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The transient nature of hydrological response in weathered clay slopes

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Shallow landslides on clay hill slopes have been widely studied in the literature. Traditionally, the prediction models are based on an infinite-slope analysis in which failure conditions are determined by an increase of pore water pressures within the slope. Most models relate the increase of pore water pressures to the rise of a quasi-steady water table generated by slope-parallel saturated groundwater flow. Such a simple view of the slope hydrology is essentially based on low-frequency measurements of water table fluctuation within open standpipe piezometers, or it is justified by the assumption of a vertical stratification of hydraulic conductivity in the slope (relatively impermeable bedrock underlying a more conductive soil cover). Real-time monitoring and numerical analyses have recently shown that the pore pressure response to rainfall on a clay slope is largely a transient phenomenon, in which the slope-normal component of the hydraulic gradient plays a key role in the variation of groundwater pressures. Stability models that do not account for the effect of rainfall infiltration may result in wrong prediction about timing and location of slope failures and, more importantly, about the choice of remedial works for landslide stabilization. In this work we present and analyse the data collected by a real-time monitoring system installed on an unstable clay slope in the Northern Apennines (Italy). The monitored area is located across the head scarp of a large earthflow (Rocca Pitigliana, Bologna Province), just upslope the main headwall scarp. The slope is made of a thin cover of weathered clay (1-3 m thick) lying on a bedrock constituted by stiff scaly clays. The monitoring system consists: i) a grid of 16 pressure sensors, buried into the soil at depths varying from 1 to 9.5 m below the ground surface and 3 soil moisture sensors. Slope movement is recorded by a surface wire extensometer (0.08 nominal sensitivity) and local rainfall by a 0.2 mm tilting bucket rain gauge. Sampling interval is 20 minutes for all sensors. Data collected during almost two years of continuous monitoring give a con-

sistent picture of the subsurface flow within the slope. During the wet season the soil is saturated at depths less than 1 m from the ground surface, and light rainfalls cause the water table to rise at the ground surface itself. More important, the groundwater flow shows a very transient behaviour: pore pressures increase sharply a few hours after the onset of the rainfall then decrease smoothly in the following hours or days. The observed sensor response can be satisfactory reproduced by numerical analyses of the infiltration processes, neglecting the slope-parallel contribution of the upslope area. Good results have been also obtained by a simplified analytical solution of the Richards equation based on the diffusion equation.