Modelling options to assess hydraulic connectivity of agricultural fields with monitoring wells for edge-of-field groundwater surveillance

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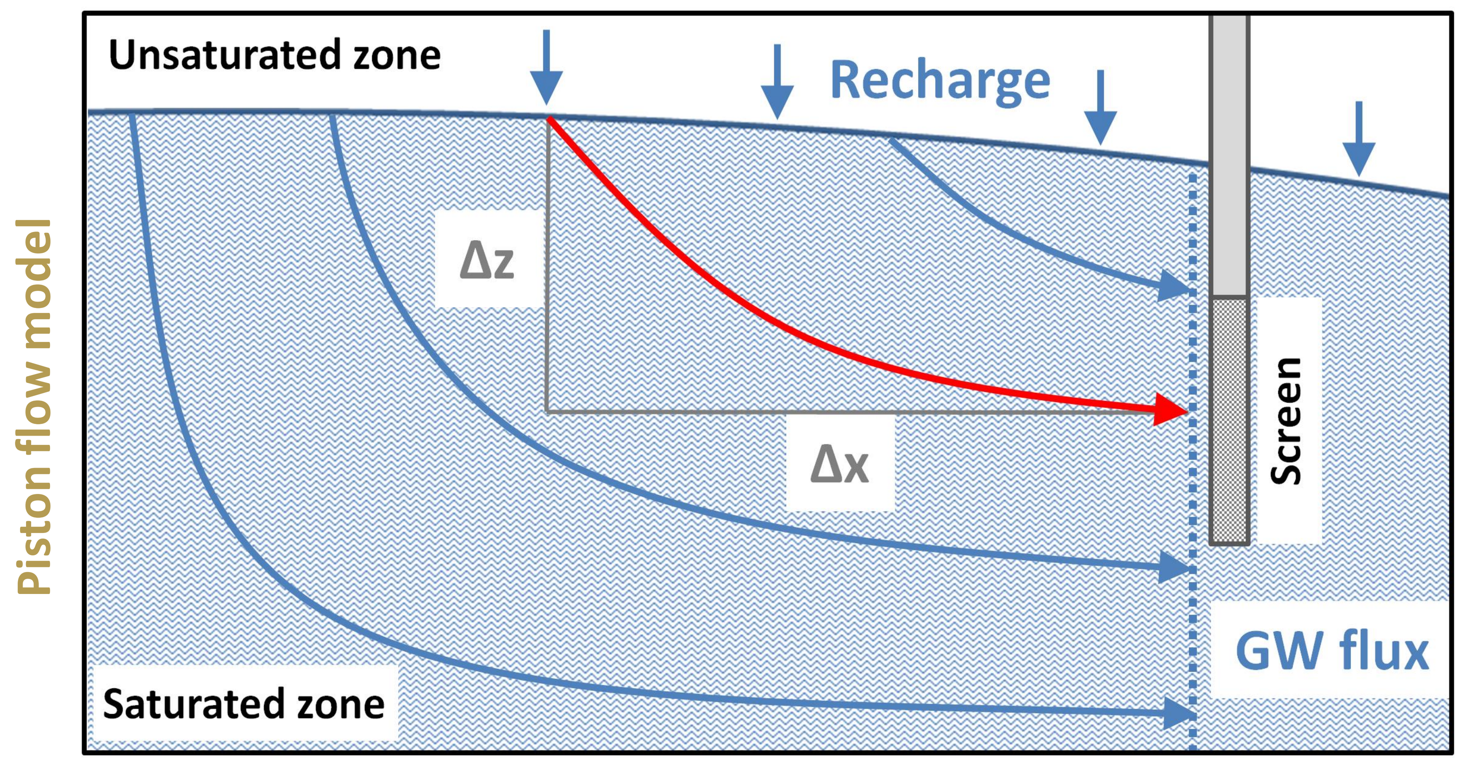
Introduction

Groundwater monitoring for residues of active substances and their metabolites is an important part of the European risk assessment scheme for the authorisation of plant protection products. In case of edge-of-field studies, monitoring wells for sample collection can be placed at various distances to test fields treated with products depending on the purpose and corresponding design of a groundwater monitoring study.

A common challenge for the design of monitoring studies and the interpretation of monitoring data is the need to demonstrate that well and filter screen are appropriately placed in order to detect potential residues. This is mainly determined by the hydraulic connectivity which depends on the well's location, filter placement in the saturated zone, and other environmental factors and properties.



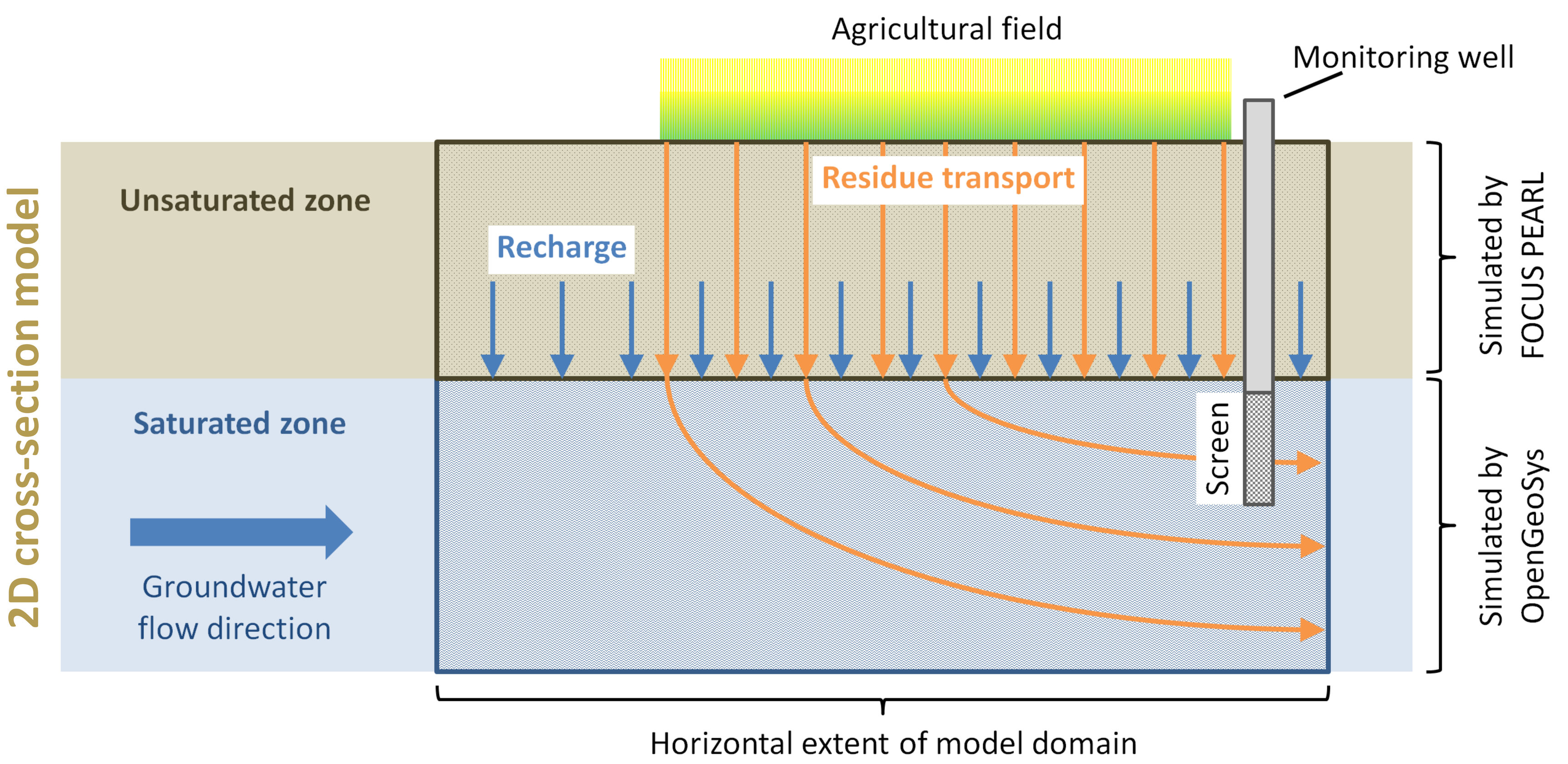
Method

We evaluated two options to assess the hydraulic connectivity quantitatively:

1. Arrival depths of residue plumes were estimated using Darcy's law and **piston flow** dynamics
2. Simulated transport and fate of substance residues based on a **2D cross-section** of unsaturated zone and aquifer

The **piston flow model** assumed

- uniform groundwater recharge along the surface,
- water packages were transported undisturbed through the aquifer,
- lateral movement of water packages followed the hydraulic gradient,
- vertical movement was generated as water packages were displaced by other packages entering the phreatic surface.



The **2D cross-section model** represented the unsaturated and saturated zone at a particular monitoring site along the observed groundwater flow direction:

- Time-dependent influx of leachate and residues entering the phreatic surface were simulated with a 1D model of the unsaturated zone, PEARL 4 [1]
- PEARL scenarios were set up according to recommendations and requirements of the European groundwater risk assessment scheme
- Transport and dispersion in the aquifer was simulated with OpenGeoSys [2], a model of thermo, hydro-mechanical, and chemical processes in porous media
- A homogeneous and anisotropic aquifer with constant thickness was assumed
- Hydraulic connectivity was assessed using the vertical distributions of predicted concentrations moving past the monitoring well over time

The evaluated compound had a low sorption coefficient and was not degraded within the saturated zone. The agricultural field covered 400 metres in the direction of the hydraulic gradient in a distance of 5 metres to the well.

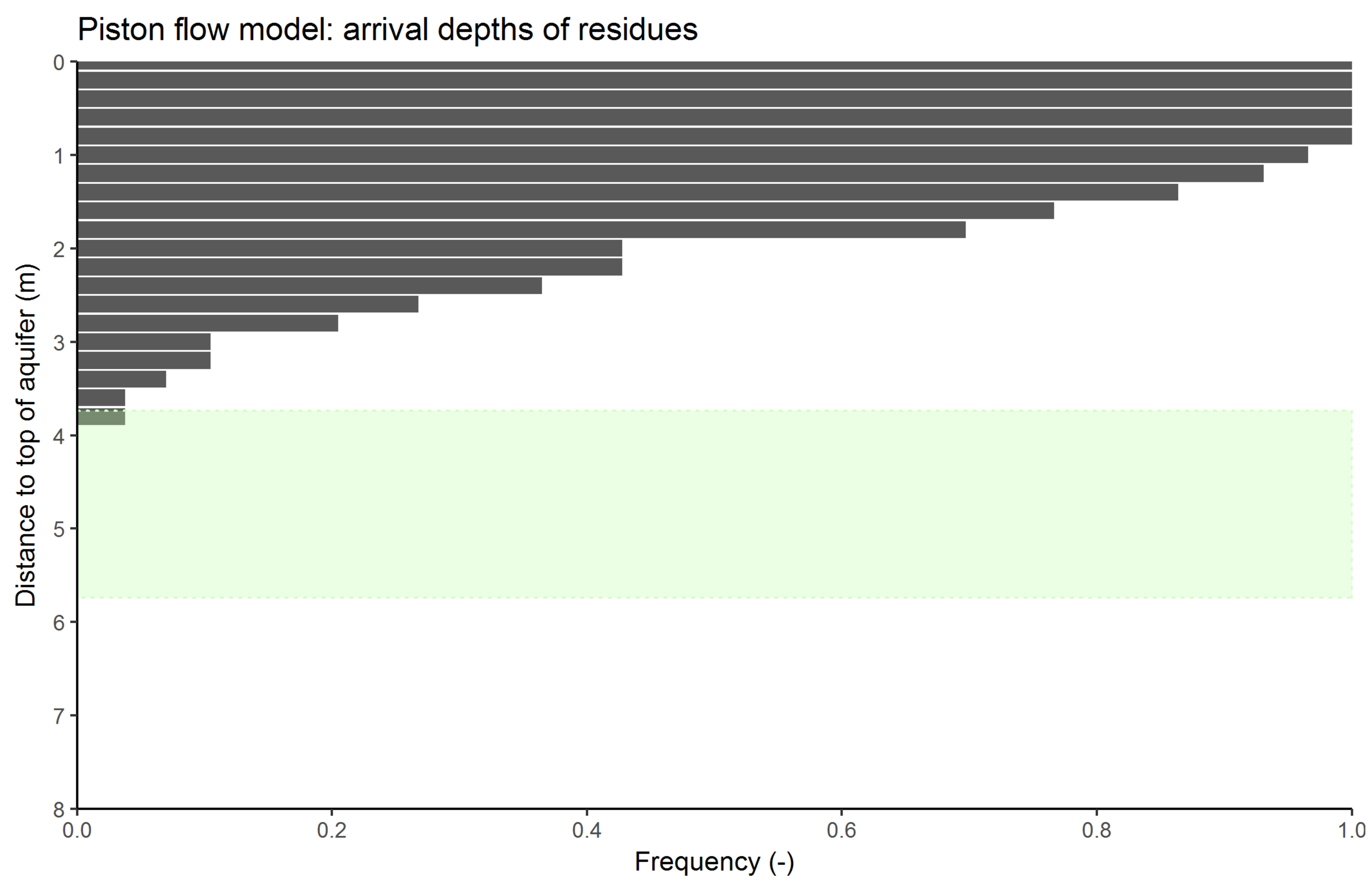
Results and discussion

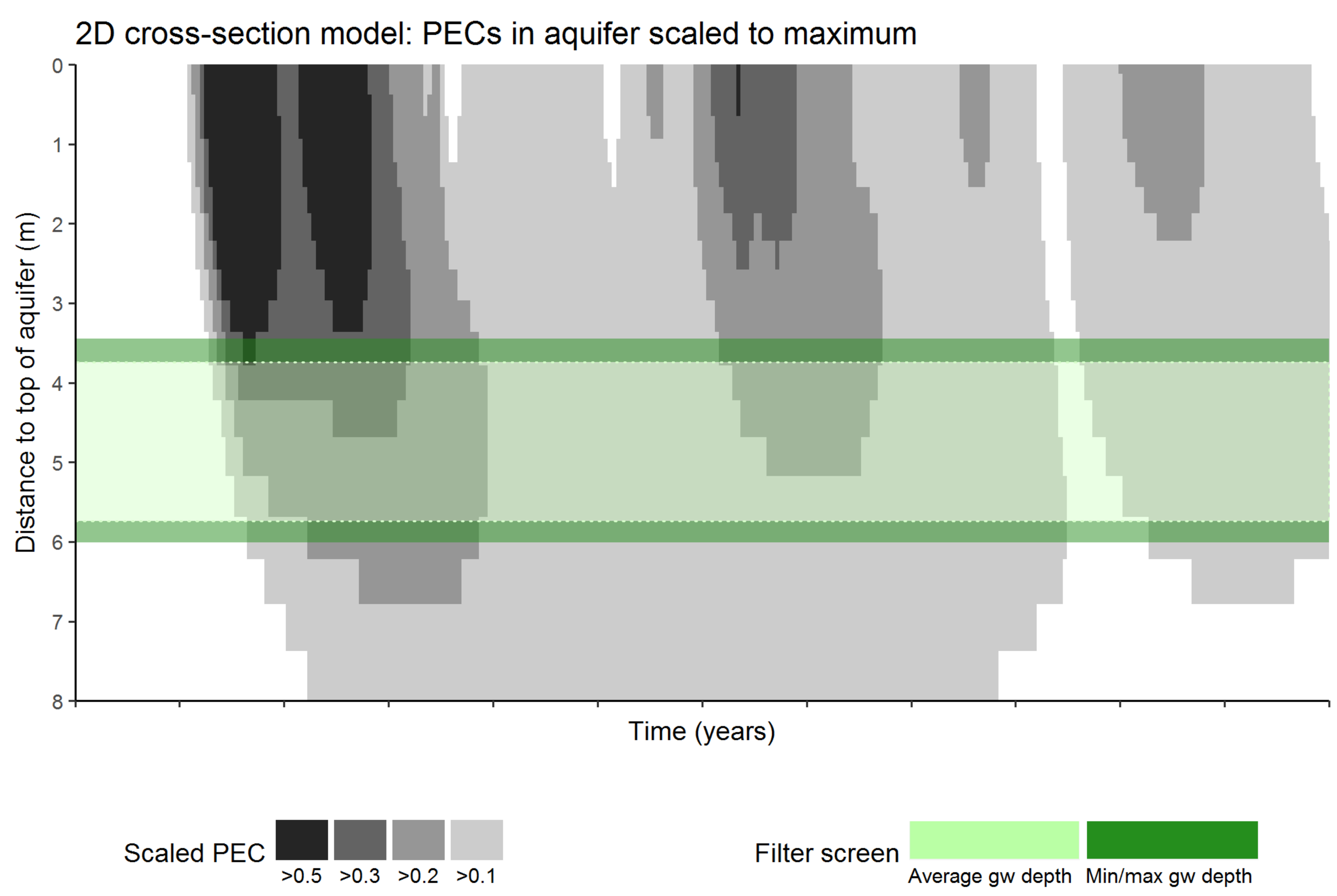
The piston-flow model (PFM) yields conservative estimates; residues are usually predicted to travel near the phreatic surface in case of edge-of-field monitoring.

- It was combined with a Monte Carlo approach to account for (natural) variability of the groundwater recharge rate to derive a distribution of arrival depths
- PFM can also be used to estimate upstream catchments for a given filter screen
- Drawing conclusions is difficult in cases where residue arrival is predicted to occur under very limited circumstances

The 2D cross-section model (2DM) provides better insight into transport dynamics in the aquifer.

- Arrival depths exhibit a larger variance compared to PFM as more processes such dispersion and time dependent groundwater recharge were considered
- Provides estimates where the highest concentrations are likely to occur
- Enables more refined assessments where connectivity with filter screen may be suboptimal; allows to draw conclusions from non-detections about occurrence of regulatory relevant concentrations in the aquifer





Conclusions

- The described methods can be used to screen for new wells or evaluation of existing monitoring wells; can be used either in a tiered or combined approach
- PFM and 2DM generally agree on depths where highest concentrations are likely to occur; i.e. connectivity according to piston-flow is a sufficient criterion
- PFM requires few parameters which may be available as part of a monitoring study; its estimates are likely to be conservative in terms of arrival depth
- 2DM can account for time-dependent dynamics, e.g. occurrence of capillary rise of groundwater (negative groundwater recharge) as well as complex flow and transport dynamics
- 2DM can accommodate various levels of data availability and model complexity
- A complex aquifer model allows to evaluate connectivity in higher detail and enables a more fine-grained evaluation of exposure and arrival depths

References

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[2] Kolditz O. et al., 2012: OpenGeoSys: an open-source initiative for numerical simulation of thermo-hydro-mechanical/chemical (THM/C) processes in porous media, Environ Earth Sci 67(2). doi:10.1007/s12665-012-1546-x