Hydrogeology MSc
Oilfield Hydrogeology MSc

Csaba ILYÉS, Assistant Research Fellow
hgilyes@uni-miskolc.hu

Definitions

Hydrology and hydrogeology

- Hidrology:
  - Science of water. It examines all kind of water that can be found on Earth, its chemical, physical and hydraulical properties.

- Hidrogeology:
  - The science of water under the surface, basically examines the chemical, physical and hydraulical properties of groundwaters, andit's interaction with the surface waters and the geological formations.

Water on Earth

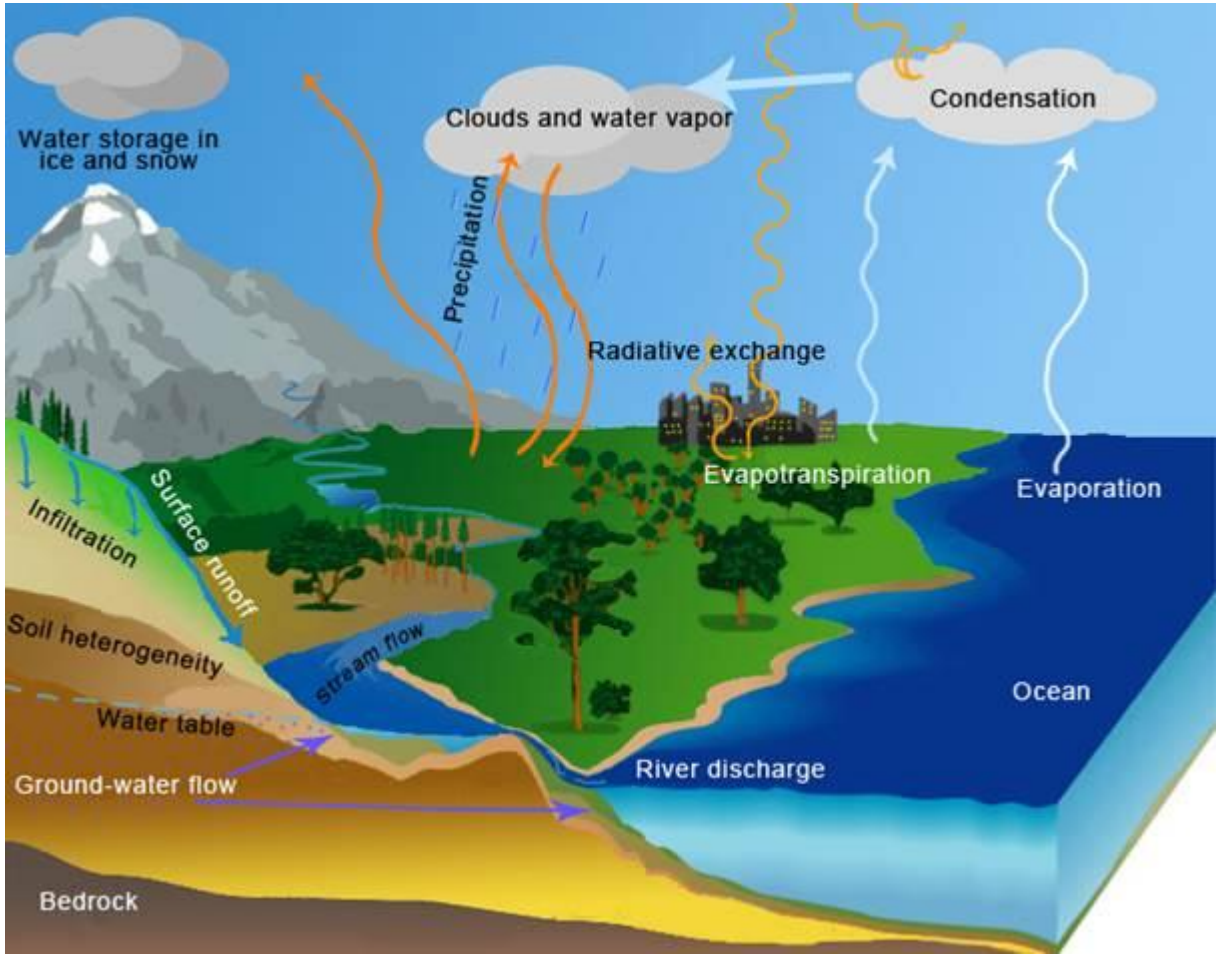
- Distribution of water:
- Water on Earth:
  - 1,4 billion km^3
  - 97,2 % salt water
  - 2,14 % ice + glacier
  - 0,61 % groundwater
  - 0,009 % surface water
  - 0,005 % soil moisture
  - 0,001 % air moisture

Hydrological Cycle: 396000 km^3/year

Hydrological Cycle

- Movement of Water:
  - Water evaporates from the ocean surface (this water does not contains salt)
  - If conditions in the atmosphere match; precipitation(cloud formation)
  - Rains from the atmosphere to the surface of oceans and land
    - Some of it is stored (snow and ice, lakes)
    - Transported to other parts (surface flows)
  - Some of the surface water infiltrates under the surface (*3 phase zone*)
  - Some of the water migrates directly to the surface, absorbed by crops, while others will reach the GW *(saturated or 2 phase)*
  - The water from the saturated zone flows under the surface, until it reaches the ground (springs)

Hydrological Cycle



Water balance – Hydrological equation

- Hydrological equation
  - The energy of this movement comes from the sun
  - The description of water balance is quantitative
- Te equation based on the principle of conservation of mass:

  Inflows = Outflows± Changes in stored Water (ΔS)
- Characteristics:
  - The equation works on any system, in any size
  - Time-dependent
  - Inflows are measurable more easily than outflows

Hydrological equation

- Hydrogeological input:
  - Rains
  - Inifiltration of surface water
  - Inflow of groundwater
  - Human-made water injection

+

- Hydrogeological output:
  - Evapotranspiration
  - Evaporation of surface water
  - Outflow of surface water
  - Outflow of GW
  - Human-made drainage

-

Basic definitions

Drainage basin

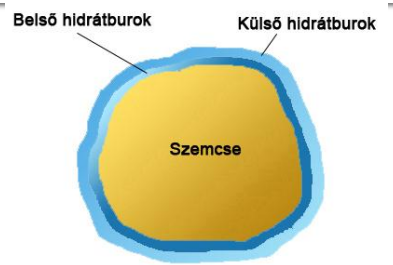
- An area, where the water from snow, and rains collected in the same surface water, thus reaching the oceans.
- Drainage basins contains the rivers, and lands, from where the water flows the same collecter.
- Drainage basins ends in watersheds, which are usually mountains

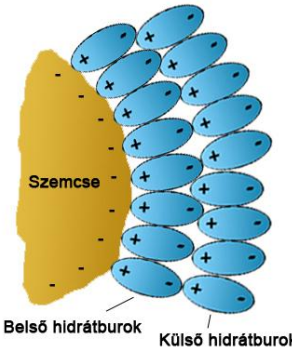
Surface waters

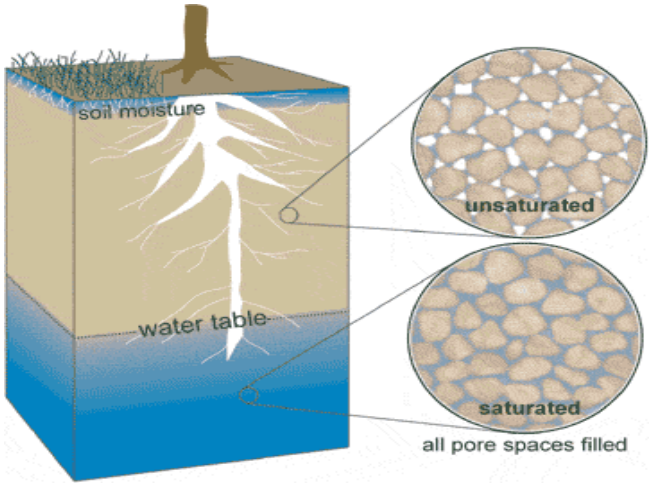
- All static and moving water on the surface (rivers, lakes, sea).
- Characteristic: always taking part in hydrological cycle.

Soil moisture, water table, groundwater

- Zone of soil moisture:
  - The 3 phase zone. The pores between the soil particles are filled with water and air.
- Water table:
  - From this starts the 2 phase or saturated zone
  - Characteristics: The pressure is equal to the air pressure. It could be some cm deep, or even 10 m deep.
- Groundwater:
  - The water stored in the pores of the ground.



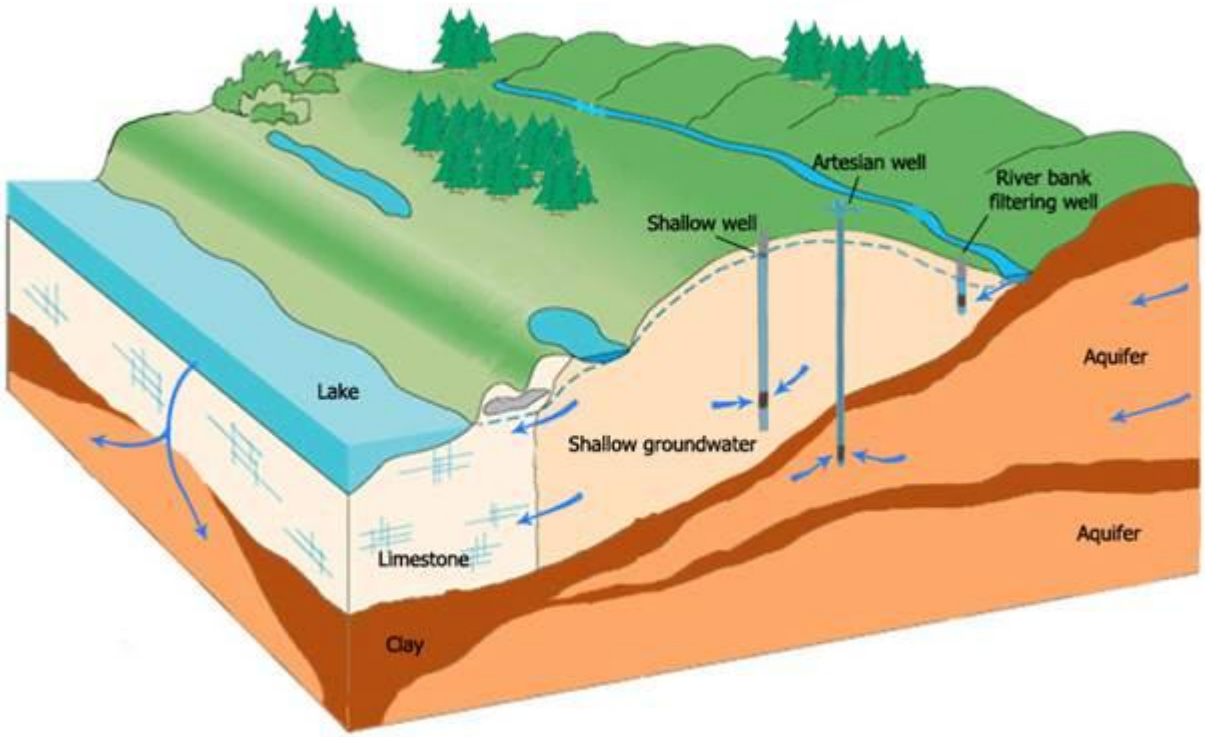




Shallow groundwater and inland water

- Shallow groundwater:
  - The first aquifer, the closest to the surface.
  - Theroretics say, The 2 phase zone, closest to the surface, above the first aquitard layer. If there is no aquitard, the 2 phase zone up to 25 m deep in the ground is considered shallow groundwater
- Inland water:
  - Origin: the water table reaches the surface and even surpassing it.
  - Nature: It happens locally, usually after some extreme meteorological and surface water conditions, such as:
    - Sudden snow melting, extreme amount of precipitation,
    - Watertable reaches the surface from extra amount of inflow.

Classification of GW



Classification of GW

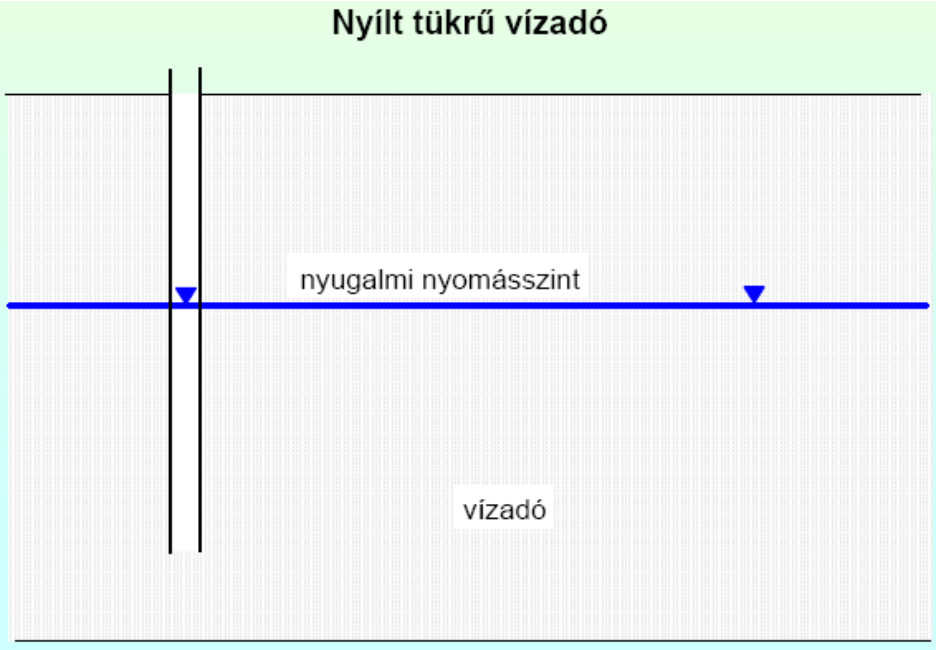
- Classification of GW:
  - 1. The soil type in which the water is stored
  - 2. Different natural forces
  - 3. The pressure of the stored water
  - 4. Hydraulic way
  - 5. Temperature
  - 6. Chemical properties
  - 7. Practical

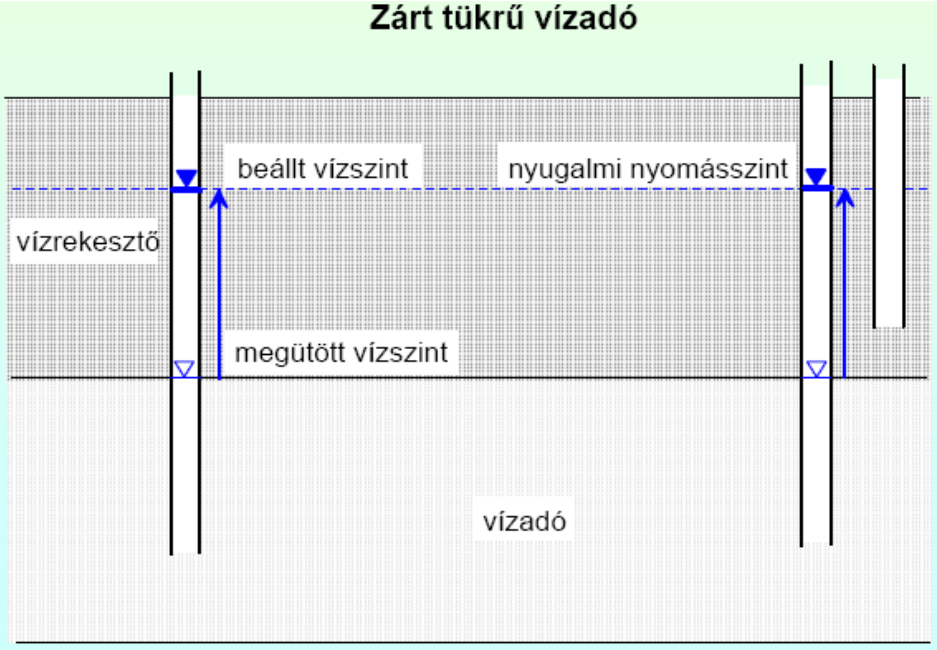
1. **Porous** or **karstic waters**

2. **Active forces:** a gravity, the capillary force, the osmotic force
   PAssive forces: molecular forces, friction, inertia, capillary forces

Classification of GW

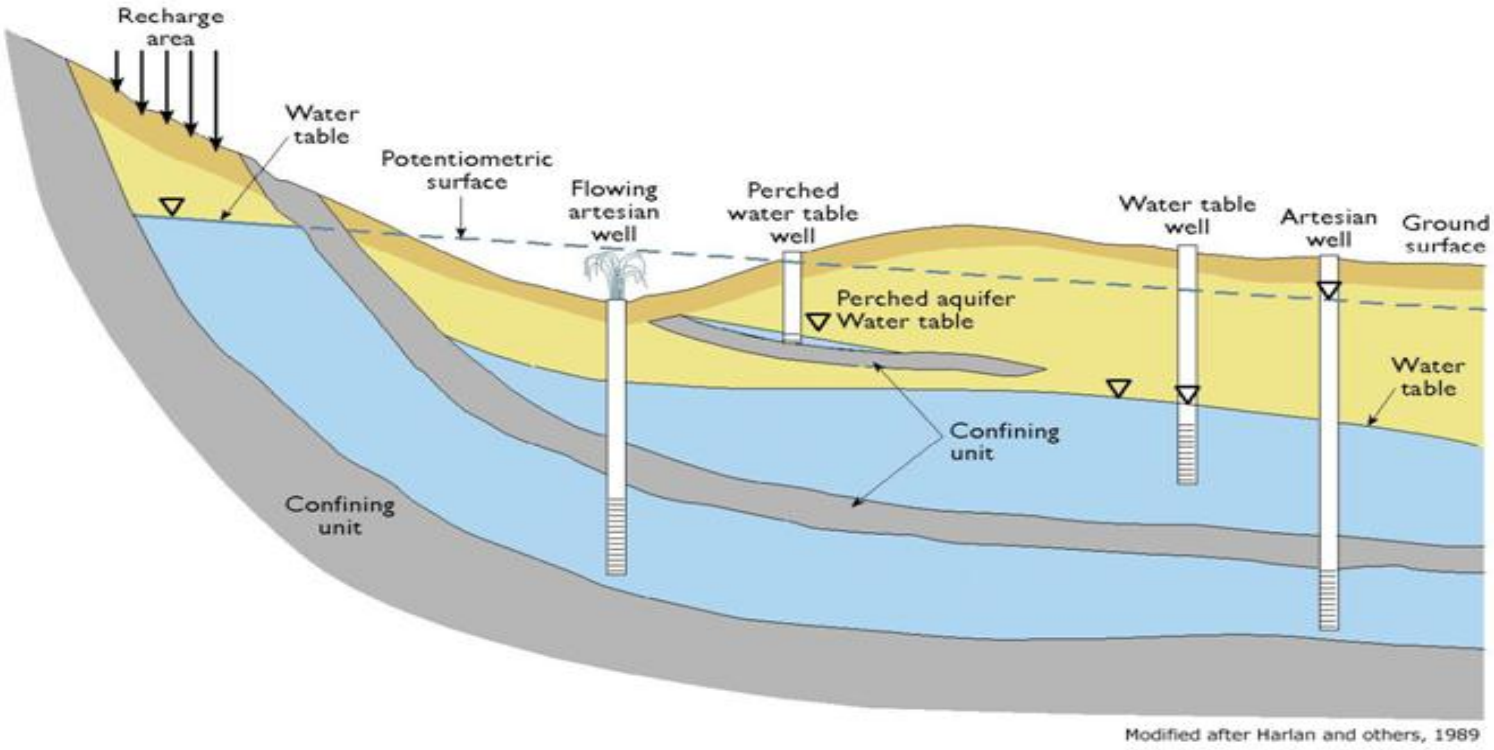
- **3. <u>The pressure of stored water:</u>**
  - Confined, and unconfined systems.





Classification of GW

- 4. **Hydraulic way:**
  - **Stagnant** and **flowing waters** (I, hydraulic gradient)



Classification of GW

- **5. Temperature.**
  - Bélteky – Papp – Schmidt:
    - 18 °C – cold
    - 18 °C – 25 °C tepide
    - 25 °C - 37 °C warm
    - 37 °C – thermal
    - 37 °C – 60 °C less hot
    - 60 °C – 90 °C hot
    - 90 °C very hot

- **6. Chemicals**
  - The dominant chemical properties or dissolved particles name the water

Classification of GW

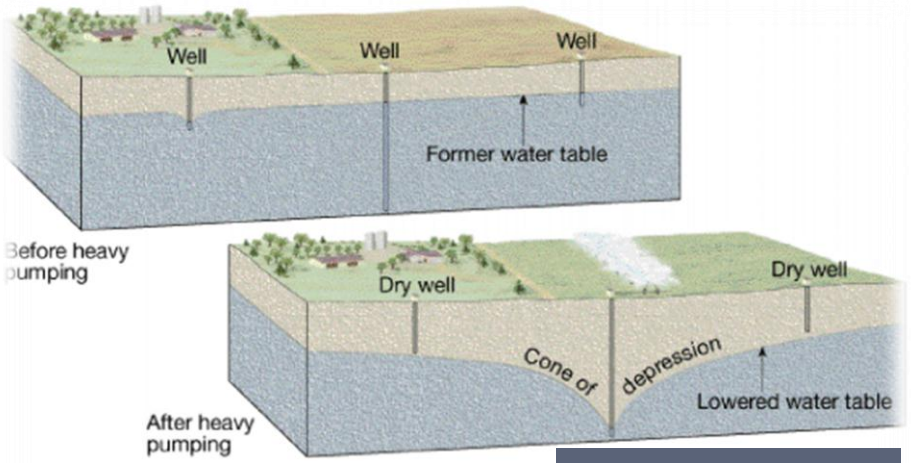
- **6. <u>Chemicals</u>**
  - Ordinary water, mineral water, thermal water
  - **Mineral water:**
    - More than 1000 mg/l total dissolved solution in it.
  - **Thermal water:**
    - Its temperature is above 30 °C

Classification of GW

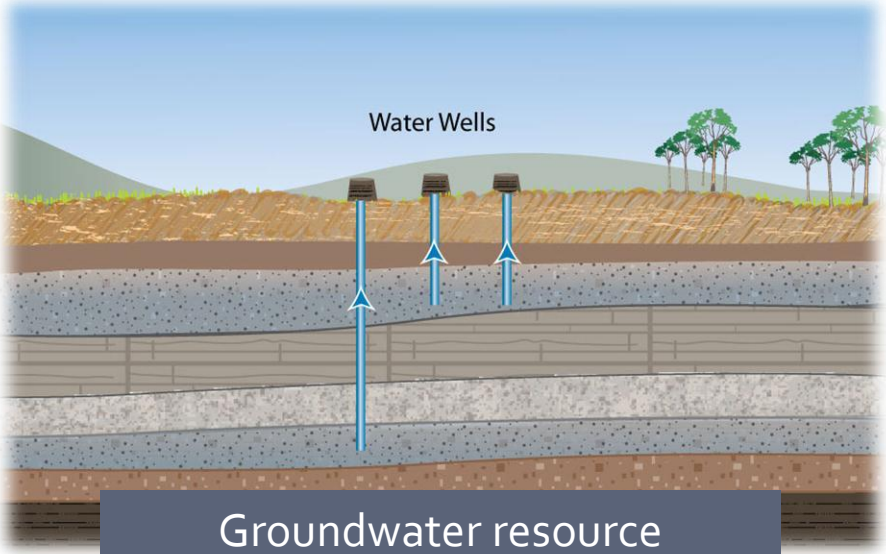
- **7. Practical classification:**
  - **River ban filtered water:** stored water near a surface water, where the produced water has more than 50 % origin from the infiltration of surface water
  - **Shallow groundwater:** till the first aquitard layer
  - **Groundwater:** water resources which are between two aquitard layer, and usually under pressure, deep under the ground. If there is no aquitard layer, water stored under 50 m depth.
  - **Karstic water:** water resources, which water is stored or flowed through karstic formations (limestone).

Classification of GW

River ban filtered



Shallow GW



Groundwater resource

Karstic water

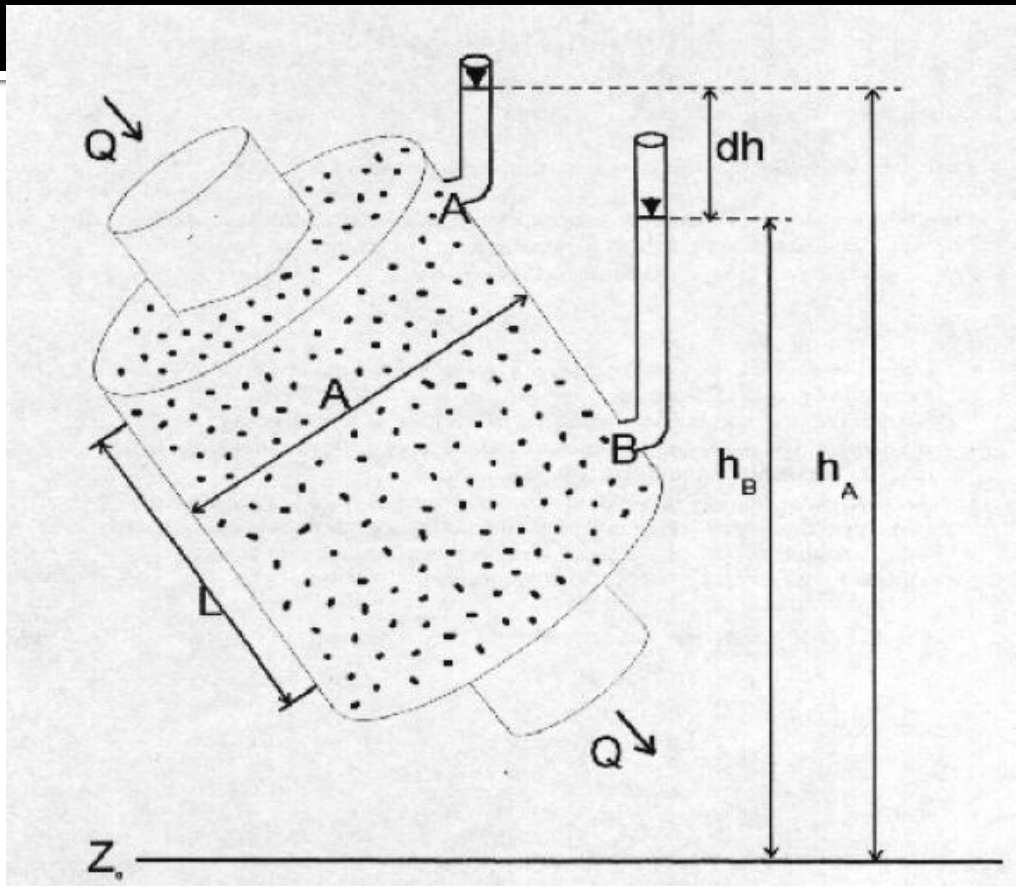
Darcy-equation

Henry DARCY (1856) carried out a large scale experimental work when he worked on the water supply system in the city of Dijon, France. Darcy published the obtained interesting results in 1856. According to this publication, the derived equation was called later as the **Darcy equation**, which is still one of the most important, and most frequently applied equation is in groundwater science.

Darcy-equation

$$Q = k \cdot A \frac{dh}{L} = k \cdot A \frac{h_A - h_B}{L}$$

- Where:
  - **A:** cross-section area of the water flow through the sand fill
  - **Q:** water discharge [m^3/d];
  - **h_A-h_B:** Levels in the water columns between the A,B points [m];
  - **L:** distance measured between the water columns [m];
  - **k:** hydraulic conductivity
  - (k) [m/d]



$$Q = k \cdot A \cdot \frac{dh}{dl} = k \cdot A \cdot I$$

- Where:
  - **I:** hydraulic gradient [m/m];
  - **k·I:** the linear velocitiy of infiltration

Permeabilityand hydraulic conductivity

- **Permeability:** In the earth sciences (commonly symbolized as κ, or k) is a measure of the ability of a porous material (often, a rock or an unconsolidated material) to allow fluids to pass through it.
  - Sign: K
  - Unit: m^2 vagy mD (milliDarcy)
- **Hydraulic conductivity:**
  - Sign: - K (internationally)
    - k (in Hungary)
  - „velocity" dimension [m/d].
  - It characterise also the rock and the fluid, which flows through it pores
- **Depending on the nature of the liquid:**
  - Density
  - Gravity (g)
  - Viscosity
  - (temperature)
- **Depending on the nature of the rock:**
  - Particle shape
  - Particle size

Transmissivity, geothermal gradient, and discharge

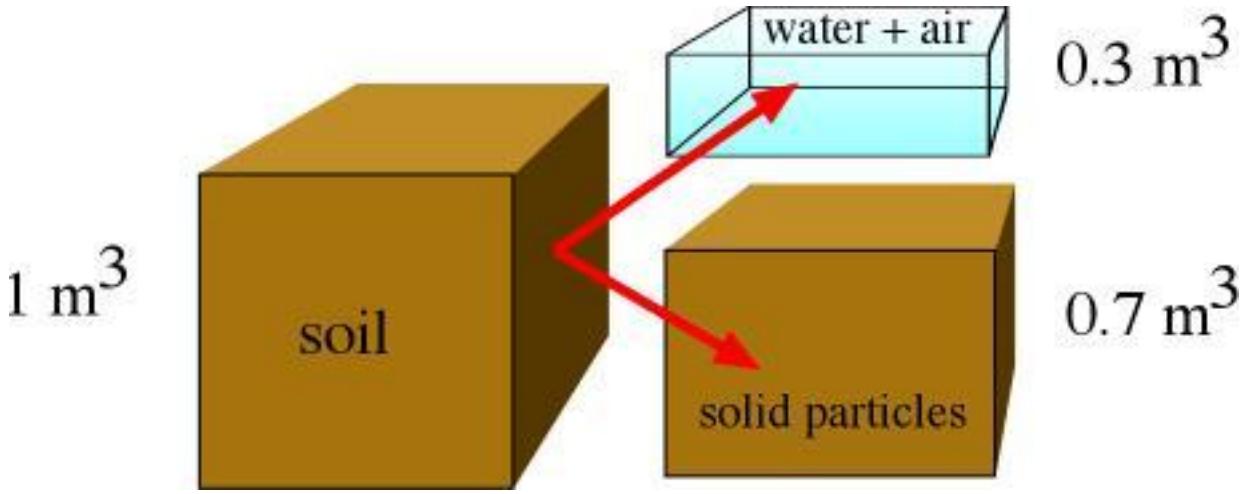
- **Transmissivity:** is a measure of how much water can be transmitted horizontally.
  - Sign: T
  - The hydraulic conductivity multiplied with the layer thickness: $T=k \cdot m$
  - Unit: $[m^2/d]$
- **Geothermal gradient:** is the rate of increasing temperature with respect to increasing depth in the Earth's interior.
  Earth average is 3°C /100 m.
  In Hungary 5-7 °C /100 m

- **Discharge:** Per unit measure of moving fluid. The amount of pumped or moving surface water during a specified time.
  - Sign: Q
  - Unit: $[m^3/d]$

Specific storage

- **Specific storage:** The **specific storage** is the amount of water that a portion of an aquifer releases from storage, per unit mass or volume of aquifer, per unit change in hydraulic head, while remaining fully saturated.
- Describes how the rock can store groundwater in its pore system.
  - Sign: S_s
  - Unit: [1/m]

Porosity



Porosity

- **Porosity (n):** The ratio of the pore volume and the whole volume.

$$n = V_{pore}/V_{whole}$$

- The **effective porosity** plays significant role in influencing the flow behavior in the rocks. The pore channels are interconnected in case of the effective porosity. This means that the effective porosity is smaller than the so called total porosity.(sign: n_o)

- The **void ratio (e):** the ratio of the pore volume and the particle volume:

$$e = V_{pore}/V_{particles}$$

- The two connected to each other:
  - $e = n/(1-n)$; $n = e/(1+e)$

- Thank You for Your Attention.