FORECASTING THE DYNAMICAL SALT CONCENTRATION OF THE SURFACE WATERS OF THE RHINELAND WATER BOARD

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ABSTRACT

Lying well below sea level, the water board of Rhineland, in the western part of The Netherlands, is constantly being intruded by brackish groundwater. During the growing season the system of surface waters has to be rinsed by fresh Rhine water, in order to keep the chloride concentration at an acceptably low level. It is expected that, due to climate change, fresh water may become scarce in this part of the country. The water board is currently preparing a long-term policy for dealing with water shortages. The dynamical salt load of the surface water was investigated by means of a Modflow-like groundwater model, supplemented with a first order time series model. These models simulated the dynamic flux of brackish groundwater to the system of surface waters. The surface waters were modelled with the surface water model Sobek. After adding other sources of salt, Sobek was used to explore various flushing scenarios. Damage to agricultural crops due to salinization was simulated by the unsaturated groundwater model Swap.

MODEL CONCEPT

To predict the effects of salt water intrusion at the water board of Rhineland we must be able to calculate the following:

- Long term salinization and flux changes.
- Short-term dynamic flux of brackish groundwater to the system of surface waters.
- Distribution of chloride through the main surface waters.
- Damage to agricultural crops.

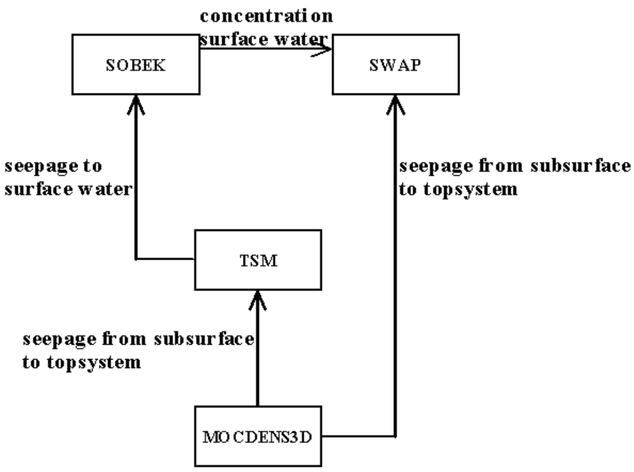

***Figure 1** System of models*

Instead of combining these features in one model a system of sequential models was proposed, using one model for each issue. (Figure 1).

First the 3d-density dependant groundwater model MOCDENS3D (Oude Essink, these proceedings) is used to calculate the seepage flux and concentration from 2000 tot 2050 on a yearly basis.
The salt load is then distributed to the surface waters using a simple first-order time series model (TSM). This model calculates the flux and concentration to small surface waters with time steps of one day.

Next the groundwater flux and its salt concentration is added as a transient boundary to the surface water model SOBEK (www.sobek.nl), that is designed to calculate the flow within the main system of canals.

Finally crop damage is calculated using SWAP (www.alterra.nl). This is a one dimensional unsaturated zone model. The lower boundary (seepage) is taken from the groundwater model MOCDENS3D and the concentration of the sprinkler irrigation water is taken from the surface water model.
Crop damage calculations are only done in areas where it is reasonably expected to occur (high concentrations in the surface waters).

GROUNDWATER MODEL

The groundwater model MOCDENS3D (Oude Essink, these proceedings) has a width of 41 kilometres and a length of 48 kilometres. The depth of the model is 190 meters below the surface.
The cell-size is 250*250 meters. This resolution makes it possible to get a detailed description of the surface water levels of the polders in the top layer of the model.
A detailed description of the model is given by Oude Essink in these proceedings.

FIRST ORDER TIME SERIES MODEL

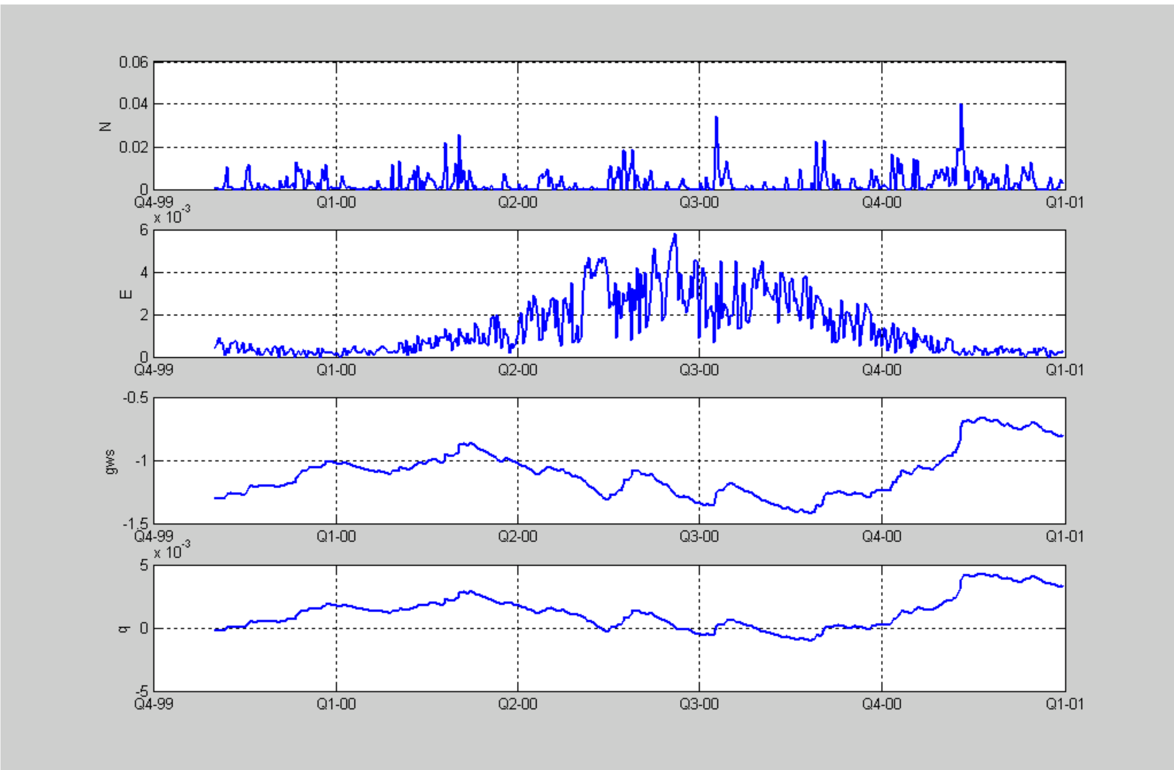

***Figure 2** Example of results of time series model.*
From top to bottom: Precipitation, evaporation, calculated phreatic level, and flux to the surface waters.

The first order time series model (TSM) is used to calculate the dynamic flux of brackish water to the system of surface waters. This model is used for each cell in the groundwater model mesh. The simulation period is one year.

The inputs are the surface water levels in the polders and the precipitation and evaporation (depending on the crop). The lower boundary is one of constant seepage that is calculated by the groundwater model.
Some results of the time series model are displayed in figure 2.

SURFACE WATER MODEL

The surface water model SOBEK is designed to calculate the flow of water and chloride within the main system of canals. In this study it is used to explore various flushing scenarios. The results of the time series model are integrated for some 100 polders and added to the surface water model as time dependant lateral recharge. In figure 3 the polders and the main canal system are displayed.

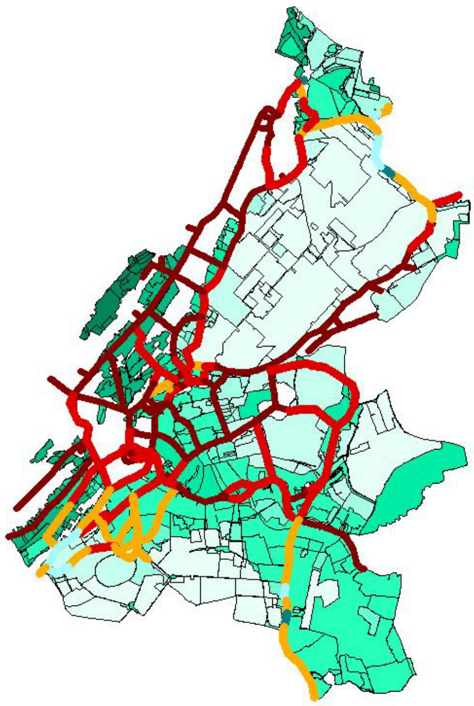

Figure 3 *Main canal system and polder layout*

CROP DAMAGE CALCULATIONS

Crop damage calculations are done with the model SWAP (Soil, Water, Atmosphere, Plant). It is a one dimensional finite difference model that simulates the vertical transport of water and solutes in the unsaturated zone at field-scale level during entire growing seasons (figure 4). The model is only applied in areas where crop damage is expected. Typically these locations have a high concentration of salt in the main canal system, combined with a crop that is sensitive to chloride. The results from the surface water model are used combined with a land use map to indicate these critical spots.

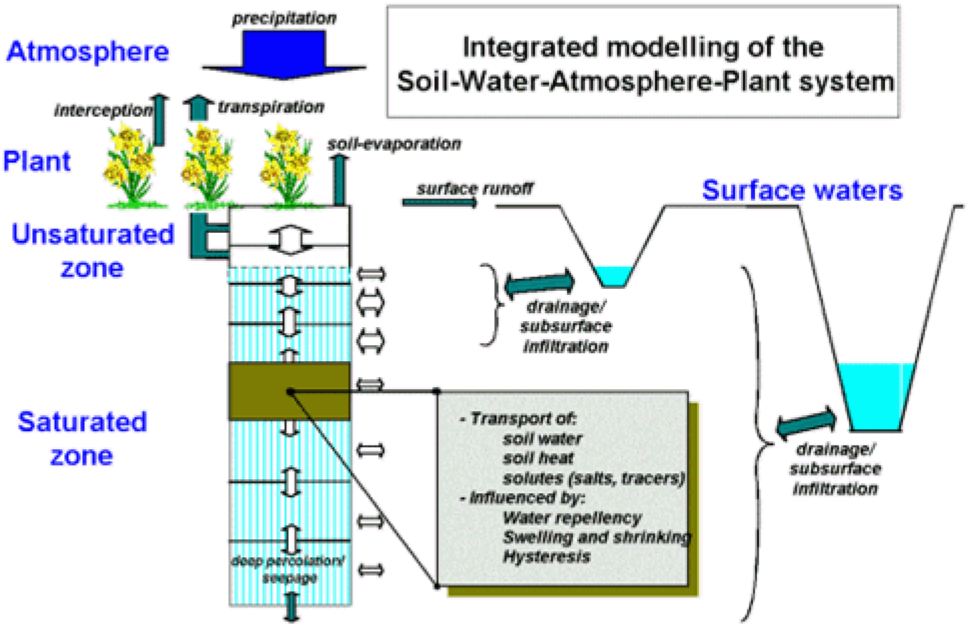

Figure 4 *SWAP scheme*

CONCLUSIONS

A system of models was proposed to calculate the effects of salt water intrusion. To predict crop damage transient modelling is necessary. This can be done efficiently by dividing the modelling process in steps, instead of trying to solve all processes at once. Numerical difficulties due to different time scales can thus be avoided.

Improvements can be made by including non-linear effects (drains and evaporation-reduction) in the time series model.