ANALYSIS OF PUMPING TEST DATA ON LARGE DIAMETER WELLS USING OPTIMIZATION TECHNIQUE

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Abstract

The pumping phase data on large diameter wells, particularly in hard rock terrane, usually show negligible aquifer response indicating that most of the water is pumped from the well storage. Therefore, the recovery data should also be taken into account to estimate the hydrogeological parameters. The observed time-drawdown recovery data is matched with the analytically or numerically drawn theoretical type curves to estimate the hydrogeological parameters. In case of a numerical method, forward modeling is carried out wherein the parameters are progressively varied so as to obtain a close match with the observed time-drawdown/recovery curve. However, a visual match is naturally subjective and biased. Besides, the process of ploting and matching is a long drawn one.

An alternative approach is presented here which ensures an unbiased, objective, and fast interpretation of the pumping test data on a large diameter well. The technique essentially consists in the minimization of the drawdown function which is the sum of squares of difference between the observed and computed drawdowns. The non-linear drawdown function is linearized around initially guessed hydrogeological parameters. The partial derivatives of this function with respect to hydrogeological parameters result into a set of simultaneous equations giving new values of these parameters. The guess values of parameters are replaced by these newly estimated parameters. This iterative process is continued till a pre-set convergence criteria is achieved.

This technique eliminates the need for a manual matching of field and computed time-drawdown curves. An illustration for interpreting the pumping test data on a large diameter well in a granitic terrane is described in detail.

INTRODUCTION

The two important hydrogeological parameters namely transmissivity and storage coefficient are an essential input for the assessment and management of ground water potential in an area. It is a common practice to estimate these parameters through pumping tests. The cost on pumping tests are minimized by utilizing the available infrastructure viz. choosing an existing large diameter well and the pump fitted on it for carrying out the test.

The pumping tests on large diameter wells indicate that initially the pumped water is only from the well storage with the negligible contribution from the aquifer. As the pumping continues the aquifer also starts contributing; the extent of the aquifer contribution depends upon the hydrogeological parameters. In case of an aquifer of low permeability particularly in hard rocks, the aquifer response is very low during the pumping phase. Under such circumstances, interpretation of the pumping phase data alone is quite ambiguous and one has to take into account the recovery data. The observed time drawdown, recovery data is matched with the analytically or numerically drawn theoretical type curves to estimate aquifer parameters. When a 'best' match is achieved, the parameters of the theoretical curve are assumed to be the same as those of the aquifer. It is needless to mention that such a matching process is generally subjective and time consuming. Instead, a computerized matching of the observed drawdown with the theoretical one provides an unbiased, objective and fast interpretation of the pumping test data. This can be achieved through an optimization technique (Yeh, 1987). The technique essentially consists in minimizing a function f which is the sum of the squares of differences between the observed drawdowns (s) and computed drawdowns (s^*) at different times. This procedure obviates the need for even drawing a time-drawdown curve. A comparison of s and s^* can be directly achieved under the control of a computer program.

THEORETICAL BACKGROUND

The drawdown/recovery in a large diameter well at any particular stage of a pumping test can be expressed as (Papadopulos and Cooper, 1967) :

$$s = (Q/4\pi T)\left\{F(u) - F'(u)\right\} \qquad (1)$$

where

- Q - is the pumping rate,
- T - is the transmissivity of the aquifer,
- F - is the well function for the pumping phase,
- u - is the dimensionless time which is a function of T, storage coefficient (S), well radius (r_w), and time (t) since pumping started.
- F' - is the well function for the recovery phase

If s is the observed drawdown, the function f which may be expressed as

$$f = \sum_{i=1}^{n} (s_i - s_i^*)^2 \qquad (2)$$

is minimized to estimate the hydrogeological parameters. Here the summation is for n number of observations.

The non-linear function f is linearized around initially guessed parameters T' and S' (Kinzelbach, 1986). Its derivatives with respect to T and S are then made to vanish. This leads to the following set of simultaneous equations :

$$\sum_{i=1}^{n} D_{S,i}^2 \cdot S + \sum_{i=1}^{n} D_{T,i} D_{S,i} \cdot T = \sum_{i=1}^{n} (s_i - s_i^*(T',S'))D_{S,i} + \sum_{i=1}^{n} D_{S,i}^2 S' + \sum_{i=1}^{n} D_{T,i} D_{S,i} T' \quad \ldots.(3)$$

$$\sum_{i=1}^{n} D_{S,i} D_{T,i} S + \sum_{i=1}^{n} D_{T,i}^2 T = \sum_{i=1}^{n} (s_i - s_i^*(T',S'))D_{T,i} + \sum_{i=1}^{n} D_{S,i} D_{T,i} S' + \sum_{i=1}^{n} D_{T,i}^2 T' \quad \ldots.(4)$$

where D_T and D_S are first derivatives of the drawdown function with respect to T and S, respectively.

The drawdown in the well is computed using equation (1) in a manner suggested by Singh and Gupta (1986) and Barker (1991) using the initially guessed value of T' and S'. These drawdowns are then used to calculate D_T and D_S and finally new set of T and S using equation (3) and (4). These new values of T and S are again used to calculate drawdown using equation (1) and again a new set of T and S is obtained. This iterative process is continued until the values of T and S as calculated in two consecutive iterations do not change significantly. If the values do not differ by more than 0.1 per cent, the iteration may be terminated.

A CASE STUDY

A pumping test was carried out on an existing large diameter well in granitic terrane of Warangal District (A.P.). The centrifugal pump already fitted on the well was used to make the test least expensive. The diameter of the well was 5.34 m and it had a water column of 4.9m at the time of pumping test. The pumping rate was monitored at a regular interval of 30 minutes (min) and maintained constant at 450.0 cubic meter per day (cu m/d). Pumping was continued for a total duration of 460.0 min and a drawdown of 4.06 m was attained at the end of the pumping period. Water level was monitored at close intervals both during the pumping and recovery phase. At the end of 5280 min of the recovery, a residual drawdown of only 0.168m remained. The time-drawdown/recovery curve is shown in Fig. 1.

It is clear from the Fig. 1 that the aquifer response during the pumping phase is negligible which is indicated by a straight line. An initial value of transmissivity was taken as 10.0 sq m/d and the storativity as 0.001. Finally the aquifer parameters were estimated as follows:

T = 18.2 sq m/d

S = 0.016

Figure 1 shows the observed and calculated time drawdown/recovery using the above parameters.

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CAPTION TO FIGURE 1

Figure 1. : Time-Drawdown/Recovery plot