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Evaluation of Ground Water Resources in Mymensingh Sadar Upazilla, Bangladesh

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Authors' contributions

This work was carried out in collaboration with all authors. Author ZAB initiated the research and conducted it. Authors MAH and AS designed the study and supervised the research. Authors ZAB and GMAR managed the literature searches and reviewed the manuscript drafts and participated in the data collection. Authors AS and MA analyzed statistical analyses. All authors read and approved the final manuscript.

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ABSTRACT

A study was conducted to make an overall assessment of aquifer, groundwater resources, and its optimum utilization as well as the potentiality of groundwater abstraction in Mymensingh sadar upazilla. The subsurface lithology was investigated from the collected data of twelve borelogs in the study area. The subsurface formation of the study area was stratified with clay, sandy clay and fine sand at the upper part while medium sand, coarse sand at the lower part of subsurface lithology. The thickness of clay and silty or sandy clay layers ranging from 6 m to 58 m having an average thickness of 33.8 m existed below the ground surface. The thickness of composite aquifer varied

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from 13 m to 75 m having average thickness of 27.6 m. Main aquifer or exploitable aquifer thickness varied from 23 m to 61 m having average thickness of 43.8 m. Transmissibility of the aquifer found by applying Jacob's time-drawdown method was 1037 m^2/day to 4430 m^2/ day and the average is 3154 m^2/day. The static water level started rising from the month of April and continued to rise up to the month of September or October The water level started to deplete from September to October and continued up to April. Average specific draw-down was 114.8 m/cumec and average specific capacity was $4.7x10^{-4}$ cumec/m obtained by multi-step pumping test method. The recharge and depletion characteristics were found to be almost in equilibrium condition. The long-term trend of ground water level was found to be in declining position in the recent years.

Keywords: Pumping test; aquifer; lithology; transmissibility; recharge and depletion.

1. INTRODUCTION

Water being one of the basic necessities for sustenance of life, the human's race through the ages has striven to locate and develop it. Over 90% of liquid fresh water available at any given moment on the earth lies beneath the land surface. Groundwater, unlike surface water, is available in some quantity almost everywhere that man can settle in, is more dependable in periods of drought, and has many other advantages. Even in areas where normally there are abundant surface water supplies through major, medium and minor irrigation projects, groundwater is playing an increasingly vital role in supplementing surface water. About 71 percent of the Earth's surface is water-covered, and the oceans hold about 96.5 percent of all Earth's water [1]. The remaining water inventory (3%) is 'freshwater'. Permanent ice (e.g., continental and mountain glaciers) is the largest freshwater storage on Earth, accounting for about 2% of the total global supply - or nearly 69% of the total freshwater supply. Freshwater is also found beneath the Earth's surface as groundwater (approximately 30% of the total freshwater supply) and in surface water storages such as lakes, streams, swamps and marshes [2]. Available fresh water is 0.05% only. At present, one quarter of world's irrigated land is supplied by groundwater and 75% of these lands are located in Asia [3]. Thus attention to the development of groundwater is necessary [4]. The national water policy of Bangladesh government also encouraged groundwater development for irrigation both in the public and the private sectors [5]. About 75% water for irrigation in the region comes from GW [6]. So, groundwater is a vast resource for irrigation. Agriculture is the largest user of water accounting for 80% of all consumption. In Bangladesh, groundwater is extracted by tubewells like deep tubewells, shallow tubewells and hand tubewells. Some dugwells are also used to get groundwater. But it is a matter of regret that information's related with this valuable resource are not collected properly prior to sinking of tubewells. Most of the tubewells had been installed without knowing details of the hydro-geological characteristics of the aquifers affecting tubewells performance and the development potentiality of the aquifer. As a result, a large number of deep tube wells are facing problem now. Shallow tubewells are failing in many areas due to declination of groundwater below suction limit. In fact, groundwater level declination is a vital problem now days. Unplanned abstraction of groundwater may cause geological and ecological problem. Hydraulic characteristics and properties of an aquifer, long-term fluctuation trend of static water level, recharge and depletion characteristics of aquifer and safe yield of the groundwater basin are the major factors that determine the yield potentiality of the aquifer. Some works already have been done in this region. Now it is needed to conduct location specific comprehensive study for realistic assessment of ground reserves and their use at present condition. For this purpose an extensive study and critical analysis of data must be needed for assisting in planning groundwater resource in this area. In context of the aforesaid situations, Mymensingh sadar upazilla has been selected to evaluate the feasibility of groundwater development. Various types of data and measurements are needed for proper investigation of the area. Hydro geological characteristics and properties of an aquifer, fluctuation of static groundwater level, recharge and depletion characteristics of the aquifer is to be known to determine the yield potentiality of the aquifer. These data are collected from different organizations and agencies in Bangladesh. The main objectives of this study are to determine the subsurface lithology and hydraulic properties of the aquifer and to evaluate long-term trend of static groundwater level of the study area.

2. MATERIALS AND METHODS

2.1 Study Area

The geographical coordination of the study area is from 24.38 to 24.52 north latitude and 90.12 to 90.31 east longitude. The study area is situated in the agro-ecological zones of AEZ No. 8 and AEZ No.9. The soil condition of this area is silt loam to silty clay. Sandy soil is also observed in the char area. Soil pH of the area ranges from 5.1 to 6.8.

2.2 Hydrogeologic Features

2.2.1 Vertical cross-section of subsurface lithology

Lithological stratification of 12 deep tubewells bore-logs have been used to determine the subsurface geology of the area and to have an idea about the occurrences of various stratigraphic layers of subsurface formations and availability of groundwater resource in this study area.

2.2.2 Fence diagram

To describe the overall view of lithological constituents, a three dimensional isometric View of the vertical and lateral stratification of the subsurface formation have been constructed using 12 borelogs of lithology which are situated in the representative locations in the whole study area.

2.2.3 Pumping test and data analysis

At the time of installation of deep tubewells by BADC pumping tests were conducted and water level data was collected by using stop watch and avometer. Each test was continued for six hours While during the first 10 min of the test, data were taken at 2 min interval, while for 10 to 30 min, 30 to 120 min and 120 to 360 min the time intervals were 5, 10 and 30 min, respectively. Pumping test of four deep tubewells was used for the determination of transmissibility (T) and storage coefficient (S) in the representative locations in the study area.

2.3 Determination of Aquifer Characteristics

The aquifer characteristics largely depend on two inherent hydraulic properties. These are transmissibility (T) and storage coefficient (S). For determining these properties, several methods are used, such as Jacob-Cooper (Time-drawdown), Theis, Hantush, Chow and Jacob method. On the basis of available data the following method was selected for determining the aquifer properties.

2.3.1 Jacob's time-drawdown method

In the Cooper and Jacob method, draw downs were plotted along the vertical axis and times were plotted along the horizontal. This method is applicable for the straight-line portion of the time-drawdown curve. The slope of the straight-line portion is proportional to the pumping rate and transmissibility. Jacob derived the following equation for determination of the transmissibility and storage coefficient from the time-drawdown graph.

$$T = \frac{2.3Q}{4\pi \Delta S} \quad (1)$$

$$S = \frac{2.25To}{r^2} \quad (2)$$

Where,

Q = pumping rate, m3 /day
T = transmissibility, m^2 /day
ΔS= drawdown across one log cycle, m
T_0 = time at which the straight line intersects the zero drawdown, min
S = Storage coefficient
r = distance of the observation well from the pumping well, m

2.4 Step-drawdown Pumping Test Data

Step-drawdown pumping test data of four deep tubewells of the study area was collected from BADC office, Khagdahar Mymensingh. These deep tubewells were tested for four steps. The duration of each step is l00 min. After completing one step, next step is continued by increasing discharge. The specific drawdown is calculated from each step by dividing the drawdown at the end of each step by the well discharge of each step. The specific capacity is also calculated taking the inverse of specific drawdown value. The average value of the four steps was also calculated. The value of specific drawdown and specific capacity was interpreted by selecting the appropriate tubewell technology.

2.5 Static Groundwater Level Data

Monthly static water level data of 9 tubewells of the study area was monitored by BADC office.

The data from 2000-2006 was collected from BADC office.

2.5.1 The long term fluctuation trend of static water level

By using the static water level data of 6 years the trend of static water level fluctuation was explained by graphical system. The water level data was plotted against time, to prepare well hydrographs.

2.5.2 Recharge and depletion characteristics

Recharge and depletion characteristics of the study area were explained by the fluctuation of groundwater level data. The declination of static water level is the combined effect of natural and artificial means. The declination of static groundwater level was estimated by calculating the fluctuation of static water level of the aquifer. The monthly recharge and depletion rate of the aquifer was calculated for the last 6 years (2000-2005). All these results of static water level were interpreted to have an idea about the dynamics of groundwater system of the study area.

3. RESULTS AND DISCUSSION

3.1 Lithological Data Analysis

Subsurface lithology of the study area was analyzed based on 12 borelogs of existing deep tubewells of 12 individual unions of Mymensingh sadar upazilla.

3.1.1 Vertical cross sections of subsurface lithology

Vertical cross sections of subsurface lithology were shown in Fig. 1. The vertical distribution of subsurface lithology of 12 Wells has been constructed according to unions. This showed the variations in lithological sequences from place to place. Table 1 show that various zone of thicknesses of different layers and Table 2 show maximum, minimum and average thickness of various zone of aquifer. It was observed that the upper part mainly consists of clay and clay with fine sand. Fig. 1 shows that the thickness of upper clay layer varied from location to location. The zone was found to be extended from 6 to 58 m below the ground surface having an average thickness of 33.8 m. Because of its lithological character, it is characterized by low permeability and low productivity. Most of dug wells are situated in this zone. The second zone was found to be composed of fine sand, medium and fine to medium sand. The thickness of this zone varies from 13 to 75 m with an average thickness of 27.6 m. It is characterized by moderate permeability because of all types of hand tubewells and some shallow tubewells are installed in this zone. It can be considered as composite aquifer. Medium coarse sand and coarse sand constitute the lower most zone. The thickness of this zone varies from 23 to 61 m with an average thickness of 43.8 m. This zone can be regarded as main aquifer. This zone is highly permeable and high productive from the lithological point of view. Most of the deep tubewells and shallow tubewells are installed in this zone. The aquifer formation constituents were also different at different locations. Thus a Wide local variation in aquifer thickness and stratification were encountered in the study area. Habib [7] reported that the upper layer extends from 0.3 to 31.5 m below the ground surface, composite aquifer thickness varied from 3.0 to 30.2 m and the main aquifer thickness varied from 24 to 69.5 m of fulfur upazilla in the same district. The similar study was conducted by some researchers [8] in Mymensingh district.

3.1.2 Strategraphic panel diagram

The three dimensional isometric view of the lithological formation (Fig. 2) showed the vertical as well as lateral extent of the sub surface formation. It is observed that the vertical profile of the subsurface lithology is stratified with clay, fine sand at the upper part While with medium sand and fine to medium sand and coarse sand at the lower part. The diagram shows that the horizontal extent of some layers varied in thickness from place to place but homogeneous throughout the study area.

Table 1. Various zone thicknesses (m) of different layers obtained from 12 bore logs

DTW No.	11	3	78	62	53	60	10	67	13	5	35	9
Upper clay thickness	36	25	21	33	6	23	26	28	58	33	7	26
Composite aquifer thickness	14	30	18	40	28	16	23	35	19	30	75	13
Main aquifer thickness	39	61	48	47	58	47	35	42	31	43	23	51

Table 2. Maximum, minimum and average thickness of various zone of aquifer

Various zone of aquifer	Maximum (m)	Minimum (m)	Average (m)
Upper clay thickness	58	6	33.8
Composite aquifer thickness	75	13	27.6
Main aquifer thickness	61	23	43.8

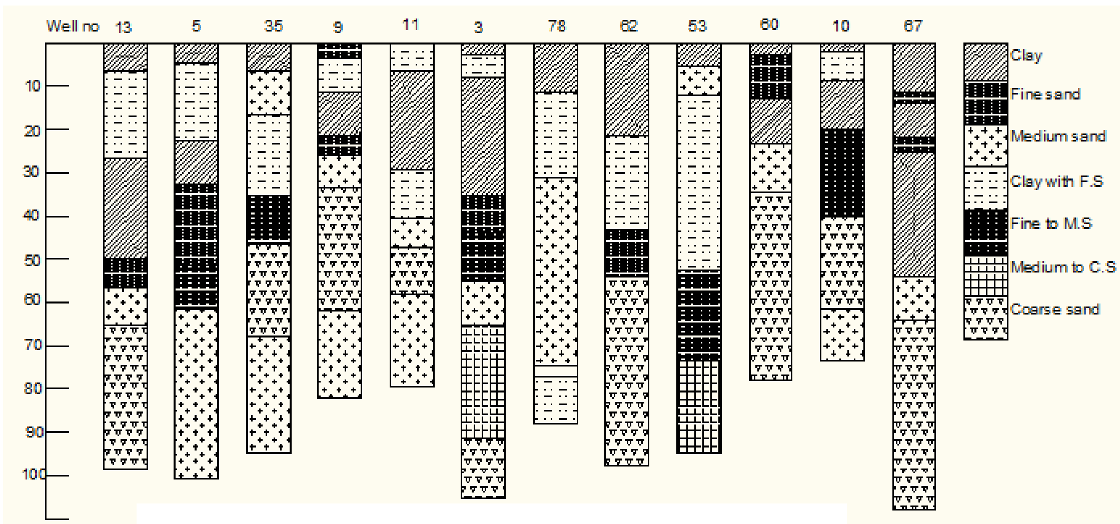

Fig. 1. Vertical cross section of subsurface lithology

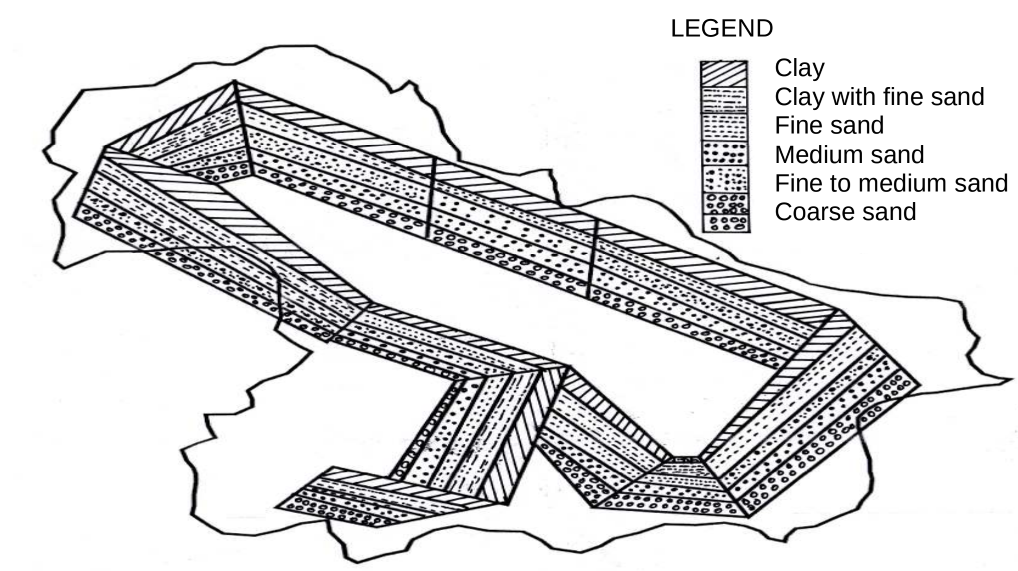

Fig. 2. Isometric fence diagram or panel diagram

3.2 Determination of Aquifer Properties

Pumping test data of 4 tubewells analyzed by Jacob's time- drawdown method shown in Table 3. From table it is seen that coefficient of transmissibility varies from 1037 to 4430 m^2/day using Jacob's Time Drawdown Method and the average of these values is 3154. The large variability in transmissibility indicates the variability of the aquifer. This should be taken into consideration while designing the deep tubewells. Edward [9] reported that if the coefficient of transmissibility of the aquifer is in the order of 1500 m^2/day or more, well yield can be adequate for irrigation purposes. Since, water levels at the observation well were not observed in the study area; coefficient of storage is not calculated. Mojid [8] found that the transmissibility of kanhor village and Trishal bazaar site under Thrishal thana of Mymensingh districe were 2668.1 and 922.0 m^2/day.

3.3 Specific Drawdown and Specific Capacity

Specific drawdown and specific capacity are other important parameter that indicates the productivity of both aquifer and wells. These data were obtained from the step drawdown data of four representative deep tubewells which are shown in Tables 4 and 5. From these results it will be able to determine the efficiency of both aquifer and wells in the study area. The highest and lowest value of specific drawdown was found to be 162.1 m/cumec and 86.2 m/cumec of wells located at Dhapunia and Kustia union respectively. The specific capacities were 7.3x 10^{-4} cumec/m and 2.4x10^{-4} cumec/m at the same places respectively. The average value of specific drawdown and specific capacity were 114.8 m/cumec and 4.7x10^{-4} cumec/m respectively. These data will help in selecting the well discharge and well screen for the investigated area. Ahshan et al. [10] Reported that the overall average specific draw-down and specific capacity are 128.9 m/cumec and 7.8x 10^{-3} cumec/m, respectively.

3.4 Trend of Groundwater Level Fluctuation

To obtain the long term fluctuation of groundwater level, the monthly static Water level data of 6 years (2000-2005) of 9 tubewells at the representative location were plotted graphically. From this hydrograph, it is found that the static water level started rising just after the month of April due to monsoon rainfall and started declining after September/October due to recession of rainfall. The water level dropped rapidly when irrigation wells started groundwater extraction. The long term well hydrographs (Fig. 3) indicate that the water level in the month of April or beginning of May dropped below the suction limit (8 m below the ground surface) in almost all the years studied. Mojid [8] found that at 10 locations of Trishal Thana, the lowest water level dropped below 8 m for 2 to 3 almost in all years.

Table 3. Aquifer properties calculated by Jacob's time-drawdown

Well no.	Location	Transmissibility m^2/day	Average transmissibility m^2/day
119	Kustia	3460	
114	Baira	3691	
94	Dhapunia	1037	3154
35	Austadhar	4430	

Table 4. Specific drawdown for four deep tubewells obtained from step drawdown pumping test

Name of union	DTW no.	Step 1 m/cumec	Step 2 m/cumec	Step 3 m/cumec	Step 4 m/cumec	Average m/cumec
Baira	114	96.1	102.5	105.9	108.9	103.3
Dhapunia	94	116.6	162.1	152.6	151.3	145.6
Austadhar	135	113.1	117.9	119.8	126.3	119.3
Kustia	119	86.2	90.7	91.6	96.1	91.1
Average:						114.8

Table 5. Specific capacity for four deep tubewells obtained from step drawdown pumping test

Name of union	DTW No.	Step 1 cumec/m	Step 2 cumec/m	Step 3 cumec/m	Step 4 cumec/m	Average cumec/m
Baira	114	2.9x10^{-4}	4.1x10^{-4}	5.3x10^{-4}	6.4x10^{-4}	6.2x10^{-4}
Dhapunia	94	2.4x10^{-4}	2.6x10^{-4}	3.7x10^{-4}	4.6x10^{-4}	3.3x10^{-4}
Austadhar	135	2.5x10^{-4}	3.6x10^{-4}	4.7x10^{-4}	5.4x10^{-4}	4.1x10^{-4}
Kustia	119	3.3x10^{-4}	4.7x10^{-4}	6.2x10^{-4}	7.3x10^{-4}	5.3x10^{-4}
Average						4.7x10^{-4} cumec/m

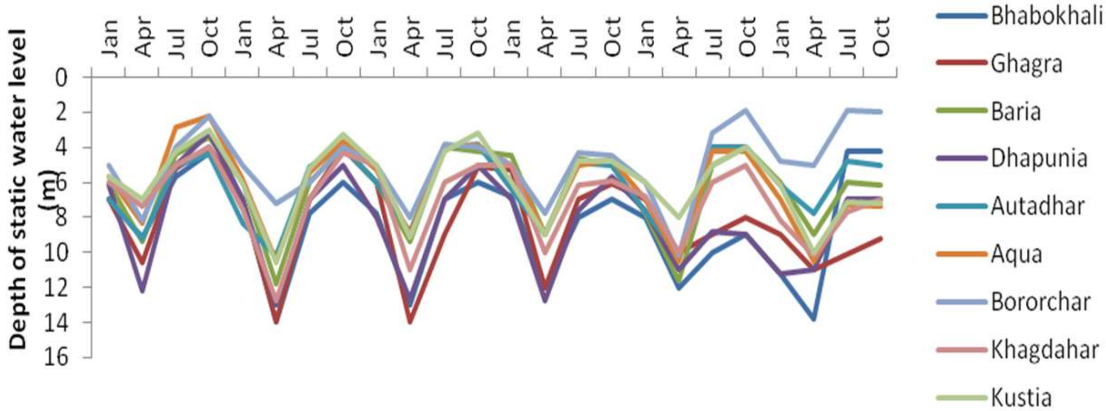

Fig. 3. Long term trend of well hydrograph

The well hydrographs showed that groundwater level depletion occurred in the dry season in the aquifer and almost completely recharged during monsoon by raising the water level back to its almost initial position. In some years, it is observed that the recharge position is not same as the previous year. But it does not indicate a declining trend. Because after this year again the groundwater level remain to it's remain to its original position based on a certain year.

From the hydrograph, it is found that the static water level among the wells in the year 2000 was higher and was less in the year 2005. This indicates that groundwater level was in a decline trend in the recent years.

3.5 Recharge and Depletion Characteristics

The monthly amount of recharge and depletion of the aquifer in the study area was calculated from the static water levels of 9 unions for the last 6 years. Six years (2000-2006) average annual recharge and depletion results were present in Table 6. Highest recharge 2.6 m was found in Bhabakhali during June, where lowest recharge was 0.1 m in Baria during October. On the other hand highest depletion 3.3 m was found in Dhapunia during March, where lowest depletion was found in Khagdohor during September.

It was observed from Fig. 4 that recharge to the aquifer started from May and continued up to October. From the results it is found that recharge is higher during June or July and the rate decreased for the rest of the months of the recharge period although there was considerable rainfall which could provide substantial recharge to the aquifer. This happened because the aquifer was recharged nearly to its full capacity during the early part of monsoon and there remain a small empty storage space to accommodate rechargeable water in the aquifer. Hence, a major portion of rechargeable water was then rejected which could have been utilized for recharge by creating more empty storage in the aquifer.

Table 6. Six year average annual recharge and depletion at 9 unions

Study area	Recharge (m)						Depletion (m)							
	May	Jun	Jul	Aug	Sep	Oct	Sep	Oct	Nov	Dec	Jun	Feb	Mar	Apr
Bororchar	1.1	1.6	1.7	0.8	1.3	1.3	0.2	0.3	0.2	0.3	1.0	1.4	1.7	0.9
Khagdohor	1.0	1.8	1.6	0.9	0.7	0.3	0.0	0.3	0.2	0.4	0.8	1.9	2.4	1.0
Kustia	0.9	1.9	1.5	0.9	1.0	0.4	0.2	0.2	0.4	0.4	0.6	2.3	2.0	1.1
Akua	1.1	1.8	1.6	1.0	0.7	0.2	0.1	0.2	0.4	0.4	0.4	1.6	2.7	1.0
Austadhar	1.0	1.8	1.8	0.9	0.5	0.2	0.1	0.2	0.4	0.5	0.6	2.3	1.7	0.6
Dhapunia	1.6	2.4	1.4	0.9	0.6	0.6	0.1	0.2	0.2	0.3	0.4	2.9	3.3	0.9
Baira	1.0	1.8	1.8	1.1	0.7	0.1	0.1	0.3	0.5	0.2	0.4	2.0	2.3	0.8
Ghagra	1.3	1.7	1.6	1.1	0.5	0.2	0.4	0.2	0.2	0.2	2.4	2.1	1.5	-
Bhabakhali	0.8	2.6	1.6	1.4	1.9	0.4	0.3	0.8	0.2	0.2	0.5	2.4	2.1	0.9

The Fig. 5 shows that water level was started to deplete from September or October and continued up to April. The rate of depletion is in a rather inconsistent manner. The higher rate of depletion occurred during January to March. This happens because; a huge amount of groundwater is abstracted for irrigation during this period.

3.6 Estimation of Annual Groundwater Recharge

The annual groundwater recharge was estimated in the study area by two methods, Groundwater level hydrograph analysis method and Sehgal's empirical method [11]. In groundwater level hydrograph analysis method, the fluctuation of groundwater level was multiplied by the storage coefficient of the aquifer. The average storage coefficient of Mymensingh sadar upazilla is 11.25×10^{-3}. The recharge was calculated for 6 years (2000-2005) of 9 representative locations (Table 7). The average of these values is 70.4 mm. The maximum recharge was obtained at the southern part and minimum recharge was obtained at the southern part and minimum recharge was obtained at the northwestern part of the study area. The recharge was low at the char area. This may happen due to less abstraction of groundwater for irrigation.

The potential recharge was estimated by Sehgal's empirical method. The recharge was varied from 420.4 mm to 731.5 mm for different years (Table 8) and the average recharge of 6 years was 585.8. Islam [12] found that the annual groundwater recharge was 546 cm which was about 27.7% of the total rainfall of 1982.0 cm during the period of 1986 to 1995.

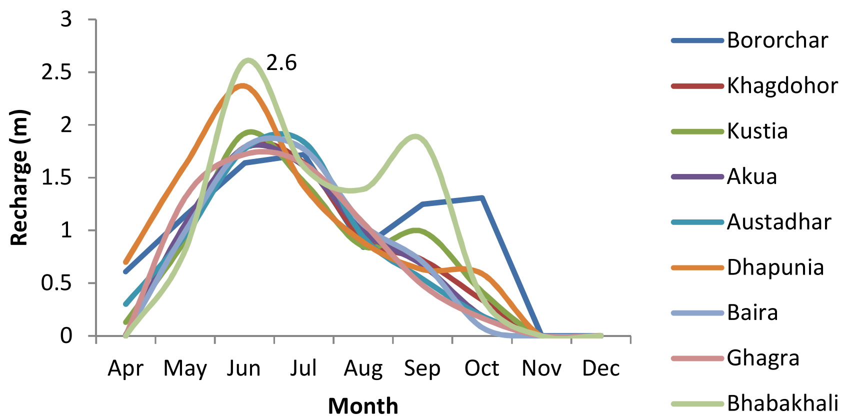

Fig. 4. Average annually recharge at study area during 2000-2006

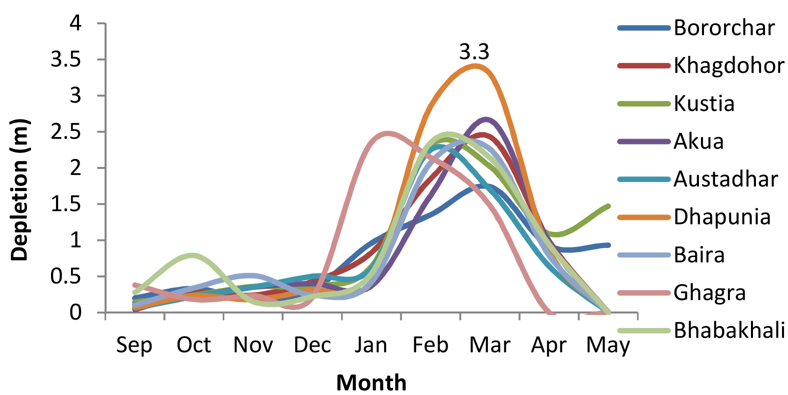

Fig. 5. Average annually depletion at study area during 2000-2006

Table 7. Annual average recharge at 9 unions (average of 6 years 2000-2005)

Union	Well no	Max. depth (m)	Min depth (m)	An. fluctuation (m)	Recharge (mm)
Bororchar	34	8.5	2.8	5.7	64.0
Khagdahar	45	11.0	5.0	6.0	67.6
Kustia	60	9.9	4.0	5.9	66.5
Austadhar	102	9.8	3.9	5.9	66.3
Akua	01	10.0	4.0	5.9	66.7
Dhapunia	51	13.2	5.7	7.5	84.5
Baira	13	10.9	4.8	6.1	68.1
Ghagra	54	12.3	6.0	6.3	70.9
Bhabkhali	65	12.4	5.4	7.0	79.0
Average					70.4

Table 8. Potential recharge (mm) estimated by Sehgal's method

Year	Annual rainfall (mm)	Recharge (mm)
2000	2318	601.3
2001	1819	426.7
2002	2451	647.9
2003	1801	420.4
2004	2563	687.0
2005	2690	731.5
Average	2273.66	585.8

4. CONCLUSION

The results obtained from this study can be considered as an informative and indicative for the entire location of study area without further verification. However, the following conclusions are drawn from this study. The subsurface formation of the study area was stratified with clay, sandy clay and fine sand at the upper part while medium sand, coarse sand at the lower part of subsurface lithology. The average thickness of upper layers, composite layers and main aquifer were 33.8, 27.6 and 43.8 m, respectively. The static water level started rising from the month of April and continued to rise up to month of September or October. The water level started to deplete from September or October and continued up to April. The recharge and depletion characteristics were found to be almost in equilibrium condition. The long-term trend of groundwater level was found to be in declining position in the recent years.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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