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A stochastic method for optimal location of groundwater monitoring sites at aquifer scale

E. Barca and G. Passarella

Water Research Institute, National Research Council, Bari, Italy (emanuele.barca@ba.irsa.cnr.it / 00390805313365)

With the growth of public environmental awareness and the improvement in national and EU legislation regarding the environment, monitoring assumed great importance in the frame of all managerial activities related to territories. In particular, recently, a number of public environmental agencies have invested great resources in planning and operating improvements on existing monitoring networks within their regions.
In this framework, and, at the light of the Water Framework Directive, the optimal monitoring of the qualitative and quantitative state of groundwater becomes a priority, particularly, when severe economic constraints must be imposed and the territory to be monitored is quite wide.
There are a lot of reasons justifying the optimal extension of a monitoring network. In fact, a modest coverage of the monitored area often makes impossible to provide the manager with a sufficient knowledge for decision-making processes. In general, monitoring networks are characterized by a scarce number of existing wells, irregularly spread over the considered area. This is a typical case of optimization and it may be solved seeking among existing, but unused, wells, all and only those able to make the monitoring network coverage, the most uniform among any arrangement. Using existing wells as new monitoring sites, allows one to drastically reduce the needed budget.
In this paper, a four step method, based on simulated annealing, has been implemented with the aim of identifying scarcely monitored zones within the groundwater system boundaries.

The steps are the following:
I. Define aquifer boundaries, number and location of the existing monitoring sites and number and location of candidate new monitoring sites. Any constraint about the network size, and wells' location and characteristics need also to be identified at this step;
II. Carry out stochastic simulations producing a large number of possible realizations of the improved monitoring network and choose the transient optimal network arrangement on the basis of the minimization of the average distances among sites (simulated annealing);
III. Draw the Thiessen Polygons (TP) for each of the monitoring wells of the new network arrangement and join together all polygons belonging to existing sites and all those belonging to simulated new locations;
IV. Choose, among the candidate new monitoring sites, those within the scarcely monitored area defined by TP.

The first step consists in defining the physical boundaries of groundwater system on the basis of expert knowledge and hydrogeological information. Furthermore, all the wells drilled within the aquifer boundaries and potentially usable for network extension must be surveyed. Just among this set of wells the new monitoring sites will be taken at step four.
Step two deals with the generation of monitoring network realizations conditioned by the existing wells. The simulated annealing technique allows us to produce several realizations and choose the most suitable with respect to geometrical imposed constraints.
Finally steps III and IV allows us to locate new monitoring sites, just crossing the position of any candidate well with the overall unmonitored area.
The whole methodology can be easily implemented within any GIS.
A practical application of the described methodology has been carried out in the framework of the "Project Tiziano" aiming to design and implement an integrated and permanent monitoring system of the Apulia's

groundwater resources (South Italy).

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