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Well Parameter Estimation using Genetic Algorithm

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Abstract

Well is an important and reliable source of fresh water for variety of purposes like domestic, agricultural and industrial. In the present work, a method is developed for estimation of well parameter, i.e., aquifer loss coefficient and well loss coefficient, by using published step draw-down test data. This is done employing genetic algorithm (GA), one of the increasingly popular global optimization methods. When compared with the actual parameters, he results of the study show that GAs are suitable as predictive models, especially when the objective function is highly nonlinear with several constraints.
Keywords: Aquifer, Parameters, Genetic Algorithm, Pumping test, well

Introduction

Ground water management is key to combat the emerging problems of drinking water scarcity. Global ground water volume stored beneath the earth's surface represents 96 percent of the unfrozen fresh water which provides useful function and service to humans and environment. An international ground water resource assessment estimates that about 60 percent of withdrawn ground water is used to support agriculture in arid and semi-arid climate, and 25-40 percent to drinking water purposes. However, ground water being a hidden resource is often developed without proper understanding of its occurrence in time and space though there is an inherent linkage between development and management of ground water resources and knowledge of aquifer and well parameters. For an effective ground water supply management, it is essential to have full knowledge of hydro-geological controls which govern the yields and behaviour of wells under abstraction stress.

Ground water as a potential resource can be characterized by two main variables: (1) the rate of replenishment, and (2) storage volume. A prior knowledge of aquifer and well parameters is important for successful and reliable modeling and proper management of ground water resources. These parameters include well loss coefficient (C), aquifer loss coefficient (B), and well efficiency. There are various methods to estimate well parameters- traditional and evolutionary.

Traditional methods

Most of the conventional well hydraulics theories are based on the assumption that laminar flow condition exists in the aquifer during pumping. If the flow is laminar, draw-down is taken directly proportional to the pumping rate. Turbulence occurs in some well, however, when they are pumped at higher rate. Jacob [1] used draw-down test datasets to develop the performance of wells having turbulent flows and proposed the following equation

$$S_w = BQ + CQ^2 \quad (1)$$

Where, laminar term (BQ) is the aquifer/formation loss and turbulent term (CQ^2) is the well loss. And S_w and Q are draw-down and pumping rate respectively.
Using this equation, Bierschenk [2], presented a simple graphical method for determination of B and C by rewriting Eq. (1) as

$$S_w /Q = B + CQ \quad (2)$$

When Sw /Q is plotted against Q, the resultant graph is a straight line with slope C and intercepts B. Thus B and C can be determined from the graph.

Application of Genetic Algorithm (GA)

GA is a search procedure based on natural selection and the mechanism of population genetics. It starts from a population of randomly populated generated guesses (called chromosome or strings), which represents variable or components. Strings are made up of genes or sub-strings. Each string, a candidate's solution, has its fitness value. The entire population of strings forms a generation. A set of genetic operators (selection, crossover, mutation) are employed on chromosomes of this generation to create chromosomes for next generation. This operation is repeated until a stopping criterion is reached. In this method the criterion has the minimization of error between the observed and the predicted value. The working of GA is well illustrated in the books of Goldberg [3] and Michalewicz [4].

Genetic algorithm can handle a wide range of difficult problems related to water resource management. Several scientist and hydrologist have applied genetic algorithm in various problems. Nagesh et al. [5] Applied GA for the optimization of reservoir in a hydropower production. Mckinney and Lin [6] showed that Genetic algorithm is a reliable tool for finding out the maximum yield from an aquifer. Uruya et al. [7] have used GA for monitoring fluctuation of ground water table. Samuel and Jha [8] used GA for determining the hydraulic characteristics of production wells. Dutta and Das [9] showed efficiency of GA in ground water management. In this paper they have shown that GA is an effective and reliable tool for the determining the hydraulic characteristics of a well.

The objective of the present study is to find optimal magnitudes of the parameters B and C, which simulate as closely as possible the published field draw-down test data. This is done employing genetic algorithm.

The equation of draw down in a production well (S_w) for a constant pump age (Q) is given as

$$S_w = BQ + CQ^p \quad \text{Batu[10]} \quad (3)$$

The value of exponent "p" is not constant as assumed earlier by Jacob [1]. Rorabaugh [11] suggested that the value of "p" should be determined individually for each well. Use of graphical method is no longer convenient as Eq. (3) would be non-linear.

The parameters B and C would be determined by minimizing the sum of the squared errors between observed and predicted values of S_w as given in Eq.(3), i.e.,

$$SSE = \min \sum_{i=1}^{N} \left[S_{wm} - \left(BC + CQ_i^{\ p} \right) \right]^2 \quad (4)$$

SSE = Sum of acquired errors [L]
N = Total no. of steps
$S_{wm,\,i}$ = Observed draw down at i^{th} step

Q_i = Discharge of production well in i^{th} step
B = aquifer loss efficient $[T/L^2]$
C = well loss co-efficient
P = exponent

Development of Coding for Genetic algorithm

Four sets of step draw-down test data Gianpietro [12] are taken for estimation of the well parameters. A string length of 20 for each input variable B, C and P is selected. This string length should be sufficient for the values the input parameters can take. After many trials, the GA scheme with a population size of 200, crossover probability 0.8, and mutation probability 0.01 is found to yield the minimum SSE.

Result and Discussion

The values of B, C, and P as obtained by GA and Jacob model [Eq.(1)]are given in Table 1. It can be seen from Table 1 that aquifer parameters varies from well to well. For well 1, P is nearly 2 as given by Jacob but for other wells it is far from being 2. And accordingly, there are much variations between values of parameters B and C obtained from GA and Jacob models. The present GA model predicts parameters more accurately than the Jocob model as the root mean square error (RMSE) of the prediction by the Jacob model [Eq.(1)] is much higher than by the GA model.

Table 1. Aquifer parameter values as predicted by the present GA model and the Jocob model

Well Set	method	B	C	P	RMSE
Well 1	Jacob [Eq.(1)]	23.53	5.28	2	27.21
	GA	1.10	1.55	1.96	.177
Well 2	Jacob [Eq.(1)]	27.34	3.48	2	57.44
	GA	.25	2.83	1.64	.044
Well 3	Jacob [Eq.(1)]	26.02	1.32	2	72.90
	GA	2.56	2.10	1.43	0.41
Well 4	Jacob [Eq.(1)]	27.43	3.12	2	77.88
	GA	.66	0.89	2.24	0.11

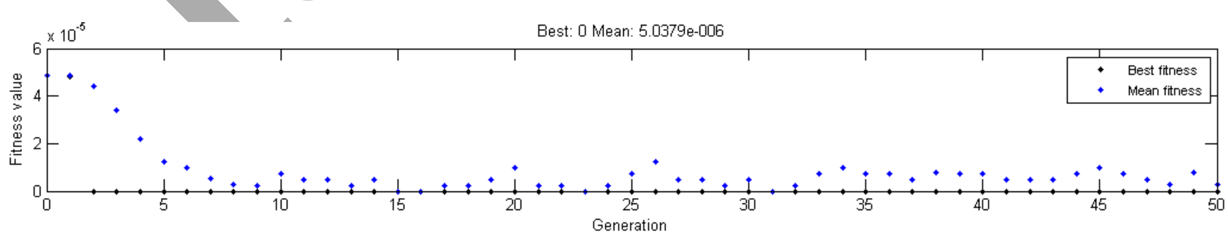

Figure 1: Fitness value variation with no. of generation (Well set 1, present study)

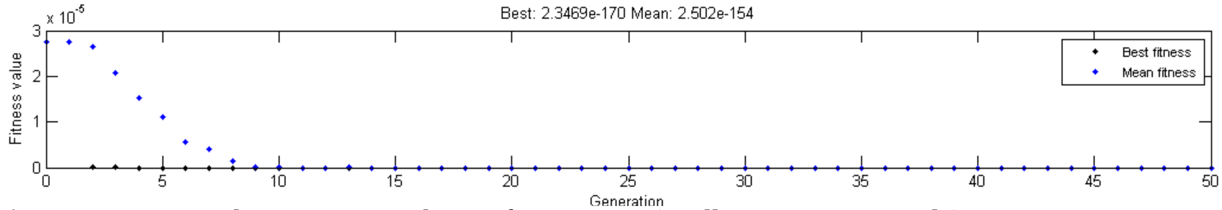

Figure 2: Fitness value variation with no. of generation (Well set 2, present study)

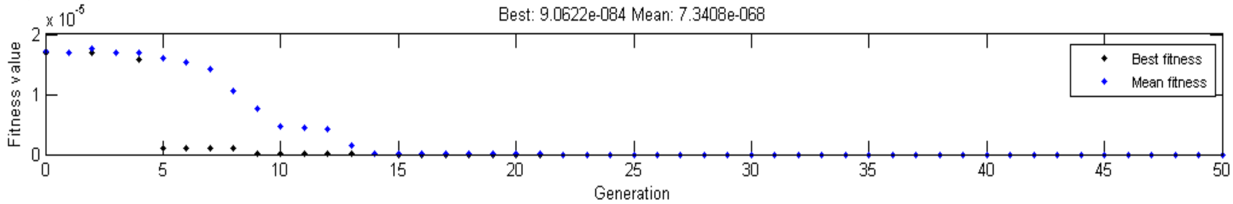

Figure 3: Fitness value variation with no. of generation (Well set 3, present study)

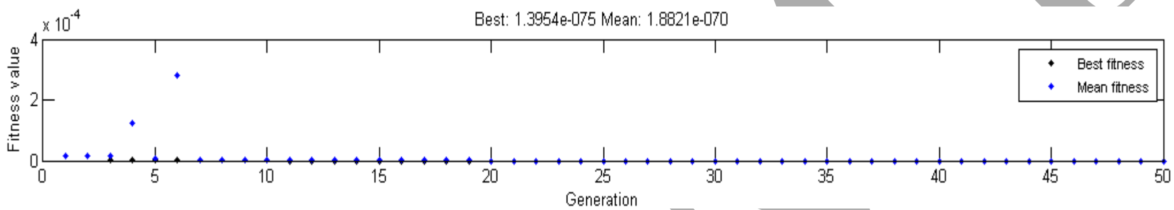

Figure 4: Fitness value variation with no. of generation (Well set 4, present study)

Conclusion

The National Ground Water Board of India has estimated that 59% of the Indian population depends on ground water for its drinking water supply from either a public source or private well. The health of an aquifer or well is reflected in their parameters. In the present study, genetic algorithm optimization technique was employed on published step draw-down test data for determination of aquifer and well parameters (aquifer loss coefficient, well loss coefficient). It was observed that the GA models are effective in such parameters determinations, especially when objective function is non-linear, discontinuous and noise-ridden, which cannot be solved either by graphical or other traditional methods. The results of the study also suggest that the value of the exponent P need not be 2 as was suggested by Jacob[1]. When compared, the present GA model is found to be a better predictive model than the Jacob model as the RMSE of the prediction by the GA model is much smaller.

References

1. Jacob, C. E. Drawdown test to determine effective radius of artesian well, American society of civil Engineers, Vol.112, pp. 1047-1070, 1947
2. Bierschenk, W.H., Determining the well efficiency by multiple step draw-down test, publication 64, International association of scientific hydrology, 1963.
3. Goldberg, D. E., Genetic algorithms in search, optimization and machine learning, Addison-Wesley, New York, 1–145, 1989.
4. Michalewicz, Z., Genetic algorithms+ data structures evolution program, Springer, New York (1992).
5. Nagesh, D., Ashok, K., and Srinivas, R., Application of genetic algorithm for optimal reservoir operations. Proceedings of Xth World Water Congress, Melbourne, Australia, 12-17 March 2000.

6. McKinney, D. C. and Lin, M. Genetic algorithm solution of groundwater management models, Water Resource, Res. 30: 1897–1906, 1994
7. Uruya, W., Kunio, W. , and Katkritta, N., Application of soft computing techniques for analysis of groundwater table fluctuation in Bangkok area and its vicinity. International Transaction Journal of Engineering Management and Applied Sciences and Technologies. Volume 1 No 1. .eISSN:1906-9642.
8. Samuel, M.P., and Jha, M.K., Estimation of aquifer parameters from pumping test data by genetic algorithm optimization technique, Journal of Irrigation and Drainage Engineering, ASCE, pp. 348-359, September 2003.
9. Dutta, B. and Amlan, D., Application of optimizing techniques in groundwater quantity and groundwater management, Sadhna, Vol. 26(4), pp. 293-316, 2001.
10. Batu, V., Aquifer hydraulics—A comprehensive guide to hydro geologic data analysis, Wiley, New York, 113–627, 1998.
11. Rorabaugh, M. I. Graphical and theoretical analysis of step drawdown test of artesian well.
a. Proc., Hydraulic. Division, Vol. 79, ASCE, 362-1–362-23, 1953.
12. Gianpietro, S., A new approach to the step-drawdown test, Montichhio Bagni, Potenza, Italy. Water SA (Online), Vol.36 (3), 2010.
13. F. G., Driscoll, Groundwater and wells, published by Johnson division, 1987 p.534-579.