What is groundwater and how is it formed?

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What is groundwater and how it is formed?
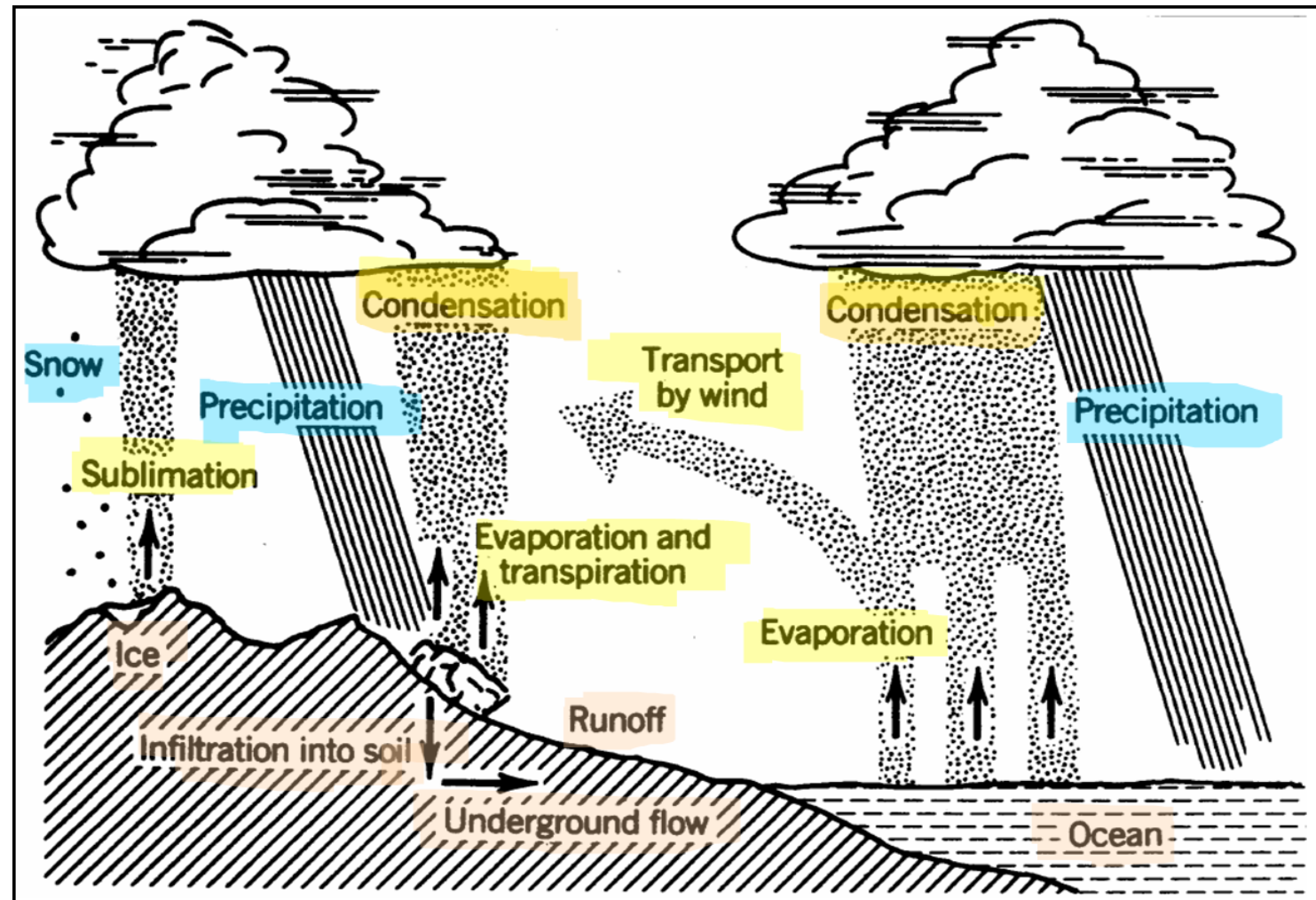
How can rivers have a continuous flow?

Where does the water come from?

What is groundwater and how it is formed

Groundwater forms the underground part of the water cycle

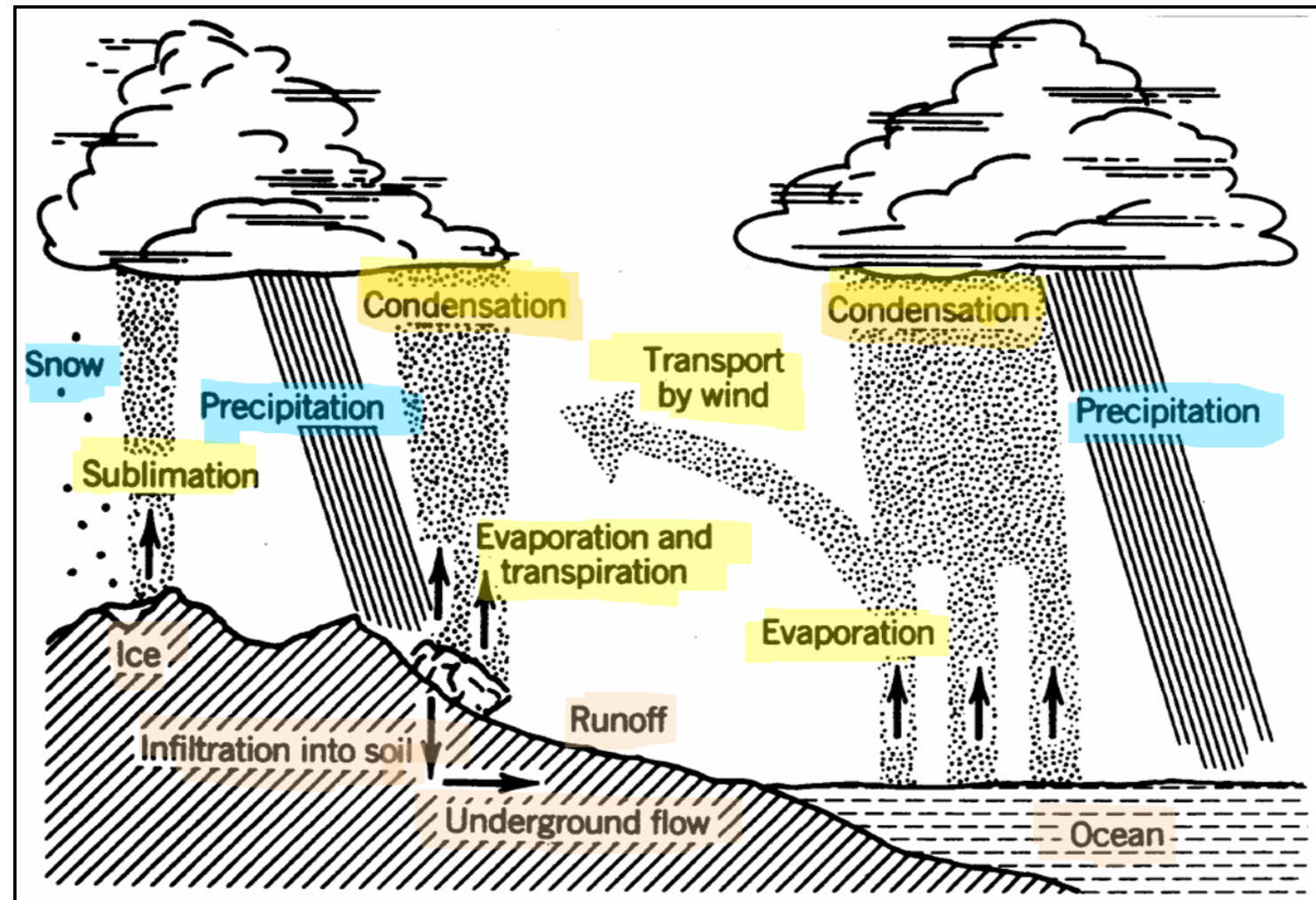In US, ~40 % of river flow originates from groundwater (https://agwt.org/content/groundwater-and-river-flow)

HydroGeology

Groundwater:

1. Underground;
2. Fills pores and cracks of rock/sediment;

1. WFD ammendment:

in direct contact with the ground or subsoil

What is Groundwater?

Groundwater is water that exists underground in **saturated zones** beneath the land surface. The upper surface of the saturated zone is called the **water table**.

Contrary to popular belief, groundwater does not form underground rivers. It fills the **pores and fractures in** underground materials such as **sand, gravel, and other rock**, much the same way that water fills a sponge. **If groundwater flows** naturally **out of rock** materials or if it can be removed by pumping (in useful amounts), the rock materials are called **aquifers**.

Groundwater moves slowly, typically at rates of 7-60 centimeters (3-25 inches) per day in an aquifer. As a result, water could remain in an aquifer for hundreds or thousands of years.
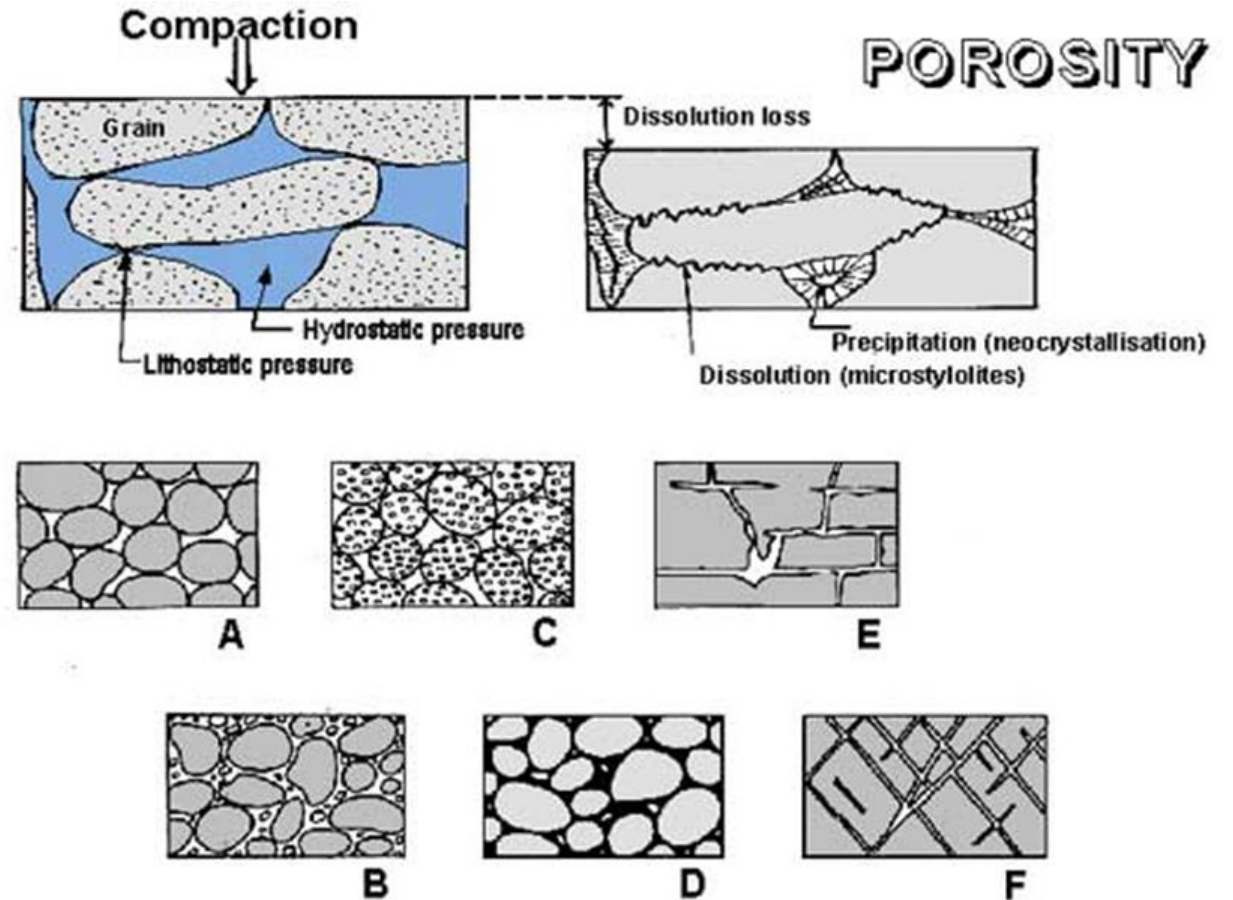
How much water is in the rocks?

Porosity

Groundwater occurs within the openings of consolidated/unconsolidated rocks

Porosity defines the volume of openings in the rock or sediment:

$$n = \frac{100V_v}{V}$$

Effective porosity - porosity of a rock or sediment available to contribute to fluid flow through the rock or sediment

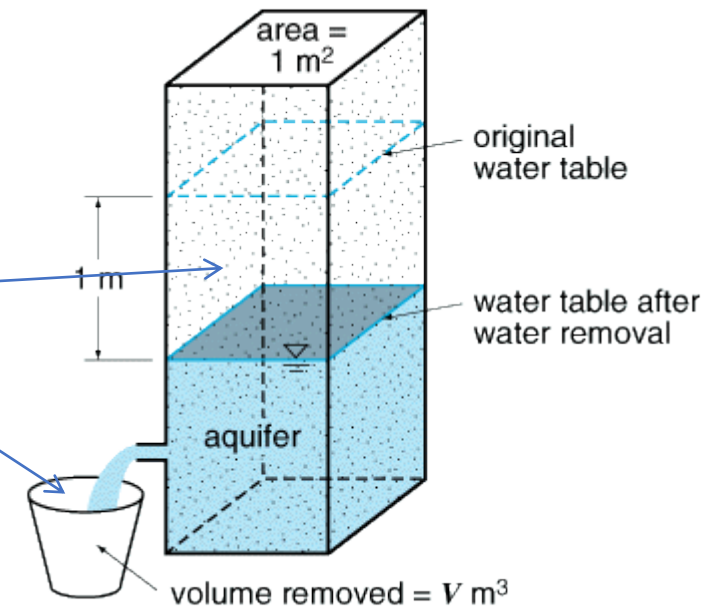http://www.learnearthscience.com/pages/Unit_Links/images/porosity1.jpg

How much water is released from the rocks?

Specific yield

Volume of water drained by gravity divided by the total volume of a saturated aquifer sample, given in %

$$S = \frac{W}{V_s}$$

Vs – total volume of soil
W – volume of water removed

area = 1 m²

original water table

1 m

water table after water removal

aquifer

volume removed = V m³

! – higher values for coarser sediments

How easily moves the water in the rocks?

Permeability (k)

Permeability (k) measures the ability of a porous medium to transmit the fluids.

It is the property of medium, independent of a fluid

SI unit cm²

Hydraulic Conductivity (K)

A combined property of the medium and the fluid

$$K = k\frac{\rho g}{\mu}$$

k = permeability
ρ = density
μ = dynamic viscosity
g = gravitational constant

How easily moves the water in the rocks?

K (cm/s)	10^2	10^1	$10^0{=}1$	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}
K (ft/day)	10^5	10,000	1,000	100	10	1	0.1	0.01	0.001	0.0001	10^{-5}	10^{-6}	10^{-7}
Relative Permeability		Pervious					Semi-Pervious				Impervious		
Aquifer/Aquitard		Aquifer										Aquitard	
Unconsolidated Sand & Gravel		Well Sorted Gravel	Well Sorted Sand or Sand & Gravel		Very Fine Sand, Silt, Loess, Loam								
Unconsolidated Clay & Organic						Peat		Layered Clay			Fat / Unweathered Clay		
Consolidated Rocks		Highly Fractured Rocks				Oil Reservoir Rocks		Fresh Sandstone		Fresh Limestone, Dolomite		Fresh Granite	

Modified from Bear 1972

How easily moves the water in the rocks?

Aquifers

Aquifer is a body of saturated rock or sediment that is capable of transmitting useful quantities of water to wells or springs

Based on lithology: **sand, gravel, sandstone,** limestone, fractured magma and metamorfic rocks

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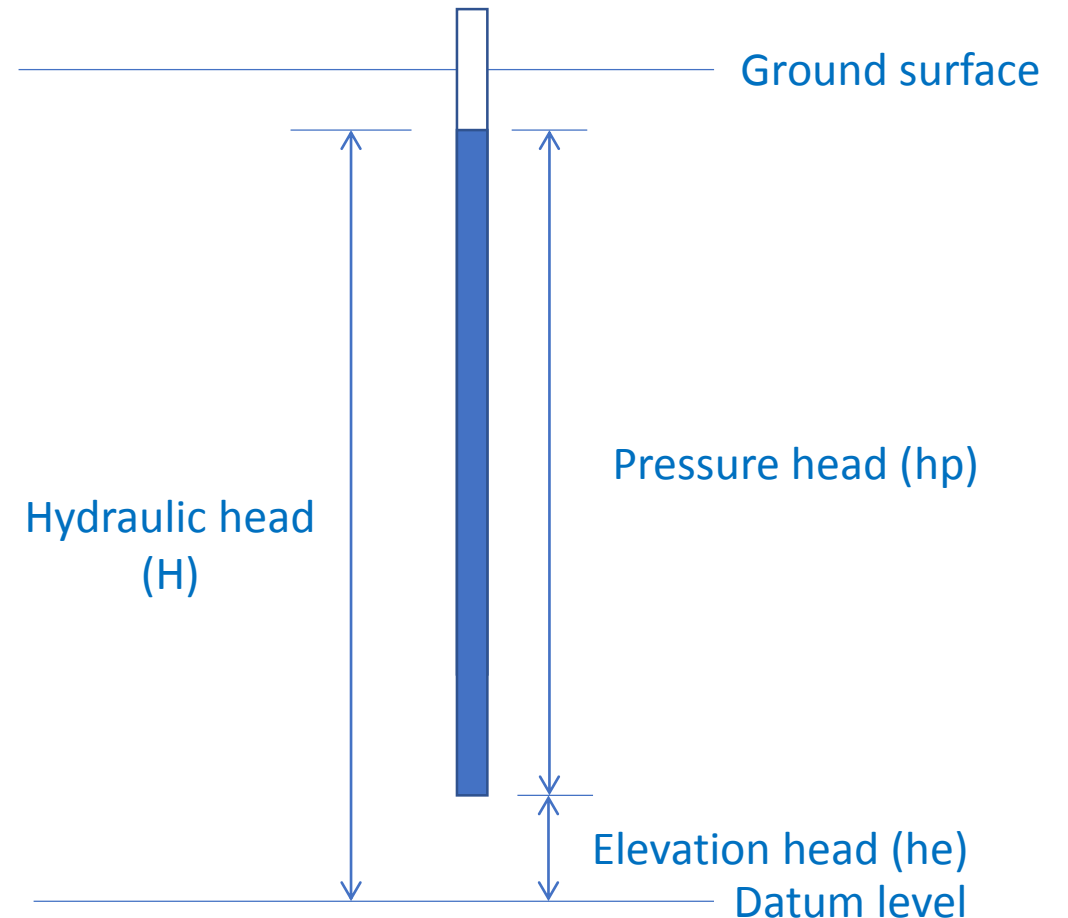
How does the water flow in the rocks?

How do we know there is water below ground surface?

We need monitoring well

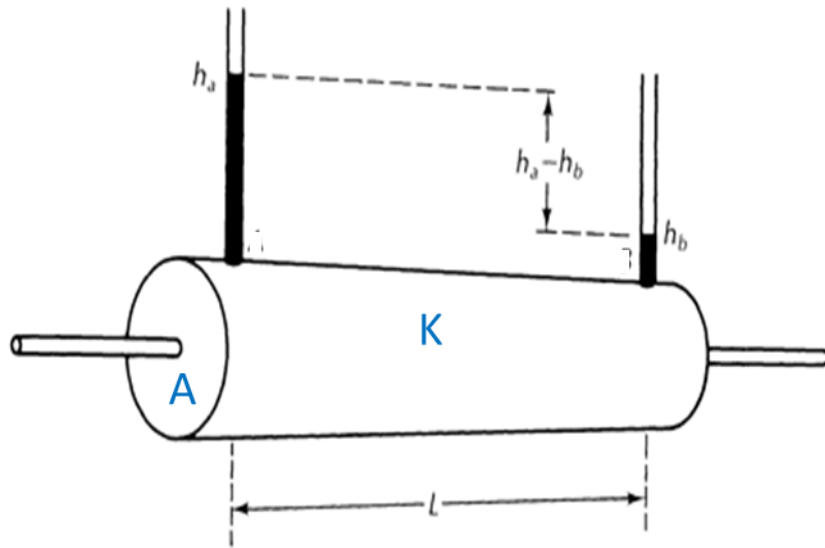**Pressure head** equals to the length of water column in pipe.

The elevation of pipe's bottom from datum is **elevation head**.

Hydraulic head is a sum of two above

Ground surface

Pressure head (hp)

Hydraulic head (H)

Elevation head (he)

Datum level
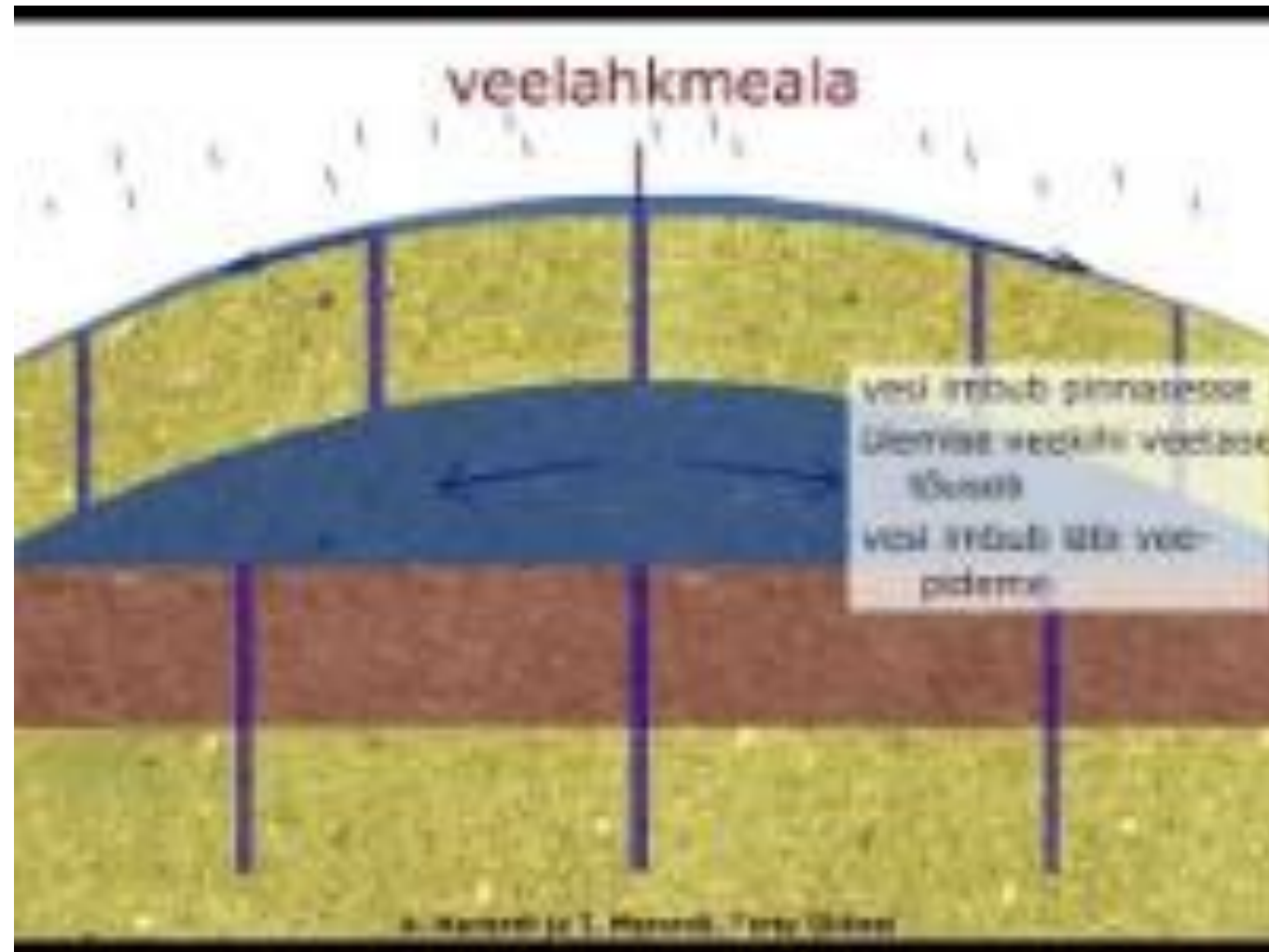
How does the water flow in the rocks?

Darcy's law

Water flows **towards the lower pressure**. The amount of flowing water **(Q)** through the cross-section area **(A)** depends on the properties of media **(K)** and the differences of pressures **(h_a-h_b)** on both ends of flow section **(L)**
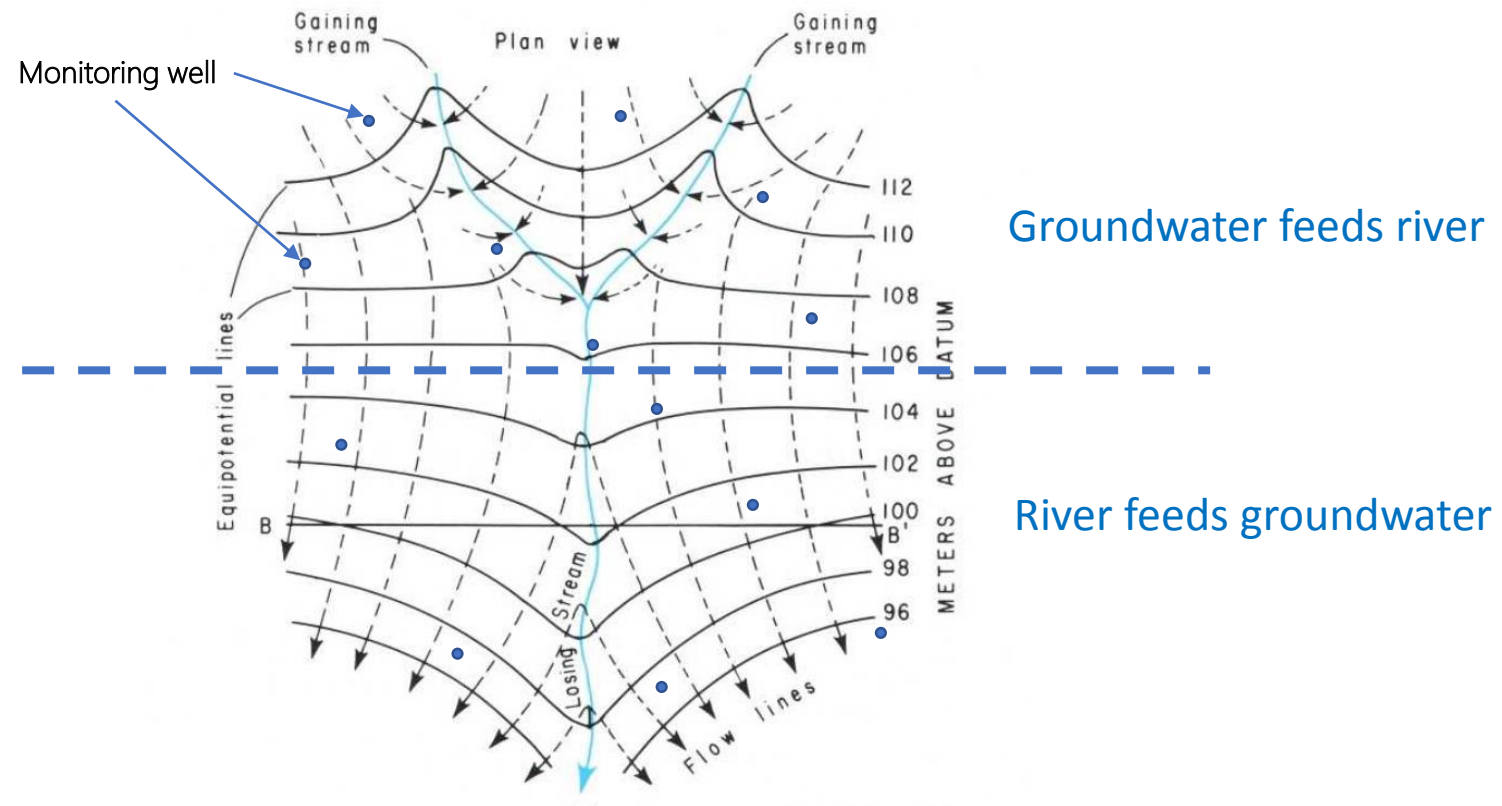
$$Q = -KA\left(\frac{h_a - h_b}{L}\right)$$

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In Nature, if groundwater is moving the head is dropping into the direction of flow

Groundwater feeds river

River feeds groundwater

Basic Groundwater Hydrology, USGS Water supply paper 2220, https://pubs.usgs.gov/wsp/2220/report.pdf

A Fool & Water Go The Way They Are Diverted

(African proverb)

bit.ly/WaterAct-project

bit.ly/WaterAct-Researchgate

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