Bulletin of Pure and Applied Sciences.
Vol.39F, Geology (Geological Science), No.1,
January-June 2020: P.32-46

Print version ISSN 0970 4639
Online version ISSN 2320 3234
DOI: 10.5958/2320-3234.2020.00003.7

Original Article

Available online at ww.bpasjournals.com

Delineation of Aquifer Zones in the Interfluves of the Rivers Brahmaputra and Kolong, Assam

*Satyajit Kataki**

Author's Affiliations:
Associate Professor, Department of Geology, Cotton University, Panbazar, Guwahati, Kamrup (M), Assam 781001, India.

***Corresponding Author: Satyajit Kataki,** Associate Professor, Department of Geology, Cotton University, Panbazar, Guwahati, Kamrup (M), Assam– 781001, India.
E-mail: satyaccg1@gmail.com

(Received on 06.02.2020, Accepted on 10.04.2020)

ABSTRACT

The present study aims at the delineation of the aquifer zones in the interfluves of the rivers Brahmaputra and Kolong, Assam by studying the hydrogeological settings in the area, nature and areal extent of aquifers, subsurface disposition of aquifers through panel diagram, well inventory data, behaviour and direction of movement of groundwater with the help of water table contour mapping etc. The area is underlain by unconsolidated alluvial sediments deposited on a granite basement which outcrops as inselbergs within the alluvial terrain. Hydrogeological data such as depth to water level, seasonal fluctuations of groundwater level were collected from 61 key well locations from the study area in both pre- as well as post-monsoon seasons. The spatial and temporal variability of groundwater levels in the area were studied with depth to water level maps and the water level fluctuation maps of both pre- and post-monsoon seasons. Maps were prepared by using the 3D Analyst Extension of ArcGIS. Panel diagram was prepared using the litho-log data of 15 exploratory boreholes to delineate the extent and nature of disposition of aquifers. In major part of the study area groundwater fluctuations remain within 1.5 m to 2 m. There are much lateral variations in the aquifer zones with lateral and vertical intercalations; however, the subsurface geology of the study area indicates the presence of very good aquifer zones. The water table conforms to the general topography of the area. The general direction of groundwater flow in the study area is towards the river Brahmaputra.

KEYWORDS: *Interfluves, Kolong, Brahmaputra, Delineation, Aquifer zones*

INTRODUCTION

Groundwater plays a crucial role to the society and the nation as a whole. Therefore, evaluation of groundwater resources requires a detailed study on the occurrence and behaviour of groundwater. Understanding of groundwater behaviour is also important for the proper management of this precious resource. This can be studied through careful monitoring of spatial and temporal variability of depth to water level, seasonal fluctuations of groundwater level, movement and flow pattern of groundwater etc.

Ground-water systems are dynamic and adjust continually to short-term and long-term changes in climate, ground-water withdrawal, and land use. Study of both short- and long-term fluctuations of groundwater level helps us to understand the depletion and recharging conditions of an aquifer.

Long-term systematic measurements provide essential data needed to evaluate changes in the resource over time, to develop groundwater models and forecast trends, and to design and monitor the effectiveness of groundwater management and protection programs (Taylor and Alley, 2001).

The investigated area is centrally located in Assam, and comprises of parts of two most thickly populated districts Nagaon and Morigaon in Assam. The area has recently witnessed heavy migration of people from nearby districts. The near-surface shallow aquifers are the main source of drinking water supply in the area. Thus, the present study is an attempt to deal with the hydrogeological setting of the study area in terms of nature and extent of aquifer, behaviour and direction of movement of groundwater etc. for the delineation of the shallow aquifer zones in the area.

STUDY AREA

The study area comprises of 2100 sq. km and is centrally located in Assam. The area is bounded by the rivers Brahmaputra at the north and Kolong at the south (Figure 1). It is spreading in the Survey of India Topographical maps No. 78N/15, 78N/16, 83B/3, 83B/4, 83B/6, 83B/7, 83B/8, 83B/10, 83B/11, 83B/12, 83B/14, 83B/15, 83F/2 on 1:50,000 scale and falls between latitudes 26º9'21"N to 26º37'17"N and longitude 91º57'6"E to 93º4'46"E.

GEOLOGY OF THE AREA

Geologically the area is underlain by unconsolidated alluvial sediments deposited on a granite basement which outcrops as inselbergs within the alluvial terrain. The slope of the basement gradually steepened from south to north, towards the river Brahmaputra. The older alluvium which occurs in the north eastern, southern and western parts of the area (Figure 2) consists of sand, pebbles, clays and silts; generally rich in concretion and nodules of impure calcium carbonate. These deposits form slightly elevated terraces, generally above the present flood level. The newer or younger alluvial deposits cover major part of the study area and consist of sand, fine to coarse grained in texture intermixed with gravels and pebbles, along with silt and clay.

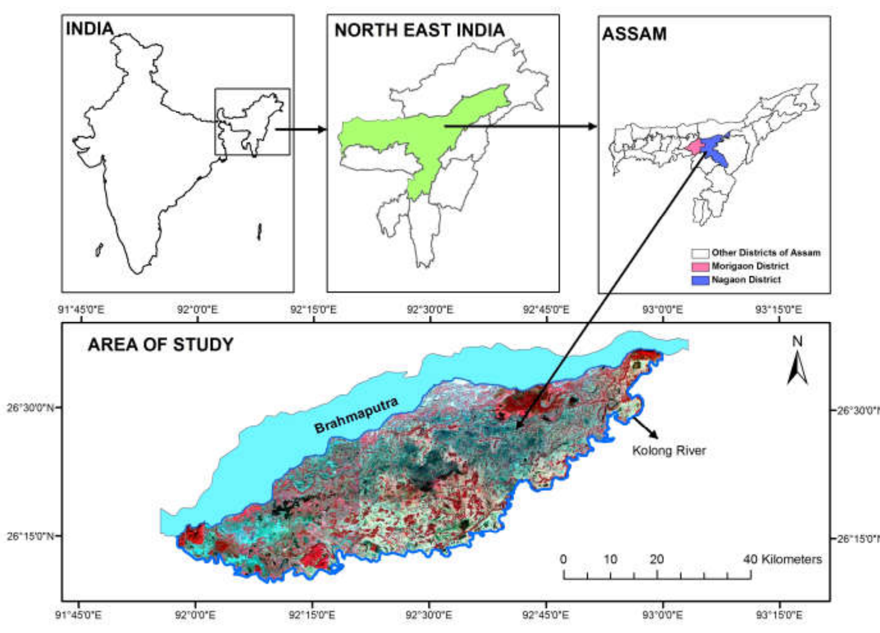


Figure 1: Location map of the study area

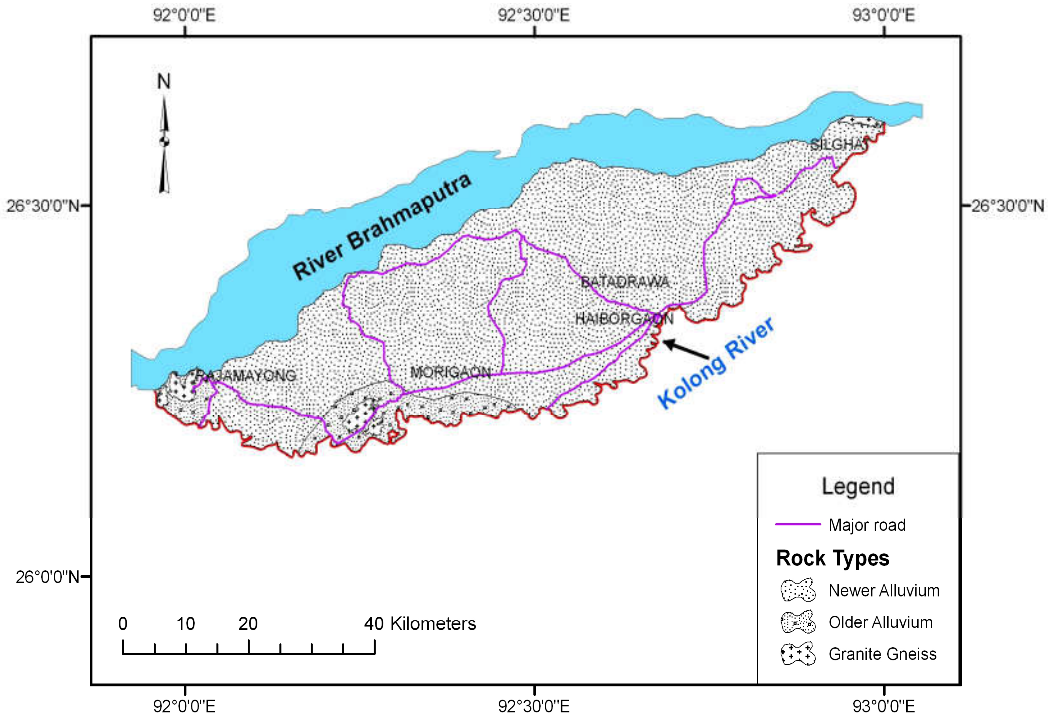


Figure 2: Map showing rock types in the study area

OBJECTIVE OF THE STUDY

The principal objective of the present study is to delineate the aquifer zones in the interfluves of the rivers Brahmaputra and Kolong, Assam, in terms of-

- hydrogeological settings of the area,
- nature and areal extent of aquifers,
- subsurface disposition of aquifers through panel diagram,
- spatial and temporal variability of groundwater levels,
- seasonal fluctuations of groundwater levels,
- movement and flow directions of groundwater

REVIEW OF LITERATURE

Karanth (1987) pointed out that the water level fluctuation maps are indispensable for estimation of storage changes in aquifers. Taylor and Alley (2001) in the U.S. Geological Survey Circular 1217, discussed in detail about the ground-water-level monitoring and the importance of long-term water-level data. They emphasized that water-level measurements from observation wells are the principal source of information about the hydrologic stresses acting on aquifers and how these stresses affect ground-water recharge, storage, and discharge.

Central Ground Water Board, NER, in 2009, had published the "Hydrogeology of Assam and Scope for Ground Water Development", Technical Report Series: D; where a number of eminent hydrogeologists had discussed the hydrogeology and ground water potentiality of the region. The groundwater conditions of Nagaon and Morigaon districts have been discussed in "Hydrogeology and Groundwater Conditions in Nagaon District, Assam", Technical Series D No.35 in Nov.1997 (CGWB, 1997), and "Hydrogeology and Groundwater Potential, Morigaon District, Assam", Technical Report, June, 2000 (CGWB, 2000) respectively.

CONCEPT AND HYPOTHESIS

Geologic depositional (sedimentation) patterns and materials can affect groundwater movement. Assuming hydrologic conditions furnish water to the underground zone, the subsurface strata govern its distribution and movement; hence the important role of geology in hydrology cannot be overemphasized (Todd, 2006).

An aquifer is characterised by its geometry, its areal extent and its depth of occurrence. Groundwater occurs in pore spaces of granular soil/lithological formation and in fractures; therefore, it is under dynamic condition and fluctuates. Water levels in aquifers reflect a dynamic balance between groundwater recharge, storage, and discharge. Because recharge and discharge are not distributed uniformly in space and time, ground-water levels are continuously rising or falling to adjust to the resulting imbalances. Water levels in wells reflect these changes in recharge and discharge and provide the principal means of tracking changes in groundwater storage over time (Conlon et at., 2005). Monitoring of groundwater fluctuations is very important on many accounts like agricultural practices, aquifer recharge and to study droughts.

DATABASE AND METHODOLOGY

Hydrogeological data such as depth to water level, seasonal fluctuations of groundwater level were collected from 61 key well locations from the study area in both pre- as well as post-monsoon seasons. Whereas, reduced level data and litho-log data were obtained from CGWB, NER, Guwahati. A panel diagram (Figure 4) was prepared using the lithological log data of 15 exploratory boreholes (Figure 3) to show the nature, extent and disposition of aquifers in the study area.

Positions of the dug wells, from where the depths to water level data were collected, were plotted on the base map for the preparation of depth to water level maps of pre- and post-monsoon seasons. Depth to water level maps and the water level fluctuation maps have been prepared using the 3D Analyst Extension of ArcGIS. The water level data were entered as attribute information against each well.

The spatial and temporal variability of groundwater levels in the area have been studied through the maps of depth to water levels in pre- and post-monsoon periods and seasonal fluctuations of groundwater level. Water table contour maps for both pre- and post- monsoon seasons have been prepared to understand the movement and flow direction of groundwater in the study area. For the construction of water table contour maps, the altitudes of the water levels with respect to the mean sea level of some representative well points have been used. These water table elevations (Table1) of the well points were plotted with respect to their positions on the base map. Water table contours were drawn at 1 m interval by following the triangulation method. After the completion of the contour lines, flow lines have been drawn at right angles to the water table contours.

RESULTS AND DISCUSSIONS

Hydrogeological settings of the Study Area

There are two distinct hydrogeological set-ups prevail in the study area. The first set-up is older alluvium which occurs along the western and south-western parts of the area surrounding the residual hill regions. These are comprised of clay, silt and sand; generally rich in concretion and nodules of impure calcium carbonate. The clay component of these formations is comparatively more than sand which is fine grained in nature. These older alluvial deposits are relatively compact in nature and form slightly elevated terraces, generally above the present flood level.

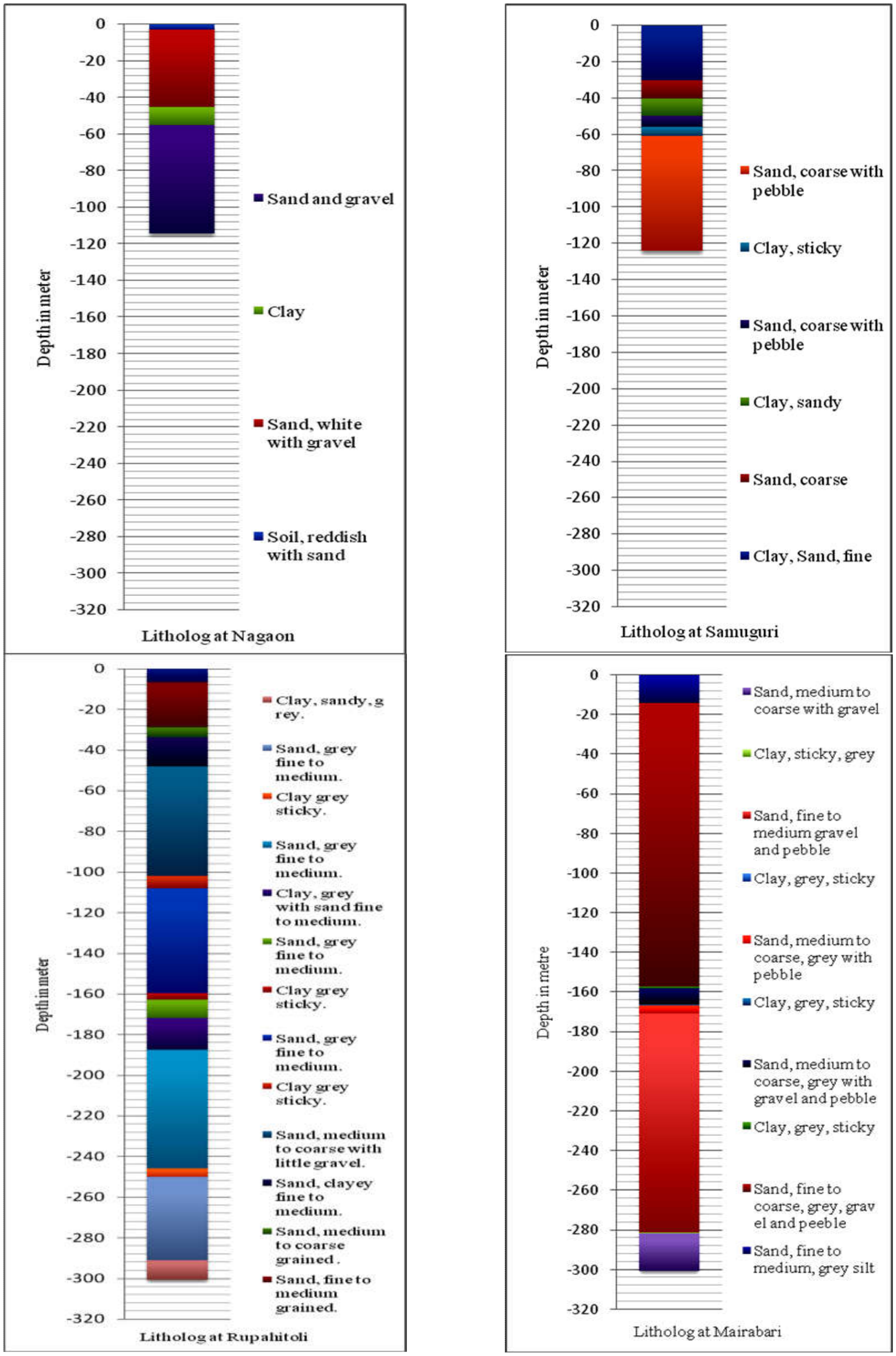
The second set up is younger alluvium which covers 90% of the area and consists of sand, fine to coarse grained in texture with intermixed gravels and pebbles along with clay and silt. In younger alluvium groundwater mostly occurs under phreatic condition in shallow horizons and under semiconfined or leaky confined condition in deeper horizons. The slope of the area in which these alluvial sediments were deposited is from south to north. Open wells and dug wells are mainly used for extraction of groundwater in this area.

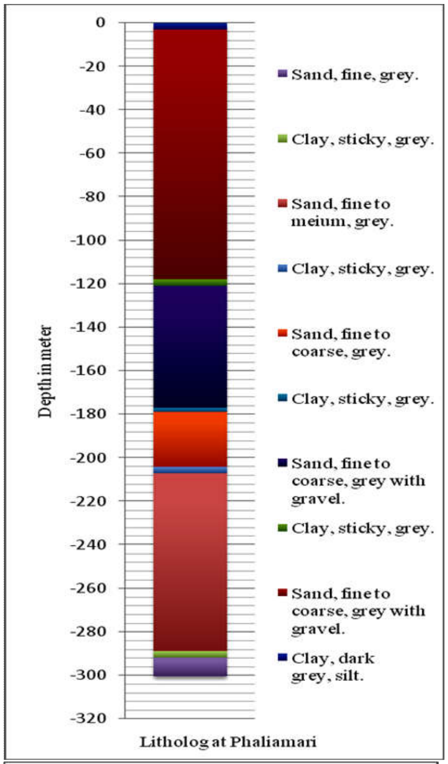
Table 1: Depth to Water Level (bmsl) and Water Table Elevation (amsl) in both pre- and post-monsoon periods

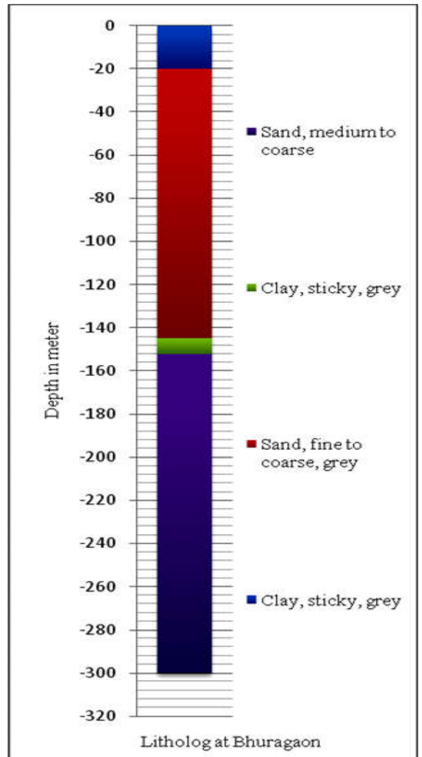
Sl. No.	Location	Latitude	Longitude	R.L. of L.S. (amsl) (m)	DTWL (bmsl) (m)		Water Table Elevation (amsl)(m)		Geology
					Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	
1	Sulung/83B3D8	26.5791	92.8805	66.48	5.86	1.41	60.22	65.07	Alluvium
2	Rangagora/83B3D1	26.458	92.917	63.51	5.2	2.41	58.31	61.1	Alluvium
3	Samuguri/83B3D7	26.408	92.829	63.75	5.8	3.25	57.95	60.5	Alluvium
4	Rupahitoli/83B3C4	26.411	92.744	59.34	3.99	2.22	55.35	57.12	Alluvium
5	Panikhati/83B3C3	26.292	92.692	58.82	3.49	1.67	55.33	57.15	Alluvium
6	Bebejia/83B3C7	26.3022	92.6264	59.06	4.5	3.04	54.56	56.02	Alluvium
7	Dhing/83B3B6	26.483	92.492	60.15	4.83	3.23	55.16	56.54	Alluvium
8	Bordowa/83B3C2	26.406	92.542	57.78	2.86	1.59	54.92	56.19	Alluvium
9	Bechamari/83B3B1	26.417	92.458	56.42	5.5	2.82	50.92	53.6	Alluvium
10	Kawoimari/83B3C6	26.428	92.675	59.94	4.99	3.18	54.95	56.76	Alluvium
11	Bogoriguri/NA	26.361	92.533	56.52	3.96	1.27	52.56	55.25	Alluvium
12	Baropujia/ASMR14	26.274	92.496	57	3.65	2.17	53.35	54.83	Alluvium
13	Phaliamari/83B3B4	26.322	92.475	56.48	3.74	2.55	52.74	53.93	Alluvium
14	Borchukhaba/83B3B5	26.303	92.428	55.38	3.57	2.3	51.81	53.08	Alluvium
15	Bonpara/NA	26.258	92.392	56.5	3.69	1.95	52.81	53.55	Alluvium
16	Tengaguri/NA	26.304	92.4	54	3.53	1.44	50.47	52.56	Alluvium
17	Patidayer/NA	26.331	92.386	54	3.8	2.02	50.2	51.98	Alluvium
18	Moirabari/83B3B3	26.454	92.411	56.47	7.08	5.6	49.39	50.87	Alluvium
19	Dhupgurigaon/NA	26.415	92.333	55.5	6.7	5.32	48.8	50.18	Alluvium
20	Bhuragaon/83B3C2	26.413	92.226	54.5	4.68	3.89	49.82	50.61	Alluvium
21	Baghara/83B4B2	26.184	92.297	60.22	6.14	4.46	54.08	55.76	Alluvium
22	Nasatra/83B4A5	26.225	92.217	57.8	2.89	2.54	54.91	55.26	Alluvium
23	Rajamayong/83B7B3	26.2531	92.0434	59	4.95	4.22	54.05	54.78	Alluvium

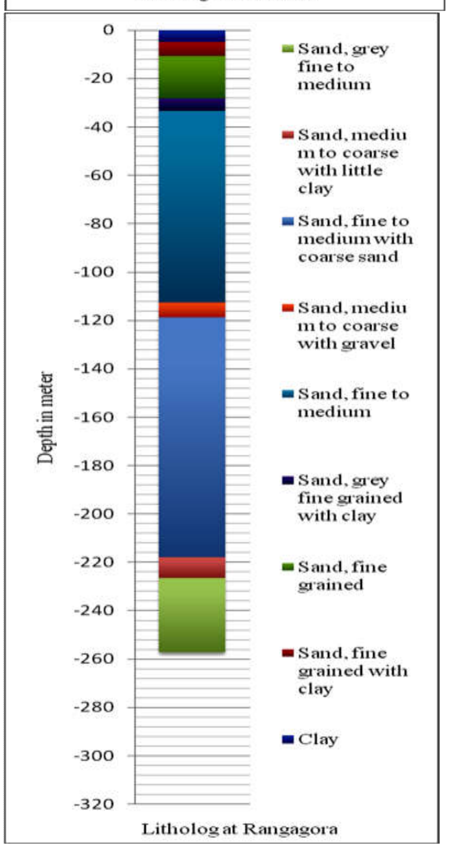
Nature and Extent of Aquifer

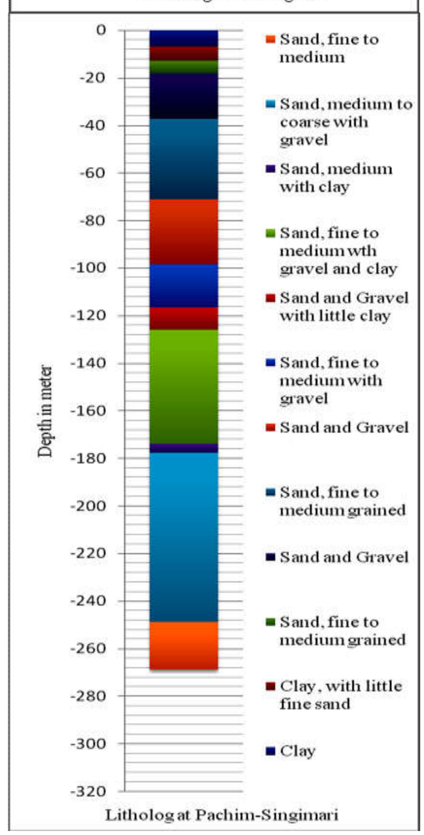
A large number of deep boreholes were drilled by the Central Ground Water Board and a few have been drilled by the Public Health Engineering and Irrigation departments of Government of Assam. These exploratory well data have revealed the nature and extent and aquifer horizons encountered at depths. The Litho-logs of 15 nos. of exploratory boreholes in the study area are shown in Figure 3. The panel diagram prepared out of these 15 nos. of bore hole litho-log data shows the disposition of aquifers in the study area (Figure 4).

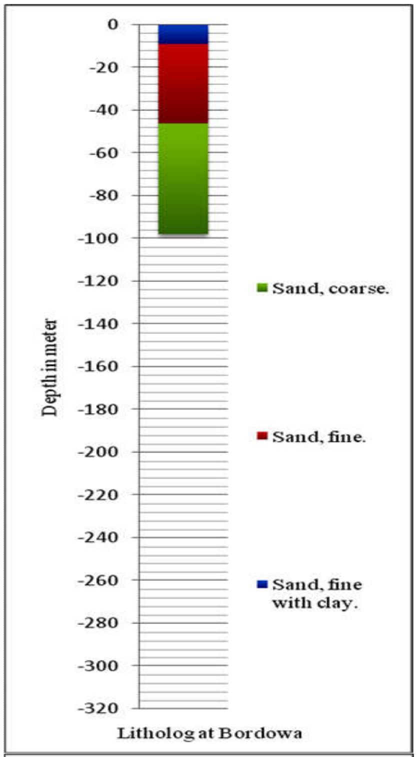

Depth in meter
Sand and gravel
Clay
Sand, white with gravel
Soil, reddish with sand
Litholog at Nagaon
Depth in meter
Sand, coarse with pebble
Clay, sticky
Sand, coarse with pebble
Clay, sandy
Sand, coarse
Clay, Sand, fine
Litholog at Samuguri
Depth in meter
Clay, sandy, g rey.
Sand, grey fine to medium.
Clay grey sticky.
Sand, grey fine to medium.
Clay, grey with sand fine to medium.
Sand, grey fine to medium.
Clay grey sticky.
Sand, grey fine to medium.
Clay grey sticky.
Sand, medium to coarse with little gravel.
Sand, clayey fine to medium.
Sand, medium to coarse grained.
Sand, fine to medium grained.
Litholog at Rupahitoli
Depth in metre
Sand, medium to coarse with gravel
Clay, sticky, grey
Sand, fine to medium gravel and pebble
Clay, grey, sticky
Sand, medium to coarse, grey with pebble
Clay, grey, sticky
Sand, medium to coarse, grey with gravel and pebble
Clay, grey, sticky
Sand, fine to coarse, grey, grav el and peeble
Sand, fine to medium, grey silt
Litholog at Mairabari

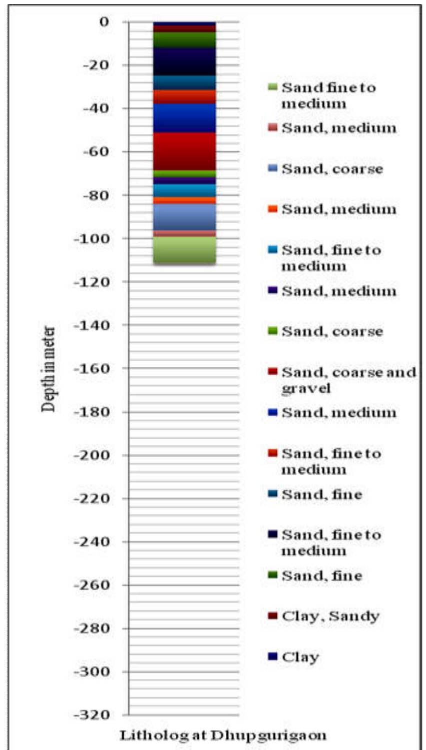

Depth in meter
Sand, fine, grey.
Clay, sticky, grey.
Sand, fine to meium, grey.
Clay, sticky, grey.
Sand, fine to coarse, grey.
Clay, sticky, grey.
Sand, fine to coarse, grey with gravel.
Clay, sticky, grey.
Sand, fine to coarse, grey with gravel.
Clay, dark grey, silt.
Litholog at Phaliamari

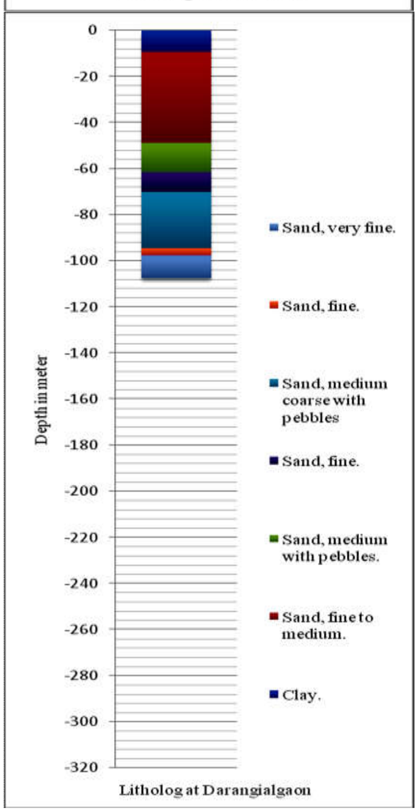

Depth in meter
Sand, medium to coarse
Clay, sticky, grey
Sand, fine to coarse, grey
Clay, sticky, grey
Litholog at Bhuragaon

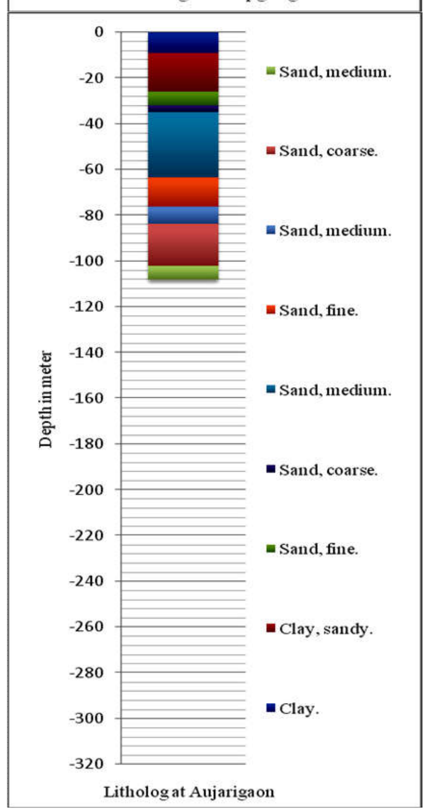

Depth in meter
Sand, grey fine to medium
Sand, mediu m to coarse with little clay
Sand, fine to medium with coarse sand
Sand, mediu m to coarse with gravel
Sand, fine to medium
Sand, grey fine grained with clay
Sand, fine grained
Sand, fine grained with clay
Clay
Litholog at Rangagora


Depth in meter
Sand, fine to medium
Sand, medium to coarse with gravel
Sand, medium with clay
Sand, fine to medium wth gravel and clay
Sand and Gravel with little clay
Sand, fine to medium with gravel
Sand and Gravel
Sand, fine to medium grained
Sand and Gravel
Sand, fine to medium grained
Clay, with little fine sand
Clay
Litholog at Pachim-Singimari


Depth in meter
Sand, coarse.
Sand, fine.
Sand, fine with clay.
Litholog at Bordowa


Depth in meter
Sand fine to medium
Sand, medium
Sand, coarse
Sand, medium
Sand, fine to medium
Sand, medium
Sand, coarse
Sand, coarse and gravel
Sand, medium
Sand, fine to medium
Sand, fine
Sand, fine to medium
Sand, fine
Clay, Sandy
Clay
Litholog at Dhupgurigaon


Depth in meter
Sand, very fine.
Sand, fine.
Sand, medium coarse with pebbles
Sand, fine.
Sand, medium with pebbles.
Sand, fine to medium.
Clay.
Litholog at Darangialgaon


Depth in meter
Sand, medium.
Sand, coarse.
Sand, medium.
Sand, fine.
Sand, medium.
Sand, coarse.
Sand, fine.
Clay, sandy.
Clay.
Litholog at Aujarigaon

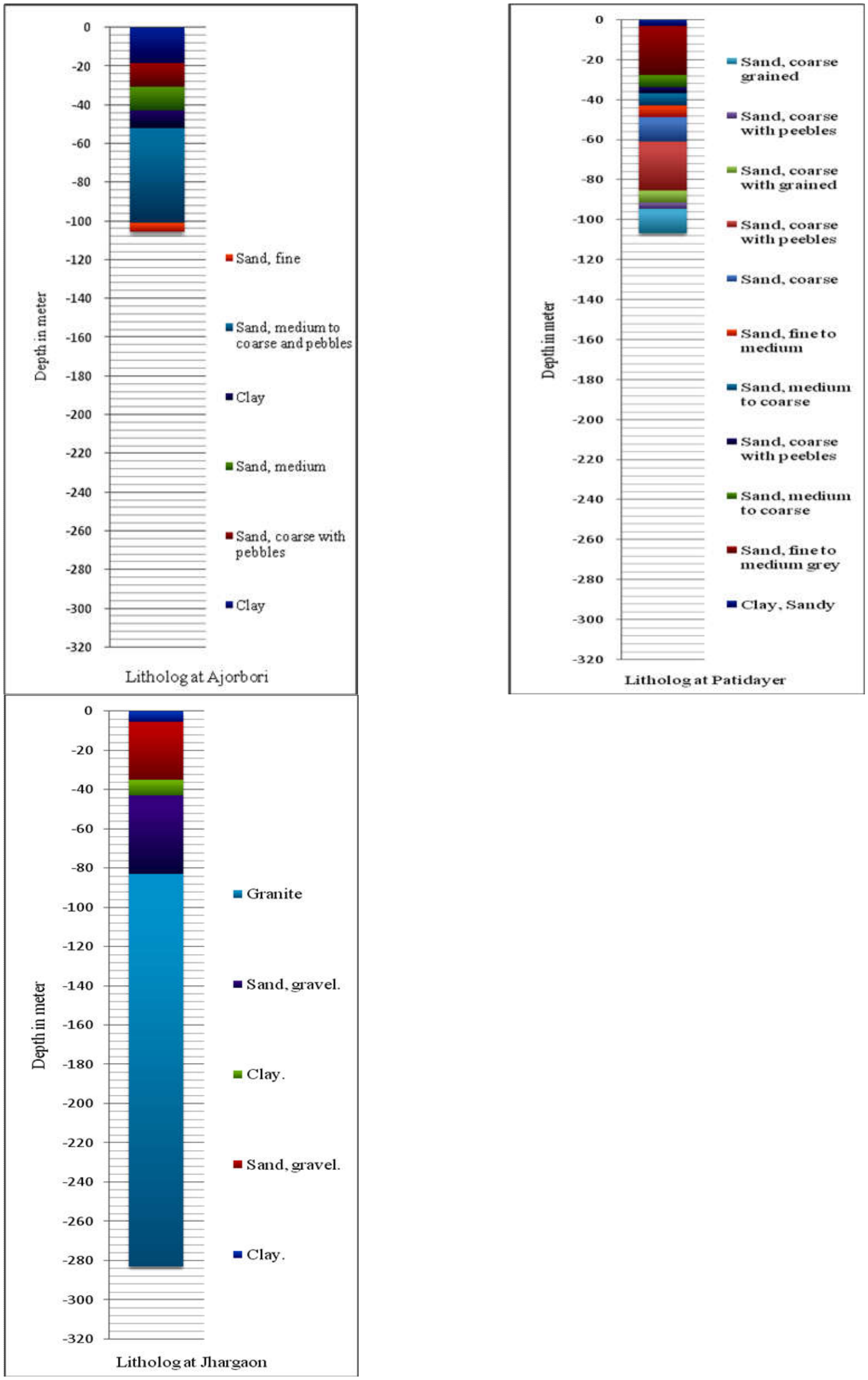


Figure 3: Litho-logs of Exploratory Boreholes

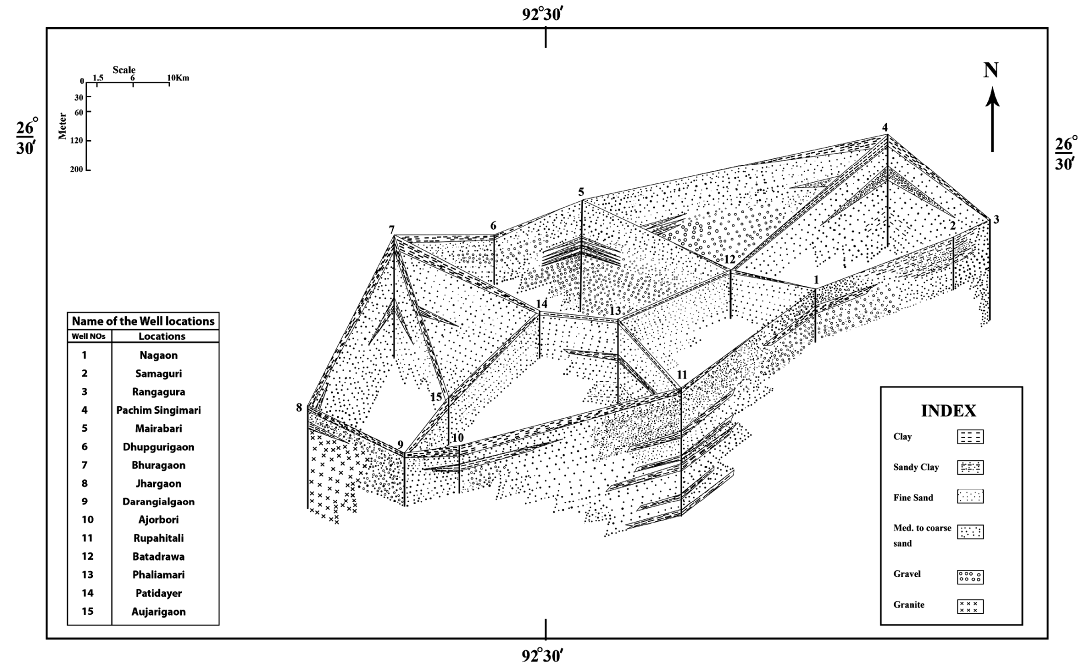
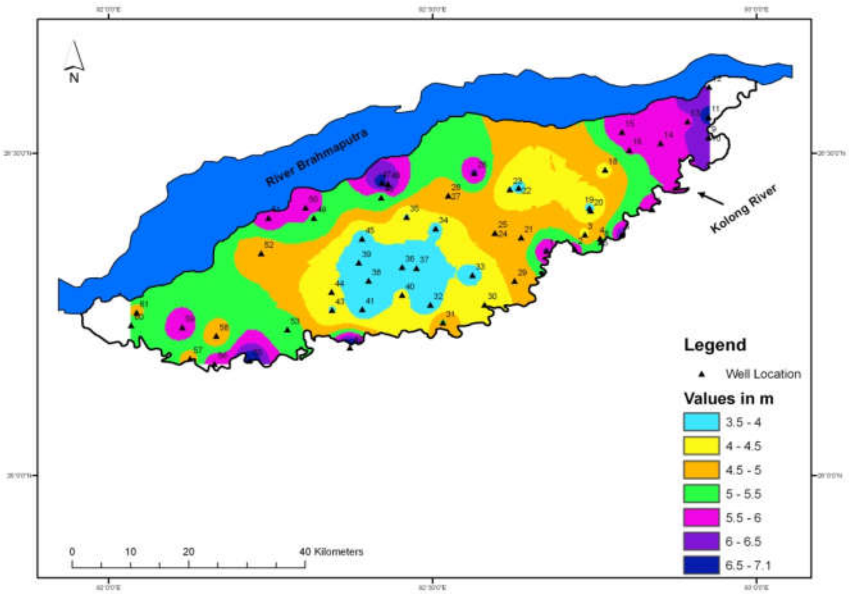


Figure 4: Panel Diagram showing the subsurface disposition of aquifers in the Study Area

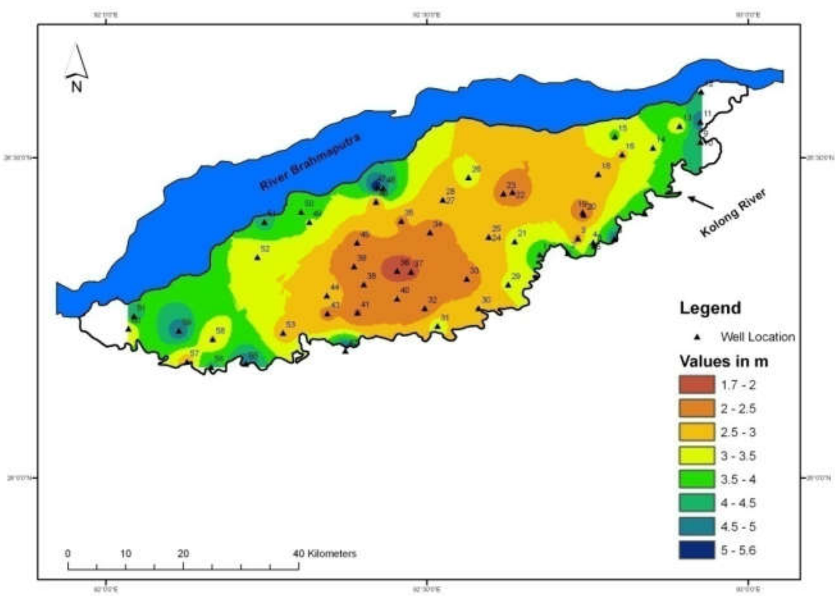
From the panel diagram it has been observed that the proportion of clay to sand is least in the northern, north-eastern, south-eastern parts of the area around Paschim Singimari, Mairabari, Dhupgurigaon, Nagaon, Rangagora, and Patidayer. On the other hand, the frequent occurrences of intercalated clay layers have been observed at shallow depths towards the south-central and southern parts around Samuguri, Ajorbori, Phaliamari, which is broadly underlain by older alluvium. The clay beds act as confining layers. This increased clay proportion may prevent free movement of groundwater in these locations and as a result it becomes difficult to get water from open wells extending to shallower depth during the lean period. But in other parts of the study area, open wells at such depths are capable of yielding water successfully as there are no such thick intercalations of clay layers except at the surface levels.

Depth to Water Level

The depths to water levels in the study area were found to be more in the pre-monsoon seasons than in the post-monsoon seasons. It varies between 3.35 m (Karhaligaon) and 7.16 m (Telahi) in pre-monsoon (Figure) and from 1.66 m (Mikirbheta) to 5.60 m (Moirabari) in post-monsoon (Figure 5a &5b). It has been observed that in pre-monsoon season maximum depth to water level occurs in Telahi area which is at the bank of river Kolong in the southern part of the study area and in post-monsoon season maximum depth to water level occurs in Moirabari area which is at bank of river Brahmaputra in the northern part of the study area.



'a'



'b'

Figure 5: Depth to water level map 'a'-pre-monsoon, 'b'-post-monsoon

Seasonal Fluctuation of Groundwater Level

Water level fluctuations are an effect computed from the differences between maximum and minimum water table levels observed in dug wells. Groundwater level in the study area fluctuates from 0.73 m bgl (Rajamayong) to 2.86 m bgl (Balikatia) with an average fluctuation being 1.75 m bgl. Fluctuations above 2 m occur in northeastern part along the river Brahmaputra and in the southern part along the river Kolong (Figure 6). The areal extent of depth to water level zones in pre- and post-monsoon seasons and water level fluctuation zones in the study area are presented in Table 2.

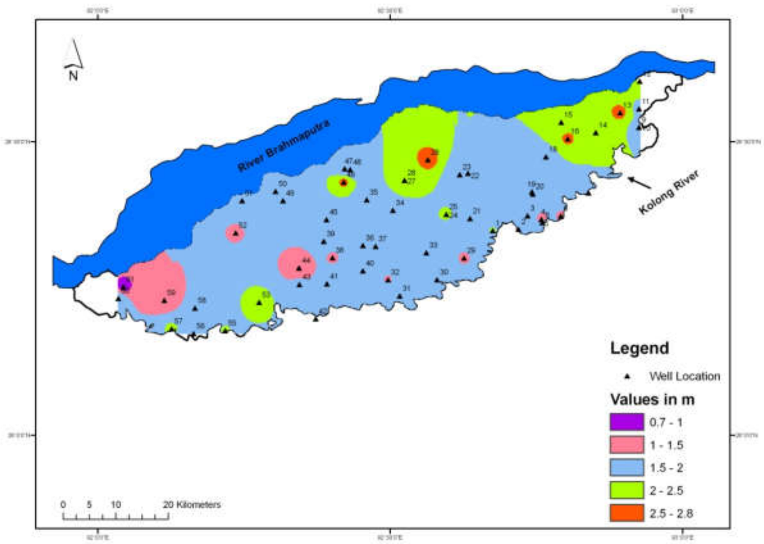


Figure 6: Water level fluctuation map

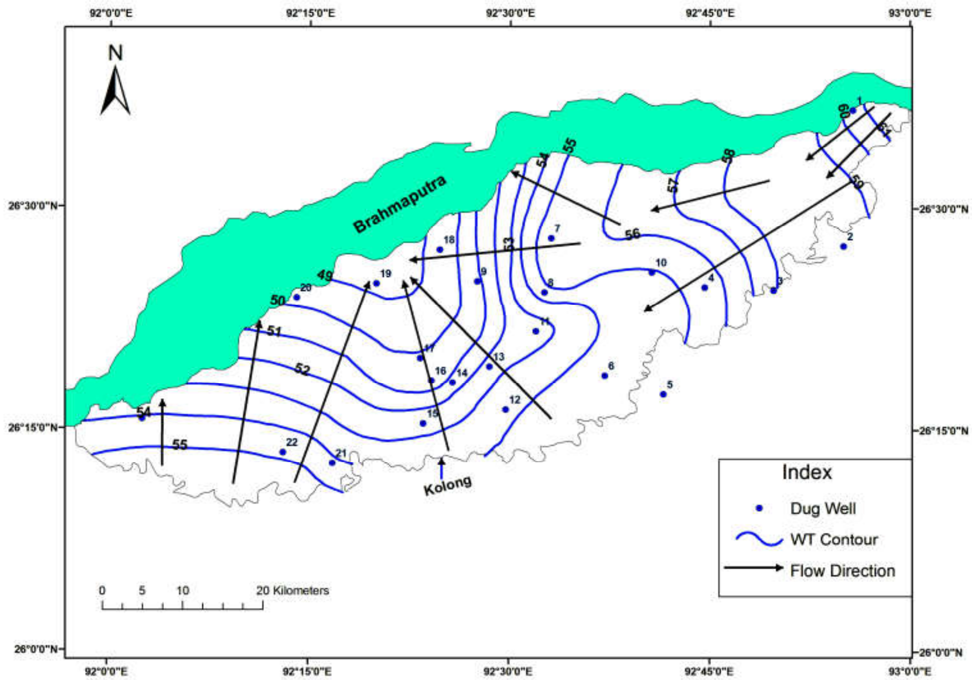
Table 2: Areal extent of depth to water level zones in pre- and post-monsoon seasons and water level fluctuation zones in the study area

Pre-Monsoon			Post-Monsoon			Water Level Fluctuation		
Depth to Water Level Zone in meter	Areal extent		Depth to Water Level Zone in meter	Areal extent		Fluctuation Zone in meter	Areal extent	
	in sq. km	in %		in Sq. km	In %		in Sq. km	in %
3.5-4	211	10.05	1.7-2	22	1.05	0.73-1	06	0.29
4-4.5	425	20.24	2-2.5	338	16.1	1-1.5	142	6.76
4.5-5	543	25.86	2.5-3	714	34	1.5-2	1540	73.33
5-5.5	570	27.14	3-3.5	525	25	2-2.5	390	18.57
5.5-6	270	12.86	3.5-4	365	17.38	2.5-2.86	22	1.05
6-6.5	70	3.33	4-4.5	106	5.05	--	--	--
6.5-7.07	11	0.52	4.5-5	27	1.29	--	--	--
--	--	--	5-5.6	03	0.14	--	--	--

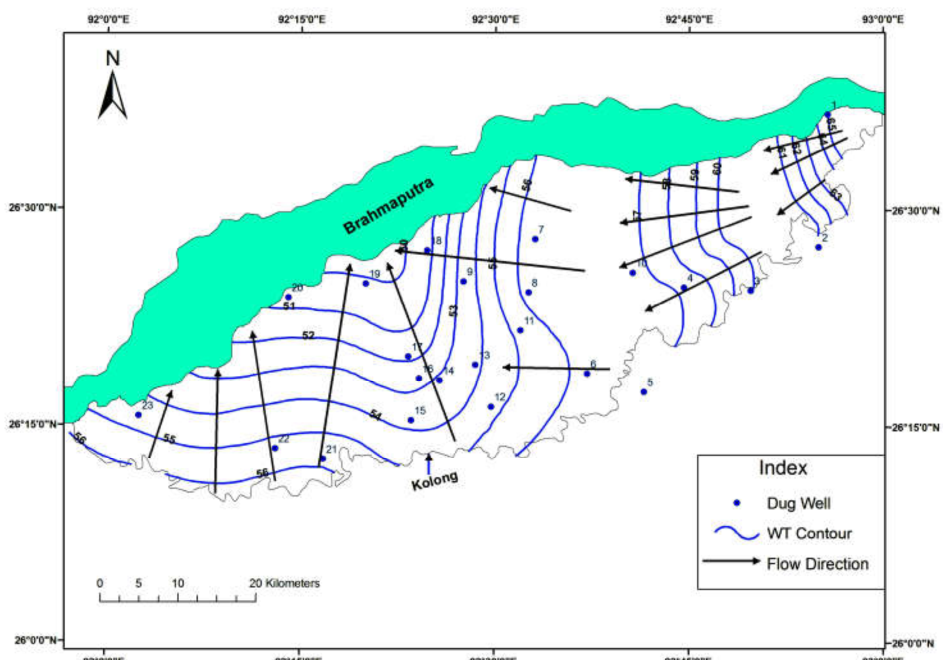
Groundwater Movement and flow direction

From the water table contour maps (Figure 7a & 7b), it has been observed that the spacing of the water table contours are not uniform all throughout the area which indicates that the water bearing formations have variable permeability and transmissivity in the study area. Particularly at two localities in the eastern and central parts of the area, contour spacing is wider indicating flat hydraulic gradients and relatively higher hydraulic conductivity of the water bearing formations. In the pre-monsoon period water table contour having the highest altitude of 61 m has been found towards the north-eastern part while the lowest altitude of 49 m water table contour has been found in the northern part of the area along the river Brahmaputra. Similarly, in the post-monsoon period water table contour having the highest altitude value (65 m) has been found towards the north-eastern part whereas the lowest altitude of 50 m water table contour has been found to occur around Moirabari in the northern part of the area near to the river Brahmaputra.

From the flow directions shown by the flow lines in the water table map (Figure 7a & 7b), it has been observed that the general direction of groundwater flow in the study area is from north-eastern part towards the central part and finally moves towards the river Brahmaputra in the north. Thus, the configuration and slope of water tables conform to the general topography of the area.



'a'



'b'

Figure 7 : Groundwater contour maps (a: Pre-monsoon b: Post-monsoon)

CONCLUSION

Based on the litho-log data, different granular zones have been identified within the depth of 300.7 m. The thickness of granular zones encountered in different boreholes has a definite bearing to the present study as they serve as possible aquifer zones in the study area. Sand and gravel are the predominant lithology in the subsurface formations of the area. The presence of thin or at some places thicker clay bands intermixed with sands at shallow as well as at deeper depths has given rise to a number of separate aquifers. The proportion of clay to sand is the least in the northern, north-eastern and south-eastern parts of the area. The frequent occurrence of intercalated clay layers at shallow depths around Samuguri, Ajorbori, Phaliamari, Paschim-Singimari, Rajagaon may prevent free movement of groundwater and as a result it becomes difficult to get water from open wells extending to shallower depth during the lean period. In other parts of the study area, open wells at such depth are capable of yielding water successfully as there are no such notable intercalations of clay layers except at the surface levels. The presence of impermeable clay strata of variable thicknesses at certain places is responsible for attributing semi-confined characteristics to the aquifer. Although there is much lateral variations of the zones with lateral and vertical intercalations, the subsurface geology of the study area indicates the presence of very good aquifer zones.

The groundwater level monitoring in the study area has indicated that changes in groundwater level occur seasonally and annually as a result of recharge to and discharge of groundwater from the system. In a major part of the study area groundwater fluctuations remain within 1.5 m to 2 m. Fluctuations above 2 m occur in north-eastern part of the area and in the southern part along the river Kolong. The general direction of groundwater flow in the study area is from north-eastern part towards the central part and finally towards the river Brahmaputra in the north. The water table conforms to the general topography of the area.

The spacing between the contours is wider at the north-eastern part indicating higher permeability of the underlying formations and it is narrower in the central part of the study area indicating lesser permeability of the underlying water bearing formations. Groundwater recharge areas are located in the north-eastern and southern parts while the Brahmaputra River segment along the northern and north-western border of the area are designated as the discharge area. The general direction of movement of groundwater in the upstream part of area is from north-east to south-west while it becomes south to north in the downstream part of the area. Again, both the rivers Brahmaputra and Kolong are neither effluent nor influent in the upstream part of the area, but towards the downstream part these rivers exhibit effluent and influent nature respectively.

The resultant database will be of enormous use in taking site specific necessary measures for the sustainable development of groundwater resources in the area. The data could be profitably utilized for taking up studies regarding the behavior of groundwater table in relation to the pattern of groundwater table variations over a period, its relation to rainfall and irrigation and to explore the possible long-term relationship between groundwater level fluctuation and climate change on a regional scale. Moreover, vast area in the study area remains water logged during the kharif crops sown and harvesting season. Any more increase in the water logged area at the cost of agricultural lands is not desirable and obviously not in the interest of the economy of the state. These studies also have vital importance in the development of water logged areas. It, therefore, becomes imperative to have a careful watch over the behavior of groundwater table on a regular basis since rise of groundwater table could be permitted only to a certain extent.

ACKNOWLEDGEMENT

The author is thankful to the Director, Central Ground Water Board, NER, Guwahati, Ministry of Water Resources, Government of India for providing the relevant literatures, and Dr. Santanu Sarma, Associate Professor, Cotton University, Guwahati for extending help in preparing the maps in GIS.

REFERENCES

1. CGWB, (2009). Hydrogeology of Assam and Scope for Ground Water Development. Technical Report Series: D. Central Ground Water Board, NER, Ministry of Water Resources, Government of India.
2. CGWB, (2000). Hydrogeology and Groundwater Potential, Morigaon District, Assam. Technical Report, June, 2000, Unpbl., Central Ground Water Board, NER, Ministry of Water Resources, Government of India.
3. CGWB, (1997). Hydrogeology and Ground Water Conditions in Nagaon District, Assam. Technical Series D No.35, Central Ground Water Board, NER, Ministry of Water Resources, Government of India.
4. Conlon, T. D., Wozniak, K. C., Woodcock, D., Herrera, N. B., Fisher, B. J., Morgan, D. S., Lee, K. K. and Hinkle, S. R., (2005). Ground-water Hydrology of the Williamette Basin, Oregon. Scientific Investigations Report, 2005-5168, U. S. Geological Survey.
5. Karanth, K. R., (1987). Groundwater assessment development and management. Tata Mc Graw-Hill, New Delhi, 720 p.
6. Taylor, C. J. and Alley, W. M., (2001). Ground-Water-Level Monitoring and the Importance of Long-Term Water-Level Data; U. S. Geological Survey Circular 1217; 68p.
7. Todd, D. K. (2006). Ground water Hydrology.2nd ed., John Wiley & Sons, New York. 535p.