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Hydrogeological Characterization and Aquifer Dispositions in the Lower-digaru Basin, Ne India: An Integrated Field and Geospatial Analysis

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ABSTRACT

The Lower-Digaru drainage basin, situated within the southern Brahmaputra Valley of Assam, NE India, exhibits complex hydrogeological conditions controlled by heterogeneous Quaternary alluvium and adjoining Precambrian crystalline formations. This study characterizes the hydrogeological framework and aquifer disposition of the basin through integrated field investigations, lithological interpretation of 11 exploratory boreholes, well-inventory surveys of 53 dug wells, and GIS-based spatial analysis. Lithological logs reveal multi-layered aquifer systems dominated by sand, gravel, and mixed alluvial units in the eastern and northern sectors, whereas shallow hard-rock formations limit groundwater occurrence in the western and southern hill zones. Depth-to-water levels range from 0.08-11.5 m (pre-monsoon) and 0.9-8.7 m (post-monsoon), with maximum depths along the Kolong/Kopili riverbank. Seasonal groundwater fluctuations vary between-1.9 and 4.3 m, with 83% of the area exhibiting <1 m fluctuation, indicating moderate recharge-discharge conditions. Water-table contour mapping reveals variable hydraulic gradients and groundwater flow from the elevated southwestern highlands toward the northern alluvial plains. Aquifer potential is highest in Jagiroad, Sonapur, and Dimoria, where thick granular zones provide favourable groundwater storage, while negligible potential is observed in Byrnihut, Bomfor, and Hastinapur due to massive crystalline bedrock at shallow depths. The findings enhance the understanding of spatial variability in aquifer geometry, groundwater availability, and flow dynamics in a rapidly urbanizing region adjacent to Guwahati. This study provides a scientific basis for sustainable groundwater planning and management in accordance with SDG-6, emphasizing the necessity of protecting both groundwater quantity and quality in a geologically sensitive basin.

Key words: *Hydrogeology, Well-inventory, Aquifer Dispositions, Digaru Basin, NE India*

Introduction

Groundwater occurs throughout much of the Earth's subsurface; however, its abundance varies considerably within the saturated zone, depending on the geological and hydrogeological properties of the underlying formations. The irregular distribution of groundwater resources results in appreciable shortages of fresh water in a number of regions throughout the country. Geology is the key to any groundwater investigation and is one of the major factors that control the occurrence and movement of groundwater in the subsurface. Geologic features play important roles in the identification of groundwater provinces. The nature of geologic materials and depositional patterns strongly influences groundwater movement. When hydrologic conditions supply water to the subsurface zone, the underlying strata control its distribution and flow. Therefore, the significance of geology in hydrology is paramount (Todd, 2006). 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). In the rock, water moves from areas of recharge to discharge under the influence of hydraulic gradients depending on the hydraulic conductivity or permeability. Water permeability depends upon the size of pores and fissures found in a rock and on their interconnectivity. Although most of the materials in the earth's crust are in a saturated state due to continuous percolation from rainfall and springs, only a few have got sufficient porosity and permeability so as to yield sizeable quantities of available groundwater.

In India, broadly two groups of rock formations, viz. porous formations and fissured formations have been identified as aquifers, depending on their characteristically different hydraulic parameters of these formations (CGWB, 2009, 2010). Porous formations have primary porosity from the time of deposition, while fissured formations have secondary porosity developed through various geological and tectonic processes. An aquifer is a subsurface layer of permeable formation with varying size and shape that can store as well as yield groundwater economically to the well tapping it. The aquifer materials vary in particle size, roundness and in their degree of assortment. Consequently, their water yielding capabilities vary considerably. Among the five distinct regions that Indian sub-continent has been divided on the basis of hydrogeological set up, Assam belongs to the Indo-Gangetic-Brahmaputra Alluvial Plains which have tremendous groundwater potentiality. It comprises of the vast plains of Ganga and Brahmaputra rivers and is underlain by thick piles of sediments of Tertiary and Quaternary age. This vast and thick alluvial fill, exceeding 1000 m at places, constitute the most potential and productive groundwater reservoir in the country. These are characterized by regionally extensive and highly productive multi-aquifer systems. In Indo-Gangetic-Brahmaputra plain, the deeper wells have yield ranging from 25-50 lps (Jha and Sinha, 2009).

Hydrogeological characteristics of the various lithological formations, such as depth of groundwater, porosity and permeability, yield etc. are of vital importance in studying the groundwater potential in an area. Moreover, to understand the crucial role that groundwater plays to the society and the nation as a whole we must have to understand the fundamentals of hydrogeology. A detailed study on the occurrence, movement and flow direction of groundwater is very much essential for the optimum utilization of groundwater resources. Hydrogeological characterization is fundamental to interpreting how groundwater occurs, how aquifers are shaped, how recharge takes place, and how water moves through the subsurface. In the Indian context, many investigations have highlighted the need for combining geological and on-ground hydrogeological surveys to accurately define aquifer frameworks. The Central Ground Water Board (CGWB) has undertaken extensive aquifer-mapping initiatives across the country, generating essential datasets on aquifer architecture, hydrostratigraphic layers, aquifer thicknesses, transmissivity values, and well yields in both alluvial and hard-rock settings. These national-scale assessments underscore the wide variability in groundwater potential across different physiographic provinces, from the Indo-Gangetic plains to the crystalline terrains of the peninsular shield. In alluvial basins, earlier works have shown that variations in lithology, sedimentary facies, and depositional settings exert strong control over aquifer continuity and hydraulic properties. Research by Chowdhury and Srivastava (2005 - 2010) in the Ganga plains and by Sarma (2012) in the Brahmaputra valley demonstrates that aquifer configurations are shaped by fluvial dynamics and paleo-channel shifts, which in turn influence groundwater distribution and flow pathways. Within northeastern India, complex Quaternary sedimentation combined with tectonic activity has been found to produce multi-layered aquifer systems characterized by spatially variable yields and groundwater storage. In hard-rock terrains, hydrogeological investigations consistently highlight the influence of weathering intensity, fracture development, and structural discontinuities on aquifer configuration and groundwater occurrence. Studies by Thangarajan (2007) and Raju (2012), indicate that crystalline rocks store groundwater mainly within the weathered zone, while actual movement of water takes place through secondary porosity features such as fractures, joints, and lineaments. Nath and Patra (2001) have demonstrated that the integration of GIS with hydrogeological datasets supports accurate assessment of water-table patterns, recharge areas, and hydrogeomorphic units. Consequently, the combined application of field observations, litho-log interpretations, aquifer-test data, geophysical surveys, and GIS techniques has become a standard and widely adopted methodology for modern hydrogeological characterization across India.

The area of study presently borders the municipal limits of Guwahati metropolitan city and part of the study area will come under its coverage due to the proposed expansion of Guwahati city. The Guwahati Metropolitan Development Authority (GMDA) is envisioning Guwahati as a wider State Capital Region (SCR) with an eye to planned and comprehensive development (ASCRDA Act, 2017). Guwahati is one of the fastest growing cities in India and the population of the city is rapidly increasing. As the price of land in the capital city has skyrocketed, the study area has witnessed heavy migration of people. This trend is expected to accelerate in the immediate future which will further compound the water supply crisis which already exists in the area. Hence, not only the overall demand but also the per capita requirement of water will increase and thereby further stressing the water supply infrastructure. The aim of this work is to assess the hydrogeological characteristics of the Lower-Digaru Drainage Basin in Assam, NE India, through integrated field investigations and geospatial techniques, in order to evaluate groundwater condition and aquifer disposition.

Materials and Methodology

Study Area

The study area lies within longitudes 91°47′28″E - 92°18′9″E and latitudes 26°1′25″N - 26°15′14″N. It lies in the Survey of India Toposheets No. 78N/15, 78N/16, 83B/4, 83B/8 on scale 1:50,000 covering an area of around 536 Sq. Km. and belongs to the Lower Brahmaputra Valley zone. It is bounded by the river Brahmaputra and Kolong/Kopili on the north, river Kopili on east, Meghalaya state on the south, and Dispur, the capital of Assam on the west (Figure 1). The Lower-Digaru drainage basin forms a part of the Brahmaputra River basin and is located in the southern part the river Brahmaputra (Figure 2). The major parts of this study area come under the Kamrup Metropolitan District, which is one of the 33 administrative districts of Assam state and some parts in the Ri-Bhoi district of Meghalaya state in north-eastern India. Based on the rainfall distribution, two rainfall zones have been identified in the study area. Good Rainfall zone: ranges from 1081 to 1100 mm, covering a total area of 15.44 sq. km, accounting for 2.90% of the study region. Very Good Rainfall zone: Ranges from 1100 to 1339 mm, encompassing a total area of 516.74 sq. km, making up 97.10% of the study area. Figure 3 represents the rainfall zone map of the study area.

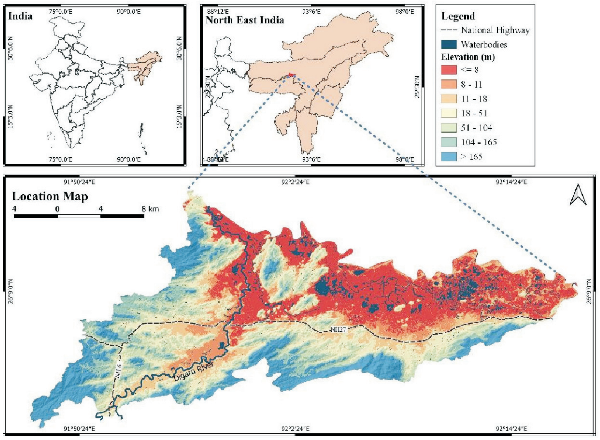

Fig. 1. Location map of the study area (reproduced from authors earlier work)

Geologically the area is a north easterly extension of the Assam Meghalaya Plateau and is a part of the basement gneissic complex as the most dominant rock. The origin and development of the study area is connected with the phases of upliftment due to tectonic movements, glaciations and erosion of the Himalayas and sinking with sedimentation (CGWB, 2005). These are the extension of the Proterozoic rocks of Meghalaya/Shillong Plateau and represent the oldest formations consisting of metamorphic complex with gneissic rocks. Geologically the study area is occupied by consolidated formations belonging to this Precambrian group of rocks, consisting of granites and gneisses, overlain by unconsolidated alluvial sediments of Quaternary age (Figure 2). Granites have been encountered in the south-eastern part of the study area which is intrusive in nature. The Archaean (?) and Proterozoic rocks form the basement is found as dissected hills as well as subdued-hills projecting out the plain alluvium stretch. The hard rocks occurring mostly in the western and southern parts in the area are highly lineated (Figure 3). Presence of lineaments in hard rocks may act as a conduit for ground water movement which results in increased secondary porosity and therefore, can serve as groundwater prospective zone. The Archean gneissic complex comprises of biotite-gneiss, biotite-hornblende gneiss, granite gneiss, migmatite, mica schist, sillimanite-quartz schist, biotite-granulite-amphibolite, pyroxene-granulite etc. The overlain unconsolidated alluvial sediments consist of clay and sands of various grades of Quaternary age. Sand, silt, pebble and clay occur extensively in the northeastern and northern part of the area. The unconsolidated, mixed sediments with variable grain size. this region has high groundwater potential because the underlying lithology dominantly comprises of loose, unconsolidated to semi consolidated materials with greater degree of interconnected pore spaces allowing water to infiltrate and move though the soil layers, and recharging the aquifer.

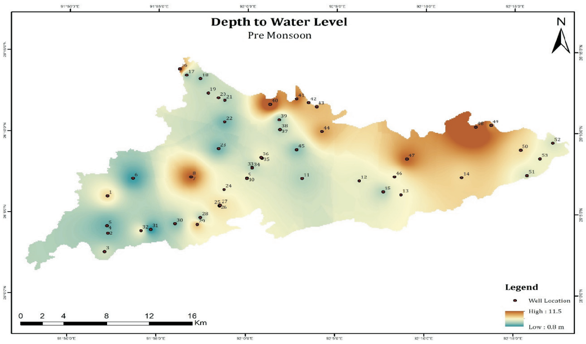

Fig. 2. Lithological map of the study area (reproduced from authors earlier work)

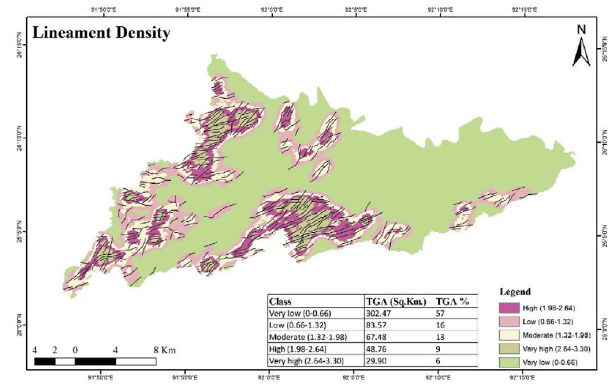

Fig. 3. Lineament Density Map (reproduced from author's earlier work)

Field Investigation: Field investigation included well inventory and collection of various hydrogeological data. Interaction with the local people was also a major part of this field investigation. During the well inventory the hydrogeological data such as depth of the well (dug well), diameter of the well, depth to water level, height of the measuring point etc. were measured with the help of a steel tape of 50 m length graduated up to 1 mm division. A brass rod of about 15 cm length attached to the lower end of the tape to make it taut during measurement. For the measurement of the depth of the water level, the wetted tape method (hold and cut method) was adopted. Both dug-wells and bore-wells were selected for well inventory in this present investigation. Hydrogeological data of 53 dug well inventories were collected in both pre- and post-monsoon periods from the study area in both pre- and post-monsoon periods, data were collected from the same well sites. During the well inventory, a more or less uniform distance between the wells has been maintained. The positions (Latitude – Longitude) of 53 locations all over the study area were obtained using a handheld GPS receiver. Based on the positional data of sample locations, a point feature class is prepared that shows the spatial distribu-

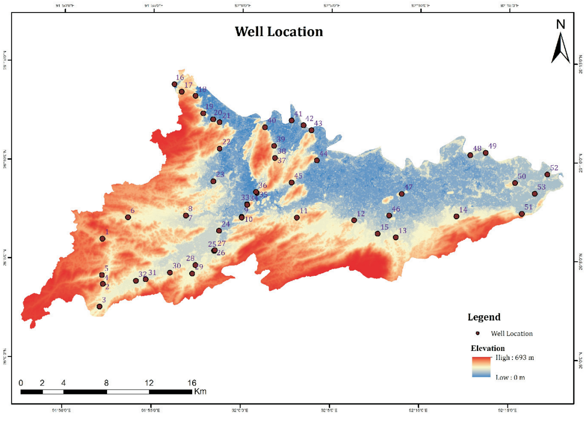

Fig. 4. Well Inventory locations in the study area

tion of 53 dug/bore wells locations (Figure 4). ESRI ArcGIS platform is used for GIS database creation and analysis.

Laboratory works

The lithological log data of 11 exploratory boreholes have been collected from the CGWB, NER, Guwahati, and Directorate of Geology and Mining (DGM), Assam. The sub-surface geology and nature and extent of the aquifers in the study area have been studied based on these lithological log data (Figure 5 a - k).

The spatio-seasonal variability of groundwater level in the area has been studied through the depth to water levels maps prepared for both pre- and post-monsoon periods (Figure 7 & 8) and subse-

(a) BH-1 (b) BH-2 (c) BH-3 (d) BH-4

(e) BH-5 (f) BH-6 (g) BH-7 (h) BH-8

(i) BH-9 (j) BH-10a (k) BH-11

Figure 5. Lithological log data of 11 exploratory boreholes [(a) – (k)]

(Source: Central Ground Water Board CGWB, NER, and Directorate of Geology and Mining (DGM), Assam quent seasonal fluctuations of groundwater levels map (Figure 9). Water table contour maps for both pre- and post-monsoon seasons have also been prepared to understand the movement and flow direction of groundwater in the study area. These maps were prepared using Spatial Analyst Toolbox in ESRI Arc GIS 10, with the data available from field surveys. IDW (Inverse distance weighted) method was used to prepare the thematic maps, where well data was utilized to model the spatial distribution over the entire study area. Depth to water level map was prepared from the depth measured at all the locations using spatial interpolation method. The same method was adopted to create ground water level fluctuation map to represent the change in the water level from pre- to post monsoon season. For the construction of water table contour maps the altitudes of the water levels with respect to the mean sea level (MSL) of some representative well points have been used. These reduce water levels of the well points were plotted with respect to their positions on the base map. This was computed as the difference of elevation and depth to water level at each well location. The elevation at each well location was extracted from DEM (Digital Elevation

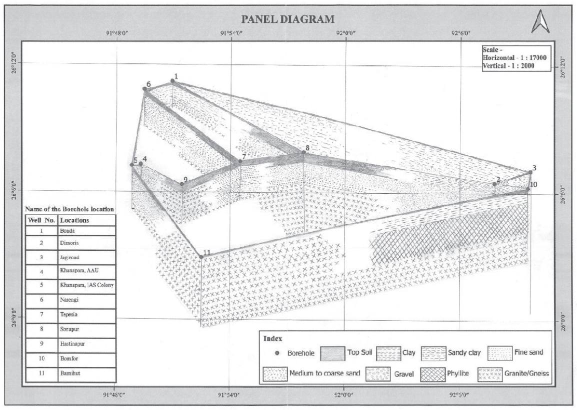

Fig 6. Panel Diagram showing the aquifer dispositions in the study area

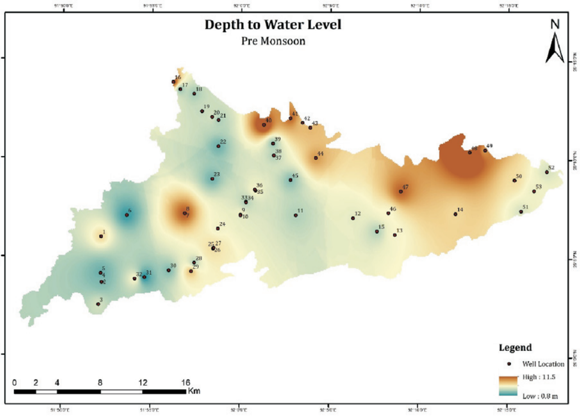

Fig. 7. Depth to groundwater level in pre-monsoon (mbgl)

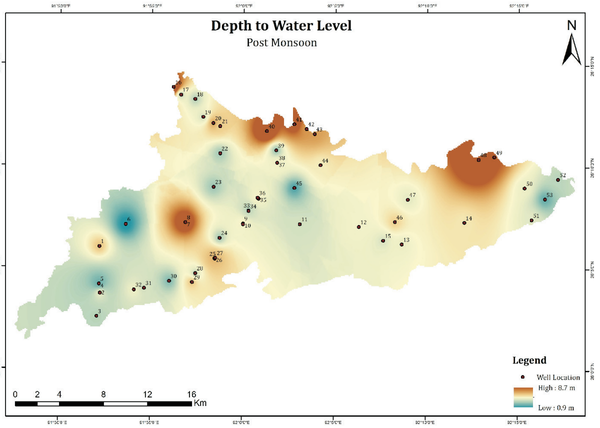

Fig. 8. Depth to groundwater level in post-monsoon (mbgl)

Table 1. Effective Thicknesses of aquifers for groundwater extraction in various locations in the study area

Sl. No.	Locations	Effective Thickness of Aquifer	Suitability for Groundwater Extraction
1	Bonda (BH-1)	15.98 - 30.52	Moderately suitable
2	Dimoria (BH-2)	5.49 - 30.5	Suitable
3	Jagiroad (BH-3)	14.98 – 63.1481.5 – 133.11	Highly Suitable
4	Khanapara AAU (BH-4)	6.7 – 37.2	Suitable
5	Khanapara (BH-5)	12.8 – 55.5	Suitable
6	Narengi (BH-6)	6.7 – 21.9433.52 – 47.24	Moderately Suitable
7	Tepesia (BH-7)	6.8 – 50.5	Suitable
8	Sonapur (BH-8)	11.85 – 37.45	Highly Suitable
9	Hastinapur (BH-9)	3- 11.0	Marginally Suitable
10	Bamfor (BH-10)	3 – 59.65	Poor
11	Byrnihat (BH-11)	None	Unsuitable

Model). Water table contours were drawn at 5 m interval (Figure 10 & 11).

Results

The hydrogeological characteristics of an area can be studied from the available drilling records of the bore holes carried out during exploratory drilling operations in an area. The distributional extent of subsurface geology of the study area has been studied on the basis of lithological log data of exploratory boreholes (Figure 5).

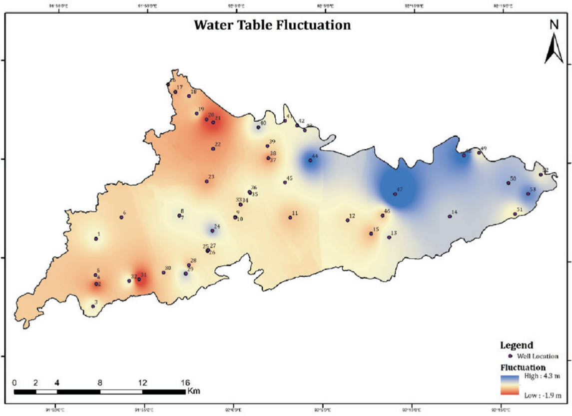

Fig. 9. Groundwater level fluctuation map

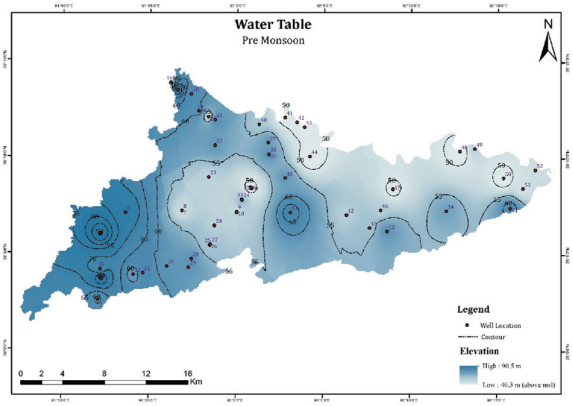

Fig. 10. Groundwater Contour Map (Pre-monsoon)

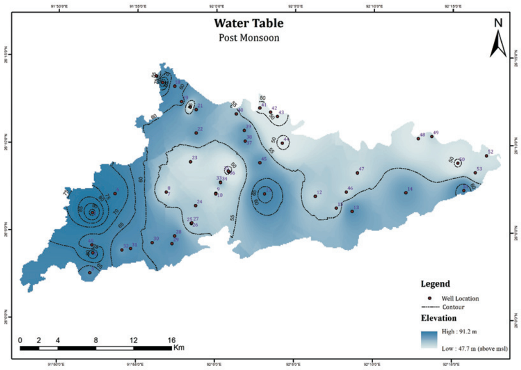

Fig. 11. Groundwater Contour Map (Post-monsoon)

BH-1 (Bonda): The lithology of Bonda area starts with earth fill, clay and sand mixture followed by alternating layers of granular/clayey sand, coarse sand with traces of quartz. It ends with hard rock at >31.02 m.

BH-2 (Dimoria): The lithology of Dimoria is mostly interbedded clay and sand which are fine to coarse grain. It ends at 36.9 m with granite cuttings.

BH-3 (Jagiroad): The lithology of the Jagiroad borehole has thick alternating layers of clay, granular sand and clayey sand. There are gravel and medium coarse-grained sand at multiple levels, hard rock is encountered at >138.35 m.

BH-4 (Khanapara, AAU): The lithology starts with clay and fined grained sand which transitions into medium to coarse grained sand and granular sand which ends with feldspathic rock cuttings which is a indication of weathered basement rock.

BH-5 (Khanapara, IAS colony): The lithology of this borehole begins with clay and soft, very fine sands with grades into fine to very coarse sands. It ends with weathered rock cuttings at 58m.

BH-6 (Narengi): The lithology of Narengi borehole is highly variable with alterations of clay and sand which are medium to coarse grained. It ends in rock cuttings at 47.7m.

BH-7 (Tepesia): The lithology consists of alternating sand and clayey sand layers from surface to 50.5m and ends in weathered rock at 52.7m.

BH-8 (Sonapur): The lithology of this borehole is fine to medium coarse sand underlain by hard rock.

BH-9 (Hastinapur): The lithology consists of shallow pediment soil till 11m over biotite gneiss (metamorphic rock) extending from 11m to 226.5m.

BH-10 (Bomfor): The lithology consists of surface sandy soil followed by thick phyllite. Hardrock is encountered at 59.65 m.

BH-11 (Byrnihut): The lithology of Barnihut borehole is entirely granite gneiss from surface to 159.9m.

Panel Diagram: The bore log data were used to construct the panel diagram to show the disposition of the aquifer/aquifers present in the area (Figure 6). The diagram connects several boreholes spaced at regular or irregular intervals. It shows the different subsurface layers e.g., clay, sand, gravel and hard rocks encountered during drilling. Panel diagram helps visualize how geological formations continue, thins out, or change between locations.

Discussion

Two distinct hydrogeological set-ups prevail in the study area. The first set-up is older alluvium which occurs along the eastern and north-eastern parts of the area. They are comprised of sand, silt pebble and clay. 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 consists mainly of loamy sand with smaller proportions of silt and clay, occurring in the south-central part of the area (Figure 2). In younger alluvium groundwater mostly occurs under phreatic condition in shallow horizons and under semiconfined or leaky confined condition in deeper horizons. The near-surface shallow groundwater is the main source of water supply in the area. Open wells and dug wells are used for extraction of groundwater from this area.

Depth to Water Level

Water levels in aquifers reflect a dynamic balance between groundwater recharge, storage, and discharge since these factors affect the timing and intensity of responses to hydrologic stresses such as precipitation or pumping. Water levels in wells reflect these changes and provide the principal means of tracking changes in groundwater storage over time. 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 0.08 m (Monpur-Nortap, well no.31) and 11.5 m (Baghjap, well no 48) in pre-monsoon (Figure 7) and from 0.9 m (Patorkuchi, well no.6) to 8.7 m (Baghjap, well no 48) in post-monsoon (Figure 8). It has been observed that in both pre-monsoon and post-monsoon seasons the maximum depth to water level occurs in Baghjap area which is at bank of river Kolong/Kopili in the northern part of the study area.

Seasonal Fluctuation of groundwater Level

Groundwater occurs in pore spaces of granular soil/lithological formation and in fractures; therefore, it is under dynamic condition and fluctuates. The magnitude of the water level fluctuation depends on climatic factors, drainage, topography and geological conditions. Monitoring of groundwater fluctuations is very important on many accounts like agricultural practices, aquifer recharge and to study droughts. The lateral movements of groundwater in the aquifer are reflected in the vertical movements of water levels. Davis and DeWeist (1966) noted that water-table fluctuations can result from changes in groundwater storage, atmospheric pressure variations, aquifer deformation, and minor chemical or thermal disturbances within the well. The groundwater level monitoring in the study area has indicated that changes in groundwater level occur seasonally and annually as a result of recharge and discharge of groundwater from the system. The groundwater level data collected from 53 nos. of dug wells from the study area during both pre-monsoon and post-monsoon seasons have been used to determine the water level fluctuations. In the study area groundwater level fluctuates between -1.9 m to 4.3 m and the area can be demarcated into three different regions as high intermediate and low. It has been observed that 7.55 % of the total study area is affected by the fluctuation levels of above 2.5 meter; 9.6% of the total area remains within the fluctuation level from 1 m to 1.5 m and, rest 83 % of the total study area is subjected to fluctuation levels of less than 1 meter (Figure 9).

Groundwater Flow Dynamics

The movement and flow direction of groundwater have been studied with the help of water table contour maps, both pre-, and post-monsoon, of the area. A groundwater contour map, also referred to as a water-table contour map or piezometric surface map, illustrates the spatial distribution of groundwater levels, expressed as the elevation of the water table across an area. The contour lines represent points of equal groundwater elevation relative to mean sea level. A high contour value means that the water table is closer to the land surface indicating a recharge zone where water infiltrates into the ground. Groundwater flows from high elevation to low elevation which indicates the flow direction of groundwater in that area. In the pre-monsoon period water table contour having the highest altitude of 90.5 m (Jorabat, well no.1)) is found in the western part while the lowest altitude of 46.3 m (Dobota, well no. 44) water table contour is found in the northern part of the area. Similarly, in the post-monsoon the highest altitude of 91.2 m (Jorabat, well no.1) water table contour is found towards the western part. The lowest altitude of 47.7 m (Gumoria, well no. 36) water table contour is found in the central part and in the northern part of the area along the river Kolong/Kopili (Figure 10 & 11). Hydraulic gradient is proportional to the spacing of equipotential (contour) lines. Steeper hydraulic gradients, reflected by closely spaced groundwater contour lines, generally occur in formations with low hydraulic conductivity. In such materials, groundwater moves more slowly, causing a sharper decline in hydraulic head over short distances. Conversely, formations with high hydraulic conductivity facilitate more efficient groundwater flow, resulting in gentler hydraulic gradients and widely spaced contour lines. Thus, the spacing of water-table contours provides an important indicator of the permeability and transmissive behaviour of subsurface formations **(Freeze & Cherry, 1979; Fetter, 2001).** From the water table contour maps of the study area (Figure 10 & 11), it has been observed that the spacing of the water table contours are not uniform all throughout the area in both pre-monsoon and post-monsoon periods which indicates that the water bearing formations have variable permeability and transmissivity in the study area. Particularly at the localities in the western, southwestern and northwestern parts of the area contour spacings are narrower in both the seasons, indicating uneven hydraulic gradients and relatively lower hydraulic conductivity of the water bearing formations from the rest part of the area. Understanding of groundwater behaviour is important for the proper management of this precious resource. This can be studied through careful monitoring of spatial and temporal variability and seasonal fluctuations of groundwater level, movement of groundwater, groundwater flow pattern etc. Study of both short- and long-term fluctuations of groundwater level helps us to understand the depletion and recharging conditions of an aquifer.

Aquifer Disposition

The nature and extent of the aquifers in the study area have been studied based on the panel diagram prepared from the bore-hole litho-log data. This panel diagram shows the disposition of aquifers in the study area. The aquifers in the study area comprises primarily of alluvial deposits comprising of clay, silt, sand and granular gravels of Quaternary age. Groundwater occurs in the intergranular pore spaces of sand and gravel horizons and the horizons of mixture of both. The effective thicknesses of aquifers for groundwater extraction in various locations in the study area are tabulated in Table 1. The panel diagram gives a 3D visualization of subsurface geological cross-sections which helps in delineating the aquifer disposition in the study area (Figure 6). From the panel diagram and the lithology data it can be inferred that there is good to very good zones marked by thick, clean or gravel layers in the boreholes locations like Jagiroad, Dimoria, Sonapur are highly favourable for groundwater development. Availability of hard rocks at shallow depths significantly limit the groundwater availability Byrnihut, Bomfor, Hastinapur. Narengi, Bonda are borderline areas with some aquifer potential, but limited in depth or quality. At Bonda (BH-1) the key aquifer zone is encountered at 15.98 m and extends up to 31.02 m where, hard rock limits deeper extraction. The aquifer zone predominantly comprises of sand which is coarse to granular and has good aquifer potential. The key aquifer zone at Dimoria (BH-2) is from 5.49 m - 30.5 m with a thickness of 25 m of multiple sand layers that are fine to coarse with occasional clay layers. It has moderate aquifer potential. The limiting factor here is granite basement encountered at 30.5m with granite cuttings. The lithology at Jagiroad (BH-3) has thick alternating layers of clay, granular sand and clayey sand. There are gravel and medium coarse-grained sand at multiple levels. The two aquifer zones have thicknesses of 48.2 m and 51.6 m respectively, which are thick sandy and gravelly zones. It has a very good aquifer potential along with high ground water potential. Hard rock is encountered beyond 138 m limiting the further exploration. The key aquifer zone at Khanapara, IAS colony (BH-5), is encountered at a depth of 6.7m and extends up to 55.5 m. The 49 m thick well sorted sands that makes this a very good aquifer zone. It includes some mixed sand-clay units that are water bearing with moderate transmissivity. The ground water potential is excellent in sandy layers especially from 12.8 m-44.8 m zone. The weathered rock cuttings encountered at 58m. In Tepesia (BH-7), the key aquifer zone is from 6.8 m- 50.5 m with a thickness of 43.7 m which comprises mostly of sandy layers with grain size fine to medium with interbedded clay that has good primary porosity. The clayey sand layers may act as semi confining layers. The lithology consists of alternating sand and clayey sand layers from surface to 50.5m and ends in weathered rock at 52.7m. In Sonapur area, the key aquifer zone is encountered at 11.85 m and extends up to 37.45 m, which comprises of thick sand body intercalated with fine to medium and coarse grained. It has a very good groundwater potential zone with a thickness of 26 m. Hard rock is encountered at depth of 37.45 m and continued up to 252 m which restricts further drilling of the borehole. The groundwater potential in Hastinapur area (BH-9) is very low. The lithology consists of shallow pediment soil till 11m which is followed by biotite gneiss (metamorphic rock) extending from 11m to 226.5m. The key aquifer zone is from 3m- 11m only in shallow pediment soil. The lithology in Bomfor area (BH-10) consists of surface sandy soil followed by thick phyllite and granite encountered at 59.65 m. A shallow aquifer zone starts from surface up to 14.2 m with clayey and sandy units. Phyllite may hold some water in fractures, but this area has a very low to moderate groundwater potentiality. At Byrnihut (BH-11), the granite gneiss is exposed at the surface and extends to a considerable depth, as indicated by exploratory drilling up to 159.9 m. The groundwater potential in this area is negligible. However, limited quantities of water may be encountered within fracture zones, which are confined to shallow depths.

In the study area, groundwater mostly occurs in the alluvium formations available in the eastern, northern and central parts of the study area, under phreatic condition in shallow horizons; and generally, follows a cyclic pattern that follows seasonal variations in recharge and discharge. The overall regional variation of depth to water level in the alluvial plain extending from the high hill zone in the western, southwestern to central part of the area appears to be controlled by the prevalent geomorphic settings of the area. High water levels occur in the rainy season when recharge from precipitation exceeds discharge; low water lev-els occur during the dry season when discharge by pumping, evapotranspiration, and leakage to streams exceeds recharge. The principal factors that affect groundwater levels are pre-cipitation, stream stage and well pumping. During the field investigation, it has been noticed that dug wells are very scarce in most part of the study area. More particularly in the extreme southwestern, western and central-southern parts of the area no dug well was found in the reserve forests.

The western and the southern parts under the study area are characterized by hilly terrain composed predominantly of gneissic rocks, which are crystalline, hard, and low permeability formations. However, the terrain exhibits a high degree of lineation and fracturing, which influence the groundwater occurrences in this part of the area. While lineaments and fractures are important for groundwater storage in hard rock terrains like gneisses, their effectiveness depends on their connectivity, depth, slope and soil conditions with subsequent recharge conditions. The groundwater contour map reveals that the water table elevations are relatively high in this zone, indicating potential groundwater recharge zones of water accumulation along structural discontinuities. However, low lineament density is scattered along the north western parts, southern parts, and very low lineament density (shown in light green colour in Figure 3) dominates the eastern and north eastern parts of the area. These regions generally have low to very low groundwater potential. The lack of fractures prevents the development of secondary porosity. Water infiltration and aquifer recharge is prohibited resulting in low groundwater potential. The northeastern and northern part of the study comprises of unconsolidated, mixed sediments with variable grain size. this region has high groundwater potential because the underlying lithology dominantly comprises of loose, unconsolidated to semi consolidated materials with greater degree of interconnected pore spaces allowing water to infiltrate and move though the soil layers, and recharging the aquifer.

Conclusion

The Lower-Digaru drainage basin, part of the southern Brahmaputra River basin in Assam, NE India, was assessed for hydrogeological characteristics using integrated field investigations and geospatial techniques. Groundwater data were collected from 53 dug wells during pre- and post-monsoon periods. The maximum recorded depth to water level was 11.5 m, with deeper water tables in the pre-monsoon season indicating limited recharge due to reduced precipitation, decreased infiltration, or increased abstraction. Such deepening may reduce water availability and affect quality, as deeper aquifers often exhibit higher dissolved mineral content. Analysis of groundwater fluctuations revealed that 7.55% of the area experiences variations above 2.5 m, 9.6% fluctuates between 1 - 1.5 m, and 83% remains below 1 m, indicating a moderate aquifer recharge-discharge state. This suggests that the aquifer is in a transitional phase, influenced by ongoing natural processes. Zones with thick, clean, or gravelly layers, such as Jagiroad, Dimoria, and Sonapur, are highly favorable for groundwater development, whereas shallow hard-rock formations at Byrnihut, Bomfor, and Hastinapur limit groundwater availability. Understanding these spatial variations is essential for sustainable groundwater management in the region.

From a global standpoint, comprehensive hydrogeological datasets are essential for formulating site-specific and sustainable groundwater management strategies, particularly in environments influenced by climatic variability and diversified geological settings. Regionally, such datasets help decipher long-term groundwater-level behaviour and its linkage with rainfall, irrigation practices, and potential climate-induced fluctuations. In the Brahmaputra Valley of Assam, where the study area encompasses both extensive Quaternary alluvium and adjoining weathered crystalline rock terrains, groundwater dynamics are controlled by a complex interplay of primary porosity in the alluvial deposits and secondary porosity features such as fractures and weathered mantles in the crystalline formations. This variability contributes to pronounced seasonal water-table fluctuations and localized waterlogging, especially during the kharif season. Further expansion of waterlogged zones at the expense of agricultural land would have adverse consequences for regional agriculture and livelihoods. Therefore, continuous monitoring and interpretation of groundwater-level trends across these contrasting hydrogeological units are vital for regulating water-table rise, mitigating waterlogging, and ensuring sustainable groundwater and land-use management in this hydrologically sensitive part of the Brahmaputra Valley.

Groundwater is a vital and finite natural resource, renewed annually through the hydrological cycle but inherently limited by the balance between recharge and discharge. Contamination of aquifers renders this resource unusable, underscoring the need to protect both its quantity and quality. Sustainable management of groundwater is therefore essential to ensure its judicious use, safeguarding water security for present and future generations in alignment with the United Nations Sustainable Development Goals (SDG 6: Clean Water and Sanitation).

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Authors Contribution

DC: Writing-Original draft, Methodology, Software, Visualization, Formal Analysis.
SJK: Conceptualization, Supervision, Writing-Original draft, Methodology, Data Analysis, Visualization, Reviewing and Editing.
AKB: Data collection, Data Analysis
SM: Data collection, Data analysis
ASK: Formal Analysis, Reviewing and Editing.

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