CE 2141 ENGINEERING GEOLOGY AND GEOMORPHOLOGY

Lecture 11~12 – Catchment Geomorphology

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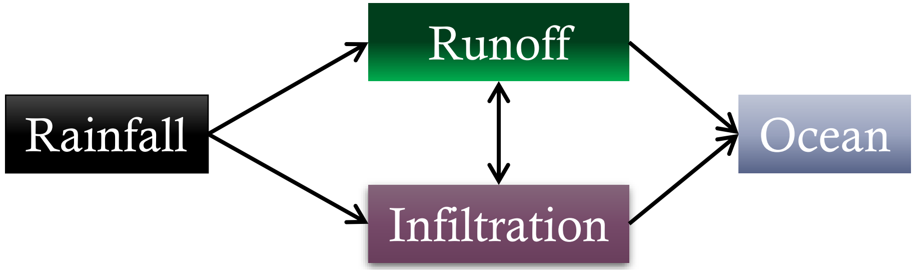
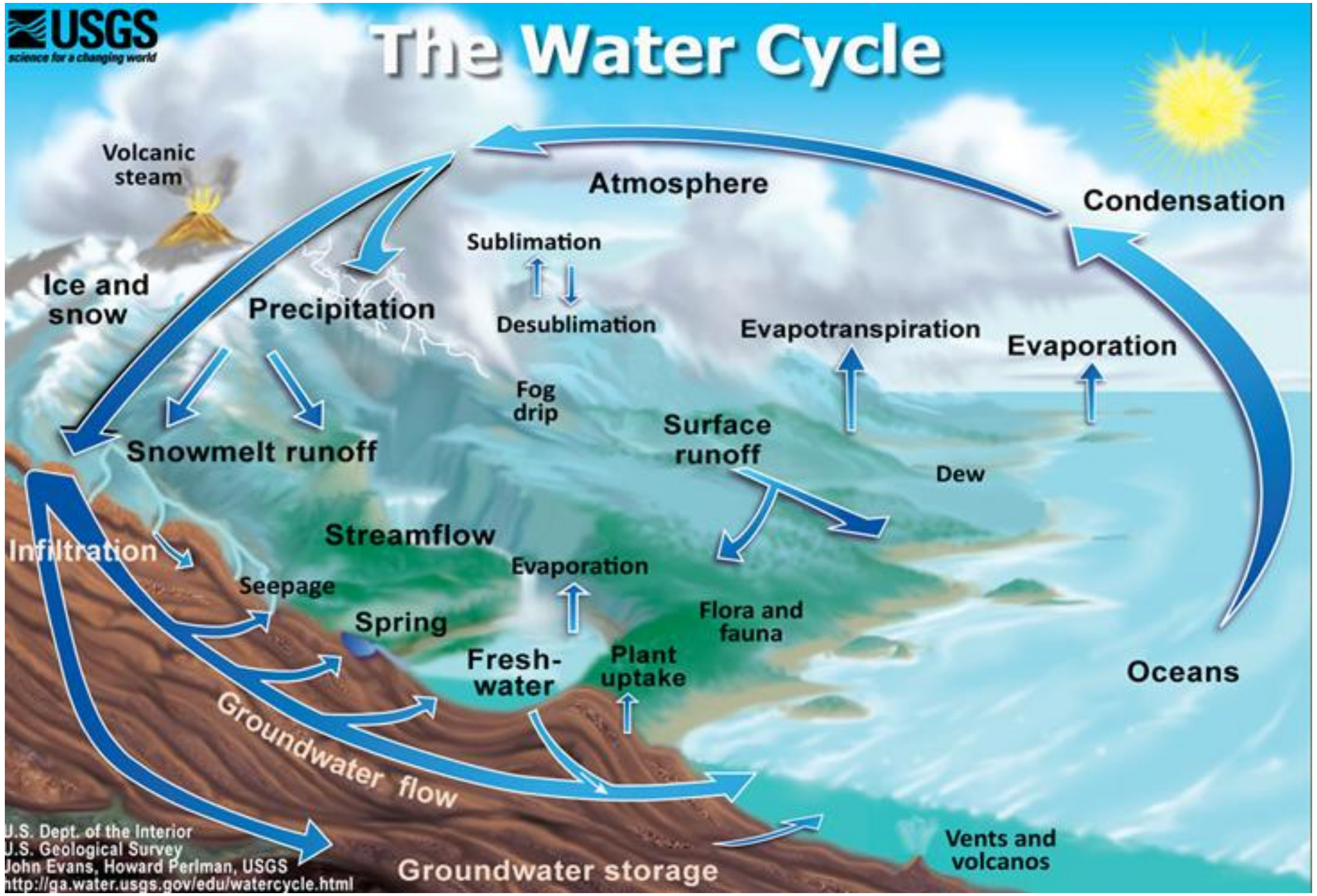
Lecture 10~12: Topics

- Infiltration & Runoff
- Catchment Characteristics
- Stream Order
- Sediment Transportation

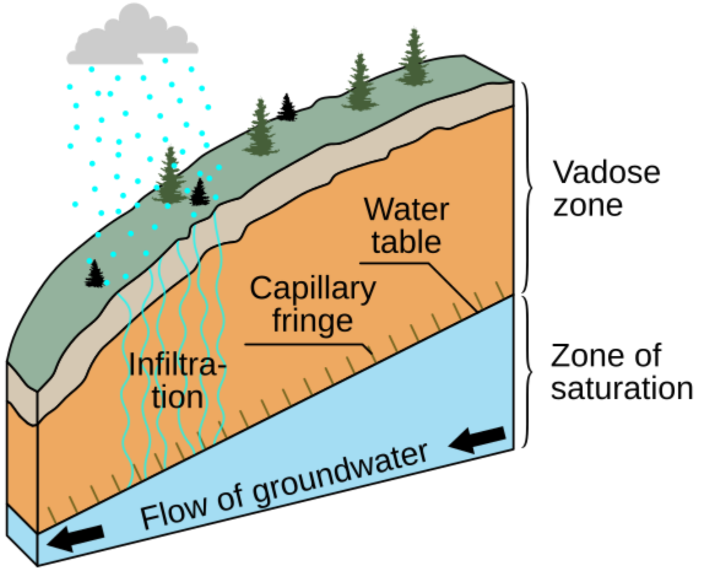
Water: From Clouds to Sea

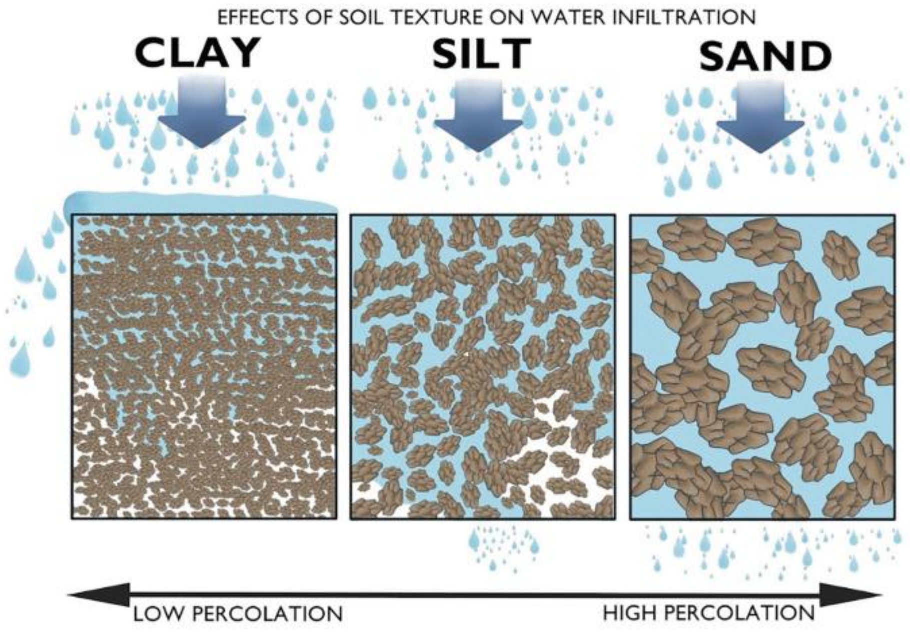
Water is the main driver of Geomorphologic Processes. The action of water starts when the rain drop reaches the ground.





Infiltration

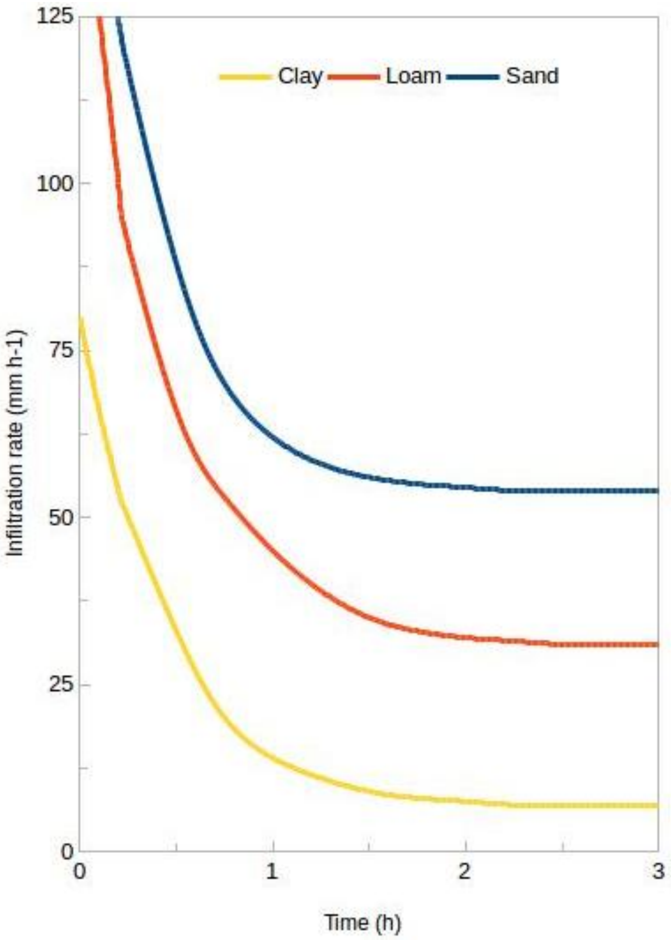


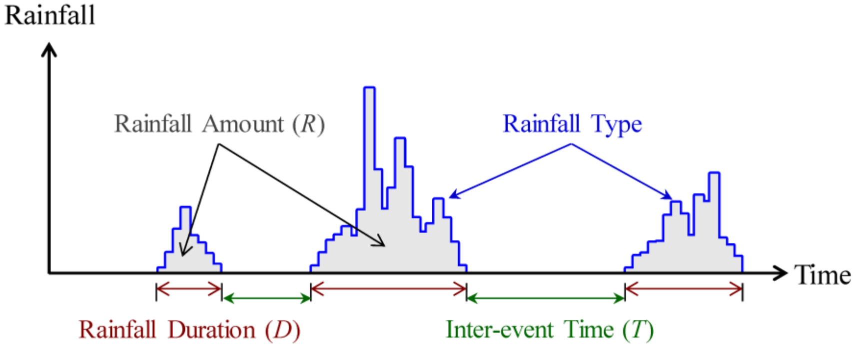


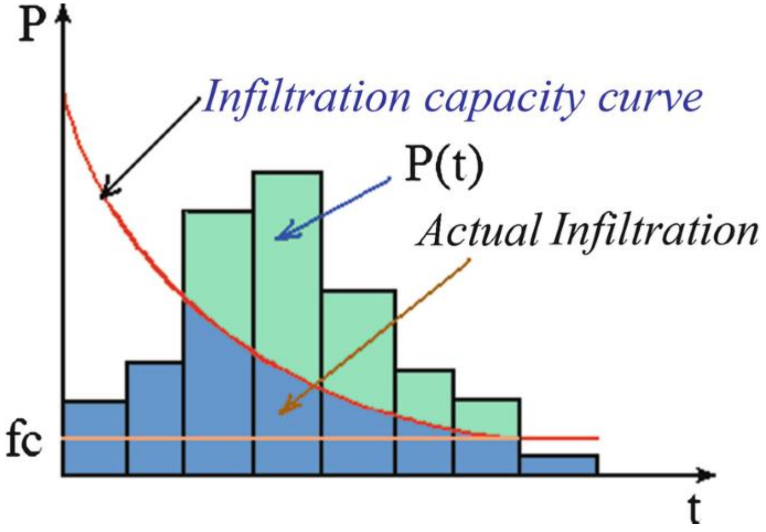
Infiltration is the process of rainwater seeping into the ground after rainfall. Initially, water enters the soil and moves through the unsaturated zone, eventually recharging groundwater. Infiltration is the entry of water into the ground, whereas percolation is the flow of water deeper into the subsurface. The rate of infiltration slows as the soil becomes saturated.

Infiltration Rate

Infiltration Rate is the amount of water enter into soil in a unit time. Initially this rate is the highest and gradually decrease, until it becomes stable. (shows with a flat line in the graph.)

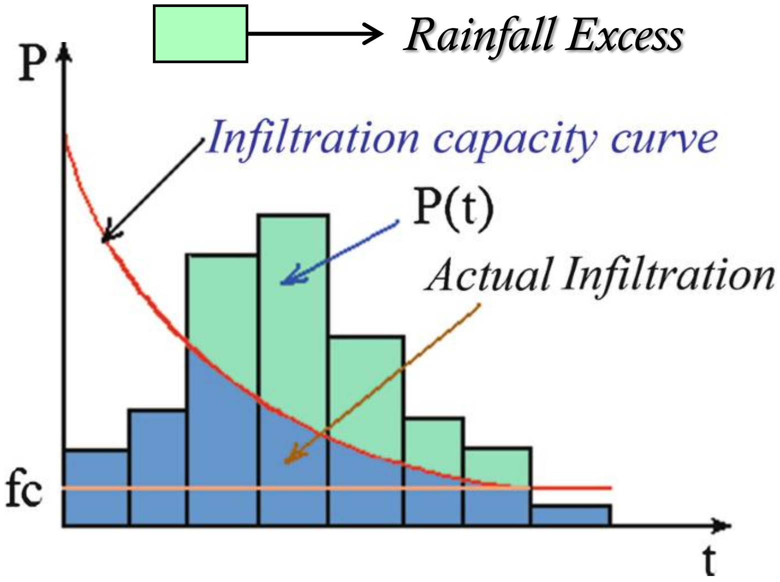


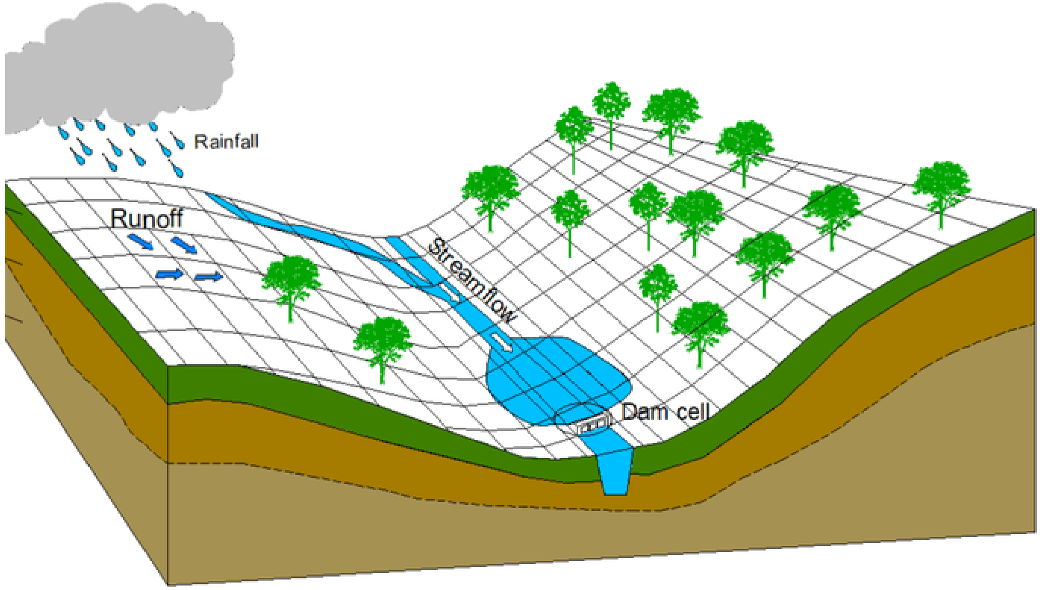




Runoff

The rainfall excess which can not infiltrate the soil travel the downslope as runoff. This excess water flow from high elevation land to low and eventually merge into stream or river.





Stream Network

Water Accumulation

↓

Sheet Flow

↓

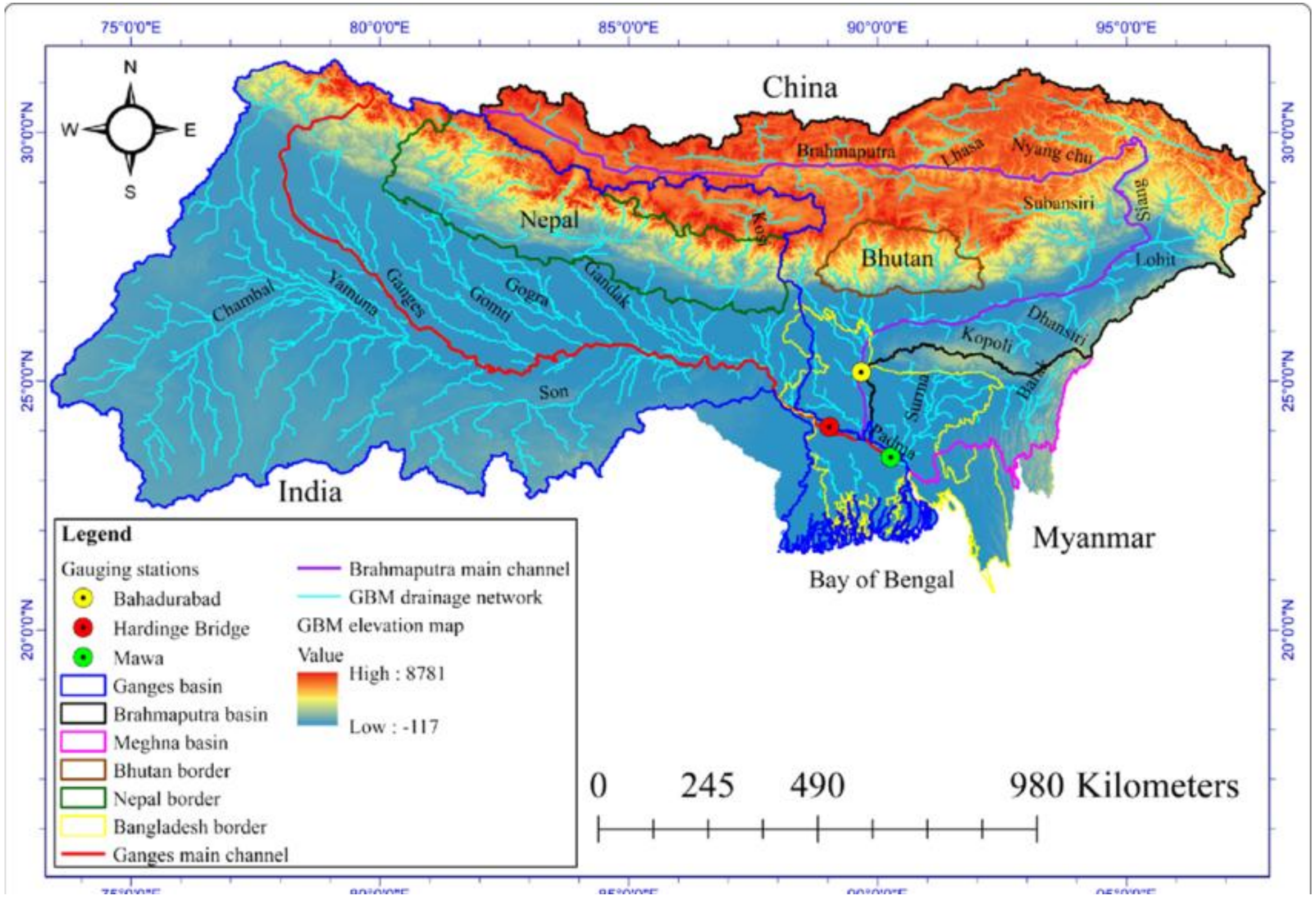
Small Stream/Gully Flow

↓

Large Stream/River

↓

Ocean/Lake

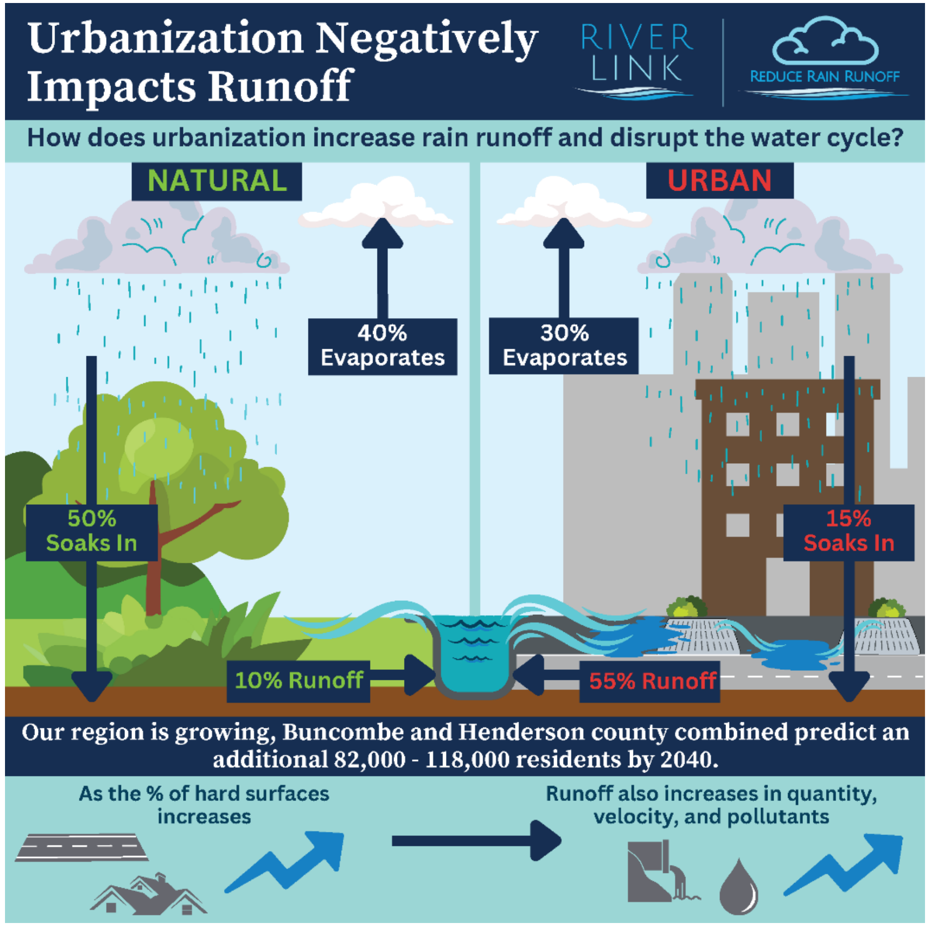


Factors Effecting Runoff

- **Rainfall:** High intensity and long duration rainfall generate more runoff.
- **Land Type:** Sandy soil soaks up water quickly. Clay soil is hard and absorbs water very slowly, creating more runoff. If the land slope is steep, there's less time for it to soak in. So, more runoff.
- **Ground Cover:** Vegetation slow down water and help it soak into the ground, thus reduce runoff. Impermeable surface like road, pavement allow little infiltration, so runoff increase significantly.
- **Human Activities:** Cutting down trees removes nature's sponge, greatly increasing runoff.
- **Initial Condition:** If the ground is already wet from a previous rain, it can't hold any more water, so all new rain becomes runoff.

Effect of Urbanization on Runoff

Urbanization drastically increases surface runoff by replacing natural, absorbent landscapes with impermeable surfaces like concrete and asphalt. This prevents rainfall from infiltrating the ground, forcing it to flow overland instead. Storm drains and channels then collect and rapidly funnel this water into nearby rivers and streams. Consequently, urban areas experience higher peak flows and greater urban flood risk following even moderate rainfall.



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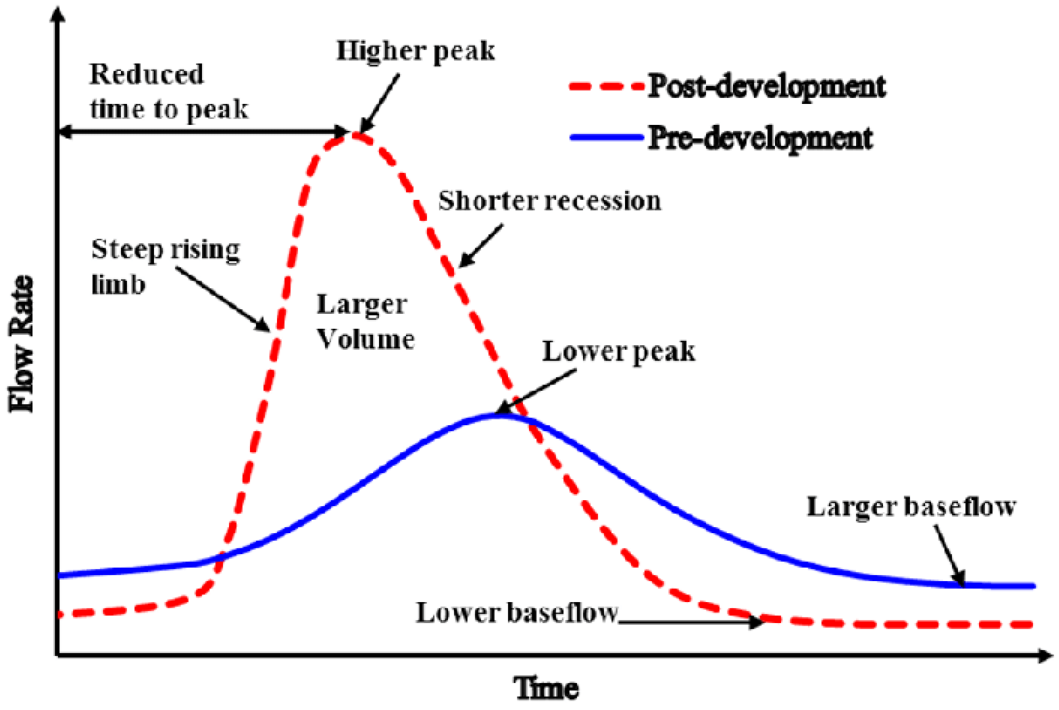

Effect of Urbanization on Runoff

Dhaka: No green area, High runoff
High Urban Flood Risk

Waxi, China: Green area, Low runoff
Low Urban Flood Risk

What is Catchment/Watershed/Basin/Drainage Area

A catchment is an area of land where all the rainwater that falls within it drains into the same river, lake, or ocean.

Calculation of Runoff using Rational Method

The Rational Method is a standard formula used to estimate the peak rate of runoff from a drainage/catchment area. This method is valid when the catchment area is small.

Peak Discharge, Q = $C \times i \times A$

Q = Peak Discharge (cubic m/sec)

C = Runoff coefficient

i = Average Rainfall intensity (mm/hour)

A = Drainage area (ha)

Ground Cover	Runoff Coefficient, c
Lawns	0.05 - 0.35
Forest	0.05 - 0.25
Cultivated land	0.08-0.41
Meadow	0.1 - 0.5
Parks, cemeteries	0.1 - 0.25
Unimproved areas	0.1 - 0.3
Pasture	0.12 - 0.62
Residential areas	0.3 - 0.75
Business areas	0.5 - 0.95
Industrial areas	0.5 - 0.9
Asphalt streets	0.7 - 0.95
Brick streets	0.7 - 0.85
Roofs	0.75 - 0.95
Concrete streets	0.7 - 0.95
Lawns	0.05 - 0.35

Source: Lindsley, 1992

Calculation of Runoff using Rational Method

Peak Discharge, $Q = C \times i \times A$

Problem 01: Calculate the **Peak Discharge** using rational method for a housing area of **20 ha**.

Where

20% area is *Asphalt Streel*

50% area is *Residential Area*

30% area is *Park*

Average rainfall intensity is **5 mm/hour**.

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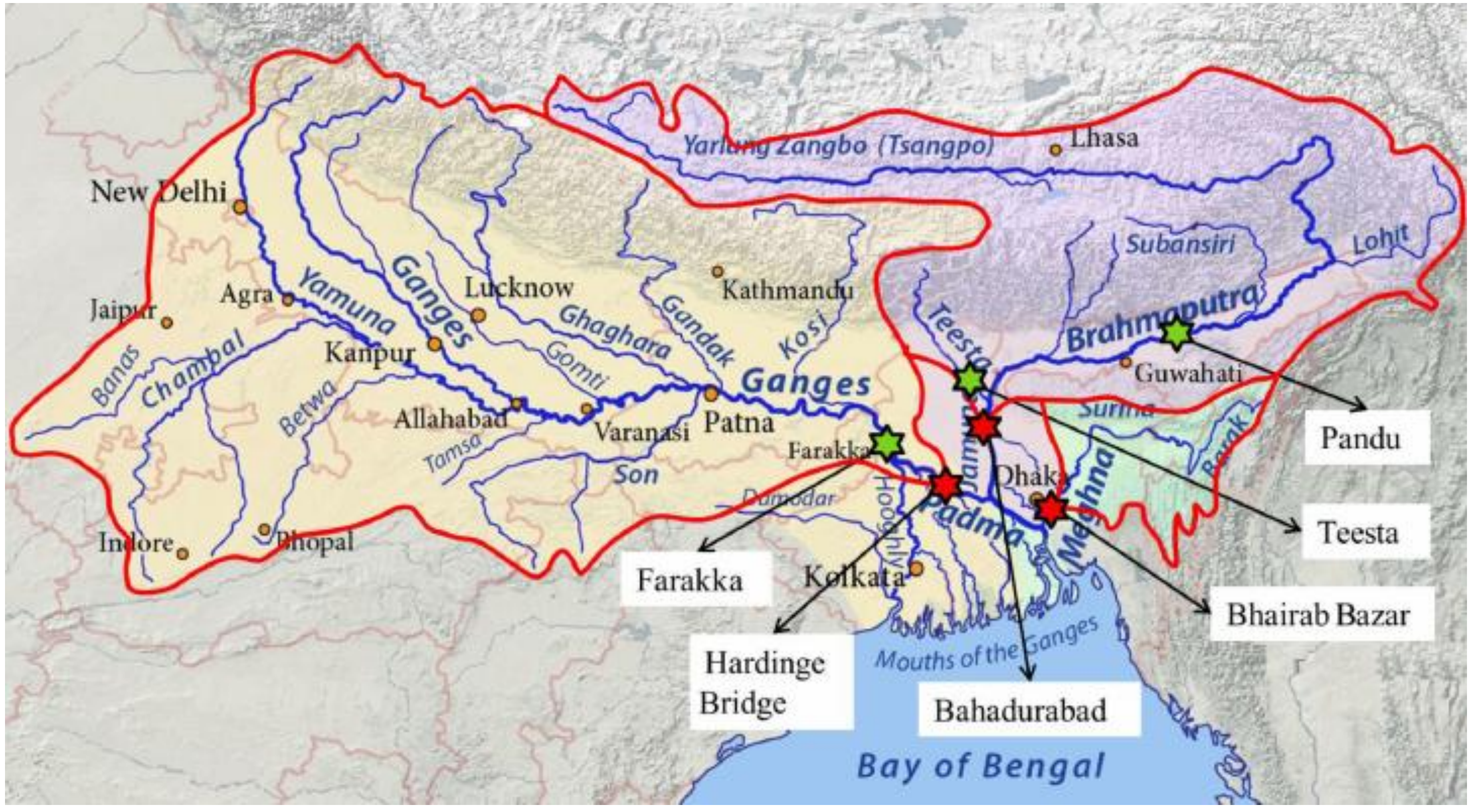
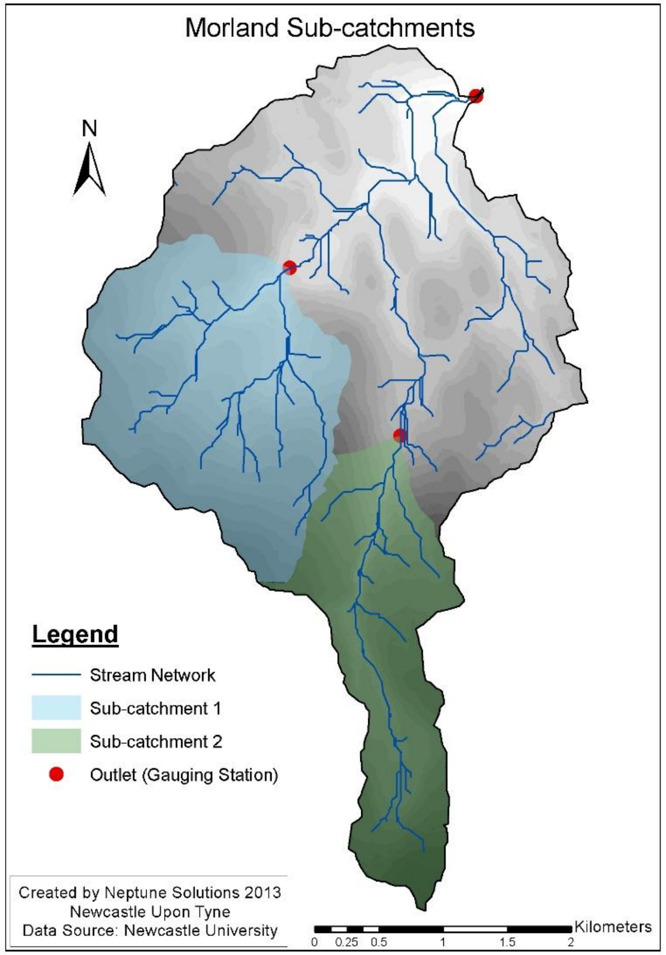
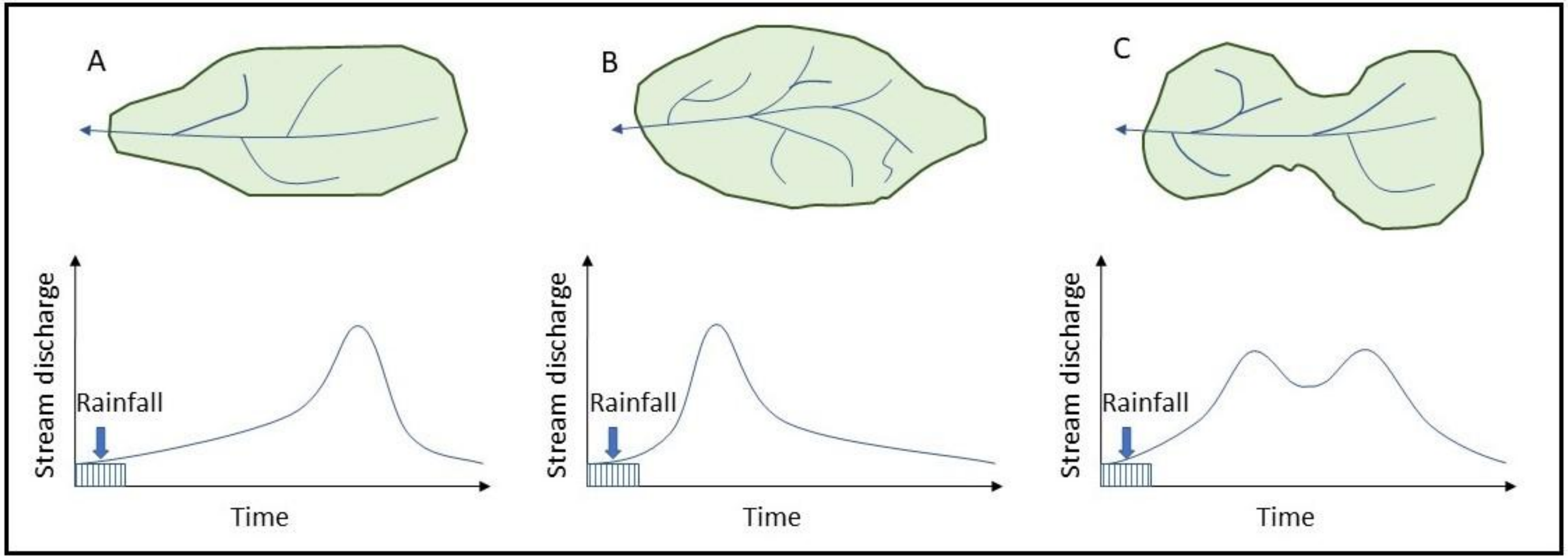
Catchment and Sub-catchments





Effect of Catchment Shape on Runoff

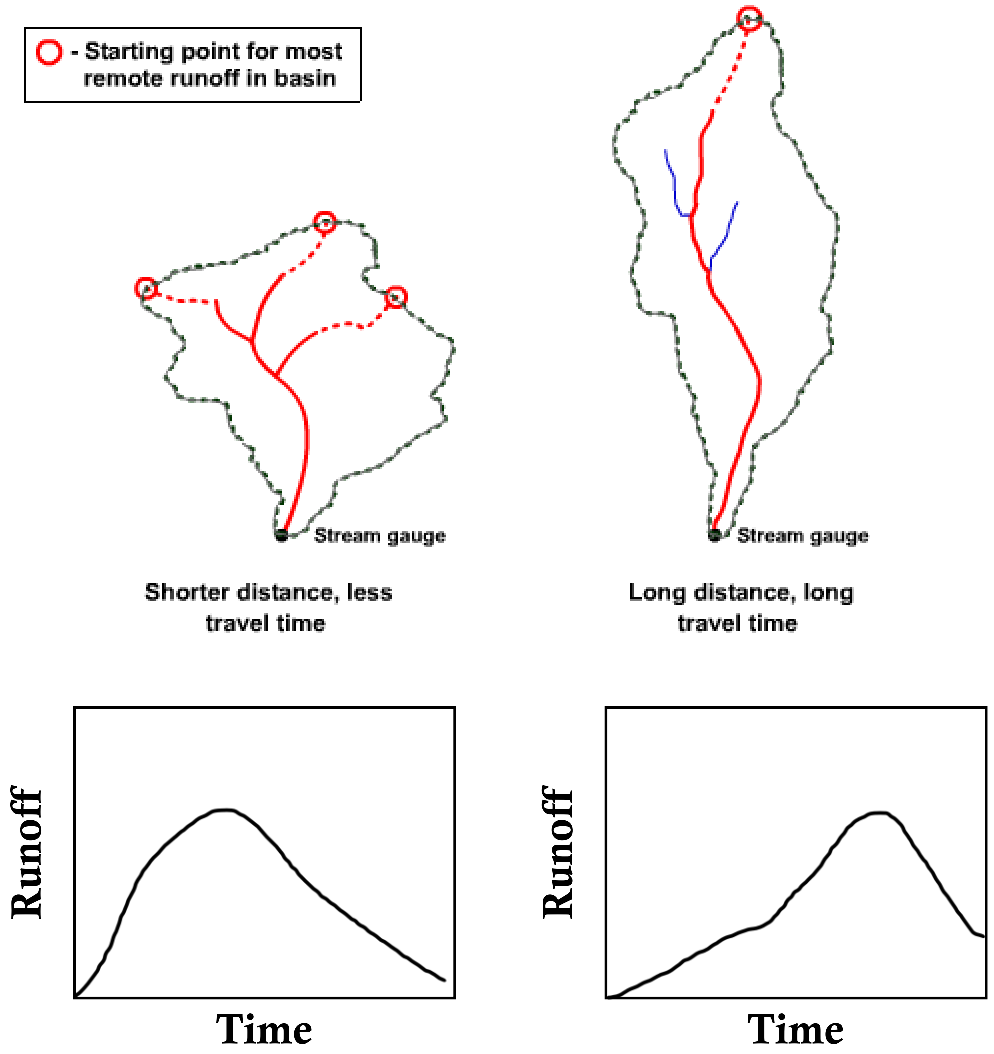


Form Factor

This value indicates the ratio of width and length of any catchment.

$$\boldsymbol{Form\ Factor = \frac{W}{L} = \frac{W*L}{L^2} = \frac{A}{L^2}}$$

The higher catchment ratio means the catchment shape is circular, where lower catchment ratio indicates elongated area.



Drainage Density

This value represents the average length of channel per unit area of catchment

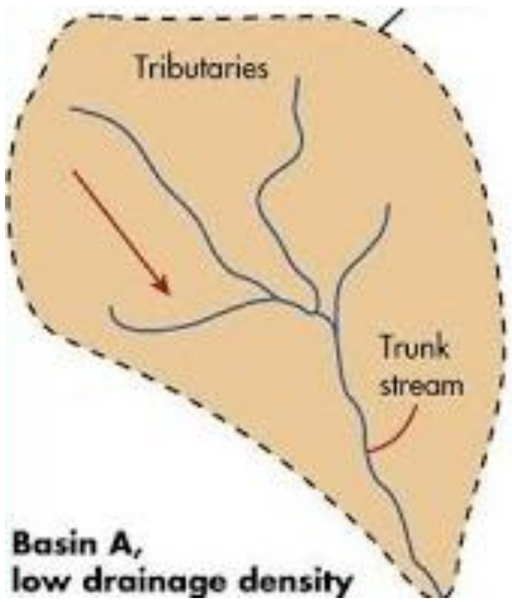
$$\boldsymbol{Drainage\ Density} = \frac{\boldsymbol{Total\ Legnth\ of\ Drain/streams\ in\ the\ Catchment}}{\boldsymbol{Area\ of\ Catchment}}$$

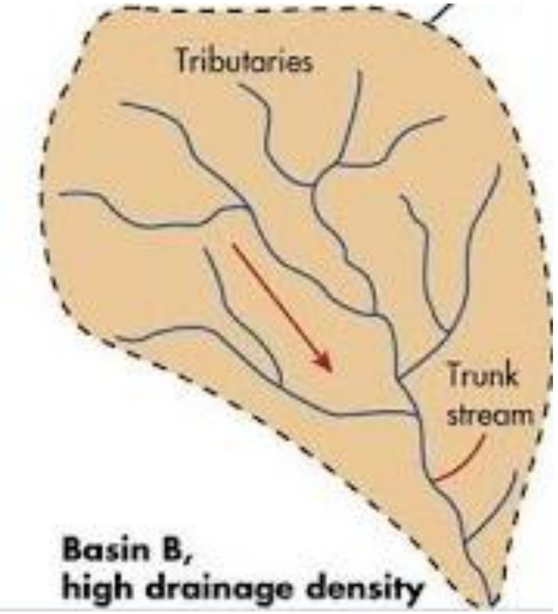
Drainage density is higher in hilly area and lower value means poorly drained flat catchments.

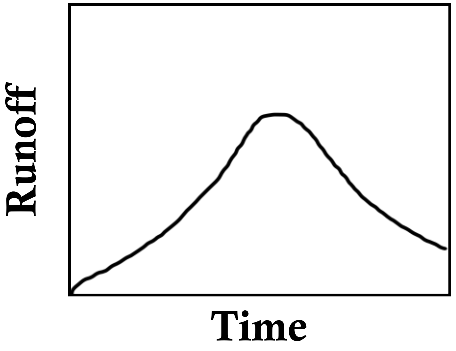
Problem 02: Calculate **Drainage Density** for following catchments. Which catchment is more prone to flooding?

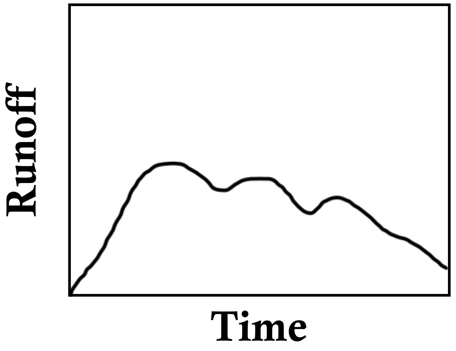
	Catchment A	**Catchment B**
Total Stream Length (m)	500	750
Total Area (sq m)	100,000	250,000

Drainage Density



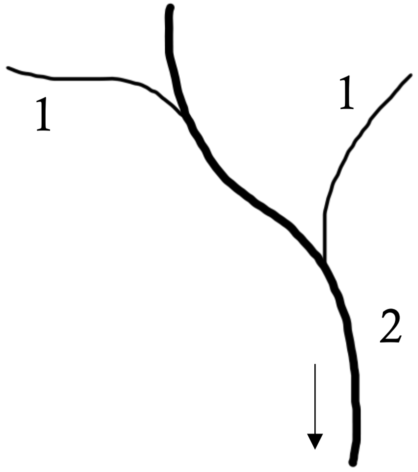


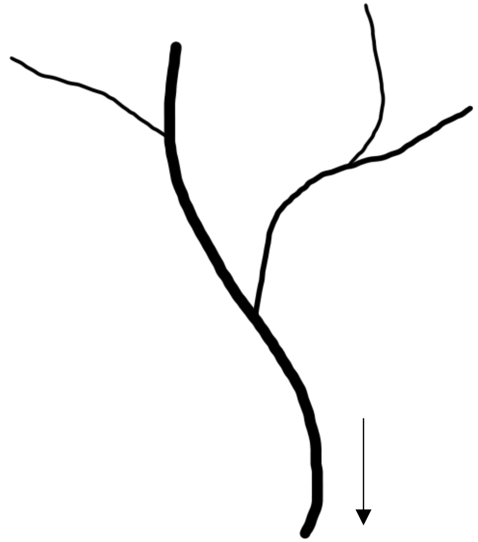




Stream Order

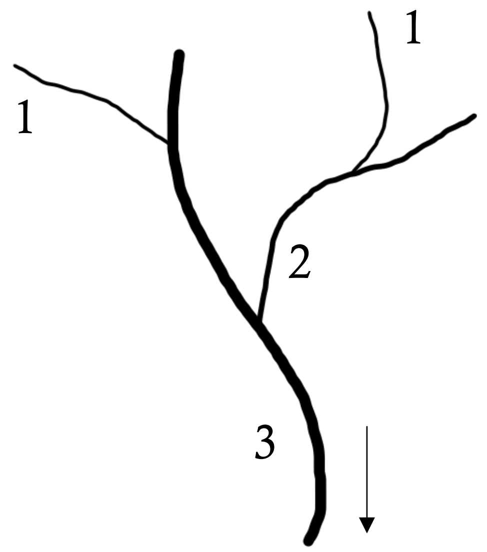
Stream order is a way of classifying streams and rivers in a drainage network based on their position in the hierarchy of tributaries. One of the most common method of stream ordering is **Horton's Method**.





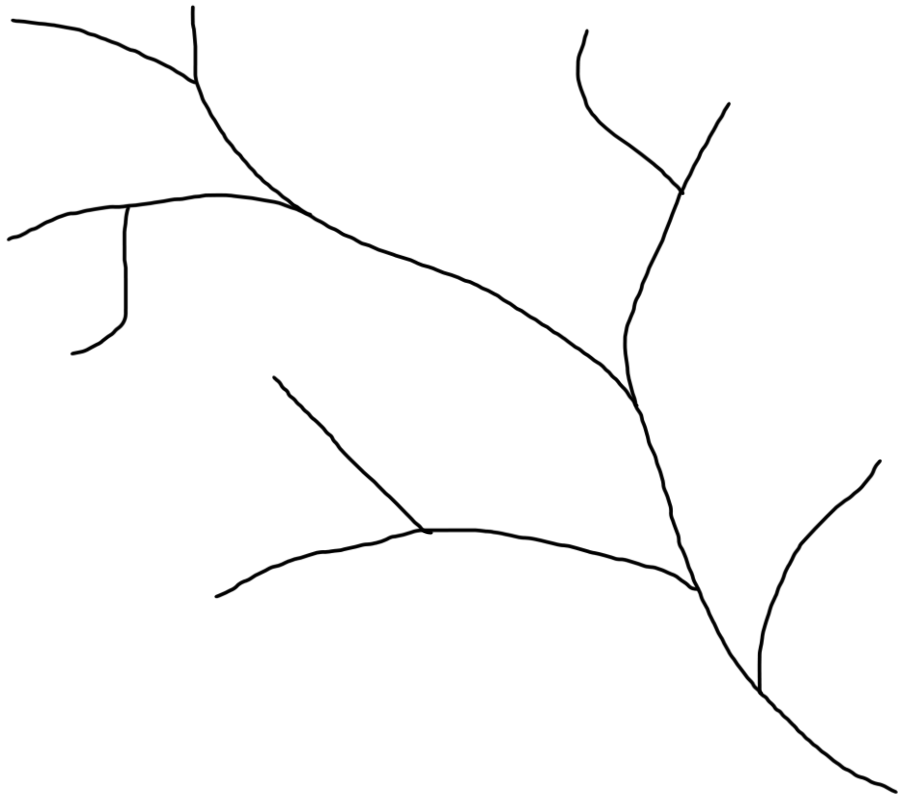
Stream Order: Horton's Method

- Identify all the smallest fingertip streams (those with no tributaries). Assign them Order 1.
- When two streams of the same order meet, the downstream segment increases by one order. Example: 1 + 1 → Order 2.
- When two streams of different orders meet, the downstream segment keeps the higher of the two orders. Example: 2 + 1 → Order 2 (no change).
- Repeat the process until you reach the main river outlet.



Stream Order: Horton's Method

Problem 03: Determine the stream order of the drainage network shown in the figure using Horton's method.



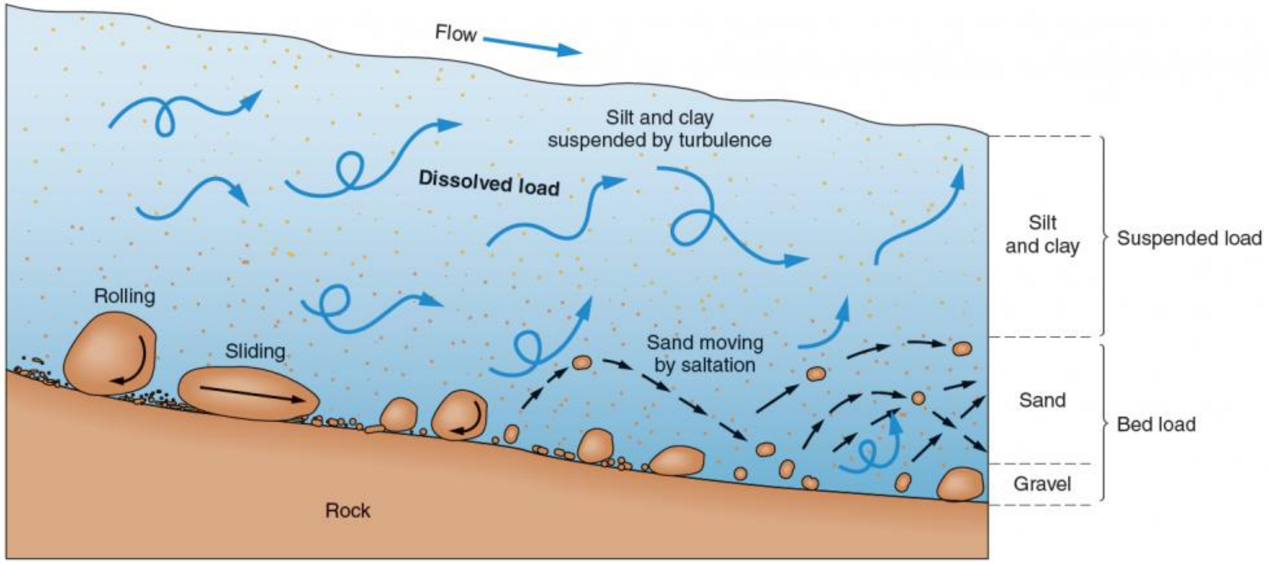
Sediment Transportation

Sediment transport is the movement of particles like soil, sand, and silt by gravity and fluids such as water, wind, and ice.

Main Mechanisms of Sediment

Transportations are –

- **Bed Load**: Gravel and Sand
- **Suspended Load**: Silt and Clay
- **Dissolved Load**: Ions and Chemicals



Factors Effecting Sediment Transportation

- **Size of particles**: Larger, denser, and more irregular particles require more energy to move.
- **Sediment Load**: A higher sediment load, requires more fluid energy to maintain its transport and can lead to deposition. Lower load cause erosion.
- **Velocity and Depth**: Higher flow velocity and greater depth increase the energy available to move sediment.
- **Bed Slope**: A steeper slope provides more gravitational force for sediment to move downhill.