HyGEM Kick-off meeting

Denver, April 26-27 2012

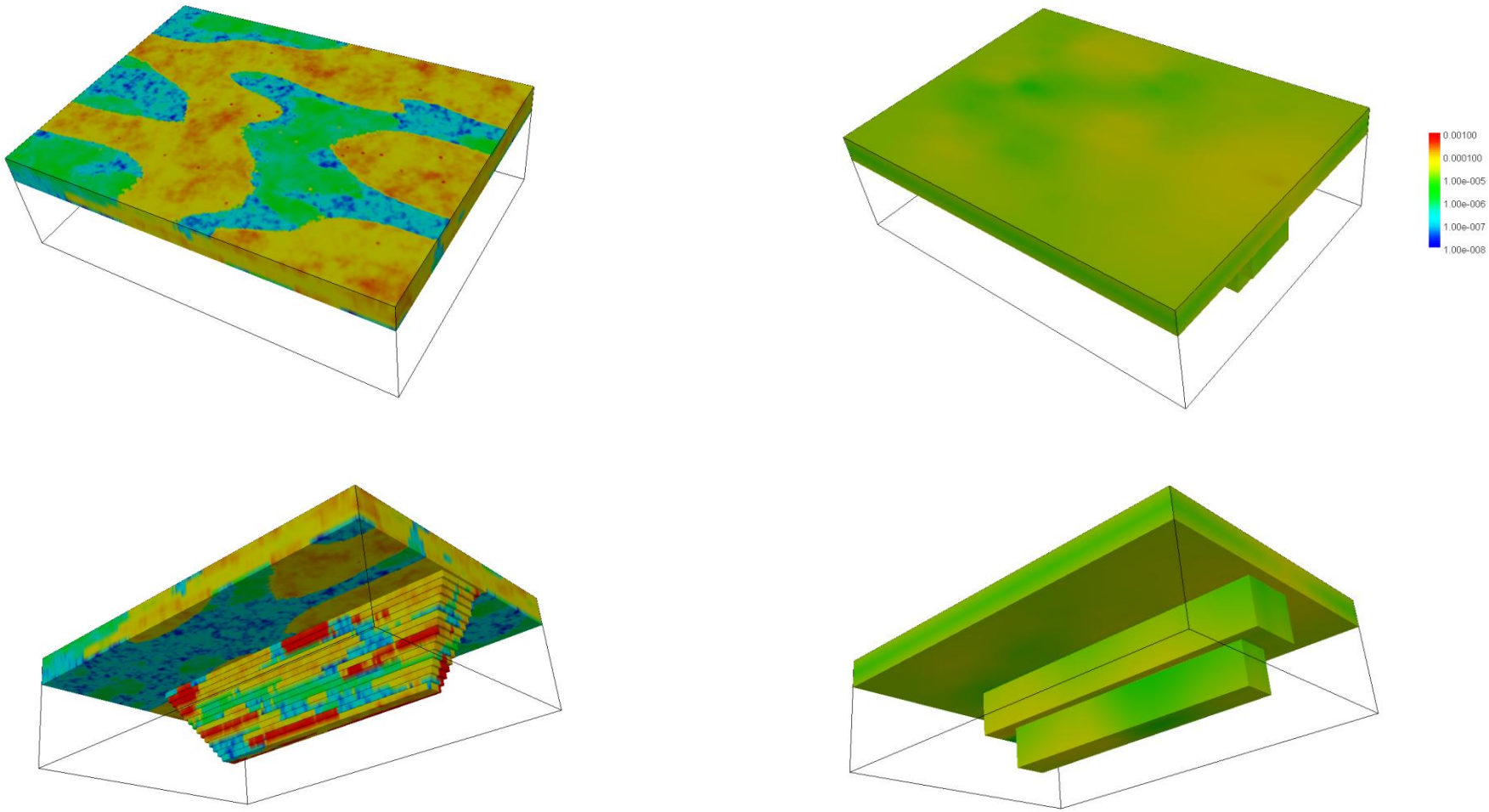
Steen Christensen

- Assoc. prof., Dept. of GeoSciences, AU
- MSc civil engineering, PhD in Science
- 8 years as consultant in water supply, water resources and hydrogeology
- AU since 1993, assoc. prof. since 1998
- Supervision of 9 PhD and 37 MSc students
- http://person.au.dk/da/sc@geo.au.dk
- http://www.researcherid.com/rid/A-2016-2012

Current research

- Hydrogeology
  - Catchment scale hydrology and hydrogeology.
  - Groundwater/surface water interactions.
  - Groundwater flow in geological complex areas.
- Modelling
  - Modelling flow in complex and heterogeneous media.
  - Quantification of uncertainty of model parameters and predictions.
  - Data requirements in model calibration.
  - Application of geophysical data in development and calibration of groundwater models.

”Real K field” versus simple model ”perfectly calibrated K field” (realisation 1)

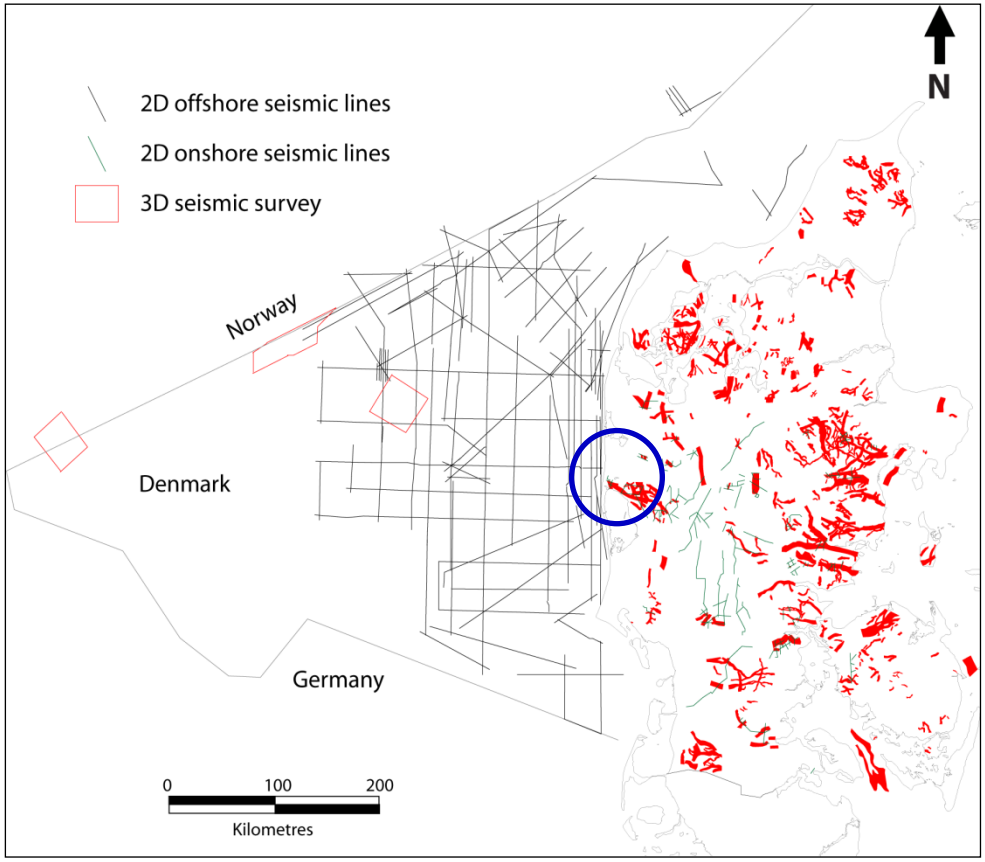


(Confining bed leakances not visualised)

People involved in HyGEM

- **Troels N. Vilhelmsen**
- Ph.d. student
- Gw. Modeling
- Complex geology
- Coupled inversion
- MRS/Pumping test

Buried valleys



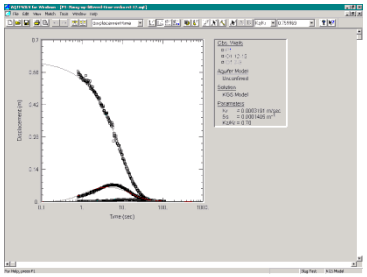
People involved in HyGEM

- **Toke H. Nielsen**
- M.Sc. student
- Coupled inversion
- MRS/Pumping test

- **Nikolaj K. Christensen**
- M.Sc. student
- Coupled inversion
- Prelim. test bench

People possibly involved in HyGEM

- **Keld Rømer Rasmussen**
- Assoc. Prof.
- Hydrology
- Stream flow
- Well logging
- HOBE



HOBE – Hydrological Observatory-catchment

Ahler Gårde, 1056 km^2, 15 m^3/s

http://hobe.dk

People possibly involved in HyGEM

- **Søren Erbs Poulsen**
- Ph.d. post doc
- Numerical modeling
- Density dep. flow/transp.
- Coastal groundwater
- Geothermal energy

Coastal groundwater

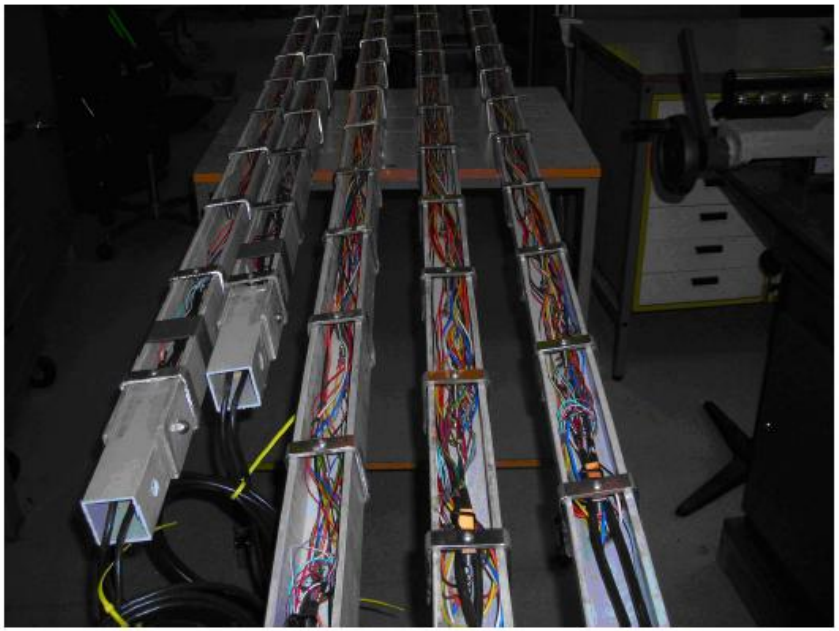
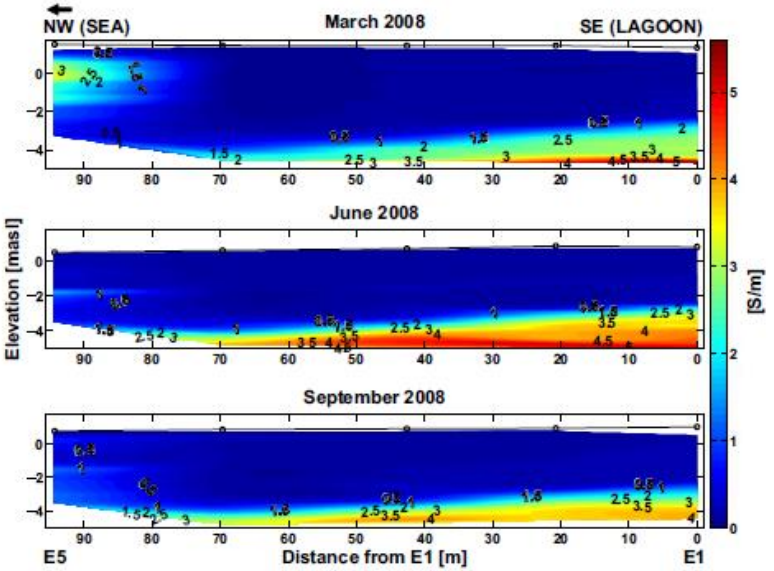


Figure 1 The 5 VMEP probes aligned in the workshop ready to be sealed with epoxy filler. Twenty mm wide steel electrodes are visible for each 250 mm and cables connecting probes to the MEP equipment during data recording are fully visible on the two left probes. Photo by Keld Rømer Rasmussen.



Electrical conductivity of porewater in March, June and September 2008 based on VMEP, equidistance=0.05 S/m, water table (*horizontal line*) and probe position (*circle*)

WP5. Hydrological and geophysical test-bench modeling

- Develop synthetic hydrogeological test-bench to test how use of extensive geophysical data can improve groundwater model calibration and prediction
- Test for various
  - hydrogeological settings
  - geophysical data
  - groundwater model predictions
  - sequential and coupled inversion schemes

Types of hydrogeological settings

- Danish:
  - Buried valley
  - ?
- American/Australian/Dutch
  - ?

Types of geophysical data

- Geoelectric
  - 1D forward/1D inverse
  - 3D forward/1D inverse
- TEM
  - 1D forward/1D inverse
  - 3D forward/1D inverse
- MRS
  - 1D forward/1D inverse
- ???

Groundwater + geophysics inversion schemes

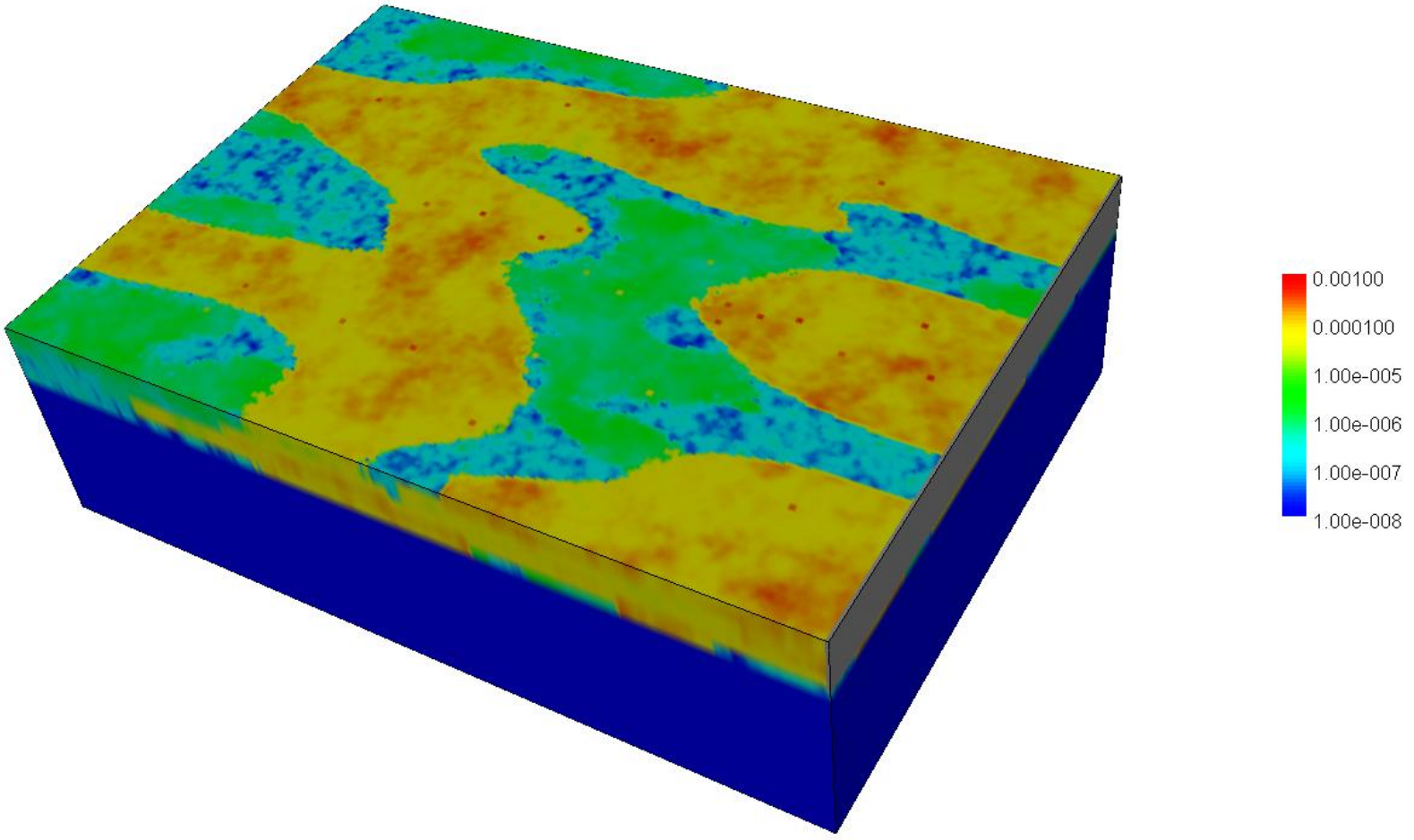
- Sequential
  - Geophysics -> Groundwater modeling
- Coupled
  - Directly
  - Regularization
  - ….
- Stochastic

Forward / inversion software

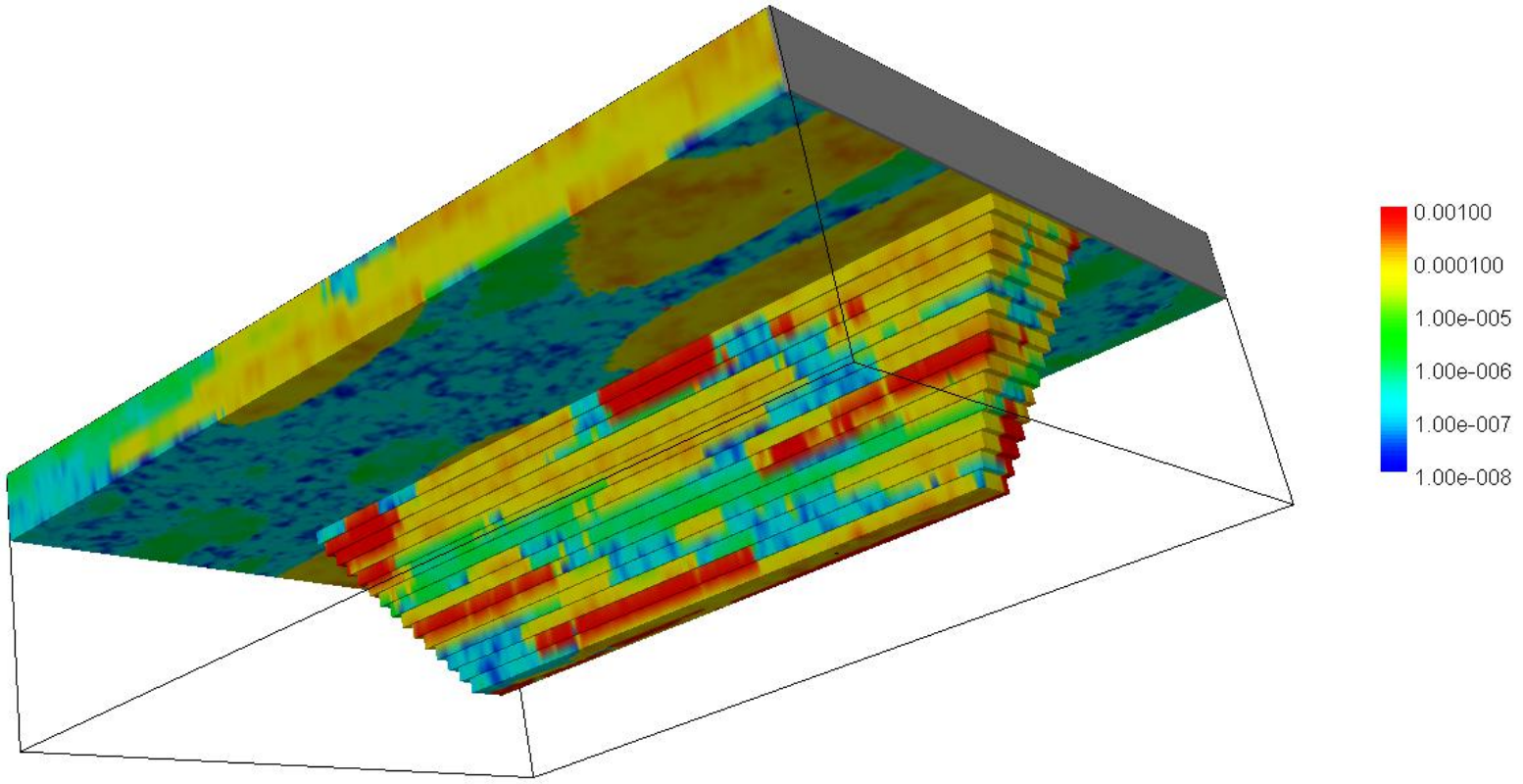
- EM1DINV
- TEMDDD
- ….
- MODFLOW
- ….
- PEST
  - Any number and types of models
  - Regularization (SVD, Tikhonov, self-defined)
  - Parallelized
  - Close cooperation with John Doherty (developer)

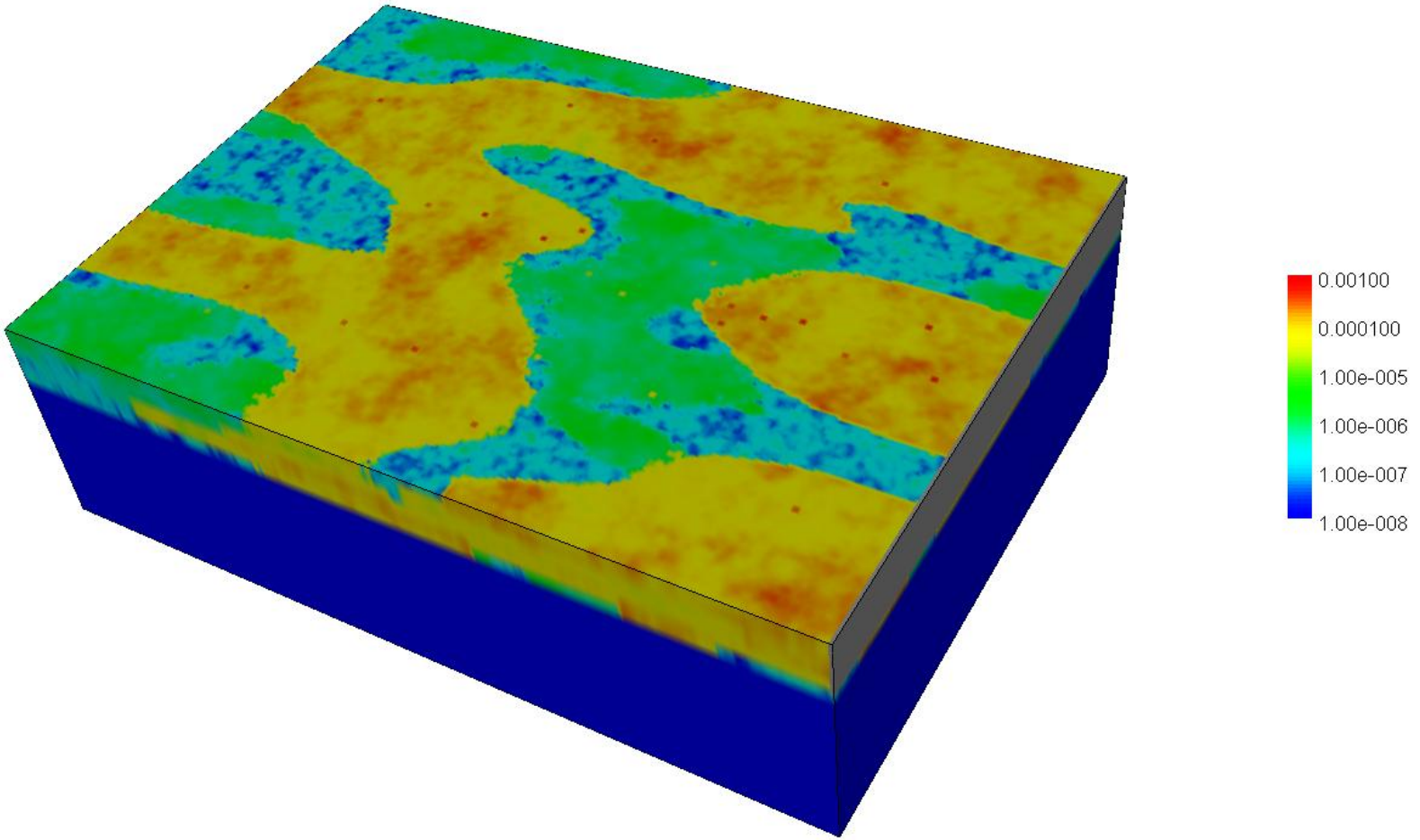
An example

Studied volume: 5 km × 7 km × 200 m Grid: 25 m × 25 m × 10 m



Studied volume: 5 km × 7 km × 200 m Grid: 25 m × 25 m × 10 m

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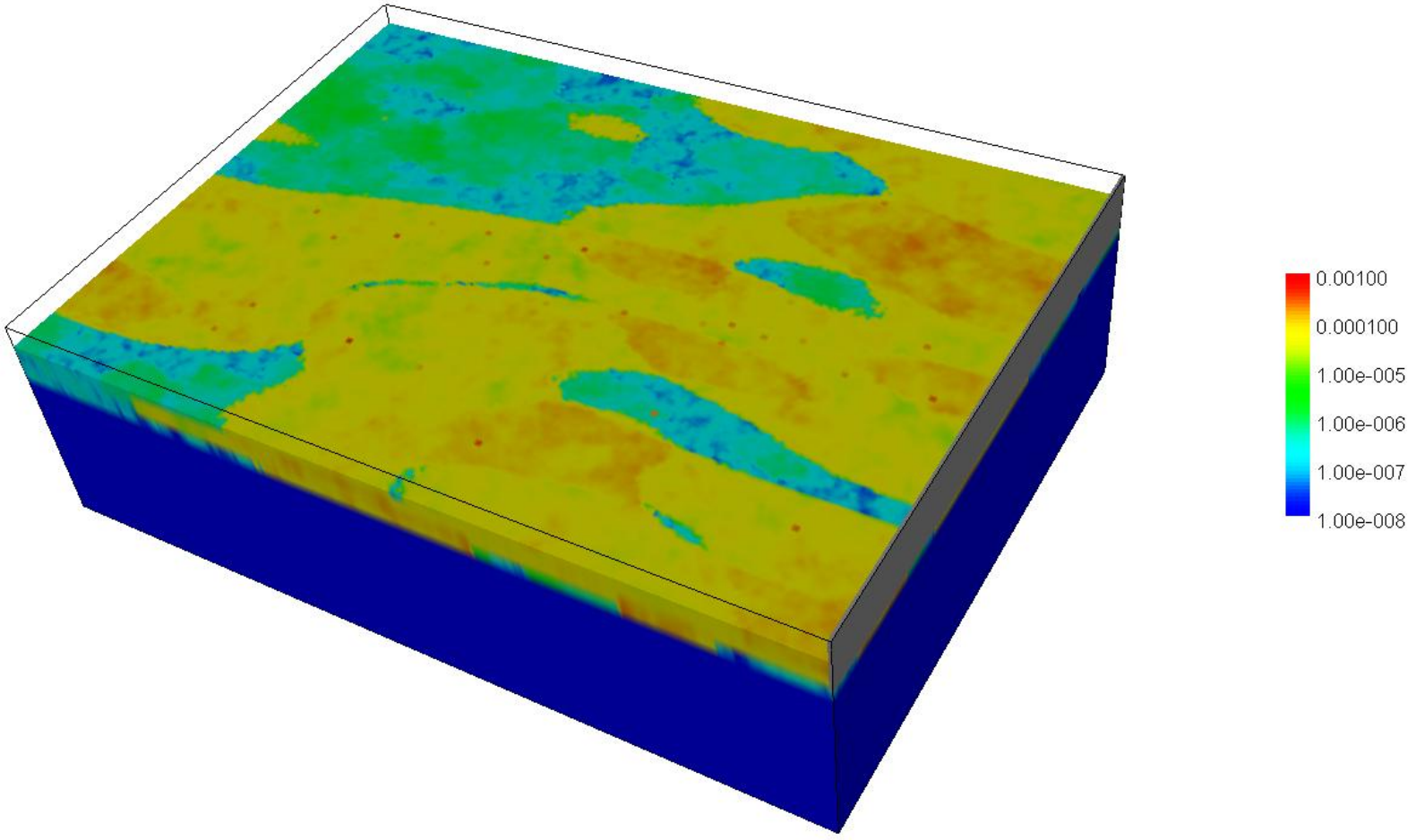
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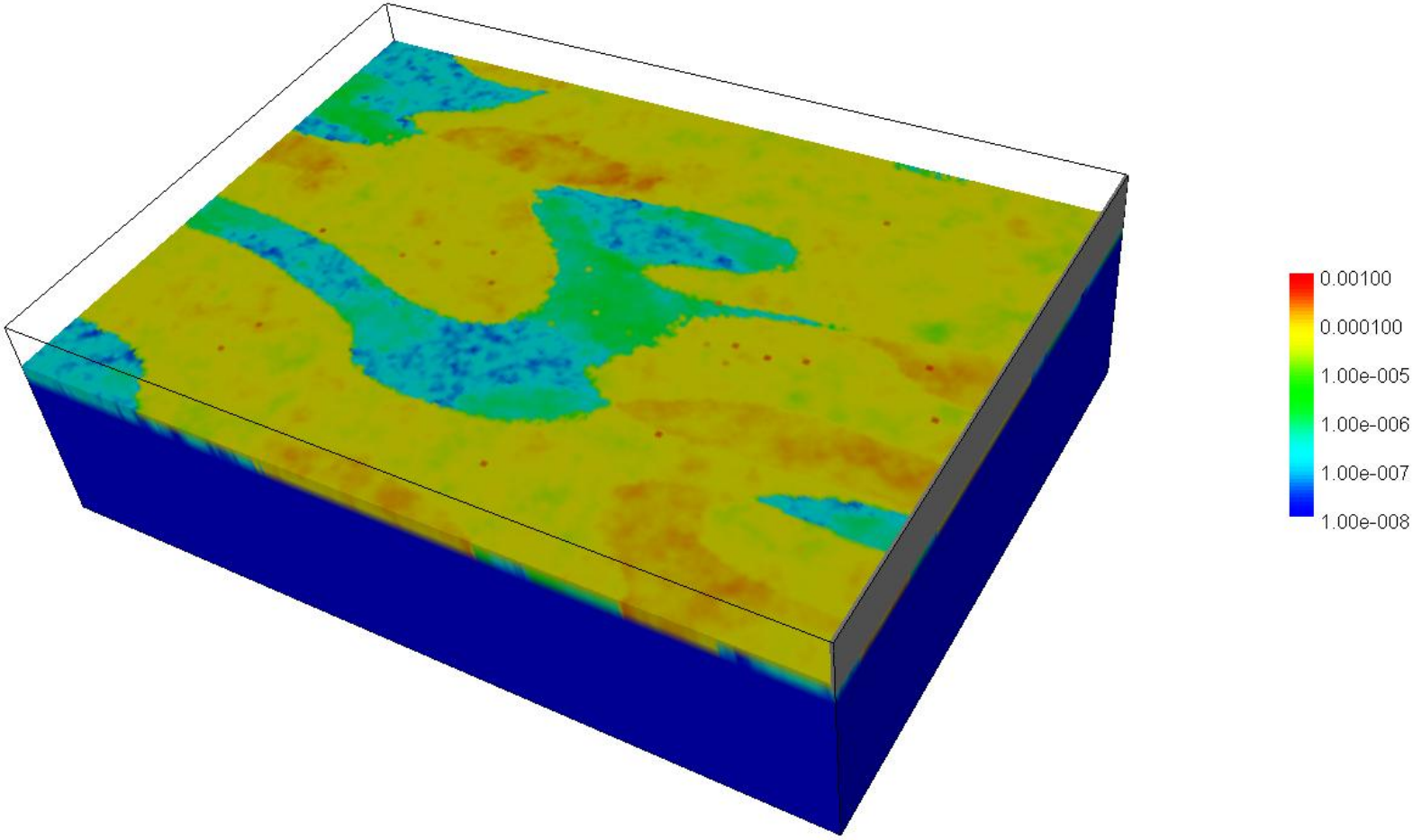
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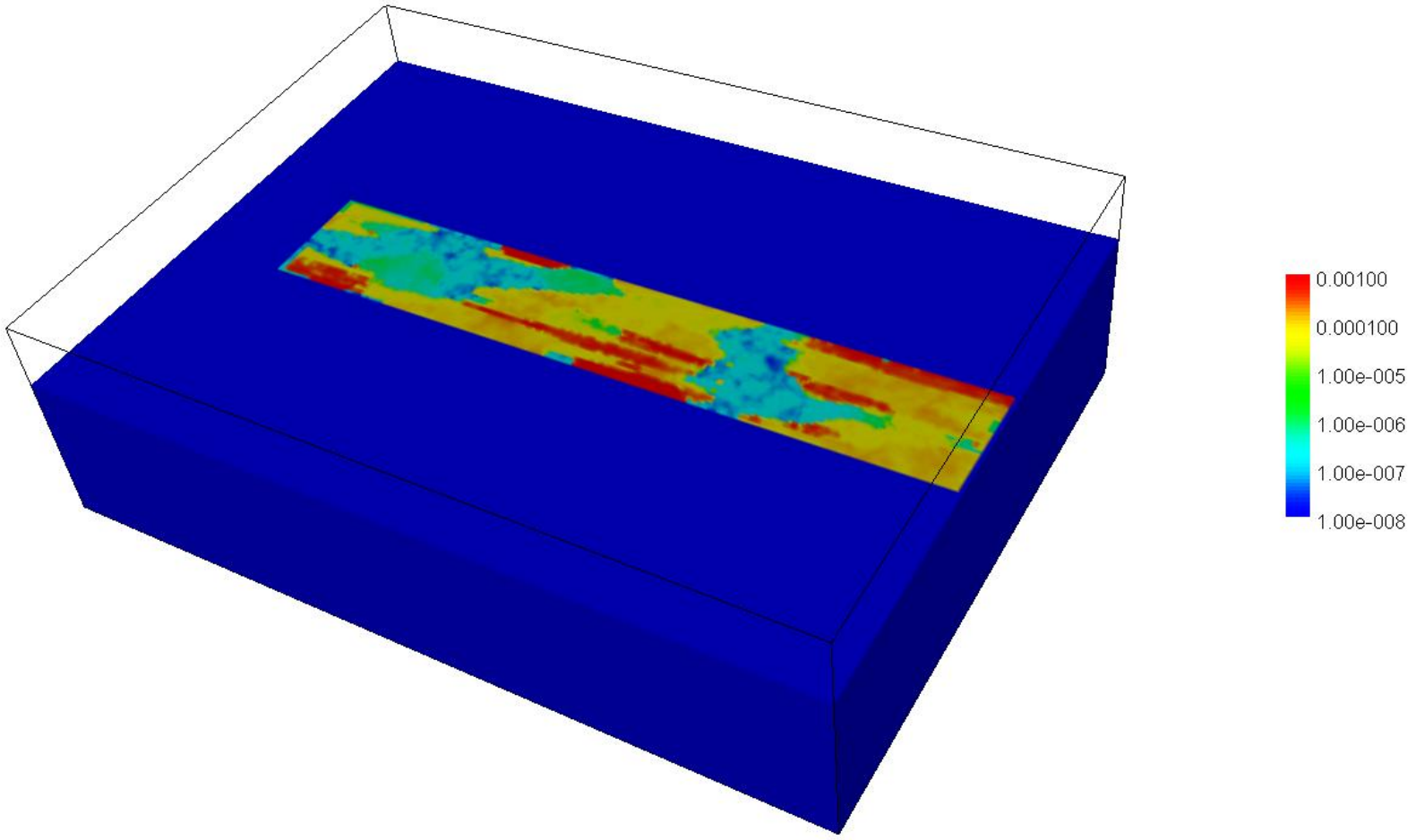
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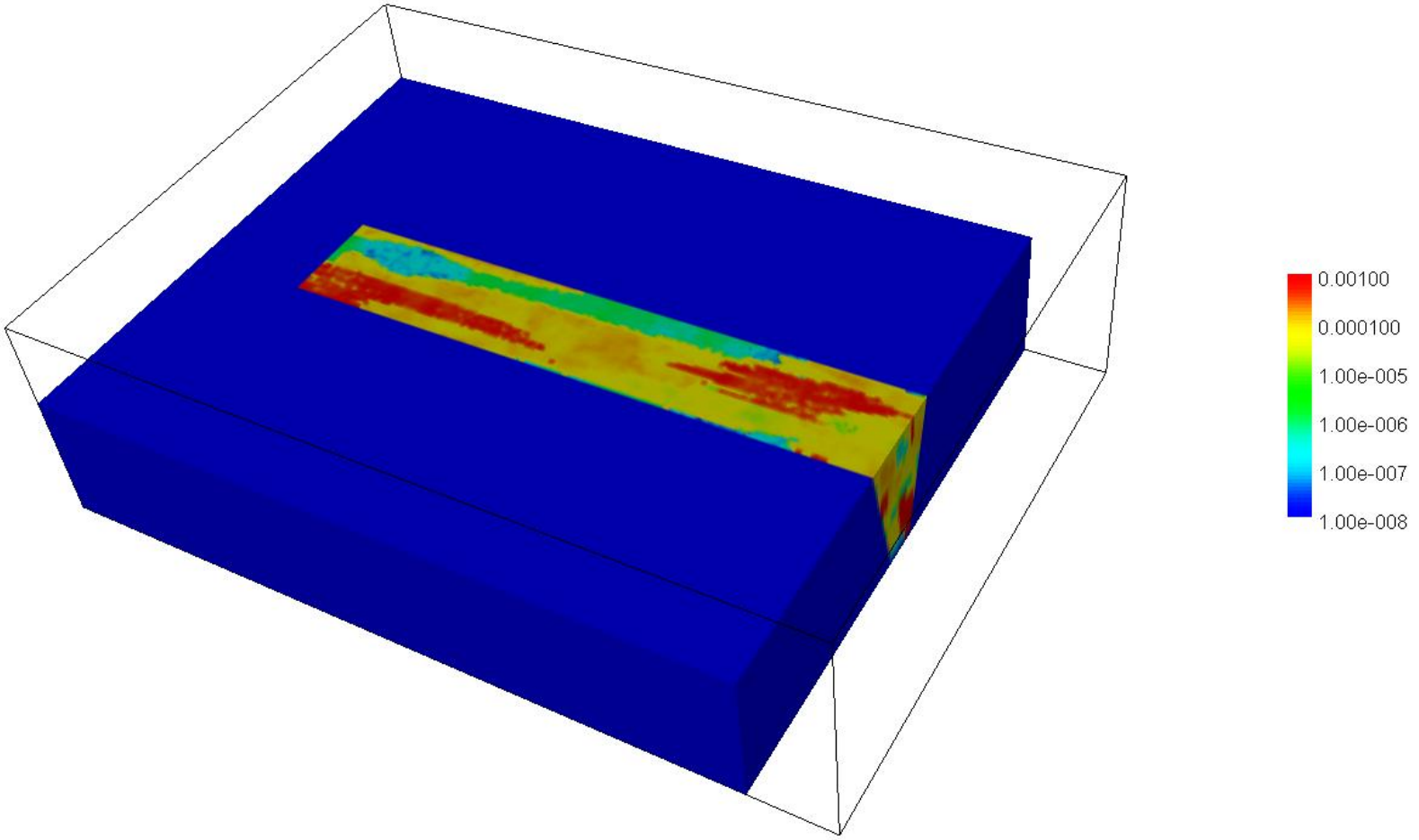
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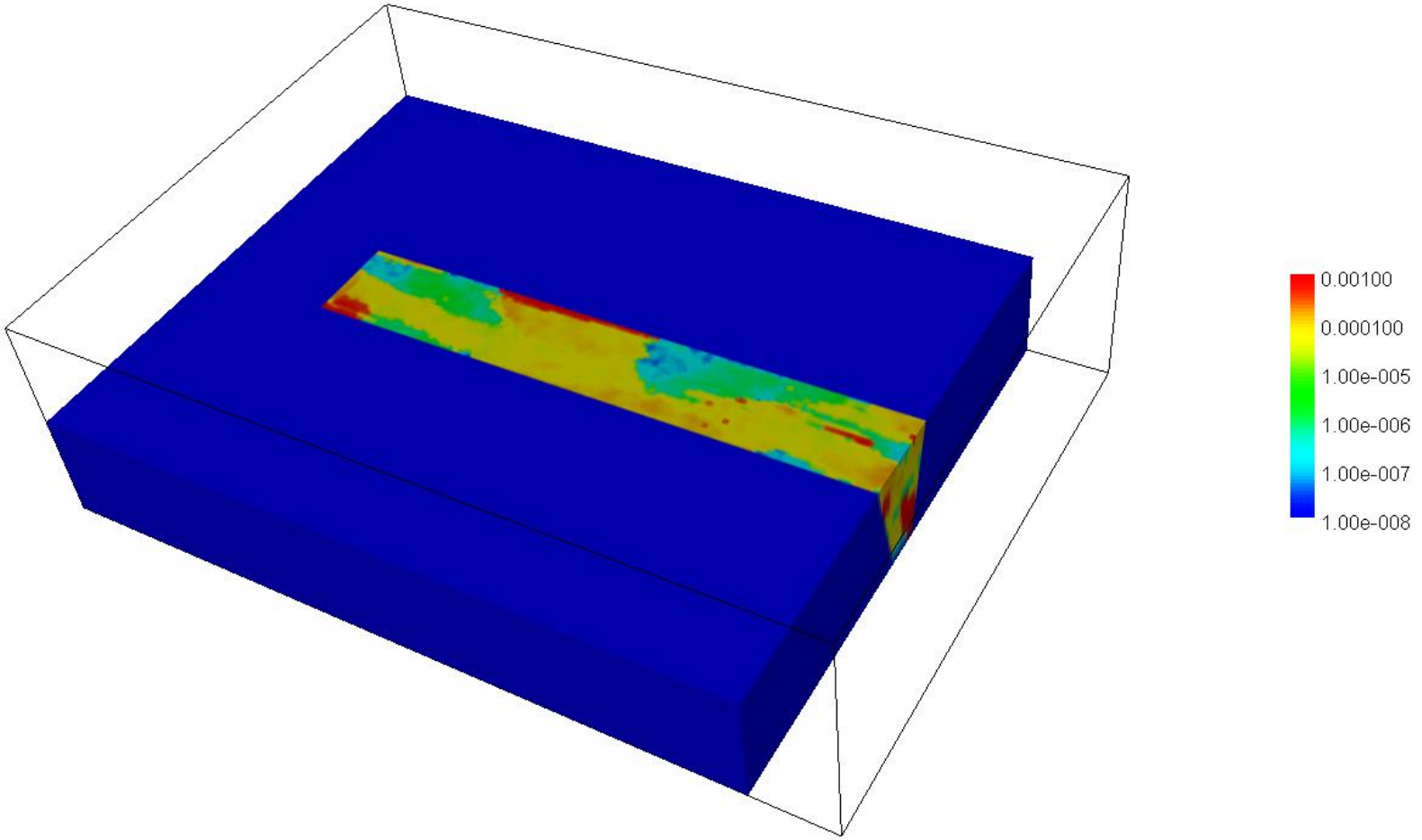
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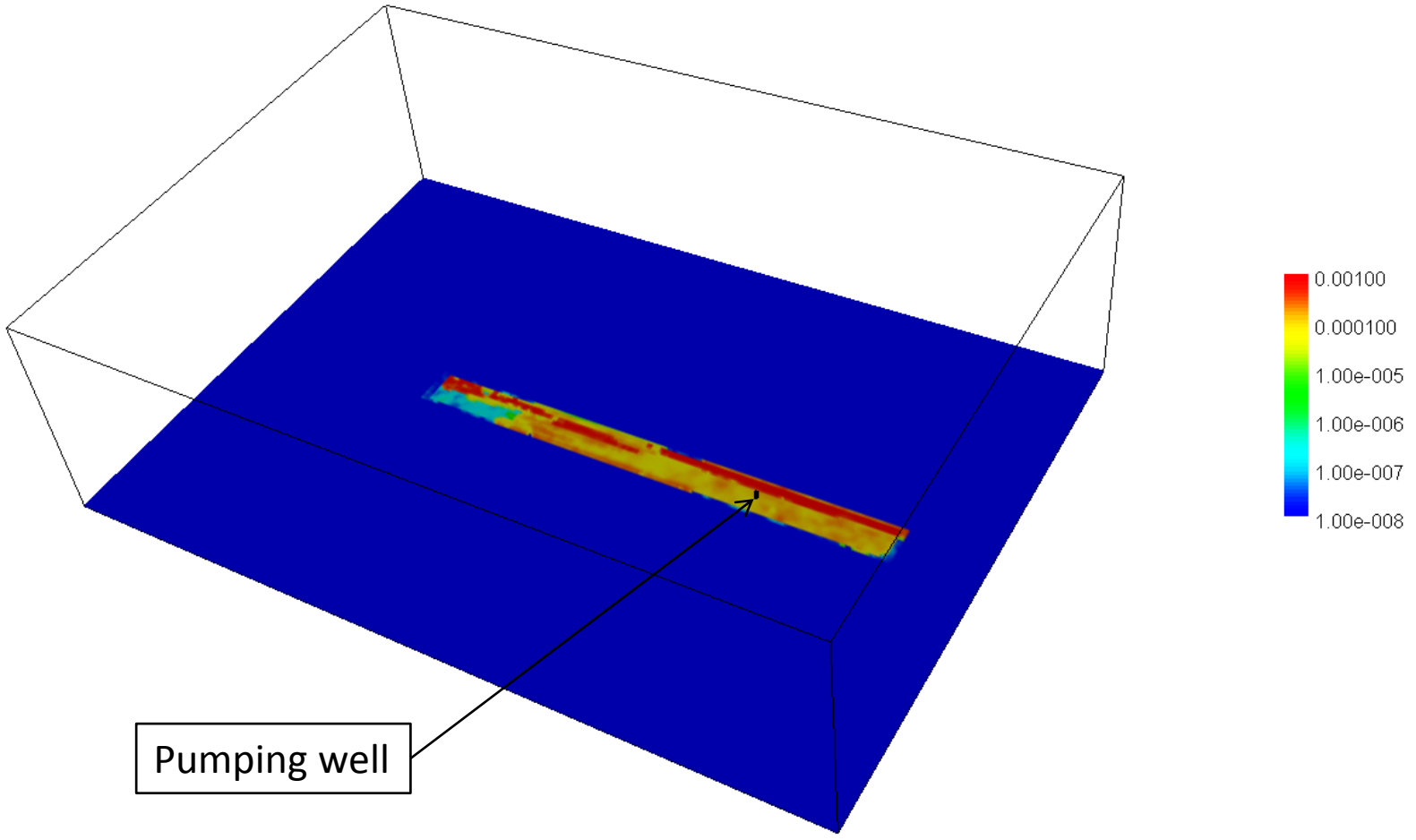
0.00100
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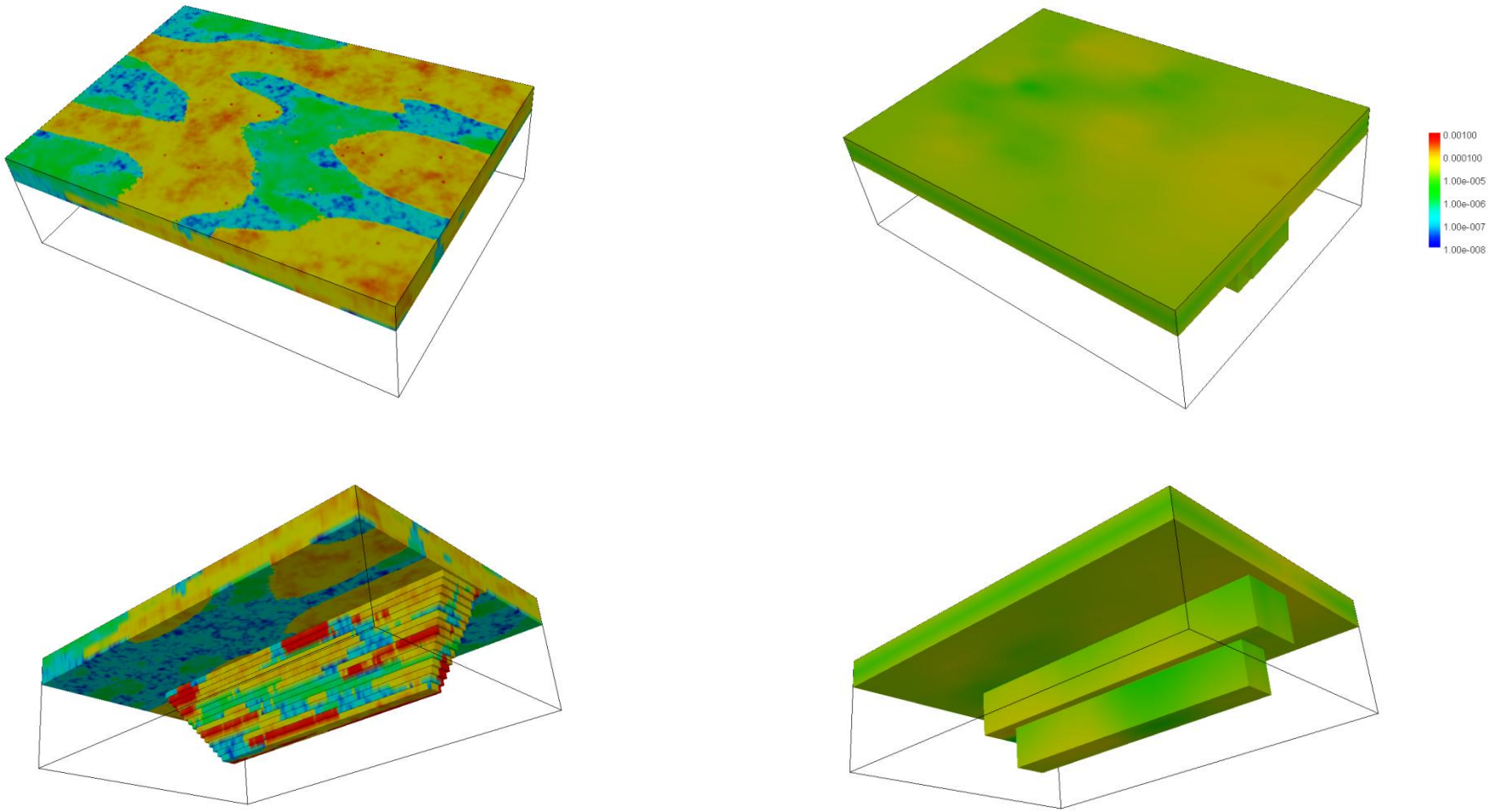
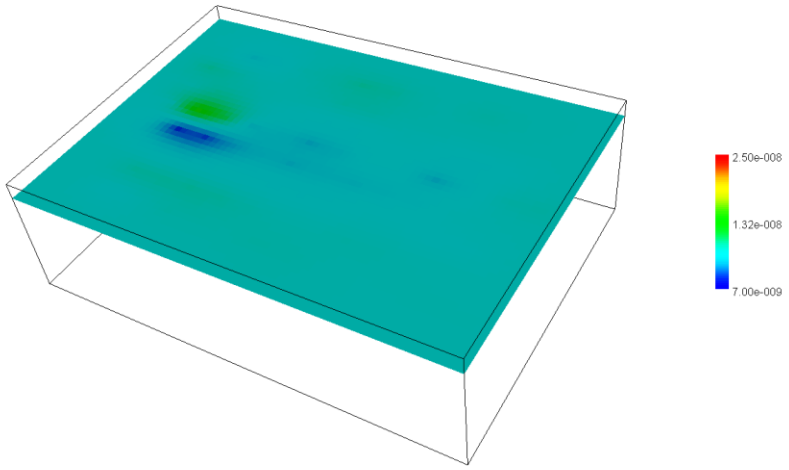
Pumping well

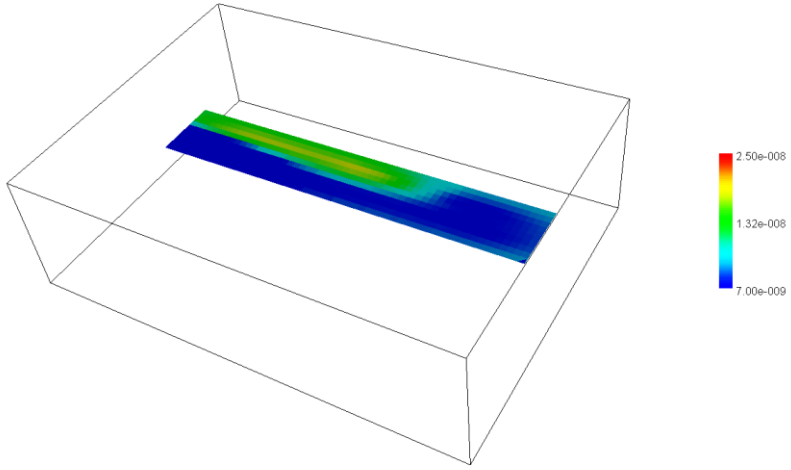
”Real K field” versus simple model ”perfectly calibrated K field” (realisation 1)

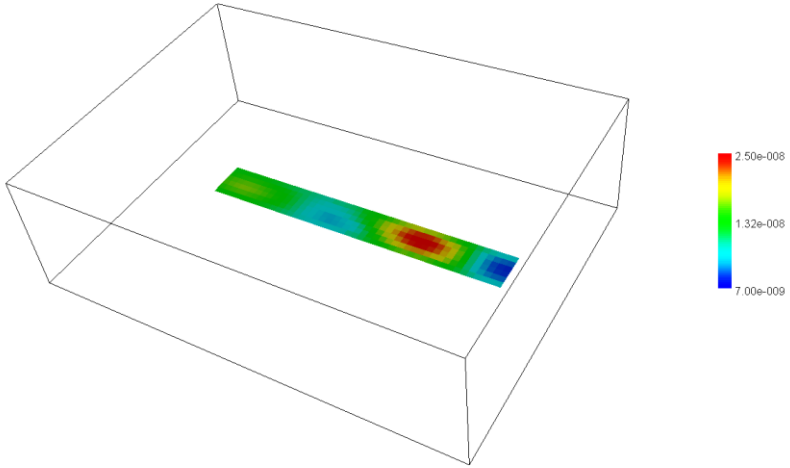


(Confining bed leakances not visualised)

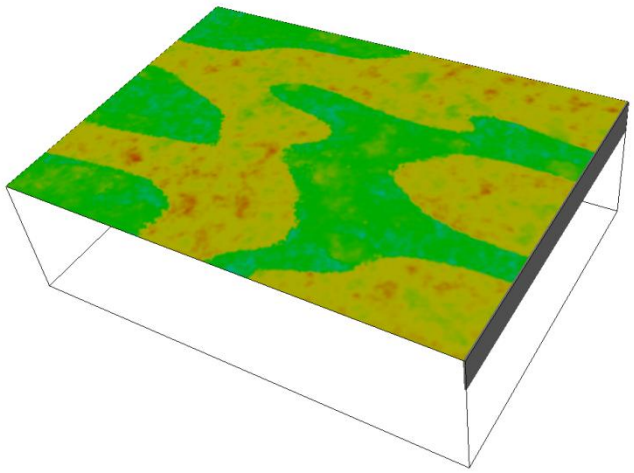
Simple model ”calibrated leakance fields” (realisation 1)

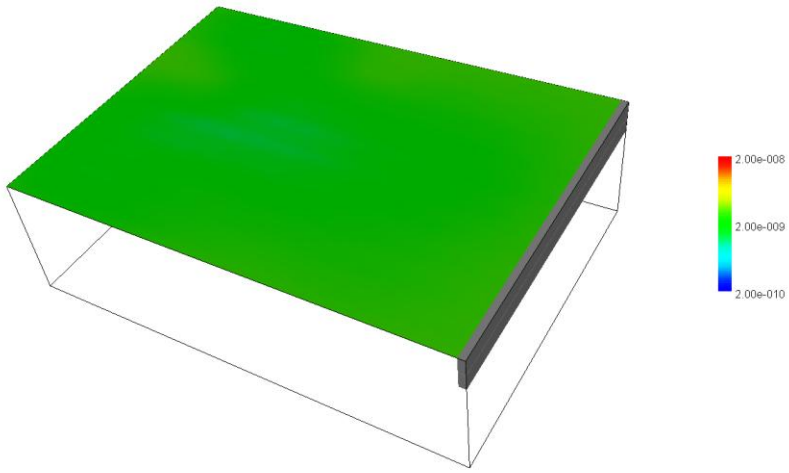






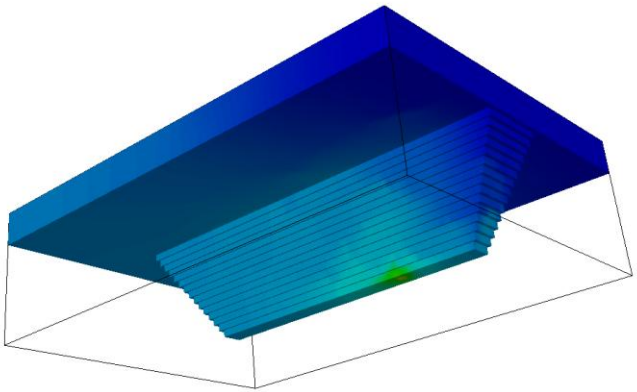
”Real recharge field” versus simple model ”calibrated recharge field” (realisation 1)

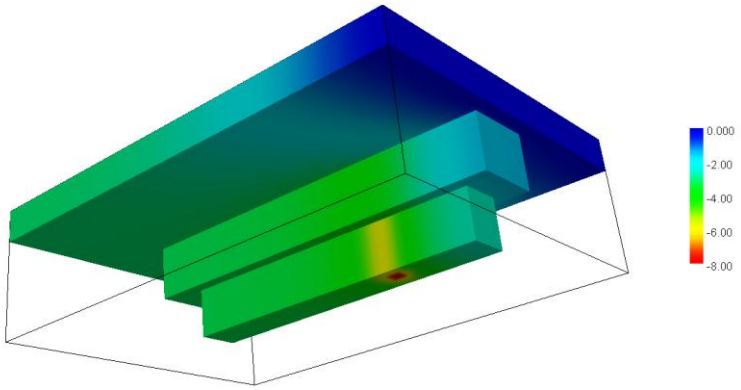




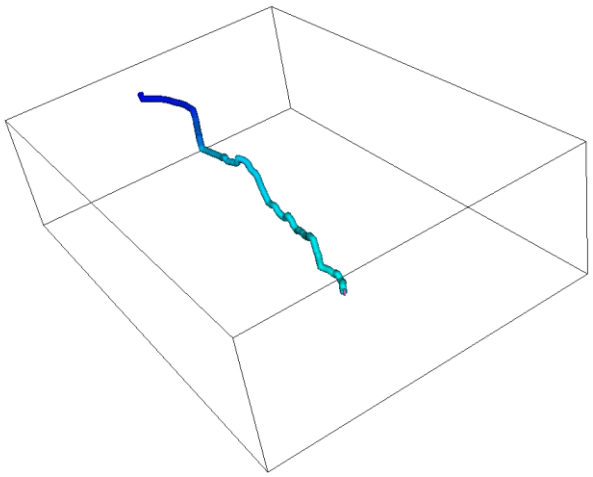
- **A ”simple” coarse-grid groundwater model can fit hydraulic head observations made in a complicated system!**

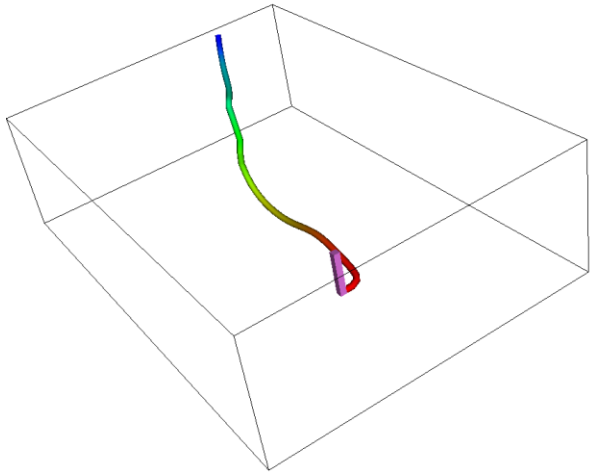
”Real drawdown” versus simple model ”predicted drawdown” (realisation 1)



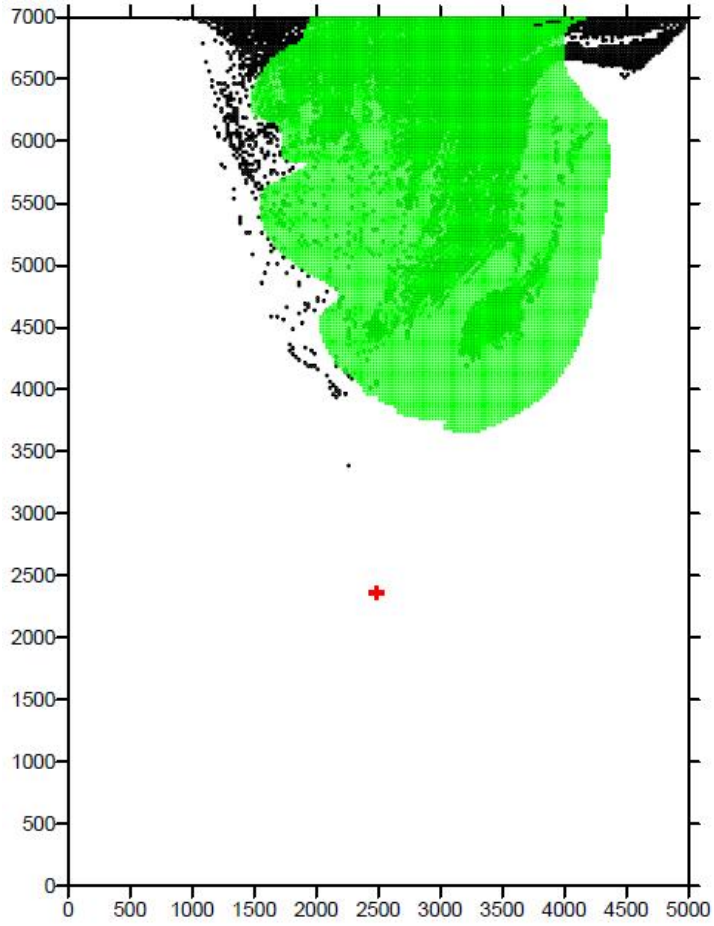


”Real pathline” versus simple model ”predicted pathline” (realisation 1)





Recharge area predictions (forward-tracking particles that end in the well)



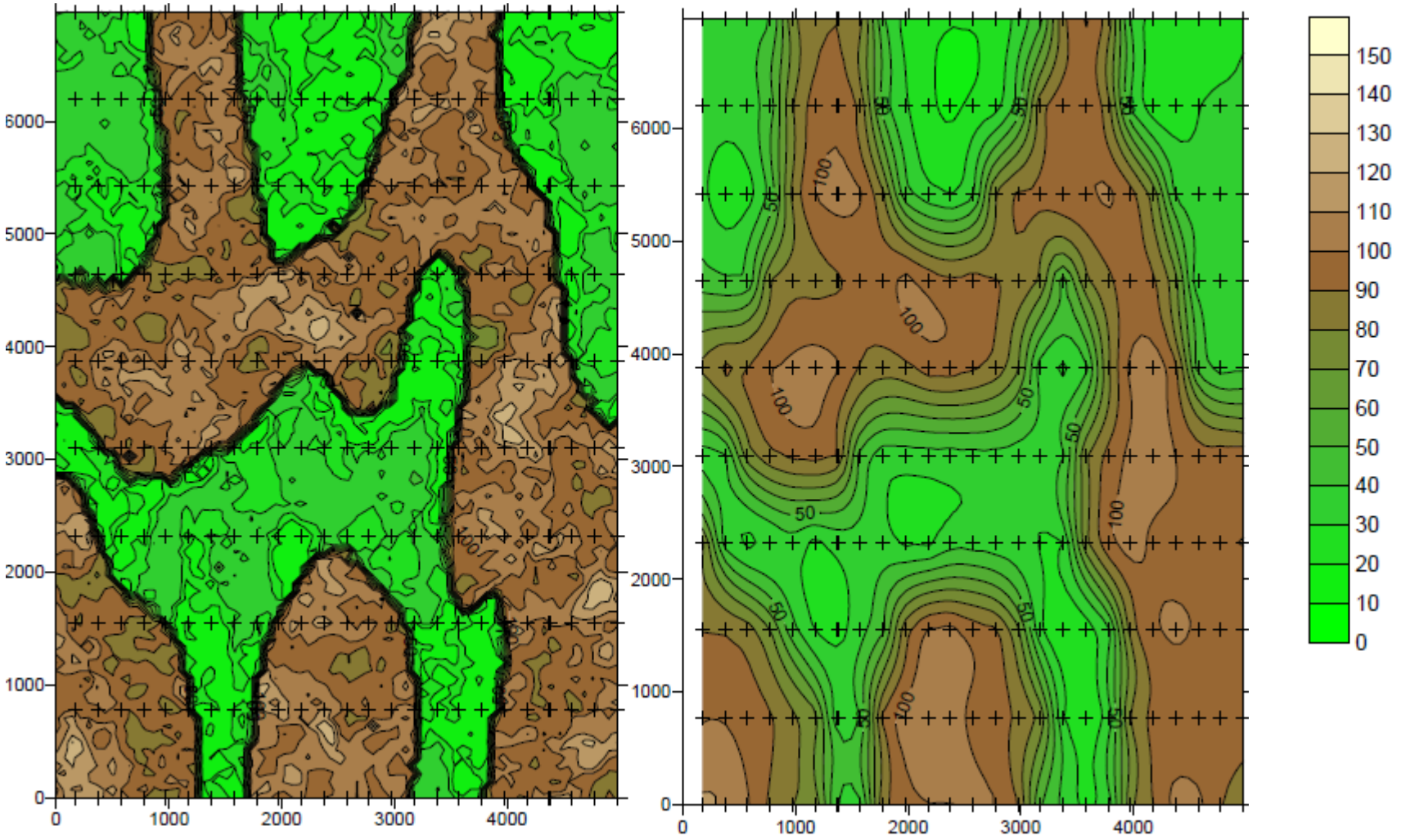
Realisation 1

- **The ”simple” model predictions may be poor!**
- **Simplification is inevitable, but less when using extensive geophysics (?)**
- **HyGEM test bench: Test the latter hypothesis**

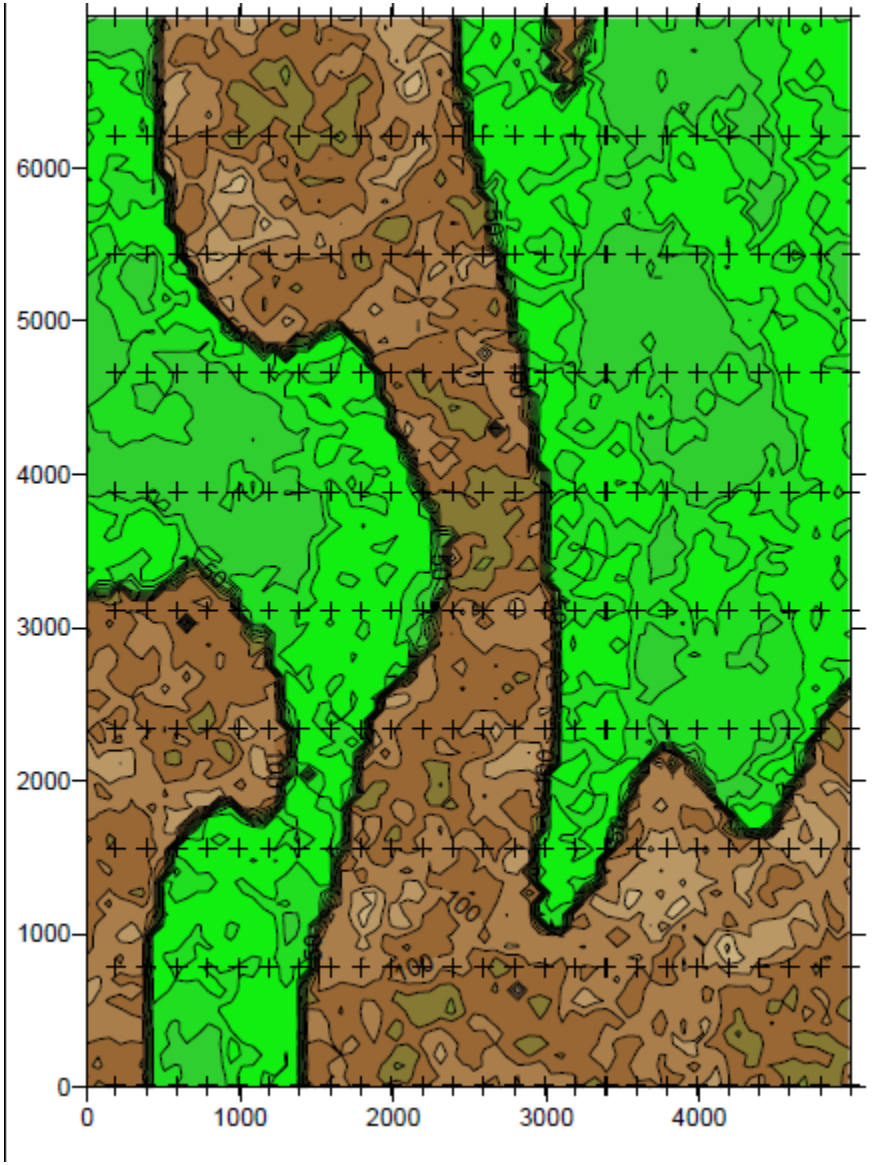
Doherty, J., and Christensen, S., 2011: Use of paired simple and complex models to reduce predictive bias and quantify uncertainty. *Water Resources Research* , Vol. 47, DOI: 10.1029/2011WR010763.

Lines of geoelectric soundings. Actual resistivity in 0-10 m depth.

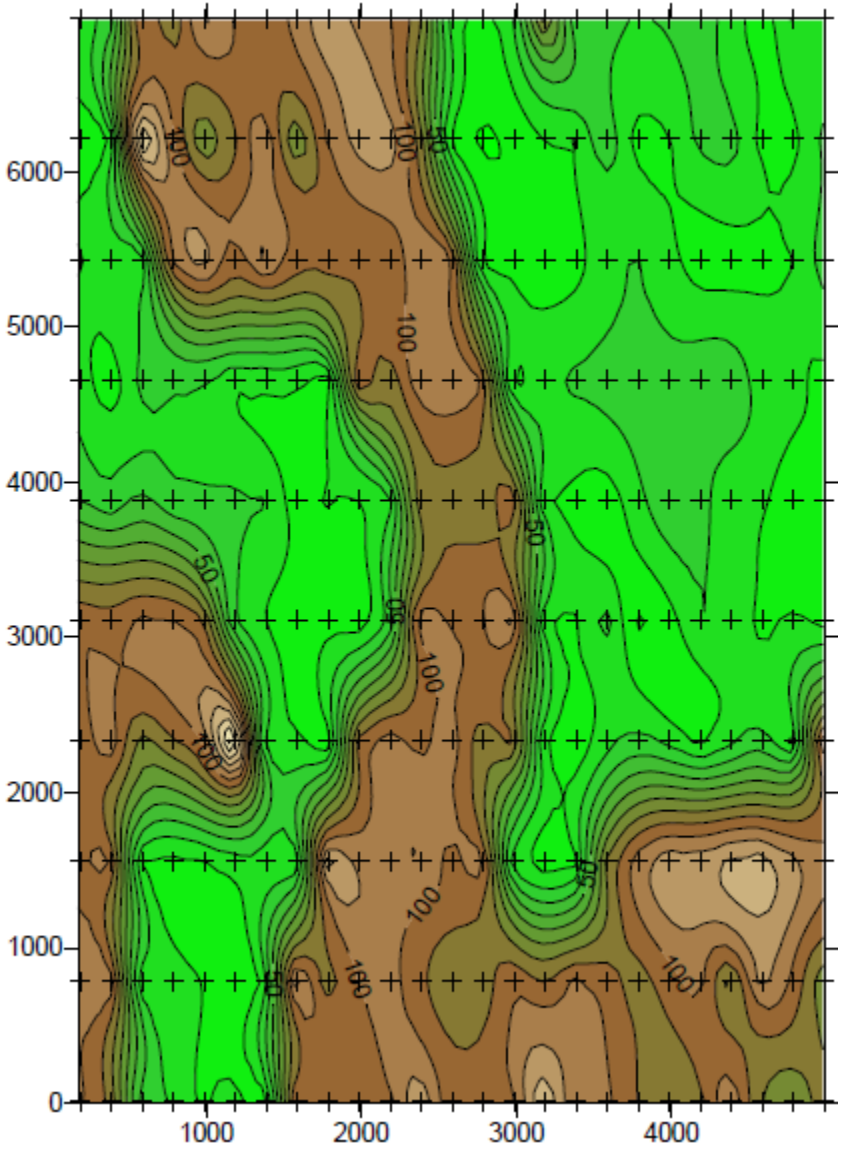
Contoured resistivities based on individual sounding inversions.



Actual resistivity in 10-20 m depth.

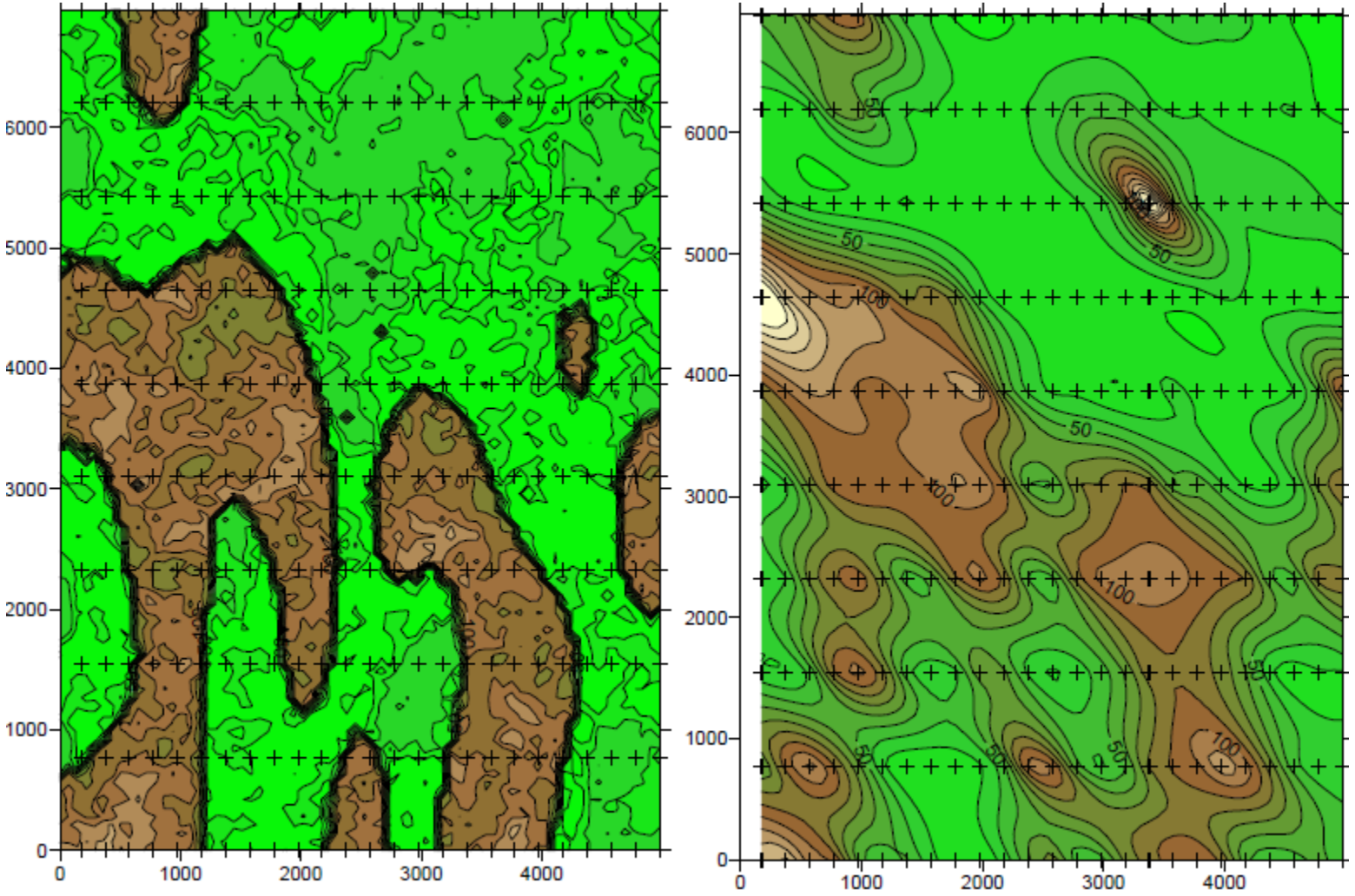


Contoured resistivities based on individual sounding inversions.



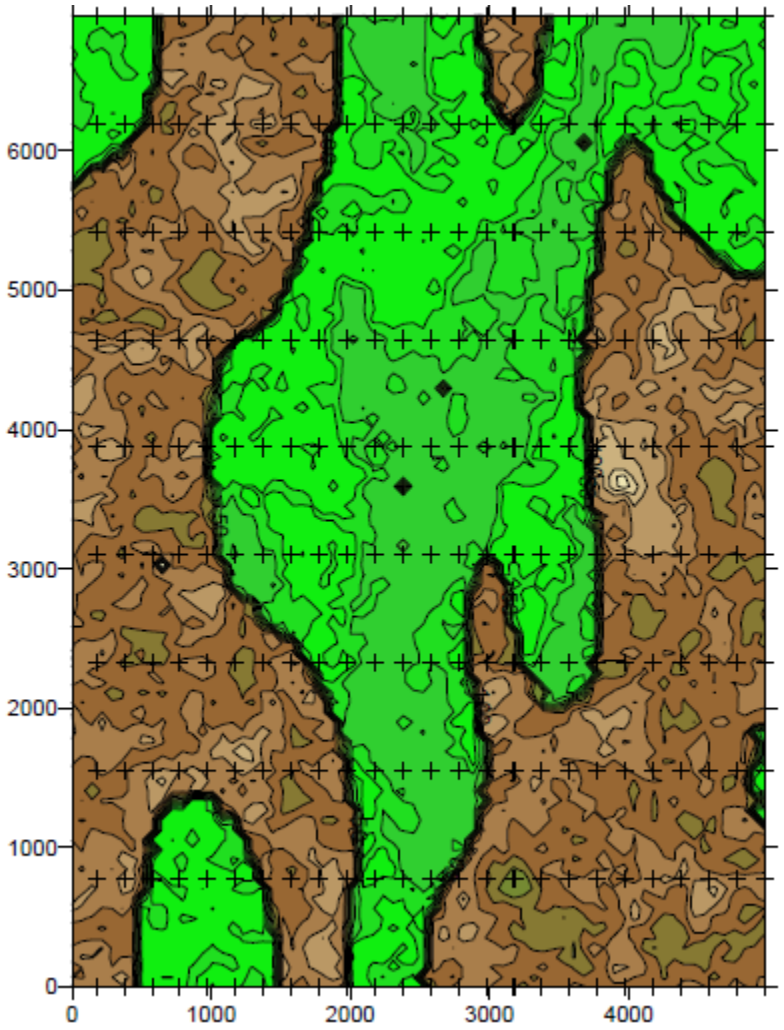
Actual resistivity in 20-30 m depth.

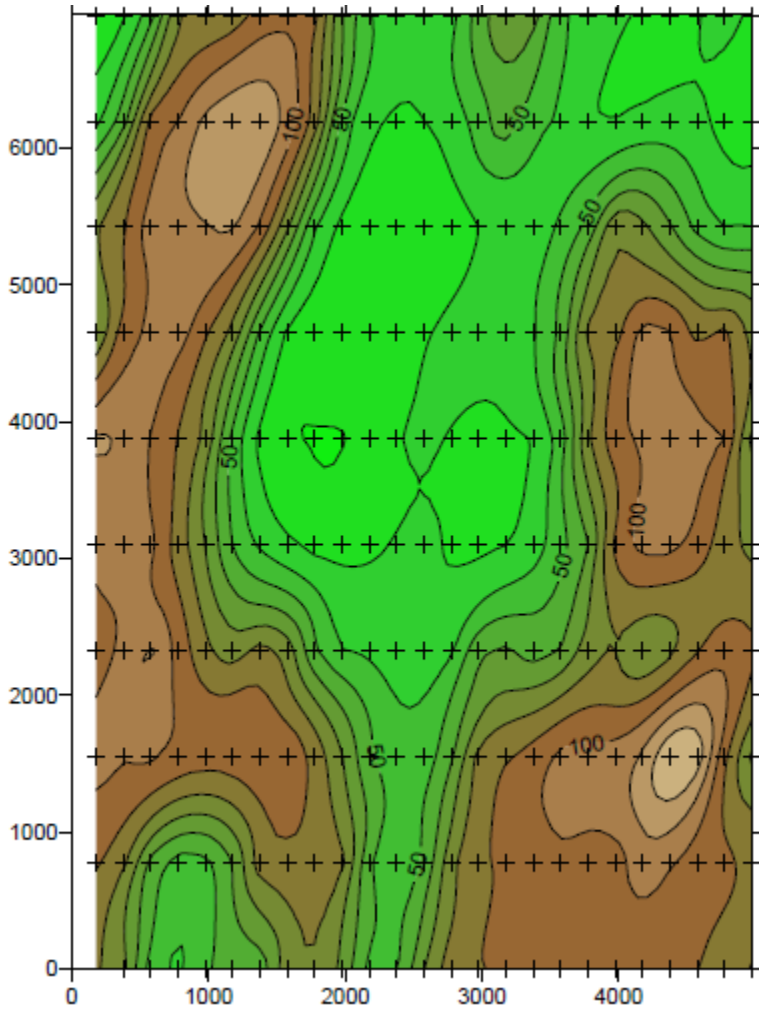
Contoured resistivities based on individual sounding inversions.



Actual resistivity in 30-40 m depth.

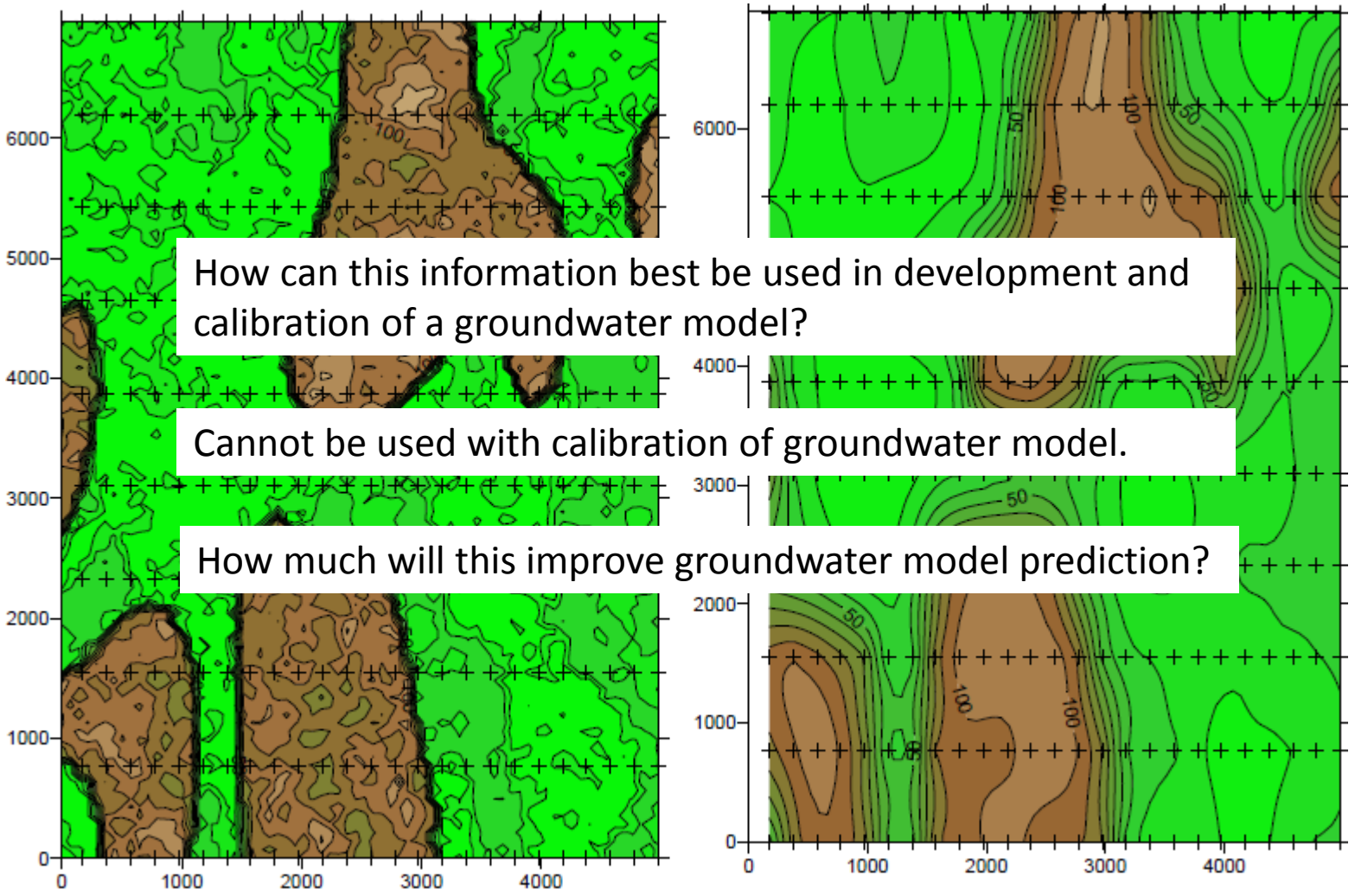
Contoured resistivities based on individual sounding inversions.





Actual resistivity in 40-50 m depth.

Contoured resistivities based on individual sounding inversions.



How can this information best be used in development and calibration of a groundwater model?

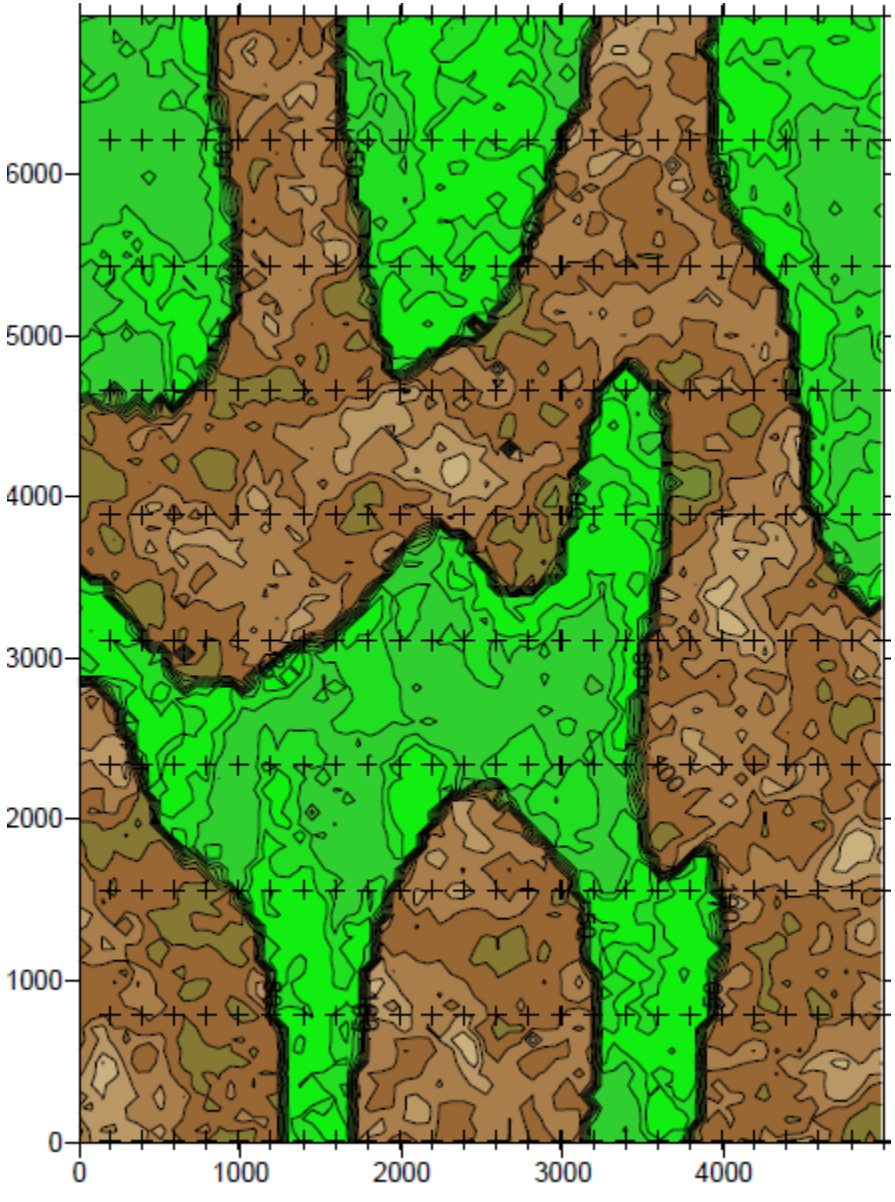
Cannot be used with calibration of groundwater model.

How much will this improve groundwater model prediction?

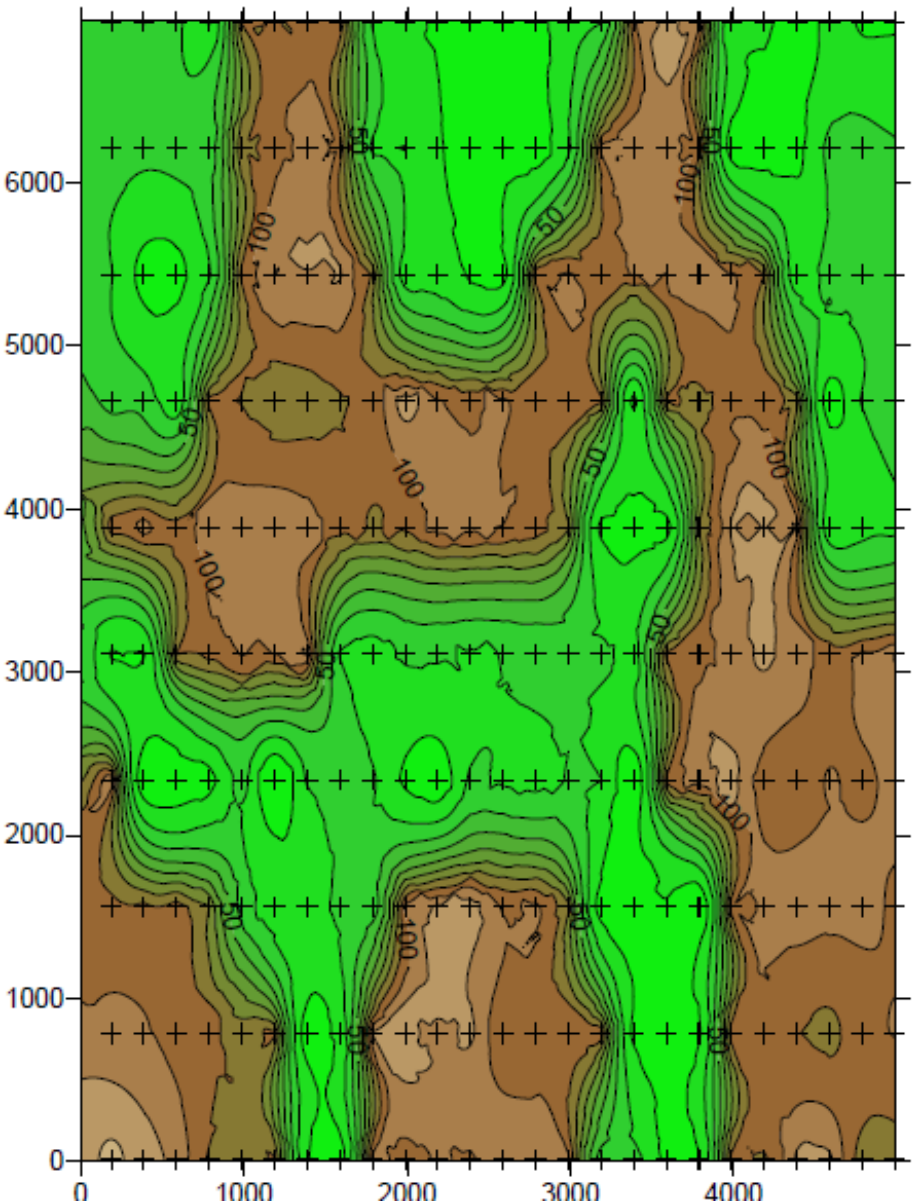
Dream world

- K/ρ relation exists, is known, and ”uncontaminated”
- 1D geoelectric data inverted by 1D model
- Groundwater and geophysical model resolutions matches actual geological resolution
- 30 head data and 250 soundings with little error
- Coupled inversion, 2500 parameters (K and ρ)

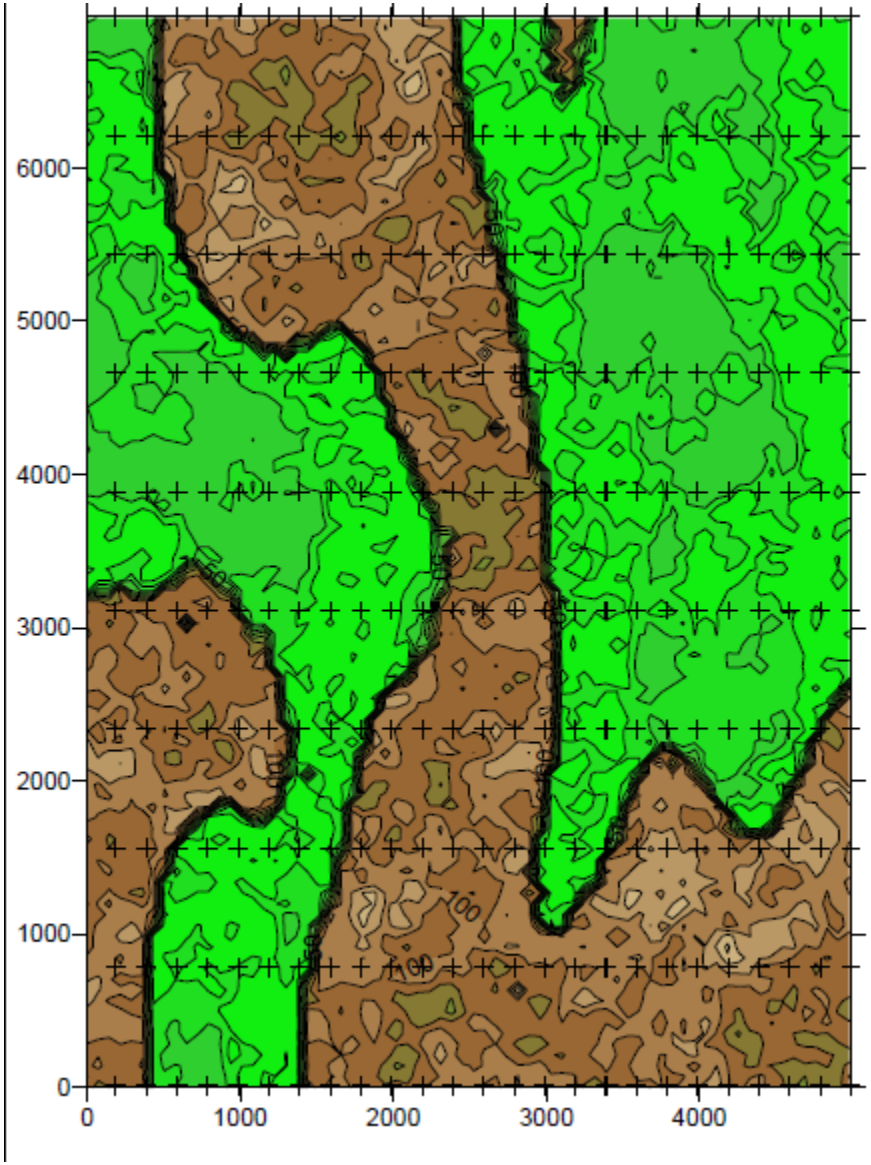
Actual resistivity in 0-10 m depth.



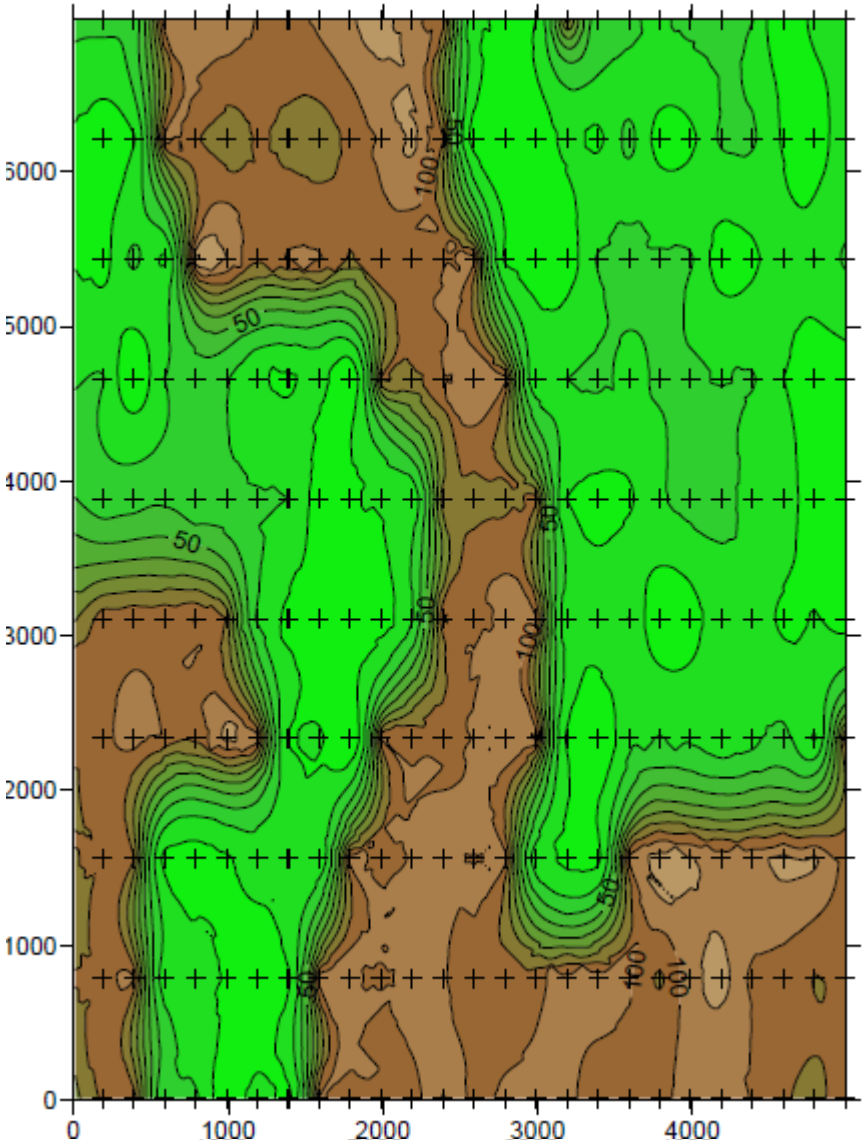
Resistivity map contoured from coupled inversion estimation



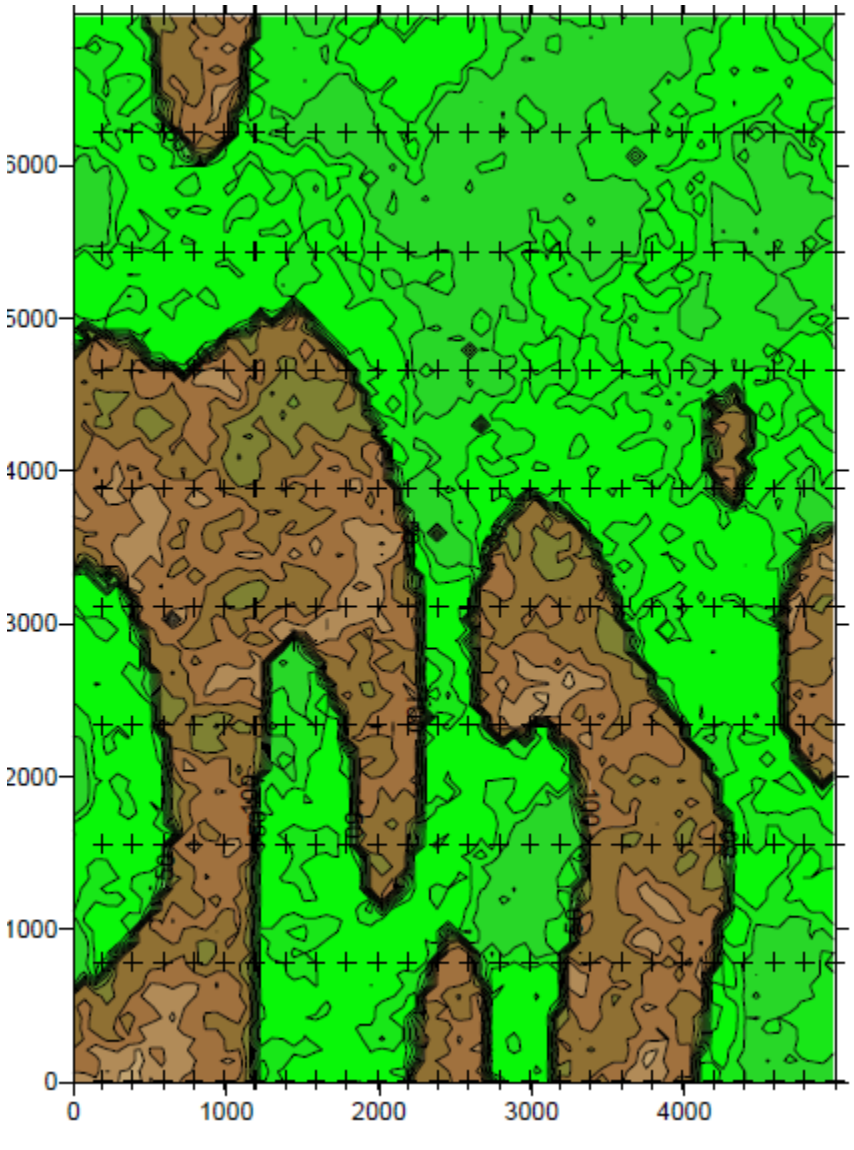
Actual resistivity in 10-20 m depth.



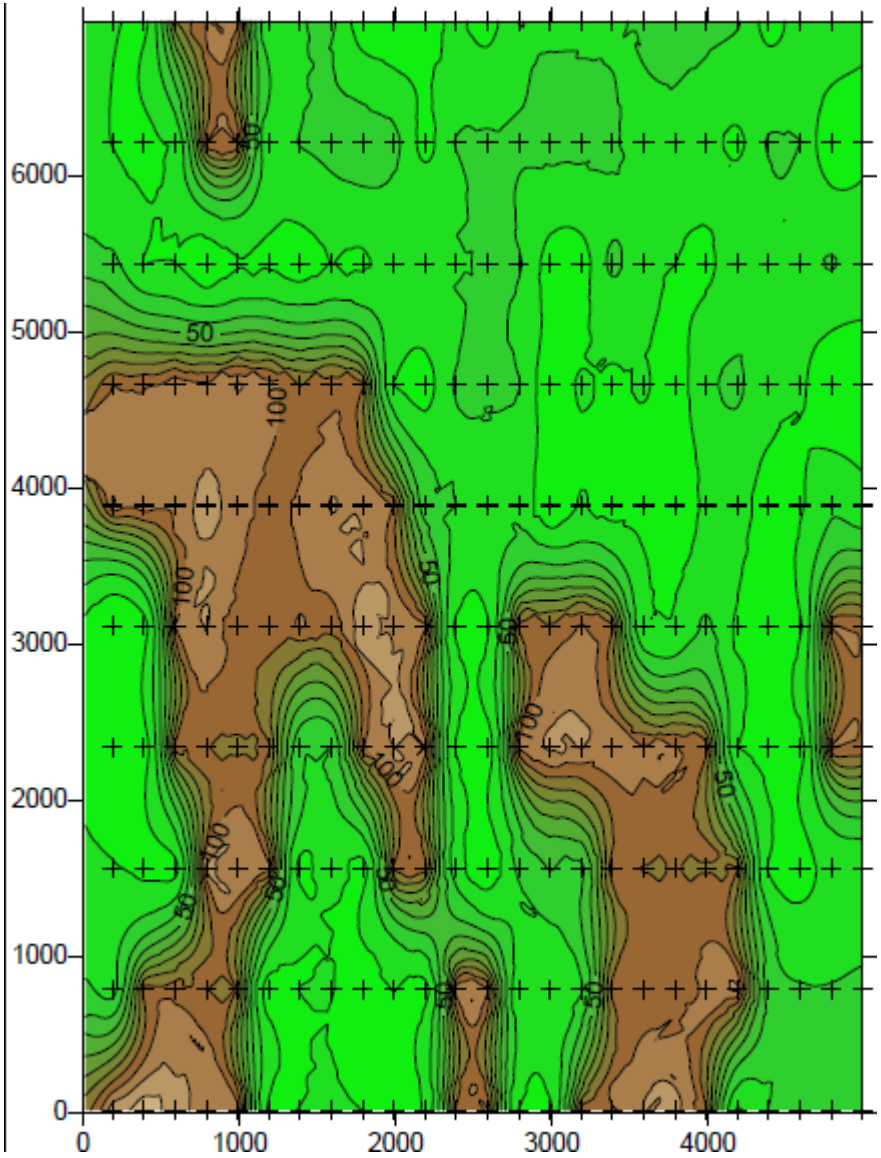
Resistivity map contoured from coupled inversion estimation



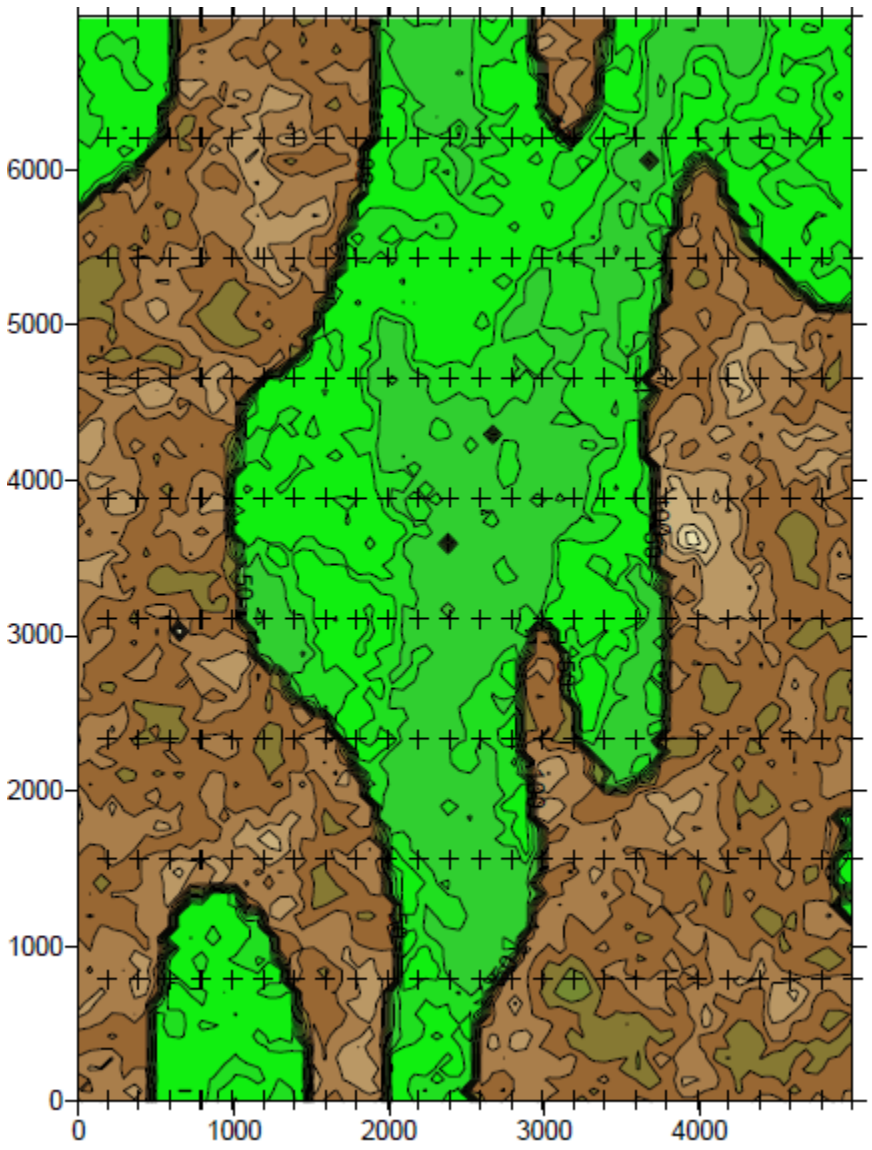
Actual resistivity in 20-30 m depth.



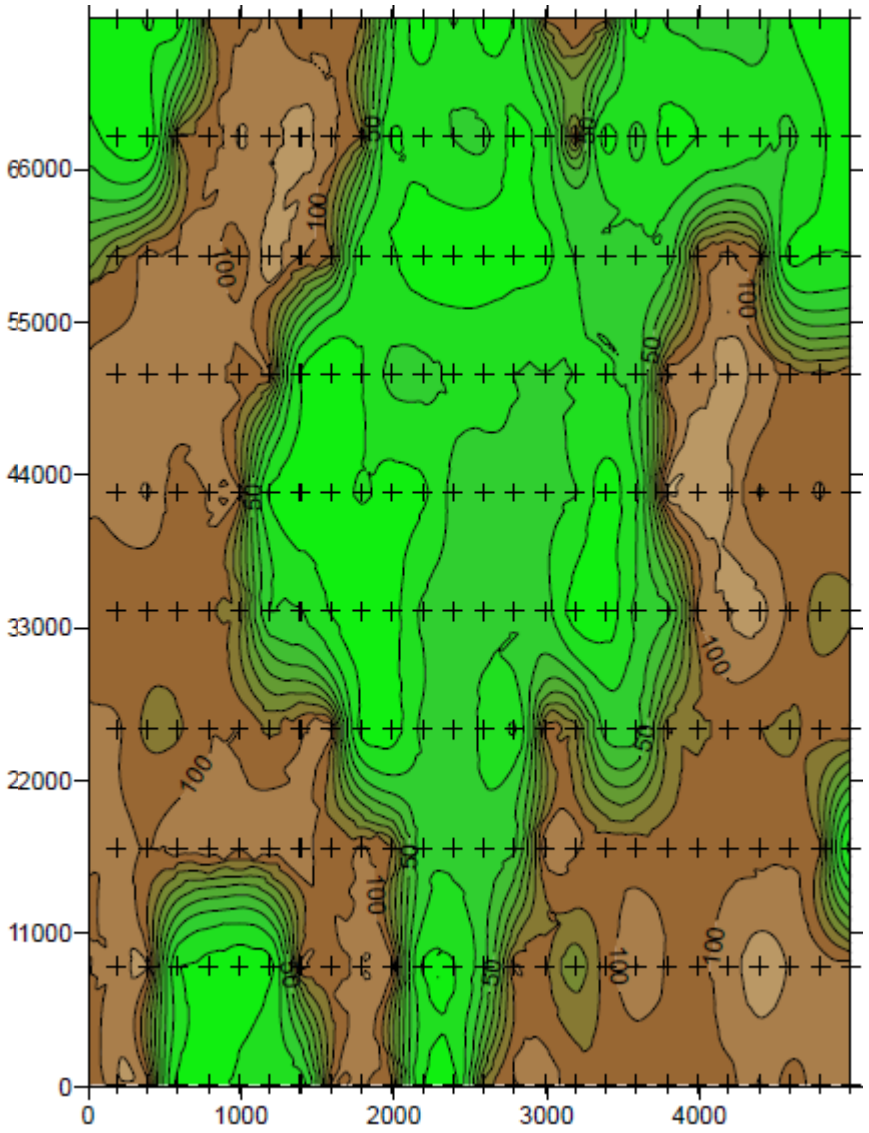
Resistivity map contoured from coupled inversion estimation



Actual resistivity in 30-40 m depth.

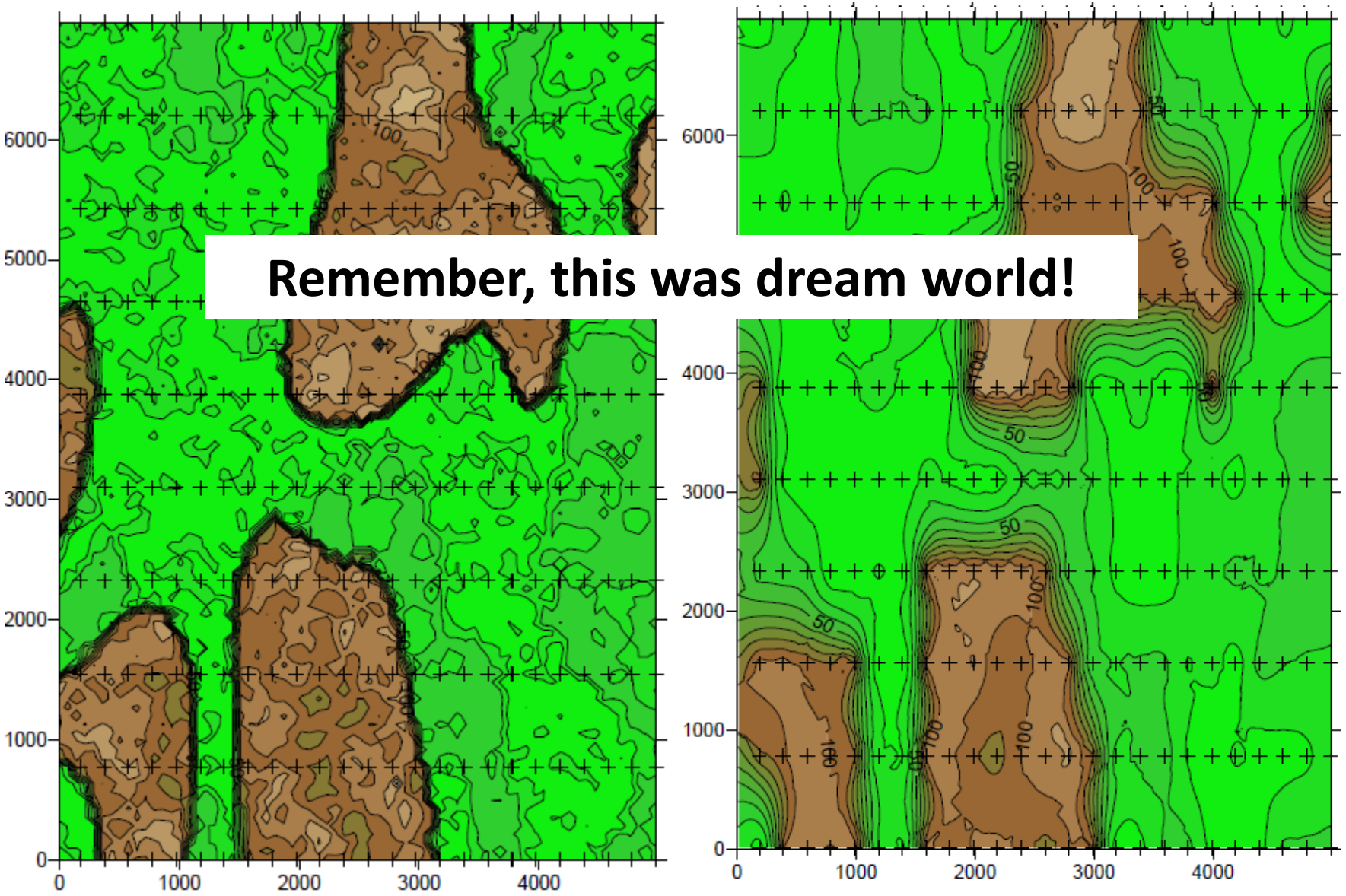


Resistivity map contoured from coupled inversion estimation



Actual resistivity in 40-50 m depth.

Resistivity map contoured from coupled inversion estimation



Remember, this was dream world!