A hydrogeological model for groundwater management under climate change of a shallow low-lying coastal aquifer in southern Finland

Samrit Luoma & Birgitta Backman
Geological Survey of Finland, GTK

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Introduction

- A shallow permeable low-lying coastal sand aquifer in southern Finland is vulnerable to the climate change and human activities
- Under future climate change, a rise in sea-level would cause some parts of the aquifer and the water intake well to be under seawater
- Together with the predicted increase in precipitation, would enhance groundwater recharge and raise the water table, consequently contributing to the potential deterioration of groundwater quality or potential flooding in the low-lying aquifer area
- An information on geological and hydrogeological characteristics of the aquifer for the climate change adaptation plan including the possible new locations of water intake wells was needed

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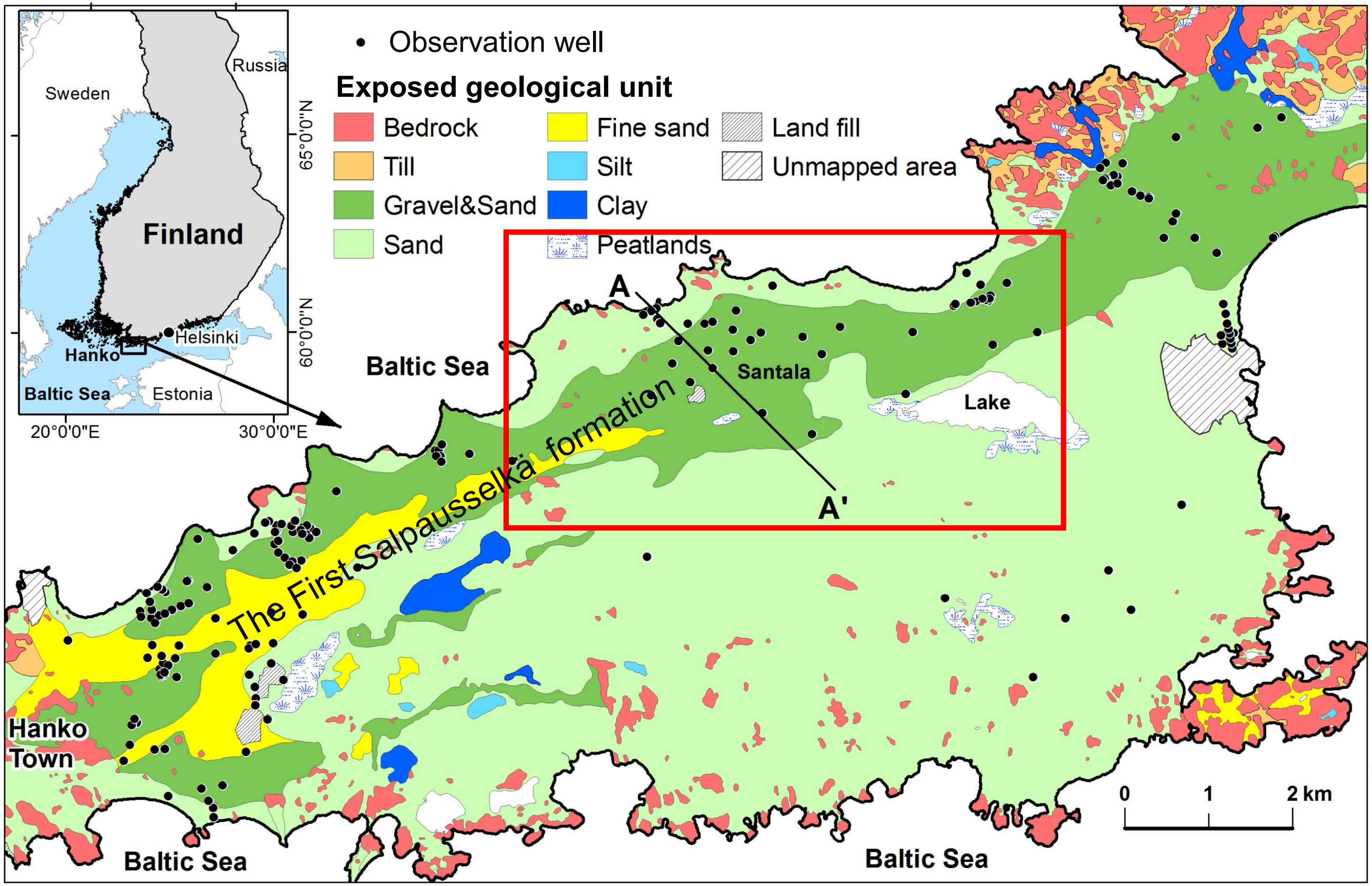
Objectives of the study

- to construct a three-dimensional (3D) geological model and evaluate heterogeneity of the shallow aquifer in Santala, southern Finland to provide a geological framework for groundwater flow model and the assessment of groundwater vulnerability
- to provide the data to support the water supply protection and groundwater management plan in the future

Location and Quaternary geological deposit map of the study area in Santala, south Finland

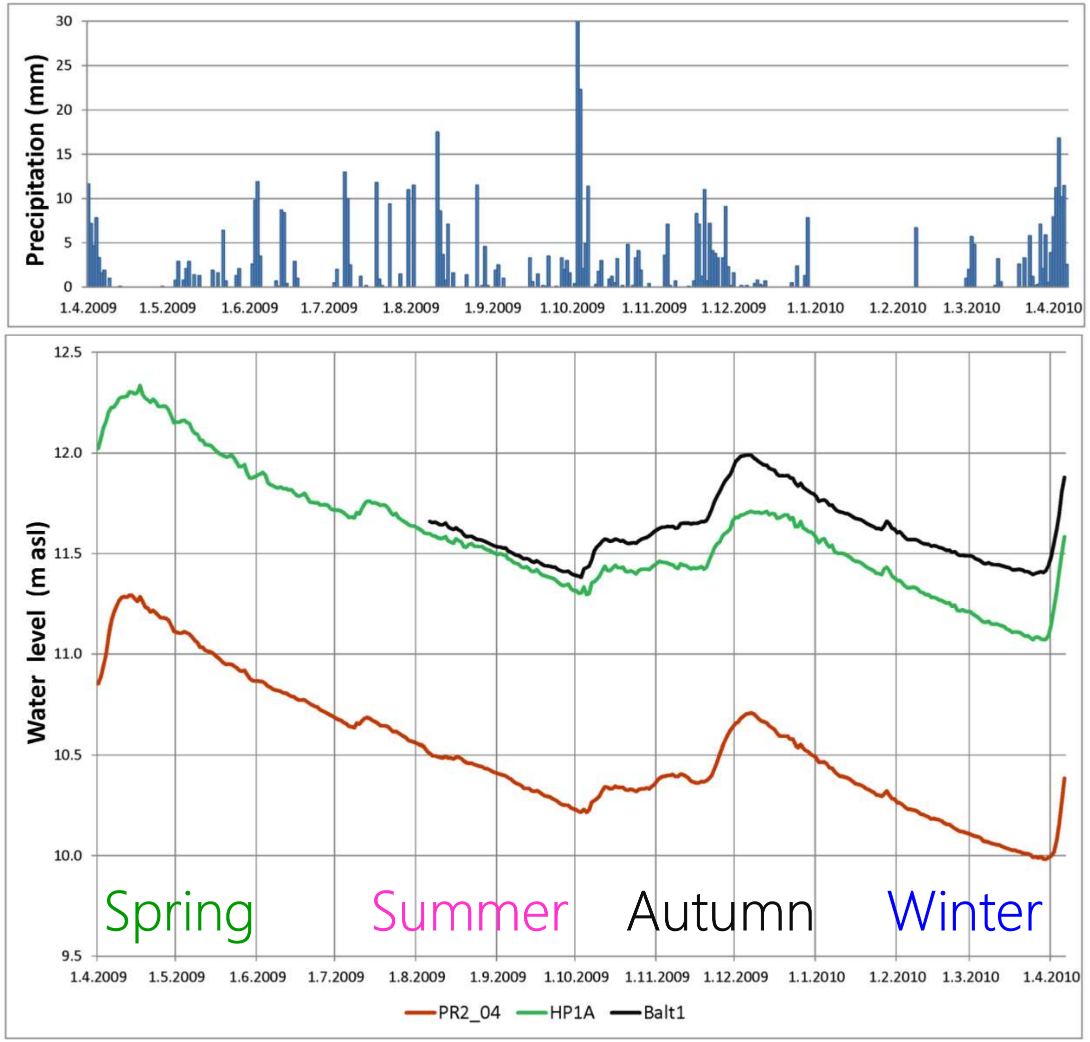


The study area – the shallow aquifer of Santala, southern Finland

- An important local drinking water resource and the main production of water supply in the area
- Already treated sources (e.g. industry contaminants, gravel extraction)
- Sensitive for climate change (GW table close to ground surface, aquifer extends to sea shore, water pumping already below sea water level)

- Need to get knowledge for water supply protection also for the future groundwater management plan

Precipitation and groundwater tables of wells in the middle of aquifer area in during April 2009 – April 2010



- The groundwater levels have rapidly responded to recharge from the spring snowmelt and rainfall

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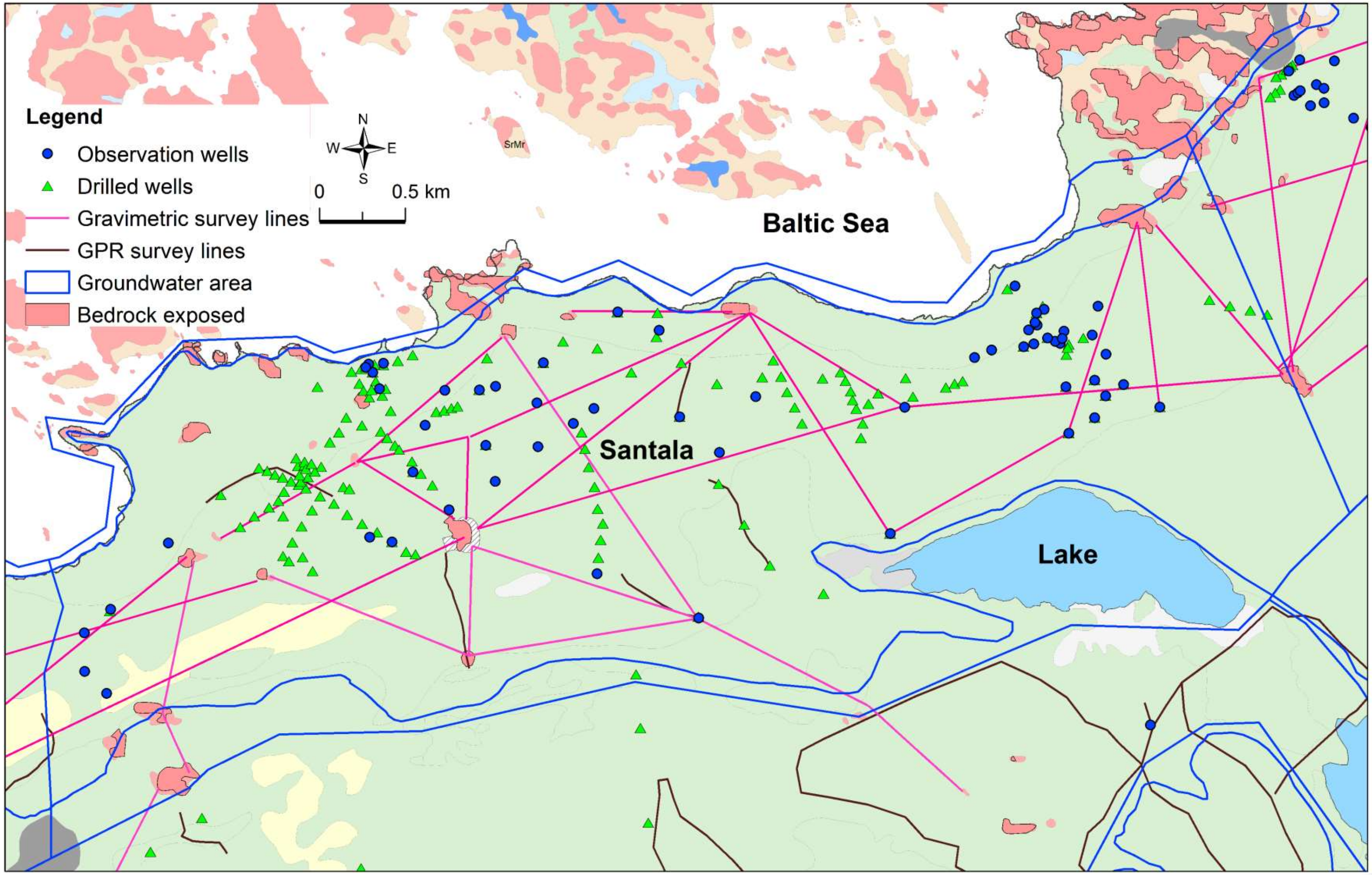
A map presenting the data used in this study



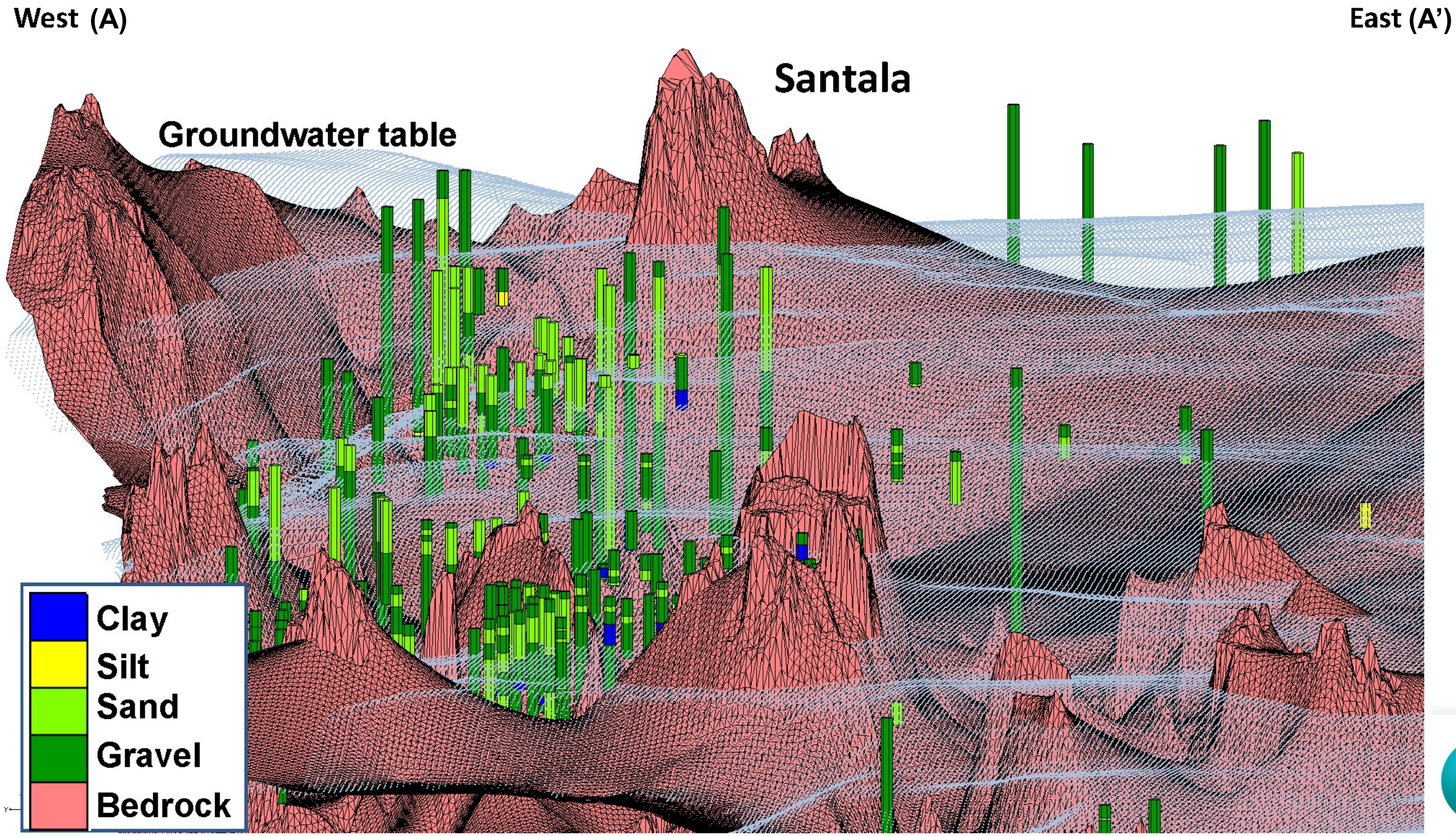
Groundwater area © SYKE).

Methods

The methods used consist of:

- a stochastic-geostatistical approach incorporated with groundwater flow model to predict the distributions of the superficial layers of a heterogeneous aquifer and to identify the distributions of the aquifer medias (sand and gravel) as well as groundwater flow system
- the LiDAR-based digital elevation model was utilized to define the flood prone areas under the climate change scenarios

The distribution of drilled wells in Santala, presented with the main four soil types: gravel, sand, silt & clay



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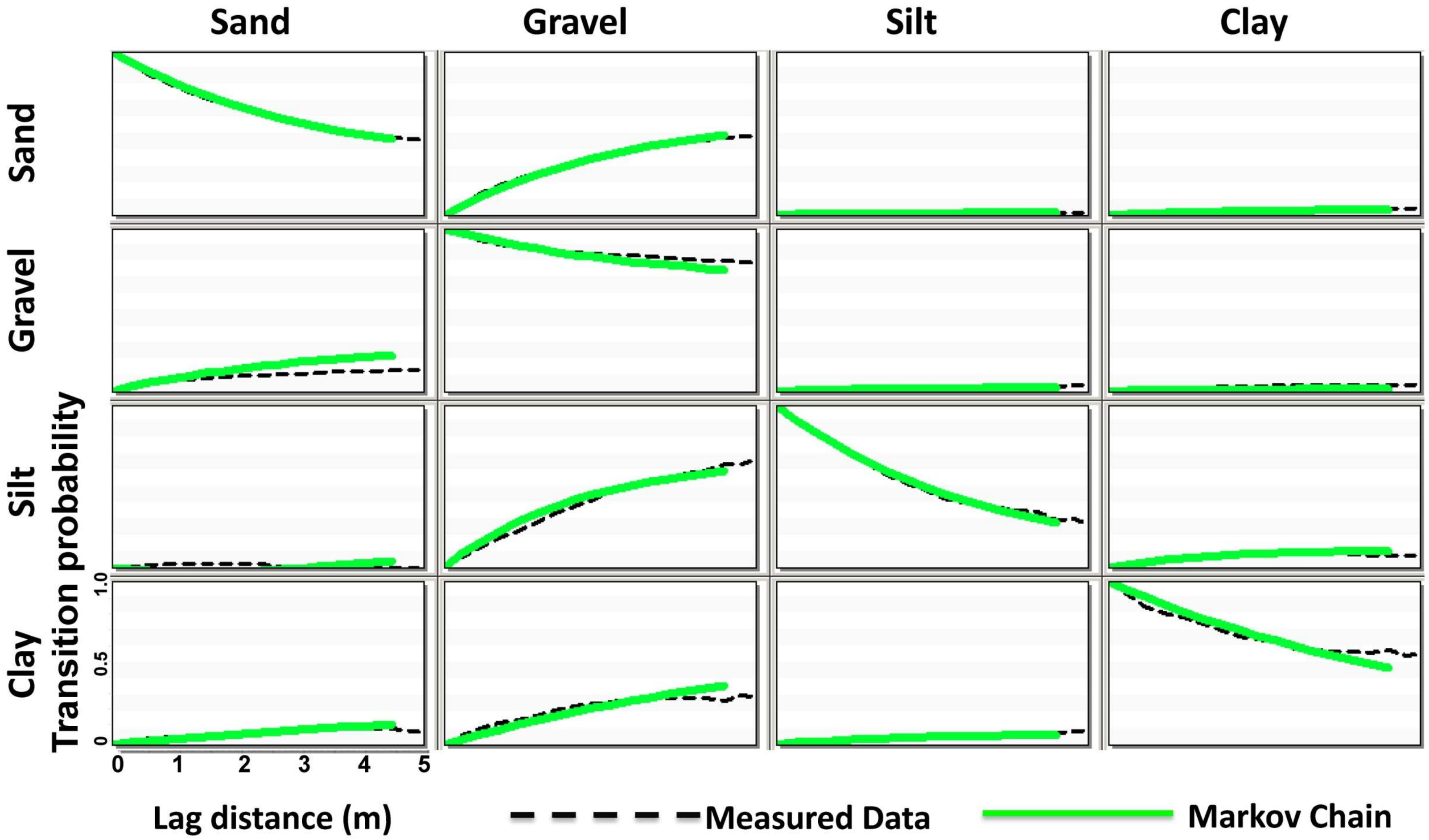
Transition probability & Markov chain analysis

- Matrix of vertical (z)-direction transition probabilities showing measured data from drilled wells (dash lines) and the Markov chain model (solid lines). The diagonal elements represent auto-transition probabilities within a category, and the off-diagonal elements represent cross-transition probabilities between categories.



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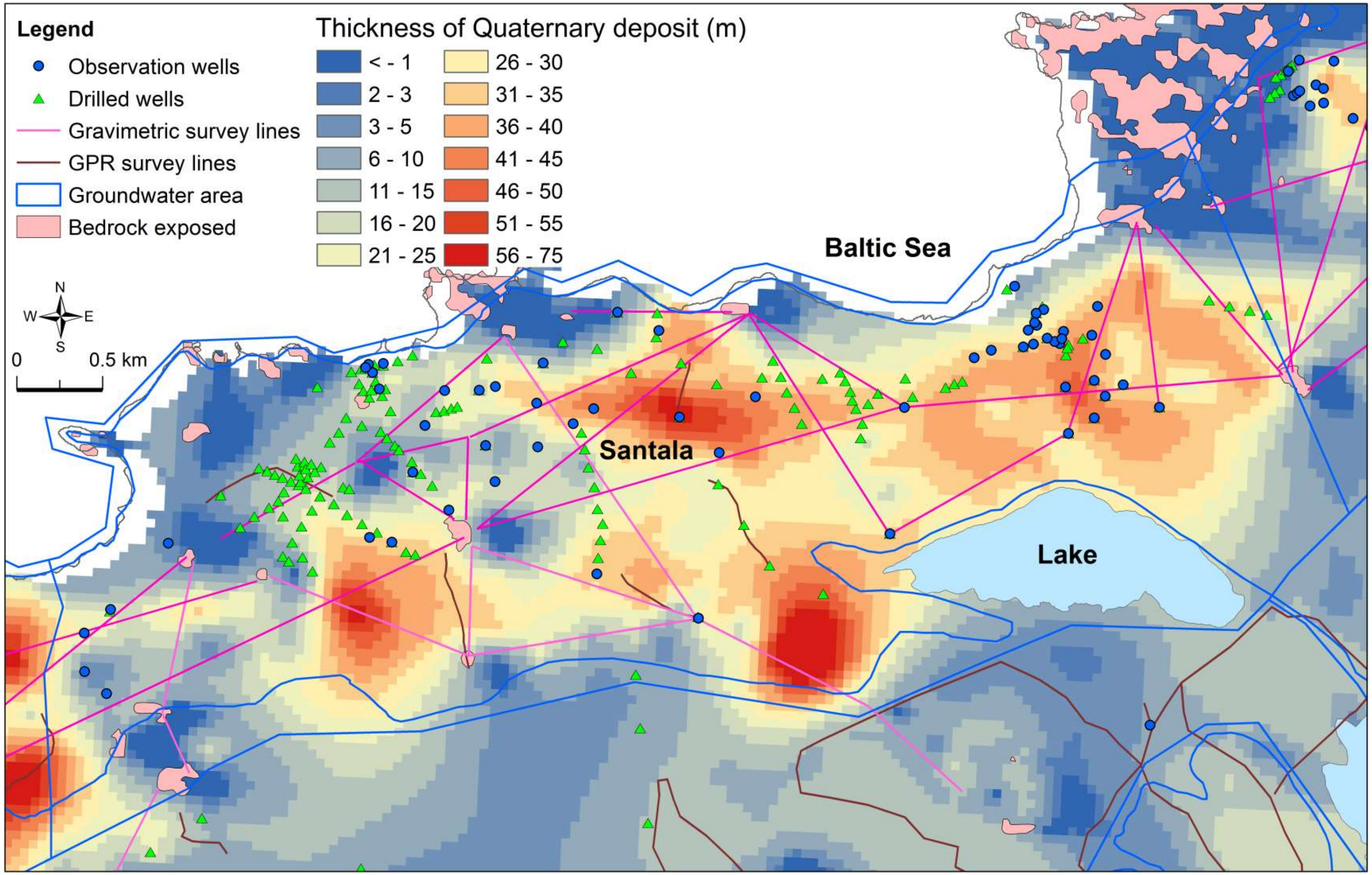
Results:

A map of thickness of the Quaternary deposit



Groundwater area © SYKE 2016).

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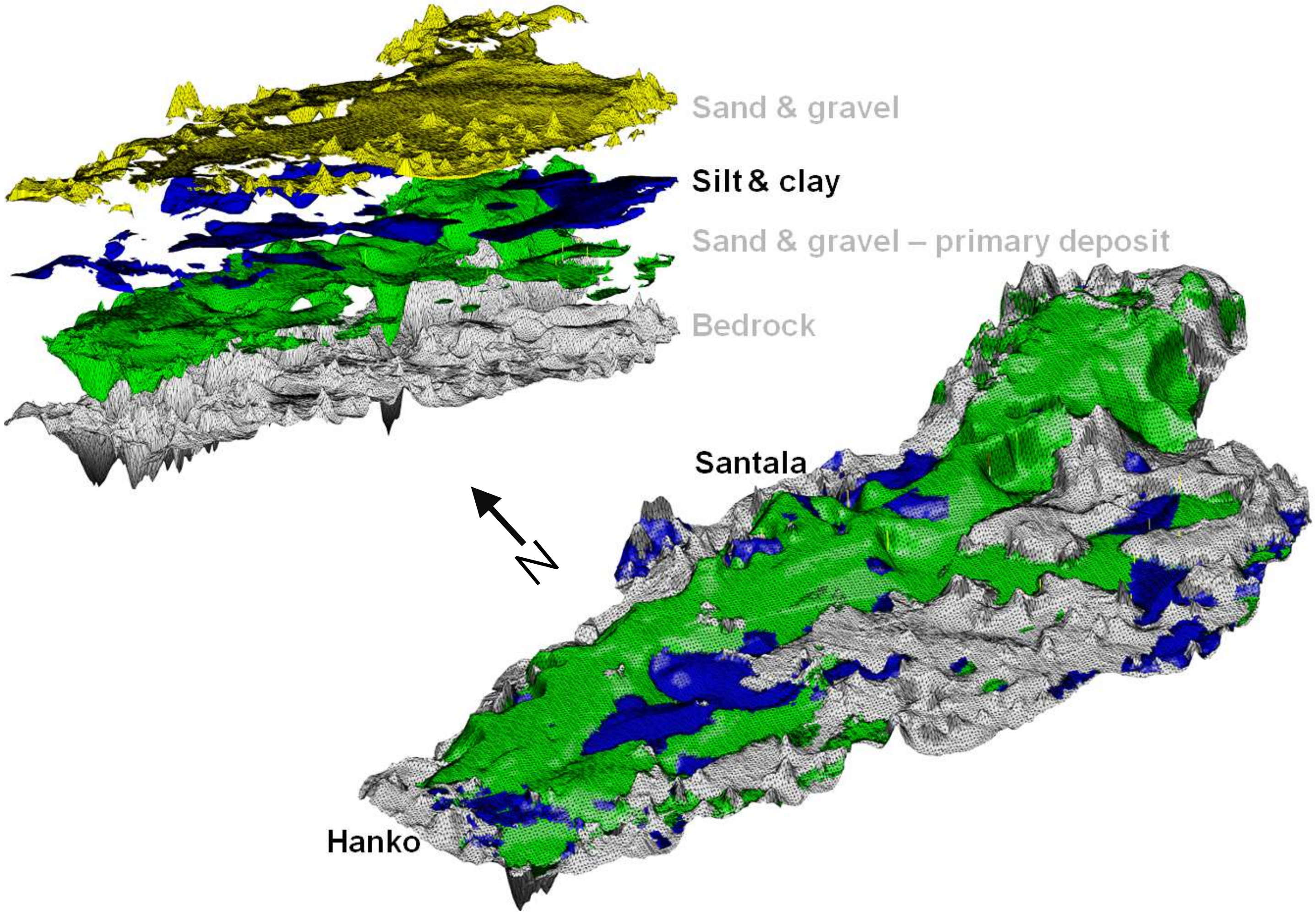
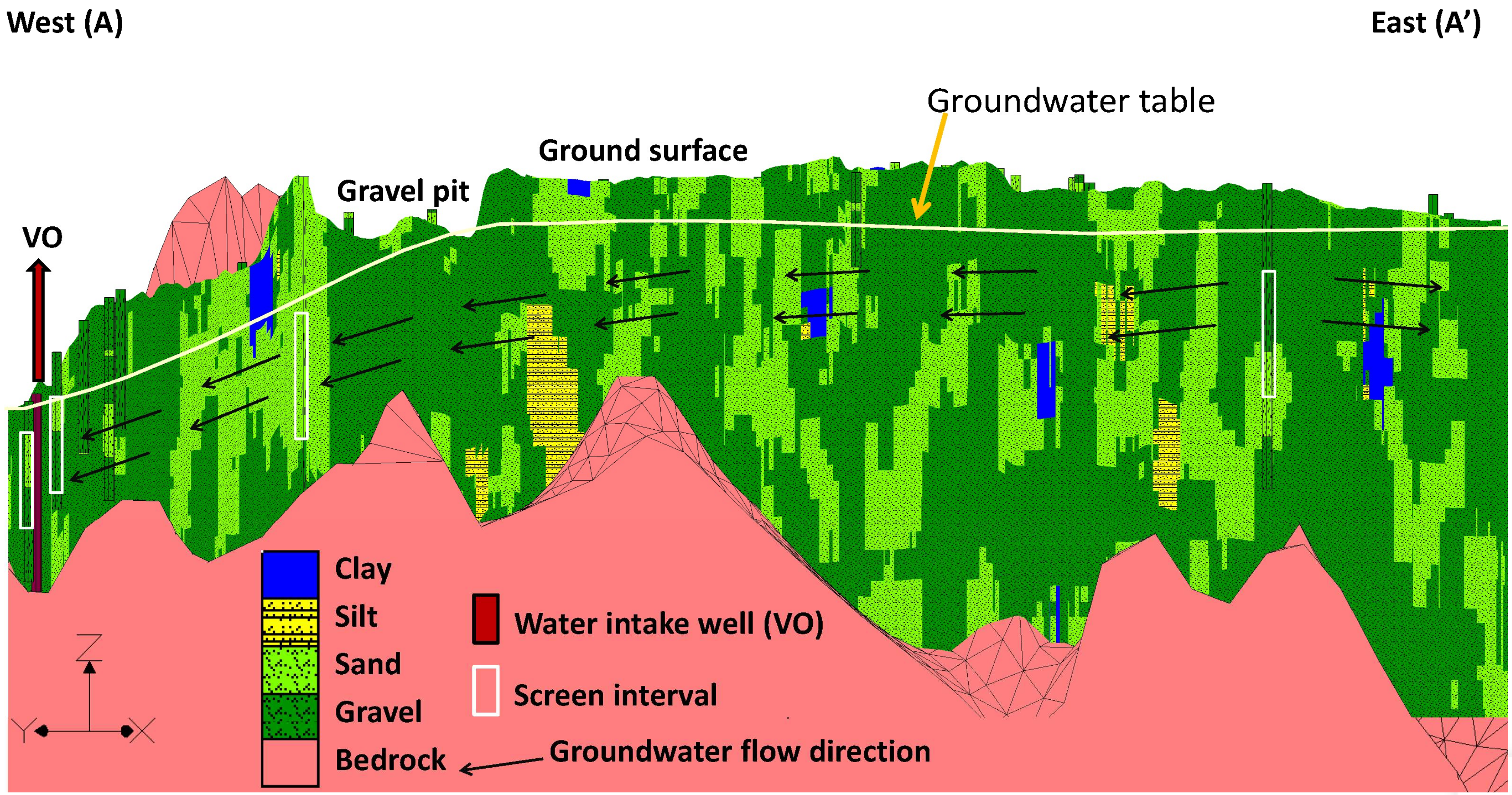
3D distribution of the main depositional units in Santala - Hanko aquifer area



A cross-section along West-East (line A-A'), presenting the spatial distribution of aquifer materials generated by transition probability (T-PROGS) / Markov geostatistics approach.



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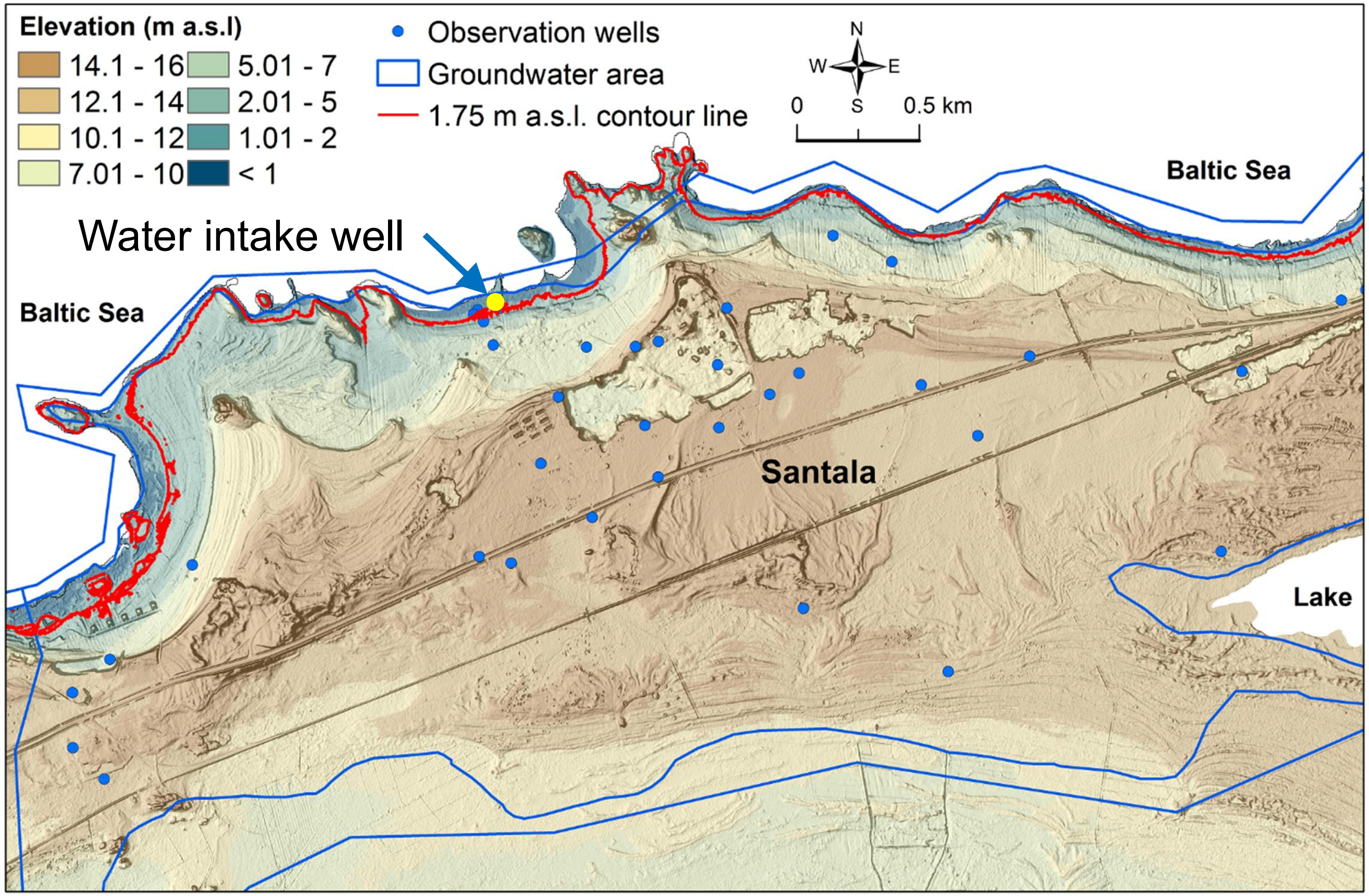
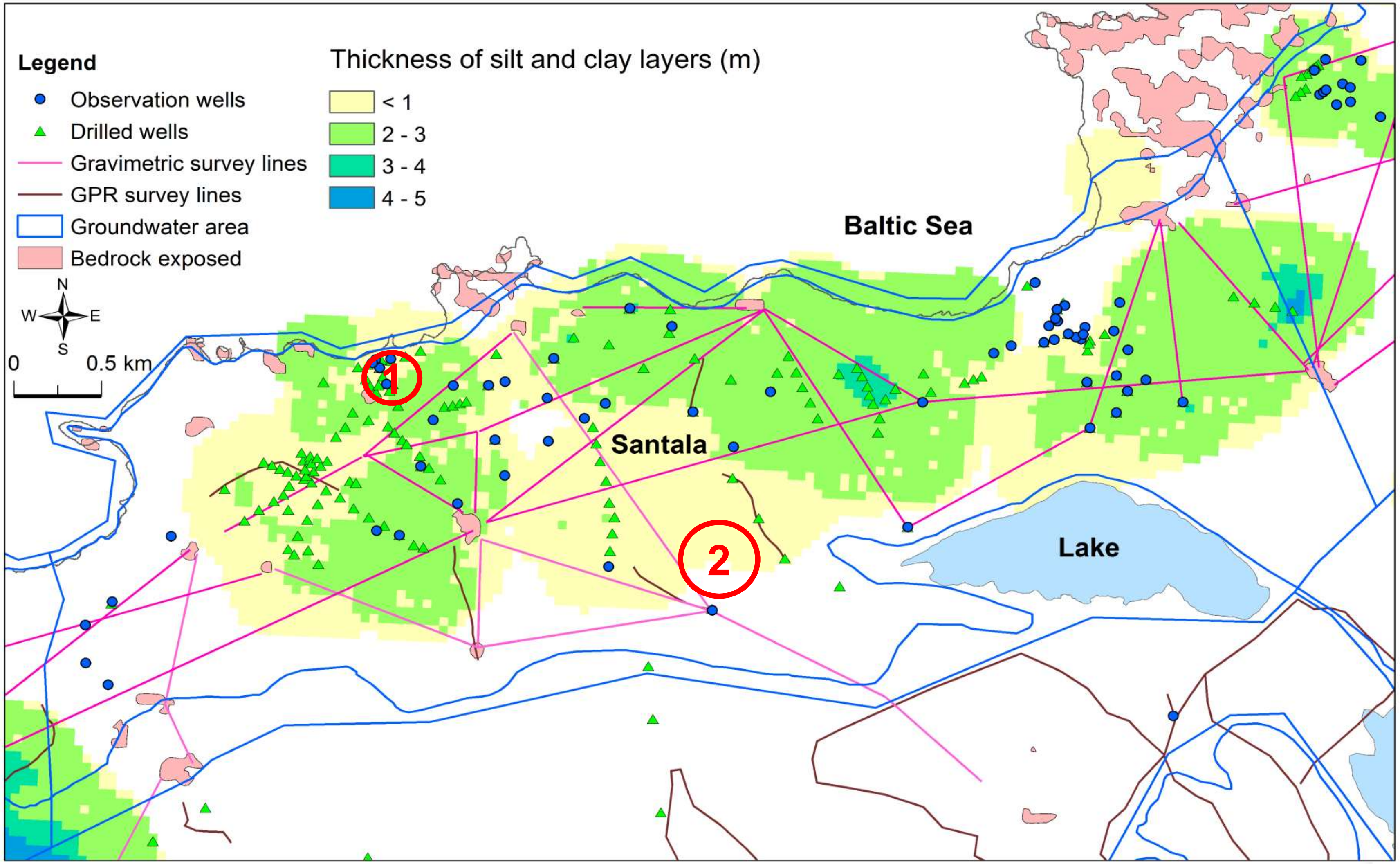
Elevation (LiDAR DEM) map of Santala area



(Topographic LiDAR Database © National Land Survey of Finland 2016; Groundwater area © SYKE).

- The highest sea-level rise at +1.24mN60 during the storm surge on 9.01.2005 base on data from 1887
- Possible maximum sea-level rise due to storm surge by the end of 2100 could reach 1.75 m a.s.l.
- The area below the 1.75 m contour line was defined as a flood prone area due to the sea-level rise and storm surge, including the current water intake well location

The proposed new locations of water intake wells



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Discussion and conclusions

- The 3D geological model provides a better characterization of the heterogeneity of the aquifer and improved reliability of subsequent groundwater flow model and vulnerability assessment in the aquifer area
- With the integration of those data and the groundwater risk areas, two proposed new locations of water intake wells were provided to the local authorities for groundwater management in future:
    - Location 1: further inland above the flood prone area
    - Location 2: the eastern part of the aquifer area, where the aquifer body is large and good yield