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Simulation of the historical development of the water cycle of the Copenhagen area, Denmark

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A complete water cycle model has been constructed for the Copenhagen area (966 km^2) in order to (1) study the development of the water cycle during the period 1850-2003, (2) to analyze the effect of future climate changes, and (3) to evaluate water management scenarios considering stormwater infiltration as a strategy to minimize negative impacts from future climate changes and groundwater abstraction in the region. The urban water cycle is quantified in terms of root zone water balance, water supply, waste water, storm water, groundwater flow between geological layers, and the interactions between these systems. Historical data of groundwater abstraction and water import to / export from each municipality were collected and converted to estimates of waste water by a reduction factor. The Daisy model was used to simulate root zone water balances on a daily basis for the entire period 1850-2003 for relevant combinations of climate, soil type and land use. Extensive use of database information was used to set up and parameterize a modified Modflow-2000 model with seven layers. Efflux to the sea was simulated by the constant head package, abstraction from wells by the well package and efflux to drains with the drain package. Groundwater exchange with streams and lakes / wetlands was simulated by the use of SFR1-package in conjunction with the LAK3-package. The two new Modflow-packages simulate interactions between ground water and (1) infiltration trenches, and (2) sewers and storm pipes, respectively. Long time series of hydraulic head, stream flow, and inflow to sewage works are used to calibrate the model parameters.

The results indicate that the model concept gives a proper large-scale description of the historical evolution of the water cycle. During the first eight years of the simula-

tion (1850-1857) groundwater abstraction and other urbanization impacts were negligible. Model results for this period can thus be used to characterize the state often denoted “the natural reference”. Ground water abstraction rates increased rapidly from the early 1900s to hit peak values in the 1960s. The climatic input of precipitation shows an evident long term tendency of increasing values throughout the simulation period, but the straight effect in net-precipitation is somewhat reduced by the urbanization (surface infrastructure), especially during the 1950s and 1960s, in terms of both modifying groundwater infiltration and generating stormwater runoff to streams. The model has its strength in quantifying interactions between the many subsystems and dissecting impacts from urbanization in terms of groundwater abstraction, surface infrastructure, and past and future climate changes on the urban water cycle. This knowledge is of obvious relevance to the establishment of criteria’s for future groundwater abstraction levels in the greater Copenhagen Area. Furthermore, the integrated model approach is believed to minimize uncertainty on predictions of different water management scenarios regarding storm water infiltration.

In the presentation the model concept and selected simulation results will be presented. Primary focus will be on historical simulations, but preliminary results regarding future storm water infiltration scenarios will also be presented.