Hydrological Cycle – Hydrological Process – Scale of the Hydrological Processes – Water Balance

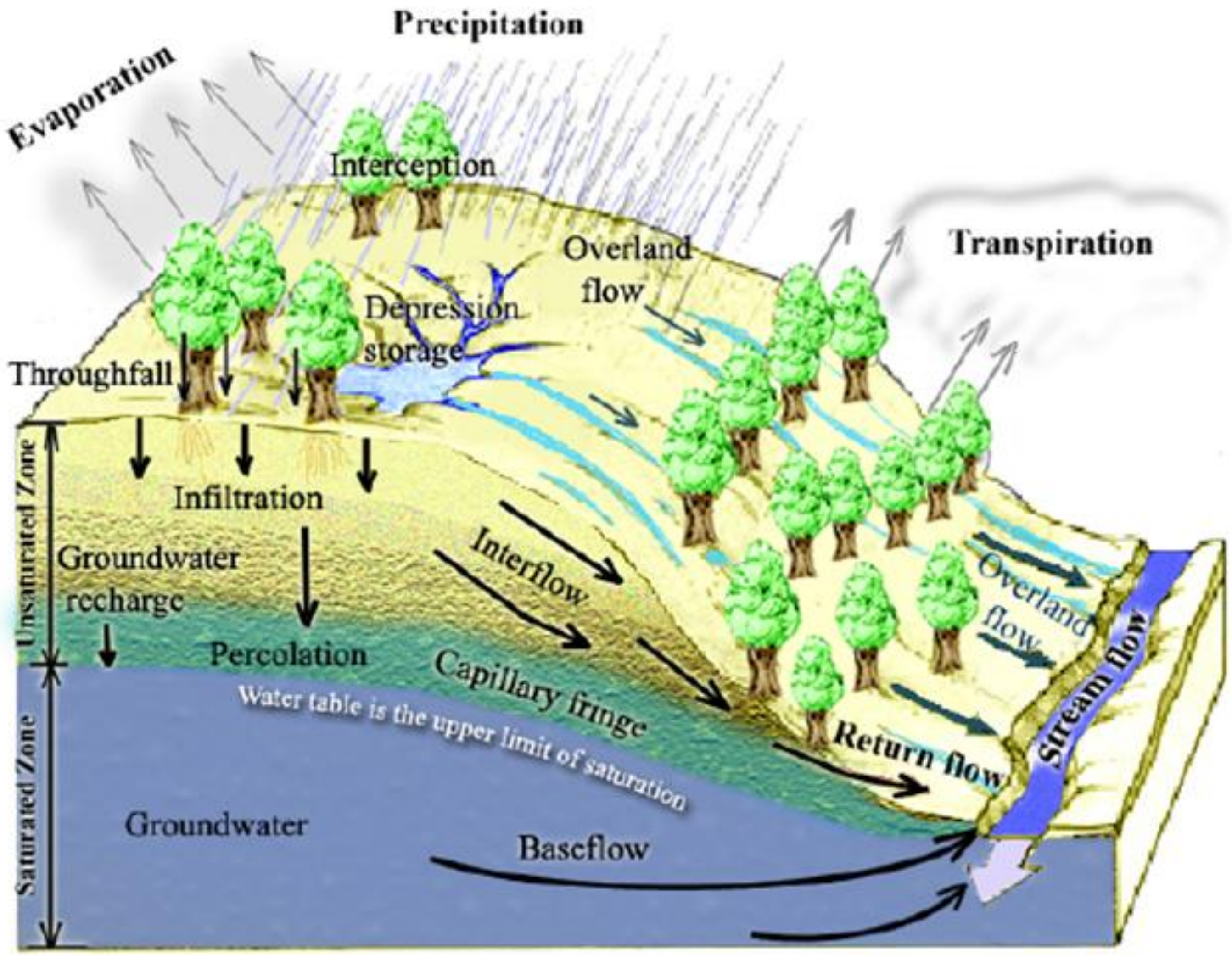
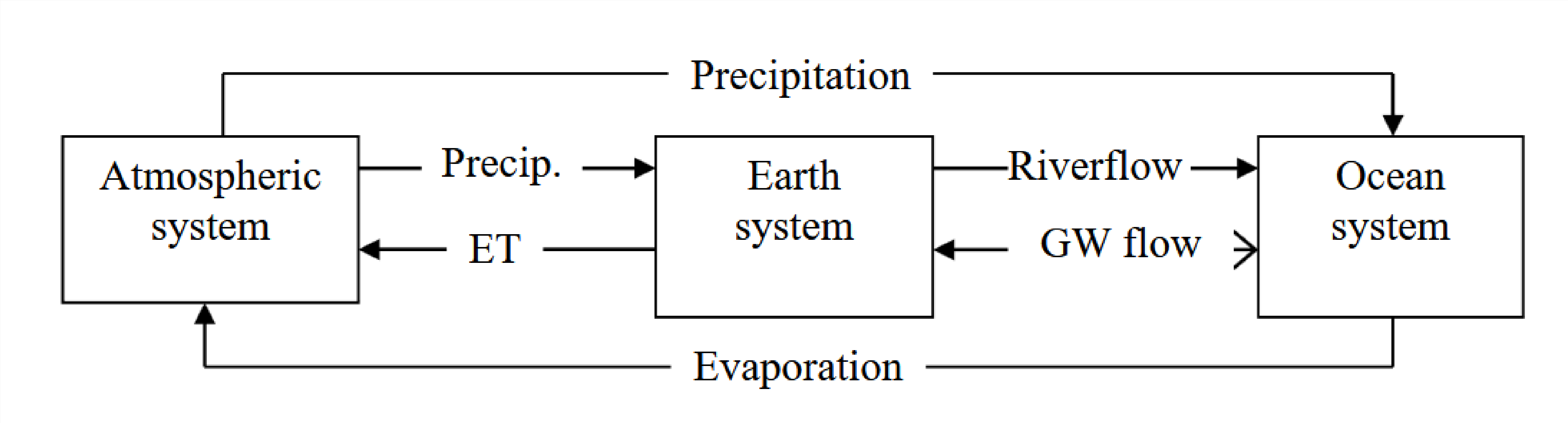


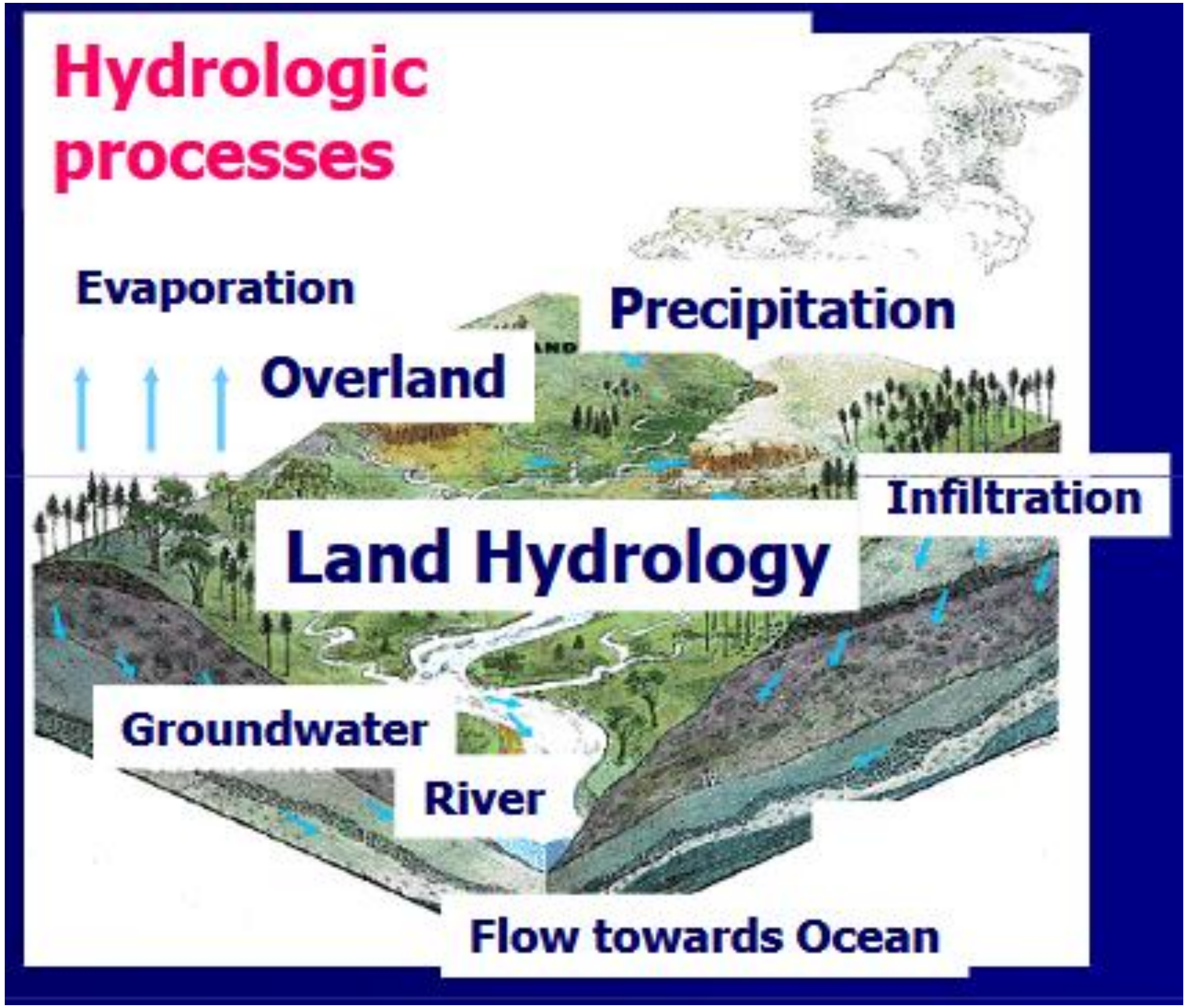
Figure 1. Physical Processes involved in Runoff Generation.

Hydrologic Cycle

- The Global hydrologic cycle is one of the most important natural cycles that operates on Earth.
- It describes the circulation of water through the atmosphere, the land, and the oceans.
- This cycle consists of set of storages (snow, soil moisture, and groundwater) and fluxes (precipitation, evapotranspiration, and runoff) that link the storages together.
- Precipitation is the main driver of the water cycle and, on average, 70% of annual precipitation is lost due to evapotranspiration.

Scales for study of Hydrological Cycles – Global Scale





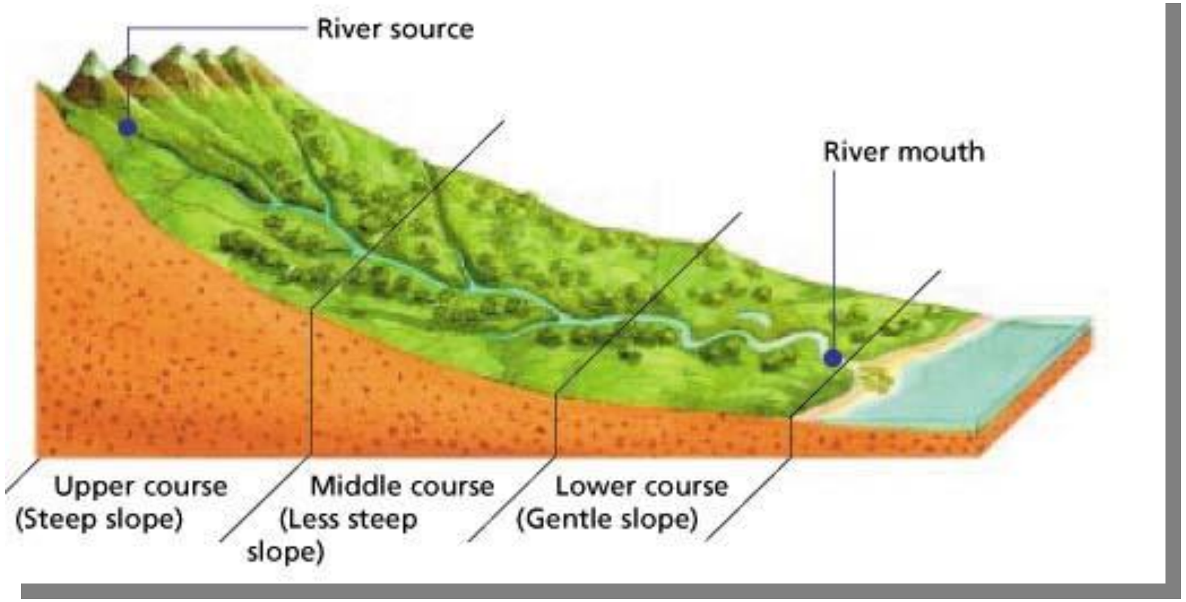
Hydrological processes - Balance between water of the earth & moisture in atmosphere

Scales for study of Hydrological Cycles – Catchment Scale

While studying the hydrologic cycle on a catchment scale, the spatial coverage can range from a few square km to thousands of km

River System

- The upper course generally steep and starting point of the river system
- The middle part of the river is called the middle course
- Near the end of the river is the lower course
- The place where the river flows into the sea or ocean is called the river mouth – Basin outlet



River System – a river and all of its tributaries

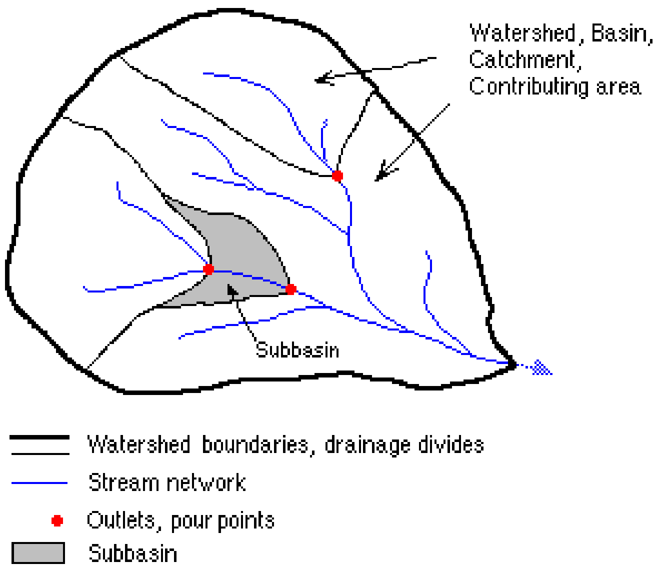
River system

❖Streams or other rivers may join the course of a river - They are called tributaries

❖The point at which a tributary joins the main river is called the confluence

❖The river and its tributaries form the river system

❖The boundary of a drainage basin is marked by surrounding highlands and is called the watershed

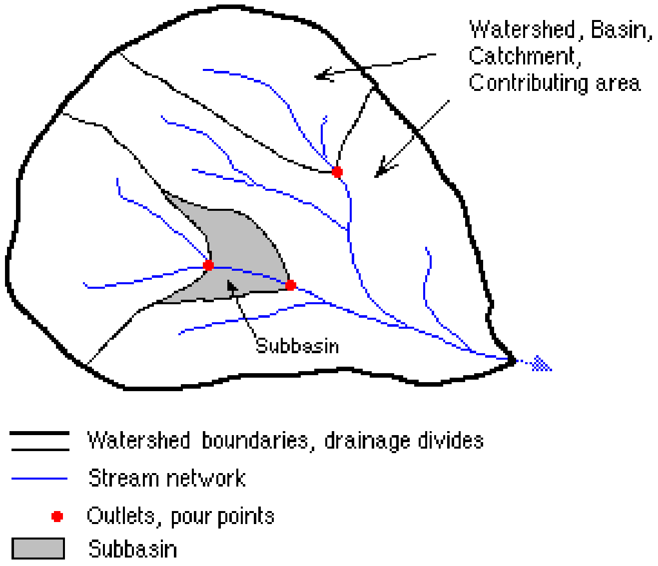


River System – a river and all of its tributaries

TRIBUTARIES OF GANGA

River Basin

- A river basin can be defined as the geographical area demarcated by the topographic limits of the system of waters.
- Watershed is a natural unit of land on which water from direct precipitation and snowmelt collects in a channel and flows downhill to a common outlet (Elshorbagy, 2005).
- River basins are important elements in water resource development and planning.
- Drainage basin, drainage area or watershed – basic hydrologic unit
- Volume of runoff and shape of runoff depend on the area, shape, drainage channel pattern



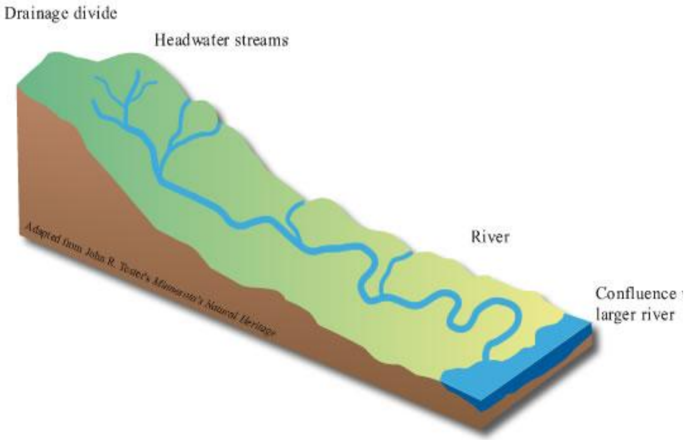
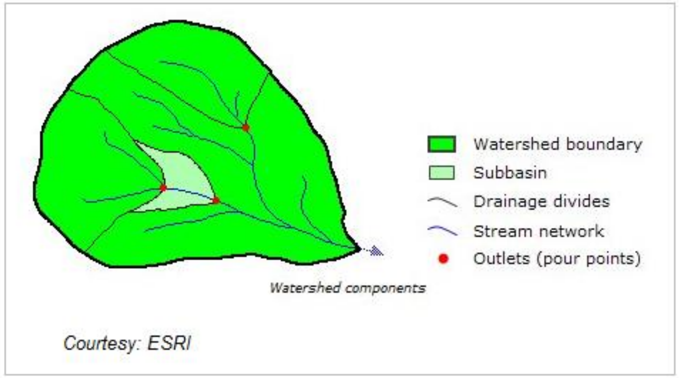
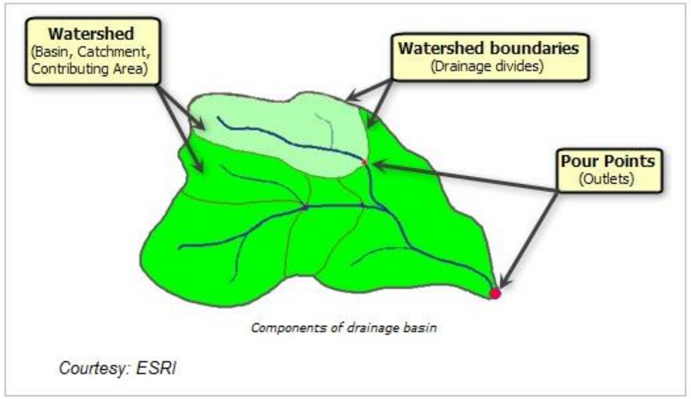


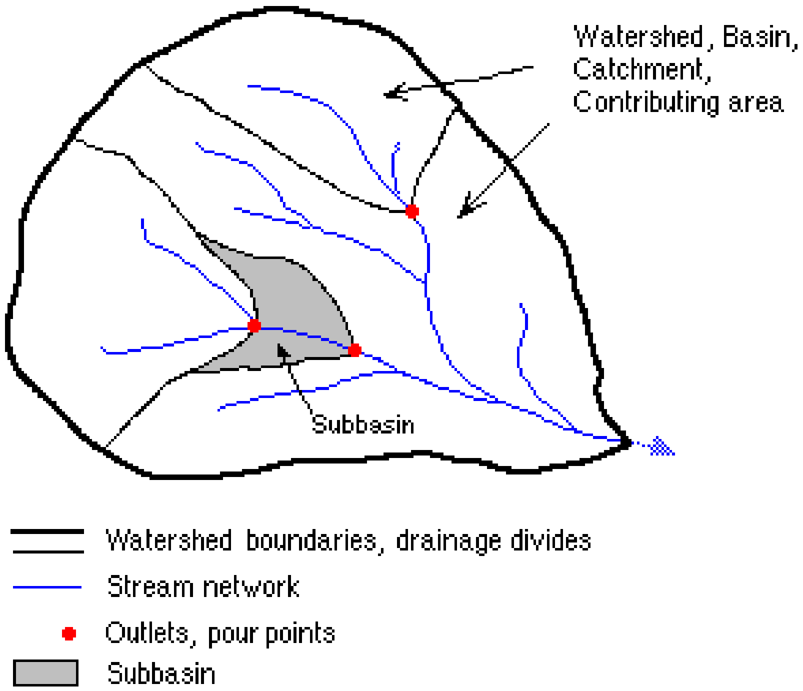
Diagram Showing Two Watersheds (Catchments)

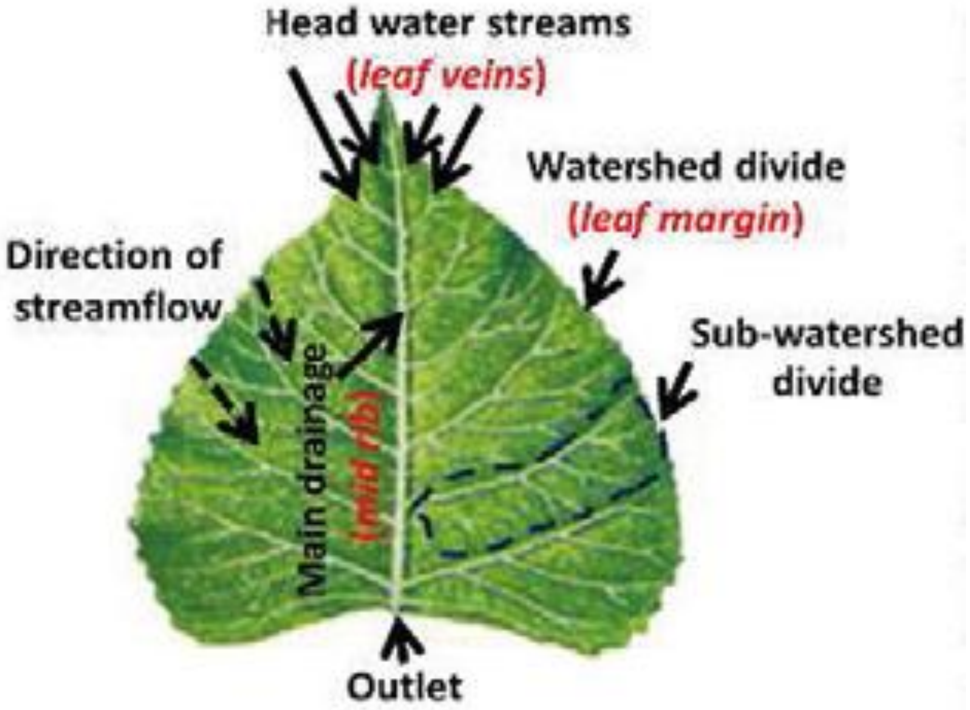
Understanding the Watershed Landscape - Watershed Delineation

- Drainage basin, catchment, and watersheds are synonymous terms
- Topographic area that collects and discharges surface streamflow through one outlet or mouth.
- Area contributing to a watershed landscape of the terrain
- Water flows in the direction of the terrain steepest downhill slope
- Drainage direction (river network) on the landscape and the resultant runoff or streamflow accumulation process



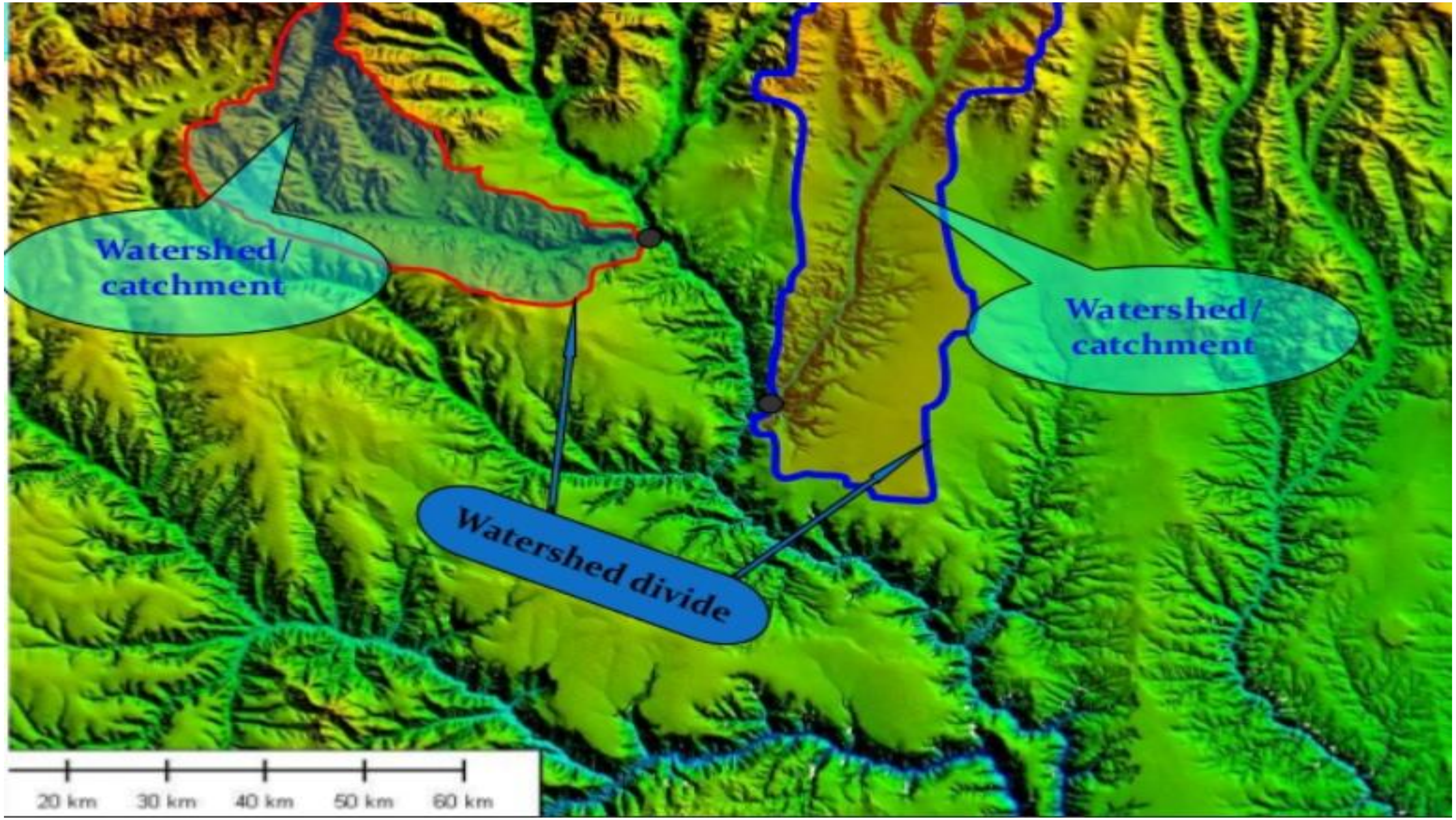



Watershed, Basin,
Catchment,
Contributing area
Subbasin
Watershed boundaries, drainage divides
Stream network
Outlets, pour points
Subbasin


Head water streams
(leaf veins)
Watershed divide
(leaf margin)
Direction of
streamflow
Sub-watershed
divide
Main drainage
(mid rib)
Outlet

Watershed delineation

- Watershed is like a bowl.
- Imagine a water drop falling on the rim of the bowl if the water droplet flows into the bowl, then the water droplet has contributed to the water body (River, Lake or pond).
- If not, the water droplet flows out and does not contribute to the water body.
- This boundary or rim of the bowl is watershed boundary.
- The process we use to estimate this boundary is called watershed delineation.


Watershed/
catchment
Watershed/
catchment
Watershed divide
20 km
30 km
40 km
50 km
60 km

The Water Cycle Balance

- Usually the water cycle is in balance, and the amount of precipitation falling will slowly soak into the ground and eventually reach the rivers
- However, if the rain falls for a long period of time or if the ground is already soaked or saturated with water, then the chance of flooding is increased.
- **The hydrological cycle is a good example of a closed system: the total amount of water is the same, with virtually no water added to or lost from the cycle.**
- Water just moves from one storage type to another.
- Water evaporating from the oceans is balanced by water being returned through precipitation and surface runoff.

“The mass in an isolated system can neither be created nor be destroyed but can be transformed from one form to another”

What is the water balance

- The water balance is defined by the general hydrologic cycle equation, which is basically a statement of the law of conservation of mass as applied to the hydrologic cycle.

- In its simplest form, this equation reads

  Inflow = Outflow + Change in Storage

- Water balance equations can be assessed for any area and for any period of time.

- The process of ‘making an overall water balance for a certain area ‘ thus implies that an evaluation is necessary of all inflow, outflow, and water storage components of the flow domain-as bounded by the land surface, by the impermeable base of the underlying groundwater reservoir, and by the imaginary vertical planes of the area’s boundaries.

What is the water balance/budget?

In order to gain better understanding of water resources in a drainage basin, we use a simple equation called the water balance.

The balance between water inputs and outputs of a drainage basin, may be shown as water budget graph-that is, the drainage basin operates as **Water Budget Equation** of a catchment for a time interval Δt is written as: Input – Output = Change in Storage

$$\mathbf{P - R - G - E - T = \Delta S}$$

Where:

P = Precipitation

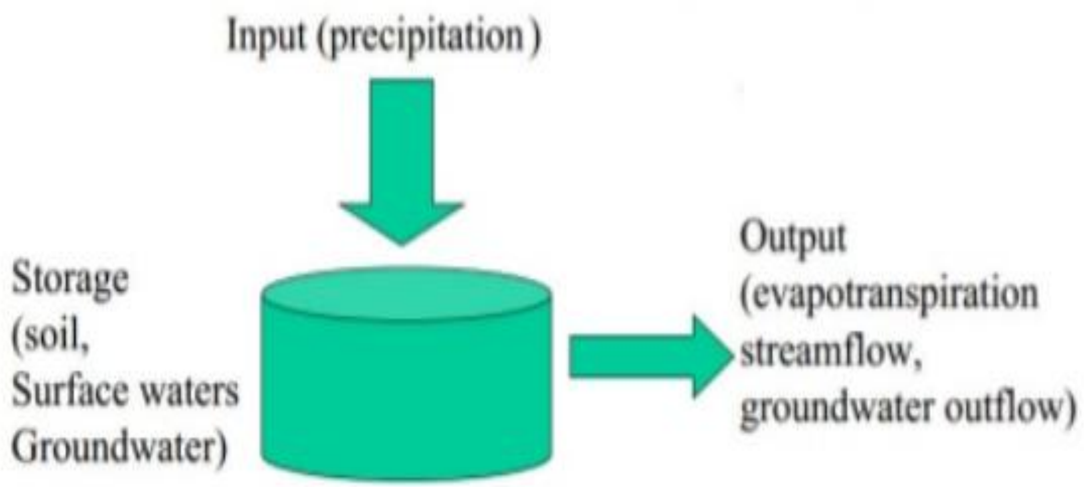
R = Surface runoff

E = Evaporation

T= Transpiration

G = Net groundwater flow out of the catchment

ΔS = Change in Storage .



HYDROLOGY - WATER BALANCE

Water balance equation →

$$R = P - ET - IG - \Delta S$$

where:

P	=	Precipitation
R	=	Runoff
ET	=	Evapotranspiration
IG	=	Deep/inactive groundwater
ΔS	=	Change in soil storage

In a given year, a catchment with an average area of 1750 km2 received 1250 mm of precipitation. The average rate of flow measured in a river draining the catchment was 25 m3/s. Estimate the total flow occurred in the year along with the runoff coefficient.

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Precipitation = 1.25 X 1750 X 10^6 = 2187.5 X 10^6 m3

Runoff coefficient = Actual flow in river / Total precipitation occurred (Runoff/Rainfall)

Total rainfall = 2187.5 X 10^6 / (365 X 24 X 60 X 60) = 69.36 m3/s

Total rate of flow = 25 m3/s

Runoff coefficient = 25 / 69.36 = 0.36 (36%)

Runoff of the catchment / Rainfall of the catchment = 36 %

That is 36% of rainfall is converting into runoff and remaining 64% is losses.

A lake has an area of 15 km2. Observation of Hydrological variables during a certain year :

P = 700 mm/year

Average Inflow, Q_{in} = 1.4 m^3/s

Average Outflow, Q_{out} = 1.6 m^3/s

Assume that there is no net water exchange between the lakes and the groundwater. Determine the evaporation during this year.

Sum of Inflows to the lake – sum of Outflows from the lake = Change in the Volume

$(P + Q_{In}) - (E + Q_{out}) = \Delta S$

Assuming storage changes over one year as Zero , $\Delta S = 0$

$E = P + Q_{in} – Q_{out}$

$Q_{in} = 1.40 \times 10^6 \times 3600 \times 24 \times 365 / 15 \times 10^6 = 2943.4$ mm

$Q_{Out} = 1.60 \times 10^6 \times 3600 \times 24 \times 365 / 15 \times 10^6 = 3363.8$ mm

$E = 700 + 2943.4 - 3363.8 = 279.6$ mm