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Evaluation of future climate change impacts in Europe on potential groundwater recharge

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Climatic warming during the next 100 years is expected to lead to changes in the global hydrological cycle and have major impacts on regional water resources. In Europe, records show that over the last century (1901-2001) the average temperature has risen by 0.95^{o}C and that climate change has caused a steepening of precipitation and temperature gradients resulting in wetter conditions in northern regions and drier conditions in southern areas (Alcamo *et al*. 2007). It is estimated that throughout Europe groundwater resources supply 75% of the population with drinking water and in Mediterranean Europe is also important in meeting the high agricultural irrigation demand (Krinner *et al*. 1999; UNEP 2003). The interpretation of climate change on these important groundwater resources is difficult to predict but will be dependent on regional hydrogeological characteristics as well as future water supply demand.

In this study, and under UNESCO's initiative GRAPHIC (Groundwater Resources Assessment under the Pressures of Humanity and Climate Change) that addresses groundwater quantity and quality, environmental interdependencies and management and policy, five areas with known groundwater resources were chosen for investigation (Northern Denmark, Aarhus catchment; Southern England, Medway catchment; Northern France, Seine catchment; Northern Italy, Po catchment; and Southern Spain, Guadalquivir catchment). Firstly, long-term river flow records for baseflow analysis and borehole hydrograph records for major aquifers, together with geological and land use information in these areas, were analysed to explain the severity, frequency

and persistence of drought and flood events in the historic record. Secondly, in order to analyse possible future changes in groundwater resources, this study made use of high-resolution grids of monthly climate for Europe (Mitchell *et al*. 2004) to calculate values of potential groundwater recharge (hydrologically effective rainfall) using a soil moisture balance model (FAO 1998). The dataset, which includes values of precipitation and temperature, comprises the observed climate record (1901-2000), a control scenario (1901-2100) and 16 scenarios of projected future climate (2001-2100) representing all combinations of four greenhouse gas emissions scenarios and four global climate models (GCMs). For analysis of the future sensitivity of potential groundwater recharge to climate change, the A1FI SRES gas emissions scenario was selected for the three time periods 2020s, 2050s and 2080s.

Compared with the 1961-90 baseline period, the results showed increases in annual potential groundwater recharge for Northern Denmark (28%), Southern England (32%) and Northern France (60%) and decreases for Northern Italy (22%) and Southern Spain (78%). Also, the frequency and severity of hydrological extremes (wet and dry periods) is shown to become greater, with flooding events more common in northern regions and drought in southern regions. It is concluded that the evident decrease in potential groundwater recharge in southern Europe as a result of climate change will seriously impact the availability of fresh water resources for drinking and irrigation uses. Regions in northern Europe are likely to experience an increase in recharge, although more concentrated in the winter season.

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