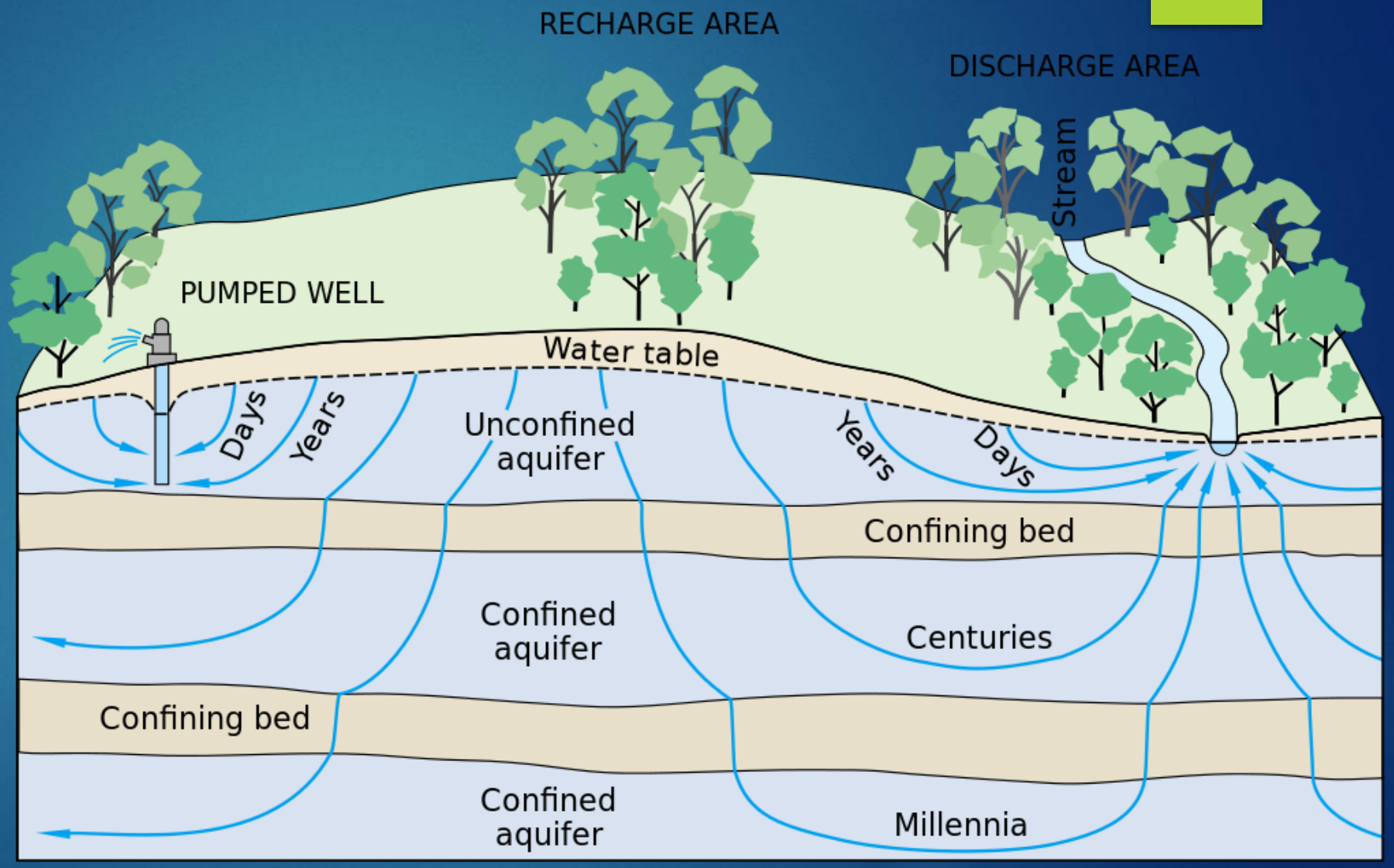
Water Utilisation, Water Damage Prevention

Groundwater flow calculations

Balázs Sándor
Department of Hydraulics and Water Resources Engineering

What is groundwater?

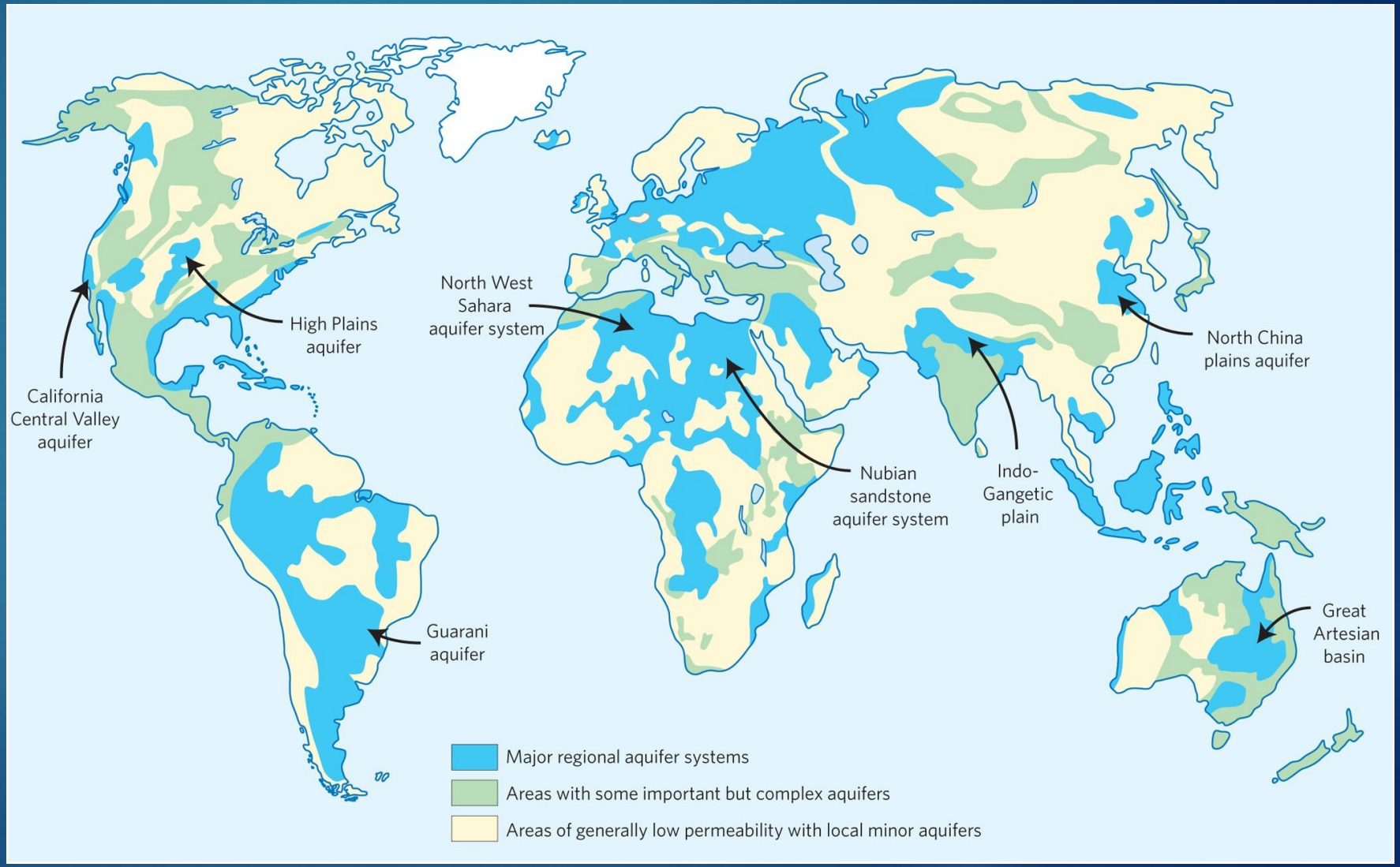
- The water beneath Earth's surface.
- It flows within aquifers and is separated by aquicludes.
- In the upper aquifer (above the surface) it flows under hydrostatic conditions, the surface of groundwater is called water table.



Source: Wikipedia

Main aquifers of Earth

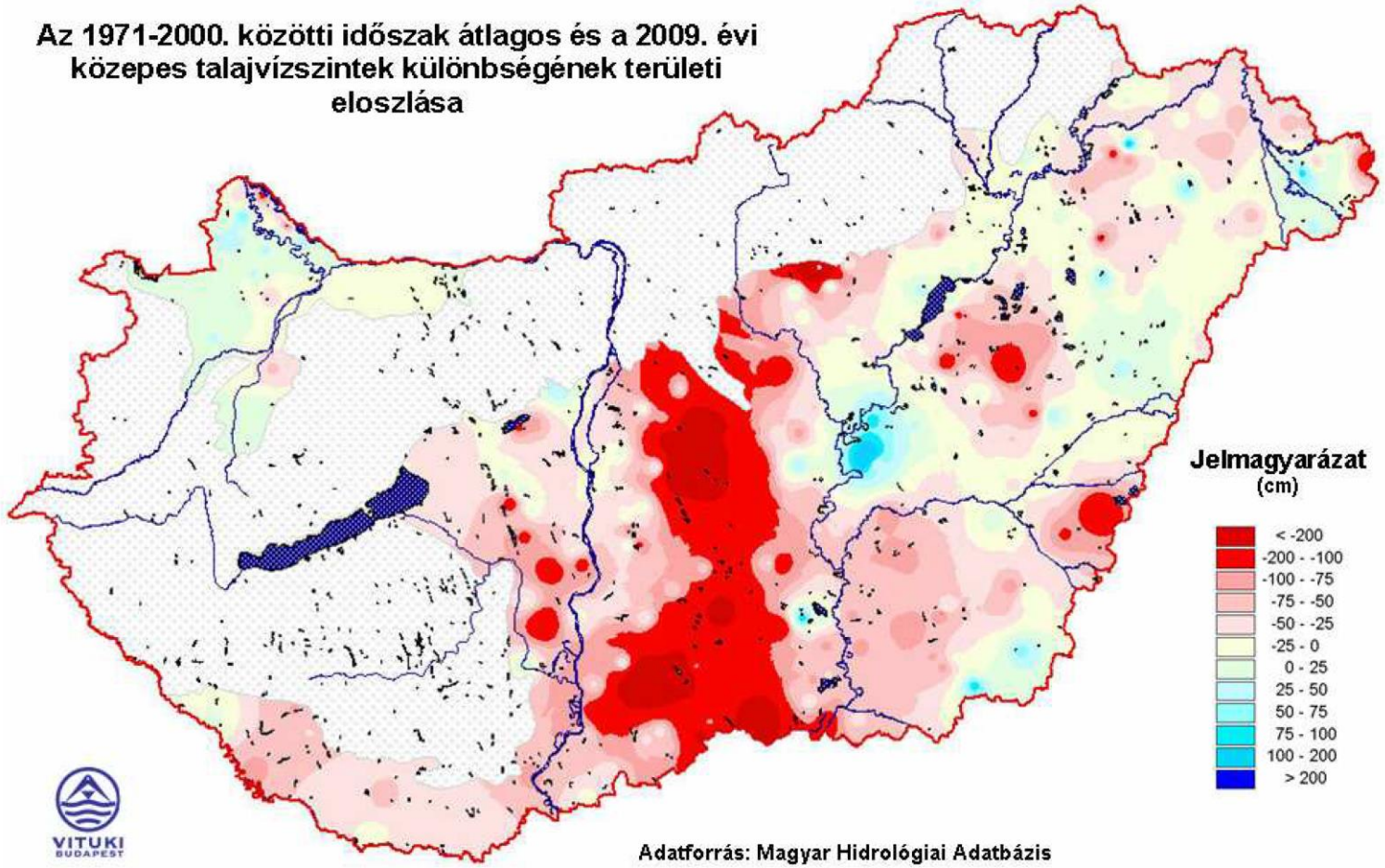
- Almost a third of Earth's readily available freshwater source is groundwater.



Source: Nature Climate Change

Water table level decrease in Hungary

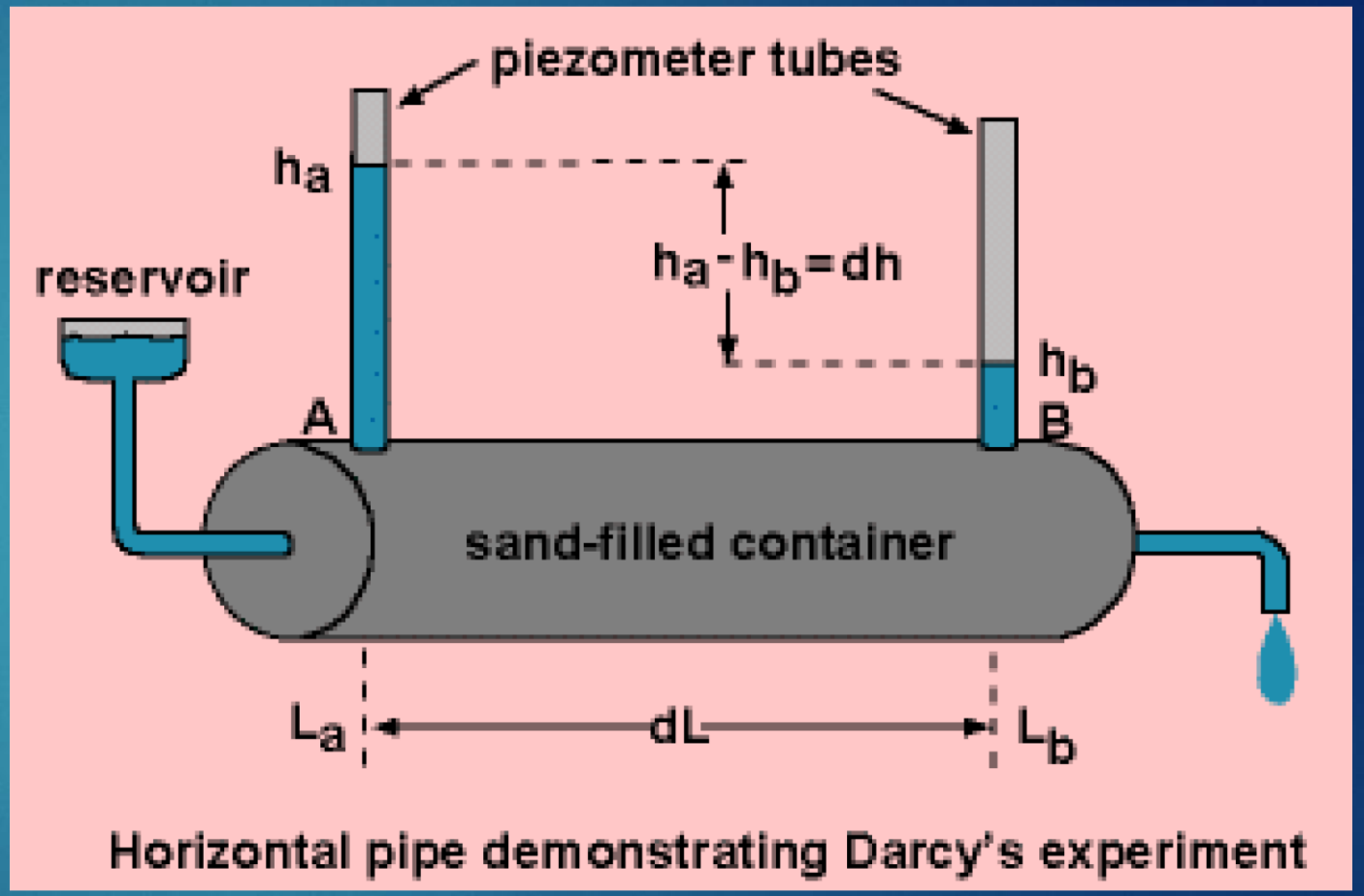
Difference of the water table level between the average of 1971-2000 and 2009.



10. ábra. Az 1971–2000. közötti időszak átlagos és a 2009. évi közepes talajvízszintek különbségének területi eloszlás

Groundwater motion

- Groundwater flow= flow through porous medium.
- The flow is described by Darcy's law.
- v : Darcy's velocity: a virtual velocity (at which the presence of soil, rock, etc. is not considered, the water only flows through the pores with a larger velocity).
- k : Hydraulic conductivity [m/s] (generally a tensor quantity).
- $\frac{dh}{dL}$: Hydraulic gradient (it can be the slope of the water table level).



Horizontal pipe demonstrating Darcy's experiment

$$v = k \cdot \frac{dh}{dL}, \qquad Q = A \cdot v = A \cdot k \cdot \frac{dh}{dL}$$

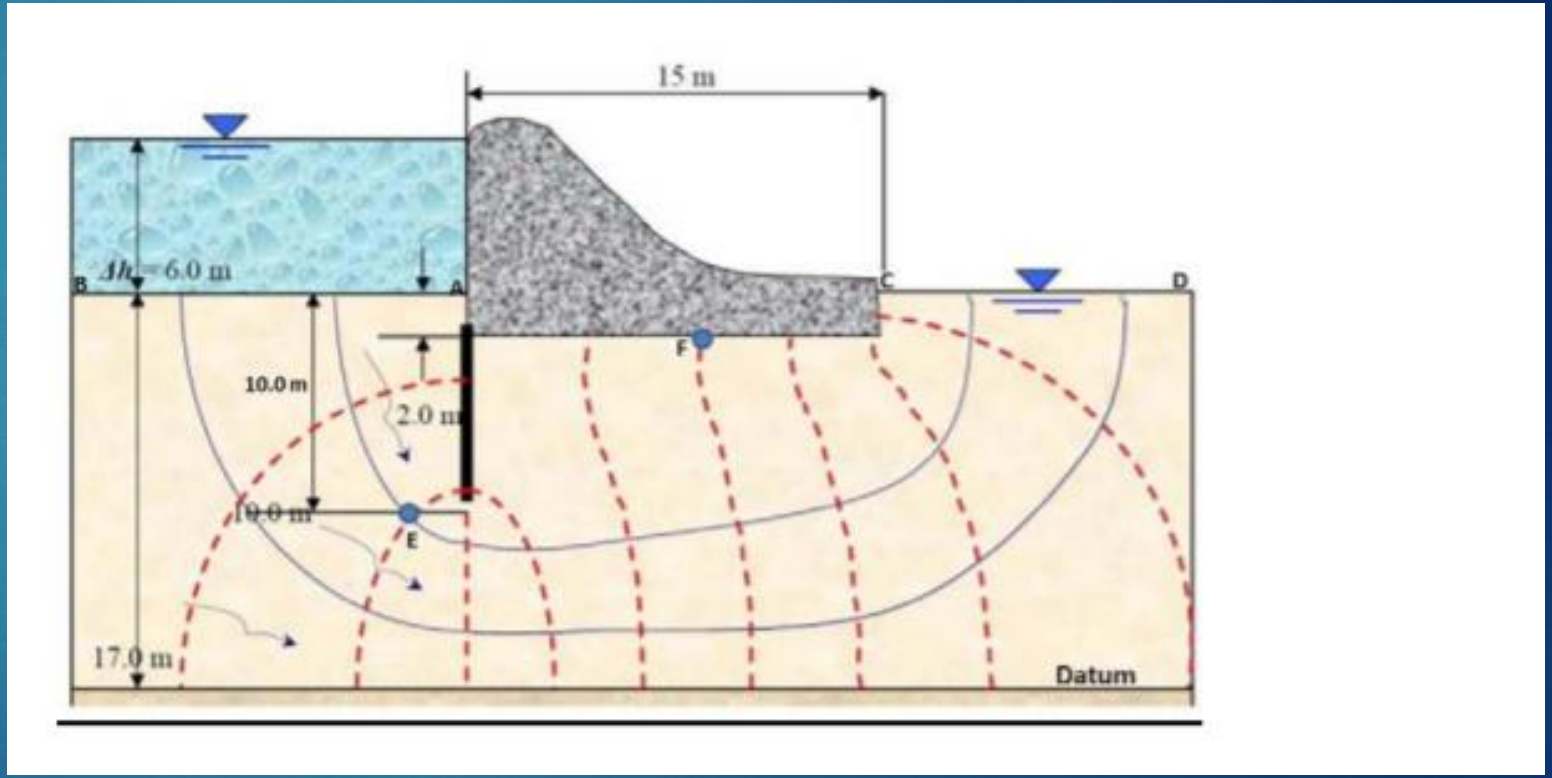
Applications of Darcy's law: calculating discharges from flow nets

Flow net: orthogonal families of streamlines and equipotential lines. Feature of incompressible and irrotational two-dimensional flows.

Calculation of flow rate (discharge) in a porous medium by application of Darcy's law on flow nets:

$$q = k \cdot \frac{m}{n} \cdot \Delta h$$

q: specific discharge
m: number of streamtubes
n: number of potential tubes



Applications of Darcy's law: drawdown curve calculation around a pumped well

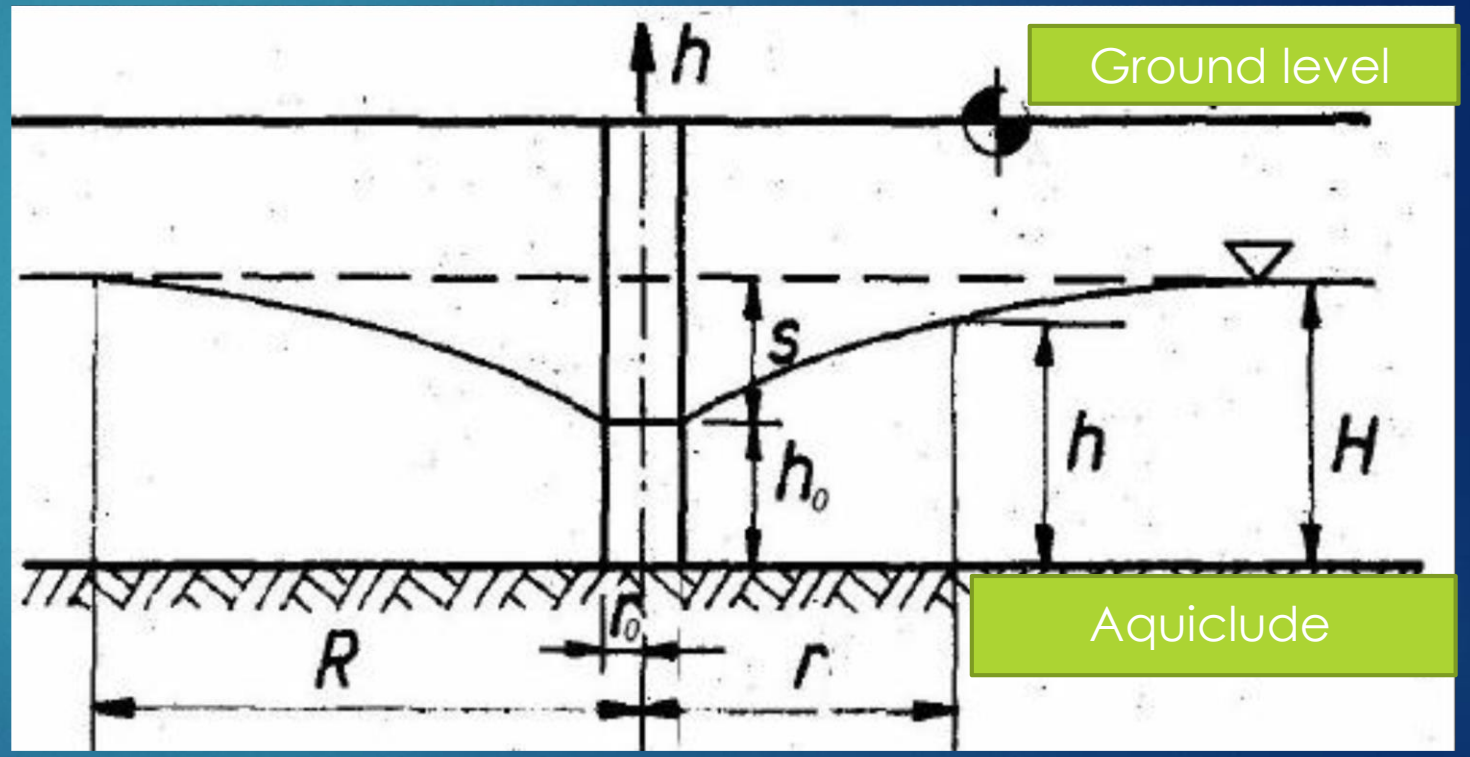
$$\frac{dh}{dr} = -\frac{Q}{2r\pi hk}$$

First order, linear, separable differential equation for the drawdown curve *h(r)*.

Boundary conditions:

$$r = 0, \quad h = h_0$$
$$r = R, \quad h = H$$

R: radius of influence (of the drawdown)
H: undisturbed water table level



$$h(r) = \sqrt{H^2 + \frac{Q(\ln R - \ln r)}{\pi k}}$$

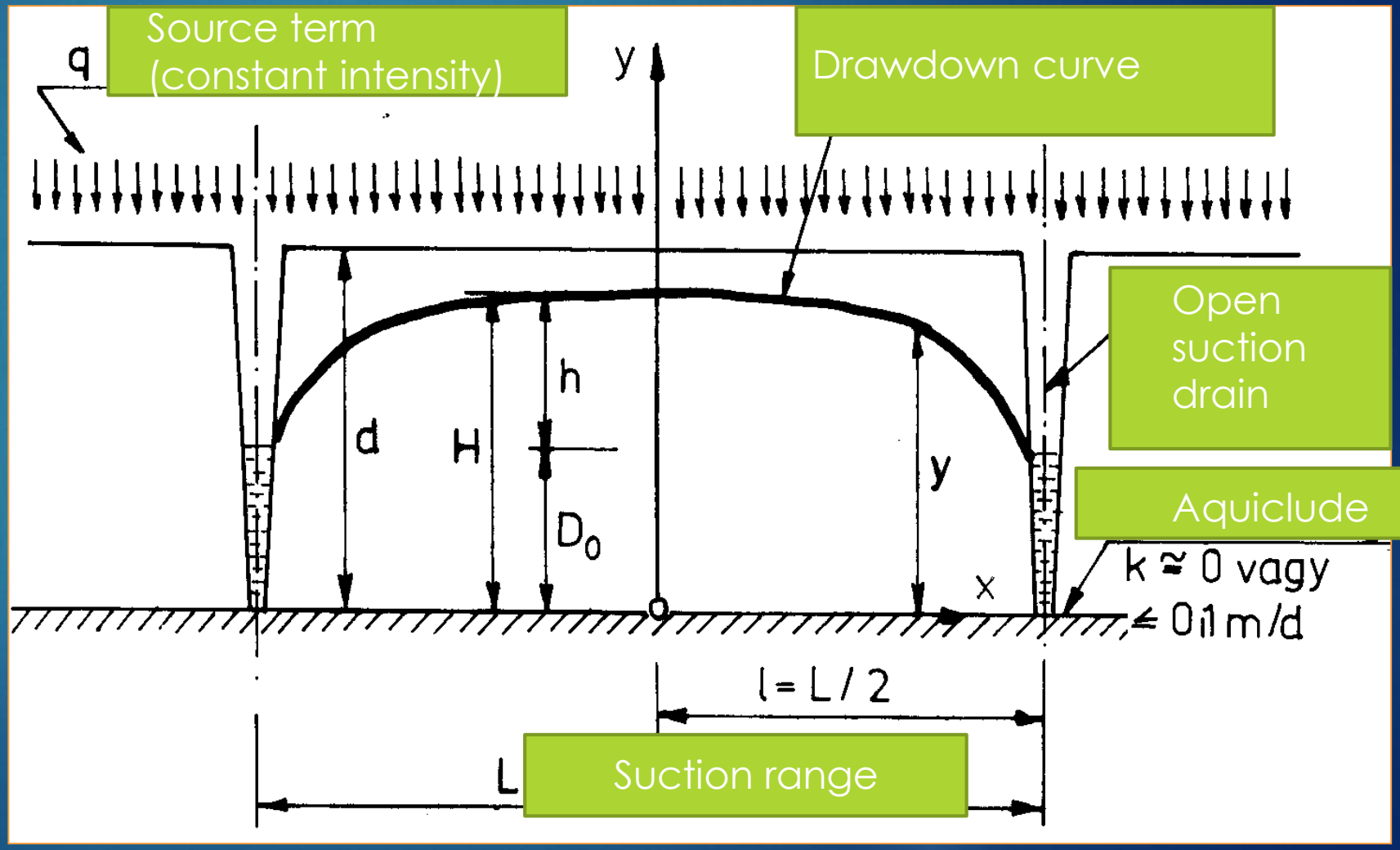
$$Q = -\frac{\pi k\left(H^2 - h_0^2\right)}{\ln R - \ln r_0}$$

Dupuit's formula

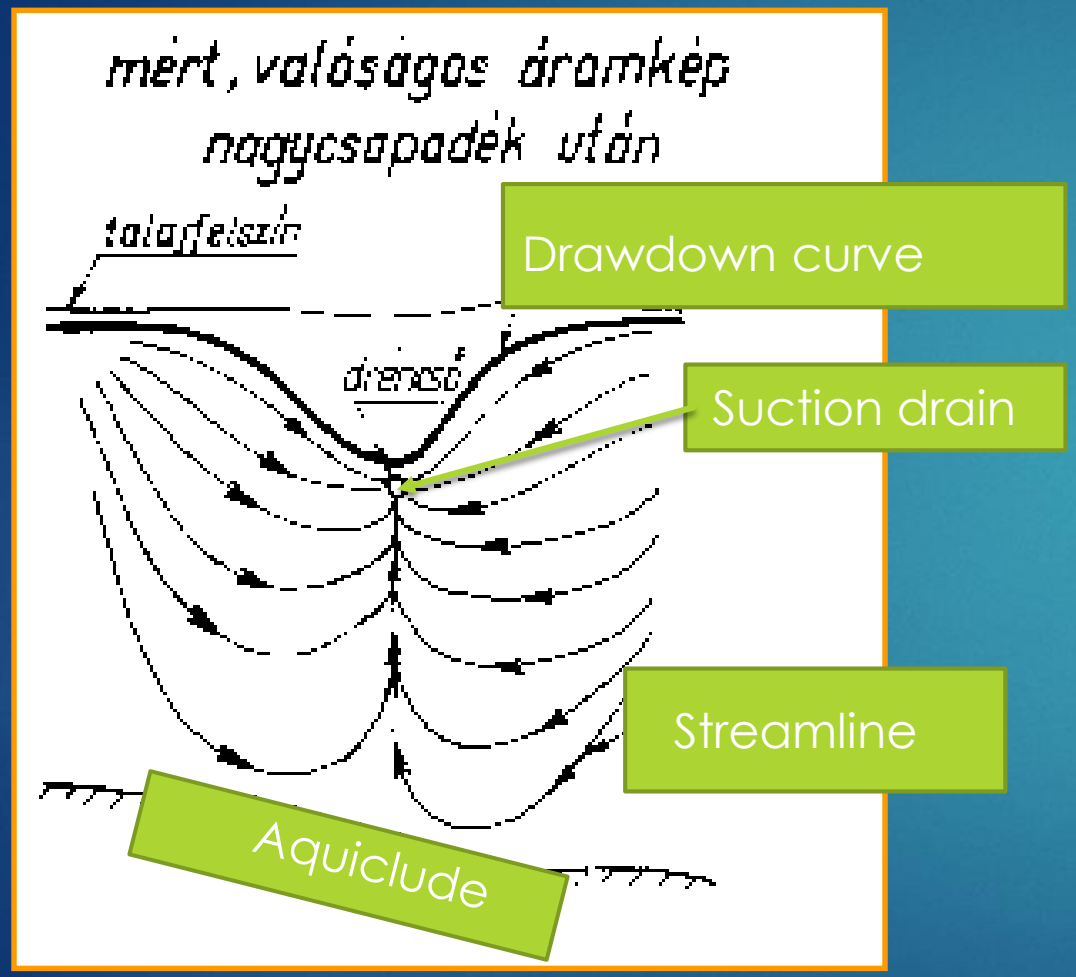
Applications of Darcy's law: drawdown curve for open suction drain

Hooghoudt formula for the suction range for parallel open suction drain channels:

$$L = \sqrt{\frac{8\,k\,D_0\,h}{q} + \frac{4\,k\,h^2}{q}}$$



Flow pattern around suction drain after big precipitation event



Questions

- What is groundwater? What do we call aquifer, aquiclude, and water table level?
- What engineering process or construction can be a good response to decreasing groundwater levels?
- Describe Darcy's experiment. How do we calculate the volume flow rate through porous medium?
- Define the flow nets.
- Describe Dupuit's formula (what do we use it for, with what simplifications, what is the mathematical form and what do the variables mean).
- Describe Hooghoudt's formula (what do we use it for, with what simplifications, what is the mathematical form and what do the variables mean).