URNRD Groundwater Modeling Project

Annual Report, March 2021

Water Sustainability Fund Application #5184

The Upper Republican Natural Resources District (URNRD) was awarded a $243,000 grant by the Natural Resources Commission in late 2017 and executed a contract with DNR in January 2018. The purpose of the project is to develop a groundwater model to predict future groundwater elevations within our District and to develop water management plans to minimize the effect that future irrigation pumping has within our District. There are several groundwater models that have already been developed for our area, so our original plan was to modify and use one of these models for our District. When we discovered that using the existing models to model our District would not work, we began to create our own groundwater model.

Progress

RRCA Model

We started our modeling effort by attempting to use the Republican River Compact Administration (RRCA) groundwater model to model the URNRD. It modeled the entire Republican River Basin and its purpose was to model surface water flow in the Republican River Basin to determine the amount of surface water that Kansas, Colorado, and Nebraska must deliver to Kansas to meet the Compact requirements. The model is extremely complex and utilizes numerous programs to generate and process the results. Thirteen batch files are used to run the preprocessor programs and five batch files are used to postprocess the output data. There are also 10 Fortran programs, including Modflow, that are used in the model. The input data and how it is processed is different for each state and has varied over time. Separate groundwater models were developed for four different time periods extending from 1918 to 2038, and the output from the earlier time period was then used as input into the next time period model. We modified the input data, the programs, the modeling process, and the model size specifically for the URNRD.

Because of the changes that we made to the model and modeling process, we tried to re-calibrate the model by comparing groundwater elevation information produced by the model to monitoring well elevation data that we had within the District, but we could not get the model's groundwater elevation to move much during the calibration process. After discussions with the RRCA model authors, it was discovered that certain input data was fixed within the Modflow code and could not be changed. The RRCA model was created to model surface water flow and timing and it was only calibrated to surface water. Hydrogeologic parameters in the district were fixed in the RRCA groundwater model, so it could not be used to model groundwater elevations within the District.

USGS 1995 model

We next attempted to use a Modflow model developed for the District by the USGS in 1995. It was relatively simple; it covered only the area that we were interested in; and there was a writeup on the input data that went into the model. We contacted the USGS and acquired the input data, executable files, and eighteen Fortran files used to run the model. We chose not to use the model, though, because we were unable to make changes to the model because the Fortran programs needed to be compiled and the version of Fortran was so old that there was no compiler that could do it. There was no documentation on how to use the model, how it was developed, or the assumptions that went into its creation. An additional 23 years of data would have had to be collected and developed, and there is no one that could assist with the model operation if it did not work.

USGS 2016 Regional Groundwater Model

We next tried to use the 2016 USGS regional groundwater model. It had several advantages. The data was relatively current covering a period from 1940 to 2009. The model was calibrated and peer reviewed. The USGS could probably provide some assistance in using the model, and the model uses the current version of Modflow and utilizes more powerful preprocessing tools and programs.

After working with this model, we decided not to use it for several reasons. The modeled area is much bigger than was needed, covering the Northern High Plains Aquifer across 5 states. The Pre1940 Modflow model, which is used to create the steady state conditions, takes about 30 minutes to run; the 1940 to 2009 Modflow model takes about 4 hours to run; and the SWB (Soil-Water-Balance) model takes about 48 hours to run. The run time length makes it infeasible to create management scenarios. We could trim the model so that it only includes the District, but that would take a significant amount of effort. In addition, the SWB model is an add-on program that has been modified specifically for this model (non-standard). The SWB model was not calibrated for hydrologic measurements such as groundwater levels and stream flows to verify that it produces recharge and pumpage values that are consistent with observable hydrologic conditions. The model is relatively sensitive to the precipitation and ET values, and precipitation and ET have large uncertainties, which could cause substantial errors in simulated recharge and pumpage, especially when reduced to a smaller area including only our District. Each cell is assigned a one land cover type. Modflow was compiled with Visual Fortran 64-bit compiler and a Visual C++ compiler. It only actually goes until 2009 so 9 years of input data will need to be developed and the model recalibrated for that period.

URNRD Groundwater Model

Because we could not modify any of the existing models to suit our needs, we created our own Modflow model from scratch using the Groundwater Vistas modeling program. We created a model grid which consisted of cells one mile by one mile and the model boundary extending a minimum of five miles outside of the District boundary. We acquired hydrogeologic parameters (K, Ss, and Sy) for each cell and aquifer characteristic parameters for each cell (ground surface elevation and aquifer bottom elevation). We created the Stream (STR) package for the model to model the various streams within the model boundary. We attempted to model Enders Reservoir and Swanson Reservoir using Modflow’s Reservoir (RES) package, but we could not get it to work because of the size of the reservoir versus the size of the cells. We collected groundwater surface elevations within seven miles of the District boundary from 1950 to the present to generate the initial conditions water surface elevation and the model boundary conditions. We collected irrigation and crop type information to generate well pumping data (WEL package). We collected soil information and precipitation data to generate groundwater recharge data (RCH Package), and we collected weather data and plant type (crop and phreatophytes) information to generate the evapotranspiration data (ET Package) used in the model. We also ran the model from 1955 to 2016 using hypothetical data to make sure that Groundwater Vistas and Modflow could run a model of this size (a problem in previous modeling attempts). All other packages used in the Modflow model have been created.

GET

In 2020, we switched from using Modflow in Groundwater Vistas to using Modflow in Olsson's Groundwater Evaluation Toolbox (GET). Groundwater Vistas would not read several of the Modflow input files created outside of the Groundwater Vistas interface. This created numerous problems and inaccuracies before it was discovered. Our input files were created for the RRCA model and would run in the RRCA's Modflow program and were formatted according to the USGS' version of Modflow. Unfortunately, these input files would either cause the Groundwater Vistas program to crash, or we would have to continually modify the input files to make the program work.

Olsson Associates created a groundwater modeling program (GET) that uses the USGS Modflow program and has pre- and post-processors to input and view the data. We sent our Modflow input files to Olsson, and they used them to create our model in GET. The model runs faster and without problems. GET also has the ability to create "zones" in our District so we can evaluate separate groundwater management scenarios for areas that may need different requirements than the remainder of the District.

Olsson and The Flatwater Group are calibrating the model to match groundwater elevation records and stream flows, and as of December 31, 2020, the calibration effort was about 75% completed.

While the model is not fully calibrated, we did use it to evaluate two variance requests in 2020. The model was sufficiently accurate to estimate relative changes in groundwater levels, so we used it to estimate the relative effect of the variance request.

Future Efforts for URNRD model

Our next step is to finish the model calibration and create an initial base model for the District. For the calibration process, we are not adjusting the aquifer properties estimated for the RRCA model such as hydraulic conductivity (K) and specific yield (Sy), but we are using the precipitation, irrigation, recharge, and evapotranspiration (ET) data to calibrate the model. The goal is to have the model's groundwater surface elevations match the actual groundwater surface elevations. The district records water elevation in over 400 wells including 12 USGS observation wells, and the model results will be compared to the elevations recorded by these wells.

Once calibrated, the model time period will be extended to 2061 to estimate the future trends in the District's groundwater elevations and to identify areas of concern to be addressed in our management scenarios. We will then model potential management scenarios including technology advances in crop water need, change in crop patterns, retiring land, allocation modifications, groundwater recharge, operation of the Rock Creek Augmentation project, and effects of wells going dry (transfer of right vs loss of well).