Towards a Modular Planning Instrument for Drinking Water Supply

Kim van Daal, Bernard Raterman and Kees Vink

Abstract

Drinking water companies in The Netherlands have recognized the need to develop adaptive strategies to deal with the direct and indirect effects of climate change. Numerous studies are undertaken to assess the environmental and social impact of climate change. Clearly, water management plays an important role in dealing with these effects. In the water sector already a broad range of models are used to study the interaction of drinking water supply and environmental or social processes. GIS-based models have been developed for hydrological and ecological impact assessment of water abstractions. Land use based models are designed to predict water quality or drinking water demand. Hydraulic models are used for the design of distribution systems. The integration of these model tools into an overall planning instrument has been leveraged by the functionality of ModelBuilder in ArcGIS 9.2. The drinking water supply can be optimized using this approach.

About Kiwa Water Research

Kiwa Water Research is the Dutch research and knowledge institute for drinking water, wastewater and related ecological and environmental aspects. Clean drinking water is vital to everyone's health. Kiwa Water Research provides the knowledge and technology necessary for obtaining optimal quality in water service and management. With and for drinking water companies we develop and manage knowledge towards impeccable drinking water quality both now and in the future.

Kiwa Water Research has been conducting the Joint Research Programme of the Dutch Water Sector (BTO) for more than thirty years. GIS-technology has been used since 1989 to support the integration of our fields of knowledge (hydrology, ecology, proces technology and distribution technology) into innovative concepts and tools.

Figuur 1. Drinking water companies in The Netherlands

Introduction

Worldwide the water supply sector is facing tremendous challenges. Shortage of good quality and readily treatable resources is increasing due to major trends like climate change and urbanisation. Drinking water companies in The Netherlands have recognized the need to develop adaptive strategies to deal with the direct and indirect effects of these trends. The current drinking water supply has to become more flexible to become more efficient and sustainable.

ArcGIS and the Modelbuilder Environment

During research projects the development of software for the drinking water companies is rarely a separate goal and the capacity for software development is rather limited (Raterman, 2006). Besides the limited time a broad range of models are already used to study the interaction of drinking water supply and environmental or social processes.

GIS-based models have been developed for hydrological and ecological impact assessment of water abstractions. Land use based models are designed to predict water quality and drinking water demand. Hydraulic models are used for the design of distribution systems. Several experts work independently on different models, each using their favorite programming environment. This may either be in Fortran, Matlab or C++ code (Raterman, 2004).

The funtionality offered by the ModelBuilder environment is effective to combine new and yet existing models through a user-friendly user interface. ArcGIS and the ModelBuilder environment make it possible to efficiently achieve modular design. Modular design is flexible in three ways:

1. Combine GIS and non-GIS models through one user-friendly interface based on ModelBuilder

2. Use different programming environments: choose the most suitable programming environment and combine models afterwards using ModelBuilder.

3. Possibility to extend with new models when water companies ask for more functionality

Modular planning instrument

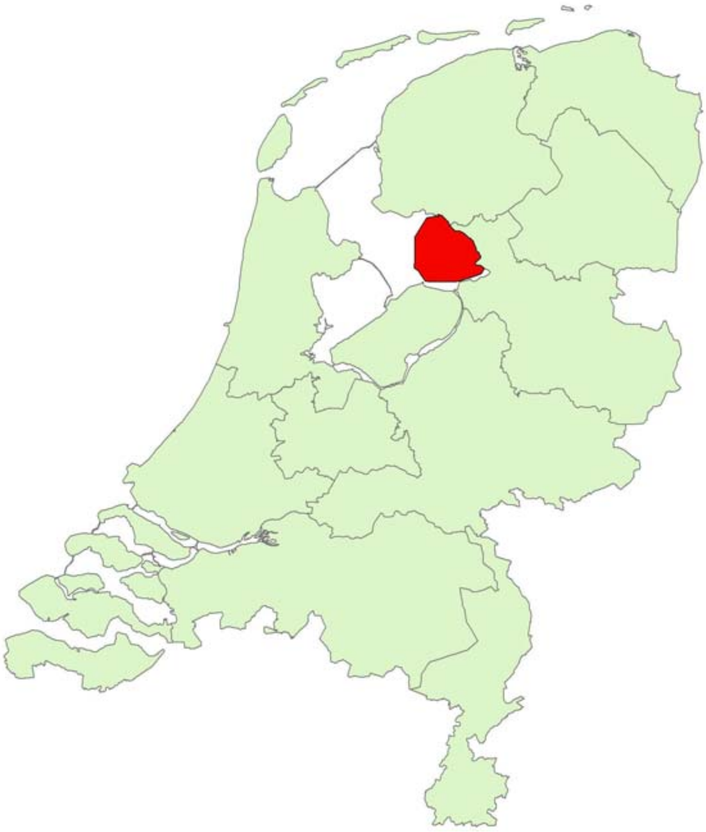
Kiwa Water Research and Vitens started a pilot project in the Noordoostpolder (NOP) to test the use of the ModelBuilder environment to accomplish a modular planning instrument.

This planning instrument will be used to generate and evaluate new concepts for production and distribution of drinking water. The general objectives are:

1. Cost efficiency
2. No adverse environmental impacts
3. Future proof drinking water supply

We applied the instrument (Named Optiwin) for this pilot study to assess the feasibility of using brackish groundwater for driniking water production.

The Noordoostpolder was the first polder in the main central lake of the Netherlands 'IJsselmeer', formerly called Southern Sea. In the nineteen thirties it was disconnected to the North Sea by a large dike of 30 km length as to protect the country against floods from the sea. Gradually the salt water changed into fresh water, but the groundwater is still mainly brackish. People decided to reclaim land in the IJsselmeer because of the need of cultivated land. The Noordoostpolder became a polder in 1942. Total land area is 46,000 hectares (about 113,500 acres).



Figuur 2. The location of the Noordoostpolder

There are several bottlenecks in the area:

1. Water is transported from outside the polder area, which is relatively expensive
2. In the future there may be not enough capacity because of population growth and increasing water demand
3. The drinking water transport network needs revision due to a changed distribution of water demands in the NOP
4. Brackish seepage water enters the surface water in the NOP, which is a problem for agriculture (irrigation water quality) and ecology (aquatic flora and fauna).

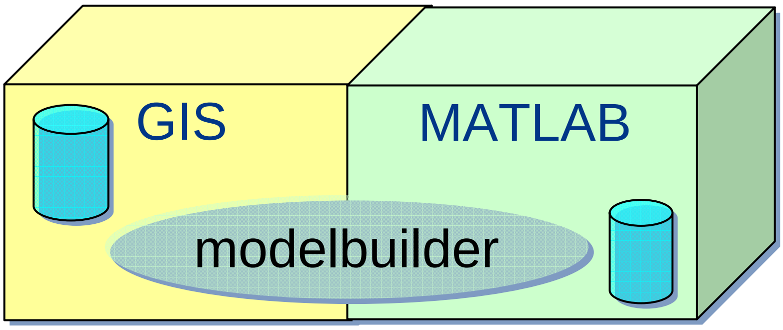
An extra groundwater source for the Noordoostpolder where brackish groundwater would be extracted can be beneficial for agriculture and ecology in the area. However, groundwater abstraction would result locally in a lowering of the groundwater level, which is adverse for agricultutral production. Therefore Kiwa Water Research and Vitens, the drinking water company in the area, decided to explore the possibilities. The primary question is: Where is the optimum location for brackish groundwater extraction?

Optiwin

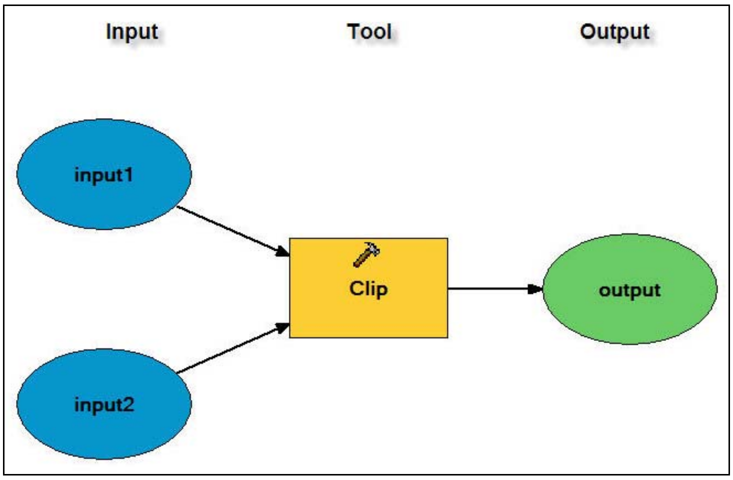
For this pilot study a set of impact models have been combined using ArcGIS 9.2 and the ModelBuilder environment. We found that ArcGIS 9.2 with ModelBuilder is a simple user interface to modify and to manage the model input data and also for presentation of the output data in maps and charts.

The input data consists of geographical data (vector or grid) and also ASCII files and single parameters. For example using standard GIS functionality a new location for a well can be chosen. Single parameters are for instance the pumping capacity or the rate of interest.

The NOP version of Optiwin comprises three external Matlab models and one GIS module. The different modules of Optiwin are:



Figuur 3. The intergration of GIS and matlab using Modelbuilder



Figuur 4. Modelbuilder programming environment

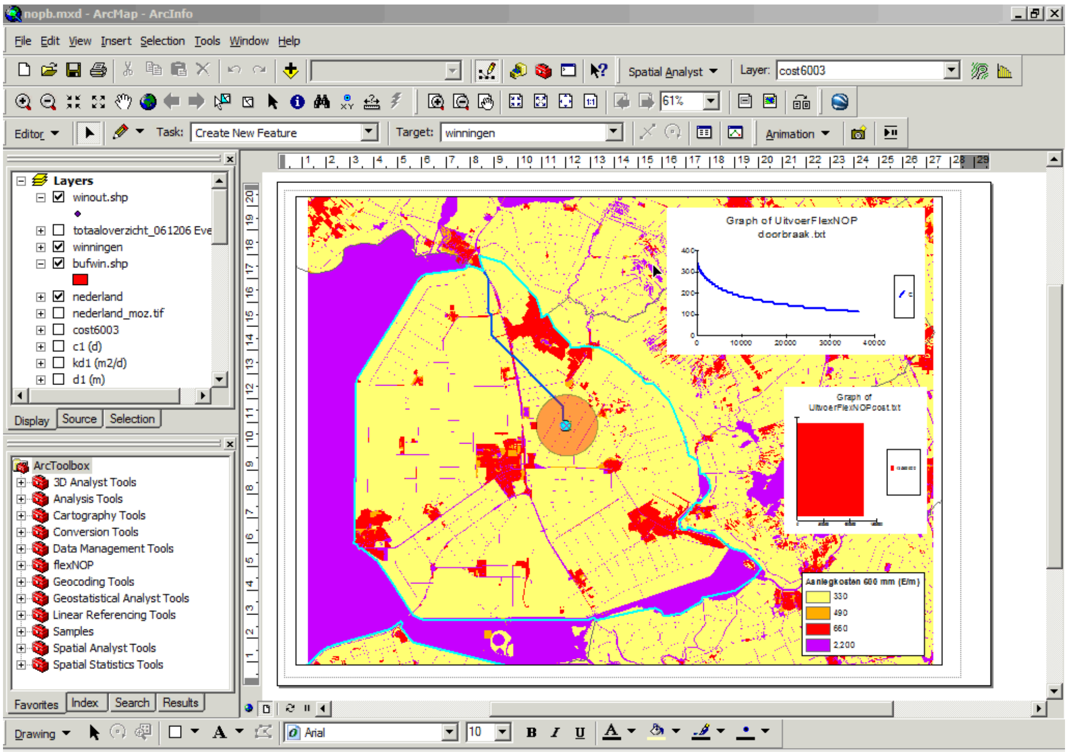
1. Flexnop.exe
   A Matlab compiled executable hydrological module that calculates the 5 centimers drawdown contour and the total amount of salt load. Flexnop contains the following processes:
   a. Sampling the geohydrological data at the well location (x,y,z) and use the values as input variables.
   b. Run the Matlab executables and save the output values in ASCII

files

c. Read the ASCII files in GIS, for example as a point layer.
d. Calculate the radius for the 5 centimers drawdown and use the buffertool to draw the contourline in the map;

2. Gleedoorbraak.exe
   A Matlab compiled executable hydro-chemical module that calculates the break-through curve of chloride (chloride concentrations over time).

3. Zuiveringskosten.exe
   A Matlab compiled executable module that calculates the total costs for treatment of the groundwater



Figuur 5. Visualisation in GIS

4. Cost-path module
   This module uses raster based GIS functionality for determination of mimimum cost trajectories of transport pipes . The basis for this function is a so-called cost landscape in which cost functions are based on soil properties and land use. The cost landscape is based on existing landuse and soil maps. The final cost landscape has a resolution of 10x10 meters. This resolution is used to be sure the that the specific costs of constructing pipes under waterways and roads are taken in account. The cost-path module uses the location of a well (user input) as a starting point and a destination point in the north of the polder, where the transport network is connected to other supply areas . The cost path function calculates the least-cost path from the source to the destination. The ideal route is drawn in the map.

Conclusion

ArcGIS and ModelBuilder can be used efficiently to achieve a good modular design and flexible implementation of tools. Simulation of complex hydrologic and hydrochemic simulations are best carried out in separately compiled modules as to reduce calculation times.

References

Raterman, B.W., J. Grijpstra and J.P.M. Witte – ArcGIS tools for the prediction and evaluation of terrestrial ecosystems. ESRI User Conference proceedings 2004

Raterman, B.W., G. Cirkel and C. Vink – Assessment of Groundwater Pollution Risks in Production Wells with RESPOND. ESRI User Conference proceedings 2006

Raterman, B.W., M. de Haan and A.F.M. Meuleman – GIS in ecological impact assessment of wetlands. ESRI User Conference proceedings 2002

Raterman, B.W., M. Griffioen and F. Schaards – GIS and MATLAB integrated for ground water modeling. ESRI User Conference proceedings 2001

Vink, C., P.J. Stuyfzand, B.W. Raterman, C. Maas, I. Leunk, D.G. Cirkel – Flexwater Pilot Noordoostpolder. Kiwa BTO report 2007.

Author Information

Kim van Daal MSc
GIS specialist
Kiwa Water Research
P.O. Box 1072
3430 BB Nieuwegein, The Netherlands
+31 30 6069605
Kim.van.Daal@kiwa.nl

Bernard Raterman Msc
GIS specialist
Kiwa Water Research
P.O. Box 1072
3430 BB Nieuwegein, The Netherlands
+31 30 6069541
Bernard.Raterman@kiwa.nl

Kees Vink PhD
Hydrologist
Kiwa Water Research
P.O. Box 1072
3430 BB Nieuwegein, The Netherlands
+31 30 6069556
Kees.Vink@kiwa.nl