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Detailed monitoring and simulation of groundwater salinity in response to extractions in a coastal aquifer system

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High-resolution three-dimensional variable-density groundwater flow and coupled salt transport models (abbreviated 3D-VD-FT models) are useful instruments to support coastal groundwater management strategies and to forecast impacts of climate change. However, the ability of 3D-VD-FT models to provide accurate groundwater salinity predictions depends on computational capabilities, availability of sufficient and adequate high-resolution data and understanding of coastal groundwater salinity processes in the subsurface. Often, local aquifer heterogeneities are simplified in numerical models. In doing so, flow and transport are simplified, and consequently, local groundwater salinity changes become difficult to predict accurately.

New avenues in data acquisition and computational methods have opened up the possibility to greatly improve the accuracy of predictions. Recent developments in innovative geophysical monitoring methods are able to observe salinity and (indirect) flow velocities in detail. For instance, one can use automated measurements with Electrical Resistivity Tomography (abbreviated ERT) to monitor salinity changes. In addition, new parallelization methods are able to overcome computational challenges that plague 3D-VD-FT models.

In this research, we are examining the ability of 3D-VD-FT models to reproduce observed groundwater salinity changes during multi-level groundwater extractions and the impact of these extractions on upconing and subsequent downconing of brackish and saline groundwater. To achieve this, we are developing a 3D-VD-FT model that is able to simulate groundwater salinity changes at high resolution that occur in response to multi-level groundwater extractions during the brackish groundwater extraction pilot project FRESHMAN in Scheveningen. The FRESHMAN project allows for a unique view in the subsurface during groundwater extractions due to close monitoring by innovative geophysical monitoring methods such as ERT.

Preliminary results show that heterogeneity of the aquitard in the study area can affect the ability of the 3D-VD-FT model to reproduce observed groundwater salinity changes. For instance,

accounting for potential high conductivity conduits in the aquitard can improve the fit of the observed upconing to the simulated upconing. To account for heterogeneity of the aquitard, sequential indicator simulation will be applied to generate multiple realizations of the aquitard. For each realization, the 3D-VD-FT model will be run and results subsequently evaluated in terms of fit and the best-fitting realizations selected. In addition, for the selected best fit realizations, hydrogeological model parameters will be further optimized using PEST in combination with chloride measurements.