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Behaviour Of Ground Water In The District Of Dhemaji In Assam, India.

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Abstract

The district of Dhemaji that lies in the north eastern part of Assam is a flood affected area. This study aims to understand the behaviour of the ground water in the vicinity of Dhemaji town in particular and in the district in general. Previous literature and data is scarce on it. An effort has been made to use the available technical data, primary data found in investigation and relevant literature reviews to infer about the behaviour of ground water in the study area. For the purpose of knowing the movement of ground water in the study area, hydrometeorology, soil characteristics, topographic slope, thickness and expansion of subsurface aquifers and hydrogeological characteristics of the area are also considered. The study reveals that ground water levels in the district are consistent over the years and long term trend of water level (rising or falling) over a period of 10 years is insignificant.

Key words : aquifers, hydraulic gradient, ground water.

1. Introduction

The district of Dhemaji in Assam occurs in the north eastern part of Brahmaputra river basin between north latitude 27^0 15' to 28^0 00' and east longitude 94^0 05' to 95^0 30' covering an area of 3,237 sq.km.

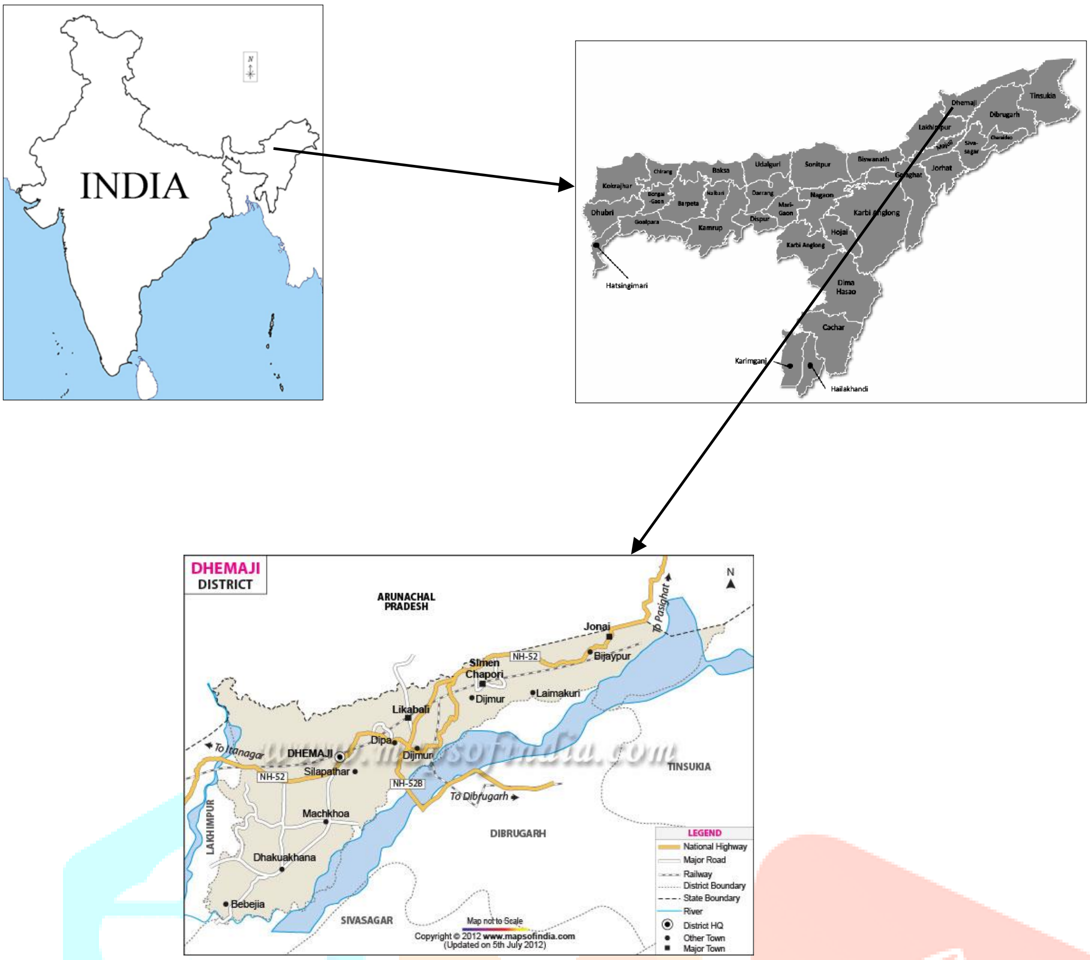

Fig. 1 : Location map of Dhemaji district

The district is vastly spread over plain land lying at an elevation f 104 metre above sea level (masl) with small hillocks. The river Brahmaputra which is a braided river flows from the east to the west and it is to the southern boundary of the district. The district is bounded by the hilly ranges of Arunachal Pradesh in the north and the east. The district of Lakhimpur is to the west.

A good number of perennial tributaries flow through the district originating from Arunchal Pradesh in the north join the Brahmaputra river in the south. The major streams that drain the area are Kumotia, Gai, Kanibil, Sisi, Simen, Dikari, Jiadhal and Royang and the Brahmaputra basin is the main drainage for the district. (Sonowal and Laskar, 2020)

1.1 Objective and scope of the study:

The objective of the study is to know the ground water levels at different location of the study area and to find the behaviour of ground water in response to the precipitation in the district. Hydro geological data have been taken from the Central Ground Water Board. First hand data of ground water levels from 11 dug wells in and around Dhemaji town have also been recorded and analysed.

1.2 Physiography of Dhemaji District

Dhemaji district can broadly be divided into three distinct units:

Piedmont zone: This is the foothill zone near the northern and eastern part of adjacent Arunachal Pradesh. This zone covers the older alluvium which consists of boulders, cobbles, **gravel, sand and silt.**

Active flood plains: These are near the River Brahmaputra and near all other major tributaries. This is of newer alluvium consisting of gravel, pebbles, coarse to medium sand, silt and clay.

Low lying alluvial belt: It covers the middle plain zone built up in saucer shape. The large number of swampy areas are common feature of this division. The underlying layer is deep aquifer in semi-confined condition.

The steep slope of Eastern Himalayas abruptly drop forming a narrow valley which widens to the western side. Numerous drainage system originating from the hills of Arunachal Pradesh flow through this narrow valley ending at the river Brahmaputra.

The slope of the district drops from northern and eastern corner towards south and western sides. The deposition of sediments by the up streams has led to the formation of saucer shaped low lying zone in the plains of the district. (https://dhemaji.gov.in.physiography)

Table 1 : The generalised geological succession based on the land forms, characteristics of sediments and other geomorphic characteristics(GSI, 1981)

Formation	**Sedimentological Characteristics**	**Age**
Recent flood plains	Sand, silt, silty-clay, Clay with occasional pebbles In foot hill region	Recent
Joihing surface	Pebbles, grit, coarse to find sand, silt, silty-clay with semi-consolidated sand but no oxidation	Upper Pleistocene
Harmati surface	Boulders, cobbles, pebbles mainly of quartzites, sandstone and gneissic rocks with argillaceous and siliceous matrix , highly consolidated and oxidized	Upper Pleistocene to Miocene
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1.3 Soil type of the district

The soil of the district is broadly classified into four groups, namely new alluvial, old alluvial, red loamy and lateritic soil. The new alluvial soil is found in the flood plain areas subjected to occasional flood and consequently receives annual silt deposit when the flood recedes. The old alluvial soils are developed at higher level and are not subjected to flooding. Red loamy soils are formed on hill slopes under high rainfall conditions.

1.4 Hydrometeorology

Dhemaji district is characterized by high rainfall due to south west monsoon which onsets in June and continues to September. The average morning humidity (recorded at 6:08 am) hovers around 90-96% and afternoon humidity (recorded at 1:08 pm) hovers around the range of 50-75%.

From the data of the period 1988-2012, it was found that maximum monthly rainfall recurred in the month of July (frequency 42%), June (frequency 38%), August (frequency 14%), May (frequency 2%) and September (frequency 2%).

The precipitation is caused almost entirely by the south west monsoon. The period of three months from June to August across the years receives around 40-55% of the annual total rainfall and it causes recurring floods every year.

Monthly rainfall gradually increases from May onwards and gains highest quantity in June to August and then decreases gradually to become scanty in December to January . July is the month of maximum rainfall received by the district.

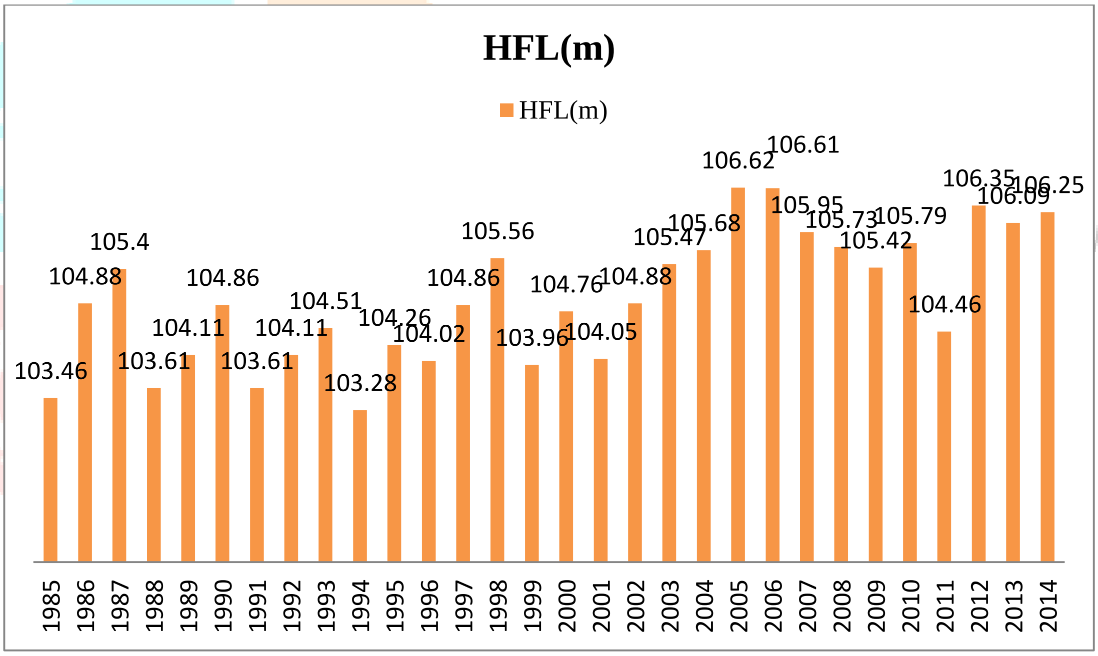

Fig. 2 : Trend of the high flood level of the river Brahmaputra at Botom suti switch/culvert at Panbari, Dhemaji district
Data source: Water Resource Engineering (Dhemaji office), Govt. of Assam

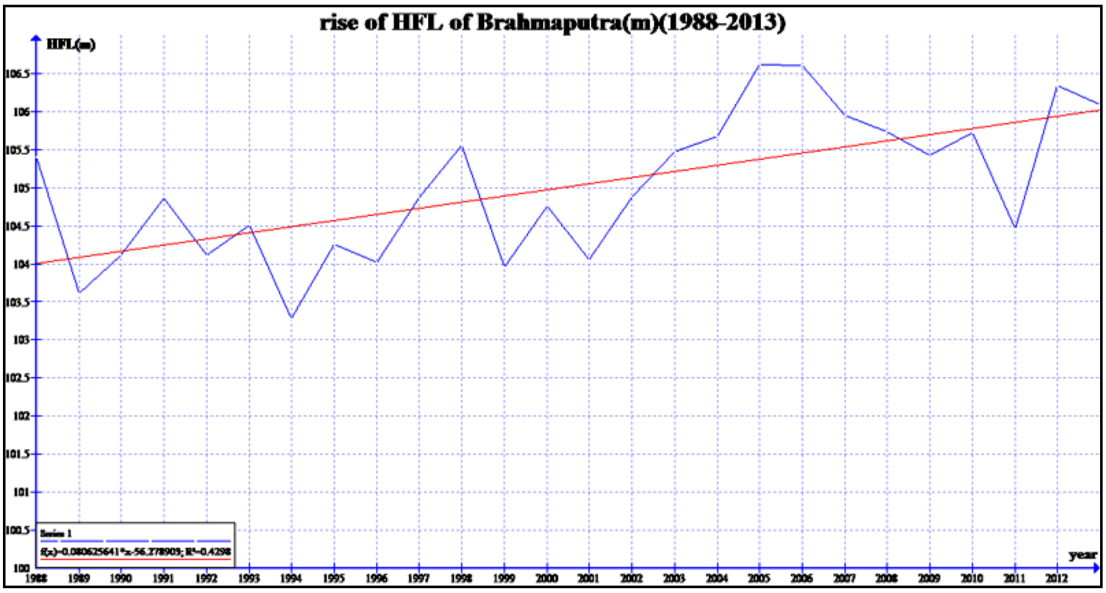

Fig. 3: Rise of HFL of Brahmaputra River in metre (1988-2013) at Botom suti switch/culvert at Panbari, Dhemaji district)

Data source: Water Resource Engineering (Dhemaji office), Govt. of Assam

The Brahmaputra is the main river of the upper Assam basin area. The water carried by the tributaries from the north and south of the upper catchment area is fed into the stream flow of the Brahmaputra

The response of a river system to the intensity and duration of rainfall is reflected by the High Flood Level (HFL) of the main river of the basin area at different locations. At a certain location, the HFL of the Brahmaputra indicates its response to the rainfall of the upper catchment area.

From graph no: 1 and 2, it is observed that there is a trend of increasing high flood level in the Brahmaputra at the specified site during the period of 1988 -2013. On the contrary, the maximum monthly rainfall during that period has shown a downward trend. The following results are observed:

In 1988, the maximum monthly rainfall was 637.3 mm in July and the HFL in the same month was 105.40m. In 2009, the maximum monthly rainfall was 585.4 mm in August and in the same month the HFL was 105 .42m. This implies that though the maximum monthly rainfall was 51.9 mm less, the HFL was almost the same.

In 1989, the maximum monthly rainfall was 529.0mm in July and the HFL was 103.61 m. In 1994, the maximum monthly rainfall was 438.8mm and the HFL was 103.28m. It indicates the less rainfall (90.2mm) also induced a very high flood level between the two periods of 1988 and 2013, There was a huge difference of maximum monthly rainfall (119.9 mm less) but it induced an increased HFL (0.69m more).It has been clearly observed that a rising trend of HFL is distinct as years pass on even if the rainfall remains the same or less. This is mainly because of the sedimentation deposits at the river bed.

The river bed of the Brahmaputra (the main drainage) possesses a much gentle slope in the valley after coming out of the upper hilly portion of the Himalayas. Further, the tributaries flowing from the hills also discharge their sediments carried by stream flow into the Brahmaputra. It significantly affects the main drainage system. During floods, though the river Brahmaputra carries a huge portion of the sediments to the sea, a portion remains at bed and after years the bed level rises. The discharge section gets constricted and it ultimately induces high flood level though the maximum monthly rainfall may be almost same.

1.5 Ground water

Water that infiltrates from the soil surface and stored underground in the spaces between sediments and the cracks within rock is known as ground water. All empty spaces of the saturated zone is filled in with ground water. The upper surface of the saturated zone is the water table and it is the boundary between the unsaturated zone above and the saturated zone below.

1.5.1 Ground water movement

Ground water is dynamic. It flows mostly downward due to gravity but also horizontally in permeable layers when interrupted by impermeable layer. Ground water moves very slowly through soil particles (7-30cm/day). The direction and speed of ground water movement is determined by characteristics of the aquifers and sub-surface rocks. Thus, the flow depends on the porosity and permeability of the aquifers.

Darcy's law (1856) is the fundamental law for hydrogeology to explain the ground water movement. The law was formulated by Henry Darcy based on results of experiments on the flow of water through beds of sands.

It states that discharge rate of ground water is proportional to gradient in hydraulic head and the hydraulic conductivity.

$$q = \frac{Q}{A} = -k.\ \frac{dh}{dt}$$

Where q= flow rate (m^3/sec),

Q= total flow, A= Gross cross sectional area of flow

K=hydraulic conductivity (m/day)= $\frac{k}{\mu} = \frac{\text{permeability}}{\text{dynamic viscosity}}$

$$\frac{dh}{dt} = \text{hydrulic gradient}$$

The negative sign is assigned to indicate that fluid flows down the hydraulic gradient from higher values to lower values. (Manning, 1997)

Hydraulic conductivity (K) is a constant of proportionality. It is a parameter that describes the ease with the flow takes place through a porous medium. It has large values for permeable units (like sand, gravel etc.) and small values for poorly permeable materials (like clay, shale etc.) The law is applicable for laminar flow which depends on Reynolds number.

The law can be extended to be used for ground water movement in consolidated rocks also if the equation of continuity is combined to it.

The hydraulic gradient which measures the change of hydraulic head is the force for which water moves from one place to another.

Permeability depends on the porosity of the material which comprise the aquifer

Table 2. Range in value of porosity (Schwartz and Zhang, 2003)

Materials	Porosity (%)
Sedimentary	
Gravel(coarse)	24-36
Gravel(fine)	25-38
Sand(coarse)	31-46
Sand(fine)	26-53
Silt	34-61
Clay	34-60

Table 3 : Porosity of common rock types. (Nonner, 2003)

Rock type	Range of Porosity
Unconsolidated rock	
Gravel	0.2-0.4
Sand	0.2-0.5
Silt	0.3-0.5
Clay	o.3-0.7
Consolidated rock	
Fractured basalt	0.05-0.5
Krastic limestone	0.05-0.5
Sandstone	0.05-0.3
Limestone, Dolomite	0-0.2
Shale	0-0.1
Fractured crystalline rock	0-0.1
Dense crystalline rock	0-0.0

The study of flow of water in soils is a challenging task. However, it can be looked into from three principles.

The first fundamental principle (Darcy's law) suggests a linear relationship between water flux density and hydraulic gradient. It is a view of steady state flow (laminar and uniform).

The second principle of 20th century states of the minimum pressure potential needed to overcome surface tension of fluid and initiate water flow through soil-air-interface. It gives cohesive explanation for water moving through layered soils. It is the microscopic view of interface- based dynamics of water flow.

The third principle of 21st century highlights the flow network embedded in heterogeneous soils. Water moves non-uniformly in natural soils following the least resistant paths but moves diffusedly into the matrix when at rest. The third principle combines both the first and second principle. Integration of above principles can advance flow theory, measurement and modelling and management of soil and water resources. (American Geophysical Union, 2016).

1.5.2 Formation of ground water system

Ground water system may be made up of a single aquifer or overlain by a aquitard (aquifer of low permeability) or aquiclude (aquifer of very low permeability). The system may be made up of a series of aquifers. They have upper and lower boundaries and sometimes abrupt lateral boundaries also.

Classification of aquifers can be done on the basis of their positions in the ground water system.

Unconfined aquifers contain ground water that is directly in contact with the atmosphere.

Semi-confined aquifers are filled with ground water; but these are overlain by aquitard. These aquifers have inflow and outflow of ground water through the overlain or underlying aquitards.

Confined aquifers are also filled with ground water but not in direct contact with atmosphere; these are located below aquicludes.

The area may be overlain by consolidated and unconsolidated rock.

In consolidated rocks, porosity depends on dimension of open spaces at joints, fractures etc. In most consolidated rocks, porosity is low (0.1m)

In metamorphic rocks, the coefficient of permeability (k) may be near to zero. Nevertheless, if the opened up joints and fractures are connected, the rock may be reasonably permeable and k may be up to 10m/day. Metamorphic rocks often present a poor ground water system. (Nonner, 2003.)

1.7 Recharge and discharge of ground water in the Dhemaji district

The main source of recharge is the precipitation (rainfall) in the monsoon period. (June to September of every year). A major part of the precipitation flows as surface runoff (storm flow). Another part flows in the ground sub- surface to the streams as base flow and the rest part of the precipitation infiltrates as the ground water and recharges the already existing ground water.

In the hilly areas of the north, the water table is almost parallel to the hill slope . Ground water which is always dynamic n nature discharges three ways:

One form is the springs. They discharge through faults both vertically and horizontally.

Another way is capillary flow from shallow ground water table. In the root zone of plants, capillary ground water evaporates directly to the atmosphere and transpires through the plants' vegetative parts.

The third way is the outflow of ground water into the surface of springs and strams as base flow.

1.6 Equipotential surfaces and flow net

For a ground water system, equipotential surfaces are those surfaces where hydraulic heads have the same value. The flow of ground water is perpendicular to these equipotential surfaces and the flows are from places of higher heads to places of lower heads.

In isotropic condition, the orientation of the surfaces can be established when the ground water flow direction are known.

Hydraulic heads can be plotted on suitable base map; by contouring the heads, the ground water contour maps are obtained and ground water flow directions can be indicated there perpendicular to the contour lines assuming the aquifers as isotropic.

If the contours are widely spaced, it indicates the hydraulic gradient is gentle and if the contours are closely spaced, it means steep slope of the water table. For the non- availability of contour map of the district the hydraulic gradients could not be ascertained.

However, from the prominent geomorphic setting (i.e. topography, relief and lithography) of the area, it can be inferred that steep hydraulic gradients exist in the northern and north eastern part of the district and ground water moves towards the discharge area of the south. The sufficient rainfall received by the catchment areas, however, leads to replenishment of ground water and natural recharge maintains to be a stable source of ground water at suitable locations. (Goswami and Dutta, 2012)

1.7 Fluctuations of ground water level

Seasonal variations are typically evident in the ground water level of the wells increasing during monsoon and reaching their lowest levels in winter when precipitation is scanty.

The magnitude of change in relative ground water level in response to climatic fluctuations is heavily influenced by the depth of the aquifers, porosity of the materials surrounding and within the aquifers and seasonal fluctuation in precipitation.

If the well is covered by a very thick unsaturated zone, it shows little appreciation in change in ground water level in response to changes in precipitation. (IWMP Tech. Report., 2003-2016)

1.8 Ground water level trend

The seasonal pattern of ground water level is also a part of the long term trend of fluctuating ground water levels in case of shifts in precipitations.

The time lag between shifts in precipitation and ground level of water is dependent on a number of factors. These are type and depth of the aquifers, soil saturation levels, land cover, and the type, quantity, and rate of precipitation.

Therefore, in addition to human ground water usage, urbanization and climate change can also have significant impact on ground water levels by altering precipitation patterns and increasing impervious surfaces. Impervious surfaces reduce the rate of ground water recharge. (IWMP Tech. Report, 2003-2016)

1.9 Ground water of Dhemaji District

Ground water in the floodplain area occurs under phreatic condition in the shallow aquifer zone and under semi-confined condition in the deeper aquifer. The flow of ground water occurs from north to the south direction. The occurrence and movement of ground water is controlled by topography, geomorphology, climate, geology etc. Rainfall is the main source of ground water recharge.

On the basis of well data received from the State Government departments, the following shallow aquifer geometry has been inferred. There is a great lateral and vertical variation of aquifer indicating various degrees of depositional agencies both in space and time.

Aquifer horizon in the shallow zone comprises sand of various grades, pebbles and boulders. Sticky clay and clay mixed with sand is encountered within 0 to 6 meter depth and pebble; boulders are encountered from 16 to 20 metre onward.

1.10 Ground water level monitoring of Dhemaji District

Ground water level at each well can be measured indirectly with an equipment known as pressure transducer water level logger. It records and digitally stores ground water level data at hourly intervals. Ground water level can also be measured manually collecting the ground water levels monthly. Ground water levels are indicated as metre above sea level (masl) or as metre below ground level (mbgl)

When comparisons among wells are made, ground water levels are expressed as the relative change in water level at each well in metre(m). Average seasonal and annual ground water levels are calculated for each well. If, however, more than 10% of the record is missing, (i.e. an annual average missing data more than 36 days) averages from those years or seasons are omitted from long- term trend analysis. (IWMP Tech. Report (2003-16).

From the table 2 (Dhemaji district), it is seen that pre-monsoon water level varies from 0.01 to 9.40 mbgl and post-monsoon water level varies from 0.56 to 8.26 mgbl. Depth to water level during pre-monsoon is higher than post-monsoon. This may be the effect of pre-monsoon rainfall. Long-term water levels show no significant change in the area.(after Central Ground Water Board, 2008-09)

Table 4 : Dhemaji District (CGWB, 2008-09)

Sl. no.	Item	statistics
1	Average annual rainfall	3435 mm
2	Major physiographic units	High level plain of Brahmaputra River Flat river flood plain area.
3	Land use	Forest (19.96%) Area sown (47.5%) Cultivable area (50.5%)
4	Predominant geological formation	Alluvial formation of Pleistocene to recent age
5	Major water bearing formation	Alluvial sediment of Quaternary and Piedmont deposits
6	No. of ground water monitoring wells (dug well) of CGWB (as on 2007)	10
7	Hydrology i) Major water bearing formation ii) Pre-monsoon depth to water level (2007) iii) Post-monsoon depth to water level (2007) iv) Long term water level trend in10 years (1997-2006) in m/yr	 Alluvial sediment of Quaternary and Piedmont deposits 0.01 to 9.40 mbgl 0.56 to 8.26 mbgl Rise/fall during pre-monsoon (0.01-0.23)/(0.02-0.08)

Table 5 : Summarised hydrogeological data of EW of CGWB for Dhemaji District.

Well location	Aquifer zone tapped (m)	Depth of construction (m)	SWL (m bgl)	Discharge LPM	Draw Down (m)	Transmissivity (m^2/day)	Permeability (m/day)	Hydraulic Conduct-ivity (m/h)
Borola mirigaon	(36-48) (54-60) Total=18	61.5	1.62	809.99	0.855	3283.20	14.62	126.896
Mohori camp	(26-29) (32-38) (42-46) (49-54) (58-59) Total=18	59.5	1.25	745.641	2.45	9831.05	258.71	55.858

In case of Assam, a total of 160 dug wells were analysed in Nov-2020. Depth to ground water level was found 0.05 mbgl (minimum) and 15.84mbgl (maximum). Out of 160 wells, depth to water level (mbgl) was found as follows (https://pib.gov.in annexture)

Table 6 : Depth to water level in Assam

Year	Depth to water level (mbgl)	Fluctuation in percentage
2014	2.94	-------------
2015	3.05	3.06
2016	3.23	6.03
2017	3.03	- 6.04
2018	2.50	-17.69
2019	2.61	4.67

1.11 Ground water level in Dhemaji district

In the district of Dhemaji, ground water level fluctuated substantially in recent years. It tended to decrease through 2014 – 2017 but increased in 2018 and ended at 2.61mbgl in 2019. (source: knoema,(2019) https://knoema.com>atlas>India)

Table 7 : Depth to water level in Dhemaji District

No. of dug wells (in Assam) (total=160)	Depth to water level (mbgl) (Range)	Percentage of well
94	0-2	58.8
54	2-5	33.8
10	5-10	6.3
2	10-20	1.3

Table 8 : Dept of ground water level in and around Dhemaji town in 11 dug wells from data measured and recorded by the investigator in the district of Dhemaji

Dist: Dhemaji					
Date of observation	Sl. No.	Location and elevation above msl	Place	Depth of ground water level in the dug well (mbgl)	Remark
23/12/2013	1	N=25°45.429’ E=93°10.307’ EL=127.4m	Ratanpur (Dhemaj town)	4.14	1) GPS set used for fixing location : etrex GARMIN (2000-2007) 2) Data (Long/ Lat) were taken in the instrument after its linkage with 4 satellites. 3) ELs (Elevations) were taken at “on hand position” about 106cm above actual GL (ground level) 4) Accuracy of the elevation =+/- (10-14) ft as mentioned in the instrument.
Do	2	N=25°52.687’ E=93°42.782’ EL=165.2m	College road (Dhemaji town)	1.68	
Do	3	N=25°52.688’ E=93°42.788’ EL=163.3m	Uday nagar (Dhemaji town)	2.31	
Do	4	N=26°02.162’ E=94°31.333’ EL=195.9m	Gohain gaon (Major chowk)	2.945	
Do	5	N=26°02.162’ E=94°31.332’ EL=196.1m	Amgurichok namghar	3.74	
Do	6	N=26°02.161’ E=94°31.332’ EL=192.3m	Chokham Tiniali	2.59	
Do	7	N=25°47.152’ E=93°10.412’ EL=116.4m	Ghilaguri gaon	2.54	
Do	8	N=26°09.796’ E=91°45.362’ EL=57.3m	1no. Baligaon	1.34	
Do	9	N=26°09.795’ E=91°45.361’ EL=56.6m	Machgaon	2.15	
Do	10	N=26°09.795’ E=91°45.372’ EL=62.1m	Goal gaon	3.15	
Do	11	N=26°21.801’ E=92°40.634’ EL=53.0m	Ghilaguri (Tarani chowk)	2.10	

1.12 Ground water level status (2013)

The investigator considered 11 existing dug wells in and around Dhemaji. Three dug wells were inside Dhemaji town and the rest were to the north and eastern side of the town. All the dug wells were in a cluster of about 40 sq. Km. The readings of depth to water level were taken in a single day on 23/12/2023.

The highest depth to water level was found at sl. no. 1 (dug well) which was 4.14mbgl and the lowest depth to water level was at sl. no. 8 (dug well) which was 1.34 mbgl.

It was seen that in a single day of the post-monsoon period, the variation of depth to water in the small clustered area was very high. It was in the range of 4.39-1.79 mbgl which means a fluctuation of 2.6m.

It is expected that if the total annual rainfall in the area decreases, the ground water recharge would also decrease though it does not follow a simple linear relationship.

Along with other factors, the depth to ground water level also depends upon the relative topographic heights of the ground surface.

1.12 Conclusions

1. Land and water use are having no impact on ground water level in the district. There may, however, be more localised changes to ground water levels driven by human activities (installation of deep wells in close density , urbanization etc)
2. Even if the total annual rainfall is same and uniform throughout a small area, it is seen that ground water level varies widely. In a small area (about 40 sq. Km) where 11 dug wells are in a cluster in and around Dhemaji , the fluctuation of ground water level is as high as 2.60m even in the same day and the elevations are fairly equal. Here It is found that ground water mainly depends on the geological settings of the area of study.
3. In the last 10 years (1997-2006), there is no significant change of ground water level trend (fall/rise). However, to identify water level trend (fall/rise of ground water level), more number of monitoring wells and data of very long period recorded from the wells are required.
4. The trend of increase or decrease of ground water level (rise/fall) and its quantification are highly uncertain even in a small area and under the same impact of rainfall.

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