

Evaluation of Subsurface Geologic Formation in the Barind Tract, Rajshahi, Bangladesh

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Abstract

Hydrogeology is the area of geology that deals with the movement of groundwater in the soil and rocks of the Earth's crust. The study area, which is a north western part of Bangladesh, is one of the most diversified physiographic unit and the irrigation is almost entirely depends on groundwater. But over exploitation indicates falling groundwater heads in this area. So, to assess the sustainability of this yield it is necessary to examine carefully the nature of the aquifer system. In this connection about 1200 borehole data have been processed and analysed to study the geologic formations. In the investigated area three subsurface geologic formations are clearly identified. Maps of formation thickness and index have been prepared to identify the geometry of the aquifer system. Representative panel diagram, 3-D stratigraphic and cross-sectional views are also prepared for necessary assessment of the variation of individual subsurface stratum in different locations.

Keywords: Subsurface, Groundwater, Aquifer, Stratigraphic.

1. Introduction

Groundwater is considered as the largest available source of freshwater in Bangladesh. The optimum development and management of groundwater resource for mitigating human demands, needs a proper investigation of the water bearing formation of an area and its properties and characteristics [1]. Hydrological condition of the area depends on many parameters such as topography, geology, drainage system, rainfall, evaporation, soil characteristics, recharge, discharge and hydraulic properties of the aquifer [2]. The qualitative and quantitative availability of groundwater is generally influenced by varying geology, physiography and climatic conditions. The groundwater resource management is vital for human survival and is not feasible unless complete assessment of the system is made. Lithological logs are a source of valuable data for hydrogeologic studies.

1.1 Geography of the Study Area

The study area Barind Tract, consists of Nawabganj, Naogaon and Rajshahi districts. It lies between 24°07' N to 25°13' N latitude and 88°00' E to 89°10' E longitude (Fig. 1). The alluvium is composed of mostly clay, silt and fine sand and are well oxidized and typically radish brown in color. The water condition is low due to firm and compact material [3]. There are three main seasons in the study area — Winter, Pre-monsoon and monsoon or rainy [4]. About 80% or more of the annual precipitation occurs during monsoon period. The average temperature ranges from 35°C to 25°C in the dry season and 9°C to 15°C in the winter season. The average population density of this area is about 804.47 km² [5].

2. Methodology and Description

Position and extent of different hydrological units is very important to understand the geometry of the aquifer. This information also important for the drillers to design the abstraction well [6]. Borehole lithological data is an important source of information for obtaining the subsurface distribution [7, 8, 9, 10, 11]. On the basis of borehole data, geological cross-sections, and panel diagram, the vertical continuity of different groundwater bearing formations are demarcated. The reliability of the information depends not only upon the accuracy of the data but also on the number of available data sources. About 1200 borehole data collected from Barind Multiple

Development Authority (BMDA) for the study area, have been processed, analyzed and interpreted for quantitative hydrogeological studies. The study area along with the data points is shown in Fig. 2. The distribution of data points in the area investigated is clearly observed from the figure. An effective study area has been drawn considering the sufficient data points within the area studied. The geometry constituted by the continuous line is considered as analytical area and different maps of interpretation are to be presented in that form (Fig. 2).



Fig. 1 Study area of Barind Tract

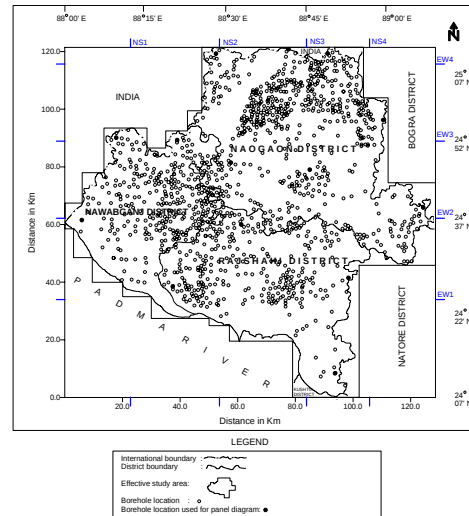


Fig. 2 Investigated area

2.1 Subsurface Layer Formation

A top clay layer, sand layer of different grain size and at the bottom (in maximum location) an impermeable clay zone is the common geologic formation in the area. Studying the grain size, the sand layer is clearly subdivided into five parts, below the top clay which is fine in grains and others below that are consist of fine-medium, medium, medium-coarse and coarse in grain generally termed as “Composite Sand”. The composite sand formation is overlying an impermeable clay zone which is very common in the area and usually known as “Black Plastic Clay” (BPC) due to high plasticity and black color. The maximum and minimum depths of borehole information are 24.3 m and 79.2 m respectively. According to the borehole information, the subsurface formations of the area are divided into three main layers:

Top Clay Layer: This clayey formation is very common in the area. The thickness of this layer is from 1.5 m to 51.8 m. Fig. 3 shows the variation of clay thickness of the study area. This clayey layer is overlying the only sandy formation recorded in the area studied.

Sand Layer: In the investigated area the composite sand formation is the only usable groundwater source. The thickness of composite sandy layer of the study area has been estimated using the lithological information and presented in Fig. 4. This figure gives a clear quantitative understanding of the presence of usable water saturated formation in different regions of the area studied. The thickness of composite sand varies between 3 m to 68.5 m. Fig. 4, it is clearly observed that in the north-western corner and in some places of middle of south-western corner, the thickness is estimated low but in the rest of the areas the thickness of composite sand formation is recorded above 20 m. So, it could be said that the area occupied high thick bed of composite sand is more favorable for groundwater exploration and the thick bed could be used for small scale abstraction.

Impermeable Zone: The impermeable zone in general, is underlying the composite sand formation. The physical shape of different layer interfaces have been presented in a generalized form with respect to a datum chosen at a depth of 60 m below mean sea level. The interbedded views along with the earth surface have been presented in a single view from two directions (Fig. 5) for a comparative study. These figures give clear and detail idea about the variation of the thickness of different formations at any specific location of the investigated area.

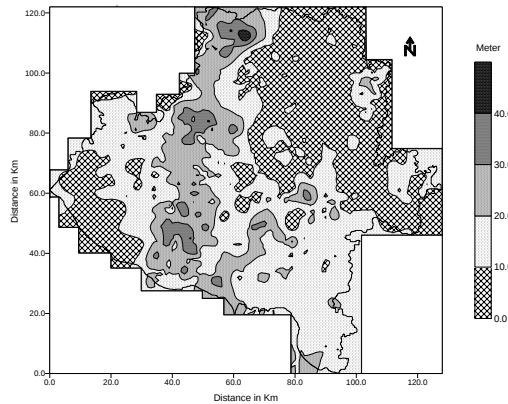


Fig. 3 Contour map of top clay (1st layer) thickness

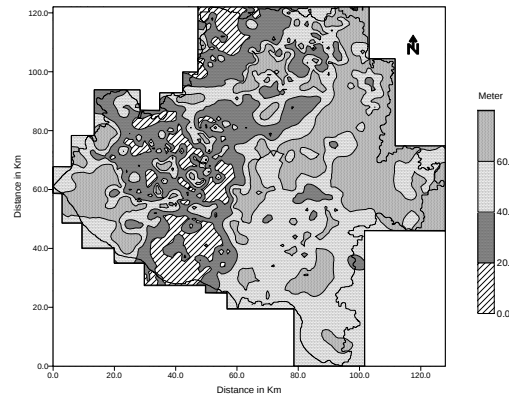


Fig. 4 Contour map of composite sand thickness

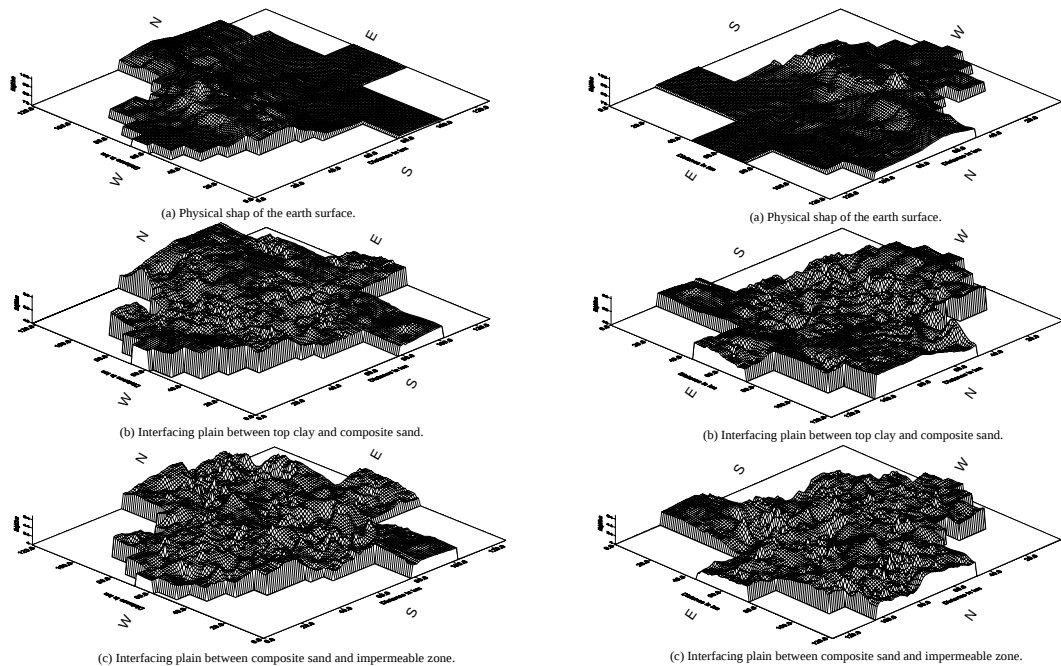


Fig. 5 Different surface views w.r.t. datum (Left: view from south-west and Right: view from north-east corner)

3. Panel Diagram

Construction of stratigraphic panel diagram is important to obtain the clear idea about the subsurface hydrological condition in different parts of the area. It also helpful to understand the geometry of the aquifer and the relation between the various beds and formation in geologic system. For this purpose, borehole data from 14 locations are selected to covering the whole study area to construct a panel diagram (**Fig. 6**) it is evident that the subsurface formation of the area is divided into clay and sand. The sand formations is embedded between top clay and lower impermeable zone. The clay thickness is very high in north-western corner and south-western part of the area. In the north-eastern part the top clay thickness is low. The overall sand thickness of the study area is good. In the western part, the presence of fine-medium and medium sand is observed. In the north-western corner, medium sand is dominated. In the eastern part thick bed of medium-coarse and coarse sand is recorded.

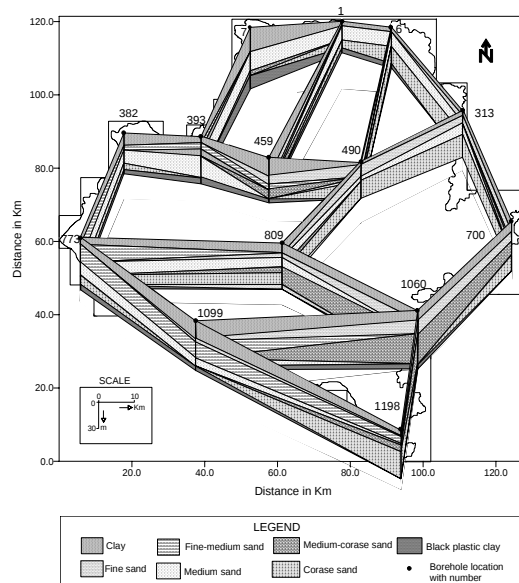


Fig. 6 Panel diagram of the study area

4. Stratigraphy

The stratigraphy is an essential tool in the search for water in areas of wide spread sedimentary rock. The position and thickness of water bearing horizons and the continuity of confining beds are of particular importance in the development of groundwater exploration zones. The three dimensional model of the individual layers of the study area have been prepared and shown in Fig. 7. This model gives a clear understanding of geologic formations of the area studied.

4.1 Stratigraphic Cross-section

Subsurface hydrological cross-sections are normally the best way to ascertain the nature and location of aquifer. To observe the cross-sectional views in different parts of the effective investigated area eight representative vertical sectioning along the profiles of both north-south and east-west directions have been prepared. The orientations of the profiles e.g., NS1, EW1, etc are shown in Fig. 2. The figures have been drawn considering the thickness of different subsurface geologic formations. The sectional views clearly distinguished the earth surface elevation and the variation of different layer formations along the profiles. Fig. 8 represent the vertical divisions of subsurface formations along the profiles oriented in the north-south and east-west direction. The cross-sections furnish a clear picture of different stratigraphic units or layers underneath. The top clay layer is present everywhere. Fine and fine-medium sand are not available every places. But medium, medium-coarse and coarse sand are present in most of the places and there thickness are also satisfactory. From this figures it could be concluded that in most of the areas the subsurface geology is favorable for groundwater development provided the other conditions are agreed. So, these sectional views would definitely play an important role for selecting suitable well sites and its designing.

5. Formation Index

Potentiality of water saturated zone may be quantitatively represented by means of some index map. Fig. 9 represent the index map of sand-clay thickness. The thickness of the composite sand formations, in general is found 3 times than the clay formation in the study area. In the total area of the north-eastern side the thickness of sand is found more than 6 times of clay thickness. In the south-western corner, gradual increase of sand thickness is observed. It is clear from the index map that in general the subsurface formation is suitable for groundwater exploration.

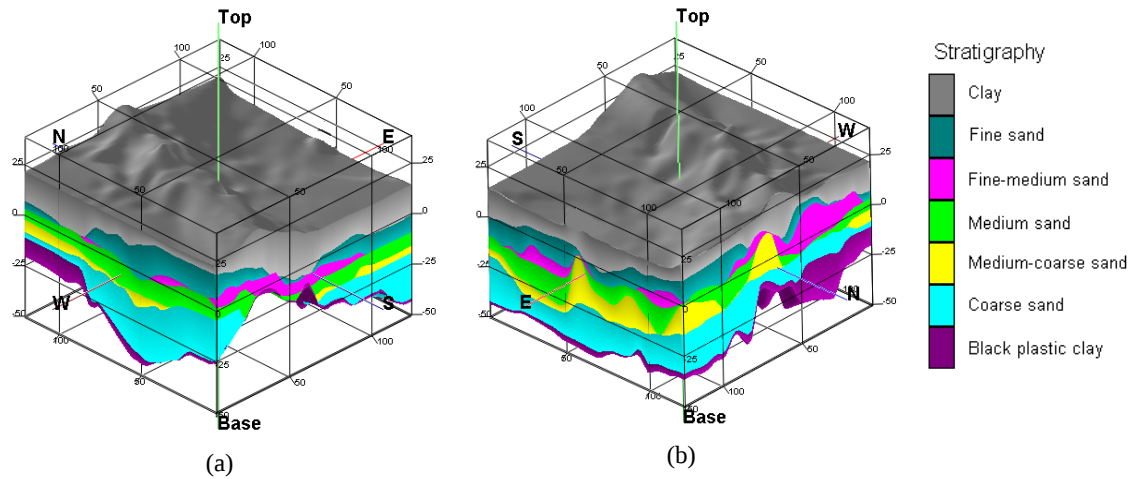


Fig. 7 3-D stratigraphic view of the investigated area (Distance in km, Height in m);
a) view from south-west corner, b) view from north-east corner.

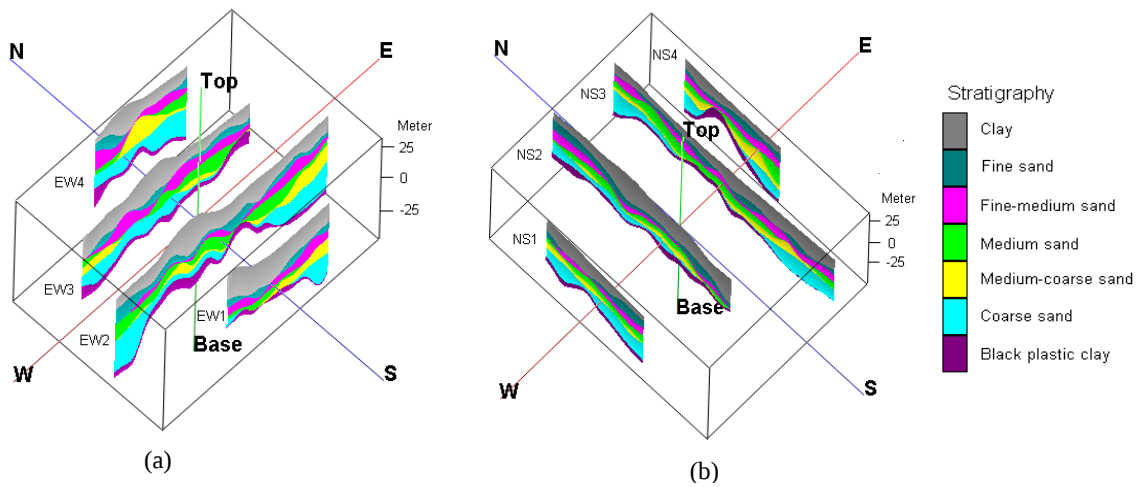


Fig. 8 Stratigraphic view along different profiles of the 3-D model of Fig. 7

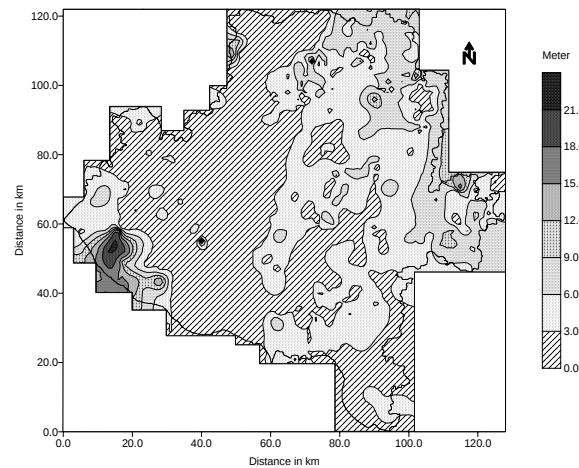


Fig. 9 Contour map of composite sand - clay thickness

6. Conclusion

The total subsurface discreteness of the study area is performed by detailed study of lithologs. Seven distinct hydrostratigraphic layers have been identified in accordance of its vertical distribution and lithological composition. They are top clay, fine sand, fine-medium sand, medium sand, medium-coarse sand, coarse sand and at the bottom impermeable BPC. Only top clay exists everywhere and the other being anomalously distributed.

To express in more convenient established terminology, aforementioned layers and units are defined into different distinct hydrogeological terminologies. On the basis of borehole information the groundwater bearing sequence of the area have been mainly divided into two hydrostratigraphic units: aquitard and aquifer consist of clay and sands of different grain size respectively. In most of the areas the thickness of the clay cover is below 20 m and only in a specific north-south stripe it is found above 20 m. The lithological data of this area have confirmed the presence of aquiferic materials of different granular, in this work this formations is termed as composite sand. This aquifer is just below the top clay. The thickness of this composite sand in the eastern side of the area is found greater than 40 m. Similar composition is observed in south-west corner. In the rest part of the area it is below 40 m. The interfacing planes of the top clay and impermeable BPC with the imbedded sands are also presented. To observed the vertical distribution of different geologic formations in different parts of the area a panel diagram has been prepared. 3D stratigraphic view of the investigated area in different angles have been constructed considering individual sand formation. Stratigraphic cross-section have also been shown along the north-south and east-west profiles. Formation index is an important parameter in groundwater development. In this relation, the composite sand-clay ratio i.e., the index map of the investigated area has been prepared.

The detail study of formation evaluation of the area investigated reveled that geologically it is suitable for groundwater exploration however for large-scale abstraction sites should be selected consciously.

Acknowledgement

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