

3.10 Falster Island case study, Denmark

Title of Case Study	Falster Island, Denmark
Location (region, Country)	Marielyst, Southern Falster, Denmark
Other information	Eleven mainly open water supply wells abstracting water from a confined fractured chalk aquifer partly affected by glaciotectionics and land reclamation in the 18 th century were investigated due to increasing salinity in some of the water supply wells. A study on climate change impacts on the aquifer were furthermore conducted (Rasmussen et al. 2013).

Description of Case Study (background information on the region)

Pilot study in collaboration with a small Danish water company supplying water to a holiday summer housing area primarily during summer time. Eleven wells were sampled and analysed for $^3\text{H}/^3\text{He}$, ^4He and ^{14}C . The wells typically abstract water from the upper 10 meter of a confined chalk aquifer highly affected by the last glaciation. On average about 2000 m³/day is abstracted during the summer while only about 300 m³/day is abstracted during winter time. Salt water intrusion processes were investigated in several national and EU projects made possible through funding from Danish ministries and EU (Horizon 2020) to assess potential impacts of climate change and sea level rise and explore possible adaptation strategies by the use of integrated groundwater and surface water modelling (Rasmussen et al., 2013). The dating tracers $^3\text{H}/^3\text{He}$ were analysed by the Helis lab. at University of Bremen to assess groundwater age and recharge since the land reclamation activities were initiated in 1861.

Description of problem (why is this location chosen for a Case Study)

Several water abstraction wells of the Marielyst waterworks experience increasing salinity. The pilot study site was selected to assess climate change impacts and potential remediation options for protecting the freshwater resources in the area.

Methods used or to be used in the Case Study (analytical and isotope techniques, modelling)

Integrated groundwater-surface water modelling, airborne geophysical measurements (SkyTEM), use of groundwater dating tracers for assessment of groundwater recharge. The case study include the application of the groundwater age indicators $^3\text{H}/^3\text{He}$, ^4He , ^{14}C , $\delta^{13}\text{C}$, as well as stable isotopes of strontium, oxygen and hydrogen.

Results from this Case Study

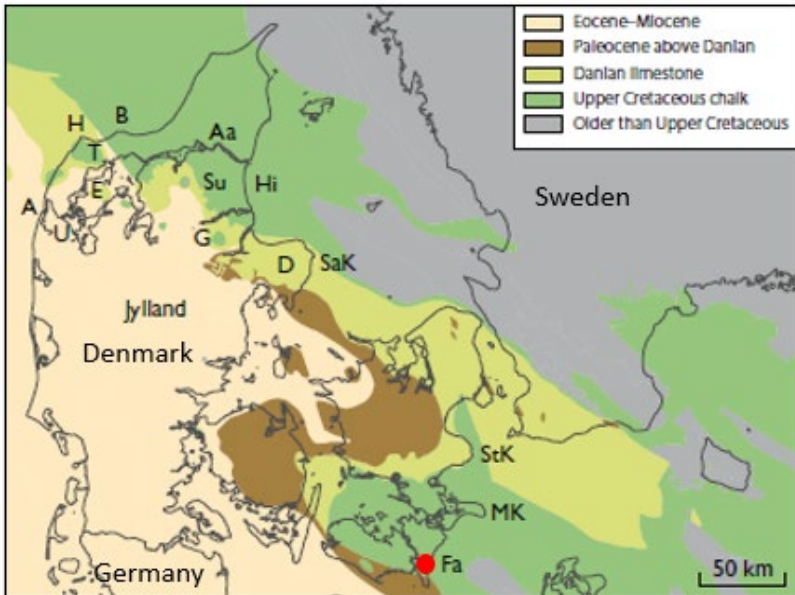
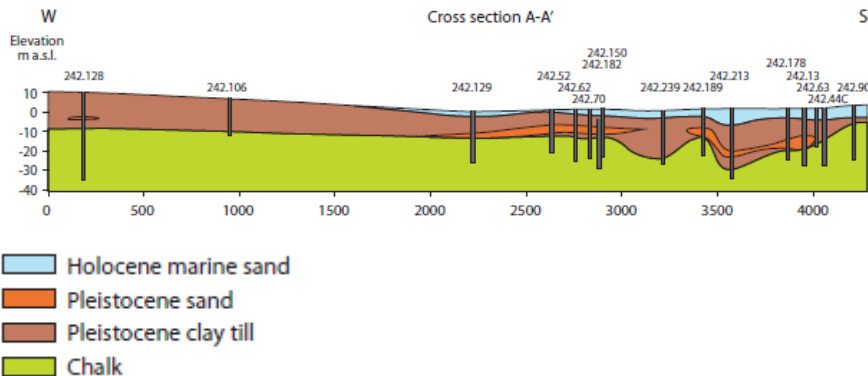
The results of the $^3\text{H}/^3\text{He}$ analyses showed no or very low tritium and tritiogenic helium in the collected samples demonstrating rather old groundwater and little groundwater recharge at the shallow depth from where water supply wells abstracts water (approx.. 10-20 below surface). This indicates that the land reclamation activities (drainage pipes, canals and pumping station) have reduced groundwater recharge in the area significantly and that water abstraction by the water works is mining the existing groundwater resources at least locally. This increases the risk of continuous salinization and calls for remediation measures such as desalinization, managed aquifer recharge and water banking e.g. storage from winter to summer to protect and ensure continuous water supply from the area.

Impact - how this Case Study contributes to the overall project aims

The case study investigate groundwater recharge and salinization processes in a coastal area affected by salt water intrusion and contributes to demonstrating how groundwater dating tracers can be used to understand groundwater recharge and vulnerability to saltwater intrusion. Hence, it contributes to both the objectives of especially HOVER WP6 and TACTIC WP5 and 6 objectives i.e. understanding groundwater recharge, flow and saltwater intrusion issues and to provide advice on groundwater management and adaptation strategies in a changing climate.

We hope that the studies will inspire to other similar studies and make the application of the dating tracers for vulnerability assessments of water supply wells towards saltwater intrusion (Rasmussen et al., 2013) much more common. Information on groundwater flow dynamics based on tracer analyses and groundwater flow modelling will enable much better management and protection of the well fields e.g. by distributing and optimizing groundwater abstraction from water supply wells to avoid increasing salinity and/or to design remediation measures e.g. applying carefully designed managed aquifer recharge of desalinized brackish waters from deeper part of the local aquifer during winter time for abstraction in the upper parts again during summer time where peak abstraction is required.

The cited references and access information are listed at the end of the following information template.

Name of pilot area / aquifers / type: Marielyst, Falster / fractured chalk glacitectorite / confined		Country: Denmark Region: Island of Falster	
Study level	Transboundary : ☐ Regional: ☐ Local: ☐ Single well(s): X		
Type of observations <i>(choose one of the options, create separate template if needed for each type if each type need specific information)</i>	☐ Short screened observation wells (not pumped) ☐ Long screened observation wells (not pumped) X Pumped wells, long screens and open wells in one aquifer ☐ Pumped wells, long screens over multiple aquifers ☐ Springs ☐ Other (eg. research wells; indicate type and information on pumping):		
Approximate location of pilot: (red circle)	 Pre-Quaternary aquifers & aquitards in Denmark		
Geological cross section / conceptual model of the pilot area:	 W Cross section A-A' SE Elevation m a.s.l. 242.128 242.106 242.129 242.150 242.182 242.213 242.178 242.13 242.63 242.90 242.52 242.62 242.70 242.239 242.189 242.64C 0 500 1000 1500 2000 2500 3000 3500 4000 ☐ Holocene marine sand ☐ Pleistocene sand ☐ Pleistocene clay till ☐ Chalk		
Name of Shape- / Geopackage file defining the area:		Projection to be used:	

Hydrological parameters:	Mean annual precipitation (mm or range in mm)	Mean annual groundwater recharge (mm or range in mm)	Mean annual groundwater recharge temperature (°C)	Thickness of unsaturated zone (range in m)
	700	80 - 400	9	1 - 2
Pumped wells only		Typical pump discharge of sampled individual well (m ³ /day): Winter (0), summer (50)	Typical pump discharge of complete well field (m ³ /day): N/A <i>If relevant</i>	
List of aquifers and aquitards in pilot area		No. of confined or semiconfined aquifers in pilot areas: 1	No. of unconfined aquifers in pilot areas: 0	
Aquifer no. (aqf): 1 Aquitard no. (aqt): 1 Aquiclude no. (aqc):	Aquifer/aquitard type and/or name	Lithology (Resource WP6 terminology)	Depth range (m)	GW age range (yr)
Aqt-1:	Clay tills	Clayey till	5-10	
Porosity type	Porous: ☐	Fissured: ☐	Fissured and porous / dual porosity: X	No hydraulically active porosity: ☐
Aqf-1:	Cretaceous chalk	chalk	~10 – ~25	>70
Porosity type	Porous: ☐	Fissured: ☐	Karst: ☐	Fissured and porous / dual porosity: X
Applied tracer age indicators (³ H, ³ H/ ³ He, ⁸⁵ Kr, ³⁹ Ar, ¹⁴ C, ³⁶ Cl, ⁸¹ Kr, ⁴ He, CFCs, SF ₆ , etc.) Applied recharge temperature indicators (¹⁸ O, D, noble gases)		Aquifer-1 ³ H/ ³ He, ⁴ He, ¹⁴ C,		
		¹⁸ O, D		
		Other applied isotope tracers: ⁸⁷ Sr/ ⁸⁶ Sr		
Number of sites (wells/springs) with age indicators		Aquifer-1 1-5: ☐ 5-10: ☐ 10-25: X >25: ☐		
GW age range (GAR) GAR-1: Modern (< 60 yr) GAR-2: Old (> 60 yr and <10 kyr) GAR-3: Paleowaters (> 10 kyr)		Aquifer-1 GAR-1: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-2: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: X GAR-3: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐		
Groundwater age ranges (GAR) estimated by:		Tracer based estimates X Flow and age model simulations ☐ Combination of model and tracer estimates (☐) Expert judgement: ☐		

Objective of age dating studies:					
Basic research or General groundwater management	Assessment of pollutant history		Assessment of the efficiency of remediation and mitigation measures		Indication of vulnerability of aquifers and water supply wells
X					X (towards salt water intrusion)
Water Usage <i>(not relevant for observation wells)</i>	Water supply		Irrigation	Industry	Other
	x		X		
Geoenergy related activities <i>(not relevant for observation wells)</i>	Shallow Geo-T	Deep Geo-T	Hydrocarbons		Nuclear waste disp.
Mining activities <i>(not relevant for observation wells)</i>	Construction materials		Minerals / metals	Coal	Other
REFERENCES					
OPEN Access reports and papers (PDF versions made available in EGD repository making them downloadable via maps and keyword / free text searches): Rasmussen, P., T. O. Sonnenborg, G. Goncear, and K. Hinsby. 2013. "Assessing Impacts of Climate Change, Sea Level Rise, and Drainage Canals on Saltwater Intrusion to Coastal Aquifer." Hydrology and Earth System Sciences 17 (1): 421–43.			Reports and papers with restricted access:		
The pilot site was part of the SubSol project on Subsurface Water Solutions: http://www.subsol.org/ (2015-2018), and presented with investigations of climate change impacts on other coastal aquifers primarily in the North Sea region in a HESS Open Access special issue (Hinsby et al., 2011, Assessing the impact of climate change for adaptive water management in coastal regions, special issue 149, Hydrological and Earth System Sciences: https://hess.copernicus.org/articles/special_issue149.html					