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title: **A methodology for determining sustainable groundwater exploitation in aquifer systems based on a simulation-optimisation approach using a multi-criteria analysis tool**

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Is has become evident in recent years that management and future planning of aquifer exploitation should be based on the concept of "sustainable development" as more and more groundwater systems are being depleted by overdrafting. Even for aquifers that are not (yet) threatened today, there is a risk that socio-economic development and climate change will ultimately lead to decreasing groundwater storage and increasing problems with water supply capabilities. In that context, the question how much can be pumped in a sustainable way is probably most crucial. The first description of "safe yield" is nearly a century old (Lee, 1915) and the concept has evolved over the years into "sustainable yield" (Alley and Leake, 2004), but all these definitions were diffuse, only descriptive and non-quatitative. The Brundtland Report (United Nations, 1987) defined "sustainable" as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Sometimes it was stated that groundwater withdrawal must not exceed the "capacity" of the aquifer system (Custodio, 2002). Many articles and books about sustainability of groundwater resources restrict themselves to listing all negative impacts of overdrafting, but do not provide a quantitative method for calculating how much can be pumped from a specific aquifer in a specific hydrogeological setting. Simple estimations were based on global water balance or water budget considerations but this has lead to much confusion. It was often thought that sustainable yield was related to the recharge of aquifers. Instead, sustainable groundwater development is determined by capture of natural discharge. Basing groundwater development sustainability on natural recharge (i.e. safe yield) is a myth and irrelevant (Bredehoeft, 1997 and 2002). Although the Brundtland definition of sustainability was vague, it cleverly captured two fundamental issues: the problem of environmental degradation that so commonly accompanies economic growth, and yet the need for such growth to alleviate poverty. The core of mainstream sustainability thinking has become the idea of three dimensions, environmental, social and economic sustainability (UCN, 2006). Therefore, a methodology for quantifying sustainable groundwater exploitation, should include the possibility to account for both hydrogeological, ecological and socio-economical impacts. This can be accomplished by using a multi-criteria analysis (MCA).

A methodology is being developed for determining sustainable groundwater exploitation rates in the groundwater bodies of Flanders (Belgium). The method extends the simulation-optimisation approach (combination of a groundwater flow model with a general optimiser) with a MCA tool to define an object function that is related to both hydrogeological, ecological and socio-economic aspects, including maximising exploitation rates. As ecological impacts have typically a strong spatial dependency (e.g. the occurrences of local habitats), a distributed groundwater model is used. This also allows for a compartimentalisation of pumping rates into different regions. A general optimisation program is used to minimise the object function and as a result quota for each subregion are obtained. To decrease calculation times, the concept of unit response functions (URF) is used to replace simulation runs with the regional models with faster URF grid manipulations. Some preliminary results obtained with this approach will be presented.

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