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Perched water during steady infiltration in a gradually layered soil: some theoretical results

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Due to the genetic layering, the hydraulic conductivity at saturation K_s is usually expected to decrease across the upper soil layers. Its effect on the soil hydrological properties is related to a number of landslide triggering mechanisms. Key information in order to evaluate the soil stability are the threshold of the infiltration rate for a saturated layer or a perched water to onset, its depth, the maximum pressure head and the water content profile above the saturated soil. Anyway if K_s is gradually decreasing, as often observed in the uppermost soil layers or in mountain not–mature soils, the position of a perched water can be a priori not known, nor could be the position of the maximum pressure head.

These topics were theoretically discussed considering an undeformable soil layer of finite depth, characterised by gradually and monotonically decreasing K_s, in which a steady one–dimensional infiltration takes place at a rate i. At the bottom of the domain a saturation condition was assumed. Two classes of soil constitutive laws were considered in order to represent the unsaturated soil behaviour. They are respectively characterised by a finite and by an infinite slope of the hydraulic conductivity $K(\psi)$ (where ψ is the matric potential) as approaching the soil saturation. The theoretical results were particularized for a soil with exponentially decreasing K_s and the profiles of the hydrological properties were determined by analytical solutions of the Darcy's law.

The analyses suggested the definition of a threshold for the infiltration rate i for the perched water to onset, and allowed to determine the characteristics of the saturated layer, its pressure head profile and the position of the maximum pressure head as a function of the infiltration rate. Moreover, the hydrological properties profiles obtained for the overlaying unsaturated soil stressed the high sensitivity of the solution to the $K(\psi)$ model near saturation. The stronger is the reduction of K nearby the saturation conditions, the higher will be the gradient of the total hydraulic head needed to let the flux take place. Thus closer to saturation conditions, in terms of matric potential, will be the soil and the downward flux will be therefore sensitively governed by gravity.