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A successive-steady-state approach to integrated surface-subsurface modelling for runoff generation on the field scale

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In groundwater dominated lowland catchments the larger part of precipitation on drained agricultural fields recharges the groundwater or reaches surface waters through subsurface drains. However, shallow subsoil structure deterioration due to sealing or compaction, shallow groundwater tables and long and intense precipitation events facilitate ponding of water at the soil surface. During a rainfall event, the ponded area on the field expands and surface runoff reaches the field boundaries when one or more series of ponds form continuous flow paths to the channels and ditches surrounding the field. To understand catchment discharge characteristics it is important to quantify the relative contributions of different flow routes in a catchment. Also, as surface runoff is the main contributor of pesticides and one of the main contributors of phosphorus to surface-water bodies, it plays an important role with regard to the contamination, the eutrophication, and the implications for ecological functioning of aquatic ecosystems.

In order to further quantify the relations between groundwater conditions, infiltration rates, and ponding and surface runoff, we developed a computer model that incorporates the saturated, unsaturated zones and a heterogeneous surface topography. The simplifications underlying the model are:

- The surface microtopography is static, therefore the configuration of ponds and their spill points to other ponds can be determined before the actual model simulation and stored in a database.
- The unsaturated zone is in hydrostatic equilibrium, therefore there is a unique relationship between the volume of water stored in a soil column and the elevation of the groundwater table. By using the total sub-subsurface storage volume as state variable, problems usually associated with saturated-unsaturated zone interactions are bypassed, while still allowing for correct computation of both groundwater flow, and unsaturated zone effects on surface infiltration and thus runoff generation.
- In the saturated zone only horizontal flow occurs. Radial flow towards the ditches is accounted for via a ditch entry resistance.

With this model it is possible to efficiently analyse, with adequate accuracy, the relations between the various compartments. In this presentation we describe the model structure, and present applications to both instructive hypothetical cases and real-work field-scale applications. Issues regarding upscaling of towards catchment and regional scales are discussed.