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Groundwater Balance Study in the High Barind, Bangladesh

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Abstract

The annual groundwater recharge and discharge of aquifer of the Sapahar and Porsha Upazillas is estimated by Thiessen polygon method varies from 106.41 to 244 Mm^3 and 93.77 to 291 Mm^3 respectively. The calculated groundwater recharge of aquifer of the study area shows that the rate of groundwater recharge of aquifer in Porsha Upazilla is higher than that of Sapahar Upazilla and is characterized by very suitable groundwater storage potential. The overall groundwater balance study in the study area indicates that there exists a balance between annual recharge and withdrawal up to 1993 but after period of 1993 discharge exceeds the recharge continuing till today. But hereforth a cumulative annual deficit is found to exist because of progressive annual discharge in Sapahar Upazilla. 23.99 to 42.08 Mm^3 of groundwater is discharged by discharging mechanisms. The rest of groundwater is discharged by natural seepage.

Introduction

The investigated area is located in the north-western part of Barind region, which includes Porsha and Sapahar Upazillas of Naogaon district (Fig.1). The north-western region between the rivers Ganges and Jamuna of Bangladesh is characterized by a prominent north-south elongated uplifted Pleistocene terrace "the Barind with thick surface clay rich in mottled paleosols with mature incised drainage network" [1]. Ground water recharge is the mean annual volume of water, which enters the saturated zone. The main source of recharge is the precipitation, which may penetrate the soil directly to the ground water or may enter the surface streams, lakes, reservoirs etc, and percolate from these channels to the ground water. The aquifer recharge is often defined, as the mean annual volume of water, which may in the long term, be available for abstraction. In certain circumstances the current rate of aquifer recharge can prove a practical as well as theoretical limit to the aquifer yield. Therefore, recharge rates for aquifers must be estimated before ground water resources are evaluated.

There are several potential sources of recharge to ground water reservoir, which vary in their relative importance across the area. These include

i) Rainfall
ii) Flood water which overflow river and stream banks that infiltrate and percolate;
iii) Lateral seepage and/or vertical percolation from rivers and canals;
iv) Percolation from permanent sources of water (water bodies lying above water table);
v) Vertical percolation of irrigation water from irrigated lands that is not evaporated or transpired by crops;
vi) Lateral flow of ground water from adjacent areas with higher water levels; and
vii) A fraction of used and lost domestic and industrial withdrawals.

Infiltration of rain water for recharge to ground water reservoir depends on several factors, chief of which are, availability of rainfall in excess of evapotranspiration, depth and duration of standing water in the fields, soil type, porosity, vertical conductivity of the top soil, storing space in the underground reservoir, vegetal cover and land use.

In this area, it is mentioned that there are good members of beels, canals, ponds that can not keep them connected with big river after the flooding season. Hence, water from these bodies are evaporated and partly percolated to recharge the under ground reservoir. Top soil of the investigated area especially Barind clay comprises mostly loose clay, silt and fine sands which are favorable for percolation of rain water. Flooding in the study area usually occurs due to heavy sudden rainfall in monsoon. This excessive rainwater remains stagnant for a considerable period.

Moreover every year during rainy season, the water level of the river rises high enough to exert lateral pressure of surface water towards land surface and, in turn, helps to recharge the ground water sources.

Discharge is measured taking evaporation loss, evaporation transpiration loss, natural discharge and leakage into account. In the present process annual discharge have been estimated only considering the fluctuation of groundwater table.

In general the main component of ground water discharge are

a) Evaporation, particularly in low-lying areas where the water table is close to the ground surface.
b) Natural discharge by means of spring flow and effluent seepage into surface water bodies.

c) Ground water leakage and out flow through aquitards into adjacent aquifer.
d) Artificial abstraction.

In the present study evaporation loss is considered as negligible, because evaporation loss occur where the water table rests within a depth where from the ground water can ascend to the land surface by capillary action. Evaporation is high where water table lies within a depth of 0.3m below ground surface. It however, decreases to an almost negligible rate where the table lies one meter deep. In as much as the water table below 10m depth in the study area, there does not seem any possibility of loss by evaporation. For this same reason, the effluent seepage to surface water bodies is not possible. Transpiration loss through plants is also minimum because of very thin vegetation and it is not in the present discharge computation.

However the significant amount of discharge occurs chiefly due to artificial abstraction.

During earlier part of 1980's Barind Multipurpose Development Authority (BMDA) initiated a irrigation programme in the Barind tract. Under this programme, a large number of deep tube wells have been installed since 1984 and still the installation program is continued. Besides, a large number of shallow tube well have been functioning in the study area.

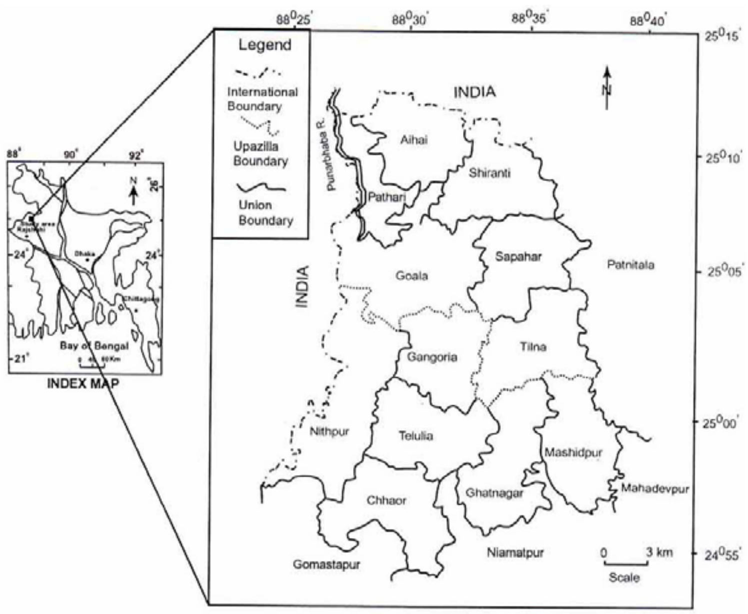

Fig.1 Location map of the study area

Hydrogeological Cross Section

Hydrogeological cross section has been constructed along NW-SE directions of the study area (Fig. 2). According to the lithological constituents and on the basis of hydrogeological types, the subsurface layers are divided into three zones.

Zone 1: The zone extends vertically up to an average depth of 6 to 36 m below ground surface and is composed mainly of clay with occasional fine sand and silt.

Zone 2: The thickness of this thin zone varies from 15 to51 m and is mainly composed of fine, medium and coarse sand with gravel.

Zone 3: in some part of the study area, there is another silty shale sequence below zone 2 ranging in thickness of about 2 to 17m.

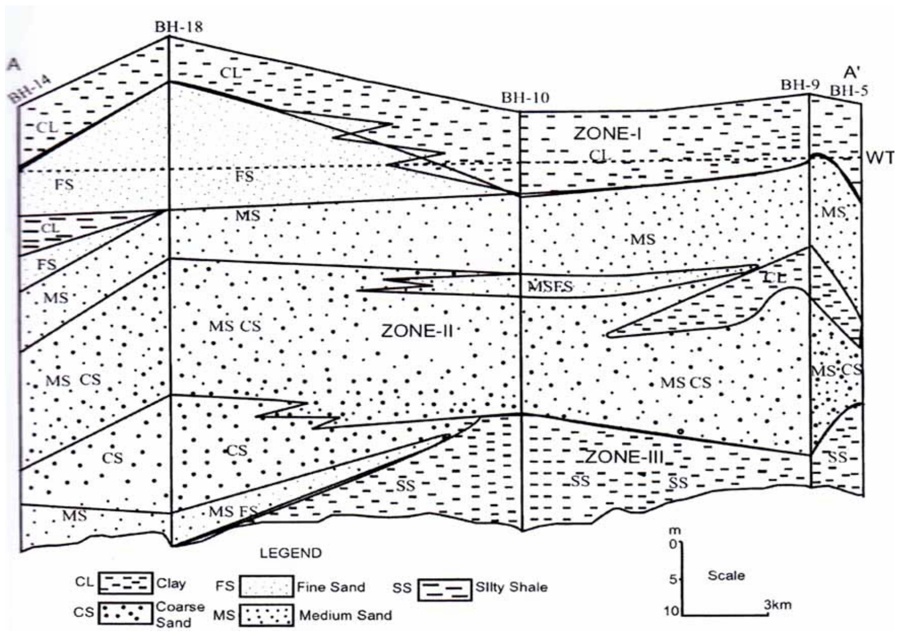

Fig. 2. Hydrogeological cross section map of the study area along AA'.

Method of Study

The ground water system in Bangladesh is considered to be in dynamic equilibrium that is the annual recharge is approximately equal to the discharge. Recharge exceeds discharge during the rainy season and ground water level rises but during the dry season discharge exceeds recharge and ground water level declines.

Recharge to ground water reservoir of an area can be estimated by

i) Water balance method;

ii) Budgeting soil moisture at root zone of the plants;

iii) Water balance based on hydrodynamic data only;

iv) Well hydrograph (safe yield);

v) Vertical infiltration rate i.e. hydraulic conductivity of top soil strata.

The accuracy of the estimation of recharge to ground water reservoir in case of water balance method depends on accurate accounting of all incoming and outgoing water in the area and actual evaporation. Is depends on extensive gauging and definite physiographic unit.

Budgeting plot-wise soil moisture of the root zone of the plants throughout the year is practically impossible for variation of the types of soils, crops, and plants from place to place in the study area. Through water balance method the potential recharge is estimated which is mainly based on hydrodynamic data, dependent on the accuracy of data of rainfall, potential evapotranspiration and the run-off coefficient of different watersheds. Except for rainfall, accurate data of the other parameters are hardly available. So the water balance method is not suitable in evaluating the actual recharge of ground water.

The well hydrograph method has been used to determine the ground water recharge of aquifer in the investigated area. In this method specific yield and cross sectional area of the aquifer is multiplied by the fluctuation in ground water levels. A quantitative assessment of groundwater recharge has been made for the study areas. Variety techniques can be used for estimating groundwater recharge. Generally recharge due to rainfall, surface water bodies and irrigation return are estimated individually using different formulas to have the total amount annual recharge. The well hydrograph method is based on the facts that all water that enters into the ground water which is being reflected in the rise of water table but some parts of it is continuously lost to the atmosphere when the water table lies very close to land surface and some part of it is lost by discharging to the nearby rivers and discharging to the lower areas. A fair indication of the maximum days of recharge to ground water is achieved from method.

But in the present process annual recharge and discharge have been estimated only considering the fluctuation of groundwater table [2]. In the case of recharge the rising of groundwater table from dry to rainy season is considered and volume change between them is calculated. Then this volume is multiplied by the specific yield of that formation filled with groundwater to have the recharge/ volume of water. But the calculated volume may be within the formation of different specific yields. This can be formulated as follows-

$$Q = V \times Sy$$

V = volume between dry and rainy season

Sy = Specific yield within the fluctuation zone

A quantitative assessment of groundwater discharges has been made for the study areas. A variety of techniques can be used for estimating groundwater discharge. For discharge estimation, volume covered by shifting water table from rainy to dry season is considered. Then this volume is multiplied by the specific yield of that formation filled with groundwater to have the discharge/ volume of water.

Specific yield values have been determined in accordance with lithological data. For this calculation the whole study area has been divided into 10 polygons (Fig. 3) following Theissen Polygon method in such a way that each polygon is under influence of a single observation well [3]. Specific yield has been calculated for different polygons from the borelogs within the same polygon [4, 5].

Different parts of the studied area form different polygons as shown in fig.3. sapahar Upazilla comprises P1, P2, P3, P4, P5a, P6b, P6c, P8a and P9a. Porsha Upazilla comprises P6a, P7b, P7c, P5d, P5c, P8b, P9b and P10.

Groundwater balance for the study area is workout using the following assuming the natural groundwater inflow to be equal to the groundwater outflow.

$$\Delta s = I - O$$

Δs=Change in storage

I=Annual input to groundwater system

O= Annual output from ground system

Adopting the above methodology, the water balance is worked out with the observation data for the period 1991-2000.

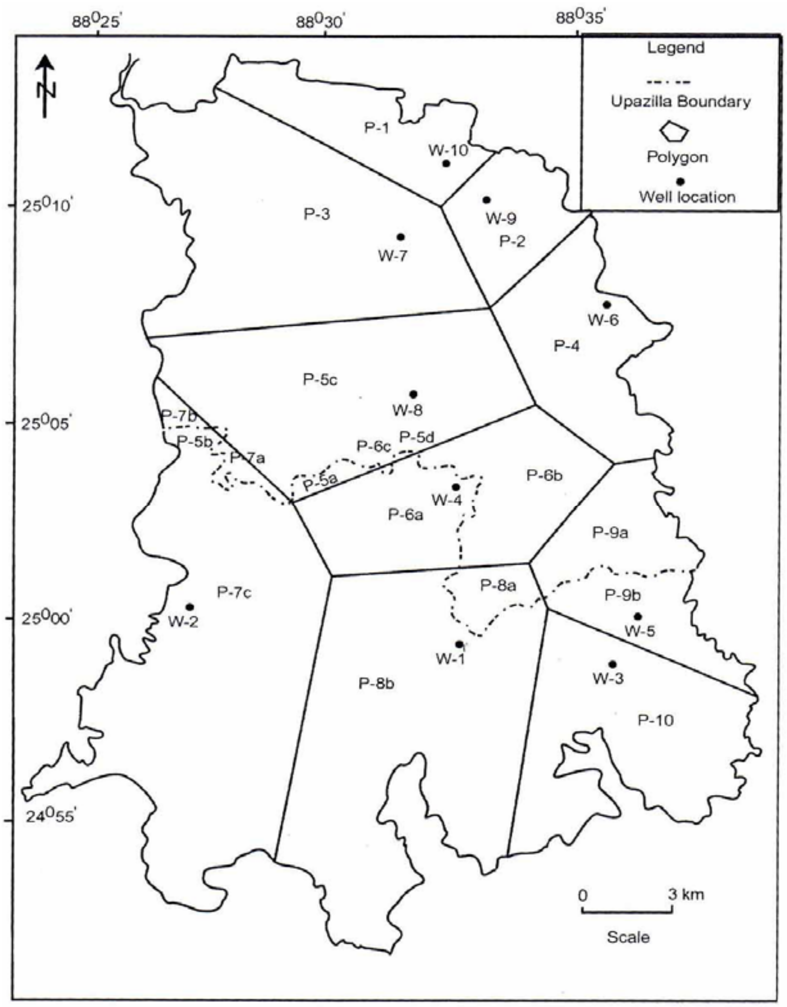

Fig.3. Polygon of the study area

Results and Discussion

For the estimation of total volume of water recharged during the 1990-1991, the first amount of water recharged consider in the water level fluctuation between dry and after rainy season of 1990. A contour map based on the calculated specific yield values of the study area is shown in fig.4. The estimated specific yield value varies from 10 to 28%. The estimated annual recharges of the year 1991 to 2000 have been tabulated in the table 1. The calculated ground water recharges of aquifer of the study area for the year 1991 to 2000 shown in the following table 1.

Table 1: The calculated ground water recharges of aquifer of the study area for the year 1991 to 2000.

Year	Sapahar Mm^3	Porsha Mm^3
1991	171.64	236.76
1992	106.41	164.63
1993	140.37	228.36
1994	110.67	187.62
1995	193.01	224.14
1996	118.26	191.77
1997	127.25	171.21
1998	167.82	244.26
1999	173.97	243.10
2000	206.06	210.03

The Annual ground water recharge of aquifer of the study area estimated by hydrograph method following Thiessen – Polygon Method varies from 173.79 to 243.1 Mm^3. The calculated ground water recharge of aquifer of the study area shows that the rate of ground water rechargeof aquifer in Porsha Upazilla is higher than that of sapahar Upazilla and is characterized by very suitable ground water storage potential.

For the estimation of total volume of water discharged during the 1991-1992 and the volume of water discharge is calculated with the fluctuation between the pre-monsoon of 1991 and dry season 1992. The estimated annual discharge of the year 1991 to 2000 has been tabulated in the table 2.

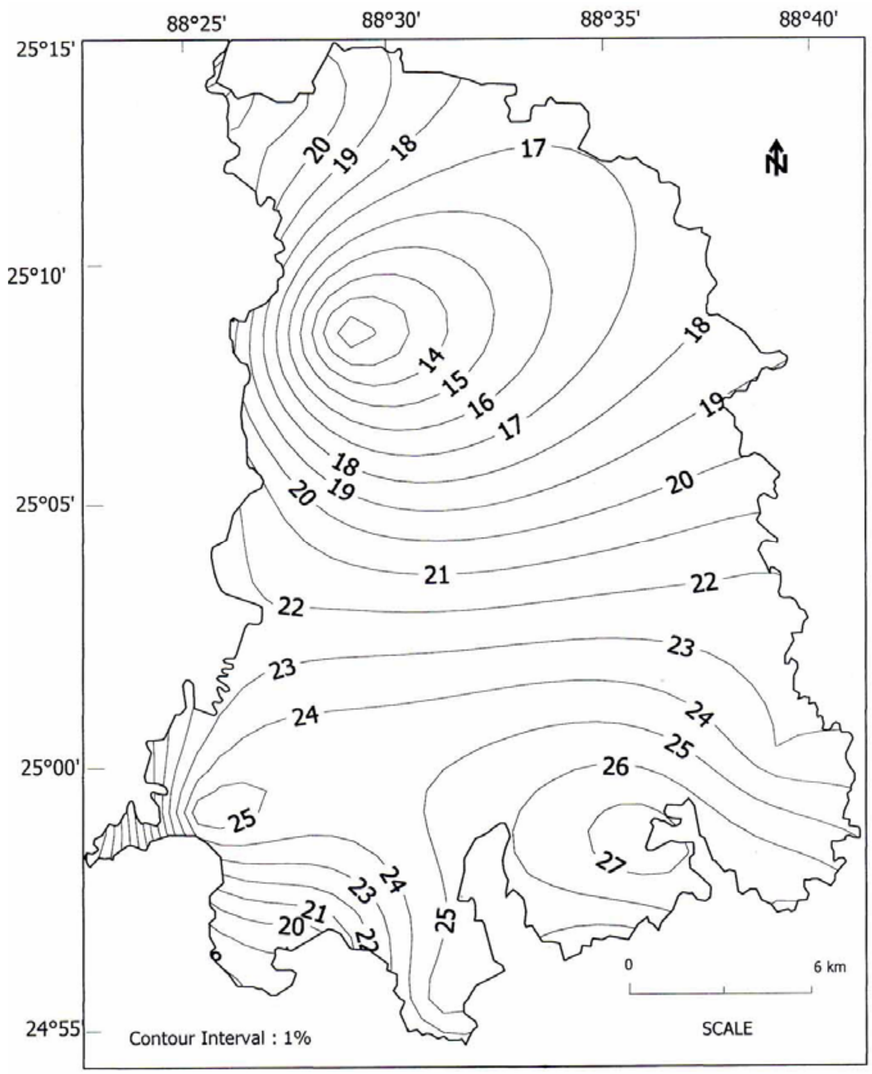

Fig. 4. Specific yield map of the study area

Table 2: Calculated annual discharge of aquifer of the study area (1991-2000)

Year	Sapahar (Mm^3)	Porsha (Mm^3)
1991	105.05	224.41
1992	93.77	170.07
1993	133.53	219.17
1994	193.46	228.76
1995	182.40	227.72
1996	136.46	175.11
1997	139.17	166.06
1998	176.15	275.05
1999	220.13	200.04
2000	276.94	291.70

It is clearly observed from the table that the amount of water overdraft during the tenure 1994-1995. The estimated annual recharge and discharge of the year 1991 to 2000 for Sapahar and Porsha Upazillas have been presented in figs.5 and 6.

Available information regarding the number of tube wells installed in each year is collected from the respective organizations. For convenience, all types of discharging equipment with their respective discharge rate and discharging hour during the year 1991 to 2000 for Sapahar and Porsha Upazillas is given in table 3 and 4. With a view to groundwater management the discharge of groundwater accomplished by the different discharging equipment is computed for a period of 1991 to 2000 for Sapahar and Porsha Upazillas is given in table 5 and 6. The discharge is calculated individually according the discharge rate and discharging hour of the respective. Discharge element that is used in the study area for both the domestic and irrigation purposes.

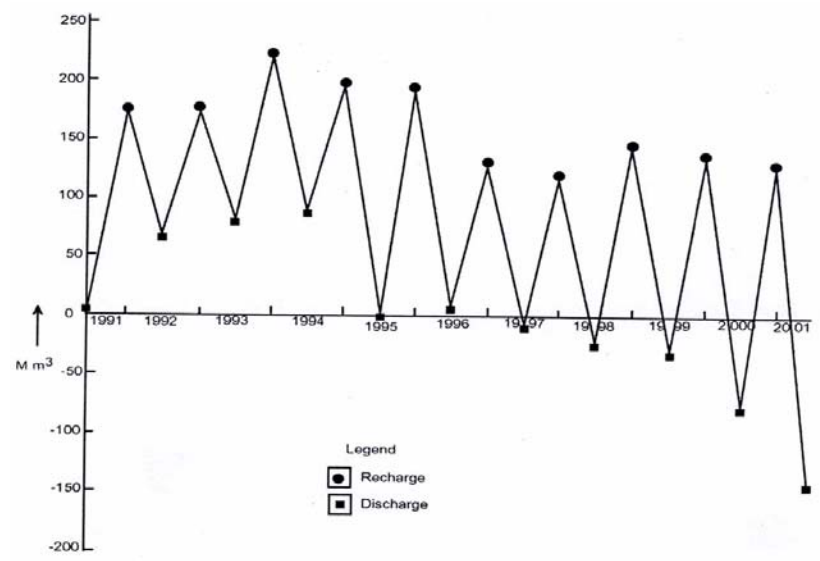

Fig. 5. Annual recharge and discharge of groundwater of Sapahar Upazilla (1991-2000)

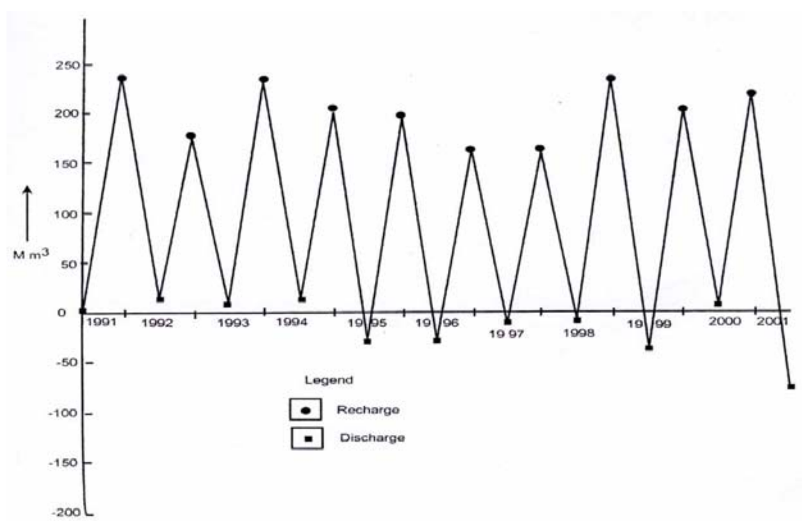

Fig. 6. Annual recharge and discharge of groundwater of Porsha Upazilla (1991-2000)

Table 3: Total number of discharging wells running throughout the year during the period 1991-2000 for Sapahar Upazilla.

Sapahar Upazilla

Discharge equipment with discharge rate and hours	Total number of discharging equipment during the period 1991-2000									
	91	92	93	94	95	96	97	98	99	2000
DTW DR=1.6cft/sec. DH=1200 hour/year	94	94	97	107	109	114	119	122	122	122
STW DR=. 5cft/sec. DH=1200 hour/year	198	198	198	198	467	467	467	484	484	484

Table 4: Total number of discharging wells running throughout the year during the period 1991-2000 for Porsha Upazilla.

Porsha Upazilla

Discharge equipment with discharge rate and hours	Total number of discharging equipment during the period 1991-2000									
	91	92	93	94	95	96	97	98	99	2000
DTW DR=1.6cft/sec. DH=1200hour/year	107	108	138	162	182	181	187	192	194	194
STW DR=. 5cft/sec. DH= 1200 hour/year	200	218	218	216	216	216	216	216	216	216

Table 5: Amount of annual discharge for both domestic and irrigation purposes due to different discharging equipment during the period 1991-2000 for Sapahar Upazilla.

Sapahar Upazilla

Period	Discharge for domestic and irrigation purposes by surface water and groundwater (Mm^3)		Total groundwater discharge (Mm^3)
	DTW	STW	
1991	14.47	9.52	23.99
1992	14.47	9.52	23.99
1993	14.88	9.52	24.40
1994	16.49	9.52	26.01
1995	16.79	22.47	39.26
1996	17.5	22.47	39.97
1997	18.26	22.47	40.73
1998	18.72	23.29	42.01
1999	18.79	23.29	42.08
2000	18.79	23.29	42.08

Table 6: Amount of annual discharge for both domestic and irrigation purposes due to different discharging equipment during the period 1991-2000 for Porsha Upazilla.

Porsha Upazilla

Period	Discharge for domestic and irrigation purposes by surface water and groundwater (Mm^3)		Total groundwater discharge (Mm^3)
	DTW	STW	
1991	16.47	9.62	26.09
1992	16.63	10.49	27.12
1993	21.25	10.49	31.74
1994	24.85	10.39	35.24
1995	28.03	10.39	38.42
1996	27.78	10.39	38.17
1997	28.7	10.39	39.09
1998	29.47	10.39	39.86
1999	29.78	10.39	40.17
2000	29.78	10.39	40.17

The annual groundwater recharge of aquifer of the study area estimated by hydrograph method following Thiessen polygon method varies from 106.41 to 244 Mm^3. The annual groundwater discharge of aquifer of the study area estimated by hydrograph method following Thiessen polygon method varies from 93.77 to 291.7 Mm^3. The annual groundwater recharge of aquifer of Sapahar Upazilla estimated by hydrograph method following Thiessen polygon method varies from 106.41 to 206.06 Mm^3. The annual groundwater discharge of aquifer of Sapahar Upazilla estimated by hydrograph method following Thiessen polygon method varies from 93.77 to 276.94 Mm^3. The annual groundwater recharge of aquifer of Porsha Upazilla estimated by hydrograph method following Thiessen polygon method varies from 164.63 to 244.26 Mm^3. The annual groundwater discharge of aquifer of Porsha Upazilla estimated by hydrograph method following Thiessen polygon method varies from 166.06 to 291.7 Mm^3. The calculated groundwater balance for Sapahar and Porsha Upazillas is given in table 7 and 8.

Table 7: Grounwater balance for Sapahar Upazilla in different years

Sapahar Upazilla

Period	Rainfall	Input in MCM	Out in MCM	Change in storage in MCM
1991	1965	171.64	105.05	+66.59
1992	1296	106.41	93.77	+12.64
1993	1320	140.37	133.53	+6.84
1994	1053	110.67	193.46	-82.79
1995	1977	193.01	182.40	+10.61
1996	783	118.26	136.46	-18.2
1997	1031	127.25	139.17	-11.92
1998	1603	167.82	176.15	-8.33
1999	1525	173.97	220.13	-46.16
2000	1485.9	206.06	276.94	-70.88

Table 8: Grounwater balance for Porsha Upazilla in different years

Porsha Upazilla

Period	Rainfall	Input in MCM	Out in MCM	Change in storage in MCM
1991	1998.8	236.76	224.41	+12.35
1992	1200.6	164.63	170.07	-5.44
1993	1420.1	228.36	219.17	+9.19
1994	1120.1	187.62	228.76	-41.14
1995	2144.7	224.14	227.72	+3.58
1996	1387.9	191.77	175.11	+16.66
1997	1055.2	171.21	166.06	+5.15
1998	1750.4	244.26	275.05	-30.79
1999	1990.4	243.10	200.04	+43.06
2000	1387.9	210.03	291.70	-75.67

Conclusions

The calculated groundwater recharge of aquifer of the study area shows that the rate of groundwater recharge of aquifer in Porsha Upazilla is higher than that of Sapahar Upazilla and is characterized by very suitable groundwater storage potential. Thus the overall study in the study area indicates that there exists a balance between annual recharge and withdrawal up to 1993 but after period of 1993 discharge exceeds the recharge continuing till today. But hereforth a cumulative annual deficit is found to exist because of progressive annual discharge in Sapahar Upazilla. It is observed that during the period 1994 and 2000, the deficit of groundwater is maximum. The amount of water overdraft during the period of 1994 - 1995 is shown in fig. 5 and 6. It appears from the results that the amount of water withdrawn varies from 23.99- 42.08 Mm^3 in the study areas of different Upazillas. 23.99- 42.08 Mm^3 of groundwater is discharged by discharging mechanisms. The rest of groundwater is discharged by natural seepage.

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