
Walla Walla River



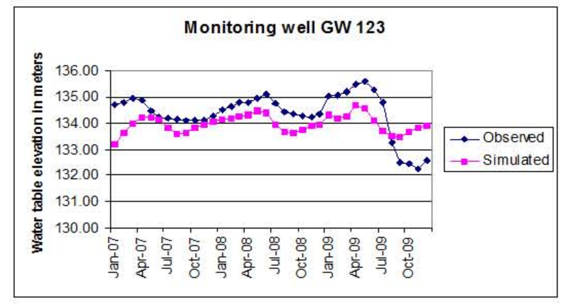


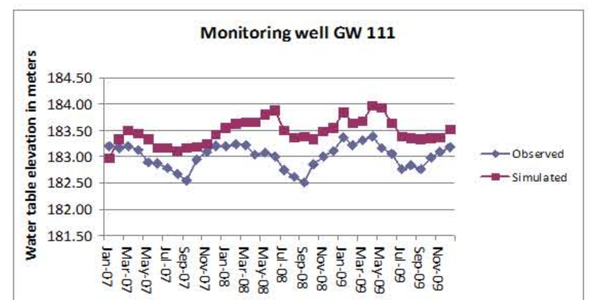
Springs





Selected Wells





Upcoming Work

The development and calibration of the Wall Walla Basin IWFM model will be described in detail in the upcoming doctoral thesis of Aristides Petrides-Jimenez

This model is, by necessity, a simplification of the system it represents. It includes interpolations, assumptions, and estimations based on the best data. The results to this point are encouraging.

In the future, as longer data sets and more field measurements become available, there may be potential to refine the model. The current version is a robust framework for a continuing effort for hydrologic modeling of the Walla Walla basin.

The process of **model validation** is currently underway. This entails collecting an input data set using 2010 data and applying the parameters determined over the calibration process. Model performance will be assessed and further revision may follow.

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- Washington Department of Fish and Wildlife
- Washington Department of Ecology

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