VULNERABILITY OF DHAKA METROPOLITAN AREA AQUIFER

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Bangladesh capital city, the metropolitan Dhaka is defendant on groundwater for domestic and industrial water supply. The demand of water for the city is increasing with time due to rapid increase in population and industry, but the rate of recharge to the aquifer is decreasing with increase in pavement area due to rapid urbanization. Due to this conflicting situation, the groundwater table in the city area is decreasing significantly putting the aquifer in vulnerable conditions. This paper presents the conditions of aquifer recharge, water demand and the future water level conditions of the city. The recharge to the aquifer is different at different locations; the maximum at the periphery of the city and close to the river and the recharge is insignificant at the central part of the city. At the central part of the city the groundwater level is continuously decreasing. The prediction of groundwater water level for future shows that the groundwater level will go down to (-) 90 m from the reference level in the year 2020 at central part of the city. The maximum rate of decline of water level is about 3 m per year. Therefore, the aquifer is vulnerable to drying of the wells, contamination of water and possible land subsidence.

INTRODUCTION

Dhaka, the capital city of Bangladesh, is growing very fast. As surface water bodies near the city are becoming increasingly polluted and costly to purify, public water utilities and other urban water users are turning to groundwater as potential source of supply. Therefore, the present water supply system of Dhaka almost entirely depends on groundwater. But exploitation of groundwater has its limit and depends on how much water is replenished during the monsoon of every year. In Bangladesh, recharge occurs primarily through direct infiltration and percolation, mostly from huge amount of rainfall and floodwater during the period from June to September. The aquifer of Dhaka city is recharged by direct rainfall, river water, and floods [MPO, 1987]. But due to rapid urbanization, the recharge area of the city is decreasing significantly with time. Within this situation the city water supply authority needs to install more tube wells to serve the ever increasing population of the city [Shahabuddin, 1996; Hoque and Shahabuddin, 1998]. It is estimated that about 450 deep tube wells are needed to be installed within the city to meet the present water demand. Thus, the current study evaluates the future aquifer conditions considering the current aquifer recharge and water withdrawal for meeting the city water demand.
STUDY AREA

The Buriganga River bound the study area, shown in Figure 1, to the south and west and Lakhya River to the east. The convergence of Turag and Balu rivers limits the western, northern and part of eastern boundaries. The metropolitan area lies approximately between $23^\circ40'$ and $23^\circ53'$ North Latitude and between $90^\circ20'$ and $90^\circ31'$ East Longitude. The city is situated on flat plain land. The lowest land is located in the Balu River and the highest land is located in the Mirpur area. The periphery of the city is low-lying area in comparison to the central part. The core of the city falls within 6 to 8 m contours with reference to mean sea level.

Figure 1. Location of the study area
Dhaka metropolitan city is expanding rapidly through urban and industrial development. The rapidly increasing paved area is affecting the recharge considerably through the change of runoff length, evapotranspiration, etc. In densely built up areas, the natural recharge is significantly reduced. However, urbanization may produce other form of recharge such as leakage from water distribution and sewerage system. The Buriganga, Balu, Turag, Tongi Khal and the Lakiya are the rivers surrounding the greater Dhaka city. The surface water system of Dhaka, comprising several depression storage (roads, lakes and submerged low-lying lands) and channels, is linked to these surrounding rivers. The city rainfall run off is accumulated in the depression storage and is discharged to the surrounding rivers through the channels.

**RECHARG EVALUATION**

Groundwater recharge from rainfall, flood water and from the adjacent river during the monsoon is the source of aquifer replenishment. This recharge to the Dhaka city aquifer is not uniform over the area. It varies with the density of population, increase of pavement area and the distance from the rivers [Hoque, at al., 1999; Hoque, et al 2002]. In the current section the recharge to the different areas of the city including a location just outside the city has been discussed.

Figure 2 shows a variation of groundwater level at old city and close to the bank of the river and the corresponding river water level for the flood years of 1995 and 1998. For both the years, the groundwater levels continued to rise until late October and reached the same level. So, during the period from July to the late October the groundwater level was replenished by about 0.6m in 1995 and by 1.2m in 1998.

![Figure 2. Fluctuation of groundwater table at old Dhaka near the riverbank](image)

The river water levels of 1995 and 1998 as shown in Figure 2, indicate that the prolonged and higher flood water level of 1998 caused the higher recharge. In old Dhaka
city, the paved area remained more or less unchanged between the years 1995 and 1998. The other impacts such as vertical recharge due to rainfall may be considered constant. So, the lateral recharge from the river has made a major contribution to 1998 recharge. Figure 3 shows the variation of groundwater level just outside the metropolitan area, where the influence of urbanization does not exist, for the flood years 1988, 1995 and 1998 and the corresponding river water levels. The figure shows that the groundwater level is replenished every year by almost 8 m. The pattern of rise of groundwater level and the river water level is similar which indicates that the river water level has significant influence on the groundwater level. At the beginning of flood season (mid July) the river water level is at the same level in 1998, 1995 and 1988, but the groundwater level is lower in the year 1998 compared to the other two years. But in 1995 the groundwater level continued to be at same level from early September until late October. However, in case of 1998, the groundwater level continued to rise sharply until the second week of September and then receded continuously unlike other two years. Therefore, it can be concluded that the vertical recharge also plays a vital role to recharge the aquifer system and the long duration of flood has significant contribution to the recharge.

Figure 3. Fluctuation of groundwater table outside Dhaka metropolitan area

Figure 4 shows groundwater levels variation with time at very densely populated commercial area of the city for the flood years 1988, 1995 and 1998. The groundwater level is falling with time at a very high rate. In the year 1988, replenishment was observed and the total replenishment was about 0.5 m and in 1995 fluctuation of water level was observed at the beginning. In the year 1998 the level was decreasing constantly and total decrease was observed at about 2 m. This indicates that in this area there is major mining of groundwater level due to excessive withdrawal and that possibly the recharge is very insignificant compared to the withdrawal.
WATER ABSTRACTION

With the increase of city area, multistoried building and population the abstraction of groundwater both at private and public level has been increasing significantly over the years. The annual abstraction in public sector has increased from 177 million m$^3$ in 1990 to 350 million m$^3$ in 1999 [DWASA, 2000]. The number of private wells has increased tremendously. From the records it is found that that the number of private wells was 130 in 1990 and this number increased to 289 in 1999. Total withdrawal from private wells, during this time period increased more than 300 %. Figure 5 presents the year wise abstraction from the Dhaka Metropolitan aquifer for both private and public sectors. It shows that the rate of increase in private sector is more than the public sector and this rate is increasing with time.

Figure 5. Groundwater abstraction in Dhaka metropolitan area
PREDICTION OF FUTURE WATER LEVEL

Based on the recharge to the aquifer and water withdrawal for city water supply for different purposes the future water level has been predicted with a mathematical model. The results of the prediction are presented in this section to show the groundwater conditions in the year 2020 at different locations of the city. Figure 6 shows the water level at Dhaka old city and relatively close to the river where lateral recharge to the aquifer is significant. The figure shows variation of water level for about 20 years beginning the year 2000. It is observed that there is a constant decrease in water level through out the period of simulation. In the year 2020 the water level would drop at (-) 58 m from the datum level. The yearly rate of decrease in water level is about 1.5 m.

![Figure 6. Predicted groundwater level variation in Dhaka old city](image)

Figure 6. Predicted groundwater level variation in Dhaka old city

Figure 7 shows the condition of predicted groundwater level in the year from 2000 to 2020 at recently developed part of the city where vertical recharge is possible to some extent, but the consumption of water is increasing with the increasing population.

![Figure 7. Predicted groundwater level variation in recently developed part of the city](image)

Figure 7. Predicted groundwater level variation in recently developed part of the city

Comparison between the Figures 6 and 7 shows that the water level at the beginning of simulation at recently developed part of the city is higher than that of old city. But at the recently developed part of the city the water level would drop down about 12 m more. This is possibly due to the effect of increasing withdrawal and decreasing recharge with time. At the beginning of simulation the water level was at (-) 22m and at the end of the
simulation the water level would be at (-) 70 m from the reference level. The rate of decrease per year is about 2.5 m, which is alarming.

Figure 8 shows the condition of water level in the central part of Dhaka city. In this area both the vertical and lateral recharge is insignificant and the withdrawal rate is higher than the other part of the city since the area is densely populated as well as commercial. At the end of simulation the water level in this part of the city would drop down to a level of (-) 90 m from the reference level. The rate of decrease in water level is about 3 m per year, which is higher than the other two locations described earlier. This is possibly due to decrease in recharge rate.

![Groundwater level chart](image)

Figure 8. Predicted groundwater at densely populated commercial area

**CONCLUSIONS**

The most alarming situations of the Dhaka city aquifer are the gradual declining trend of water level. For the present abstraction rate, the water level is declining at the rate of about 2 to 3 m per year depending on the locations. At the central part of the city is at (-) 30m the groundwater level will go down at the level of (-) 90 m in the year 2020. The vulnerable conditions of the aquifer may result in drying of existing wells, land subsidence, and intrusion of contaminated water from adjacent rivers.

**REFERENCES**


