Geophysical Research Abstracts
Vol. 12, EGU2010-6584, 2010
EGU General Assembly 2010

Modeling Recharge in a Fractured Bedrock Aquifer to Evaluate the Potential Effects of Climate Change on Groundwater Availability: new techniques

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This paper describes how we modified a soil-water-budget model initially developed by the United States Geological Survey (USGS) to include fracture recharge through mapped fault zones and then to use this model to better understand the effects of a warming climate on the sustainability of an important groundwater supply. In extended drought conditions, the normally perennial streams in parts of the Western United States stop flowing and, for the City of Laramie, Wyoming, the Casper Aquifer becomes the only source of water to the local water utility. This community, situated in a high desert valley approximately 150 km North of Denver, Colorado, normally uses a combination of surface water from a local stream and groundwater wells. In this arid landscape groundwater is a critical component of the water supply but little is known about how much water enters the exposed recharge area along a mountain front East of town. Groundwater level measurements and geochemistry suggest that the aquifer system has a fast and slow component. Some runoff water becomes recharge where ephemeral streams intersect fractures at the surface and another component of slower recharge occurs as slower percolation through very thin soils. Based on monitoring data, recharge occurs primarily in late winter and early spring during snowmelt. In the past several decades the City Utility has seen annual groundwater levels dropping in municipal wells as the amount of water withdrawn exceeds annual inflows. However, in 1983 water levels in the Casper Aquifer rose significantly following a winter of higher than average snowfall. The analysis presented in this paper outlines how we adapted the general soil-water-budget model to calculate the various components of recharge and then how we considered the effects of warming winter conditions on the sustainability of the bedrock aquifer in this arid region of the country. Or analysis suggests that warming winter conditions could limit snowpack and nearly eliminate recharge. All of these results were used to develop local laws to restrict development in the recharge area to protect water quality in the aquifer and recharge to the system.