Estimation and Evaluation of Subsurface Formation of Pabna-Sirajgonj Districts, Bangladesh

Md. Saiful Islam
Electronic and Telecommunication Engineering
Pabna University of Science and Technology
Pabna, Bangladesh

Abstract:- Groundwater is an important natural source of water supply throughout the world. It is precious and most widely distributed resource. The use of groundwater is increasing day by day in irrigation, domestic water supply, municipalities, rural areas, and industries. It gets its replenishment from precipitation, surface flow and reserves. Now a day's large scale abstraction results in lowering of groundwater level is a serious threat to future groundwater irrigation development. Bangladesh is no more exception to the deteriorating condition of the water resources systems. So, a detailed study is needed to identify the subsurface formations. One of the most important aspects for groundwater investigation program is the knowledge about the underlying formations. It gives a clear picture of the information needed, such as, the probable aquifer, its location, thickness, composition, etc.

In this research, the lithological borehole data of 467 locations have been collected, compiled, processed, analyzed and interpreted for studying the hydro-geological properties of 18 upazillas of the study area. Borehole log is one such method that furnishes information on substrata in vertical line from the surface. These furnish a description of the geologic character and thickness of each stratum encountered as a function of depth, thereby enabling aquifers to be determined. Shaded contour maps of clay, fine sand and composite sand thickness have been presented for qualitative study of groundwater potentiality of the area. Yield potential index map of the water saturated zone selects the suitable potential zone and hence identifies the proper location of well-sites. Stratigraphic and cross-sectional views in various orientations are prepared to visualize the subsurface of the study area. Stratigraphy influences the formation and distribution of groundwater. It studies the surface feature of the area and plays an important role in selecting the well sites. The availability and abundance of groundwater at different places are influenced by the stratigraphic feature.

Keywords:- *Stratigraphy; Uncofined Layer; Fence Diaram; Groundwater Exploration; Abstraction.*

I. INTRODUCTION

Bangladesh is one of the largest deltas in the world. It has fertile agricultural land, abundant water in wet season but limited water at the time of need in dry season (January to April). Agricultural productivity holds the key to the country's overall economic growth and welfare to its people. So, agriculture is the backbone of the country. Economy largely depends on the agricultural development, which is possible only by producing more crops. Irrigation is the lifeline of agriculture [1].

Adequate knowledge of the characteristics of subsurface water bearing zones is very essential for the development of groundwater in any area. Here the composition and thickness of subsurface formations are important. Lithological data clearly identified seven subsurface geologic formations such as clay, fine sand, fine-medium sand, medium sand, medium-coarse sand and coarse sand-gravel layers in the area investigated. These formations of the area are divided mainly into two layers viz. upper clay layer and composite sand layer according to their water bearing potential. The clay is found as the top layer and the composite sand layer of different grain size.

Geology plays the vital role in the distribution and occurrence of groundwater. Geological mapping of an area depicts the distribution of rock types, their structural relationship and stratigraphy [2].The groundwater geology of the study area has been studied. The subsurface modeling is performed by detailed study of 467 litholog data available in the study area. The thickness of the different geologic formations have been studied and presented in the form of shaded contour maps. The maps of composite sand thickness and yield index have been presented for qualitative study of groundwater potentiality in different regions of the area studied. The three dimensional stratigraphic and cross-sectional views of the study area have been prepared in various profiles to assess the variation of the individual subsurface stratum in different areas.

II. MATERIALS AND METHODS

An effective and fruitful research does not depend not only on the availability and quality of requisite data but also on the appropriate methodology. The subsurface formation is not visible; it resides under the earth's surface. So it not possible to identify the subsurface formations through direct visual measurement and its properties are not be identified and estimated. The present research work has been conducted and completed through appropriate data acquisition. About 467 borehole litho logical data and 85 static water level data have been collected from various relevant organizations as the secondary data. Some primary data like latitude, longitude and elevation of the related locations of the study area have been measured through direct field investigation. Borehole litho log data would provide valuable information of subsurface water bearing formations and help to estimate the thickness of different layers of formation. It would also provide the stratigraphic correlation from well to well; these may be used for detection of bed boundaries, porous and permeable zones. Stratigraphic and cross-sectional views are prepared to visualize the subsurface of the study area. The study area map, the lithological locations map, various formation maps and strtigraphic maps in various extents were generated with the help of available computer programs.

III. DESCRIPTION OF THE STUDY AREA

The study area of the research is the Pabna and Sirajgongonj districts. It lies in the east-southern part of Rajshahi division. The area is bounded by Padma river, Kusthia and Rajbari districts on the south; Jamuna river, Jamalpur, Tangail and Manikganj districts on the east; Natore district on the west and Bogra district on the north. The total area of it is 4869.42 Sq.km and it is situated in 23°48´N to 24°47´N latitudes and 89°00´E to 89°59´E longitudes. The river Padma flows in the extreme boundary of the southern side of the study area and the river Jamuna flows in the extreme boundary of the eastern side of the area. These two rivers meet with each other in the south-eastern corner of the study area. Many rivers like Baral, Ichamati, Atrai, Hurasagar, Chiknai,karatoya and Phuljuri are flowing within this study area. The largest Chalan beel is also situated in this area. Chalan beel is a wet land in Bangladesh. It is a large inland depression, marshy in character, with rich flora and fauna. Forty seven rivers and other waterways flow into the Chalan beel. As silt builds up in the beel, its size is being reduced. Besides, there are a large number of beels here. The study area is located in the flood plains of the Ganges, the Brahmaputta and the Meghna river systems [3].

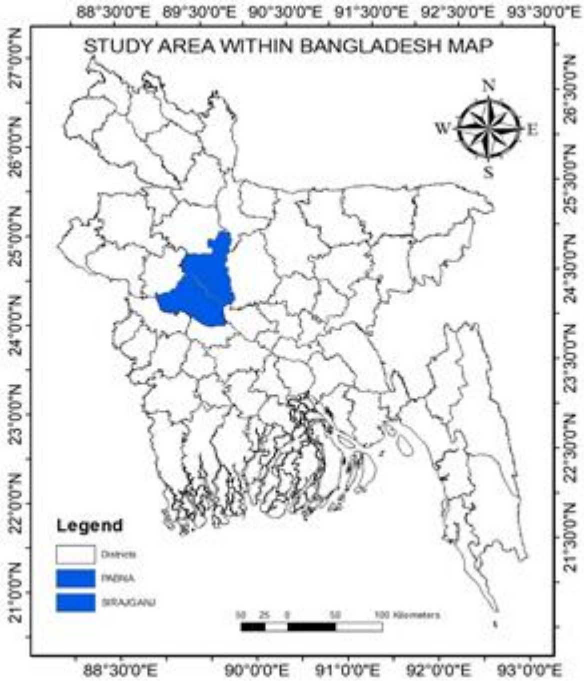


Fig 1:- Study Area within Bangladesh Map.

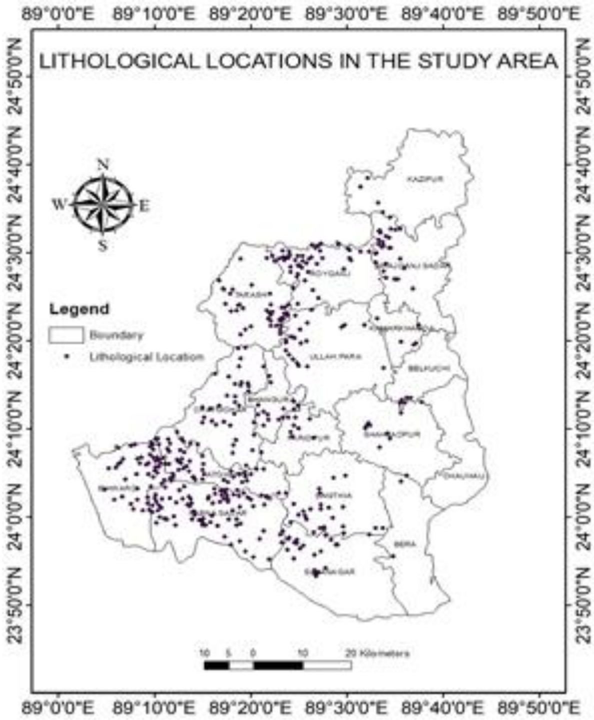


Fig 2:- Distribution of Litholog Points in the Study Area

IV. ANALYSIS OF SUB-SURFACE FORMATION

A. Top Clay

Soils of the investigated area are predominantly clay loam with a few slits at places. This clayey formation is very common in the area. A shaded contour map of the thickness of top clay at 4m interval is shown in Fig.3. The depth of the layer varies from 0.11m–36.26m. The depth of top clay layer of 0.11 m- 4.11 m is found very discretely in the middle and upper portions of the area studied. The clay layer of 4.11m - 8.11m depth is found in the middle-eastern and in the north-western regions of the study area. Some small pockets of the same range of top clay are distributed discretely in almost all over the part of the investigated area. There is a trend of 8.11m-12.11m depth of clay lies in between the range of 4.11m-8.11m of the area that starts from the eastern part and ends to the western part. The 12.11m -20.11m depth of clay layer is found as the major portion of the study area. Two trends of this type of layer are found in the lower and upper portions of the study area. The 20.11m-24.11m depth of clay layer is found in the southern part of the study area which actually lies in the area of Pabna region. Another layer of 24.11m -28.11m is also found in the southern portion of the study area. The 28.11m -36.11m depth of clayey layer has observed rarely. This range of clay layer is not countable as compared to the previous ranges of clay layer. The extraction of groundwater from the thin clayey area would be economical provided other conditions are satisfactory. The clayey layer is overlying the only sandy formation of various types present in the area studied.

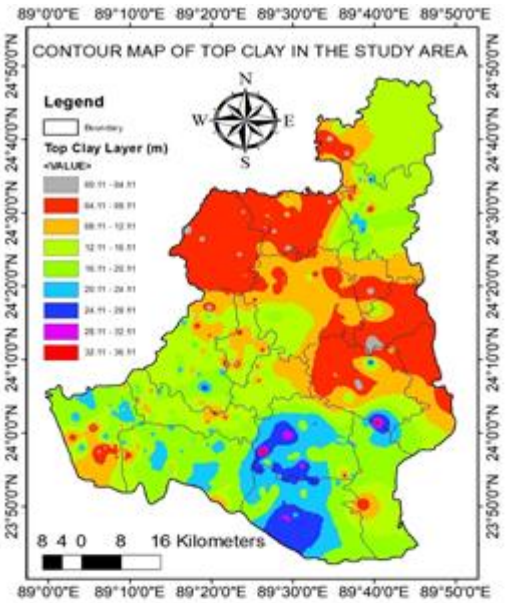


Fig 3:- Contour Map of the Thickness of Top Clay (Interval =4m).

B. Thickness of Fine Sand

The geologic formation of fine sand as the second layer is considered in the study area. The thickness of the fine sand layer has been estimated using the lithological information. A shaded contour map of the fine sand as the second layer has been prepared at 5.40 m interval with the help of available computer software as shown in Fig.4. The map shows that the thickness of the fine sand ranges from 0.25m to 48.85m. The maximum thickness is found in the east-southern portion of the investigated area. It is notable that such portions are negligible as compared to the entire study area. The maximum portion of the investigated area ranges from 11.5m to 16.45m is found in the middle of the study area. A few portions are also found in the northern and southern regions of the study area. There is a trend of the range from 5.65m to 11.05m is found that stars from the western region and ends to the eastern region and it lies in the upper portion of the study area. Besides, some discrete distributions of this formation are found in the northern and southern portions of the area. The rest ranges are not so much prominent and these are distributed discontinuously in the study area. Basically, these formations lie below the clayey formation situated in the top surface of the earth. Where the thickness is high, the groundwater condition of the area is suitable for the extraction of groundwater.

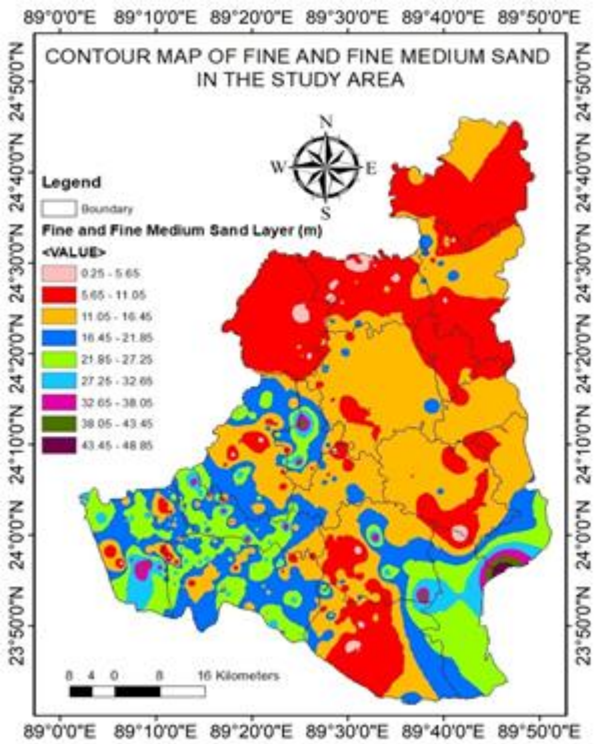


Fig 4:- Contour Map of the Thickness of Fine Sand (Interval =9.08m).

C. Thickness of the Composite Sand

The thickness of the composite sand layer of the study area has been estimated using 467 borehole lithological information. The composite sand is formed with the combination of medium sand, medium-coarse sand, coarse sand and coarse sand gravel. The combination of sand layers of different grain sizes in the study area forms the useable aquifer which extends below the depth of 91.44m and its thickness is undetermined from the available litho logic information. However, in the present work a shaded contour map at 9.08 m interval is prepared from the principal components of sand composition at different litho logical points as shown in Fig.5. The figure shows that the thickness of the sandy formation varies from 9.25 m to

ISSN No:-2456-2165

63.75 m. However, it is observed that there is a trend of the sandy layer of thickness between 27.41 m and 36.50 m from the south-eastern to the north-western corner of the study area.

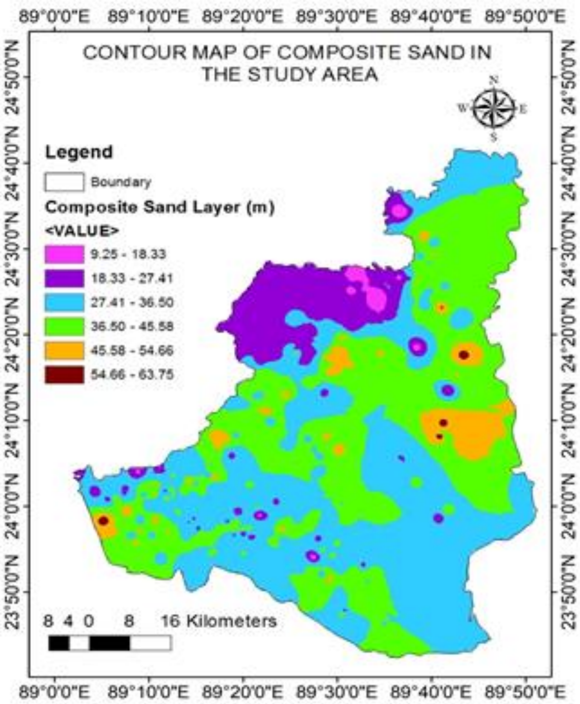


Fig 5:- Contour Map of Composite Sand Thickness (interval = 9.08m)

This trend covers the major portion of the study area. The thickness of the sandy formation between 36.50 m and 45.58m covers a large portion of the study area which is less than the previous one. There are some pockets of this range of the thickness are distributed in irregular manner. The thickness of the composite sand of the range 45.58m to 54.66m is also found as the discrete manners. The highest range of the thickness of composite sand is 54.66m to 63.75m that is found in negligibly in the study area. The thickness of the composite sand of range 18.33m to 27.41 m is found especially in the north-western region of the area investigated. The composite sand thickness map of the study area reveals that this geologic formation could be treated as good groundwater reservoir. However, almost all the area is more suitable regions for groundwater potentiality excepting some portions of it, but the south-eastern side is more suitable for the exploration groundwater.

V. STRATIGRAPHIC ANALYSIS

A. Yield Potential Index

The yield potential index of any area is defined as the ratio of the total thickness of sandy formation to the total thickness of clayey formation. It indicates the proportion of sand thickness and the clay thickness. The area possesses the highest proportion indicates the aquifer dominated area and vice versa. The aquifer dominated area indicates the good regions for groundwater reservation and abstraction. On the other hand, the lowest value of proportion indicates the bad potentiality. This measure is very much effective for the site selection of well construction. The yield index map of the area has been prepared by considering the combined thickness of sand

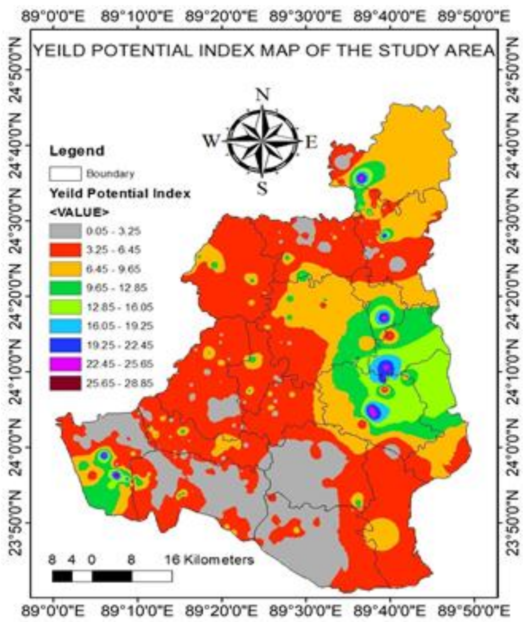


Fig 6:- Distribution of yield potential index.

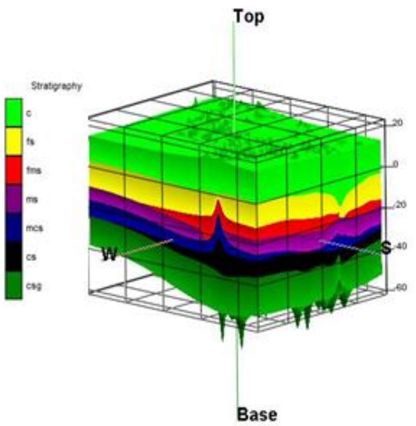
And the thickness of the top clay–silt. Therefore, the distribution of total aquifer yield index has been processed in Fig.6. The aquifer dominated high groundwater potential yield zone having values of 9.65-25.65 and above occupy around 15% region in the study area. The aquitard dominated zones (almost 80 % area) with yield potential index of 0.05-9.65 distributed across the study area indicate a bad potentiality. The higher groundwater potential zone of yield index of 9.65- 25.65 is distributed in the middle of the eastern side of the study area. From the map it is observed that the major portion of the study area having the values of 3.25-6.45 indicates the moderate yield index. This portion is found from the southeastern side to the Middle Western side of the area investigated. There is another trend of lowest values of yield index which extends from the southern part to the western corner of the study area. This area indicates the lowest potentiality for groundwater abstraction. From the observation it is obvious that the upper part of the eastern side and a small region in the south-western corner have the satisfactory potential yield of the study area. These portions are favorable for selecting of well sites. This yield potential index map is widely used for selecting the location of well sites.

B. Panel Diagram

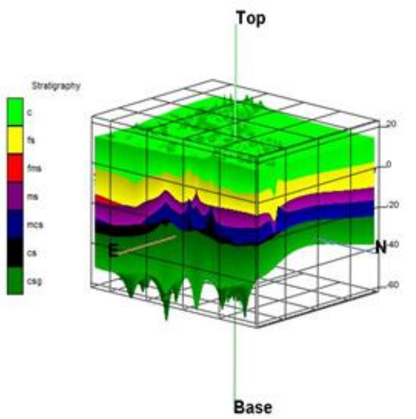
This diagram is extremely useful in predicting the vertical distributions of the subsurface formations. Panel diagram represents an overall view of the subsurface geological formation delineating the major aquifer zones.

The geologic formation is an important factor for the identification of groundwater potential zone. The stratigraphy describes the geometrical and age relations between the various lenses, beds and formations in geologic systems of sedimentary origin. Construction of stratigraphic panel diagram is important to obtain the clear idea about the subsurface hydrogeological condition in different parts of the area. It is also helpful to understand the geometry of the aquifer and the relation between the various beds and formation in geologic system. The diagram is extremely useful in predicting vertical distribution of the subsurface formations. Panel diagram represents an overall view of the subsurface geologic formation delineating the main aquifer zones. Borehole lithological data are an important source of information for obtaining the subsurface formation distribution. The reliability of the information depends not only upon the accuracy of data but also on the number of available data sources. It is customary to present borehole litho logs in a vertical section so that the formation distribution as they actually occur would be recons [4]. For this purpose, borehole data from 467 locations are selected to cover the whole area to construct a panel diagram.

The subsurface geology of the study area has been studied up to the depth of 91.44 on the basis of 467 litho logical logs. The stratigraphic panel diagram is shown in Fig.7. From the diagram it is evident that the subsurface formation of the study area is divided into clay, fine sand, fine medium sand, medium sand, medium coarse sand and coarse sand gravel.



(a). View from south-east corner.



(b). View from the north-east corner.

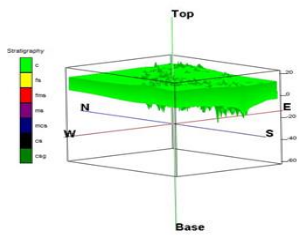
Fig 7:- 3D Stratigraphic view of the study area (Distance in Km, Height in m).

C. Stratigraphic Views

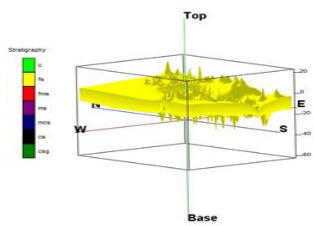
Stratigraphy helps to locate the position and thickness of water bearing formations and continuity of confining beds whereas structural geology helps to locate water bearing formations which have been displayed by earth's movements [5]. The distribution of aquifers and aquitards in a geological system are controlled by lithology, stratigraphy and structure of the geologic formations. The lithology is the physical make up of the sediments or rocks that form the geologic system. Unconformities are stratigraphic features of particular impotents in hydrogeology. Aquifers are commonly associated with unconformities, either in the weathered or fractured zone immediately below the surface of the buried landscape or in permeable zone in coarse-grained sediments laid down on the top of this surface. In terrain that has been deformed, aquifers would be difficult to discern because of geologic complexity.

One of the prime objectives of the present research is to assess the hydrological condition of the investigated area and to delineate the potential zone of the aquifer. For the purpose, on the basis of borehole log data, some lithological cross-sections are drawn over the study area.

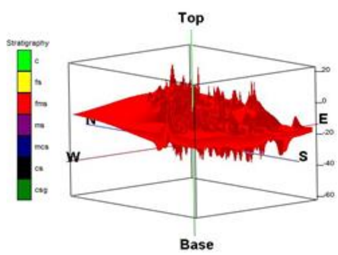
An integrated study of the evaluation of subsurface geologic formation is useful to understand the occurrence of porous and permeable zones. The subsurface runoff is governed in part, by the geology which depends on the development of underground formations and their infiltration and transmission characteristics. So, the stratigraphy is an important 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. Three dimensional models of individual layer of the study area have been prepared in various directions and shown in Fig.8. This model gives a clear understanding of geologic formations of the study area.



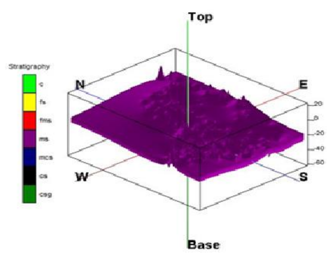
(a). Thickness of clay.



(b). Thickness of fine sand.

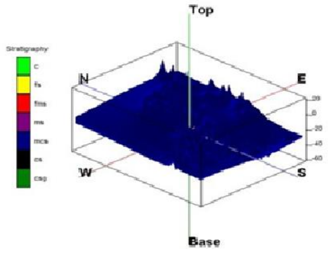


(c).Thickness of fine medium sand.

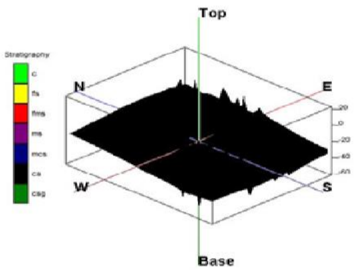


(d). Thickness of medium sand.

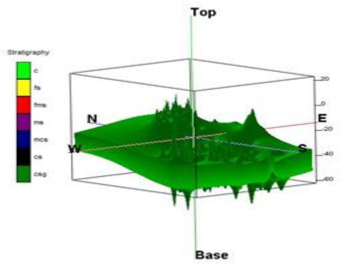
ISSN No:-2456-2165



(e). Thickness of medium coarse sand.



(f). Thickness of medium coarse sand.



(g). Thickness of coarse sand gravel.

Fig 8:- Three dimensional models of individual layer of the study area.

The sand formations in the subsurface below the top clay is the only geologic formation could be used for groundwater exploration. In this work, the sand formation is termed as composite sand formation because of the combination of different sandy formations of different grain sizes situated in different depth. The thickness of the composite sand formation has the great importance for the identification of favorable groundwater potential zone. In this regard, the 3D view of various sand formations along with the top clay of the study area is prepared.

D. Fence Diagram

The character and the nature of distribution of water bearing litho logic layers are the important criteria for identifying the groundwater potential zone. The stratigraphy describes the geometrical and age relation between the various lenses, beds and formations in geologic systems of sedimentary origin.

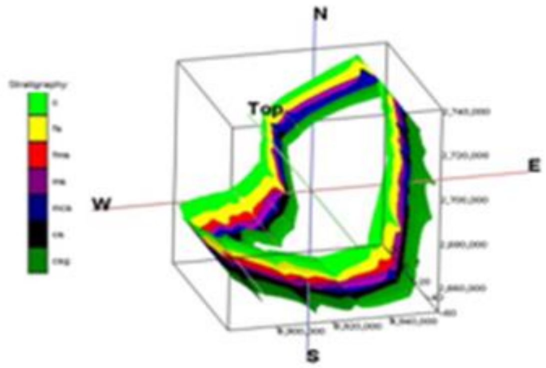
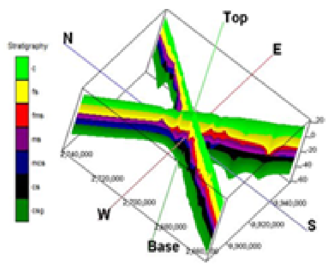


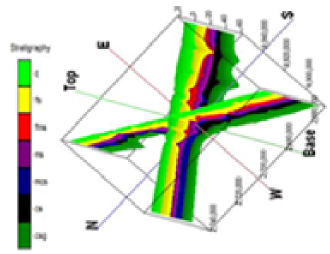
Fig 9:- Fence Diagram of the Investigated Area.

Various directions and are presented in Fig.10. This shows the variation of formation of the study area. The fence diagrams are extremely useful in predicting three dimensional distribution of the subsurface formation. This diagram represents an overall view of the sub-surface geological formation delineating the major aquifer zones. Another type of cross-sectional views are also prepared and presented in Fig.11.

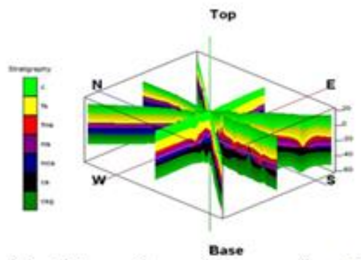
The area consists of seven sub-surface layers. It is noted that all the layers stated above are not continuous. Every layer does not exist at a certain litholog point at a time. There are some places where fine sand is absent. Similarly, fine medium sand and the rest of all other layers of sand are absent in various places but not simultaneously. In a word, discontinuity of similar layers is observed in the investigated area. But the top clay layer exists everywhere in the entire part of the investigated area. No impermeable bed below the sand layers are identified from the borehole information, i.e., the thickness of the composite sand layer is still undetermined.



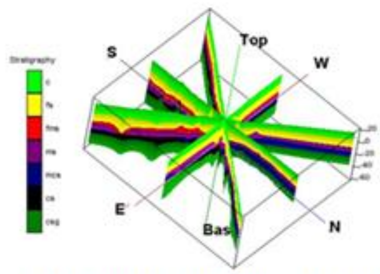
(a).View along diagonal directions.



(b). View along diagonal directions.

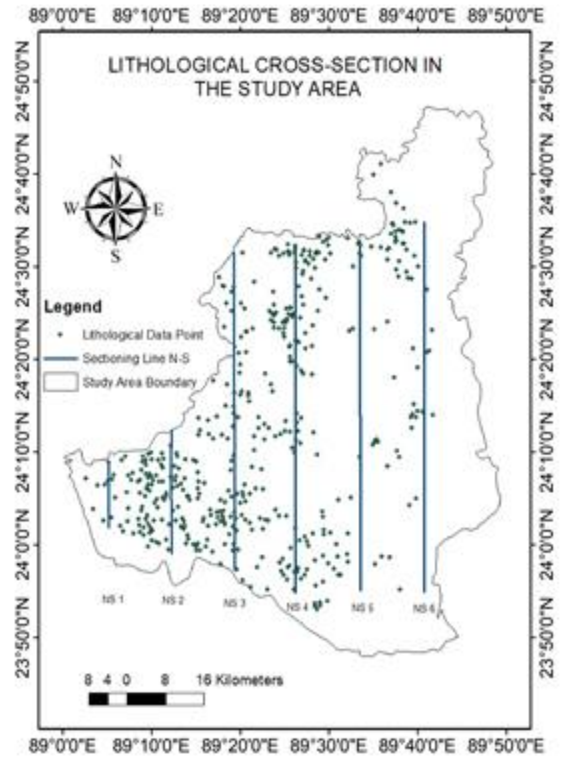


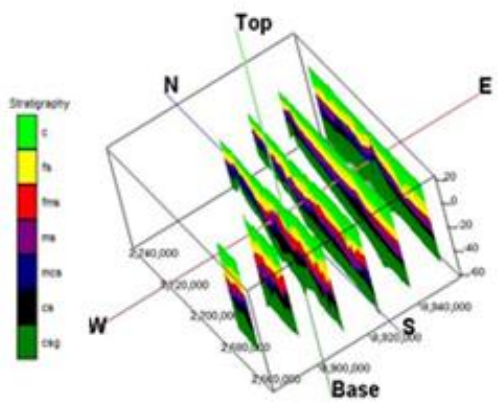
(c) View along diagonal and middle directions.



(d) View along diagonal and middle directions.

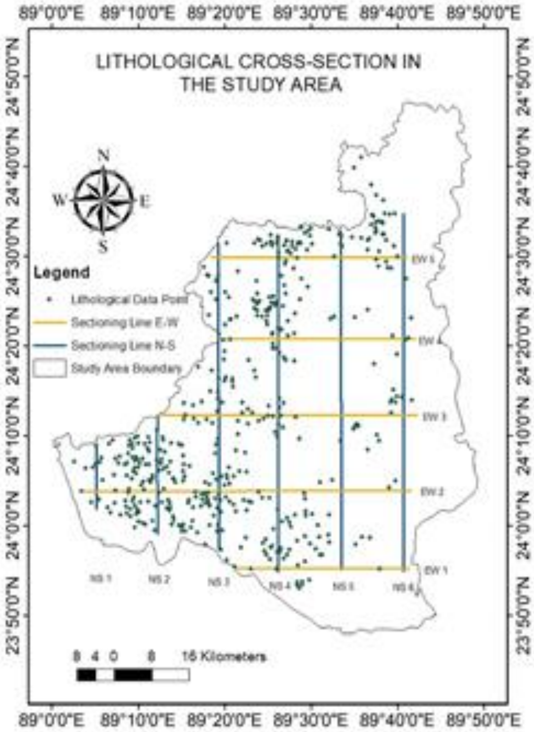
Fig 10:- Formation Variation along Different Directions.

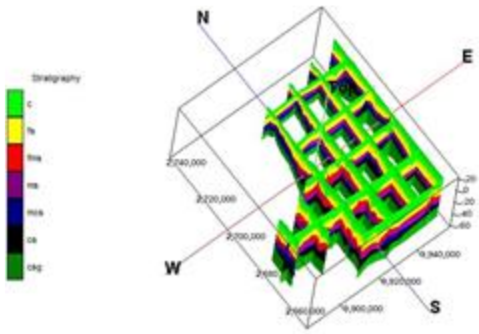




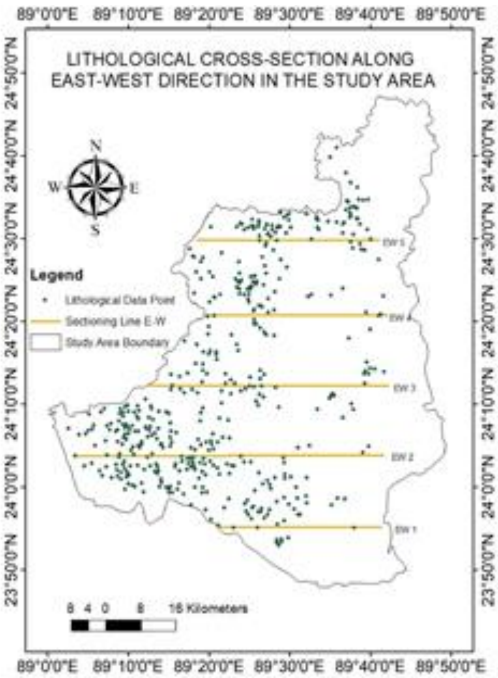
(a): Cross-sectioning along vertical condition (NS).

ISSN No:-2456-2165

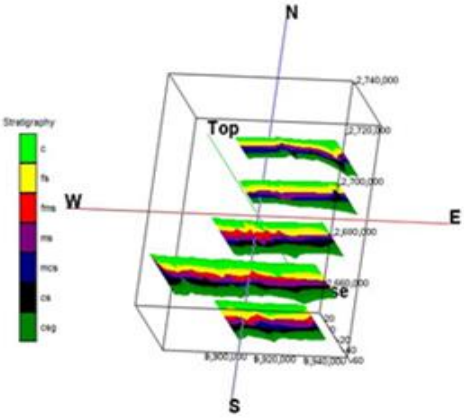




(b): Cross-sectioning along horizontal and vertical conditions.



ISSN No:-2456-2165



(c): Cross-sectioning along horizontal condition(WE).
Fig 11:- Cross-sectional views in various directions.

The area consists of seven sub-surface layers. It is noted that all the layers stated above are not continuous. Every layer does not exist at a certain litholog point at a time. There are some places where fine sand is absent. Similarly, fine medium sand and the rest of all other layers of sand are absent in various places but not simultaneously. In a word, discontinuity of similar layers is observed in the investigated area. But the top clay layer exists everywhere in the entire part of the investigated area. No impermeable bed below the sand layers are identified from the borehole information, i.e., the thickness of the composite sand layer is still undetermined.

VI. CONCLUSION

The subsurface formations of the study area have been studied from 467 borehole litholog data. Seven discrete hydrostratigraphic layers have been identified in accordance of its vertical distributions and lithological composition. They are top clay, fine sand, fine-medium sand, medium sand, medium-coarse sand, coarse sand and the coarse sand gravel. The physical and geometrical change of different layers in different parts of the area has also been observed. To observe the vertical distribution of different geologic formations in different parts of the investigated area three dimensional stratigraphic views are prepared to visualize the subsurface of the area. Stratigraphic cross-sectional views along different directions are also prepared and displayed. From the analysis it can be concluded that the south-eastern side and some portions of Atghoria, Faridpur, Chatmohor and Ishwardi upazillas of the study area are potential for groundwater abstraction. Geologically it is suitable for groundwater exploration. But for large-scale abstraction sites should be selected consciously.

From the observation it is found that a top clay layer of varying thickness is clearly observed in all over the area. All the sandy layers of different grain size are counted below the common top clay layer. The only sandy formation is used as groundwater source. The overall thickness of the composite sandy formation is suitable for groundwater potentiality. No other impermeable layer is found below the sandy formation. Basically, the area is unconfined in nature. The detailed study of formation evaluation of the area investigated reveals that geologically it is suitable for groundwater exploration, however, for large-scale abstraction sites should be selected consciously.

ACKNOWLEDGEMENT

The research work has been accomplished in the Geophysics Laboratory of the Department of Electrical and Electronic Engineering of Rajshahi University, Rajshahi, Bangladesh. The “Panasi Project” under the department of Bangladesh Agriculture Development Corporation (BADC), Pabna, Bangladesh and the BADC of Sirajgonj, Bangladesh have given their full co-operation through supplying their valuable information. The work has been conducted through the direct supervision of my guide who is appointed for my research work. I am very much grateful to the institutions for supplying me relevant information about the work studied.

REFERENCES

[1]. MISR, 2007, Minor Irrigation Survey Report 2006-2007, Government of the People’s Republic of Bangladesh, Ministry of Agriculture, Bangladesh Agricultural Development Corporation, Dhaka, Bangladesh, P. 2
[2]. Barnes,J.W., 1981, Basic Geological Mapping, Geological SocietyHandbook, Open University Press, New York, p.112
[3]. Khan,F.H.,2001, Geology of Bangladesh, The University Press Limited, Dhaka, Bangladesh, P.8-182.
[4]. Haque, M.N., 2008, Delineation of Groundwater Potential Zones in the Western Part of Greater Kushtia District Based on Integrated Hydrogeological and Geophysical Approach, PhD. Thesis, University of Rajshahi, Bangladesh. P.33-34.
[5]. Patra, K.C.2001, Hydrology and Water Resources Engineering, Narosa Publishing House, New Delhi, India, p.193-205.