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Estimation of the Aquifer Parameters from Pumping Test Data of Phulambri Watershed (GP 8), Aurangabad District, Maharashtra (India)

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ABSTRACT

The aim of this study is to analyze pumping test data of Phulambri watershed area from Aurangabad District, Maharashtra (India) by using cooper-Jacob's time drawdown approximation of Theis method to estimate the aquifer parameters. In the present study, total of 04 aquifer performance test were conducted at different locations within the shallow basaltic aquifers. The advantage of this method is that, it is validation for any stepped pumping. The output of this research is that, the method can be used for estimating the pre-monsoon and post-monsoon efficiency of the wells. In the study area, the dug wells are in the depth ranged from 7.00 to 17.00 m and the diameter of the wells is between 2.70 to 4.50 m. The aquifer performance results seen that transmissivity values of the wells is varies from 3.25 to 446.21 m^2/day (pre monsoon 2013) and 10.84 to 510.33 m^2/day (post monsoon 2013). Storativity values of studied wells were observed varies from 0.0047 to 0.17 (pre monsoon 2013) and 0.0093 to 0.319 (post monsoon 2013). Whereas the specific yield of the wells is varies from 0.47 m^3/ day to 11.13 m^3/ day in winter (post monsoon) and 1.59 m^3/ day to 31.96 m^3/ day in summer (pre monsoon). The present study is useful to identify seasonal variation in drawdown and recuperation through numerical and graphical presentation.

KEYWORDS: *Hydrogeology, aquifer parameters, Cooper-Jacob's straight line method, Deccan Trap.*

INTRODUCTION

Pumping test is one of the most useful means of not only determining the aquifer hydraulic characteristics but also the determination of yield, drawdown, specific capacity and design of wells. These data give a measure of the productive capacity of the well. Properly and correctly computed data of pump test gives the most accurate information which can be used for groundwater development plans. In fact one of the primary objectives of most groundwater resources studies is the determination of maximum possible pumping rates that are compatible with hydraulic environment from which the water still be taken.

Quantitative understanding of most problems in hydrogeology, it is necessary to have an accurate knowledge of the aquifer parameters like Coefficient of Transmissivity (T), Coefficient of Storativity (S) determine by Slichter method (1906). Among the various methods available for the determination of aquifer parameters, since the last decade there are many experiences that are tried to discover a method to estimate the aquifer parameters through analyze aquifer test data such many papers and references that dispose to storativity value in absence of observation wells it mainly depends on radial distance of pumping well to measure drawdown (Todd, 2000; Kruseman, et. al, 1991; Yaran, 1969; Boonstra, et. al, 2001; Neven, 2006 and Michael, 2006). Storativity determine by the effective well storage methods (Choi, 2007; Ballukraya et. al, 1991), consequent equation for storativity and recovery (Keith et. al, 2006), equation derived for transmissivity for single test (Razack and David, 1991) to determine transmissivity through specific capacity data.

Study Area

In the present study researcher has select the Phulambri watershed which is situated in Girja-Purna river basin for estimation of aquifer parameters. This watershed is a part of Girja-Purna river basin therefore it is also known as GP 8 watershed. Phulambri watershed (GP 8) is falls in survey of India toposheet number 46 P/8, 46 P/12 and 47 M/5. The Phulambri watershed (GP 8) is bounded by Latitude 20°00' to 20°10' N and Longitude 75°25' to 75°30' East. Phulambri River is the major stream draining the Girja-Purna river basin towards north-east from south-west. Phulambri watershed is mapped about 227.5 sq. kilometres. It is elongated watershed with basaltic formation exposed in the river channel (Fig.2). The water level in the stream channel during monsoon season (July to September, 2013) varies from 2.00 to 6.00 meters and the quality of water is potable. The aquifer material probably belongs to consolidated rock of basaltic rock formation, which consisting of massive basalts. Vesicular basalt, amygdaloidal basalts, jointed basalts and some places covers weathered basalts.

The groundwater can be withdrawn from 7.00 to 17.00 meters from below the ground level. The groundwater table rises during high rains in monsoon season. During drought season it declines and also deteriorates the quality of groundwater. There is no any other source of surface water to recharge the aquifer except rains with high or low intensity. The climate of the study area is known as arid, which is very hot in summer, the temperature ranges from 41°C to 47°C, while in winter it ranges from 4°C to 15°C. The mean average rainfall of the study area is 600 mm with a variation of 100 mm. The period of rainfall is very limited. Mostly it falls during monsoon season, which starts from June to September.

Geology

The present study area is covered by Deccan trap lava flows of upper Cretaceous to lower Eocene age. The chief geological formation occurring in Aurangabad district is basaltic lava flows. On the basis of their lithological characteristics different flows and flow units have been differentiated such as vesicular, amygdaloidal, porphyritic and compact. These flows are horizontal and each flow has two different units viz. vesicular and amygdaloidal nature is found in the upper unit while compact nature in the lower unit. The vesicles are either rounded or irregular in shape and are often filled with secondary minerals such as quartz and zeolite. The bottom of the flow is marked by pipe amygdales capped by a surface comprising the ropy structure. Red bole beds are occurring as lenticular units. These are used as marker horizons in differentiating flows. The Deccan trap succession is divided into Sahyadri Group (Godbole et al. 1996). The lava piles of Sahyadri Group are made up of irregular layers of Pahoehoe and Aa flows. The Sahyadri Group is further divided into Ajanta and upper Ratangarh formations (G.S.I, 1976).

METHODOLOGY

In the present study, pumping tests was undertaken to study the aquifer characteristics. The essential data like diameters, depths, and initial water level were recorded for the wells under study. The groundwater was pumped out continuously for 3 hours and changes in water level both for drawdown and recuperation were recorded. In the study area, 04 Aquifer Performance Tests (APT) were conducted at different locations within the shallow basaltic aquifer (Table 1). The depth of the dug wells varied from 7.00 to 17.00 m. All the wells selected were large diameter dug wells (more than 4 m).

Table 1: Coordinates of well locations

Well Number	Name of village	Longitude	Latitude	Altitude (m amsl)
1	Pophla	19°56'06''E	75°25'30'' N	637
2	Pathri	19°58'39''E	75°25'07'' N	900
3	Phulambri Town	19°57'45''E	75°25'08'' N	808
4	Murshidabadwadi	19°56'15''E	75°22'48'' N	626

Figure 1: Location Map of the Phulambri Watershed (GP-8)

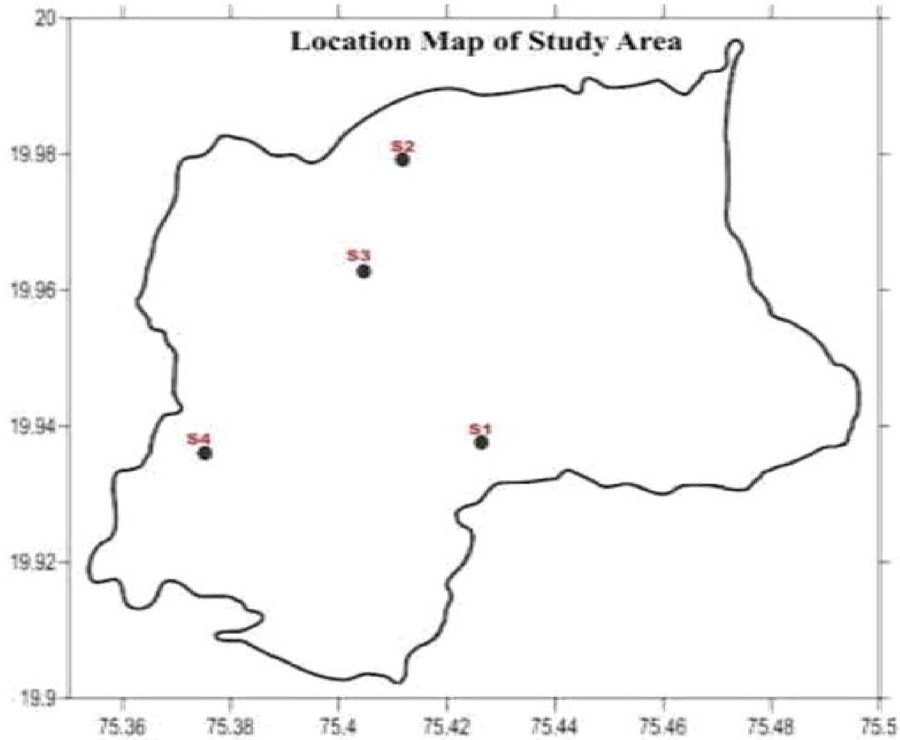


Figure 2: Location of the Aquifer Performance Test wells

The cooper and Jacob (1946) solution is a late-time approximation derived from Theis type-curve method. Analysis with the cooper and Jacob method involves matching a straight line to drawdown data plotted as a function of the logarithm of time since pumping began. Theis (1963), a groundwater hydrogeologists with the United State Geological Survey (USGS), derived the following approximate linear equation to predict residual drawdown in a homogeneous, isotropic and non leaky confined aquifer assuming a fully penetrating line sink that discharged at a constant rate prior to recovery:

$s' = 2.303\ Q\ 4\ \pi\ T\ \log\ t\ t'\ -\ \log\ s\ S'$ (1)

Where,

- Q is pumping rate $[L^3/T]$
- s′ is residual drawdown [L]
- S is storativity during pumping [dimensionless]
- S′ is storativity during recovery [dimensionless]
- t is elapsed time since start of pumping [T]
- t′ is elapsed time since pumping stopped [T]
- T is transmissivity $[L^2/T]$

To apply the Theis recovery method given by (equation 1), plot s′ as a function of log (t/t′) on semi-logarithmic axes and draw a straight line through the data. Determine T using the following equation:

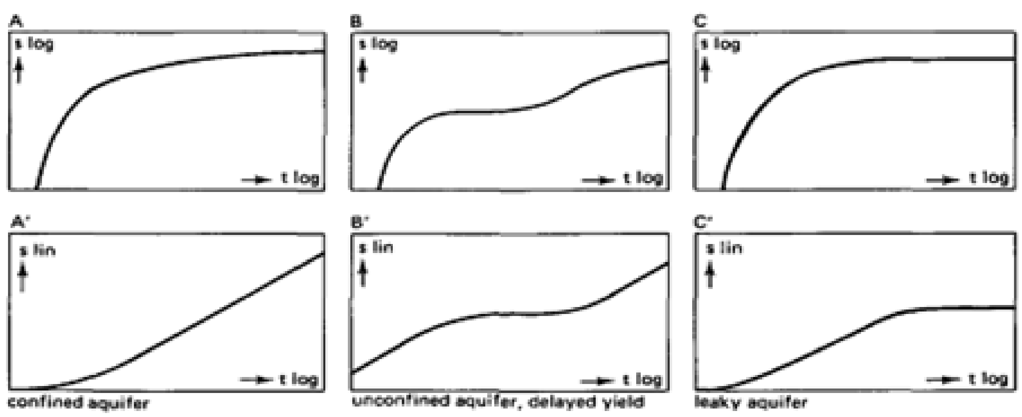
$T = 2.303\ Q\ 4\ \pi\ \Delta\ s'$ (2)

Where,

$\Delta s'$ is the slope of the fitted line (change in residual drawdown per log cycle equivalent time) S/S′ is found from the intersection of the line with the log (t/t′) axis of the plot. In the absence of boundary effects, S/S′ should be close to unity. A value of $S/S'>1$ suggests recharge during the test; whereas $S/S'<1$ may indicate a no-flow boundary.

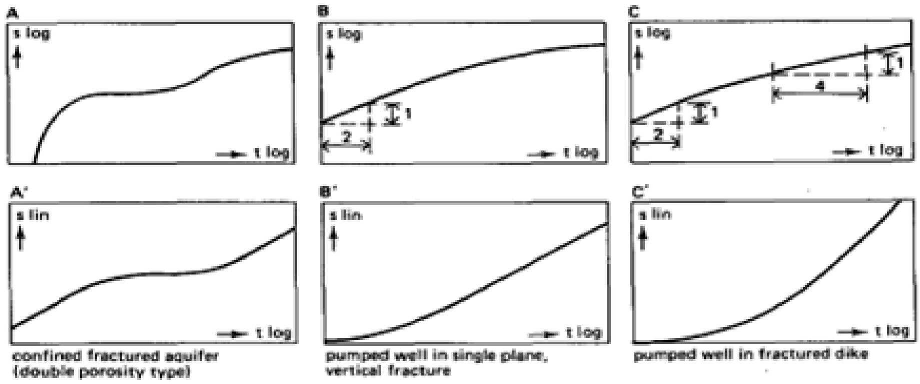
From the semi-log plot seen that the time-drawdown relationship at early pumping times is not linear, but at later times it is linear. If a linear relationship like this is found, it should be used to calculate the hydraulic characteristics because the results will be much more accurate than those obtained by matching field data plots with the curve. Parts B and B' of Figure 3 show the curves for an unconfined, homogeneous, isotropic aquifer of infinite lateral extent and with a delayed yield. These two curves are characteristic. At early pumping times, the curve of the log-log plot follows the curve for the confined aquifer shown in fig 3. Then, at medium pumping times, it shows a flat segment. This reflects the recharge from the overlying, less permeable aquifer, which stabilizes the drawdown. At late times, the curve again follows a portion of the curve as earlier. The semi-log plot is even more characteristic: it shows two parallel straight-line segments at early and late pumping times. Parts C and C' of Figure 3 refer to a leaky aquifer. At early pumping times, the curves follow those of A'. At medium pumping times, more and more water from the aquitard (or aquitard) is reaching the aquifer. Eventually, at late pumping times, all the water pumped is from leakage through the aquitard (s), and the flow towards the well has reached a steady state. This means that the drawdown in the aquifer stabilizes, as is clearly reflected in both graphs (Krusemen, et. al, 1991).

In Fig. 4 Parts A and A' of this figure refer to a confined, densely fractured, consolidated aquifer of the double-porosity type. In an aquifer like this, we recognize two systems: the fractures of high permeability and low storage capacity. Parts B and B' of Figure 4 represent the curves for a well that pumps a single plane vertical fracture in a confined, homogeneous, and isotropic aquifer of low permeability. The fracture has a finite length and a high hydraulic conductivity. Characteristic of this system is that a log-log plot of early pumping time shows a straight-line segment of slope 0.5. This segment reflects the dominant flow regime in that period: Parts C and C' of Figure 4 refer to a well in a densely fractured, highly permeable dike of infinite length and finite width in an otherwise confined, homogeneous, isotropic, consolidated aquifer of low hydraulic conductivity and high storage capacity (Krusemen et. al., 1991).



Log-log and semi-log plots of the theoretical time-drawdown relationships of unconsolidated aquifers:
Parts A and A': Confined aquifer
Parts B and B': Unconfined aquifer
Parts C and C': Leaky aquifer

Figure 3: Log and semi-log plots of the theoretical time-drawdown relationships of unconsolidated aquifer



Log-log and semi-log plots of the theoretical time-drawdown relationships of consolidated, fractured aquifers:
Parts A and A′: Confined fractured aquifer, double porosity type
Parts B and B′: A single plane vertical fracture
Parts C and C′: A permeable dike in an otherwise poorly permeable aquifer

Figure 4: Log-log and semi-log plots of the theoretical time-drawdown relationships of consolidated, pumped well in single plane, and fractured aquifers

RESULTS AND DISCUSSION

The pump test data of wells (pre and post monsoon) is determined by using Cooper-Jacob methods (1946). The pump test results of respective wells has represented in Table 2, 3, 4, 5, 6, 7, 8 and 9. The drawdown and recuperation graphs of respective wells (pre and post monsoon) has depicted in Figure 5 to Figure 8. The mathematical relationship developed between time verses drawdown and time verses recovery period, also specific capacity of the well is determined. The drawdown observation were used to plot time drawdown curve at initial stage it shows linear relation and gradually it become non linear this is because the delay yield effect and after that aquifer start contribution to pumping time. The pre monsoon drawdown relation represent by the equation, S = 0.0047+0.011, Coefficient of correlation = 0.011 and post monsoon drawdown relation equation, S = 0.0093 to 0.0171, Coefficient of correlation = 0.0171. The pre monsoon recuperation relation represent by the equation, S = 0.0047+0.011, Coefficient of correlation 0.011 and post monsoon recuperation relation equation, S = 0.0093 to 0.0171, Coefficient of correlation = 0.0171.

Aquifer performance results of wells from the studied region were depicted in Table 10. The transmissivity values of the studied well is varies from 3.25 to 446.21 m^2/day for pre monsoon 2013 and 10.84 to 510.33 m^2/day for post monsoon 2013. It is observed that wells number 2 and 3 have higher transmissivity (Table 10). High transmissivity values are the results of gentle slope of the area and presence of fractured and jointed basalt. In other hand well number 01 and 04 have low to intermediate transmissivity were observed, this may cause of moderate slopes and absence of secondary porosity in the country rock. Storativity values of studied wells were varies from 0.0047 to 0.17 for pre monsoon 2013 and 0.0093 to 0.319 for post monsoon 2013. Low values indicate high discharge which is resulted due to elevations and steep slopes in the watershed (Well 01 and 04).

Table 2: Pre-monsoon (2013) Pumping test data of the Pophla village (Well No. 01)

Time (minutes)	Depth of water level (DWL)	Drawdown in meter (S1)	Time in min. since pump stopped (t1)	Recuperation in meter	Recuperation in meter from draw down stopped
10	04.00	-	0	05.33	-
20	04.22	0.22	10	05.31	0.02
30	04.39	0.39	20	05.29	0.04
40	04.59	0.59	30	05.27	0.06
50	04.69	0.69	40	05.25	0.08
60	04.92	0.92	50	05.23	0.10
70	04.99	0.99	70	05.21	0.12
80	05.07	1.07	90	05.19	0.14
90	05.22	1.22	110	05.17	0.16
100	05.26	1.26	130	05.13	0.20
110	05.28	1.28	150	05.10	0.23
120	05.30	1.30	170	05.08	0.25
-	05.33	1.33	200	05.05	0.28
-	-	-	230	05.03	0.30

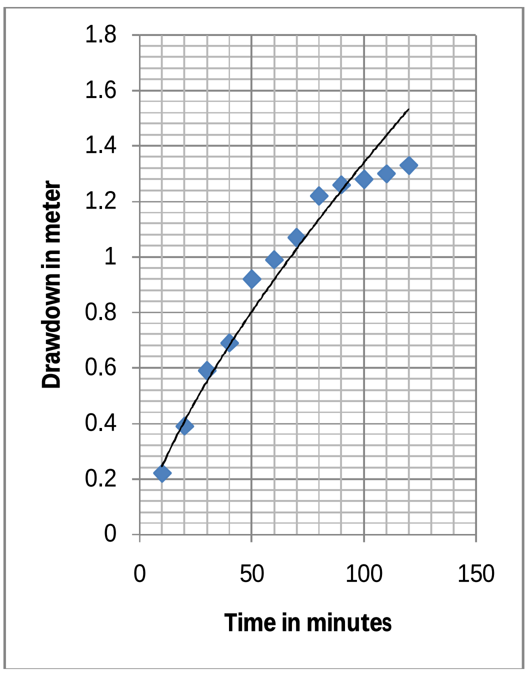


Fig. 5 (a)

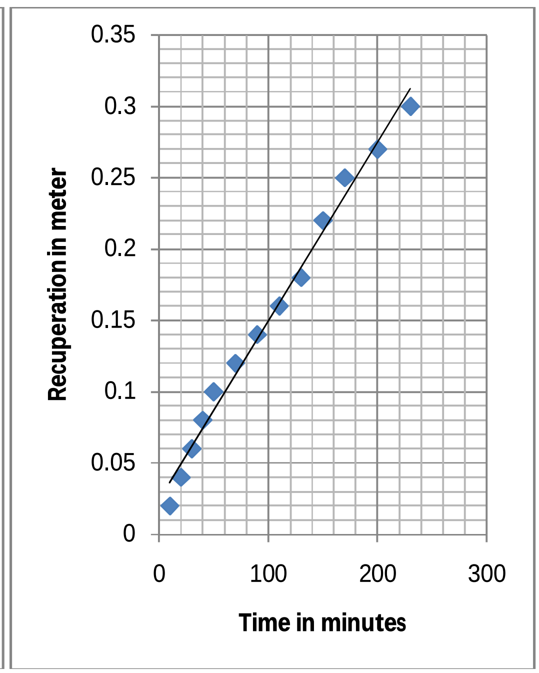


Fig. 5 (b)

Figure 5: (a) Drawdown Fig. 5 (b) Recuperation graph of Pre-monsoon 2013 (Well No. 01)

Table 3: Post-monsoon (2013) Pumping test data of the Pophla village (Well No. 01)

Time (minutes)	Depth of water level (DWL)	Drawdown in meter (S1)	Time in minute Since pump Stopped (t1)	Recuperation in meter	Recuperation in meter from draw down stopped
0	7.00	-	0	8.26	-
10	7.19	0.19	10	8.24	0.02
20	7.38	0.38	20	8.22	0.04
30	7.56	0.56	30	8.20	0.06
40	7.68	0.68	40	8.19	0.07
50	7.80	0.80	50	8.17	0.09
60	7.90	0.90	70	8.14	0.12
70	7.98	0.98	90	8.11	0.15
80	8.04	1.04	110	8.08	0.18
90	8.10	1.10	130	8.06	0.20
100	8.16	1.16	150	8.04	0.22
110	8.21	1.21	170	8.02	0.24
120	8.26	1.26	200	8.00	0.26
-	-	-	230	7.98	0.28

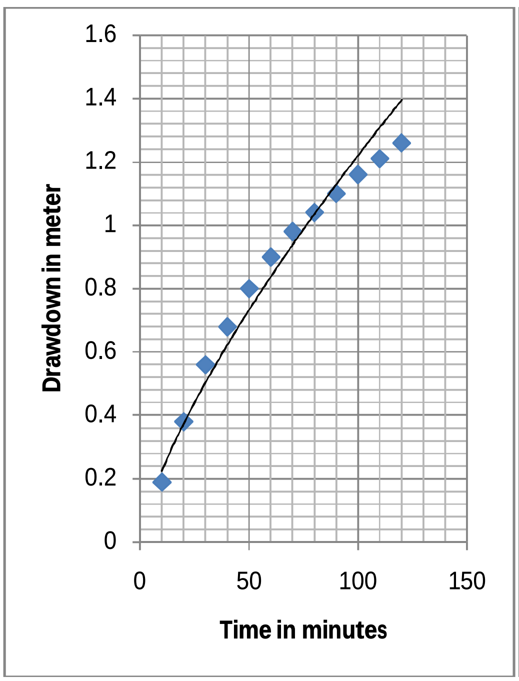


Fig. 5 (c)

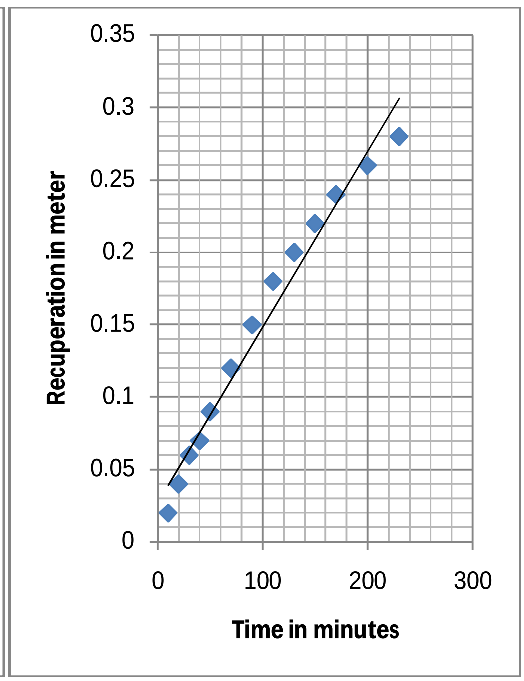


Fig. 5 (d)

Figure 5: (c) Drawdown Fig. 5 (d) Recuperation graph of Post-monsoon 2013 (Well No. 01)

Table 4: Pre-monsoon (2013) Pumping Test data of Pathri village, Aurangabad (Well No. 2)

Time (minutes)	Depth of water level (DWL)	Drawdown in meter (S1)	Time in min. since pump stopped (t1)	Recuperation in meter	Recuperation in from draw down stopped
0	3.00	-	0	4.25	-
10	3.20	0.20	10	4.22	0.03
20	3.36	0.36	20	4.19	0.06
30	3.45	0.45	30	4.17	0.08
40	3.59	0.59	40	4.14	0.11
50	3.68	0.68	50	4.10	0.15
60	3.77	0.77	60	4.00	0.25
70	3.90	0.90	70	3.95	0.30
80	4.00	1.00	80	3.92	0.33
90	4.50	1.50	90	3.87	0.38
100	4.10	1.10	100	3.82	0.43
110	4.15	1.15	110	3.79	0.46
120	4.20	1.20	120	3.65	0.60
130	4.25	1.25	150	3.55	0.70
-	-	-	180	3.50	0.75
-	-	-	210	3.47	0.78
-	-	-	240	3.45	0.80

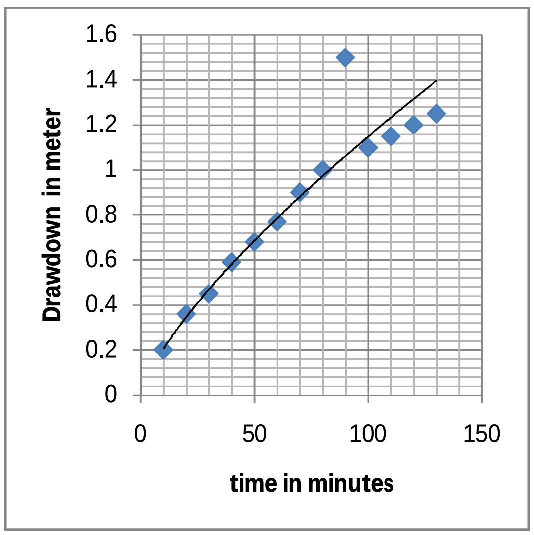


Fig. 6 (a)

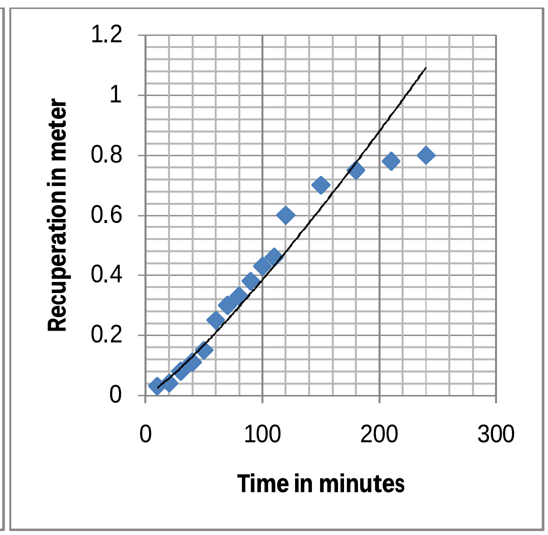


Fig. 6 (b)

Figure 6: (a) Drawdown Fig. 6 (b) Recuperation graph of Pre-monsoon 2013 (Well No. 02)

Table 5: Post-monsoon (2013) Pumping Test data of Pathri village, Aurangabad (Well No. 2)

Time (minutes)	Depth of water level (DWL)	Drawdown in meter (S1)	Time in min. since pump stopped (t1)	Recuperation in meter	Recuperation in meter from draw down stopped
0	2.00	-	0	3.07	-
10	2.12	0.12	10	3.06	0.01
20	2.24	0.24	20	3.04	0.03
30	2.35	0.35	30	3.02	0.05
40	2.45	0.45	40	3.00	0.07
50	2.55	0.55	50	2.99	0.08
60	2.65	0.65	60	2.97	0.10
70	2.75	0.75	70	2.96	0.11
80	2.83	0.83	80	2.94	0.13
90	2.90	0.90	90	2.92	0.15
100	2.95	0.95	100	2.90	0.17
110	3.00	1.00	110	2.89	0.18
120	3.03	1.03	120	2.87	0.20
130	3.07	1.07	150	2.85	0.22
-	-	-	180	2.84	0.23
-	-	-	210	2.83	0.24
-	-	-	240	2.82	0.25

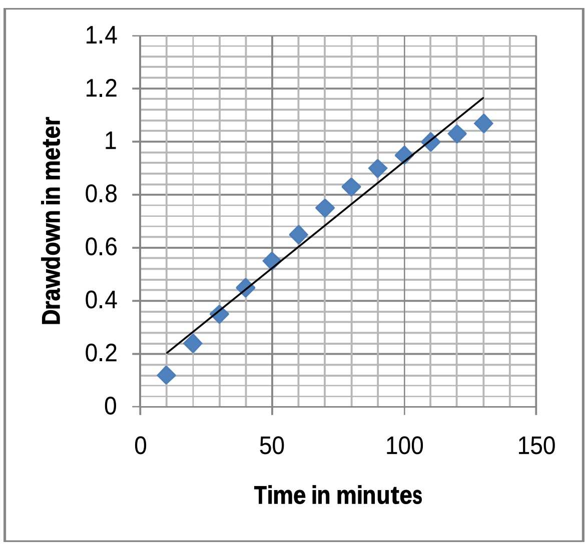


Fig. 6 (c)

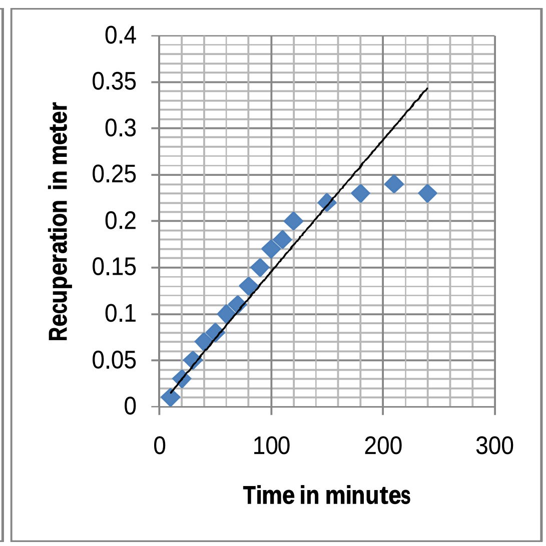


Fig. 6 (d)

Figure 6: (c) Drawdown Fig. 6 (d) Recuperation graph of Pre-monsoon 2013 (Well No. 02)

Table 6: Pre-monsoon (2013) Pumping Test data of Phulambri Town (Well No. 03)

Time (minutes)	Depth of water level (DWL)	Drawdown in meter (S1)	Time in min. since pump stopped (t1)	Recuperation in meter	Recuperation in meter from draw down stopped
0	4.00	-	0	4.94	-
10	4.11	0.11	10	4.92	0.02
20	4.23	0.23	20	4.86	0.08
30	4.31	0.31	30	4.84	0.10
40	4.37	0.37	40	4.80	0.14
50	4.44	0.44	50	4.76	0.18
60	4.49	0.49	60	4.73	0.21
70	4.56	0.56	70	4.68	0.26
80	4.63	0.63	80	4.65	0.29
90	4.70	0.70	90	4.63	0.31
100	4.78	0.78	100	4.61	0.33
110	4.85	0.85	120	4.57	0.37
120	4.94	0.94	150	4.55	0.39
-	-	-	180	4.53	0.41
-	-	-	210	4.50	0.44
-	-	-	240	4.49	0.45

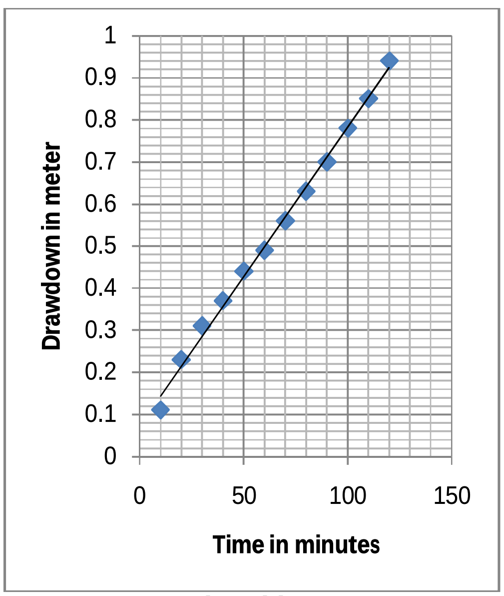


Fig. 7 (a)

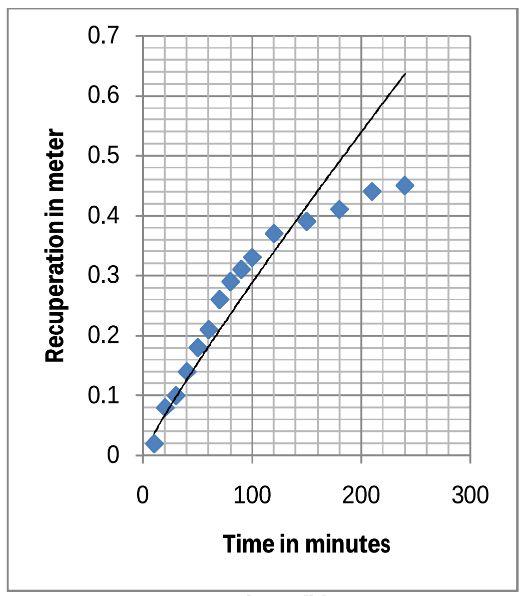


Fig. 7 (b)

Figure 7: (a) Drawdown Fig. 7 (b) Recuperation graph of Pre-monsoon 2013 (Well No. 03)

Table 7: Post-monsoon Pumping Test data of Phulambri Town (Well No. 03)

Time (minutes)	Depth of water level (DWL)	Drawdown in meter (S1)	Time in min. since pump stopped (t1)	Recuperation in meter	Recuperation in meter from draw down stopped
0	2.00	-	0	2.57	-
10	2.09	0.09	10	2.53	0.04
20	2.13	0.13	20	2.49	0.08
30	2.19	0.19	30	2.45	0.12
40	2.24	0.24	40	2.42	0.15
50	2.28	0.28	50	2.39	0.18
60	2.30	0.30	60	2.36	0.21
70	2.34	0.34	70	2.34	0.23
80	2.39	0.39	80	2.32	0.25
90	2.44	0.44	90	2.28	0.29
100	2.49	0.49	100	2.26	0.31
110	2.53	1.53	120	2.24	0.33
120	2.57	0.57	150	2.22	0.35
-	-	-	180	2.20	0.37
-	-	-	210	2.19	0.38
-	-	-	240	2.18	0.39

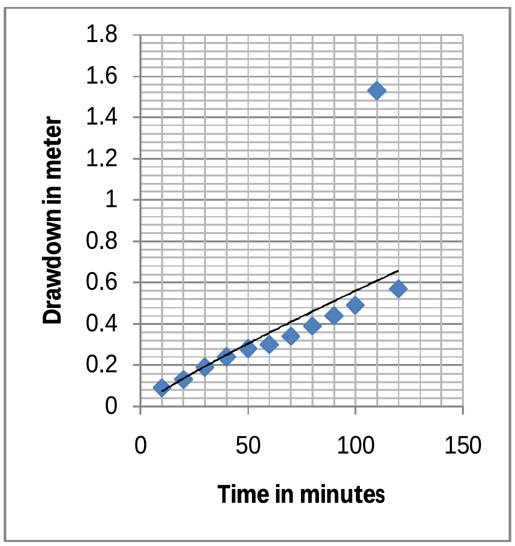


Fig. 7 (c)

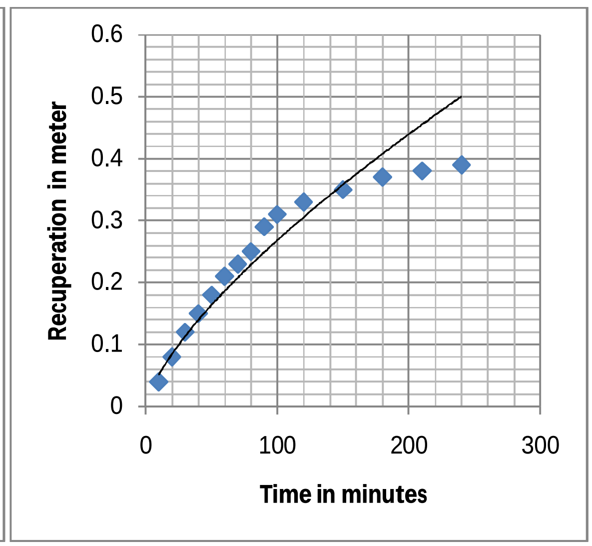


Fig. 7 (d)

Figure 7: (c) Drawdown Fig. 7 (d) Recuperation graph of Pre-monsoon 2013 (Well No. 03)

Table 8: Pre-monsoon Pumping Test data of Murshidabadwadi (Well No. 04)

Time (minutes)	Depth of water level (DWL)	Drawdown in meter (S1)	Time in min. since pump stopped (t1)	Recuperation in meter	Recuperation in meter from draw down stopped
0	5.93		0	6.63	
10	5.99	0.06	10	6.60	0.03
20	6.13	0.20	20	6.58	0.05
30	6.19	0.26	30	6.56	0.07
40	6.23	0.30	40	6.53	010
50	6.28	0.35	50	6.50	0.13
60	6.33	0.40	60	6.48	0.15
70	6.37	0.44	70	6.46	0.17
80	6.42	0.49	80	6.44	0.19
90	6.49	0.56	90	6.42	0.21
100	6.53	0.60	100	6.40	0.23
110	6.57	0.64	110	6.38	0.25
120	6.63	0.70	120	6.37	0.26
-	-	-	140	6.35	0.28
-	-	-	160	6.33	0.30
-	-	-	180	6.30	0.33
-	-	-	210	6.28	0.35
-	-	-	240	6.27	0.36

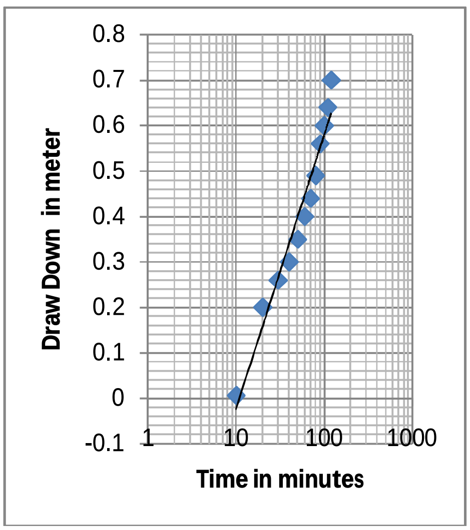


Fig. 8 (a)

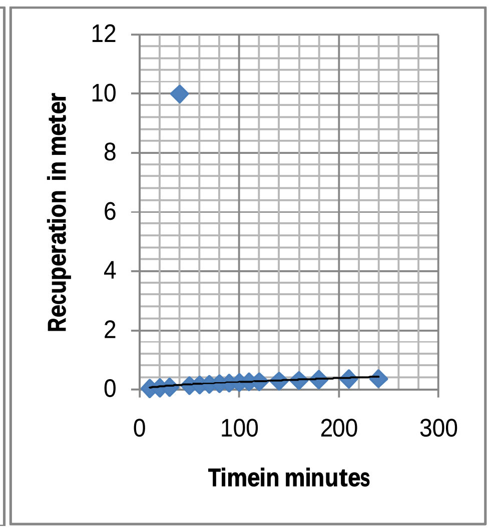
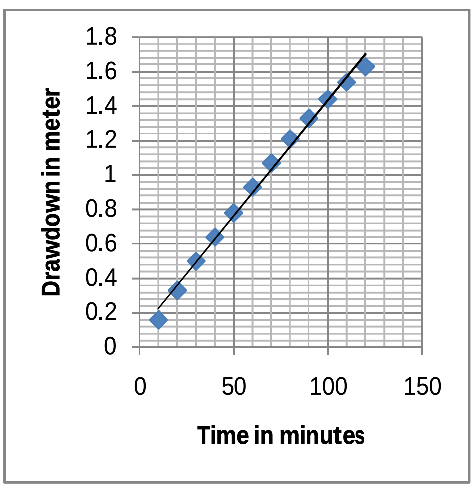


Fig. 8 (b)

Figure 8: (a) Drawdown Fig. 6 (b) Recuperation graph of Pre-monsoon 2013 (Well No. 04)

Table 9: Post-monsoon (2013) Pumping Test data of Murshidabadwadi (Well No. 04)

Time (minutes)	Depth of water level (DWL)	Drawdown in meter (S1)	Time in min. since pump stopped (t1)	Recuperation in meter	Recuperation in meter from draw down stopped
0	5.00	-	0	6.63	-
10	5.16	0.16	10	6.59	0.04
20	5.33	0.33	20	6.55	0.08
30	5.50	0.50	30	6.51	0.17
40	5.64	0.64	40	6.48	0.15
50	5.78	0.78	50	6.44	0.19
60	5.93	0.93	60	6.40	0.23
70	6.07	1.07	70	6.36	0.27
80	6.21	1.21	80	6.33	0.30
90	6.33	1.33	90	6.30	0.33
100	6.44	1.44	100	6.27	0.36
110	6.54	1.54	110	6.24	0.39
120	6.63	1.63	120	6.21	0.42
-	-	-	140	6.15	0.48
-	-	-	160	6.10	0.53
-	-	-	180	6.05	0.58
-	-	-	210	6.00	0.63
-	-	-	240	5.95	0.68



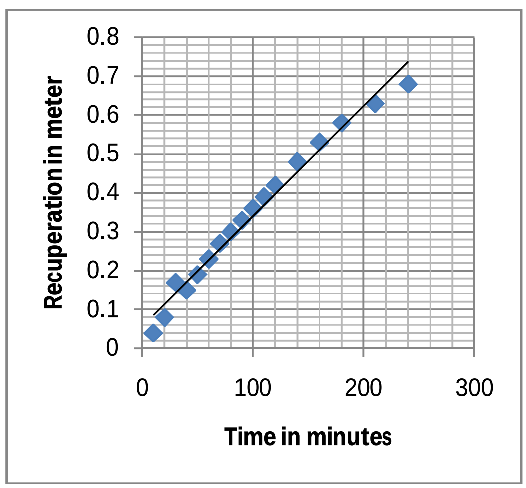


Fig. 8 (c) **Fig. 8 (d)**

Figure 8: (c) Drawdown Fig. 6 (d) Recuperation graph of Post-monsoon 2013 (Well No. 04)

Table 10: Aquifer performance results of wells (Pre-monsoon 2013 and Post-monsoon 2013)

Well No.	Season	Q (m^3/min)	rw (m)	Δs (m)	t0 (min)	T (m^2/day)	class type	S	S. Y. %
1	Pre monsoon	2.81	2.75	0.79	0.20	3.25	Low	0.0047	0.47
	Post-monsoon	59.98	2.75	0.10	0.19	10.84	Intermediate	0.0093	0.93
2	Pre monsoon	155.14	2.75	0.19	0.20	280.47	High	0.015	1.59
	Post-monsoon	290.50	2.75	0.63	0.12	525.18	High	0.082	8.22
3	Pre monsoon	246.82	2.00	0.38	0.11	446.21	High	0.17	1.74
	Post-monsoon	282.29	2.00	0.21	0.09	510.33	High	0.319	31.96
4	Pre monsoon	135.00	3.5	0.34	0.06	82.98	Intermediate	0.011	11.13
	Post-monsoon	221.71	3.5	0.77	0.16	181.960	High	0.0171	1.71

Where, Q - is constant rate pumping test [$m^3.sec^{-1}$]; rw - is radius of the well [m]; Δs - is slope of the line per one log cycle [m]; t_0 - is the initial time of pumping test at zero drawdown [sec or min]; T - is Transmissivity [$m^2.sec^{-1}$]; S - is Storativity [unit less] and S.Y % - Specific yield %.

CONCLUSION

The yield from studied wells is varies from 0.47 m^3/day to 11.13 m^3/day in winter (post monsoon) and 1.59 m^3/day to 31.96 m^3/day in summer (pre monsoon). The recovery curve rate is seen to be fast in initial phase and gradually decreases as the static water level is approached. The initial fast recovery rate is due to the steep hydraulic gradient. Some wells become a dry in summer, mostly due to inadequate depth. The yield of these wells depends upon the geological formations, their location with respect to geomorphology, depth, diameter, thickness and the nature of the aquifer.

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