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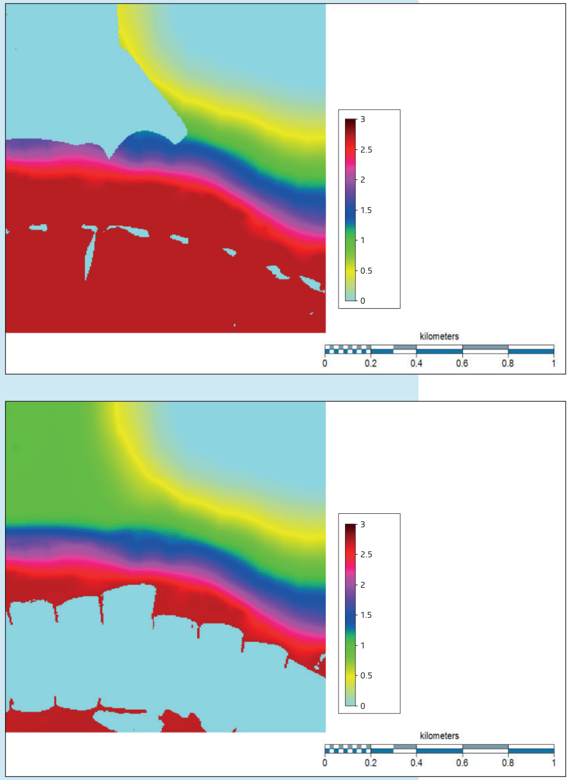
Numerical modelling of water pressures in dikes

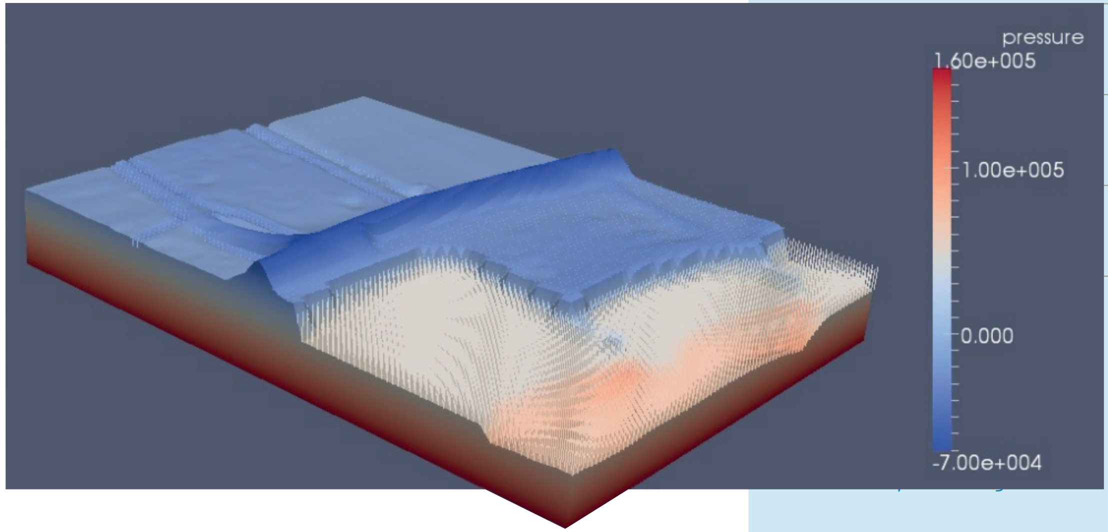


Regional-scale output from iMODFLOW

Dikes and dams prevent flooding. However, water penetrating the dike and the subsoil during high water periods reduces the strength of the structure due to the increase in pore pressure. Moreover, the rise in the hydraulic head in deeper layers may lead to the uplift of the top layer on the polder side of the dike. Finally, an increase in the potential head gradient can result in an internal erosion process known as backward erosion piping. To assess these effects it is important to have an adequate knowledge of the pore water pressure field, which can be obtained by solving the groundwater flow problem.

The coupled use of the finite volume code iMODFLOW, which is an accelerated Deltares version of MODFLOW, and the finite element code DgFlow solve the groundwater flow problem more efficiently by addressing the problem using multiple resolutions. iMODFLOW captures saturated flow at a regional scale (2x2km) by assuming that groundwater flows in a horizontal direction through highly permeable aquifers and vertically through low permeable aquitards. DgFlow simulates saturated and unsaturated flows at a local scale (100x100m) using a three-dimensional domain in combination with deformations in the subsoil.

The two programs are coupled by exchanging hydraulic heads (iMODFLOW to DgFlow) and fluxes (DgFlow to iMODFLOW) for each stress period at the boundary shared by the two model domains. As DgFlow addresses the physical processes in more detail, more time steps are needed in a stress period for a DgFlow computation than for an iMODFLOW computation. Furthermore, higher spatial resolution is needed for a DgFlow computation than for an iMODFLOW simulation. The simulated pore water field for a high water situation is imported in the geotechnical finite element code Plaxis, where the stability of the dike is analysed.



A simplified version of this approach, which is based on one-way coupling between IMODFLOW and DgFlow, has already been used in a research project funded by Rijkswaterstaat. The aim of this project was to assess the effect of a three-dimensional time-dependent groundwater flow on the stability of the dike in three locations alongside the river Waal. The hydraulic head distribution in a region measuring 1.5 x 1.5 km near Herwijnen was obtained from an iMODFLOW computation. The picture on the left shows the distribution for the low permeable cover layer and the picture on the right shows the hydraulic head in the sandy layer underneath. This model provides the boundary conditions for the DgFlow model, which captures a domain of 500 x 500 metres and includes a section of the Waaldijk. The groundwater model was calibrated on the basis of piezometer readings and the calibrated model was then used to predict the water pressures in the dike and the subsoil, which supports the dike during periods of high river-water runoff. A Plaxis computation based on the simulated water pressure distribution was used to assess the safety of the dike.

Further reading:

Van Esch et al. (2013). Modeling transient groundwater flow under dikes and dams for stability assessment. Conference paper at ComGeo III, Krakow Poland.