Inter-aquifer water transfer through combination well for artificial recharging of the deeper aquifer system in Patna urban area

Patna, with a population of nearly 20 lakhs, is unique amongst the cities of India as its entire water supply is dependent on ground water sources. The population of the city has increased from 6.02 lakh in 1971 to 17.2 lakhs in 2011 (ref. 1). A network of 96 high discharge deep tube wells operated by Patna Jal Board, tapping the deeper aquifer constitutes the backbone of water supply in the urban area (Figure 1). Besides, thousands of households, apartments and housing societies and commercial establishments have their private tube wells tapping the deeper aquifer system for their water requirement. Commensurate with the increase in population, there has been corresponding increase in the groundwater draft, resulting in decline in the piezometric level and consequent depletion in aquifer storage. The depletion in aquifer storage during the past 30 years has been assessed as 14.37 million m^3 (ref. 2). To arrest the declining trend of the piezometric level of the deeper aquifer in the urban area, artificial recharging of the deeper aquifer system warrants attention. Based on the detailed hydrogeological evaluation of the urban area, the present study examines the possibility of artificial recharging of the deeper aquifer system from the overlying phreatic aquifers to the underlying deeper aquifer system by inter-aquifer water transfer through combination well which consists of a dug well section tapping the phreatic zone and a tube well section screened in the deeper aquifer which is targeted for recharge.

Hydrogeological set-up of the urban area has been discussed earlier[2,3]. About 700 m thick pile of alluvial sediments deposited over the Precambrian Basement constitutes the multiple-aquifer systems of Patna urban area. Aquifer configuration up to 250 m depth has revealed the existence of an aquitard layer at the top. It is made up of clay mixed with fine sand, silt and calcareous nodules or *Kankar* (calcrete) with thickness varying between 20 and 70 m (Figure 1). Within this aquitard layer there also occurs perched aquifers of limited lateral extent. The dug wells and shallow hand pumps are mostly within the aquitard layer. These constitute the shallow aquifer

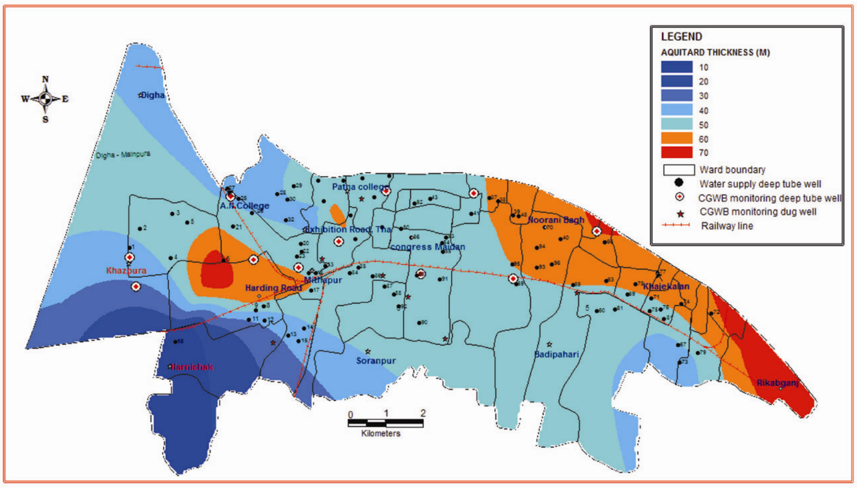

Figure 1. Isopach map of the aquitard overlying the deeper aquifer on the ward map of Patna urban area showing water supply deep tube wells and monitoring stations of CGWB.

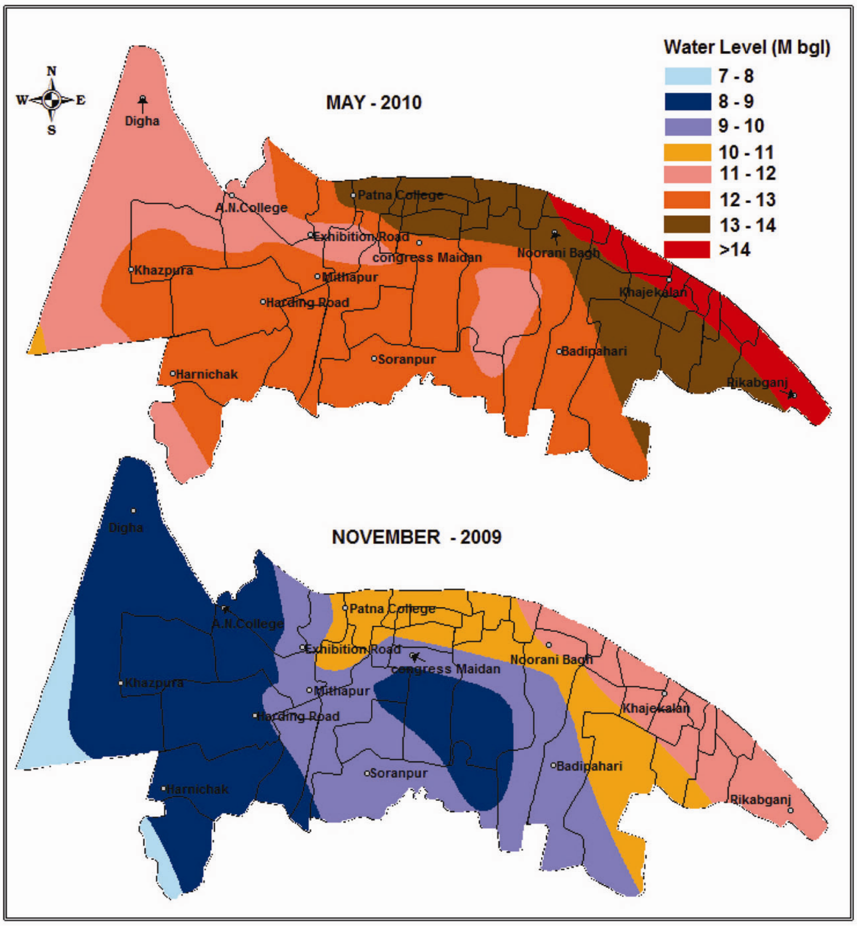

Figure 2. Post-monsoon (November 2009) and pre-monsoon (May 2010) depth to peizometric surface map of Patna urban area, showing deeper peizometric surface in the north and north northwestern part of Patna urban area.

system of Patna urban area. However, at present, these are sparingly being used in Patna urban area. The deeper aquifers extending up to the explored depth of 250 m are made up of medium to coarse grained sand grading towards gravelly sand at the bottom. From 2008 onwards, the Central Ground Water Board (CGWB), Patna has been extensively monitoring the shallow and deeper aquifer systems in Patna urban area and its locations are shown in Figure 1.

The deeper aquifer system meets the major share of water supply (>95%) in Patna urban area. Exploration by CGWB[3] reveals that the deeper aquifer system commencing below the aquitard, continues up to the depth of 220 m bgl with minor intercalations of clay layers of 5–8 m in between. At depths between 220 and 260 m, a prominent clay layer has been encountered in a few locations; the lateral continuity of which could not be ascertained throughout the urban area as the depth of drilling at other locations is less than 220 m. The deeper aquifer consisting of medium to coarse grained sand becomes gravelly towards the bottom. The depth to bedrock, however, has been ascertained to be about 650 m through deep seismic refraction survey in the southern part of Patna[4]. Towards north, around Patna urban area, sharp drop in bedrock depth forming a deep trough of unconsolidated alluvium is indicated.

To delineate the areas suitable for artificial recharge the water level of the shallow and the piezometric level of the deeper aquifers have been studied. Time series analysis of the water level data of the shallow aquifers in the urban area does not show any major change over the last 20 years[2], rather a slightly rising trend has been found. The pre- and post-monsoon depth to piezometric surface map of the deeper aquifer is shown in Figure 2. The figure indicates that the piezometric level remains deeper in the northern, north-eastern and north-central parts of the city during both the pre- and the post-monsoon periods. These are also the areas where there is greater concentration of the municipal water supply wells and require artificial recharge on priority basis.

As the shallow aquifers are barely used in the urban area while the deeper aquifers are extensively being exploited and the water level in the overlying shallow aquifer rests about 5–6 m above the piezometric level of the deeper aquifers[2], inter-aquifer water transfer through combination well[5] (Figure 3) may be a feasible option for artificial recharging of the deeper aquifers in Patna urban area. A combination well consists of a dug well section tapping the phreatic zone and a tube well section screened in the deeper aquifer to be recharged[6] (Figure 3). The design of the dug well portion should be such as to sustain full, continuous flow through the tube well section ensuring that the water is naturally filtered before injection. In order to ensure that the water level in the dug well does not fall below a desired level, the intake part of the tube well diverting water to the deeper aquifer should be kept above the desired level. A filter should also be packed around the intake portion of the tube well.

The recharge capacity of a well is the maximum rate at which it can take in and dispose of water admitted at or near its upper end and is approximately equal to the product of the specific capacity and the available pressure head[7]. However, in a recent experimental study conducted in the urban area, the actual recharging capacity for a well with specific capacity of 9 m^3/h/m (dia 10 inches with a screen length of 6 m) has been found as

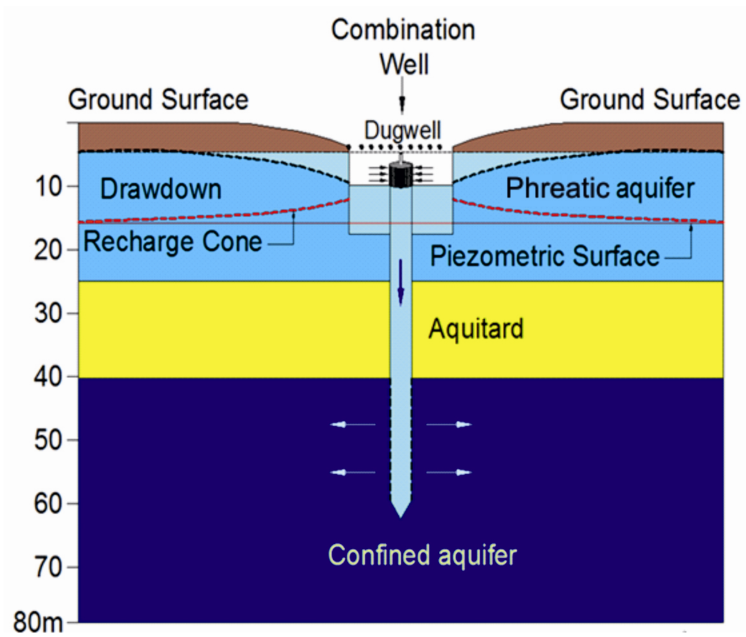

Figure 3. Schematic sketch of the combination well (modified from Karanth[6]).

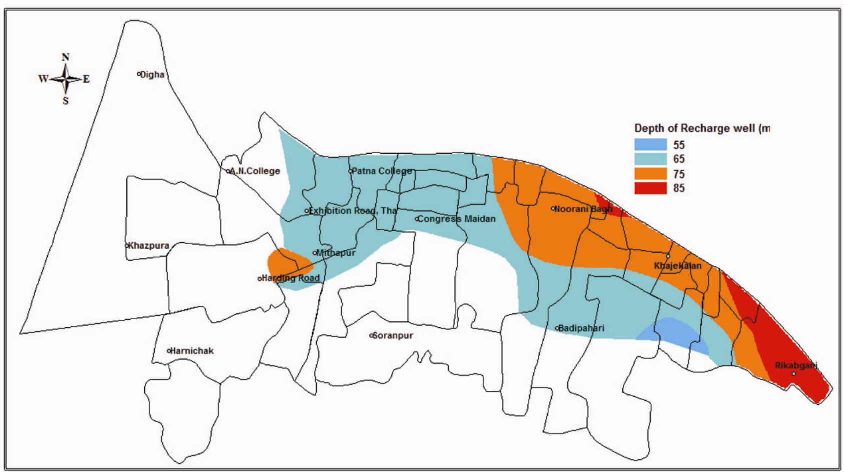

Figure 4. Area suitable for artificial recharge in Patna urban area showing minimum depth of recharge bore well.

11 m^3/hr which varies significantly from that estimated through Meinzer's approximation[8]. Thus, one combination well can recharge ~250 m^3/day. Considering 60 days/year as suitable for recharge, one combination well can recharge 0.015 million m^3/year. As the average annual depletion in aquifer storage in the past 30 years is 0.479 million m^3/year, about 32 combination wells are required to arrest the annual storage depletion in future from the present level. The minimum depth of the combination well in the area identified for recharge is shown in Figure 4. The combination wells are more suitable along the banks of the River Ganges, as they will also derive the benefit of bank storage that builds up during the high river stage of the River Ganges in the monsoon season. The only caution that needs to be exercised in adopting this technique for recharge is to have stringent groundwater quality-monitoring mechanism around the combination well site to ensure that by no means the water quality of the deeper aquifer system gets impaired. Combination wells should not be located in those parts of the urban area where the groundwater quality of the shallow aquifer is not suitable for drinking as well as in areas where open channel carries sewage and waste water as in such areas faecal tests have been found positive in samples from dugwells[9].

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Erratum

Human-wildlife conflict or co-existence: what do we want?

Palatty Allesh Sinu and M. Nagarajan
[*Curr. Sci.*, 2015, **108**, 1036–1038]

The sentence 'Biologists suggest that selective culling of both males and females based on the demography status may be allowed to reduce this problem.'

should be replaced by

'Biologists strongly opposed the selective culling of both males and females by the farmers in retaliation to macaque crop-raiding.'

This error has been corrected in the online version.