URNRD Groundwater Modeling Project

Final Project Report

Water Sustainability Fund Application #5184

The Upper Republican Natural Resources District (URNRD) was awarded a $243,000 grant by the Natural Resources Commission in 2018 to develop a groundwater model to help evaluate water supplies under different pumping scenarios to help inform district decisions and policies regarding volumes and locations of groundwater pumping. The project has been completed and the model is now being used in a manner consistent with the project description in Application #5184. All grant funds have been expended.

Project Objectives

Prior to the WSF-funded project, the URNRD lacked a groundwater model that could be used to help predict aquifer reactions to varying levels of irrigation withdrawals. This created a deficiency in our ability to understand the usable life of the aquifer throughout the URNRD under current rates of water withdrawals for irrigation and variable withdrawal rates produced by revised pumping regulations and/or creation of new programs from the URNRD designed to reduce groundwater pumping. A model was also needed to analyze possible aquifer impacts of periodic requests from landowners to move pumping locations, i.e. ceasing irrigation in one area to allow the same or less volume of pumping for irrigation in another area. Analytical tools are needed to help stabilize groundwater in areas of the URNRD where groundwater levels have steadily declined for approximately 50 years. Annually, groundwater levels have dropped an average of about .75' annually in the URNRD and on average groundwater levels are approximately 25 feet lower now than when irrigation development began in the 1960's. The steepest declines are approximately 60-70 feet. Additional steps such as those proposed in the project need to be taken to ensure water supplies in some areas of the district don't diminish to levels where fully irrigating crops is not possible within coming decades.

Project Development

The following is a very cursory overview of the model development that doesn't include details such as borehole analysis, layer design, and boundary conditions. If the reader of this report would like more information on those aspects of model construction, feel free to contact the URNRD.

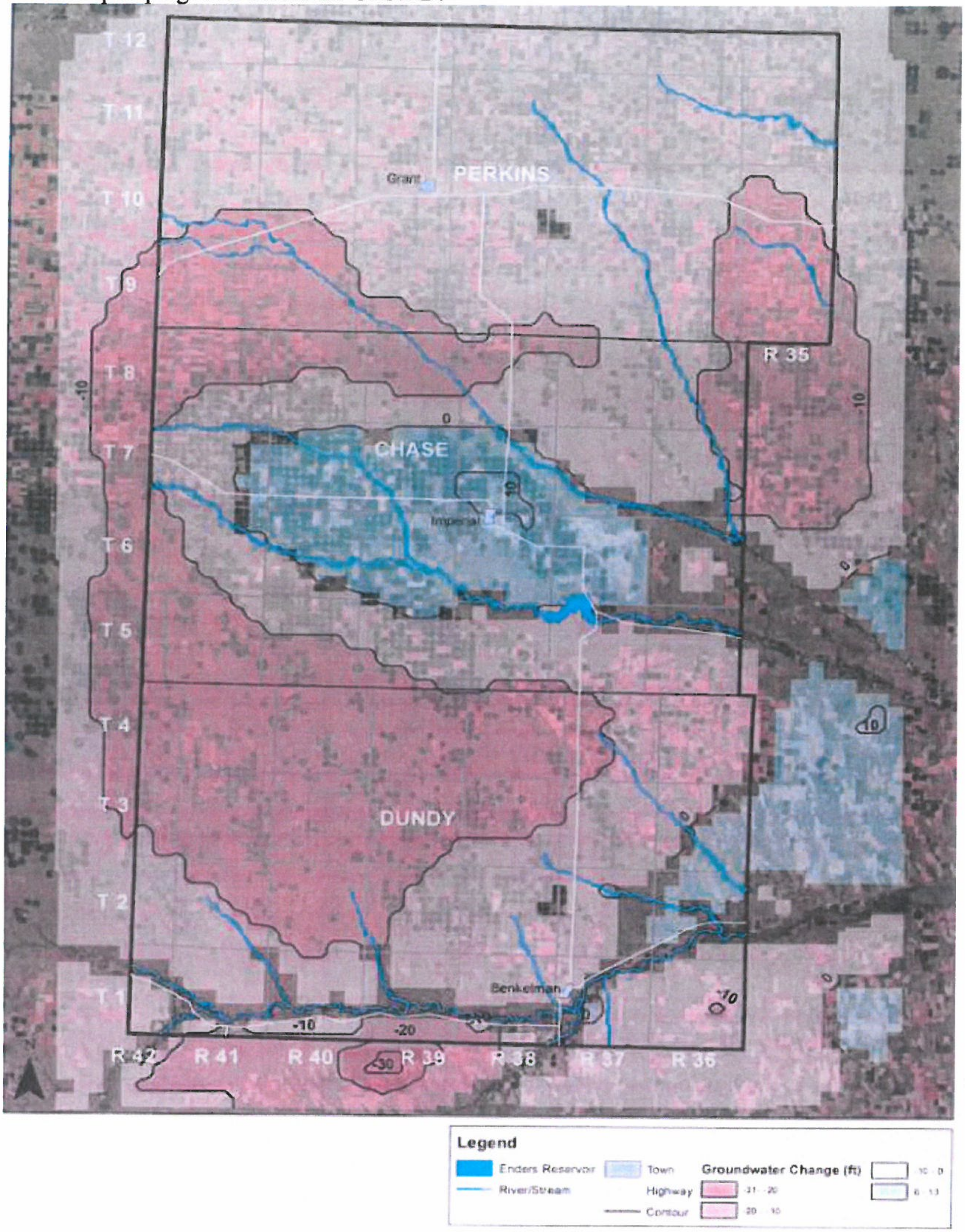
A refined subregional groundwater model was constructed to encompass the URNRD and the surrounding areas. The refined subregional groundwater model uses the MODFLOW 6 program. This version of the industry standard USGS modeling software called MODFLOW provides substantial flexibility in model discretization by removing the traditional layer-row column approach for implicitly defining cell connectivity and replaces this with explicit details of the way in which each cell interacts with any other cells. MODFLOW 6 was used to include complex geologic layering, such as discontinuous aquifer layers as well as lateral spatial refinement within the NRD border.

The model grid utilizes varying cell sizes to accomplish a higher degree of spatial accuracy within the URNRD, while still utilizing data inputs and outputs from the area outside of the URNRD. The largest cells in the model area measure 1.0-mile by 1.0-mile. Cells within the URNRD are refined down to a size of 660-ft by 660-ft (10 acres). The 10-acre grid cells in the URNRD cannot be bordered by a grid cell larger than 1,320-ft by 1,320-ft (40 acres), which allows the focus of the model to remain on the URNRD while including the boundary areas in the model without requiring the same refined inputs.

The model was further refined to contain up to two layers at any specific location using well data from multiple sources including the Nebraska Department of Natural Resources' inventory of registered wells and the University of Nebraska-Lincoln's Conservation and Survey Division. Well logs were analyzed to determine the degree of good aquifer materials by separating well data into hydrostratigraphic groups. This helped create a three-dimensional statistical interpolation technique used to map out the aquifer properties below the entire URNRD, which encompasses three counties. The pairing of these data sets led to the drawing and creation of layers for the model.

Pumping and recharge estimates were calculated with a watershed model that combines a climate model, a soil water balance model called CROPSIM, and a regionalized soil water balance model. The climate model uses weather data from 50 weather stations to produce precipitation, temperature, and reference evapotranspiration data. CROPSIM computes inflows and outflows of the soil-water balance based on characteristics such as crop type, soil class, management, and irrigation on a daily basis. The daily calculations are aggregated into monthly summaries of runoff, evapotranspiration, and deep percolation. The final component of the watershed model is used to develop estimates of pumping and recharge for incorporation into the groundwater model as MODFLOW WEL and RCH files. Pumping estimates are based on Net Irrigation Requirements (NIR) by crop type, irrigation system information, assumptions about irrigation management, and application efficiency. Additionally, the development of the pumping estimation in the model was supplemented by measured water use provided by the URNRD, when available.

The model was calibrated using the parameter estimation tool called PEST (Doherty and Hunt 2010). The goal of the calibration process was to produce simulated water levels that compare favorably to the observed water levels and produce a good representation of the hydrologic system. This goal was quantified as being met when the weighted absolute residual mean was less than 5% of the range of observations. For the steady state model simulation, the primary calibration targets used in the calibration process consisted of water level observation data from the URNRD, where groundwater levels are annually measured at approximately 400 monitoring wells. Primary water level observations were obtained from the URNRD and associated with the correct location within the model domain (USGS 2022). Absolute observed water level elevations were calculated using the LiDAR elevation as the reference elevation from which drawdown measurements were taken. The final calibration run in PEST with the steady state model had a total of 1,273 targets from water level measurements. The estimated final model parameters, obtained through the model calibration process described above, produced a well calibrated model with an excellent representation of the hydraulic system. The final model simulation was conducted using the calibrated model parameters. Following is an illustration of model results of groundwater elevation changes over a multidecade period assuming a uniformly different pumping level across the URNRD.



Recent and Future Model Use

We have used the model multiple times over the past several months, primarily to evaluate impacts of relocating groundwater pumping from an existing area to a new area as proposed by landowners. Such requests are relatively common and there are several motivations for doing so; often it's the desire to irrigate more productive farmland. URNRD rules and regulations prevent more water from being pumped in the new, proposed locations by limiting allocations at the new locations to what historical pumping suggests could occur at the old locations. While we have been able to prevent an increase in overall pumping and may have caused an overall decrease in impacts to stream flow by largely prohibiting relocations to areas closer to streams, it was very difficult in the pre-model period to evaluate other localized and regional effects.

Typical of recent requests has been to conduct multiple model runs to provide the board of directors, staff and public with as much information as possible to evaluate and compare the effects of the status quo versus relocated pumping. The information seems to have been particularly interesting to neighboring landowners, as they can now see informed estimates of how much groundwater elevations on their property may change because of the introduction, or removal, of nearby groundwater pumping.

The presentation of the model results in six relocation requests led to discussions of groundwater level changes, like the amount of change and the size of the areas covered by various levels of change. These discussions were especially important in the cases where neighbors brought forth concerns about the effects of new wells and irrigation on groundwater levels in the area. Two of the six relocation requests have been denied.

The model has also been used for discussions of future district-wide effects of different pumping scenarios mainly involving various levels of reduced allocations over multidecade periods. These discussions will aid long-term planning of allocations to help meet targets related to mitigation of groundwater declines over the long term. Generally, the model has been helpful in giving the board a visual representation of how different pumping relocation requests will affect groundwater levels and what the effects will be on other wells in the area. We believe it will continue to be a great tool for both the board as it considers location-specific pumping scenarios and district-wide impacts of potential policies. We very much appreciate the Natural Resources Commission's decision to fund development of this tool that we strongly believe will help the URNRD make more informed decisions for years to come.

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