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# HYDROGEOLOGICAL POTENTIALITY OF INTENSIVE FARMER- MANAGED TUBEWELL IRRIGATION SYSTEMS IN BANGLADESH - A CASE STUDY[1]

M. A. SATTAR[2] and K. A. HAQ[3]


## ABSTRACT

A field study was conducted in 10 farmer- managed deep and shallow tubewell irrigated areas of Barind Tract ground water basin, Bogra, Bangladesh with the specific objectives of: a) assessing the ground water recharge in the study area, b) evaluating the fluctuation of ground water table of aquifers and its response on rainfall and river stage in the vicinity , c) evaluating the aquifer characteristics and properties and d) recommending the safe utilization of tubewells based on discharge-drawdown relationship and well spacing for sustainable ground water management in crop production.

The study indicated that the intensity of tubewells at present are 5 per sq. kilometer with an average discharge capacity of about 56 l/sec. The average irrigated acreage of all the tubewells was 0.83 ha/l/sec under rice crop which was much above the national average(0.40 ha/l/sec). The 10 years (1977-1986) ground water table indicated that the highest lowering of ground water table was 7.87 meter in the month of March which was below the operation level of shallow tubewell. A multiple regression relationship with groundwater table (Y) as dependable variable and rainfall (X1) and river stage (X2) as independent variables was done. The study revealed that there is a significant direct relationship among rainfall, ground water table fluctuation and stream flow. The lithological investigations indicated that 100 percent screenable materials was available from depth of 12 meters and beyond. The average transmissivity and storage coefficient values were 4388 $m^2$/day and 0.000587,respectively which indicated that the study area has potential for tubewell utilization. A model for safe well spacing was developed between discharge versus spacing of well. The findings indicated that for shallow deep well with discharge rate of 11 to 20 l/sec the spacing was in the range of 122 to 250 meters. However, for deep tubewell with discharge capacity of 47 to 54 l/sec the spacing was in the range of 300 to 390 meters for safe and sustainable utilization of ground water.


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[2] Senior Scientific Officer, Irrigation and Water Management Division, Bangladesh Rice Research Institute, Gazipur, Bangladesh.

[3] International Irrigation Management Institute, P.O. Box 2976, Khartoum, Sudan.

# INTRODUCTION

Groundwater in Bangladesh generally occurs under water table conditions but in some areas, particularly in deeper aquifer, the water may be under semi-artisan or artisan condition. The depth to the water table varies from zero to more than 15 meters below the ground surface depending upon the location and season. Hydrogeologically, the upper fine sand and lower medium sand from one hydraulically interconnected aquifer was covered by semi-permeable semi-confining layer of silt and clay (MPO, 1984). The static water level generally lies within the semi-confining layer. The deep tubewells (DTWs) and shallow deepwells (STWs), all extract water from a common aquifer, although from different but hydraulically connected layers.

Bangladesh can be divided into four major ground water zones: (i) younger alluvium, (ii) complex geology, (iii) older alluvium and (iv) coastal area (Jones, 1972). Among the older Alluvium, surficial deposits in the area consist of fine grained older alluvium, chiefly the pleistocene Madhupur clay formation. The finer material extended to great depths in some areas and therefore very little attempt has been made to develop large-capacity wells. Geophysical investigations indicate that there are some relative good prospects of ground water development in Bogra District and in the Southern part of Tangail District.

Surface water is scarce in many parts of Bangladesh (mainly North and North West part of Bangladesh) during the irrigation season, so ground water has to be developed as an alternate and dependable source. But ground water is also limited and there exists many constraints for its development. Therefore, it is essential to determine the quantity of ground water that can be withdrawal safely for different uses. Ground water withdrawal causes large decline in ground water levels during the dry season in some typical areas where use has increased greatly in recent years (MPO, 1984). The areas are Bogra, Rajshahi, Comilla, Dhaka an Mymensingh Districts. Haq and Sattar's (1986) study at Bangladesh Rice Research Institute,Gazipur indicated that the ground water table during the dry season over six years period progressively declined and was closed to 1.7 meter per year. This yearly lowering of the ground water table could be an indication that the annual rates of withdrawal from the ground water basin has been greater than the yearly rates of recharge. The present study aims to find out the geohydrological potentiality of intensive deep and shallow tubewells farmers managed irrigation system for safe utilization of groundwater.

The specific objectives of the study were:

1) To assess the groundwater recharge in the study area;
2) To evaluate the fluctuation of ground water table of aquifer and its response on rainfall and river stage in the vicinity;
3) To find out the aquifer characteristics and properties;
4) To determine the safe utilization of tubewells for sustainable ground water management

## MATERIALS AND METHODS

### Selection of the study area

The study area has been selected based on the geohydrological zone of Bangladesh (Figure 1). It is mainly occupied by pleistocene deposits viz. Barind tract of Bogra district (Morgan and McIntire, 1959). The river Karatoa flowing towards South-West at the Western margin of Kahalu Upzilla have a great effect on ground water reserve. To fulfill the objectives of the study a pilot area has been selected in Kahalu Upzilla covering 10.10 sq. kilometer which has one of the most intensive DTWs and STWs in the Bogra district. Upazilla-wise deep tubewells location map and as well as number of shallow wells within the study region were collected from Bangladesh Agricultural Development Corporation (BADC) local office. Year wise increment of DTW and STW for greater Bogra district from 1976-77 to 1983-84 together with 1985-86 tubewell status of present Bogra district are shown in Figure 2.

### Farmers' Managed Irrigation System (FMIS)

Ten DTWs and STWs of FMIS were considered for this study. The DTWs were mainly implement by Bangladesh Agricultural Development Corporation (BADC) since 1977 and the group of the farmers have received the use of the DTWs on a rental basis of Tk 3500 (approx. $145) per year. However, by 1981 rental procedures were discontinued and DTWs sells for Tk 70,000 (approx. $3000) to the farmers group. The procedures to procure deep tubewells begins with farmers who either organize themselves or are organized into user group. Mandal (1982) provides examples in which the farmers themselves took the initiative to form a management committee to procure a deep tubewell and to manage the wells by themselves. The shallow tubewell is mainly procured and managed by the individual farmer.

## Hydrogeological Information

Daily groundwater table was measured by using electric probe method from seven production wells (DTWs) and eight installed observation wells for monitoring the groundwater table in the study area. Rainfall data and river water stage were collected from the local Bangladesh Water Development Board (BWDB) office for a period of 10 years from three gaging stations of major rivers namely, Nagor, Karotoa and Katakhali which are the main aquifer connected rivers within the study basin. Eight available deepwell logs were analyzed based on soil texture. These were plotted on positive and negative axes of aquifer and aquitard as probability of occurrence of hydrogeology interpretation. The aquifer characteristics were determined through pumping test by using Jacob's method with the approaches of time-drawdown,distance-drawdown and recovery method. An attempt was made to find out the safe distance from DTW to STW by step draw down test through the relationship between discharge (Q) vs radius of interference (R). Two deep tubewells and one shallow tubewell were selected for the test. The production wells were pumped at several successively higher pumping rates and draw down for each rate was measured in each observation well. In each step, the radius of interference was determined from drawn down curve. Each of the tubewell discharge was measured by horizontal scale (L-Scale) and their respective service area was recorded.

# RESULTS AND DISCUSSION

## Seasonal Fluctuation of Ground Water Table

Measurement of depth to water table in tubewell provides the record of change in the ground water storage. Some record aids in determining the relationship of various fact as of recharge to the groundwater reservoir. Weekly water table data were compiled for the analysis. Ground water level starts rising from the later part of May or June and it rises upto first part of October. Ten year secondary ground water monitoring data have been used to show the behavior of the ground water table fluctuation (Fig. 3).

## Rainfall Pattern

Annual rainfall of Bogra district from the year 1977 to 1986 indicates that 92% of the annual rainfall occurred from May to October and the rest from November to April. These rainfall variations directly affect the ground water recharge (Fig. 3).

## Assessment of Surface Water

The river water stage data of Bogra district showed the maximum flow from June to October and minimum in the month of April (Fig. 4). The highest and lowest river stages were 15.75 m and 11.21 m in the year 1984 and 1983 respectively.

## Relationship among rainfall, river stage and ground water table

An investigation was carried out to analyze the interrelation of rainfall with ground water table as well as with river stage data within the few selected sites of the study area. The analysis was made based on the monthly records of rainfall, groundwater table and river stage. A multiple correlation analysis was made to establish the response of ground water table (Y) to rainfall (X1) and river stage (X2) and is given by the equation :

$$Y = 12.5647 + 0.0399X_1 + 0.7675\ X_2 \quad (r^2 = 0.60*)$$

The equation indicate a significant relationship of groundwater table with rainfall and river stage and shows that the rise in both ground water table and surface water levels are influenced directly by the rainfall. The river water level starts rising from the last part of April upto first of August and it falls sharply at the end of monsoon (september and October). The ground water level on the other hand, starts to rise from last April upto October and then declines until april of next year.

## Lithological Characteristics

One test boring of 3.8 cm diameter was done upto a depth of 60 meter to determine the continuity of aquifer depth on the study area. The sample were taken at every 1.5 meter interval to observe the lithology of subsurface formation. The stratigraphic views of lithological log of under ground soil formation consists of clay, silt, very fine sand, fine sand, medium sand, coarse and an gravel. From the lithological investigation it was found that the first screenable material begins from a depth of 12 meter. The extent of this screenable material could not be identified since the bore log information beyond a depth of 60 meter is not available. On the other hand, BADC bore log analysis reveals that the first possible screenable aquifer can be expected with 12 percent probability at 9 meter depth. Below 9 meter depth the percent of non screenable material reduces sharply and varies from 12 to 15 percent (Fig. 5). From 21 meter upto a depth of 58 meter the probability of screenable material is 100 percent and suitable for installing both shallow and deep tubewells. The test boring indicated that 100 percent screenable material was available from depth of 12 meter and above whereas BADC boring logs indicated that 100 percent screenable material is obtainable from a depth of 21 meter and beyond.

## Determination of Aquifer Characteristics

The yield of a well depends on the characteristics of the aquifer formation such as transmissivity (T) and the storage coefficients (S) as well as the design and constructions of the well. Transmissivity indicates how much water will move through the water bearing formation. Water storage coefficient is the volume of water from the aquifer releases from or takes into storage per unit surface area per change in head normal to the surface (Michael, 1985). Transmissivity and storage coefficient are two important parameters for estimation of ground water resources of an area. Johnson (1986) stated that transmissivity and storage coefficient are especially important because they define the hydraulic characteristics of water bearing formation. If these two coefficient can be determined for a particular aquifer, predictions of great significance can usually be made.

The aquifer characteristics were determined through pumping test by using Jacob. method. Three types of analysis were performed, these are: i) time-drawn-down, ii) distance drawdown and iii) recovery methods. One deep tubewell was selected for the pump test. Five observation wells were installed radially in a straight line to record water response to pumping. The distance of the observation wells from 10 meter to 360 meter. To estimate the aquifer properties (T & S), mathematical and graphical solution for one set of data were made. Transmissivity values were 4562 m2/day, 4214 m2/day by time-drawdown method respectively (Figures 6a, 6b, & 6c). The storage values were 0.000648 and 0.000527 by time-drawdown and distance-drawdown methods respectively. These values are much higher than the values obtained by Sir MacDonald and Partners (1977). The values indicate that the aquifer has good potential for ground water development.

## Model for safe well spacing

A linear regression model was developed between discharge versus radius of interference. The model shows that there is significant relationship between discharge and radius of interference. At the higher discharge rate the spacing of well will be more compared to lower discharge rate (Table 1). A type curve has also been developed by plotting discharge (Q) versus radius of interference (R) on normal graph paper (BRRI, 1989). From the type curve the spacing for any particular discharge rate can be estimated (Figure 7).

## Tubewell performance and utilization

The irrigated acreage of the tubewell (area irrigated per unit time) discharge per unit time and the total amount of water applied is shown in table 2. A maximum of 1.24 ha/L/sec was irrigated in DTW no. 10 by operating the pump for 1660 hrs and a minimum of 0.56 ha/sec was irrigated in DTW no. 5 by operating the pump for 1583 hrs during the dry season for rice cultivation. On an average the irrigated acreage of all tubewells was 0.83 ha/L/sec. Therefore the tubewells under the study were utilized upto their optimum level.

## Advantages and Disadvantages of Intensive DTWs and STWs

The advantages of intensive DTWs and STWs are: a) can be used as supplemental irrigation source during high water demand of the crop, b) to increase cropping intensity by the alternative sources of water, c) to increase service area through combination of deep and shallow wells even the topography of the service area is not level and, d) more economic use of water by DTWs and STWs where the water table is near the ground surface.

The disadvantages are: a) low discharge of well if there is interference of DWT & STW located in the same vicinity which increase high cost of operation and, b) more risk of crop production during dry season by using STW if the water table goes below the operation level.

# SUMMARY AND CONCLUSION

The study area has intensive tubewells for crop production. The numbers of intensity of tubewells per sq. km. is 4 to 5 with discharge capacity of 11 to 57 L/sec. Increasing the number of DTW/STWs from year to year in the study area may further lower the ground water table due to overdraft which was observed in the study period during conduct of the study. There is a significant relationship among rainfall, ground water table fluctuation and stream flow in the vicinity. Groundwater started to rise after one month with a cumulative rainfall of 15 cm. The study also indicated that the stream flow influence groundwater recharge favorably. The lithological investigation showed that the 100% screenable material lies 12 m from the ground surface and extend up to 60 m depth. The aquifer characteristics like transmissivity and storage coefficient were determined from pump test data. The results indicated that the aquifer has good potential for ground water development. But the present trend of increasing the numbers of deep tubewells and shallow tubewells installed every year in the study area may lower the ground water table below the operation level. This was indicated during the test of radius of interference between deep and shallow wells at the full operation time. However, this issue can be solved technically from the findings of the study by using the distance-drawdown and spacing relationships. Accordingly, a proper policy should be implemented in future for installation of potential number of wells in these farmer-managed tubewell irrigation systems for sustainable ground water management.

## LITERATURE CITED


BRRI, 1989. Annual Report of 1989. Bangladesh Rice Research Institute, Gazipur, Bangladesh.

BWBD, 1987. Bangladesh Water Development Board, Local Officer, Bogra, Bangladesh.

HAQ, K.A. and M.A. SATTAR, 1986. Ground water table fluctuation and response to rainfall on a Micro- level Basin. Published in the Bangladesh Journal of Agricultural Engineering, Bangladesh Agricultural University, Bangladesh, Mymensingh, Vol. 1 No.1.

JOHNSON, 1986. Ground water and wells. Published by Johnson Division, St. Paul, Minnesota 55112.

JONES, J.R. 1972. Brief summary of the hydrogeology of Bangladesh USGC open file report prepared in cooperation with the GWD/BWDB, Dhaka, Bangladesh.

MANDAL, M. A. S. 1982. Socio-economic constraints in selected irrigation project. In on farm Irrigation water management problems. Bureau of Socio-economic Research and Training, Bangladesh Agricultural University, Mymensingh.

MASTER PLAN ORGANIZATION. 1984. Third interim report. Ministry of Irrigation and Flood Control, Government of Bangladesh, Dhaka, Bangladesh.

MICHAEL, A.M. 1985. Irrigation theory and practice. Indian Agricultural Research Institute, New Delhi.

MORGAN, J.P. and W.G. McINTRE, 1959. Quarternary geology of the Bengal Basin, East Pakistan and India.

SIR MACDONALD and PARTNERS, 1977. North-west Bangladesh ground water modeling study, Cam bridge, England.

Table 1. Discharge versus spacing for deep and shallow tube wells at Kahalu Upzilla, Bogra.

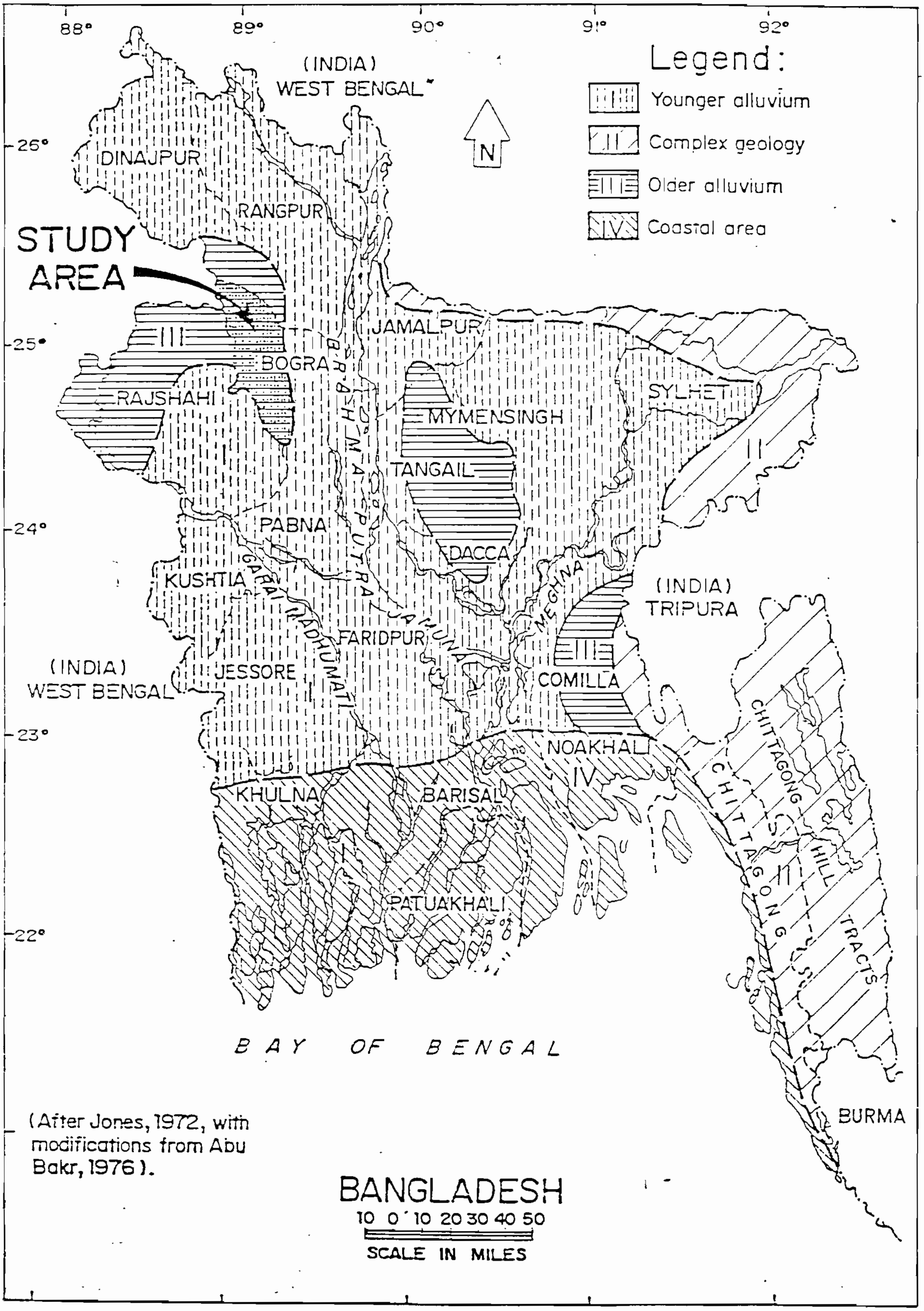
| Sl. No | Discharge (L/sec) | Spacing (meter) |
|---|---|---|
| 1 | 11 a/ | 120 |
| 2 | 20 a/ | 250 |
| 3 | 47 b/ | 355 |
| 4 | 57 b/ | 390 |
| 5 | 30 b/ | 300 |
| 6 | 50 b/ | 360 |
| 7 | 32 b/ | 305 |
| 8 | 54 b/ | 340 |

a/ Indicates the discharge of shallow well
b/ Indicates discharge of deep wells.

Table 2. Water utilization in the selected deep tubewells at Kahalu Upzilla, Bogra. a/

| DTWS No. | Location (Village) | Total operating hours | Discharge of pump (L/sec) | Total area irrigated (ha) | Area irrigated per unit discharge (ha/L/sec) |
|---|---|---|---|---|---|
| 1 | Narhatta | 1390 | 74.00 | 44.20 | 0.60 |
| 2 | Buril | 1316 | 42.00 | 35.51 | 0.85 |
| 3 | Damai | 1350 | 39.10 | 29.15 | 0.75 |
| 4 | Raushan Chapor | 1349 | 39.37 | 38.92 | 0.99 |
| 5 | Katnahar | 1583 | 39.84 | 22.27 | 0.56 |
| 6 | Kait | 1152 | 34.50 | 26.87 | 0.78 |
| 7 | Vagdubra | 1500 | 40.55 | 28.34 | 0.70 |
| 8 | Muril | 1620 | 38.50 | 40.49 | 1.05 |
| 9 | Vishropur | 1620 | 41.42 | 30.36 | 0.73 |
| 10 | Bokra | 1600 | 45.62 | 56.41 | 1.24 |

a/ Shallow tubewells' command area were not included




FigI. Approximate boundaries of ground water areas.

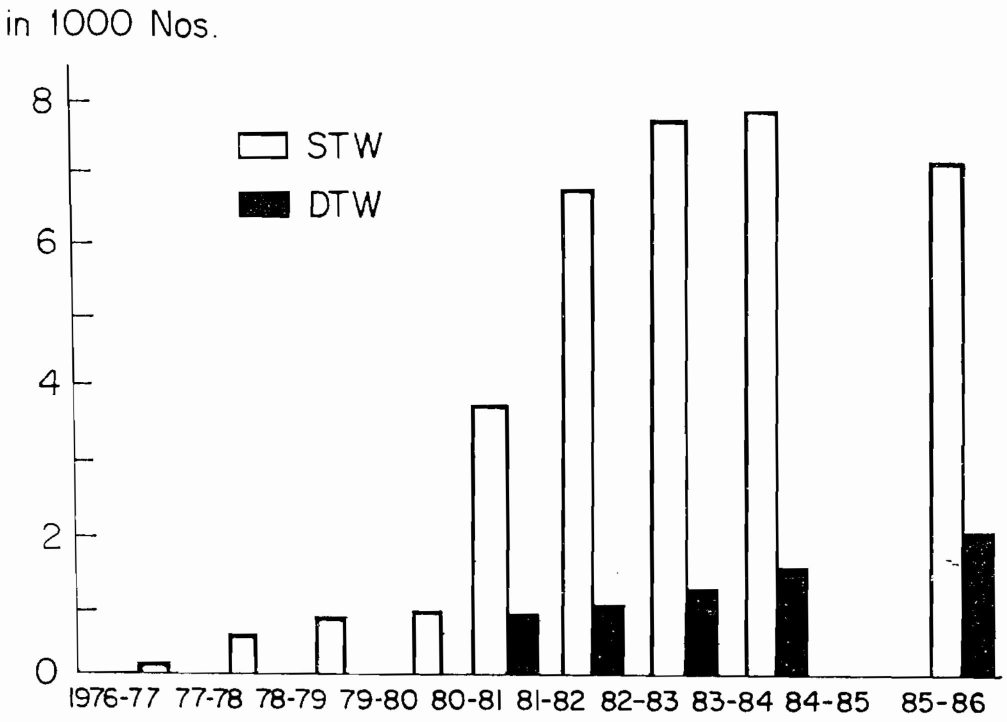



Fig. 2. Shows yearwise increment of STW and DTW in Bogra District.

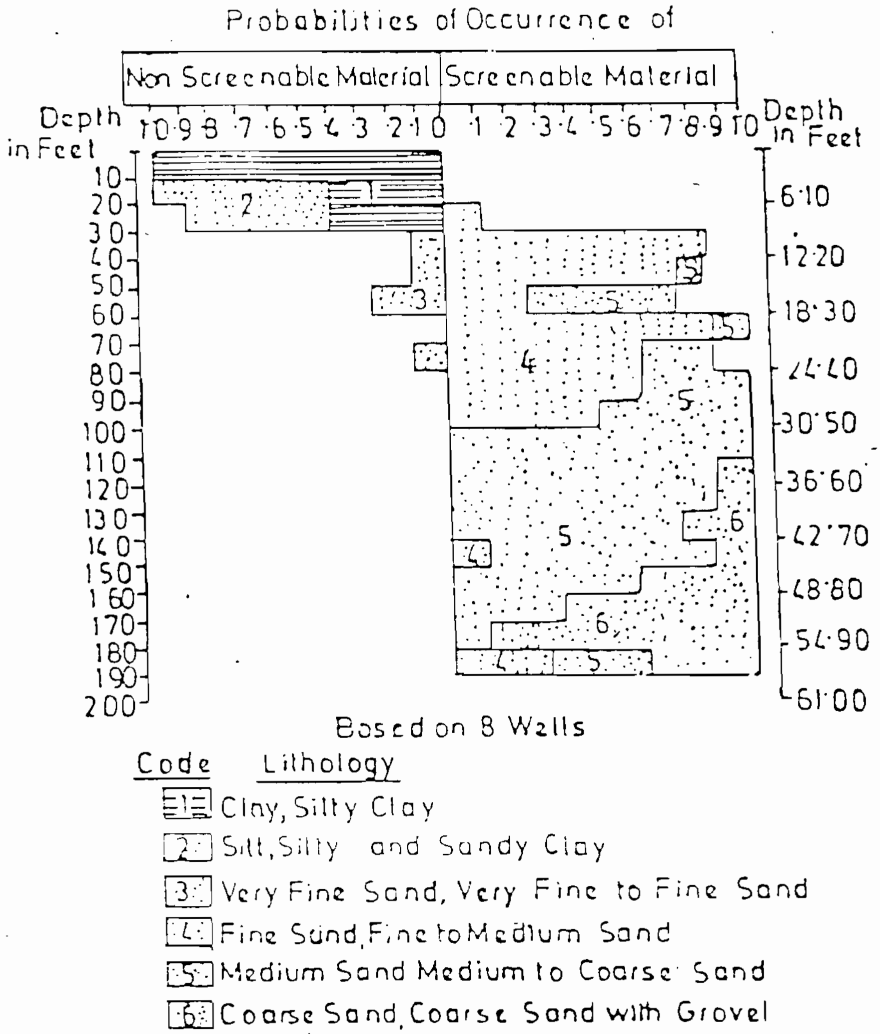



Fig.5 Probability of occurence of hydrogeology interpretation

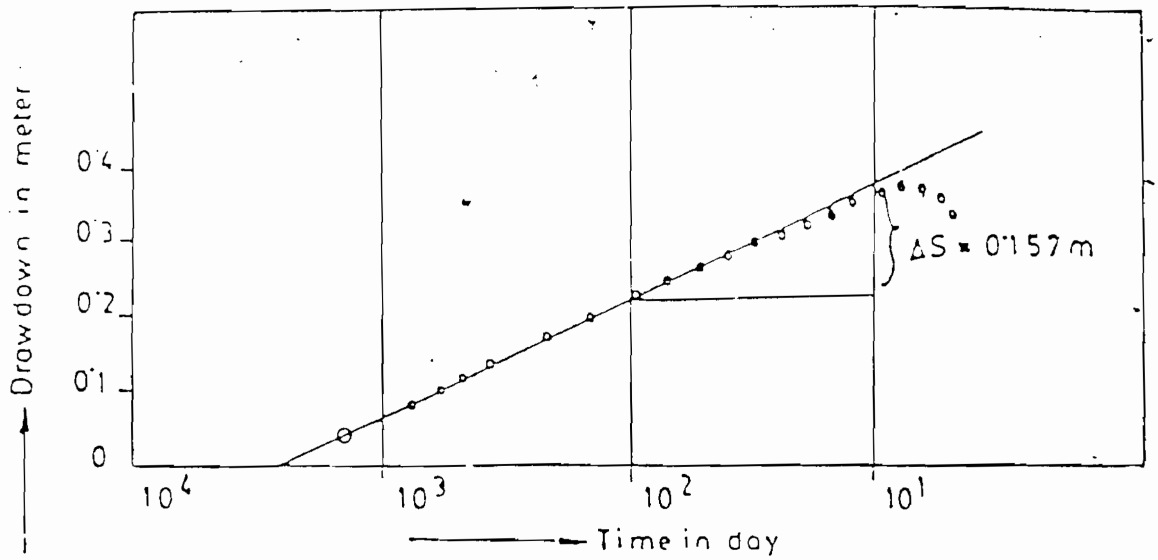



FIG. 6A. Time drawdown analysis by Jacob method

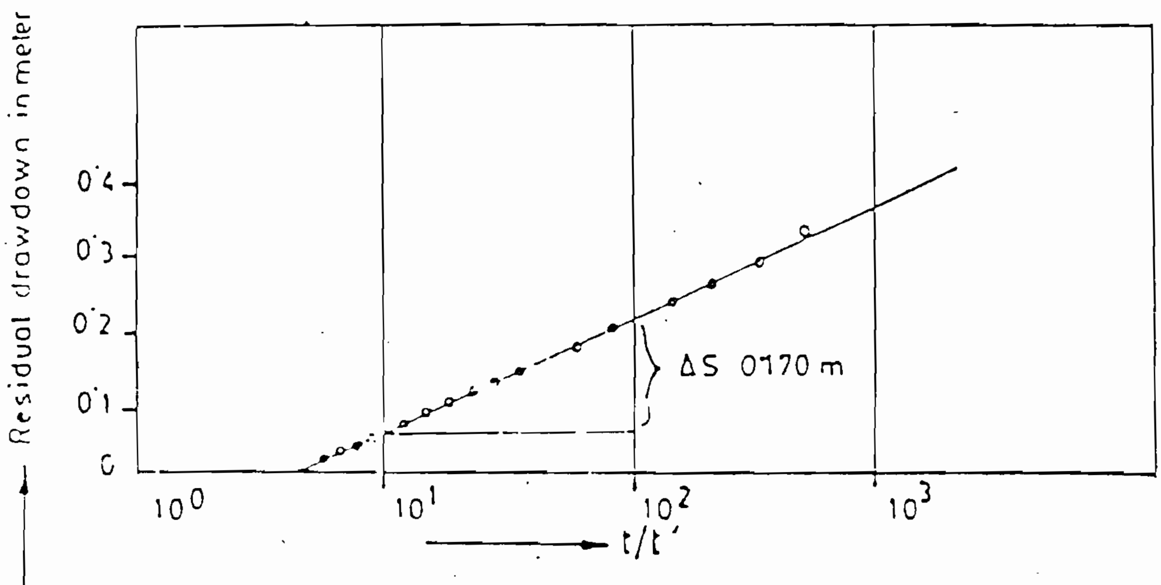



FIG. 6B. Recovery solution for transmissivity

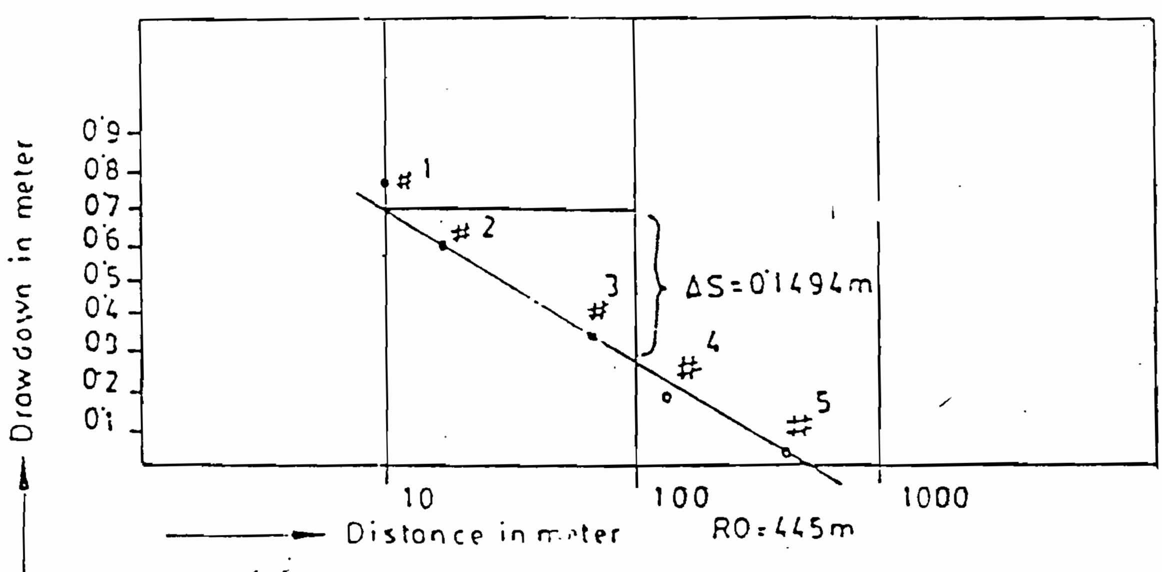



FIG. 6C. Distance drawdown analysis by Jacob method

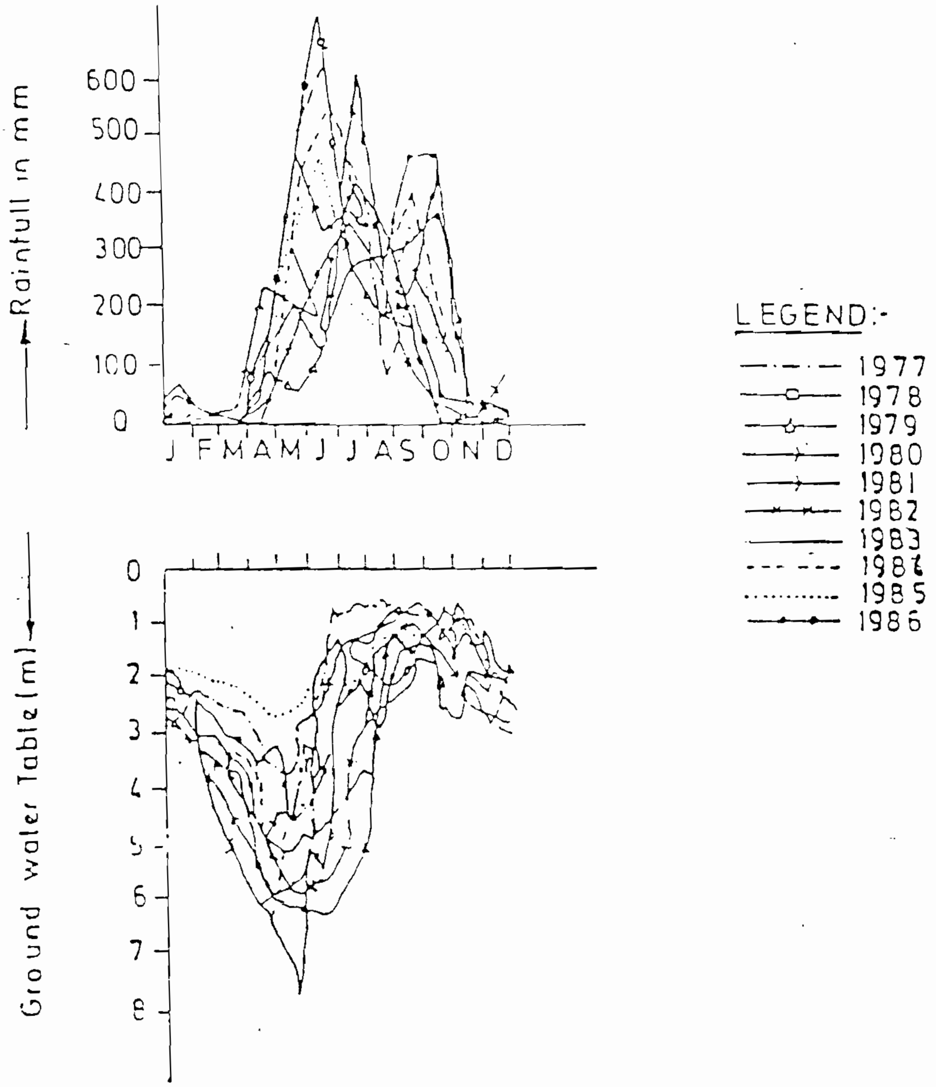



Fig.3 .FLUCTUATION OF GROUND WATER TABLE & RAINFALL PATTERN (1977-1986)

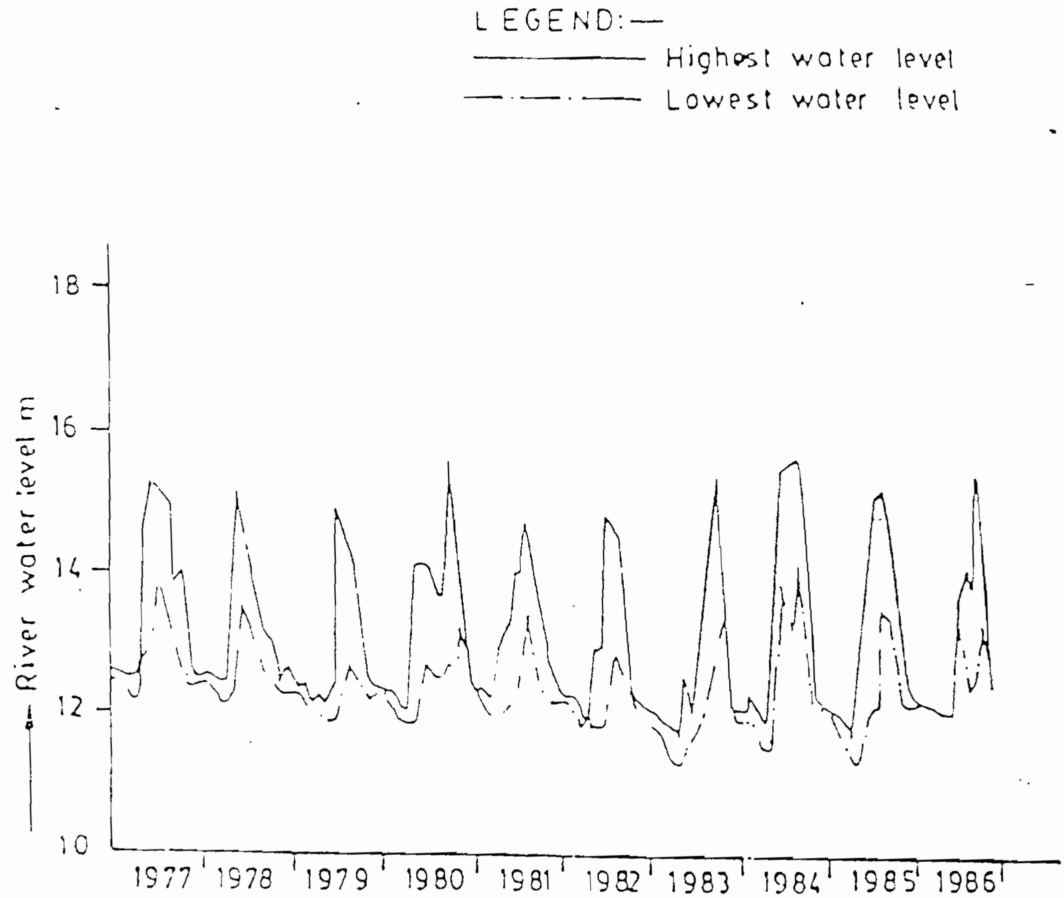



Fig 4. HYDROGRAPHS SHOW THE HIGHEST & LOWEST WATER LEVEL OF KARATOA RIVER FROM 1977 TO 1986

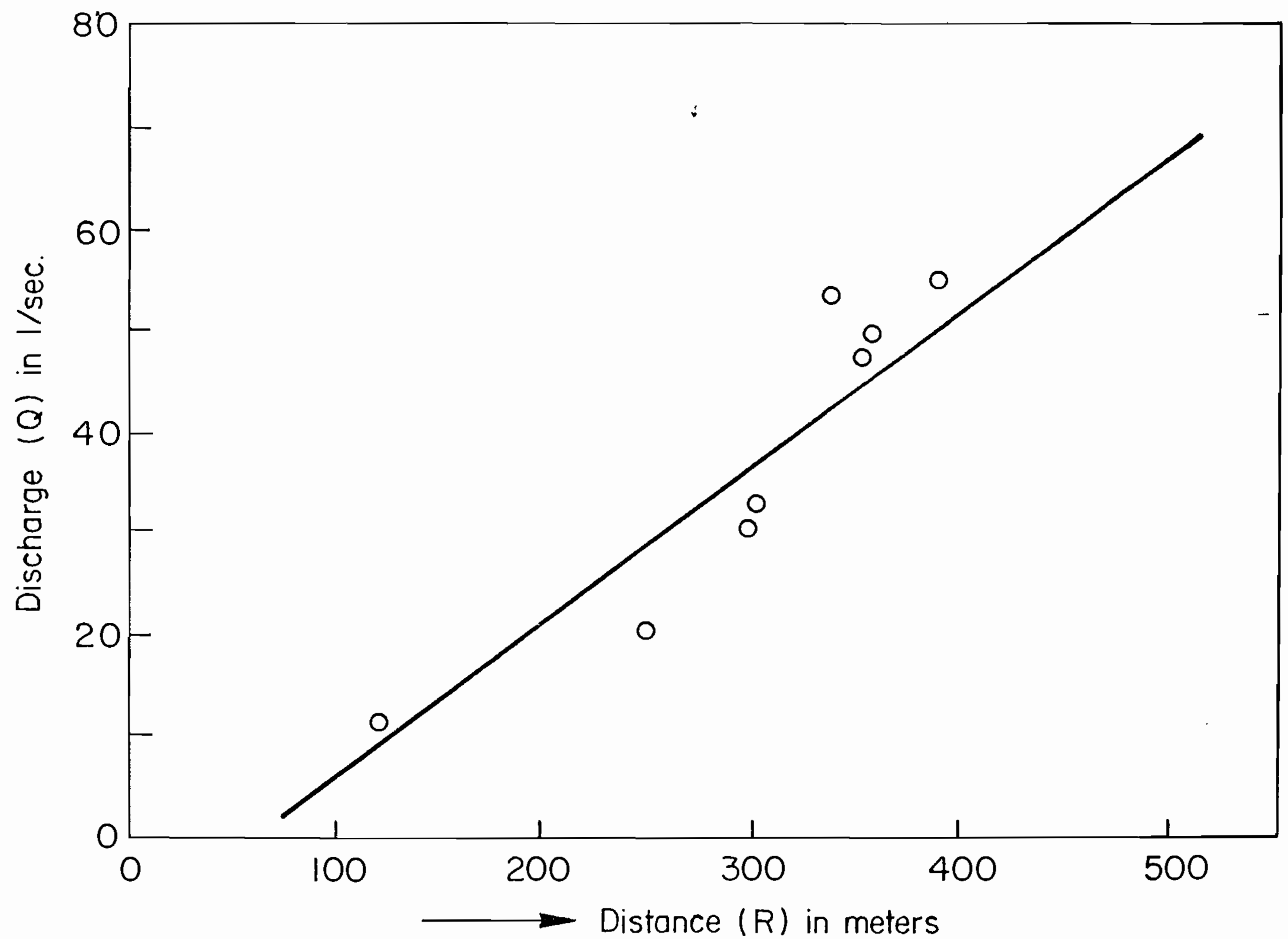



Fig. 7. A type curve of Discharge versus Distance for production well.