Upper Niobrara Basin Integrated Modeling: August 2012 Update

By James Gilbert

Summary: Update on the progress of the Niobrara Basin integrated modeling project. CROPSIM, groundwater, and operations models have been developed and are being calibrated. Discusion of potential applications of the modeling tools.

Purpose of the modeling effort

The purpose of the modeling effort is to describe the effect that human development has had on the Niobrara River basin. A specific aim addressed through the models is to quantify important changes in regional water supplies to inform management decisions.

Modeling the upper Niobrara basin is also part of a US Bureau of Reclamation "WaterSMART" grant which includes plans to develop models for the entire Niobrara River basin. Beyond providing a more complete geographic assessment of basin supplies and uses, a goal of this project is also to assess basin response under various climatological scenarios.

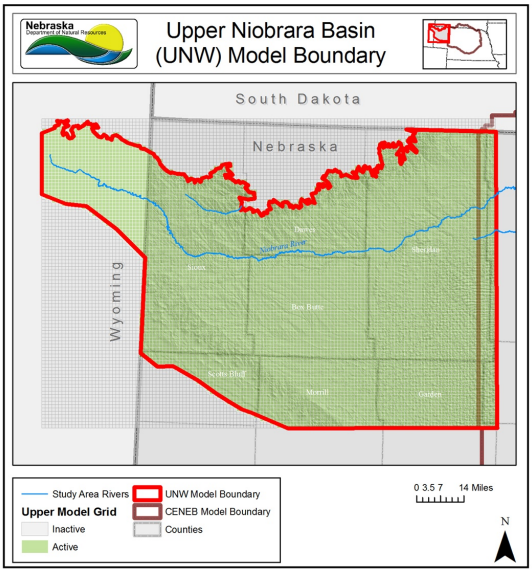

Figure 1. The Upper Niobrara Basin and the model boundary

Multiple models are being developed

NDNR and collaborators have adopted a modeling approach based on a total water budget concept. This approach uses several linked models to approximate flows and storage of water in the hydrologic system.

The three models employed to do this in the upper Niobrara basin account for water use and partitioning at the land surface, groundwater flow, and routing of surface water through canals and reservoirs. The models all share some connection – outputs from one model feed in to another. This approach helps ensure the quantity and movement of important components of the water budget can be tracked through the system

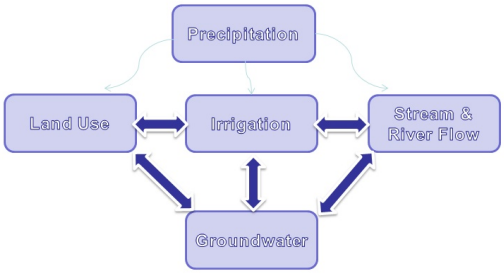

Figure 2. Each model is conected to another

Determining land use over time

UNWNRD developed a database of certified irrigated acres that was essential to modeling the changes in land use over time in the basin.With that database, DNR created a time series of land use changes due to the development of irrigation that was then used to determine the change in water use over time.

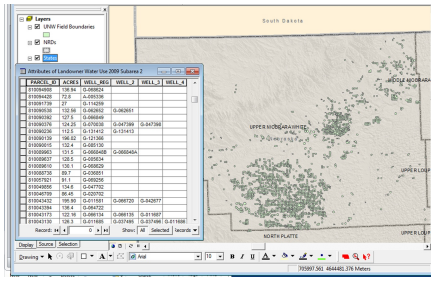

Figure 3. The development of the land use time series

Figures 4 through 6 show how this development looks like over time. The dark green spots in Figures 5 and 6 are where dryland was converted to irrigated acres.

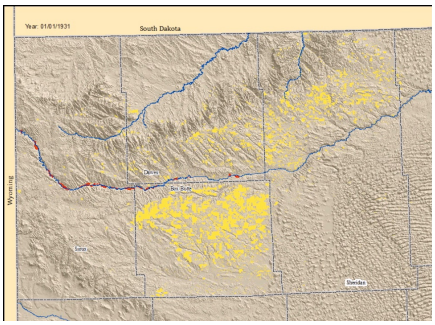

Figure 4. Predevelopment

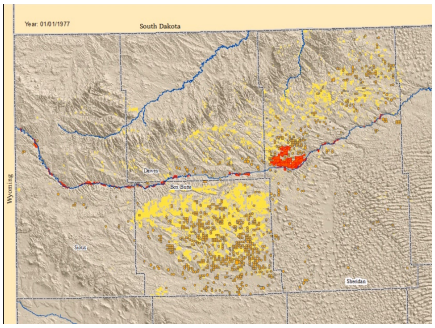

Figure 5. 1977

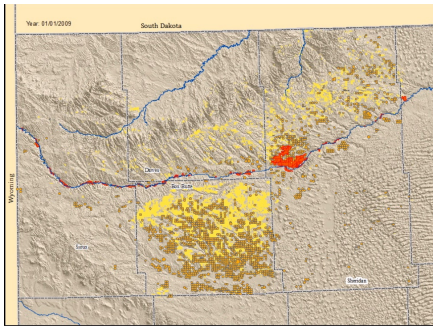

Figure 6. 2010

From land use to water use over time (CROPSIM)

One of the three models, CROPSIM, is used to convert the land use dataset into an estimate of water use over time. CROPSIM is a soil-water balance model which estimates crop water needs by using weather, soil and crop data. CROPSIM partitions water from precipitation and irrigation into the amount of water that enters the streams, rivers and aquifer.

Groundwater modeling (MODFLOW)

The CROPSIM model is used to determine how much water is going into the aquifer as recharge, and how much is coming out as pumping to irrigate crops. This information is translated to the MODFLOW groundwater model, which simulates water movement in the aquifer to and from wells, rivers, and streams. This modeling is useful because it can help estimate changes in water levels in an area due to pumping. It can also help assess whether and how much the impact of that pumping is propagated to nearby rivers or streams. In upper Niobrarara study area, the groundwater model is being used to help quantify these sorts of phenomena in Box Butte County and in the Niobrara River valley.

Operations Model (STELLA)

The operations model is a method for tracking how surface water is stored and moved through the canal and reservoir infrastructure. It can track and simulate diversions and estimate Box Butte reservoir operations. The STELLA model provides feedback to CROPSIM and MODFLOW models.

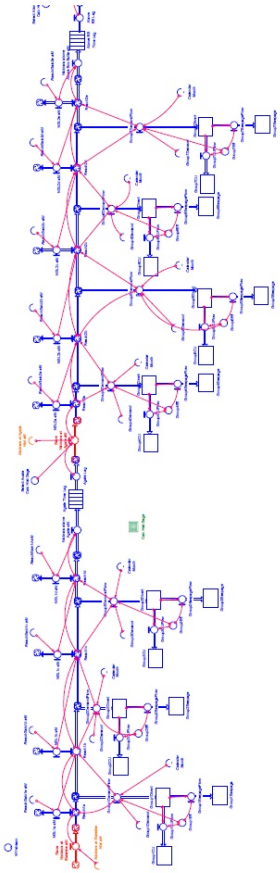

Figure 7. STELLA Schematic

Early results -- matching historic water levels and streamflow

While the CROPSIM and MODFLOW models are still being calibrated, simulations are showing a favorable match between calculated and measured historic drawdowns and streamflows. Future work will focus on fine-tuning each of the models to ensure a reasonable match with historical records and consistency across models.

Below the Conservation and Survey Division's mapped drawdowns for predevelopment to 2011 are compared with he early results of drawdown from the MODFLOW model.

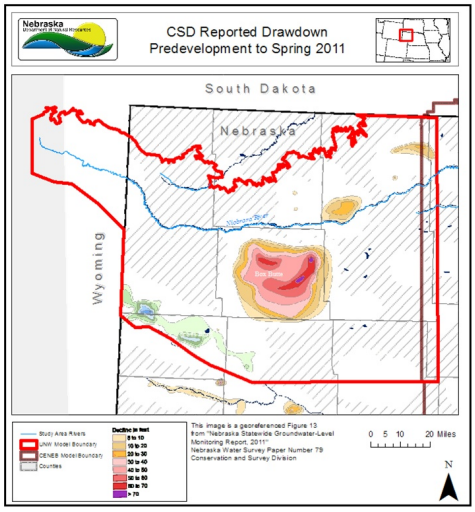

Figure 8. CSD mapped Drawdown, predevelopment to 2011

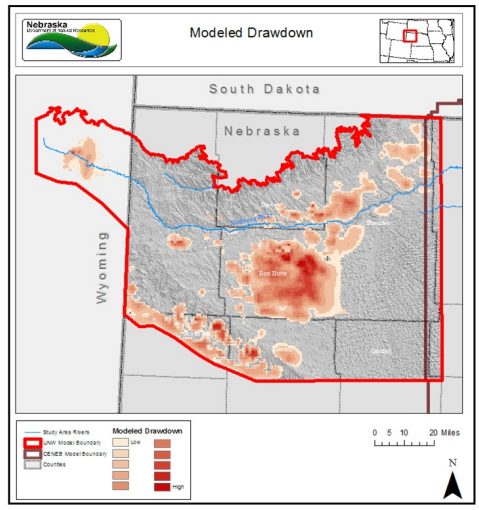

Figure 9. DNR modeled Drawdown, predevelopment to 2010

The effect of groundwater development on streamflow is also crucial for management of the basin. The calibration of streamflows in the groundwater model is also underway. Below is a graph of the annual baseflow volume (in acre-feet) coming across the Wyoming-Nebraska state line. The red line represents the baseflow estimated from the historic record at the stateline gage. The blue line represents the model simulated baseflow at the same location.

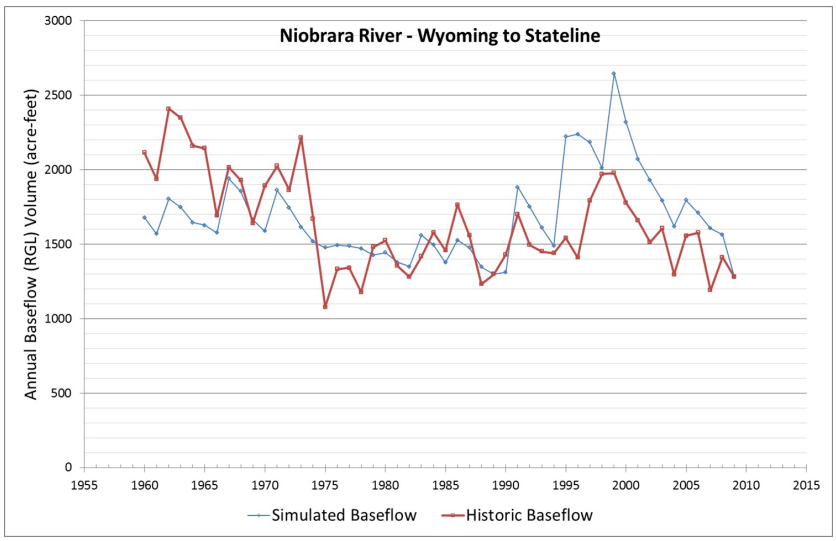

Figure 10. Baseflow over time

How these models can be applied

What questions can we investigate with these models?
Some examples include:

"What is the effect of reducing pumping in Box Butte County on water level declines in the area?" (figure 11)

"What are the long-term impacts of shutting down groundwater irrigation near the Niobrara River upstream of Box Butte Reservoir?"

"How might transfers of groundwater irrigation away from the river impact baseflow gains?" (figure 12, below)

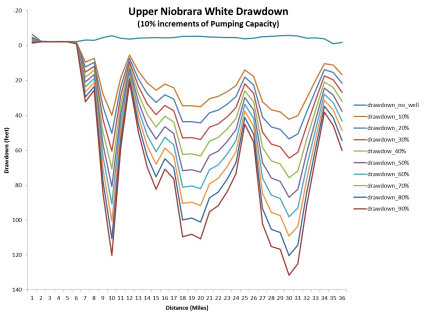

Figure 11. Estimated drawdown in a cross section across Box Butte County with different percent reductions of pumping

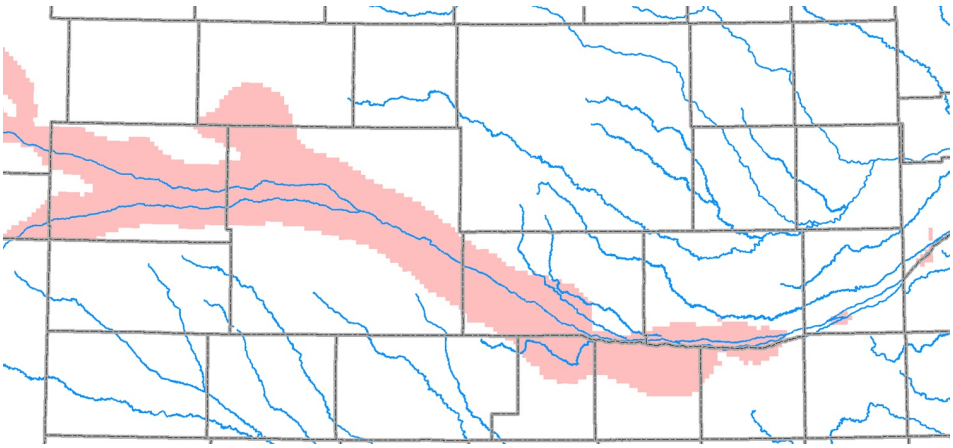

Figure 12. This is a platte river analysis of proximity to river. The shaded area above shows the extent of the '28/40' area along the Platte River, as determined by a groundwater model. The '28/40' designation means that, over a span of 40 years, 28% or more of the total water pumped comes from the river. A similar analysis could be performed for the Niobrara Basin to determine the benefit of moving wells farther from the river.

Conclusion

The development of the modeling effort in the upper Niobrara basin is showing significant progress. Calibration of the models is ongoing and some early analysis scenarios have been tested. Future work will focus on fine-tuning each of the models and developing management scenarios.

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