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Research Paper :

Determination of aquifer properties for a confined aquifer with graphical analysis in MS-Excel

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ABSTRACT

Hydraulic properties of a confined aquifer was determined with two methods *viz.* Jacob's method with manual graphical analysis and Theis method with interactive Theis 'type curve' in MS Excel environment. The graphical analysis in Excel was found much more convenient over the manual graphical analysis. The transmissivity and the storage coefficient for the confined aquifer were found to be 1019.80 m^2/day and 5.62 x 10^{-4}, respectively with the interactive Theis 'type curve' in MS Excel environment.

Key words : Confined aquifer, Transmissivity, Storage coefficient, MS-Excel

Proper management of groundwater resources requires an accurate evaluation of the parameters (hydraulic properties) that control the movement and storage of water. These properties are required in most groundwater supply and contaminant transport investigations. Aquifer tests are performed by pumping a well at a constant rate and observing the resulting changes in hydraulic head in the aquifer to determine the aquifer hydraulic properties. The pumping test data are studied by graphical type curve analysis, in which dimensionless 'type curves' derived from an assumed analytical model of groundwater flow to a pumped well are used to analyse time-drawdown measurements of hydraulic head in observation wells and piezometers. These analysis are done to estimate the transmissivity and storativity of confined aquifers or the hydraulic conductivity and specific yield of unconfined aquifers. Many of these aquifer test analysis methods were developed in an era when computers were not widely available and graphical matching was the only way to fit type curves to drawdown data. Although graphical matching works very well for simple aquifer models (such as Theis solution), when the number of parameters exceed 3 or 4, graphical matching becomes complicated and time consuming. This limitation is readily overcome today by using computers to analyse aquifer tests. Here an attempt has been made to find the aquifer properties for a confined aquifer with Modified Jacob method (manually) and Theis method (with interactive Excel environment). Use of the Microsoft Excel's utilities has been made to prepare an interactive 'type curve' and 'observed data curve' and to find the aquifer properties with much ease.

One of the popular methods for transient radial flow from a well tapping a confined aquifer as proposed by Theis (1935) is used in the present investigation. For a well pumping out water at a constant rate with the boundary conditions such that (h=H) for (t=0) and (h→H) at (r→∞) for (t ≥ 0) the expression appears as Theis solution.

$$s = H - h = \frac{Q}{4\pi T}\int_u^{\infty}\frac{e^{-u}}{u}\,du = \frac{Q}{4\pi T}W(u) \qquad (1)$$

W(u) is an exponential integral known as well function [M^0 L^0 T^0] and

$$u = r^2S/4Tt \qquad [M^0\ L^0\ T^0\ ] \qquad (2)$$

where

s= drawdown [L]

H = head above the impermeable basal boundary at distance R from pumping well [L]

h = head above the impermeable basal boundary in the observation well [L]

Q = pumping rate [L^3 T^{-1}]

T = aquifer transmissivity [L^2 T^{-1}]

R = distance from pumping well at which H is measured [L]

r = distance of the observation well from the pumping well [L]

S = aquifer storativity [L^3 / L^3]

t = Time [T]

For determination of aquifer properties by Theis method a 'type curve' of Theis well function needs to be prepared on double log paper using table of functions of Theis. Another graph needs to be prepared between the observed drawdown versus t/r^2 on double log paper. This observed data graph needs to be matched with the 'type curve' to determine the aquifer properties.

Jacob method:

Jacob (1950) noted that the well function can be represented by a series

$$W(u) = \left[-0.577216 - \ln u + u - \frac{u^2}{2 \cdot 2!} + \frac{u^3}{3 \cdot 3!} - \frac{u^4}{4 \cdot 4!} + \cdots\right] \quad (3)$$

For small values of r and large values of t, u becomes small (valid when u < 0.01), most of the terms in the series can be dropped leaving

$$W(u) = \left[-0.577216 - \ln \frac{r^2 S}{4Tt}\right] \quad (4)$$

Noting that - ln u= ln 1/u and ln 1.78= 0.5772

Above equation becomes

$$W(u) = \left[\ln \frac{2.25Tt}{r^2 S}\right] \quad (5)$$

and ln u = 2.3 log u

Therefore equation (1) becomes

$$s = H - h = 2.30 \frac{Q}{4\pi T}\left[\log_{10} \frac{2.25Tt}{r^2 S}\right] \quad (6)$$

Since Q, r, T, and S are constants, curve of drawdown versus log t will plot as a straight line. By reading two values of time and the corresponding values of drawdowns (over one log cycle) from the plot, transmissivity and storativity can be determined with equation 7 and 8, respectively.

$$T = \frac{2.3Q}{4\pi \Delta(H - h)} \quad (7)$$

$$S = \frac{2.25Tt_0}{r^2} \quad (8)$$

where t_o is the time intercept and the straight line intersects the zero drawdown.

METHODOLOGY

For determination of aquifer hydraulic properties pumping test was performed on a tube well tapping the confined aquifer. The experimental site was located at village Amodpur in Midnapur district of West Bengal. The tube well of 10 cm diameter with a brass strainer of 12 cm length tapped confined aquifer of 12 m thickness. Total length of the tube well was 45 m. The steady discharge was ascertained with a V notch installed for the purpose. Pumping rate was measured by volumetric method as well as by V-notch. The pumped water was collected in a steel drum of 220 litres capacity and time to fill the drum was noted to give the rate of flow of water discharged. As a check 90^0 V-notch was also used to measure the rate of flow of water while pumping water from the tube well in pumping test. The pumping test was conducted and the draw-downs in the observation well were recorded. The observation well was 3 m from the pumped well. The draw-down values in the observation well with elapsed time are given in Table 1. The steady state discharge was 7.46 litres per second (lps).

Table 1: Drawdown in the observation well

Time since pumping began, minutes	Draw-down in observation well, metre
30	0.255
60	0.285
90	0.305
120	0.320
150	0.330
180	0.340
210	0.345

Jacob method:

The drawdown versus time graph was prepared on a semi-log graph paper with drawdown on arithmetic scale

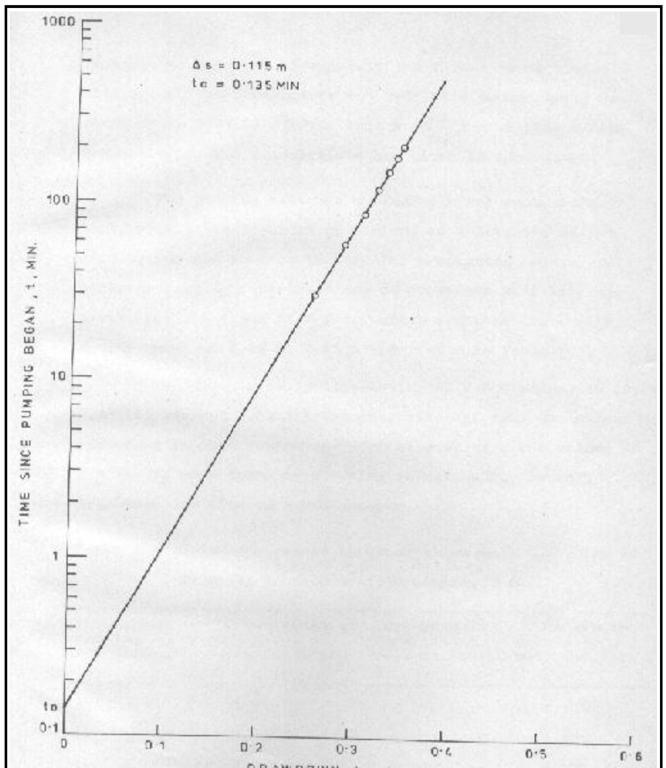

Fig. 1 : Jacob's method for the solution of non-equilibrium equation

and the time on log scale as shown in Fig 1. The values of transmissivity and storage coefficient were determined with equation 7 and 8, respectively.

Theis method with interactive Excel environment:

Manual procedure of plotting Theis 'type curve' and 'observed data curve' is tedious and time consuming. Therefore, in this investigation, Theis curve analysis has been attempted with Excel utilities. For this two scroll bars were drawn in an Excel workbook and its properties set. These scroll bars help to change the values of transmissivity and storage coefficient, respectively. The data for 'type curve' was prepared by writing a small macro for Theis well function with visual basic editor. The graph of the data of 'type curve' and that of observed data were plotted together. The graph of observed data is fixed but the shape of the 'type curve' changes as we change the values of transmissivity and/or storage coefficient (with scroll bars). Therefore, by adjusting these two values with the two scroll bars the type curve is positioned such that it fits the observed data accurately. It should be noted that changing the shape of the type curve with scroll bars is very convenient. The picture of the final workbook with Theis type curve matched with the observed data is shown in Fig 2.

RESULTS AND DISCUSSION

The plot of drawdown versus time is shown in Fig 1. From the graph it is found that ΔS = 0.115 m and t_0 = 0.135 min. Putting the values of known parameters in equations 7 and 8, values of transmissivity and storage coefficient were found as 1027.16 m^2 /day and 4.01 x 10^{-4}, respectively.

Aquifer properties by Theis method with interactive Excel environment:

As discussed the Theis 'type curve' and the 'observed data curve' were plotted with the Excel interactive environment. The graph of Theis 'type curve' accurately fitting the observed data as obtained from the Excel workbook is shown in Fig 3. From the workbook,

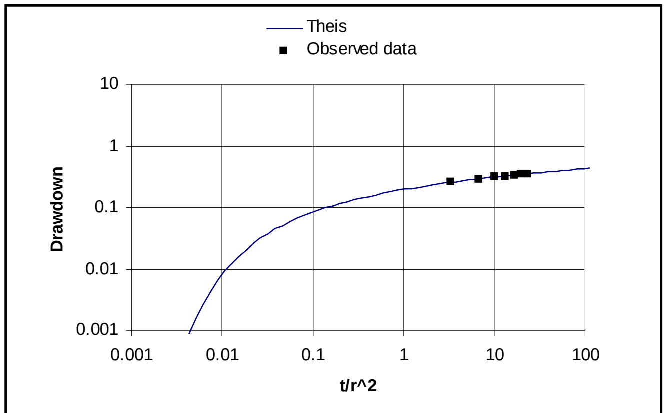

Fig. 3: Fitting of the Theis type curve to the observed drawdown data

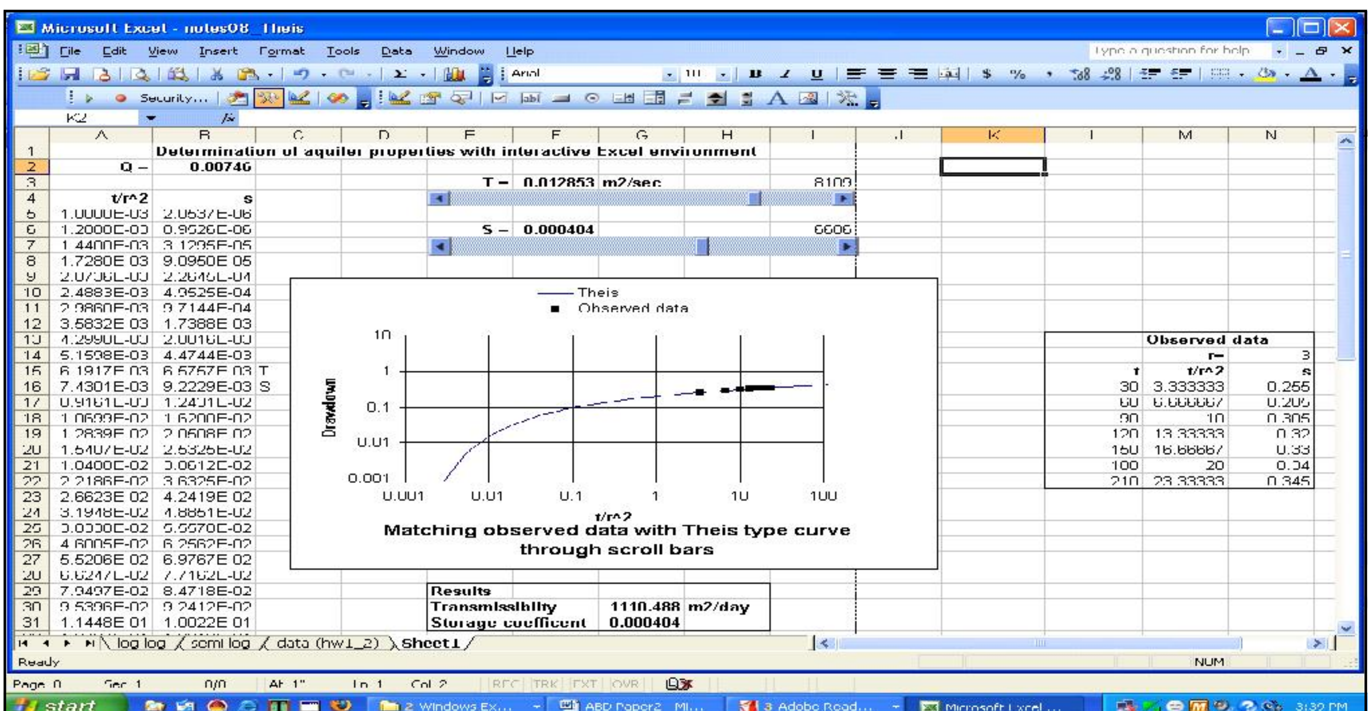

Fig. 2 : Complete Excel workbook of interactive Theis 'type curve'

for this fit of data the two scroll bars displayed the values of transmissivity and storage coefficient as 1019.80 m^2 / day and 5.62 x 10^{-4}, respectively.

Conclusion:

From the study it is concluded that computer analysis may be preferred in place of manual graphical analysis for analysing the pumping test data for determination of aquifer properties. Computer analysis is much more convenient over the manual analysis. About the two methods studied, the Jacob method gave the values of transmissivity and storage coefficient as 1027.16 m^2/day and 4.01 x 10^{-4}, respectively, whereas Theis method with interactive 'Theis curve' gave the respective values as 1019.80 m^2/day and 5.62 x 10^{-4}, respectively. Though there is not much difference in transmissivity values in the two methods, there is difference in the storage coefficient values. The Jacob method is valid for small values of 'r' and large values of t (valid when $u < 0.01$), whereas in the present investigation the values of 'u' did not fall in the valid range.

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REFERENCES

Jacob, C.E. (1950). *Flow of groundwater in 'Engineering Hydraulics*' (ed. H. Rouse), John Wiley and Sons, Inc, New York.

Thies, C.V. (1935). The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage. *Trans. American Geophysical Union*, **16** : 519-524.

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