3.22 Description of the Skåne (SW and NE) case study, Sweden

Title of Case Study	Skåne (SW, NE)
Location (region, Country)	Skåne
Other information	

Description of Case Study (background information on the region)
The southernmost part of Sweden, known as Scania, is one of the country's most densely populated regions. Scania relies on groundwater for 50% of its water supply, and groundwater is also extracted for agricultural and industrial purposes. Groundwater pressure is substantial, both in quantitative and qualitative terms. Groundwater contamination is a prevalent concern throughout the region and during more recent years, certain areas have repeatedly suffered from seasonal groundwater shortages. With predicted effects of climate change, negative water balances are likely to become more prevalent in both time and space. Geologically and hydrogeologically, Scania is a heterogeneous and thus inherently complex though interesting region to study. The geological record is extensive, and the stratigraphy varies substantially within the region, often over relatively short distances. This is due to Scania's location, on a previously glaciated and once tectonically much active border region between Precambrian crystalline rocks of the Fennoscandian shield, and a range of sedimentary rocks typical to Phanerozoic Europe. Types of aquifers span fractured gneisses and sandstones, dual-porosity lime- and sandstones and a wealth of superficial to more or less buried glacifluvial deposits. The total amount of delineated groundwater bodies within the region is just over 200, most of which equals porous sand-gravel aquifers.

Description of problem (why is this location chosen for a Cases Study)
Scania is one of few regions in Sweden where groundwater age assessments have been performed. This is likely due to the relatively high regional groundwater pressure and thus vulnerability, as well as the Geological Survey of Sweden's local presence. The hydrogeological heterogeneity has also spurred a general interest for tracer methodology testing in the area in general.

Methods to be used in the Case Study (analytical and isotope techniques, modelling)
The Skåne-pilot relies solely on previous studies and has not involved any novel sampling or analysis. The pilot, however, is the first compilation and joint assessment of existing data, albeit on a relatively simplified and general, conceptual scale. Available data mainly involves sporadic, single, isolated tracer analyses in individual long-screened pumping wells. Tritium is the overall most common tracer applied though later work has also included CFCs, SF_6, noble gases, ^{3}H-^{3}He, ^{39}Ar and ^{85}Kr. ^{14}C-analyses are known from some areas.

Results from this Case Study
The amount of available tracer data from Skåne is relatively substantial. However, thorough analyses of age ranges and hydraulics within individual aquifers are scarce. Limitations include a lack of longer time-series, multi-tracer analyses and analyses from observation-wells. Regional groundwater management would benefit from more holistic and systematic analyses of existing and supplementary tracer data, including coupled tracer-modelling assessments of age ranges

and hydraulics, with the aid of (in places already existing) numerical hydrogeological models.
Groundwater ages in aquifers in the region vary from <1 yr to >10 kyrs. At specific locations within Skåne, one may observe general trends and patterns in terms of groundwater age with e.g. depth. However, due to the general hydrogeological heterogeneity, patterns are oftentimes inherently difficult to deduce over some distance, both vertically and horizontally. Rather, on a regional scale and with regards to existing tracer data, it appears more suitable to discuss and infer GAR at a given location depending on the specific aquifer type in question, specifically with regards to porosity type (possibility for fissure flow or not) and level of confinement. E.g., surficial, unconfined porous aquifers are likely to exhibit relatively narrow groundwater age ranges spanning mainly recent decades, with a relatively young mean groundwater age. Deep, semi-confined aquifers with possibility for fissure flow may, at the other end of the scale, exhibit relatively wide groundwater age ranges spanning hundreds to thousands of years. While the mean groundwater age ought to be somewhat older, the most recent contributions might still be significantly young, i.e. <1 yr.
Overall, modern waters (< 60 yrs) appear considerably present down to standard depths for drinking water wells in most aquifer types throughout the region, indicating a large degree of regional vulnerability in terms of e.g. pollution risk. The only apparent exception in this regard - based on available data - appears to be narrow portions of deep, confined aquifers.
In terms of specific tracers, previous studies have shown that:

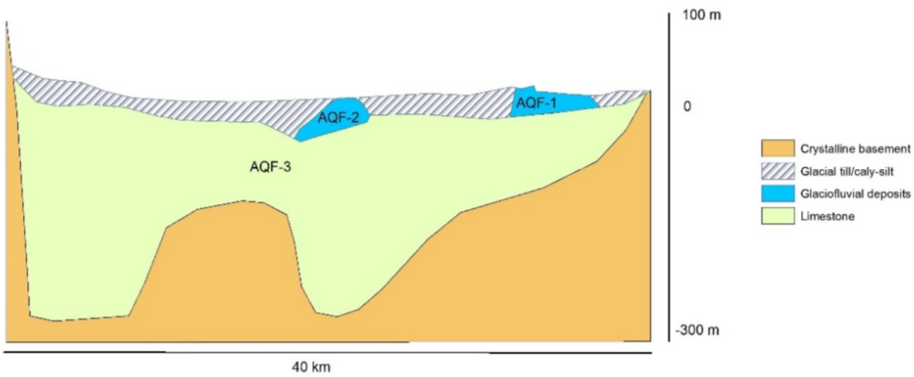
- SF_6-concentrations throughout the region are among the highest ever reported and are interpreted to stem from natural sources. Accordingly, SF_6 does not appear a suitable groundwater tracer in the area. However, the region ought to be considered an interesting site for studies into natural SF_6-sourcing.
- He-concentrations are generally high, suggesting Skåne is an interesting area for studies into the mechanisms and rates of radiogenic ^{4}He release in mixed young groundwater.
- Local contamination sources of CFC’s appear regionally considerable.

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

This case study contributes to:

- Establishing a European-wide harmonized database on groundwater age tracers and indicators.
- Identifying and describing important European aquifers with a significant amount of age indicators.
- Demonstrating the use (and limitations) of groundwater age tracer analyses with regards to characterisation and management of important European aquifers.

<table>
<tr><td colspan="2">Name of pilot area / aquifers / type:
Skåne NE / Quaternary sand aquifers, Cretaceous limestone and sandstone aquifer / porous, dual-porosity</td><td colspan="4">Country: Sweden

Region: Skåne</td></tr>
<tr><td>Study level</td><td colspan="2">Transboundary: ☐</td><td>Regional: x</td><td>Local: ☐</td><td>Single well(s): ☐</td></tr>
<tr><td>Type of observations
(choose one of the options, create separate template if needed for each type if each type need specific information)</td><td colspan="5">☐ Short screened observation wells (not pumped)
☐ Long screened observation wells (not pumped)
X Pumped wells, long screens in one aquifer
☐ Pumped wells, long screens over multiple aquifers
☐ Springs
☐ Other (eg. research wells; indicate type and information on pumping):</td></tr>
<tr><td>Approximate location of pilot:</td><td colspan="5">
</td></tr>
<tr><td>Geological cross section / conceptual model of the pilot area:</td><td colspan="5">
</td></tr>
<tr><td colspan="2">Name of Shape- / Geopackage file defining the area:</td><td colspan="4">Projection to be used:
WGS84 (Epsg4326)</td></tr>
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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)**
	600-800	<200-300	8-9	0-5 m
Pumped wells only		**Typical pump discharge of sampled individual well (m^3/day):** 1-1000		**Typical pump discharge of complete well field (m^3/day): -** *If relevant*
List of aquifers and aquitards in pilot area* **Given no:s = along cross section < within full pilot area*		**No. of confined or semiconfined aquifers in pilot area:** 2		**No. of unconfined aquifers in pilot area:** 1
Aquifer no. (aqf): 3 **Aquitard no. (aqt):** 1	**Aquifer/aquitard type and/or name**	**Lithology *(Resource WP6 terminology)***	**Depth range (m)**	**GW age range (yr)**
Aqf-1:	Glaciofluvial deposits, locally confined	Fine sand to gravel	0-30	<5 - >60
Porosity type	Porous: X	Fissured: ☐	Karst: ☐	Fissured and porous / dual porosity: ☐
Aqt-1:	Glacial till/clay-silt	Clay-silt, clayey-clay till		
Porosity type	Porous: ☐	Fissured: ☐	Fissured and porous / dual porosity: X	No hydraulically active porosity: ☐
Aqf-2:	Glaciofluvial deposits	Fine sand to gravel	0-50	<5 - >60
Porosity type	Porous: X	Fissured: ☐	Karst: ☐	Fissured and porous / dual porosity: ☐
Aqf-3:	Cretaceous limestone and glauconitic sandstone	Limestone, sandstone	20-300	<5 - >5 000
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, $^{3}H/^{3}He$, ^{4}He, CFC, SF_6, noble gases **Aquifer-2** ^{3}H, $^{3}H/^{3}He$, ^{4}He, CFC, SF_6, noble gases **Aquifer-3** ^{3}H, $^{3}H/^{3}He$, ^{4}He, CFC, SF_6, noble gases, ^{14}C		

Number of sites (wells/springs) with age indicators	**Aquifer-1** **1-5: X* 5-10: ☐ 10-25: ☐ >25: ☐** **Total no. of samples from similar type-aquifers within the greater pilot area*
	Aquifer-2 **1-5: X* 5-10: ☐ 10-25: ☐ >25: ☐** **Total no. of samples from similar type-aquifers within the greater pilot area*
	Aquifer-3 **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%: X** **GAR-2: 1-10%: X 10-25%: ☐ 25-50%: ☐ >50%: ☐** **GAR-3: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐** **GAR extrapolated from similar aquifer-type in greater pilot area*
	Aquifer-2* **GAR-1: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: X** **GAR-2: 1-10%: ☐ 10-25%: X 25-50%: ☐ >50%: ☐** **GAR-3: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐** **GAR extrapolated from similar aquifer-type in NW Skåne*
	Aquifer-3 **GAR-1: 1-10%: ☐ 10-25%: ☐ 25-50%: X >50%: ☐** **GAR-2: 1-10%: ☐ 10-25%: ☐ 25-50%: X >50%: ☐** **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: X**

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

Water Usage *(not relevant for observation wells)*	**Water supply**	**Irrigation**	**Industry**	**Other**
	x	x	x	

Geoenergy related activities *(not relevant for observation wells)*	**Shallow Geo-T**	**Deep Geo-T**	**Hydrocarbons**	**Nuclear waste disp.**	**CO_2 storage**
	x				

Mining activities *(not relevant for observation wells)*	**Construction materials**	**Minerals / metals**	**Coal**	**Other**
	x			

REFERENCES

OPEN Access reports and papers (PDF versions made available in EGDI repository making them downloadable via maps and keyword / free text searches):	**Reports and papers with restricted access:**
Gustafsson O., Andersson J-E. and De Geer J., 1979. Sammanställning av hydrogeologiska data från Kristianstadslätten. SGU-Ser. Rapporter och meddelanden 12. Sveriges geologiska undersökning/Geological Survey of Sweden. **Gustafsson O., Jonasson S.A., Magnusson E. and Andersson C., 1988.** Grundvattenundersökningar på Kristianstadslätten 1976–1987. SGU-Ser. Rapporter och meddelanden 52. Sveriges geologiska undersökning/Geological Survey of Sweden. **Persson G.N., 1974.** Tritium data from groundwater in the Kristianstad plain, southern Sweden. Conference abstract. IAEA-SM-182/3. **Åkesson M., 2014.** On the scope and assessment of pesticides in groundwater in Skåne, Sweden. LUNDQUA Thesis 74. Quaternary Sciences, Department of Geology, Lund University.	**Possnert G. 2008.** Ålder – en väsentlig kvalitet. Single analysis report to Malmberg Borrning AB from Ångströmslaboratoriet, Uppsala University 2008-07-07. **Åkesson M., Suckow A., Visser A., Sültenfuss J., Laier T., Purtschert R. and Sparrenbom C.J., 2015**. Constraining age distributions of groundwater from public supply wells in diverse hydrogeological settings in Scania, Sweden. Journal of Hydrology 582: 217-229.

Remarks / other relevant information:

The conceptual model is, obviously, a simplification but meant to visualise general stratigraphy and aquifer types within the region, and the general GAR-pattern. Please note that AQF-1, AQF-2 and AQT-1 are not spatially continuous units and that within the entire region, there are really several AQF-1's, AQT-1's and AQF-2's. Also, AQF-3 is sometimes regarded as two separate hydraulic units: an upper dual-porosity limestone aquifer, and a lower porous glauconitic sandstone aquifer.

The provided information on age range for AQF-1 and -2 is based on information from similar aquifer types in the region, although not from the specific aquifers along the given section.

Note that tracer data and thus GAR-estimates ought to be regarded as maximally representative down to standard depths of drinking water wells (here max c. 100-150 m).