Forest Hydrology: Lect. 9

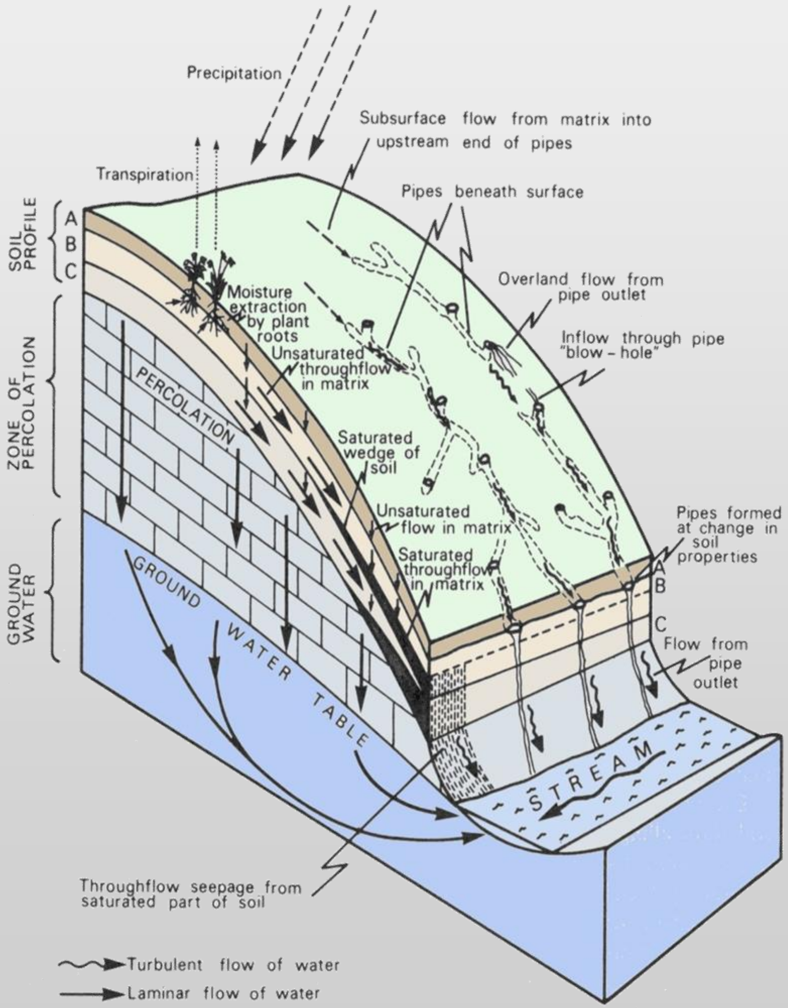
Contents

•Runoff, soil water and infiltration

Learning objectives:

- Hillslope runoff generation processes;
- Dynamics of runoff generation processes;
- Hortonian and Dunnian processes for the generation of surface runoff;
- Schematic summary of controls on runoff pathways

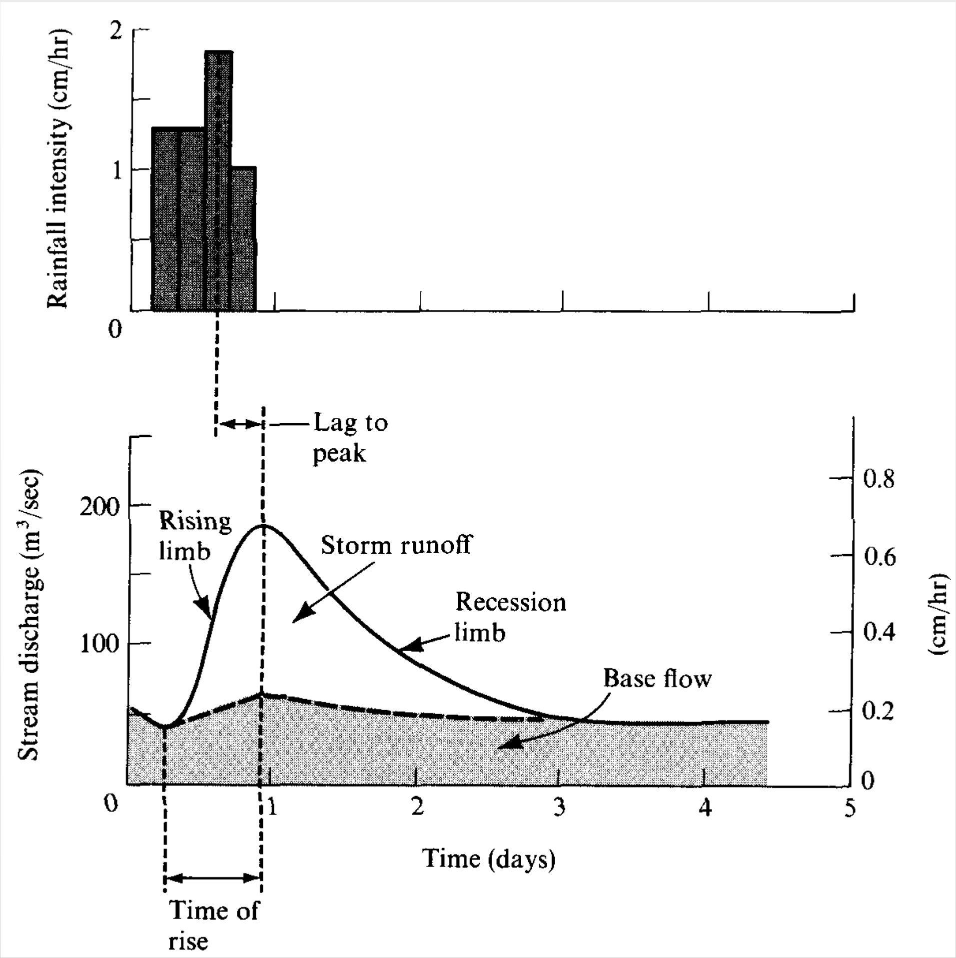
Hillslopes and hillslope runoff processes



The 'hillslope' is defined as the morphological unit of the catchment that does not include perennial flows.
As such, it is the portion of the catchment where runoff is generated.

Looking at the diversity of runoff generation processes, we identify a morass of process complexity.
In the following, we will try to simplify this by searching for first order controls.

Streamflow and runoff



Terminology

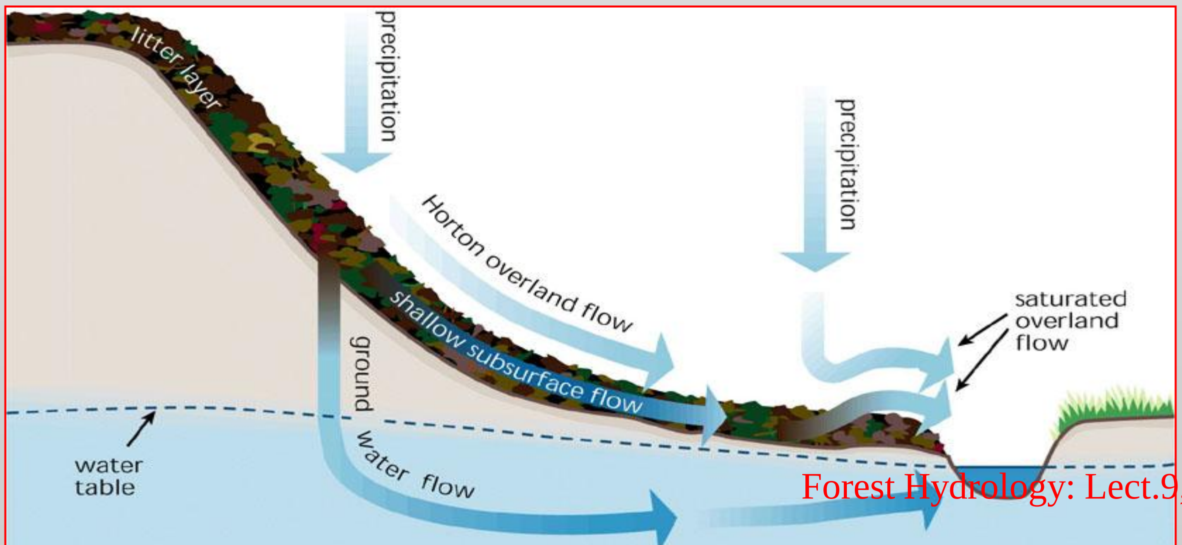
Streamflow (runoff) =
storm runoff + baseflow

or

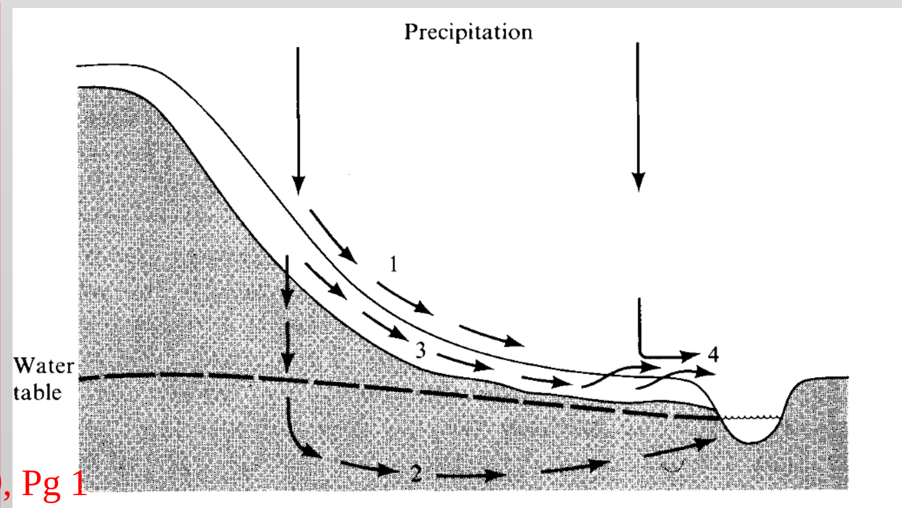
quickflow + delayed flow

Runoff generation processes (1)

When rain and meltwater reach the surface of the ground, they encounter a filter that is of great importance in determining the path by whoch hillslope runoff will reach the stream channel.
The paths taken by the water (see figures below) determine many of the characteristics of the landscape, the uses to which land can be put, and the strategies required for wise land management.
If the rate of rainfall or melting is greater than the capacity of the soil to absorb water, the unabsorbed excess beomes overland flow, referred to aften as Horton overland flow (Path n. 1 in the figures below)



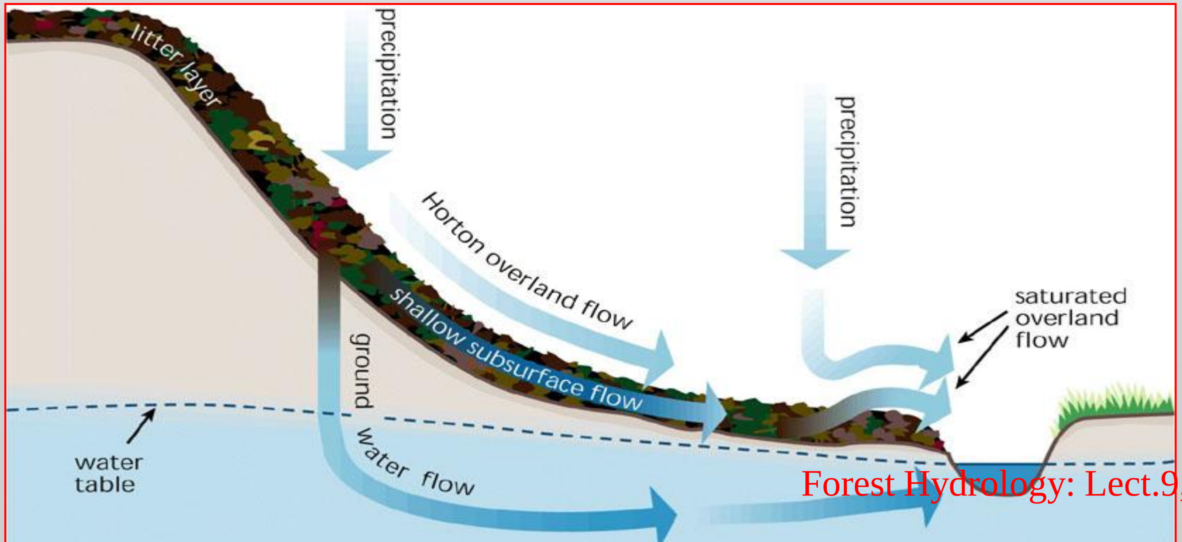
www.usda.gov/stream_restoration/chap1.html



Runoff generation processes (2)

If the precipitation is first absorbed by the soil, it may be stored there, or may move toward stream channels by a variety of routes. If the soil or rock is deep and of uniform pemeability, the subsurface water moves vertically to the zone of saturation, and thence follows a curving path to the nearest stream channel (groundwater flow) (Path n. 2 in the figures).

If at some shallow depth in the soil or rock, percolating water encounters an impeding horizon, a portion of the water will be diverted horizontally and will reach the stream channel by a much shorter route (shallow subsurface flow) (Path n. 3 in the figures).



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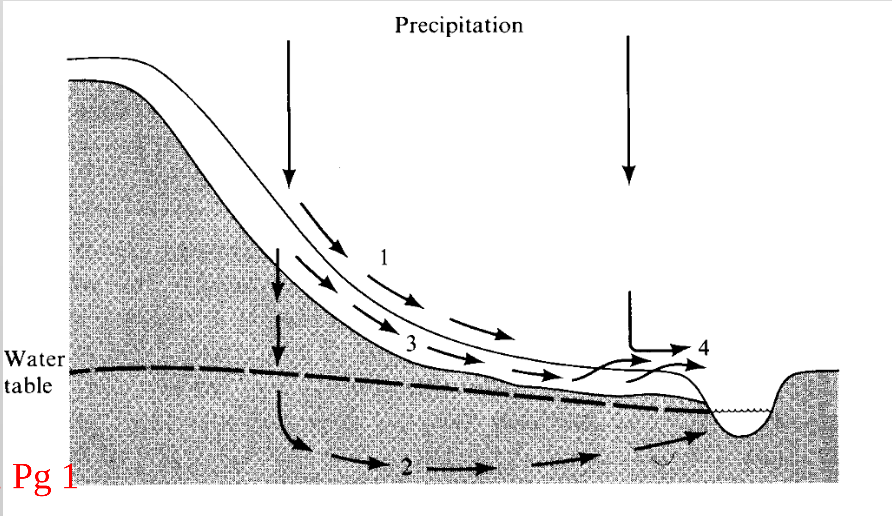
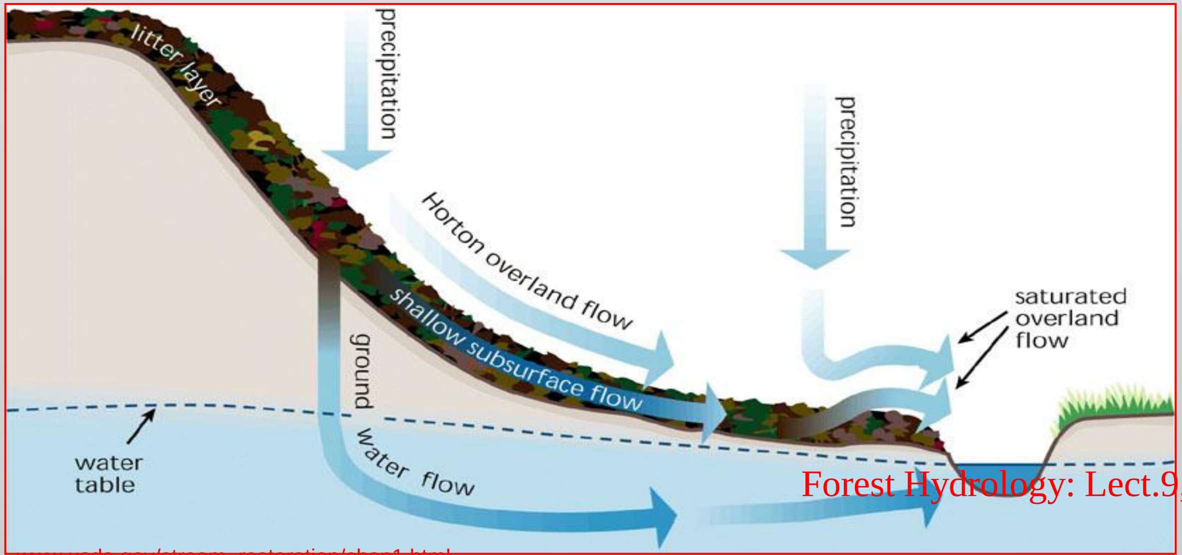


Runoff generation processes (3)

In some parts of a hillslope, vertical and horizontal percolation may cause the soil to become saturated throughout its depth. When this happens some of the water moving by the shallow subsurface path emerges from the soil surface and reaches the stream channel as overland flow. Such water can be referred to as return flow.

Rainfall onto the saturated areas cannot infiltrate, but runs over the surface. This contribution, termed direct precipitation onto saturated areas is difficult to separate from return flow. Storm runoff from these two sources are classified together as saturation overland flow (Path n. 4 in the figures).



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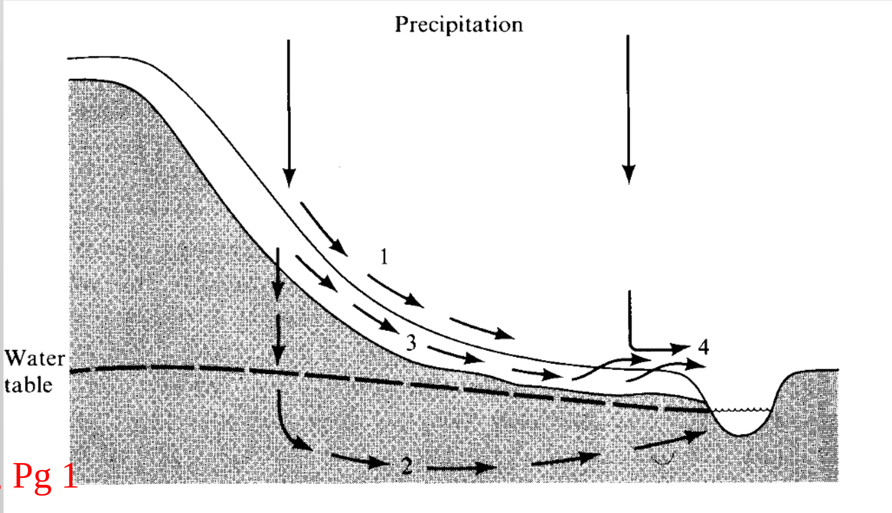
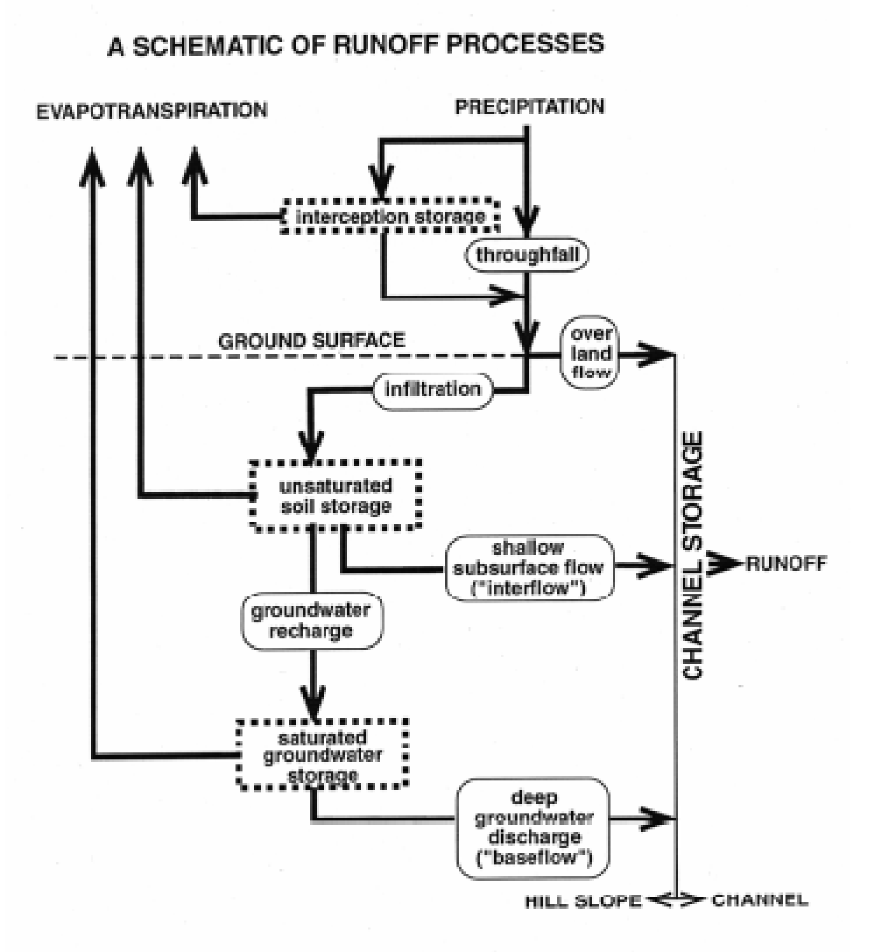
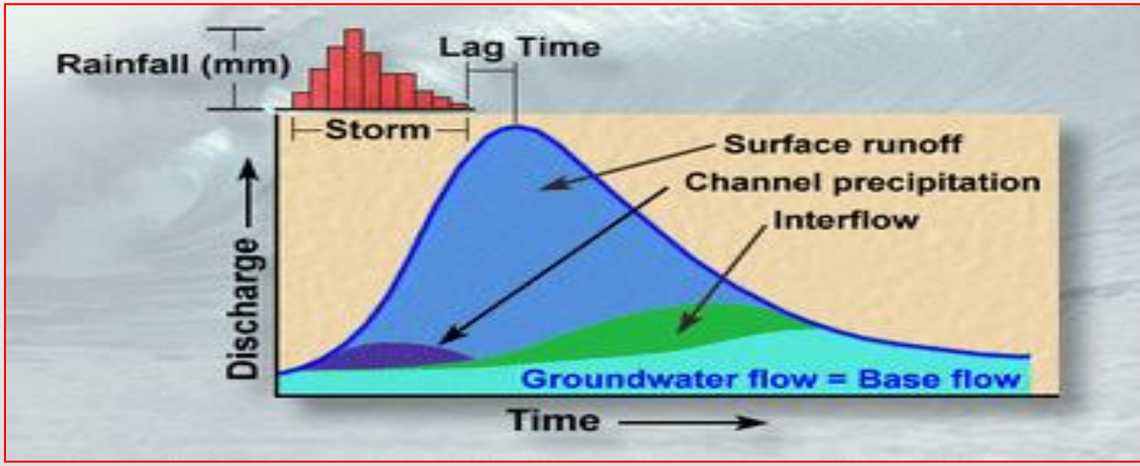


Runoff generation processes (4)





The scheme illustrates the interaction among the various runoff generation processes operating at the hillslope scale.
In the figure above, the term ‘interflow’ indicates shallow subsurface flow.

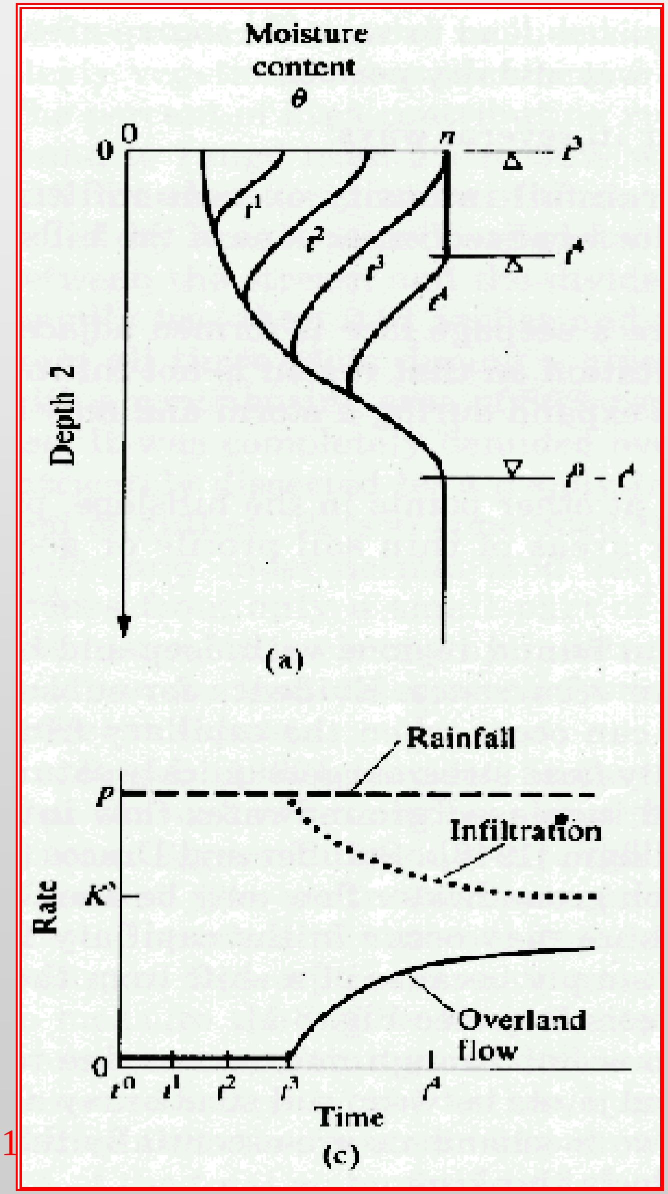
Dynamics of the runoff generation process

Infiltration excess overland flow (Hortonian runoff generation)

Runoff is generated when the rain rate **p(t)** exceeds the infiltration capacity **f(t)**. This induces the production of runoff, equal to the difference between the rainrate and the infiltration capacity.

The Hortonian mechanism is typical os arid and semi-arid climates, but not only. It is however rare to find Hortonian runoff generation in humid catchments characterised by deep and permeable soils.

A climate is arid when potential evapotranspiration exceeds precipitation (on a climatic basis – i.e. as a mean annual values along at least 30 years).
See Thornthwaite classification system



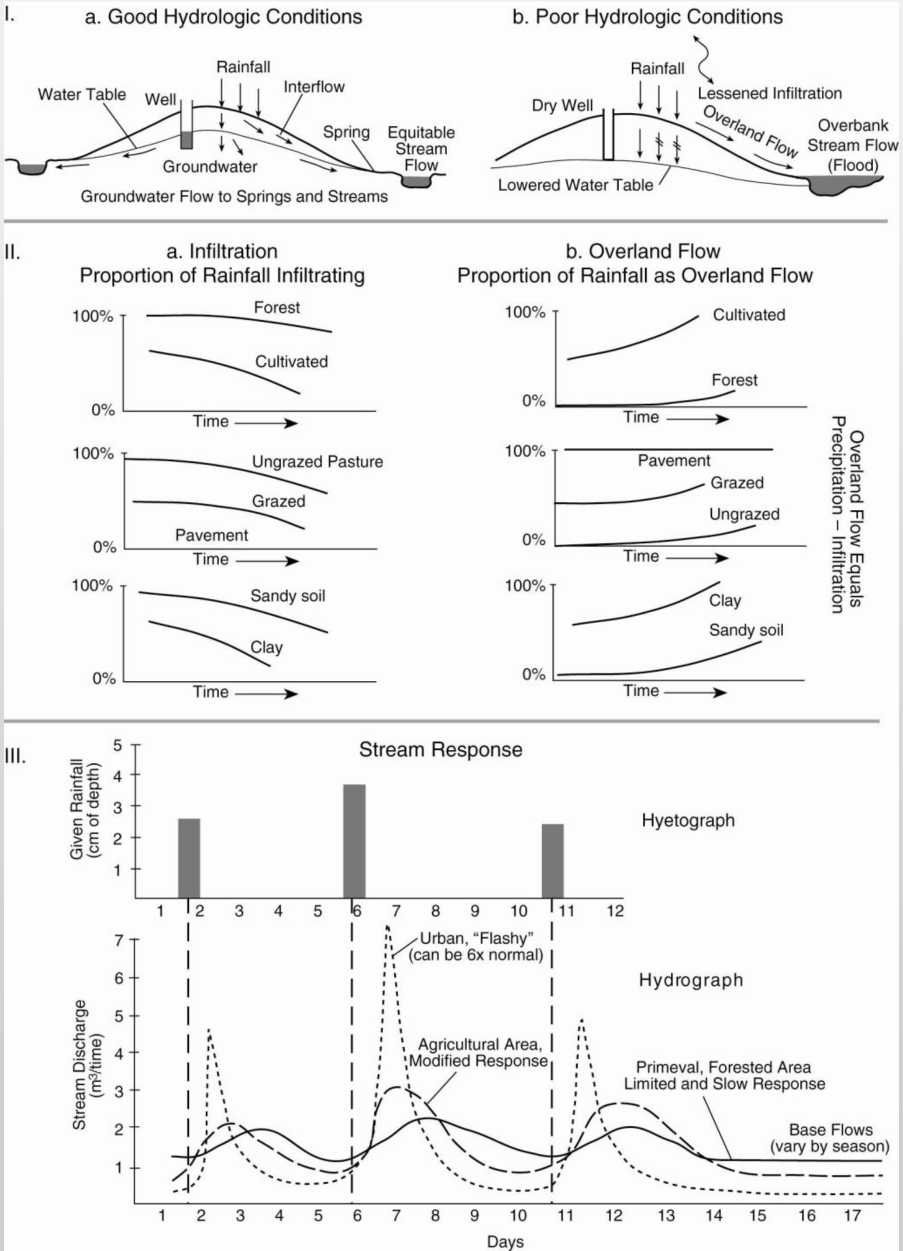
Controls on infiltration capacity (mainly effective hydraulic conductivity K_{sat})

- Population of pore sizes (micro to macro) and therefore texture, structure, biotic activity, organic content, etc. blocking of pores by frost
- Vegetation cover/litter/soil macrofauna/macropores. Root zone collapse (burning; trampling; traffic)
- Surface crusting (especially in silty soils).
- Soil cover (asphalt..)
- Antecedent moisture of the soil (previous rainfall pattern) affects rate of convergence of f on K_{sat}.

Hortonian overland flow

Sparsely vegetated, low-infiltration landscapes

Land use, hydrologic conditions and stream response

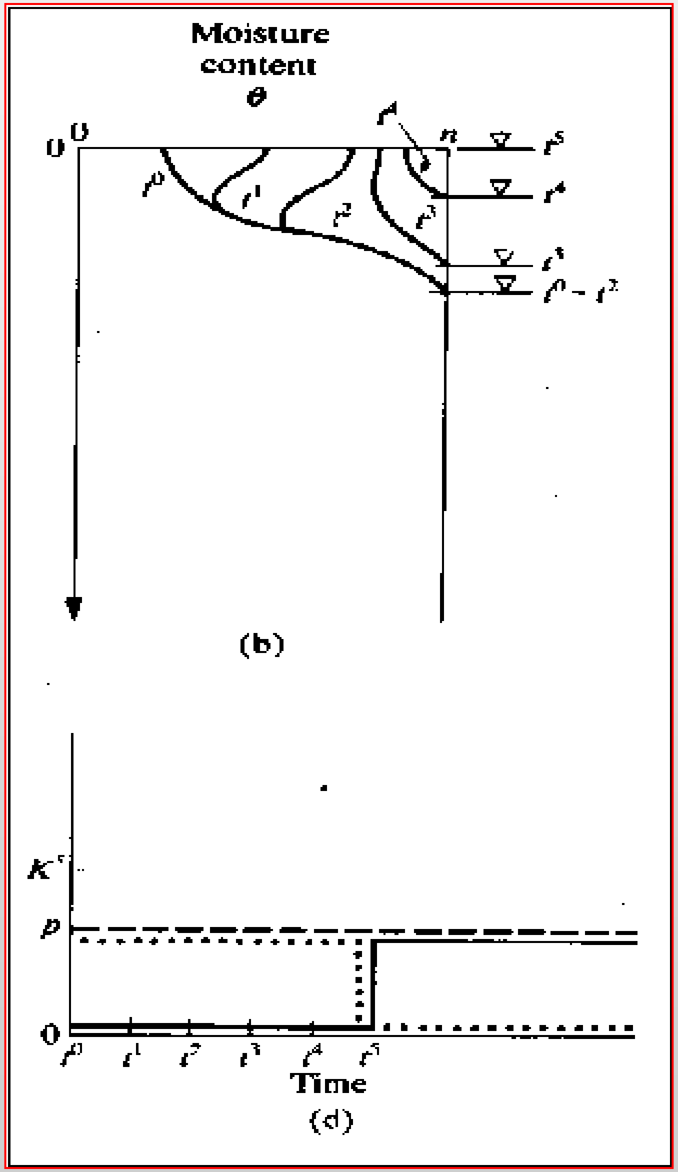


Runoff generation – Dunnian mechanism (1)

Saturation overland flow (Dunnian mechanism)

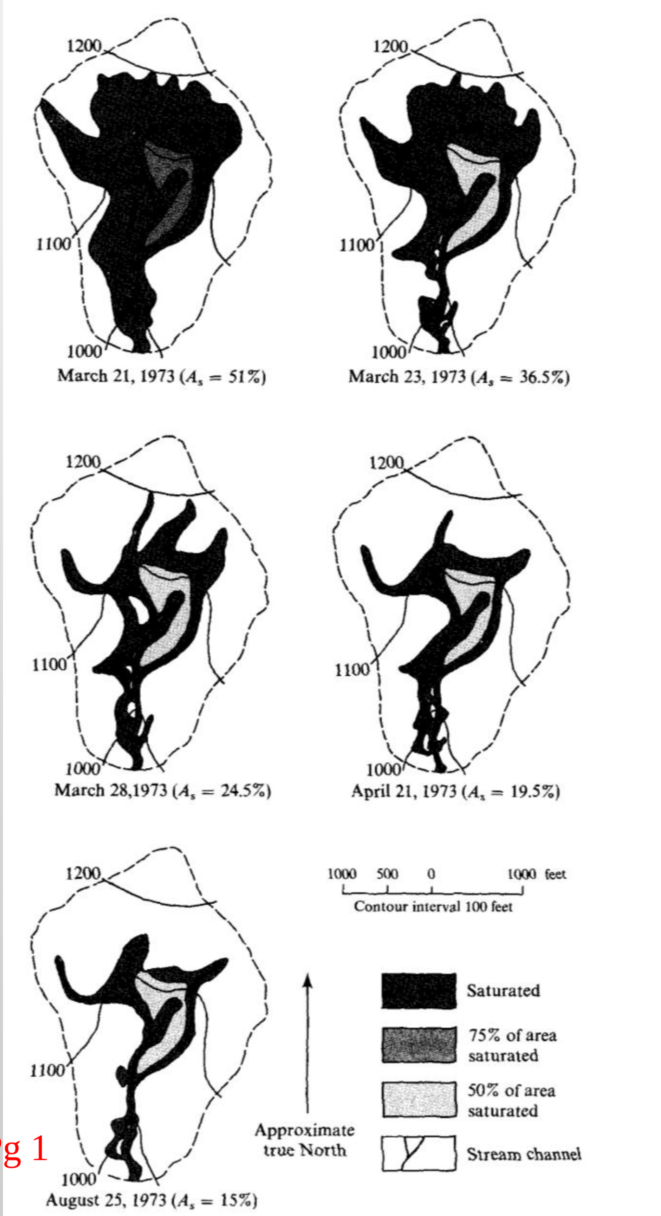
Saturation overland flow is overland flow that occurs due to saturation from below. It consists of direct water input to the saturated area plus the return flow contributed by the 'breakout' of ground water from upslope.

The extension of the saturated area varies with time according with the rate of the subsurface flow.



Runoff generation – Dunnian mechanism (2)

Seasonal variation of saturation overland flow on low-permeability glacial till, Vermont



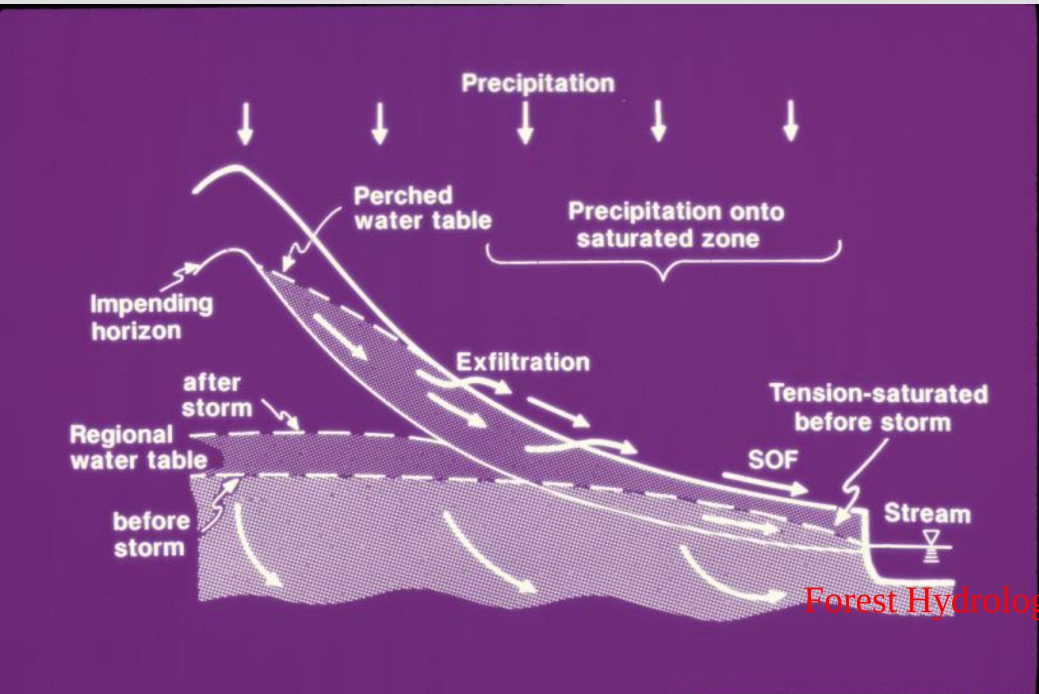
Runoff generation – Dunnian mechanism (3)

Saturation overland flow from spring snowmelt, near Wenatchee, E. Washington

Runoff generation – Dunnian mechanism (4)

Interflow, exfiltration and direct precipitation generate saturation overland flow on parts of landscapes

Saturation overland flow from spring snowmelt, near Wenatchee, E. Washington



Runoff generation – Subsurface flow dominated landscapes

Steep, shallow, forested soil over volcanic rocks, Japanese Alps generates shallow subsurface flow (throughflow/interflow)

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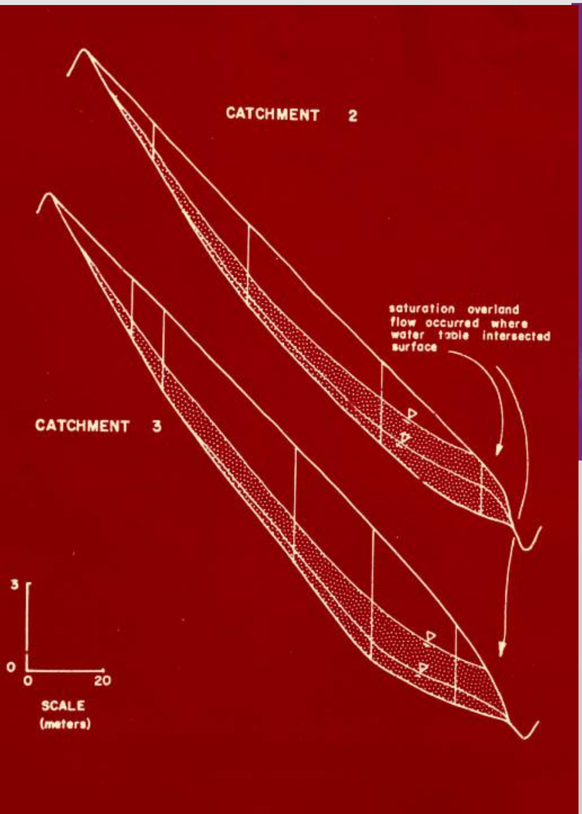
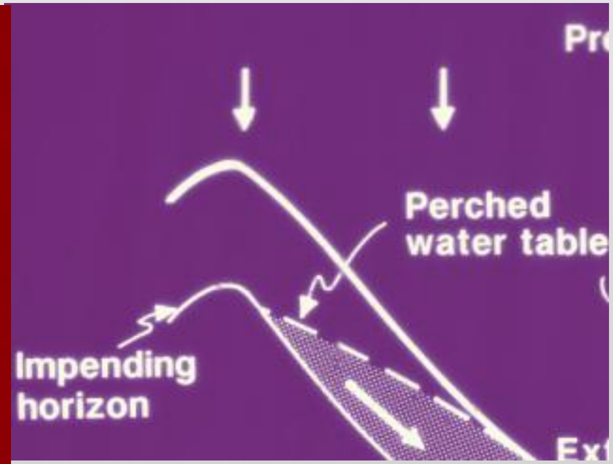
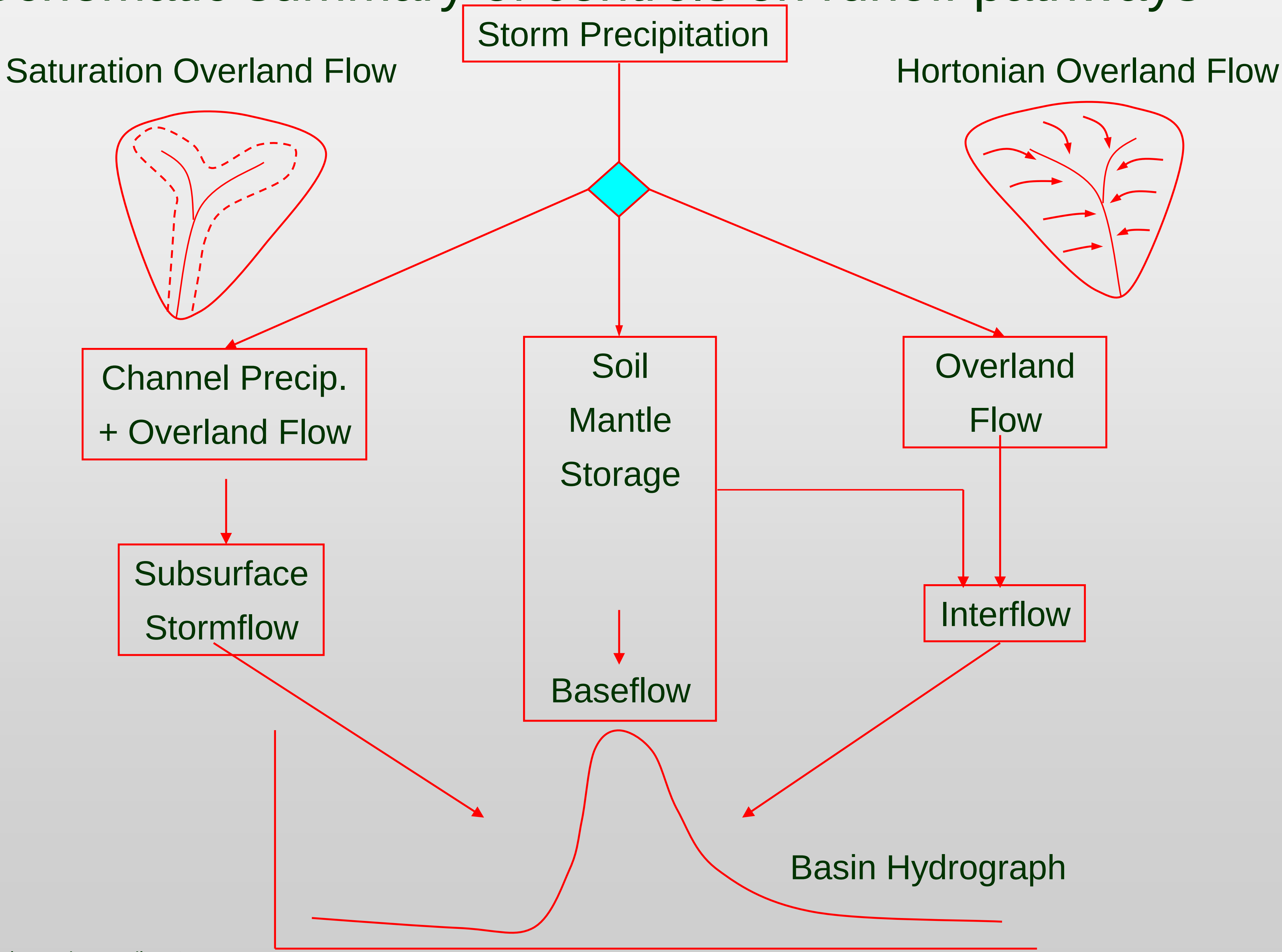
Steep, shallow, forested soil over volcanic rocks, Japanese Alps generates shallow subsurface flow (throughflow/interflow)

Interflow



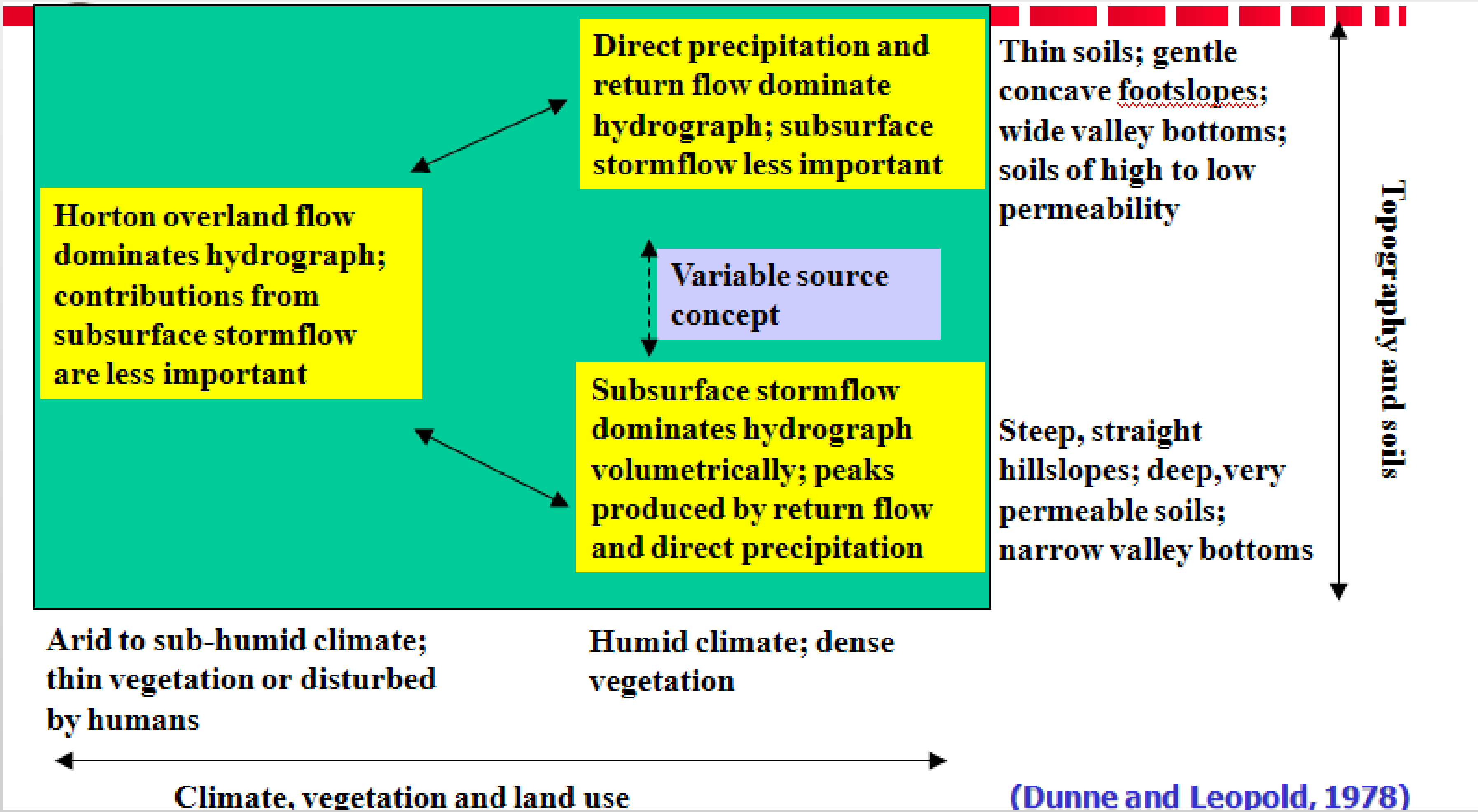


Schematic summary of controls on runoff pathways



Re-drawn from Hewlett and Troendle, 1975

Dominant processes of hillslope response to rainfall



Runoff generation and impact on lag time and flood peak