Impact of the 1998 Flood on Groundwater Recharge in Dhaka

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Abstract

Floods have severe adverse impacts on agriculture, communication network, river channel process, and public health. Despite its adverse impact, floods have some positive impact also and one of the major positive impacts of floods is the groundwater recharge. The impact of 1998 flood on the recharge of Dhaka City aquifer has been evaluated. The Old Dhaka city close to the river Buriganga received a reasonable recharge during 1998 floods. The Sutrapur area received a net recharge of about 1.5m in 1998 as observed in the well at Jagannath College compound. The Lalbag area received a net recharge of about 0.9m during the 1998 flood. The central part of the city received insignificant net recharge due to paved area and high withdrawal. This includes Motijheel commercial area, which is fully paved and also distant from the river. The low lying unpaved areas on the periphery of the city where both the vertical and the horizontal components of recharge have played important role, received significant net recharge during the flood period. The maximum net recharge to this area during 1998 is about 6.6m. In summary, it may be concluded that the 1998 flood has made significant contribution to the recharge to the aquifer of Dhaka city except to the central part of the city.

INTRODUCTION

Due to its geographical location, each year about 18% of Bangladesh is flooded. During severe flood the affected area may exceed 36% of the country and almost 68% of the net cultivable area. The catastrophic flood of 1987 and 1988 submerged more than 50% of the country causing huge economic loss. The flood of 1998 was more severe due to its long duration and this flood caused enormous damages to the infrastructure, industry, agriculture, and human health. In spite of many adverse effects of floods, in some areas, floods bring positive impacts. One of such positive impacts is the groundwater recharge (Hoque, et al., 1999; Hoque and Shahabuddin, 1998; Shahabuddin, 1996). In Bangladesh, recharge occurs primarily through direct infiltration and percolation, mostly from the huge amount of rainfall and floodwater during the period from June to September. During the dry season, groundwater becomes a major source of domestic, industrial, and agricultural water supply. But in many areas of the country the groundwater level is declining gradually posing a threat to the availability of water during the dry season. Therefore, recharge to the groundwater is considered an important phenomenon in water resources system. The city of Dhaka is growing very fast. The present water supply system of Dhaka almost entirely depends on groundwater. 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. But exploitation of groundwater has its limit and depends on how much water is replenished during the monsoon. The aquifer of Dhaka city is recharged by direct rainfall, river water, and floods (MPO, 1987). The current study evaluates the extent of recharge due to floods, especially the flood of 1998 which had a long duration compared to other past floods.

STUDY AREA

The study area, shown in Fig. 1, is bounded by the Buriganga river 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 $23^{o}40'$ and $23^{o}53'$ North Latitude and between $90^{o}20'$ and $90^{o}31'$ 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 in comparison to the central part. The core of the city falls within 6 to 8 m contours with reference to mean sea level. Dhaka 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 Lakhya 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 k*hals* (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 *khals*.

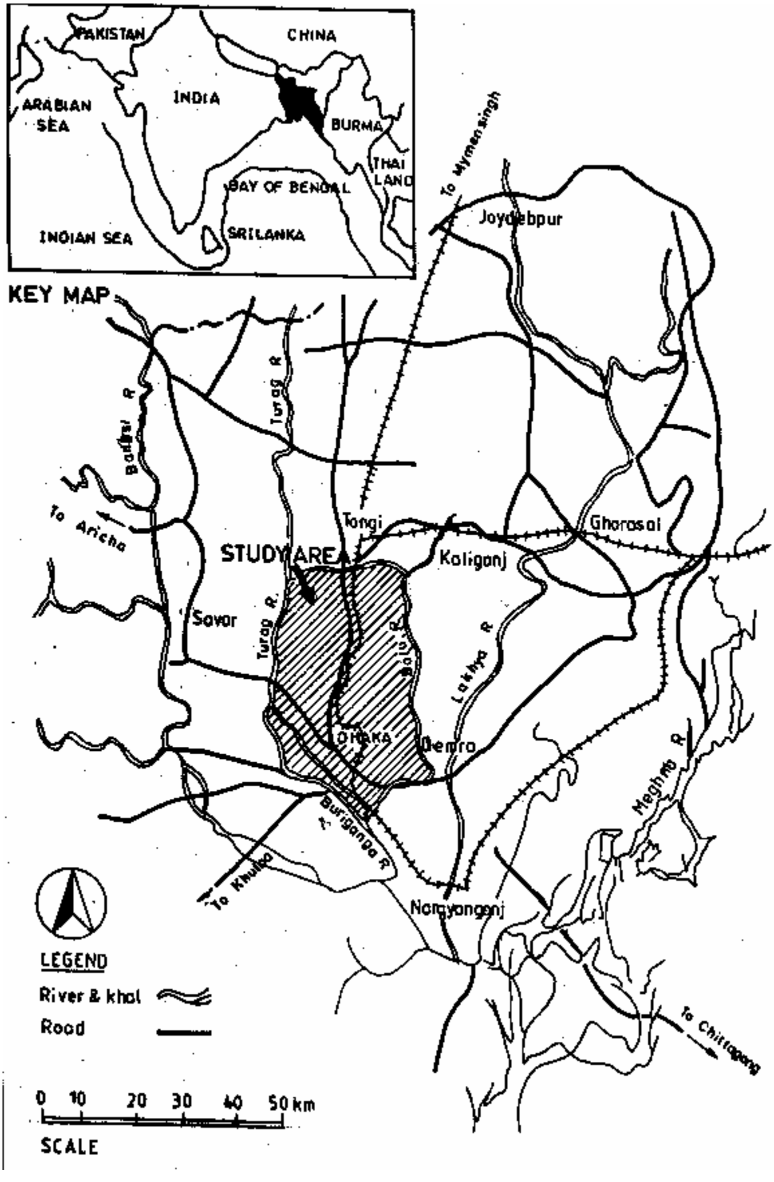

Figure 1: Location of the study area

METHODOLOGY

The study is based on the secondary data. The groundwater level and the river water level data have been collected from the relevant organizations. For groundwater observation data, several observations wells maintained by the Groundwater Circle of Bangladesh Water Development Board (BWDB) have been selected. The river water level data for the same period from 4 stations, one on each river, have also been used for analysis. The groundwater observations wells and the river water level gauges selected for this study are shown in Fig. 2. The groundwater observation wells under the influence of different rivers have been grouped together as listed in Table 1. The analysis has been done mostly graphically. A comparison has been made between the impacts of 1998 floods and that of the other big floods.

Table 1: River water level stations and groundwater observation wells with locations

Water level						
Rivers			Wells			
Name	Measuring Station	No.	Well No.	Place	Ordinate	
					Latitude (N)	Longitude (E)
Tongi Khal	Tongi	299	DA-103	Maniknagar, Cantonment	23°58'05"	90°38'10"
			DA-70	Cheragali Market, Tongi	23°42'00"	90°24'45"
Turag	Mirpur	302	DA-108	Mohammadpur	23°45'00"	90°22'55"
Balu	Demra	7.5	DA-A12	Banani \WDB, Gulshan	23°51'58"	90°19'26"
			DA-112	Malibagh, Motijheel	23°43'35"	90°23'35"
			DA-123	South Basabo, Motijheel	23°44'05"	90°25'30"
			DA-124	South Khilgaon, Motijheel	23°45'00"	90°25'15"
Buriganga	Millbarak	42	DA-13	Jagannath College, Sutrapur	23°42'00"	90°24'45"
			DA-A13	BUET, Lalbagh	23°45'00"	90°17'04"
			DA-111	Charakghata, Mohammadpur	23°45'20"	90°21'25"

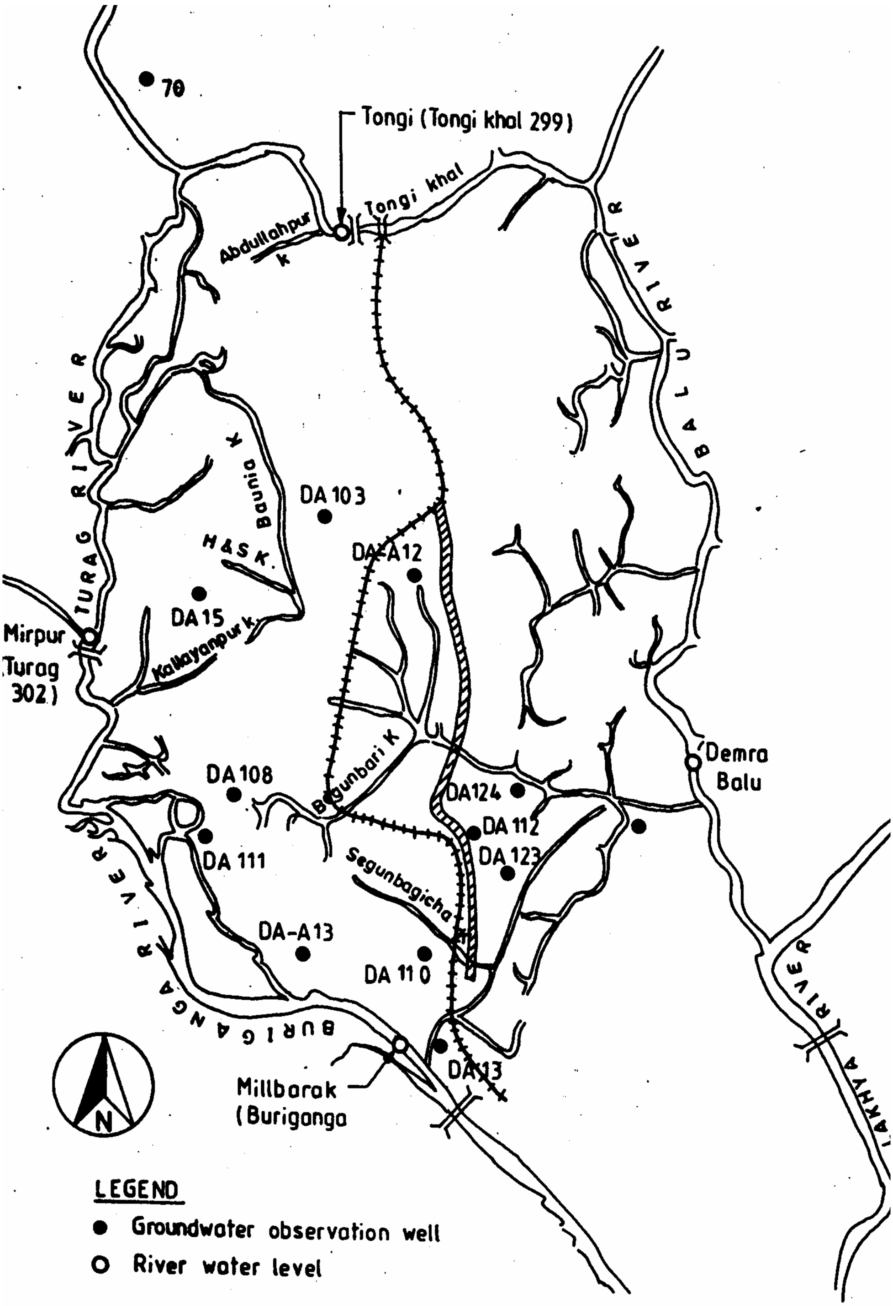

Figure 2: Groundwater observation wells and the river water level gauges

RESULTS AND DISCUSSIONS

Fig. 3 shows a variation of groundwater level at DA-13, an observation well located at Jaganath College compound under Sutrapur thana and the river water level in the river Buriganga at Milbarak (Gauge Station 42) for the flood years of 1995 and 1998. In July 1998, before the beginning of the flood, the water level at the well was much lower (about 0.6 m) than that of 1995. For both the years, the groundwater levels continued to rise until late October and reached the same level (about 1.2 m) from the base flow. It is observed that at the beginning of flood seasons, the groundwater level of 1995 was about 0.6 m higher than that of the 1998, but finally they reached the same level in the middle of October. So, during the period from July to late October the groundwater level was replenished by about 0.6m in 1995 and by 1.2m in 1998. The river water levels of 1995 and 1998 as shown in Fig. 3, indicate that the prolonged and higher flood water level of 1998 caused the higher recharge in 1998 than 1995. The lag time between the peak flood and the peak groundwater level of 1995 is about 10 weeks, but the lag time for 1998 is about 6 weeks. The recession part shows that the falling rate of flood level for 1995 is slightly higher than that of 1998. 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.

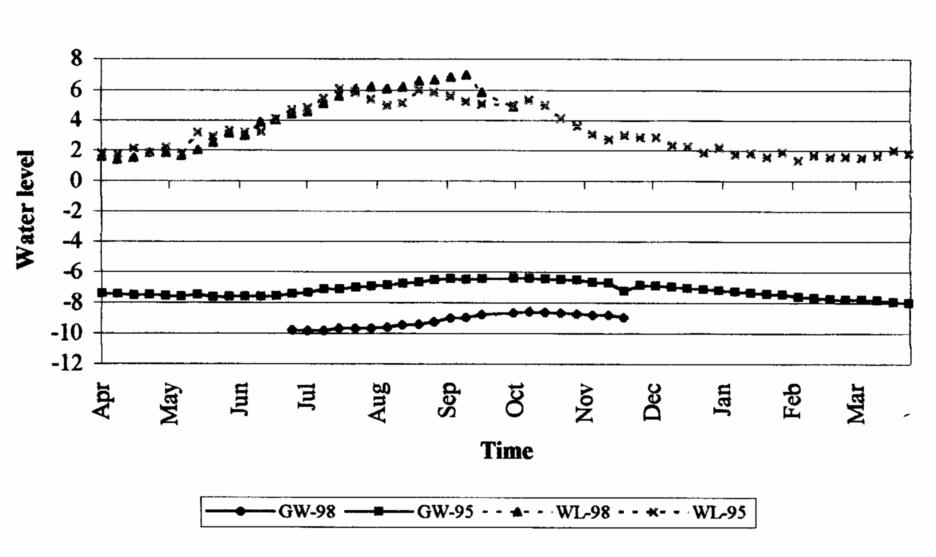

Figure 3: Responses of groundwater level at Well DA-13 located at Jagannath College to the water level at Millbarak of Buriganga River

Figure 4 shows the variation in groundwater level at the well DA-A 13, located at BUBT campus under Lalbag thana for the year 1987 and 1998 and the corresponding water level in the river Buriganga at Gauge Station 42, located at Millbarak. The rise in water level started from the middle of July in both the year from the same level and at the beginning the rise in 1987 is faster than that of 1998, although the water table reached the same level during middle of October. The total recharge during the flood seasons of 1987 and 1998 is almost same (about 1 m). But the river water level in 1998 is significantly higher than that of 1987. The recession curve at the beginning is steeper in 1998 than in 1987. The lag time between the highest peak in groundwater level in observation well DA-A13 and the river water level at Millbarak is about 31 days in 1998 and about 45 days in 1987. In 1987 this longer lag time is possibly due to a rise in river water level during middle of September and a very slow recession of river water level in comparison to 1998. The flood of 1998 has contributed to the recharge of groundwater at BUET campus area to some extent but the total replenishment is not enough to raise the water to the level of the previous year. This is mostly a paved area, and there is no surrounding water body. Therefore, whatever replenishment has taken place is possibly due to the lateral recharge from the river.

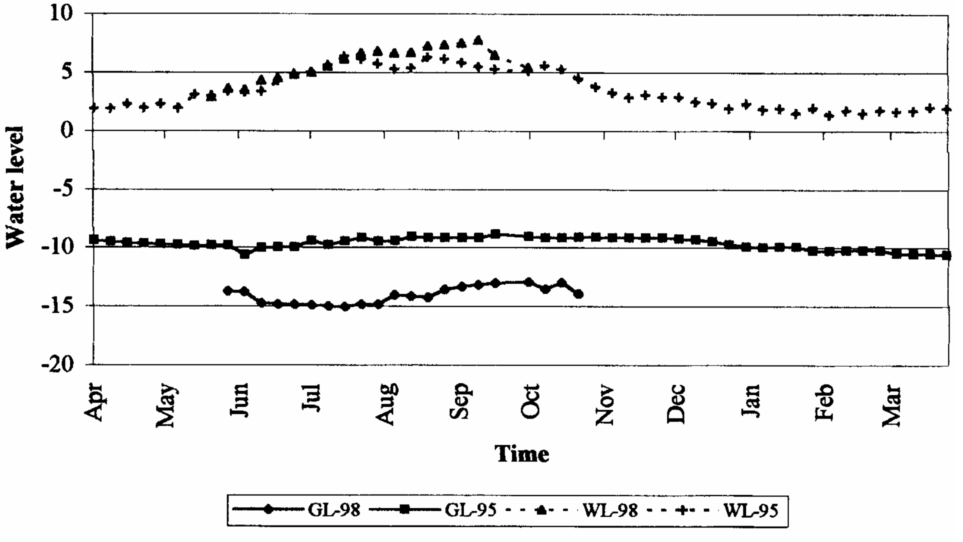

Figure 4: Responses of groundwater level at Well DA-A13 located at BUET Campus to the water level at Millbarak of Buriganga River

Figure 5 shows the variation in groundwater levels at observation well DA-103, located at Maniknagar, Cantonment for the flood years 1995 and 1998 and the corresponding flood water levels at Gauge Station 302 in the river Turag at Mirpur. For the year 1995 the groundwater level continued to rise until the middle of September but in 1998 the groundwater level continued to rise until the end of September. At the beginning of the flood season, during the third week of July, the groundwater level in 1998 was almost 1 m lower than that of 1995. At the end of replenishment, the total rise in groundwater level is 2.0 m in 1998 and about 0.5 m in 1995. So, the total replenishment in 1998 is 1.5 m (300%) higher than that of 1995. When compared the flood levels in the river Turag at Station 302, the flood level was found to be increasing until the middle of September in 1998, but in 1995 there were three peaks each lower than those during 1998. Therefore, the constant rise (duration) and higher peak have caused the higher recharge in the year 1998. The lag between the peak in river water level and the groundwater level is almost 2 weeks in 1998. This area is characterized by a rapid increase in population as well as paved area due to heavy construction. The declination rate is very high as the vertical recharge area is decreasing and the withdrawal rate is increasing. Therefore, it can be concluded that the 1998 flood has made a significant contribution to the groundwater recharge in this area due to its high magnitude especially due to its long duration.

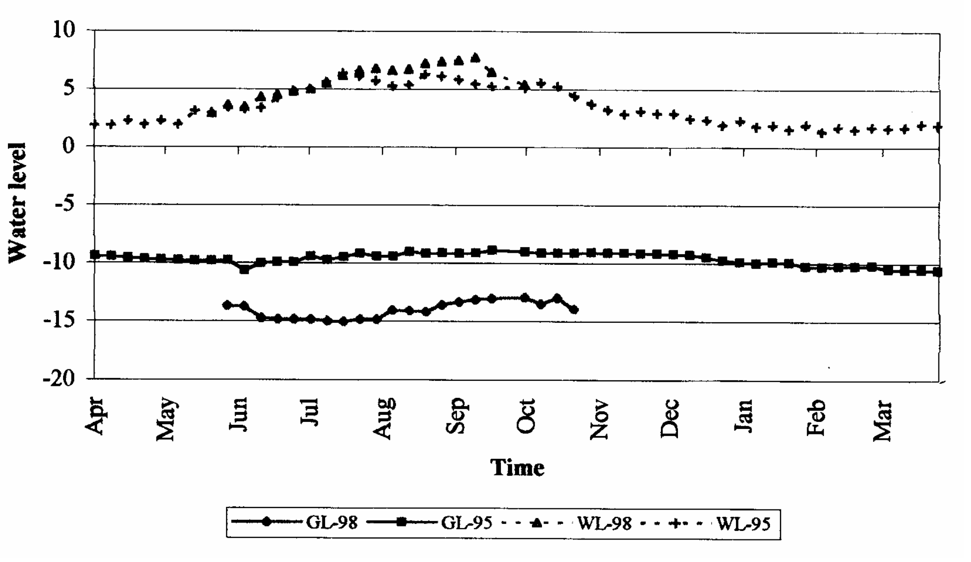

Figure 5: Responses of groundwater level at Well DA-103 located at Maniknagar, Cantonment to the water level of Turag River at Mirpur

Figure 6 shows the rise of groundwater table in well DA-70, located at Charagali Market, Tongi, Gazipur District, for the flood years 1988, 1995 and 1998 and the corresponding water levels of Tongi *Khal* at Tongi (Gauge Station 299). The figure shows that during April - May the water level is almost at same level in three years, which are very similar to the river water level. 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. For 1988, the water level continued to rise until September and then receded sharply followed by a rise again until the middle of November. This is possibly due to the second peak in the river level. But in 1995 the groundwater level continued to be at same level from early September until late October. This is possibly due to water level rise and fall, and rise again. 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. The recharge rate in 1998 is slightly higher than the other two years, which has similarity with the flood level in the river Tongi *Khal* at Tongi. It is observed that the lag time between peak water level in the river and the peak groundwater level in the well is significantly shorter than the other wells, which are located in the metropolitan areas of the Dhaka city. It is interesting to see that the rate of rise of groundwater level in this area is almost the same as the rise in the river water level. This is possibly due to the fact that this well is located in such a place where the man-made intervention is less than that of the city area and the aquifer is hydraulically well connected with the river. Therefore, the response of the aquifer to the river level is very fast and the peaks at the river level and groundwater level were attained on the same day. The vertical and lateral recharge rates are significantly high due to favorable conditions. Therefore, the flood of 1998 had tremendous impact on the recharge to the aquifer where both the vertical and lateral recharge is possible. 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 7 shows the groundwater level variations for the flood years 1995 and 1998 at observation well DA-l 11, located at Charakghata, Mohammadpur with corresponding river water level at Millbarak (Gauge Station 42) in the river Buriganga. In 1998 the groundwater level started rising from April and continued the trend of rise until peak was achieved. But in 1995, the groundwater level started rising in the middle of May and had two peaks, one in August and the second one in November. At the beginning of flood period (first week of June) the groundwater level in 1995 was higher than that of 1998 by almost 1.5 m. This indicates that the rate of rise in 1995 is higher than the rate of rise in 1998.

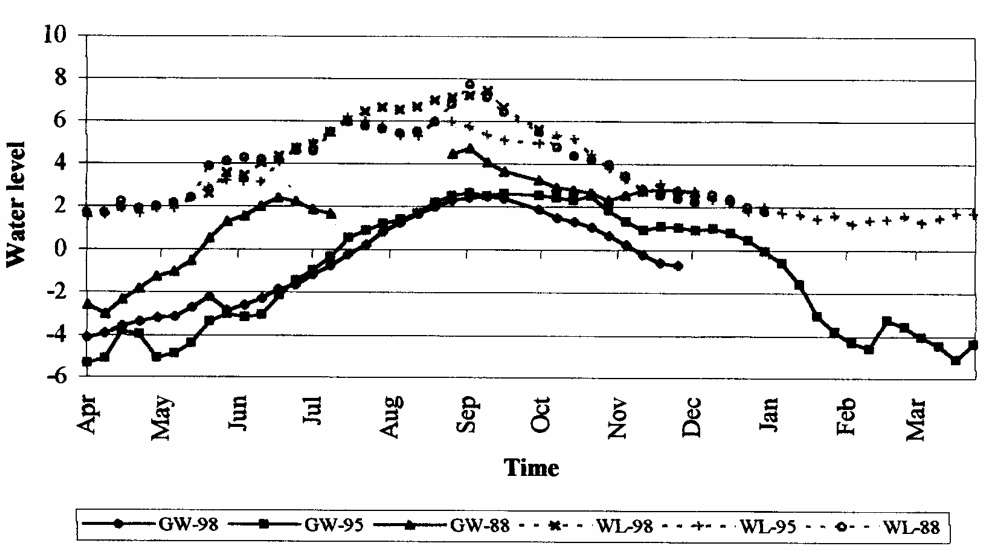

Figure 6: Responses of groundwater level at Well DA-70 located at Cheragali Market to the water level at Tongi *Khal*

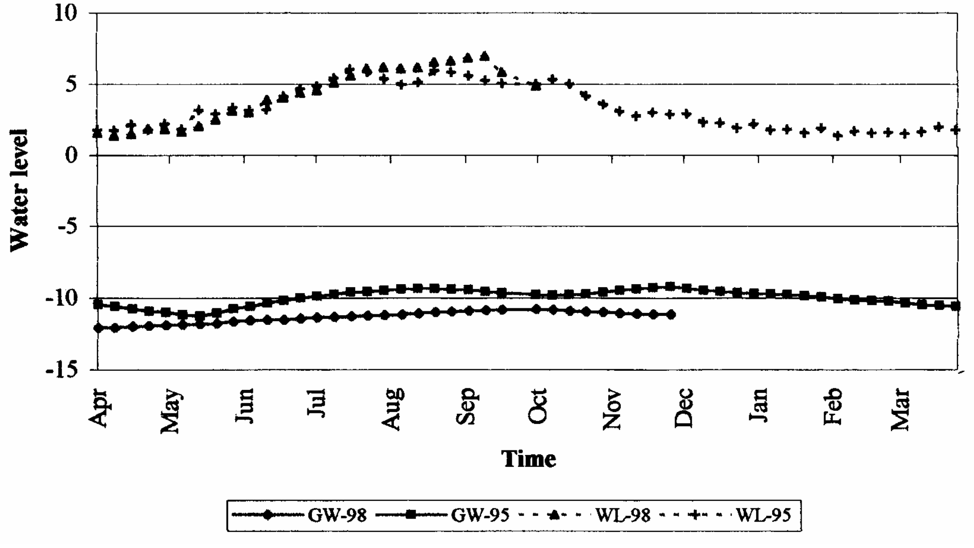

Figure 7: Responses of groundwater level at Well DA-111 located at Charghata, Mohammadpur to water level at Millbarak of Buriganga River

The river water level in 1995 was also seen slightly higher than the river water level of 1998. But the difference between the water level of 1995 and 1998 is much lower than the difference between groundwater rise between 1995 and 1998. So, there is a significant contribution to the recharge from other sources in the year 1995. But in the year 1998 major contributions came from the river as the figure indicates that there is a continuous rise in the groundwater level until October with similar pattern to the rise of river water level in 1998. The influence of river water level to the recharge in 1998 is less than that of 1995 and this may be due to the presence of embankment during the 1998 flood. The lag time between the peak water level in the river Buriganga at Millbarak and the peak level of groundwater is about two weeks. This area is very close to the river Buriganga and Turag, but despite its location, the withdrawal rate is more than the rate of replenishment by flood. This is due to significant increase in paved area with the construction of buildings and other infrastructures. Thus as a result of the combined effect of a decrease in area of vertical recharge and the increase in withdrawal, the flood of 1998 could not show a higher recharge compared to the previous years. However, the figure shows that the recovery is more during the flood of 1998 in comparison to the recovery of 1995.

Figure 8 shows the groundwater levels recorded at observation well DA-A12, located at Banani under Gulshan thana for the flood years 1987 and 1998 with the corresponding river water level of the river Balu at Demra (Gauge Station 7.5). For the year 1987 the groundwater level continued to rise until the middle of October, but in 1998 the water level continued to rise until the end of October. In 1987 the response of the groundwater rise to the river water level is found to be faster than that of 1998. The lag time in 1987 is almost 5 weeks whereas the lag time in 1998 is more than 5 weeks. Total replenishment in 1987 is about 3.5 m whereas in 1998 total replenishment is about 1 m. So, the recharge conditions in 1987 were much better than those of 1998. This may be due to the increase in the rate of withdrawal and decrease in the recharge area due to the increase in pavement area. The pavement area decreases the rate of vertical recharge and the vertical recharge plays a significant role to the aquifer recharge.

Figure 9 shows groundwater levels variation with time at observation well DA-124, located at south Khilgaon, Motijheel for the flood years 1988, 1995 and 1998 with corresponding river water levels at Demra (Gauge Station 7.5) on the river Balu. It is seen that the river water level at different years is almost the same, but there is a big difference in groundwater level at different years. The groundwater is falling with time at a very high rate. The influence of the river water level on the groundwater level is decreasing gradually and the influence of other factors responsible for replenishment of groundwater level is decreasing as well. In the year 1988, the difference between the highest groundwater level and the lowest groundwater is only about 2 m and in other two years the difference is even smaller. In this well the groundwater table is constantly decreasing and therefore it is not possible to determine the influence of 'the peak river water on the groundwater table. This indicates that in this area there is a major mining of groundwater level due to excessive withdrawal and that possibly the recharge is very insignificant compared to the withdrawal.

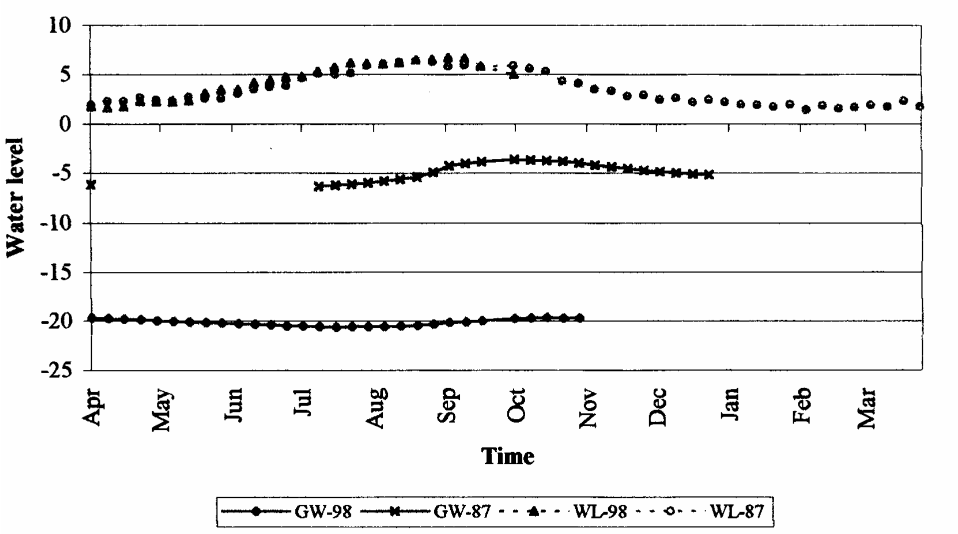

Figure 8: Responses of groundwater level at Well DA-A12 located at Banani to the water level of Balu River at Demra

Figure 10 shows the groundwater variation with time at observation well DA-l12, located at Malibag, Motijheel for the years 1988, 1995 and 1998 with corresponding river water levels on the river Balu at Demra, Gauge Station 7.5. The figure shows that there is a significant decrease in water level with time and the flood level has insignificant influence on the replenishment of the groundwater table. Possibly during flood season the influence of river water level is compensated by the overdraft and as a result there is no significant resultant increase in the groundwater table. Similar to the well DA-124, the groundwater table in well DA-112 is constantly decreasing and it was not possible to identify the influence of the river water level in this well in terms of depth or lag time. Therefore, it can be concluded that in the Motijheel area, recharge is insignificant even during the very big floods, like the one of 1998.

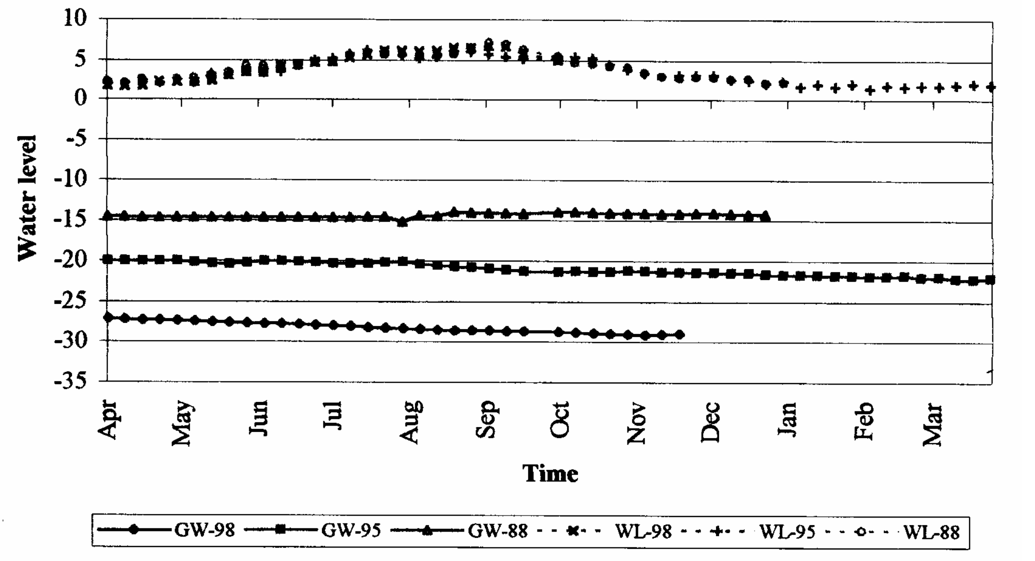

Figure 9: Responses of groundwater level at Well DA-124 located at South Khilgaon to the water level of Balu River at Demra

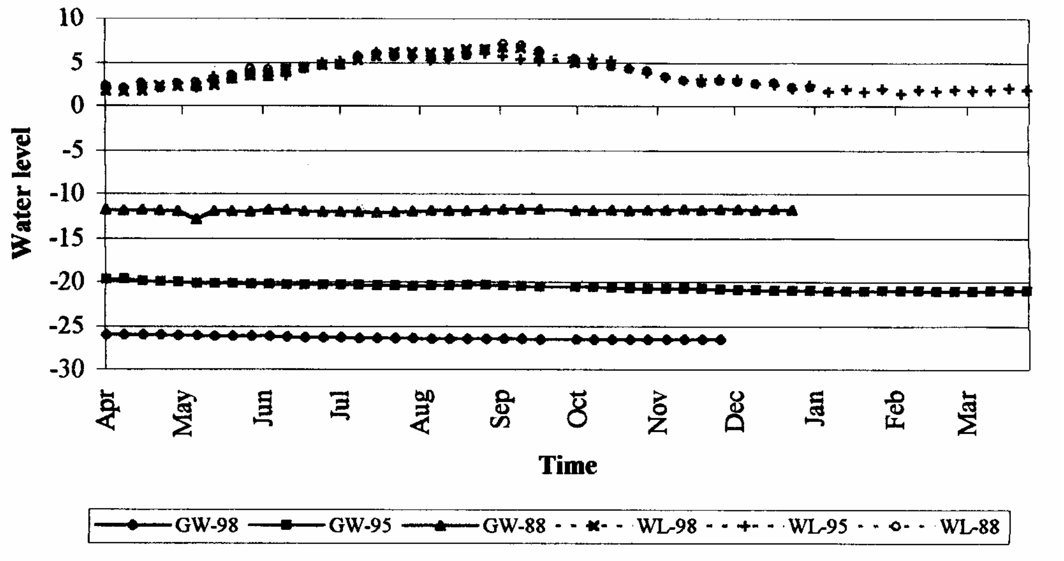

Figure 10: Responses of groundwater level at Well DA-112 located at Malibagh to the water level of Balu River at Demra

CONCLUSIONS

In general the flood of 1998 has contributed significantly to the recharge of the Dhaka city aquifer. The impact of 1998 flood to the recharge is observed more at the periphery of the City where the area is relatively low, unpaved and close to the river. In densely populated and fully paved centrally located areas, the recharge from 1998 flood is insignificant. The net recharge is significantly decreasing with increasing urbanization due to an increase in paved area. The impact of flood on recharge is a function of the distance from the rivers, unpaved/paved area and rate of withdrawal. Even the major flood like one of 1998 could not protect the groundwater level from mining or declination with time at the central part of the city.

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