Geophysical Research Abstracts
Vol. 13, EGU2011-12726, 2011
EGU General Assembly 2011

Using a large scale groundwater model to quantify water resources availability in an arid aquifer system

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The availability of freshwater is a limiting factor for societies in arid and semi-arid regions. This is the case for the Najd area in Southern Oman, located in one of the most arid zones in the world. Due to an increasing demand for agricultural products, farming areas irrigated with pumped groundwater are being established and more are planned. Though it is well known that a deep groundwater reservoir is present for most of the area, little is known about current recharge, groundwater flow systems or storage capacities of the formations. To consistently integrate the existing geological, hydrogeological and meteorological information, a first comprehensive groundwater model for the region, enhanced by recent sampling including hydrochemistry and isotopes, is constructed. The model aims at gaining a better understanding of the dynamics of the groundwater and enabling a better planning of the use of the groundwater resources in the Najd area.
The main aquifers in the Najd area are located in the Paleocene and Lower Eocene Umm Er Radhuma Formation (UER). This limestone formation is up to 450 m thick, contains different hydrogeological units and is present over the whole Najd area. The Southern border of the Najd area are the Dhofar Mountains with an elevation of up to 1800 m a.m.s.l. This mountain chain constitutes a clear division between the monsoon influenced coastal plain and the dry hot desert climate of the Najd area, and represents the surface water divide. The location of the subsurface water division is not known well, and because the geological formations are dropping north into the Najd, a part of the seepage water at the mountains presumably flows northward into the Najd. Furthermore, the rare but intensive rain events from cyclones trigger surface discharge in distinct and large Wadi systems directed Northwards into the Najd area. Often, the Wadis are eroded into the upper UER itself and therefore a direct local recharge during such events may occur.
Our working hypothesis is that the recharges from the Dhofar Mountains after the monsoon rain and from cyclone events are the major input into the Najd groundwater system. The open question is to assess the relative amount and temporal dynamics of these recharges, as well as the underlying hydrogeological processes. To estimate the recharge from the Dhofar Mountains we installed data loggers of the groundwater level north and south of the subsurface water division. The first results for these monitoring points will be available in March 2011. Based on the time-response of the groundwater level we intend to estimate the storage capacity of the aquifer. We plan to compare these estimations with isotope data from Al-Mashaikhi et al. (in preparation).
The estimated recharge will be used as input for the groundwater model. The groundwater model is set up using the model code OpenGeoSys (Kolditz & Bauer, 2004). It covers around one third of the Najd area (around 30 000 km^2), located in the central part and with the mountain chain as the Southern model boundary. In the structural model all formations younger then the Cretaceous are included. The UER is divided into the upper part (Aquifer B) and the lower part (Aquifer C and D). On top of the UER are the Rus and Dammam Formations, which constitute another aquifer (Aquifer A). Since only scarce data are available (drilling depth, water level), Aquifer C and D as the main aquifers for agricultural use are combined into one model layer. From the monitoring data of the years 2000-2010 isolines of water levels were created and used as initial conditions for future groundwater modelling runs. At the Southern border (mountain chain), where the outcrops of the UER are located, local discharge and springs and overflow to the coastal plain aquifer occurs. In the East and West the boundaries were chosen along flow lines. For the Northern boundary a general head BC was defined. This model is run in a first step as a steady-state model for the period before the exploitation period starting at present.

Kolditz, O. & Bauer, S. (2004): A process-orientated approach to compute multi-field problems in porous media. - International J. Hydroinf., 6: 225–244.
Al-Mashaikhi, K., Oswald, S., Attinger, S., Knöller, K., Strauch, G. (2010):Evaluation of groundwater dynamics and quality in the Najd aquifers located in the Sultanate of Oman. (in prep.)