Coupled modeling of water level dynamics and energy use for operational well fields in the Denver Basin

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Abstract. The South Metro Denver area in Colorado has been experiencing rapid growth in recent years and many municipalities in this region rely on the groundwater resources available in the Denver Basin as their chief water supply. As the population continues to increase, municipal water demands must be met with a sustainable approach. The Denver Basin aquifer system consists of the following four principal aquifers: the Dawson, the Denver, the Arapahoe, and the Laramie-Fox Hills. Each aquifer is comprised predominantly of sandstone and confined by layers of siltstones or shales. These confined aquifers receive little annual recharge and consequently the groundwater available within them is a finite resource. Declining water levels coupled with interference between pumping wells contributes to losses in well productivity, which translates to higher energy costs associated with water production. Although regional scale numerical models have been developed for the Denver Basin aquifer system, local scale analyses are needed to effectively manage existing groundwater well fields. This research project utilizes production well data from the town of Castle Rock, Colorado to test the merits of using an analytical approach to model water levels at the well in the Denver Basin aquifers. The model applies superposition of the Theis solution throughout both space and time to consider the combined effects of pumping from multiple wells. Three years of hourly pumping and water level data were used to constrain the modeling. Primary objectives of this modeling effort include the following: test using the analytical solution as a predictor of continuous water levels at pumping wells, demonstrate a novel method for estimating aquifer properties using data from an operational well field, and provide a better understanding of cross-well interferences in order to reduce energy use and enhance sustainability of the aquifer. Calibrated models developed for both the Denver and Arapahoe aquifers in two of Castle Rock's municipal well fields validated the use of this analytical solution for the proposed objectives. Model results were used to evaluate alternative pumping scenarios intended to reduce energy costs associated with water production and increase sustainable yields from these aquifers. Each of the seven alternative pumping scenarios that were constructed yielded a net reduction in energy consumption and led to a stronger conceptual understanding of how each aquifer responds to varying pumping conditions. This research demonstrates that the analytical solution modeling approach may be beneficial for application to many other projects involving groundwater supply management and optimization.