NAGROM
A groundwater model for the Netherlands

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Introduction

NAGROM (NAtional GROundwater Model) is a model for groundwater flow in the saturated zone and will eventually cover the whole of the Netherlands. It is built by RIZA in co-operation with NITG-TNO Delft. NAGROM is a modular system of groundwater models. Each main model (figure 1) has been built independently of the other models, but all models can be physically connected.

NAGROM is based on the Analytic Element Method of O.D.L. Strack (University of Minnesota).

Figure 1: Supra-regional models of NAGROM
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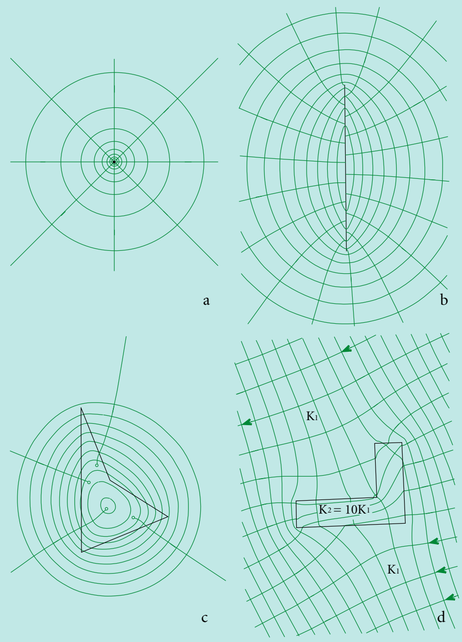

Figure 2: Examples of analytic elements, (a) well, (b) line-sink, (c) area-sink, (d) inhomogene y

The Analytic Element Method (AEM)

An AEM model is a combination of different types of analytic elements. Analytic elements are analytic solutions of the differential equation that describes groundwater flow.
The combination of elements is equal to superposition of analytic solutions.

Examples of analytic elements are the well, the line-sink, the area-sink and the inhomogeneity (figure 2). Each type of analytic element can simulate different types of geohydrological features (abstraction wells, rivers, polders, infiltration areas, aquifer-inhomogeneities, etc.). Actually, modelling with analytic elements is selecting elements for geohydrological features rather than generating parameter values of elements in a mesh.

Forthcoming features in the analytic element method consist of time-dependent flow, of flow in situations with a sloping base and of transport of solutes.

Analytic elements are valid in infinite aquifers. The boundary of an AEM model is actually a surrounding zone that consists of analytic elements (figure 3) generating the effects of the outside world. Connection of models is carried out simply by interchanging elements of the surrounding zone and those of an adjacent model.

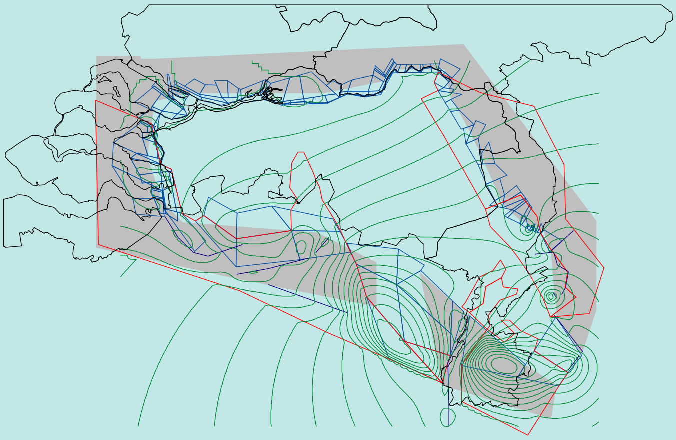

Figure 3: Surrounding zone of the supra-region Brabant

The modelling concept

The geohydrologic layers in NAGROM consist of aquifers and aquitards. The flow computation is semi three-dimensional, because the vertical resistances within the aquifers are lumped with the resistance of the adjacent aquitards.

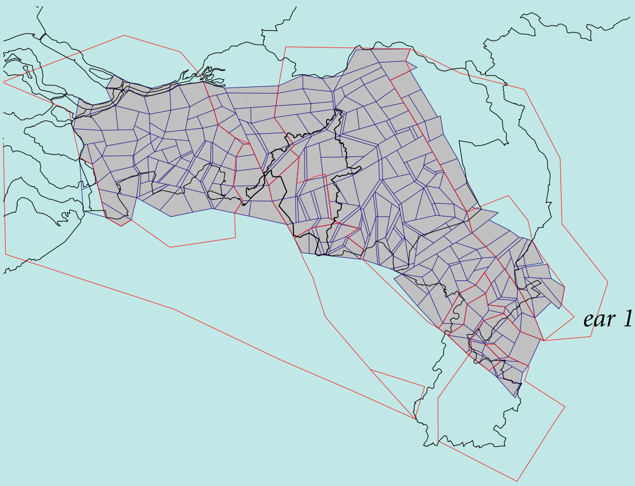

Figure 4: Model of the supra-region Brabant

Geohydrological features like wells, rivers, canals and inhomogeneities occur in aquifers and are modelled with elements defined in aquifers. Polders, infiltration areas, lakes and leakage layers occur on top of or between aquifers and are modelled by area elements. Figure 4 shows the area-sinks in the model of the supra-region Noord-Brabant as it has been used for computations on national scale.

ear 1990

The basic structure of NAGROM consists of three aquifers with standard properties. These model aquifers simulate different parts of the country. By this basic structure, the connection of any two of the models is possible. Aquifer properties are localised by using inhomogeneities (figuur 2d).

Input and output

Each element is stored with its topographic and geohydrological properties. Elements are stored by type and by layer. The dataset of a NAGROM model consists of a series of small files and is maintained by using a dedicated data management system.

The original dataset of NAGROM has been accomplished without GIS and automatic mapping and translation systems. Since 1995, the hydrological top system of NAGROM is generated by the interface MONA between NAGROM and the national model for groundwater flow in the unsaturated zone MOZART.

NAGROM is capable of generating any output needed for common groundwater problems. As an example, figure 5 shows the computed groundwater head distribution for 1990 in the supra-region Brabant.

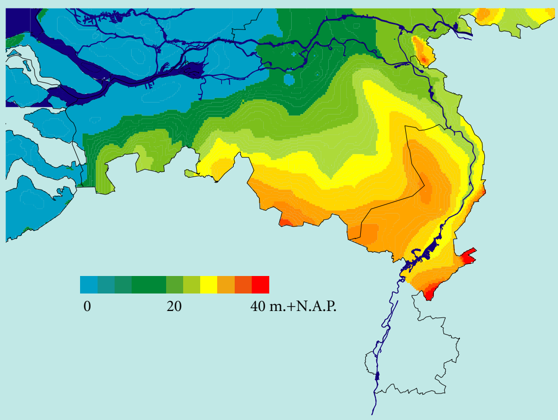

Figure 5: Computed groundwater head distribution for the supra-region Brabant, y

Applications

Since 1995, NAGROM has been used for the computation of different scenarios for national water policy analysis. The computation results clearly showed the differences in the effects generated by the different scenarios.

NAGROM has been used, on a regional scale, to determine the effects of semi-permanent changes in the water level of the river Meuse in the southern part of the Netherlands. In the vicinity of the river, the model has been refined and partly reconstructed (changing the types of the analytic elements). The results clearly showed the impact of the measures considered in the study.

Figure 6 illustrates the refinement in a region in the model of Brabant (figure 4), which has been carried out for policy analysis of the province of Noord-Brabant.

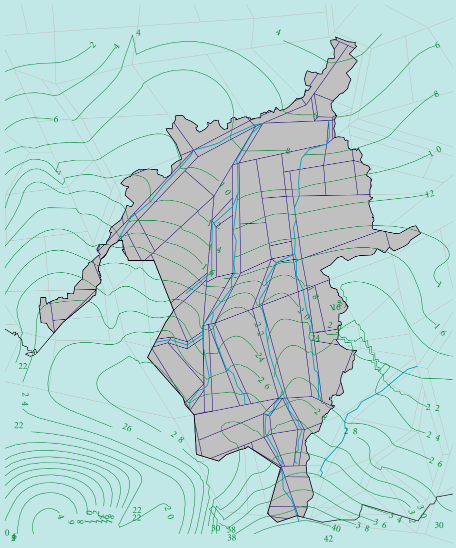

Figure 6: Partly refined model of the supra-region Brabant

Accounting for the effects of salt groundwater in the coastal zo

Along the entire coast (250 km) of the Netherlands, a mixture of fresh and salt groundwater is found. A three-dimensional distribution of the density is derived from chloride contents measured in irregularly distributed filters. This distribution is directly used in the computation with the analytic element method. Figure 7 shows the interpolated density distribution in the province of Friesland.

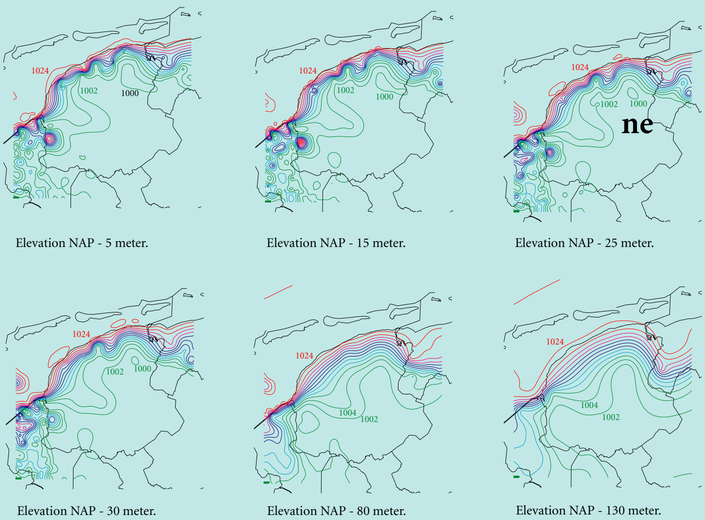

Figure 7: Density distribution in a region of the province of Friesland

The model of the area of the province of Friesland has been applied (by NITG-TNO Delft) to compute the changes over time of the density distribution. It appeared that the distribution only changes very slowly; it will take thousands of years to get relevant changes.

Concluding remarks

NAGROM has shown to be useful at national, regional and local scale. Also, NAGROM is generally available for use by third parties in the entire country of the Netherlands. Therefore, the model will be permanently maintained by using the improvements made by users, by keeping up with new developments in the analytic element technique and by growing towards the national geohydrological database of the Netherlands REGIS (maintained by NITG-TNO Delft) which will be accomplished in the coming years.