Hydrology

Hydrology is a Greek word: 'Hydro' means water and 'logy' means study. Thus, Hydrology means the study of the science of water.

Hydrology is the 'water science' that deals with the occurrence, circulation and distribution of water of the earth and earth's atmosphere.

A good understanding of the hydrologic processes is important for the assessment of the water resources, their management and conservation on global and regional scales.

Hydrology can be classified as:

Scientific Hydrology – the study of the role of water in natural processes;

Engineering or Applied Hydrology – application (use and protection) of water resources.

Engineering Hydrology deals with:

1. Study of the processes (rainfall, infiltration, runoff, evaporation etc.) and their interactions.
2. Estimation of water resources (surface water and groundwater).
3. Study the hydrologic problems (floods, droughts, drainage etc.) and mitigation measures.

The practical application of hydrology is called Applied Hydrology/Engineering Hydrology.

Application of hydrosciences for planning, design and operation of various water related facilities.

- design rainfall events, stream flows, time histories for optimization, operation and continuous simulation.

- hydraulic structures, water supply, wastewater treatment and disposal, irrigation, urban drainage, reservoirs and spillways, floodplain analysis and delineation, erosion and sediment control, (etc).

Major branches of **Hydrology** are:

- Surface Water Hydrology - is the study of hydrologic processes that operate at or near the earth's surface.
- Groundwater Hydrology - is the study of the presence and movement of ground water.
- Ecohydrology - is the study of interactions between organisms and the hydrologic cycle.
- Hydrometeorolgy - is the study of the transfer of water and energy between land and water body surfaces and the lower atmosphere.
- Hydroinformatics - is the adaptation of information technology to hydrology and water resources applications.
- Hydrometry – is concerned with the measurements of all the variables in the hydrologic cycle.
- Hydrogeology – is the study of the relationships of geologic materials and flowing water.

Some facts about water:

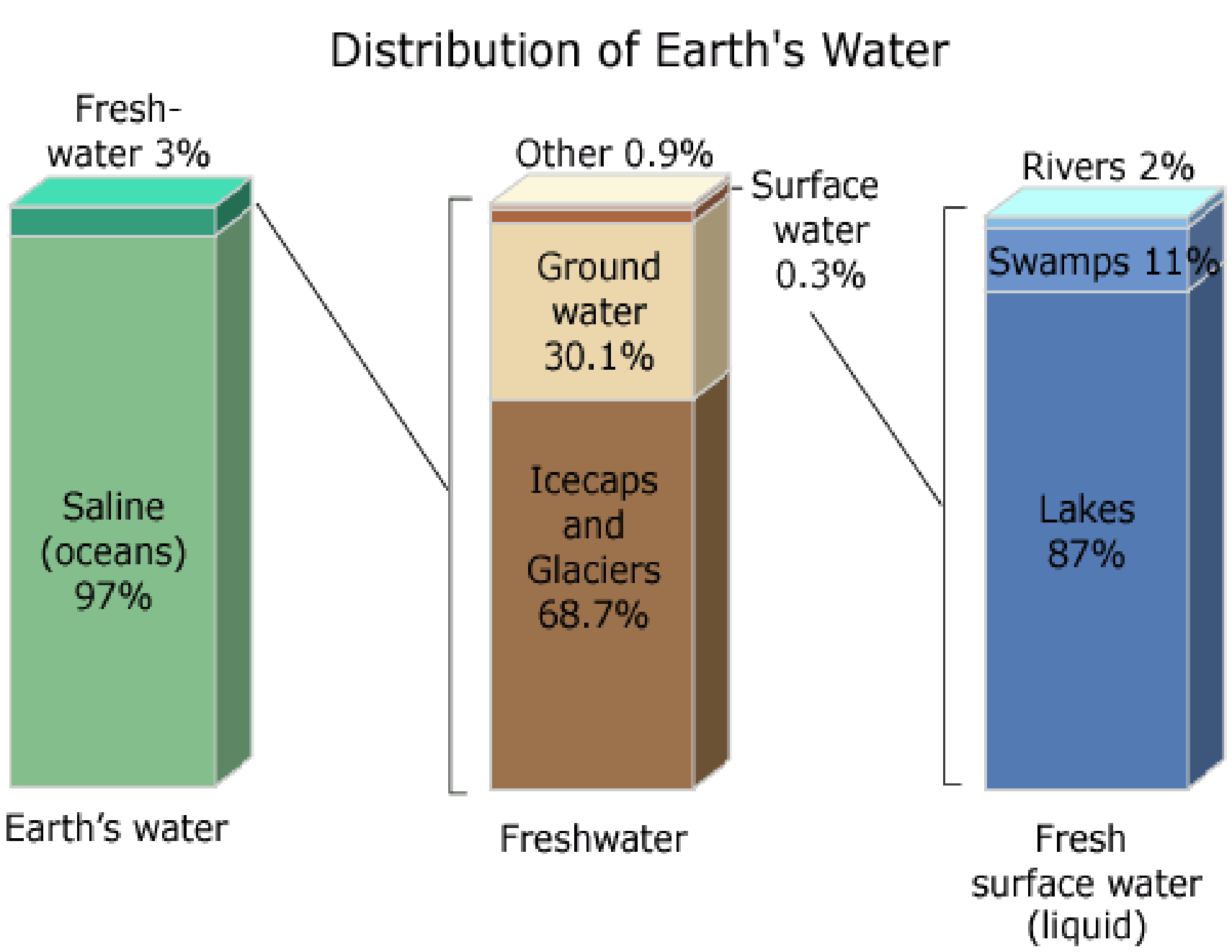
- Water covers nearly three-fourths of the earth's surface (362 m km^2 of 510 m km^2)
- Out of the earth's total allotment of 1,386 million cubic km (M km^3) of water:
  - 97% is sea water
  - 2% is frozen in polar ice caps.
  - 0.6% is in aquifers deep below the earth's surface.
  - 0.4% passes the planet's lakes and streams, is atmospheric moisture and is locked within the bodies of living things.
- About 2.5% of world's water is fresh water and only about 0.50% of it is both liquid and fresh.
- Groundwater represents about 90% of the world's readily available liquid freshwater resources, and some 1.5 billion people depend upon groundwater for their drinking water (97% of people of Bangladesh depend on groundwater for drinking water).
- Agricultural water use accounts for about 75% of total global consumption, mainly through crop irrigation, while industrial use accounts for about 20%, and the remaining 5% is used for domestic purposes. In Asia, almost 84% of the water withdrawal is used for agricultural purposes (more than 95% in Bangladesh).
- It is estimated that the average person in developed countries uses 500-800 litres of water per day (lpcd), compared to 60-180 litres per day in developing countries.

World Water Budget

Total quantity of water in the world is estimated as 1386 Mkm^3

- 1337.5 M km^3 of water is contained in oceans as saline water
- The rest 48.5 M km^3 is land water
  - 13.8 M km^3 is again saline
  - 34.7 M km^3 is fresh water
    - 10.6 M km^3 is both liquid and fresh
    - 24.1 M km^3 is frozen ice and glaciers in the polar regions and mountain tops

99% of all earth's water is held in storage in form of oceans, lakes, glacial ice or groundwater.
The remaining 1% is involved in the continuous sequence of movement and change in the form of atmospheric moisture, precipitation, and subsequent runoff and drainage, perhaps temporarily stored en route.


Distribution of Earth's Water
Fresh-
water 3%
Saline
(oceans)
97%
Earth's water
Other 0.9%
Ground
water
30.1%
Icecaps
and
Glaciers
68.7%
Freshwater
Surface
water
0.3%
Rivers 2%
Swamps 11%
Lakes
87%
Fresh
surface water
(liquid)

Hydrologic Cycle

Hydrologic cycle is the continuous process by which water is transported from the ocean to the atmosphere to the land and back to the ocean.

It is the endless circulation of water among ocean, atmosphere, land and geologic formations.

The sun is the source of energy for the hydrologic cycle.

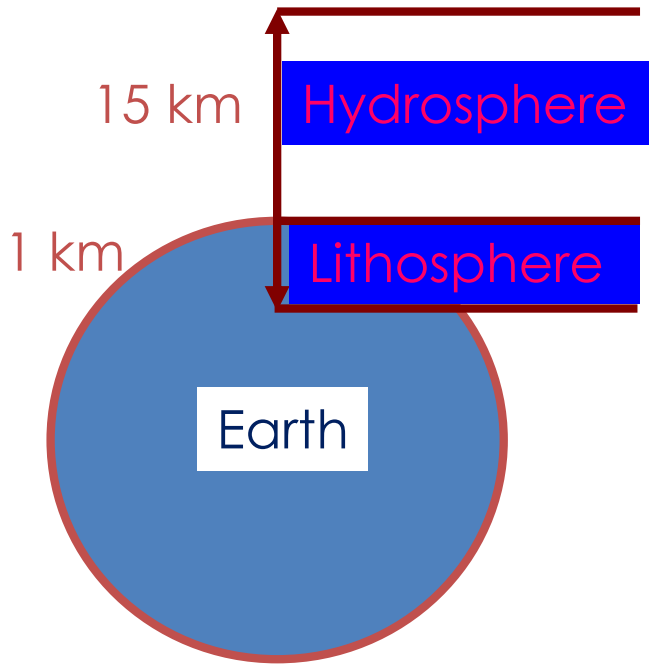
The gravitational force keeps the water moving from the ocean to the atmosphere, to the land and back to the ocean.

Each path or phase of the hydrologic cycle involves one or more of the following aspects: (a) transportation of water (b) temporary storage and (c) change of state. d) change of quality

The quality of water may change during the passage from one form to another during the cycle.

The five important phases of the hydrologic cycle are: (a) Evaporation and Evapotranspiration (b) Precipitation (c) Infiltration (d) Runoff and (e) Groundwater

Hydrologic Cycle



Water on earth exists :

- in a space called Hydrosphere (15 km up into the atmosphere)
- in the crust of the earth (1 km down into the Lithosphere)

Water circulates in the hydrosphere and the lithosphere through the maze of paths constituting the Hydrologic Cycle.

Hydrologic Cycle

The sun, which drives the hydrologic cycle, heats water in oceans and seas. Water evaporates as water vapour into the air. Ice and snow can sublimate directly into water vapor.

Evapotranspiration is water transpired from plants and evaporated from the soil.

Rising air currents take the vapor up into the atmosphere where cooler temperatures cause it to condense into clouds. Air currents move water vapor around the globe, cloud particles collide, grow, and fall out of the sky as precipitation.

Most of the precipitation falls back into the oceans or onto land as rain, where the water flows over the ground as surface runoff.

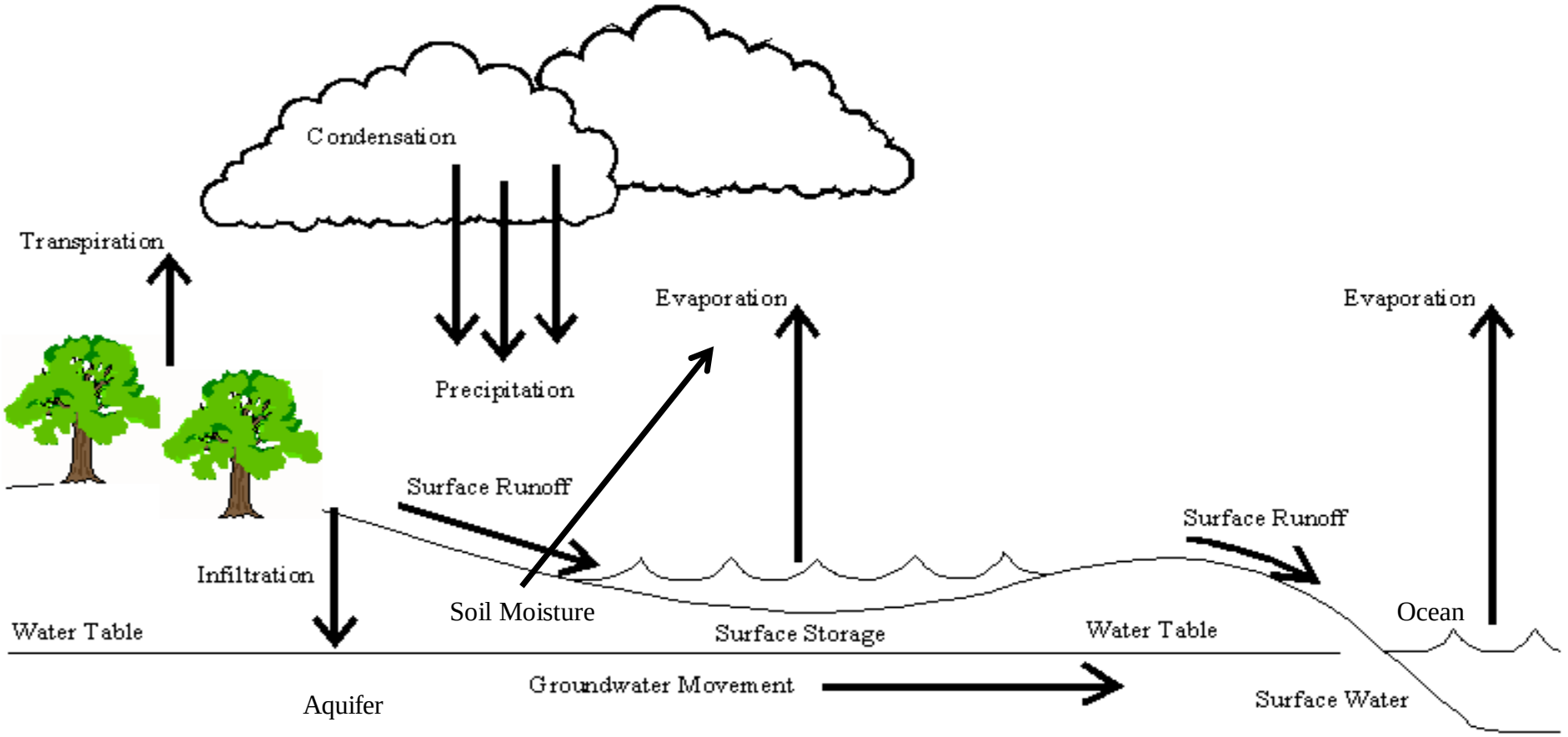
A portion of runoff enters rivers in valleys in the landscape, with water moving towards the oceans. Some of the runoff is stored as freshwater in lakes, also called surface storage.

Not all runoff flows into rivers, much of it enters into the ground as infiltration.

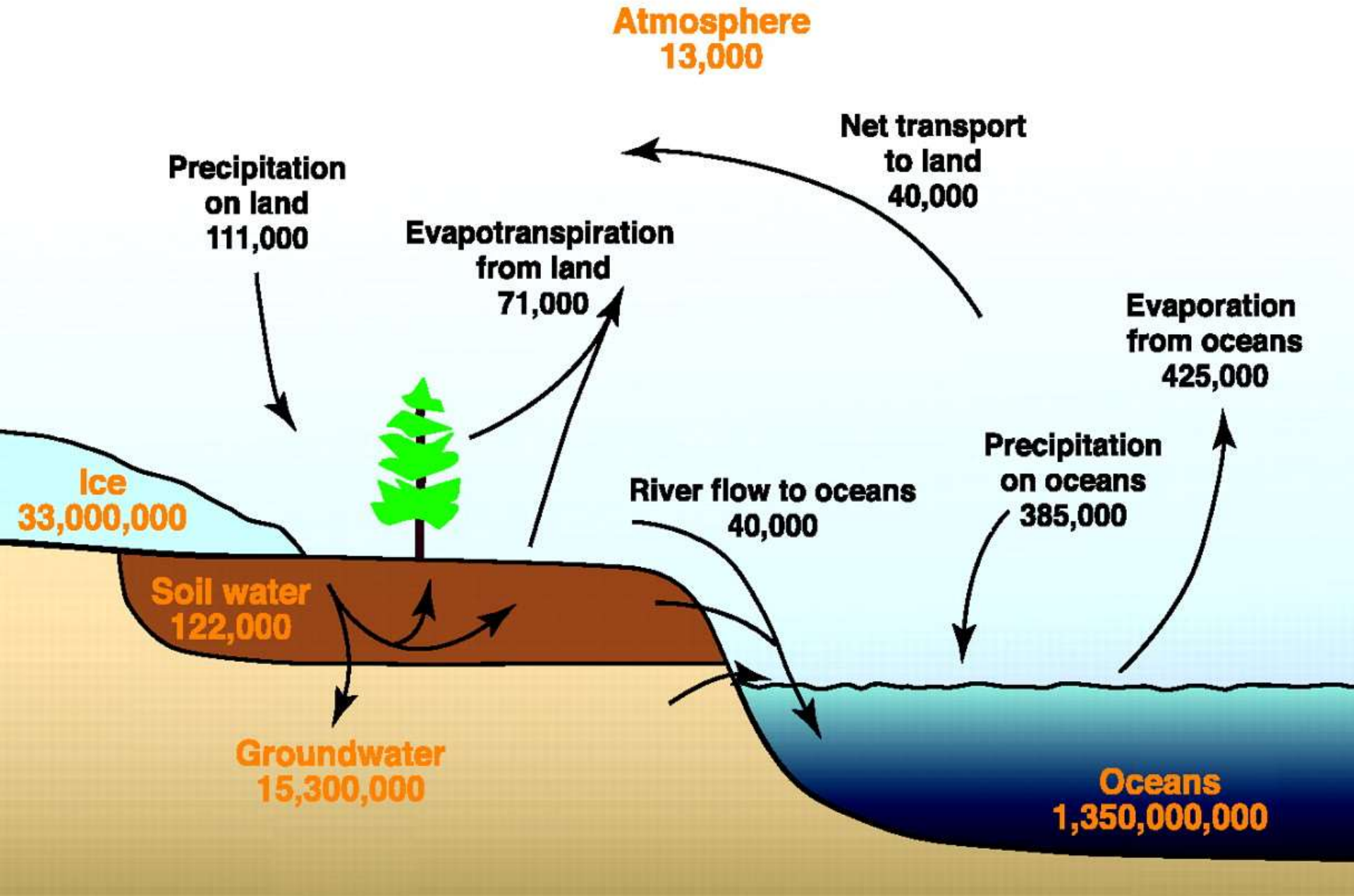
Some infiltration stays close to the land surface as soil moisture and can return to atmosphere as evaporation or evapotranspiration.

Some water infiltrates deep into the ground and replenishes aquifer, which store freshwater for long periods of time. Water from the aquifer can seep back into surface-water bodies (and the ocean) as groundwater discharge. Over time, the water returns to the ocean, from where the water cycle started.

Hydrologic Cycle



Global Water Volumes & Fluxes (km^3)



Hydrologic Cycle

System Concept

A system is set of components (connected parts) that work together to meet an objective.

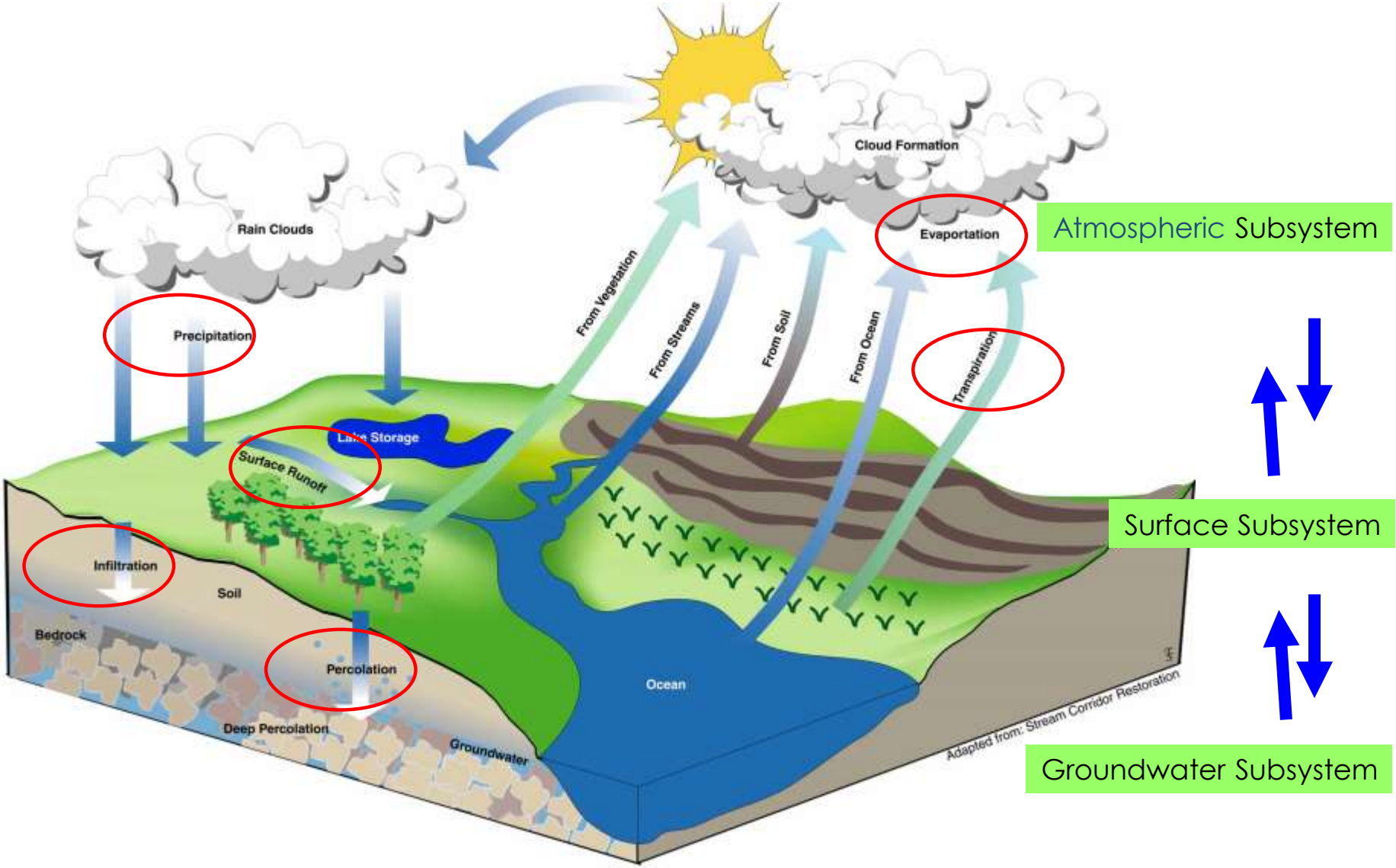
Hydrologic cycle is a system whose components are precipitation, evaporation etc. which are called subsystems. These subsystems are analyzed separately and then can be combined into the system.

The global hydrologic cycle has three subsystems – atmospheric water system, surface water system and subsurface (groundwater) system.

For most hydrological problems/analysis only a few components (processes) are considered at a time and also *considering a small portion of the earth's surface*.

Thus, hydrological system is defined as a volume in space surrounded by a *boundary* that accepts water and other inputs, operates on them internally and produces them at outputs. As nothing is lost in the system, the inputs must equal the outputs (conservation of mass during a given time).

Hydrologic System



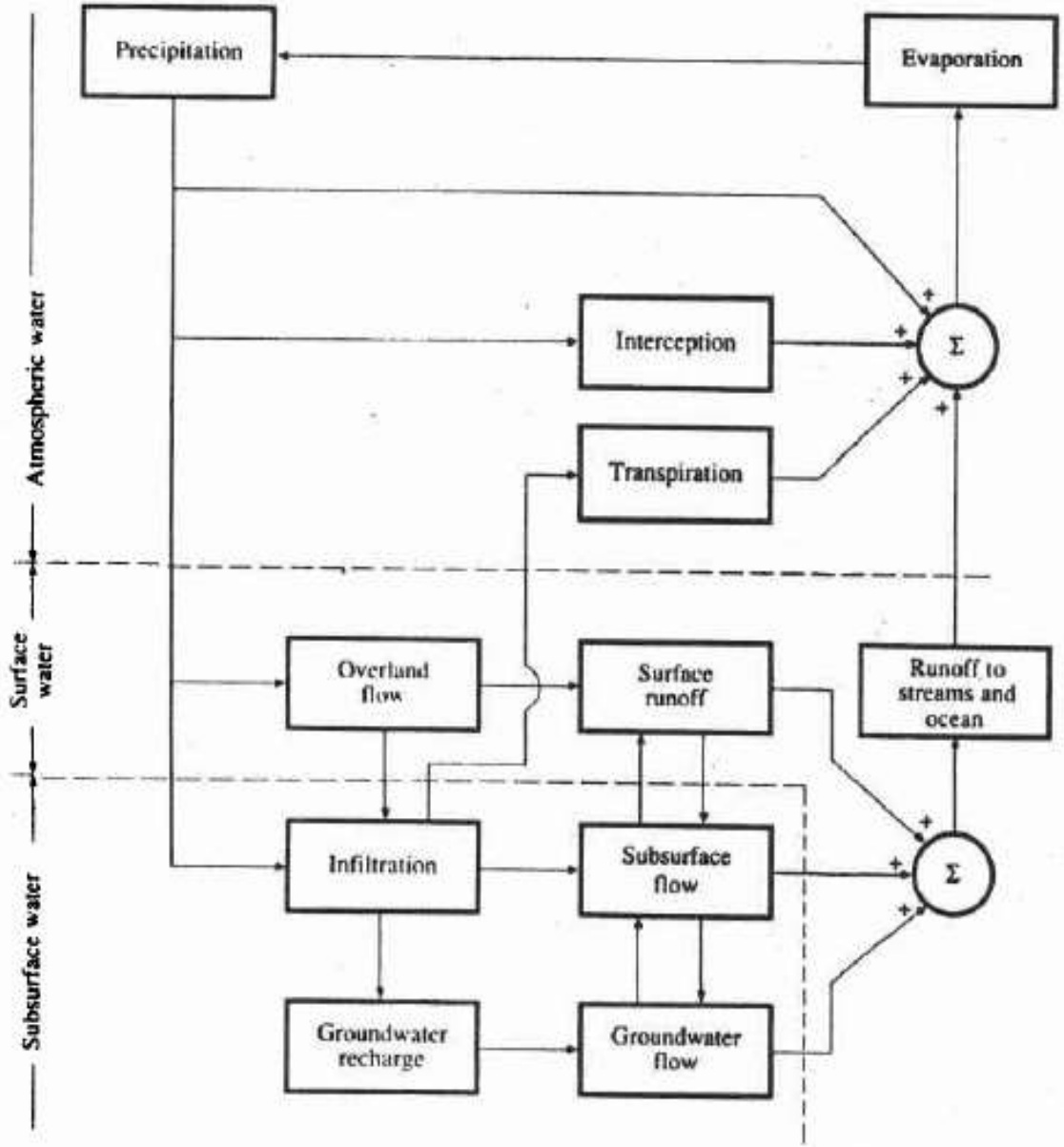
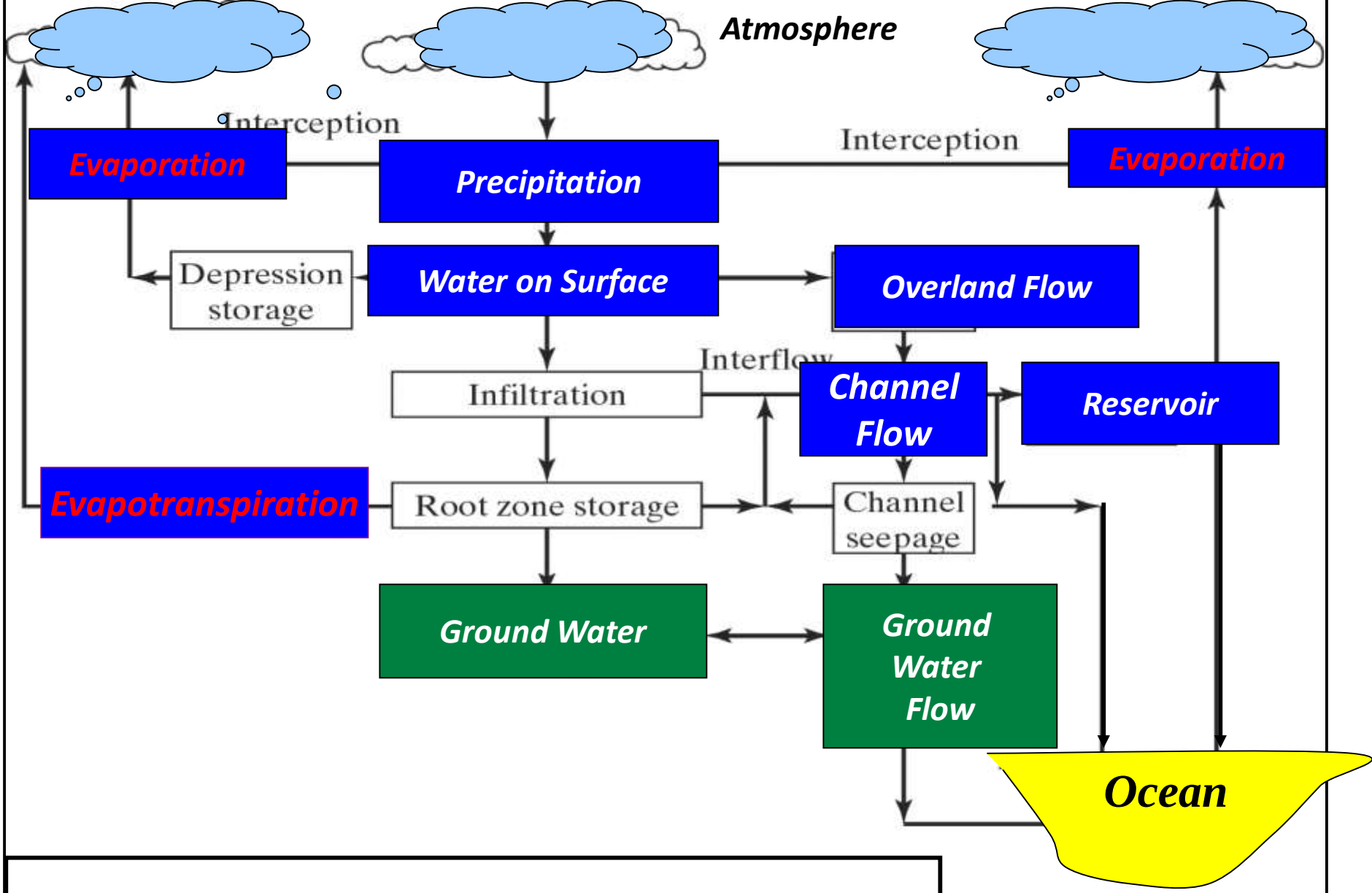


FIGURE 1.2.1
Block-diagram representation of the global hydrologic system.



The sub-systems of the Hydrologic Cycle

Figure 1.23

Components of the hydrologic cycle.

Drainage Basin

Depending upon the hydrologic problem under consideration, the hydrologic cycle or its components can be treated at different scale of space or area.

The global scale is the largest spatial scale and the watershed or drainage basin or catchment is the smallest scale.

A drainage basin or watershed or catchment is a topographically defined area drained by a river (rivulet, stream, creek, canal, drain) or a river system of connected rivers such that all outflow is discharged through a single outlet.

The area of land draining into a river or system of rivers at a given location is defined as the watershed or catchment or drainage basin at that location.

It should be clearly understood that the watershed boundary does not usually or necessarily coincide with the territorial boundary.

A drainage basin can be of any size: as small as a parking lot or as large as the Ganges-Brahmaputra-Meghna river basins.

Watershed and watershed divide

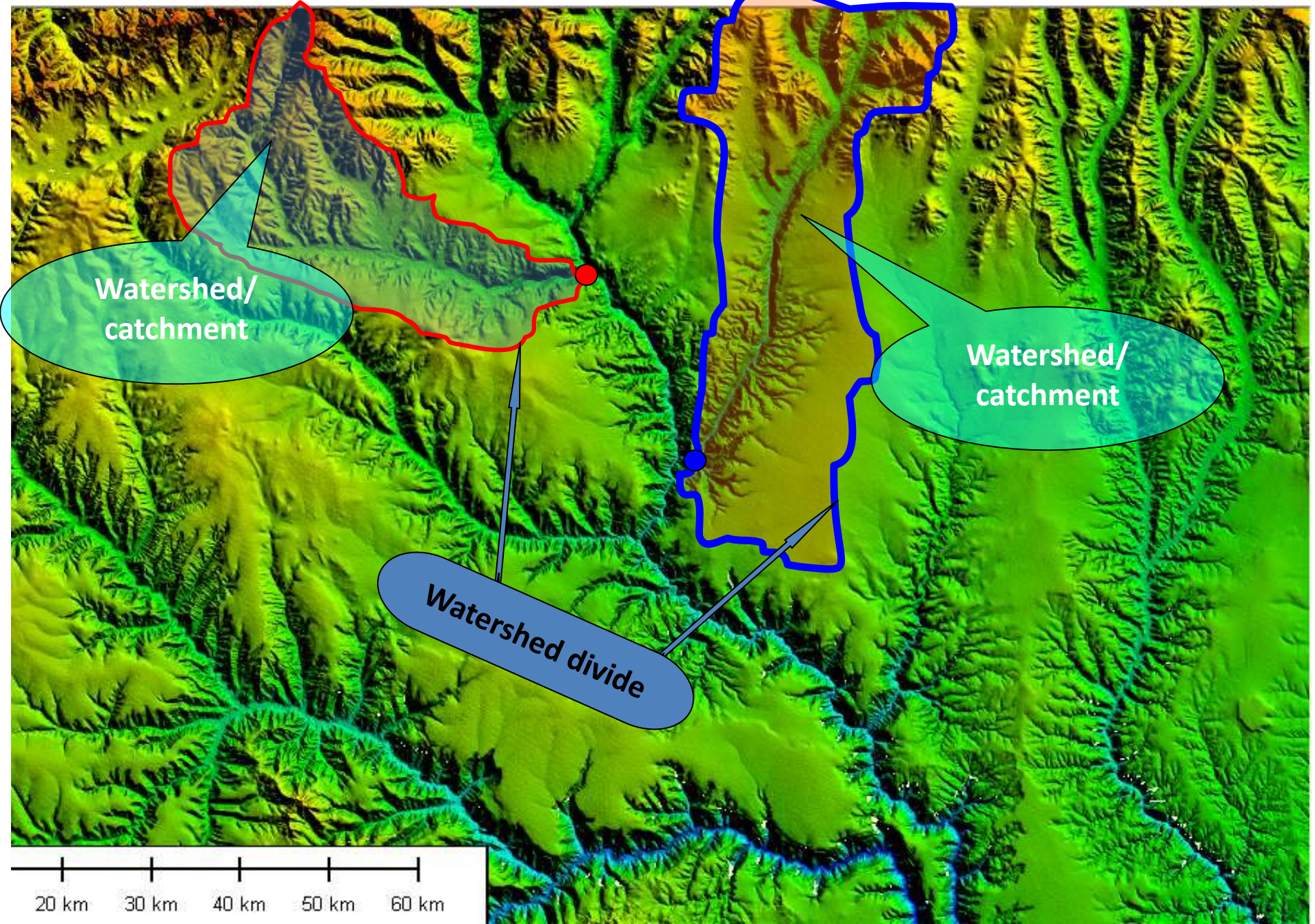
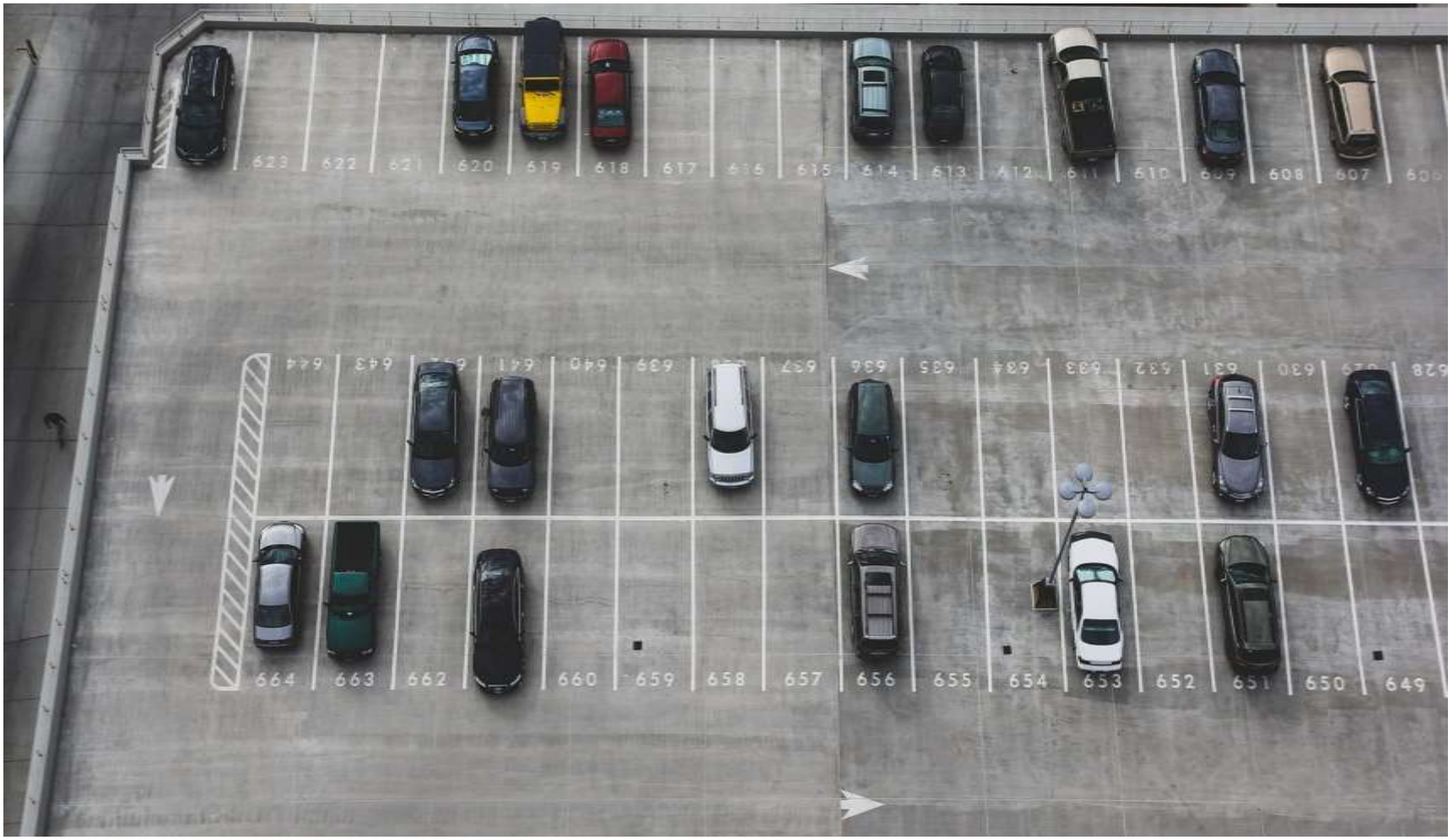


Diagram Showing Two Catchments

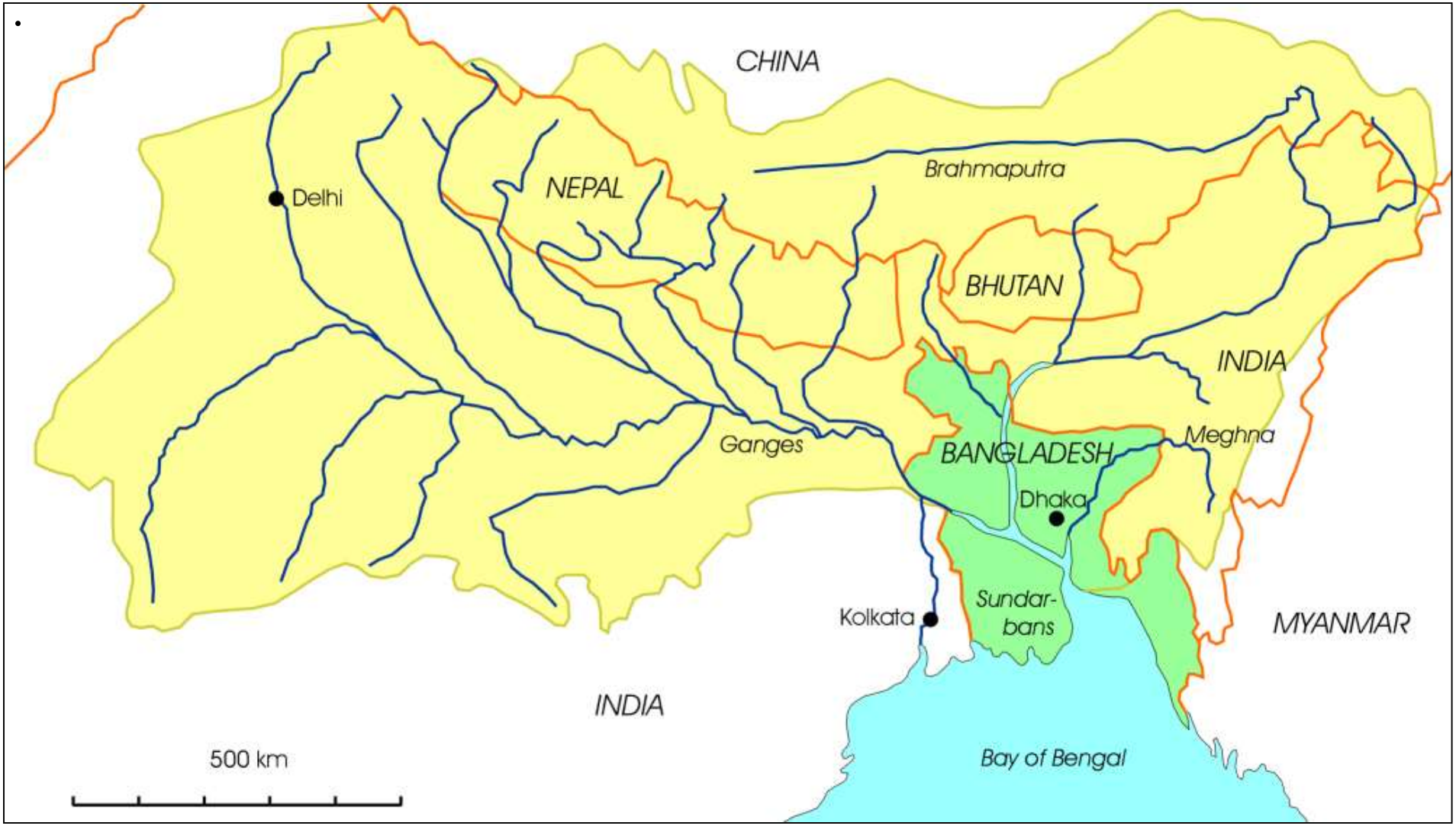


Is this a catchment?

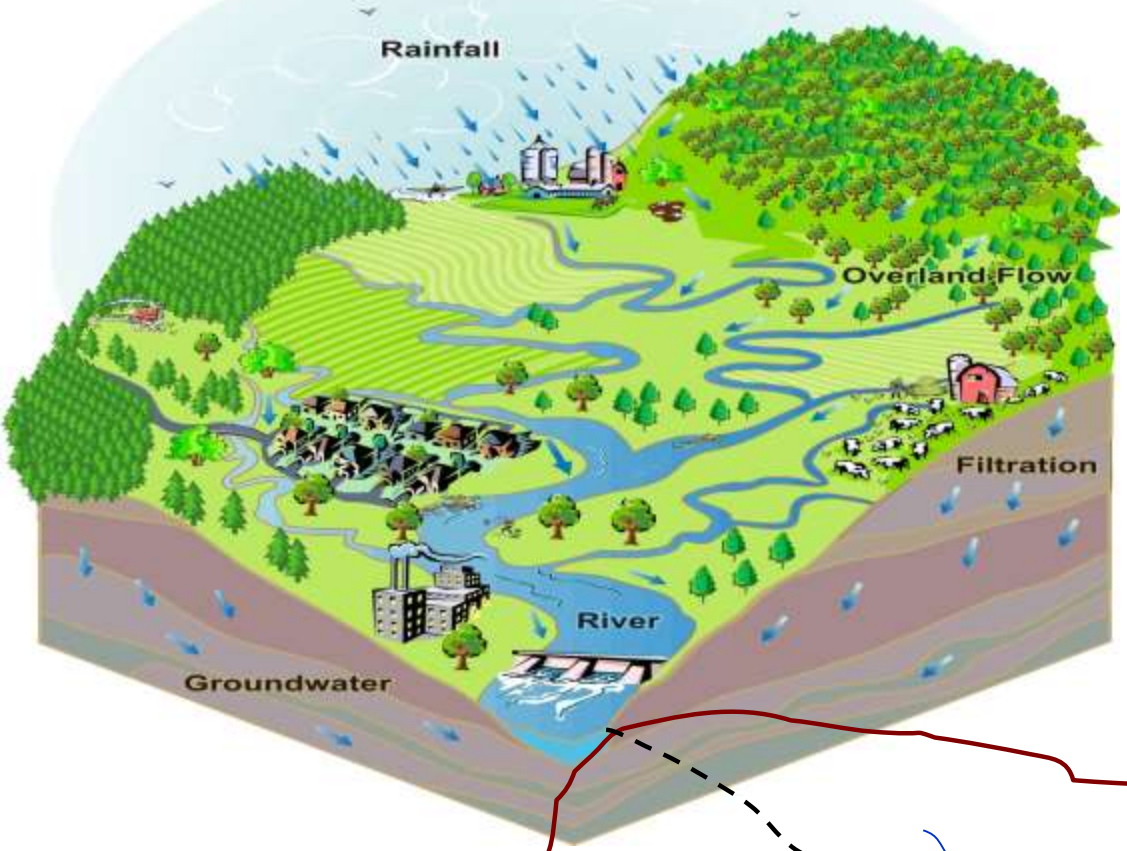


The combined total catchment area of Ganges, Brahmaputra and Meghna river basins is about 1.7 million km^2 extending over Bangladesh, Bhutan, China, India and Nepal.

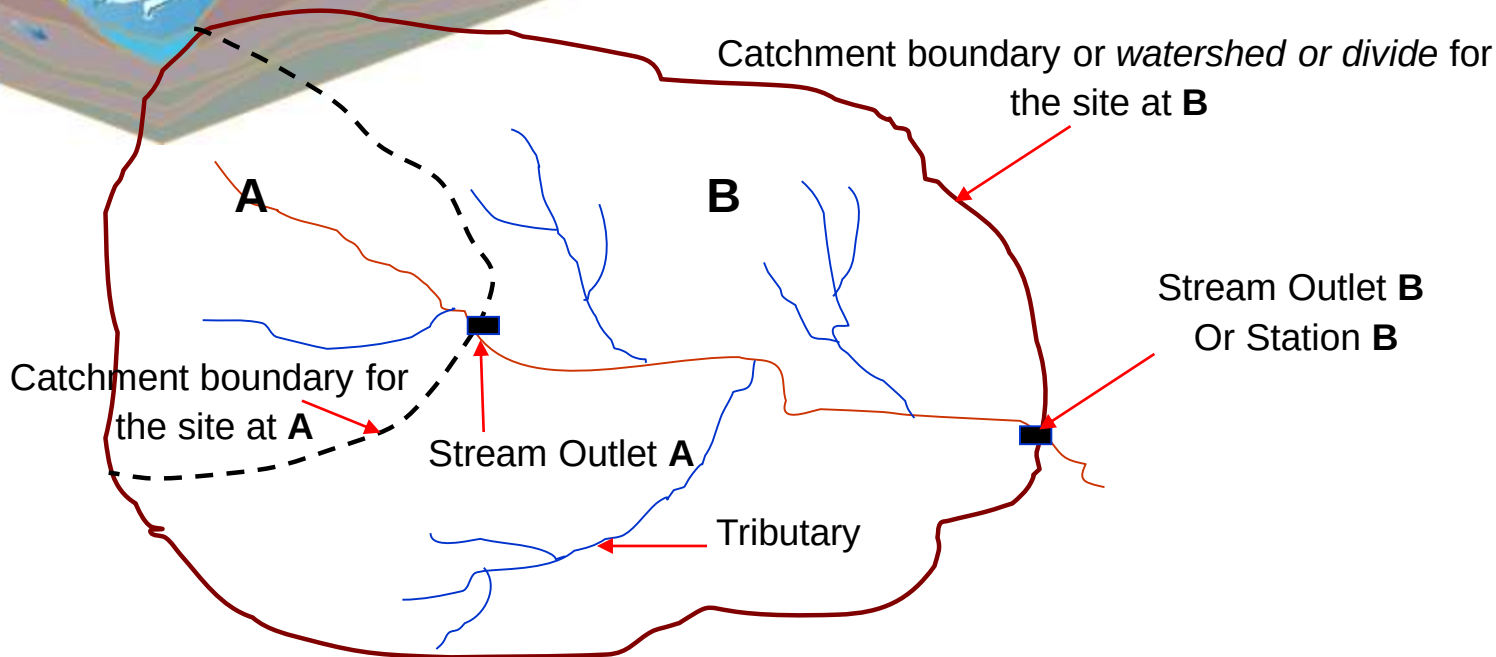
Out of this huge catchment area, only about 7% lies in Bangladesh.



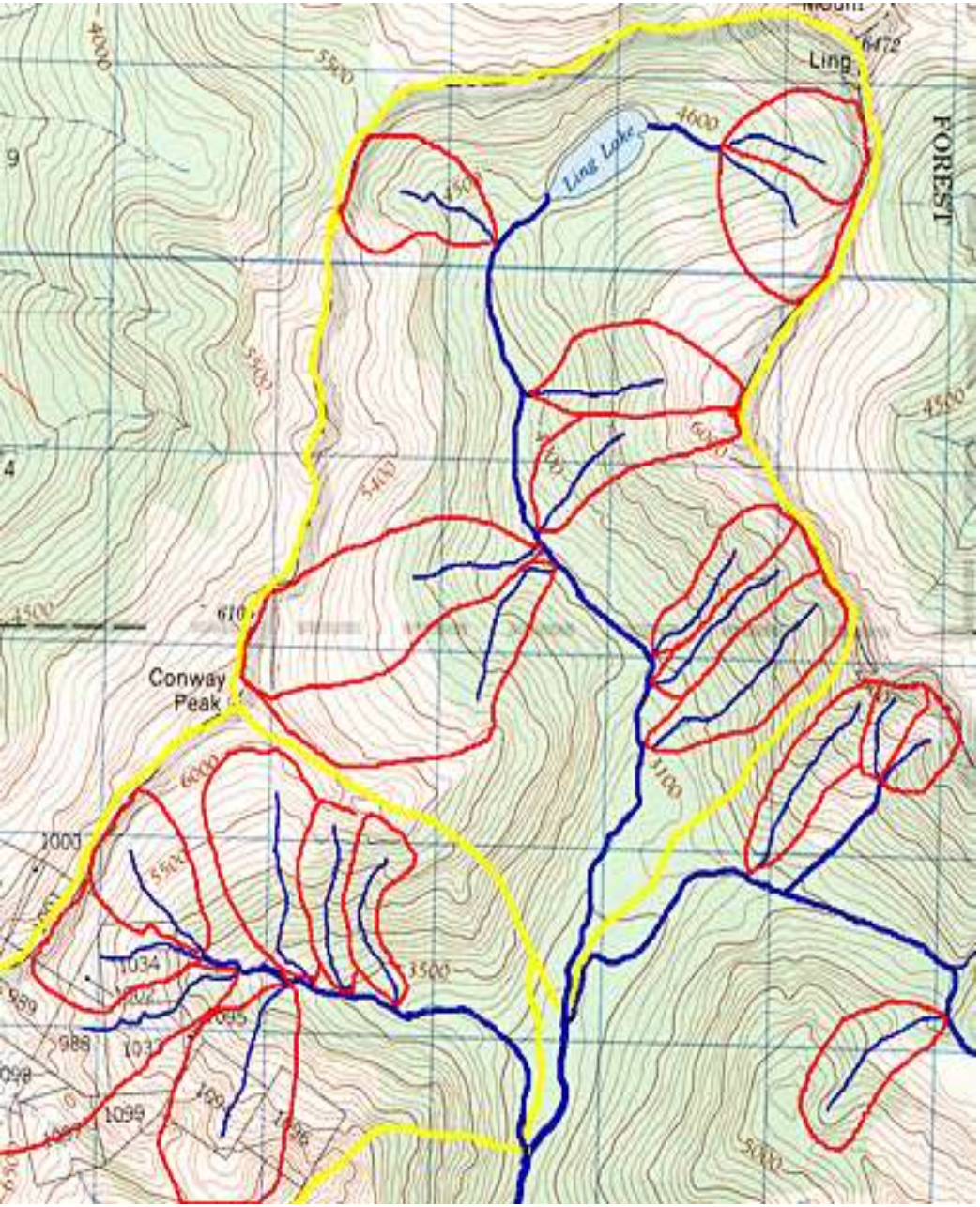
A typical catchment or drainage basin or watershed

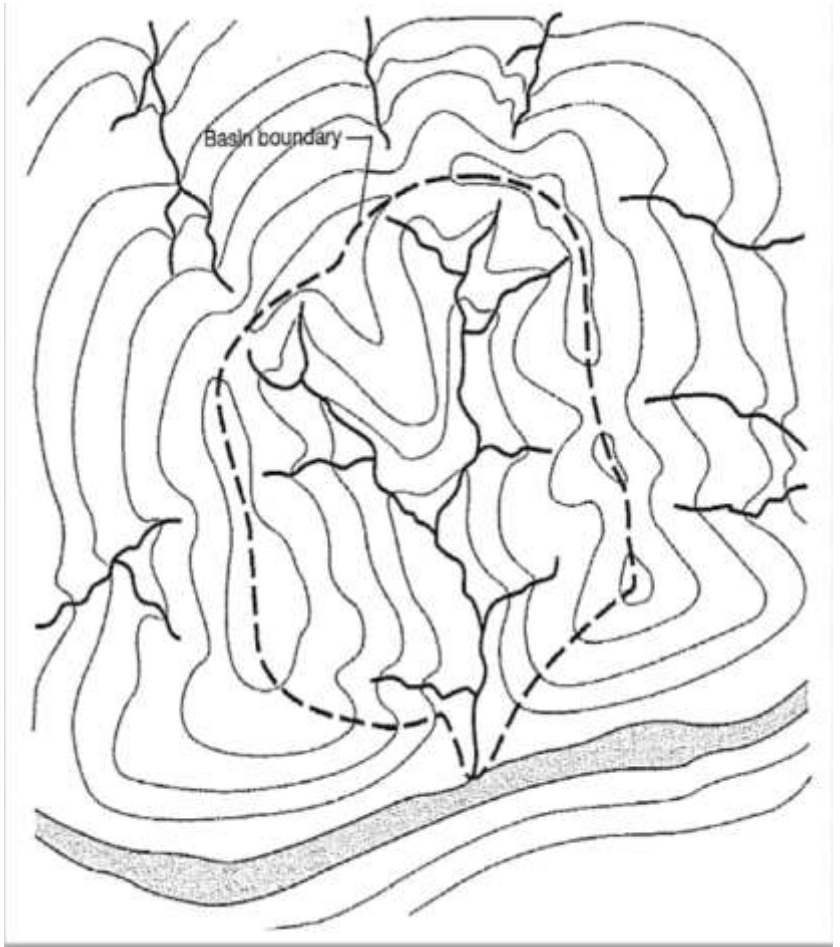


Sub-catchments of a large catchment



Catchment delineation from Topographic map.

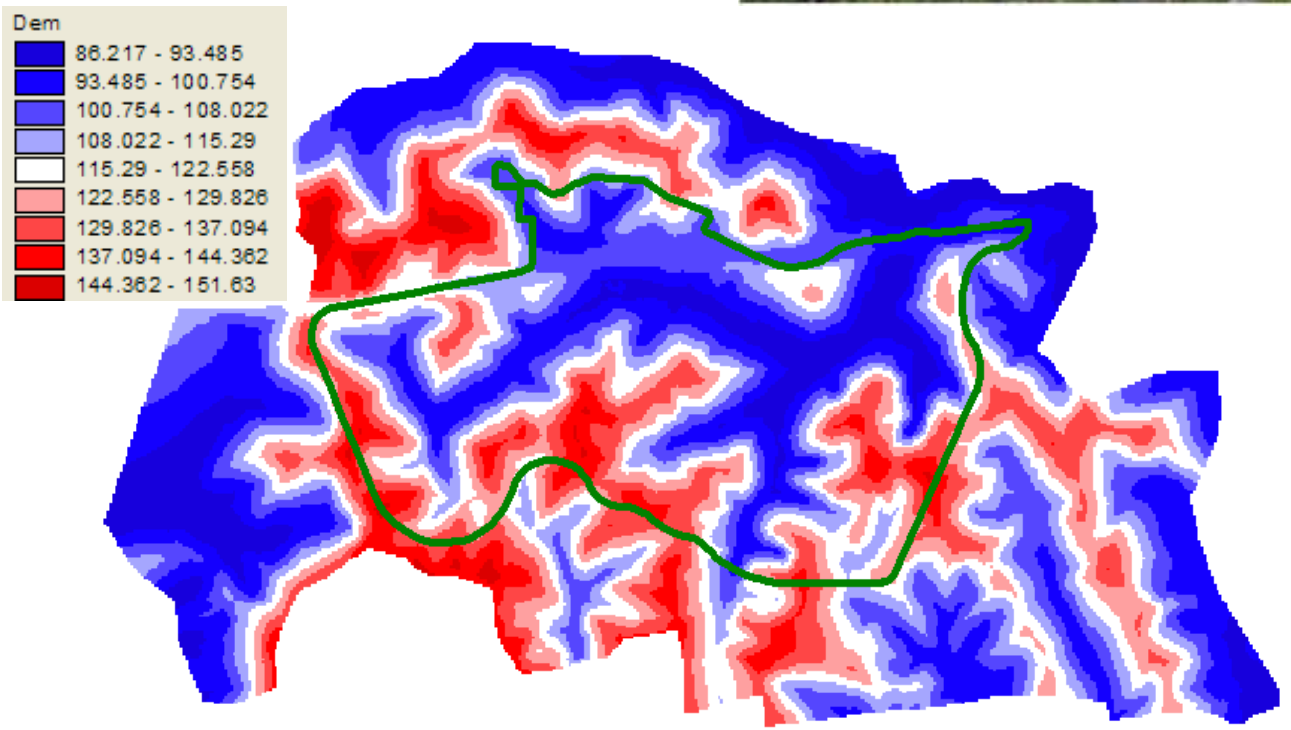


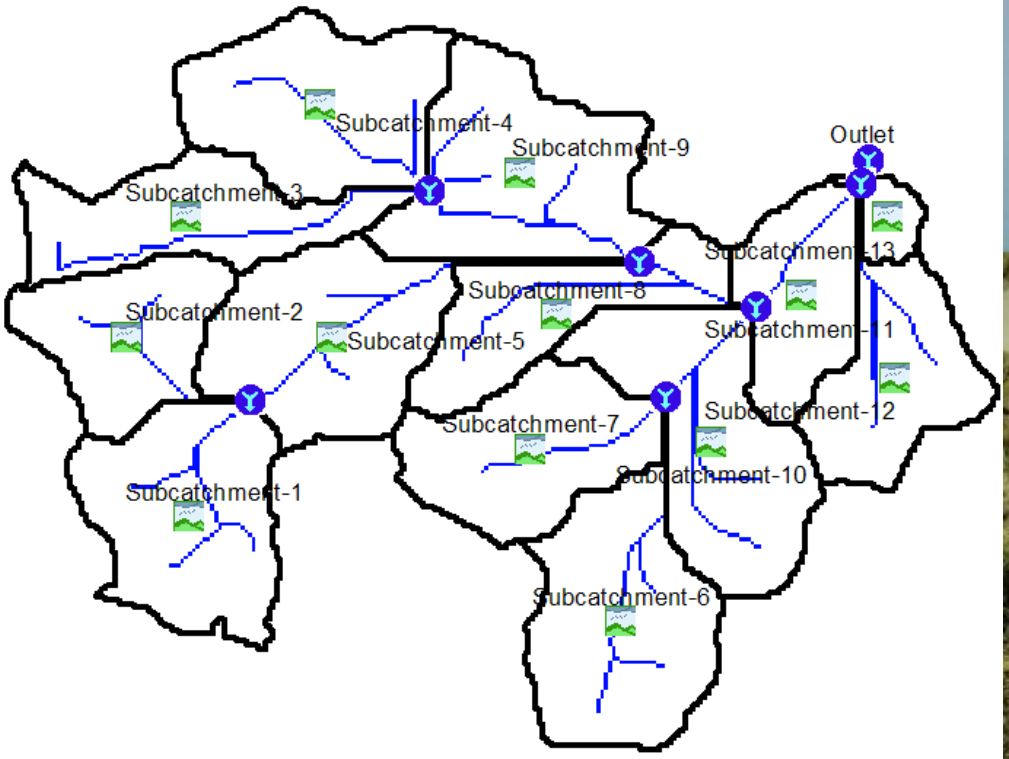


Hydrological Study for the Chittagong Site of Asian University for Women

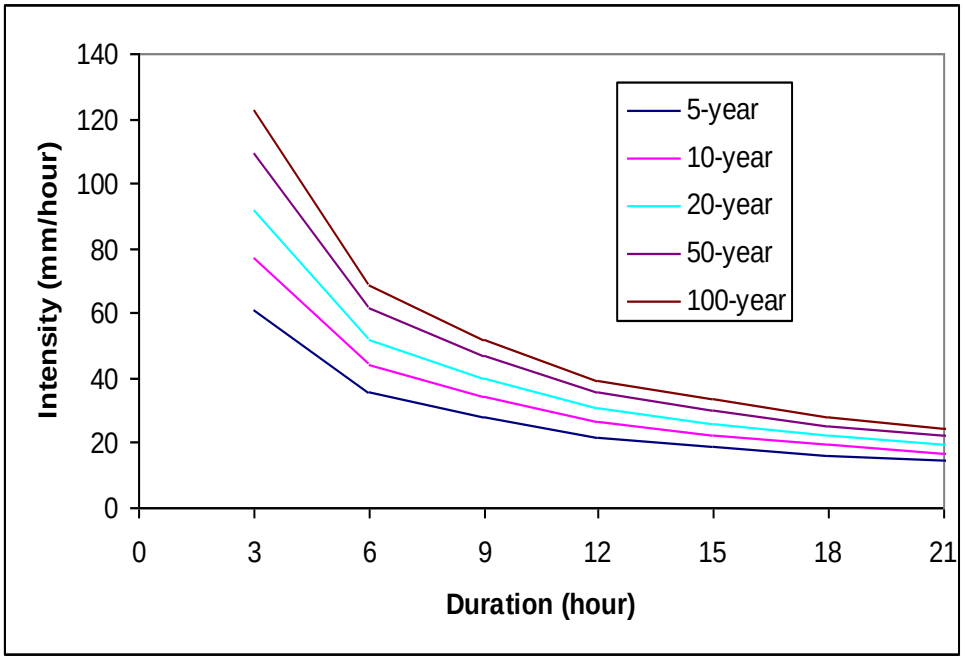






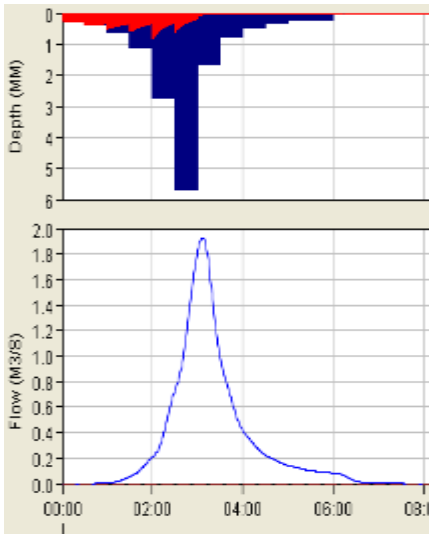


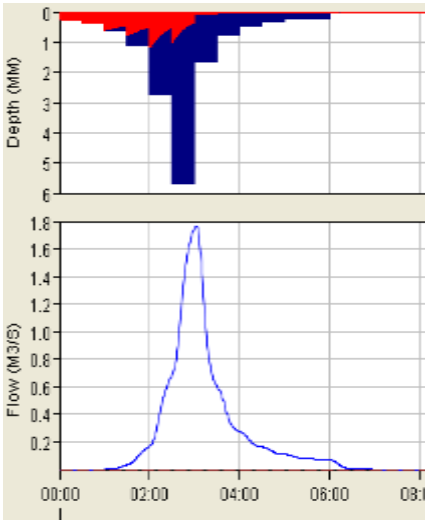




(a) Subcatchment-1

(b) Subcatchment-2





Hydrologic Budget

Hydrologic Budget or Water Balance

A watershed is a geographical unit in which the hydrological cycle and its components can be analysed.

The hydrologic cycle can be described by applying the law of conservation of mass.

The total quantity of water available to the earth is finite and indestructible.

The hydrologic budget or water balance is a mathematical statement of the hydrologic cycle.

The quantity of water going through various individual paths of a hydrologic cycle can be described by the continuity equation known as hydrologic budget or water balance equation.

Water Budget Equation

- For a given catchment, in an interval of time Δt, the continuity equation for water in its various phases can be given as:

  Mass inflow – Mass outflow = Change in mass storage

- If the density of the inflow, outflow and storage volumes are the same:

$$\forall_i - \forall_o = \Delta S$$

V_i - Inflow volume in to the catchment, V_o - Outflow volume from the catchment and ΔS - change in the water volume

Water Balance Equation

Water balance equation is expressed by equating the difference between inflow I and ouflow O of a drainage basin to the rate of change of storage within the basin ΔS, for a specified period of time Δt. Thus, the water balance equation can be written as:

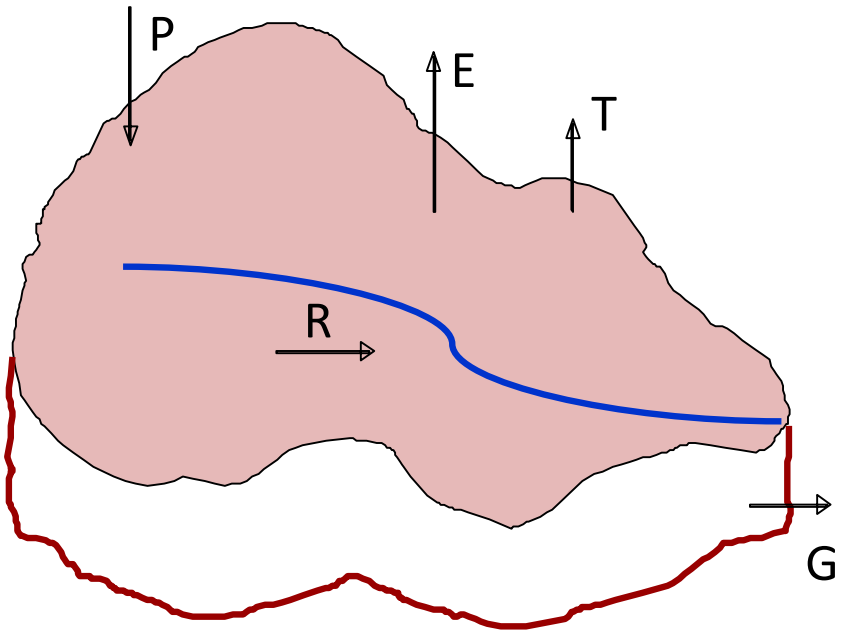
$$\frac{\Delta S}{\Delta t} = I - O \qquad \text{..... (1)}$$

$$\frac{S_2 - S_1}{\Delta t} = \frac{I_2 + I_1}{2} - \frac{O_2 + O_1}{2} \qquad \text{..... (2)}$$

The subscripts 1 and 2 correspond to the value of the variables at the start and end of the time interval $\Delta t = t_2 - t_1$.

For a drainage basin, the inflow may be rainfall. The runoff, evaporation etc. may be outflow and the components of storage may be surface storage and subsurface storage.

Water Budget in a Watershed



P = precipitation
E = evaporation
T = transpiration
R = surface runoff
G = net groundwater flow
Δ S = change in storage

$$P - R - G - E - T = \Delta S$$

$$(P - R - G - E - T) / \Delta t = \Delta S / \Delta t$$

If irrigation is applied then input is:

$$P + I$$

Example

A small catchment of area 150 ha received a rainfall of 105 mm in 90 minutes due to a storm. At the outlet of the catchment, the stream draining the catchment was dry before the storm and experienced a flow lasting for 10 hours with an average discharge of 2.0 m^3/sec. The stream was again dry after the runoff event.

1. What is the amount of storage (water which was not available as flow)?
2. What is the ratio of total flow to precipitation?

Solution

- The water budget equation for the catchment in a time Δt is :

$$I - O = \Delta S / \Delta t$$

- Δt = Duration of flow = 10 hours
- I = Precipitation = 150x100x100x105/1000 = 157,500 m^3
- O = Outflow volume = 2.0x10x60x60= 72,000 m^3

  ΔS = 157,000 - 72,000 = 85,500 m^3 = Water not available to flow = Loss.
- Outflow / rainfall = 72,000 / 157,500 = 0.457 or 45.7%