Inferring Critical Zone structure from hydrologic function: Dominant runoff generation mechanisms at Gordon Gulch, Colorado USA and testable hypotheses of shallow subsurface architecture.

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Critical zone (CZ) coevolution describes the reciprocal interaction and mutual evolution of landscape structure and function. Biotic and abiotic components of the CZ, such as vegetation cover, regolith depth, porosity, lithology, and topography establish the prevailing CZ structure. CZ functions include biogeochemical cycling, soil formation, erosion, habitat sustainability, and water transmission and storage. CZ coevolution is driven by processes at the interface of structure and function. In this work, we investigate hydrologic processes in the Boulder Creek Critical Zone Observatory at Gordon Gulch to elucidate how CZ structure controls hydrologic function.

Hydrologic function in Gordon Gulch is quantified with catchment- and hillslope-scale observations of water flux and storage. Four consecutive water years (2010 – 2013) of data show that Gordon Gulch receives 500 – 600 mm of annual precipitation (28 – 65% as snow) and annual runoff ratios range from 0.08 – 0.23. From catchment-scale observations, we hypothesize that runoff is primarily generated through saturated subsurface flow and the magnitude of runoff events is mediated by antecedent subsurface water storage. To test this hypothesis, we "open the black box" by analyzing groundwater hydraulic data from two hillslopes. Hillslope discharge is strongly correlated with water table depth and hydraulic gradient, supporting the hypothesized dominance of saturated subsurface flow. A Darcian model of hillslope discharge indicates that effective hydraulic conductivity ranges from 10^{-6} – 10^{-3} m/sec and decreases non-linearly with depth. Additionally, data indicate the occurrence of a transmissivity feedback mechanism in Gordon Gulch, where runoff generation is exacerbated by rising water tables intersecting progressively more permeable subsurface layers. Overall, this work summarizes long-term hydrologic records in Gordon Gulch to identify dominant runoff generation processes and develop testable hypotheses of shallow subsurface architecture.