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Application of an Optimization Method to Groundwater Contamination Problems

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Abstract

The optimal designs of groundwater problems of contaminant containment and cleanup using linear programming and genetic algorithm are provided. In the containment problem, genetic algorithm shows the superior feature to linear programming. In cleanup problem, genetic algorithm makes reasonable optimal design. Un this study, it is demonstrated through numerical experiments that genetic algorithm can be applied to remedial designs of groundwater problems.

Key word: optimization, containment, linear programming, genetic algorithm

1. Introduction

Since the groundwater is recognized one of the main resource for water, especially for drinking water the optimal management for water supply or groundwater remediation has also studied seriously. Aguado and Remson (1974) applied linear programming to one- and two-dimensional, steady state and transient aquifer systems to yield allowable maximum pumping rate for water supply. Javandal and Tsang (1986) made capture zones using analytical solution for several locations of pumping wells. In these days, the mathematical programming like linear or non-linear programing and global optimum searching method like simulated annealing, artificial neural network, and genetic algorithm are often applied to the optimal design of groundwater remediation problems.

In this study, the results of numerical experiments contaminant containment problems using linear programming and genetic algorithm are compared.

2. Contaminant Containment Problem

For designing an optimal solution, the constraints and limitations are required. The constraints and limitations used I this study are:

$$C_k < C^* \qquad k = 1, \cdots, K \tag{1}$$

$$s_k \leq s_{max} \qquad k = 1, \cdots, K \tag{2}$$

$$Q_{i,min} \leq Q_i \leq Q_{i,max} \qquad i = 1, \cdots, N \tag{3}$$

where C_k is the concentration on observation well k; C^* is the concentration constraint; K is the number of observation wells; s_i is the drawdown in observation well i; s_{max} is the drawdown constraint; $Q_{i,min}$ is the lower limitation of pumping rate on pumping well i; Q_i is the pumping rate on pumping well i; $Q_{i,max}$ is the upper limitation of pumping rate on pumping well i. The time constraint is set 10 years. The simulation-optimization method is used and MODFLOW (McDonald and Harbaugh, 1988) and MT3D (Zheng, 1990) is used as the flow and transport simulator, respectively. The objective function for minimum pumping rate is given by

Table 1. Values of Parameter

Parameters	Value
C^*	1.0mg/L
s_{max}	10m
$Q_{i,min}$	$0m^3/day$
$Q_{i,max}$	$180m^3/day$

$$\text{Maximum} \qquad \sum_{i=0}^{n} Q_i \tag{4}$$

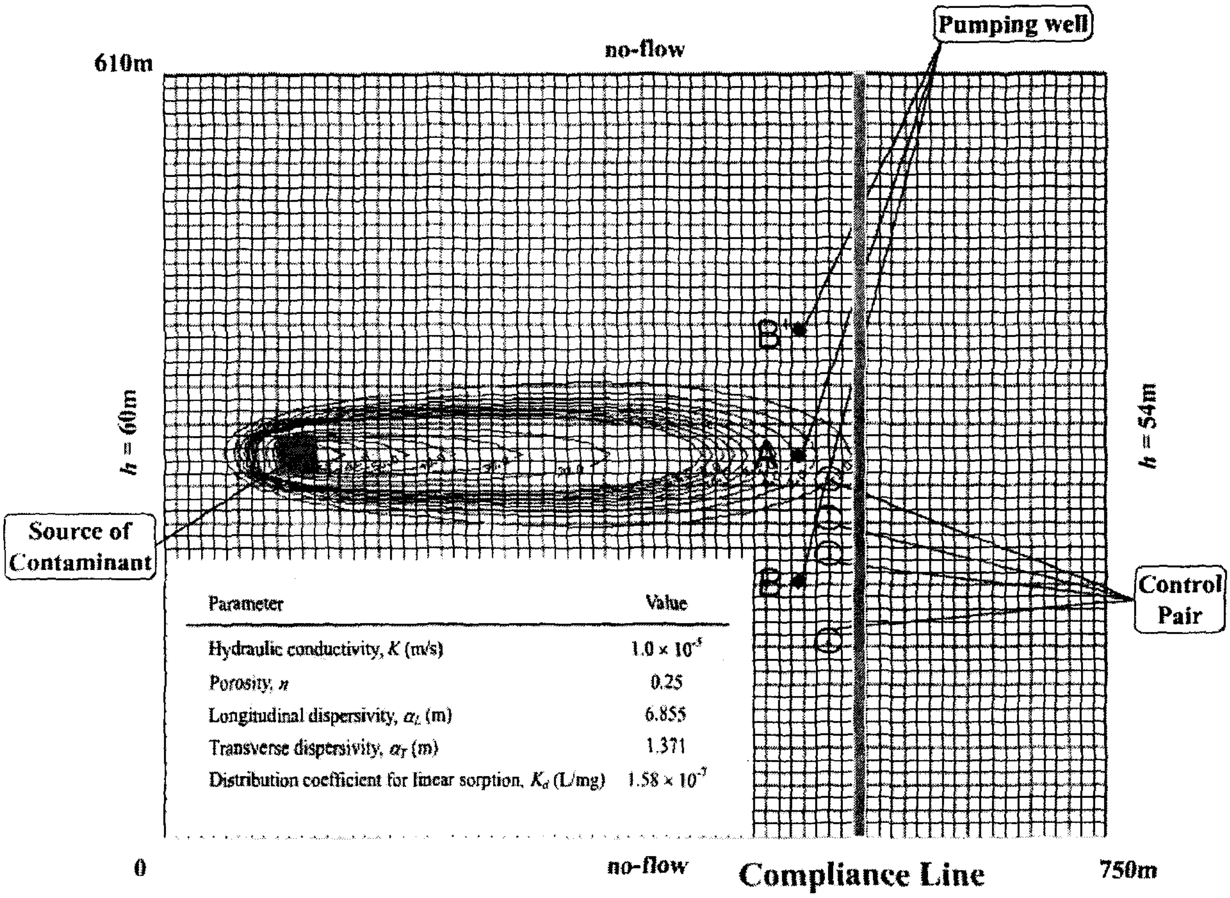

Figure 1. Initial condition and parameters for containment problem

2-1 Linear Programming

The result is produced by maintaining reverse gradient of groundwater. This design can prevent the contaminant from going over the compliance line.

Table 2. Optimal design using linear programming

Pumping well	Pumping rate(m^3/day)
Q_A	14.265
Q_B	101.952
$Q_{B'}$	14.265

2-2 Genetic Algorithm

In the same constraints and objective function, the optimal design using genetic algorithm has smaller pumping rates than that of linear programming. The center well has the most pumping rate by intuition. It shows that genetic algorithm may show better performance than other mathematical programming.

Table 2. Optimal design using genetic algorithm

Pumping well	Pumping rate(m^3/day)
Q_A	1.760
Q_B	41.496
$Q_{B'}$	1.760

3. Contaminant Cleanup Problem

In hypothetical contaminated aquifer system, the optimal design for cleanup is computed. The objective function is given by

$$\text{Minimizing} \quad \sum_{i=0}^{n}(Q_i \times t + a_1 N) \qquad (5)$$

where t is the required time; N is the number of necessary pumping wells; a_1 is the weighting factor for the number of pumping well to the objective function. In this study, a_1 is below one order of expected objective function value.

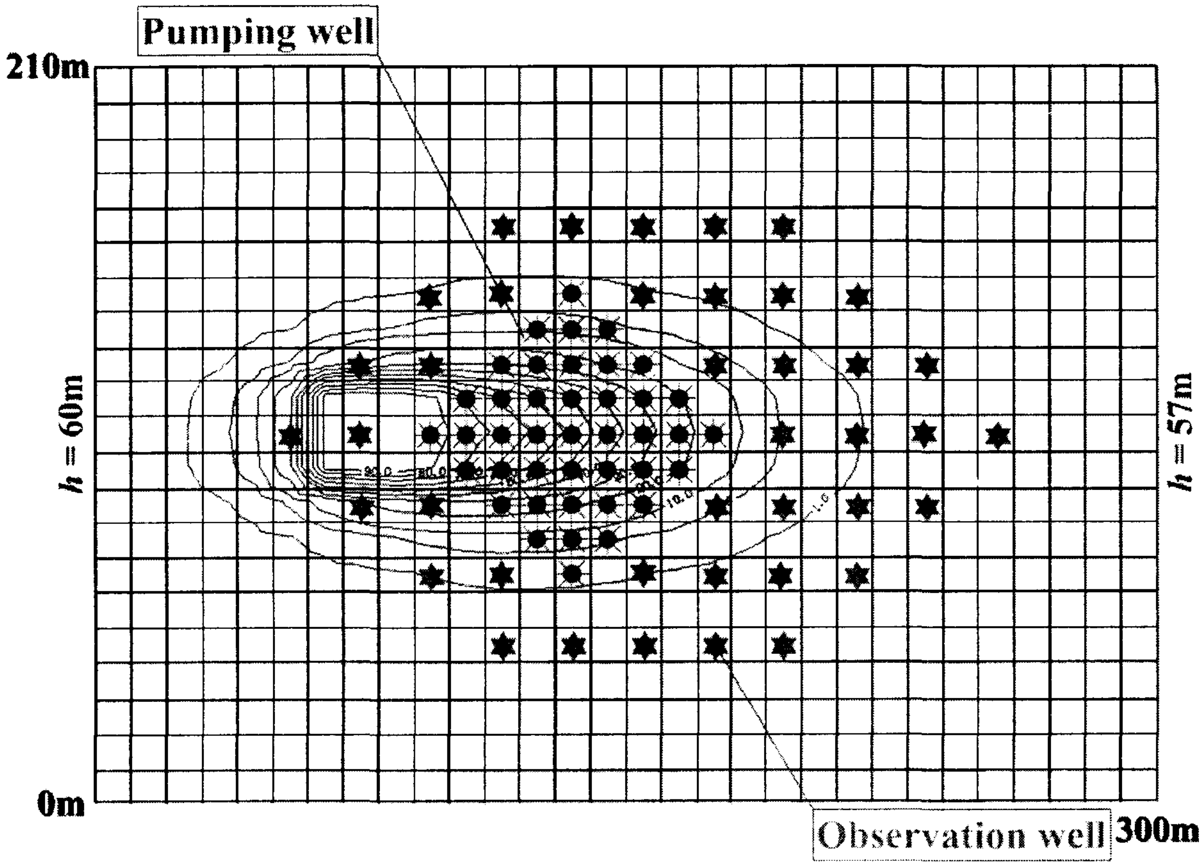

Figure 2. Initial distribution of contaminant concentration and well locations for cleanup problems

In the result, the main pumping wells are located on centerline of the initial distribution of contaminant. This is in accord with the conventional concepts, the wells on centerline and down-gradient direction are effective for cleanup. The time constraint makes the hot-spot well had large pumping rate, and the drawdown constraint requires additional

				0				
			0	0	0			
		0	0	0	17.42	0		
	0	0	0	0	0	0	0	
0	110.4	0	25.71	57.18	0	0	68.71	51.05
	0	0	0	0	0	0	0	
		0	0	0	17.42	0		
			0	0	0			
				0				

(m^3/day)

Total pumping rate: 349.87 m^3/days
Required time: 1058.5days

Figure 3. The optimal design for cleanup

two wells that is not on centerline.

4. Summary and Conclusion

Linear programming and genetic algorithm is applied to the contaminant containment and cleanup problems in groundwater. In the containment problem, genetic algorithm shows more optimal design though linear programming is easier in application than it. In the cleanup problems, genetic algorithm presents reasonable optimal design that is dependent on the several constraints. It is sure that genetic algorithm is applicable to the optimal design of groundwater contaminant problems, and expecially, it is more efficient when the design has many decision variables.

5. Acknowledgement

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6. References

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