Netherlands Hydrological modelling Instrument for fresh and saline groundwater in the Dutch coastal zone

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ABSTRACT

The so-called Netherlands Hydrological modelling Instrument (NHI) includes a module to take into account fresh and saline groundwater in the coastal zone. This paper informs you about this NHI fresh-saline groundwater module, which assesses on a national scale the impact of stresses such as sea level rise, land subsidence, increasing groundwater extraction and changes in natural groundwater recharge on groundwater in the Dutch coastal zone. Modelling results show that the water system significantly becomes more saline these coming 50-100 years, and that water courses need to be flushed more intensively if water boards want to maintain the water quality in the surface water system. This module is ready to play a role in assessing the effectiveness of mitigation and adaptation strategies to make our water system climate proof.

INTRODUCTION

Nowadays, one of the major water issues in the low-lying Netherlands is to make The Netherlands climate proof for the coming century. Second to safety against flooding, climate proof fresh water supply is a top priority in the Delta Programme and in the National Water Plan. To assist water managers in their choices to make our country ready for future stresses such as flooding, drought, land subsidence and salinisation, a modeling framework has been set up. This Netherlands Hydrological modelling Instrument (NHI) will be one of the tools within the Delta programme to assess the impacts of future stresses to the water system and to come up with feasible and robust strategies for future water management. In the Dutch coastal zone, brackish to saline groundwater is an important driver for the salinisation of the surface water system, and thus, a fresh saline module on a national scale is needed within NHI. This so-called NHI fresh-saline groundwater module is discussed within this paper. It considers the following physical processes: 1. the autonomous internal salinisation due to past head differences in the top system (e.g. sea level relative to low-lying polder water levels), 2. climate change, 3. land subsidence, and 4. water level variation in the large fresh water lake IJsselmeer.

METHODS

National databases on topography, geology (REGIS), chloride concentration (combining Vertical Electrical Soundings (VES), borehole measurements and analyses with the brackish-saline interface within the ZZREGIS database), geohydrology (extraction rates) and hydrology (surface water system, precipitation, evapotranspiration, drain and water channels characteristics) are used to set up the 3D module for the simulation of variable-density groundwater flow and coupled salt transport. The initial chloride distribution is determined with 3D interpolation of analyses, VES and borehole measures via geostatistical procedures and a mapped brackish-saline interface of 1000 mg Cl^{-}/l (taking into account the geological set-up of the groundwater system), see Figure 1. The module is constructed with the code MOCDENS3D (Oude Essink, 1999). The dimension of the covered area is 325 km by 300 km by 290 m thick, whereas over 20.6 million active model cells of 250*250m^2 were used in 31 model layers (the top layers are thinner than the lower ones) to characterize the vertical distribution of fresh-brackish and saline groundwater with enough detail. A 64 bit compiler was used to make the simulation of this large number of model cells possible, whereas the MOCDENS3D code has been optimized to efficiently process large amounts of data. Controls with salt load data out of several polder areas are executed to increase the reliability of the module.

SOME PRELIMINARY RESULTS

Figure 1 shows some snap-shots of the 3D chloride distribution, based on monitoring results and interpolation techniques. The distribution of fresh, brackish and saline groundwater is closely related to the Holocene transgressions, as during these transgressions, saline water could easily and rapidly infiltrate the aquifers via free convection. In the hinterland, however, old marine evaporate deposits also contributes to high chloride concentrations. Figure 2 shows that the groundwater system in the coastal zone is brackish to saline within some tens of meters, and that inversions of saline-fresh groundwater occur in the top system. The module shows that variable-density groundwater should be considered in the coastal zone, as otherwise incorrect head and flow patterns occur (Figure 3). Salt load to the surface water system is severe in the low-lying polders where seepage values are large and the chloride concentration is brackish to saline (Figure 4). The zone of influence is surprisingly limited to areas within 10 km of the coastline and the main rivers. The reason is that the increased head in the first aquifer coast can easily be released through the highly perforated Holocene confining layer (e.g. by sandy layers).

CONCLUSIONS

A 3D variable density groundwater flow and coupled salt transport module (on a 250*250m^2 grid) has been be constructed to analyze the effects of water management strategies on climate proof fresh water supply on the national level of The Netherlands (scale 325*300km^2, consisting of ~20 million model cells). No difficult numerical problems were detected (e.g. salt-fresh inversions can easily be included) when executing 100-year-simulations with computation times of only some days.

REFERENCES

Oude Essink, G.H.P. 1999. Simulating 3D density dependent groundwater flow: the adapted MOC3D. Proc. 15th Salt Water Intrusion Meeting, Ghent, Belgium: 69-79.

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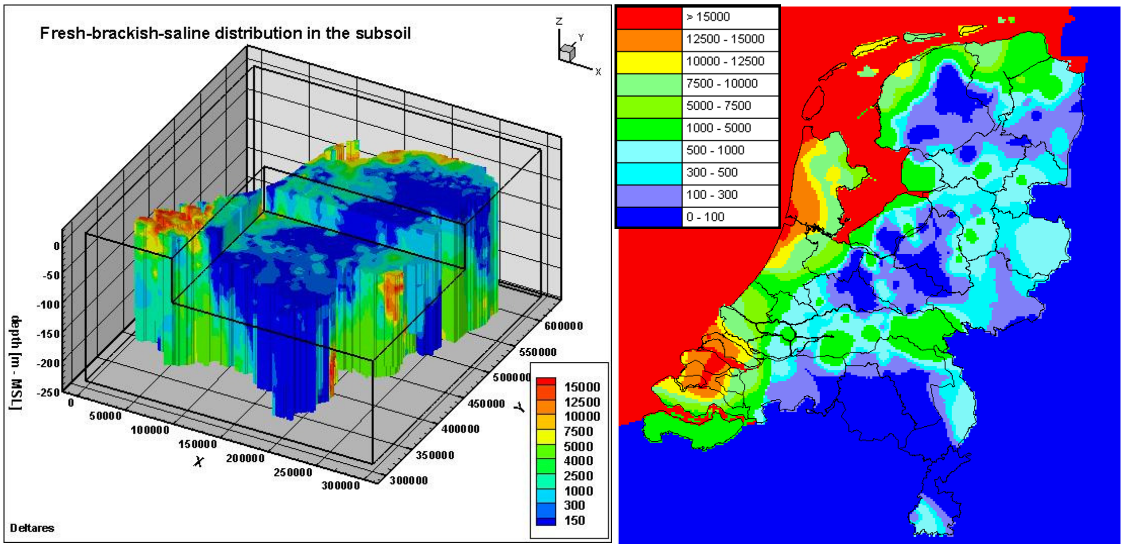

Figure 1. a. 3D chloride distribution, b. chloride distribution in the horizontal plane, at -20m MSL (values at the Wadden Islands are NOT correct).

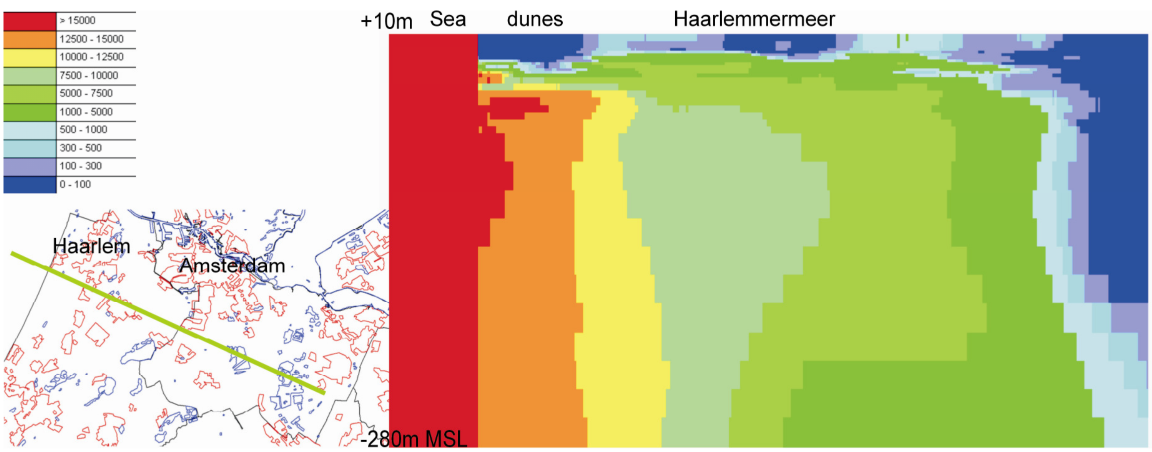

Figure 2. 2D profile of fresh-brackish and saline groundwater over a part of the coastal zone.

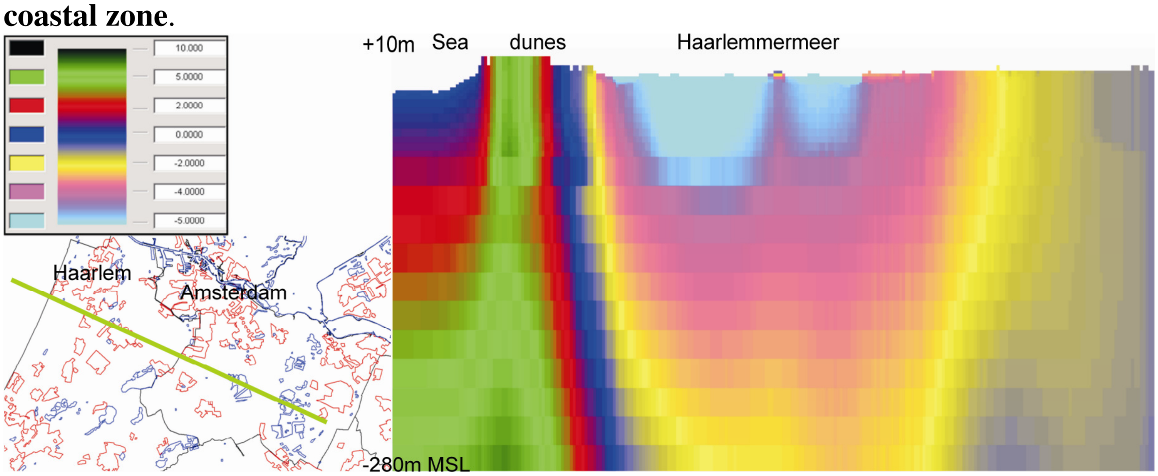

Figure 3. 2D profile of the freshwater head over a part of the coastal zone.

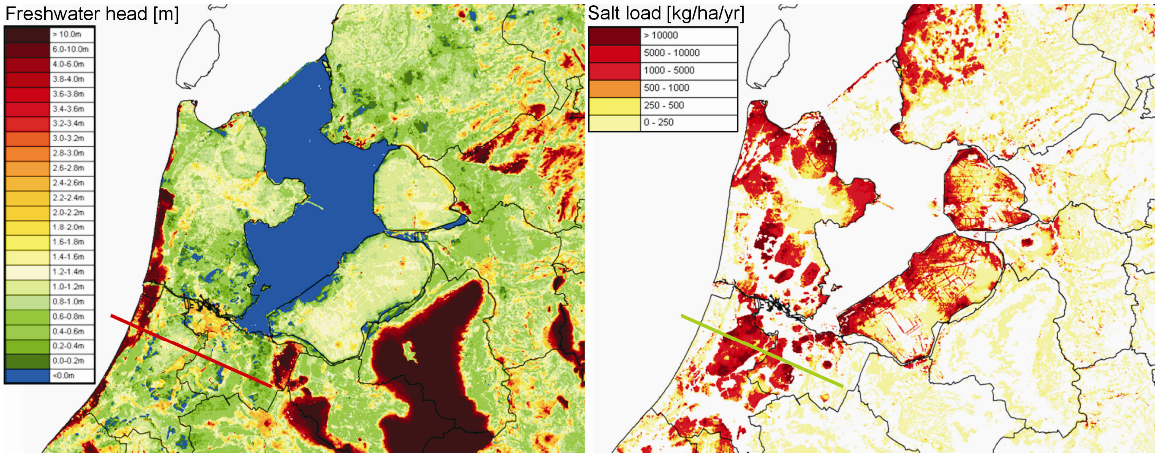

Figure 4. Freshwater head and salt load to the surface water system at a section of the coastal zone.