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Stochastic rainfall-runoff equations for quantifying runoff and pollutant connectivity between hillslopes and streams.

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A single-event steady-state rainfall-runoff model (including runoff-runon phenomena) is derived, that for the first time quantifies the effect of the random spatial arrangement of rainfall and soil properties on i) infiltration-excess runoff delivery at a downslope boundary, and ii) the distribution of the "connected length" (the upslope length with a continuous runoff pathway adjacent to the stream boundary). The analytic stochastic runoff connectivity (SRC) model assumes a planar hillslope geometry of independent strips and utilises established asymptotic mathematical representations available from the stochastic theory of queues. The accumulation and loss of runoff down a slope is represented as a first-in first-out (FIFO) GI/G/1 queuing system. Runoff flow (time rate of volume) at a downslope boundary is analogous to the waiting time in the queue in this representation. Probability distribution functions and/or the moments for the asymptotic distribution of runoff flow at a downslope boundary are derived for the case of normally distributed rainfall and log-normally distributed infiltration capacity, and for some other common distributions. The distribution of connected length was able to be represented analytically using a FIFO M/M/1 queuing system, and distribution functions are also derived for this property. Together these distributions characterise the degree of connectivity of the overland flow pathway (and by extension its associated pollutant load) for a given set of rainfall and soil conditions. The model is restricted to conditions where the mean infiltration capacity is greater than the mean rainfall rate, conditions which are often encountered, particularly in temperate forests.