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Does the double paradox require hydraulic connectivity between hillslope and channel?

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Studying the connectivity between hillslopes and channels encounters a double paradox (Kirchner 2003): First, often rapid responses of stream discharge to rainstorms are observed, although pre-event water usually predominates in the stream. Second, stormflow stream water often differs significantly from baseflow, pointing to two different pools of pre-event water, and a quick switch between the both. Different mechanisms have been proposed to solve that paradox, but were usually restricted to a limited number of catchments. Here, a more general perceptual model is presented that questions our understanding of connectivity between hillslope and channel. For this model, the unsaturated topsoil layer of the riparian zone plays a crucial role. Although saturation excess surface runoff is widely accepted as a predominating runoff generation process, a close-up to the "saturated areas" reveals an irregular pattern of saturation patches due to the micro relief of the soil surface. These patches are hydraulically connected by short sub-surface flowpaths through the forest floor and uppermost mineral soil. Thus, event water mixes with a large pool of pre-event water, that is chemically very similar to hillslope vadose zone water. On the other hand, water transport within the saturated patches is very fast, thus explaining the rapid response of the hydrograph. Moreover, mixing of event-water with pre-event water within the riparian phreatic zone was observed during heavy rainstorms and snowmelt periods. In addition, there is strong evidence that even in the saturated zone a mobile and an immobile soil water fraction can be differentiated which is clearly at odds with the homogeneity assumption in many models. Due to its short residence time, the mobile fraction tends to resemble more the vadose zone (and thus hillslope) soil water than the immobile fraction. Thus, stream water might exhibit a hillslope water signature, without any physical contribution of hillslope water during short storms. Consequently, a hydraulic connection between hillslope and channel, e.g., via interflow or pipe flow

is not required, although it might add to these processes at single sites. According to the presented model, micro-scale processes in the vadose zone and in the uppermost layers of the phreatic zone play a decisive role for stormflow solute concentration in the stream. This model needs to be tested at various sites. Pathways to follow for a rigorous test will be presented.

Reference: Kirchner, J.W., 2003. A double paradox in catchment hydrology and geochemistry. Hydrological Processes 17: 871-874.