Geophysical Research Abstracts
Vol. 15, EGU2013-9263, 2013
EGU General Assembly 2013

Modeling the hydraulic behavior of deep-seated rockslides in metamorphic rocks

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While groundwater flow in shallow and soil type landslides has been studied intensively, groundwater flow in deeper landslides composed of fractured rocks is usually only described with simplified conceptual descriptions. However, detailed characterisations of groundwater flow and pore pressure in deep seated rock instabilities, especially those located close to reservoirs, are sometimes necessary. In addition, unsaturated flow in fractured rock slopes is rarely investigated and not considered in most numerical groundwater flow and stability models.
In this work, characteristic curves for unsaturated water flow and pressure in typical rockslide units are derived based on field data from one study site in Austria and few theoretical studies as presented in literature (e.g. Pruess & Tsang 1990, Wang & Narashimhan 1985, 1993). Saturation-pore pressure and saturation-hydraulic conductivity functions are derived for fine-grained shear zones and stable rock masses. Based on such functions we discuss the impact of variable material properties and boundary conditions on the pore pressure conditions in 50-200 meter deep rockslides. The results are based on a generic numerical model of a deep seated rockslide, and of a case study located in the Tyrol (Austria), where subsurface pore water pressure data are available from surface and subsurface boreholes. Further, we present transient modeling results for changing reservoir lake levels at the rock slope toe and seasonal variations of groundwater recharge from rainfall and snow melt. Distributions of transient pore pressure fields and groundwater flow paths in different parts of the rockslide are discussed.
Numerical results confirm observations, that most translational rockslides show no significant seepage zones above the lake levels and most of the infiltrated water is drained at the base of the rockslide mass due to the high hydraulic conductivity contrast between the partially saturated rockslide, the shear zone and the stable rock mass. Depending on the geometry of the rockslide and selected material parameters, numerical modeling suggests that suctions of up to several hundred kPa develop at the base of the rockslide mass. Transient pore pressure fluctuations, which are measured by piezometric borehole sensors, can be successfully explained. In the actual case study there is no noticeable time lag between reservoir level fluctuations and groundwater pressures in the toe area of the rockslide mass. This stands in contrast to deep groundwater table elevations and pore pressures, which are mainly controlled by annual recharge cycles from snow melt. Short-term recharge events (e.g. heavy summer rains) do not result in a comparable rise of the groundwater level.

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