Regional scale flow and transport modelling for the management of groundwater and surface water bodies in the framework of the EU Water Directive

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(...) river basin district (...) is identified as the main unit for management of river basins

(DIRECTIVE 2000/60/EC « Water Framework Directive »)
An integrated management at regional scale requires characterization and modelling (Goderniaux, 2010)
As managing tools in the framework of the EU Water Directive, regional scale models should provide:

• quantitatively
  • an estimation of the evolution of water balance terms (reserves), groundwater-surface water interactions (baseflow), and hydraulic head trends for several scenarios with regional impacts

• qualitatively
  • an estimation of the evolution of nitrate trends for several input scenarios
However, flow and transport models at regional scale face specific problems:

- **complexity** of geology and hydrogeology
- **heterogeneity** of level of knowledge
- **representativity** of measured parameters
- **time-consuming** simulations

How can we deal with these problems while meeting the manager needs?
The approach we developed is characterised by regional scale transient flow and transport models including no more complexity than needed or supported by the data. These models provide:

• quantitatively
  • an estimation of water balance, groundwater-surface water interactions, and hydraulic head trends
• qualitatively
  • an evaluation of nitrate trends
Presentation of the approach

Applications of the approach

Synclinorium of Dinant: quantitative results
Geer basin: qualitative results
Presentation of the approach

Applications of the approach

Synclinorium of Dinant: quantitative results
Geer basin: qualitative results
The approach, implemented in SUFT3D, consists in three steps:

1. subdividing the zone of interest into subdomains corresponding to independent hydrogeological units or variously characterised zones

2. selecting the equations governing flow and transport into each subdomain

   - poor level of knowledge/interest → simple linear reservoir
   - high level of knowledge/interest → flow in porous media
   - advection - dispersion

3. defining internal boundary conditions between subdomains: 1st type, 2nd type impervious or 3rd type
Groundwater-surface water interactions are taken into account through 3rd type boundary conditions

\[ Q_{sw}^{gw} = \frac{K \times L \times l}{e} \times (H_{sw} - H) = \alpha \times (H_{sw} - H) \]

hydraulic head

= unknown of the problem
Presentation of the approach

Applications of the approach

Synclinorium of Dinant: quantitative results

Geer basin: qualitative results
Three water bodies located in the Synclinorium of Dinant have been modelled for helping the management of their water resources.
The subdomains and the internal boundary conditions have been defined based on the hydrogeological units and the hydrologic sub-basins for:

• considering the hydraulic head shift between sandstones and limestones units

\[ 3^{rd} \text{ type internal boundary condition} = \]

efficient way to consider implicitly a thin low permeable shale unit

• evaluating groundwater flux exchanges between the main hydrologic sub-basins
Flow in porous media equations have been used in each subdomain except in the highly karstified limestones where linear reservoirs have been used.
The calibration has been performed in steady-state (UCODE_2005) using both hydraulic head and baseflow rate observations.
The groundwater flow calibration has then been performed in transient regime using both hydraulic head and baseflow rate observations.
The calibrated model has been used for:

- obtaining additional information about the water balance of key sub-basins

What are the groundwater flux exchanges between sub-basins?

- obtaining boundary conditions for a local impact model linked to an open pit extension project
Presentation of the approach

Applications of the approach

Synclinorium of Dinant: quantitative results

Geer basin: qualitative results
The chalk aquifer of the Geer basin constitutes important groundwater resources for the city of Liege but nitrate concentration in groundwater is increasing for 50 years.
The zone of interest has been subdivided vertically into two subdomains interacting through a 3rd type internal boundary condition for taking implicitly into account a low permeable layer separating two permeable chalk layers.

Flow in porous media equation and mixing cell for transport has been used in each subdomain.
The **groundwater flow calibration** has been performed in **steady-state** (high and low groundwater level periods) using **hydraulic head observations**.
The calibration of transport has been performed on the calibrated steady-state flow field using tritium data and nitrate trends.
The calibrated model has been used for evaluating the evolution of nitrate trends until 2060 using a simplified input scenario.

Assuming a future nitrate input signal of 50 mg/L, will the increasing nitrate trends be inverted in the future?

The model answer is yes in the southern but no in the northern and eastern parts of the basin with thicker unsaturated zones.
The approach proposed for regional scale groundwater flow and transport modelling has proved to meet the manager needs of Wallonia in the framework of the EU Water Directive. The models allow:

- **quantitatively**
  
  - obtaining additional information on water balance and particularly on inter-basin groundwater flux exchanges
  
  - simulating future hydraulic head trends and groundwater-surface water interactions based on transient calibration

- **qualitatively**
  
  - evaluating the evolution of nitrate trends in the future
Although flow and transport model at regional scale face a lot of problems, this approach is promising for helping the integrated management of water resources as required by the EU WFD.
Thanks for your attention!