Geophysical Research Abstracts
Vol. 21, EGU2019-10358, 2019
EGU General Assembly 2019

Integration of space-time variable water fluxes in a 3D complex regional groundwater model

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A 3D hydrodynamic model is used as a tool for assessing aquifer responses to intensive exploitation and for a better understanding of the sustainability of intensively exploited aquifers in the center of Tunisia. In this context, the plain of Sidi Bouzid where surface waters are absent, groundwater is the only water supply source. During the last two decades, the global groundwater depletion have increased and generated an annual drawdown of water table of approximately 0.5 m. To cope with, the only alternative is setting up spreading perimeters of floodwater for artificial recharge.

To understand the impacts of the artificial recharge on regional hydrological processes, we implemented a comprehensive flow model using the numerical tool FEFLOW that can simulate the integrated water balance in the vadose zone and the regional groundwater. The present study does not only provide a detailed evaluation of the complexity of space-time variable water fluxes, but also a specific methodology of data acquisition and data integration in transient groundwater modeling to overcome the limited knowledge of the required input data of the model. The variation in space and time of artificial recharge, evaporation, groundwater pumping and water exchange between river and the aquifer in the given complex aquifer (800 km2) has been assessed by integrating various available data and modeling approaches. The data set and approaches include information about measured flood hydrographs, a modified modeling approach for water uptake by evaporation, the FAO-56 method using satellite data and a GIS to estimate groundwater pumping volumes, field experiments, and preliminary one-dimensional numerical studies.

Particular attention has been paid to characterize the heterogeneous unsaturated zone. The one-dimensional numerical approach showed that the spatial variation of the hydrodynamic parameters of the soil horizons have a significant impact on the infiltrated water and stored quantity in the vadose zone of approximatively 20% and 15%, respectively for various spreading perimeters. The conclusions drawn provided valuable information about how to build the 3D regional model for the entire area of the Sidi Bouzid plain which considers the variation of the hydraulic parameters of the soil in both the vertical and horizontal directions. Then the model was used to simulate the hydrological processes under different numerical sensitivity scenarios. The results for the simulation of a 20 years period, from 1993 to 2013, showed that the ground water recharge is largely overestimated when the water blade is applied on the entire area of the spreading perimeters. In addition, numerical simulations showed that the annual natural recharge from the wadi el Fekka is estimated to 56 mm. Finally, the predictive simulation results confirmed that the groundwater table will keep dropping in the next 10 years. Therefore, artificial recharge might help to maintain the actual groundwater table only when the pumping rates applied to the groundwater are reduced.

Key words: 3D modeling, deep vadose zone, aquifer in semi-arid climate, Feflow, spreading perimeters, water balance