

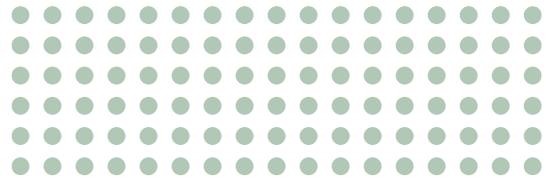
FROM GROUNDWATER FLOW TO SOCIETAL CLIMATE ADAPTATION



A Transdisciplinary Journey



JUDIT MÁDL-SZŐNYI
ILDIKÓ ERHARDT



Jura Mountain, Switzerland



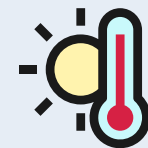
<https://peakvisor.com/range/jura-mountains.html>



Illustration by Borut Peric



Severe hydrological extremes



Increasing temperature



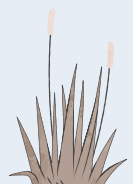
**Intensified water cycle
—
less frequent but more
intense rainfall events**



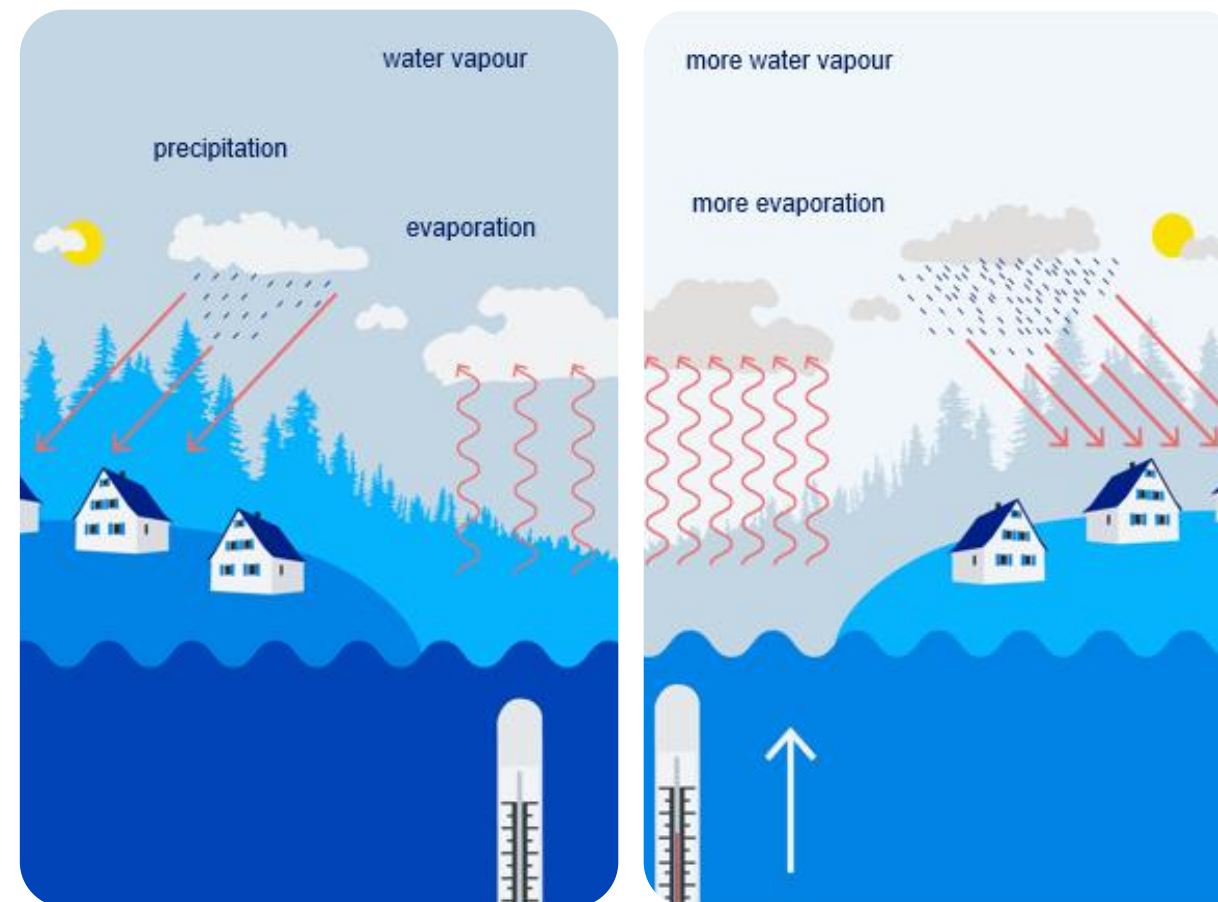
**worsening drought, falling
water levels**



intermitting flood events



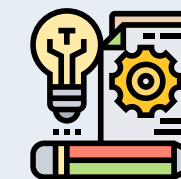
dry of wetlands



(Climate Council)



significant economic damage



forced adaptation...

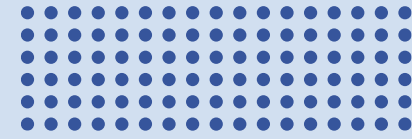
Invisible part of the water cycle: Where does the water want to go?



Not only the rock spaces count but also the water movement

Shifted focus from the rock to the groundwater flow





wooclap

Let's interact :)



1

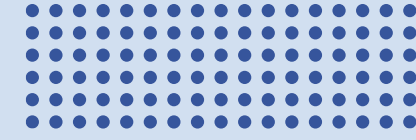
Go to wooclap.com

2

Enter the event code in the top banner

Event code

CHARMWATER



Groundwater movement – key scientific insight



My thinking about groundwater has changed

Specialized in understanding groundwater flow at the regional scale

<https://regionalgwflow.iah.org/>



Prof Joe Tóth
1933 -

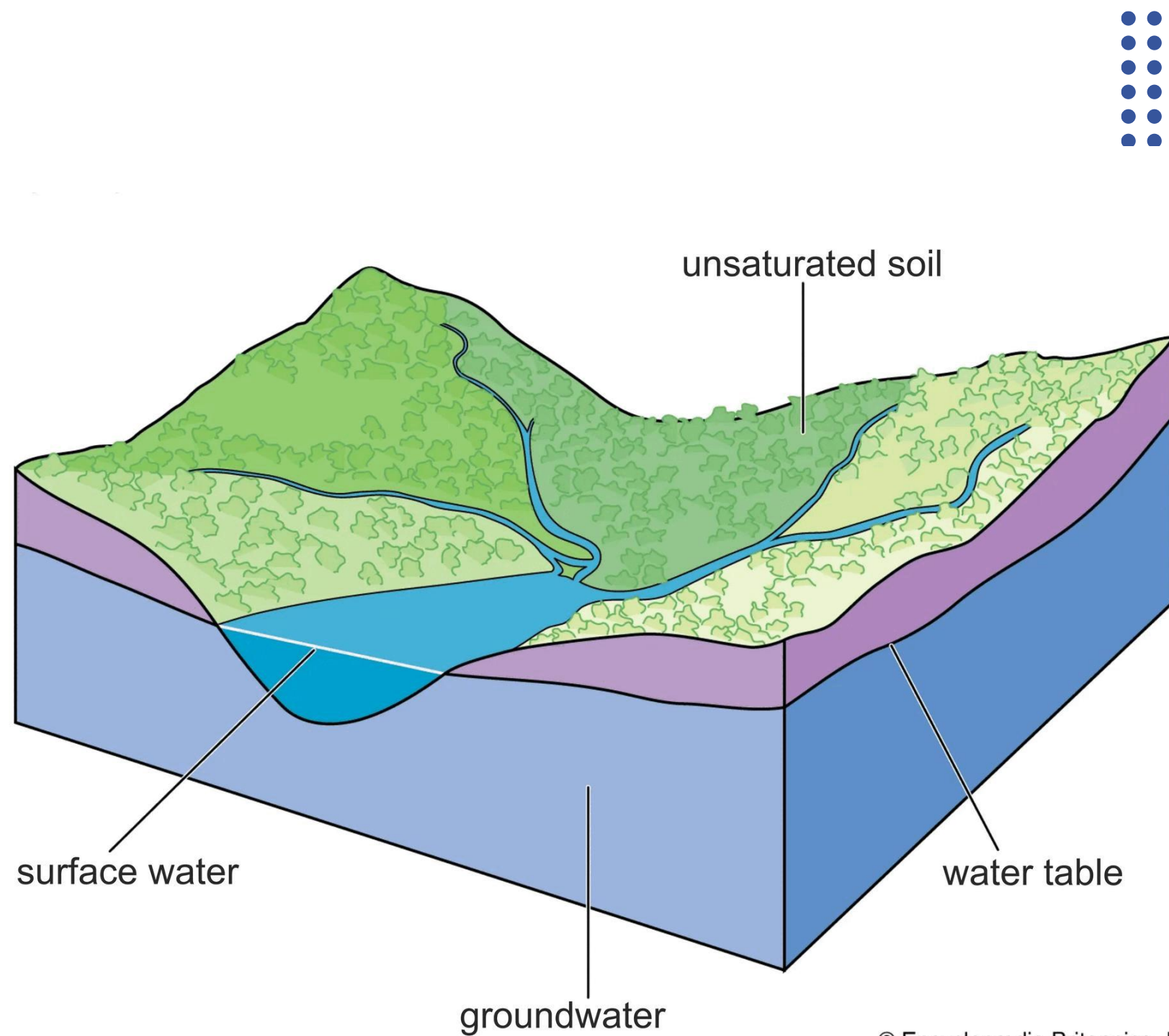


<https://tothprofesszura.elte.hu/?lang=hu>

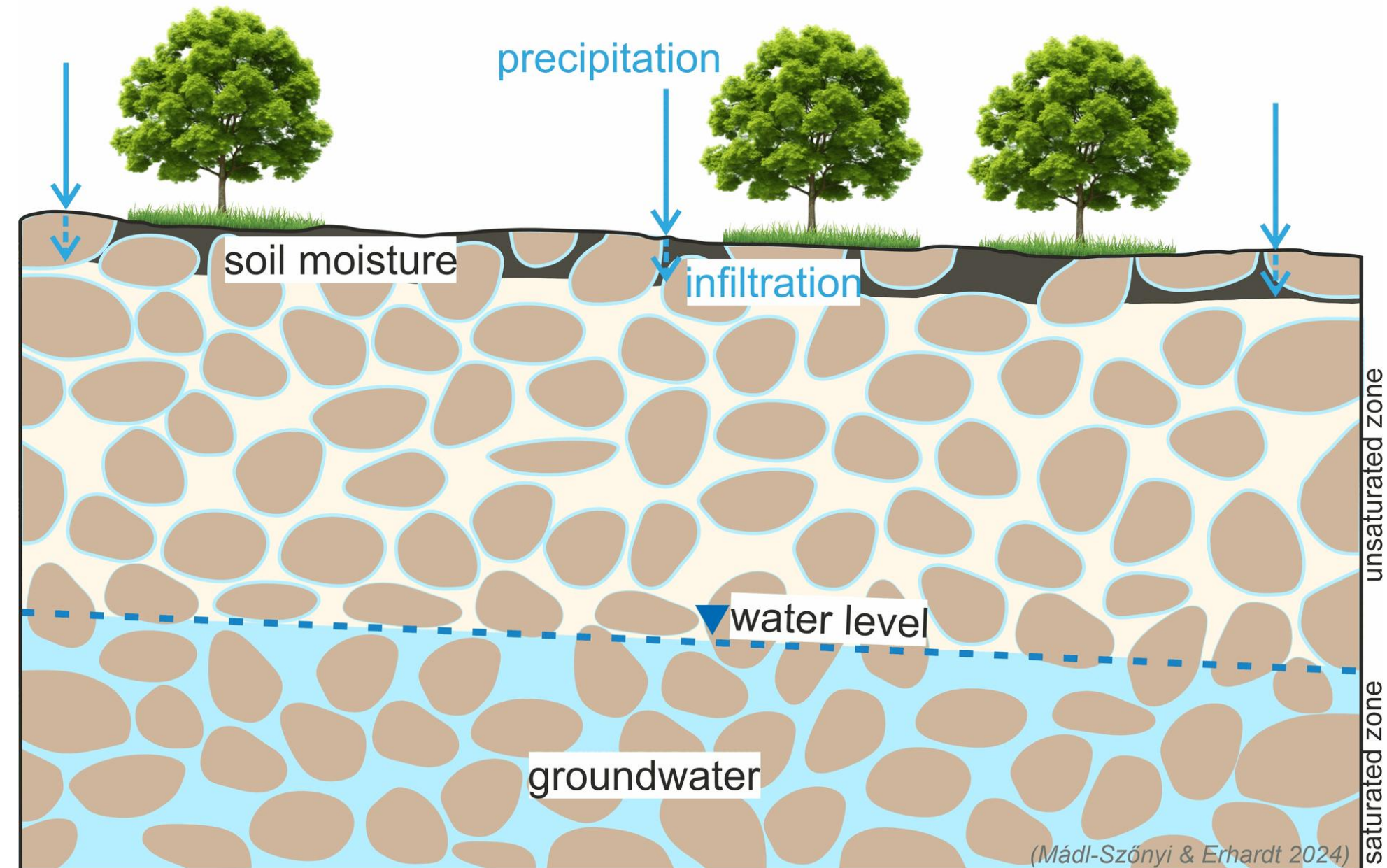
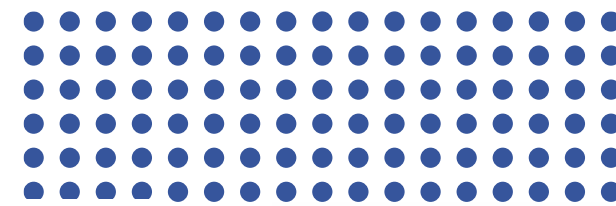


A closer look at groundwater movement

1) Continuous water table with pores and cracks in the rocks saturated with water.

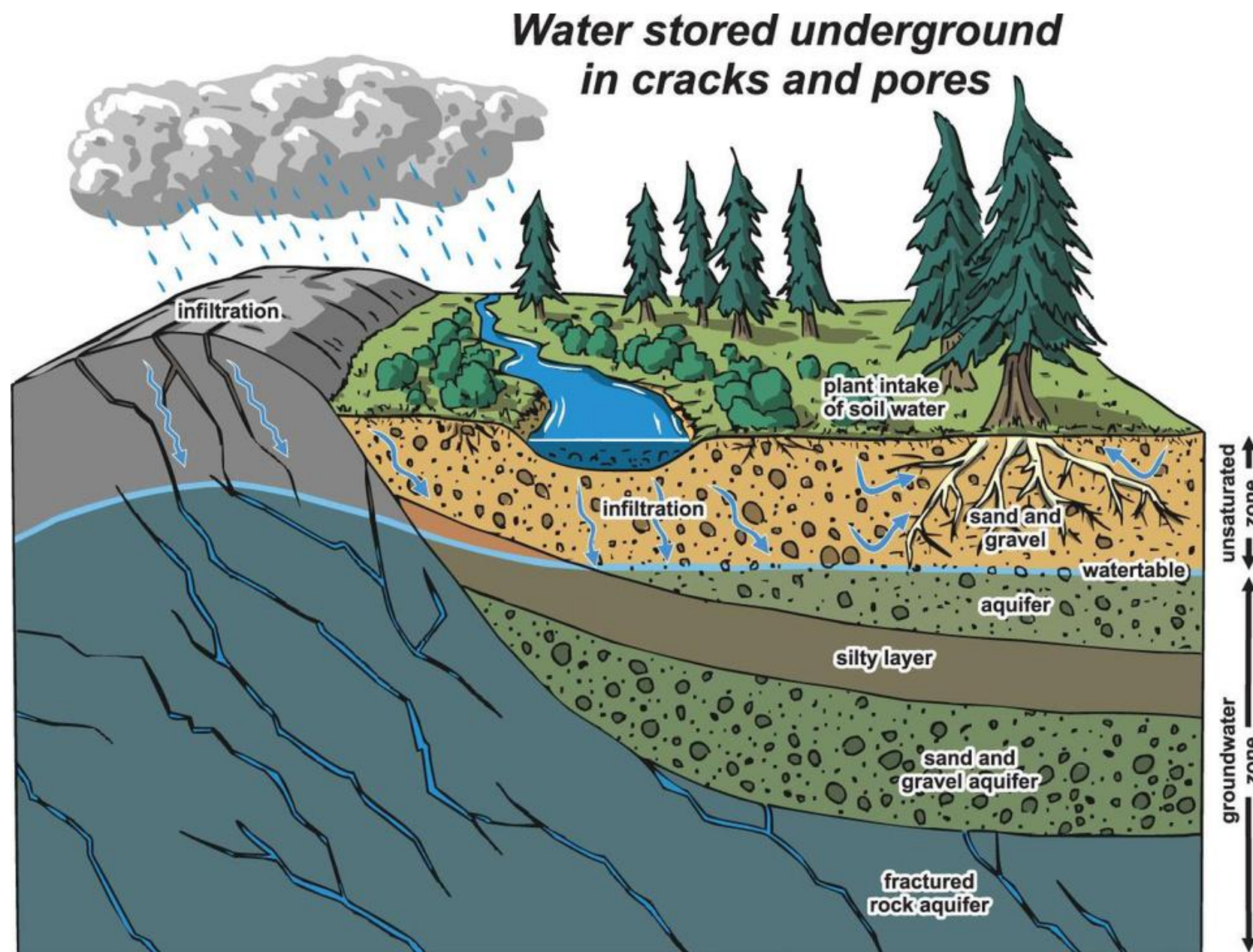
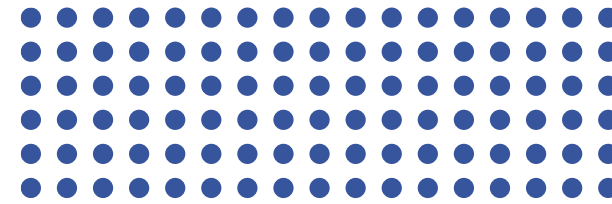


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(Mádl-Szőnyi & Erhardt 2024)

A closer look at groundwater movement

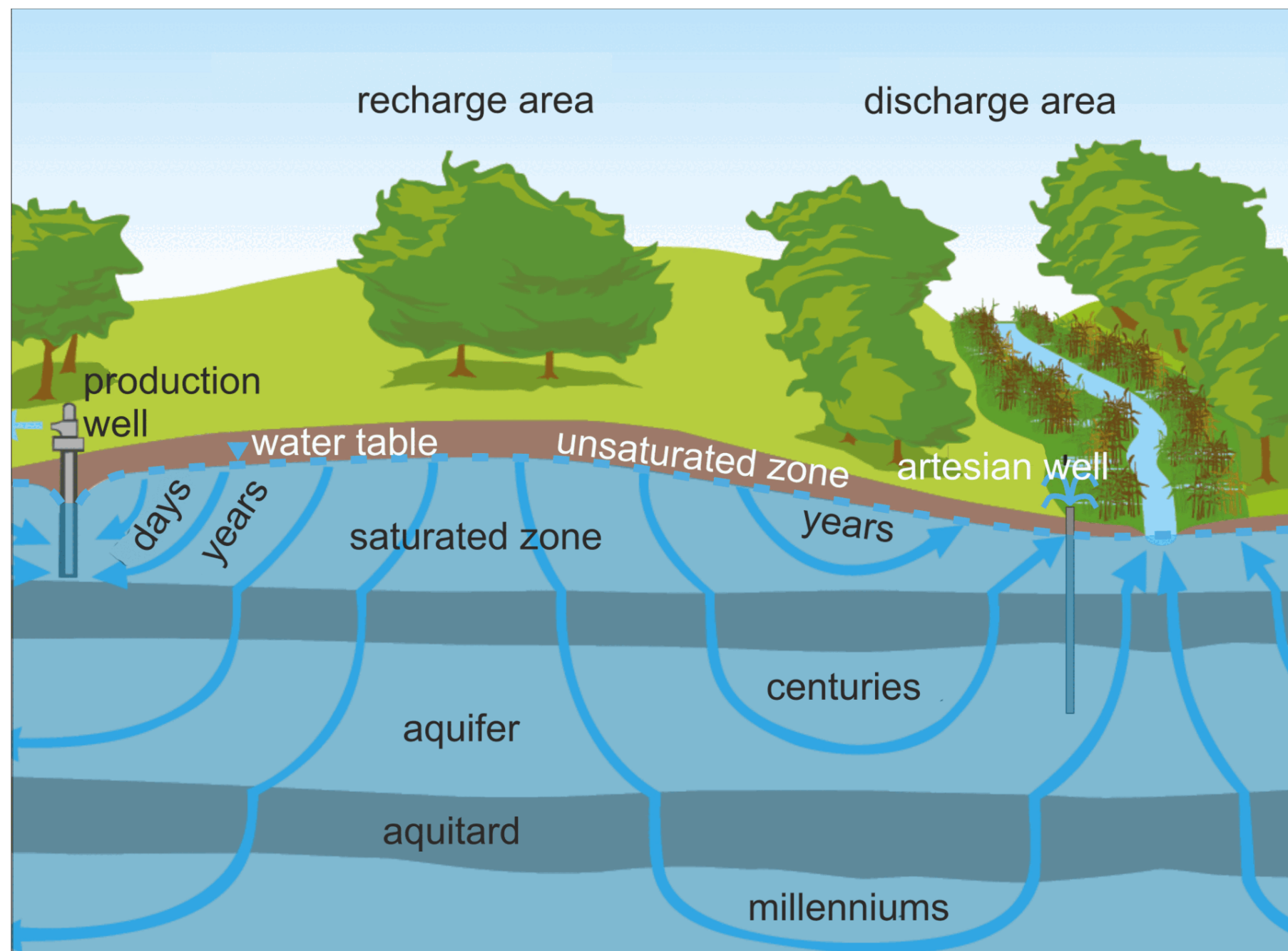
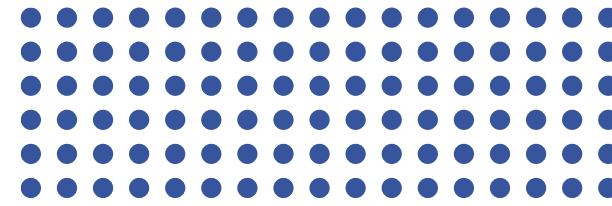


2) In nature, there is NO perfect impermeable rock, due to the complexity of geological formations.

Water move through of them, so the waters below the surface are interconnected.

For this reason, we should think about groundwater in landscape scales...

Understanding flow: recharge and discharge



3) Physically describe the continuous movement of groundwater.

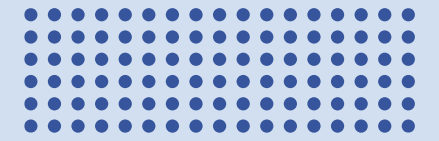
4) Driven by differences in water levels.

5) Flows from areas of higher elevation (recharge zones) to lower areas (discharge zones) like river valleys.

6) This movement is slow, seepage. The residence time of water below the surface varies widely (days to millions of years).

Invisible groundwater flow is affecting the surface water conditions and ecosystems!

Climate change - less infiltration



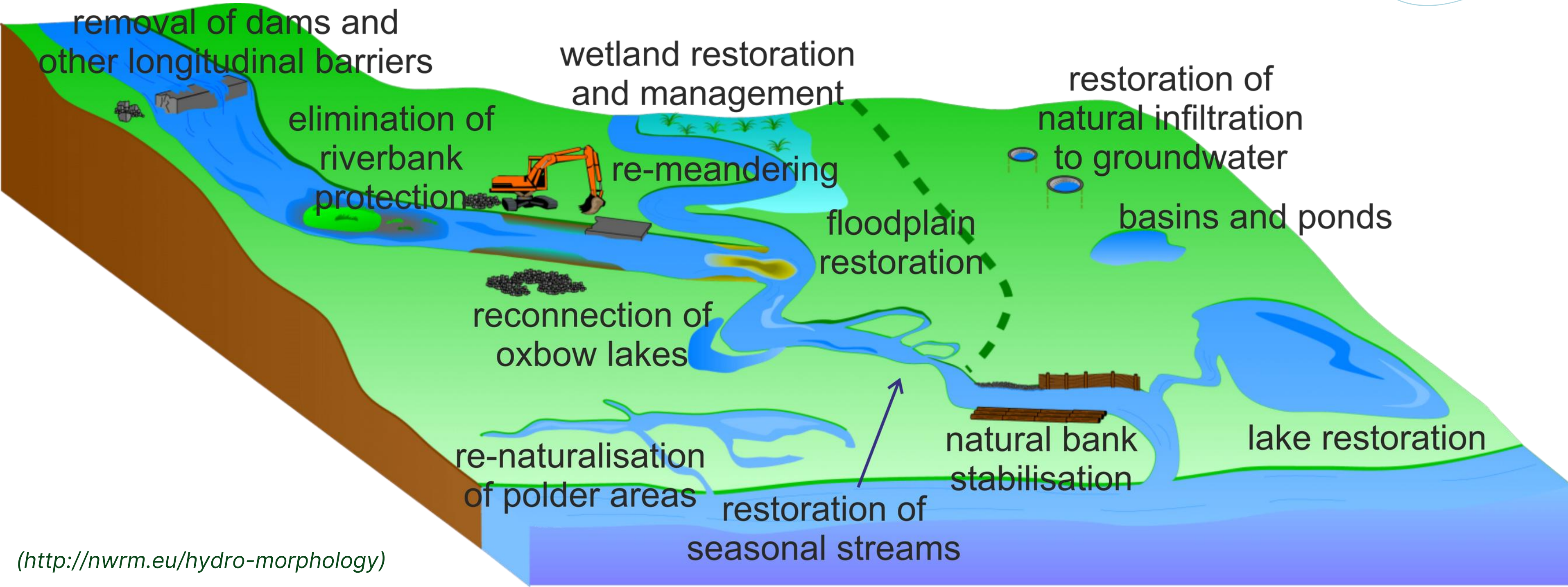
Infiltration - Wirksworth Running Club



Runoff - Street Photography Berlin

Store water: natural surface water retention

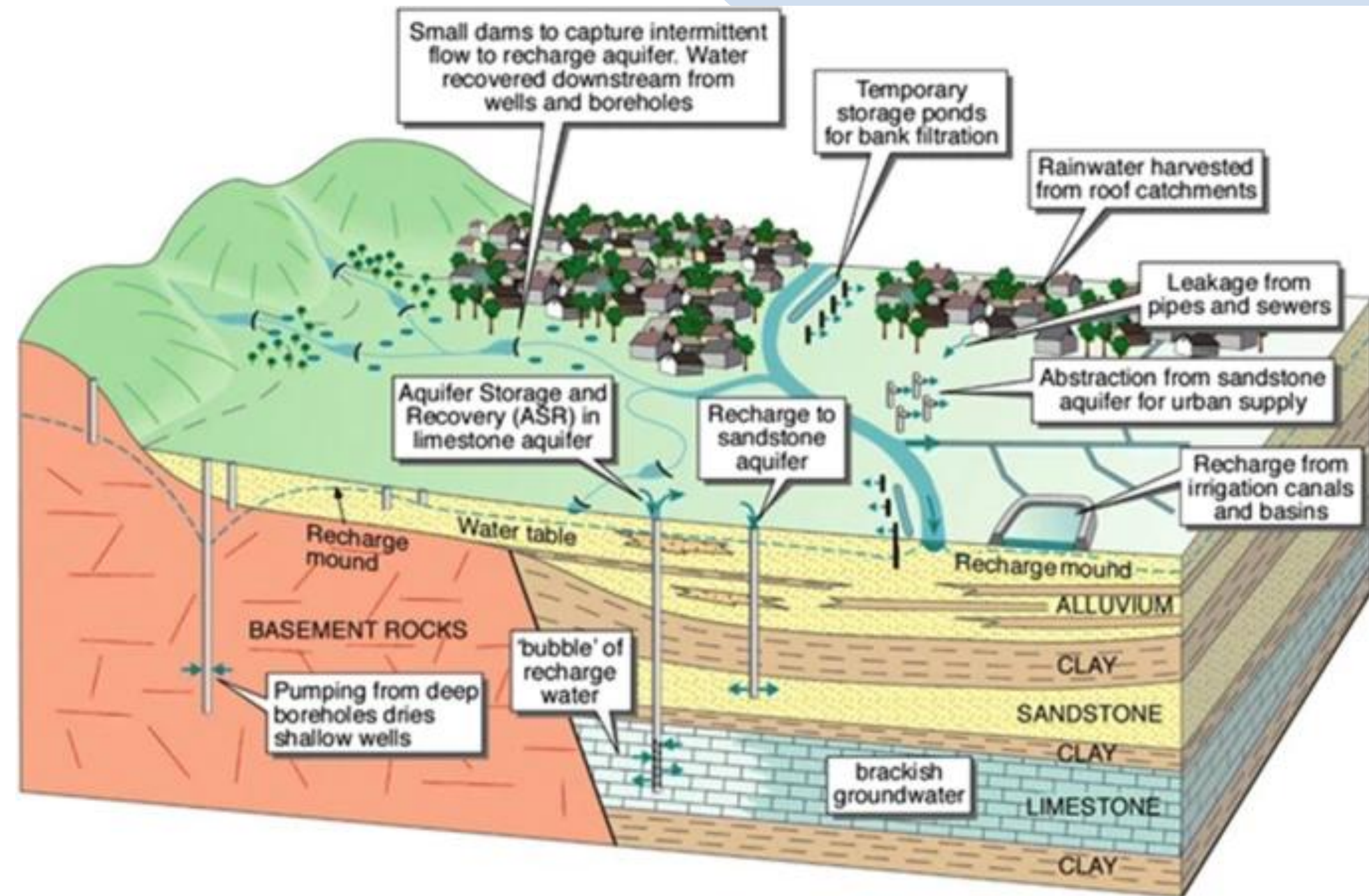
What can we do about this serious situation?

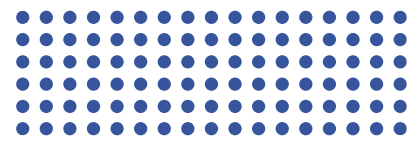


The biggest storage space is underground: MAR (Managed Aquifer Recharge)

How does MAR work?

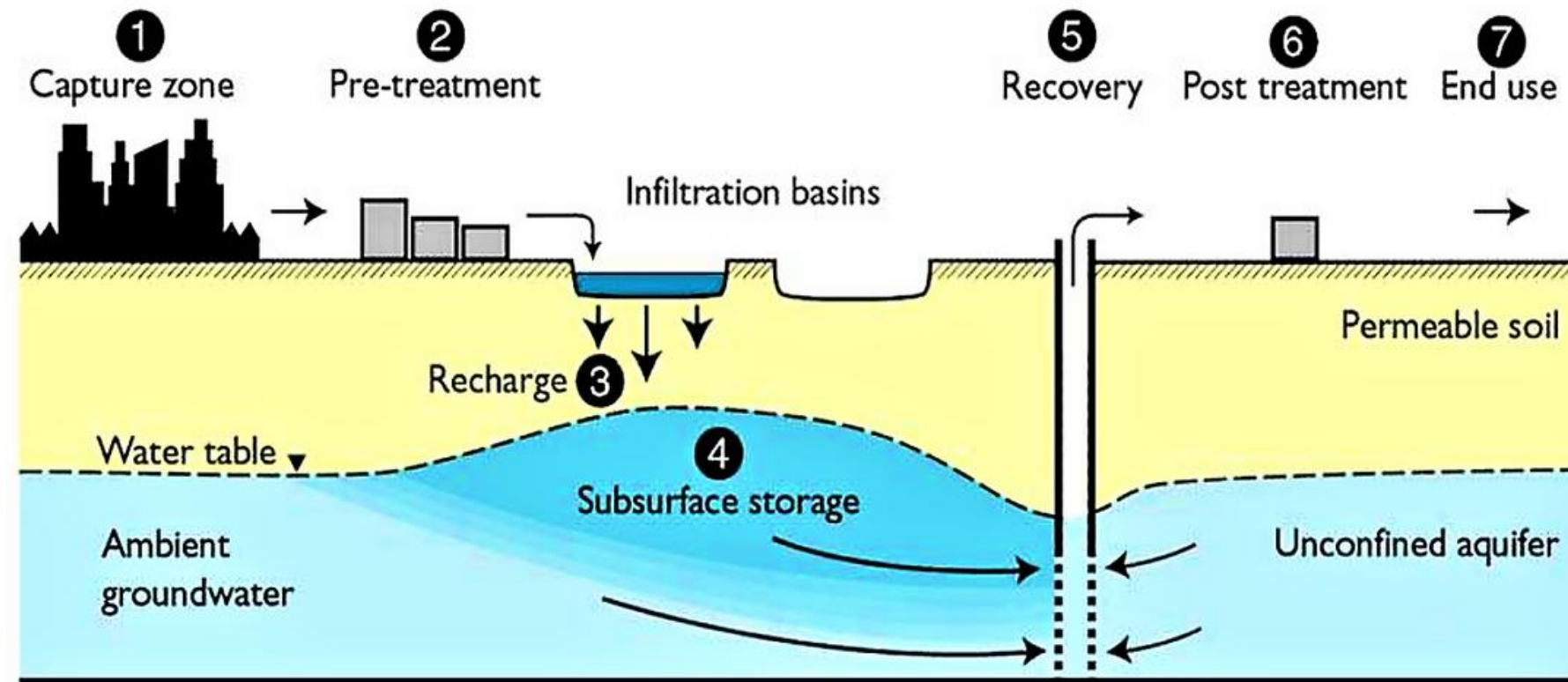
- Intentional disposal of excess water in underground reservoir rocks.
- To keep water on local-scale.
- To achieve later recovery or environmental benefits.



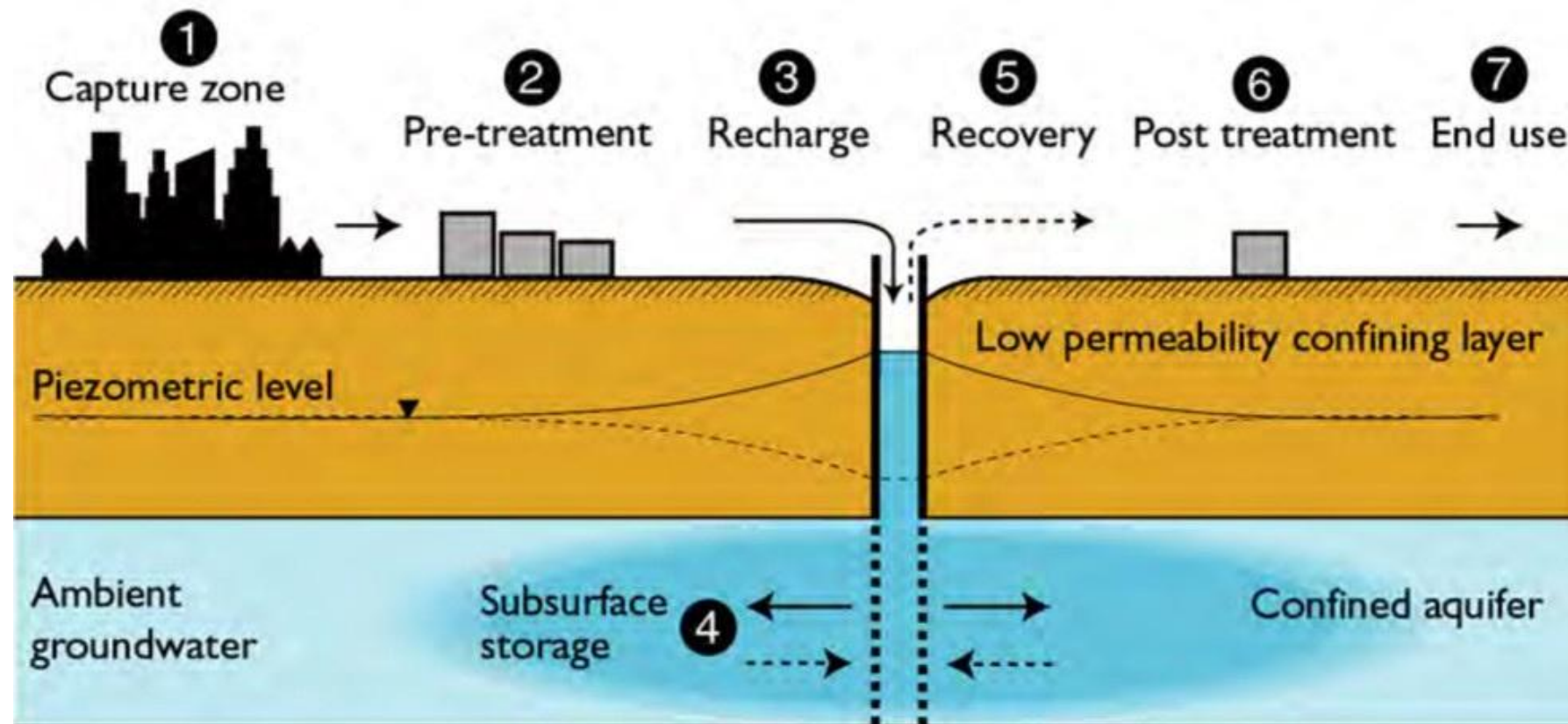


Sources and location of recharge

Shallow permeable rock



Deeper permeable rock



Elements

Excess water source:

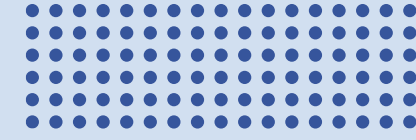
- precipitation
- treated wastewater
- floodwater
- etc.

Permeable rocks - reservoir:

- sand
- limestone
- etc.

Water injection method:

- infiltration basin
- well etc.

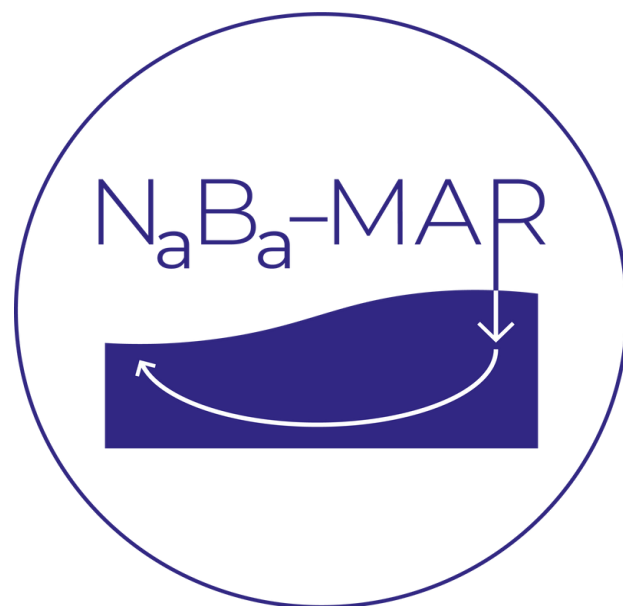


Identify a problem to be solved





From problem to solution: Know-how: NaBa-MAR



Questions:



Surface water retention is great - how does it affect groundwater?

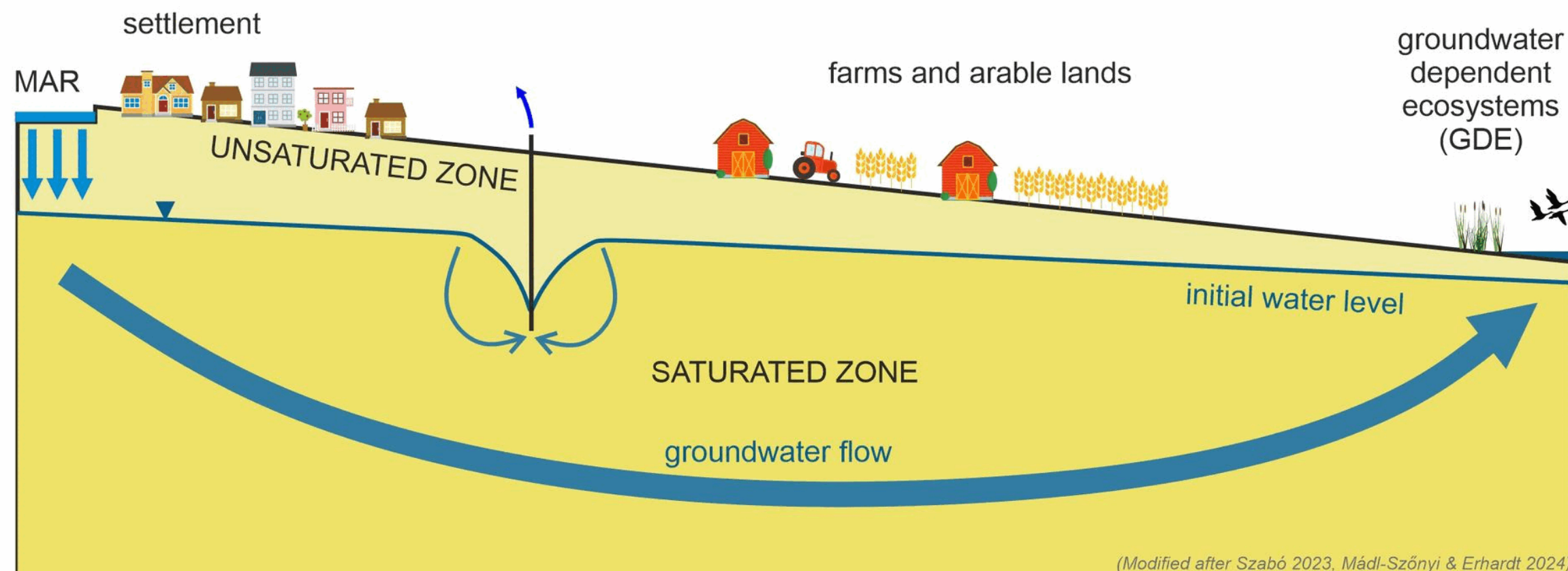


How groundwater influences the effectiveness of surface water retention?

RECHARGE AREA

THROUGHFLOW AREA

DISCHARGE AREA

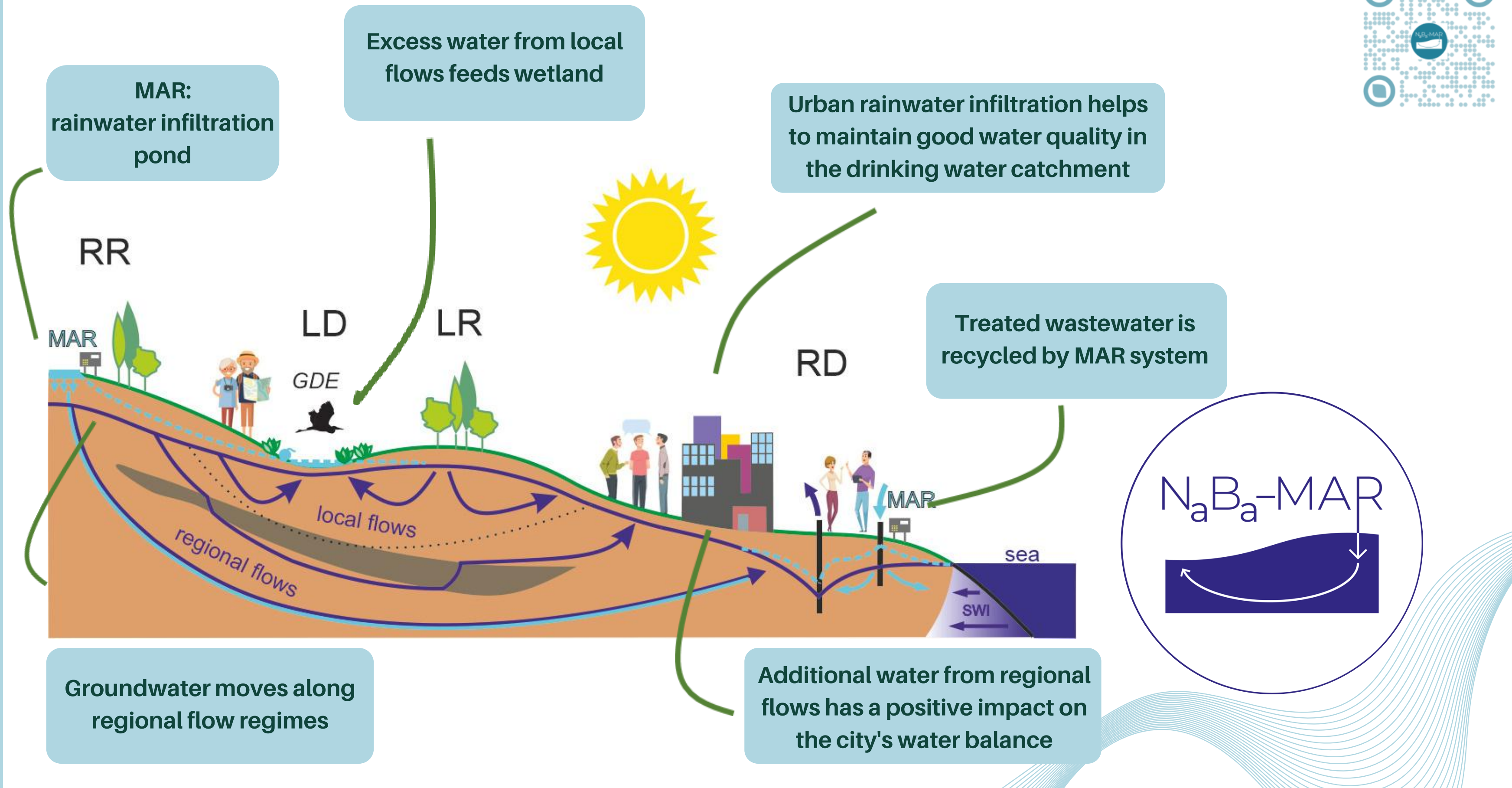


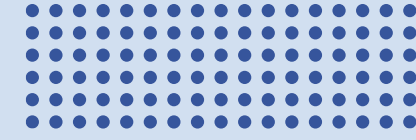
(Modified after Szabó 2023, Mádl-Szőnyi & Erhardt 2024)

The ELTE's landscape-scale NaBa-MAR innovation offers a solution...

- **combining local-scale MAR technics with natural groundwater flow**
- **harness natural groundwater flow to mitigate hydroclimatic extremes**
- **scales up solutions to landscape scale**

How NaBa-MAR works in a complex landscape?





Reaching society and decision makers



**Co-funded by
the European Union**



Transdisciplinary approach



Metodology development



Exploring social and economic impacts



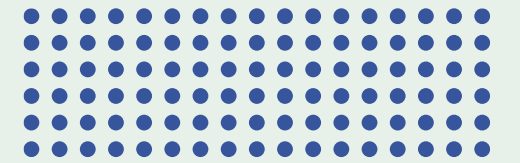
Improving public policy frameworks



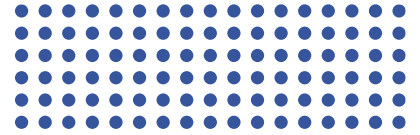
Creating a decision support tool



Improving social awareness



Public perception - Representative survey



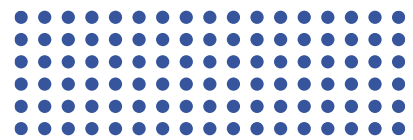
A Survey was conducted on a representative sample of 1000 people in Hungary (*Varga et al. 2025*):

- society underestimates the importance of groundwater
 - several scientifically outdated beliefs about the existence of entirely impermeable layers
 - limited knowledge about groundwater flow
 - society's attitudes towards groundwater are generally positive
-
- the use of rainwater, flood water and surface water for MAR is basically supported
 - this is not so clear for the use of treated wastewater

The survey is being continued among

- university students of ELTE, TCD, UU, UB and UZ,
- university students participating in CHARM-EU programs,
- secondary school students, landowners, and residents of the municipalities concerned.

Implementation of various tools to enhance knowledge and acceptance of NaBa-MAR solutions.

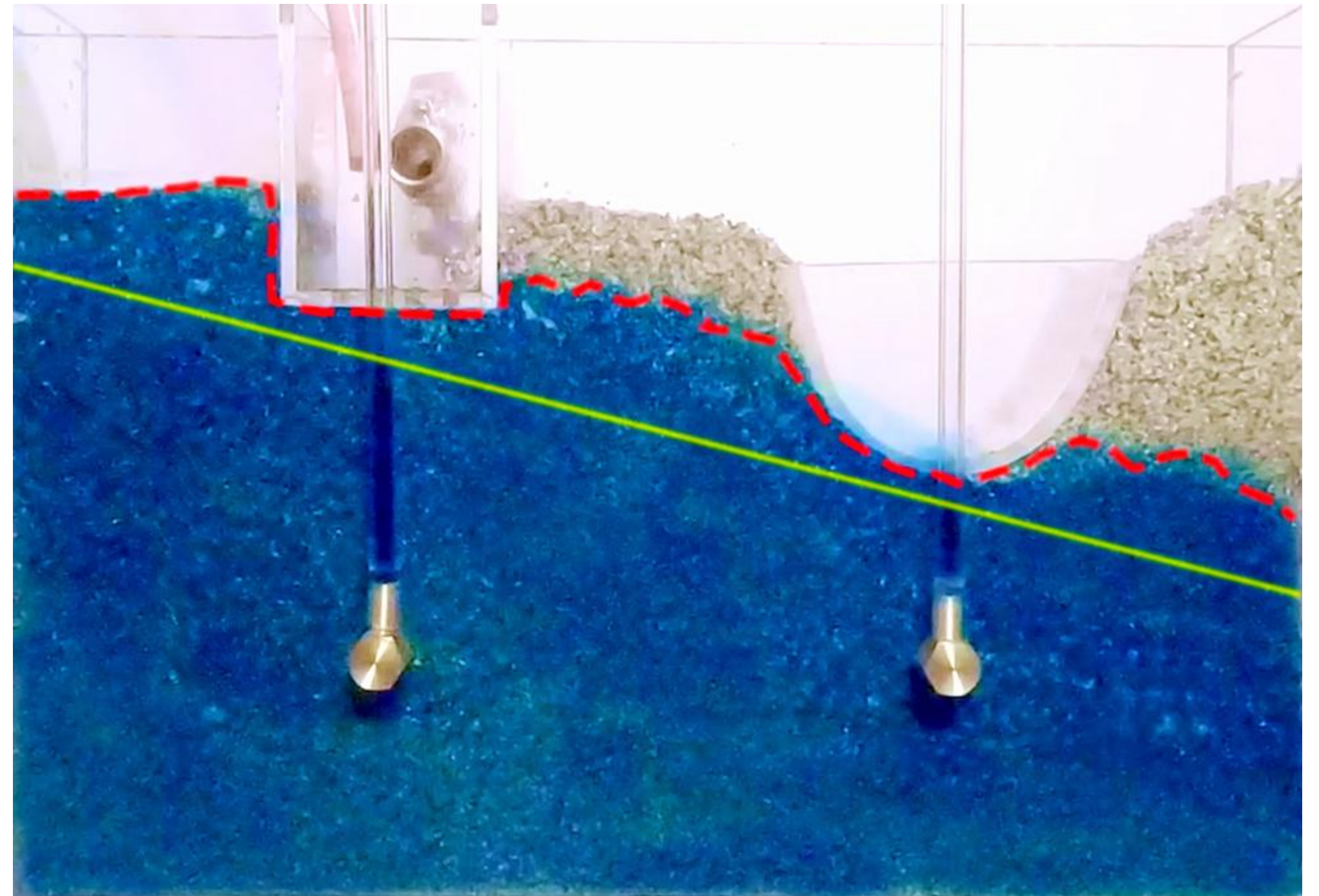
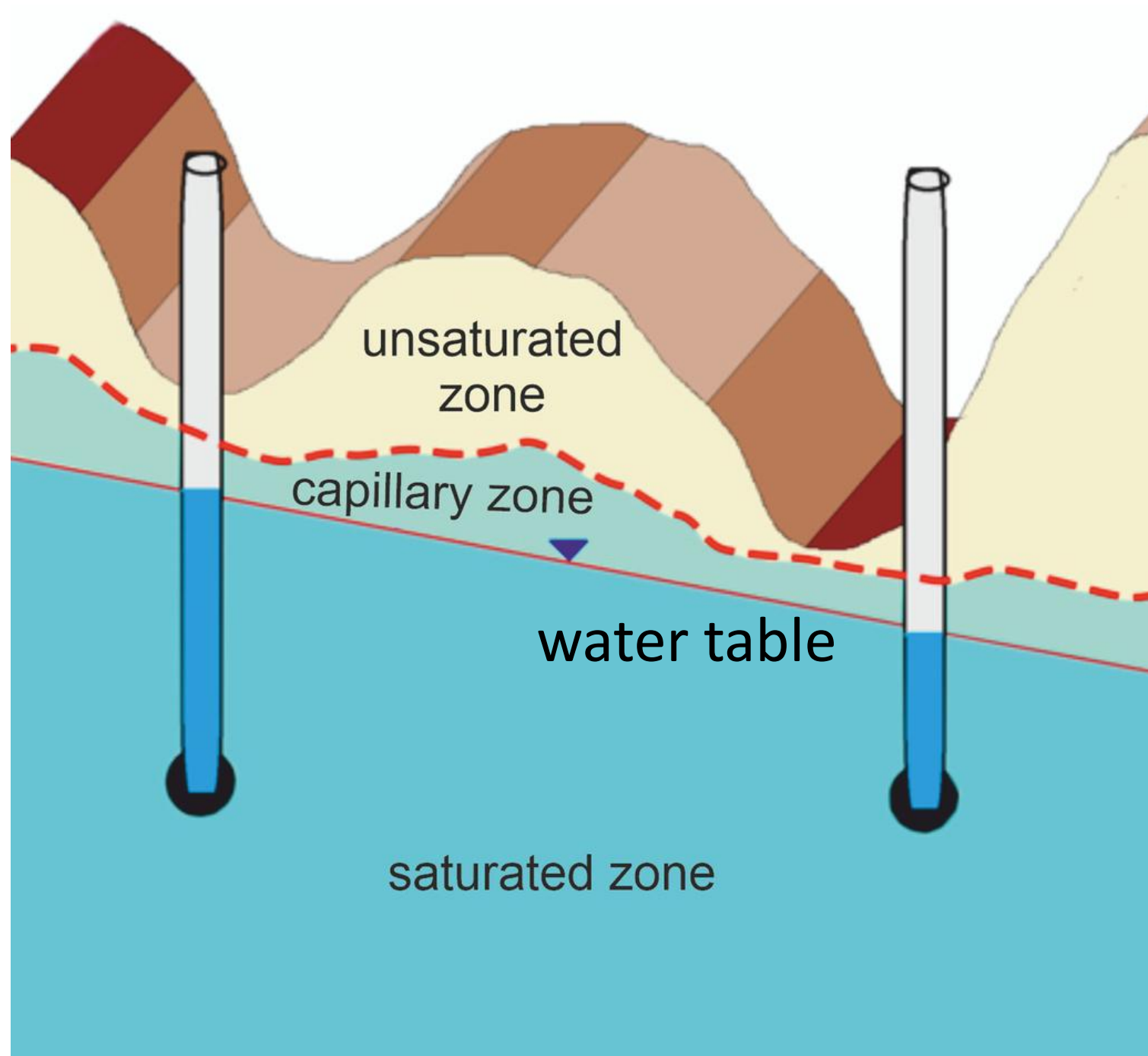


Making the invisible visible

The physical model

infiltration basin

canal

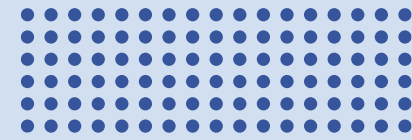


Physical model



ELTE | TTK
TERMÉSZETTUDOMÁNYI KAR

Part 3: Infiltration-based managed aquifer recharge



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What have we learned?



1

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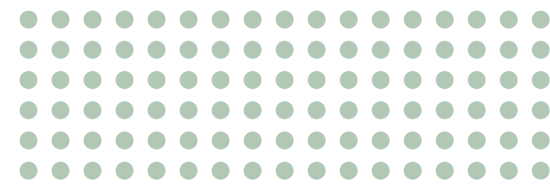
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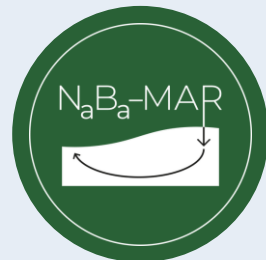


Take home messages

Scientific



Groundwater is the primary water reserve for humanity and ecosystems, and it can buffer against extreme water conditions.



NaBa-MAR provides a comprehensive solution for the adaptation to hydroclimatic extremes.

Personal



Come to see my own path as a scientist differently: transitioning from traditional science to transdisciplinary collaboration.



Cooperation with social scientists would help me see how I can apply innovation for communities.

General



Trans-disciplinary research opens up new dimensions of research innovation and societal impacts.



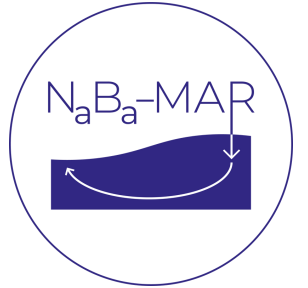
The CHARM-EU University Alliance is fantastic platform for this kind of work.



<https://tothprofesszura.elte.hu/>
<https://nabamar.elte.hu/>



THANK YOU!



Inspired by CHARM-EU Alliance and based on the results of its R&I project TORCH

The development of the NaBa-MAR innovation and the participation at the summer school was supported by the Excellence Fund of Eötvös Loránd University.

The ClimEx-PE project received funding from the European Commission and Ministry of Culture and Innovation of Hungary from National Research, Development and Innovation Fund; the Irish Environmental Protection Agency; the Dutch Research Council and the Agencia Española de Investigación in the frame of the collaborative international consortium ClimEx-PE financed under the 2022 Joint call of the European Partnership 101060874 — Water4All.

This work has been implemented by the National Multidisciplinary Laboratory for Climate Change (RRF-2.3.1-21-2022-00014) project within the framework of Hungary's National Recovery and Resilience Plan supported by the Recovery and Resilience Facility of the European Union.



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