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Full Length Research Paper

Classification of transmissivity magnitude and variation in calcarious soft rocks of Bhaskar Rao Kunta Watershed, Nalgonda District, India

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Pumping test was used for the appraisal and evaluation of groundwater potential and design of well. Pumping tests of the calcarious sedimentary rocks of Bhaskar Rao kunta watershed area were carried out for twenty five selected bore wells for quantitative understanding of the groundwater for crop water requirement and groundwater use efficiency. The tests were carried out independently for short duration under constant rate conditions. The acquisition of the drawdown data was interpreted by Jacob straight line method. The results of transmissivity vary from 2.67 to 236.9 m^2/day with mean of 37 m^2/day, whereas the specific capacity varies from 5.47 to 451.63 m^3/d/m with a mean of 76 m^3/d/m. Spatial variation of transmissivity values was further analyzed using statistical testing and Krasny's classification systems; from the results of the statistical testing, 72% of the wells were under covered background transmissivity anomalies; 12% under positive anomalies; 8%, negative anomalies and remaining 8%, positive extreme anomalies. From the results of Krasny's classification system, 12% of the wells was under high magnitude (withdrawals of lesser regional importance), 40% of wells was under intermediate magnitude (withdrawals for local water supply), 48% was under low magnitude (smaller withdrawals for local water supply) and 100% of the wells was under covered moderate variations (fairly heterogeneous hydrogeological environment). Spatial variation of transmissivity magnitude and variation was identified as best useful in management practices.

Key words: Transmissivity, magnitude, variation, statistical testing, Krasny's classification.

INTRODUCTION

Quantitative understanding of most problems in hydrogeology (Ramakrishna, 1998), determination and evaluation of aquifer parameters of transmissivity and storage coefficient from aquifer test data is a continual field research (Birpinar, 2003); it is field–scale prediction (Illman and Tartakovsky, 2006) and integral part of assessment and management of groundwater study (Sarwade et al., 2007; Mayooran et al., 2011; Sudher Kumar et al., 2012). Generally, there are two types of pumping tests evaluation methods for determining aquifer parameters: (i) drawdown and (ii) recovery. In the present study, only drawdown test was conducted.

The present study was done in a semi-arid region of Bhaskar Rao kunta watershed area (40 km^2), which is a

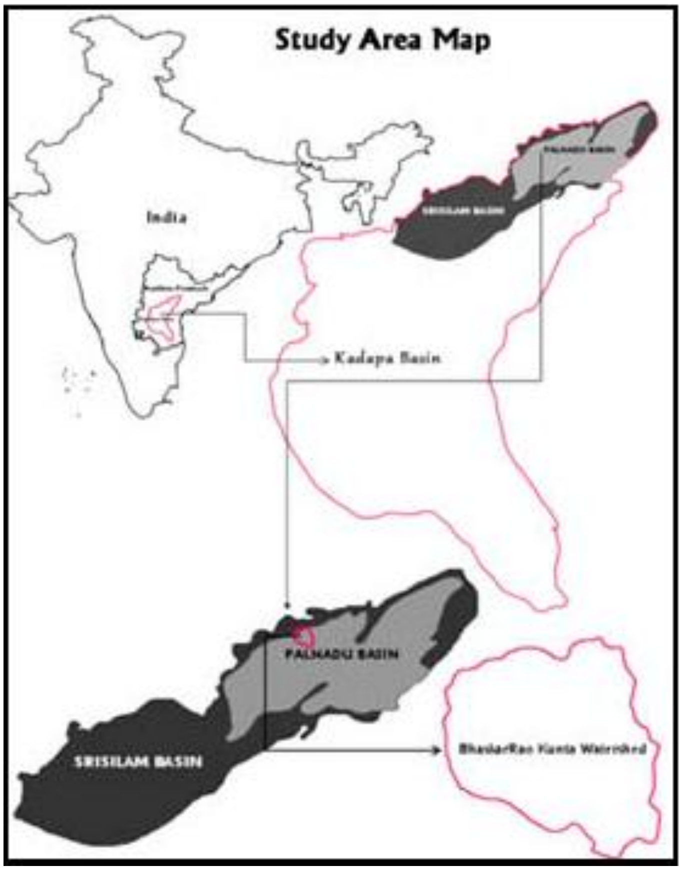

Figure 1. Location map of the study area.

purely remote and tribal area in the Nalgonda District. The Government Organization of Andhrapradesh State Irrigation Development Corporation (APSIDC) was incited to help each selected group of economically backward farmers by giving them a single bore well with a nominal subsidy to share the groundwater for irrigation use only. After the completion of bore wells drilling in the area, randomly pumping tests were conducted to check the availability of quantitative understanding of the groundwater used for a few number of bore wells. It is valuable and useful for crop water requirement and enhances agriculture productivity and sustainable development of the farmers.

Study area

Semi-arid region of Bhaskar Rao kunta watershed geographically lies between Northern latitudes from 16° 42' 25" to 16° 37' 58" and Eastern longitudes from 79° 28' 15" to 79° 32' 30" of the Krishna Lower Basin. The watershed elevation ranges between 80 and 140 m above the mean sea level, with slightly undulating terrain to moderate slopes (2 to 3%); its annual normal rain fall is 737 mm. The average maximum and minimum temperature is 40 and 28°C, respectively. The drainage system has dendritic to sub-dendritic pattern, governed by regional slope; its homogenous lithology and relief are exhibited by 146 streams (1^{st}, 2^{nd} and 3^{rd} order streams), which curve and contribute to the flow of mostly dry stream except for seasonal run-off. Soils are covered with red sandy and black clay.

Geology

The study area, part of the Kurnool group of Palnadu sub basin (Upper Proterozoic period of Vindyan rocks), is partially covered by Srisailam succession of Kadapa Super Group (Pre-Cambrian period of Archaean rocks) (Figure 1). Srisailam sub basin rocks are exposed with Quartzites; the Quartzites are inter bedded with thin siltstone units and are usually thick bedded, with dense and fine to medium grain. Palnadu sub-basin rocks are exposed with Calcareous sedimentary rocks of quartzites, shales and flaggy-massive limestones (Geology and Mineral Resources, 2006). General sequence of sub-surface strata is encountered in the top soil, weathered/semi weathered layered shale inter bedded with quartzite.

Hydrogeology

In the study area, groundwater occurs mainly along the bedding planes, cleavages, solution channels, cavernous formations and joints. Aquifers often have different hydraulic heads, caused by various surface topographic undulations or cap rock structures. Aquifers are under confined to semi-confined conditions with shallow to deep zones. The shallow aquifer depth and thickness range between 30 to 40 m and 5 to 25 m (Kotturu, Kalvakatta Villages), respectively. Deep aquifer depth and thickness range between 40 to 60 m and up to 60 m (Banjaranagar Thanda, Gonina Thanda, Champla Thanda, Ham Thanda and JK Thanda) respectively. It has been found that, most of the aquifer zones are encountered within 40 to 60 m depth. The depth of open wells ranges from 5 to 20 m, whereas the bore wells are about 60 m deep. An average yield is 448 m^3/day (Table 1). Due to fluctuations of the groundwater in the monsoon pattern, static water levels were changed in depth from 1 to 7 m below ground level.

MATERIALS AND METHODS

Acquisition of data

In the study area, twenty five pumping tests data were collected and carried out in selected bore wells (Figure 2). The average depth of bore wells is 60 m below ground level. Submersible pump of 7.5 HP is lowered to a depth of 40 m. Static water level and drawdown were recorded with automatic water level indicator. During duration pumping test for 300 min, to ensure uninterrupted

Table 1. Results of aquifer parameters of twenty five bore wells.

Well No.	Pumping duration (min)	Static water levels (m)	Drawdown (m)		Discharge (m^3/day)	Specific capacity (m^3/d/m)	Transmissivity (m^2/day)
			Min.	Max.			
1	300	5	16	29.8	130	4.36	3.65
2	300	1	2.9	4.9	726	148.16	69.98
3	300	5.8	13.3	26.95	473	17.55	16.98
4	300	6	4.25	11.4	453	39.81	16.59
5	300	1	2.5	29.6	162	5.47	2.67
6	300	1	2	13.9	466	33.53	12.91
7	300	0.2	2.6	14.55	602	41.37	16.22
8	300	6	1.15	2.85	971	451.63	236.9
9	300	7.15	1.35	6.75	773	114.52	54.17
10	300	1.5	7.65	15.76	456	29	9.73
11	300	1.3	1.4	2.3	869	377.83	186.15
12	300	6.8	9.45	22.58	359	15.9	7.07
13	300	0.2	18.6	35	272	7.77	5.41
14	300	6.2	12.3	28.3	188	6.76	6.53
15	300	2.1	1.6	4.55	727	199.18	102.39
16	300	4	16.2	31	250	8.06	4.82
17	300	6	0.15	13.5	227	16.81	5.21
18	300	1.2	2.3	5.4	512	94.81	52.13
19	300	0.2	2.5	6.6	455	68.94	26.01
20	300	3.5	0.2	12.7	557	43.86	8.43
21	300	7	8.2	25.2	235	9.36	10.26
22	300	7	0.8	12	173	14.42	6.14
23	300	6	14.1	24	225	9.38	5.87
24	300	6	0.6	7.6	413	54.34	20.43
25	300	6.2	1.7	13.3	216	17	5.31
Minimum		0.20	0.15	2.30	130.00	5.47	2.67
Maximum		7.15	18.60	29.6	971.00	451.63	236.90
Mean		3.89	5.33	15.45	448.33	76.06	37.01
Standard Deviation		2.67	5.66	9.93	233.54	115.76	59.55

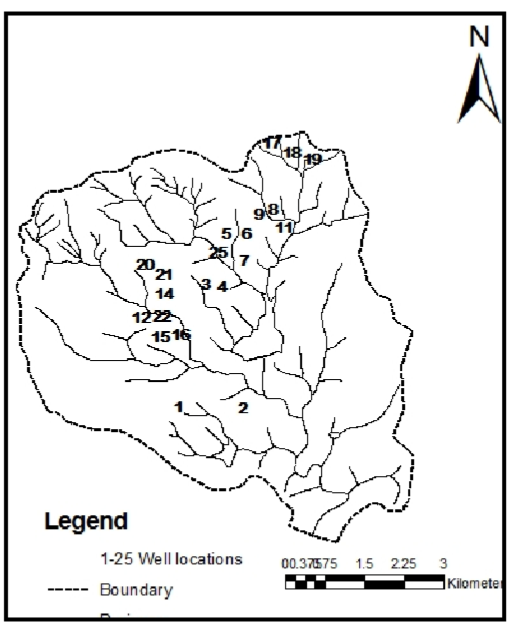

Figure 2. Pump testing locations in the study area.

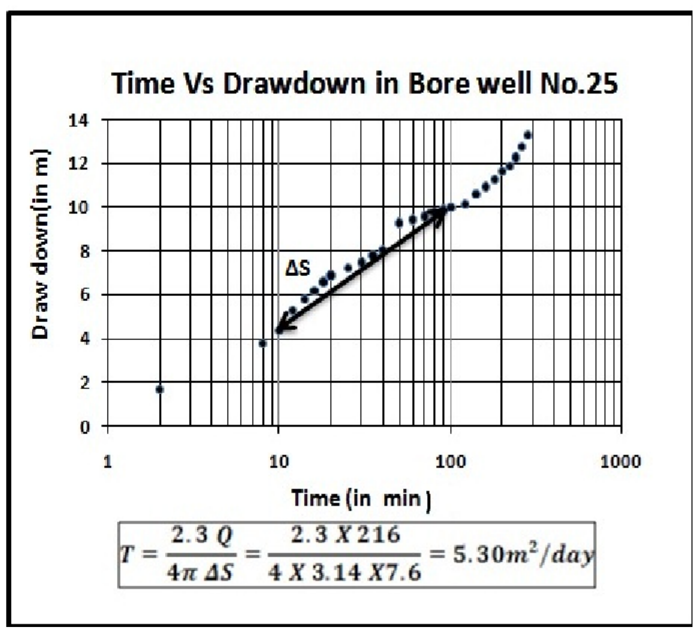

Figure 3. Data Interpretation on log-log graph in Jacob method.

Table 2. Transmissivity analysis based on transmissivity index 'Y' classification.

Classification	Description	Range of T index 'Y'
Negative extreme anomalies	Less than [mean – (2 * standard deviation)]	Less than 4.13
Negative anomalies	Between (mean – standard deviation) and [mean – (2 * standard deviation)]	4.13-4.66
Background transmissivity	Between (mean – standard deviation) and (mean + standard deviation)	4.66-5.74
Positive anomalies	Between (mean + standard deviation) and [mean + (2 * standard deviation)]	5.74-6.28
Positive extreme anomalies	Greater than [mean + (2 * standard deviation)]	Above 6.28

power supply a stand by 15 KV diesel generator was used. 200 L drum was used for measuring discharge. In the present study, a single well drawdown test was adopted, as an aquifer pre-test to determine an optimal pumping rate of the wells and neighboring wells could not be used as observation wells due to field limitations. In single well test drawdown well is influenced by well losses as well as well-bore storage. Pumping test data were statistically analyzed by MS Excel-2007 version.

Data interpretation

The pumping test data were interpreted by Jacob straight line method (Jacob, 1950). To determine transmissivity, on the semi-log paper the values of 'drawdown' were plotted against the corresponding values of 'time' and a straight line was drawn through the plotted points; and to determine the slope of the straight line ' ΔS' the drawdown difference was plotted over one log cycle of time (Figure 3). The transmissivity is determined from the following equation:

$$\frac{.}{\Delta}$$

Where, T=Transmissivity in m^2/day, Q=Pumping well discharge in m^3, Δs = Slope of time vs drawdown plot.

RESULTS AND DISCUSSION

Spatial analysis of transmissivity

The transmissivity analysis is carried out using two methods. One method is based on descriptive statistical testing by identifying transmissivity and anomalies and the other method is based on a classification scheme introduced by Krasny in 1993.

Statistical testing

In this approach, all the transmissivity values collected are pooled in a particular region using Transmissivity index 'Y'. The relationship between transmissivity (T) and logarithmic transmissivity index (Y) is;

$$T(m^2/day) = 10^{Y-8.96} X\ 86400 \quad (1)$$

Found by Jetal and Krasny in 1968, it is used to calculate the logarithmic transmissivity index (Y) from transmissivity (T) values. The above stated equation can be modified as, Logarithmic Transmissivity Index,

$$Y = log\left[\frac{T}{86400}\right] + 8.96 \quad (2)$$

Where T – Transmissivity in m^2 / day

The logarithmic transmissivity index (Y) values are calculated using the modified equation and the calculations are tabulated in Table 2. The mean value of transmissivity index is obtained as 5.2 and the standard deviation of transmissivity index is 0.54. By using these two values, the classification is found as given in Table 4. From the results of the statistical testing, 72% of the wells are under covered background transmissivity anomalies; 12%, under positive anomalies; 8%, negative anomalies and remaining 8%, positive extreme anomalies. The values outside this interval are considered as positive or negative anomalies. The positive anomalies represent prospective zones for groundwater exploration relatively compared to the areas of background transmissivity and the negative anomalies represent less favorable zones. The areas with extreme positive anomalies are highly suitable for local water.

Krasny's classification

Jiri Krasny (1993) proposed a transmissivity classification system based on transmissivity and standard deviation of transmissivity index magnitude and variation of the transmissivity and transmissivity index values. The methods of classifications for transmissivity magnitude and variation are tabulated in Table 3. By using the classification given in Table 3, the groundwater supply potential was identified as given in Table 4, and the standard deviation value of 0.54 observed in transmissivity index 'Y' represents a moderate transmissivity variation and fairly heterogeneous hydro geological environment. From the results of classification of magnitude, 12% of the wells are under high magnitude (Withdrawals of lesser regional importance),

Table 3. Krasny's classification of transmissivity of magnitude and variation.

Classification of T Magnitude				Classification of T Variation			
Coefficient of T (m2/d)	Class of T magnitude	Designation of T magnitude	Groundwater supply potential	Standard deviation of T Index (Y)	Class of T Variation	Designation of T Variation	Hydro geological environment
> 1000	I	Very high	Withdrawals of great regional importance	< 0.2	a	Insignificant	Homogeneous
1000 - 100	II	High	Withdrawals of lesser regional importance	0.2 – 0.4	b	Small	Slightly heterogeneous
100 - 10	III	Intermediate	Withdrawals for local water supply (small communities and plants)	0.4 – 0.6	c	Moderate	Fairly heterogeneous
10 - 1	IV	Low	Smaller withdrawals for local water supply (private consumption)	0.6 – 0.8	d	Large	Considerably heterogeneous
1-0.1	V	Very low	Withdrawals for local water supply with limited consumption	0.8 – 1.0	e	Very large	Very heterogeneous
< 0.1	VI	Imperceptible	Sources for local water supply are difficult	> 1.0	f	Extremely large	Extremely heterogeneous

Table 4. Results of summary statistics of transmissivity index (Y), Krasny's magnitude and variation.

Well No.	T (m2/day)	T Index 'Y'	Results of T index 'Y'	Results of 'T' magnitude	Results of 'T' variation
1	3.65	4.59	Negative anomalies	Smaller withdrawals for local water supply	Extremely heterogeneous
2	69.98	5.87	Positive anomalies	Withdrawals for local water supply	Extremely heterogeneous
3	16.98	5.25	Background transmissivity	Withdrawals for local water supply	Extremely heterogeneous
4	16.59	5.24	Background transmissivity	Withdrawals for local water supply	Extremely heterogeneous
5	2.67	4.45	Negative anomalies	Smaller withdrawals for local water supply	Extremely heterogeneous
6	12.91	5.13	Background transmissivity	Withdrawals for local water supply	Extremely heterogeneous
7	16.22	5.23	Background transmissivity	Withdrawals for local water supply	Extremely heterogeneous
8	236.9	6.40	Positive extreme anomalies	Withdrawals of lesser regional importance	Extremely heterogeneous
9	54.17	5.76	Positive anomalies	Withdrawals for local water supply	Extremely heterogeneous
10	9.73	5.01	Background transmissivity	Smaller withdrawals for local water supply	Extremely heterogeneous
11	186.15	6.29	Positive extreme anomalies	Withdrawals of lesser regional importance	Extremely heterogeneous
12	7.07	4.87	Background transmissivity	Smaller withdrawals for local water supply	Extremely heterogeneous
13	5.41	4.76	Background transmissivity	Smaller withdrawals for local water supply	Extremely heterogeneous
14	6.53	4.84	Background transmissivity	Smaller withdrawals for local water supply	Extremely heterogeneous
15	102.39	6.03	Positive anomalies	Withdrawals of lesser regional importance	Extremely heterogeneous
16	4.82	4.71	Background transmissivity	Smaller withdrawals for local water supply	Extremely heterogeneous
17	5.21	4.74	Background transmissivity	Smaller withdrawals for local water supply	Extremely heterogeneous
18	52.13	5.74	Background transmissivity	Withdrawals for local water supply	Extremely heterogeneous
19	26.01	5.44	Background transmissivity	Withdrawals for local water supply	Extremely heterogeneous
20	8.43	4.95	Background transmissivity	Smaller withdrawals for local water supply	Extremely heterogeneous
21	10.26	5.03	Background transmissivity	Withdrawals for local water supply	Extremely heterogeneous
22	6.14	4.81	Background transmissivity	Smaller withdrawals for local water supply	Extremely heterogeneous
23	5.87	4.79	Background transmissivity	Smaller withdrawals for local water supply	Extremely heterogeneous
24	20.43	5.33	Background transmissivity	Withdrawals for local water supply	Extremely heterogeneous
25	5.31	4.75	Background transmissivity	Smaller withdrawals for local water supply	Extremely heterogeneous

40% of wells are under intermediate magnitude (withdrawals for local water supply), 48% are under low magnitude (smaller withdrawals for local water supply) and 100% of the wells are under covered moderate variations (fairly heterogeneous hydrogeological environment).

CONCLUSION AND RECOMMANDATIONS

The study has shown that the transmissivity varies from 2.67 to 236.9 m^2/day (with a mean of 37 m^2/day), whereas the specific capacity varies from 5.47 to 451.63 m^3/dd/m (with a mean of 76 m^3/d/m). Spatial variation of transmissivity values was further analyzed using statistical testing and Krasny's classification systems. From the results of the statistical testing, 72% of the wells are under covered background transmissivity anomalies; the remaining 12, 8 and 8%, under positive, negative and positive extreme anomalies, respectively. From the results of Krasny's classification system, 48, 40 and 12% of the wells aree under covered low magnitude (smaller withdrawals for local water supply), intermediate magnitude (withdrawals for local water supply) and high magnitude (withdrawals of lesser regional important) respectively. 100% of the wells are under covered moderate variations (fairly heterogeneous hydrogeological environment). Spatial variation of transmissivity magnitude and variation were identified as best useful in management practices and sustainable development of groundwater.

A much more appropriate quantitative understanding of the groundwater for a long time pumping test and observation is well required.

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Conflict of Interests

The author(s) have not declared any conflict of interests.

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