Selected Technical Facets of the KINEROS2 Watershed Model

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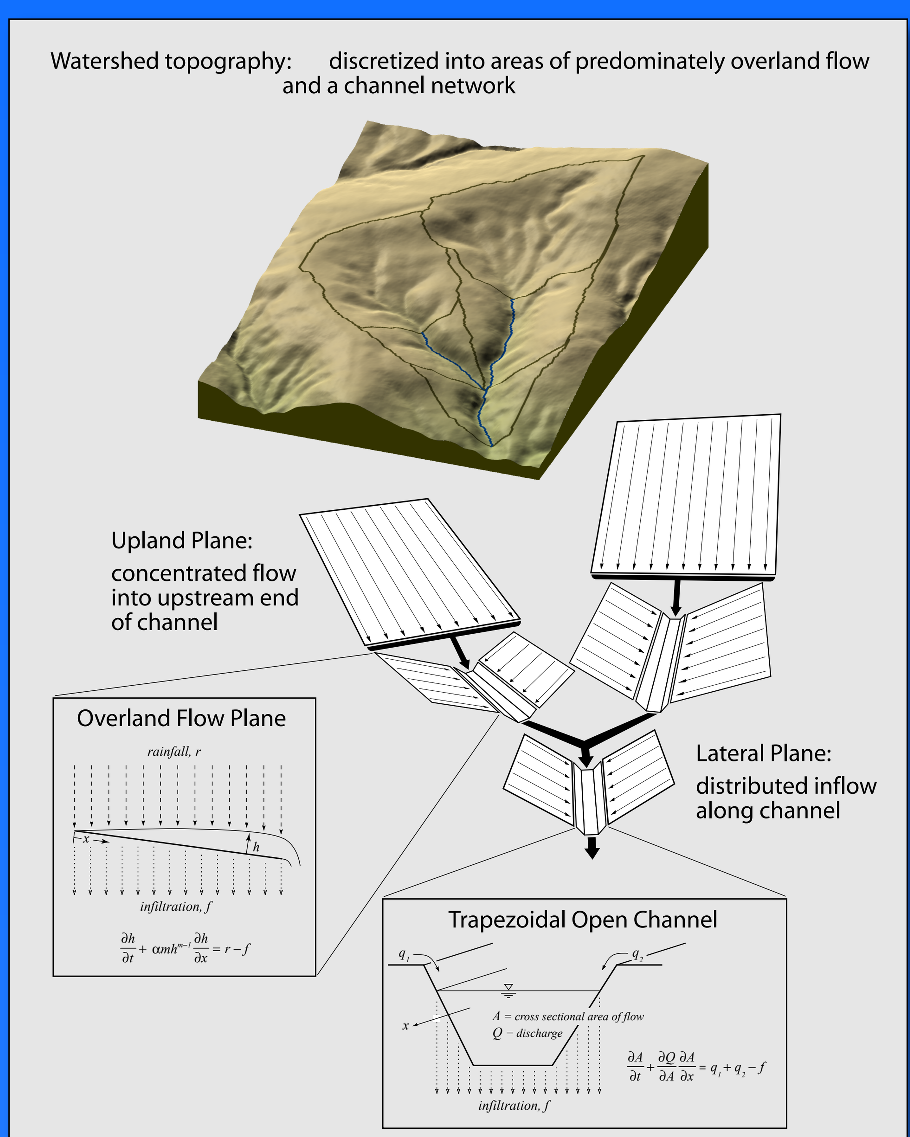
Primary Model Attributes

In KINEROS2, the conceptual model is an array of spatially distributed elements, configured to effectively abstract the watershed into a collection of simple geometric shapes (rectangular overland flow planes, trapezoidal prismatic open channels, etc.) oriented so that one-dimensional flow can be assumed. The process by which topographic data and channel network topology are abstracted into the simplified geometry defined by KINEROS2 elements is illustrated below. Further subdivision can define hydrologically distinct portions of the watershed, e.g. large impervious areas, abrupt changes in slope, soil type, or hydraulic roughness, and so forth. Cascades of rectangular overland flow elements can approximate converging or diverging flow.



Computational Features

A four-point finite difference solution approximates the partial differential equations describing flow and erosion, at user-defined time and distance steps. The time step may be reduced internally to accommodate rainfall breakpoints, or optionally to satisfy the Courant condition, and the spatial increment is based on a user-defined characteristic length. There is no limit to the number of model elements that can be used to describe a watershed. The linkage and computational order of elements is defined by the user.

Attributes for each type of KINEROS2 model element

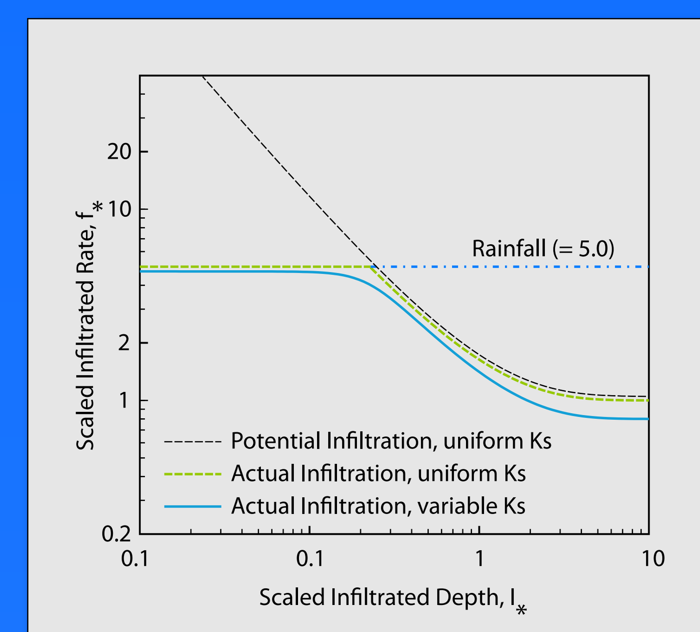
Overland flow	Planes; cascading, with varied lengths, widths, and slopes; microtopography
Urban overland	Mixed infiltrating/impervious with runoff-runon
Channels	Simple and compound trapezoidal
Detention Structures	Arbitrary shape, controlled outlet - discharge f(stage)
Culverts	Circular with free surface flow

Hydrological processes represented in KINEROS2

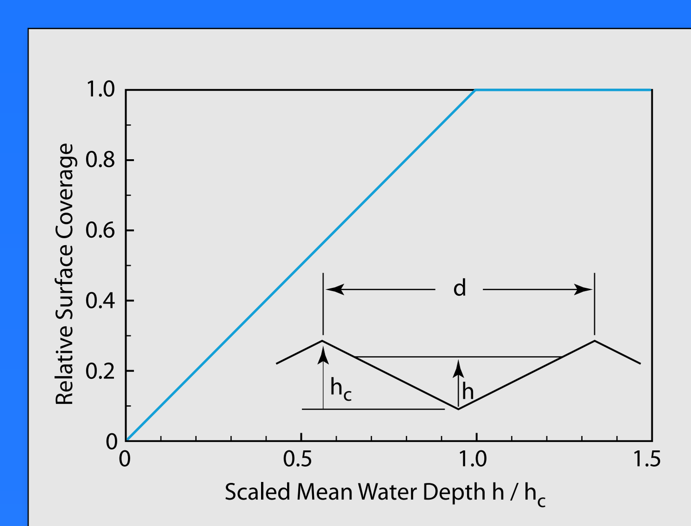
Interception	Reduces rainfall intensities to simulate partial areal vegetation coverage
Soil Moisture	Externally required initial condition; physically-based approximation for the redistribution of soil water during a rainfall hiatus
Infiltration during rainfall	Smith-Parlange/Green-Ampt; lognormal distribution of small scale variability of hydraulic conductivity is represented; single or two layer systems to simulate infiltration or saturation excess runoff generation
Infiltration during rainfall hiatus and on recession	Microtopographic reduction in wetted area; recovery of infiltration capacity during a hiatus; and modified infiltration rates following a hiatus
Routing	Kinematic wave; interactive with infiltration/erosion; treats channel transmission losses with same infiltration approximation as in overland elements; Manning's and Chezy roughness
Base flow	User specified in channel elements

Soil Infiltration

Conceptually, KINEROS2 represents a soil as either one or two layers, with a user-defined upper layer depth, exhibiting lognormally distributed, small scale random variation of saturated hydraulic conductivity, K_S. This spatial variation results in an areal effective K_S which increases with rainfall rate. The surface of the soil can also exhibit microtopographic variations which are characterized by a mean micro-rill spacing and height. Infiltration from the portion of the surface covered by water proceeds at the infiltrability rate, and the remaining area will have a value of f determined by the rainfall rate. Thus infiltration proceeds during recession flows depending on the micro-topography.



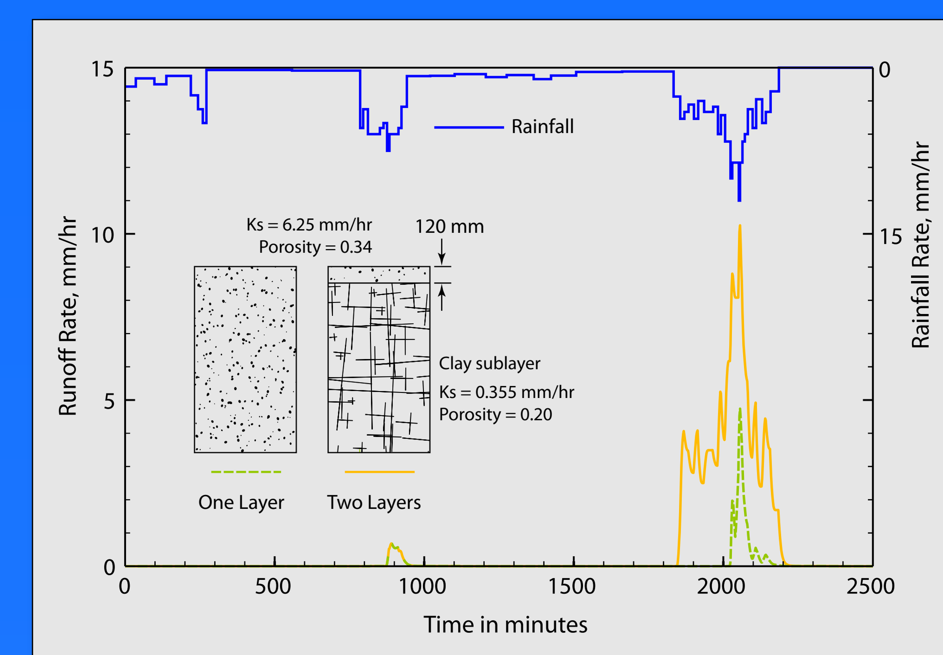
Comparison of infiltrability with and without randomly varying Ks



Geometry of microtopography showing relation between relative area covered by surface water and mean water depth.

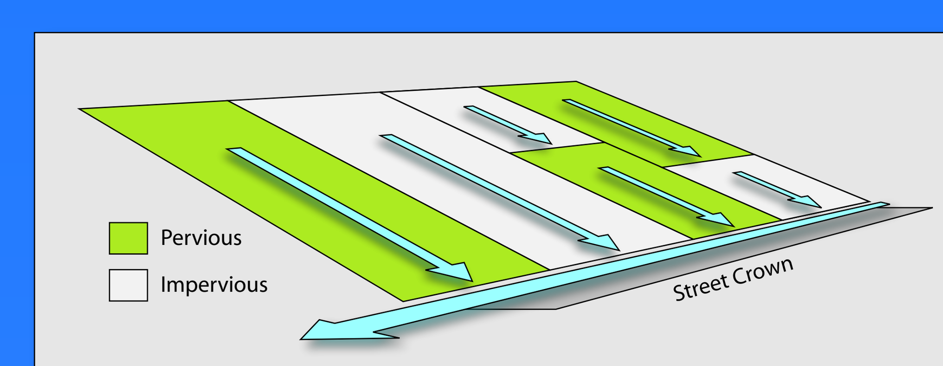
For a soil with two layers, either layer can control the infiltration rate, depending on the soil properties, thickness of the surface layer, and the rainfall rate. There are several possibilities, and KINEROS2 attempts to model all cases in a realistic manner, including saturation excess and the redistribution of soil water during periods when r is less than Ks and runoff is not generated.

An example of runoff generation from a single and two-layer soil profile is illustrated below. Both the single layer profile and the upper soil layer in the two-layer profile have identical porosities and saturated hydraulic conductivities. The lower layer in the two-layer case is significantly less permeable than the upper layer. Note that the second burst of rainfall produces identical Hortonian runoff from both profiles - the wetting front has not yet reached the less permeable lower layer in the two-layer profile. But the subsequent period of low-intensity rainfall fills the available pore space in the upper layer, so when the rainfall intensity increases again, runoff is generated via saturation excess. The single layer profile again generates runoff via rainfall excess.



Urban Element

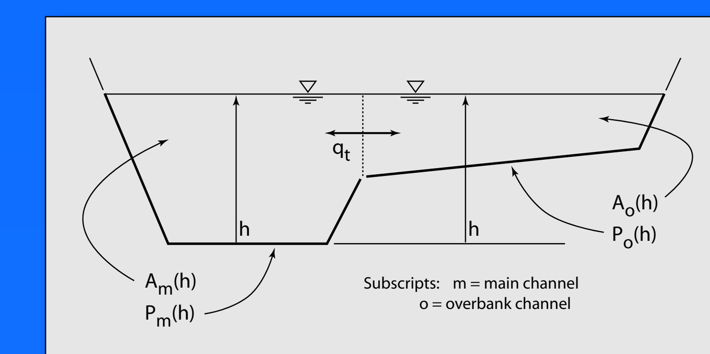
The urban element represents a composite of up to six overland flow areas, including various combinations of pervious and impervious surfaces, contributing laterally to a paved, crowned street. This type of model element was conceived to provide an aggregate representation of a typical residential or urban block without describing each roof, driveway, lawn, sidewalk, etc., as individual model elements



Layout of the urban element showing the configuration of contributing areas

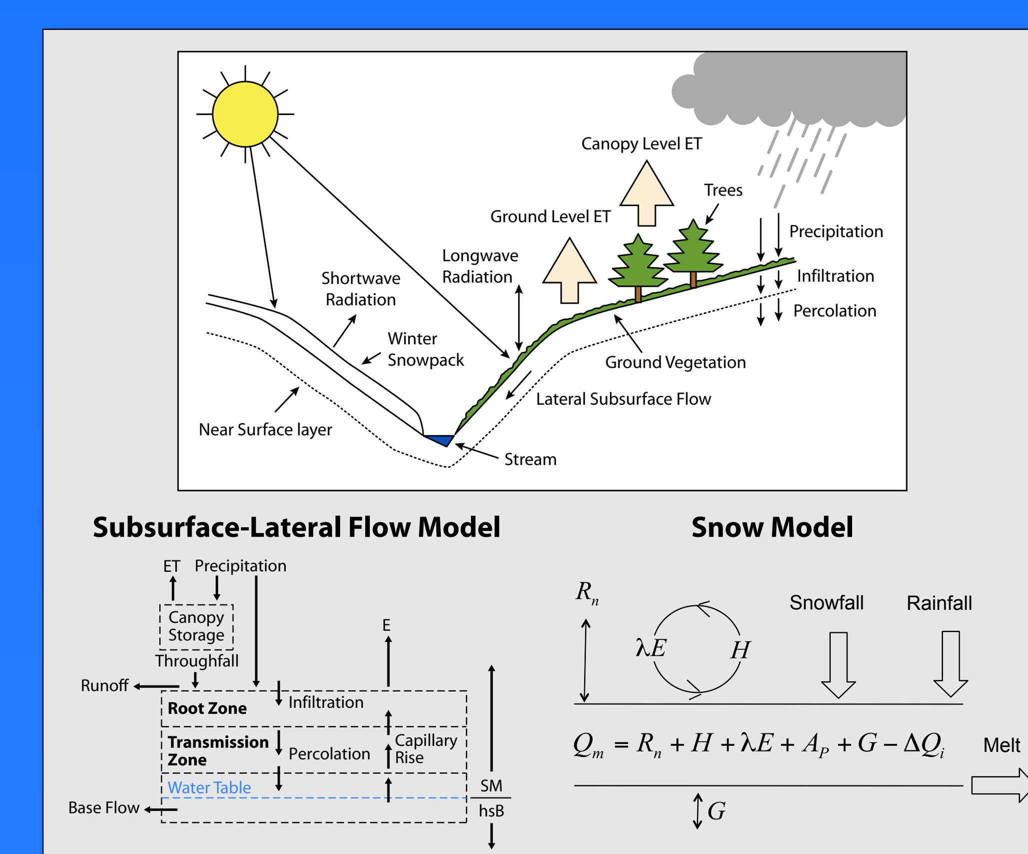
Compound Channel

A compound trapezoidal channel is obtained from two independent kinematic equations describing a parallel pair of channels, each with its own hydraulic and infiltrative characteristics. For each channel, the geometric relations for cross-sectional area of flow A and wetted perimeter P are expressed in terms of the same depth, h, whose zero value corresponds to the level of the lower-most channel segment (see below). Note that the wetted perimeters do not include the interface where the two sections join, i.e., this constitutes a frictionless boundary (dotted vertical line). There is no need to explicitly account for mass transfer between the two channels, as it is implicit in the common depth (level water surface) requirement.



New Capabilites

Components from the soil moisture hillslope storage Boussinesq (SM-hsB) model are being added to increase the accuracy of KINEROS2 for watersheds dominated by groundwater or lateral subsurface flow. A snow model is being added for situations where melting snow or rain on snow are significant inputs. The first module of the soil moisture hillslope storage Boussinesq (SM-hsB) consists of a distributed water and energy balance model of the vegetation canopy and the land surface. The second module is the soil water balance model and the third module operates at the hillslope scale treating lateral saturated subsurface flow for complex hillslopes. The last module is receives deep percolation from the lateral flow module. The snowmelt component is an energy balance model that allows snow to accumulate on the land surface until it is warm enough for snowmelt to occur. Incoming energy can include net radiation; sensible and latent heat transfer, ground heat flux, and heat release caused by rain falling on snow.



Conceptual model for the different components of SM-hsB