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# Regional scale assessment of groundwater resources quantity with respect to water supply issues and the ecological role of groundwater

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**ABSTRACT**

Recognition of climatic change and the obligations enforced by the European water framework directive (WFD) have brought the assessment of the state of water resources in the centre of focus of water related sciences. The assessment of climate change and the WFD approach for the management of water resources demand for a regional and integrated assessment on a river basin scale (> 10,000 $km^2$) in order to bridge the gap between the global effects predicted by Global Climate Models and to meet the environmental, social and economic objectives of modern water resources management. Local and regional scale groundwater resources assessment, however, require completely different approaches. It should also be noted that the widely used hydrological assessment approaches (hydrological models, water balance approaches) are not sufficient to describe groundwater systems since they neglect the vertical differentiation of the subsurface. Furthermore, in comparison to surface water systems the state of groundwater resources is more difficult to assess because of their three-dimensional nature, the less well defined boundaries, the limited accessibility and the resulting lack of data.

Groundwater resources assessment can be divided in two branches: groundwater quantity and groundwater quality issues. The question of which branch is in the centre of focus depends mainly on the regional climatic and socio-economic conditions. In most of the states of the European Union it seems that much more work was recently dedicated to groundwater quality issues than to quantitative aspects, leading to a lack of quantity related approaches. A reason might be that the main goal of the WFD is the restoration of the natural (past) state of water bodies, i.e. a focus on minimizing human impacts (withdrawal, over-use, contamination) on water resources. Upcoming natural influences brought upon by climate change are of minor concern in the WFD. However, scenario based predictions published by IPCC indicate that there will be severe changes to the hydrological cycle including, of course, changes of groundwater quantity. Here it is very important to remember, that groundwater quantity is not only important for water supply but also plays a very important role in ecology. The role of groundwater in ecology is most well known from cases where decreasing groundwater tables have already led to damages or destruction of wetlands. Furthermore, groundwater contributes quite often a large portion of river discharge in dry periods (baseflow or groundwater discharge). That means if groundwater quantity decreases for any reason, river discharge decreases as well with all the known ecological, economic and social consequences ranging from problems with water supply and irrigation, navigation, fishery, hydropower generation, cooling water for industry and nuclear power plants to touristic attraction of regions. All of the problems just mentioned were observed in central Europe, i.e. a sub-humid to humid region, in the exceptionally dry summer of 2003. It is now very important to investigate whether such extreme events will occur more often and how the general climate change might influence the groundwater quantity in the future.

In order to do this, two main things must be accomplished:

1) to evaluate the actual state of a groundwater resource and its connections to neighbouring systems (i.e. surface water bodies, wetlands)

2) to predict future changes as a consequence of changing boundary conditions (climate – groundwater recharge, river discharge)

Groundwater resources assessment and the prediction of future states is not a new task in hydrogeology. However, related research was usually carried out where first signs of problematic situations had already been observed. A prime example is the High Plains Aquifer in Colorado, Kansas, Texas, and Nebraska (e.g. Sophocleous, 2005). In such areas the relationship between cause (pumping) and effect (groundwater depletion) are well known. The situation is completely different in regions where groundwater resources are less intensively used or climatic conditions have until now provided sufficient natural groundwater recharge. In such areas the in-out-storage relationships and, in general, the reactions of the systems to changes of the boundary conditions are much more difficult to evaluate.

The first inherent problem in the assessment of groundwater resources is the lack of well defined boundaries. The extent (width, depth ..) and storage volume of a groundwater resource can not exactly be defined since connections to other resources (subsurface and surface) may exist in all directions. A second problem is related

to the main parameters that can be used in the assessment: groundwater (piezometric) levels and groundwater recharge. Even if they can be determined very accurately, the actual values of both parameters cannot directly be related to the actual quantity stored in a groundwater body or to the amount available in the future. A trend analysis is usually required to evaluate the system changes. This trend analysis however has to be carried out and interpreted aquifer specific, since every aquifer reacts differently to changes of outer boundary conditions (withdrawal, climate change …) depending on a large number of geometric and hydraulic characteristics. This means that general indicators such as the quite often used head change per year are not sufficient to meaningfully describe past changes and to derive reliable future predictions. The resulting task is therefore to generate simple, yet meaningful indicators that can be used in decision making or presented to stakeholders from very complex, case specific analyses.

In this paper an integrated approach to assess groundwater availability for water supply purposes as well as for ecological demands under conditions of climatic and socioeconomic change is presented. This approach is embedded in the DSS DANUBIA which was developed by the GLOWA-Danube research cooperation during the past six years. DANUBIA is a fully coupled system that is comprised of 16 individual models to describe all compartments of the hydrological cycle (natural and socioeconomic) of the Upper Danube catchment (Germany, 80.000 $km^2$). The approach presented here allows for the assessment of 405 groundwater bodies (hydrogeological response units) within the Danube catchment which are delineated by intersecting 150 surface watersheds and four main aquifer systems. The assessment results in a classification of each groundwater body in five status categories (good … very bad) which are called “groundwater quantity flags”. Those flags are mainly used by the six socio-economic models contained in DANUBIA which are based on a common multi-actor approach. Here individual actors can interpret and use the flag values according to their attributes and preferences in order to simulate decisions. The groundwater quantity flags are calculated monthly based on three exchange variables provided by two natural science models in DANUBIA: groundwater recharge, groundwater level and infiltration from groundwater to surface water (“baseflow”) – aggregated monthly for each groundwater body. The calculation includes the individual characteristics of the groundwater bodies by using a combination of response times and weights for each exchange variable.

In the conference contribution, after a definition of the problem, the three main aspects of the developed approach will be introduced: 1) the delineation of groundwater bodies, 2) the assessment methodology and the required parameters, 3) the integration of the results in socio-economic models.

**References:**

Sophocleous, M. (2005): Groundwater recharge and sustainability in the High Plains aquifer in Kansas, USA, Hydrogeology Journal, 13: 351-365.

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