Calibration of a sharp interface model using interpolated interface measurements.

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ABSTRACT

The objective of this paper is to present a new approach for the calibration of sharp interface models for the simulation of seawater intrusion and upconing. A three-dimensional representation of the interface elevation is obtained through interpolation of measurements of the interface depth, which were obtained with a variety of measurement techniques. The elevation of the interface is a comprehensive representation of the time-averaged hydrological heads if the interface is in equilibrium with the current hydrological conditions. Calibration of a sharp interface model against the three-dimensional model of the interface elevation gives much better results than calibration against measured heads. The new calibration approach was used to develop a model of the island of Terschelling in The Netherlands. The model was used to develop novel maps of viable locations for new drinking water wells on the island.

PROJECT DESCRIPTION

Vitens Water Supply Company is searching for new locations to extract fresh groundwater on the island of Terschelling in the Netherlands. Good locations for new drinking water wells need to comply with two requirements. First, the well needs to be able to pump the required discharge without the danger of significant upconing of the interface below the well. Second, the effect of the new pumping well on the groundwater table in the ecologically valuable dune area needs to be minor. To find locations that fulfill both requirements, a sharp interface model was developed with MODFLOW-SWI (Bakker and Schaars, 2005). The model consists of three layers, of which the top layer is the unconfined dune area (Figure 1). The simulation time is 10 years and the timestep size is 10 days. A comprehensive data set is available, including measured heads, discharges, and the elevation of the interface.

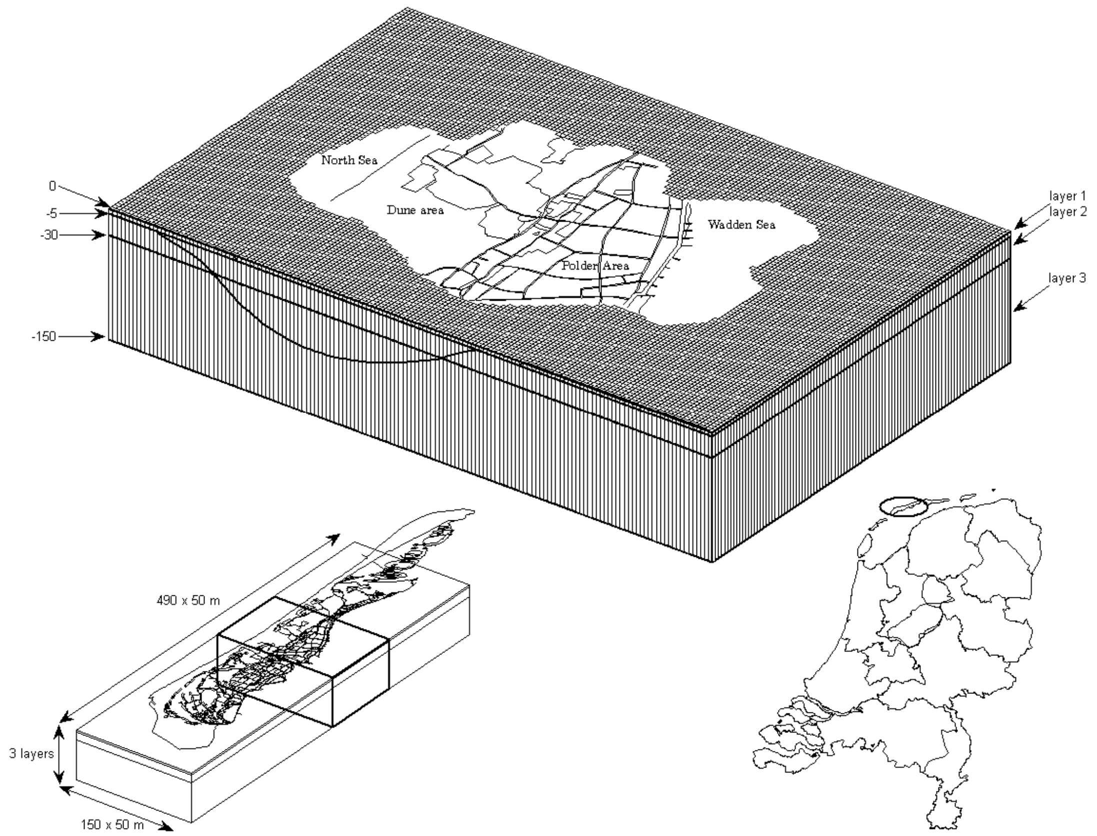

Figure 1. Model setup: 3 layers, 150 rows, 490 columns. 50*50 meter gridsize.

MODEL CALIBRATION

A three-dimensional representation of the depth of the interface was developed by combining different types of measurements, including electrical sounding, borehole-logs, groundwater sampling and cone penetration tests. These measurements provide a very consistent image of the depth of the interface, as will be shown in the presentation. This makes it possible to create a three-dimensional representation of the interface, and to use interpolation to compute the "measured" depth of the interface for each cell of the model. We assume that the interface is in equilibrium with the current hydrological conditions. In that case the depth of the interface is a comprehensive representation of the time-averaged groundwater heads in the lower aquifers. We will show that, for calibration purposes, this is far more valuable than the measured heads, which are available as point-data only and span a limited, not always representative period. Special care was taken to keep a balance between the available data and the complexity of the model. During the calibration process, the hydraulic conductivities were adjusted, and the approach to calculate the recharge was modified. A good fit was obtained between measured and computed heads, fluxes, and of course the elevations of the interface (Figure 2). At the western part of the island the simulated interface is lower than we expect from measurements. Future research will focus on the question whether this relatively new part of the island is in equilibrium.

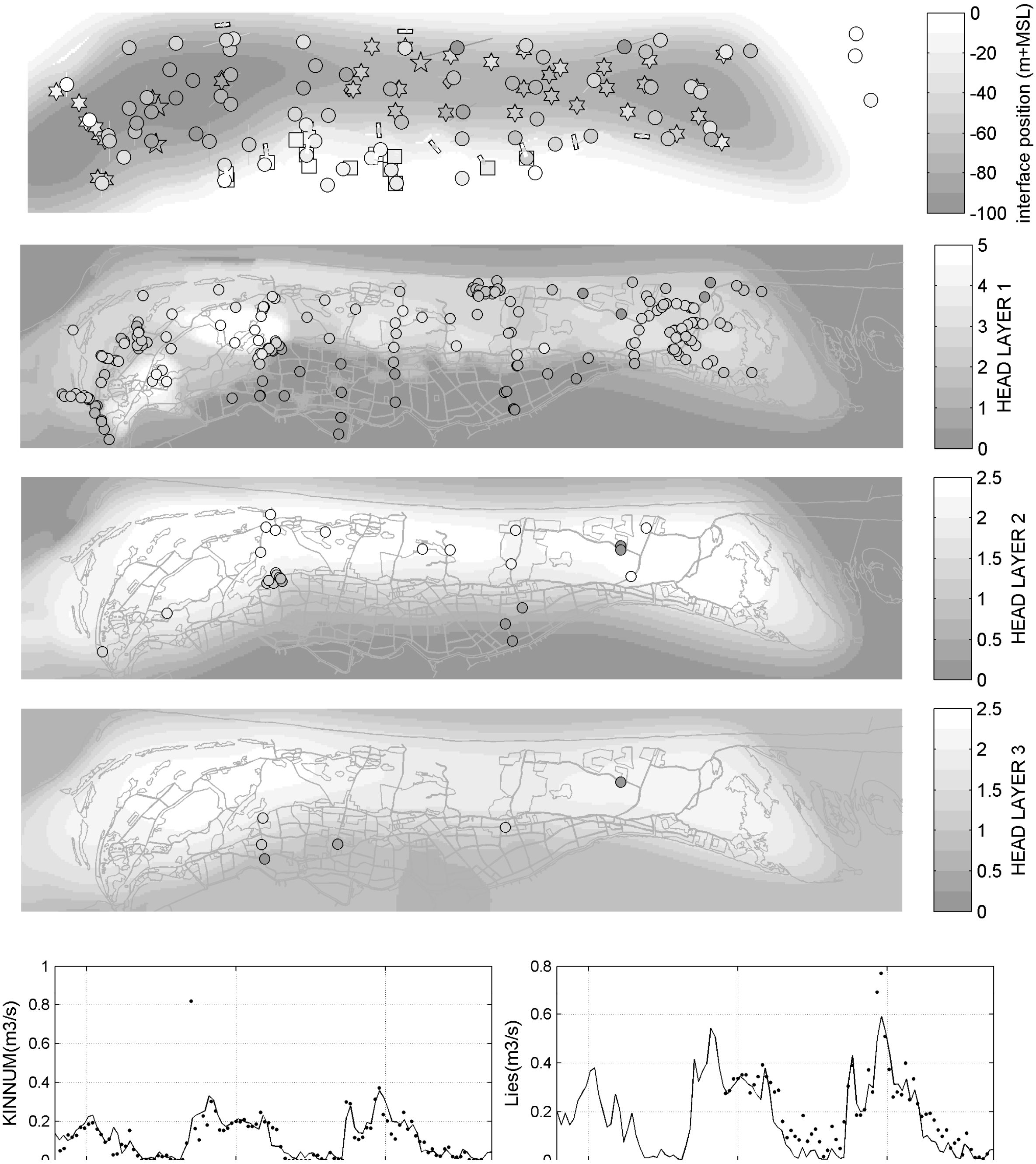

Figure 2. Calibration results from top to bottom: maps of interface depth and head in layer 1 to 3. Symbols are point measurements, background is the model result. The bottom two graphs are the discharge from two polders as a function of time. Measurement points versus model result (continuous line).

VIABLE LOCATIONS FOR NEW DRINKING WATER WELLS

The calibrated model was used to develop maps of what we termed a "traveling pumping station". A rectangular, regularly spaced grid of N by N points was developed. The model was run N^2 times with the well located at one of the grid points. For each model run, the largest head decrease in the unconfined aquifer was computed and assigned to the grid point where the well was located. In this fashion, a map was produced that shows the largest head decrease in the unconfined aquifer when the well is located at that grid point. In the same fashion, a map was created with the risk for upconing due to a head decrease in the deeper aquifer. The combination of these two maps (see figure 3) was used to determine viable locations for the new extraction wells.

Figure 3. Results traveling pumping station. The circles are search-locations for new extraction wells.

CONCLUSION

This study is unique because of the large data-set that is available. The depth of the interface has been measured in one way or another across the entire island. All measurements can be combined into a three-dimensional representation of the interface for the entire island. Calibration against the interface depth leads to a significant improvement of the model, and the model predictions. Therefore our recommendation is to focus monitoring efforts on the interface depth, rather than on head measurements. In addition, it is noted that even for this complicated case with a lot of available data, an interface model is complex enough to determine viable locations for new drinking water wells. Future plans include a comparison with recent measurements, airborne geophysics (SkyTem), the addition of a brackish zone, and measuring (and calibrating) the movement of the interface.

REFERENCES

Bakker M., Schaars, F. 2005. The Sea Water Intrusion (SWI) Package Manual Part I. Theory, User Manual, and Examples. Version 1.2. Available from www.bakkerhydro.org/swi.