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PFAS transport and retention during riverbank filtration and in saturated columns

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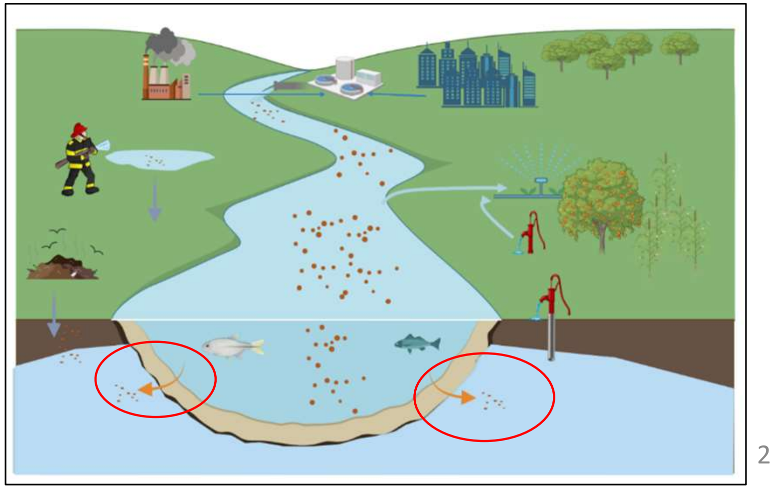
Introduction

- PFAS (Per- and polyfluoroalkyl substances) are synthetic chemicals with favourable physicochemical properties, but at the same time they are persistent, mobile, and toxic
- The 4 major points sources categories (Meegoda et al., 2020) are:
  - Industry, WWTPs, solid waste (landfills), firefighting foam
- The focus of this study is on the pathway to drinking water through riverbank filtration (RBF)
- RBF is a cost-effective method to reduce unwanted waterborne agents, but the effectiveness for PFAS is not known

https://riversideca.gov/press/understanding-pfas



Research questions

- Which PFAS compounds are present at RBF sites in the Danube catchment?
- What are the PFAS concentrations in groundwater and how do these relate to the applicable Water Directive?
- To what extent are these compounds filtered/retained in RBF systems?

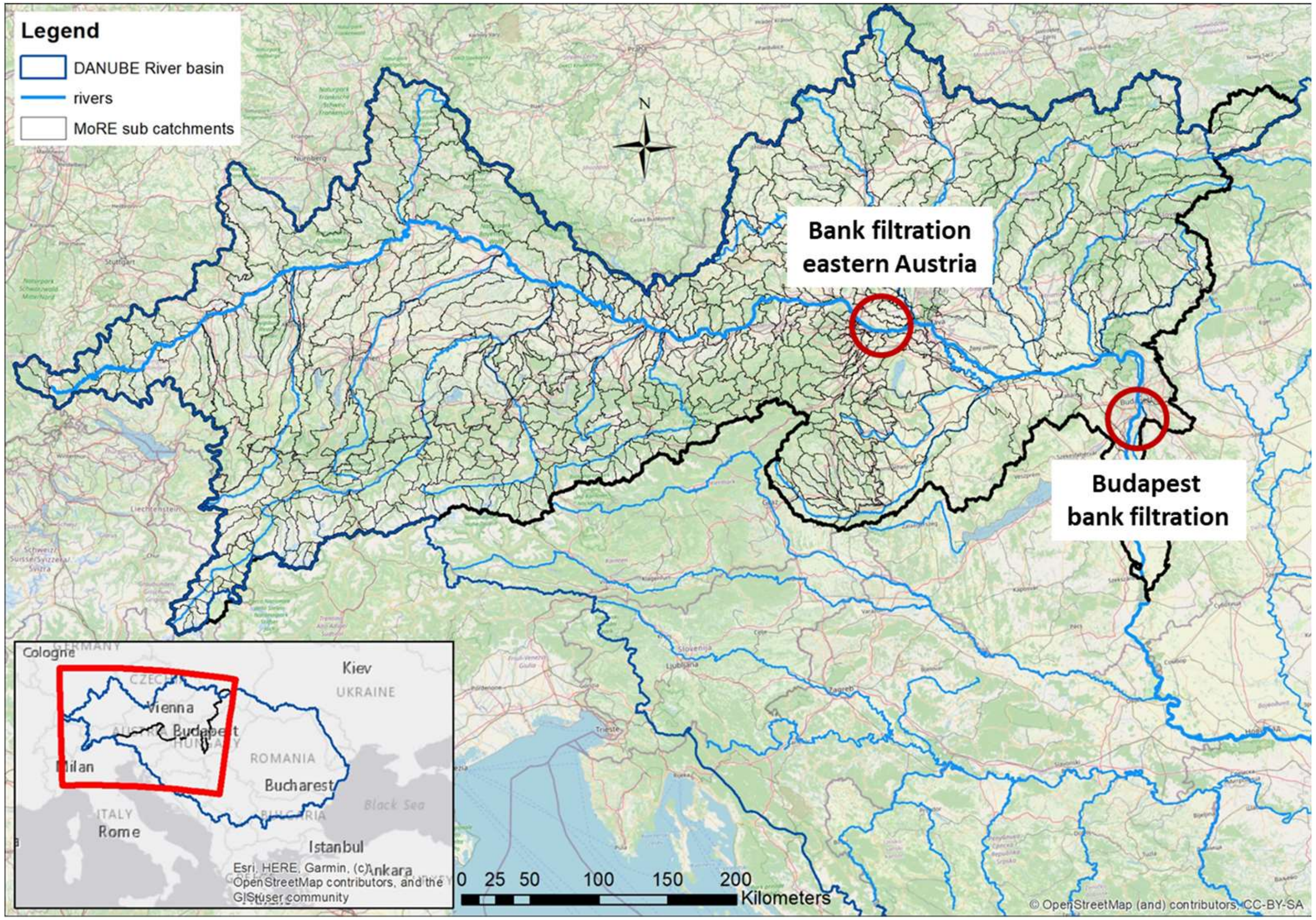
Methods

1. Monitoring and modelling of PFAS in river- and groundwater at 4 RBF transects along the Danube

2. Saturated soil column experiments with a mix of PFAS to study sorption under controlled conditions

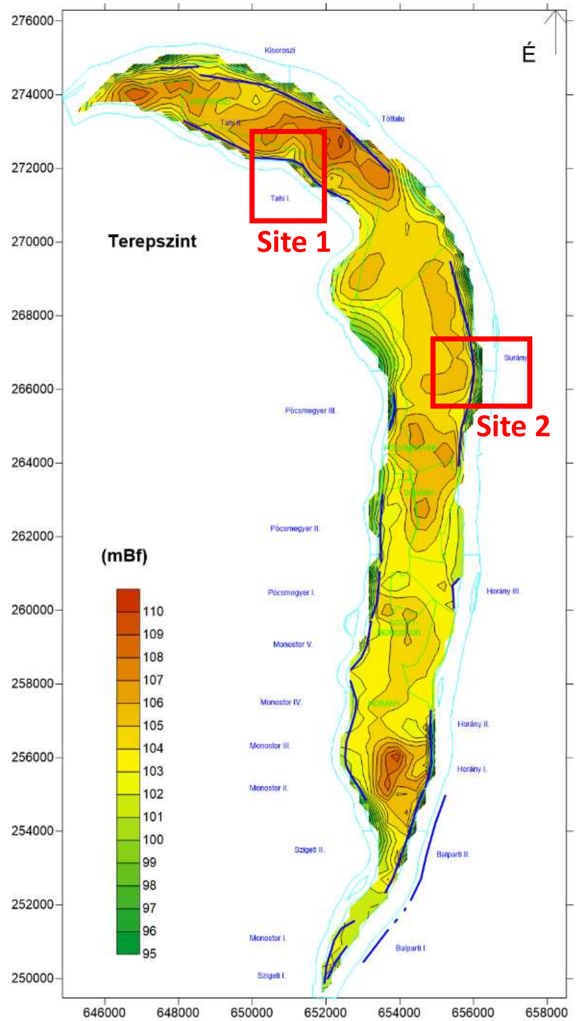
Monitoring sites

- Danube Bank Filtration
- Studies in Vienna & Budapest
- Vienna: 1 transect
- Budapest: 2/3 transects



Budapest Danube Island Transects

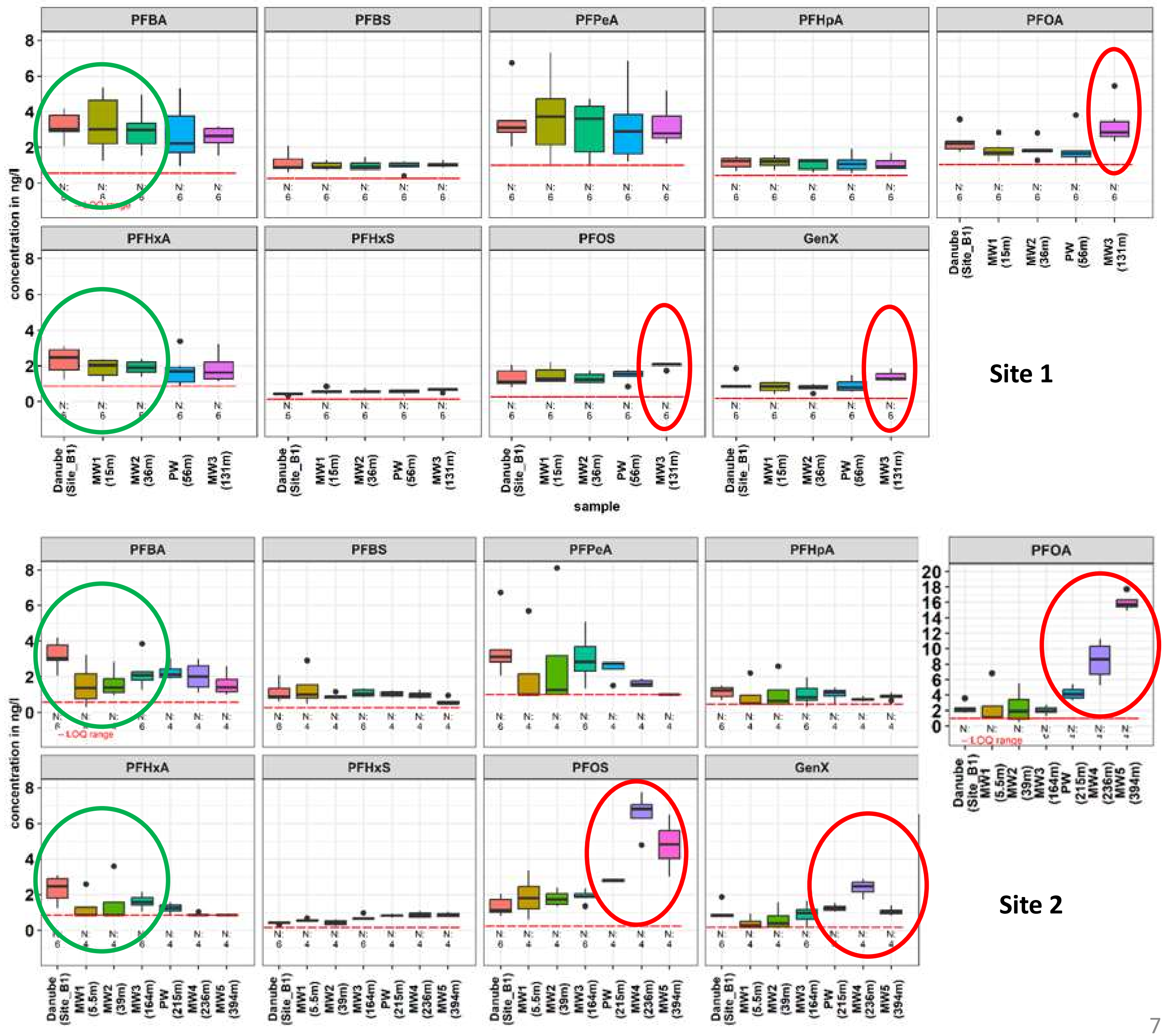
- Danube island
- Used for drinking water abstraction
- 2 transects
    - Site 1, „Tahi“: 3 MWs, 1 PW, max distance 131 m
    - Site 2, „Surany“: 5 MWs, 1 PW, max distance 394 m
- Aim: to study removal by BF in a forced gradient flow field, without clogging of the river bed, at varying river stages
- (3rd transect: southern Budapest Danube island, not modelled due to lack of MWs)



MW = Monitoring Well
PW = Pumping well

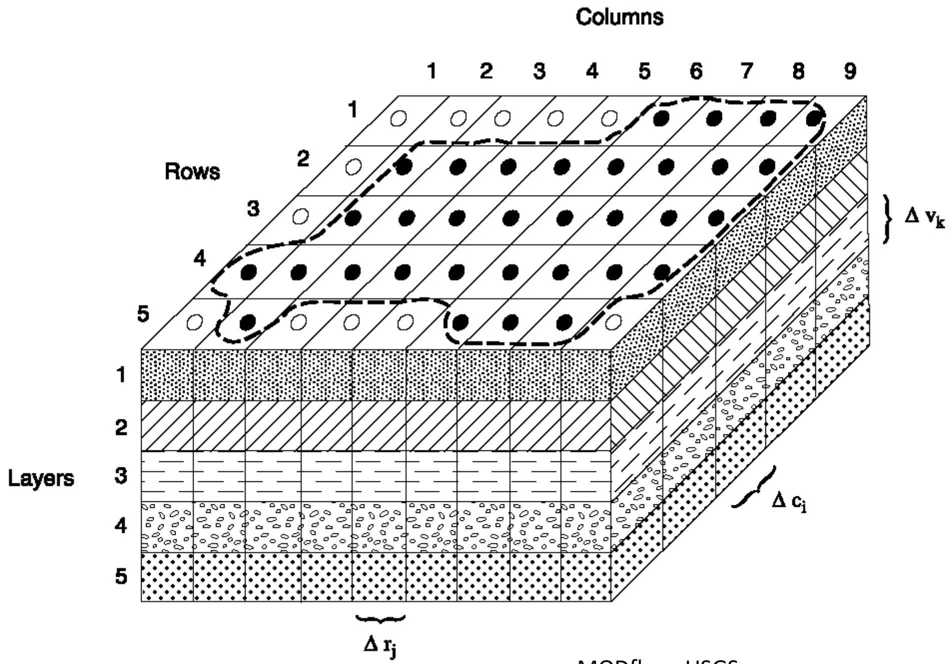
Monitoring results

- Legal limit (Σ_{20PFAS}<100 ng/l) in EU DWD not breached (max: 29 ng/l)
- Minimal PFAS removal (sorption) during riverbank filtration
  - Depends on substance and location
- Elevated concentrations inland
  - Local PFAS sources
    - Wildfires
    - Agricultural (Pesticides, compost, sludge?)
    - Construction sites
  - Groundwater flow direction?



Modelling goals

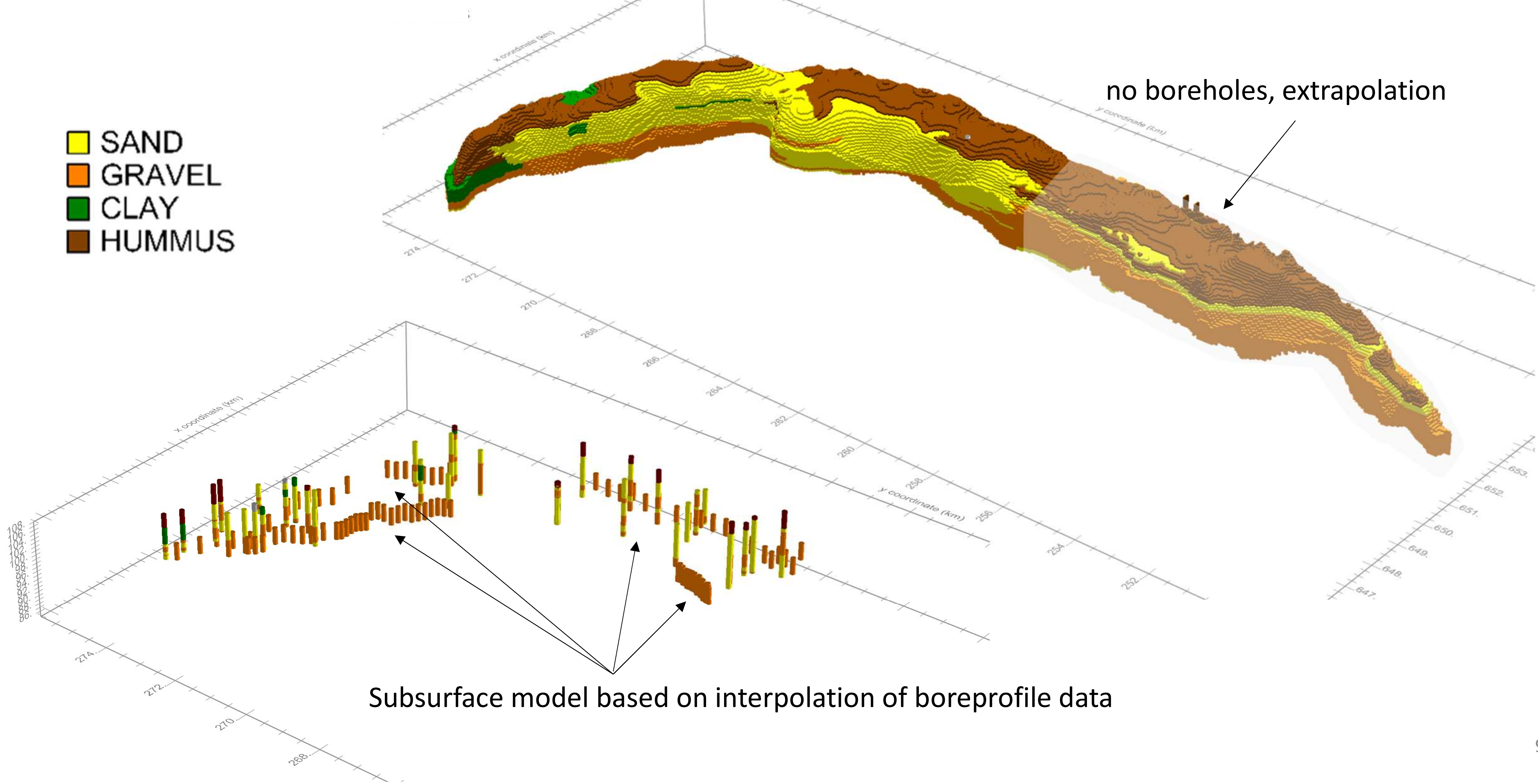
- Large scale:
  - Water flow pathways
    - To better understand the impact of inland PFAS sources
  - Water age
- Small scale:
  - Focus on slight sorption during BF
  - To validate column test results on a field case study
- Scenarios (by linking with catchment scale model)
  - To understand the impact of future changes, accidents, and management measures
  - Future scenarios for: demographic/water management/climate change
  - Calamities scenarios: e.g. spills, large fires



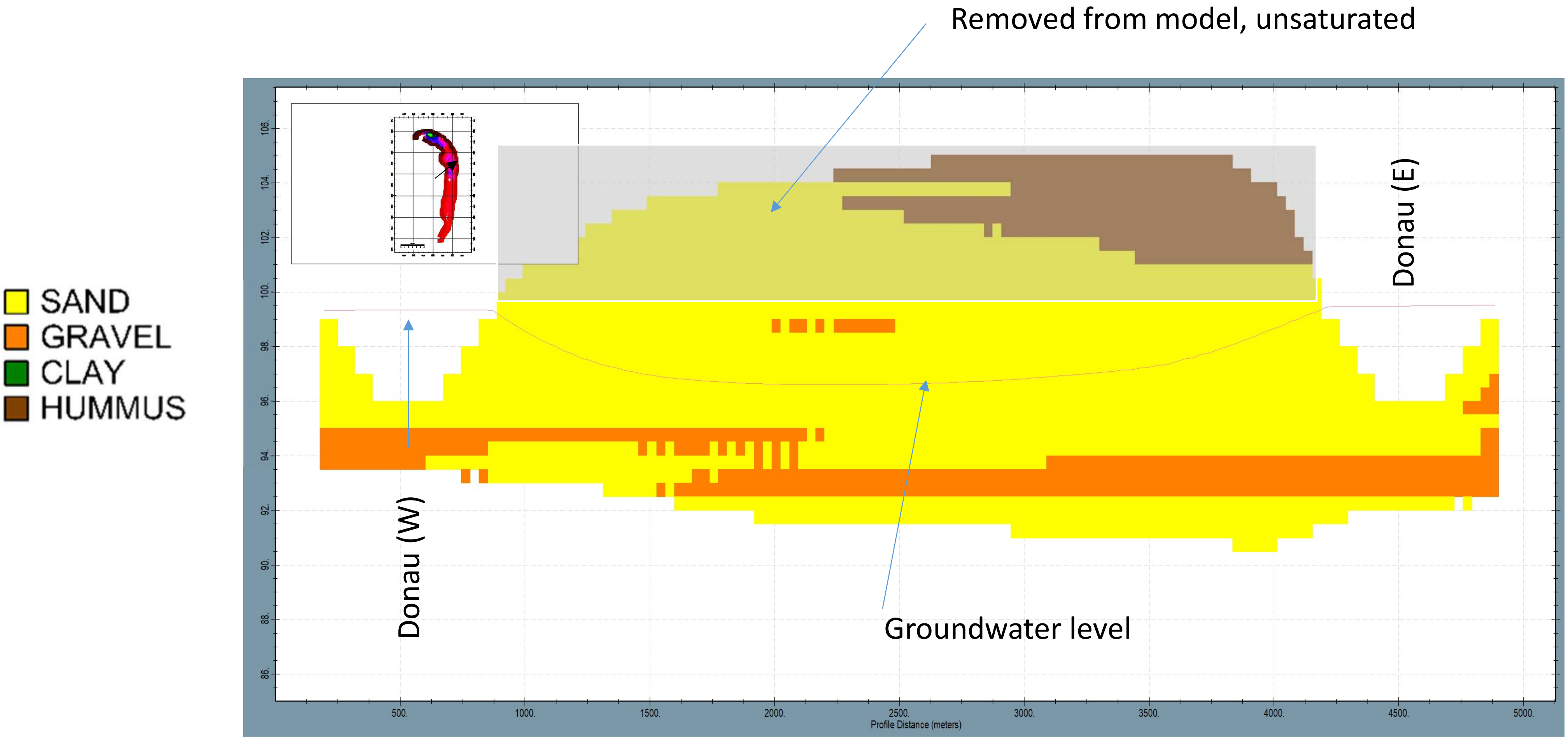
MODflow, USGS

Subsurface

43 layers started at 107.5m AMSL
each layer is of 0.5 m thickness



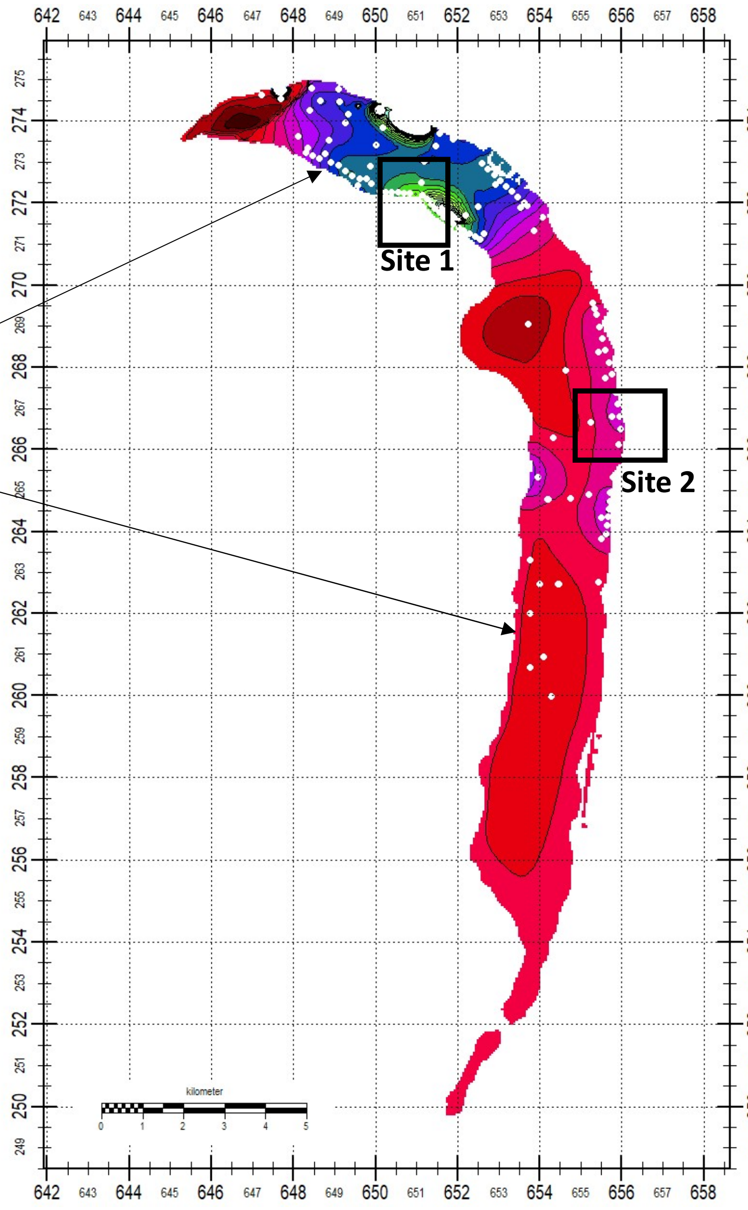
Geology and saturation

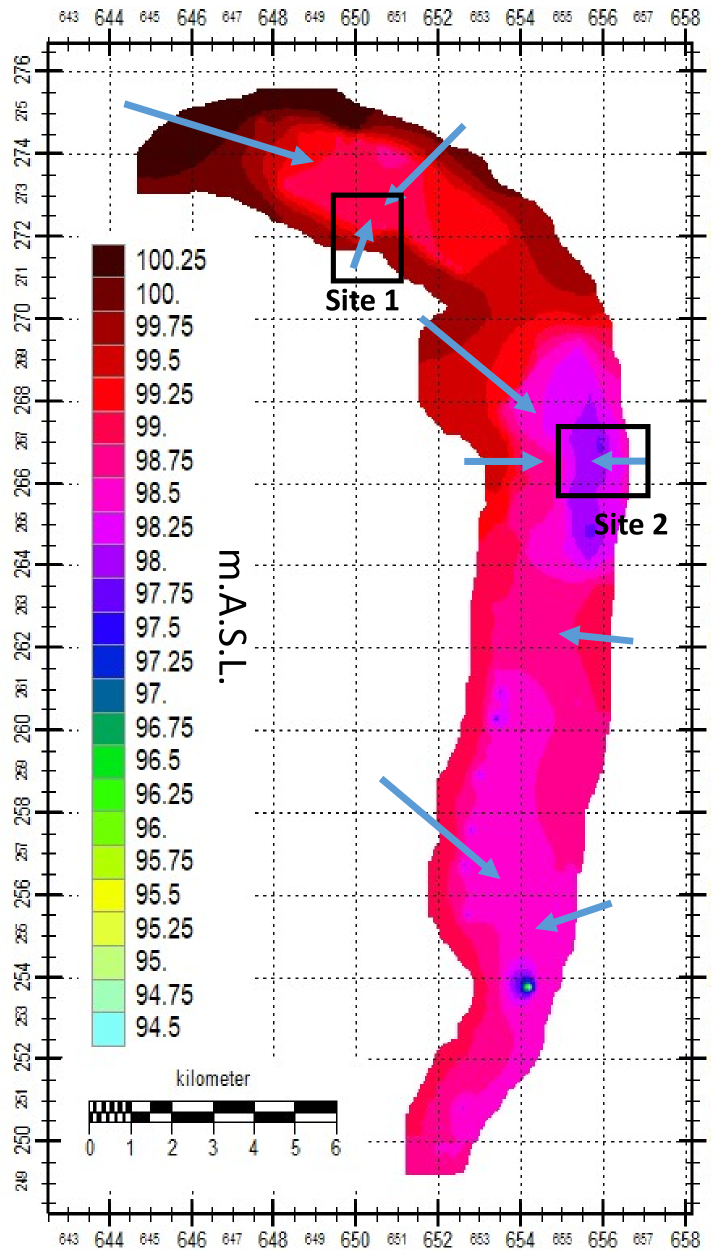


Calibration & Groundwater flow

○ = Observation points

⟶ = Groundwater flow direction

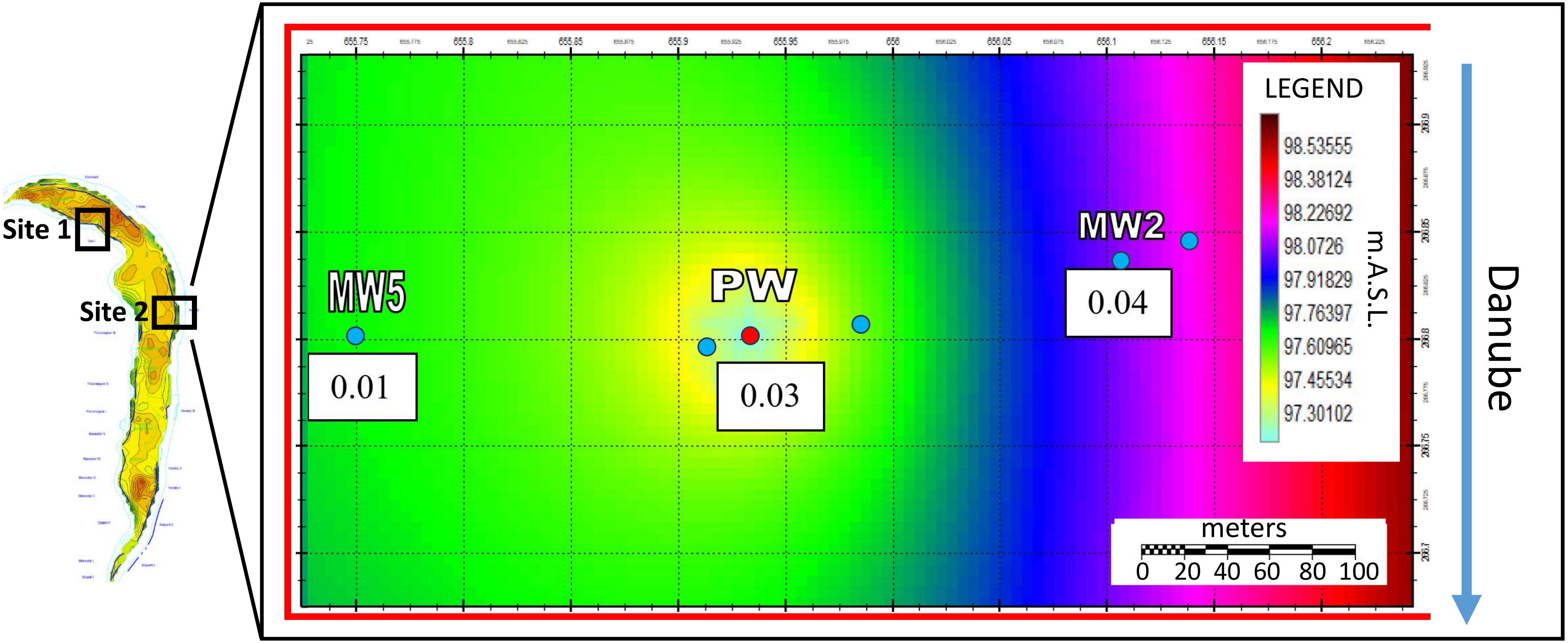




Parameters for calibration:

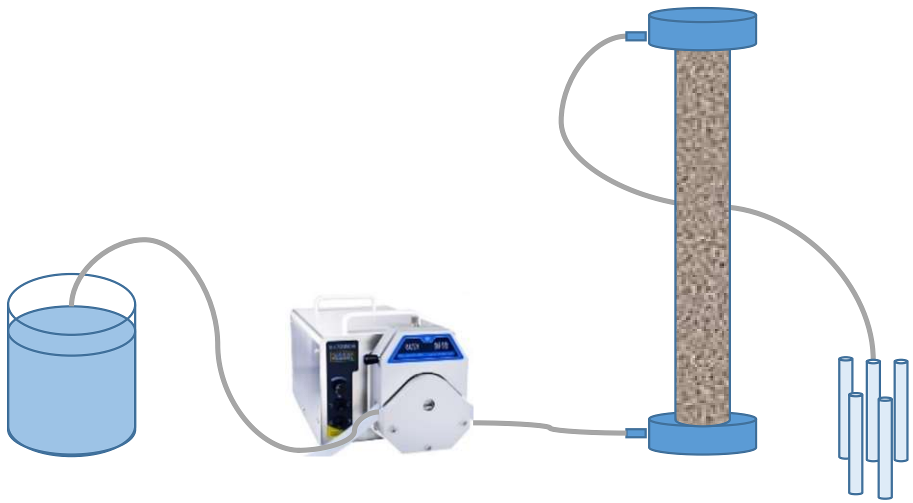
- Hydraulic conductivity and vertical anisotropy per lithology
- Storage coefficient
- Danube river conductance

Calibration of cut-out model (Site 2, Surany)



- Steady state: (October 2022), 10th percentile low flow in the Danube for about 1 week
- : Constant/variable head boundary, taken from regional model output
- 0.01 : Absolute difference between measured and observed water levels (in m)
- Hydraulic conductivity of 86 m/day (9.95*10^{-4} m/s) after calibration, assumed for the whole domain

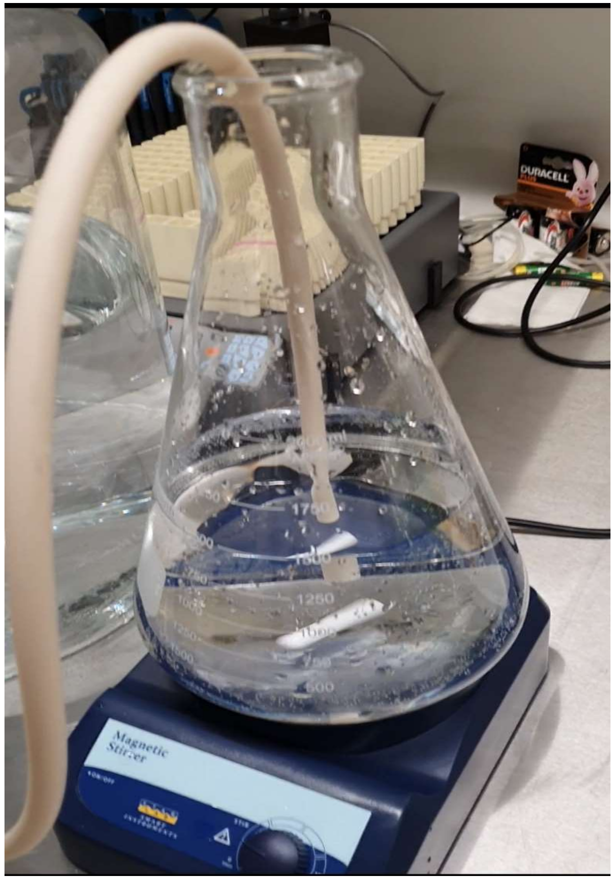
Soil column test setup



- 50 cm long & 7 cm diameter glass column, packed with:
  - Lab-grade quartz sand
  - Natural soil from the study area
- Mix of 10 PFAS at 2.5 µg/l
- Bromide used as a conservative tracer
- 38 effluent samples + 5 influent samples of the injection solution
- Post experiment: Methanol washing of injection solution flask, column system and sand

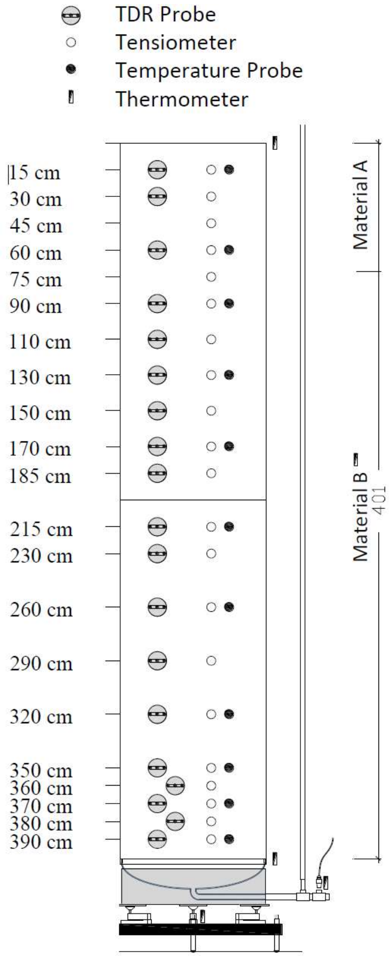
Injection solution

- The injection solution (2 PV) was continuously stirred
- Samples from the injection solution were collected
  - 1) by pouring from the top and
  - 2) by pipetting at the depth of the injection tube
- 5 samples were taken during injection



Column tests: Outlook

- Test with lower concentrations
  - 250 ng/l instead of 2500 ng/l
  - Concentration-dependence
  - Done, waiting on results
- Test in a large, undisturbed gravel column
  - 4 m instead of 50 cm
  - Scale-dependence
  - Planned for summer



Conclusions

- PFAS concentrations in river and groundwater are below the current limit according to the EU drinking water directive ☺
- Sorption during bank filtration seems to be very low ☹
- * Preliminary: RBF can delay, but not remove, certain types of PFAS