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An Assessment of Ground Water Recharge Potential Through Tube Well

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***Abstract*: Water is limited vital natural resource which is indispensable for the existence of all living of all matter; plant, animal and man. Farmers of the Saurashtra region are tempted to use more irrigation water from the tube well due to erratic and uneven rainfall to meet the requirement if intensive cropping, this has been resulted in very heavy withdrawal of ground water therefore, it is a need to recharge the runoff water on their field. The study has been undertaken at the Instructional Farm, College of Agricultural Engineering and Technology, Junagadh agricultural University, Junagadh. The aquifer properties like transmissibility, storage coefficient and specific capacity of the well was found through pumping test at Instruction farm well. Similarly, they were found through recovery test.. The determined aquifer properties were verified by the recovery test. The observed data on drawdown at various times since pumping started was analyzed by the Jacob approximation method. The observed data on residual drawdown at various times since pumping stopped were analyzed to determine the aquifer properties using Theis recovery method. The potential rate of ground water recharge for the aquifer of this region through tube well was found higher as the depth of tube well increases. The cost of ground water recharge was found nominal as compared to that of under surface storage water. The benefit cost ratio for wheat, cumin and green gram grown by utilizing recharged water was found higher, so one can go for bore well recharging for getting higher yield.**

Keywords: groundwater recharge, irrigation, aquifer, recovery method, transmissivity

I. INTRODUCTION

In India the arid and semi-arid regions, due to uncertainty of monsoon and scarcity of surface water, dependence on ground water resource has increased tremendously in recent years. The importance of ground water for domestic, industrial and agricultural uses and its readily and locally available characteristics have lead to random extraction of this precious natural resource. Technological development in construction of deep tube wells; water abstraction devices and pumping methods have also contributed to large scale exploitation of ground water from depths exceeding 300 m below ground level. In many parts of India especially in the arid and semi-arid regions, due to uncertainty of monsoon and scarcity of surface water, dependence on ground water resource has increased tremendously in recent years. Easy availability of credit from financial institutions for sinking tube wells coupled with provision of subsidized free electricity for pumping in many states has exacerbated the increased extraction of ground water. Both consolidated and unconsolidated geological materials are important as aquifers. Of the consolidated materials (i.e. bedrock), sedimentary rocks are the most important because they tend to have the highest porosities and permeability. Although most bedrock aquifers are within sedimentary rock, in some areas igneous or metamorphic rock can be important as aquifers. Artificial recharging is the planned, human activity of increasing the amount of ground water available through works designed to increase the natural replenishment or percolation of surface waters into ground water aquifers, resulting in a corresponding increase in the amount of ground water available for abstraction. It has been used for many beneficial purposes although the primary objective of this technology is to preserve or enhance ground water resources. The recharge tube wells can be easily constructed at places like topographical depressions, abandoned canals and canal escapes, where excess surface runoff either accumulates or it is conveyed for disposal. The Gujarat state is divided in to eight agro ecological zones. Gujarat mainly divided in major four regions Saurashtra, Kutchh, North Gujarat and south Gujarat. In three parts Saurashtra, Kutchh and North Gujarat are inclined mostly to use of ground water for its winter crops, only South Gujarat part of the state have good irrigation facilities through canal network of Mahi, Narmada and Tapti. After full functioning of Narmada canal project some part of North Gujarat as well as Kutchh will cover under canal irrigation.

On the other hand, rapid urbanization and land use changes has decreased drastically the infiltration rate into the soil and has diminished the natural recharging of aquifers by rainfall. All the above factors have contributed to lowering the water table so much that many dug wells and tube wells gave sufficient yield in past, are decreasing now in their yield and ultimately drying up. The situation becomes more unstable during summer when most of the yield of dug wells and shallow tube wells either reduces considerably or dries up. The drinking water crisis prevalent in most of the villages in summer imposes serious health hazards to the rural masses and is responsible for the loss of huge livestock population for want of drinking water and fodder.

II. BACKGROUND

The development of ground water recharge through wells, tube wells and reservoirs may result in regular rising of water table and it is an important need of the country. (Olankar 1981) discussed that in order to study the potential of Deccan basalts as aquifers, the properties of transmissivity and storativity must be considered. Analysis of large-diameter dug wells tapping unconfined aquifer in the deccanbesalts shows that there exists a relationship between porosity and specific yield. The aggregate porosities of weathered basalts, vesicular basalts and fractured-jointed basalts are respectively up to 34%, 50% and 15%. On the contrary, specific yield has a maximum value of 7%, 4% and 1% respectively. (Ojha and Swamee 1990) studied that the storage co-efficient and transmissivity important aquifer parameter that are useful in measuring the ground water potential of an aquifer. They developed an empirical equation for well function valid for all values of the argument. (Kaledhonkar et. al., 2003) studied two-recharge tube wells were installed in the bed of old Sirsa branch canal to recharge the depleting groundwater artificially. The location and depth of recharge tube wells were selected based on the results of the resistivity survey to ensure better chances of recharge due to presence of pervious strata in the aquifer. Filter pit was provided to prevent the entry of sediments and suspended solids in recharging water. The recharge tube wells performed well during the entire experimental period covering two monsoon seasons without any drastic reduction in recharge rate. An average of 10.5 lps due to individual recharge tube well was observed, which was reasonably good.

III. MATERIAL AND METHODS

Thestudy area is belongs to the CAET Instructional Farm of Junagadh Agricultural University Campus, Junagadh. It is located about 1.5 km South-West of Junagadh town, bearings are 21031′ N latitude and 70036′ E longitude and elevation above mean sea level is 82.92 m. The total geographical area of CAET Instructional Farm is 19.14 ha. The soil of the study area was observed to be sandy clay loam to silt loam in texture. The soils are dark to light gray in colour and taxonomically is classified as Typical Udorthents. The climate of the study area is subtropical and semi-arid. The average annual rainfall (2001–2011) was 1006 mm. The main source of water in the area is ground water. The ground water depth varies from 10 m to 25 m during 2012-13. The main source of ground water recharge is rainfall, through infiltration, deep percolation and seepage.

A. Well Testing for Aquifer Properties

Volumetric Measurement

The container of known volume was used for the collections of water discharging from the delivery pipe of pump installed in the tube well.

$$Q = \frac{V}{t} \qquad (1)$$

Where, Q = discharge (m^3/h), V = volume of water collected in a container in time t (m^3), t = time of collection of water (h)

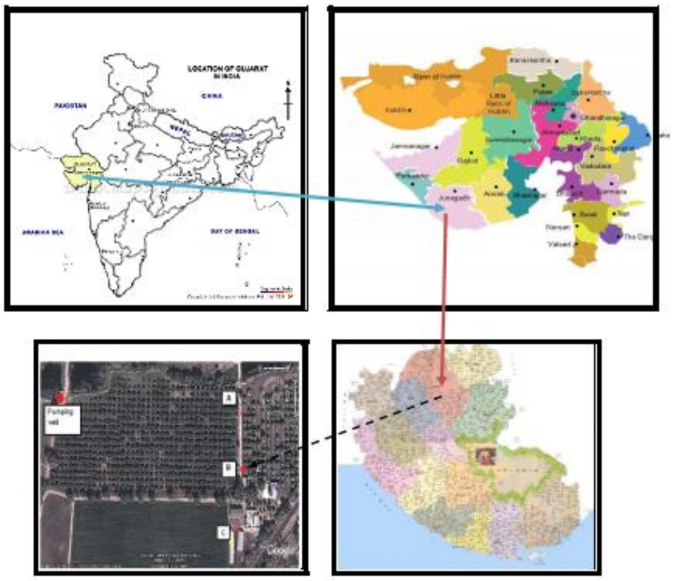

Fig. 1: Study area map

Measurement of depth water

The static water level in the pumping as well as observation tube well was measured before starting the pumping. The water level recorder was used to measure the water level in a tube well. The pressure sensor was connected with a wire marked with linear measurement. The wire was marked in meter and centimeter. The other end of the wire was connected with data logger. For the water level measurement in a tube well, the sensor connected with wire was entered in the tube well until it touches the bottom of the tube well. The depth of water is automatically recorded and displayed on the screen of the data logger.

Determination of aquifer properties through draw dawn measurement in pumping well

The discharge of the pump was measured in the methods as described in the equation 3.1. After measuring the static water level in well, the pumping was started. The water level reading at different time interval was measured and recorded. The draw down obtained at different time was calculated by using following formula.

$$s_t = WL_t - SWL \qquad (2)$$

Where, s_t = draw down in well at time t,WL_t= water level in well at time t,SWL = static water level in well before started pumping

The method suggested by Jacob, 1950 was followed to determine the storage co-efficient and transmissibility of the aquifer. This method is applicable for large values of t ($t \geq \frac{R^2}{0.04T} S$).The following formula was used.

$$s = \frac{2.3Q}{4\pi T} \log_{10} \frac{2.25Tt}{r^2 S} \qquad (3)$$

If s_1 and s_2 are the drawdown at time t_1 andt_2 since pumping started

$$s_2 - s_1 = \frac{2.3Q}{4\pi T}\log\frac{t_2}{t_1} \qquad (4)$$

The draw down $s_1$and s_2 per unit log cycle was obtained from a semi log graph. If the draw down difference $\Delta s(s_2 - s_1)$ are taken per unit log cycle, then equation (4) will be simplified as below.

$$T = \frac{2.3Q}{4\pi\Delta s} \qquad (5)$$

The storage coefficient of the aquifer (S) was calculated using the equation (4) as below. In equation (4), if S =0, when

$$\log_{10}\left(\frac{2.25Tt}{r^2S}\right) = 0 \quad \text{i.e.} \frac{2.25Tt}{r^2S} = 1 \qquad (6)$$

The straight line of the semi-log plot was extra plotted to intersect the zero-draw down axis. The time (t_0) for s=0 was noted and s was computed as below.

$$s = \frac{2.25Tt_0}{r^2} \qquad (7)$$

Determination of aquifer properties through Theis recovery method

In Theis recovery method, the residual draw down in a pumped well measured at different time intervals after pumping stopped, could be used to find transmissibility and storage coefficient of aquifer.The well was pumped at a constant rate (Q). The pumping was stopped after a time t' since pumping stopped was measured at different times. The recovery of piezometric head could be determined by considering a negative discharge i.e. recharge in a sense) for the time t'. For small r and large t', Jacob (1946-1950) approximation could be made and the residue draw down s' after time t ($t=t_1 + t'$) since pumping started could be obtained.The required mathematic expression was derived as below.

$$s' = \frac{2.303Q}{4\pi T}\log_{10}\left(\frac{2.25Tt}{r^2S}\right) - \frac{2.303Q}{4\pi T}\log_{10}\left(\frac{2.25Tt'}{r^2S}\right)$$

$$= \frac{2.303Q}{4\pi T}\log_{10}\left(\frac{t}{t'}\right) \qquad (8)$$

The semi-log plot of residual draw down s' (on simple arithmetic scale) and t/t' (on log scale) was drawn. The difference of residual drawdown ($\Delta s'$) per unit log cycle of t/t' was obtained from the plot. The transmissibility (T) could be obtained similar to Jacob method as below.

$$T = \frac{2.303Q}{4\pi\Delta s'} \qquad (9)$$

The storage coefficient (S) could also be determined from the time draw down plot (Jacob, 1946-1950) of the data during pumping using equation (7).

B. Potential recharge rate

Calibration of pressure sensor

By putting the pressure sensor on surface of water level and check manually that whether it touched the water surface or not. After confirming that the sensor was touched on the water surface, switched on the water level recorder and set it at zero. Then after the pressure sensor was put at the bottom of tube well and confirm the reading shown on the screen of the data logger by manually checking the depth of tube well using measuring tape. It is necessary that both the readings are same.

Ground water recharge through tube well

There were three tube wells for ground water recharge named A, B, and C. The tube well A, B, and C having depth 6.00 m, 26.90 m and 55.48 m respectively. The distance between tube wells A and B was 64.60 m, distance between tube wells B and C is 67.72 m and between tube well A and C is 132.32 m. The schematic diagram of experimental setup is shown in Figure 2. The pressure sensor was set at the bottom of observation tube wells. Pumping was started to recharge the tube well with constant rate which was considered as the recharge well and others are as observation wells. Then after the variation in the water level of observation tube wells were measured and recorded for 2 days. The recharge wells were changed vise-versa for other measurement. Constant rate of water flow is mandatory to recharge the tube well.

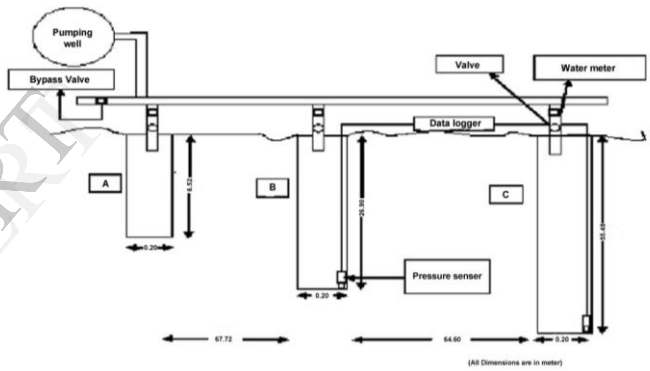

Fig.2: Schematic diagram of experimental setup

Fig.3: Water level recorder

Determination of aquifer properties through recharge rate

The recharge rate plays an important role in the determination of aquifer properties. If the water gets drained completely while recharging than it can be said that the well is located in an unconfined aquifer or if not then the well is located in a confined aquifer. More recharge rate indicates the confined aquifer.

C. Runoff Computation

Rational Method

This is a most common method used to predict the peak runoff rate defined as the maximum runoff, to be used as capacity for a given structure that must carry the runoff. Rational method used the following formula for computing the design runoff. (Ramser, 1972).

$$Q = \frac{CIA}{3600}$$

Where,Q = peak runoff rate (lps), C = runoff coefficient, I = mean intensity of precipitation (mm/h) for a duration equal to time of concentration, and for an accidence probability, A= area (m^2)

Calculation of Runoff (R)

R = C x P

Where,R = runoff (mm), C = runoff coefficient, P = precipitation (mm)

CRF Equation

A capital recovery factor is the ratio of a constant to the present value of receiving that annuity for a given length of time. Using an interest rate i, the capital recovery factor is (Goodman, 1984)

$$AC = \frac{PC\ X\ i\ X\ (1+i)^n}{(1+i)^n - 1}$$

Where,i = Interest rate (fraction), n = Expected life of recharge system (years), PC = Present cost of recharge system (Rupees), AC = Annual cost of recharge system (Rupees)

Calculation of benefit cost ratio

By using CRF equation, the annual cost for the volume of water, which could be recharge by suggested recharge structure or bore well was estimated. The area of different Rabi crops, which may be grown additional by using this recharge water, was estimated. Then the economical study was carried out for the crops grown in additional area. It is necessary to calculate the benefit cost ratio for checking economical viability of the suggested recharge structure or bore well. Beneficial cost is the ratio of net return to the actual cost. Benefit cost ratio must be greater than 1.

$$B/C = \frac{Net\ Return}{Annual\ Cost}$$

Where, NR = GR – CC, NR = Net return (Rs/yr), GR = Gross return(Rs/ha), CC = Cost of cultivation (Rs/yr)

IV. RESULTS AND DISCUSSION

A. Well Testing for Aquifer Properties

The observation tube well diameter and depth of static water level from ground was 0.20 m and 6.35 m respectively. The observation well was not located nearby the recharge well, therefore, the tube well was considered as a observation well. The HDPE column pipe (75 mm x 10 kgf/cm^2) was used as delivery pipe with the submersible pump of 15 hp x 6 stages. The deliver pipe was connected with the conveyance pipe made of PVC 110 mm x 4 kg/cm^2The outlet of conveyance pipe was fitted with 75 mm PVC bypass assembly. The 75mm PP ball valve was fitted with the one end of the bypass. The other end was diverted to recharging tube well. The discharge rate of the pumps was found as 15 lps.

B. Aquifer Properties

The aquifer properties of the CAET instructional farm were determined by conducting the aquifer test in tube wells. The tube well located in Instructional farm of CAET, JAU, Junagadh was tested by pumping from it and taking the water level observations in itself. The observation wells near to pumping well were not existed. Therefore, the drawdown was observed in the pumping tube well itself.

The pumping rate was measured by noting the time required to fill barrel of 209 liters capacity. The same technique was adopted for selected sites. The pumping rate was maintained constant throughout the test period. The constant pumping rates of submersible pump at wells of CAET instructional farm was found as 4.80 lps. The pumping rate was verified at every one hour during the test period.

Jacob (1940) approximation method was adopted to determine the transmissibility, storage coefficient of aquifer and specific capacity of well using the observed drawdown data during the pumping test. Those determined properties were verified by conducting the recovery test. Theis recovery method was adopted to calculate the aquifer properties using the residual draw down data obtained through recovery test. The results data are presented in Table 1.

Table 1: Aquifer Properties Determined by Pumping Test at Various Locations.

Sr. No.	Method	Aquifer Properties		
		Transmissivity m^3/h	Storage coefficient	Specific Capacity $m^3/h/m$
1	Copper Jacob drawdown method	26.45	0.27	18.89
2	Theis recovery method	27.57	0.28	19.69

The data presented in Table 1 showed that the values of aquifer properties determined by different methods are matching. The recovery test was also conducted on same day to verify the values of properties determined by pumping test. The residue drawdown observed during recovery test for the various ratios of t/t' (ratio of time since pumping to time since pumping stopped) are depicted in Fig 5.

C. Potential recharge rate

Table 2:The comparison of recharge rate with the depth of the tube well

Recharge tube well	***Depth of tube well (m)***	***Recharge rate of the tube well (lps)***
A	6.00	0.03
B	26.90	1.56
C	55.48	12.50

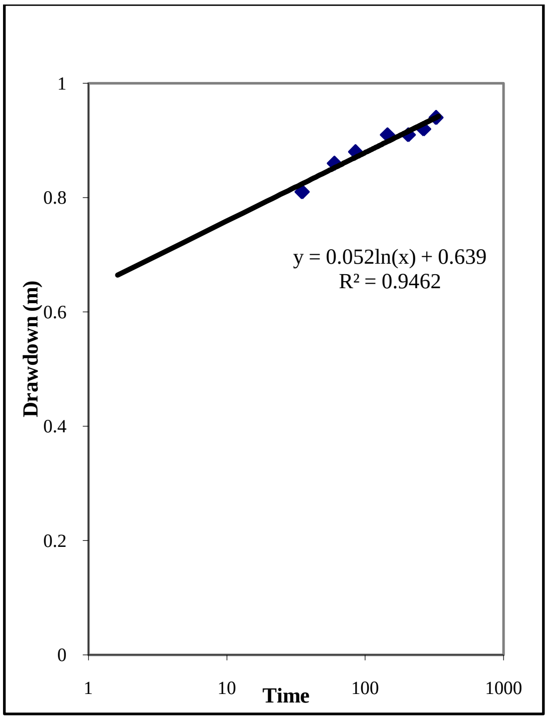

Fig. 4: Drawdown observed at Instructional farm

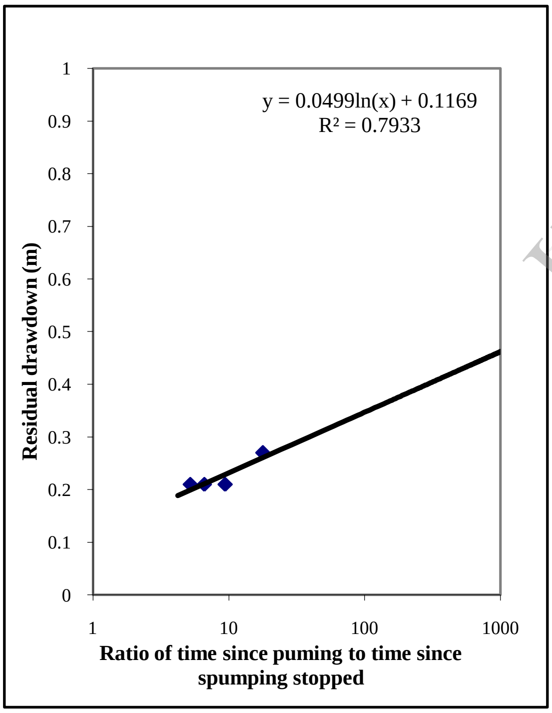

Fig. 5: Recovery test observed at Instructional farm

D. Runoff measurement

The peak rate of runoff for 1 ha area was calculated by using Rational formula by taking the value of runoff coefficient as 0.30, rainfall intensity as 60 mm/hr. by this way the attained peak rate of runoff is 50 lps. The rate is too large as comaperd to recharge rate of 12.50 lps (55.48m depth tube well). Threfore, the excess runoff should be stored temporaly.

By observing last 10 years hourly rainfall data, it was found that 5 storms of 100 mm rainfall during 2 hours was occurred normaly. By taking the value of runoff coefficient as 0.30, the value of runoff was estimated as 30 mm during 2 hours by using runoff formula. For 1 ha area the runoff can estimated as 300 m^3/day. The 24 hr rainfall of 10 cm which can be provided runoff 300 m^3 in 2 hr which provides the recharge rate of 3.47 lps/ha. The recharge rate of tube well C was found 12.50 lps, by converting the unit from lps to m^3/day we may get 1080 m^3/day. So, during the time of rainfall occurring i.e. 2 hours recharge volume can be estimated as 90 m^3.

The runoff was estimated 300 m^3/day/ha, so it was from 2 ha may be estimated as 600 m^3/day. Now for a single tube well only 90 m^3 volume can be recharged, it is needed to recharge remaining runoff of 510 m^3. Therefore, the temporary storage structure of should be constructed. Therefore, it was suggested that a temporary sump 510 m^3 capacity and 150 feet deep tube well should be constructed to meet the recharge of excess runoff.

Now a days, the cost of earth work is running Rs 52/m^3, so it will cost Rs. 26,520 per 2 ha water storage temporary sump. The making of 150 feet deep tube well will cost Rs 13,500 at Rs 90/feet. The casing of PVC 200 mm diameter X 10 kgf/cm^2 of 30 feet will cost Rs 9,000 at Rs 300/ft. The cost of recharge filter is Rs 5,000. The other necessary cost is Rs 2,500. So the total of cost of making a 150 feet deep tube well is Rs 30,000. By this way the total cost of temporary storage structure and tube well is Rs. 56,520. By using the CRF formula the Actual Cost of temporary storage structure and tube well shaving life of 20 years can be calculated as Rs 6,645.62/yr.

It was estimated that the runoff of 300 m^3 is obtaining for every storm. By considering 5 storms of 100 mm rainfall per year, the total runoff would be 1,500 m^3/yr. Therefore, the cost of ground water structure would be Rs 14.43/m^3 if the actual cost is considered as Rs 6,645.62/yr.

By using this recharged water, the wheat crop having 50 cm water requirement per season can be growm in the additional area of 0.60 ha, the yield from this additional area can be assumed as 3,000 kg (@ 5,000 kg/ha). The price of 1 kg wheat is Rs 15, so the gross rate would be Rs 45,000. If it's cost of cultivation is considered as Rs 30,000 (@ Rs 50,000/ha). Therefore, the net return would be Rs 15,000. If the actual cost is Rs 6,645.62 and net return is Rs 15,000 then the beneficial cost ratio would be 2.25.

Similarly, the cumin crop having 25 cm water requirement per season can be growm in the additional area of 1.20 ha, the yield from this additional area can be assumed as 1,200 kg (@ 1,000 kg/ha). The price of 1 kg cumin is Rs 100, so the gross rate would be Rs 1,20,000. If its cost of cultivation is considered as Rs 48,000 (@ Rs 40,000/ha). Therefore, the net return would be Rs 72,000. If the actual cost is Rs 6,645.62 and net return is Rs 72,000 then the beneficial cost ratio would be 10.83.

Similarly, by using this recharged water, the green gram crop having 30 cm water requirement per season can be growm in the additional area of 1.00 ha, the yield from this additional area can be assumed as 1,800 kg (@ 1,800 kg/ha). The price of 1 kg green gram is Rs 20, so the gross rate would be Rs 36,000. If its cost of cultivation is considered as Rs 20,000 (Rs 20,000/ha). Therefore, the net return would be Rs 16,000. If the actual cost is Rs 6,645.62 and net return is Rs 16,000 then the beneficial cost ratio would be 2.41.

V. CONCLUSIONS

- The aquifer properties like transmissibility, storage coefficient and specific capacity of the well was found as 26.45 m^3/h, 0.27 and 18.89 m^3/h/m respectively through pumping test at instructional farm well which showed that the aquifer of the study area was unconfined.
- The aquifer properties like transmissibility, storage coefficient and specific capacity of the well was found as 27.57 m^3/h, 0.28 and 19.69 m^3/h/m respectively through recovery test.
- The potential rate of ground water recharge for the aquifer of this region through 0.20 m diameter tube well would be 0.03 lps, 1.56 lps and 12.50 lps for the depth 6.00 m, 26.90 m and 55.98 m respectively.
- The cost of ground water recharge (for 12.50 lps recharge rate) was found as Rs 4.43/m^3, which was so far higher than that of Rs 20/m^3under surface storage water.
- The benefit cost ratio for wheat, cumin and green gram grown by utilizing recharged water was found as 2.26, 10.83 and 2.41 respectively.

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