Western Water Use Management Modeling

The Western Water Use Management (WWUM) modeling effort began in 2009 and consists of three independent models including a ground water flow (GW) model, a regionalized soil water balance (RSWB) model, and a surface water operations (SW) model. These models are integrated through modeling datasets and provide a detailed and holistic view of water resources in the region. The purpose of the effort is to provide data centered decision support to assist the North Platte and South Platte Natural Resources Districts in defining and analyzing management decisions that directly affect reaching the goals of their individual Integrated Management Plans (IMP) and other ground water management objectives.

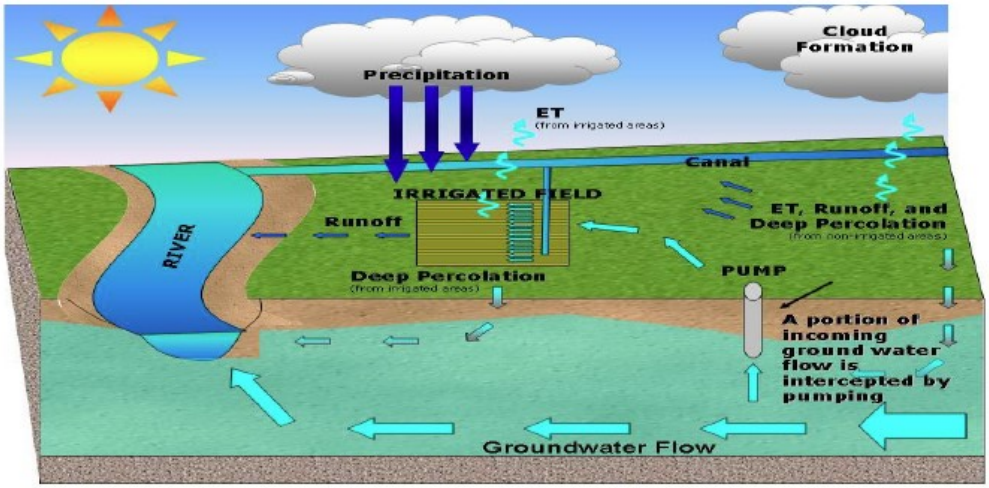
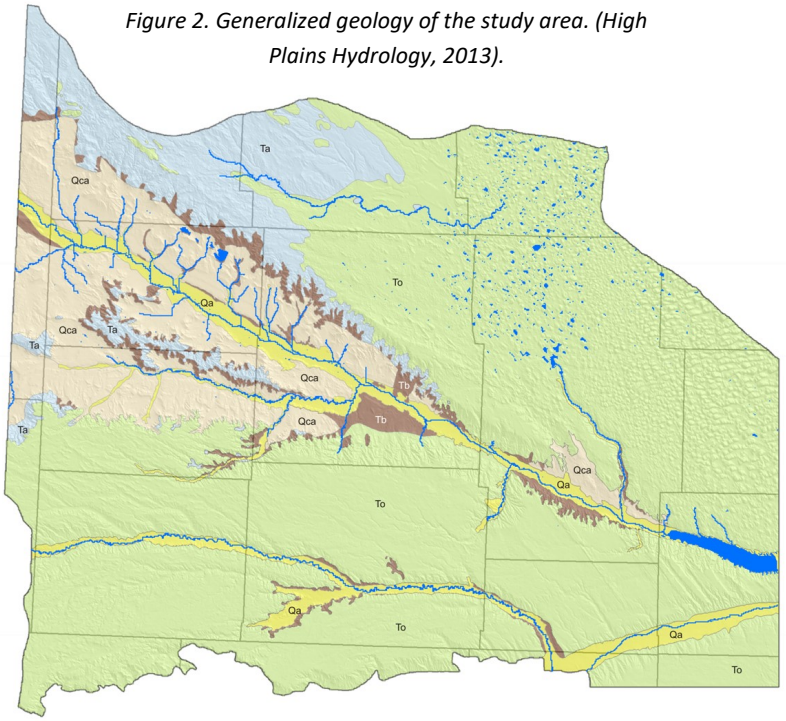


Figure 1. Illustration of hydrologic cycle in which irrigation is important (The Flatwater Group, 2016).

Each model tracks water through a portion of the water cycle, demonstrated in Figure 1. With the complexity of the water cycle, it is necessary for the various models to share and incorporate data at multiple points in the modeling effort. For example, changes in ground water pumping and crop types affect surface water demand as well as the amount of recharge and where it occurs. Changes in precipitation and surface water availability, in turn, affect recharge and groundwater pumping. The GW and RSWB models share the same geographical domain, with the SW model being limited to the North Platte River's alluvial valleys and areas of surface water development. All three models utilize historical data where available.

The GW model follows water through the subsurface, simulating the effects of recharge and pumping on unconfined aquifers in the region. Local geology largely determines the characteristics of the aquifers and their ability to sustain pumping. Within the model domain, ground water development is concentrated in shallow alluvial aquifers (Qa) with large hydraulic conductivity and sufficient saturated thickness for high capacity production. These aquifers are located along the North and South Platte Rivers and their tributaries, as well as portions of Lodgepole Creek. Pumping also occurs in the High Plains Aquifer that includes the Ogallala (To), Arikaree (Ta), and Brule (Tb) formations, demonstrated in Figure 2. Development is largely constrained to Ogallala Group deposits with some pumping in the finer-grained Arikaree Group; in most areas, the Brule Formation acts as an impermeable base for High Plains and alluvial aquifers in the model area. The system is modeled using MODFLOW-2000 ground water modeling software. This software solves the ground water flow equation across a three-dimensional grid that encompasses the model area; determining the impacts from pumping and recharge on water levels and streamflow in the region. The GW model begins in May 1953 and simulates ground water conditions through April 2014. Model response to ground water development was calibrated using historical water level readings throughout the model area, as well as comparing simulated stream baseflow (the ground water component of total streamflow) with historical gage flow.

Figure 2. Generalized geology of the study area. (High Plains Hydrology, 2013).



The RSWB model allocates water from precipitation and irrigation, including the evapotranspiration, runoff, and deep percolation components that affect surface and ground water flow. Information about the climate, soils, land use, and farming practices are also considered for determining the irrigation needs of crops in the area; which is used by the GW and SW models in determining pumping and diversion amounts. The model considers historical and regional climate variations when determining crop demand as well as evaporative demand. This includes the use of historical weather station data within the model area. To standardize crop water use across the region, a single crop (tall alfalfa) was utilized to represent evaporative demand in the local climate. Soil characteristics, such as water holding capacity, also play a major role in the RSWB model. The variety of soil types present throughout the model area were grouped together based upon similar properties (Figure 3) and narrowed to three representative soil classes for the modeling effort. Soil properties also tracked changes in land use and production practices through time. The RSWB model reflects historical changes in irrigation and tillage practices. These changes, such as the shift from flood to sprinkler irrigation systems, affect the relationship between crop demand and efficiency. Generally, newer practices are more efficient and have decreased the amount of water needed to meet crop demand, as less water is lost through inefficiencies. Within the RSWB model, the modeled or historical ground water pumping and surface diversion data are tied to the physical parcel where that water was applied. The model then simulates the portion of that water that is utilized by the crop, the portion that is lost to evaporation, the portion that runs off the parcel to adjoining model cells or surface water features, and the portion that recharges the subsurface through deep percolation.

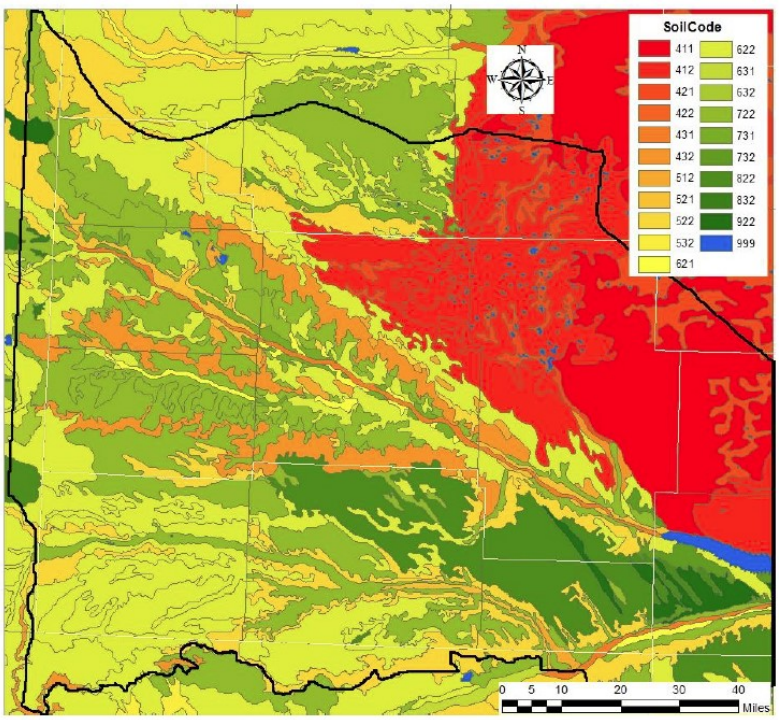


Figure 3. CropSIM soil class coverage for the WWUM model (The Flatwater Group, 2016).

The SW model tracks and allocates water across the major canal and stream systems in the region which is based on demand and the prior appropriation surface water rights system that determines if and how much water each diversion receives based on their appropriation date (Figure 4). The model simulates the period from 1933 through 2013 and reflects the historical hydrologic conditions in the region. Historical streamflow, reservoir levels, and diversions were compared to the SW model simulated values for calibration from 1960 through 2013. The model used various regions based on surface water diversions and irrigated land distribution to accurately simulate the effects of pumping and recharge on the surface water system. Pumping and recharge transmit through the surface and ground water systems which directly impacts streamflow. The SW model also determines water transmission loss through canal seepage; which acts as a significant source of ground water recharge to the underlying aquifers.

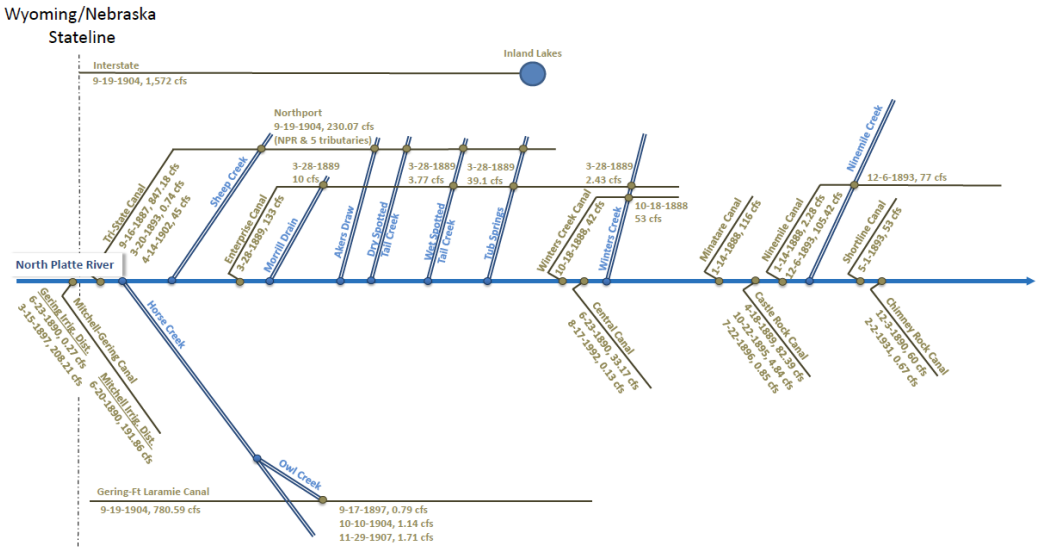


Figure 4. North Platte River Planning Model Area Straight-Line Diagram of Surface Water Appropriations — Wyoming/Nebraska Stateline to Chimney Rock Canal (Wilson Water Group, 2015).