Reliability of Remediation Design Using Stochastic Optimization Method

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1. Introduction

In groundwater management problems, it is widely accepted that the management strategy using a optimization technique may have uncertainty due to the scarcity of information about a hydrogeological setting or contaminant distribution. So, stochastic optimization approaches have been employed in order to consider the uncertainty from incomplete information by limited point measurements (Freeze and Gorelick, 1999).

In this study, the objective is to optimize reliable groundwater remediation designs considering the uncertainty of hydraulic conductivity by multiple realization approach. From the limited sampling measurements, the reliable remediation designs were obtained and analyzed for design factors and reliability.

2. Optimization of Groundwater Remediation Designs under Uncetain Parameters

2.1 "True" and Interpolated Domains

A two-dimensional unconfined aquifer was generated as a 'true' contaminated aquifer environment (Fig. 1). The concentration contours represente 80.0, 50.0, 20.0, 10.0, and 1.0 mg/L from outside. 40 locations were selected for measurements of hydraulic conductivity and pollutant concentration from the true domain (Fig. 2).

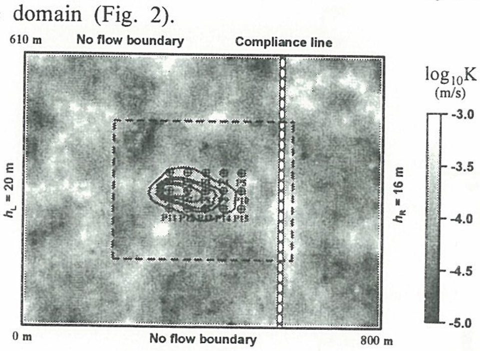

Fig. 1 "True" domain.

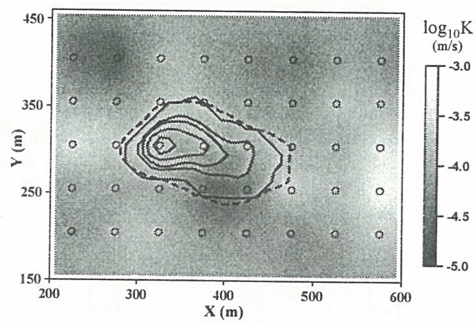

Fig. 2 Interpolated domain.

2.2 Objective Function

The objective function was set to minimize a total pumping volume and the number of pumping wells:

$$\text{Minimization} \quad \text{Pumping Volume} = q_{\text{well}} \times t \ \ \& \ \ N_{\text{well}} \tag{1}$$

where q_{well} is the pumping rate; t is the required time for remediation; N_{well} is the number of pumping wells. The maximum allowable concentration, time, pumping rate, and drawdown are 1.0 mg/L, 1095 days, 200 m^3/day, 4.0 m, respectively. The candidate design is cosidered as failure to satisfy the goal if the concentration at the compliance line is over 1.0 mg/L.

2.3 Stochastic Optimization Using Multiple Realization Approach

In the multiple realization approach, a certain number of realizations are involved in optimization process, and a simulation-optimization method is used individually on each realization (Feyen and Gorelick, 2004). If 50 realizations (or stacks) of hydraulic conductivity field are supposed, a simulation-optimization method is involved in 50 realizations. These have same influences of 50 constraint sets on optimization process. If the candidate design can meet the constraints of all realizations, or has the maximum fitness in all realization, it is determined as an optimal remediation design. A genetic algorithm is used as an optimization method.

3. Results

A series of optimal remediation designs were determined with various stack size, which means the number of realizations involved in multiple realization approach: 1, 2, 5, 10, 20, and 50. The more stacks are included, the more number and rates of extraction wells are required.

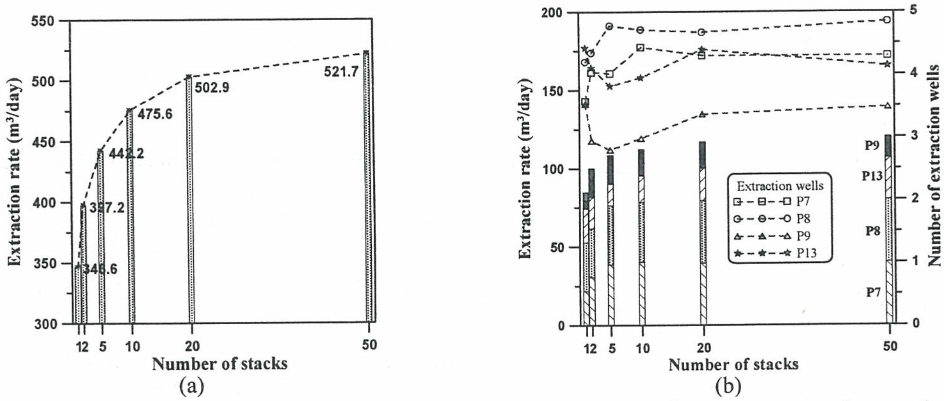

Fig. 3 Averages of (a) total extraction rate and (b) usage frequency and average rates of extraction wells.

The reliability increases as the more realizations are included in the multiple realization approach. In small stack size, the optimal designs may be only available on the small part of generated realizations. As the more stacks are involved, the domains satisfying the remediation goals also increase. So, the designs obtained in the larger stack size have the more reliability because a wider uncertainty in hydraulic conductivity is involved.

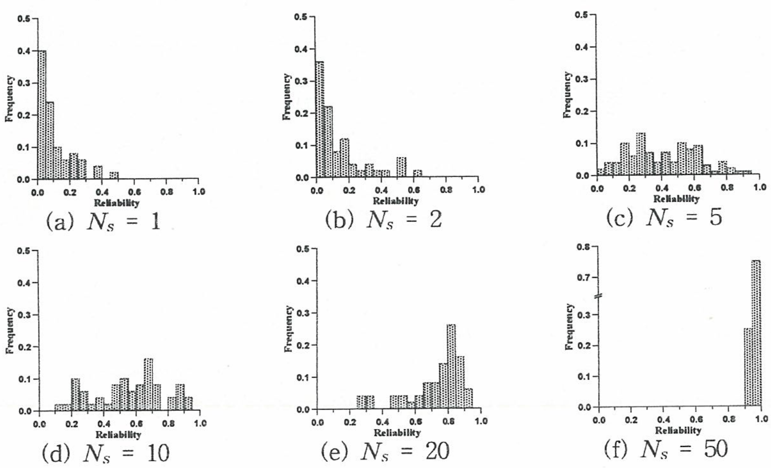

Fig. 4 Reliability histograms for the each number of stacks (N_s).

4. Conclusion

Reliable designs of groundwater remediation using pump and treat method were optimized considering the uncertainty of hydraulic conductivity by multiple realization approach. In multiple realization approach, the more stack size is given, the more total remediation cost, extraction rates, and the number of selected wells are required and the more reliable designs can be achieved. Although this method requires many computing resources, stochastic simulation-optimization method can give various merits for practical remediation designs by selection of extraction wells as well as consideration of uncertainty in hydraulic parameters.

REFERENCES

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[2] Freeze, R.A. and Gorelick, S.M., "Convergence of stochastic optimization and decision analysis in the engineering design of aquifer remediation", Ground Water, 37(6), 934-954(1999).