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Optimisation of groundwater level monitoring networks using geostatistical modelling based on the Spartan family variogram and a genetic algorithm method

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Groundwater level monitoring networks provide essential information for water resources management, especially in areas with significant groundwater exploitation for agricultural and domestic use. Given the high maintenance costs of these networks, development of tools, which can be used by regulators for efficient network design is essential. In this work, a monitoring network optimisation tool is presented. The network optimisation tool couples geostatistical modelling based on the Spartan family variogram with a genetic algorithm method and is applied to Mires basin in Crete, Greece, an area of high socioeconomic and agricultural interest, which suffers from groundwater overexploitation leading to a dramatic decrease of groundwater levels. The purpose of the optimisation tool is to determine which wells to exclude from the monitoring network because they add little or no beneficial information to groundwater level mapping of the area.

Unlike previous relevant investigations, the network optimisation tool presented here uses Ordinary Kriging with the recently-established non-differentiable Spartan variogram for groundwater level mapping, which, based on a previous geostatistical study in the area leads to optimal groundwater level mapping. Seventy boreholes operate in the area for groundwater abstraction and water level monitoring. The Spartan variogram gives overall the most accurate groundwater level estimates followed closely by the power-law model. The geostatistical model is coupled to an integer genetic algorithm method programmed in MATLAB 2015a. The algorithm is used to find the set of wells whose removal leads to the minimum error between the original water level mapping using all the available wells in the network and the groundwater level mapping using the reduced well network (error is defined as the 2-norm of the difference between the original mapping matrix with 70 wells and the mapping matrix of the reduced well network). The solution to the optimization problem (the best wells to retain in the monitoring network) depends on the total number of wells removed; this number is a management decision. The water level monitoring network of Mires basin has been optimized 6 times by removing 5, 8, 12, 15, 20 and 25 wells from the original network. In order to achieve the optimum solution in the minimum possible computational time, a stall generations criterion was set for each optimisation scenario. An improvement made to the classic genetic algorithm was the change of the mutation and crossover fraction in respect to the change of the mean fitness value. This results to a randomness in reproduction, if the solution converges, to avoid local minima, or, in a more educated reproduction (higher crossover ratio) when there is higher change in the mean fitness value. The choice of integer genetic algorithm in MATLAB 2015a poses the restriction of adding custom selection and crossover-mutation functions. Therefore, custom population and crossover-mutation-selection functions have been created to set the initial population type to custom and have the ability to change the mutation crossover probability in respect to the convergence of the genetic algorithm, achieving thus higher accuracy. The application of the network optimisation tool to Mires basin indicates that 25 wells can be removed with a relatively small deterioration of the groundwater level map. The results indicate the robustness of the network optimisation tool: Wells were removed from high well-density areas while preserving the spatial pattern of the original groundwater level map.

Varouchakis, E. A. and D. T. Hristopulos (2013). "Improvement of groundwater level prediction in sparsely gauged basins using physical laws and local geographic features as auxiliary variables." Advances in Water Resources 52: 34-49.