# HYDROLOGICAL INVESTIGATION ON AQUIFER SYSTEM AT UNION LEVEL OF RAJSHAHI DISTRICT, BANGLADESH

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## ABSTRACT

Groundwater is a vital source for drinking and agricultural purposes in Rajshahi district. The scarcity of water in surface water bodies causes high dependency on groundwater resources. The aim of this paper is to investigate the aquifer system and groundwater level up to union level of Rajshahi district. Existing historical data has been collected from BWDB, BMD and other relevant agencies. Rainfall data has been collected for the duration of 1985 to 2022. Existing hydro-geological data that includes groundwater level, lithologs and aquifer properties has been collected from available secondary sources. In addition, to fulfill the data gap, a comprehensive field investigation program has been conducted that includes exploratory drilling at 19 locations. Borelog data indicates that the aquifer system mostly falls under two physiographic units: Barind Tract and Ganges Flood plain. Tanore and Godagari upazilas fall under the unit of Barind Tract. The thickness of the aquifer varies from 3 to 6 m. Groundwater table for 1st aquifer is 23 to 34 m. In Badhair union, no aquifer exists below the 1st aquifer up to a drilling depth of 426m. Thick aquifer presents in Soranjai, Pachandor, Talando and Kumargaon unions in the eastern part of Tanore and Godagari upazila where the aquifer thickness varies from 27 to 72m. In the area groundwater table has declined down to a depth of 25-27 m. Puthia, Bagha, Paba, Charghat and Bagmara and part of Mohanpur upazilas fall under the unit of Ganges River Floodplain. The groundwater table exists within suction limit (7 m) except some parts of Mohonpur and Bagmara uapzilas. There is a negligible declining trend is seen in the groundwater level of Charghat upazila. But from the analysis of groundwater level of Tanore upazila, there is a huge and alarming declining trend is seen. About 8 m decline has been found for Tanore during 2005 to 2022. Morover, Mohonpur, Tanore and Godagari areas, declining trend of water level is very alarming. From the identification of water stress area, it has been found that 3 unions of Godagari upazila, 1 union of Mohonpur upazila, 3 unions of Paba upazila and 6 unions of Tanore upazila under Rajshahi district falls in the very high water stress area. It also has been found that 2 unions of Bagha upazila, 1 union of Baghmara upazila, 1 union of Charghat upazila, 3 unions of Durgapur upazila, 3 unions of Godagari upazila, 4 unions of Mohanpur upazila, 1 union of Paba upazila, 1 union of Tanore upazila under Rajshahi district falls in the high water stress area. In the high water stress area no additional abstraction should be allowed as because it exceeds the safe yield limit and to keep the static water level in present condition.

***Keywords:*** *Aquifer, Groundwater, Borelog, Water stress and Water level.*

## 1. INTRODUCTION

Water is a primary natural resource that is required for various activities, including industrial, agricultural, drinking, household, recreational, and environmental ones (Iqbal & Gupta, 2009; Raju et al., 2011; Dhanasekarapandian et al. 2016). Globally, irrigation activities and industrial as well as domestic water supplies are largely dependent on the Ground water reserve (Adhikary et al., 2011; Hoque et al., 2007). However, this resource, like many other valuable natural resources, is being exploited at an alarming rate all over the world. Therefore, development and management of this useful resource is an important subject matter in the field of modern hydrogeology (Hoque et al., 2007; Elango and Sivakumar, 2005; Butler, 2000).

As water is a critical element in development, and many efforts have been made in Bangladesh to improve safe drinking water coverage, while optimizing the use of water for irrigation, industrial use, and other uses; but these efforts often overlook the holistic perspective of sustainable development. Sustainable solutions to water problems require a paradigm shift from compartmental sub-sector-wise development to holistic water governance. Such a paradigm is encapsulated in the Integrated Water Resources Management (IWRM) concept. Rice production depends on groundwater irrigation. But over-exploitation of groundwater resource leads to a sharp declination of the overall water table because the groundwater recharge rate is not as fast as the extraction rate. A study by Adham et al (2010) showed that around 85% of the area has low, and rest has moderate groundwater recharge potentiality and only 8.6% of the total average annual precipitated water (1685mm) percolates into subsurface and ultimately contributes to recharge the groundwater. National Water Policy (1999) emphasis on the conjunctive use of surface water-groundwater and its economic use for sustainable groundwater supply and management. A study by Haque at el, (2012) showed that the declining trend of groundwater level in dry season in the vicinity of Padma happen due to lowering of peak river water level and substantial use of groundwater. Groundwater level in the Barind areas is gradually declining causes anxiety for the national food security and livelihoods. The global goal for water of UN will call for improved water governance and action in the area of policy making, legislation, planning, coordination and administration. A study by Zahid (2022) is also mentioned that in developing countries like Bangladesh, a scientific and instrumental management is lacking. Therefore, the paper examine to investigate the aquifer system and groundwater level up to union level of Rajshahi District.

## 2. METHODOLOGY

### 2.1. Location of the Study Area

The study area is located in Charghat, Paba, Bagmara, Puthia, Durgapur, Tanore, Mohanpur, Godagari, Bagha Upazilas of Rajshahi district. It consists of 9 (nine) Upazilas, 14 (fourteen) Pourasavas and 71 (seventy one) unions. Its total area is 96.69 km$^2$ and is situated on the northern banks of the river Padma. This study area belongs to the dry humid zone with average annual rainfall varies from 1200mm to 1400mm. Rice is the predominant crop in all season. Three types of rice such as Aus, Aman, Boro are grown in this area. Among them, Boro rice is fully irrigated rice that is mostly fulfilled by groundwater.

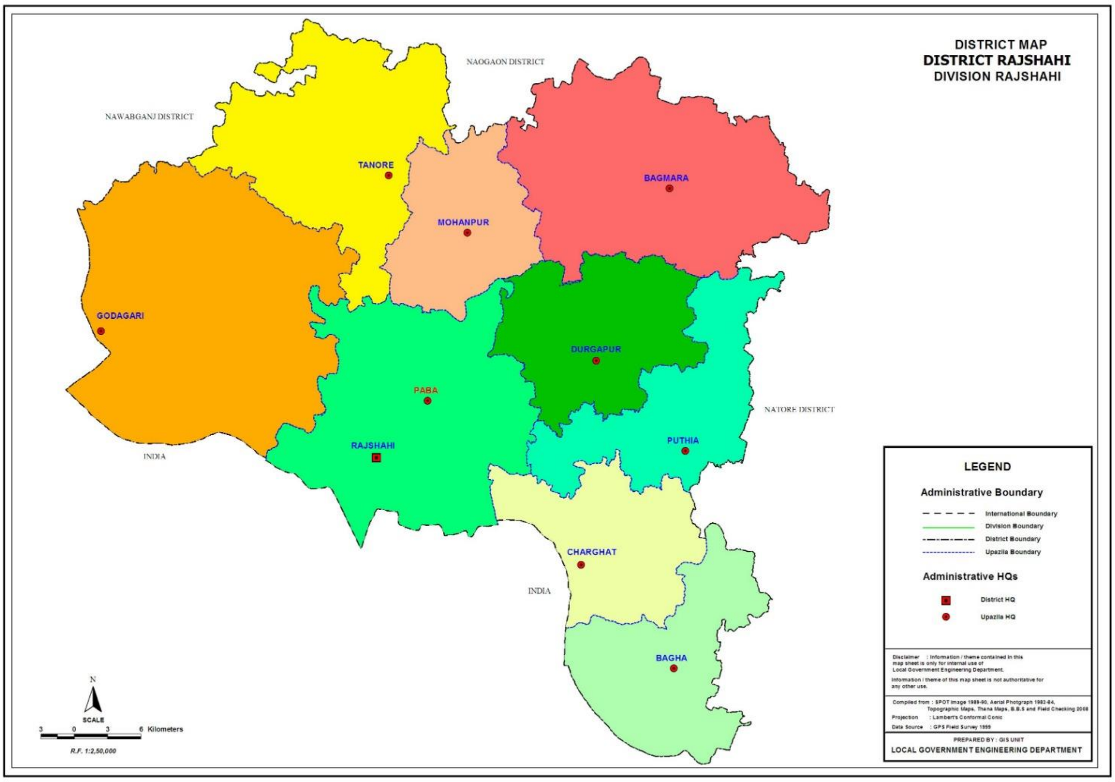


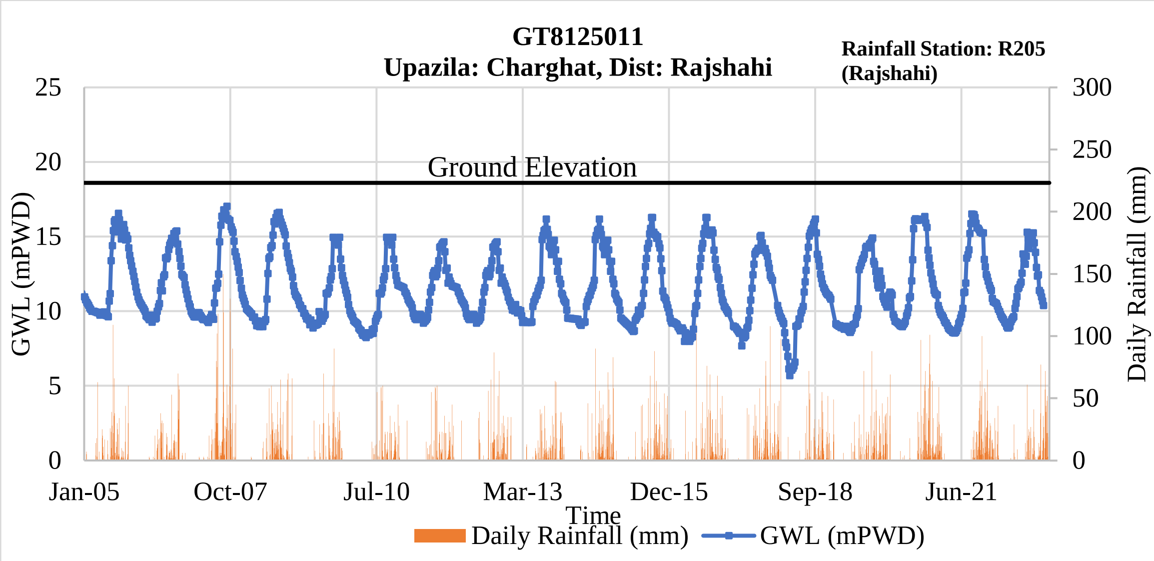

Figure 1: Location of base map of Rajshahi District

## 2.2. Data Collection

Hydro-meteorological data that has been collected for the study includes rainfall, evaporation, temperature, relative humidity, sunshine hours. BWDB and BMD have very good data collection network. Existing historical data have been collected from BWDB, BMD and other relevant agencies. Rainfall data have been collected for the duration of 1985 to 2022. Existing hydro-geological data that includes groundwater level, lithologs and aquifer properties have been collected from available secondary sources. In addition, to fulfill the data gap, a comprehensive field investigation program have been conducted that includes exploratory drilling at 19 locations in 2020. Exploratory drilling depth of the study area varies from 116 m to 426 m. During exploratory drilling washed sediment samples have been collected at 3m intervals. For assessing the aquifer geometry of different aquifer systems exist in and around the study area, 220 Nos. of litholog data have been collected from BADC, BMDA, BWDB and DPHE. The depth of collected data varies from 39m to 450m.

## 2.3. Groundwater Level

There are 10 nos. of BWDB groundwater monitoring wells located in the study area which have been monitored by BWDB for a long period and have long term time series data for modelling. To fill up the data gap and comparison with the existing data collected from secondary sources, 36 nos. of groundwater monitoring wells have been installed in the study area. The deep exploratory drillings at Badhair union shows that only one aquifer exists at the depth of 36-48 m upto the drilling depth of 426m. Groundwater level data is being checked for consistency following the standard procedures of Institute of Water Modelling (IWM) Handbook. Plot of groundwater level at Charghat (GT 8125055) along with rainfall of Rajshahi (R205) and Plot of groundwater level at Tanore (GT 8194046) along with rainfall of Tanore (R219) is shown in Figure 2. There is a negligible declining trend is seen in the groundwater level of Charghat. But from the analysis of groundwater level of Tanore, there is a huge and alarming declining trend is seen. About 8 m decline has been found for Tanore area over the period of 2005 to 2022.



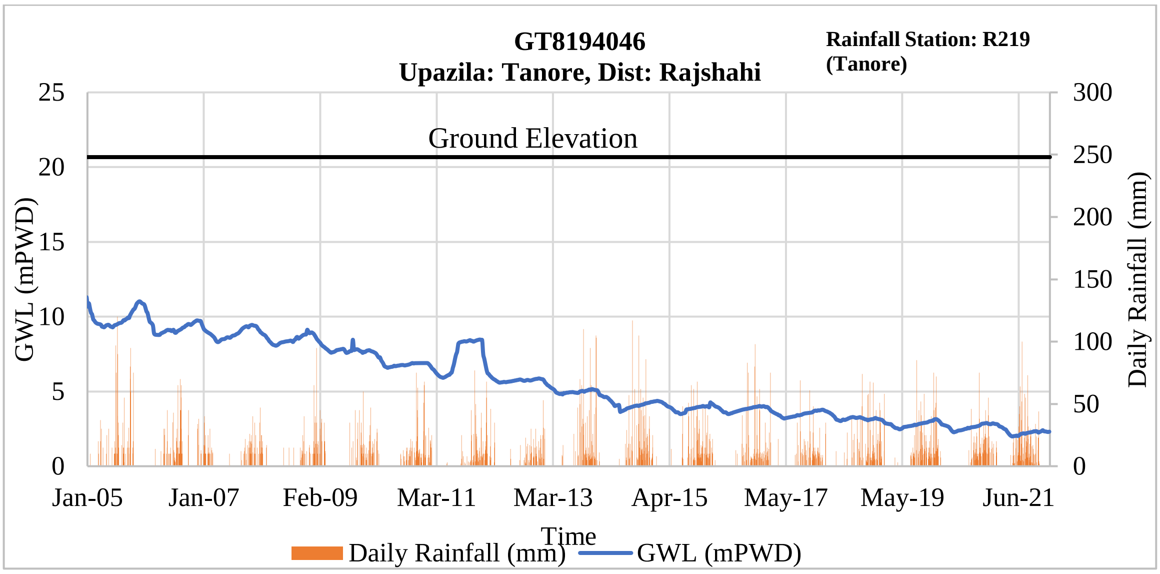




Figure 2. Plot of Groundwater Level Data at Charghat in GT 8125011 and at Tanore in GT 8194046

## 2.4. Groundwater Level Trend Analysis

To perform the groundwater level trend analysis the annual maximum and minimum water table depth of groundwater readings have been extracted from the database and a linear regression performed on each set. The rate of variation (slope) of each set has been extracted and classified into the trend types according to the definitions as shown below.

| TYPES | RATE OF VARIATION (**MAXIMUM DEPTH**) | RATE OF VARIATION (**MINIMUM DEPTH**) | DESCRIPTION |
|---|---|---|---|
| Type-I | falling @ > 0.00 m/yr | falling @ > 0.15 m/yr | These wells have strongly declining levels in both minimum groundwater depths and maximum groundwater depths. There is little or no wet season recovery observed. Note that some of the early stage decline patterns have characteristics of Type 2. In this case abstractions and losses are much higher than annual recharge leading to rapid declines in both maximum and minimum depths of the water table. |
| Type-II | falling @ 0.00 to 0.58 m/yr | falling @ 0.025 to 0.15 m/yr | Groundwater trends where the dry season minimum groundwater depth is declining and the wet season induced recharge top-up appears insufficient to fully restore groundwater levels. This type is characterised by strong declines in the maximum depth of the water table and some decline in the minimum depth. Whilst recharge is being induced by a deeper water table at the end of the dry season abstractions and losses, the monsoon top-up appears insufficient to return the water table to its previous position |
| Type-III | falling @ 0.025 to 0.30 m/yr | falling @ 0.025 to rising @ 0.08 m/yr. | Groundwater trends where the maximum depth is declining but there is no decline in the minimum depth. The decline in seasonal maximum water table depth reflects increasing abstractions and losses. There is some induced recharge occurring due to increased capacity for recharge during the wet season. The wet season recharge is currently sufficient to make up the dry season deficit |
| Type-IV | falling @ 0.025 to rising @ 0.025 m/yr | falling @ 0.025 to rising @ 0.025 m/yr | Both minimum depth and maximum depth show no trend. These wells have steady groundwater levels which fluctuate seasonally but the wet season recharge is at least sufficient, or more than sufficient, to account for the dry season losses and abstractions |

From the trend analysis of groundwater level data at 52 locations, it has been found that 16 nos. fall under Type-I (these wells have strongly declining levels in both minimum groundwater depths and maximum groundwater depths), 31 nos. fall under Type-II (groundwater trends where the dry season minimum groundwater depth is declining and the wet season induced recharge top-up appears insufficient to fully restore groundwater levels), 04 nos. fall under Type-III (groundwater trends where the maximum depth is declining but there is no decline in the minimum depth) and only 01 no. fall under Type-IV (both minimum depth and maximum depth show no trend ) indicating occurrence of insufficient recharge to compensate abstractions in most part of the study areas which is very alarming which is shown in Table 1.

Table 1: Different Trend Types based on Observation Wells

| District | Upazila | No of Observation Wells | | | |
|---|---|---|---|---|---|
| | | **Type-I** | **Type-II** | **Type-III** | **Type-IV** |
| Rajshahi | Baghmara | | 03 | 01 | |
| | Charghat | | 05 | | |
| | Durgapur | | | 01 | |
| | Godagari | 03 | 10 | | |
| | Mohanpur | | 03 | | |

| | | | | | |
|---|---|---|---|---|---|
| | Paba | 03 | 07 | | |
| | Puthia | | 02 | 02 | 01 |
| | Tanore | 05 | | | |
| | Porsha | 05 | 01 | | |
| **Total** | | **16** | **31** | **4** | **1** |

## 3. RESULTS AND DISCUSSION

### 3.1. Aquifer System Based on Lithologic Logs

The borelog data available in secondary sources and exploratory drilling under this study has been used to define the lithological formation of the study area. Rajshahi district mostly falls under the two physiographic units: Barind Tract and Ganges Flood plain. Tanore and Godagari upazilas fall under the unit of Barind Tract where a thin aquifer exists in the shallow depth except some eastern part of Tanore and Godagari upazila. The thickness of the aquifer varies from 3 to 6 m and depth to groundwater table for 1st aquifer varies from 23 to 34 m for these areas. In Badhair union of Tanore upazila, no aquifer exists below the 1st aquifer up to a drilling depth of 426m. A thick aquifer presents in Soranjai, Pachandor, Talando and Kamargaon unions in the eastern part of Tanore and Godagari upazila where the aquifer thickness varies from 27 to 72 m. In the area depth to groundwater table has declined down to a depth of 25-27 m. Puthia, Bagha, Paba, Charghat and Bagmara and part of Mohanpur upazilas fall under the unit of Ganges River Floodplain where multi-aquifers exist. The depth to groundwater table ranges from 3 to 21 m except some parts of Mohonpur and Bagmara uapzilas. In Mohonpur, Tanore and Godagari area, declining trend of water level is very alarming and further abstraction of groundwater is not recommended. Mundumala pourashava and Badhair union falls under critical conditions in terms of subsurface lithology and groundwater level declining trend that required special attention for further development. The upazila wise description of lithologic cross sections of Rajshahi district are shown in Figure 3.

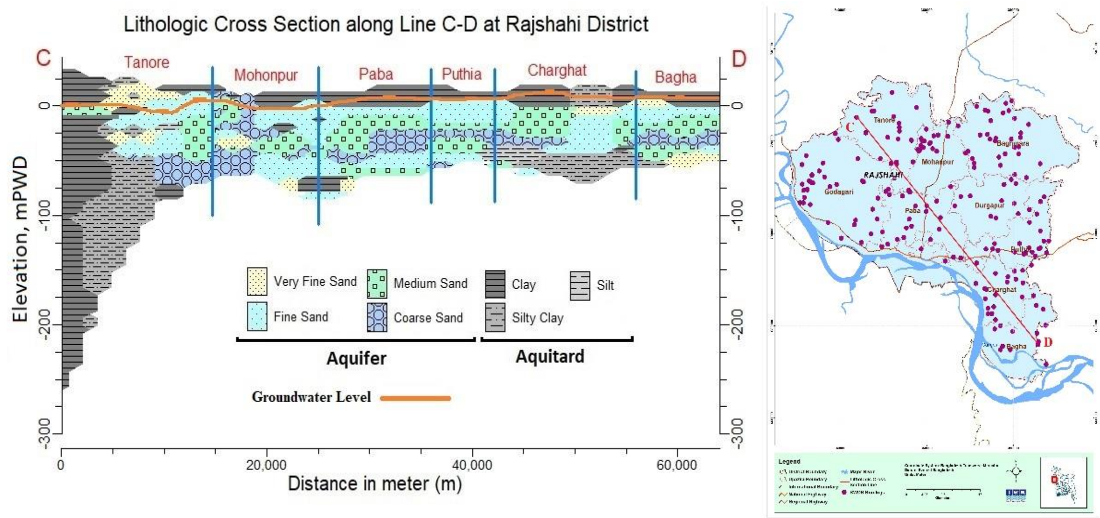



Figure 3: Lithologic Cross Sections with Groundwater Table along Line C-D at Rajshahi District

To understand the aquifer geometry of different aquifer systems, exist in and around the study area, lithologic cross section has been prepared. A sample of lithologic cross section at Tanore upazila under Rajshahi district is shown in Figure 4. From the diagram it reveals that aquitard are mostly composed of clay and silty clay sediment materials and aquifers are mostly composed of medium to coarse sand with occasionally fine sand sediments. It also reveals that the northwestern part of Rajshahi district is dominated by clay and silty clay layers and the opposite part (southeastern) is dominated by medium to coarse sand layers.

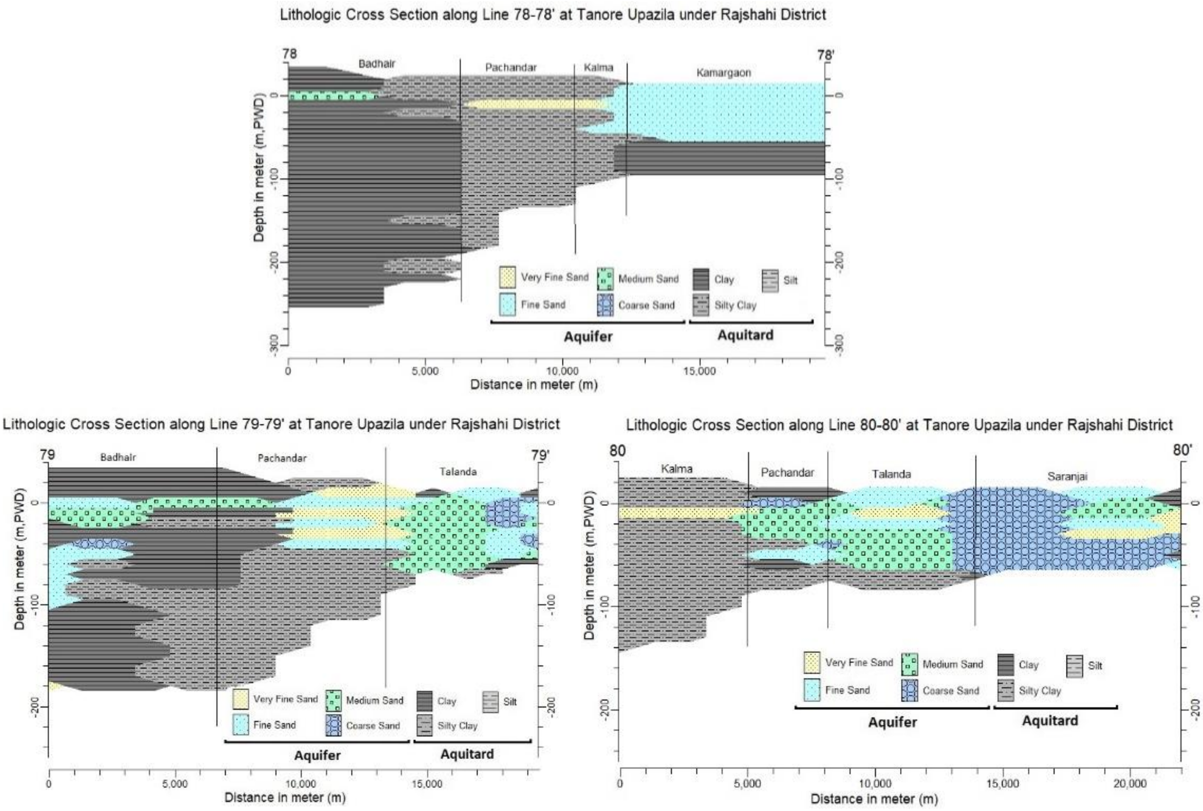



Figure 4: Lithologic Cross Sections under Different Unions of Tanore Upazila.

### 3.2. Hydraulic Characteristics of Aquifer Sediments

For the calculation of hydraulic properties of aquifer at Rajshahi district, 22 aquifer pump tests data were collected from 9 upazilas of Rajshahi district. Among them 10 aquifer pump tests were conducted in the existing Deep Tubewell (DTW) of BMDA, and 3 aquifer pump tests were conducted in newly installed Production Well (PW). The rest of the tests data are collected from secondary sources. The aquifer pump test data have been analyzed by AQTESOLV software considering Theis's method, Cooper-Jacob method and Theis's Recovery methods, wherever applicable. The location of collected aquifer pump tests data from different sources are shown in Table 2. The transmissivity values at Rajshahi district vary from 643 to 7437 m2 /day whereas the storage coefficient ranges from 0.0000124 to 0.0133 for 1st aquifers. At Bagha, Bagmara, Durgapur, Mohonpur, Puthia, and Paba upazila, the aquifer possesses moderate to high transmissivity values. At Charghat upazila, the aquifer has low value in Sardah union whereas Chandpur, Kakramari and Nimpara union have moderate transmissivity value. These types of variation occur due to aquifer thickness as well as lithologic variation in shorter distance. In Tanore upazila at Kalma union has moderate transmissivity value whereas at Talando, Tanore and Chanduria unions have high transmissivity value. At Godagari upazila, the aquifer in Deopara union has lower transmissivity value. Storage coefficient values and geological section indicates that the aquifer might be semi-confined to confined aquifer in nature.

Table 2: Hydraulic Properties of Aquifer Sediment Based on Aquifer Pump Test at Rajshahi District.

| Sl. No | Upazila | Union | Pump Locations | | Transmissivity ($m^2/d$) | Storage coefficient |
|---|---|---|---|---|---|---|
| | | | Latitude | Longitude | | |
| **Primary Aquifer Pump Test Data** | | | | | | |
| 1 | Bagha | Bajubagha | 24.20068 | 88.85528 | 5003 | 0.0005013 |
| 2 | Bagmara | Bhabaniganj | 24.58628 | 88.81994 | 2702 | 0.0009173 |
| 3 | Bagmara | Goalkandi | 24.55623 | 88.85174 | 2278 | 0.0006804 |
| 4 | Charghat | Chandpur Kakramari | 24.25474 | 88.76562 | 2198 | 0.0004545 |
| 5 | Charghat | Nimpara | 24.34713 | 88.83285 | 2422 | 0.0133153 |
| 6 | Durgapur | Joynagar | 24.44962 | 88.69660 | 4668 | 0.0011549 |
| 7 | Mohonpur | Raighati | 24.60125 | 88.67437 | 4678 | 0.0004678 |
| 8 | Paba | Nawhata | 24.45239 | 88.58545 | 2600 | 0.0004121 |
| 9 | Puthia | Geopara | 24.41109 | 88.86434 | 2091 | 0.0034492 |
| 10 | Tanore | Tanore | 24.54381 | 88.57348 | 6387 | 0.0071758 |
| **Secondary Aquifer Pump Test Data** | | | | | | |
| 11 | Bagha | Manigram | 24.21000 | 88.79630 | 2226 | 0.001000 |
| 12 | Bagmara | Gobindapara | 24.67376 | 88.74136 | 2363 | 0.0000527 |
| 13 | Charghat | Sardah | 24.31260 | 88.72550 | 916 | 0.000551 |
| 14 | Durgapur | Maria | 24.44425 | 88.76186 | 2919 | 0.000072 |
| 15 | Godagari | Deopara | 24.42289 | 88.50383 | 643 | 0.000671 |
| 16 | Mohonpur | Royghati | 24.62365 | 88.66596 | 3165 | 0.0000181 |
| 17 | Puthia | Puthia | 24.37152 | 88.83786 | 2814 | 0.001773 |
| 18 | Tanore | Chanduria | 24.52011 | 88.56024 | 4734 | 0.0020146 |
| 19 | Tanore | Kalma | 24.67630 | 88.56220 | 1363 | 0.000357 |
| 20 | Mohonpur | royghati | 24.61305 | 88.63559 | 4433 | 0.0004269 |
| 21 | Rajshahi Sadar | Shahmukhdum | 24.39777 | 88.62563 | 3949 | 0.0004525 |
| 22 | Tanore | Talando | 24.60519 | 88.56337 | 7437 | 0.0000124 |

## 4. CONCLUSIONS

From analysis of groundwater table trend, it has been found that groundwater table in most of the area are declining. It is revealed that 29 unions of different upzilas of Rajshahi district has been identified as high water stress area. On the other hand, the deep expoloratory drilling at Badhair union shows that only one aquifer exists at the depth of 36-48m upto the drilling depth of 426m. At Badhair union, the groundwater table is 32.92m. In some areas such as Kalma union and Mundumal pourashava under Taonre upazila as well as Deopara union and Kakonhat pourashava under Godagari upazila, the groundwater table has declined to aquifer layer which is very alarming for these areas. Mohonpur, Tanore and Godagari areas, declining trend of water level is very alarming.

At Bagha, Bagmara, Durgapur, Mohonpur, Puthia, Paba and Rajshahi upazilas, the aquifer possesses moderate to high transmissivity values. At Charghat upazila, the aquifer has low value in Sardah union whereas Chandpur, Kakramari and Nimpara union have moderate transmissivity value. These types of variation occur due to aquifer thickness as well as lithologic variation in shorter distance. From the identification of water stress area, it has been found that 3 unions of Godagari upazila, 1 union of Mohonpur upazila, 3 unions of Paba upazila and 6 unions of Tanore upazila under Rajshahi district falls in the very high water stress area. It also has been found that 2 unions of Bagha upazila, 1 union of Baghmara upazila, 1 union of Charghat upazila, 3 unions of Durgapur upazila, 3 unions of Godagari upazila, 4 unions of Mohanpur upazila, 1 union of Paba upazila, 1 union of Tanore upazila under Rajshahi district falls in the high water stress area. In the high water stress area no additional abstraction should be allowed as because it exceeds the safe yield limit and to keep the static water level in present condition. In the low stress area, some abstraction exceeding the present limit may possible.

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