MAR suitability mapping combined with field examination and numerical simulation in the Danube-Tisza Interfluve

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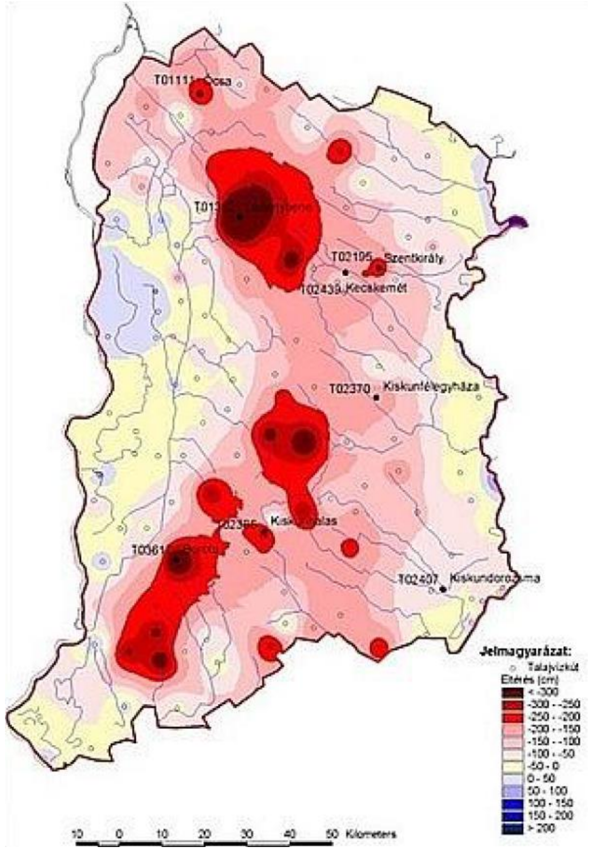
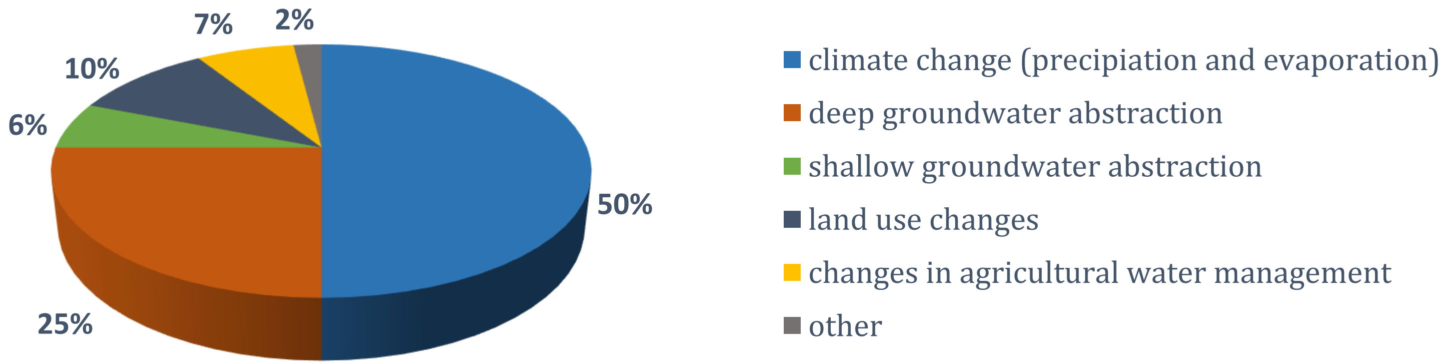
1. Introduction and aims

- **Water level drawdown** in the area due to climate change and additional anthropogenic effects
- Numerous replenishment plans were worked out in the past decades but using **Managed Aquifer Recharge** hasn't been considered yet
- The aim of this research is to find **suitable areas** for MAR and to assess water recharge possibilities in a local study area



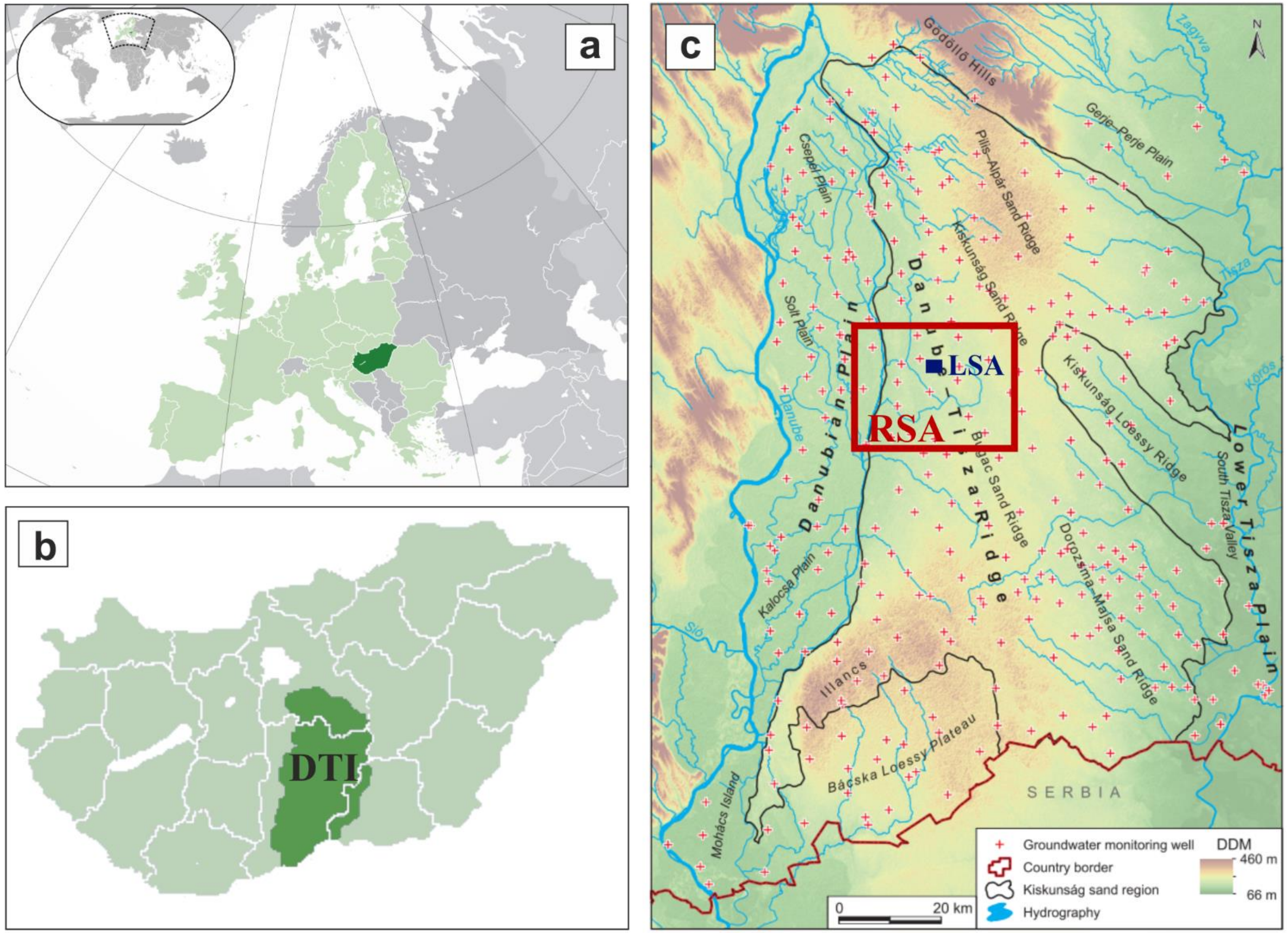
Water level changes between 1956-60 and 2002
(VITUKI, 2002)



Reasons of groundwater level reduction
(based on Pálfai, 2010 and Nagy et al., 2016)

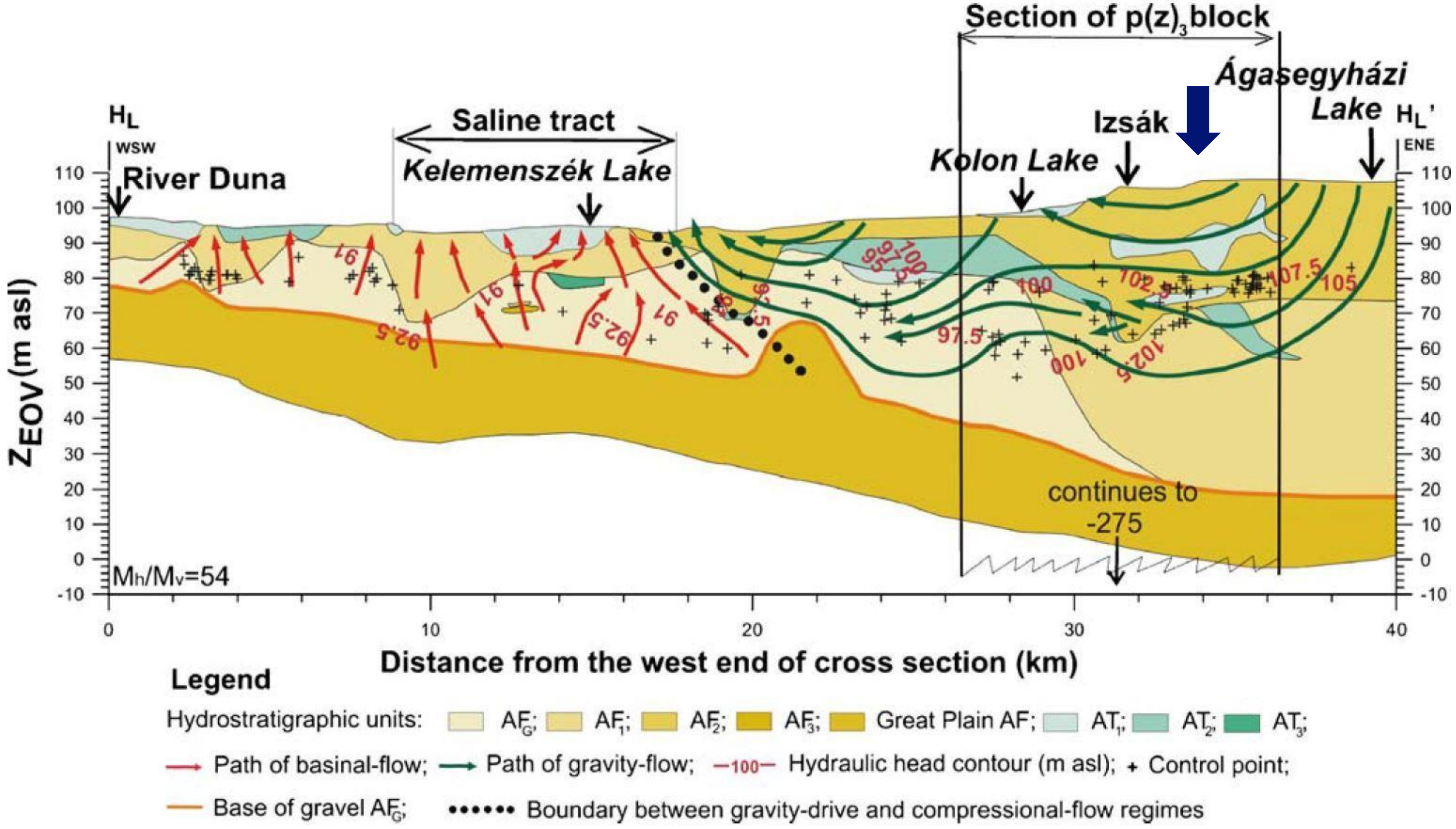
2. Study area

- Located in Hungary, in the Danube-Tisza Interfluve (DTI)
- DTI is a ridge region, up to 130 m a.s.l. between Danube and Tisza Rivers
- The river valleys are situated at 85-90 m above sea level
- Alluvial sediments of Danube and aeolian sands



Location of Hungary (a), the Danube-Tisza Interfluve – DTI (b), the regional study area – RSA (c, red rectangle) and the local study area – LSA (c, blue rectangle)
(Fig. 1c map modified from Kohán & Szalai, 2014)

2. Study area



Hydrostratigraphic and hydraulic section for the Western part of the Duna-Tisza Interfluve, AF-aquifer, AT-aquitard

Mádl-Szőnyi & Tóth, 2009

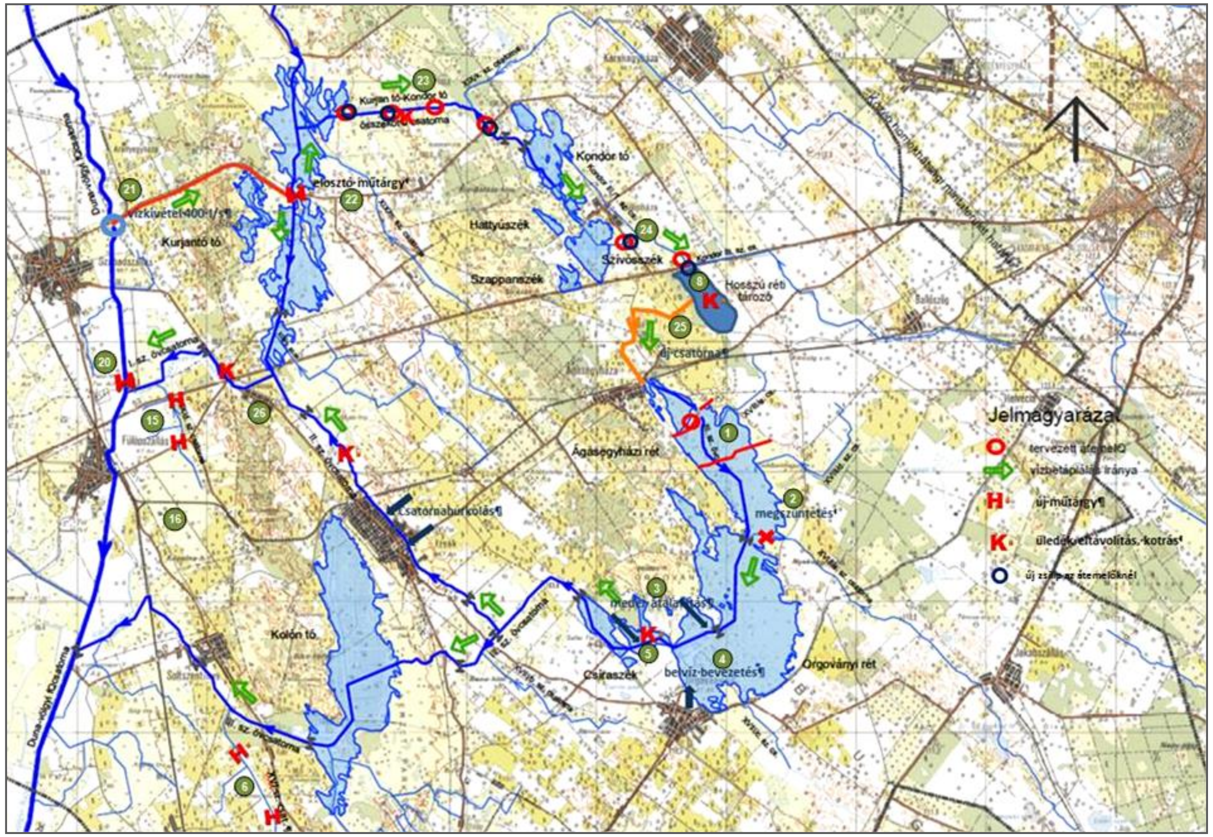
- The area's groundwater flow systems are characterized by a **gravity driven meteoric water** and an **over-pressured saline water**.
- The shallow flow systems of the elevated ridge region are under the effect of gravity driven meteoric flow regime.

3. Research background

- Water management problems in the broader area have been known for decades
- One of the most recent plans was to move water from the Danube Valley Channel to the center of the ridge, through existing channels and lakes (Nagy et al., 2016)
- Too expensive and not effective enough as the water can easily infiltrate from the channels and it would not reach the higher regions in sufficient amount
- One of the aim of this research is to find suitable areas for MAR utilisation

Lake Kondor

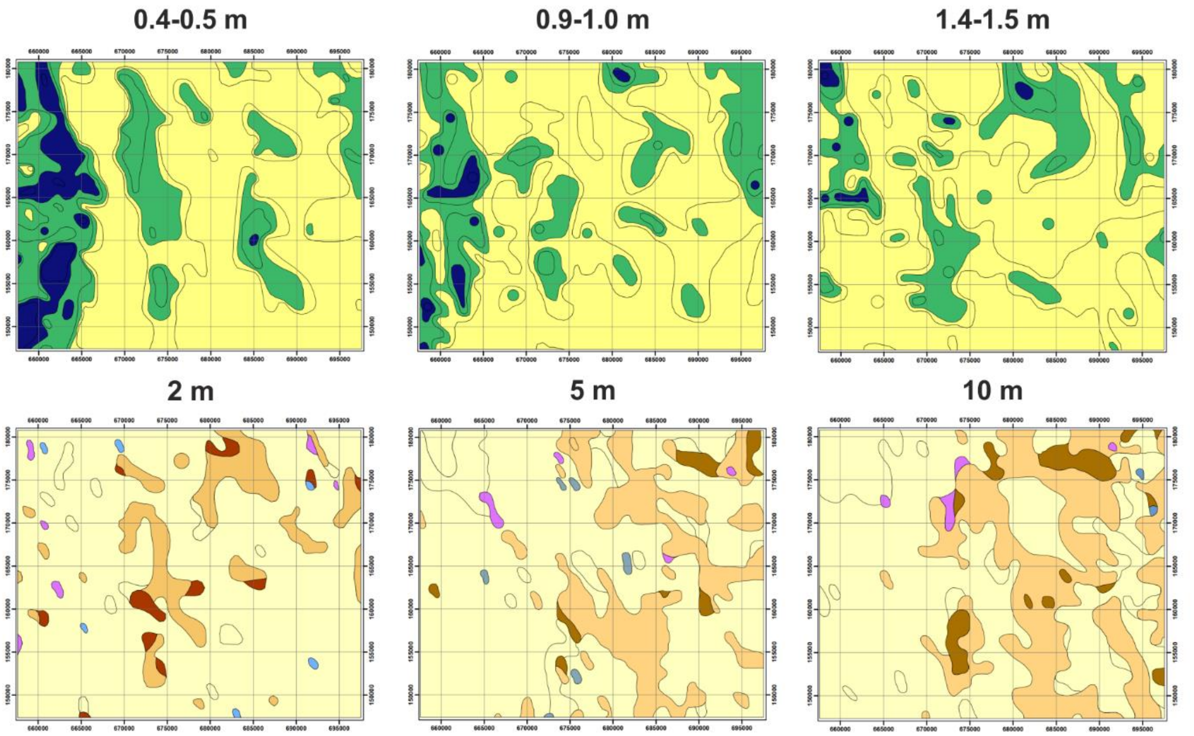
Western Water Supply Plan (Nagy et al. 2016)

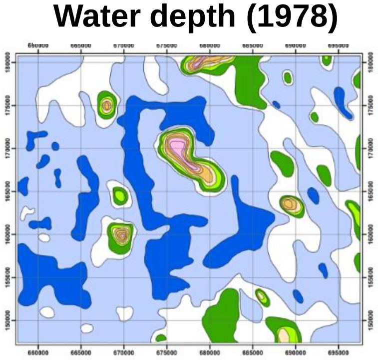


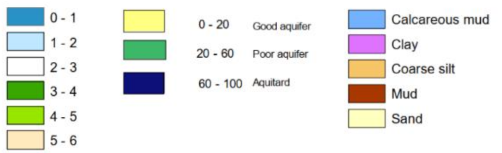
4. Methods

- **Suitability mapping** (Silva Cisneros, 2019) for the Western Water Supply Area (Regional Study Area – RSA)
- **Field measurements** (Local Study Area – LSA)
  - ERT and RMT geophysical measurements
  - Drilling by hand and soil sampling
  - Water level and water chemical meausements
- **Laboratory measurements** (LSA)
  - Water chemical measurements
  - Sieving and elutriation of soil samples
- **Numerical modeling** (LSA, cross section)

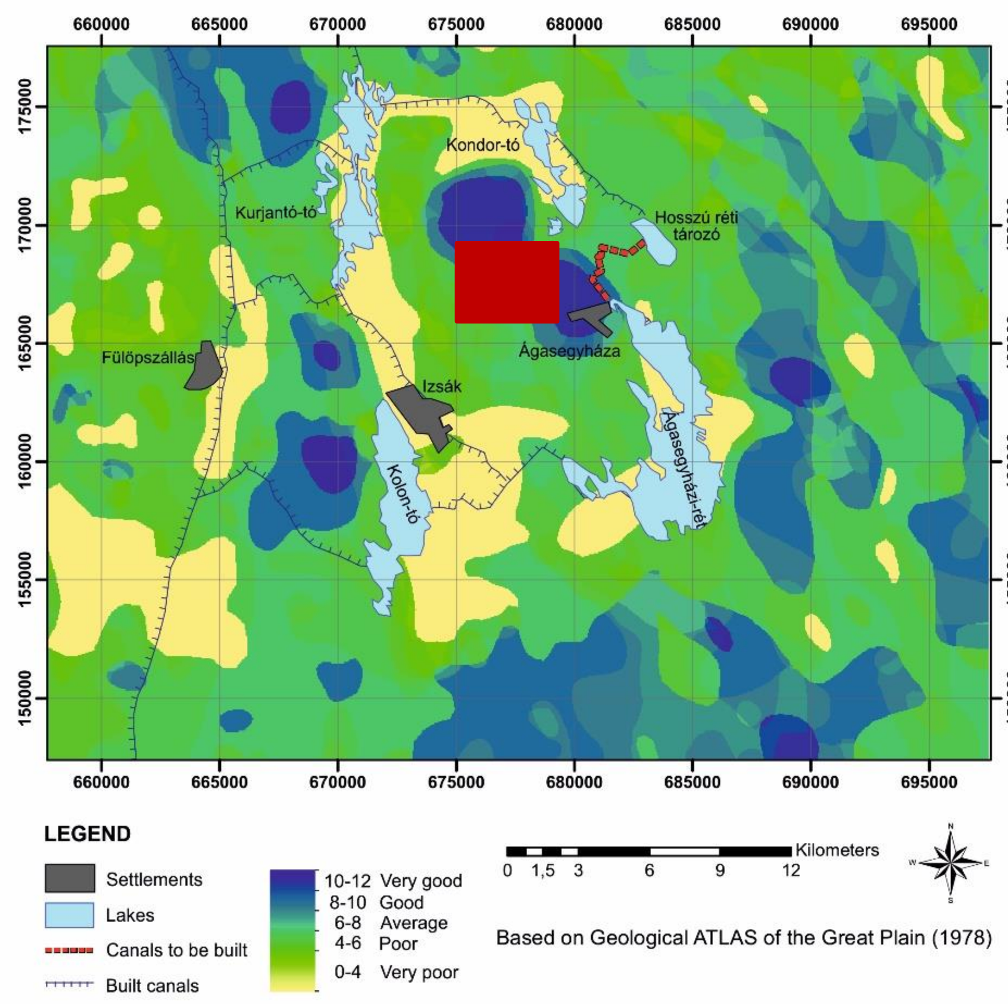
5. Suitability mapping





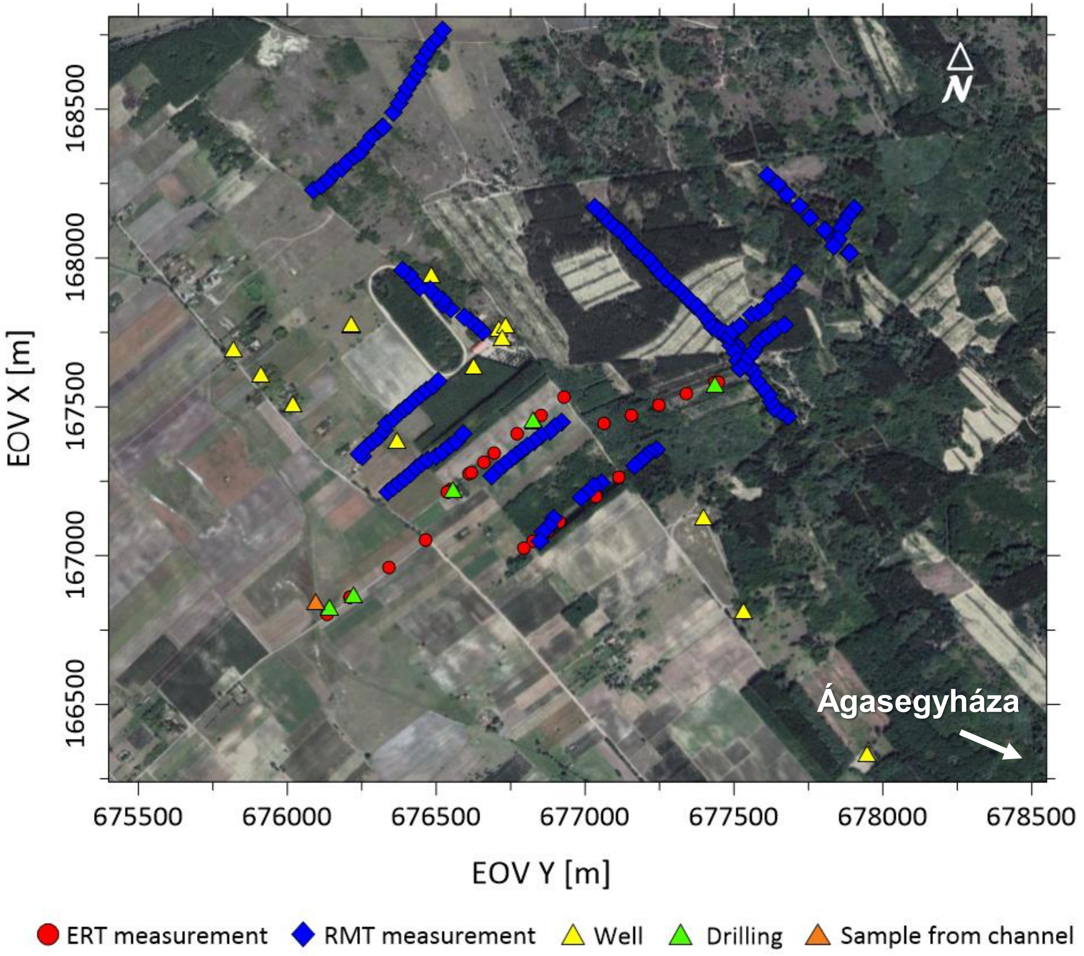


Silva Cisneros, 2019
and Mádl-Szőnyi et al., 2019



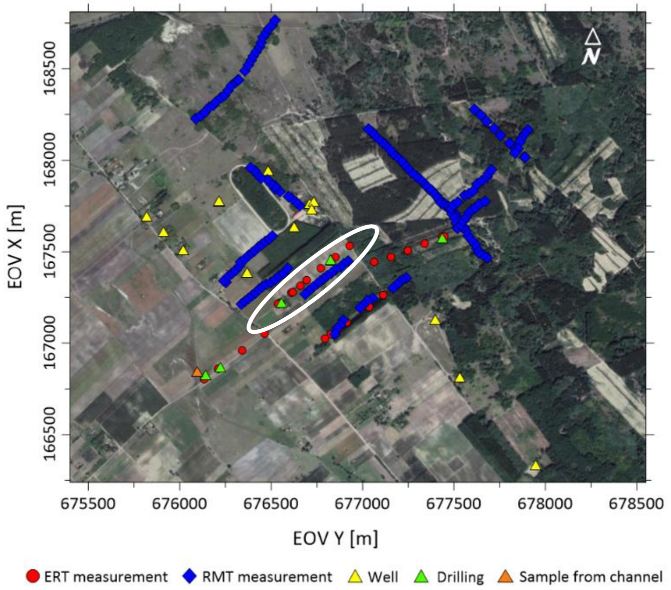
- Based on near surface geology and water table depth (slope is not an important factor in this area)
- A **local study area** was chosen based on the final suitability map

6. Field measurements



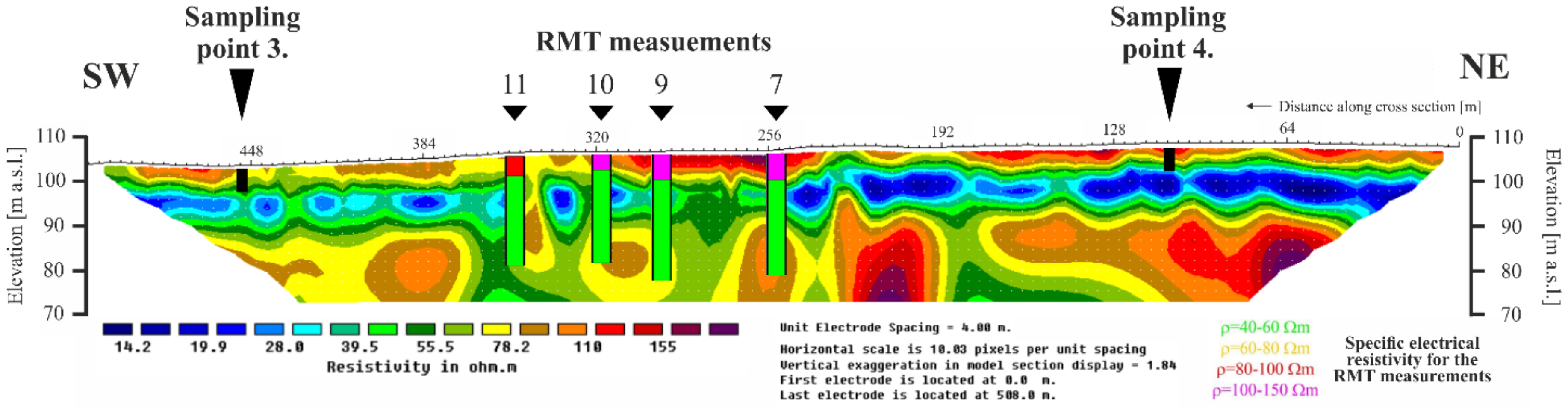
- Geophysical measurements (RMT, ERT)
- Drilling and soil sampling
- Water level and water chemical measurements

7. Results of field measurements



Based on ERT and RMT measurements 3 different layers could be distinguished:

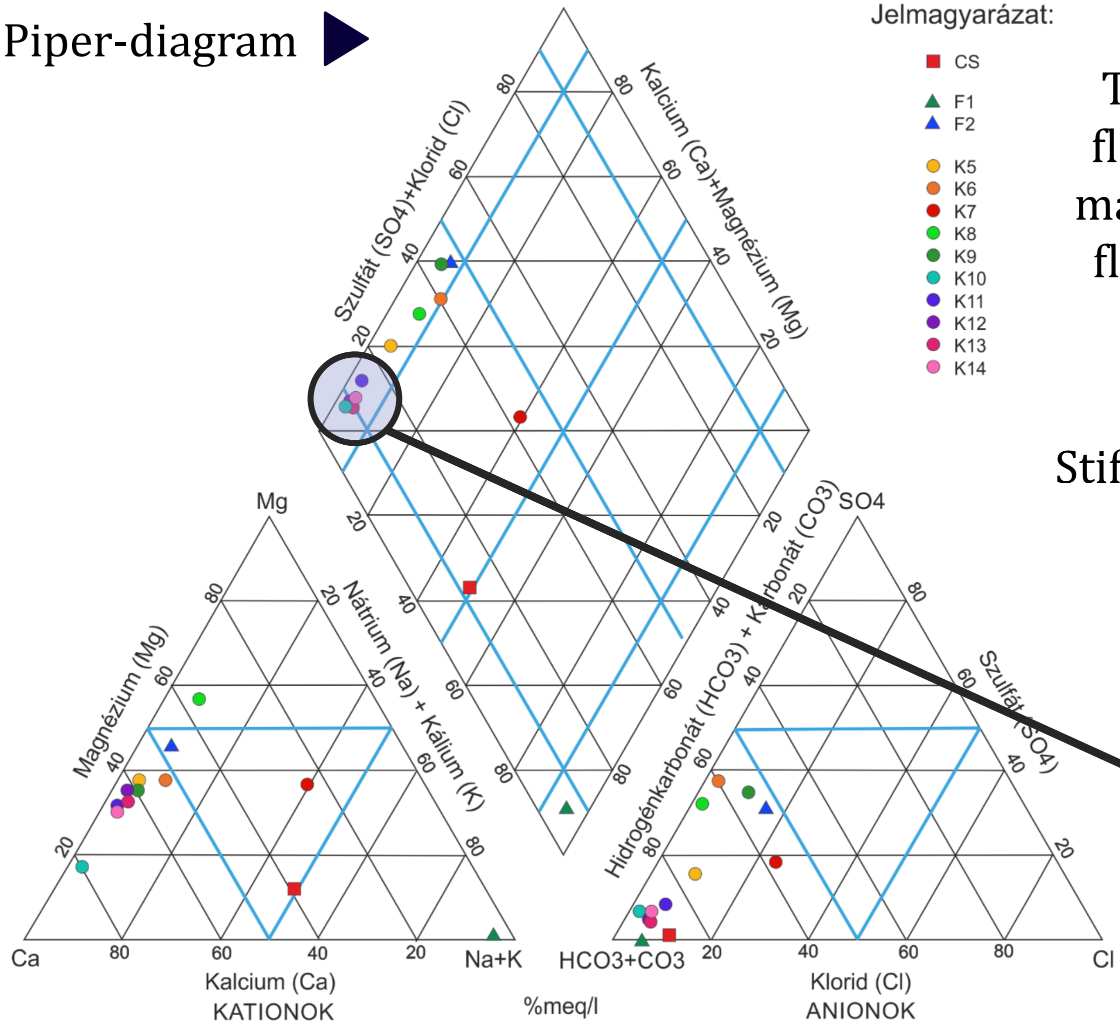
1) **Upper aquifer:** a relatively dry upper layer which is approximately coincident with the vadose zone (based on the geophysical measurements it can not be distinguished unequivocally).
2) **Aquitard:** a middle layer, with relatively low resistivity, higher clay content.
3) **Lower aquifer:** a third layer, which is probably more compact and has a lower hydraulic conductivity, than the upper layer, but still a relatively good aquifer.



Inverted result of the ERT measurement (ERT 2); RMT measurements (11-7), and the locations of soil samples

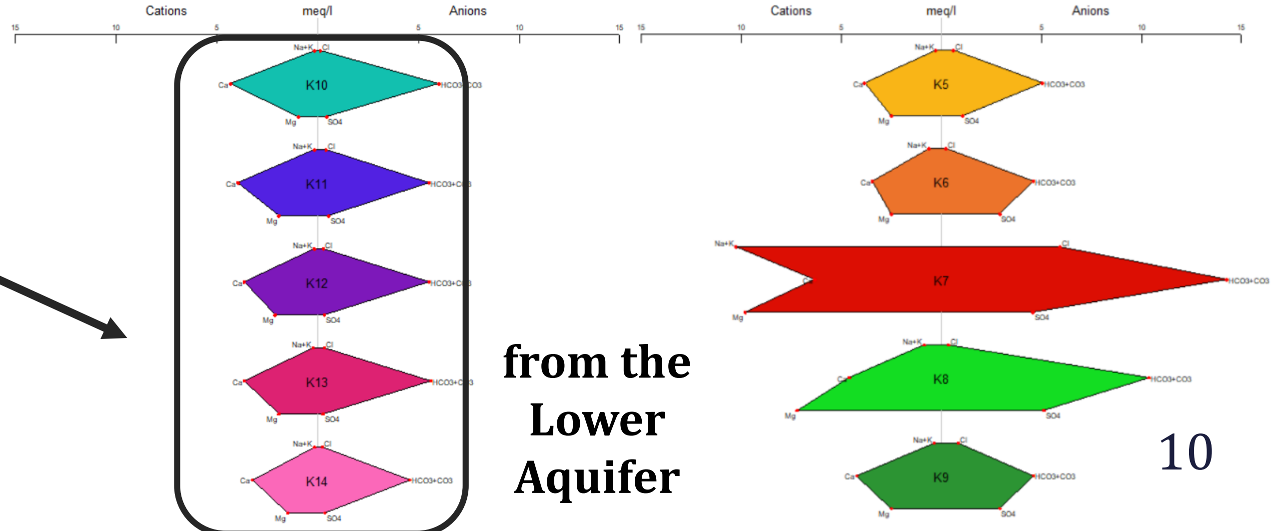
7. Results of field measurements

Piper-diagram



Tomographic fluid potential map, horizontal flow direction

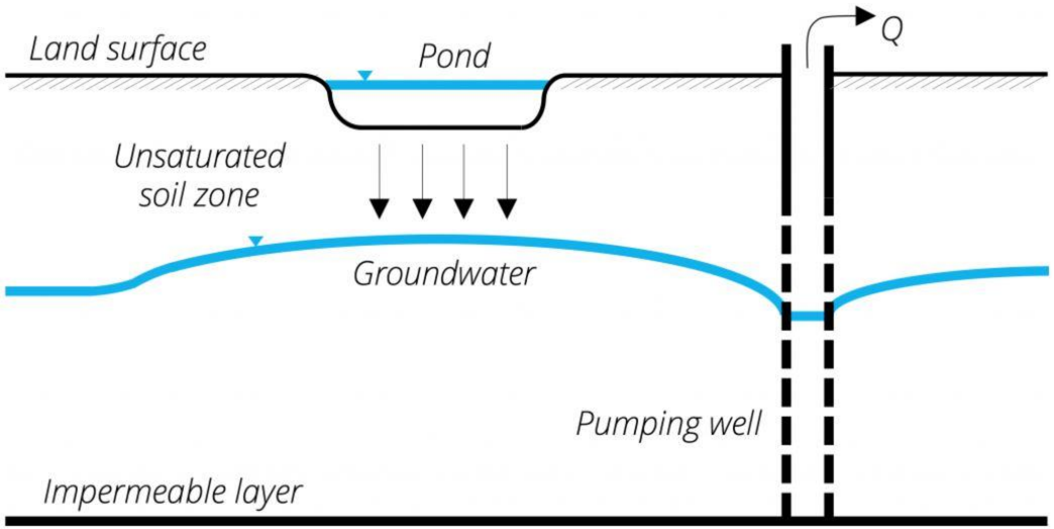
Stiff-diagrams



from the Lower Aquifer

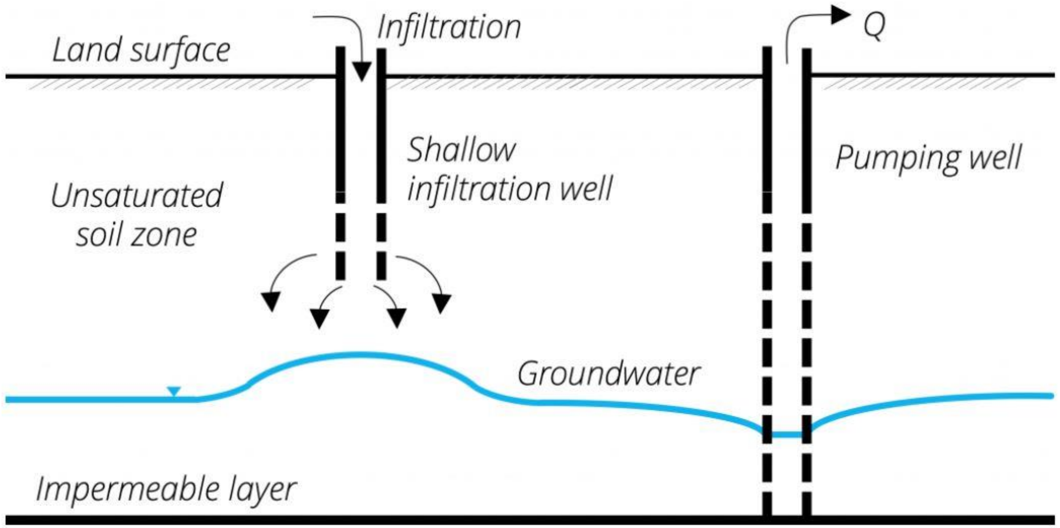
Possible Managed Aquifer Recharge methods

Infiltration pond

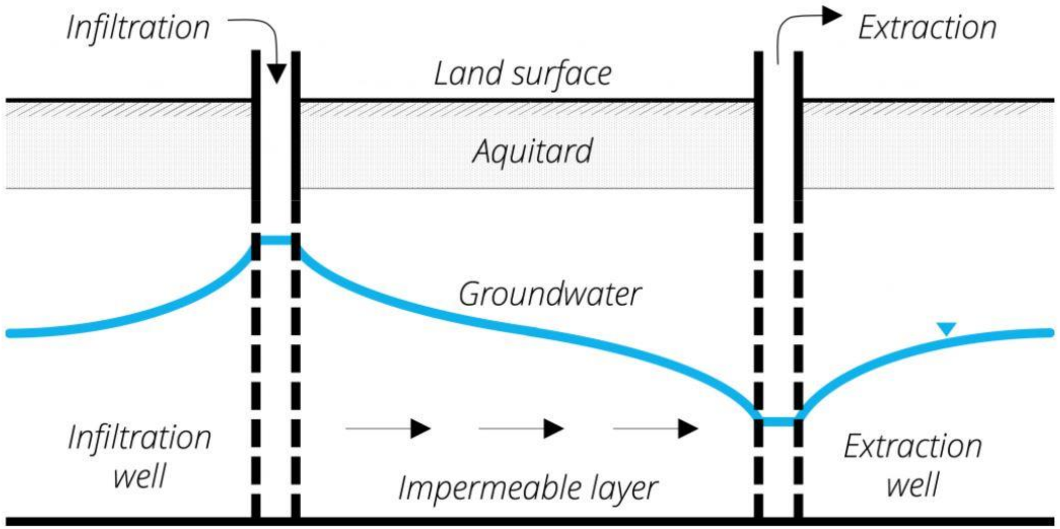


https://inowas.com/managed-aquifer-recharge/

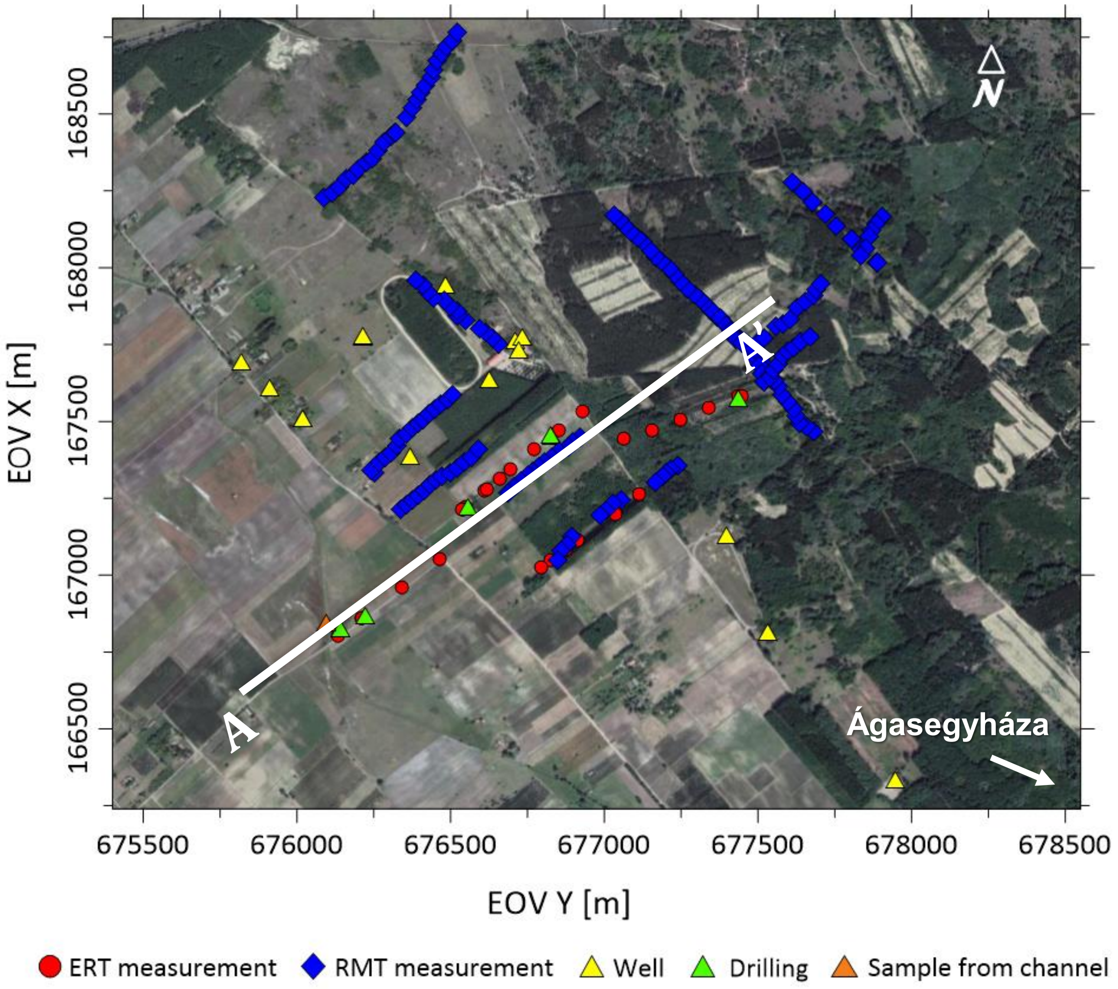
Shallow well



ASTR



8. Numerical modeling



❖ **Possible modeling scenarios regarding geological build-up**

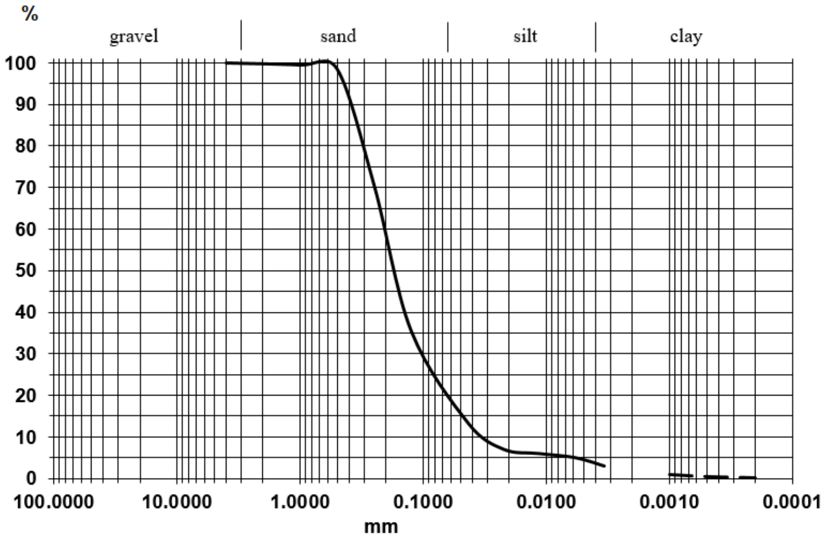
1. Homogeneous, 1-layer model for only the Upper Aquifer
2. 3-layer model (continuous aquitard in between)
3. 3-layer model (aquitard in between, with discontinuities)

❖ **Possible modeling scenarios regarding MAR methods**

1. Infiltration basin
2. Shallow well
3. Deeper well recharging the Lower Aquifer

- **Material properties** based on laboratory measurements and geophysical measuments
  - Upper Aquifer: K ~ 1e-05 m/s
  - Aquitard: K ~ 1e-06 m/s (Müller et al. 2008)
  - Lower Aquifer: K ~ 5e-06 m/s (Müller et al. 2008)

  Vertical/Horizontal anisotropy: 0.1

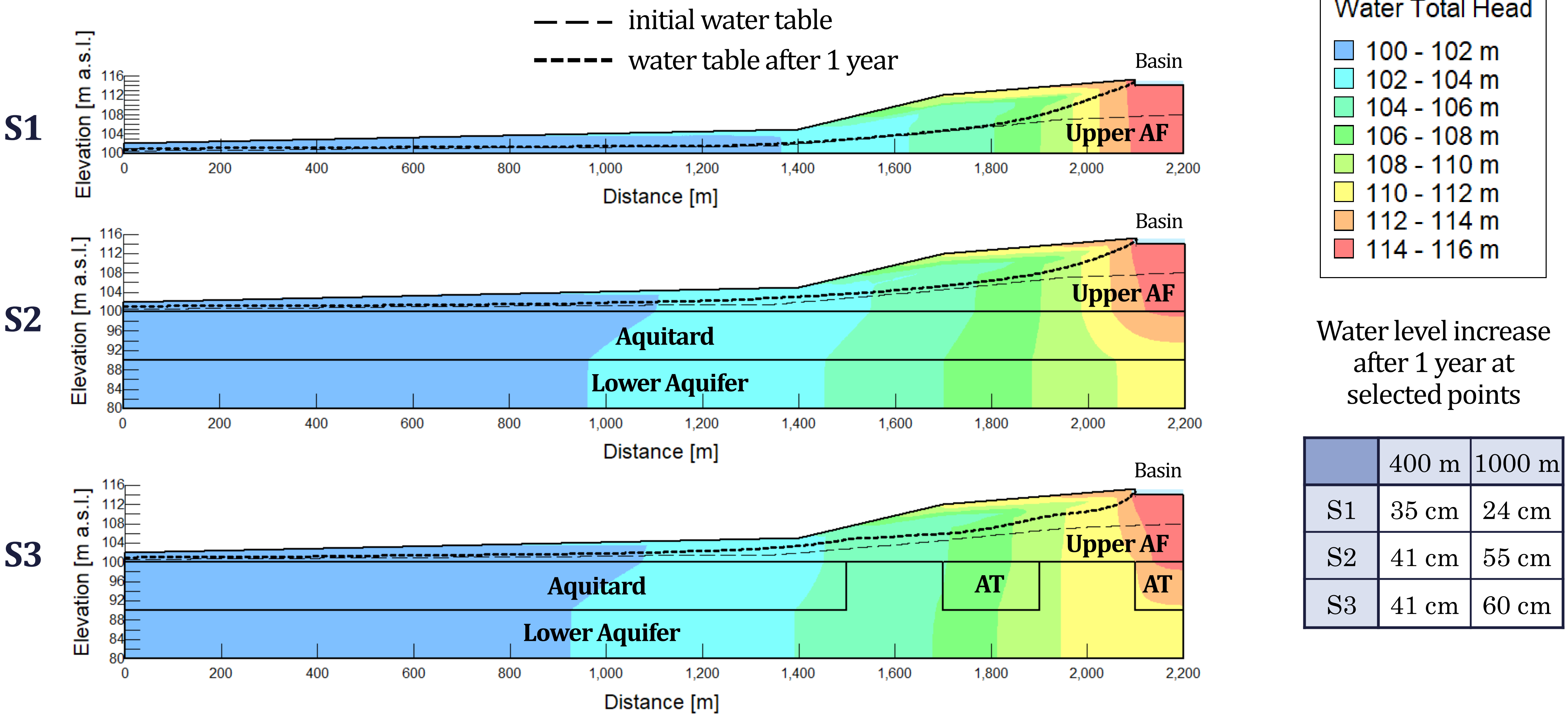


- **Initial water table** specified based on Great Plain Atlas of Hungary, 1978 and field measurements
- **Boundary conditions:**
  - Top boundary: annual recharge of 100 mm/year (Szilágyi et al. 2012)
  - Right boundary: no flow (highest elevation)
  - Left boundary: outflow based on natural hydraulic gradient: 3.4e-08 $m^3/s/m^2$, 3.4e-09 $m^3/s/m^2$ and 1.8e-09 $m^3/s/m^2$ for the different layers, respectively
  - Bottom boundary: no flow *(moderate recharge area, adequate outflow rate is under assessment)*
- **Transient model**: 1 year (300 exponentially increasing time steps)

Preliminary results of numerical modeling

using GeoStudio 2019 SEEP/W

Infiltration basin → width: 100 m, water level: 1 m (constant)



Water level increase after 1 year at selected points

	400 m	1000 m
S1	35 cm	24 cm
S2	41 cm	55 cm
S3	41 cm	60 cm

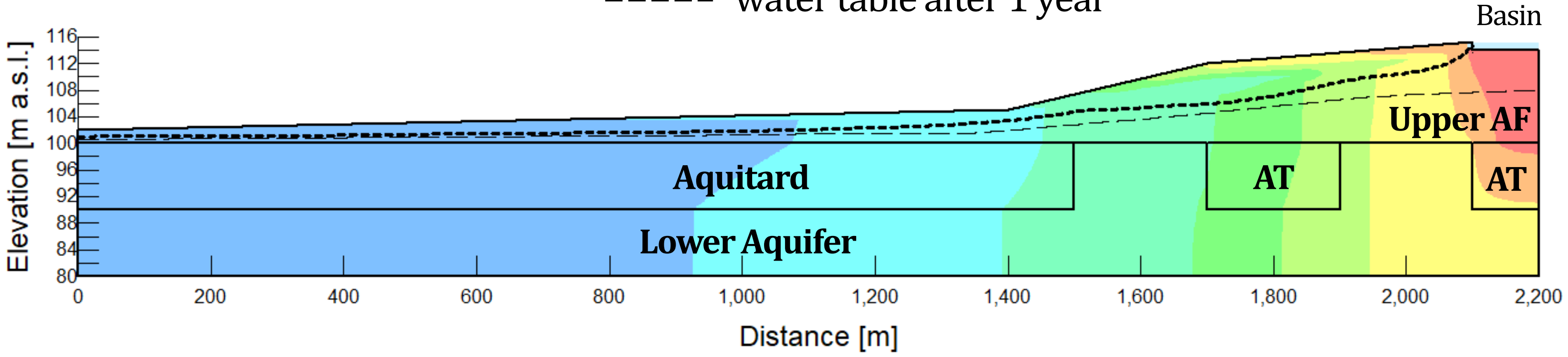
Preliminary results of numerical modeling

using GeoStudio 2019 SEEP/W

Infiltration basin → width: 100 m, water level: 1 m (constant)

— — — initial water table
----- water table after 1 year

S3

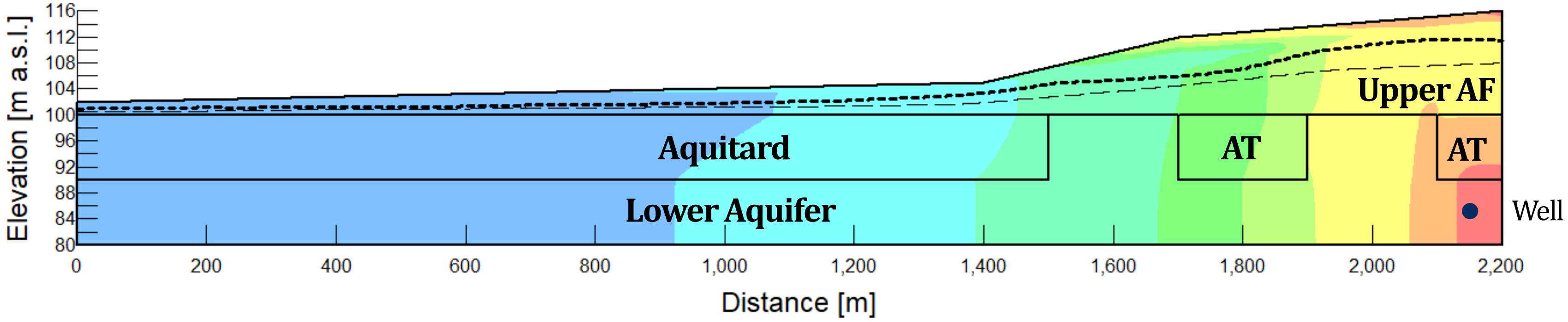


Water Total Head

- 100 - 102 m
- 102 - 104 m
- 104 - 106 m
- 106 - 108 m
- 108 - 110 m
- 110 - 112 m
- 112 - 114 m
- 114 - 116 m

Well → equivalent amount of water (Q ~ 2e-05 m^3/s)

S3



Water level increase after 1 year at selected points

S3	400 m	1000 m
Basin	41 cm	60 cm
Well	41 cm	59 cm

→ Similar results (due to no flow boundary at the bottom + sloping terrain)

9. Conclusions

- The research area **can be suitable** for using Managed Aquifer Recharge methods
- Possible methods: surface infiltration, shallow wells and deeper wells
- With the modeled infiltration basin, water level can be increased by 0.5 m in 1 year
- Groundwater flow regime can influence MAR possibilites, thus it **must be considered**
- **Local scale solutions** could ease the water shortage of this area

Further research aims:

- Scenario models for different MAR solutions
- A more detailed geological and hydrogeological study in the area → validation of modeling results
- (Rain)water infiltration experiments

10. References

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Thank you for your time!