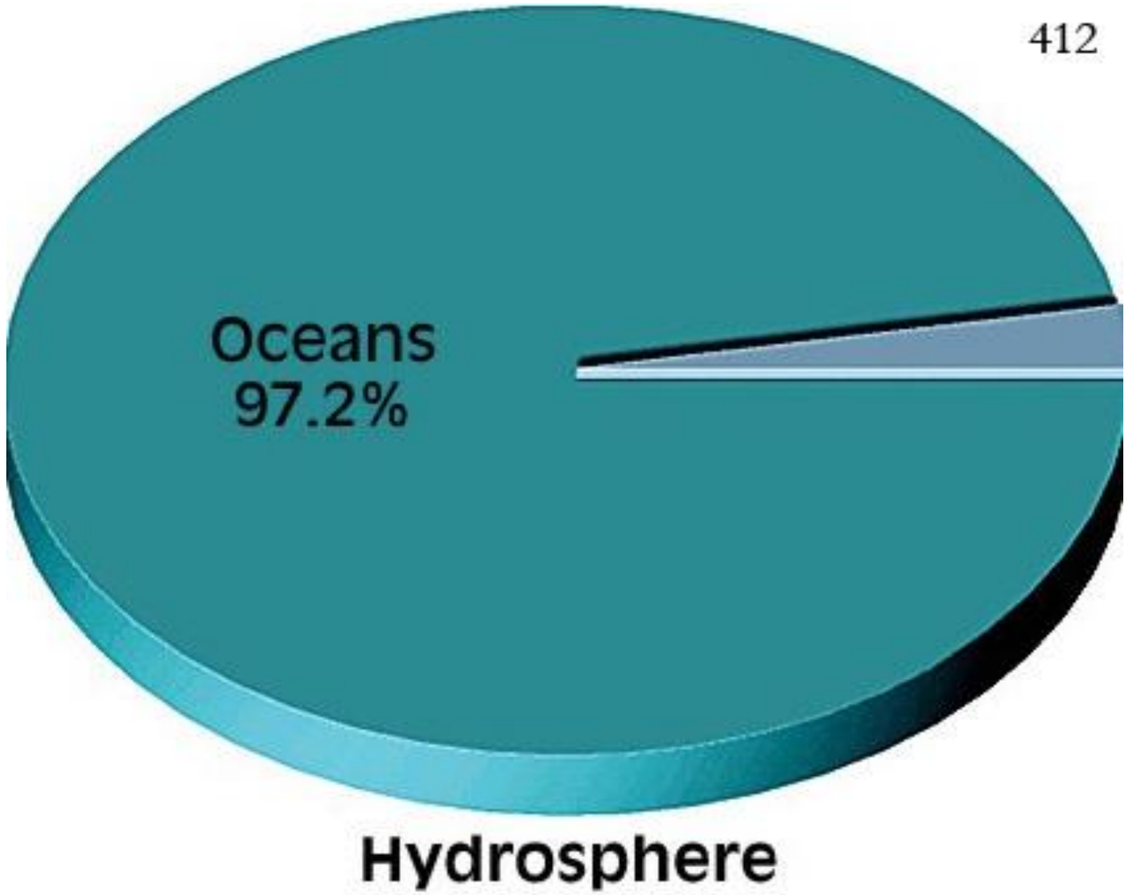
INTRODUCTION TO WATER RESOURCES

Earth's Water

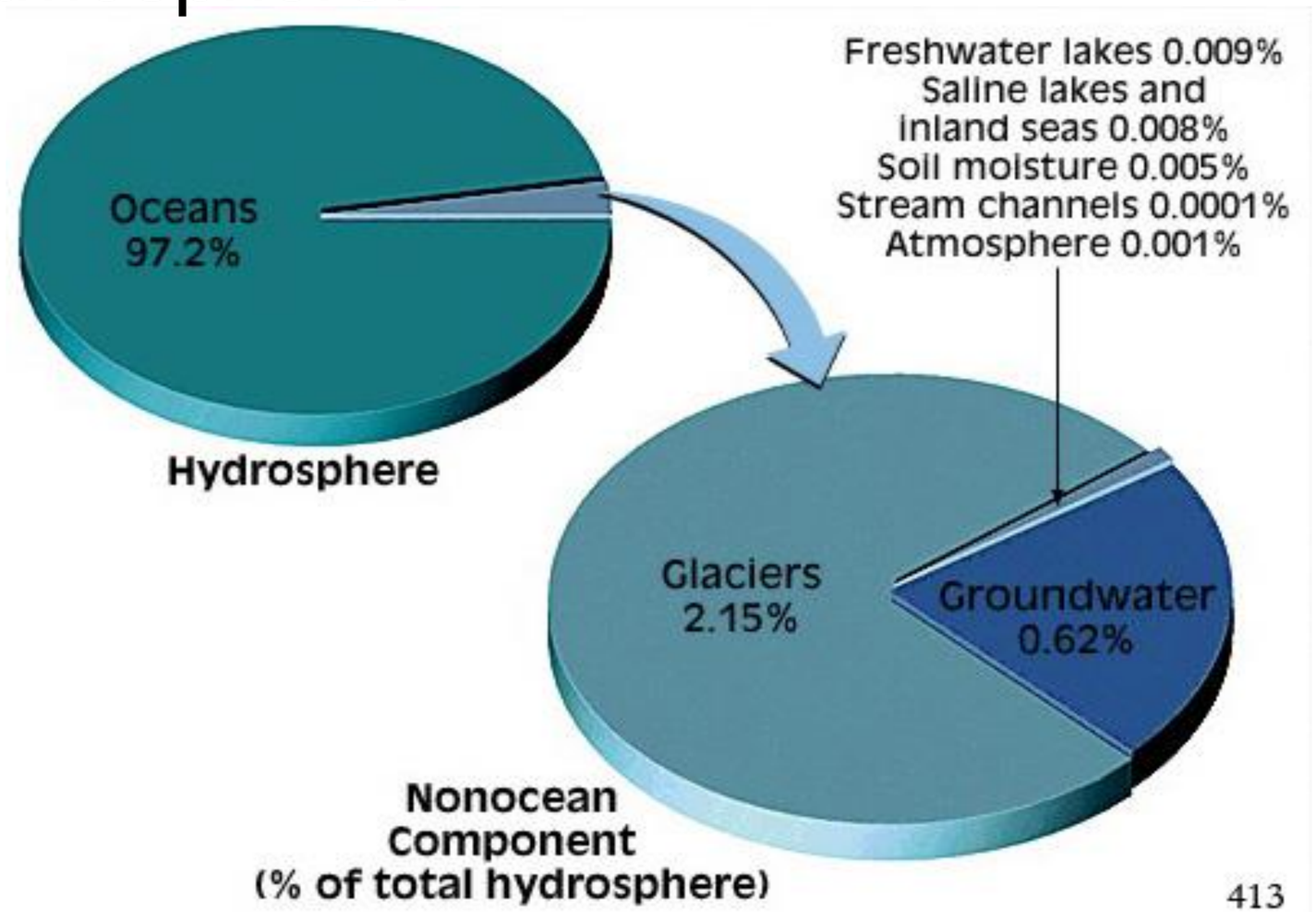
The amount of water on Earth is immense – an estimated 1.36 billion cubic kilometres.

- Most of it is in oceans.



Earth's Water.....(2)

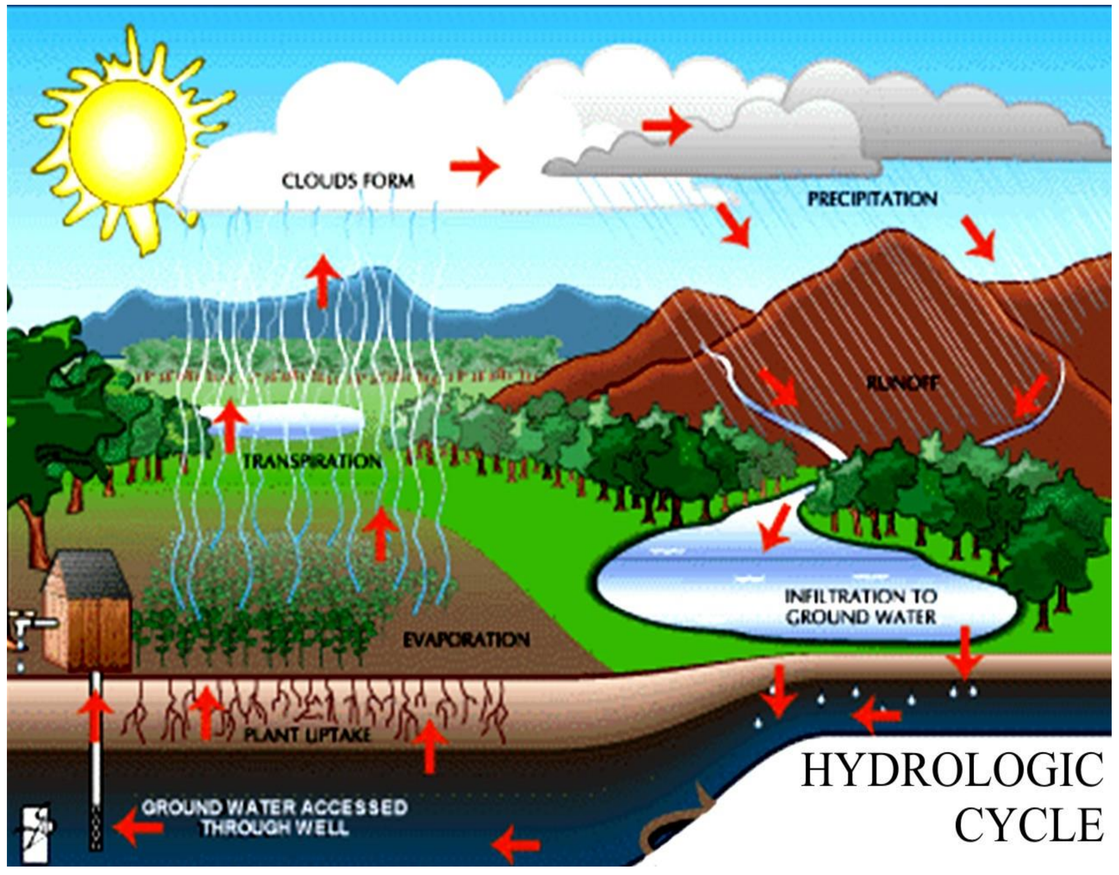
- The remainder is distributed among ice sheets & glaciers, groundwater, lakes, streams & atmosphere.



The Hydrologic Cycle

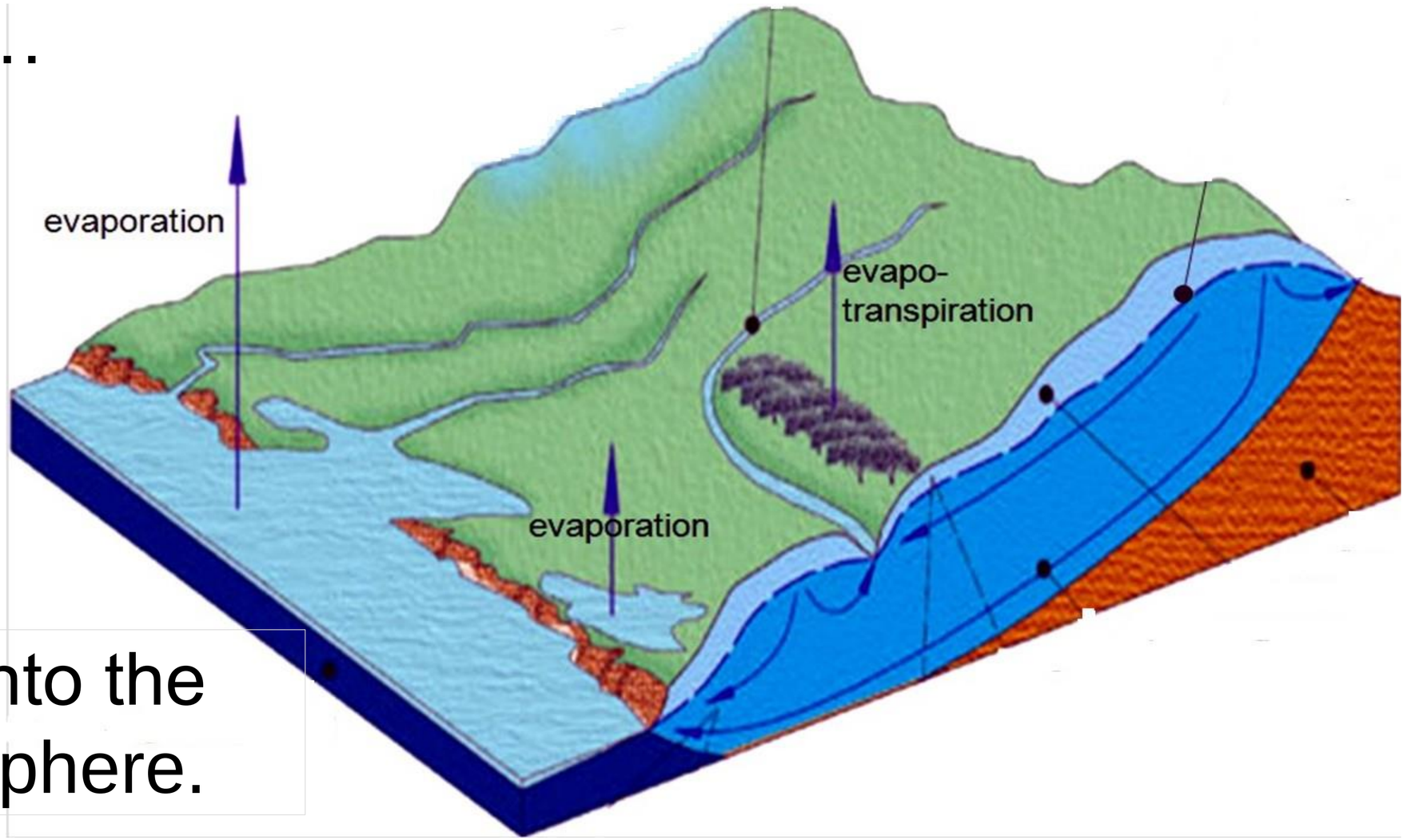
Water on earth moves in a continuous cycle – the WATER or HYDROLOGIC CYCLE.

- It is a continuous process of water transportation from OCEANS to ATMOSPHERE to LAND and back to OCEANS.



The Hydrologic Cycle.....(2)

Lifting of water vapour by wind & sun's energy (EVAPO(TRANSPI)RATION from oceans, over land, & vegetation…



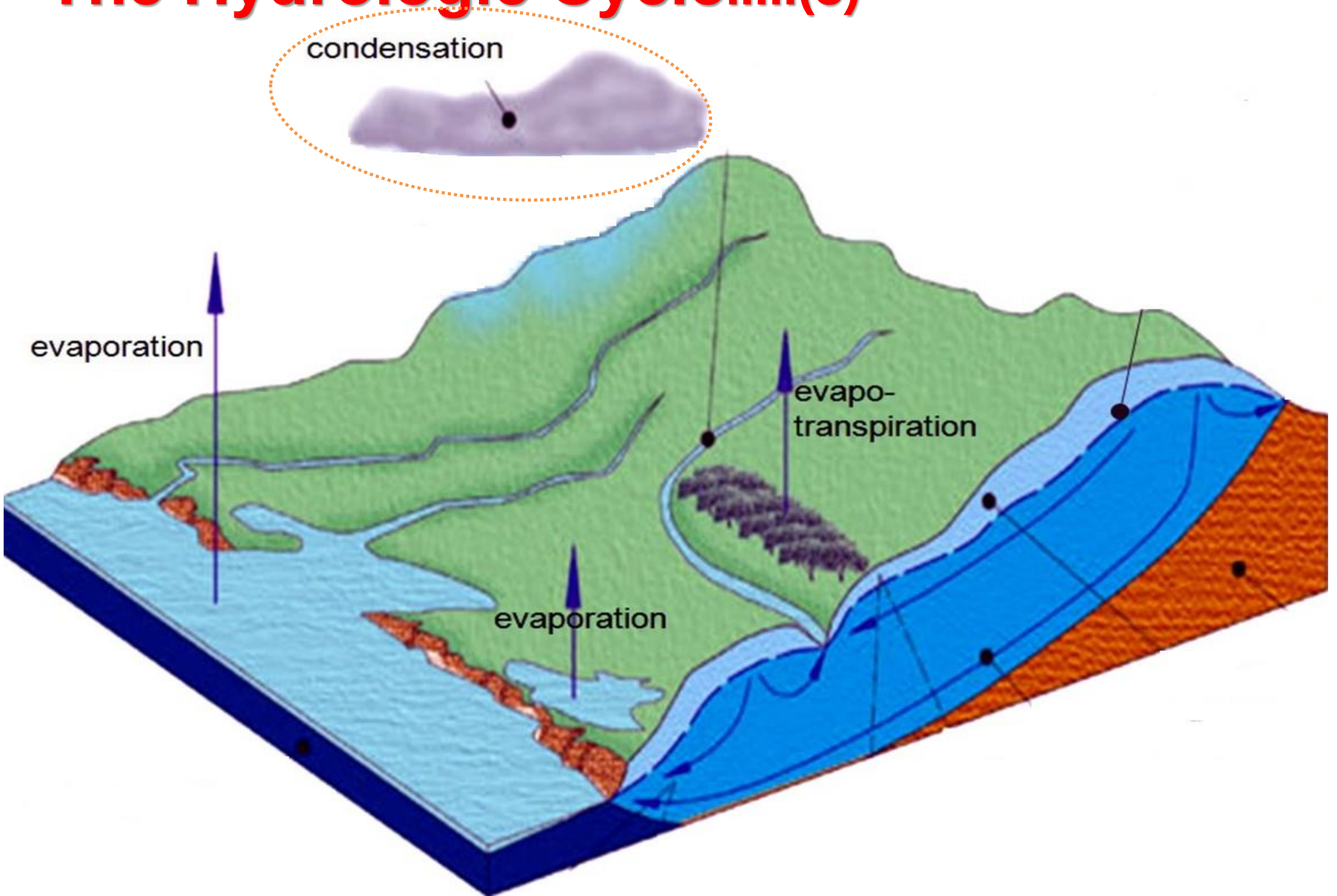
…….into the atmosphere.

The Hydrologic Cycle.....(3)

Evapotranspiration

- Combined net effect of two processes: evaporation & transpiration.
- Evaporation – process of returning moisture (on any surface, especially surfaces of ponds, streams, rivers, lakes, & oceans) to atmosphere thru water vapour.
- Transpiration – process by which plants return moisture to atmosphere.

The Hydrologic Cycle.....(3)

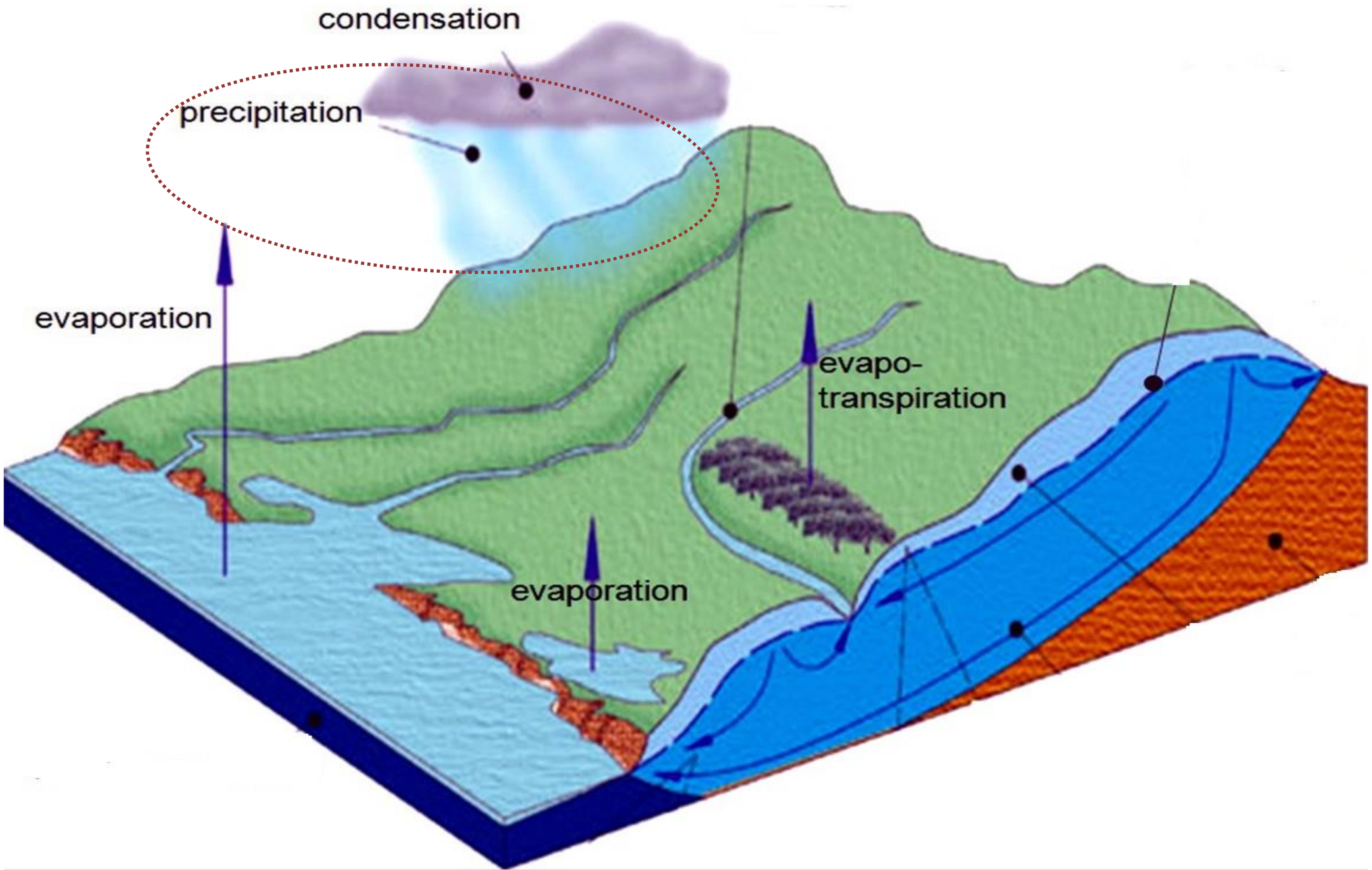


The Hydrologic Cycle.....(4)

Condensation

- Cooling of water vapour until it becomes liquid:
  - As dew-point is reached, water vapour forms tiny visible water droplets.
  - When droplets form in sky, and other atmospheric conditions are present, clouds will form.
  - As the droplets collide, they merge and form larger droplets resulting in precipitation.

The Hydrologic Cycle.....(5)

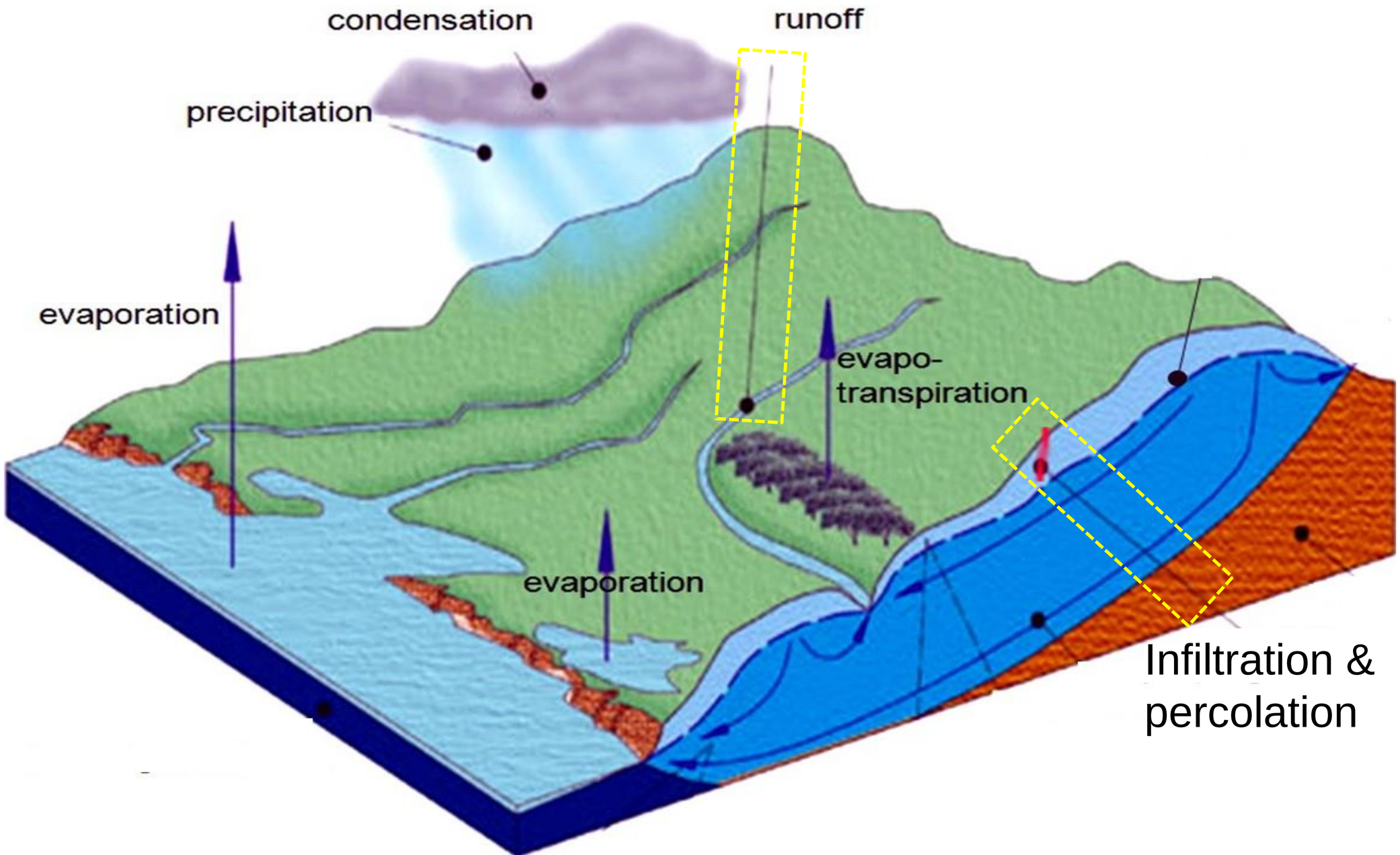


The Hydrologic Cycle.....(6)

Precipitation

- Moisture that falls from atmosphere as rain, snow, or hail.
- Varies in amount, intensity, and form by season and geographic location.
- Recorded as amount of rainfall – vital info for:
  - determination of average rainfalls for location & for classifying rain-storms...
  - engineering design of water control structures & flood control.

The Hydrologic Cycle.....(7)



The Hydrologic Cycle.....(8)

Runoff

- Movement of water, usually from precipitation, across earth's surface towards depressions & low-points in earth's surface – *stream channels, lakes, oceans.*
- Affected by
  - rainfall duration & intensity
  - soil type
  - ground cover
  - slope of ground

The Hydrologic Cycle.....(9)

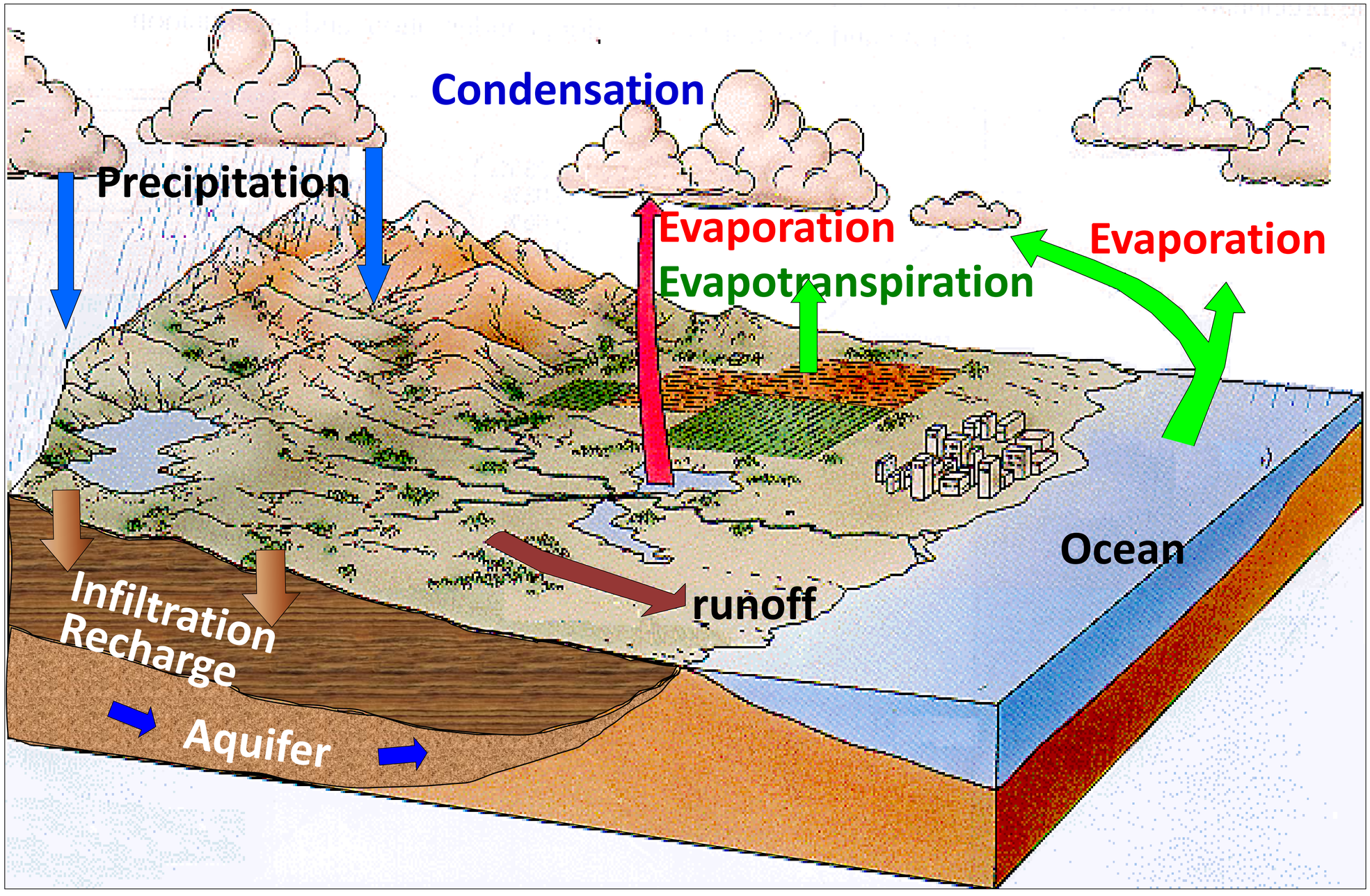
- ***Infiltration***
  - Entry of water into soil – sole source of water to sustain growth of vegetation
  - Sustains groundwater supply to wells, springs and streams.
  - Its rate usually influenced by *physical characteristics of soil, soil cover, water content of the soil, soil temperature & rainfall intensity.*

The Hydrologic Cycle.....(10)

Percolation

- Downward movement of water through soil & rock to groundwater store (aquifer)
  - Water moves from space to space along fractures in rock, through sand and gravel, or through channels in formations such as cavernous limestone.
- Occurs beneath root zone, after plant water requirements have been met.

Summary


Condensation
Precipitation
Evaporation
Evapotranspiration
Evaporation
Ocean
runoff
Infiltration
Recharge
Aquifer

Summary.....(2)

- **Evaporation / transpiration** – *transformation of water into vapour from a combination of surface water bodies and plants.*
- **Condensation** – *saturation/cooling of air masses/vapour to liquid as dew point is reached.*
- **Precipitation** – *falling of moisture on Earth's surface from atmosphere.*
- **Runoff** – *movement of water from ppt across Earth's surface towards streams, lakes, oceans,…*
- **Infiltration** – *Entry of water into the soil.*
- **Percolation** – *downward movement of water thru soil/rock (below root zone) to grdwater store.*

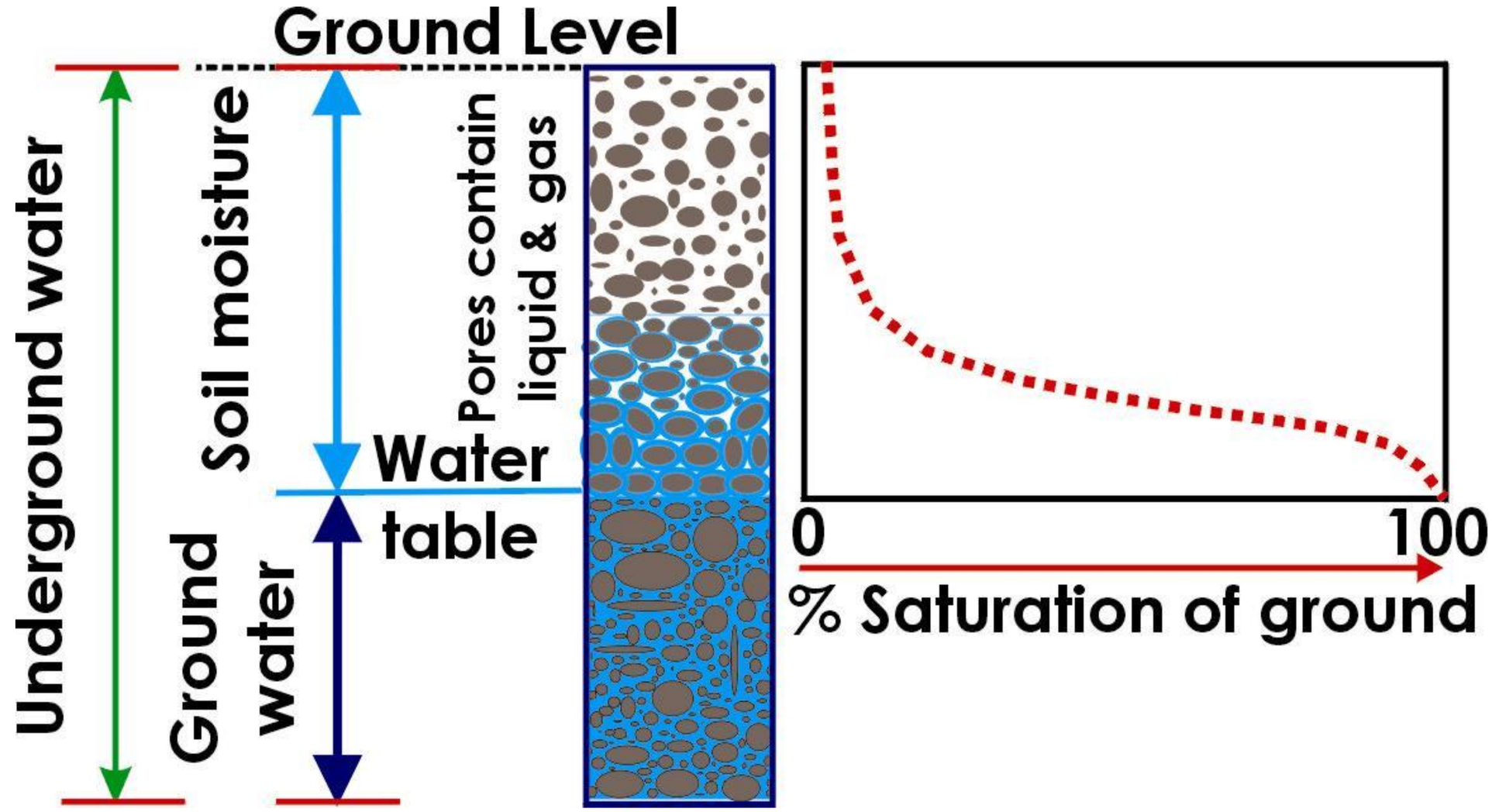
GROUNDWATER

What is groundwater?

- Rainfall that soaks into the ground and moves downwards into soil pore spaces and cracks in rocks.

The study of geological formations that store groundwater is essential for a comprehensive understanding of groundwater.

Groundwater vs Underground Water



Water table – level @ which porewater is @ atmospheric pressure.

Formation of Groundwater

Formed from

- **Infiltration** component – Entry of water into the soil
- **Percolation** of infiltrated water – downward movement of water thru soil/rock (and occurs below root zone).

Formation of Groundwater…..(2)

Both infiltration & percolation depend upon:

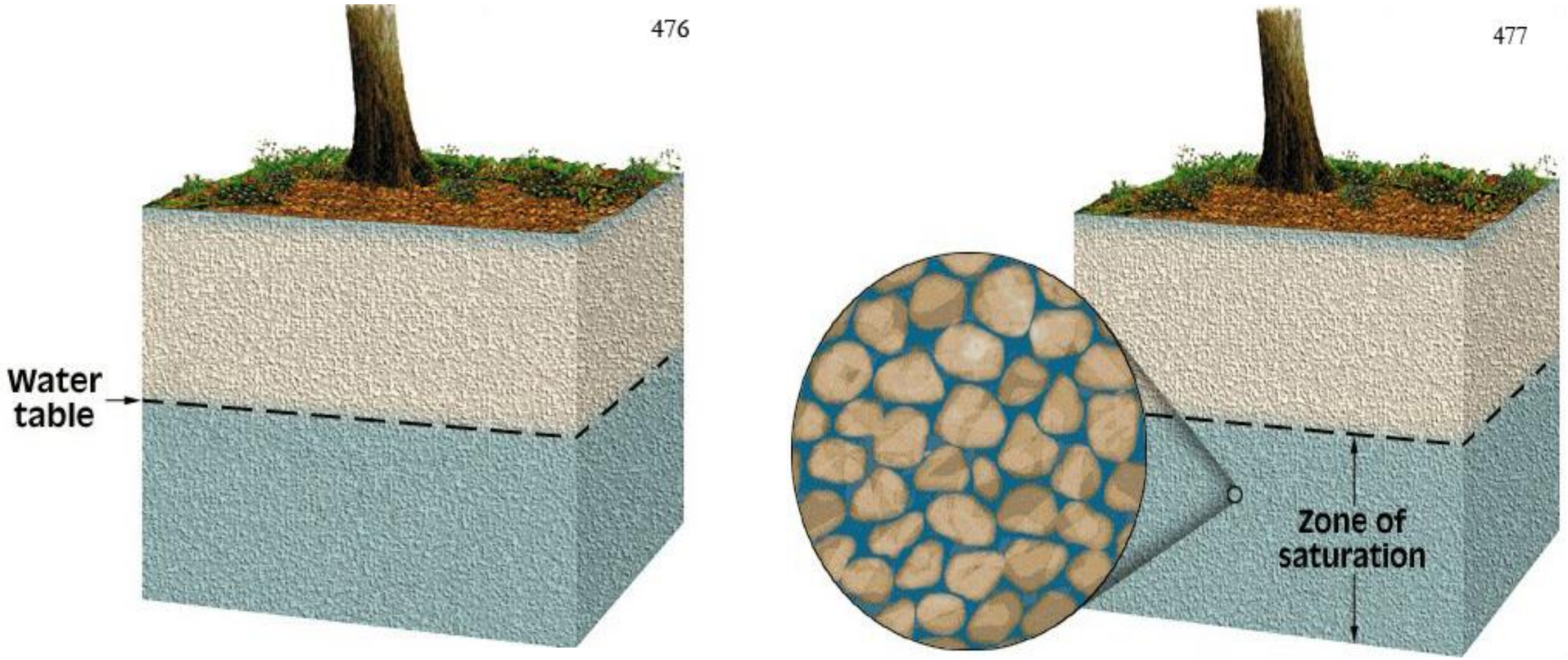
- Size of pores in soil / rock
- Total porosity of soil / rock
- Interconnectivity of soil / rock pores
  - Smaller pores have smaller hydraulic radius, & greater friction between water & pores.
  - Well-graded soils have smaller pores than uniform graded soils.
  - Dense soils are less permeable than loose soils

Groundwater Occurrence

Occurs below surface in **voids, spaces and cracks** between particles of soil and rock

Groundwater Occurrence.....(2)

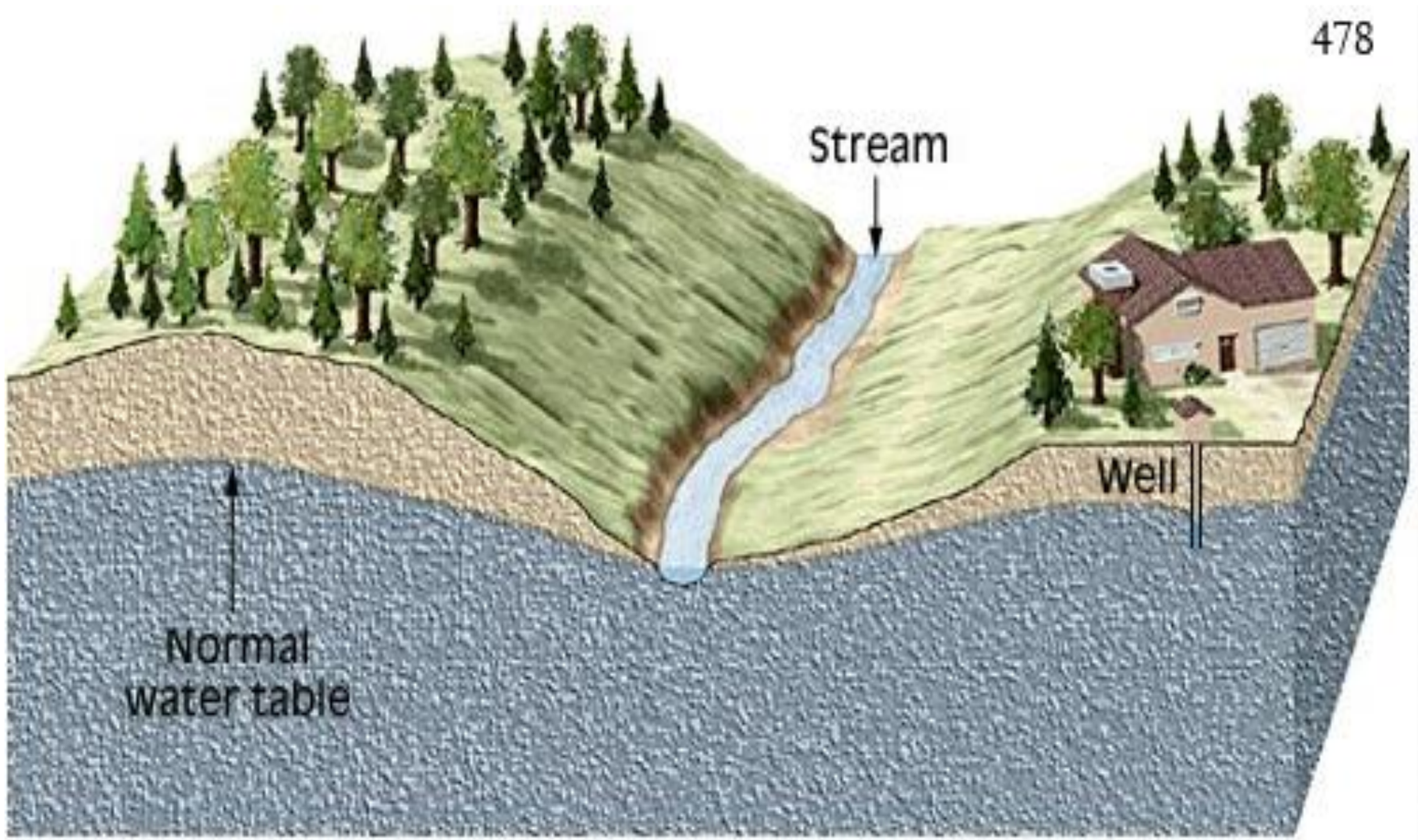
Ppt percolates downwards to the **water table.**



- Below the water table, all pore spaces in sediment & rocks are *filled* with water.
- This is the **zone of saturation**

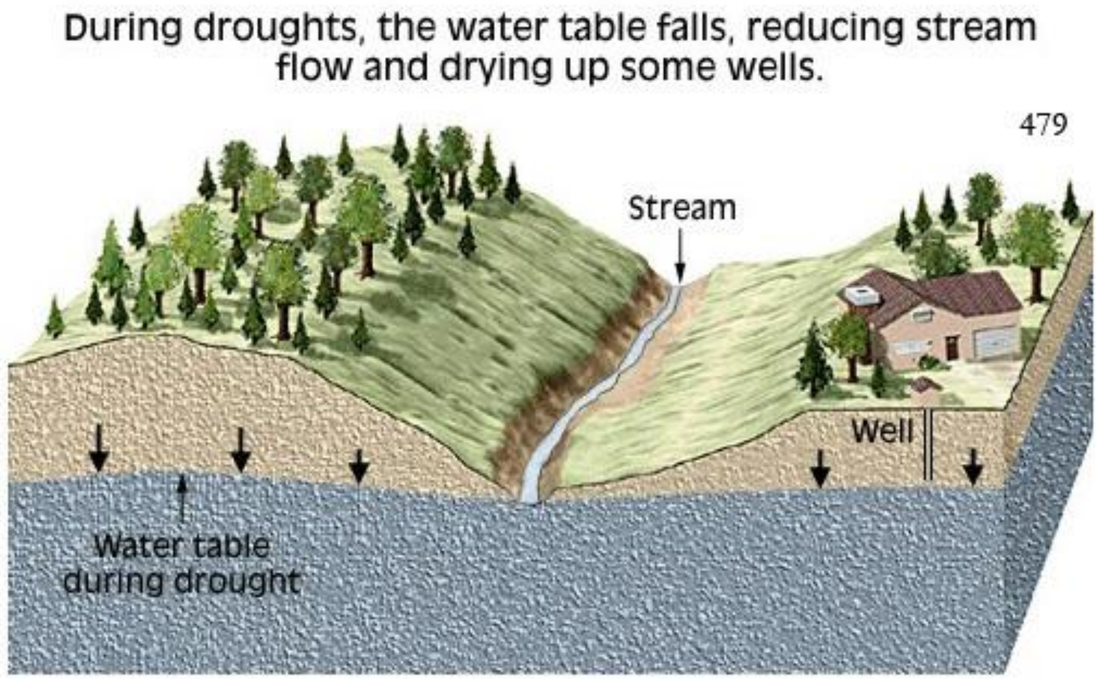
Groundwater Occurrence.....(3)

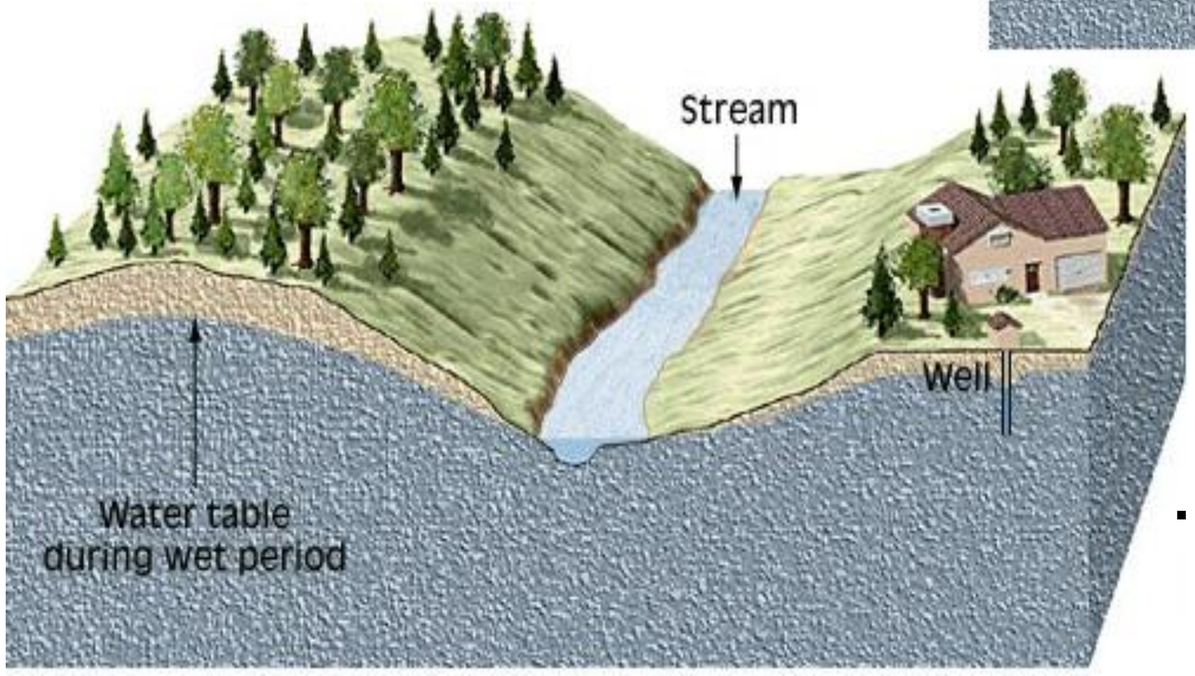
Water table is rarely level. Instead, its shape is a subdued replica of surface topography.



Groundwater Occurrence…..(4)

The height of the water table fluctuates. During droughts, it drops….

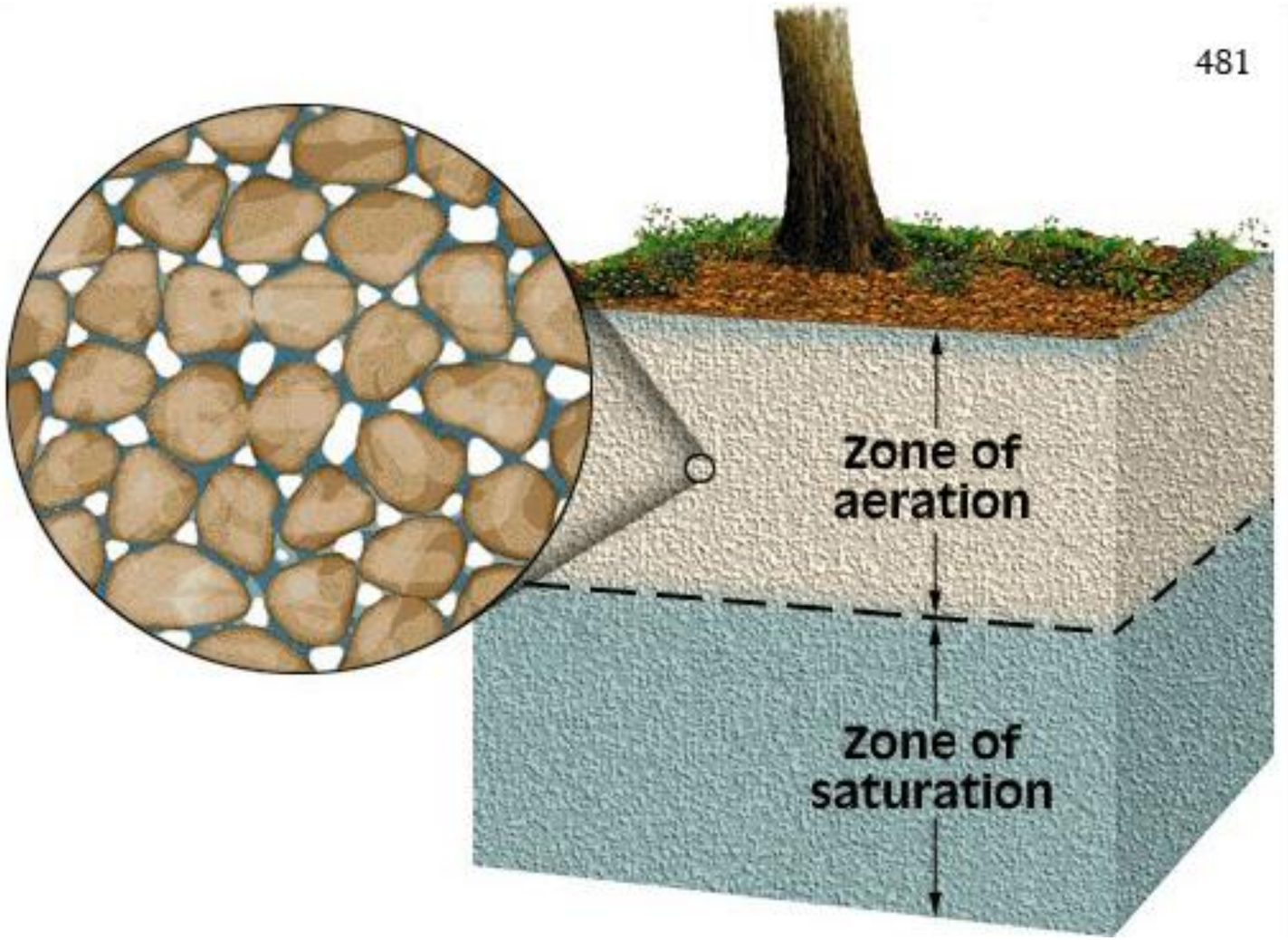




…and rises during wet periods

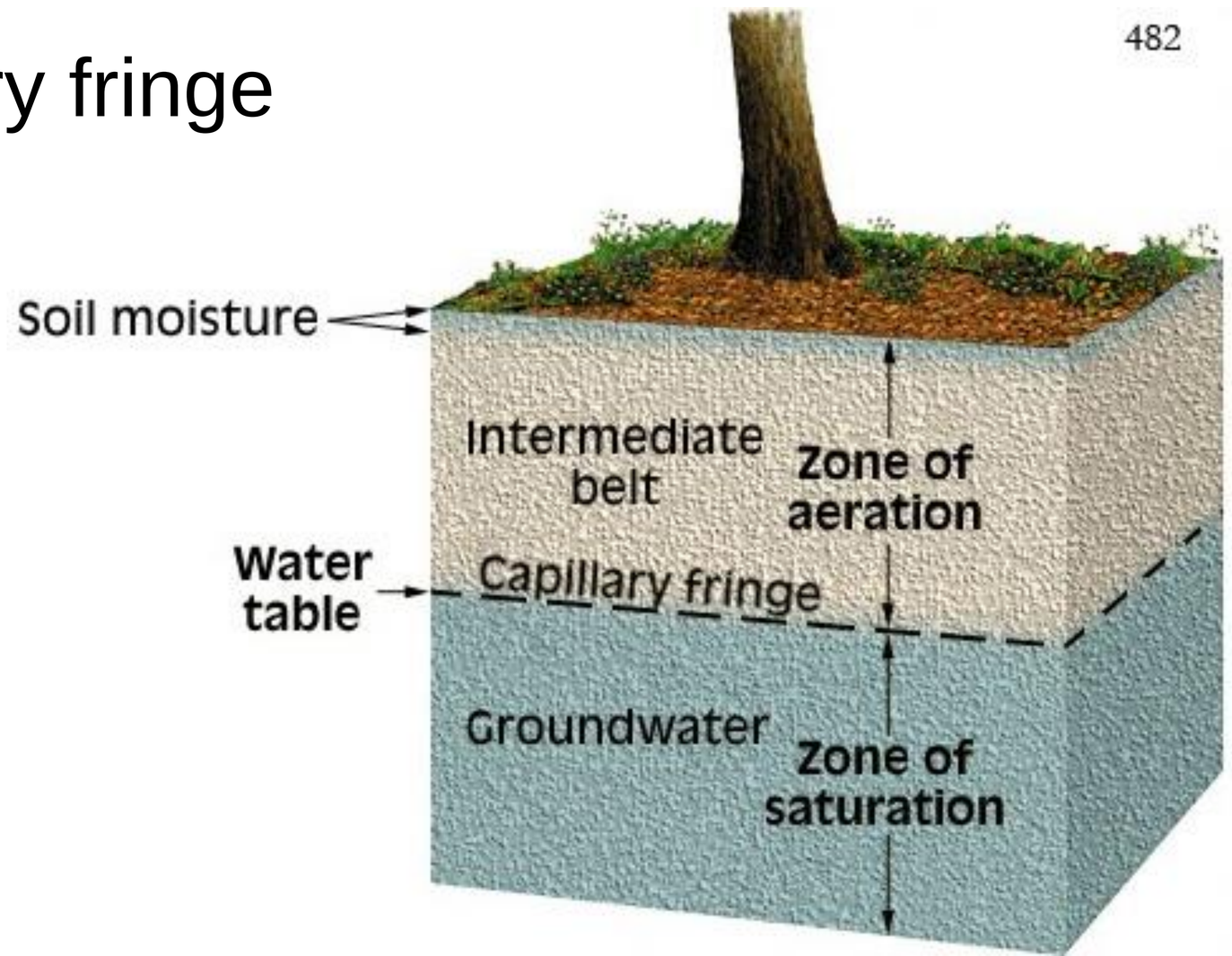
Groundwater Occurrence.....(5)

Above the watertable, pore spaces are unsaturated and filled mainly with air. This is called the zone of aeration.



Groundwater Occurrence.....(6)

The zone of aeration can be further divided into the zone of soil moisture, the intermediate belt and the capillary fringe



Groundwater Occurrence.....(7)

Parts of the Hydrosphere	Volume of Freshwater (km^3)	Share of Total Volume of Freshwater (percent)
Ice sheets and glaciers	24,000,000	84.945
Groundwater	4,000,000	14.158
Lakes and reservoirs	155,000	0.549
Soil moisture	83,000	0.294
Water vapor in the atmosphere	14,000	0.049
River water	1,200	0.004
Total	28,253,200	100.000

Role of Groundwater

Groundwater is very important source of drinking water, & for irrigation.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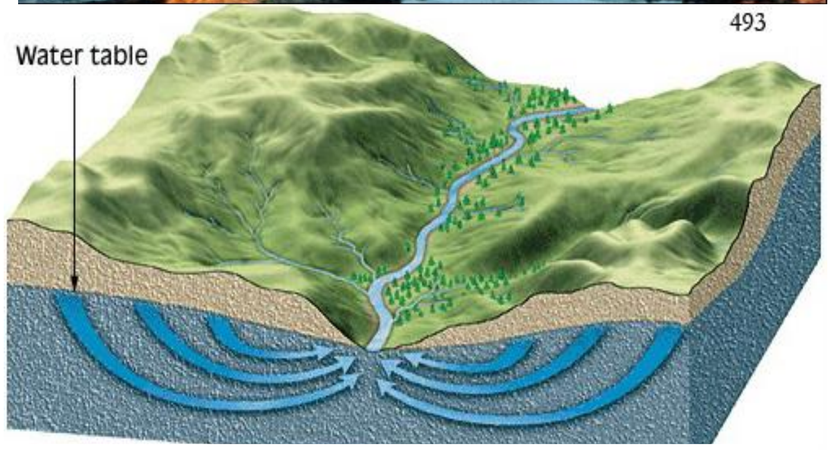
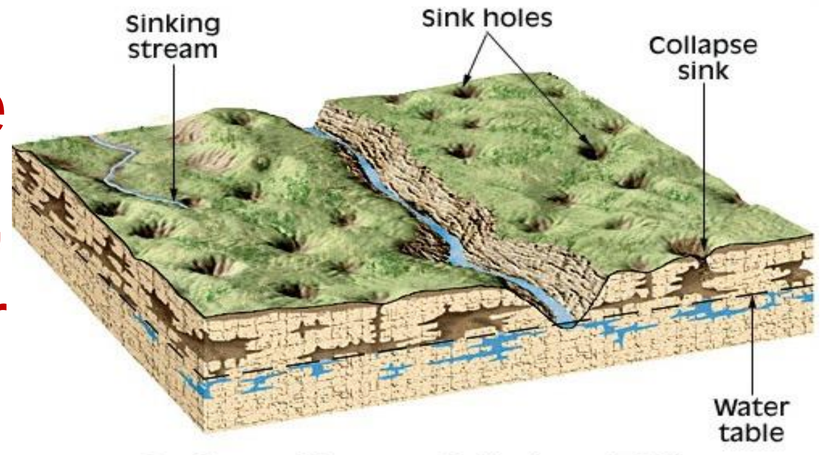
Groundwater has important geologic roles. In humid regions, it contributes significantly to flow of streams



In regions underlain by soluble rocks e.g. in limestone, dissolving action of groundwater creates sinkholes…..



Regions with many sinkholes exhibit *karst* topography.

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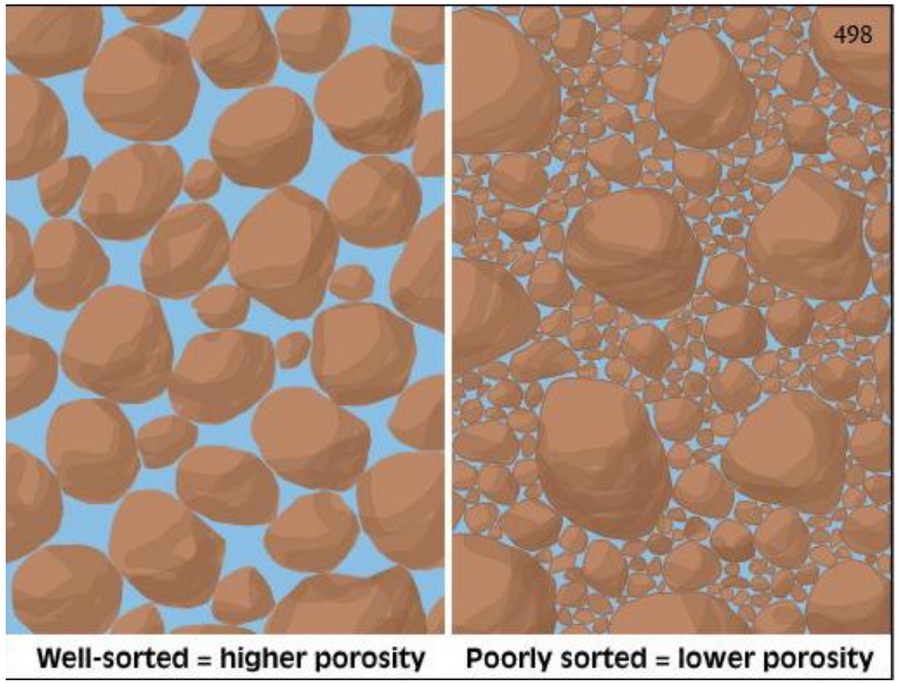
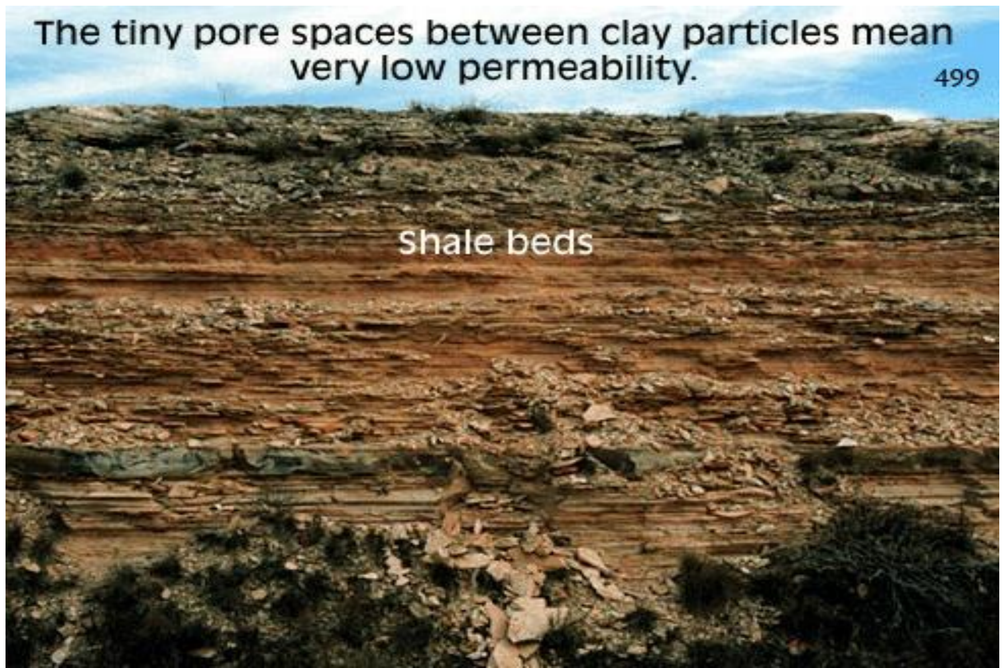
Parameters governing groundwater flow



Quantity of grdwater that can be stored depends on *porosity* of material.

Porosity = *%age of total volm of rock/sediment that consists of pore spaces.*

Permeability = ability of a material to transmit a fluid. If pore spaces are too small, surface tension keeps the water from moving.



Parameters governing groundwater flow…..(2)

- Porosity (stores) η and Permeability (transmits) k

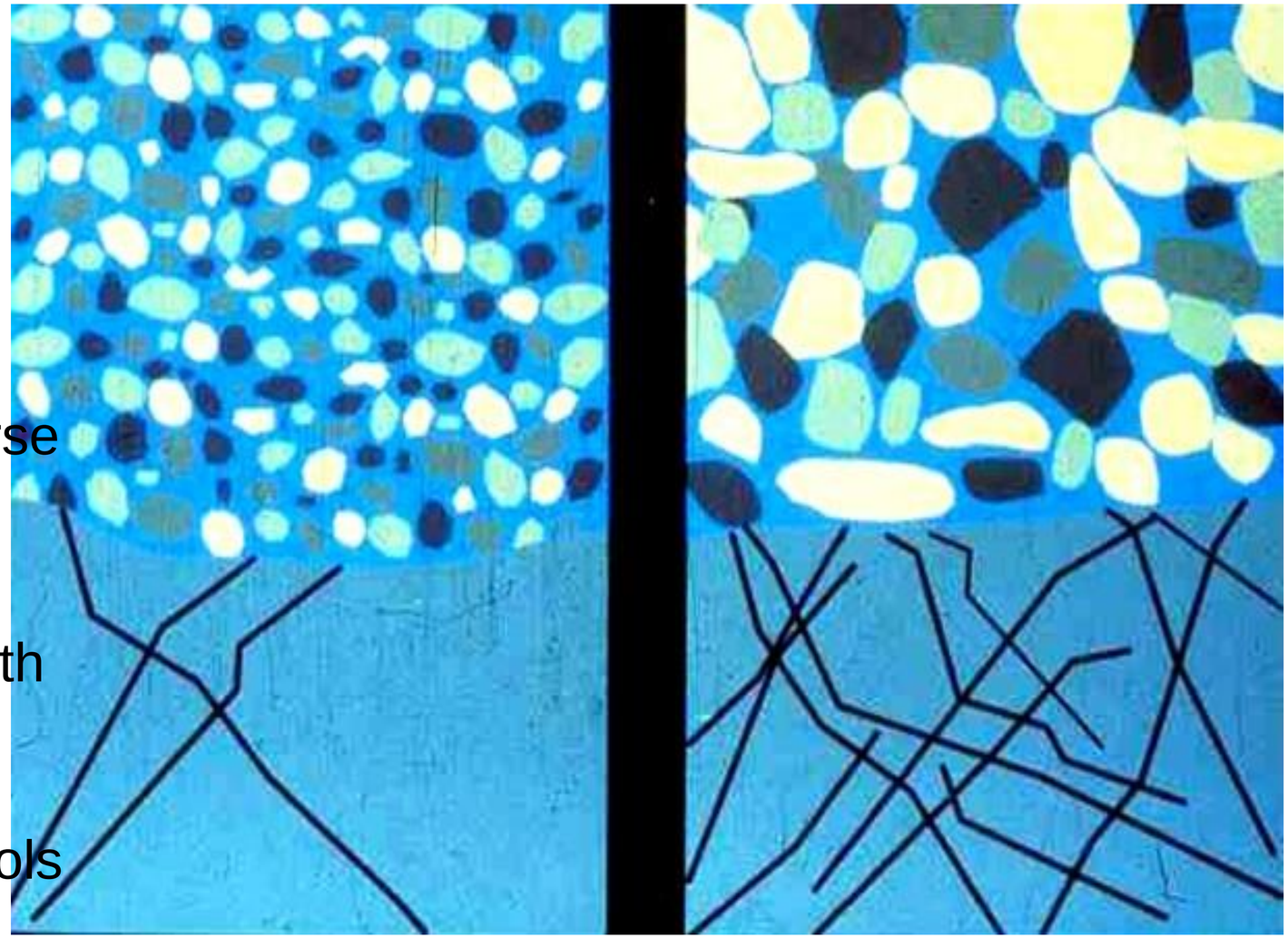
Sediments:

- granular rocks from detrital material
- matrix flow
- Primary porosity

- Fine grained & Coarse grained – shale, sst.

Crystalline rocks:

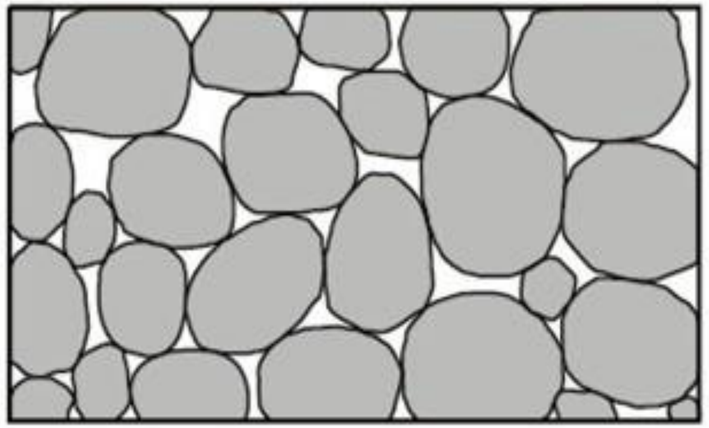
- fractures
- Secondary porosity with water flow only in fractures
- Fracture density controls yield – granite, basalt



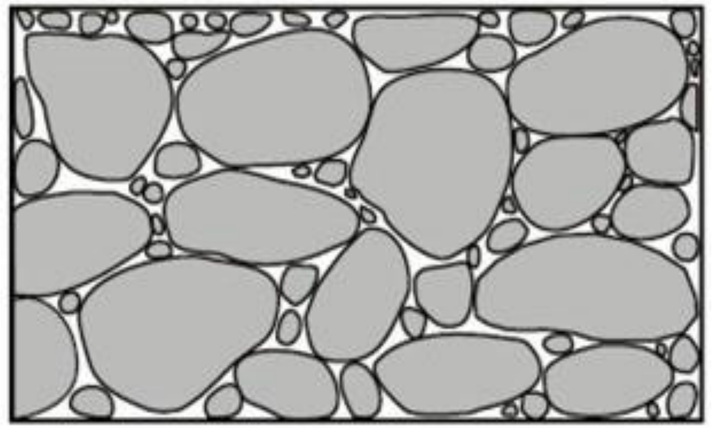
high η, low k
low η, low k

high η, high k
low η high k

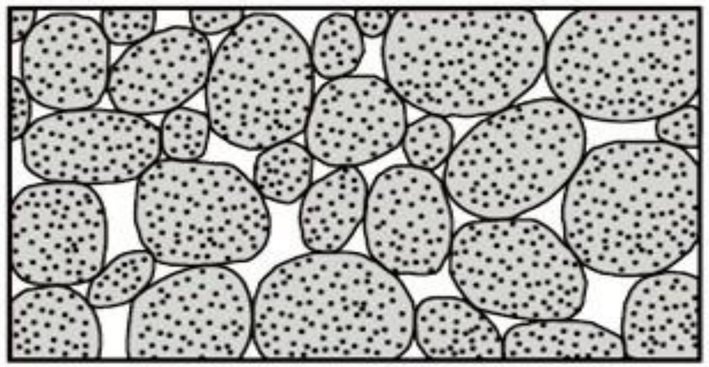
Parameters governing groundwater flow…..(3)



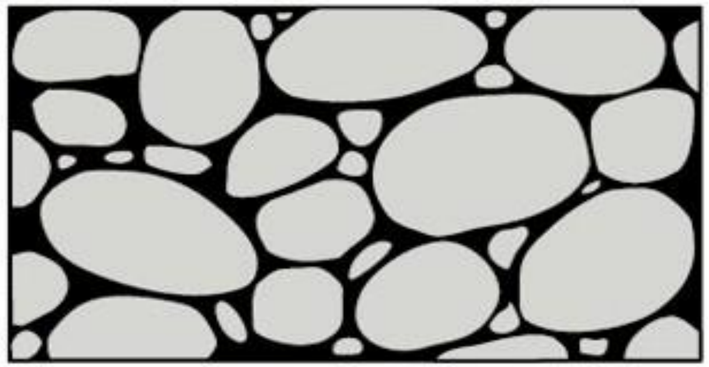
(A) Well-sorted, unconsolidated sedimentary deposit having high porosity



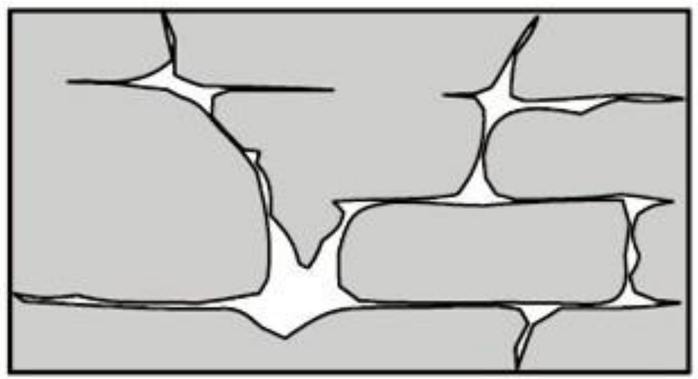
(B) Poorly sorted sedimentary deposit having low porosity



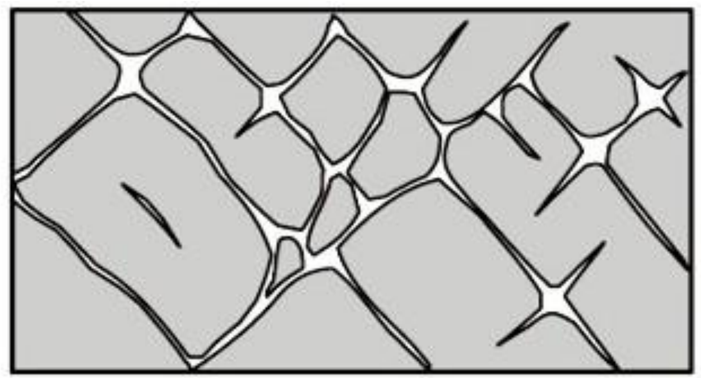
(C) Well-sorted sedimentary deposit consisting of pebbles that are themselves porous, so the deposit as a whole has high porosity



(D) Sedimentary deposit whose porosity has been diminished by the deposition of mineral matter between the grains



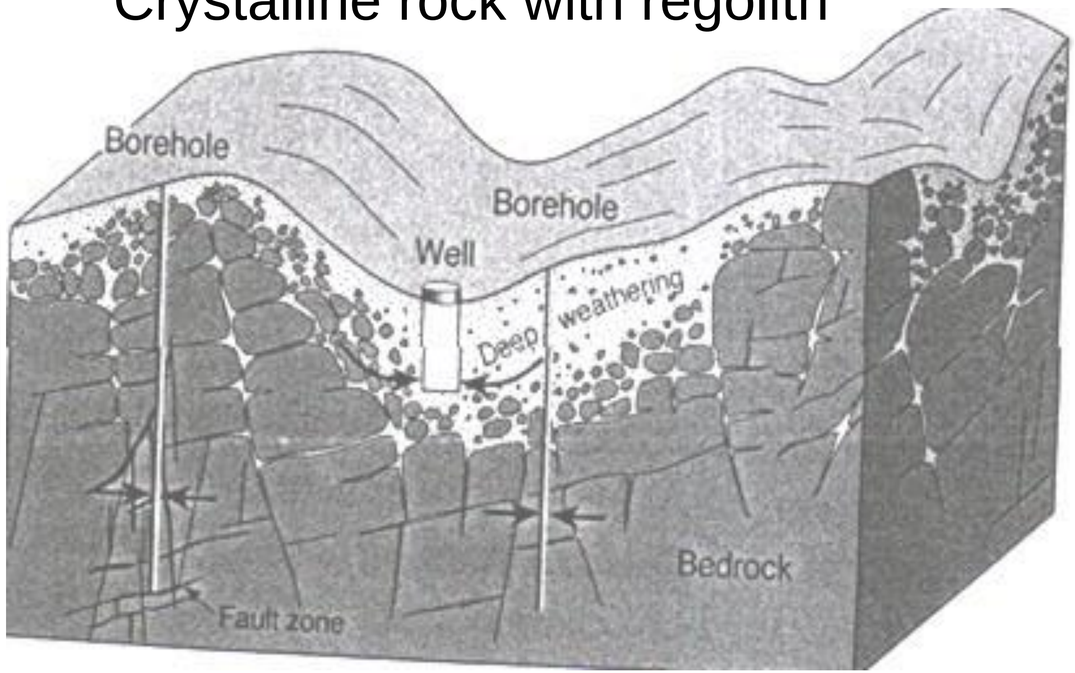
(E) Rock with porosity increased by solution

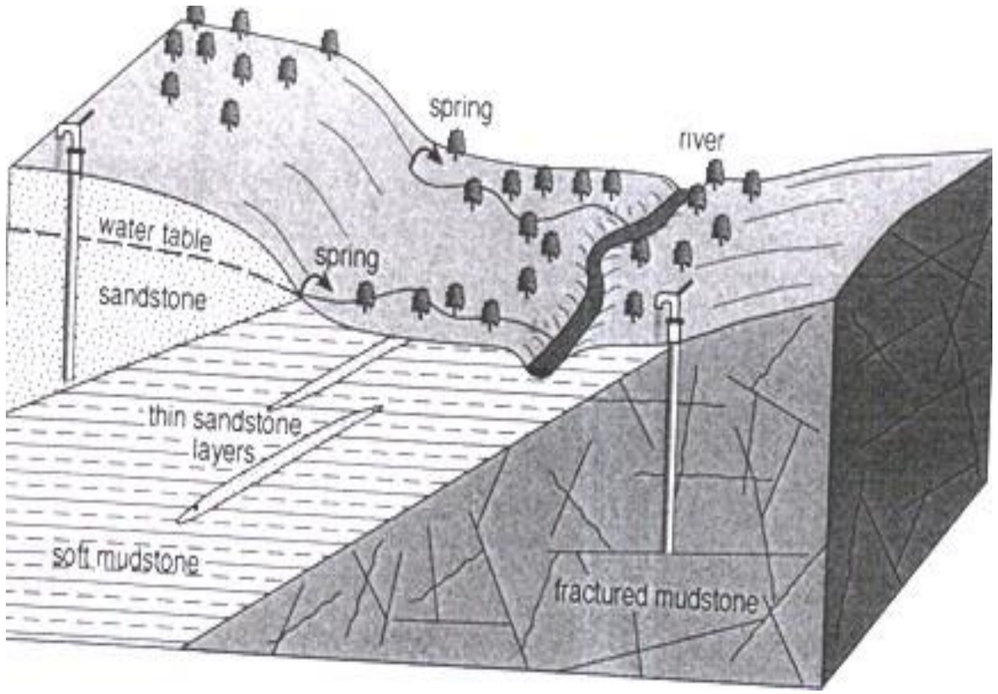


(F) Rock with porosity increased by fracturing

Parameters governing groundwater flow

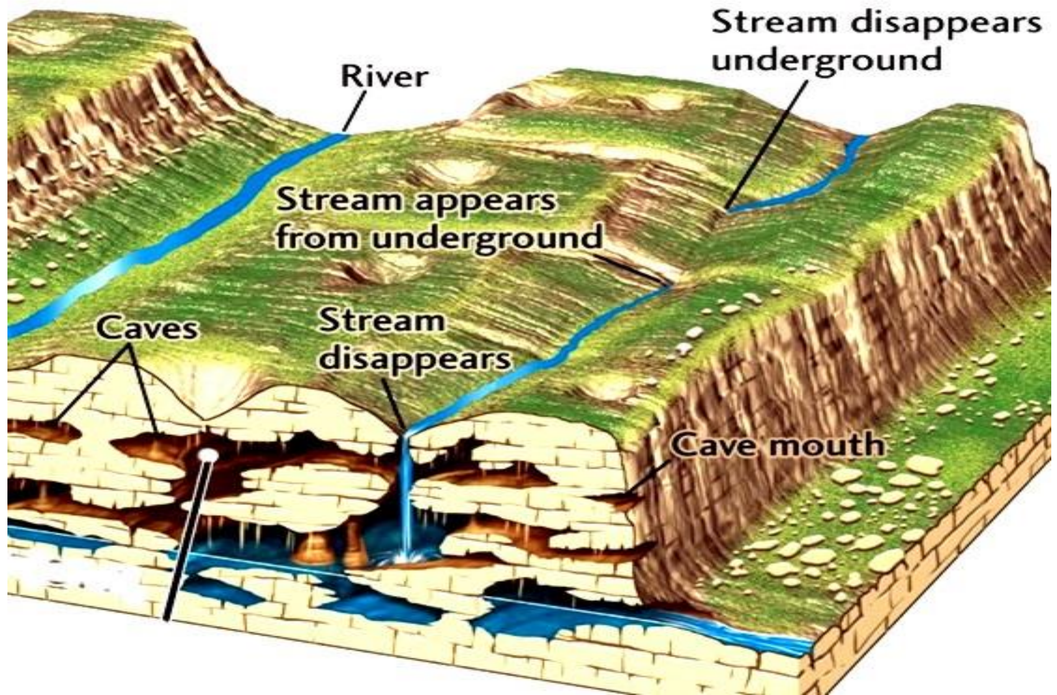
Crystalline rock with regolith



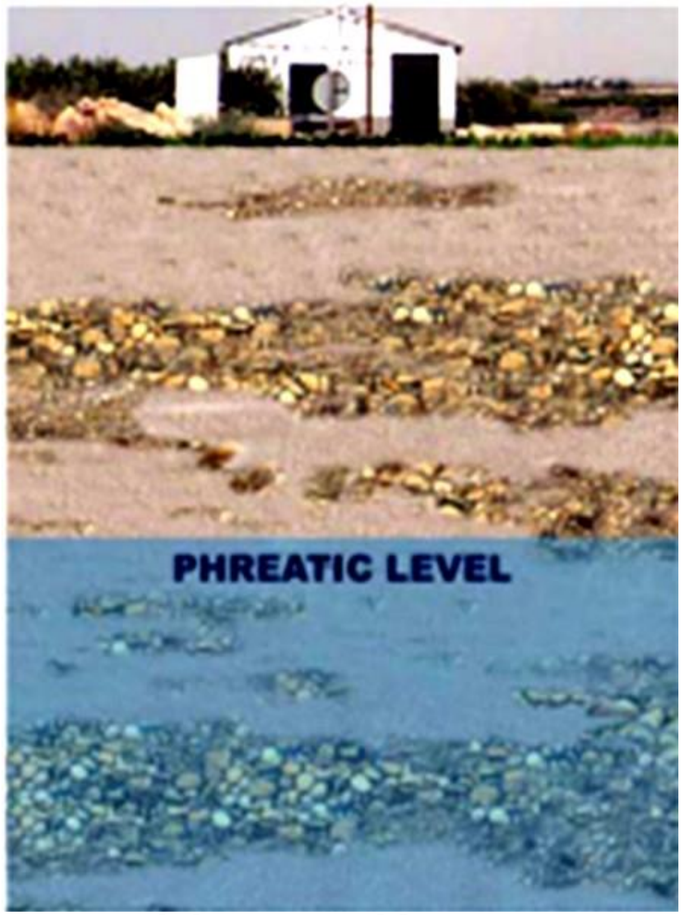


Sedimentary rocks of different types

Karst marble



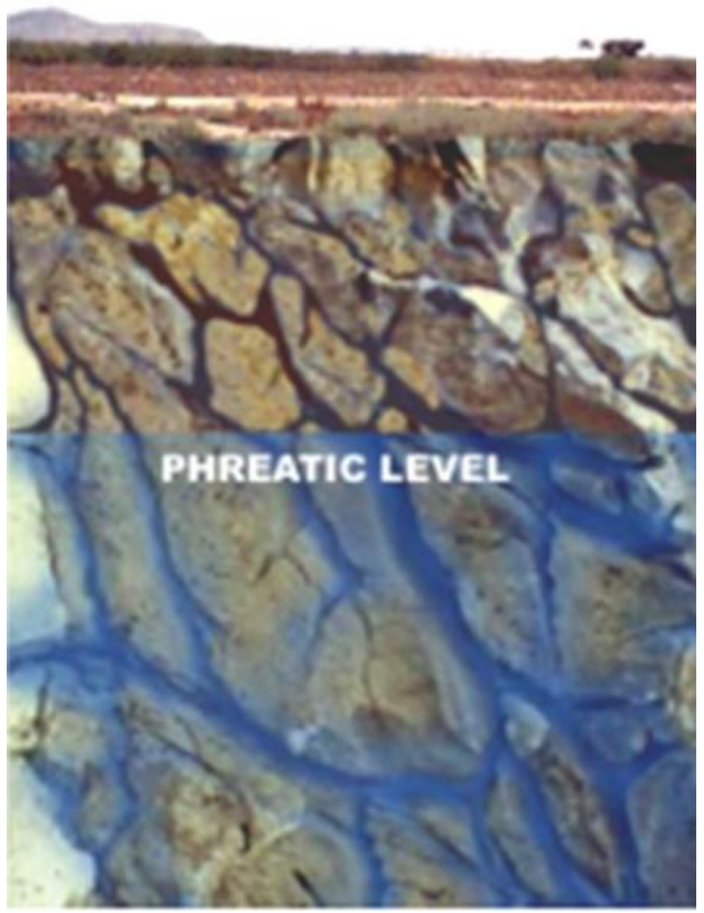
Hydrogeological diversity



Detritic aquifer

Unconsolidated rocks:

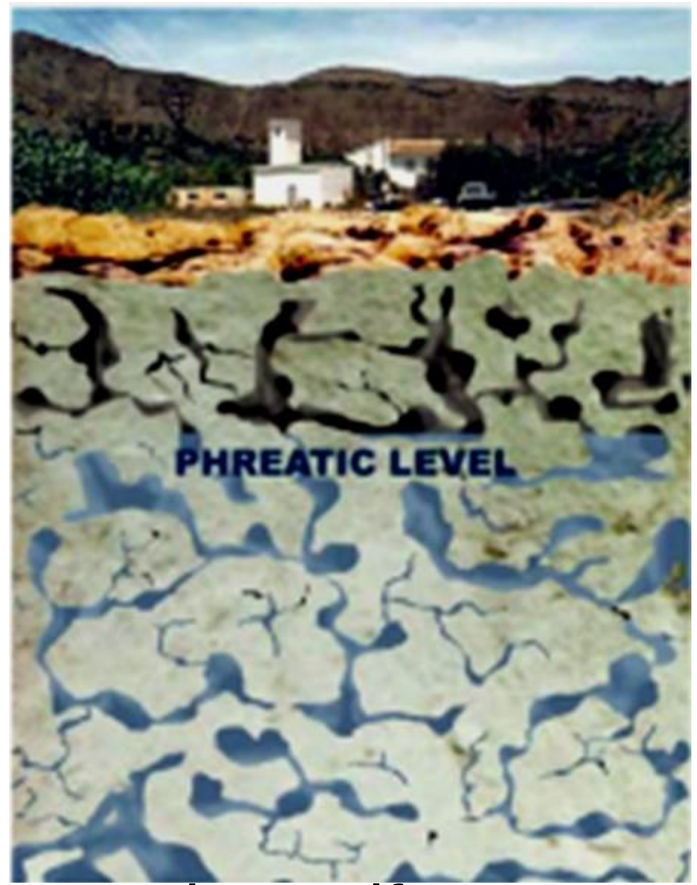
- Primary Porosity
- Large storage
- Locally high permeability



Fissured aquifer

Consolidated rocks:

- 2ndary fracture porosity
- Small storage
- Low permeability



Karstic aquifer

Consolidated rocks:

- Karsts (enlarged fractures)
- Moderate storage
- High permeability

GROUNDWATER SUPPLIES & ITS QUALITY ASPECTS

Special characteristics of Groundwater

- Is a vital resource to most of the people, who depend on it for their water supplies.
- It provides low-cost, drought-reliable & high-quality water supplies for both urban + rural populations

  ∴ will be vital for achieving water MDGs.
- its replenishment is finite & ltd. to shallower aquifers, & whose quality can seriously be degraded by pollution.

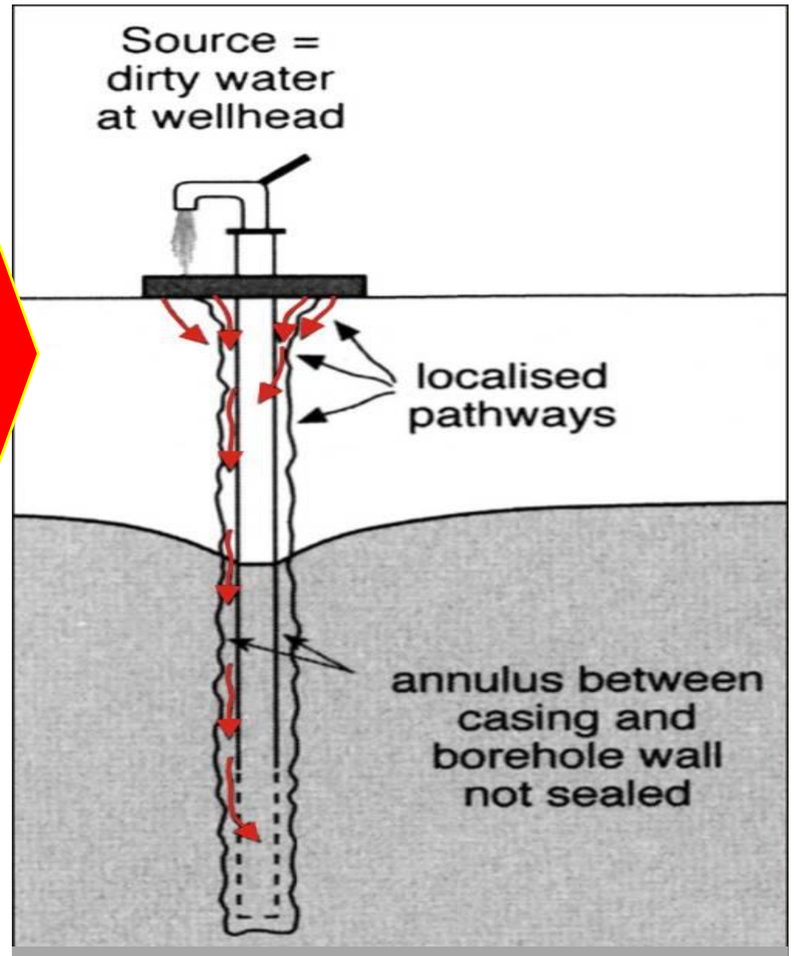
Groundwater – A source of rural water supply

- Currently supplies about 47% of Africa‘s rural population [while 53% still remains without access to safe water (AfDB 2009)]
- Is a predominant source of ***Safe drinking water*** through hand-dug-wells and drilled wells with hand pumps.
  - Frequent reports (in literature) indicate elevated nitrate levels and bacterial contamination.

Contamination sources for rural water supplies

dirty water at well head recirculating into the well

Nkhuwa, 2009



McDonold et. al. (2005)

Contamination sources for rural water supplies (2)

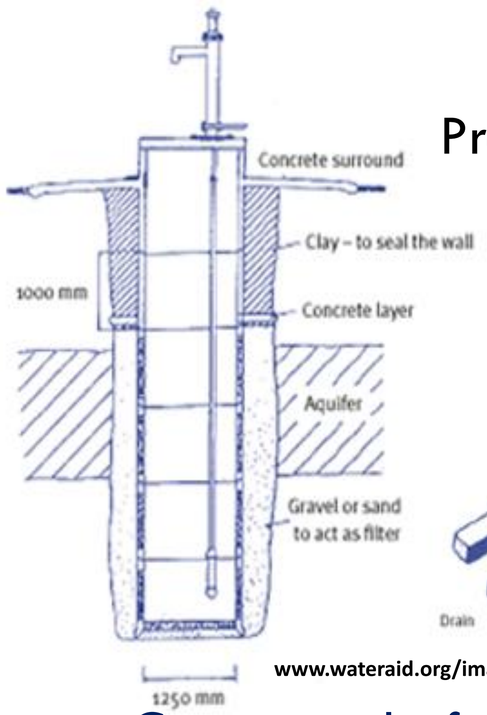
Nkhuwa, 2006 Pollution from animal-faeces

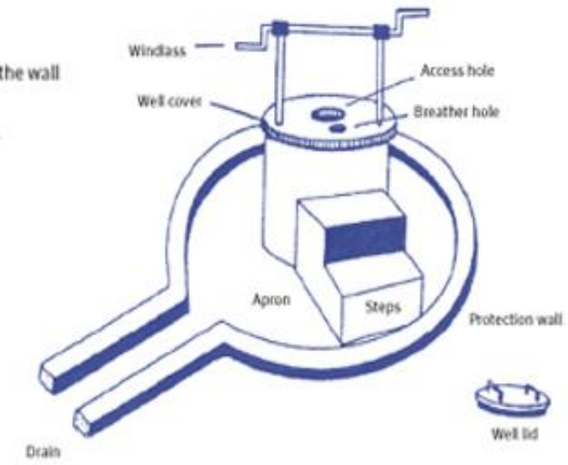
Remedial measures for rural water sources

- Proper well construction can significantly improve water quality
- Well location upstream/away from pollution sources – *pit latrines, waste dumps, cemeteries, etc.*
- Concrete platforms around well, & with proper drainage
- Animals must be kept away by a fence.

Protection measures…..(2)

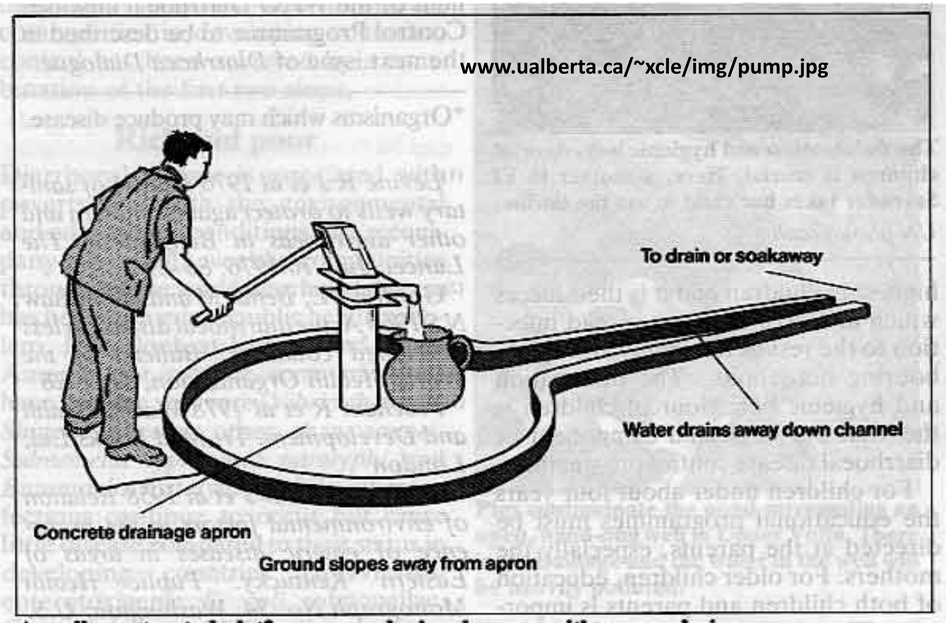
Proper well construction





www.wateraid.org/images/cm_images/pump-web.jpg

Concrete platforms around the well



A well constructed platform around a hand pump, with proper drainage.

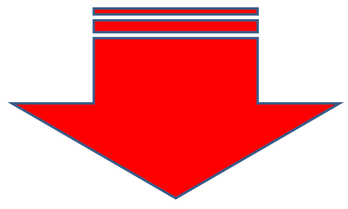
Fencing to keep away animals

Wells must be located upstream/away from pollution sources – *pit latrines, waste dumps, cemeteries, etc.*

Peri-urban settlements

Present situation in Peri-urban settlements in Africa:

- Uncontrolled settlement
- Predominant use of on site-sanitation
- Uncontrolled waste dumping
- Water supply predominantly from dug wells or water ponds



- Extensive contamination by nitrate, nitrite, ammonia, and faecal bacteria
- Frequent outbreaks of water-borne diseases (cholera).

Contamination sources in Peril-urban settlements…..(2)

Choice of location of pit latrines in high-density settlements

Strategies to improve water pollution in peri-urban areas

- Connection to public water supply (piped water system)
- Connection to sewerage system

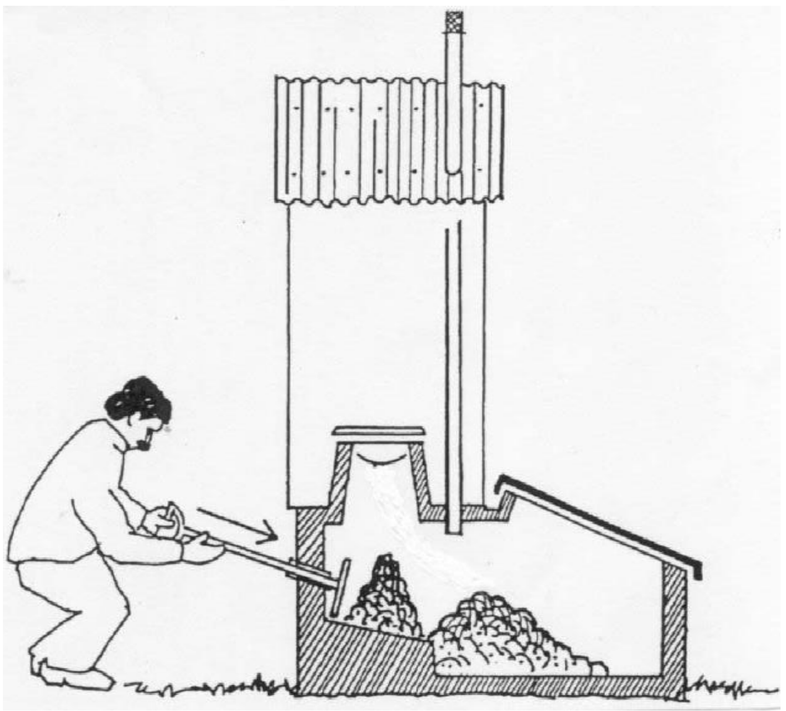
Both these options are very expensive

∴ Ecosan Toilets would provide alternative systems

Strategies to improve water pollution in peri-urban areas

- Improvement of on-site sanitation through reuse of faecal matter (dry toilets – ecosan).

Dehydrating toilets

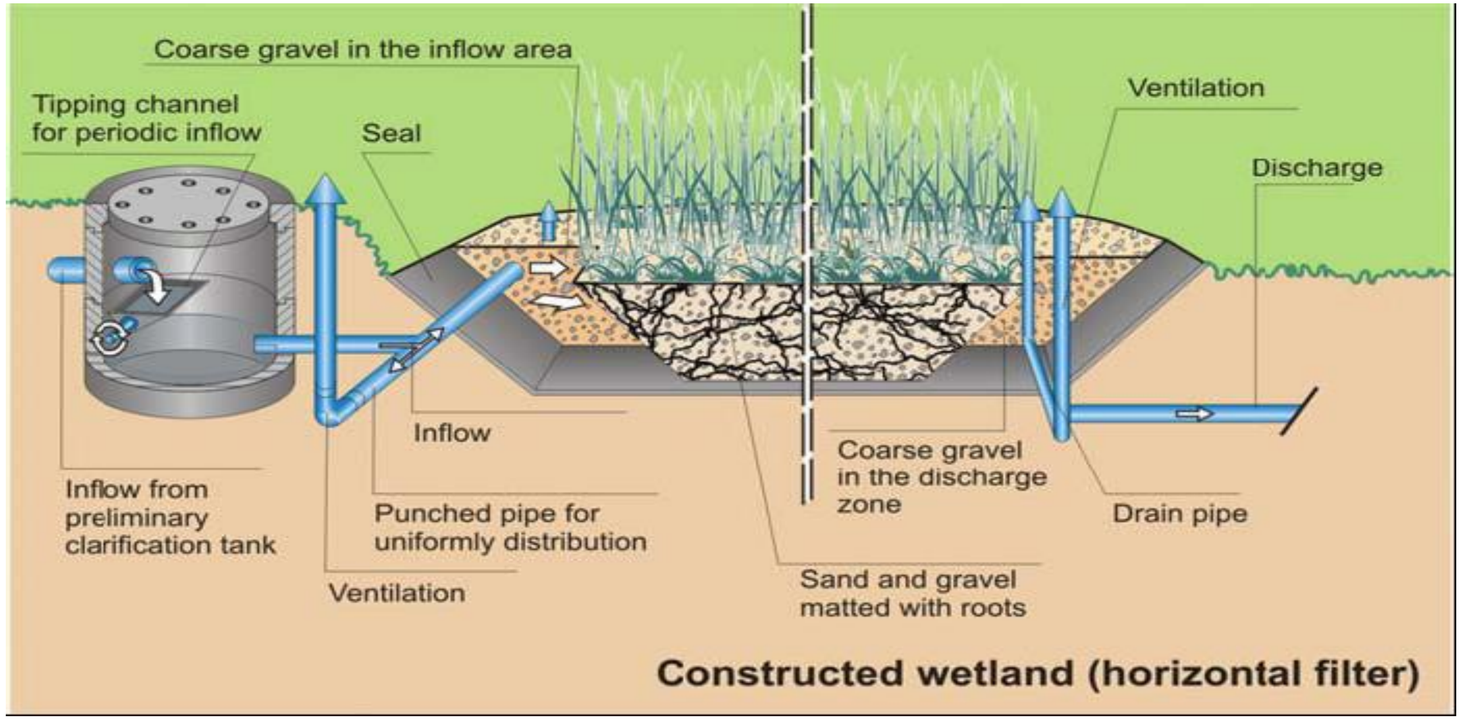


Source: CSIR 2004

Strategies to improve water pollution in peri-urban areas

- Improvement of on-site sanitation through use of low cost wastewater treatment.

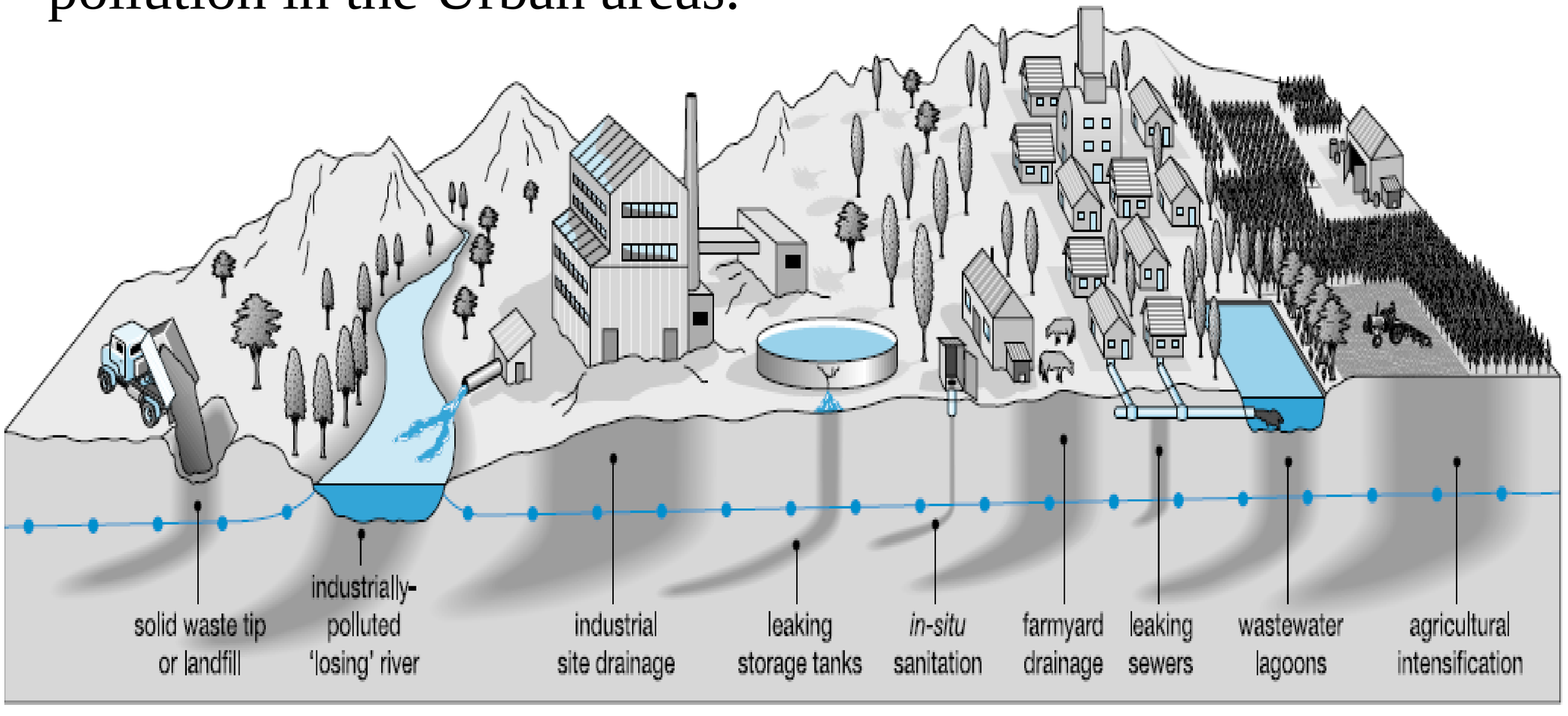
Wastewater treatment



Source: BGR 2008

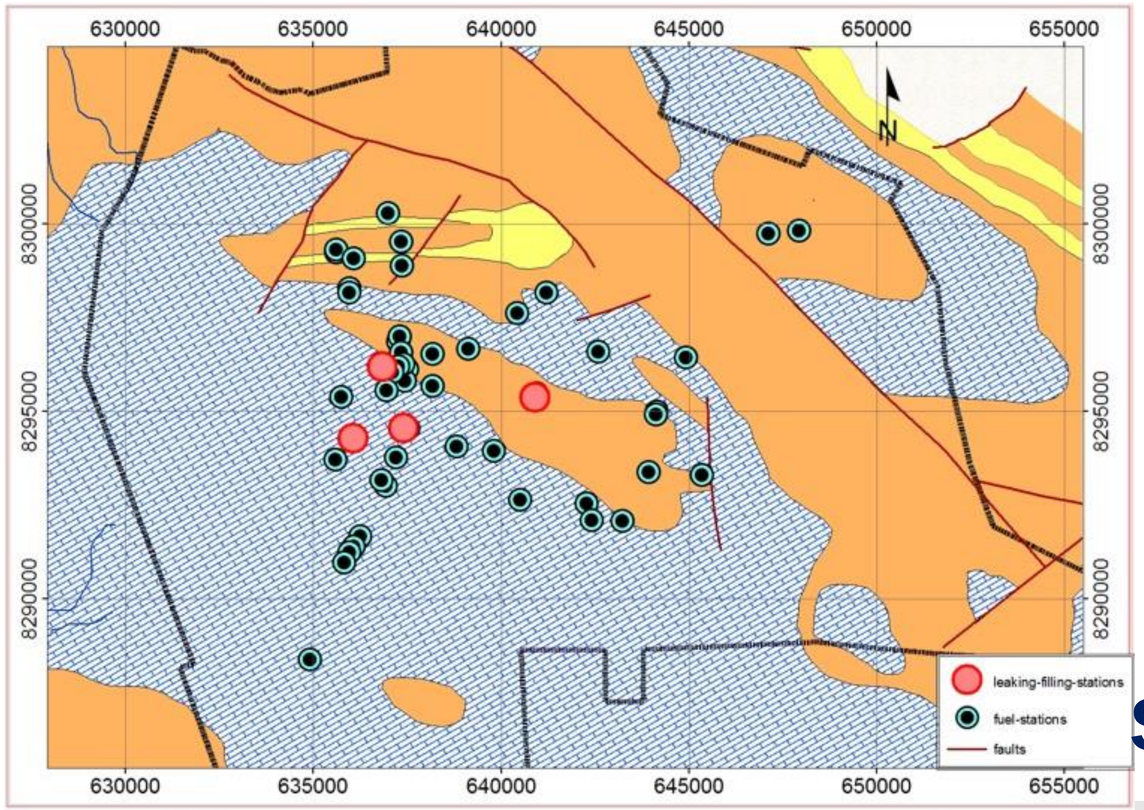
The Urban Environment

Land-use activities commonly responsible for groundwater pollution in the Urban areas.

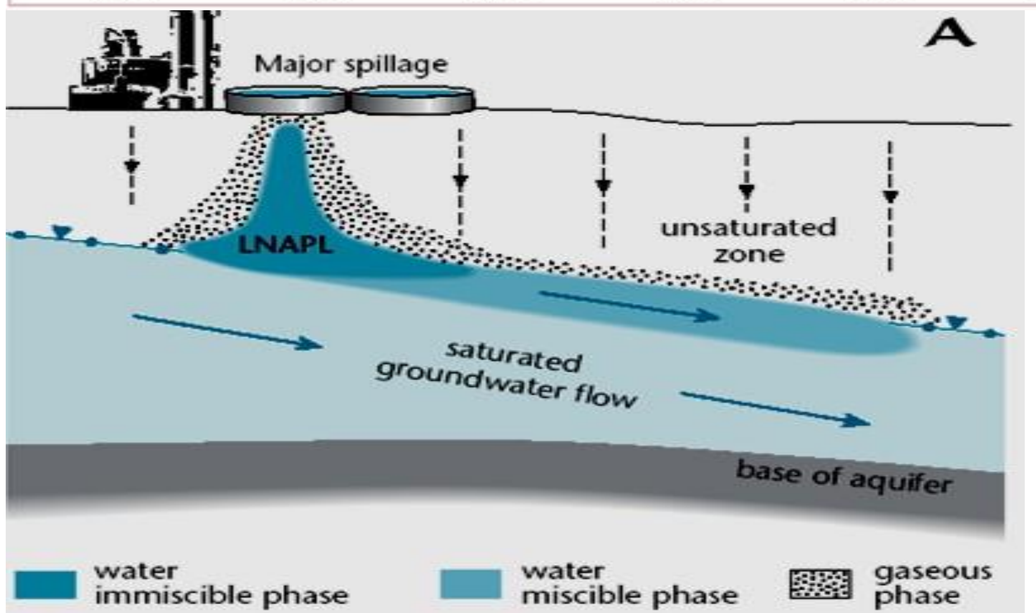


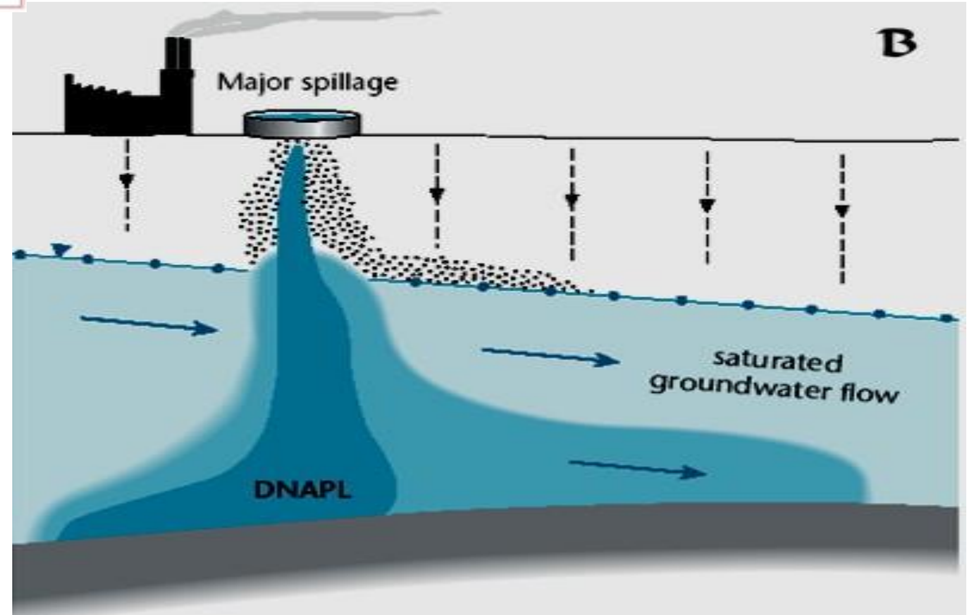
Source: GW-Mate

Contamination sources in urban settlements



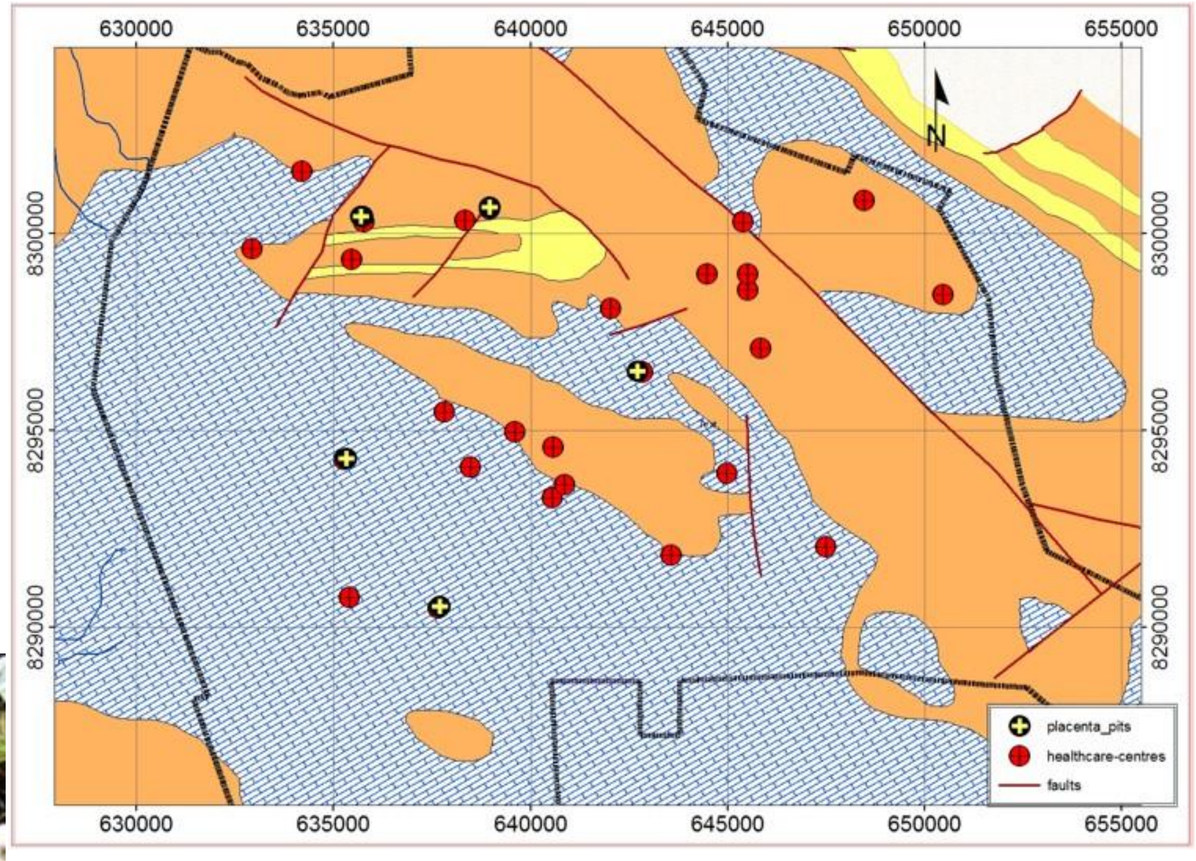
Spread of filling stations





Contamination sources in urban settlements.....(2)

Spread of filling stations...



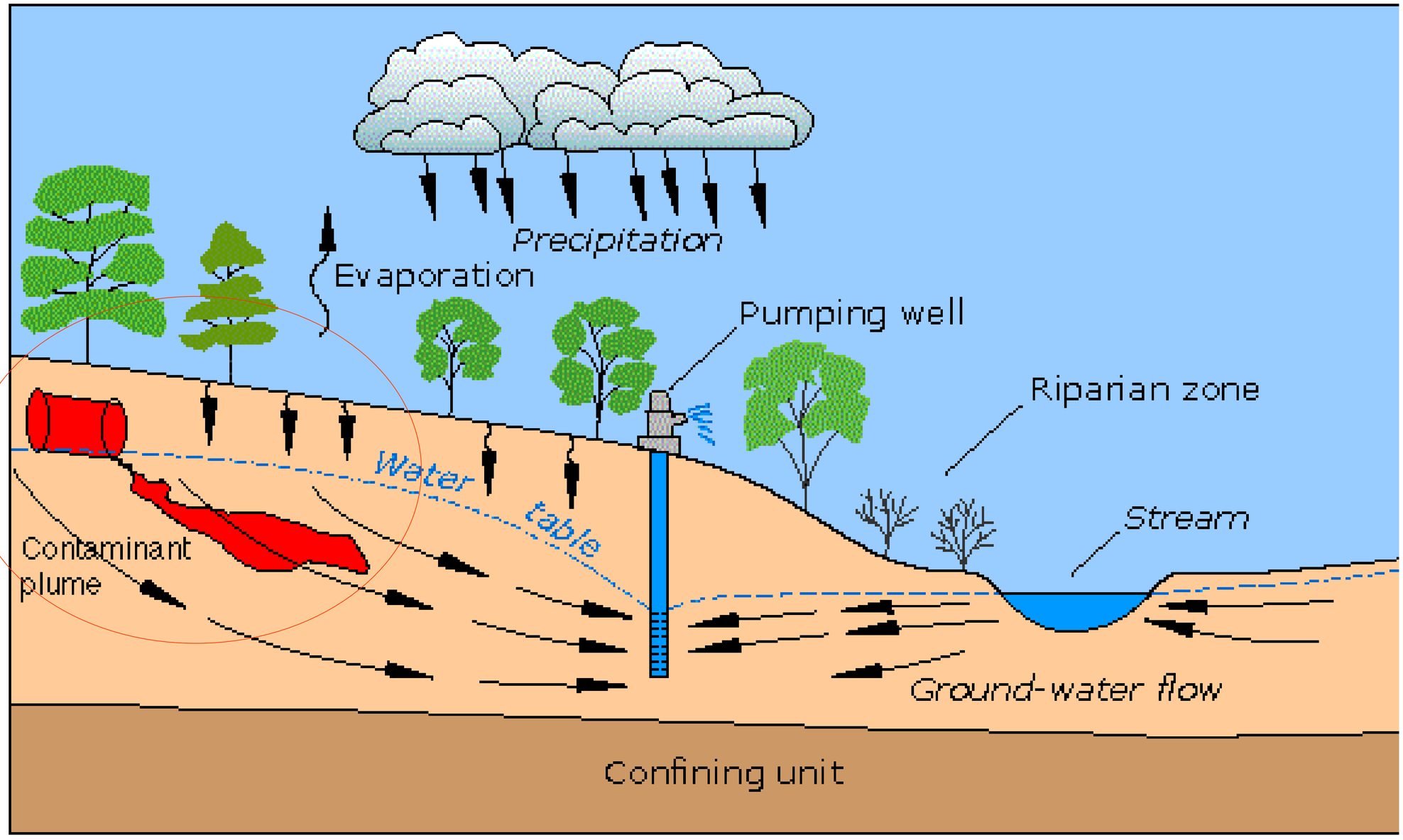
Contamination sources in urban settlements.....(3)

Contamination sources in urban settlements…..(4)

Disposal of
Incinerated material

Contamination sources in urban settlements.....(4)

Contamination sources in urban settlements.....(5)



Remedial measures

Protection of the Resource:

- Common approach worldwide:
  - Protection of water resources by Groundwater Protection Zones (GPZ) – *will deal with this later.*

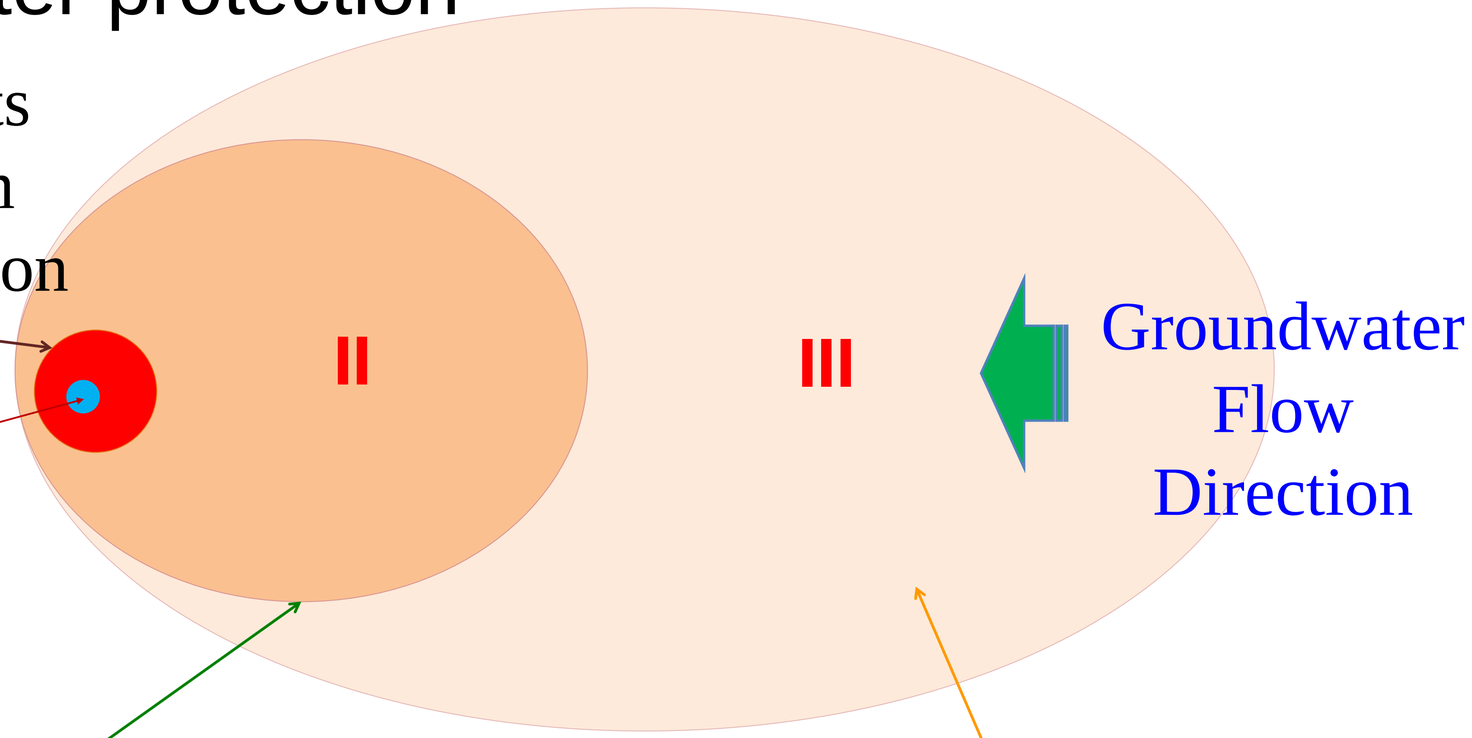
General aim:

- To Protect drinking GROUNDWATER resources, upstream of a well or spring, from pollution.

Remedial measures.....(2)

....Groundwater protection

Zone 1 – Protects well/spring from direct contamination



Zone II – Protects drinking water source against pathogenic micro-biological constituents *bacteria*, *viruses*, *parasites*.

Zone III – Protects against contamination affecting drinking water source over long distances (for chemical substances, which are non- or hardly degradable)

End of Lecture