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INTRODUCTION

Quality and quantity monitoring networks are essential tools for the effective management of groundwater resources but the costs of monitoring well installations and sampling can prove prohibitive. The challenge is to obtain adequate water quality and quantity information with a minimum number of wells and sampling points, a task that can be approached objectively and effectively using numerical optimization methods. One recently developed optimization approach involves particle swarm optimization (PSO), a population based stochastic optimization technique that was inspired by the social behavior observed in bird flocks and schools of fish. The system is first initialized with a population of randomly generated particles (i.e. potential solutions); thereafter, searches for optima are conducted iteratively. However, unlike genetic algorithms, PSO has no evolutionary operators (e.g. crossover and mutation) and instead, potential solutions "fly" through the problem space by following the current optimised particles. To demonstrate the effectiveness of the PSO approach, the particle swarm algorithm was used to optimize an existing network of 57 monitoring wells located in the Astaneh aquifer in the north of Iran. The traveling salesperson problem (TSP) analogy was used to represent the existing condition and PSO was used to solve the problem and thereby provide the optimal solution.

TRAVELING SALESPERSON PROBLEM

The TSP is one of the most intensively studied problems in computational mathematics and involves finding the shortest itinerary between a series of cities under the condition that each city may be visited only once. In TSP, the distance between cities and the order of visiting are important. However, in the application of PSO to the optimization of monitoring networks, the distance between wells and the order visited are not directly related to the objective function and problem constraints. Distances between wells do, however, affect the accuracy of the water level estimation.

PSO-TSP ALGORITHM

In this algorithm, the particle selects a well to visit based on the relative importance of that well compared to its neighbors. The objective function is designed to minimize the overall data loss in the optimized monitoring network. It can be quantified using the root mean square error (RMSE) for each well where a constant number of wells is considered. The function is:

$$\min Z = \sqrt{\frac{\sum_{i=1}^{m}\left(\frac{WT_{est,i} - WT_{act,i}}{\min(WT_{est,i}, WT_{act,i})}\right)^2}{m}}$$

where $m = S_{goal}$, and represents the total number of wells that should be eliminated as selected by the user, $WT_{act,i}$ is the observed (or "actual") groundwater level in eliminated well i, $WT_{est,i}$ is the estimated groundwater level in eliminated well i based on observations in neighboring wells.

The results of the optimization showed that the number of observation wells in the Astaneh aquifer monitoring network could be reduced from 57 to 42 without any significant loss of information. The root mean square error (RMSE) for the final optimized network was 0.322 m.

Fig. 1 shows a comparison between potentiometric contours generated using 57 monitoring wells (solid line) and 42 monitoring wells (dashed line).

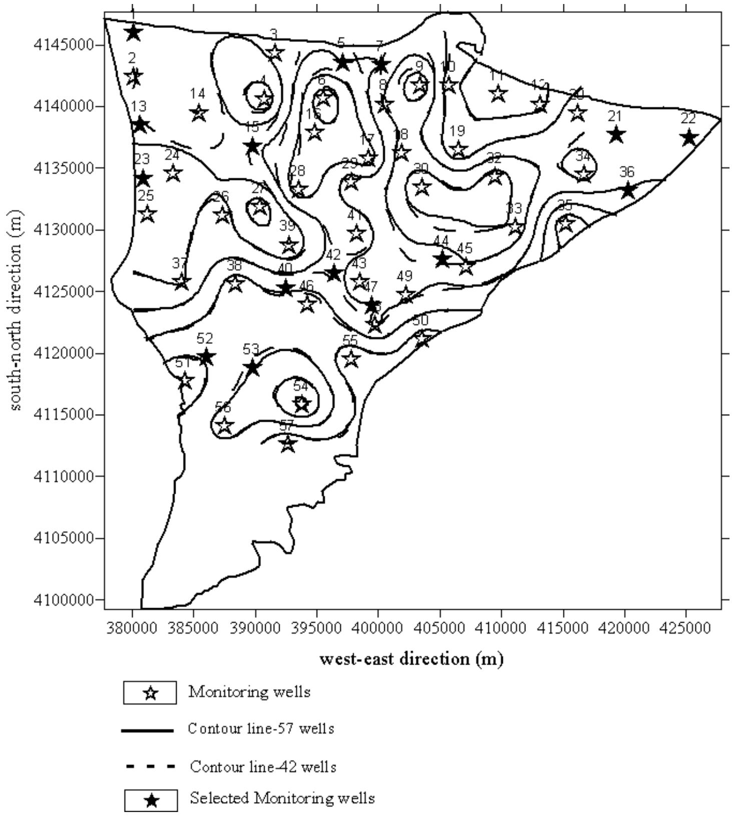

Figure 1. Comparison between groundwater levels using 42 and 57 wells.

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