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**Europe**

# 3D numerical modelling of an in-situ field scale pulsed pumping process of a large DNAPL pool in a keyed enclosure

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GROUNDWATER REMEDIATION

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# Objective

Pilot-scale

In situ experiments

Numerical modelling

Feasibility of a pulsed pumping process

Large DNAPL pool

Alluvial aquifer

# SILPHES: a 3,5 million euro partnership project

inovyn



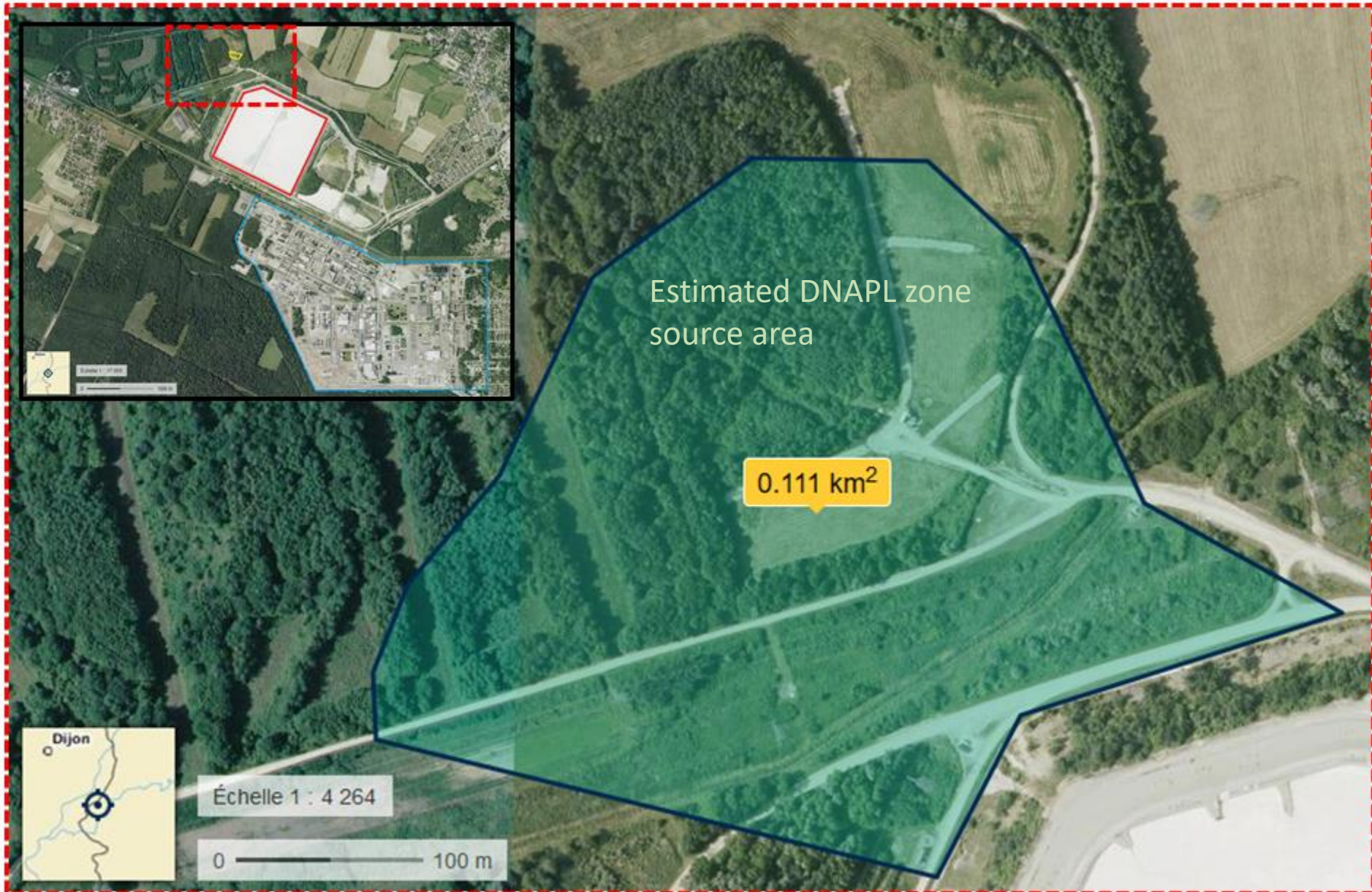
ADEME



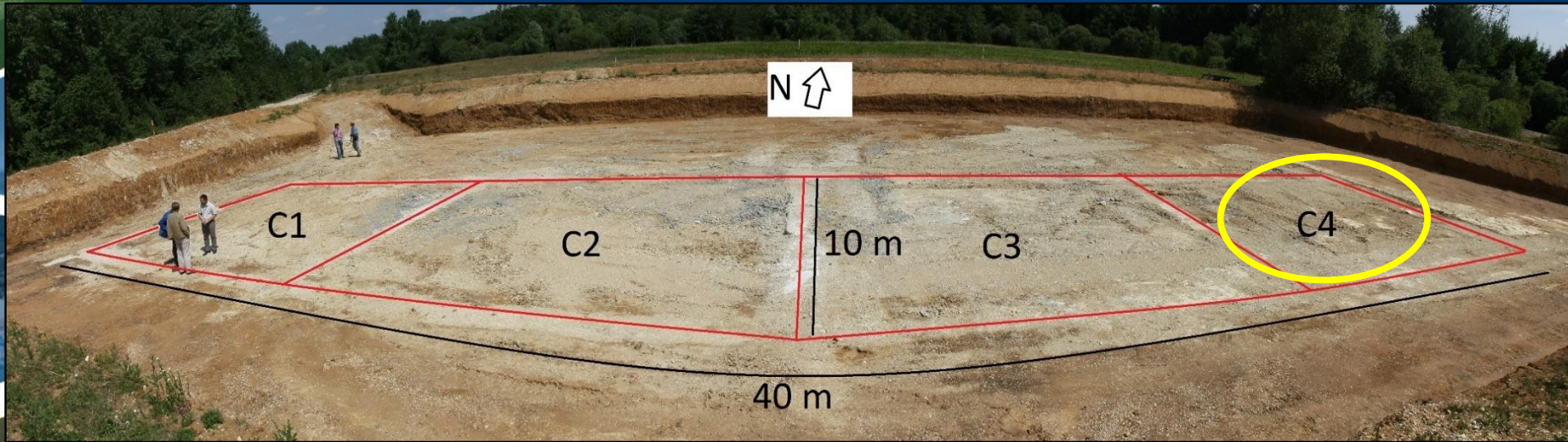
Agence de l'Environnement  
et de la Maîtrise de l'Energie



# A brief history of the study site



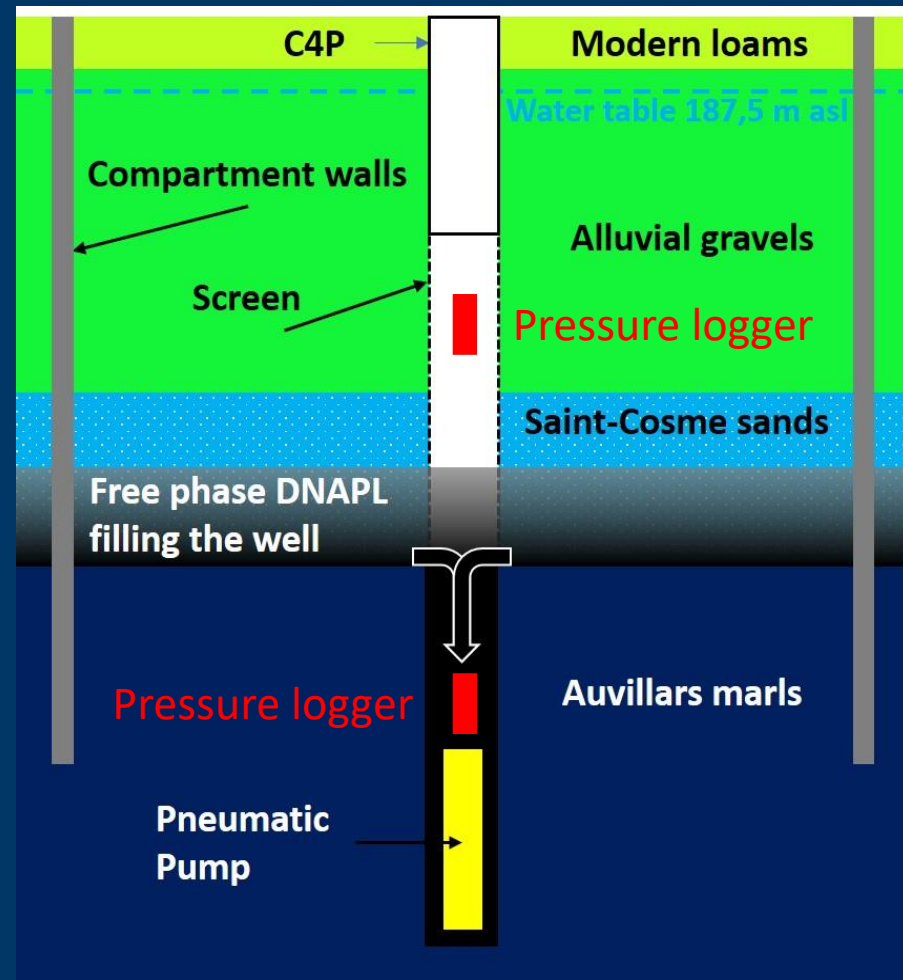
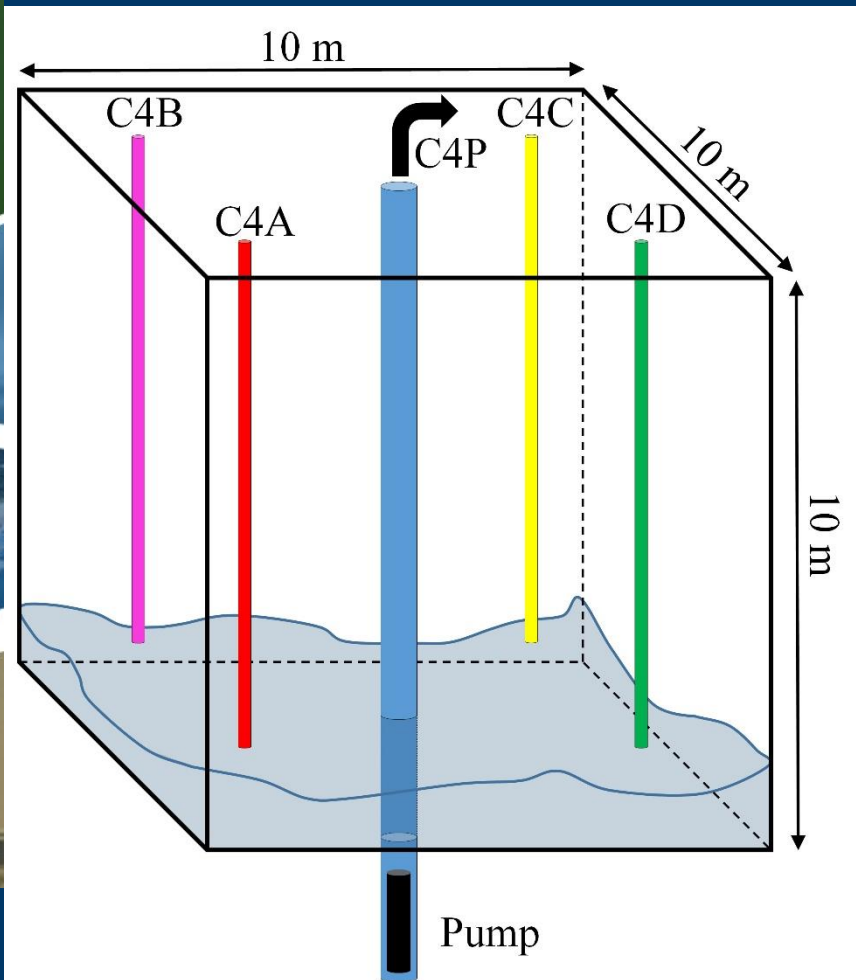
# Low permeability keyed enclosures a.k.a. the big boxes



Credits : Quentin Giraud

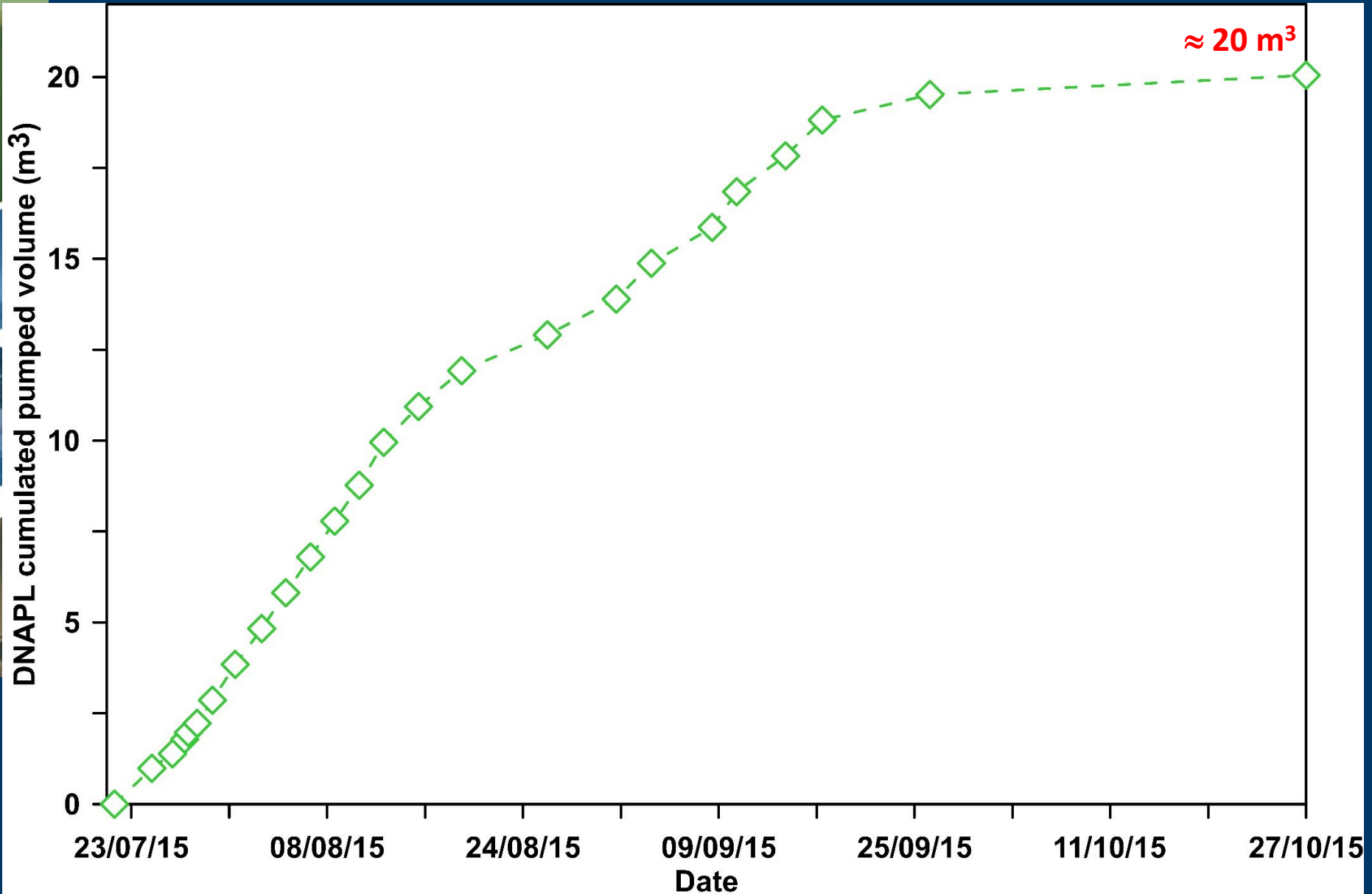
4 cubic compartments with slurry walls embedded into the substratum

# You've got to pump it up!

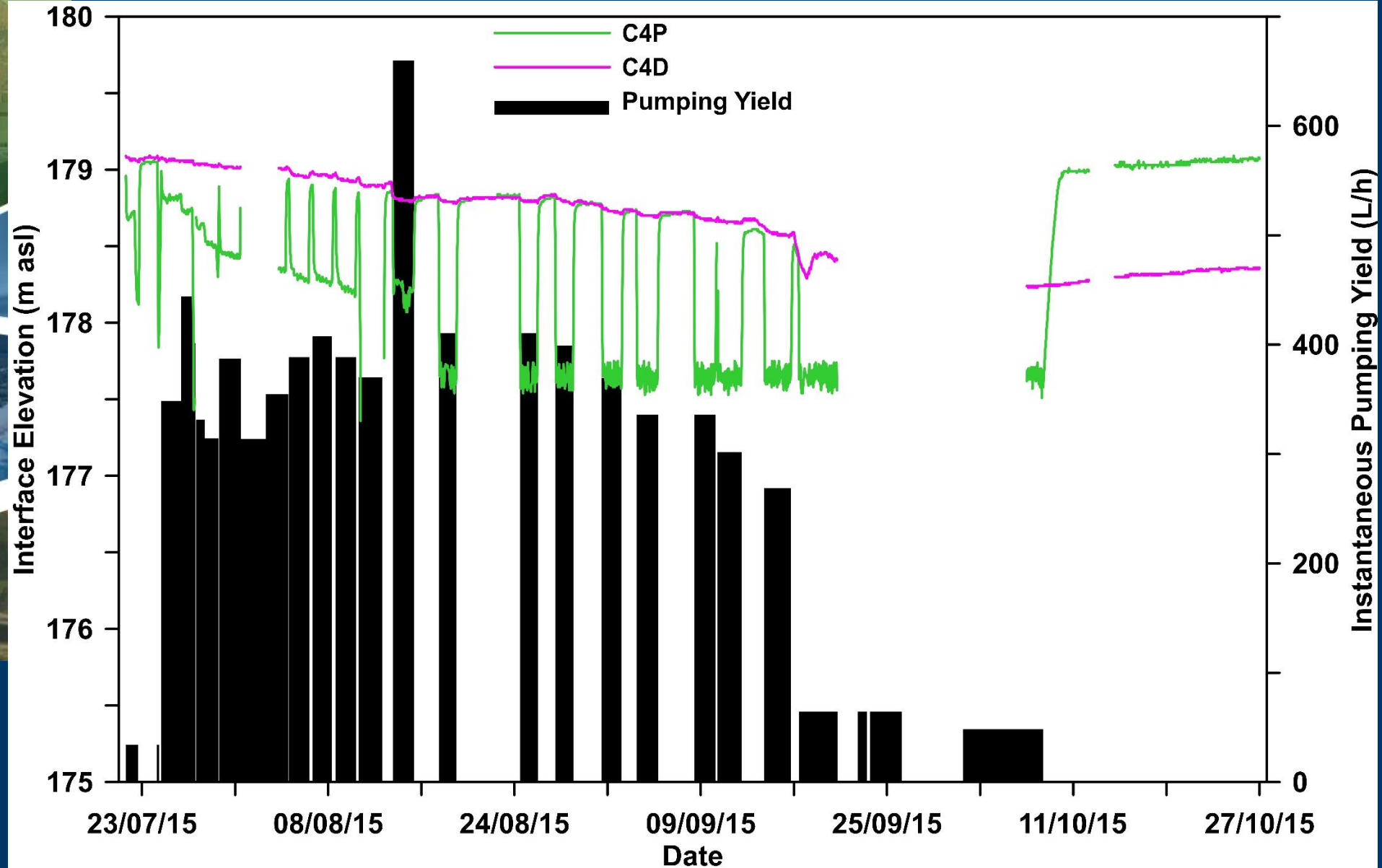


- Controlled pulsed pumping process : 10 sec pumping, 150 sec recovery

# A lot of DNAPL!



# Less and less until... more and more?!





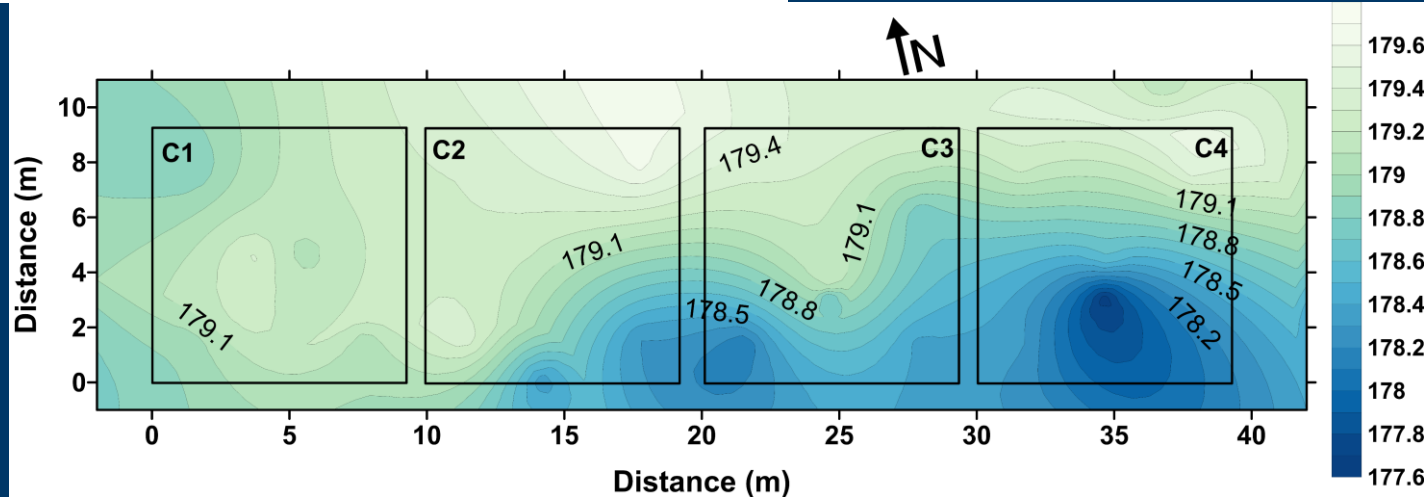
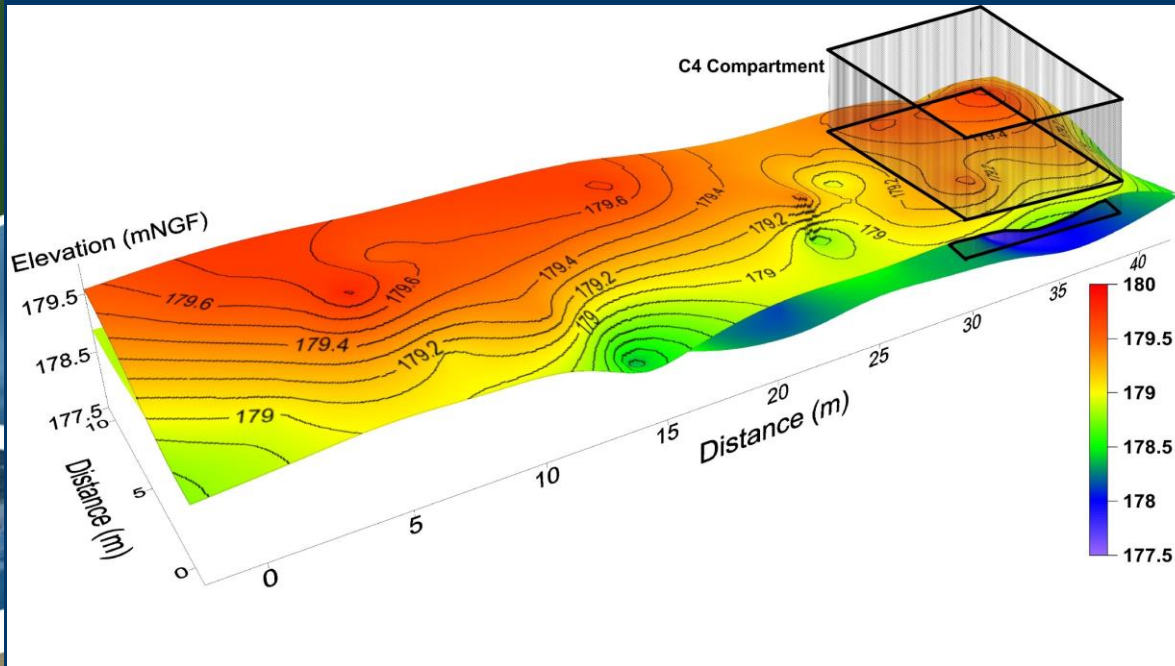
Easy peasy, numerical modelling?

**ONE DOES NOT SIMPLY**

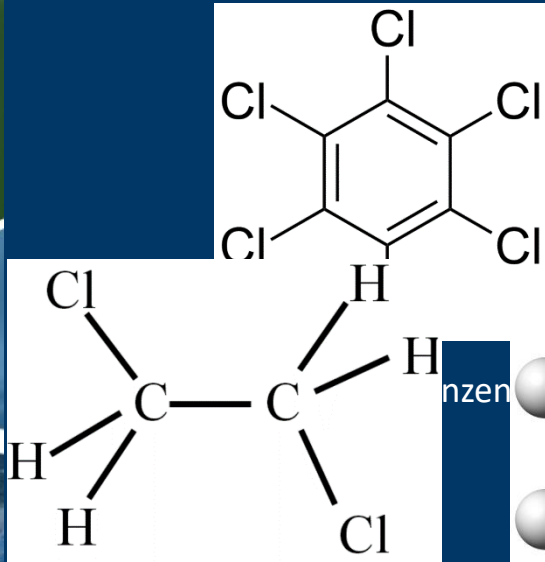
**MODEL MULTIPHASE FLOW**

imgflip.com

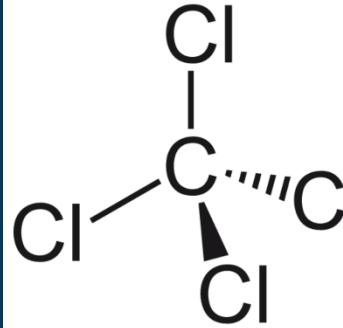
# What's beneath our feet?



# A DNAPL "cocktail" you should not drink!



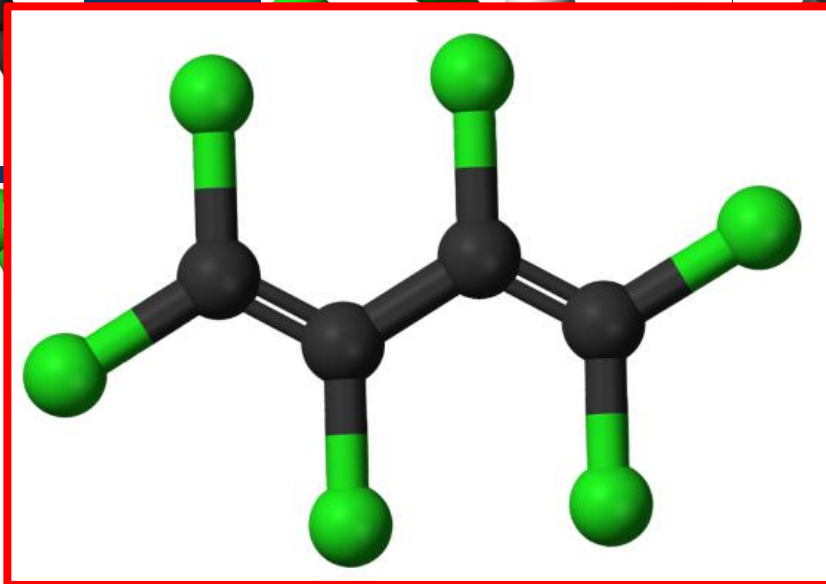
1,2 dichloroethane



Carbon Tetrachlorure

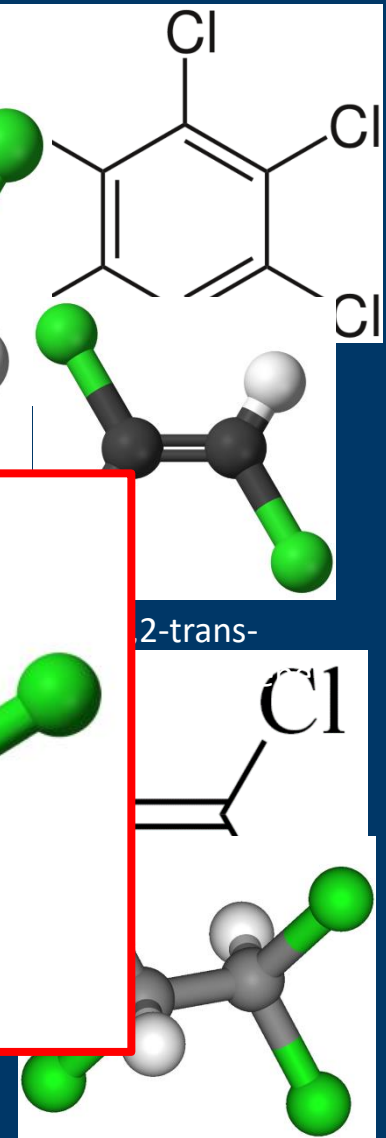


1,2 dichloropropane



Hexachlorobutadiene

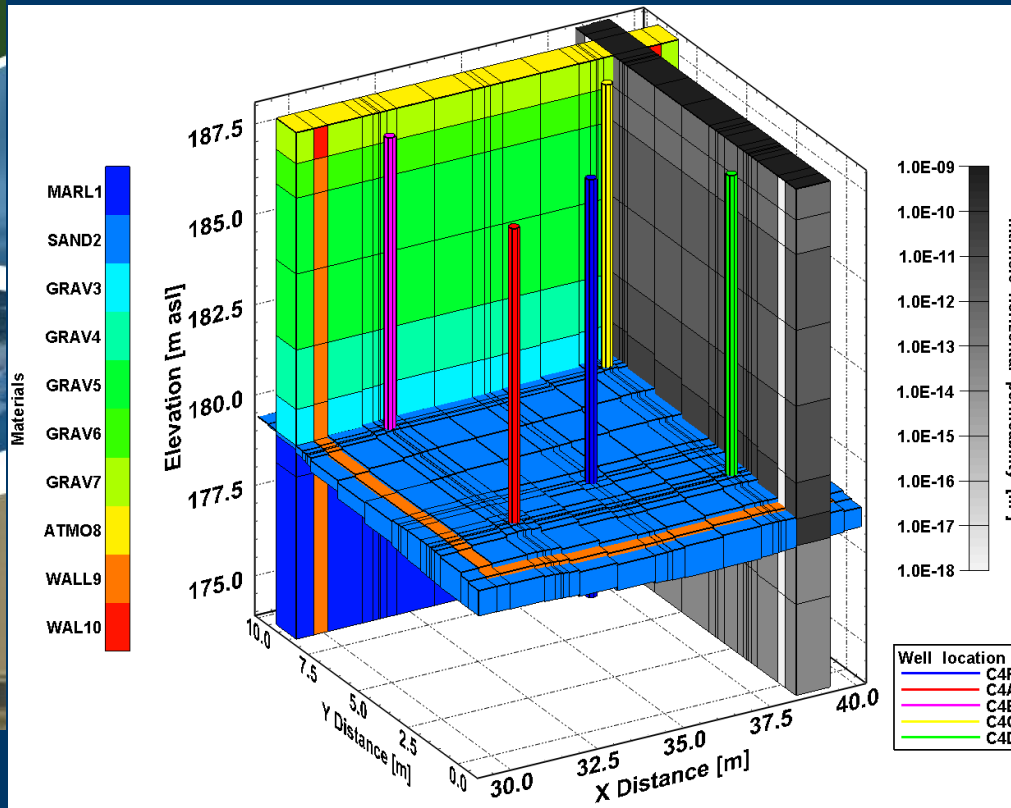
1,1,2,2 tetrachloroethane



# Choose your weapon: TMVOC

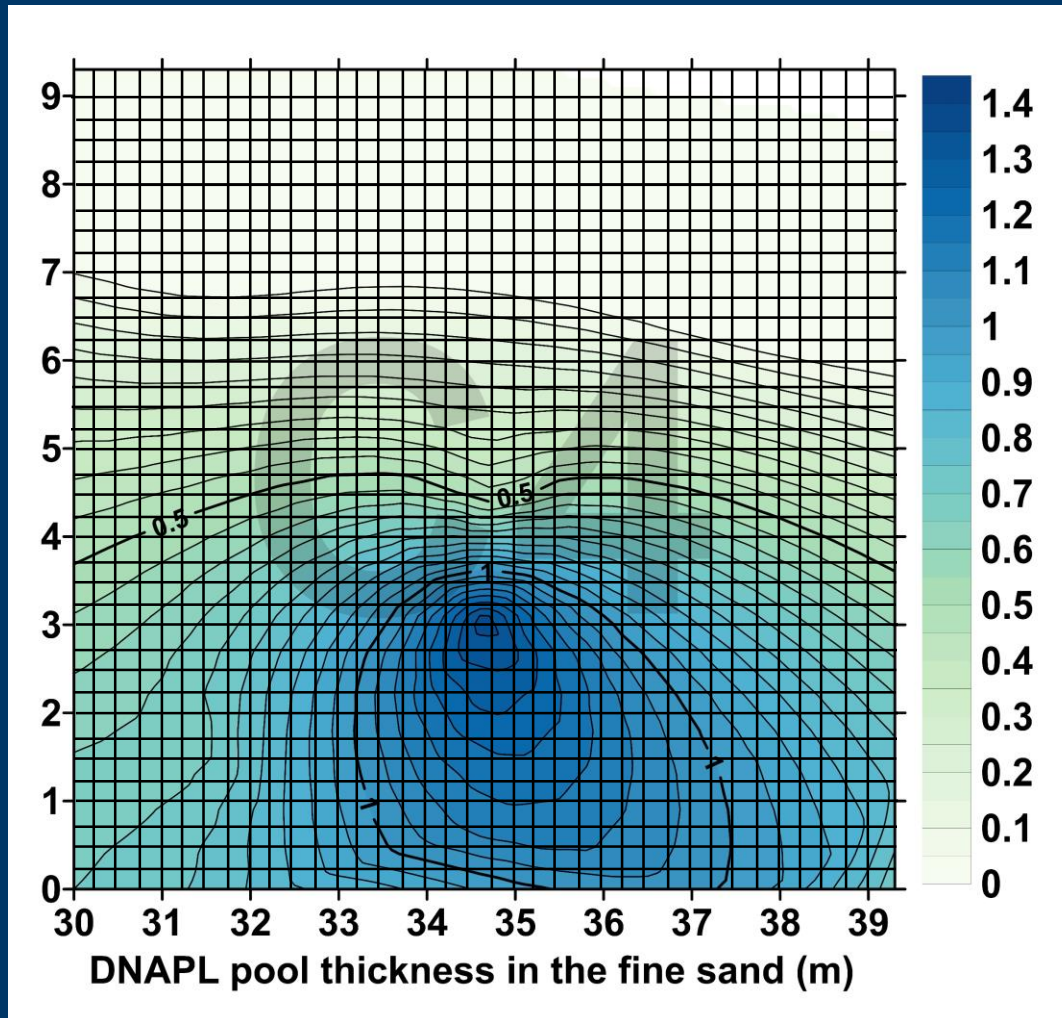
- Three-phase flow numerical simulator in 3D heterogeneous porous media
- Non-isothermal
- Multicomponent mixture of volatile organic chemicals
- Integral finite differences
- TOUGH2 simulator extension, developed by the Lawrence Berkeley National Laboratory, CA, U.S.A.
- Modelling of contaminant behaviour:
  - Under natural environmental conditions
  - For engineering processes

# 3D geometrical model



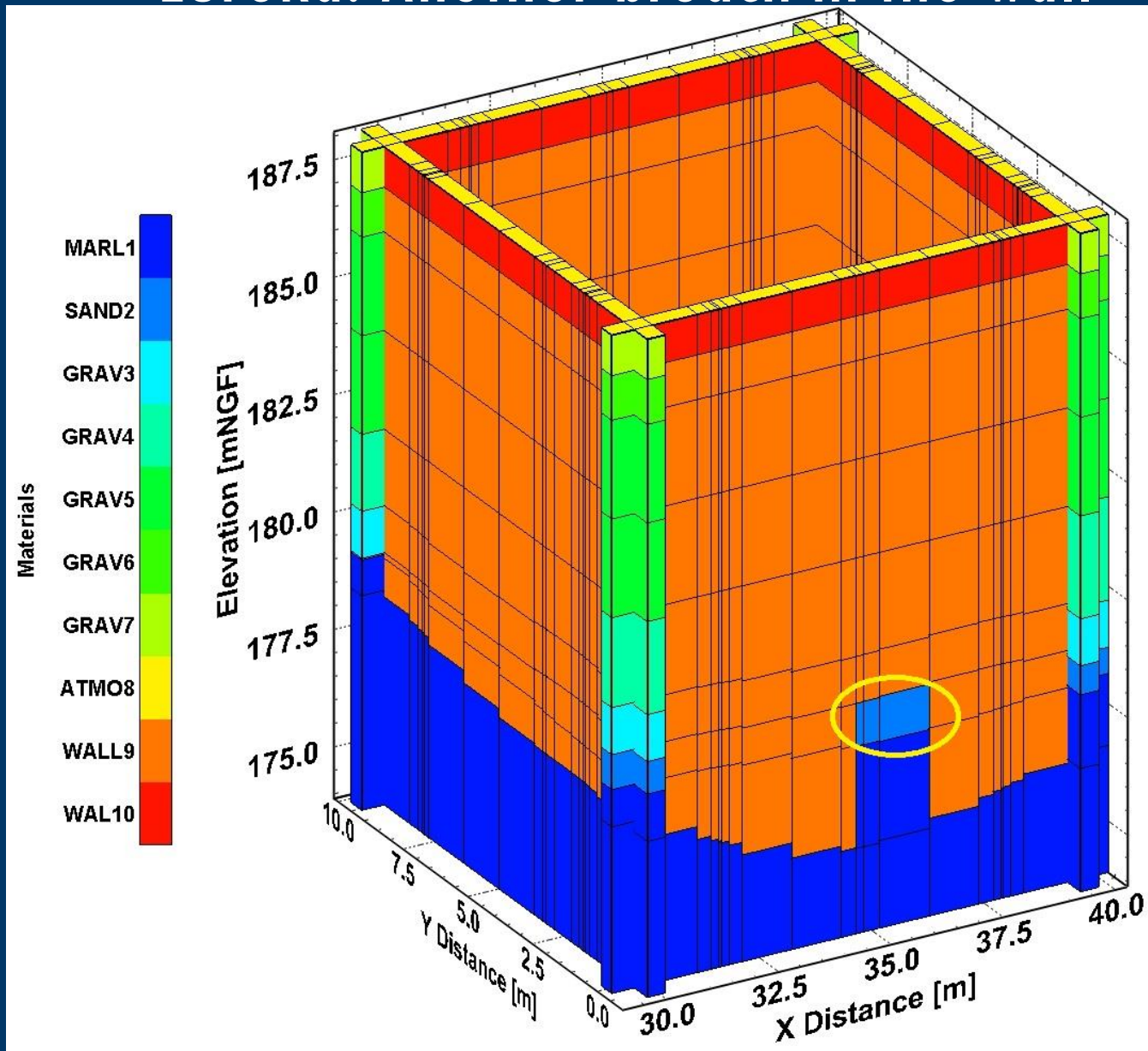
- 5060 grid blocks
- 10 numerical layers
- Walls included
- 0,5m width exterior belt
- Simple well model:
  - 99,99% porosity
  - No capillary pressure
  - Screen included
  - Very high vertical permeability

# “Houston, we have a problem.”

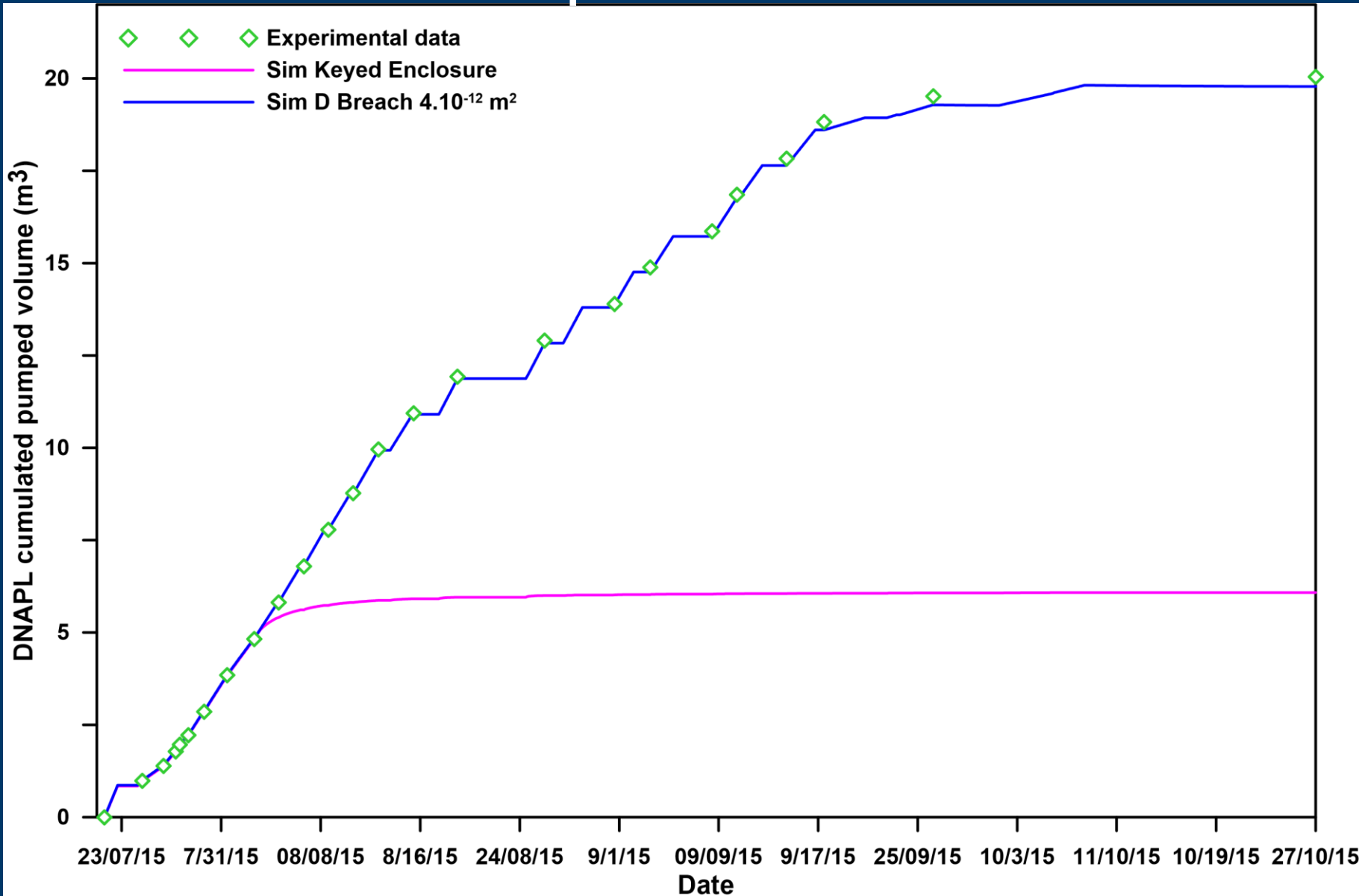


Estimation of the initial volume: 6,2 m<sup>3</sup>

# Eurêka! Another breach in the wall

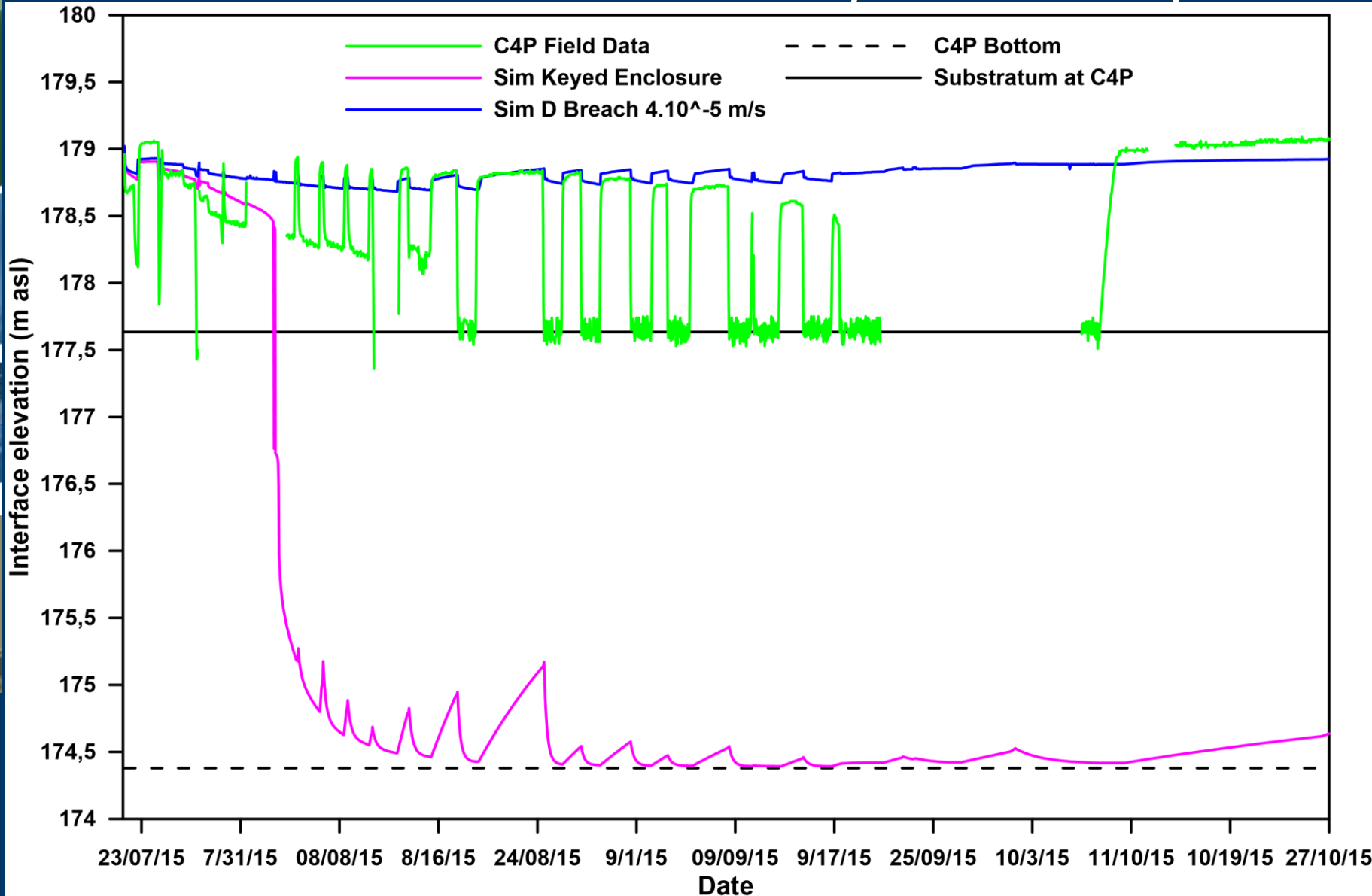


# The “perfect match”





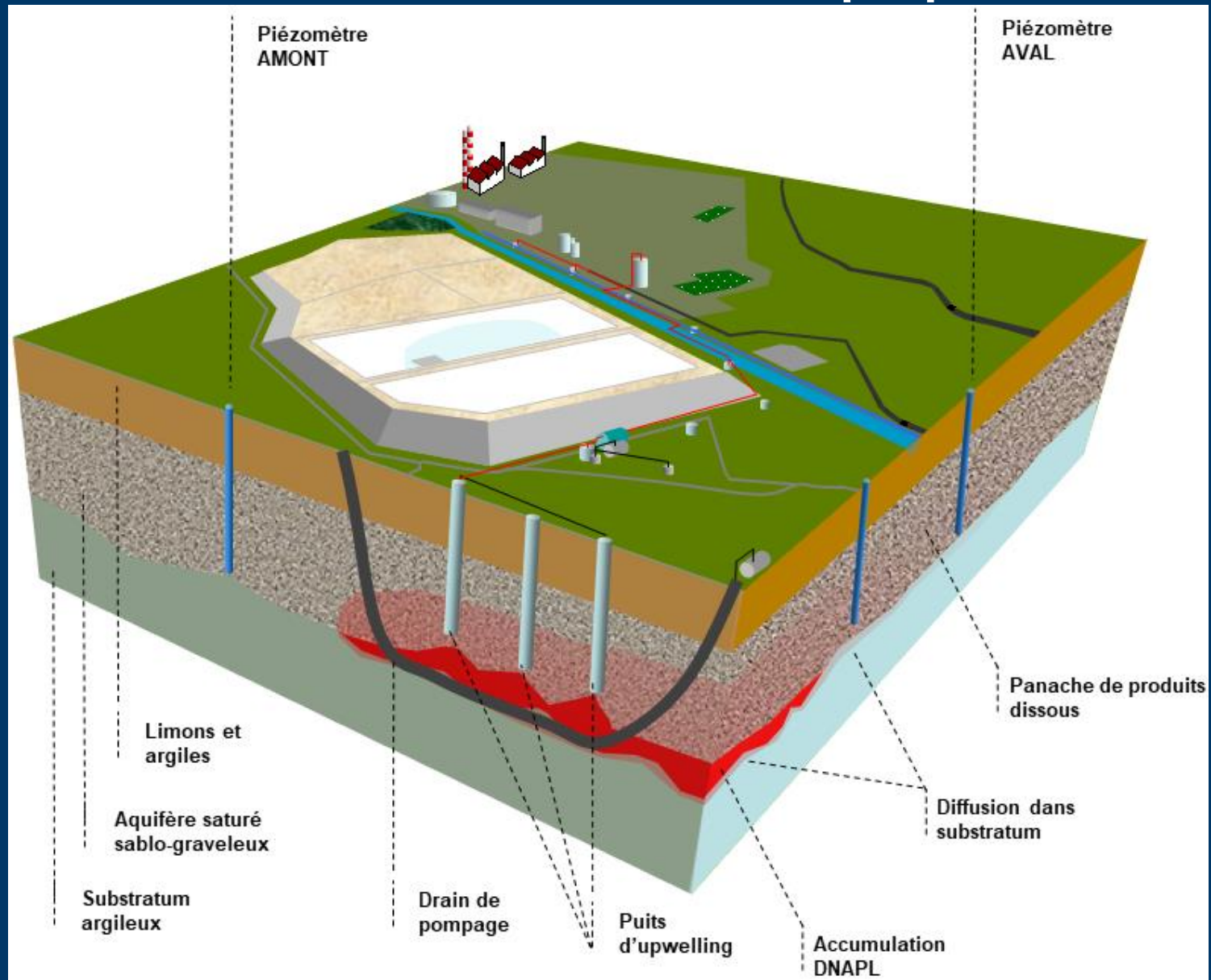
# Better simulation with the “leaky box” assumption



# Take-home messages



- First successful study combining in-situ DNAPL pumping process with its 3D numerical modelling
- Simulations show an excellent agreement between field and simulated data for extracted DNAPL free-product volumes
- Lower but reasonable agreement for the interface elevations:
  - Finer vertical discretisation
  - Using the more complex well model developed by Sleep *et al.*, 2015
  - Integration of the hysteretic behaviour for the capillary pressure functions (Doughty, 2013)
- Evidence, by the simulation, of the leaky enclosure with a breach
- Pumping process optimisation can be performed

# What's next? PAPIRUS project





## 3D numerical modelling of a pulsed pumping process of a large DNAPL pool: *In situ* pilot-scale case study of hexachlorobutadiene in a keyed enclosure

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**Thank you for your attention,**

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