Artificial Groundwater Recharge through Recharge Tube Wells: A Case Study

M J Kaledhonkar, *Non-member*
O P Singh, *Non-member*
S K Ambast, *Non-member*
N K Tyagi, *Non-member*
K C Tyagi, *Non-member*

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 resitivity 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 recharge rate of 10.5 l/s due to individual recharge tube well was observed, which was reasonably good.

Keywords: Artificial groundwater recharge; Recharge tube wells; Recharge case study; North-East Haryana; Groundwater management

INTRODUCTION

Overexploitation of groundwater resources and as a consequence decline in water table are the causes of serious concern in some parts of Haryana, Gujarat, Rajasthan, Tamilnadu, Andhra Pradesh, Maharashtra and Punjab[1] . In the state of Haryana, present availability of water is 2 M ha m, which includes 1.1 M ha m surfacr water and 0.9 M ha m groundwater. Yearly fluctuations of water table depths in the North-East region of the state indicate the declining trends of fresh groundwater resources. In the districts of Ambala, Kurukshetra and Karnal the groundwater, withdrawal, mainly from fresh water zone, is at the rate of 192%, 158% and 725% of annual recharge, respectively[2]. The exploited groundwater along with canal water supply is used to meet water requirements of wheat and one or two rice crops grown under intensive agriculture. The paddy fields and unlined canals also contribute to the groundwater. However, these contributions are not sufficient to keep groundwater balance in favourable condition for depleting groundwater areas. Decline of water table makes pumping of groundwater more costly, difficult and increases uncertainty about availability of fresh water. The situation demands recharging of freshwater zones in declining water table areas with artificial means to maintain the groundwater table at optimum levels. Artificial recharge is important for groundwater management as it provides storage space free of cost, avoids evaporation losses and allows the use of stored water in dry seasons.

Several methods of groundwater recharge like spreading, pit, induced recharge and well method are practiced. The area requirement of spreading method sometimes limits its use. Artificial recharge by wells has been attempted in India only during the last decade. The recharge/ injection tube wells directly feed depleted aquifers with fresh water from ground surface. The recharge through this technique is fast and has no transit losses or evaporation losses. Feasibility study near Ahmedabad was carried out to recharge overexploited deep confined aquifer from phreatic aquifer recharged by Sabarmati river[3]. Recharging of confined aquifer by injection tube wells along the Narwana branch canal in Kurukhestra district has indicated that water recharges at the rate of 7.2 m^3/day/tube well.

The non-availability of fallow lands in North-East region of Haryana restricted the adoption of different recharge techniques like surface spreading or other methods. Therefore, the recharge tube well was identified as suitable recharge technique. Lithology of region favoured the artificial groundwater recharge through tube wells. 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. It may ensure timely disposal of the excess runoff as well as replenishment of aquifer. As the structure of recharge tube well remains underground, there is hardly any loss of land. Considering these aspects feasibility study on groundwater recharge was undertaken through two recharge tube wells constructed in the bed of old Sirsa branch canal, which flows on seasonal basis.

M J Kaledhonkar, O P Singh, S K Ambast and N K Tyagi are with Central Soil Salinity Research Institute, Karnal; and K C Tyagi is with Irrigation Department, Kurukshetra.

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MATERIALS AND METHODS

The old Sirsa branch canal, a branch of Western Yamuna canal, passes through the fresh groundwater depleting area of North-East Haryana and primarily runs during rainy season to carry excess runoff. It is found that the static ground water level in the area generally varies between 6 m to 14 m. It is shallow near the canal and the seasonal fluctuations of water table are around 1m to 3 m. On the basis of lithology, declining trend of water table, availability of excess water supply and accessibility by the road, the site in bed of the old Sirsa branch canal near village Manak Majara (in the Nilokheri block) was selected as an experimental site for artificial groundwater recharge studies.

In order to find out the potential area (location) for recharge, an geo-electrical resistivity survey was carried out. Apparent resistivity of a sub-surface material was evaluated by passing a known electrical current through the ground and measuring its potential difference between two points. Five probes were used to yield a map of iso-resistivity lines and to detect the changes in bed rock or aquifer depth. The interpreted geological section on the basis of geo-electrical resistivity survey is shown in Figure 1. It was assessed that top layer of very fine to fine sand was present, which varied in thickness from 10 m to 30 m, approximately. At location N_1, silty clay/ clayey sand was present at 30 m depth. This layer was absent at all other points. At location N_2, silty sand was assessed at a depth of 17 m from the ground surface, which was a localized formation. At all other locations, medium sand to coarse sand was present beneath the fine sand layer, which promised good prospects for the groundwater recharge. Considering the results of resistivity survey, points N_4, and N_5 were selected as locations for installation of recharge tube wells.

The recharge tube wells were installed at a distance of 50 m between the points N_4 and N_5 in bed of the old Sirsa branch canal to recharge groundwater artificially. The rotary drilling was used to bore hole of 50 cm diameter to the depth of 45 m. The soil samples collected during drilling operation from the recharge tube well locations verified the results of resistivity survey, as generally sand was present for the major part of the profile. At greater depths gravel was also reported. Presence of gravel provided good possibility of recharge. The slotted PVC pipes of 20 cm diameter were lowered in the bore hole as conduit for recharging water. The slots (3 mm × 75 mm) on the PVC pipes were provided throughout the pipe length. Annular space between the bore hole and the pipe was filled with gravel of 9 mm to 12 mm in diameter through which the most of water should percolate down to the aquifer. To prevent entry of sediments and suspended solids in recharging water a filter pit was provided. Keeping recharge tube well at, a 6 m × 6 m × 4 m pit was excavated and filled with filter material. Most of the part of the pipe inside the filtering pit was slotted and was wrapped with coconut coir to allow the water to get in and to prevent entry of sand, silt and suspended particles in order to prevent the choking of the slots. The upper most part of the pipe was not provided with the slots for safety purpose. The cap at top of pipe was designed to facilitate the cleaning operation and pumping during the drought conditions.

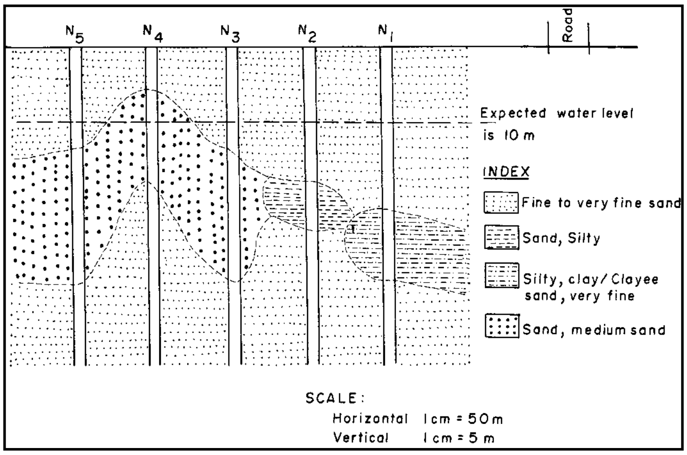

Figure 1 Geological section based on geoelectrical resistivity survey

The gradation curve (Figure 2) was prepared on basis of results of mechanical analysis of base material (soil samples collected from the bed of Sirsa branch canal) and suitable material for filter fit was selected using filter design criteria[4,5]. It was expected that the material should limits set by design criteria, which is 50% size (d_{50}) of filter to 50% size (d_{50}) of base should be 12 to 58. In case of the uniformly graded filter and base material a filter stability ratio (*ie*, d_{15} of filter to d_{85} of base) should be less than 5. In case of a riprap, permeability of protective construction is maintained. The design criterion for the permeability is d_{15} of one filter (coarse) layer to d_{15} of adjoining filter (fine) should be between 5 to 40. The minimum thickness requirement for filter layers constructed under dry condition are 0.05 m to 0.10 m for sand and fine gravel, 0.1 m to 0.2 m for gravel and 1.5 to 2 times the largest stone diameter for stones. These criteria were satisfied while designing the filter. The design of recharge tube well along with arrangement of coarse sand, gravel and pebble layers in filter pit is shown in Figure 3. The provision of an air vent was done in the recharge tube well to allow trapped air to escape outside in the atmosphere in the case of sudden entry of floodwater in the rainy season.

The observation wells were constructed by percussion method. The digging was done manually and the perforated pipe of 2″ diameter was used in the bore hole. A network of observation wells was provided, to monitor the changes in water table as the result of recharge tube wells (Figure 4). All observation wells were installed along left hand side of the canal assuming that recharge to right side would be the mirror image of recharge to the left side. There were four rows of observation wells perpendicular to the canal. In front of each recharge tube well a row of observation wells was provided. First observation well was in embankment of the canal. Second observation was approximately at a distance 35 m while third was at of 85 m. The distance between second and third observation well was increased with assumption that slope of seepage line would decrease with distance as one goes away from the recharge tube well. A row of three observation

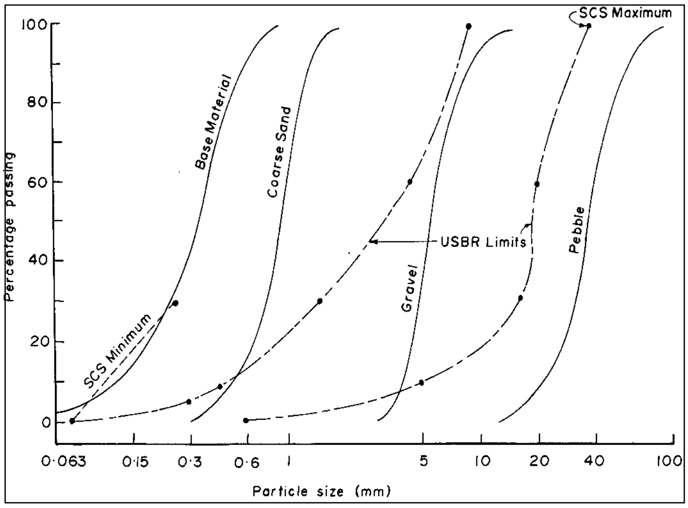

Figure 2 Design of filter material for recharge tubewell using SCS and USBR criteria

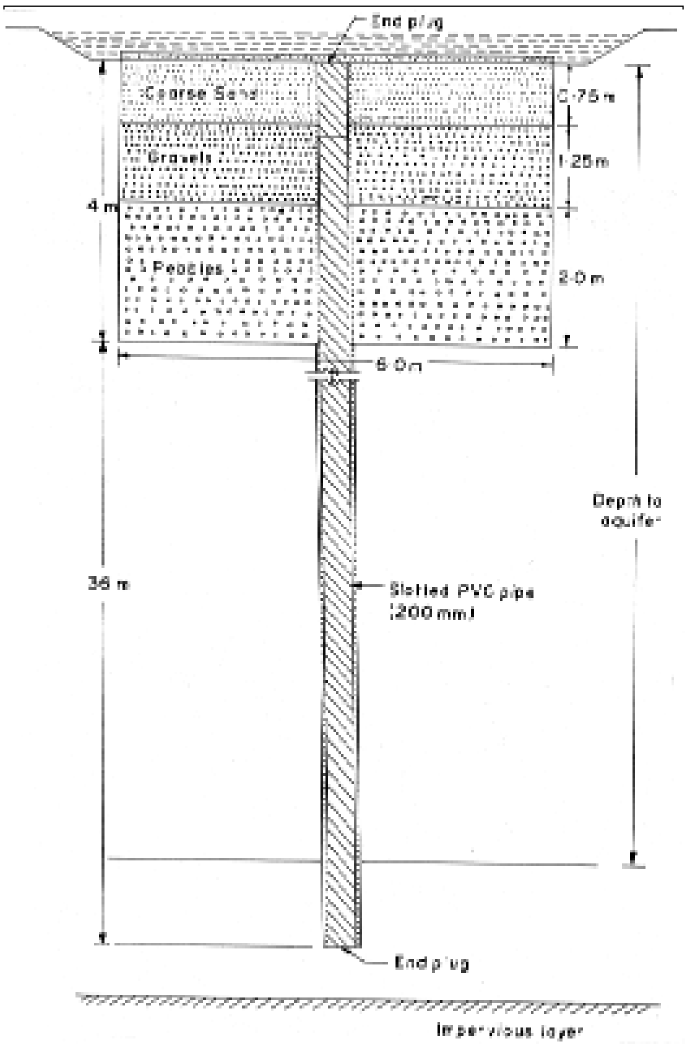

Figure 3 Recharge tubewell

wells was provided in between the two rows (in front of recharge wells) to assess influence of one recharge well on the other. One separate row of three observation wells in upstream direction (at 320 m) was provided to understand recharge, which was taking place due to canal seepage and paddy field under natural condition. Data on drawdown from different observation wells were collected regularly starting from the month of June 1998. Water samples were also collected simultaneously. Fluctuations in water table of observation wells were studied to monitor the functioning of recharge tube wells. Chemical analysis of water samples for electrical conductivity and dissolved sodium concentration was also carried out.

Recharge tube well admits water from the surface and conveys it to fresh aquifer. Its flow pattern is the reverse of the pumping tube well pattern. Hence, the equation, of radial flow, generally used in determining steady pumping rate, can be applied to estimate the recharge rate of a tube well. Steady state recharge rate under unconfined condition can be expressed with following expression[6].

$$Q_r = \frac{\pi K (h_1^2 - h_2^2)}{\text{In}(r_2 / r_1)} \tag{1}$$

where Q_r is the recharge tube well, m^3/day; K, the hydraulic conductivity m/day; h_1 and h_2, the heads at the observation wells, m; and r_1 and r_2 is the distances of respective obsrevation wells from the recharge tube well, m.

As recharge tube well was installed in the canal itself, recharge from the recharge tube well was superimposed on the seepage from the canal. Therefore, seepage from the canal had to be

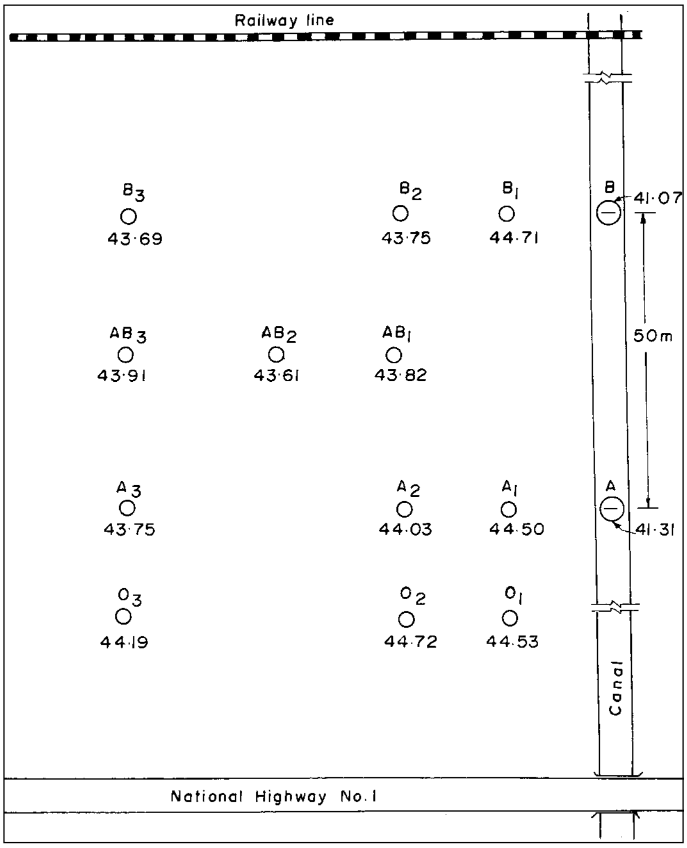

Figure 4 Layout of recharge tubewells and observation wells set-up with reduced levels

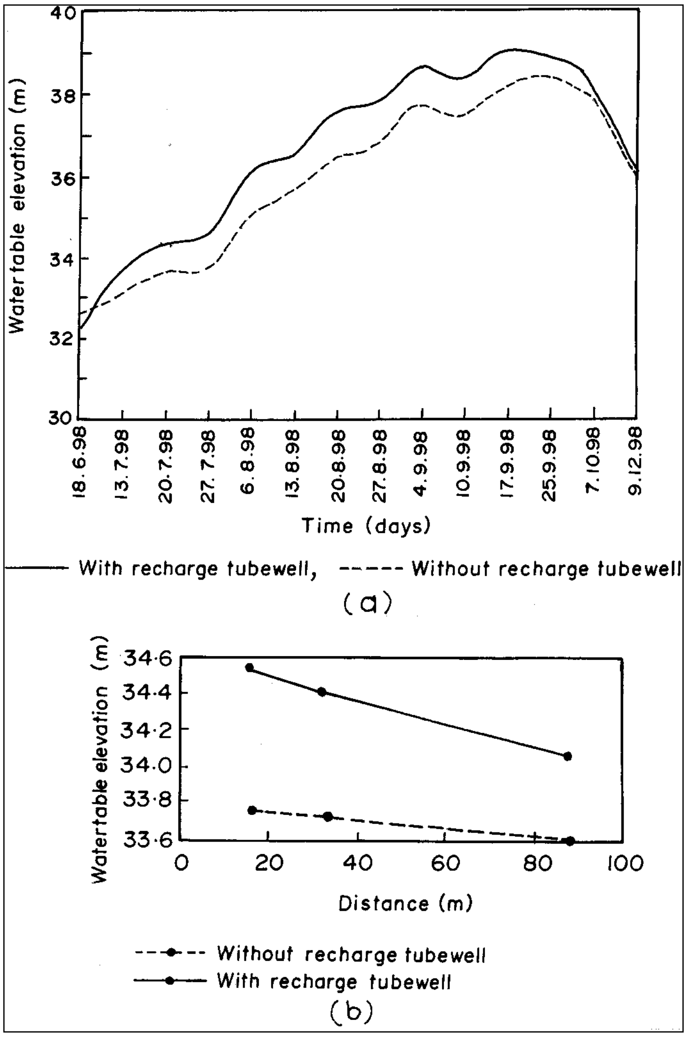

Figure 5 (a) Watertable fluctuations at 16 m from canal; and (b) Watertable elevation with distance from the canal on July 27, 1998

separated from the total recharge to estimate the recharge due to tube well. For this purpose, net change in water table due to canal seepage for particular time period was noticed and it was deducted from total head (the head due to canal and recharge tube well together) observed at the end of the same time period to determine expected head due to recharge tube well only. This was true, where observation wells were located in front of recharge tube well at 90° to canal flow direction. The bottom of the recharge tube well was selected as datum elevation. The recharge taking place above the water table elevation (in unsaturated zone) would be controlled by local hydraulic gradient. The recharge in saturated zone would depend upon regional gradiant as well as transmissivity of the aquifer layers. The expected heads due to recharge tube well were used to calculate the recharge rate according to equation (1).

RESULTS AND DISCUSSION

Water Table Fluctuations

Effectiveness of recharge tube wells was understood by comparing water table fluctuations in the observation well (A_1) located in front of recharge tube well A with water table fluctuations in the observation well (O_1) located at the same distance (*ie,* at 16 m) from canal but towards upstream side (Figure 4). The water table elevation at observations well A_1 and O_1 with time are shown in Figure 5(a). Higher water table elevations at obversations well A_1 clearly indicated the enhancement of recharge due to recharge tube well. Also, water table fluctuations at observation wells A_2 and A_3 were compared with water table fluctuations at observation wells O_2 and O_3, respectively. Similar results were observed as in earlier case. It suggested that there was an increase in recharge rate due to recharge tube well.

Table 1 Electrical conductivity and dissolved Na^+ concentration at observation wells

Date	Electrical Conductivity, dS/m				Dissolved Na^+ Concentration, meq/l			
	Canal Water	A_1	B_2	O_1	Canal Water	A_1	B_1	O_1
First Year								
August 06, 1998	0.204	0.352	0.417	0.686	4.66	5.92	5.92	10.70
August 13, 1998	0.250	0.409	0.429	0.699	4.90	5.29	6.57	11.44
August 20, 1998	0.246	0.425	0.411	0.686	5.29	6.90	7.56	10.34
August 27, 1998	0.222	0.417	0.391	0.676	4.05	4.66	6.57	9.27
Second Year								
August 02, 1999	0.218	0.326	0.498	0.677	4.75	6.75	7.05	13.08
August 13, 1999	0.221	0.368	0.372	0.694	4.12	5.36	7.16	14.56
August 24, 1999	0.232	0.406	0.549	0.656	2.55	5.26	6.50	9.88
September 10, 1999	0.248	0.365	0.380	0.631	4.05	4.60	6.20	10..60
September 21, 1999	0.241	0.355	0.346	0.493	1.68	6.26	6.20	11.74

Table 2 Field data used for recharge rate estimation by analytical approach

Date	h_1, m	h_2, m	Q_r, m/day	Q_r, l/s
First Year				
August 06, 1998	33.55	33.15	989	11.45
August 13, 1998	33.38	33.01	911	10.54
August 20, 1998	33.57	33.08	1211	14.02
August 27, 1998	33.49	33.13	889	10.29
Second Year				
August 02, 1999	33.83	32.38	1088	12.59
August 13, 1999	32.96	32.56	972	11.25
August 24, 1999	33.11	32.77	831	9.62
August 10, 1999	35.05	32.70	853	9.87
August 21, 1999	32.82	32.49	799	9.25

Note : h_1 (m) : net head at r_1; h_2 (m) : net head at r_2; r_1 : 16.2 m; r_2 = 88.2 m; and K : 20 m/day

Data on water table elevations at wells A_1, A_2 and A_3 were plotted with data of O_1, O_2 and O_3 (Figure 5(b)). The figure indicated that water table elevations in case of observation wells located in front of recharge tube well were higher as compared to water table elevations at observation wells in the absence of recharge tube well. It also suggests that the radius of influence of the recharge tube well was around 100 m. Therefore, for future projects on artificial recharge, the spacing between the recharge tube wells might be kept more than 100 m.

Chemical Analysis of Water Samples

The chemical analysis indicated that groundwater had higher electrical conductivity than canal water. The electrical conductivity and dissolved Na^+ concentration of water samples from observation wells A_1, A_2 and A_3 (or B_1, B_2 and B_3) were lower compared to samples from O_1, O_2 and O_3). This might have happened due to more dilution of groundwater due to higher recharge at A_1, A_2 and A_3 than O_1, O_2 and O_3. The electrical conductivity and dissolved Na^+ concentration of water samples at A_1, B_1 and O_1 during first and second year are given in Table 1.

Recharge Rates from Recharge Tube Wells

Recharge rates of recharge tube well determined using calculated expected heads in equation (1) are given in Table 2. The value of hydraulic conductivity (K) was assumed[7] as 20 m/day. The similar value was reported for the region. The average recharge rate was approximately 11.50 l/s and 10.50 l/s during first and second year, respectively (Table2). Thus, the average recharge rate due to the recharge tube well was good. The average values were calculated using all related data. Some of the values used in average rate calculations are not shown in the Table 2.

CONCLUSION

Artificial groundwater recharge is possible in the depleting water table areas of Indo-Gangetic plains using recharge tube wells. Estimation of availability of rechargeable water is very important before planning any groundwater recharge project. The geo-electrical resistivity survey may be effectively used to search suitable sites for recharge. Provision of silt basin and suitable filter can ensure long life for recharge tube well. The recharge tube well performed well continuously for two monsoon seasons. The average recharge rate of 10.5 l/s was estimated due to one recharge tube well, which was reasonably good. Radius of influence of recharge tube well was 100 m approximately. Hence, the distance between two recharge tube wells should be more than 100 m for recharge studies in the North-East Haryana. Information and technology generated through this scientific endeavour may help a lot in planning of artificial ground water recharge projects, which may be expected in near future.

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