Water Resources Engineering and Management

(CIVIL-466, A.Y. 2024-2025)

5 ETCS, Master course

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Platform of hydraulic constructions

Lecture 2-1: Water resources, hydrological cycle and availability

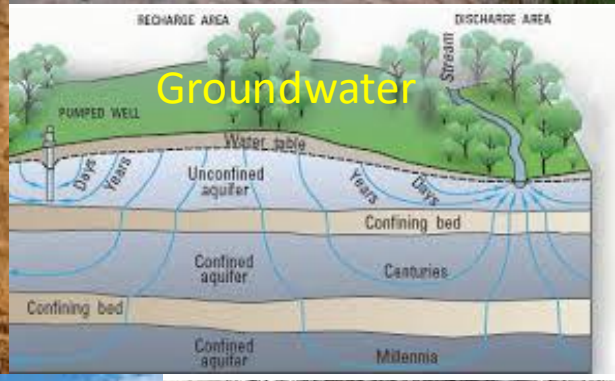
Water engineers and managers deal with several water related problems…

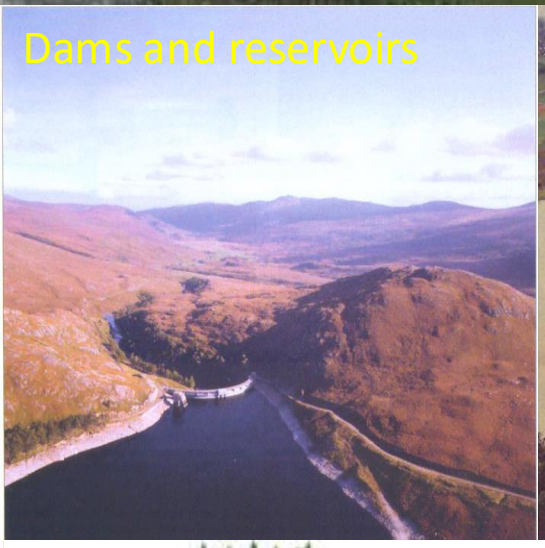

Rainfall

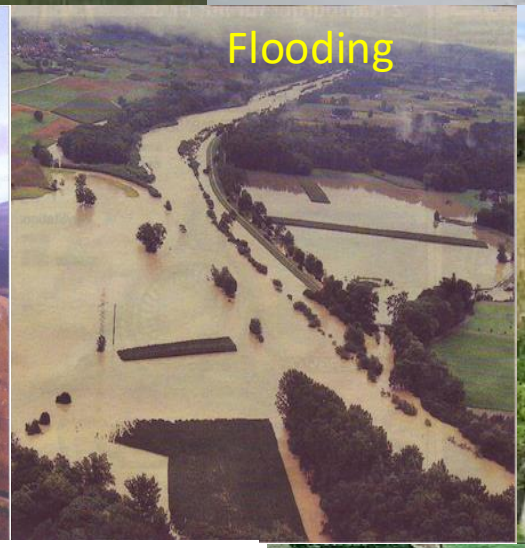

Snowfall


Vegetation and
soil moistures


Surface Runoff


RECHARGE AREA
DISCHARGE AREA
Stream
Groundwater
PUMPED WELL
Water table
Days
Years
Unconfined
aquifer
Years
Days
Confining bed
Confined
aquifer
Centuries
Confining bed
Confined
aquifer
Millennia


Dams and reservoirs

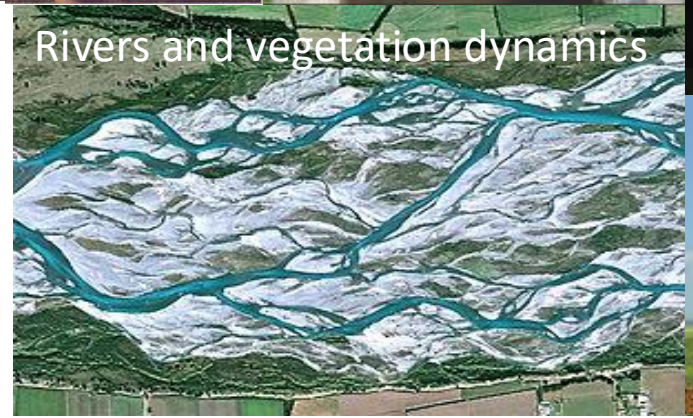

Flooding


Irrigation
and
drainage
systems

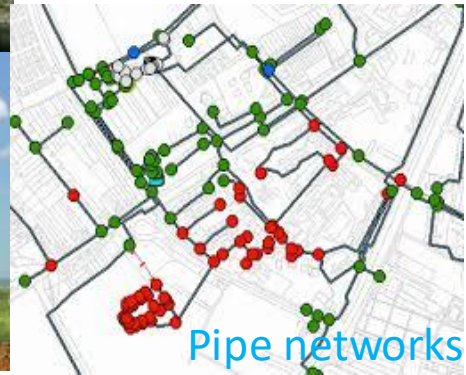

Aqueducts


Sewer
systems


Hydropower
Head Water
Tail Water
1 Gates
2 Penstocks
3 Inlet valve
4 Turbine
5 Generator
6 Automation, control, protection
7 Medium-voltage switchgear
8 Power transformer
9 High-voltage switchgear
10 Transmission line


Rivers and vegetation dynamics

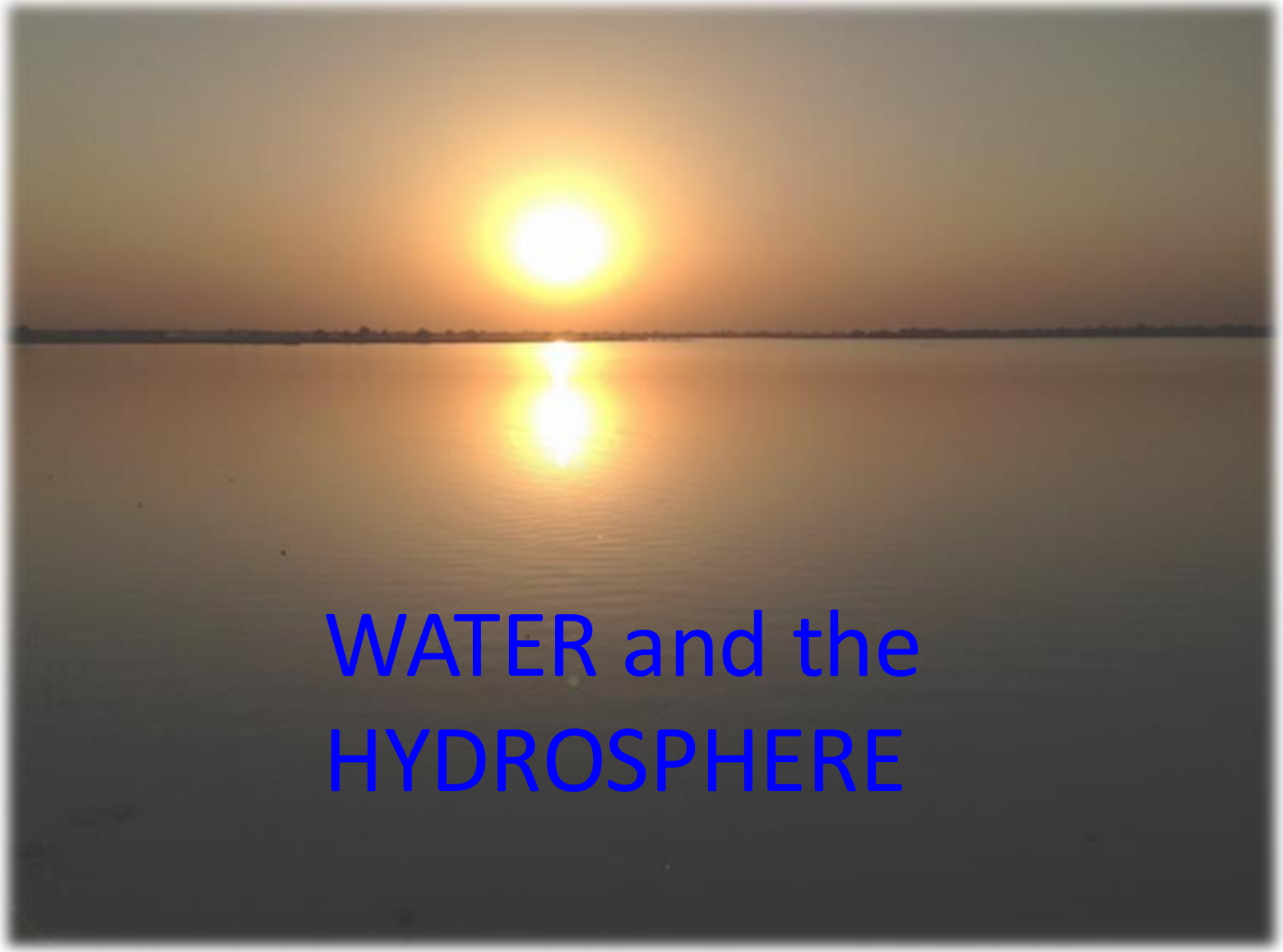

Embankment
and protection


Pipe networks

Some typical questions to answer

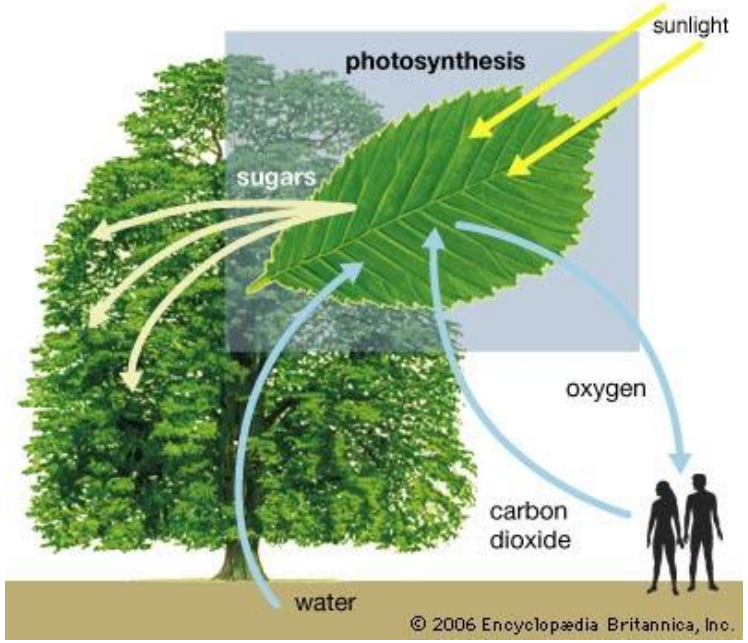
- How much water and for how long is it available?
- Too much water, what do we do?
- Too less water, what do we do?
- How much water can be withdrawn and used?
- Limits of groundwater recharge?
- How to maintain water quality (physical and chemical)?
- Period of renewal of water bodies?
- What is the level of sharing of water bodies among riparian states?
- What are and how to consider environmental uses?
- How do we solve conflicts with cooperative solutions?

Let‘s begin then with revisiting water availability on Earth…



Water is integral to life

- Water is the dominant working fluid of our bodies
- Water plays an important role in the body's thermal regulation system, particularly in preventing overheating.
- Water functions as an important reactant in the food chain:
  - Green plants: $6CO_2 + 6\ H_2O$+ sunlight energy $\rightarrow C_6H_{12}O_6 + 6\ O_2$
  - Our bodies: $C_6H_{12}O_6 + 6O_2 \rightarrow$ metabolic energy + $6CO_2 + 6\ H_2O$
- Water is an essential, natural waste product of metabolic processes.



Some physical properties of water

- Over the range of ordinary environmental temperatures and pressures, water exists widely in all three phases: solid, liquid and gas.

Property	Symbol	Value
Density	ρ	0.998 g/cm^3
(Dynamic) viscosity	μ	0.0100 g/cm s
Kinematic viscosity	ν	0.0100 cm^2/s
Thermal conductivity	k_T	0.59 W/m K
Specific heat	C_p	4.182 J/g K
Latent heat of melting (1atm, 0^{0}C)	h_{melt}	334 J/g
Latent heat of evaporation	h_{evap}	2450 J/g

ρ_{ice}=0.92 g/cm^3

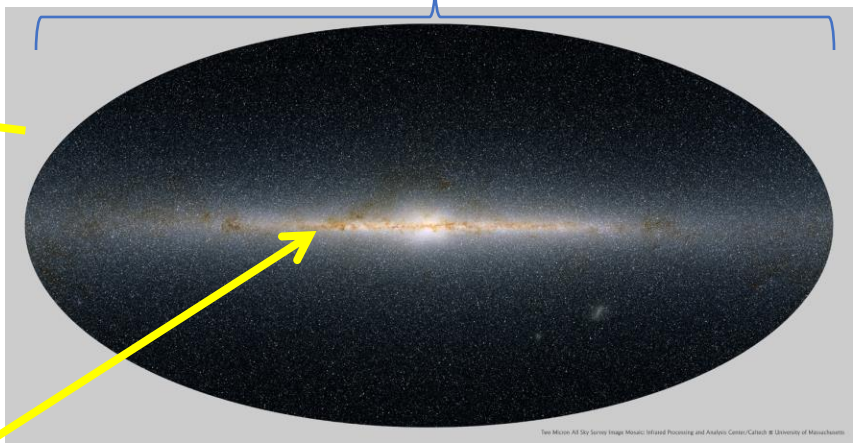
1 g/cm^3

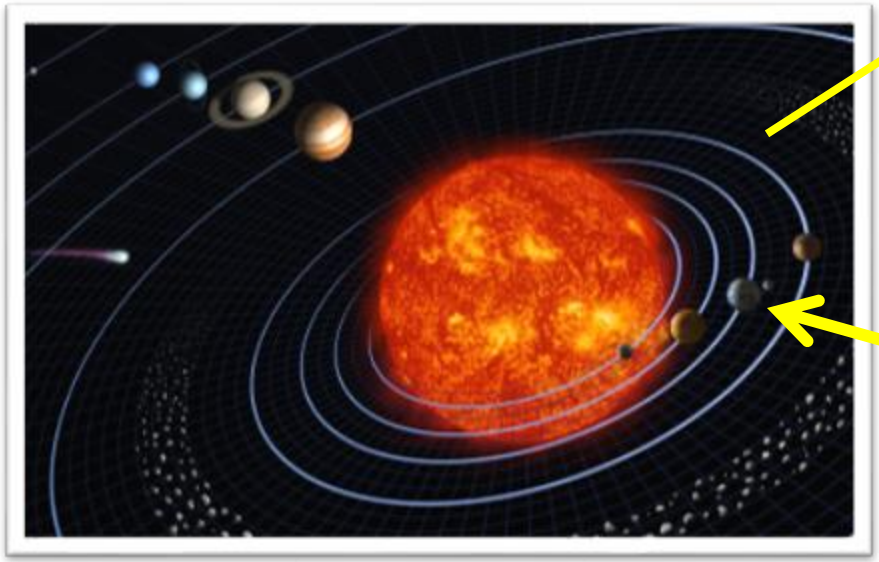
Hydrological cycle: astronomic glance

100 - 200 000 000 000 Galaxies

100 000 light years;

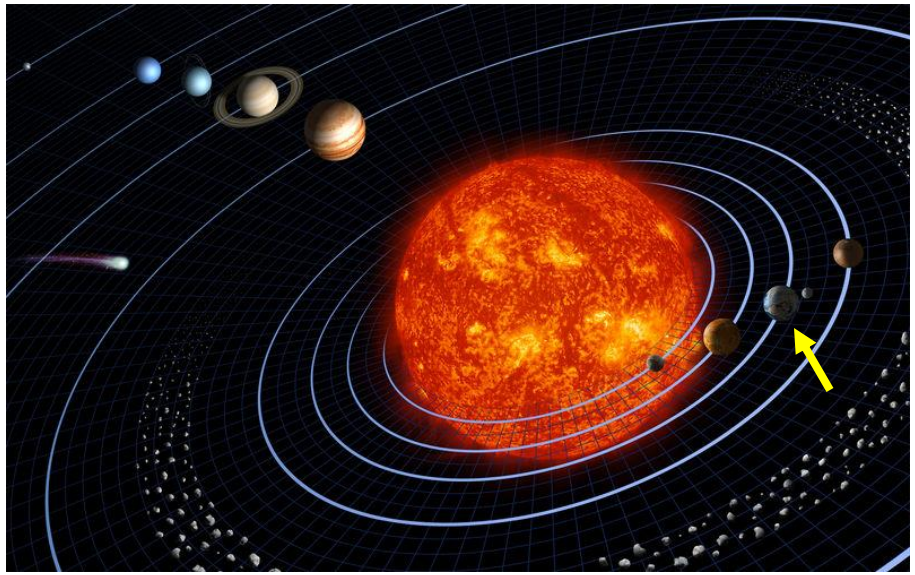
300 000 000 000 stars

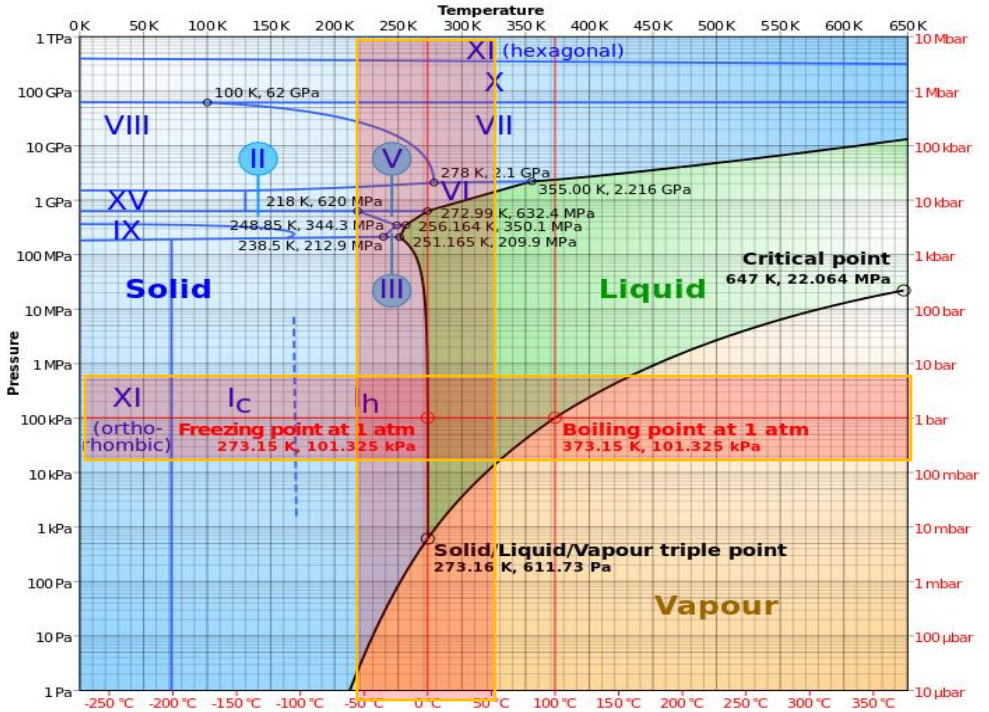




Life on Earth is sustained by the presence of water

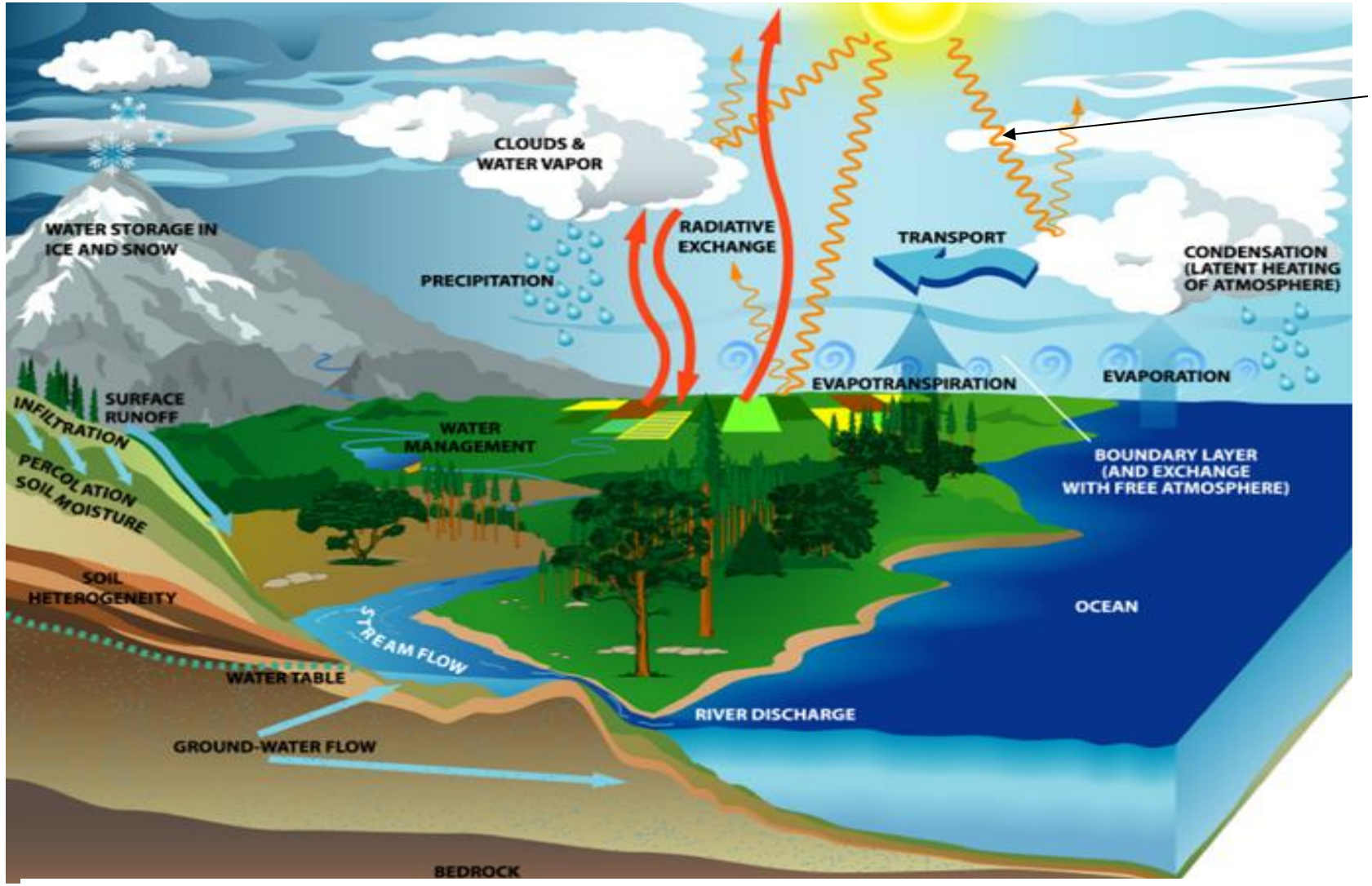
- On Earth water existence in his form (e.g., near the critical point of the phase diagram) is guarranteed by the particular location of our Planet in the solar system.





- Compared to our „neighbourest“ planets (e.g., Venus and Mars), Earth is therefore special.
- Water availability throughout Earth is driven by the hydrologic cycle

THE HYDROLOGICAL CYCLE



Conceptualization of the Water Cycle (Schematic view) from US Global Change Research Program

On Earth solar radiation (~1440 W/m^2) and related exchange establishes a delicate equilibrium which guarrantees the existence of water in all its three phases

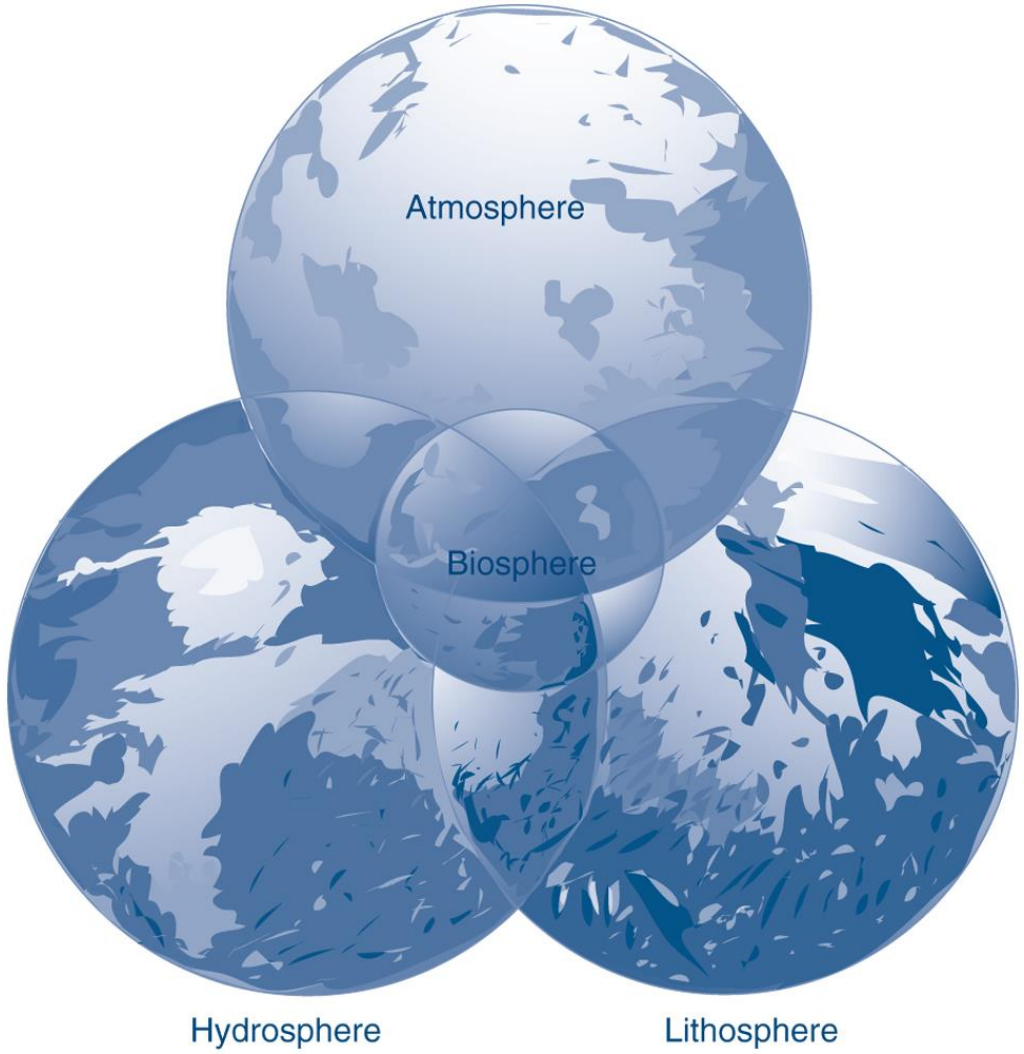
(Remember: Venus, evaporation prevails; Mars, freezing prevails)

Digression on ecosystems structure and link to the water cycle

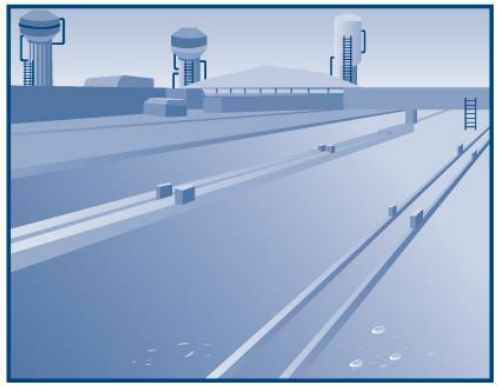
Any intersection between the biotic sphere and an abiotic one forms an ECOSYSTEM.

All ecosystems of the world form the ECOSPHERE

Ecology is the discipline that studies the structure and functions of the ecosphere



Natural and engineered ecosystems

Lake	Grassland	Biological waste treatment
		
Physical–chemical environment: water, coupled to the atmosphere and lake sediments and influenced by the meteorology characteristic of a specific latitude and altitude.	Physical–chemical environment: soil, coupled to the atmosphere and soil-water reserves and influenced by the meteorology characteristic of a specific latitude and altitude.	Physical–chemical environment: wastewater, largely uninfluenced by the meteorology characteristic of a specific latitude and altitude.
Energy source: the sun	Energy source: the sun	Energy source: organic wastes (originally from the sun)
Primary production: algae, aquatic plants, and certain bacteria	Primary producers: grasses and flowers	Primary producers: none
Energy transfer: zooplankton, fish	Energy transfer: grasshoppers, ground squirrel, coyote	Energy transfer: bacteria, protozoans

Among the engineered ones we have also landfills, constructed wetlands, bioretention cells, wastewater treatment ponds, etc.

Some basic definition

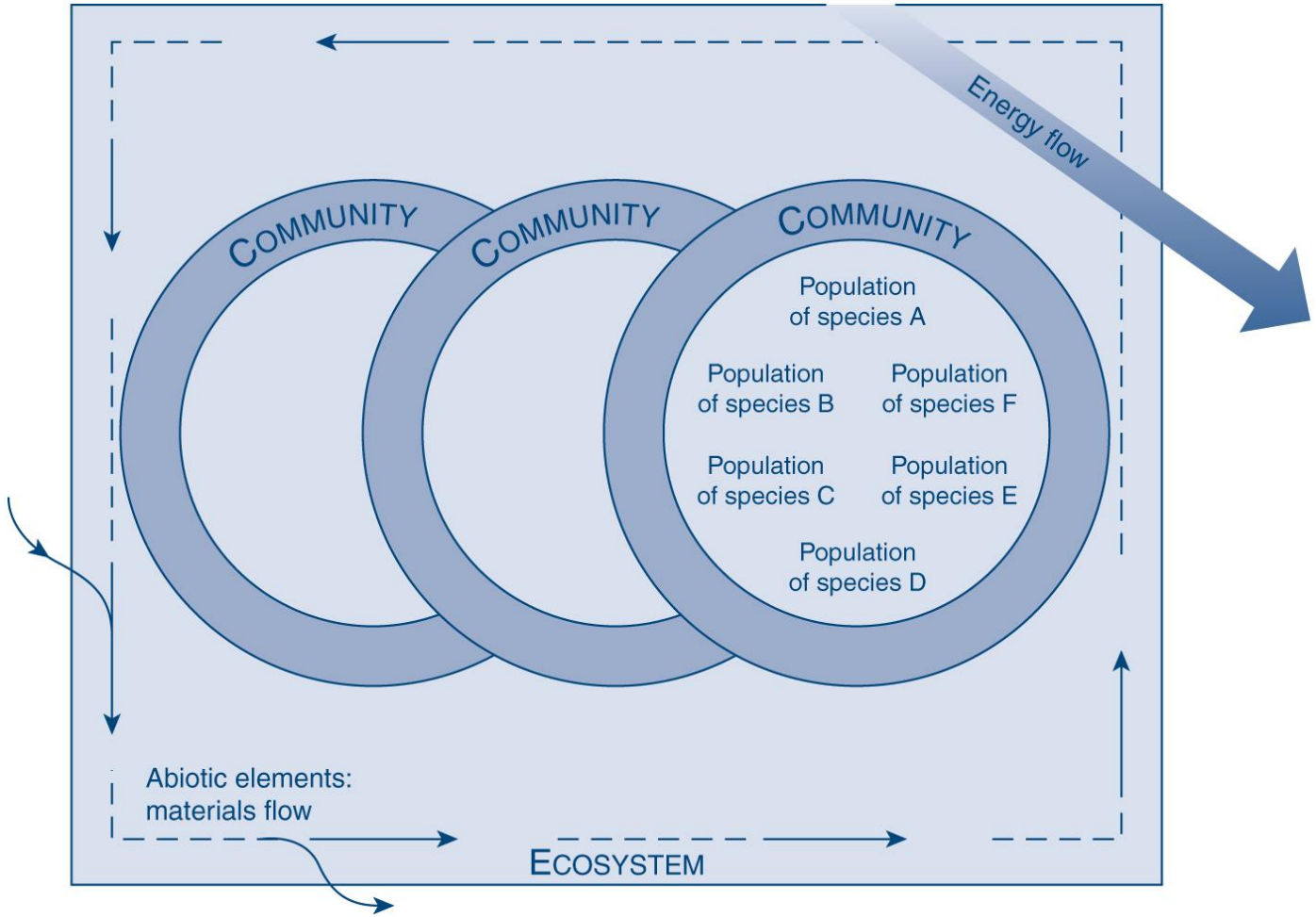
Species: group of individuals that possess a common gene pool;

Population: all members of a species in a given are, e.g. trout fish in a river reach;

Community: All of the populations (of different species) that interact in a system;

Ecosystem: all of the communities plus the abiotic factors that sustain them;

Ecosphere: all of the ecosystems



The hydrological cycle is a fundamental mass flow process that sustains all ecosystems

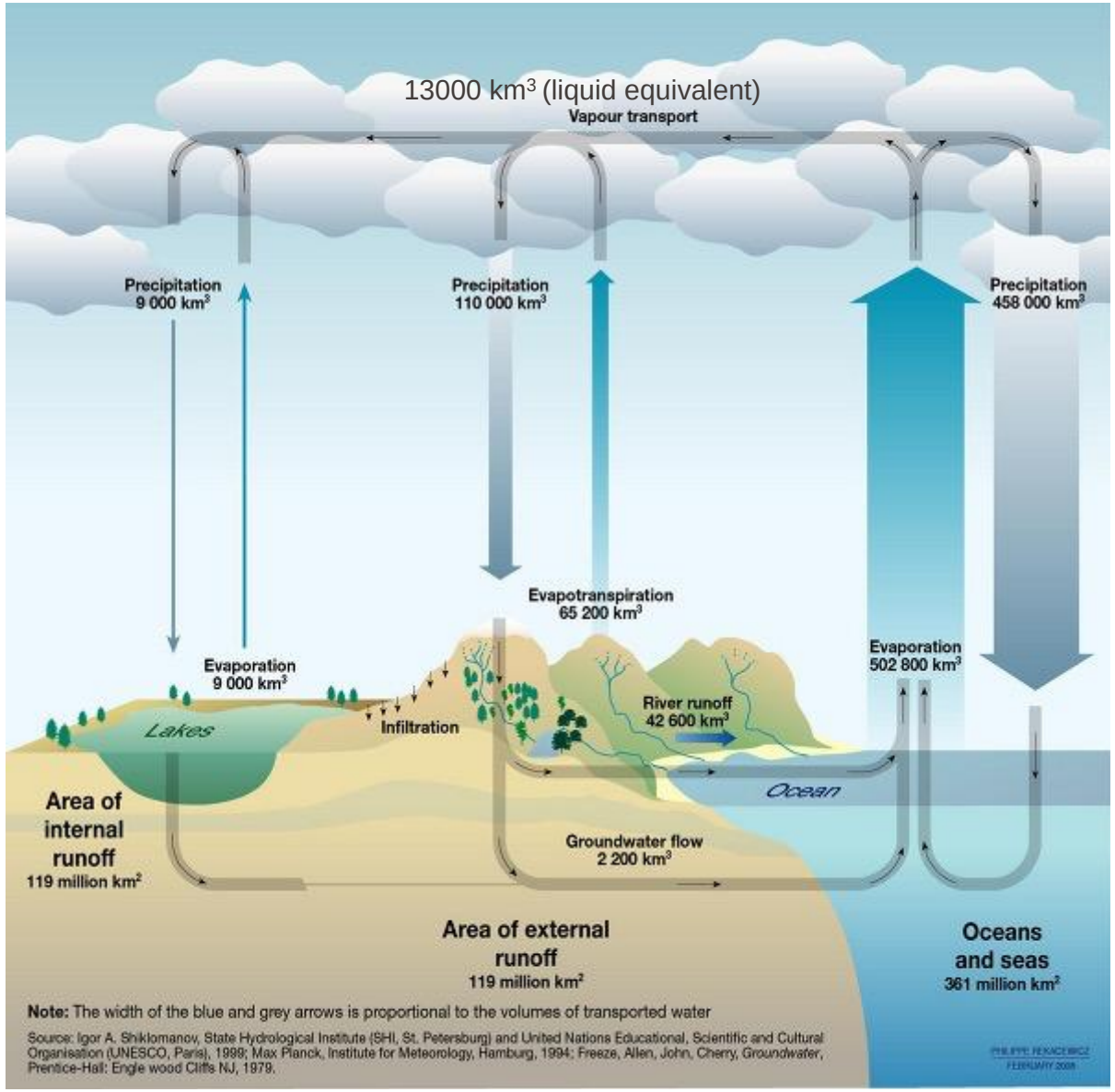
The hydrological cycle

Water volumes transfer across the globe through transport processes (advection, convection and diffusion mainly).

Atmospheric processes make water distribution spread overall the globe enhancing either equilibrium or non equilibrium local mass exchanges.

These disparities are fundamental to maintain active the hydrologic cycle

Around 25% of terrestrial evaporation is discharged into the sea, with the remaining 75% precipits on land.

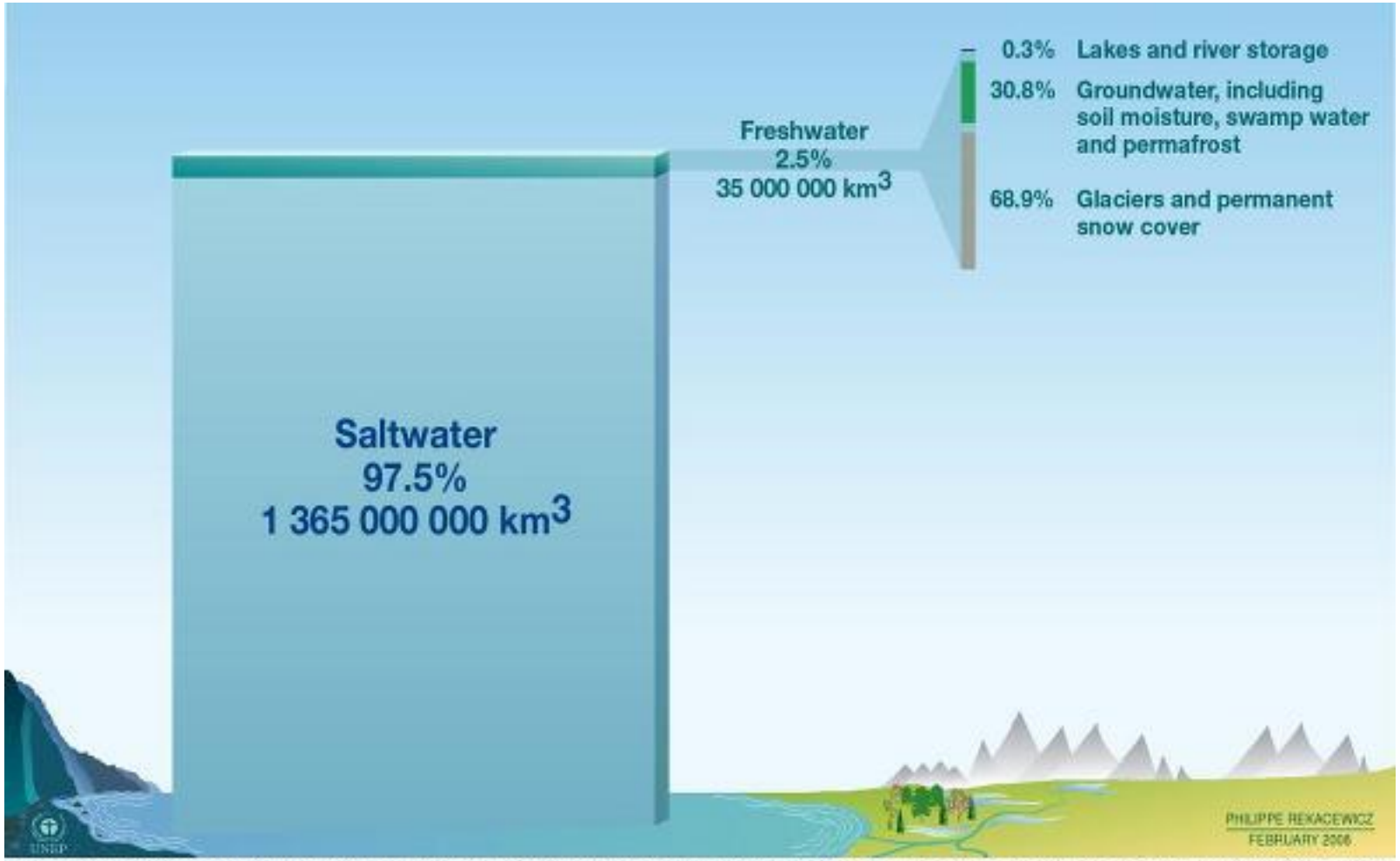


How much water on Earth is readily available for Humans as Potable Water?

Of the total Water on Earth:

A. 0.0075%
B. 17%
C. 35%
D. 68%
E. >96%

Availability and distribution of the water resources on the globe



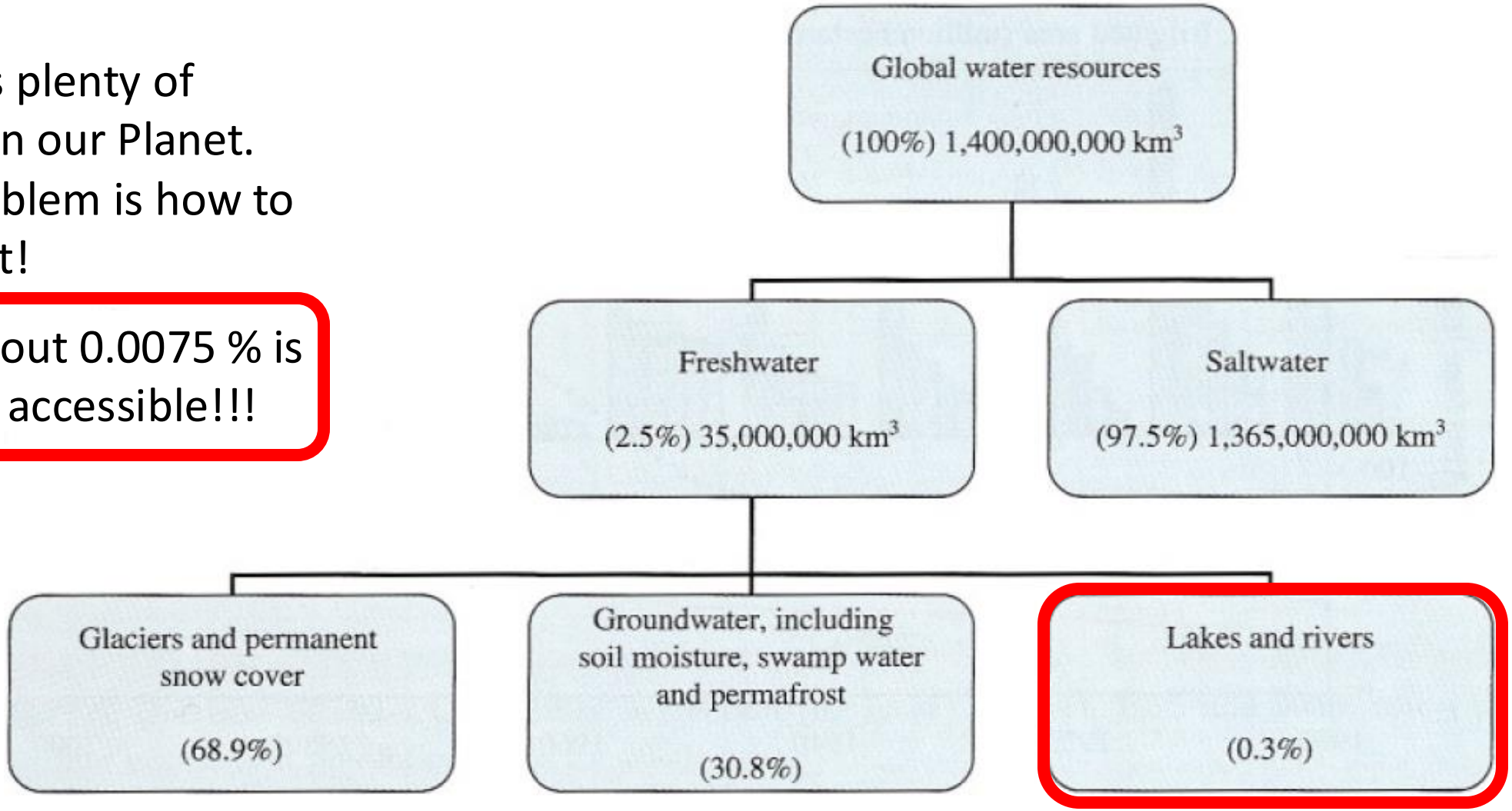
Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational, Scientific and Cultural Organisation (UNESCO, Paris), 1999.

- Total water is the amount of all forms of water some of which are not accessible at all
- Renewable water is the amount that is being renewed either annually or along longer durations
- Available water is the amount that humans can access and use for their consumpion

Water accessibility

There is plenty of water on our Planet. The problem is how to access it!

Only about 0.0075 % is directly accessible!!!



Availability and distribution of water resources on the globe (from Dinar et al. 2007)

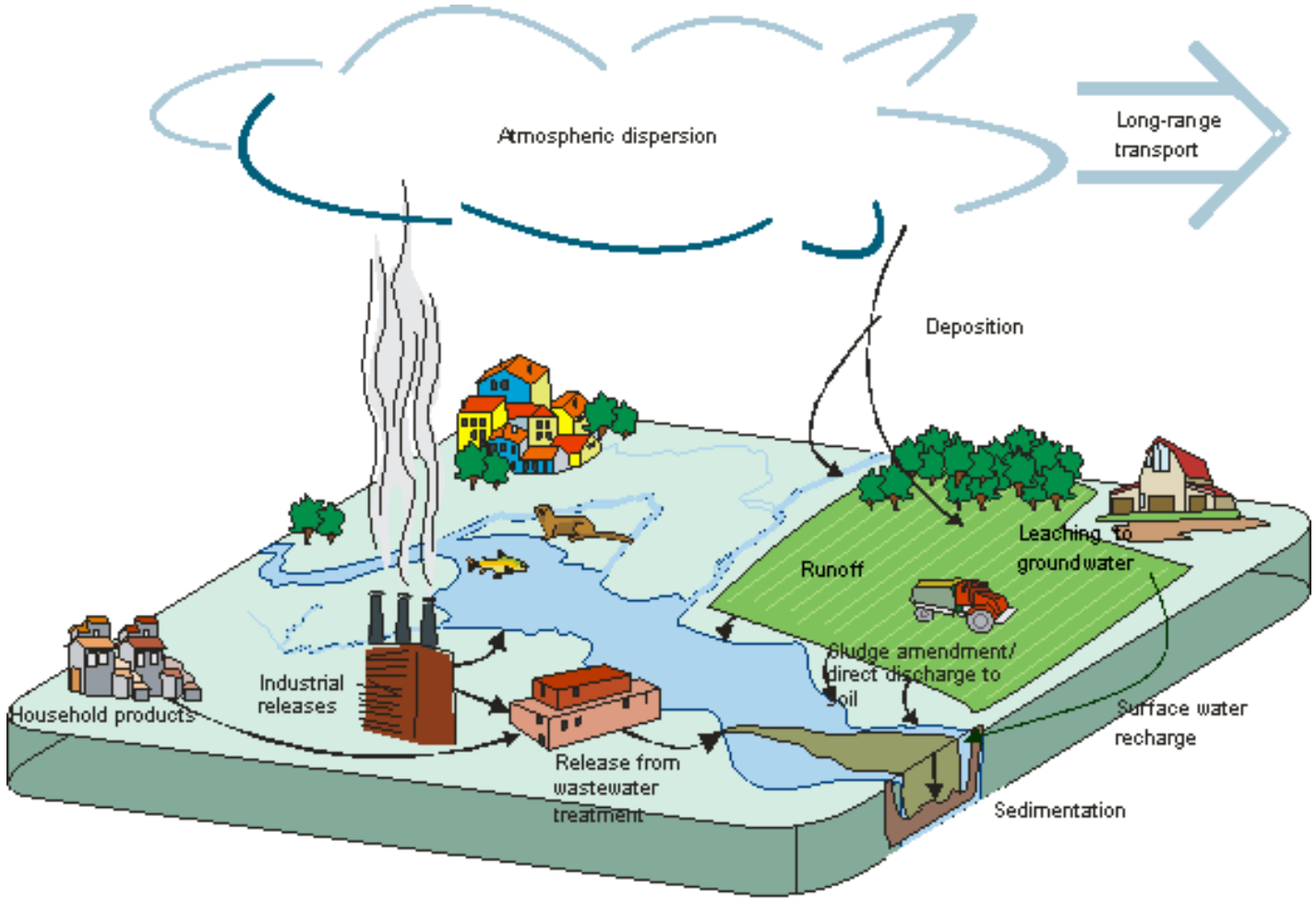
WATER RENEWAL PERIOD IN THE HYDROSPHERE

Water of Hydrosphere	Period of renewal
World Ocean	2500 years
Ground water	1400 years
Polar ice	9700 years
Mountain glaciers	1600 years
Ground ice of the permafrost zone	10000 years
Lakes	17 years
Bogs	5 years
Soil moisture	1 years
Channel network	16 days
Atmospheric moisture	8 days
Biological water	several hours

In the process of turnover the river runoff is not only recharged quantitatively, but its quality is also restored. If it were so that man could suddenly stop to contaminate rivers, then with time water could return its natural purity. So the river runoff, actually representing the renewable water resources, is the most important component of hydrological cycle. SOURCE: http://webworld.unesco.org/water/

What human activities can affect the water cycle?

What human activities can affect the water cycle?



Source: Dr. A. Semiao, The University of Edinburgh ©

- Dams and reservoirs
- Irrigation diversions and drainage returns
- Potable water supply
- Wastewater treatment
- Changes in land use
- Flood mitigation
- Changes in climate conditions
- Domestic use (Pollution)
- Industrial use (pollution)
- Agricultural use (pollution)
- Deforestation/reforestation