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# Modelling the efficiency of subsurface water solutions for controlling saltwater intrusion: Parameter identification of fractured chalk aquifer affected by glaciotechtonics

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## 1. Introduction and objectives

At the Marielyst Waterworks on the island of Falster groundwater is abstracted from a coastal chalk aquifer strongly affected by the last glaciation (Fig 1 and 2).

Increasing saltwater concentrations and in some cases exceeding drinking water standards have been seen primarily in the wells closest to the Baltic Sea on the east coast of the island, /1/.

The chalk aquifer is covered by 5 m marine sand and 5 m clayey till. The upper 30 m of the chalk formation is a fractured chalk aquifer altered by glaciotechtonics (Fig. 2).


Fig. 1. Test site and wells

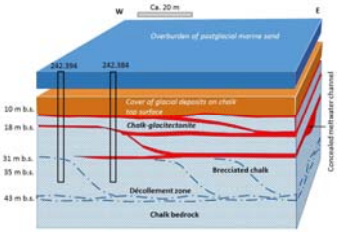


Fig. 2. Conceptual geology

Subsurface Water Solutions (SWS) are practical concepts developed for protection, enlargement and utilization of freshwater resources in coastal areas /2,3/.

The objective is to test the SWS concepts 'Freshkeeper' and 'ASR Coastal' in a fractured chalk aquifer pumping and injecting brackish and freshwater, respectively, at different depths, providing control over the position of the fresh-brackish interface /2,3/ (block 5).

Field tracer tests were conducted to collect field data for estimating transport parameters for the dual domain modelling of the behavior and effect of the SWS concept in a fractured chalk aquifer.

## 2. Tracer test setup

A tracer test site was established around an existing groundwater abstraction well with increased chloride content.

The test site included one tracer injection well (T2), one groundwater injection well (UB1), one groundwater abstraction well (UB2), and two CMT monitoring wells with a total of 14 groundwater sampling screens at 1 m interval (Fig 3, 4, 5, 6).

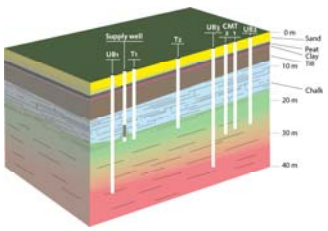


Fig. 3. Boreholes, red color indicates increasing salinity with depth

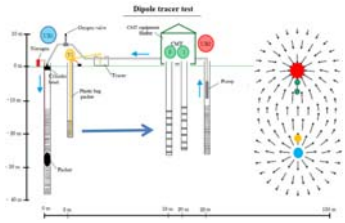


Fig. 4. Principle and setup

Fig. 4. Injection saltwater

Fig. 5. Measuring SEC

*Injection figures:*

- 1 m³ saltwater injected: 2800 mg Cl/l, 8500 µS/cm, 25 °C
- Injection time: 30 minutes
- Injection depth: 13,5 – 20.5 m b.g.l.
- Monitoring interval: 14 - 26 m b.g.l.
- 3 consecutive tracer tests => => =>
- Forced gradient: 2.5 – 9.8 %

| Test no. | Pumping rate [m3/h] | Start pumping | Injection |
|---|---|---|---|
| 1 | 13.0 | 15-04-2018 | 16-04-2018 |
| 2 | 4.9 | 30-04-2018 | 01-05-2018 |
| 3 | 9.1 | 22-05-2018 | 23-05-2018 |


## 3. Experimental results

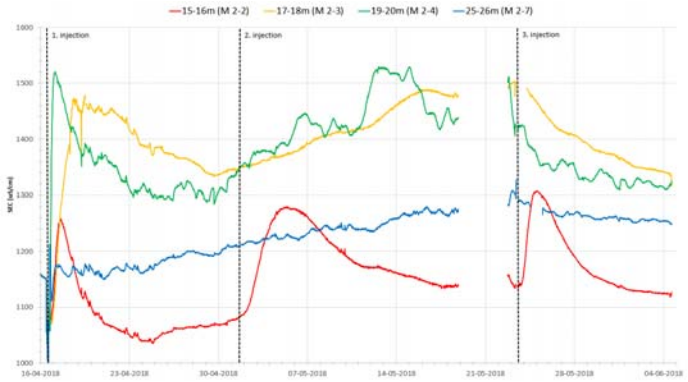


Fig. 6. Continuously registration of specific electrical conductivity (SEC) in 12 (four shown) monitoring filters between 14 – 26 m b.g.l. Vertical dotted lines indicate the times for tracer injection

## 4. Dual porosity modelling

A dual porosity model is established with STANMOD and GMS.

- STANMOD software are used for evaluating solute transport in porous media using analytical solutions of the convection-dispersion solute transport equation
- GMS (MODFLOW, MT3DMS) used for simulating trace experiment

*Parameters:*
Longitudinal disp.=2.5m
Immobile porosity=0.35
Mass transfer rate=0.45h$^{-1}$

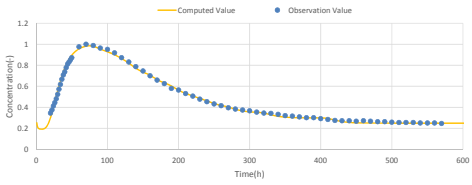


Fig. 7. Modelling SEC from M 2-2

## 5. Modeling of SWS solutions

The tracer tests and simulations of tracer breakthroughs provide hydraulic parameters for the local dual domain variable density model.

Model scenarios with the SWS concepts 'Freshkeeper' and 'ASR Coastal' applied in the local chalk aquifer will be used for assessment of most efficient scheme for securing future freshwater abstraction at the Falster site:

- 'Freshkeeper': Brackish water is pumped from the deeper part of UB1, desalinised and re-injected at different pumping rates in wells at different distances and depths upstream the water supply well.
- 'ASR Coastal': Injecting and storing freshwater during the winter period with excess precipitation, and abstracting groundwater during the summer period with high water demand.

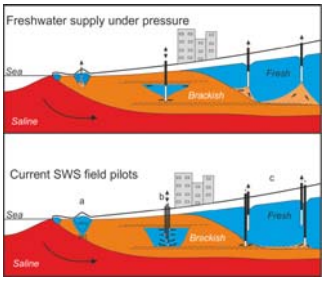


Fig. 8. SWS concepts: a) Freshmaker, b) ASR Coastal, c) Freshkeeper

## 6. References

/1/ P. Rasmussen, T. O. Sonnenborg, and K. Hinsby. 2013. Assessing impacts of climate change, sea level rise, and drainage canals on saltwater intrusion to coastal aquifer. Hydrol. Earth Syst. Sci., 17, 421–443, 2013. www.hydrol-earth-syst-sci.net/17/421/2013/. doi:10.5194/hess-17-421-2013.

/2/ Zuurbier, K., Raat, K., Paalman, M., Oosterhof, A. & Stuyfzand, P. (2016).Water Resour Manag 31(2), 671–687. doi:10.1007/s11269-016-1294-x

/3/ Subsurface Water Solutions: http://www.subsol.org/



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