TECHNISCHE UNIVERSITÄT DRESDEN

IWAS

Faculty of Forestry, Geosciences and Hydrosciences, Department of Hydrosciences, Institute for Groundwater Management

CASE STUDY OF THE GROUNDWATER RESOURCES USAGE FOR A COASTAL ARID REGION IN THE AL BATINAH, OMAN

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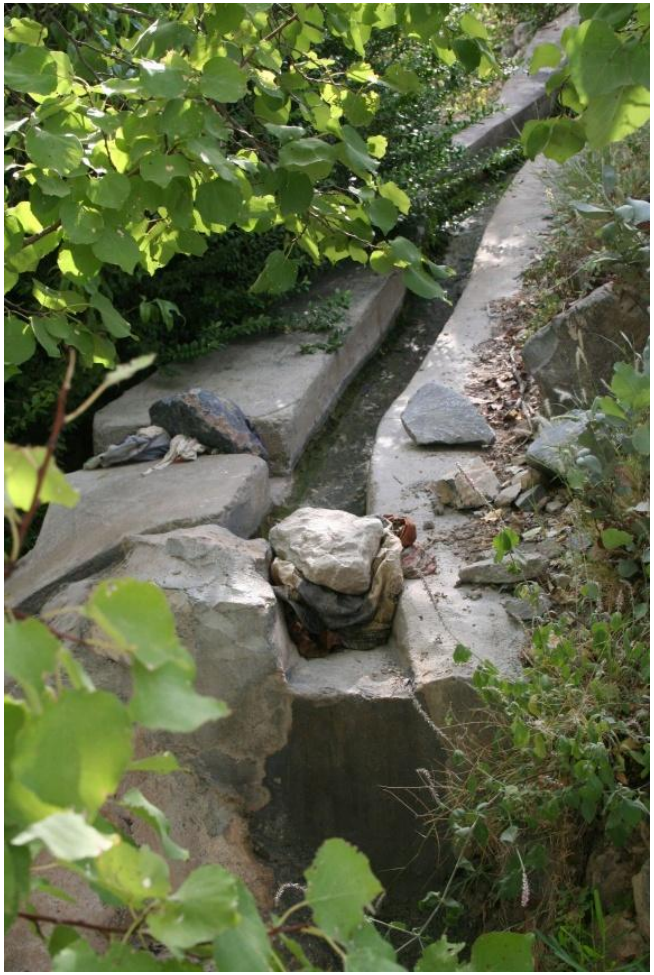
THE IWAS INITIATIVE
PROJECT REGIONS

STUDY REGION
AL BATINAH COAST

STUDY REGION
AL BATINAH COAST

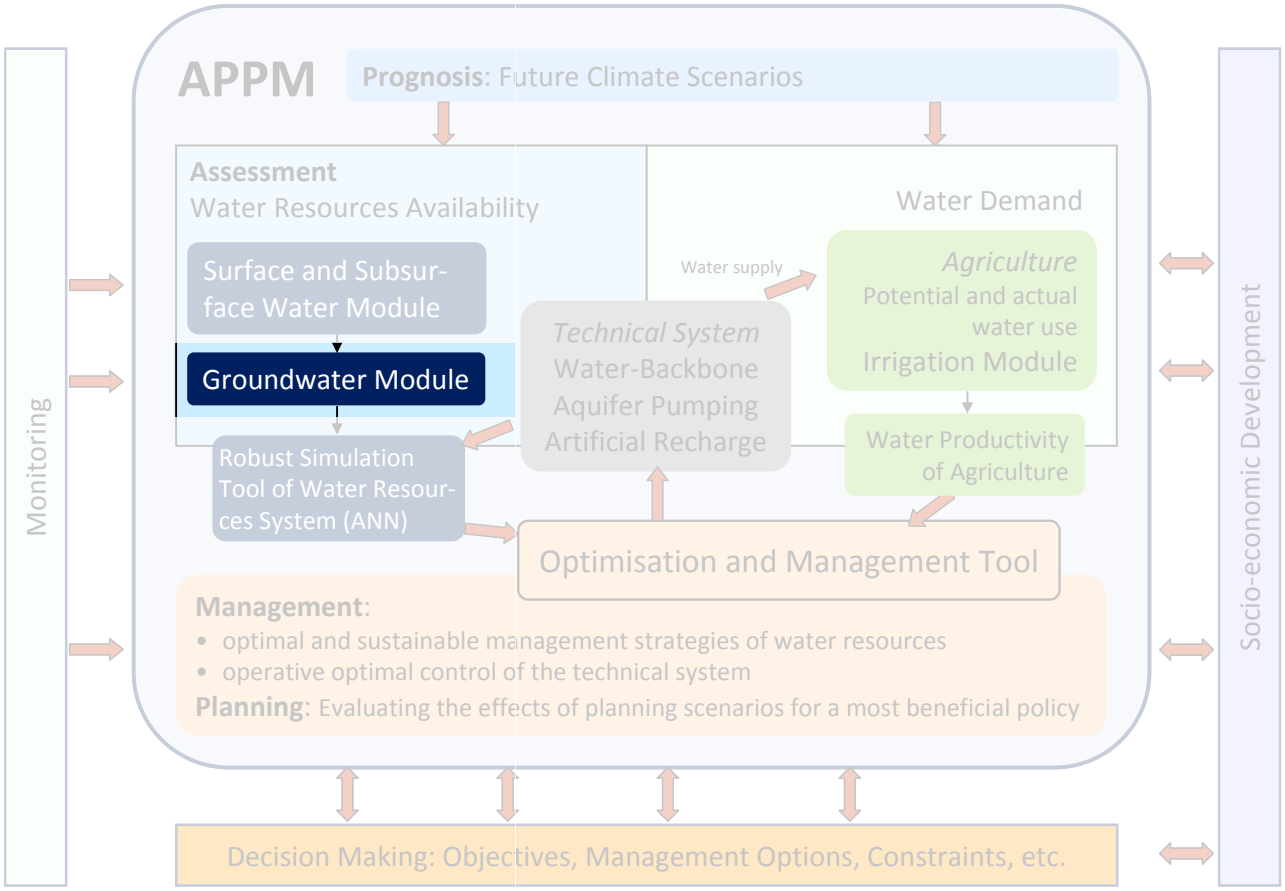
- Three wadis in northern coastal area along Gulf of Oman
- Highest population density of Oman,
  strong economical and population growth
- Highly productive soils
  → Large amount of agriculture

TRADITIONAL WAYS OF IRRIGATION – AFLAJ SYSTEM



NOWADAYS IRRIGATION

IWRM FOR STUDY AREA

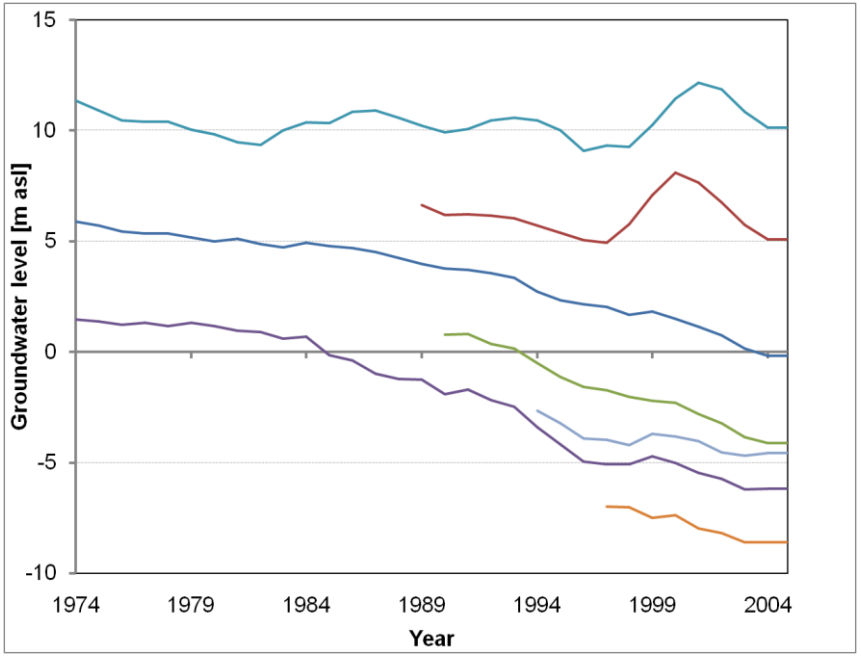


Grundmann, et al., 2011

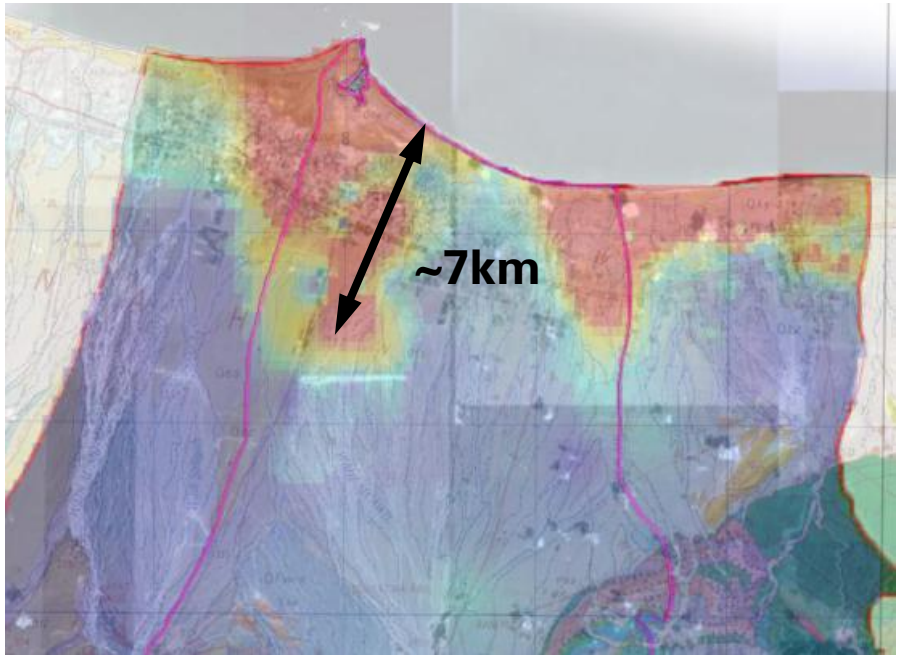
CHALLENGES FOR GROUNDWATER MANAGEMENT

- Rapid decrease of GW-level due to overpumping/mining of GW (since 1970s) (*quantitative* constraint)
- Reversion of natural groundwater gradient
  → Marine saltwater intrusion
  (*qualitative* constraint)

CHALLENGES FOR GROUNDWATER MANAGEMENT



Decreasing Groundwater Level



Saltwater intrusion (2000)

PROJECT GOALS
FROM GROUNDWATER'S VIEW

- Target region: Protection and securing of local (ground-)water resources in the frame of an IWRM
- Evaluation of fresh/saltwater interface
  - Three-dimensional, density dependent model
  - Different scenarios of water usage and agricultural irrigation
  - Define target values: "Who gets how much water?" (agriculture, industry…)

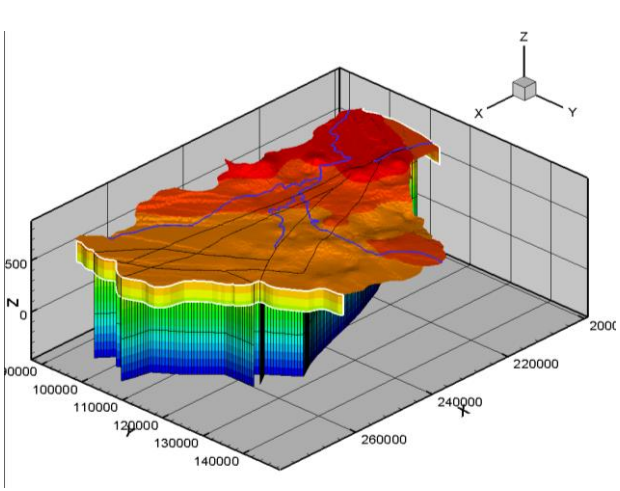
→ Evaluation of most-likely scenarios considering an optimized groundwater usage

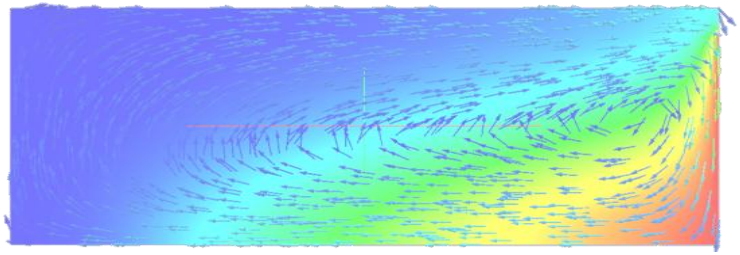
→ Reduction of marine saltwater intrusion

NUMERICAL MODELING SOFTWARE PACKAGE OpenGeoSys

- Open source code developed at Helmholtz Centre Leipzig
- OpenGeoSys (OGS) addresses many THMC processes (thermal, hydraulic, mechanical, chemical) incl. coupling
- www.OpenGeoSys.net

  Kolditz, et al., 2012

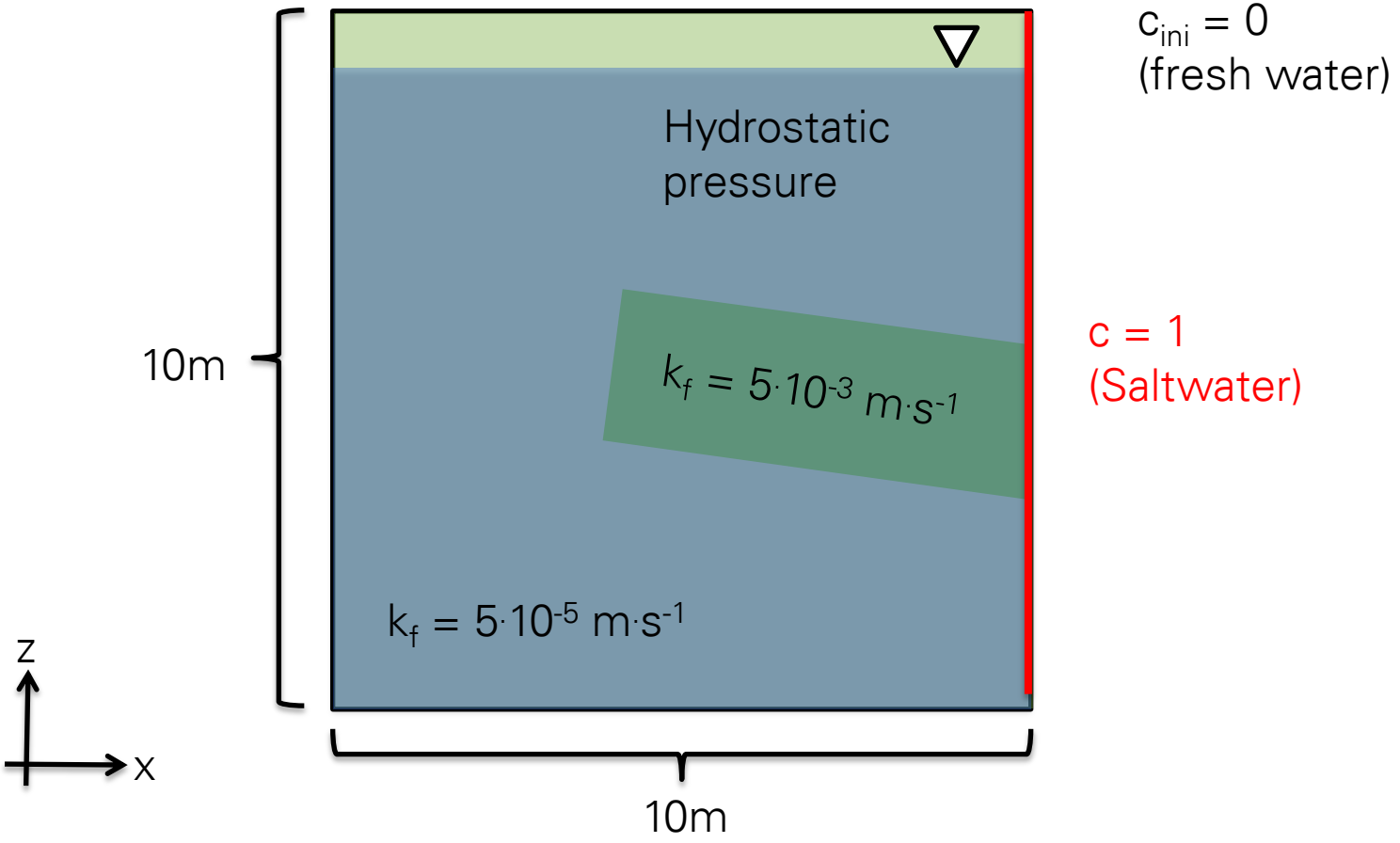




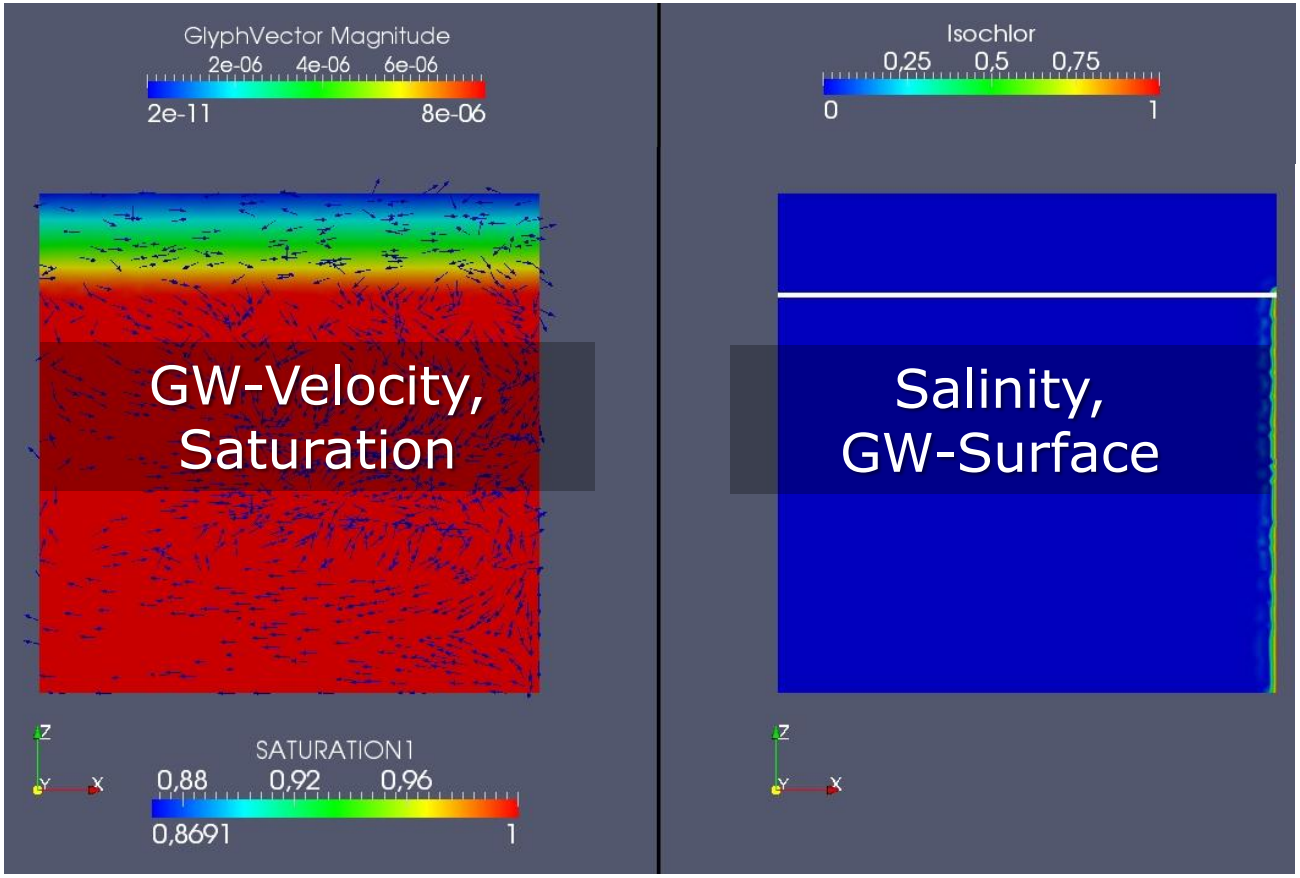
Effort vs. Result

DENSITY DEPENDENCY – WHY?

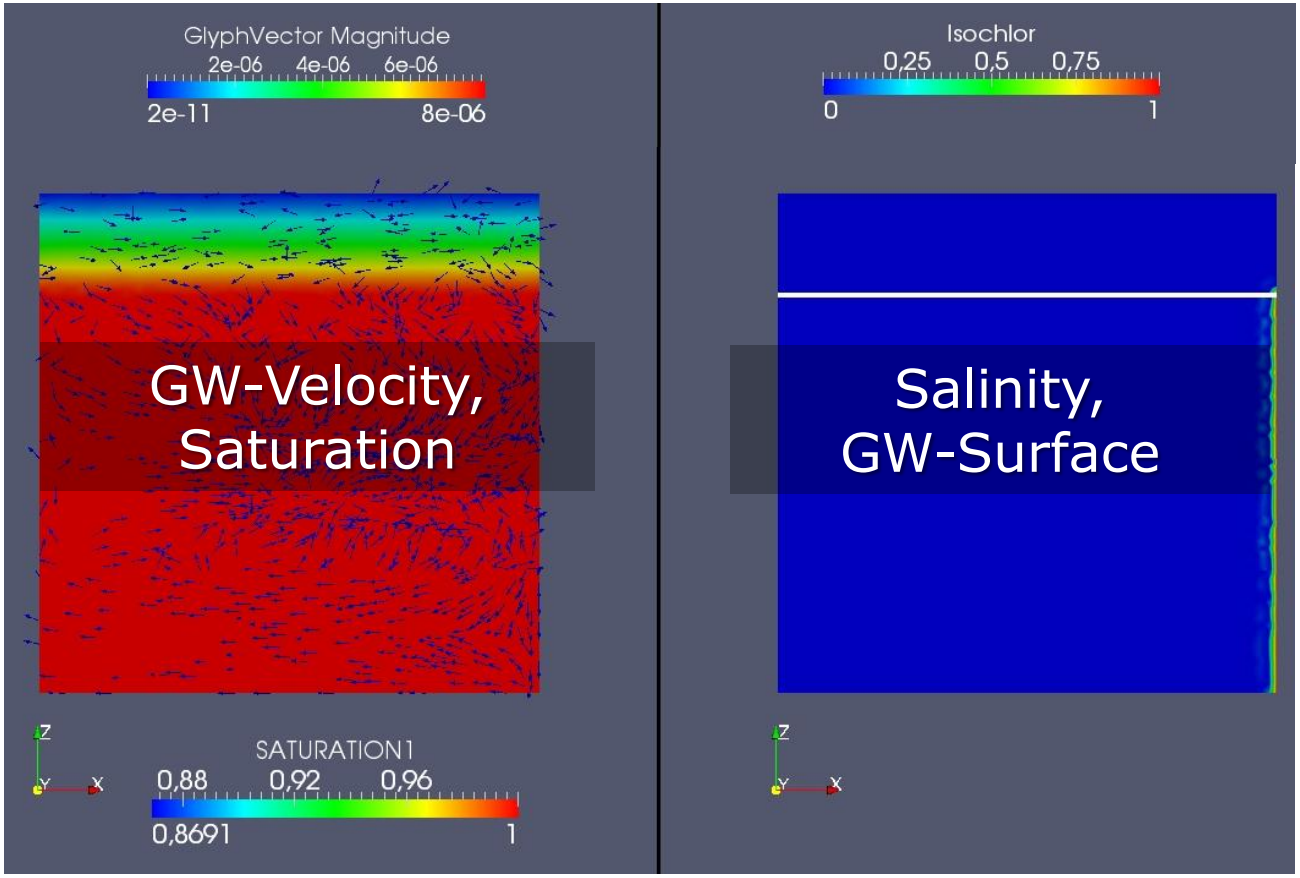
MODEL WITH/WITHOUT DENSITY DEPENDENCE



MODEL WITHOUT DENSITY DEPENDENCE



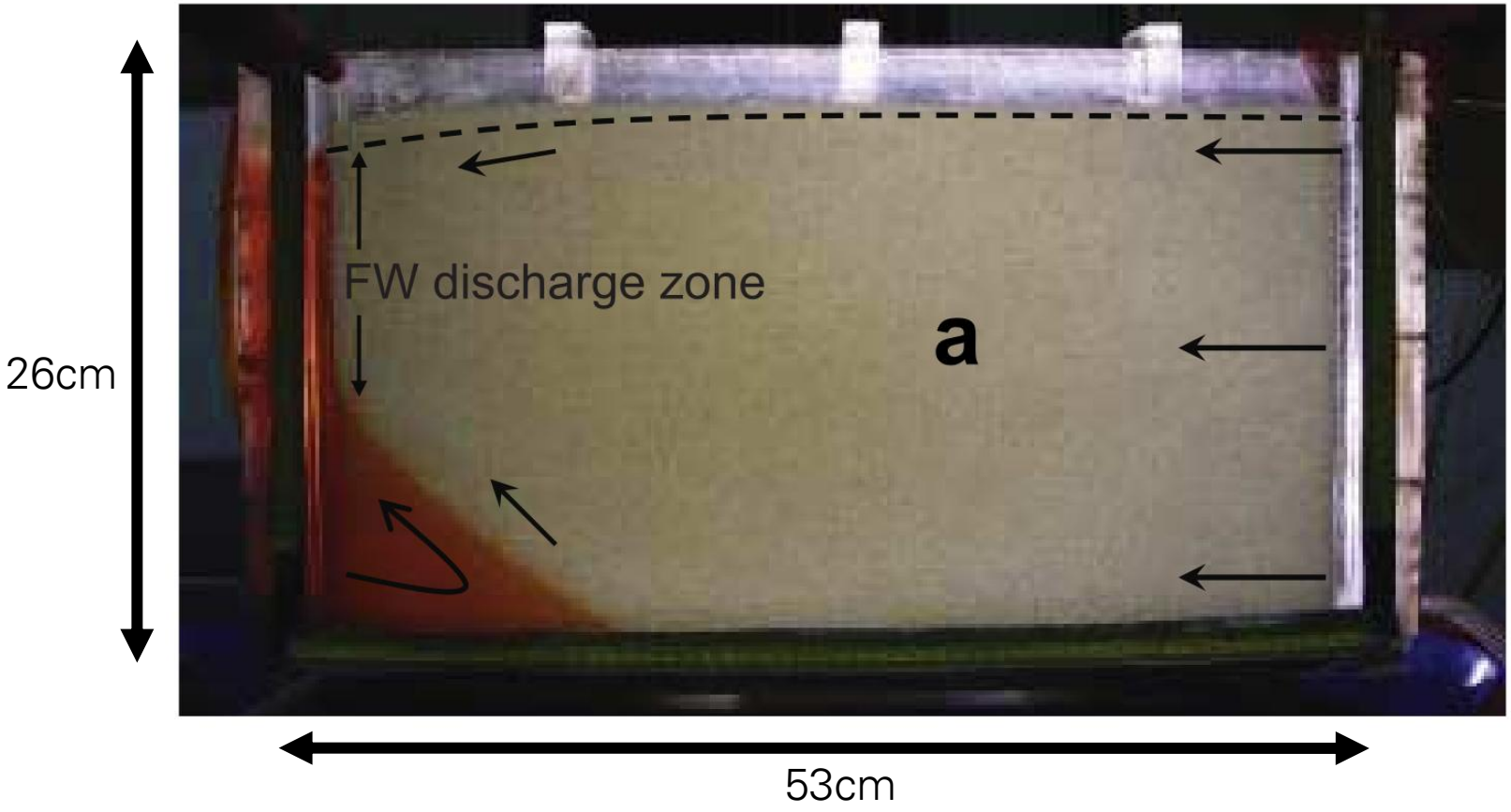
MODEL WITH DENSITY DEPENDENCE



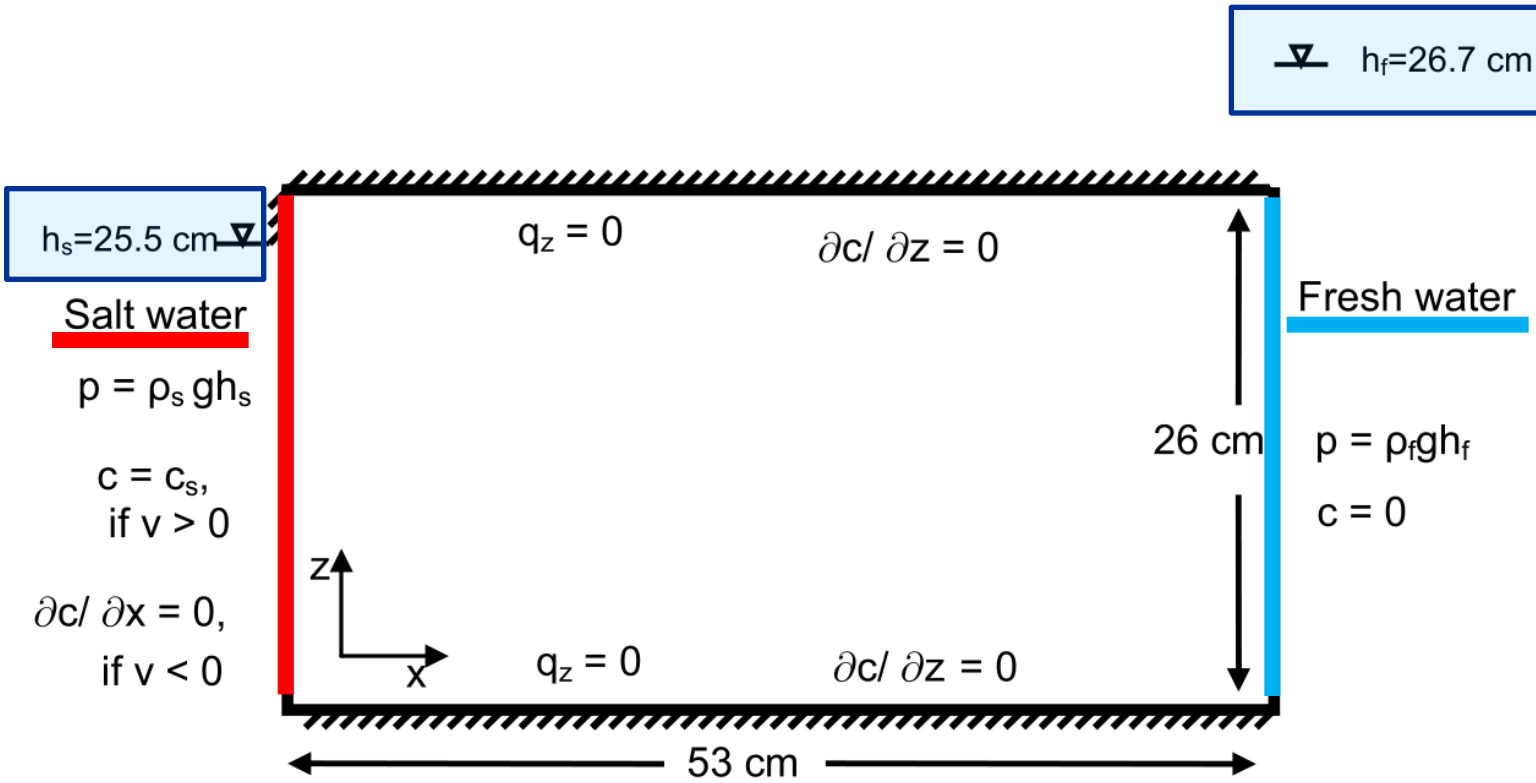
Verifying the Modelling Software OpenGeoSys

DENSITY DEPENDENT BENCHMARK

BENCHMARK AFTER GOSWAMI ET AL. (2007)



EXPERIMENT VS. SIMULATION (SMALL SCALE MODEL)



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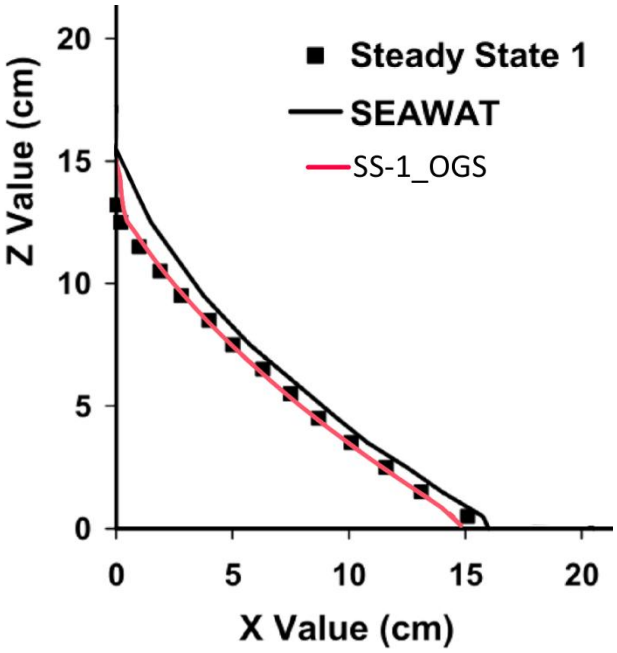
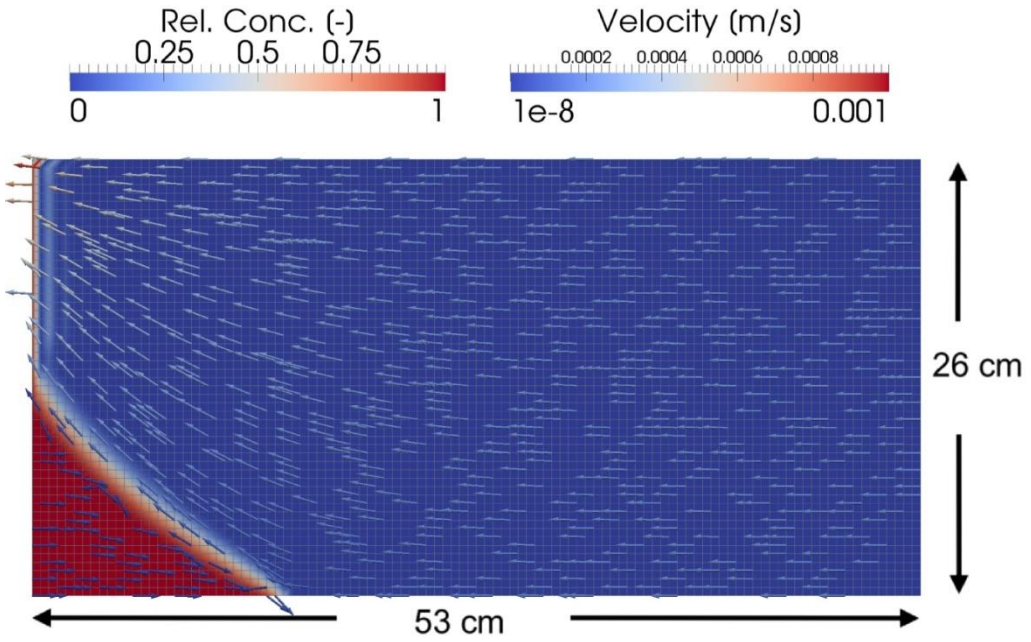
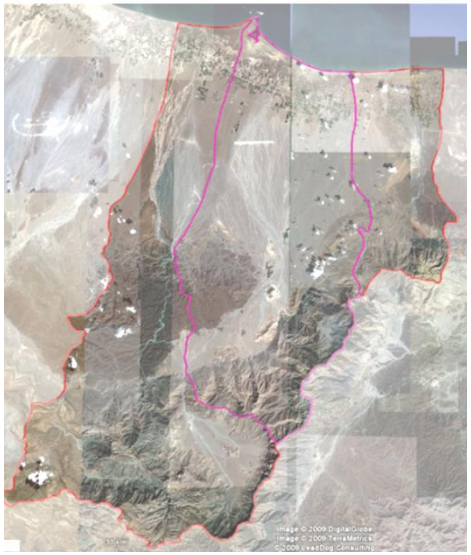


Isolines for C=0.5



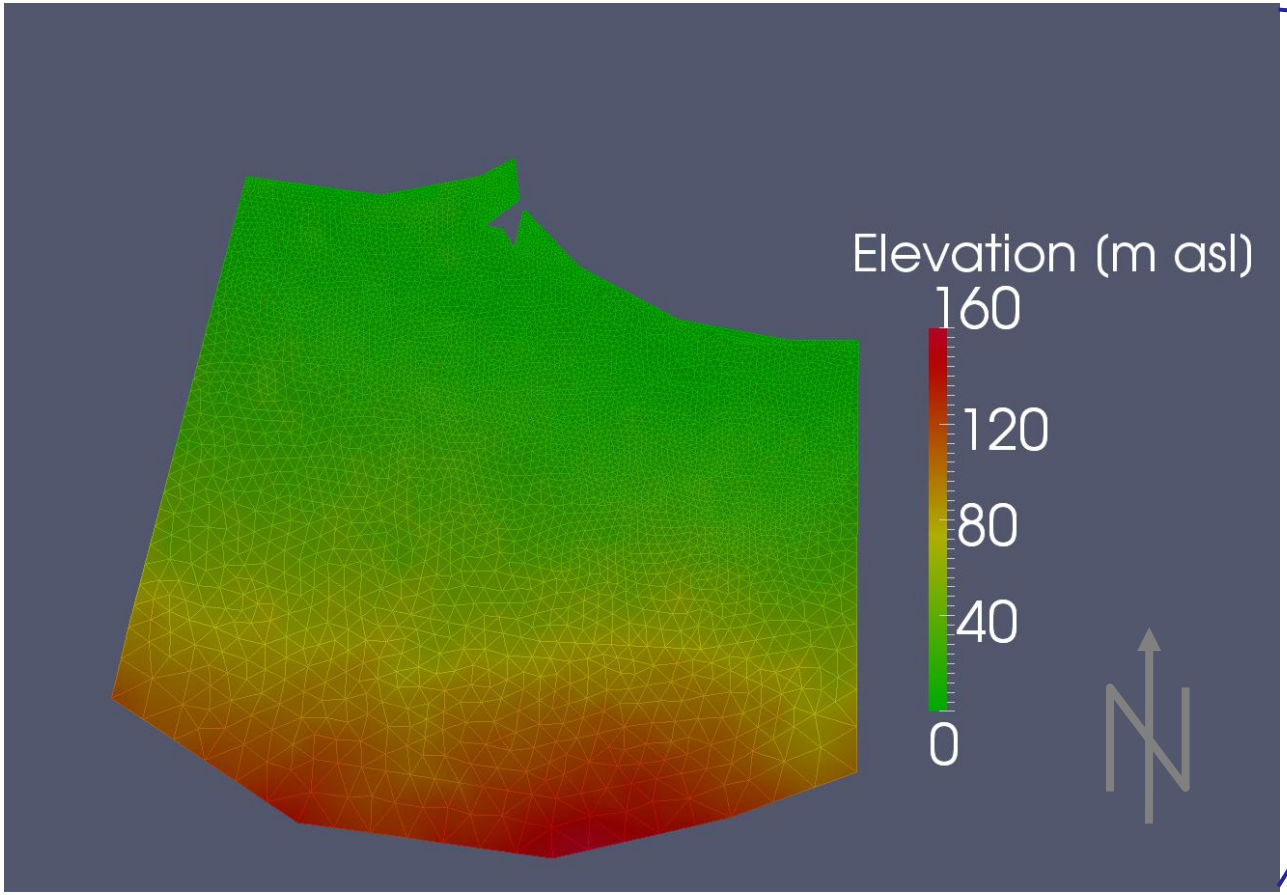
Concentration & Velocity field

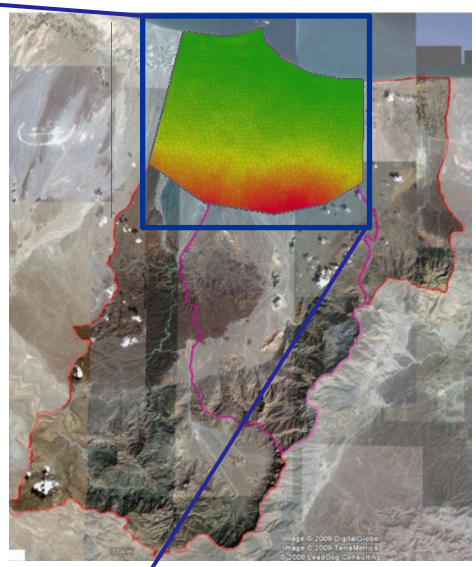


Regional Scale Application for Al Batinah

TARGET AREA MODEL

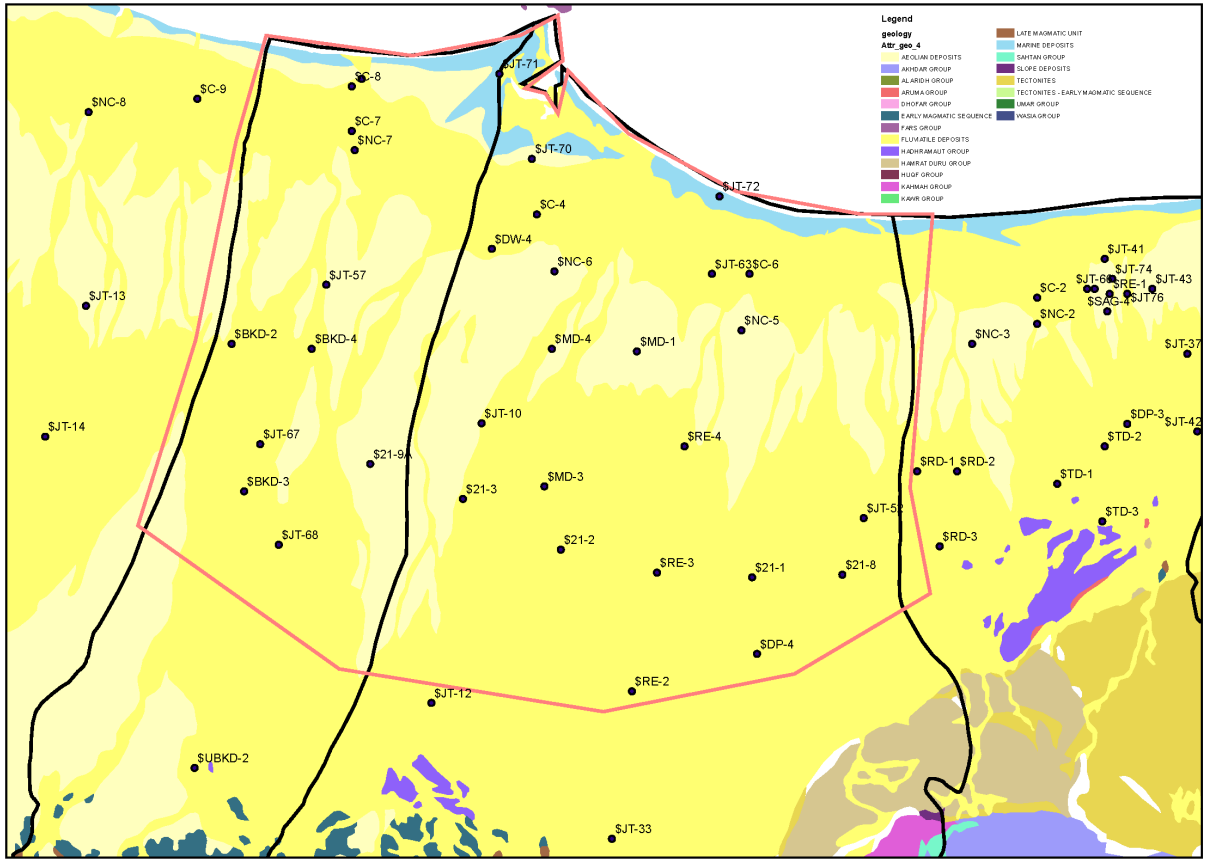
MODEL AREA





30x40km²
25 Layer
300‘000 Elements

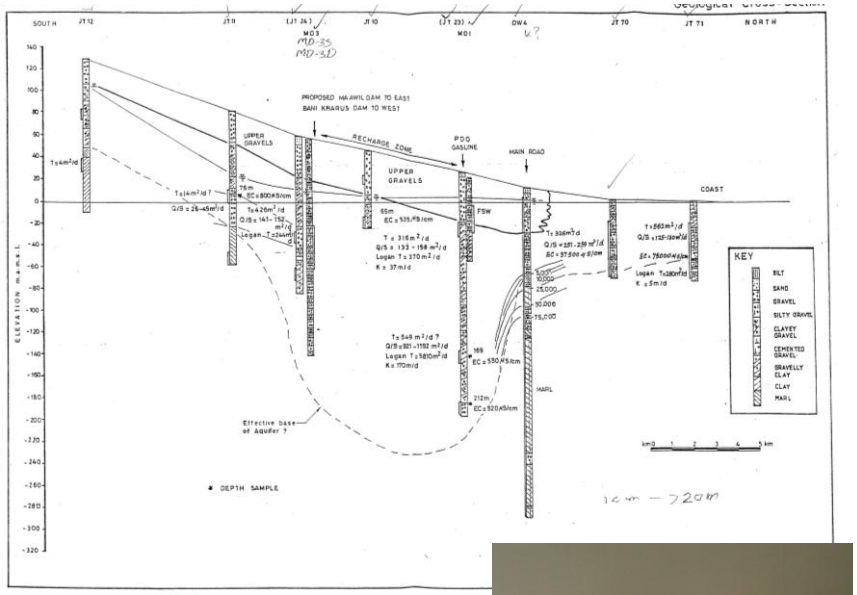
HYDROGEOLOGY IN COASTAL PLAINS



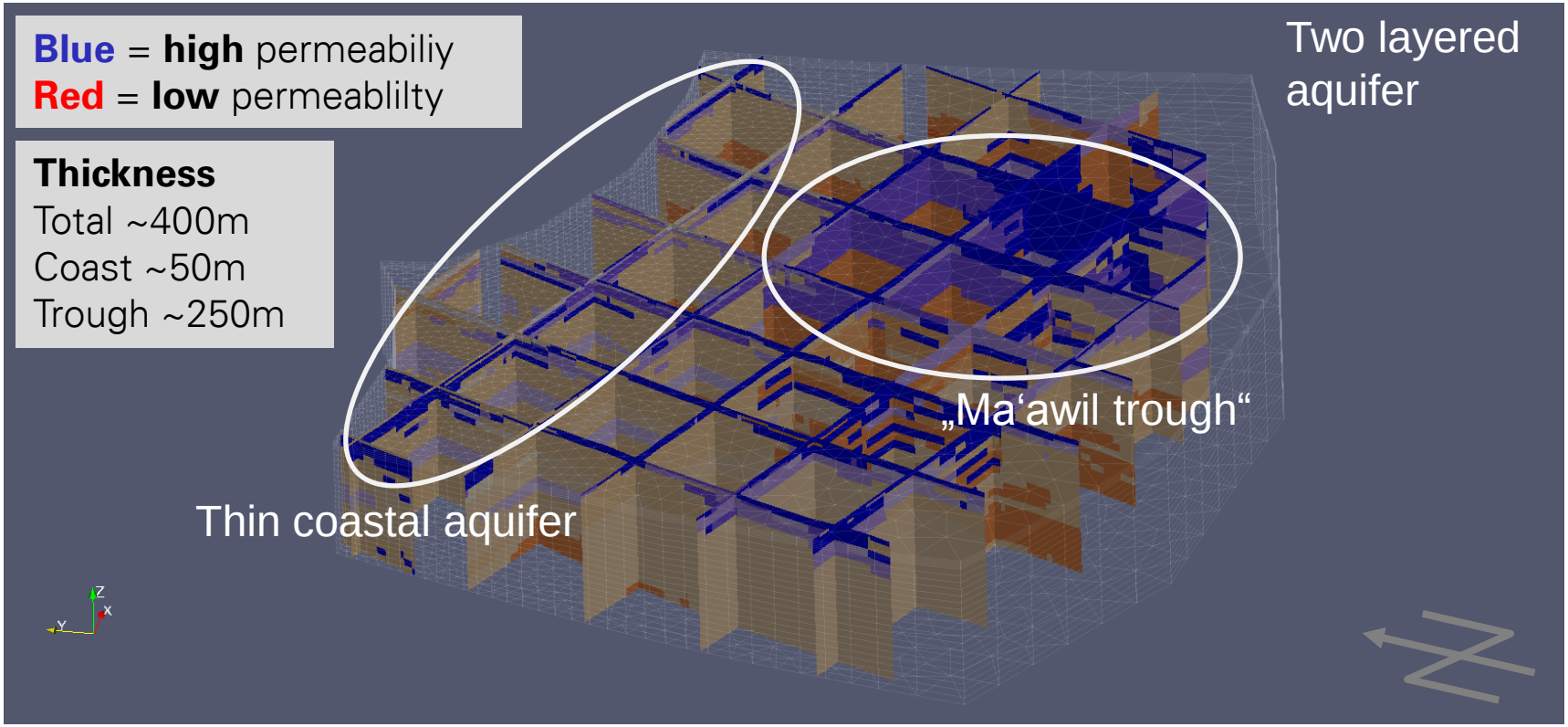
Fluviatile, Marine, Aeolian Deposits

HYDROGEOLOGY
DATA COLLECTION

- Data gathering from various sources
  Tables, Figures, Drilling Logs…
- Meetings/Conversations with Omani hydrogeologists
- 12 major „materials“ (e.g. gravel, silt, clay, bedrock…)

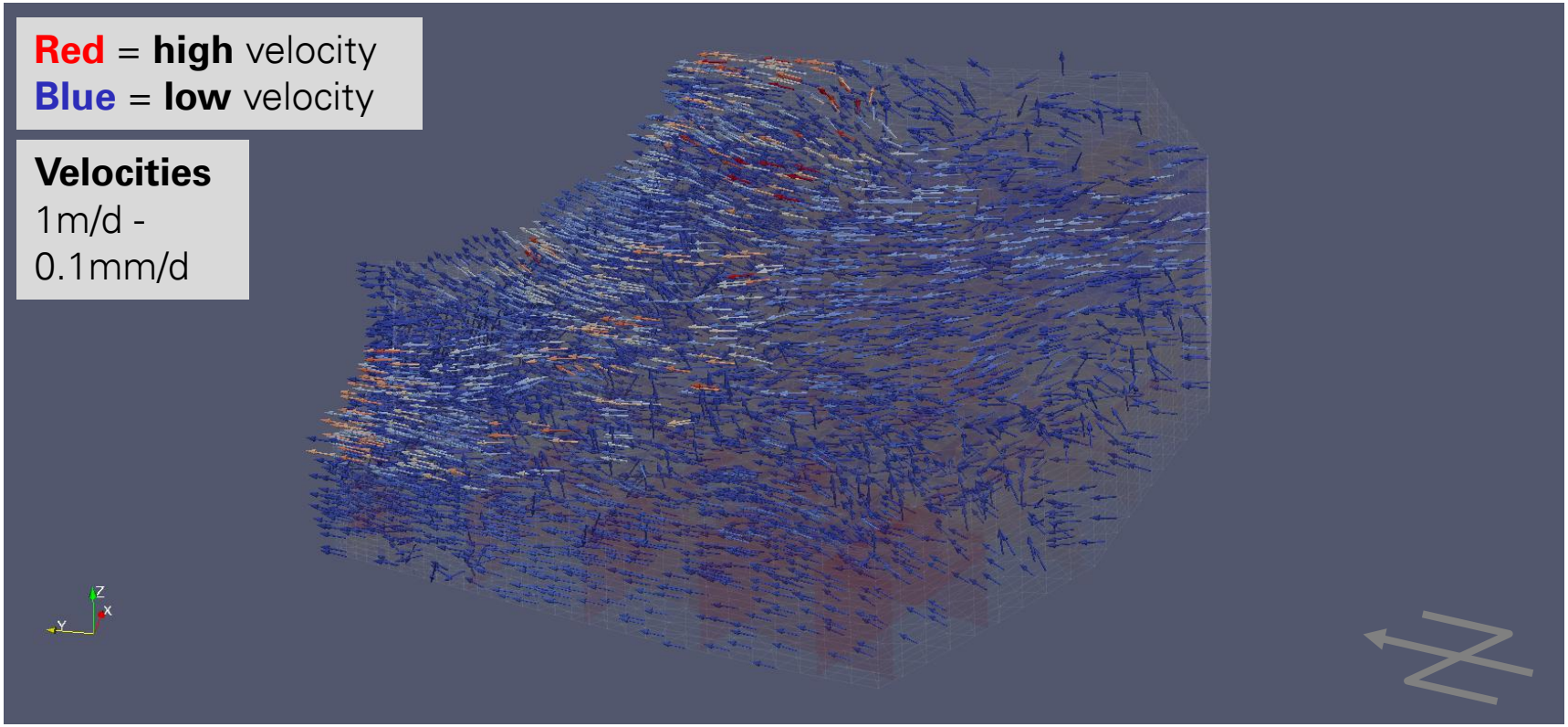


HYDROGEOLOGY
INTERPOLATION USING MODIFIED INVERSE DISTANCE WEIGHTING

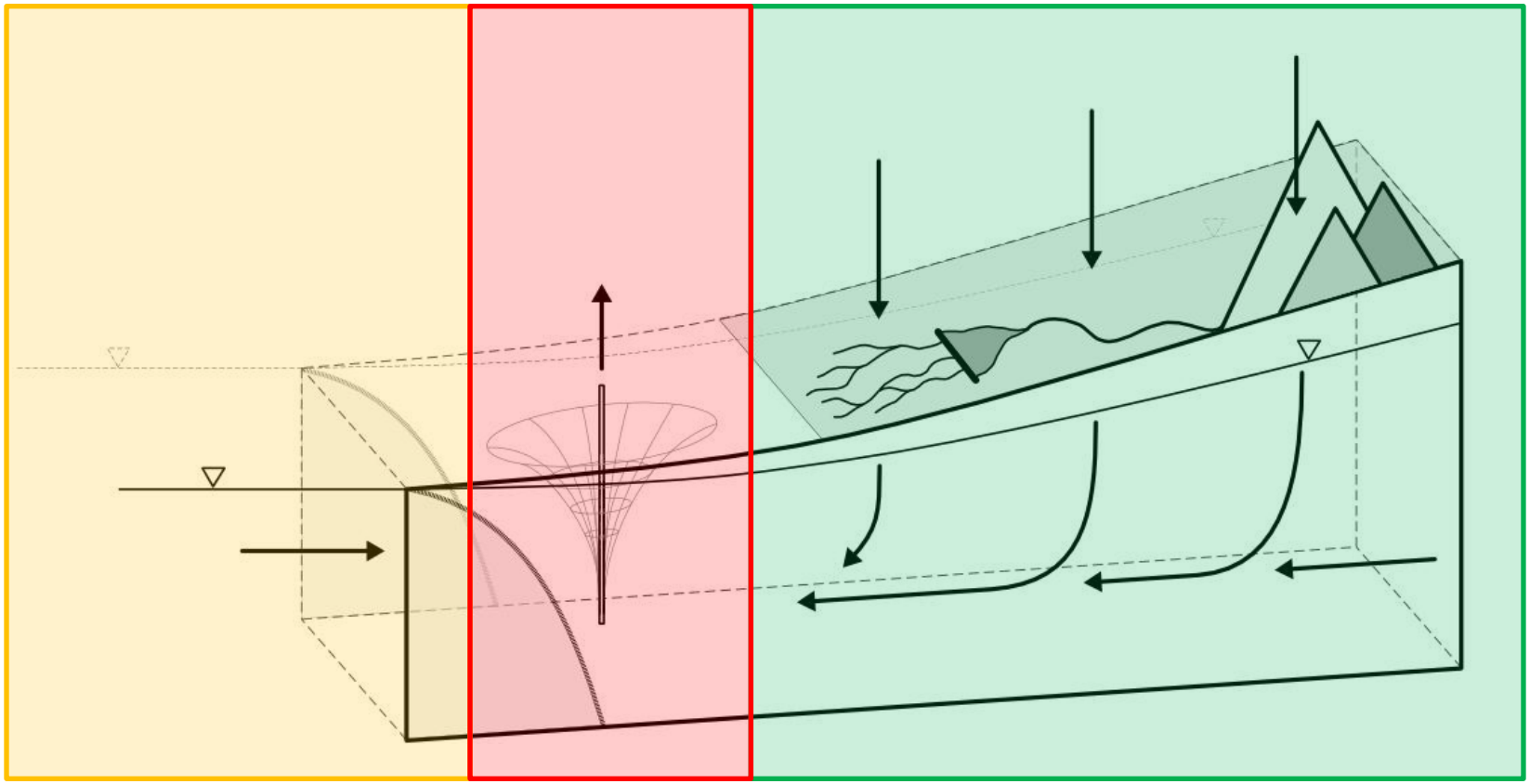


Walther, M., et al. 2011

VELOCITY FLOW FIELD



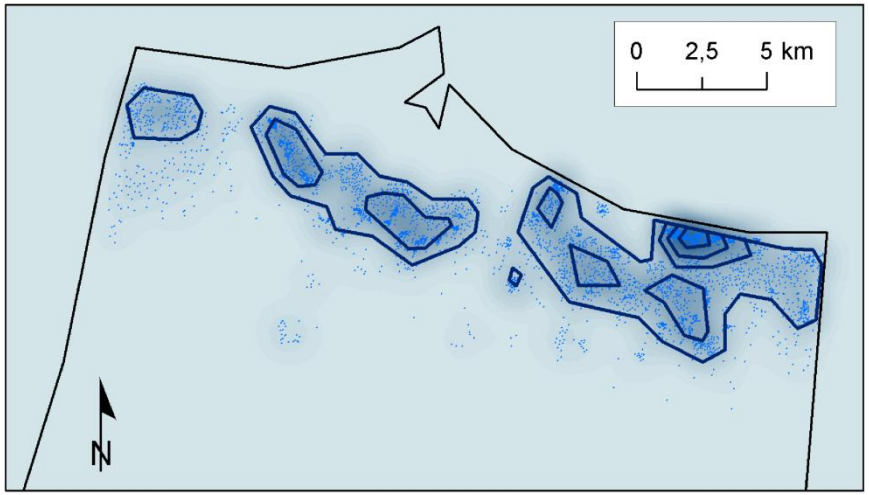
BOUNDARY CONDITIONS



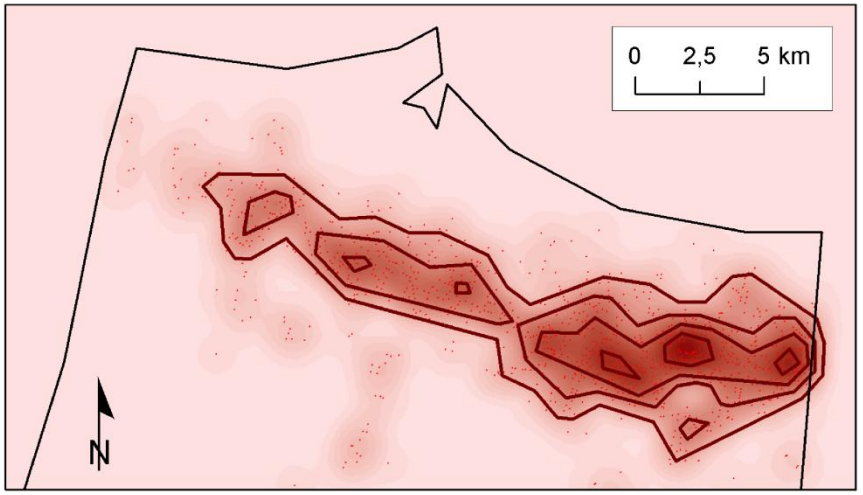
BOUNDARY CONDITIONS
ABSTRACTION THROUGH PUMPING

Estimate of total abstraction rates until 1970s Q~40 mio m^3/a

(Ministry of agriculture and fisheries, Technical Report, 1992; Al-Shoukri, 2008)



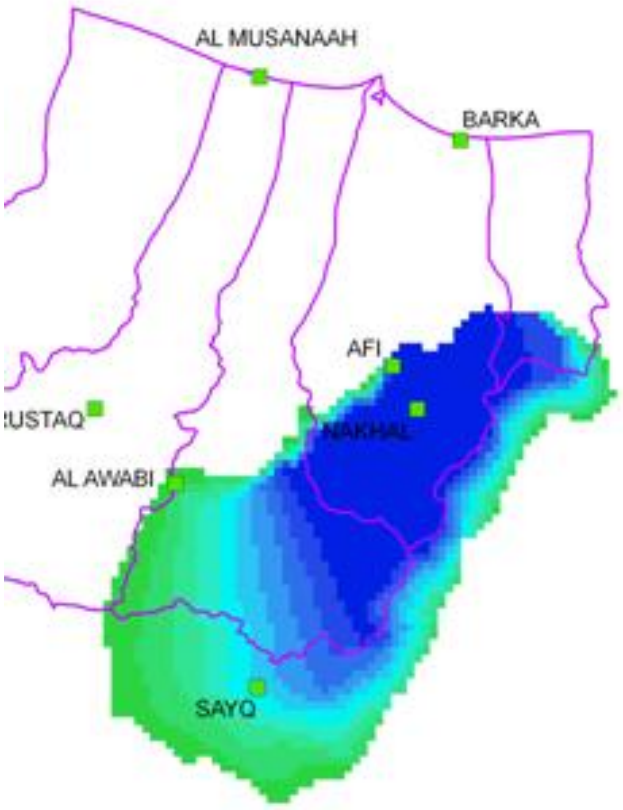
Dug wells



Borehole wells

BOUNDARY CONDITIONS
SUBSURFACE UPSTREAM INFLOW

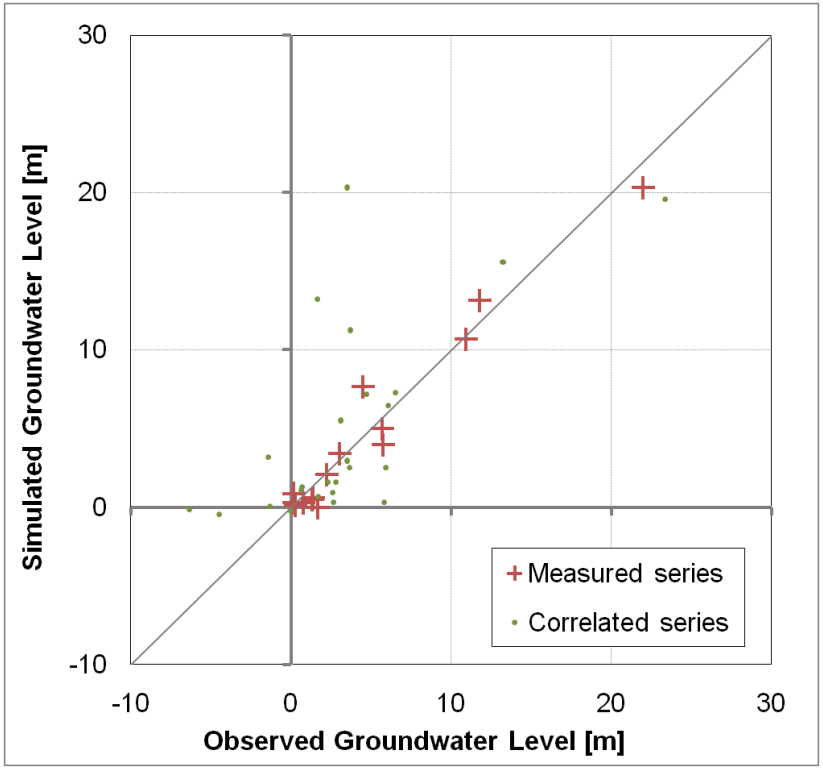
- Recharge estimations via fuzzy-approach (APLIS model),
  → Gerner, et al. (2012)
- Bandwidth of subsurface discharge into plains between 60 – 140 mio m^3/a



Fuzzy upstream recharge area

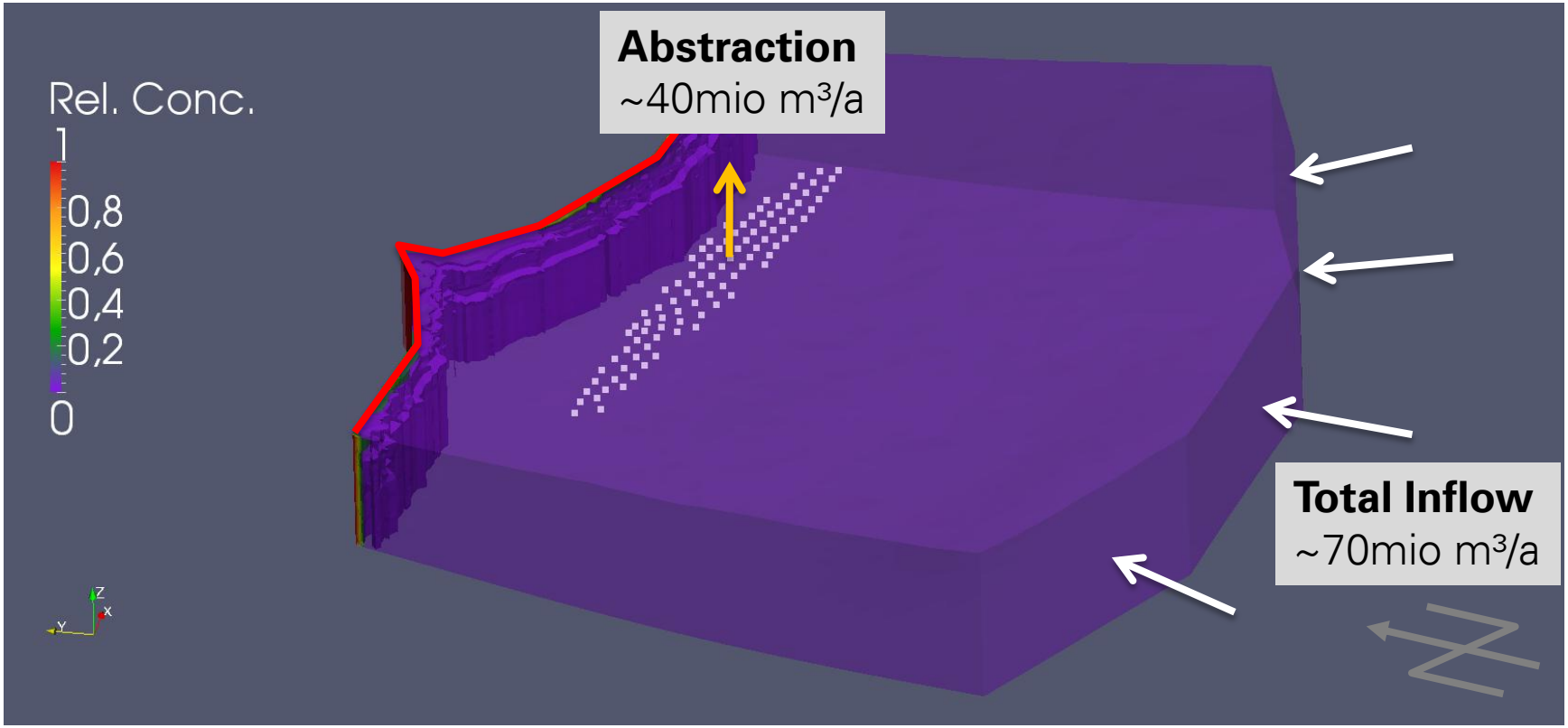
PEST CALIBRATION
STEADY-STATE (1974)

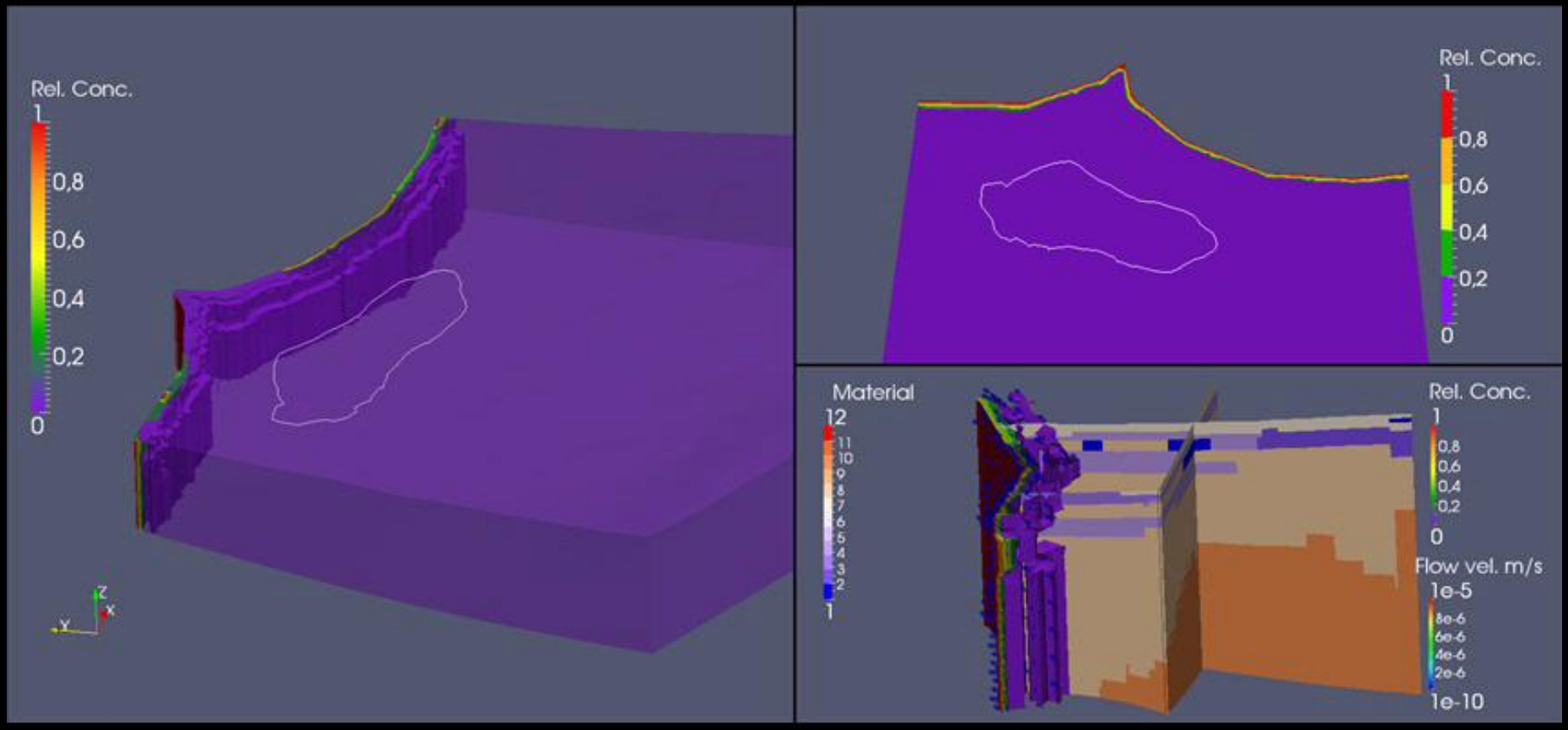
- PEST = Parameter Estimation Tool, widely used in groundwater applications
- Only 14 groundwater level observation series starting in 1974, many starting later
- PEST Results
  - Biased correl. coeff. > 0.9
  - Inflow ca 68 mio m³/a
    Extraction ca 37 mio m³/a
  - Material properties
    (ie hydraulic conductivity)
    „as expected“



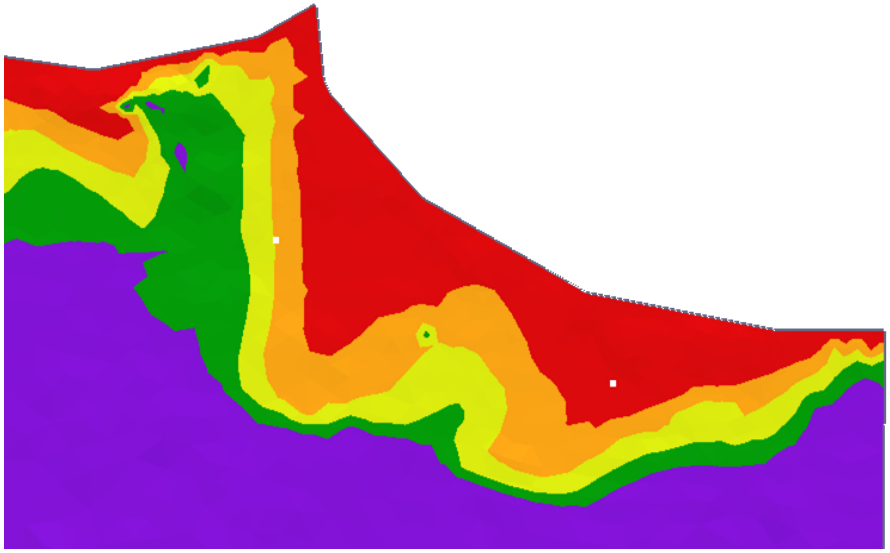
Scatter plot steady state calibration

TRANSIENT „SCENARIO“ SIMULATION
INITIAL AND BOUNDARY CONDITIONS

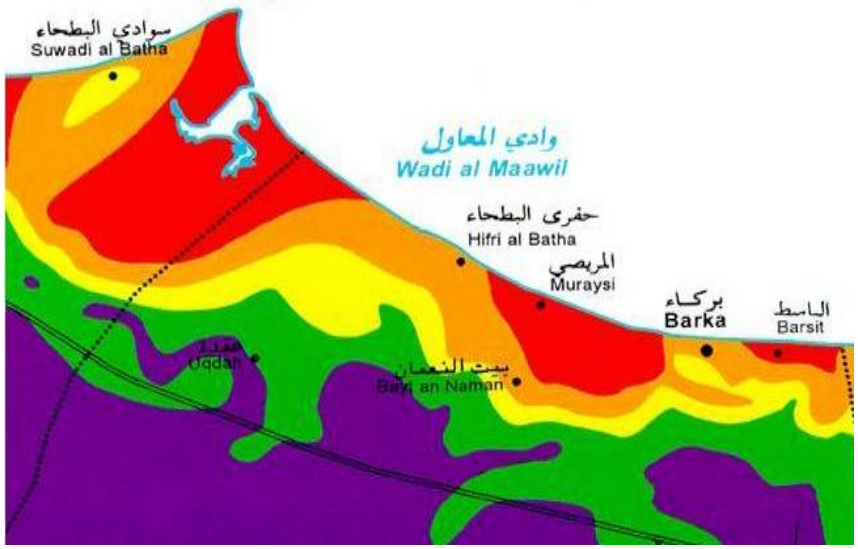



Rel. Conc.
1
0,8
0,6
0,4
0,2
0
Z
X
Y
Rel. Conc.
1
0,8
0,6
0,4
0,2
0
Material
12
11
10
9
8
7
6
5
4
3
2
1
Rel. Conc.
1
0,8
0,6
0,4
0,2
0
Flow vel. m/s
1e-5
8e-6
6e-6
4e-6
2e-6
1e-10

COMPARISON SALINE INTRUSION
MODEL VS. REALITY



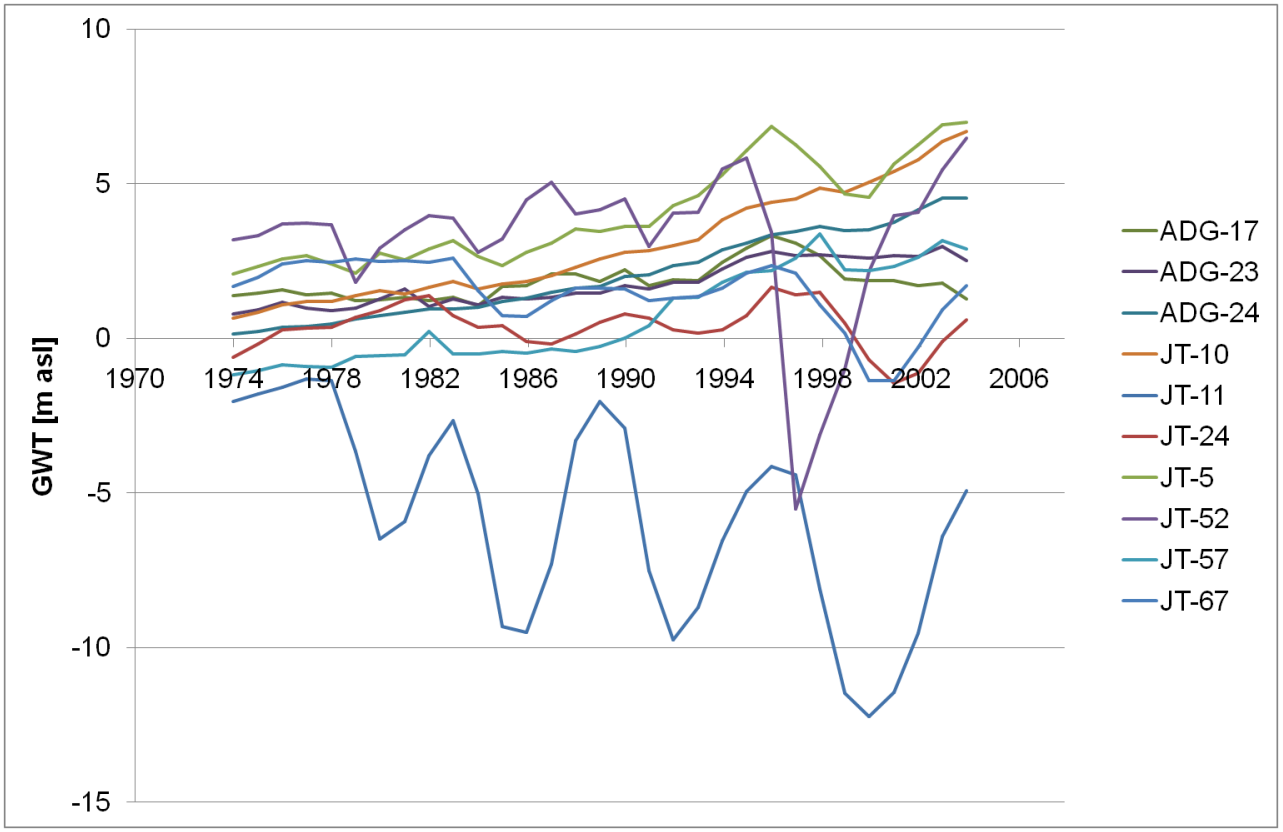
Simulation



Measurement
(Ministry of Regional Municipalities, Environment and Water Resources, 2005)

Salinity at 10 m below water surface

OUTLOOK: TRANSIENT CALIBRATION



GW level difference Simulation - Measurement

SUMMARY

- Better transient calibration & validation (also vs. salinity)
- Scenario simulations for best/worst case
- Cross-check results of GW-model with other groups‘ results

Thank you for your attention!

S.S.M. Al-Shoukri, Mathematical Modeling of Groundwater Flow in Wadi Ma'awil Catchment, Barka in Sultanate of Oman. Master's thesis; Arabian Gulf University, Bahrain, 2008.

Gerner, A. and Schmitz, G. H.: Portrayal of fuzzy recharge areas for water balance modelling - a case study in northern Oman. Advances in Geosciences (accepted).

Grundmann, J., Schütze, N., Schmitz, G.-H., & Al-Shaqsi, S. (2011). Towards an integrated arid zone water management using 10.1007/s12665-011-1253-z.

Kolditz, et al: OpenGeoSys: an open-source initiative for numerical simulation of thermo-hydro-mechanical/chemical (THM/C) processes in porous media. Environmental Earth Sciences. 10.1007/s12665-012-1546-x.

Ministry of agriculture and fisheries. Bureau de Recherches Gologiques et Minires, Study of a New Organization of Irrigation in Barka–Rumais Area, Data Analysis and Modelling Report, Technical Report, 1992.

Ministry of Regional Municipalities, Environment and Water Resources (2005): Water Resources in Oman; Ministry of Regional Municipalities, Environment and Water Resources; Sultanate of Oman; 136pp.

Walther, M., Böttcher, N., & Liedl, R. (2011). A 3D interpolation algorithm for layered tilted geological formations using an adapted inverse distance weighting approach. ModelCare 2011 Proceedings (accepted).