Eco. Env. & Cons. 20 (3) : 2014; pp. (1019-1025)
Copyright@ EM International
ISSN 0971–765X

Estimation of hydrological parameters in Wakal river basin of Rajasthan

Pravin Dahiphale[1], R.C. Purohit[2], P.K. Singh[3], K.K. Yadav[4] and Sandip Nikam[5]

[1]Research Scholar, SWE Deppt., CTAE, MPUAT, Udaipur, Rajasthan
Email: pravin.dahiphale59@gmail.com
[2]Professor, SWE Deppt. CTAE, MPUAT, Udaipur. Email: purohitrc@yahoo.co.in
[3]Professor and Head, SWE Deppt., CTAE, MPUAT, Udaipur. Email: pksingh35@gmail.com
[4]Assistant Professor, SWE Deppt., CTAE, MPUAT, Udaipur. Email: kkyadavctae@gmail.com
[5]Assistant Professor, Agriculture College, Dhule, Maharashtra
Email: drspnikam@gmail.com

(Received : 3 March, 2014; accepted 18 April, 2014)

ABSTRACT

The hydrological quality of an aquifer system is evaluated by means of two parameters: its capabilities to transmit water (transmissivity, T) and to store water (storage coefficient, S). Obtaining reasonable hydrological input parameters is a key challenge in groundwater modeling. Hence, the study conducted in hard rock area of Wakal river basin for the estimation of hydrological parameters. The pumping test is the standard technique for determination of transmissivity and storage coefficient. In this research we have conducted ten pumping test in selected wells of different geological formation. These parameters were estimated by Papadopulos and Cooper method, Boulton and Streltsova and Sen method. A correlation was established between these methods. Papadopulos and Cooper method and Boulton and Streltsova method was strongly correlated with each other for transmissivity values. Papadopulos and Cooper method and Sen method was moderately correlated with each other for transmissivity values. Papadopulos and Cooper method and Sen method was negatively correlated with each other for storage coefficient values. Boulton and Streltsova and Sen method was moderately correlated with each other for storage coefficient values.The transmissivity values ranges from 132.82 m^2/day to 343.94 m^2/day by Papadopulos and Cooper method. The transmissivity values ranges from114.36 m^2/day to 257.96 m^2/day by Boulton and Streltsova. The transmissivity values ranges from 35.81 m^2/day to 98.14 m^2/day by Sen method.

Key words : *Transmissivity, Storage coefficient, Pumping test*

Introduction

Groundwater is the main source of irrigation and is utilized through dug wells, dug cum bore well and tube wells. Large diameter wells have proved more successful than the tube wells in hard rock areas which have low transmissivity. On the earth 97.5 per cent of salt water, and only 2.5 per cent is fresh water of which surface water 0.4 per cent, glaciers 68.7 per cent, groundwater 30.1 per cent, permafrost 0.8 per cent (Shiklomanor and Rodda, 2003). Rajasthan's economic growth is largely dependent on groundwater. Totally 71 per cent of the irrigation and 90 per cent of the drinking water supply meet through groundwater (Rathore, 2003). So there is need to estimating the hydrological parameters to

***Corresponding author's email:** pravin.dahiphale59@gmail.com

understanding the aquifer behavior. The transmissivity and storage coefficient are two important properties that control groundwater flow in aquifer and are practical importance of water resources development and management. The hydraulic characteristics of subsurface aquifers are important properties for both groundwater and contaminated land assessments, and also for safe construction of civil engineering structures. Groundwater hydrologists often conduct pumping tests to obtain hydrological parameters, such as transmissivity and storage coefficient, which are necessary information for quantitative groundwater studies. Hydraulic conductivity (K), Transmissivity and Storativity (S) are common applied hydraulic parameters in groundwater flow modeling (Freeze and Cherry, 1979).

Previous work on Hydrological Parameter Estimation

Boulton and Streltsova (1976), Fenske (1977); Rushton (1978); Radhakrishana and Venkateshwarlu (1980); Herbert and Kitching (1981); Rushton and Singh (1983); Miller and Weber (1983); Butt and McElwee (1984); Jat (1990); Dash and Prasad (1997) etc. carried out study on Aquifer Parameter Estimation. Moench (2003) studied that effects of drainage from the vadose zone by the analysis of a 72-h, constant-rate aquifer test conducted in a coarse-grained and highly permeable, glacial outwash deposit on Cape Cod, Massachusetts. Soupios *et al.* (2007) done study on combined use of geophysical method with pumping test for the estimation of hydrological parameters. Mathon *et al.* (2008) have done study on estimation of transmissivity and storage coefficient by coupling the Cooper-Jacob method and modified fuzzy least squares regression. Mjemah *et al.* (2009) have done study on determination of aquifer parameters by using pumping test for the evaluation of groundwater potential. Chang and Yeh (2010) carried out study on constant head test for estimation of hydrological parameters. Sethi (2011) carried out study for the determination of hydrodynamic parameters.

Material and Methods

Study Area and Data Acquisition

Wakal river is one of the tributaries of Sabaramati river basin. It is a rainfed river basin lies on the west coast of India between 24° 46' 34.65'' N to 24° 8' 49.41'' N latitudes and 73° 6' 23.41'' E to 73° 35' 54.18" E longitudes and spread across the states of Rajasthan and Gujarat (Fig. 1). The Indian Meteorological Department has divided Rajasthan into two meteorological sub divisions i.e. West Rajasthan and East Rajasthan, with the Wakal basin falling within the East Rajasthan sub division. The period from March to June is marked by a continuous increase in temperatures. May is generally the hottest month of the year with a mean daily maximum and minimum temperature of 38.3°C and 23.9°C respectively. The summer is milder than in the desert regions. The area is characterized by sub-humid climate with an average annual rainfall of 630 mm. Kharif crops are mainly dependent on the rainfall and thereby subjected to either complete or partial failures in either case of excessive or shortage of rainfall during monsoon. More than 95% of the rainfall received during monsoon months of June to September. Uneven and erratic rainfall distributions by prolong rain less days is a common phenomena in this region.

In present study, a total ten pumping tests were performed in different geological formation of selected wells in the Wakal River Basin. Wells selected for pumping test were large diameter open dugwells, which while pumped extract groundwa-

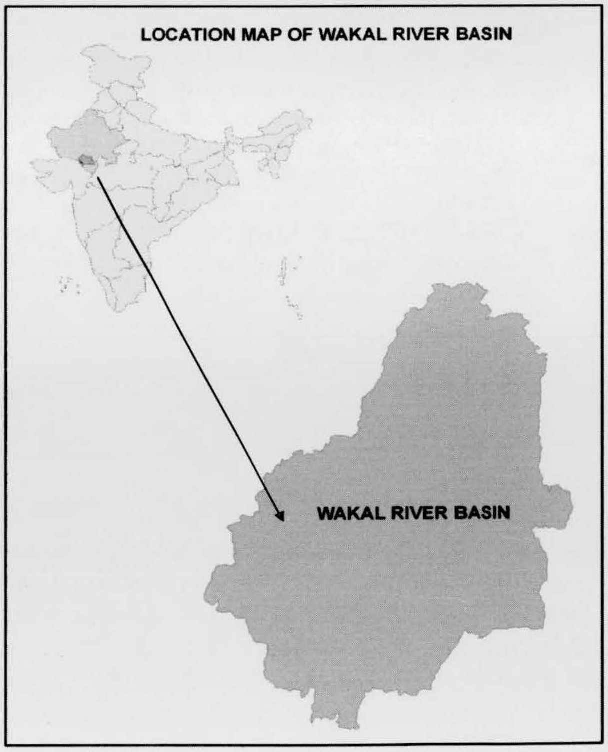

Fig. 1. Location map of Wakal River Basin

ter from the unconfined aquifer. The data of time-drawdown was collected. In a pumping test or an aquifer test, a well is pumped at constant/variable rate for a certain period of time. The effect of pumping on the water level is measured in pumped well. Hydrological parameters (T and S) are then found by substituting the measured drawdown, discharge and the well function by use of a graphical technique called curve matching.

Well number G_1, G_2, G_3 and G_4 located in Ambaba, Vas, Kirat and Surimal village respectively. These wells are located in Gogunda Tehsil. Well number J_1, J_2, J_3 and J_4 are located in Meran, Jhal, Nandbel and Saldari village respectively. These wells are located in Jhadol Tehsil. Well number K_1 located in Jogivar kin nal and well number K_2 located in Kotra Tehsil (Fig.2). The detail location and description of all wells are given in Table 1.For the estimation of hydrological parameters we have used three models and comparison was made between these models.

Papadopulos and Cooper method

This method is applicable for unsteady state flow to large diameter well fully penetrating in a confined aquifer. Using following equations partially penetrating large diameter well in an unconfined aquifer was analyzed.

$$s_w = \frac{Q}{4\pi T} F(u_w,\alpha) \quad ..1$$

$$u_w = \frac{r_w^2 S}{4Tt} \quad ..2$$

Where,

s_w = drawdown in well, Q = discharge rate of the well, T = transmissivity, $F(u_w, \alpha)$ = well function

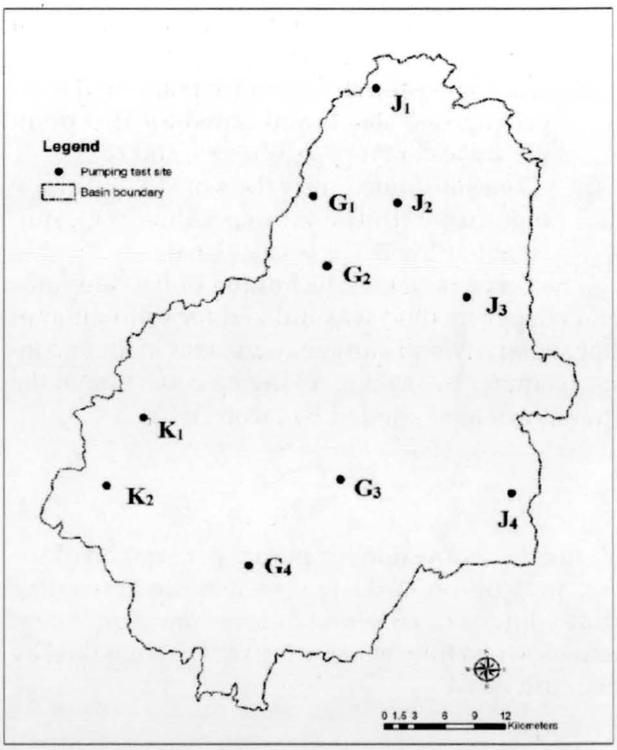

Fig. 2. Map showing location of pumping test sites

S = storage coefficient, t = time since pumping start, r_w = effective radius of well screen or open hole

Procedure

(1) On log-log paper family of type curves F (u_w,α) versus $1/u_w$, for different values of α was plotted

(2) On another sheet of log-log paper of the same scale, data curve s, versus t was plotted.

Table 1. Location and description of wells

Latitude	Longitude	Well No.	Well dia.(m)	Depth of well (m)	Test duration (min)	Aquifer thickness (m)
24⁰ 38′ 04.70″ N	73⁰ 26′ 04.30″ E	G_1	3.29	8.15	242	11.55
24⁰ 34′ 26.20″ N	73⁰ 22′ 21.70″ E	G_2	4.25	14.60	418	29.70
24⁰ 22′ 8.35″ N	73⁰ 23′ 03.45″ E	G_3	4.20	9.40	410	13.47
24⁰ 17′ 11.10″ N	73⁰ 18′ 11.00″ E	G_4	5.20	14.00	280	31.04
24⁰ 45′ 51.30″ N	73⁰ 23′ 51.10″ E	J_1	5.80	5.00	232	8.54
24⁰ 38′ 04.62″ N	73⁰ 26′ 04.06″ E	J_2	4.95	6.14	284	14.46
24⁰ 32′ 39.50″ N	73⁰ 29′ 52.00″ E	J_3	4.72	11.00	335	20.98
24⁰ 21′ 22.00″ N	73⁰ 32′ 16.20″ E	J_4	4.44	14.35	395	28.75
24⁰25′ 42.20″ N	73⁰ 12′ 30.90″ E	K_1	5.00	14.05	404	29.4
24⁰21′ 47.40″ N	73⁰ 10′ 34.30″ E	K_2	6.20	12.00	333	29.12

(3) Then the matching of data curve with one of the type curves was done.

(4) Then choosing the arbitrary point on the superimposed sheets and noted for that point the values of $F(u_w, \alpha)$, $1/u_w$, s_w, and t..

(5) Then substituted the values of $F(u_w, \alpha)$ and s, together with the known value of Q, into equation 1 and T was calculated.

The curve matching technique of Papadopulos and cooper method was utilized for estimation of transmissivity and storage coefficient in an unconfined aquifer by making following correction in the drawdown as suggested by Jacob (1963).

$$S_c = s_{uc} - \frac{s_{uc}^2}{2m} \quad .. 3$$

Another correction for partial penetration of the well in an unconfined aquifer is made by converting draw-downs of confined aquifer into equivalent drawdown in fully penetrating well as suggested by Hantush (1964).

$$s_{fc} = s_c - \frac{s_c^2}{2L} \quad .. 4$$

Where,

S_c = equivalent drawdown in a confined aquifer.

S_{uc} = drawdown observed in an unconfined aquifer.

S_{fc} = equivalent drawdown in a fully penetrating well in confined aquifer.

m = initially saturated thickness of the aquifer

L = penetration depth of the pumped well.

Boulton and Streltsova

Boulton and Streltsova proposed the most general equation describing the drawdown in a large diameter well taping unconfined aquifer at a constant rate of pumping. The transmissivity and storage coefficient was calculated by using following equations.

$$T = \frac{Q \times W}{4\pi s} \quad .. 5$$

$$S = \frac{4Tt}{r_w^2} \quad .. 6$$

Where,

T = Transmissivity, S = Storage coefficient, s = drawdown, r_w = radius of well

Procedure

1. On log-log paper the family of type curves w verses was plotted.
2. On another sheet of log-log paper of the same scale, the data curve s, versus t was plotted.
3. The data curve matched with one of the type curves.
4. Then one arbitrary point was selected on the superimposed sheets and for that point the values of w, s_w and t was noted.

Sen method

Sen give the exact solution of transmissivity and storage coefficient by using following formula.

$$T = \sqrt{\pi} \times Q \times W(u)/2Ls \text{ and} \quad .. 7$$

$$u_w = \frac{r_w^2 S}{4Tt} \quad .. 8$$

Where ,

T = Transmissivity, Q = discharge rate,W(u) = well function, s = drawdown in well

Table 2. Transmissivity (T) and storage coefficient (S) by Papadopulos and Cooper, Boulton and Streltsova and Sen method

Well	Papadopulos and Cooper method		Boulton and Streltsova		Sen method	
No.	(T) (m^2/day)	(S)	(T) (m^2/day)	(S)	(ST (m^2/day)	(S)
G_1	174.69	0.00176	254.77	0.00126	52.69	0.00934
G_2	159.52	0.00214	164.01	0.001111	35.81	0.00194
G_3	155.35	0.00958	257.96	0.00192	70.43	0.003512
G_4	343.94	0.00452	131.027	0.001055	50.58	0.001069
J_1	334.39	0.00636	131.02	0.00808	36.85	0.007612
J_2	300.82	0.0163	123.54	0.001374	49.54	0.003803
J_3	343.94	0.00247	152.86	0.00288	43.10	0.00430
J_4	236.72	0.02113	171.97	0.001148	98.14	0.004032
K_1	132.82	0.00564	114.36	0.00101	52.02	0.005134
K_2	343.94	0.00981	229.29	0.001391	82.63	0.001023

L= 2×maximum radius of influence

Maximum radius of influence $(r_e) = \sqrt{4Tt/s(\frac{1}{u})}$ .9

Results and Discussion

The study was undertaken to determine the hydrological parameters in Wakal River Basin by using three models. For this study pumping test carried out in ten operational wells in study area. The results obtained in these models are discussed below.

Papadopulos and Cooper method

The well number J_1 was operated at constant discharge rate at 480 m^3/day. The drawdown corresponding to time was recorded with the help of continuous water level recorder. Time verses corrected drawdown field data curves were plotted on double logarithmic paper for the all test wells. All the values of transmissivity and storage coefficient are reported in Table 2. The radius of well was found to be 2.9 m. The total match point coordinates for well no. J_1 from Fig. 3 were obtained as t = 30 min, s = 0.8 m, $F(u_{w,}\alpha) = 7$,$1/u_w = 500$.Using Equation (1), Transmissivity (T) for total match point was calculated as T = 334.39 m^2/day and storage coefficient was calculated by using Equation (2)S = 0.00636. From the Table 2 it is evident that transmissivity values of the Papadopulos and Cooper method for well number K_2, J_3 and G_4 were same. The lowest transmissivity was observed in well number K_1 and it was 132 m^2/day. The highest transmissivity value obtained in the well number J_3, K_2 and G_4 i.e. 343.94 m^2/day. The highest storage coefficient value obtained in well number J_2 and it was 0.0163 and lowest value obtained in the well number G_1 i.e. 0.00176. About 50.21 per cent area of the Wakal river basin having transmissivity value in between 200-250 m^2/day (Fig. 4).

Boulton and Streltsova method

The well number J_1 was operated at constant discharge rate of 480 m^3/day. The drawdown corresponding to time was recorded with the help of acoustic water level recorder. The time versus drawdown were plotted on the double log paper and matched with type curve (Fig 5). All the values of transmissivity and storage coefficient reported in Table 2. The coordinates of the match point were: Q = 480 m^3/day, w = 6, t = 90 min. $\theta = 6\times10^3$, p = 0.230, s=0.9 m, On using Equations 5 and 6 transmissivity

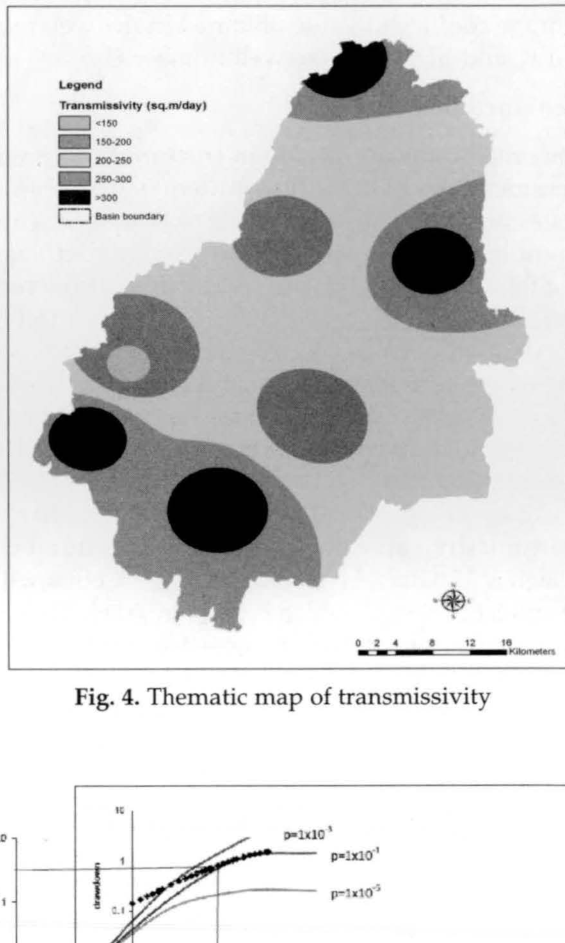

Fig. 4. Thematic map of transmissivity

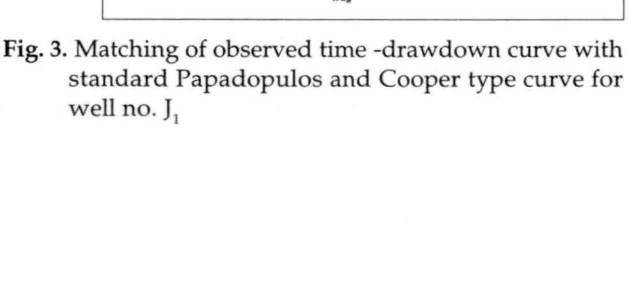

Fig. 3. Matching of observed time -drawdown curve with standard Papadopulos and Cooper type curve for well no. J_1

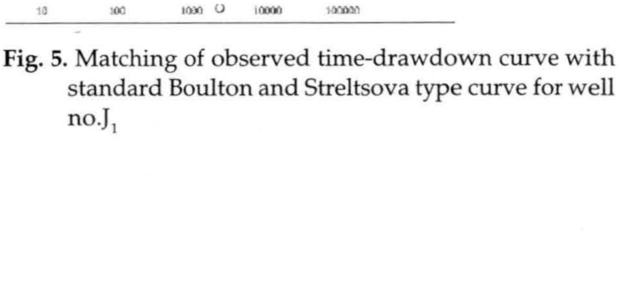

Fig. 5. Matching of observed time-drawdown curve with standard Boulton and Streltsova type curve for well no.J_1

Table 3. Transmissivity correlation between different methods

	Papadopulos and Cooper method	Boulton and Streltsova	Sen method
Papadopulos and Cooper method	1	0.825	0.624
Boulton and Streltsova	0.825	1	0.443
Sen method	0.624	0.443	1

and storage coefficient were calculated as

T = 254.77 m^2/day and S = 0.00126. From Table 2 transmissivity value ranges from 131.02 m^2/day to 257.96 m^2/day and storage coefficient values ranges from 0.00101 to 0.00808. The lowest transmissivity value obtained in the well number G_1 and highest value obtained in the well number J_3. The lowest storage coefficient value obtained in the well number K_1 and highest in the well number G_1.

Sen method

This method is applicable in fractured rocks with considerations of linear flow pattern under unsteady state condition. Curve matching technique was used to estimate transmissivity and storage coefficient. For this matching of time-drawdown and type curve was used (Fig. 6). The matching of data with type curve in other wells was also done as like Fig. 5. All the values of transmissivity and storage coefficient are reported in Table 2. The match point coordinates for well no. J_1 from Fig. 6 were W(u) = 10, s = 0.5 m, t = 60 min, $1/u_w$ = 110. From equation 7 and 8, T=52.69 m^2/day and S=0.0093407. The lowest transmissity value obtained in the well number J_2 which is 35.81m^2/day and highest value obtained in the well number G_4 which is 98.14 m^2/day. The storage coefficient values ranges from 0.001023 to 0.00934. The lowest value obtained in well number K_2 and highest value obtained in well number J_1. The

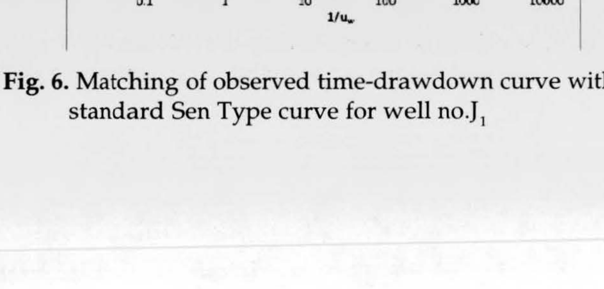

Fig. 6. Matching of observed time-drawdown curve with standard Sen Type curve for well no.J_1

correlation between different methods also determined (Table 3).

Conclusion

In hard rock area of Wakal river basin the average transmissivity obtained by Papadopulos and Cooper method was 252.613 m^2/day whereas average storage coefficient was 0.007971. The Papadopulos and Cooper method and Boulton and Streltsova method shows strong correlation of transmissivity values. Papadopulos and Cooper method and Sen method shows moderate correlation of transmissivity value. Boulton and Streltsova method and Sen method also shows the moderate correlation of transmissivity values. All the models show the negative correlation of storage coefficient values.

References

Boulton, N.S. and Streltsova, T.D. 1978. Unsteady flow to a pumped well in an unconfined aquifer. *Journal of Hydrology*. 37 : 349-363.

Chang, Y.C. and Yeh, H.D. 2010. A new analytical solution solved by triple series equations method for constant-head tests in confined aquifers. *Advances in Water Resources*. 33 : 640–651.

Dash, Trilochan and Ishwar Prasad M. 1997. Estimation of hydraulic–parameters from the pumping test data of bore wells in hard rocks terrain of drought prone areas by analytic method. *Journal of Applied Hydrology*. 10(1-2):75-79.

Fenske, P.P. 1977. Radial flow with discharging well observation well storage. *Journal of Hydrology*. 32 : 87-96.

Freeze, R. A. and Cherry, J.A. 1979. *Groundwater*. Prentice-Hall, Englewood Cliffs, N.J., 604 p.

Hantush, M.S. 1964. Hydraulics of wells, in Advances in *Hydroscience* (V.T.Chow,ed.). Academic press. New York. 1:281-432.

Herbert, R.and Kitching, R. 1981. Determination of aquifer parameters from large-diameter dug-well pumping tests. *Ground Water*. 13(3): 251-253.

Jacob, C.E. 1963. Corrections of draw downs caused by a pumped well tapping less than the full thickness of aquifer in methods of determining permeability, transmissivity and drawdown. U.S. Geol. Survey. Water supply paper. 1536-I: 272-282.

Jat, M.L. 1990. Estimation of aquifer parameters in selected hydrological formations of Udaipur, M.E. Thesis submitted to M.P.U. & T., Udaipur.

Mjemah, I.C., Camp, M.V. and Walraevens, K. 2009. Groundwater exploitation and hydraulic parameter estimation for a Quaternary aquifer in Dar-es-Salaam Tanzania. *Journal of African Earth Sciences.* 55: 134-146.

Mathon, B.R., Ozbek, M.M. and Pinder, G.F. 2008. Transmissivity and storage coefficient estimation by coupling the Cooper-Jecob method and modified fuzzy least squares regression. *Journal of Hydrology.* 353 : 267-274.

Miller, C.T. and Weber, W.J. 1983. Rapid solution of the nonlinear step drawdown equation. *Ground Water.* 21(5): 584-588.

Moench, A.F. 2003. Estimation of hectare-scale soil-moisture characteristics from aquifer-test data, *Journal of Hydrology.* 281: 82-95.

Papadopulos, I.S. and Cooper, H.H. 1967. Drawdown in a well of large diameter. *Water Resource Research.* 3 (1) : 241-244.

Radhakrishna, I. and Venkateshwarlu T. 1980. Aquifer response in ultramafic field area of Sukhanda Valley Orrisa (India). *Ground Water.* 18(5) : 479-489.

Rathore, M.S. 2003. Community based management of groundwater resources: a case study of Arwari River Basin. Institute of Development Studies, Jaipur (Project report submitted to British Geological Survey).

Rushton, K.R. and Singh, V.S. 1983. Drawdown in large diameter wells due to decreasing abstraction rates. *Groundwater.* 21(6): 670-677.

Sethi, R. 2011. A dual-well step drawdown method for the estimation of linear and non-linear flow parameters and wellbore skin factor in confined aquifer systems. *Journal of Hydrology.* 400 : 187-194.

Shiklomanov, I.V. and Rodda, J.C. 2003. World Water Resources at the Beginning of the Twenty First Century. *International Hydrology Series.* p: 8-25.

Soupios, P.M., Kouli, M., Vallianatos, F., Vafidis, A. and Stavroulakis, G. 2007. Estimation of aquifer hydraulic parameters from surficial geophysical methods: A case study of Keritis Basin in Chania (Crete – Greece). *Journal of Hydrology.* 338 : 122-131.

Verma, R.P. 2007. Groundwater assessment and planning appropriate strategy for its utilization in Phyllite hard rock area at Udaipur. M.E. thesis submitted to M.P.U.A. & T, Udaipur.