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Analytical solutions for recession analyses of sloping aquifers – applicability on relict rock glaciers in alpine catchments

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Rock glaciers as aquifer systems in alpine catchments may strongly influence the hydrological characteristics of these catchments. Thus, they have a high impact on the ecosystem and potential natural hazards such as for example debris flow. Therefore, knowledge of the hydrodynamic processes, internal structure and properties of these aquifers is important for resource management and risk assessment. The investigation of such aquifers often turns out to be expensive and technically complicated because of their strongly limited accessibility. Analytical solutions of discharge recession provide a quick and easy way to estimate aquifer parameters. However, due to simplifying assumptions the validity of the interpretation is often questionable. In this study we compared results of an analytical solution of discharge recessions with results based on a numerical model. This was done in order to analyse the range of uncertainties and the applicability of the analytical method in alpine catchment areas. The research area is a 0.76 km^2 large catchment in the Seckauer Tauern Range, Austria. The dominant aquifer in this catchment is a rock glacier, namely the Schöneben Rock Glacier. This relict rock glacier (i.e. containing no permafrost at present) covers an area of 0.11 km^2 and is drained by one spring at the rock glacier front. The rock glacier consists predominantly of gneissic sediments (mainly coarse-grained, blocky at the surface) and extends from 1720 to 1905 m a.s.l.. Discharge of the rock glacier spring is automatically measured since 2002. Electric conductivity and water temperature is monitored since 2008. An automatic weather station was installed in 2011 in the central part of the catchment. Additionally data of geophysical surveys (refraction seismic and ground penetrating radar) have been used to analyse the base slope and inner structure of the rock glacier. The measured data are incorporated into a numerical model implemented in MODFLOW. The numerical model was then compared to the analytical solution based on the one dimensional Boussinesq equation for unconfined flow in sloping aquifers. Field observations as well as results from the numerical model suggest that the rock glacier has a complex internal structure with zones of low hydraulic conductivity and a high conductive layer on top. The analytical solution attempts to represent this heterogeneous aquifer by an equivalent homogeneous medium. However, as the relative contribution of the different aquifer components varies throughout the recession, the parameter estimates are not easily interpreted in terms of actual aquifer properties. Employing analytical solutions for recession analysis in this type of setting therefore requires a sound understanding of the internal structure and its influence on the flow and storage processes within the rock glacier.