Interactions between the Meuse River and its heterogeneous alluvial deposits at a contaminated brownfield

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CBH – BCH study day
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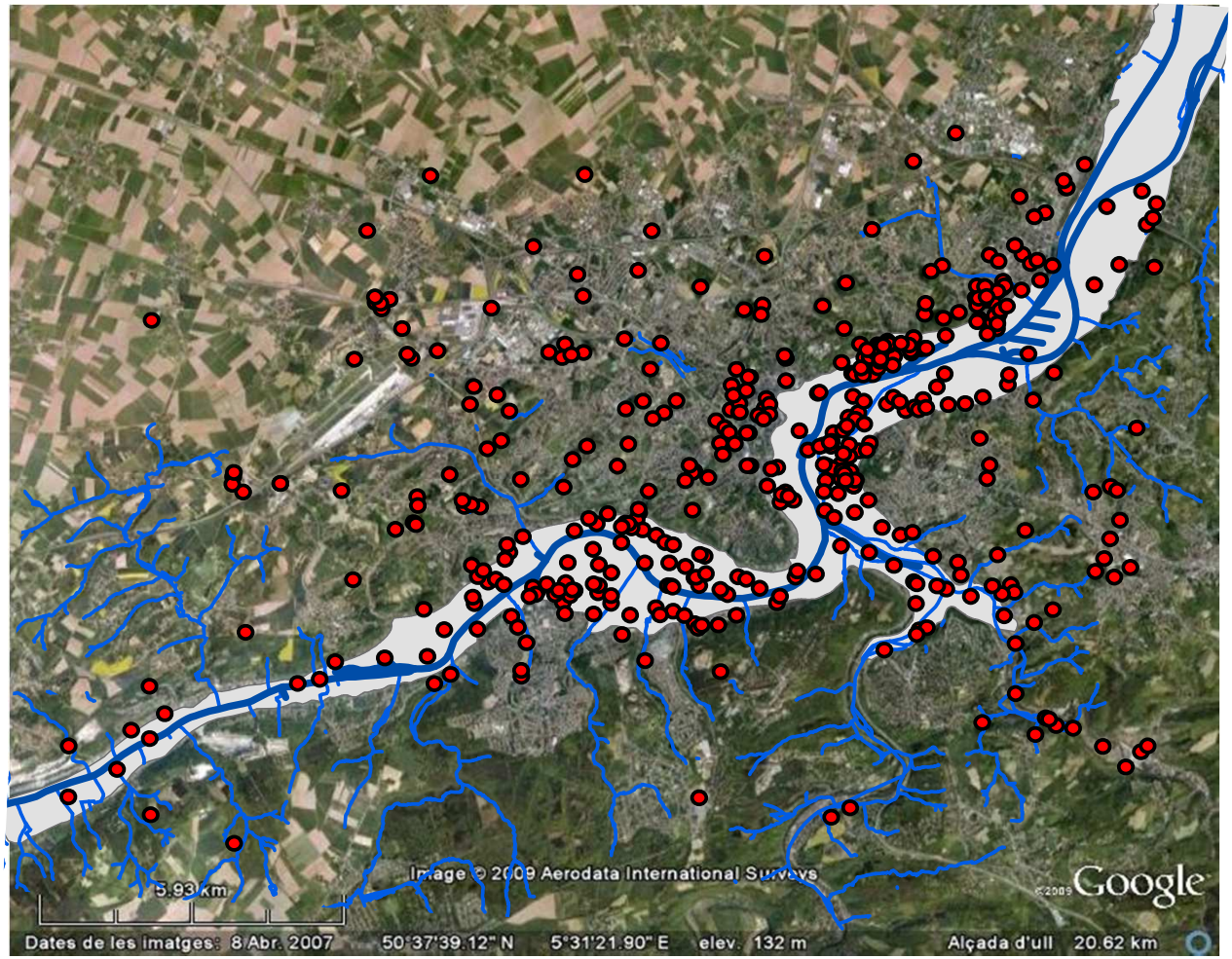
Rivers are evident ways for transportation of industrial products and alluvial plains have received many potentially polluting activities



In this context, different questions arise

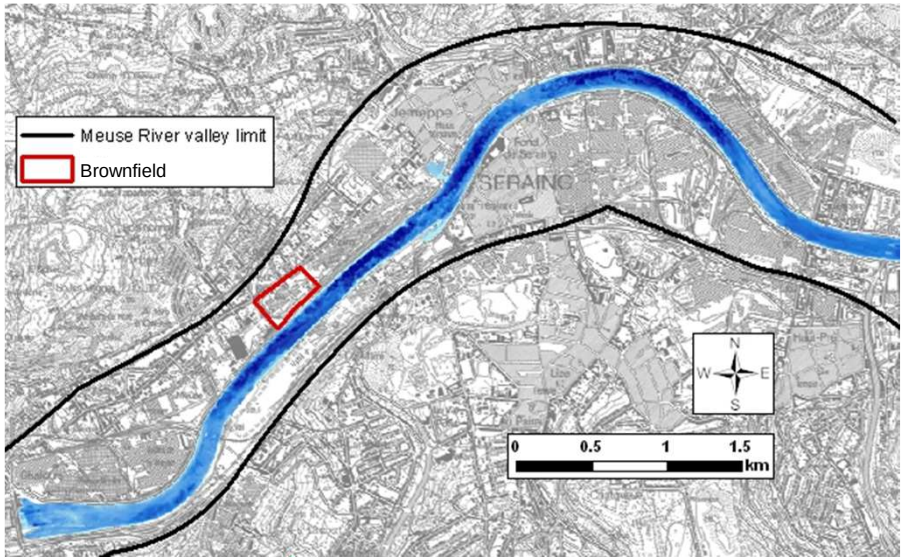
Is there any risk of groundwater contamination and, through groundwater discharge, river water contamination?

Are there groundwater – river interactions at such sites?

If so, how can we efficiently quantify fluxes of water and pollutants in groundwater and at the interface with the river?

And finally, what is the influence of groundwater – surface water interactions on the possible dynamics of pollutants in groundwater?

To answer these questions, investigations and modelling performed in a brownfield in the area of Liège



Alluvial aquifer

25 m from the Meuse River

Polluting activities from 1922 to 1984

Soil and groundwater highly polluted by organic (BTEX and PAHs) and inorganic (metals, Fe and sulphate) compounds

Previous investigations performed

Outline

1. Assessing groundwater – river interactions

2. Numerical modelling of groundwater – river interactions

3. Some conclusions

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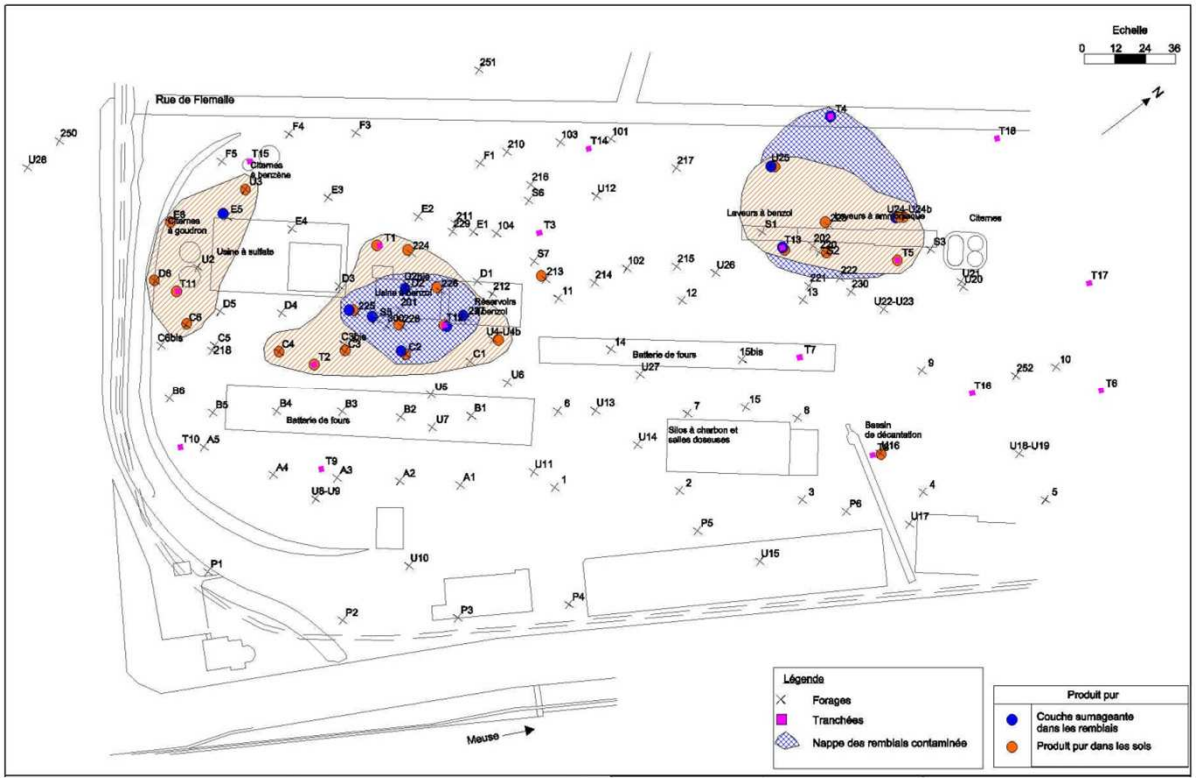
The challenges …

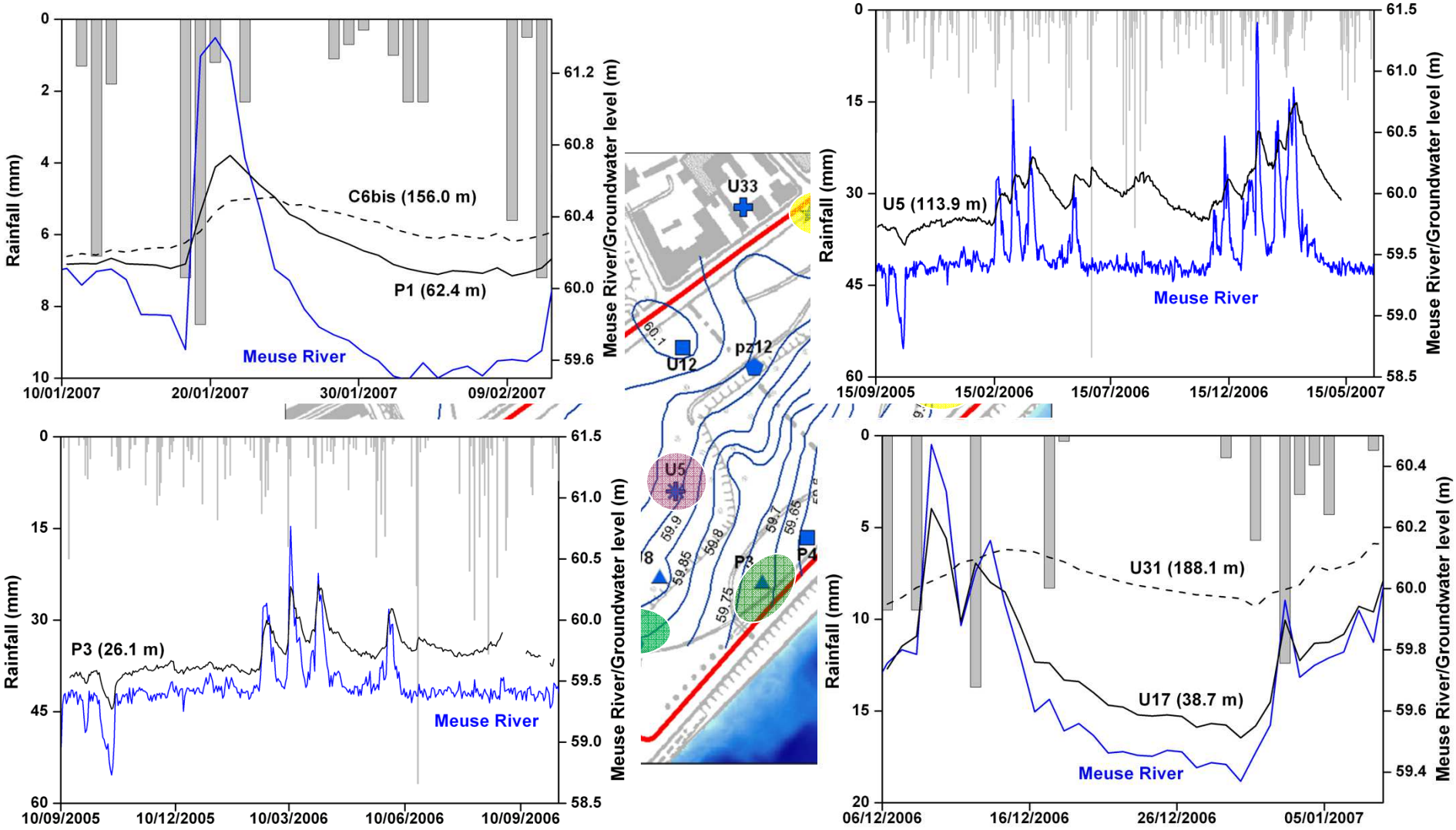
The brownfield is contaminated and the river – aquifer interacting zone is urbanised (road, waterworks, cable ducts, pipes…)



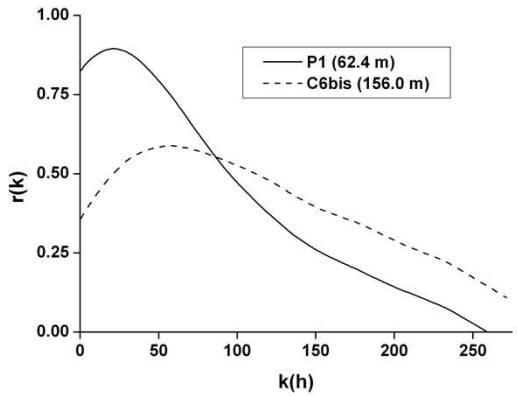
The site is hardly accessible
for classical hydrogeological investigations

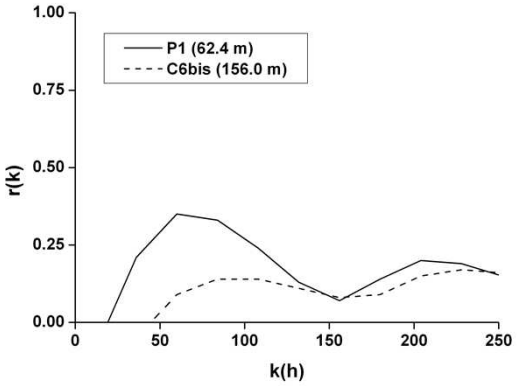
The solution … shake out the tablecloth!

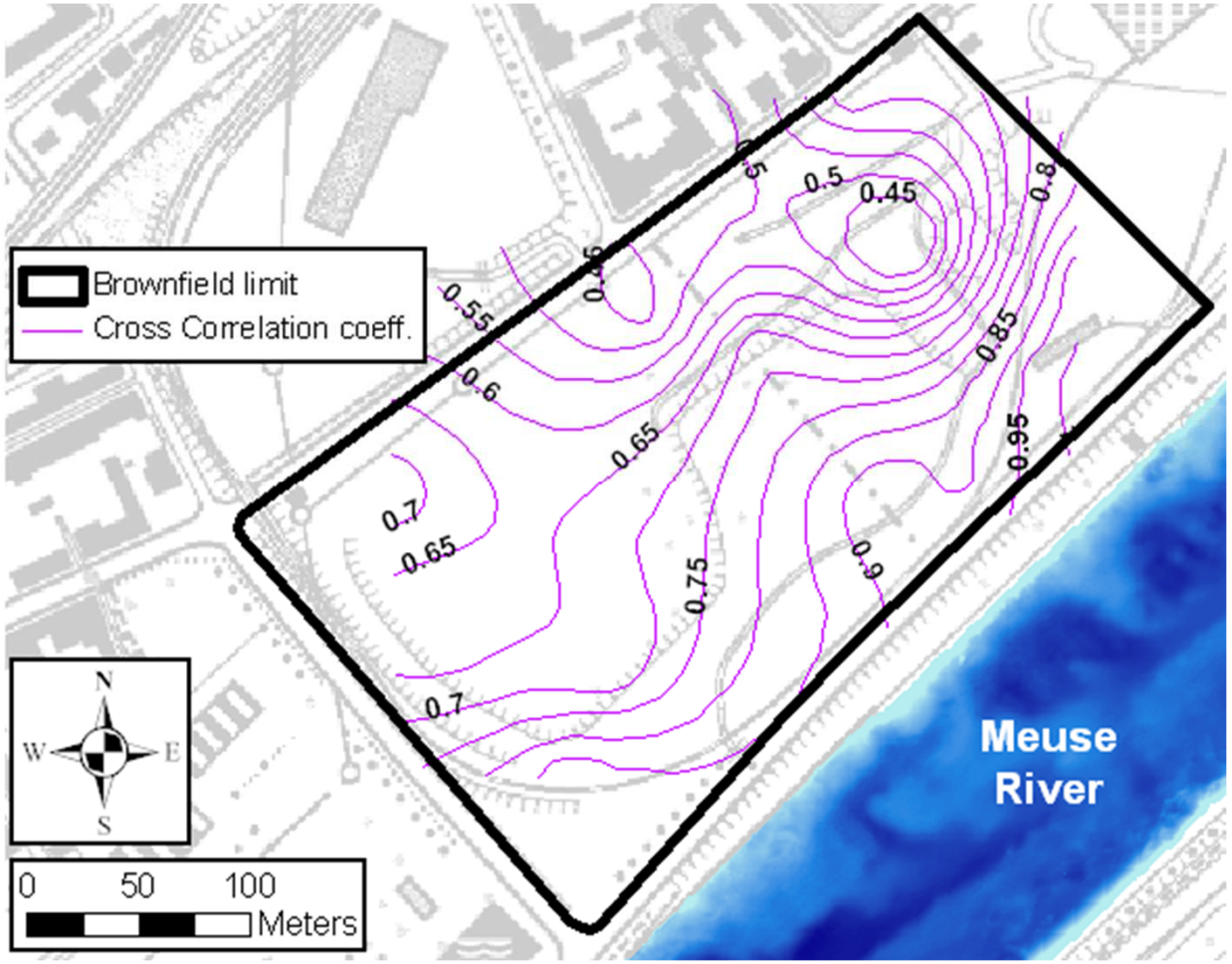
Detailed monitoring of river levels and groundwater levels in 16 piezometers distributed throughout the site



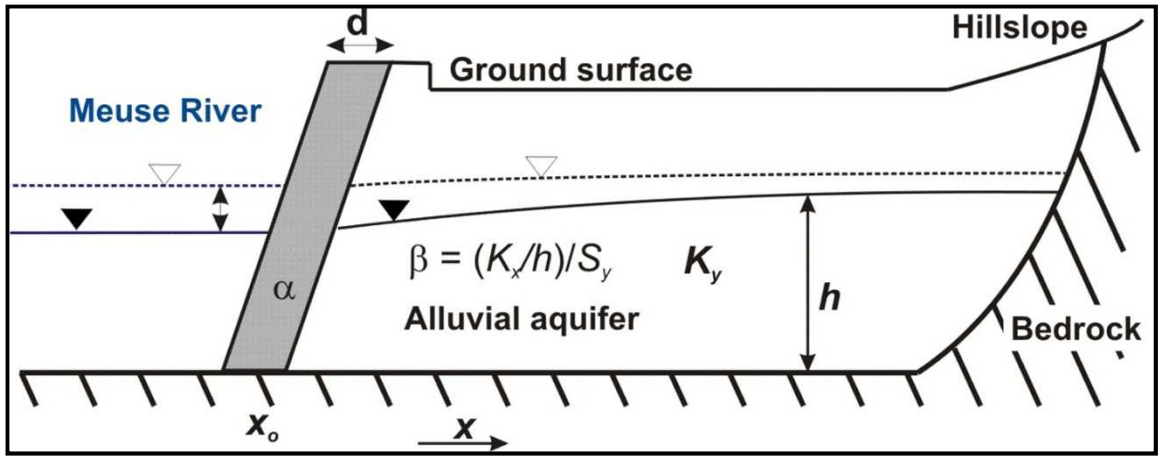
Evident cross-correlation between changes in groundwater and river levels



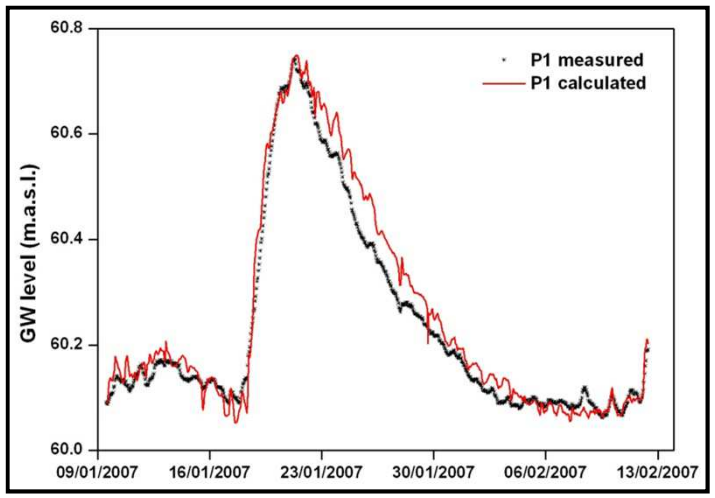


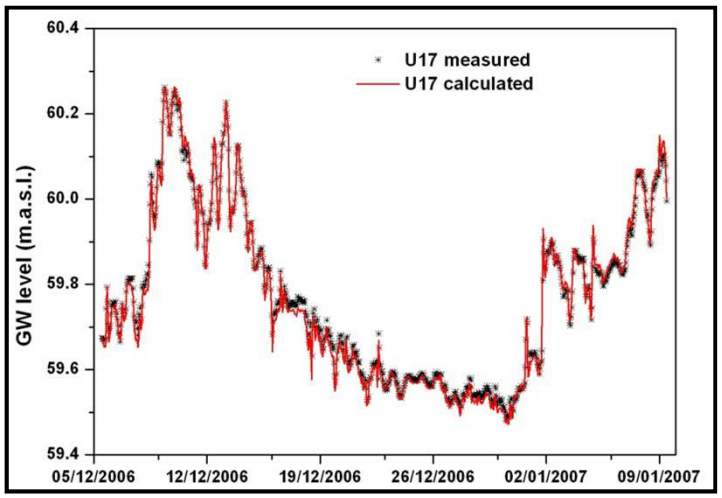


Even if the dynamics are complex, they are elegantly captured by “simple” analytical models …



Analytical modelling using USGS code STWT1 (Barlow and Moench, 1998)





But we are expecting more than that from the dataset …

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Modelling groundwater – river interactions is also challenging …

Groundwater flows are not restricted to the brownfield

The Meuse alluvial plain extends to hundreds of meters around (NE, SW, NW)

Data are mostly restricted to the brownfield

Many piezometers drilled for site investigations, nothing outside

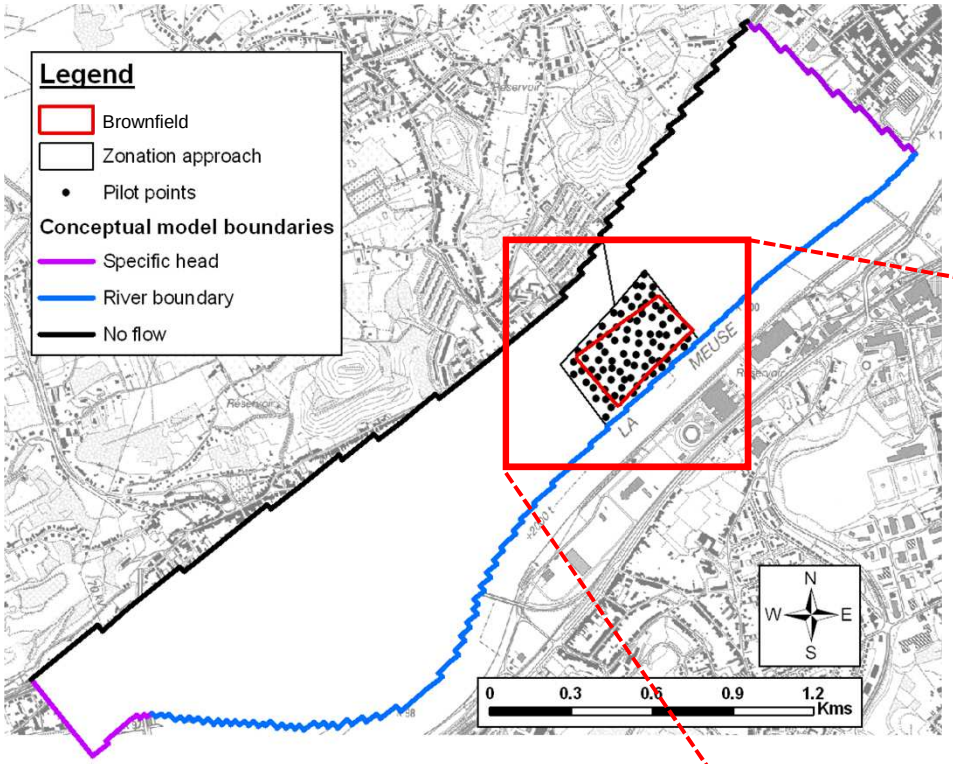
Alluvial deposits are supposed to be relatively heterogeneous

Importance on groundwater fluxes, groundwater discharge to the river and contaminant dynamics

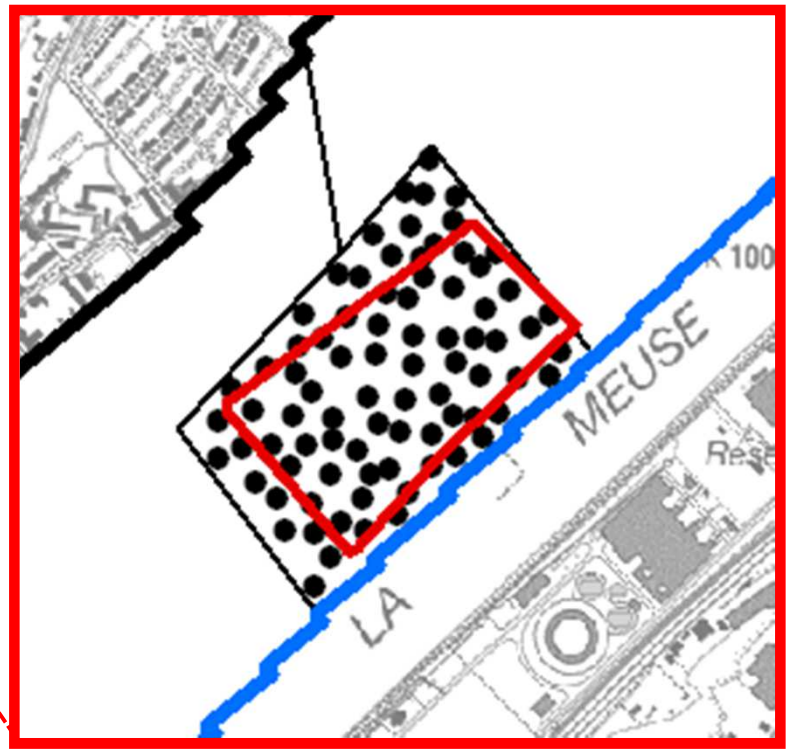
Monitored groundwater and river levels are almost the only source of information

The calibration should be based on that

The model is developed with MODFLOW 2000, using a dual-scale, regional and local approach



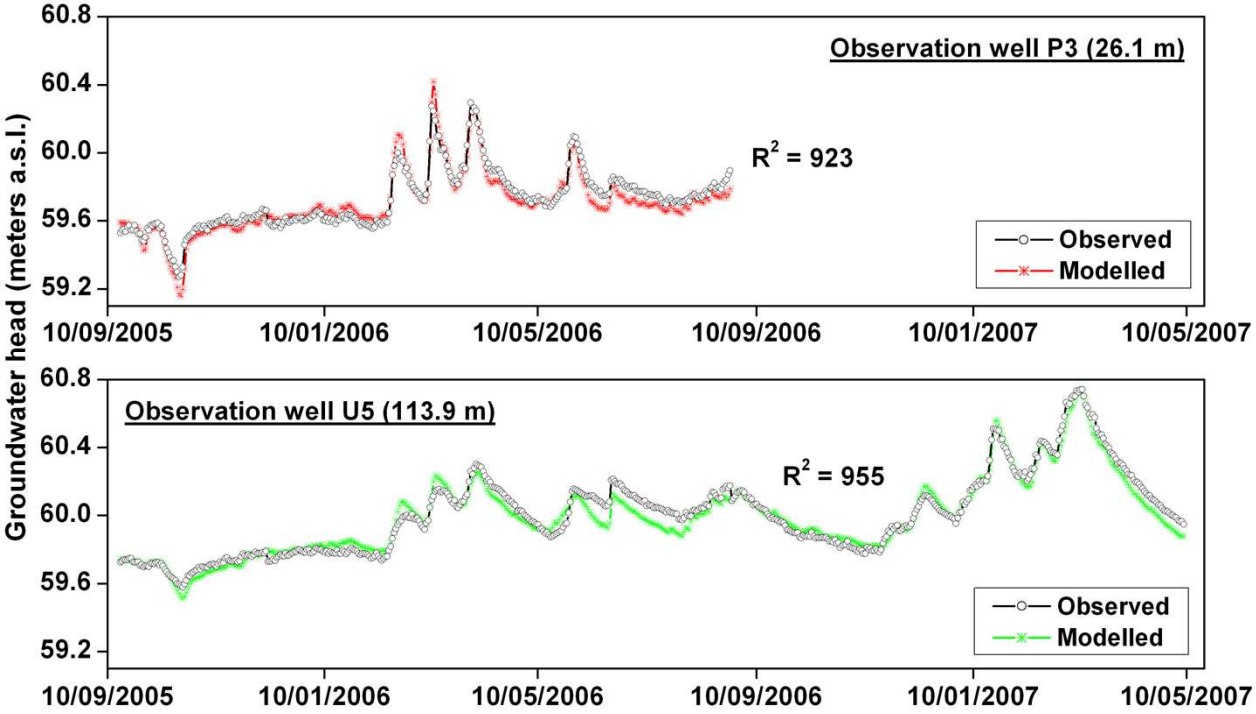
At regional scale : zonation approach with very restricted number of zones

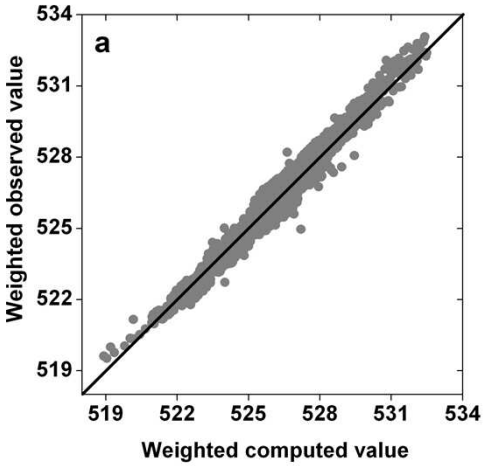


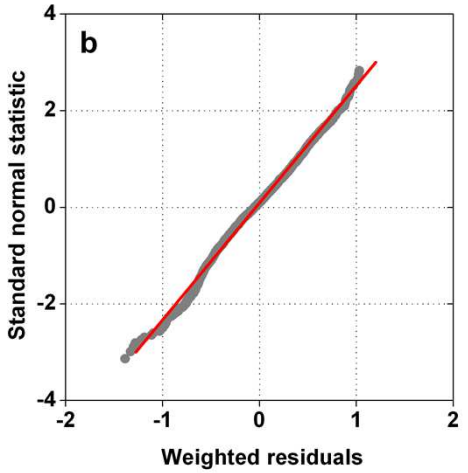
At site scale : pilot points to capture as much as possible the heterogeneity of the alluvial deposits

To calibrate the model, the river is used as a stressor for groundwater level variations

Calculated groundwater level time series adjusted to monitored ones, using inverse modelling code **PEST**

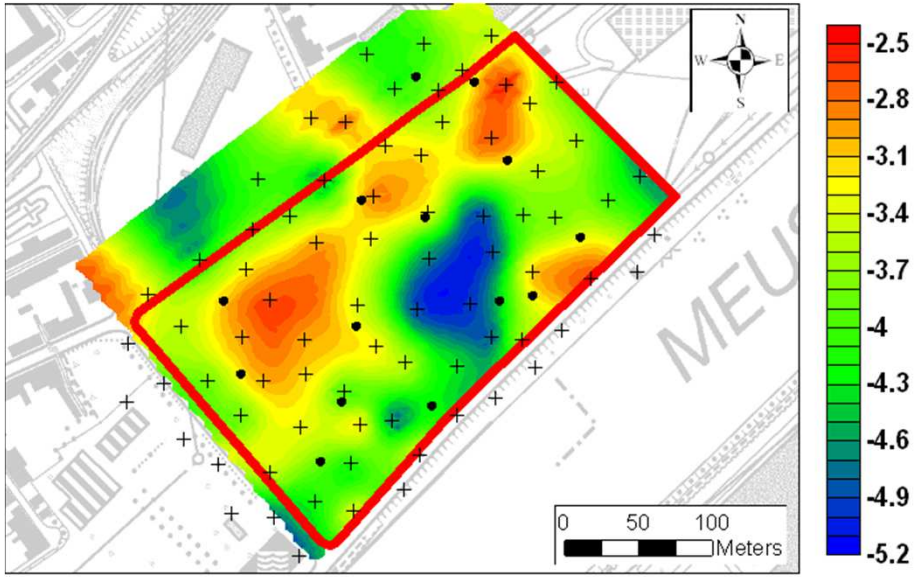






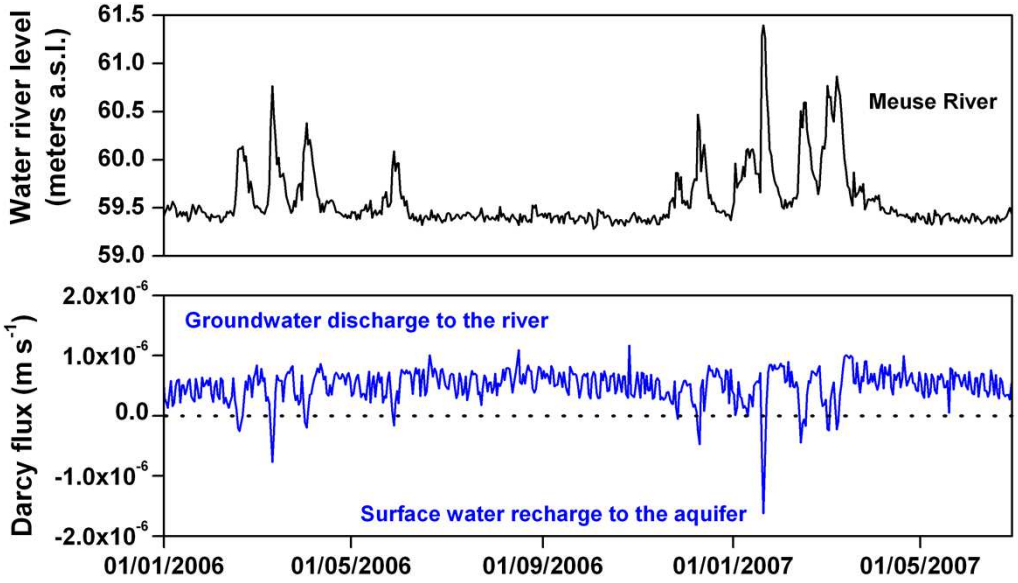
RMSE Observed vs. Computed GW heads: 0.048 m.

Modelling results give us answers to our initial questions

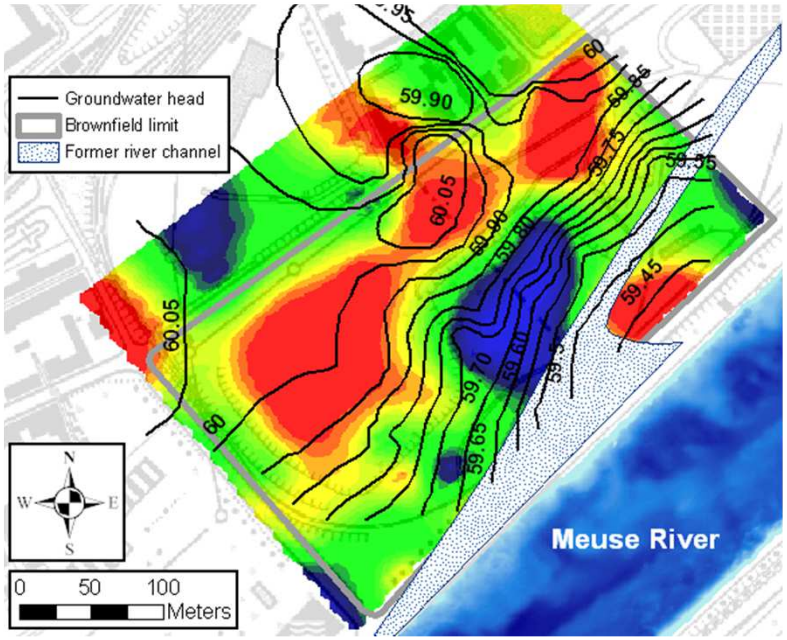


Almost 3 orders of magnitude between low-K and high-K zones

Variable fluxes at the groundwater – river interface



However, can we rely on this model (1)?

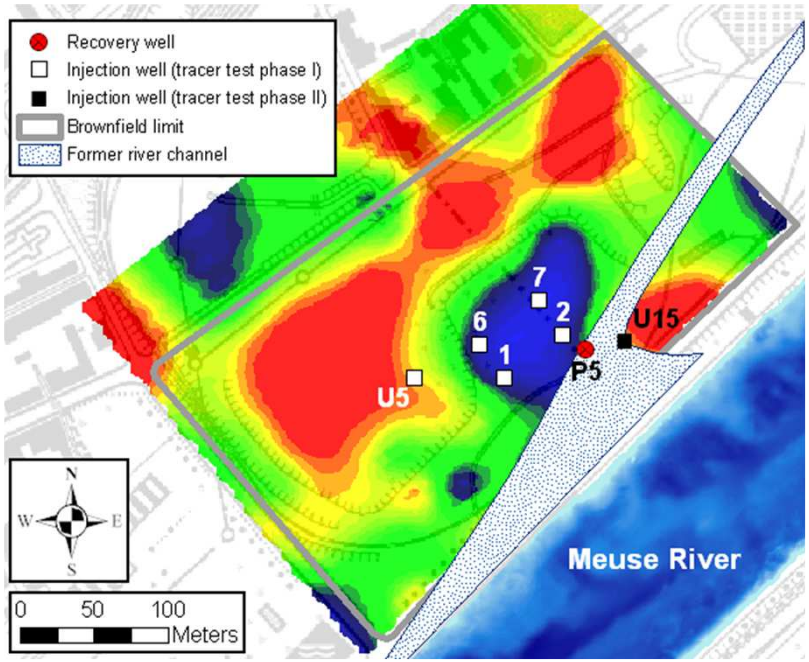


Calibration indicators satisfactory

The model reproduces very well the trend in piezometry

Historic data report
a former river channel
that fits well with the K field

However, can we rely on this model (2)?



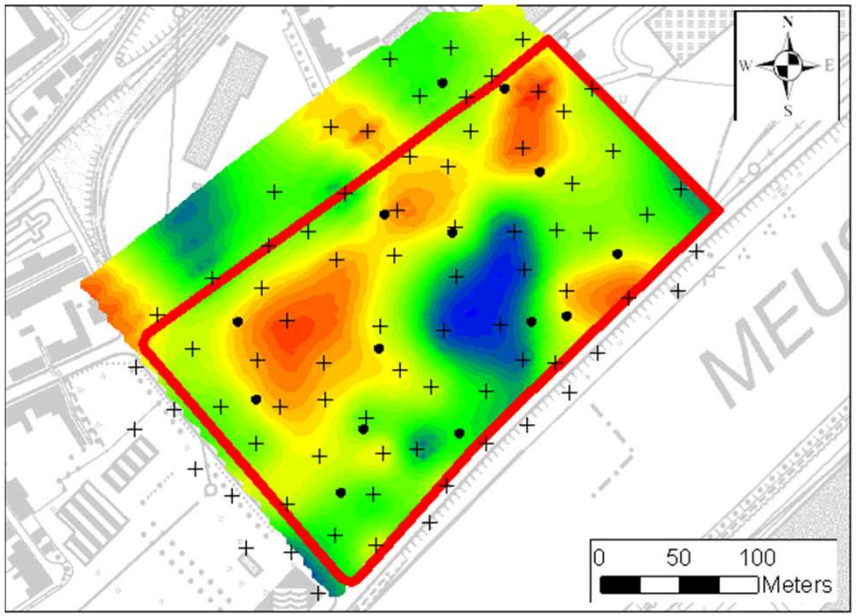
Results of tracer experiments more easily explained in the light of the K-field

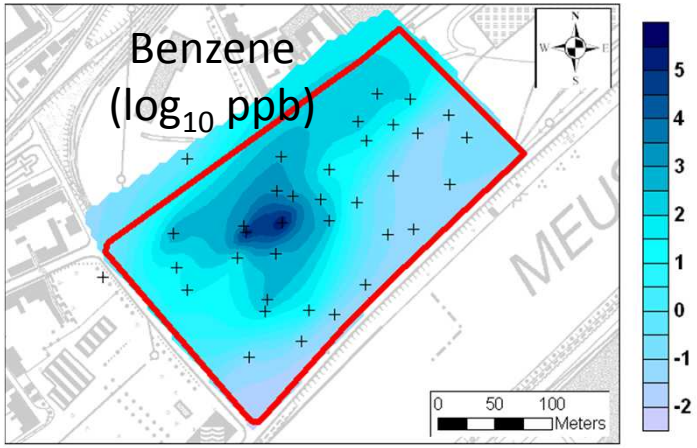
Pz1 Pz2 Pz6 Pz7 U5 :
no recovery at P5

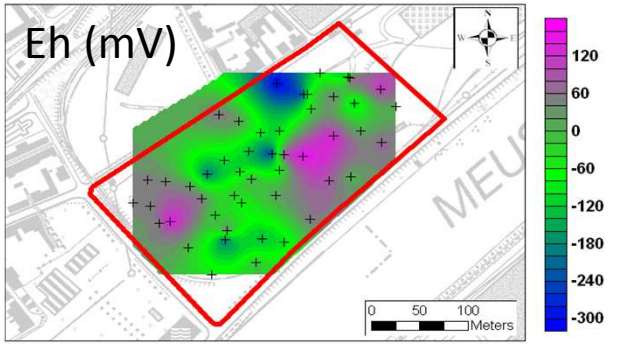
U15 : recovery at P5 which drained most probably water from the Meuse

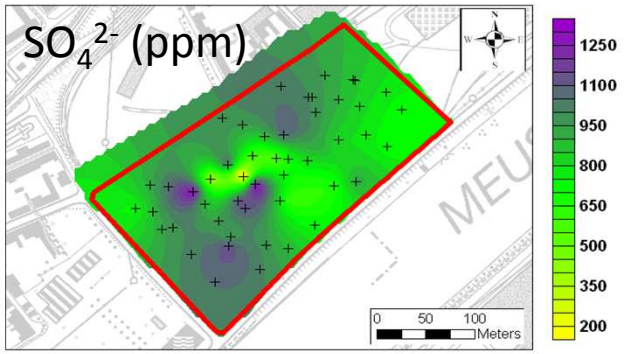
However, can we rely on this model (3)?

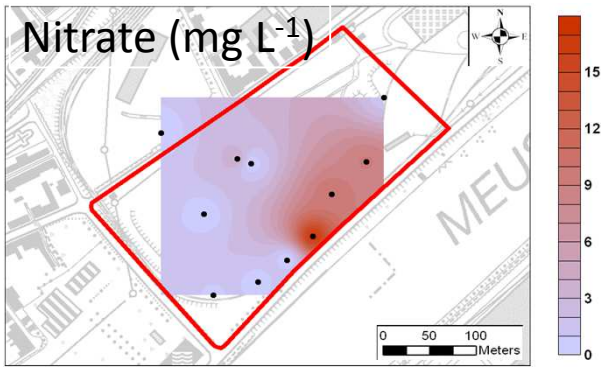
Benzene distribution and redox indicators compliant with K field





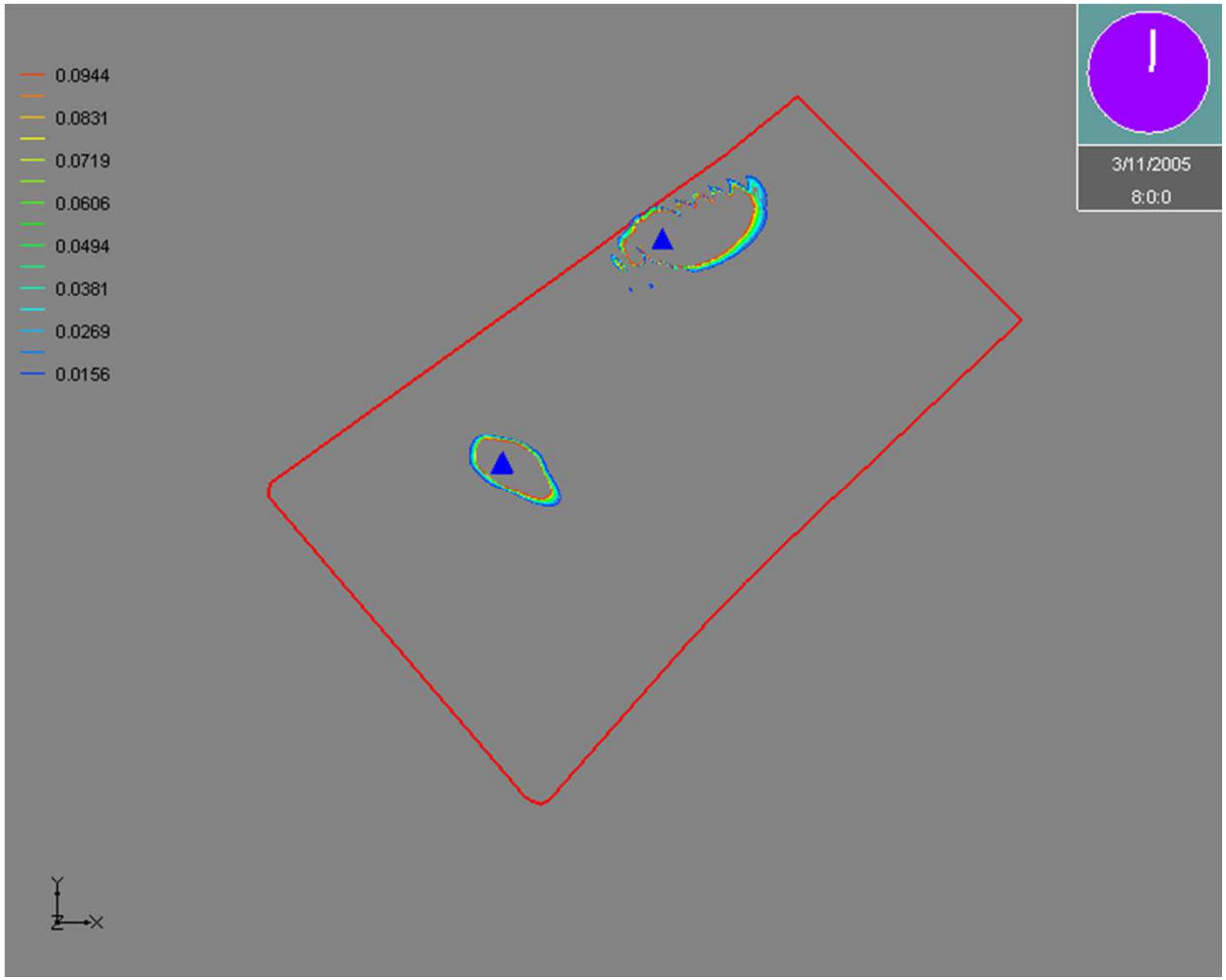






Pollutants dynamics strongly related to groundwater – river interactions

Transport model (MT3DMS) calibrated fitting measured breakthrough curves in radially convergent tracer tests



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Conclusions

Regardless of the Meuse embankment, groundwater – river interactions are strong and bidirectional

Such interactions might add noise to our experiments; however we can efficiently take advantage of them for the characterization and modelling of alluvial deposits and groundwater fluxes to rivers

The model allows us to quantify groundwater fluxes at the interface between the alluvial aquifer and the river

On a mean basis, Darcy fluxes are on the order of 5.0×10^{-4} m/s; however, these fluxes are highly variable, with possible reversed flow direction during high river stages

The coupled groundwater – river system can have a strong influence on the dynamics of contaminants in the subsurface

Time changes in contaminant concentrations and fluxes, mixing and dispersion, degradation …

Thank you for your attention!

Further reading

J.Batlle-Aguilar, Groundwater flow and contaminant transport in an alluvial aquifer: in-situ investigation and modelling of a brownfield with strong groundwater - surface water interactions, PhD thesis, University of Liège, Faculty of applied sciences, 2008. Avaliable at : http://bictel.ulg.ac.be/ETD-db/collection/available/ULgetd-10282008-103833/

Batlle-Aguilar, J., Brouyère, S., Dassargues, A., Morasch, B., Hunkeler, D., Höhener, P., Diels, L., Vanbroekhoven, K., Seuntjens, P., & Halen, H. (2009). Benzene dispersion and natural attenuation in an alluvial aquifer with strong interactions with surface water. Journal of Hydrology.