Project title	Sub-Marine Groundwater Discharge to the Sea
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Project description

Many countries around the world are surrounded by oceans. In Denmark, rivers are the primary corridor for discharge of freshwater from coastal catchments to oceans. This discharge is easily measured. The largest uncertainties on the water balance for coastal catchments are typically associated with the input of water, i.e., measurement and quantification of precipitation and evapotranspiration. Diffuse groundwater discharge to the ocean is often neglected because it can be very difficult to measure and quantify. This loss of water can potentially be a big and unknown component in the water balance. Especially sub-marine discharge through deeper formations is difficult to quantify, mainly because the geology of coastal formations is often not well understood as there is limited interests in groundwater resources in these areas. Also, the location of the saltwater-freshwater boundary is not known precisely and therefore the thickness of the freshwater zone available for groundwater discharge is uncertain.

The main objective of the project is to quantify groundwater discharge to the sea from both shallow and deep groundwater aquifers of the Skjern River Catchment (SRC). The following tasks are envisioned; (1) Construction of a geological model for the coastal zone using existing data and new geophysical explorations, (2) Interpretation of geophysical mappings of the saltwater-freshwater interface, (3) Use of well tests and groundwater sampling to characterize aquifers, (4) Numerical modelling of the saltwater-freshwater interface, and (5) Estimation of sub-marine discharge to the sea from the SRC using a hydrological model.

(i) A geological model for the area of Ringkøbing Fjord in the western part of SRC should be constructed. The model should be based on existing large-scale geological models, new 200 m deep groundwater wells, and new geophysical data collected through SkyTEM surveys and seismic explorations.

(ii) Information on the location of the saltwater-freshwater interface in the Ringkøbing Fjord area should be inferred from the SkyTEM surveys and from the results of borehole logging in the deep wells. Based on these results and a co-interpretation with the geology, a map of the depth to the saltwater–freshwater interface for the examined areas is to be constructed.

(iii) Hydrogeological information should be collected from borehole logging, pump tests, and environmental tracers (^{14}C, ^{39}Ar) in order to assess transmissivity and groundwater age.

(iv) A two-dimensional saltwater model should be constructed for the east-west oriented cross sections through the Ringkøbing Fjord, where the SkyTEM surveys have been carried out. The saltwater models can be used to predict the location of the saltwater-freshwater boundary given the established geological model and inferred hydraulic parameters. The model should provide insight into the dynamics of the freshwater flux and the stability of the saltwater boundary. The uncertainty of the location of this boundary as a function of, e.g., hydrogeological parameters and boundary conditions should be evaluated.

(v) An existing three-dimensional hydrological model for the SRC should be used to quantify the total groundwater discharge to the sea. The new geological model should be incorporated and the knowledge about the location of the saltwater-freshwater interface should be build into the model as boundary conditions (e.g. sharp interface). The model will be used to quantify where and how much groundwater is discharging from the SRC and to analyse where the freshwater emerges off-shore through the sea bottom of the North Sea. Quantification of the shallow groundwater flux to Ringkøbing Fjord may also be carried out through manual measurements if needed.