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Subsurface Network Structure and Soil Hydrologic Response Groups at the Shale Hills Catchment, USA

H. Lin and X. Zhou

Dept. of Crop and Soil Sciences, The Pennsylvania State University, University Park, PA 16802, USA. (Email: henrylin@psu.edu, phone: (814) 865-6726, fax: (814) 863-7043)

Understanding complex subsurface heterogeneity and modeling preferential flow dynamics are not easy tasks. Despite significant progress made in the past decades, our ability to determine and predict preferential flow patterns, velocities, and pathways in the subsurface across space and time remains limited. *In situ* soils often have distinct pedogenic features (such as structure, macropore network, and horizonation) that have profound impacts on the initiation and continuation of preferential flow under varying conditions. It appears that an internal network structure exists in the subsurface of many hillslopes, which governs vertical and lateral preferential flow dynamics and a threshold-like hydrologic response under different precipitation inputs, soil types, and antecedent soil moisture conditions. We investigated subsurface network-like structure and soil hydrologic response groups at the Shale Hills, a humid forested catchment in central Pennsylvania, USA. An integrated approach of soil-landscape mapping, geophysics, hydropedology, hydrometry, and real-time monitoring of soil moisture, precipitation, and stream discharge was used to map, monitor, and model subsurface flow networks (potential and active ones) and critical nodes (i.e., important junctions of flow networks in the subsurface that control the threshold behavior of hillslope subsurface stormflow). Based on extensive soil moisture data collected from this catchment, different soil hydrologic response groups that show different wetting-drying patterns in response to rainfall events were proposed, which can help understand and model subsurface preferential flow and the first-order controls at the pedon-, hillslope-, and catchment scales. We developed an integrated framework to understand the complex landscape-soil-hydrology relationships across scales, and used the iterative cycle of "mapping, monitoring, and modeling" (3M) to investigate flow and transport processes in the catchment. Our strategy includes: 1) map first, then

design, and 2) direction first, then velocity. We are now in the process of developing a spatially-explicit catchment network model that can capture major controls on the threshold-like nonlinear hydrologic responses observed at this catchment and use it as a quantitative framework for further systematic examinations of the physical-chemical-biological mechanisms that formed the subsurface network.