STUDY & ANALYSIS OF THE GROUNDWATER LEVEL SCENARIO (2013-2017) IN THE HOOGHLY DISTRICT OF WEST BENGAL

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ABSTRACT

Periodical monitoring of ground water regime covering different hydrogeomorphic, hydrogeological units is an effort to acquire information on behavior of ground water levels, chemical quality and temperature of formation water through representative sampling. The process is essential in both spatial and temporal domain, to consolidate a detailed knowledge about ground water scenario of an area with respect to its behavior, availability and quality. Thus, data so collected during monitoring becomes one of the most important inputs for a holistic ground water management. This paper attempts to compile the data collected by the CENTRAL GROUND WATER BOARD, Ministry Of Water Resources (Govt. of India), during the period 2013-2017 for some selected Ground Water Monitoring Wells established by the Board in the Hooghly District of West Bengal and present its detailed analysis in a comprehensive manner in the form of charts and statistical analysis. The statistical data incorporates the ranges of water levels and water level fluctuations, minimum and maximum values of water level, number of wells measured, and percentage of monitoring stations falling in different ranges with the block-wise breakup in different categories. The declining trend of static groundwater level (SGWL) is more conspicuous particularly for the Hooghly district since it falls under the intensive agricultural practice zone of West Bengal, which depends on its cultivation of the various crops and paddy to a large extent.

Keyword: - *Depth to Groundwater Level, Groundwater Level Fluctuations, Statistical data analysis, Comparative Study, Trend Analysis, Hooghly District, West Bengal*

1. INTRODUCTION

The importance of groundwater for the existence of human society cannot be overemphasized by any statement. Groundwater is the major source of drinking water in both urban and rural India. Besides, it is an important source of water for the agricultural and the industrial sector. Being an important and integral part of the hydrological cycle, its availability depends on the rainfall and recharge conditions. Till recently it had been considered a dependable source of uncontaminated water. The demand for water has increased over the years and this has led to water scarcity in many parts of the world. The situation is aggravated by the problem of water pollution or contamination. India is heading towards a freshwater crisis mainly due to improper management of water resources and environmental degradation, which has lead to a lack of access to safe water supply to millions of people. This freshwater crisis is already evident in many parts of India, varying in scale and intensity depending mainly on the time of the year. Groundwater crisis is not the result of natural factors; it has been caused by human actions. During the past two decades, the water level in several parts of the country has been falling rapidly due to an increase in extraction. The number of wells drilled for irrigation of both food and cash crops have rapidly and indiscriminately

increased. India's rapidly rising population and changing lifestyles has also increased the domestic need for water. The water requirement for the industry also shows an overall increase. Intense competition among users — agriculture, industry, and domestic sectors is driving the groundwater table lower. The quality of groundwater is getting severely affected because of the widespread pollution of surface water. Besides, discharge of untreated waste water through bores and leachate from unscientific disposal of solid wastes also contaminates groundwater, thereby reducing the quality of fresh water resources. So it's a high time that we understand and realize the importance of groundwater and its conservation and take every possible measure to sustain it for the future. This paper aims at pointing out the groundwater scenario of the Hooghly district of West Bengal. The region selected is small so as to understand the condition of the groundwater of the particular region in a great detail and interpret its condition in the near future.

2. MATERIALS

2.1 Study Area

Hooghly is one of the central districts of West Bengal extending between 20°30′32″ and 23°1′20″ of North latitude and between 87°30′20″ and 88°30′15″ East longitude. This district has a total area of 3,149 sq km which is about 3.55% of the total geographical area of the state. The district is flat, with no place having an elevation of more than 200 meters. The River Hooghly borders it to the east. An estimation of groundwater storage change indicates that fall in both pre-monsoon and post-monsoon condition in three blocks namely Pandua, Balagarh and Singur amounting to 15126, 12455 and 7170 Hectare-metre (ha-m) and 1755 ha-m volume of water respectively has been actually lost from the system in 6 years of time from 2007 to 2013. A similar trend could be observed in other three nearby blocks namely, Chanditala I, Chanditala II and Tarakeswar in the same district. According to Groundwater Block Categorization Status, during 1994-2004 only 2 blocks, Goghat I and Pandua of Hooghly district appeared in the critical category. But surprisingly within a period of 6-7 years four more blocks of this district namely, Polba-Dadpur, Singur, Arambag and Chinsurah-Mogra have freshly entered in the same category by 2011.

2.2 Data Source

Groundwater Level data for the Hooghly district of the state of West Bengal for the period of 2013 to 2017 obtained from the CENTRAL GROUND WATER BOARD, Ministry Of Water Resources (Govt. of India) forms the major data source.

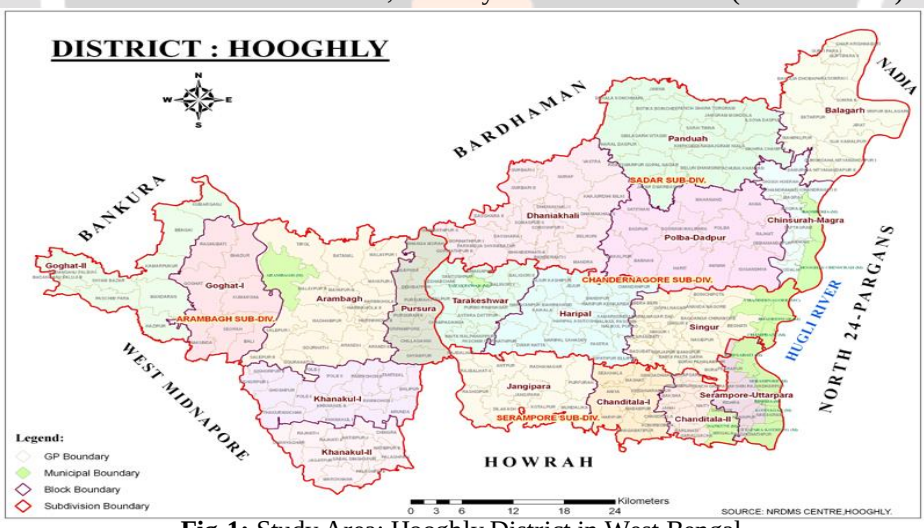

Fig-1: Study Area: Hooghly District in West Bengal

3. METHODOLOGY

The Depth to Ground Water Levels were obtained from the Data Source for the 18 different blocks of Hooghly District, namely, Arambag, Balagarh, Chanditala I, Chanditala II, Chinsurah-Mogra, Dhaniakhali, Goghat I, Goghat II, Haripal, Jangipara, Khanakul I, Khanakul II, Pandua, Polba-Dadpur, Pursura, Singur, Srirampur-Uttarpara & Tarakeswar and then analysed mathematically using the tools of statistics.
Computation of descriptive statistical analysis was done using SCILAB 2016 and MS Excel.

4. RESULTS & DISCUSSIONS

4.1 SCENARIO OF GROUNDWATER LEVEL IN THE HOOGHLY DISTRICT OF WEST BENGAL DURING THE GROUND WATER YEAR 2013-2014

Table-1: Inferences for 2013-2014

	No. of wells analysed	Depth to Water Level (mbgl)		No./ Percentage of Wells Showing Depth to Water Table (mbgl) in the Range of									
		Min.	Max.	0-2	%	2-5	%	5-10	%	10-20	%	20-40	%
Apr-13	32	0.94	21.47	2	6	5	16	1	3	21	66	3	9
Aug-13	30	0.22	21.35	6	20	1	3	10	34	12	40	1	3
Nov-13	28	0.05	20.22	5	18	4	14	15	53	3	11	1	4
Jan-14	31	0.96	19.67	4	13	2	6	14	45	11	36	0	0

Table-2: FLUCTUATION IN GROUNDWATER LEVEL (*for the period Apr-13 to Jan-14*)

NUMBER OF STATIONS ANALYSED	FALL						RISE						TOTAL NO. OF WELLS	
	0-2 (m)	%	2-4 (m)	%	>4 (m)	%	0-2 (m)	%	2-4 (m)	%	>4 (m)	%	FALL	RISE
50	2	4	0	0	0	0	10	20	16	32	22	44	2	48

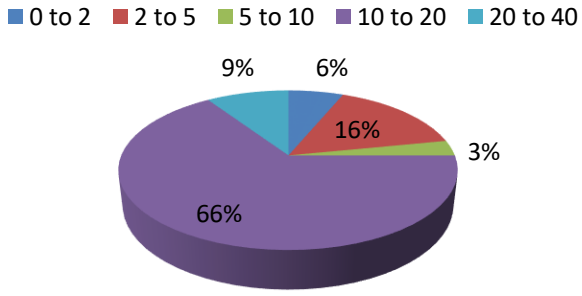

Fig-2: Depth to Water Table (mbgl) for Apr-13

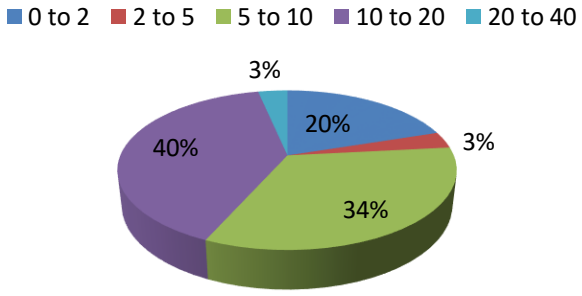

Fig-3: Depth to Water Table (mbgl) for Aug-13

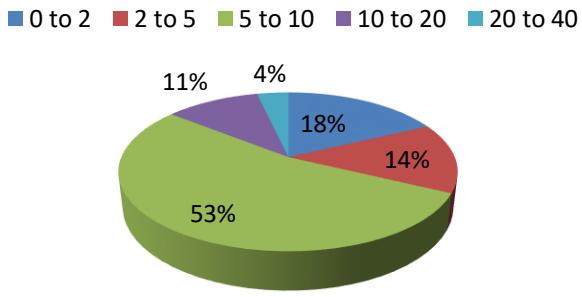

Fig-4: Depth to Water Table (mbgl) for Nov-13

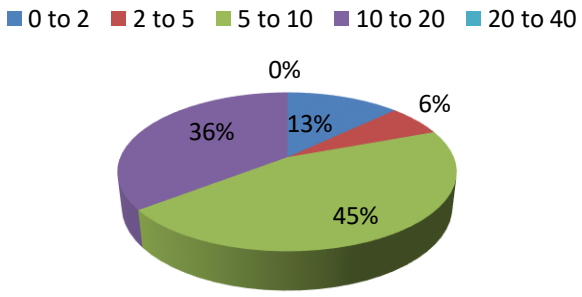

Fig-5: Depth to Water Table (mbgl) for Jan-14

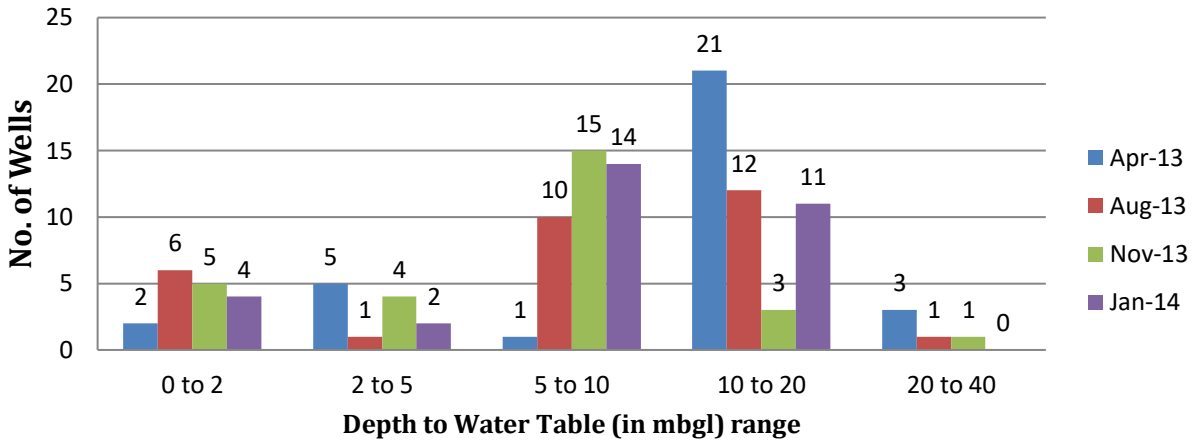

Fig-6: Comparative Study of the Depth to Water Table (mbgl) for Ground Water Year 2013-2014

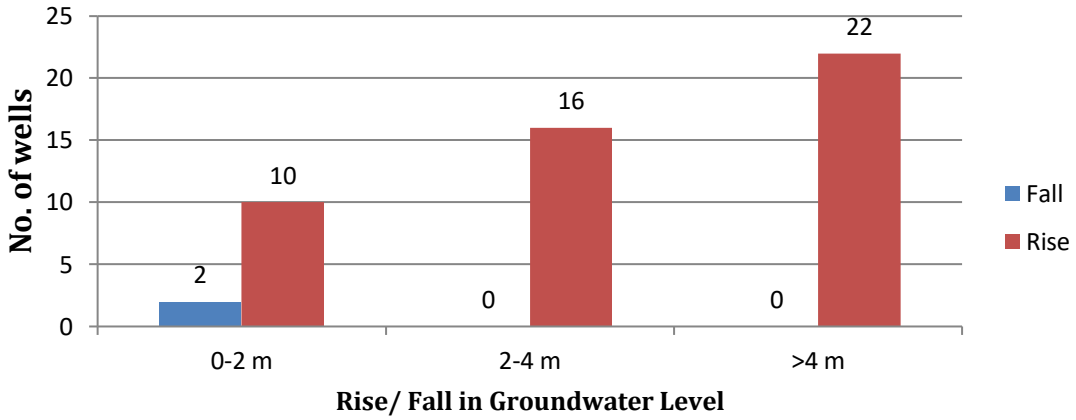

Fig-7: Comparative Study of the Fluctuation in Groundwater Table (mbgl) for 2013-2014

Five groups are made based on the range of water levels, viz. 0-2, 2-5, 5-10, 10-20 and > 20 mbgl. The number of ground water monitoring wells (GWMW) falling under the different ranges during the ground water year 2013-2014 are given under:

RANGE OF WATER LEVEL (in mbgl)	NO. OF GROUNDWATER MONITORING WELLS
0-2	17
2-5	12
5-10	40
10-20	47
>20	11

The fluctuation in water level between April 2013 and January 2014 indicates the change in water level from pre-monsoon measurement to January measurement. Fluctuation in water level between April, 2013 and January, 2014 is mostly dominated by rise in water level. Out of 50 analyzed wells, 2 wells are grouped under falling zone category and 48 wells are grouped under rising zone category. For April 2013 the minimum and maximum depth to water table is shown by Uttarpara and Goghat area respectively. For August 2013 the minimum and maximum depth to water table is shown by Tarakeswar and Goghat area respectively. For November 2013 the minimum and maximum depth to water table is shown by Polba and Goghat area respectively. For January 2014 the minimum and maximum depth to water table is shown by Uttarpara and Goghat area respectively. In general Goghat block shows increasing trend in Groundwater level in the Ground Water Year 2013-2014.

4.2 SCENARIO OF GROUNDWATER LEVEL IN THE HOOGHLY DISTRICT OF WEST BENGAL DURING THE GROUND WATER YEAR 2014-2015

Table-3: Inferences for 2014-2015

	No. of wells analysed	Depth to Water Level (mbgl)		No./ Percentage of Wells Showing Depth to Water Table (mbgl) in the Range of									
		Min.	Max.	0-2	%	2-5	%	5-10	%	10-20	%	20-40	%
Apr-14	28	0.02	21.27	2	7	4	14	1	4	20	71	1	4
Aug-14	30	0.15	20.01	5	17	2	7	8	27	14	46	1	3
Nov-14	32	1.02	17.35	5	16	2	6	11	34	14	44	0	0
Jan-15	33	1.36	22.6	3	9	4	12	5	15	18	55	3	9

Table-4: FLUCTUATION IN GROUNDWATER LEVEL (*for the period Apr-14 to Jan-15*)

NUMBER OF STATIONS ANALYSED	FALL						RISE						TOTAL NO. OF WELLS	
	0-2 (m)	%	2-4 (m)	%	>4 (m)	%	0-2 (m)	%	2-4 (m)	%	>4 (m)	%	FALL	RISE
62	10	16.1	2	3.2	4	6.5	30	48.4	8	12.9	8	12.9	16	46

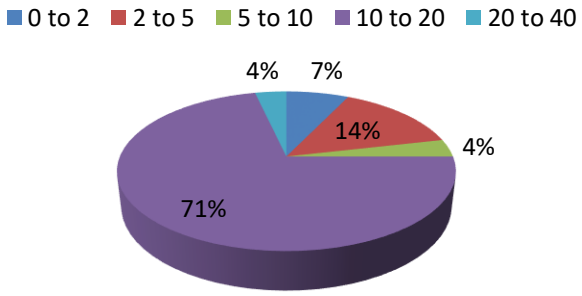

Fig-8: Depth to Water Table (mbgl) for Apr-14

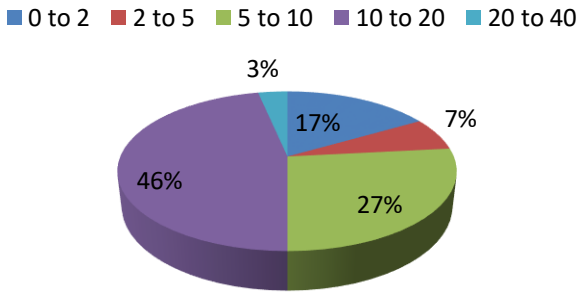

Fig-9: Depth to Water Table (mbgl) for Aug-14

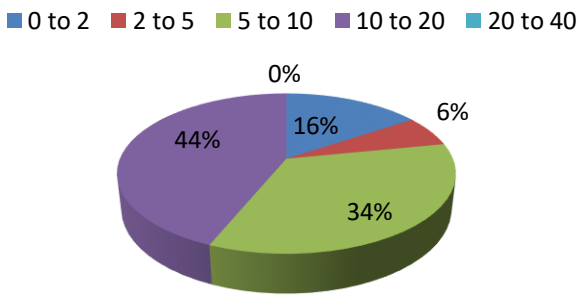

Fig-10: Depth to Water Table (mbgl) for Nov-14

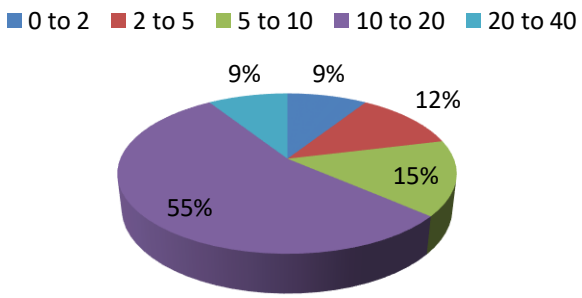

Fig-11: Depth to Water Table (mbgl) for Jan-15

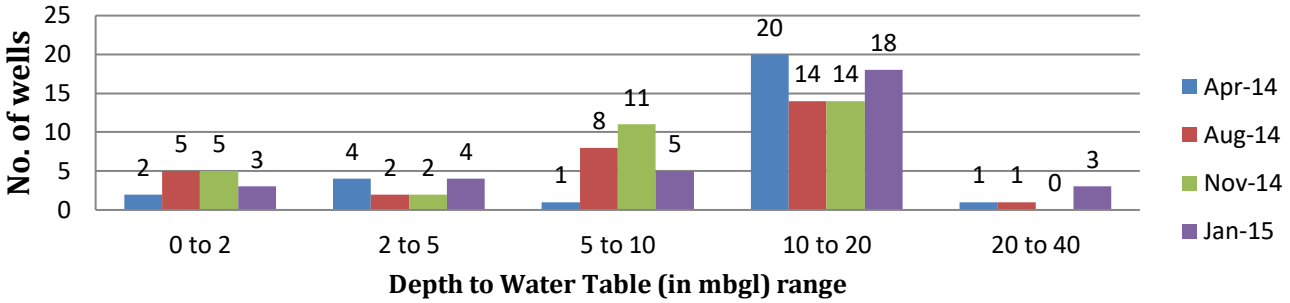

Fig-12: Comparative Study of the Depth to Water Table (mbgl) for Ground Water Year 2014-2015

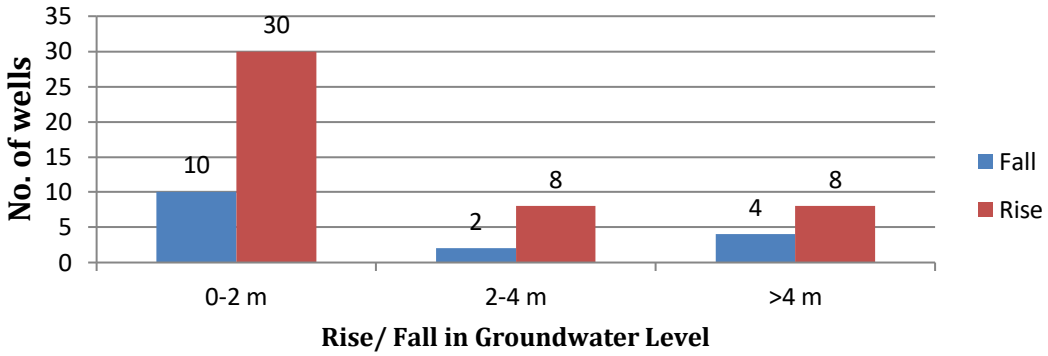

Fig-13: Comparative Study of the Fluctuation in Groundwater Table (mbgl) for 2014-2015

Five groups are made based on the range of water levels, viz. 0-2, 2-5, 5-10, 10-20 and > 20 mbgl. The number of ground water monitoring wells (GWMW) falling under the different ranges during the ground water year 2014-2015 are given under:

RANGE OF WATER LEVEL (in mbgl)	NO. OF GROUNDWATER MONITORING WELLS
0-2	15
2-5	12
5-10	25
10-20	66
>20	5

The fluctuation in water level between April 2014 and January 2015 indicates the change in water level from pre-monsoon measurement to recession period of water level. Fluctuation in water level between April, 2014 and January, 2015 is mostly dominated by rise in water level. Out of 62 analyzed wells, 16 wells are grouped under falling zone category and 46 wells are grouped under rising zone category. However fluctuation is mostly restricted within 2 m (55.1%). The minimum and maximum depth to water table shown by the various blocks/ area of Hooghly district at various periods of the Ground Water Year 2014-2015 are given under:

Period of Ground Water Year 2014-2015	Region showing minimum depth to water table	Region showing maximum depth to water table
April 2014	Uttarpara	Goghat
August 2014	Tarakeswar	Goghat
November 2014	Uttarpara	Goghat
January 2015	Uttarpara	Ramnagar

In general, Goghat again shows increasing trend in the groundwater level, whereas Uttarpara shows decreasing trend for the Ground Water Year 2014-2015.

4.3 SCENARIO OF GROUNDWATER LEVEL IN THE HOOGHLY DISTRICT OF WEST BENGAL DURING THE GROUND WATER YEAR 2015-2016

Table-5: Inferences for 2015-2016

	No. of wells analysed	Depth to Water Level (mbgl)		No./ Percentage of Wells Showing Depth to Water Table (mbgl) in the Range of									
		Min.	Max.	0-2	%	2-5	%	5-10	%	10-20	%	20-40	%
Apr-15	23	2.48	21.87	0	0	5	22	1	4	13	57	4	17
Aug-15	28	0.17	20	5	18	3	11	8	29	11	39	1	3
Nov-15	31	0.93	20.5	4	13	2	6	7	23	17	55	1	3
Jan-16	23	1.2	25.9	3	13	3	13	1	4	13	57	3	13

Table-6: FLUCTUATION IN GROUNDWATER LEVEL (*for the period Apr-15 to Jan-16*)

NUMBER OF STATIONS ANALYSED	FALL						RISE						TOTAL NO. OF WELLS	
	0-2 (m)	%	2-4 (m)	%	>4 (m)	%	0-2 (m)	%	2-4 (m)	%	>4 (m)	%	FALL	RISE
40	11	27.5	0	0	4	10	19	47.5	5	12.5	1	2.5	15	25

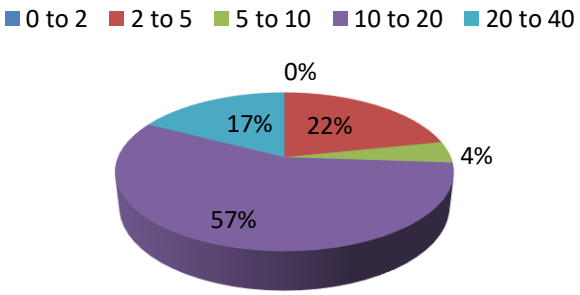

Fig-14: Depth to Water Table (mbgl) for Apr-15

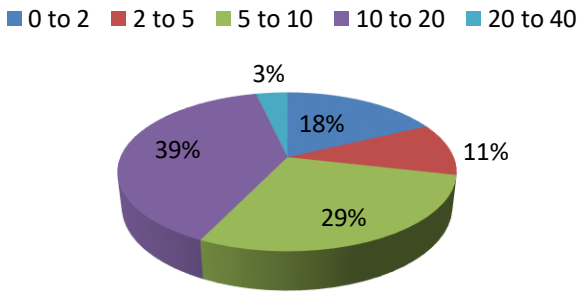

Fig-15: Depth to Water Table (mbgl) for Aug-15

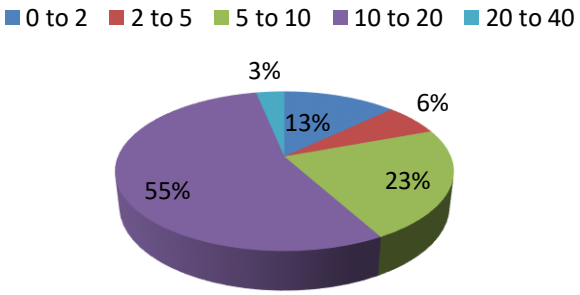

Fig-16: Depth to Water Table (mbgl) for Nov-15

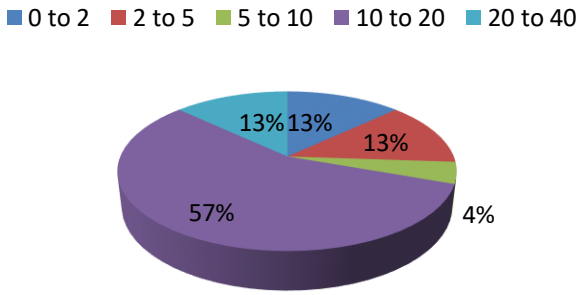

Fig-17: Depth to Water Table (mbgl) for Jan-16

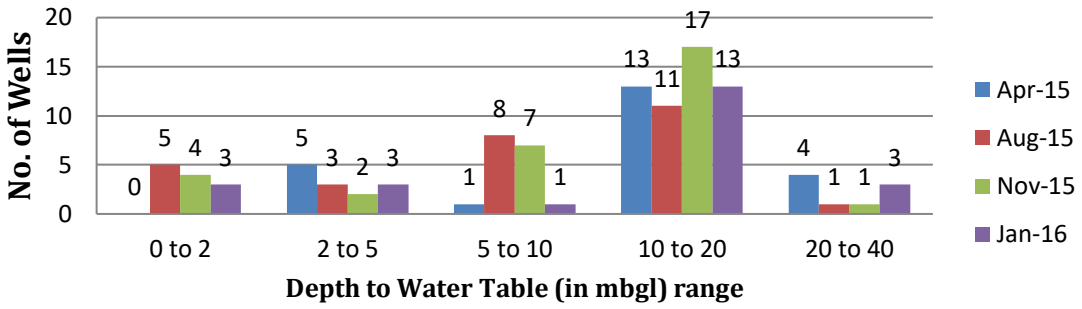

Fig-18: Comparative Study of the Depth to Water Table (mbgl) for Ground Water Year 2015-2016

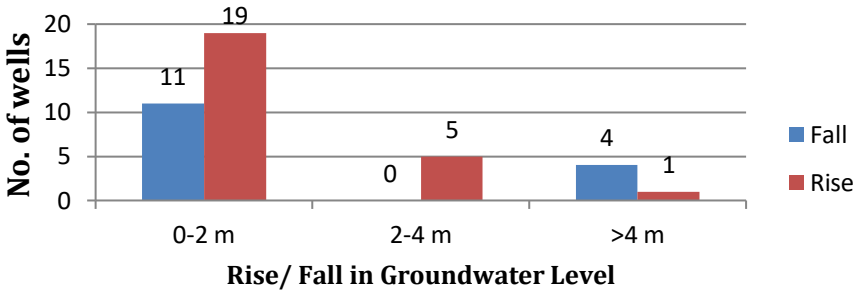

Fig-19: Comparative Study of the Fluctuation in Groundwater Table (mbgl) for 2015-2016

Five groups are made based on the range of water levels, viz. 0-2, 2-5, 5-10, 10-20 and > 20 mbgl. The number of ground water monitoring wells (GWMW) falling under the different ranges during the ground water year 2015-2016 are given under:

RANGE OF WATER LEVEL (in mbgl)	NO. OF GROUNDWATER MONITORING WELLS
0-2	12
2-5	13
5-10	17
10-20	54
>20	9

The fluctuation in water level between April 2015 and January 2016 indicates the change in water level from pre-monsoon measurement to recession period of water level. Fluctuation in water level between April, 2015 and January, 2016 is mostly dominated by rise in water level. Out of 40 analyzed wells, 15 wells are grouped under falling zone category and 25 wells are grouped under rising zone category. However fluctuation is mostly restricted within 2 m (76%). The minimum and maximum depth to water table shown by the various blocks/ area of Hooghly district at various periods of the Ground Water Year 2015-2016 are given under:

Period of Ground Water Year 2015-2016	Region showing minimum depth to water table	Region showing maximum depth to water table
April 2015	Uttarpara	Gourhati
August 2015	Tarakeswar	Goghat
November 2015	Tarakeswar	Goghat
January 2016	Uttarpara	Gourhati

In general, Goghat and Gourhati areas show increasing trend in the groundwater level, whereas Uttarpara and Tarakeswar areas show a significant decreasing trend for the Ground Water Year 2015-2016.

4.4 SCENARIO OF GROUNDWATER LEVEL IN THE HOOGHLY DISTRICT OF WEST BENGAL DURING THE GROUND WATER YEAR 2016-2017

Table-7: Inferences for 2016-2017

	No. of wells analysed	Depth to Water Level (mbgl)		No./ Percentage of Wells Showing Depth to Water Table (mbgl) in the Range of									
		Min.	Max.	0-2	%	2-5	%	5-10	%	10-20	%	20-40	%
Apr-16	19	0.93	21.6	3	10	3	10	1	4	20	69	2	7
Aug-16	25	0.01	21.64	4	16	1	4	5	20	14	56	1	4
Nov-16	18	1.51	15.4	3	17	3	17	2	11	10	55	0	0
Jan-17	19	1.06	24.5	3	16	3	16	1	5	9	47	3	16

Table-8: FLUCTUATION IN GROUNDWATER LEVEL (*for the period Apr-16 to Jan-17*)

NUMBER OF STATIONS ANALYSED	FALL						RISE						TOTAL NO. OF WELLS	
	0-2 (m)	%	2-4 (m)	%	>4 (m)	%	0-2 (m)	%	2-4 (m)	%	>4 (m)	%	FALL	RISE
49	15	30.6	4	8.2	1	2	24	49	1	2	4	8.2	20	29

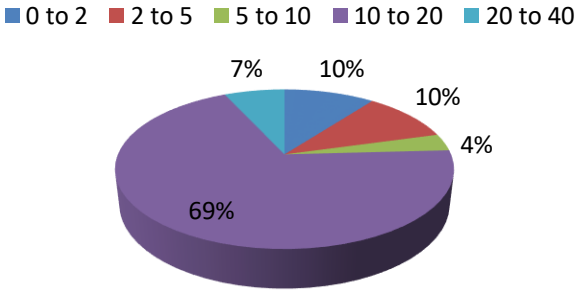

Fig-20: Depth to Water Table (mbgl) for Apr-16

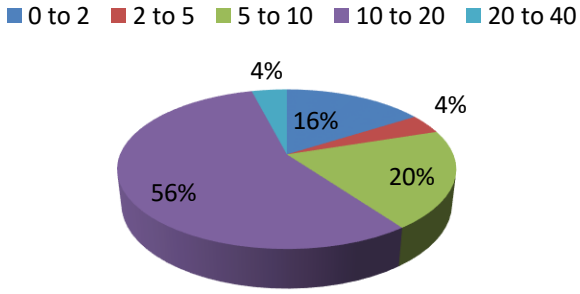

Fig-21: Depth to Water Table (mbgl) for Aug-16

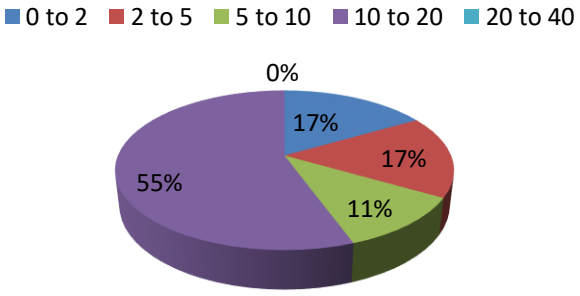

Fig-22: Depth to Water Table (mbgl) for Nov-16

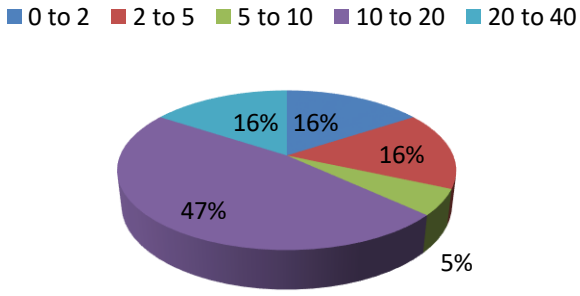

Fig-23: Depth to Water Table (mbgl) for Jan-17

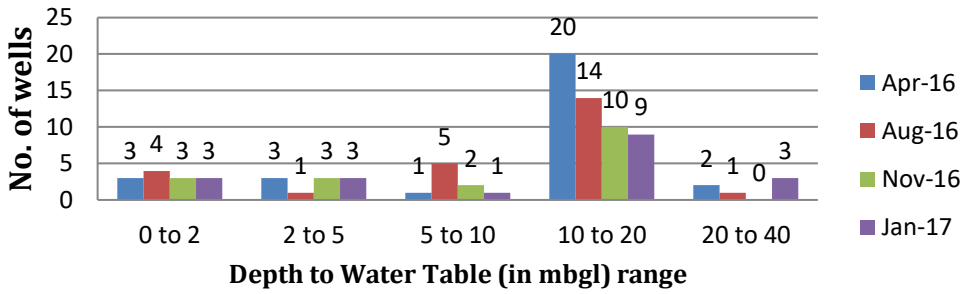

Fig-24: Comparative Study of the Depth to Water Table (mbgl) for Ground Water Year 2016-2017

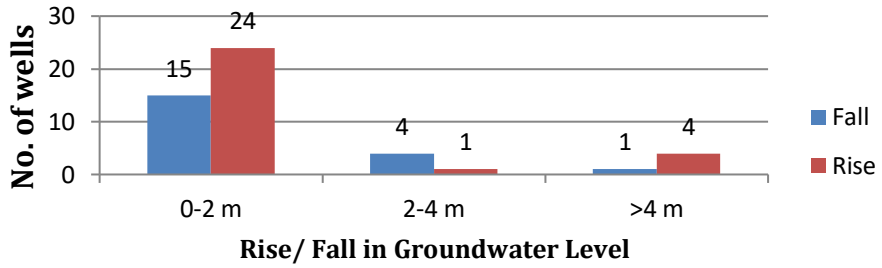

Fig-25: Comparative Study of the Fluctuation in Groundwater Table (mbgl) for 2016-2017

Five groups are made based on the range of water levels, viz. 0-2, 2-5, 5-10, 10-20 and > 20 mbgl. The number of ground water monitoring wells (GWMW) falling under the different ranges during the ground water year 2016-2017 are given under:

RANGE OF WATER LEVEL (in mbgl)	NO. OF GROUNDWATER MONITORING WELLS
0-2	16
2-5	13
5-10	9
10-20	53
>20	6

The fluctuation in water level between April 2016 and January 2017 indicates the change in water level from pre-monsoon measurement to recession period of water level. Fluctuation in water level between April, 2016 and January, 2017 is mostly dominated by rise in water level. Out of 49 analyzed wells, 20 wells are grouped under falling zone category and 29 wells are grouped under rising zone category. However fluctuation is mostly restricted within 2 m (76%). The minimum and maximum depth to water table shown by the various blocks/ area of Hooghly district at various periods of the Ground Water Year 2016-2017 are given under:

Period of Ground Water Year 2016-2017	Region showing minimum depth to water table	Region showing maximum depth to water table
April 2016	Uttarpara	Goghat
August 2016	Tarakeswar	Goghat
November 2016	Uttarpara	Pandua
January 2017	Uttarpara	Ghoshpur

In general, Goghat and Pandua areas show increasing trend in the groundwater level, whereas Uttarpara and Tarakeswar areas show a significant decreasing trend for the Ground Water Year 2016-2017.

GROUNDWATER LEVEL FLUCTUATION MAPS OF WEST BENGAL

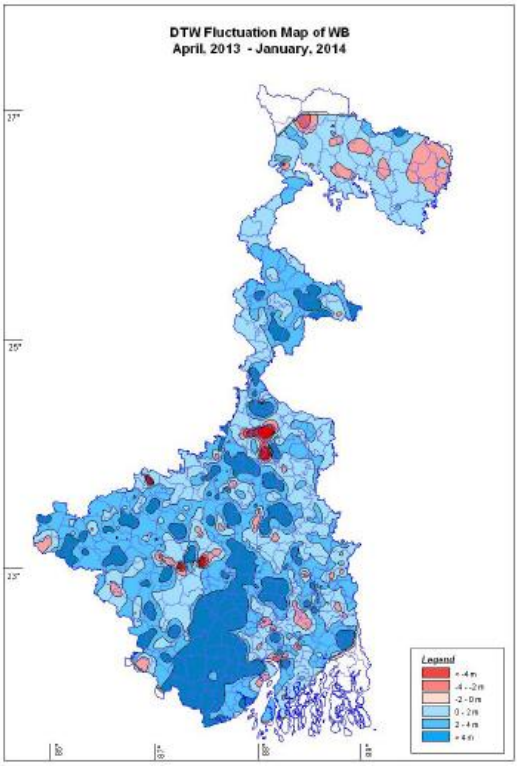

Fig-26: APR-13 TO JAN-14

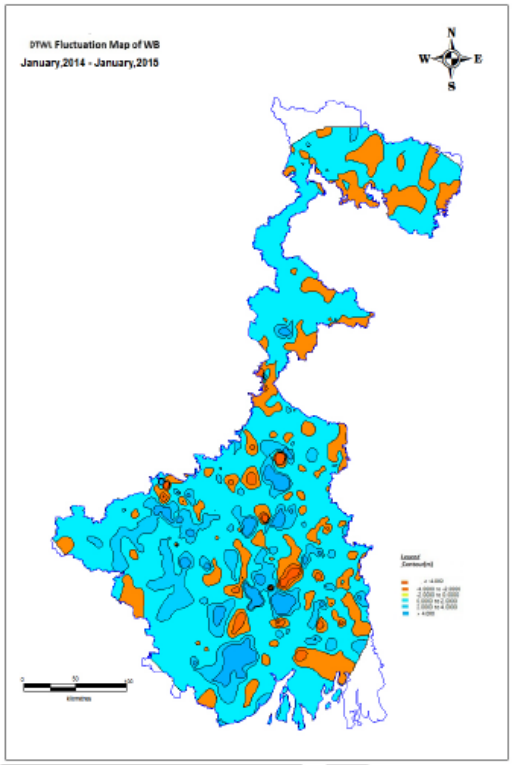

Fig-27: APR-14 TO JAN-15

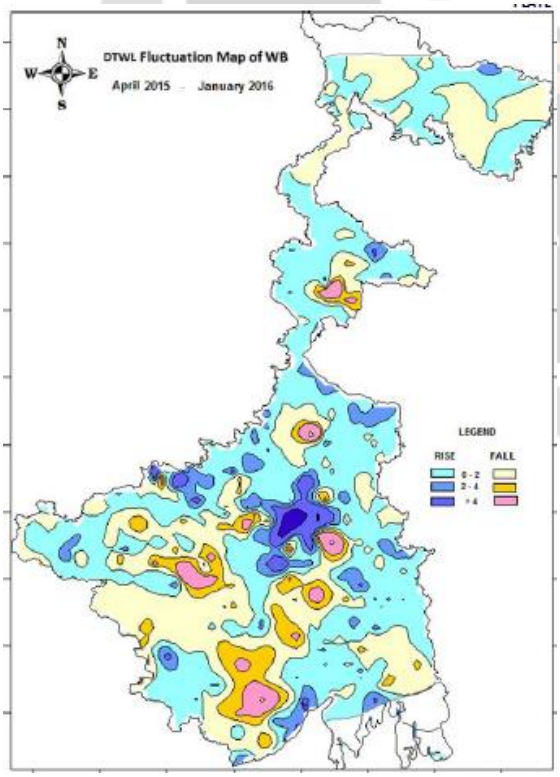

Fig-28: APR-15 TO JAN-16

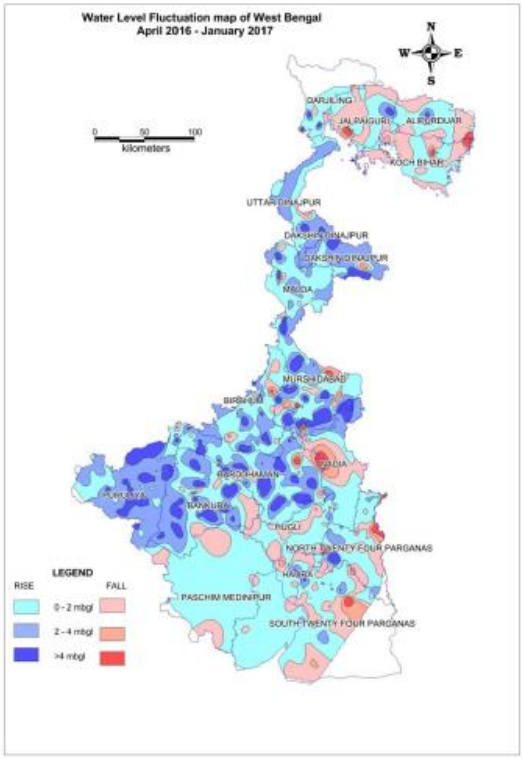

Fig-29: APR-16 TO JAN-17

Table-9: MEAN CHANGE IN GROUNDWATER LEVEL FOR HOOGHLT DISTRICT FOR THE PERIOD JANUARY 2007 TO JANUARY 2017

NUMBER OF STATIONS ANALYSED	NO./ PERCENTAGE OF WELLS SHOWING FLUCTUATION												TOTAL NO. OF WELLS		RANGE OF FLUCTUATION			
	RISE						FALL								RISE		FALL	
	0 - 2 (m)	%	2 - 4 (m)	%	>4 (m)	%	0 - 2 (m)	%	2 - 4 (m)	%	>4 (m)	%	FALL	RISE	Min	Max	Min	Max
21	4	19	0	0	1	4.8	7	33.3	3	14.3	6	28.6	5	16	0.01	8.65	0.5	10.84

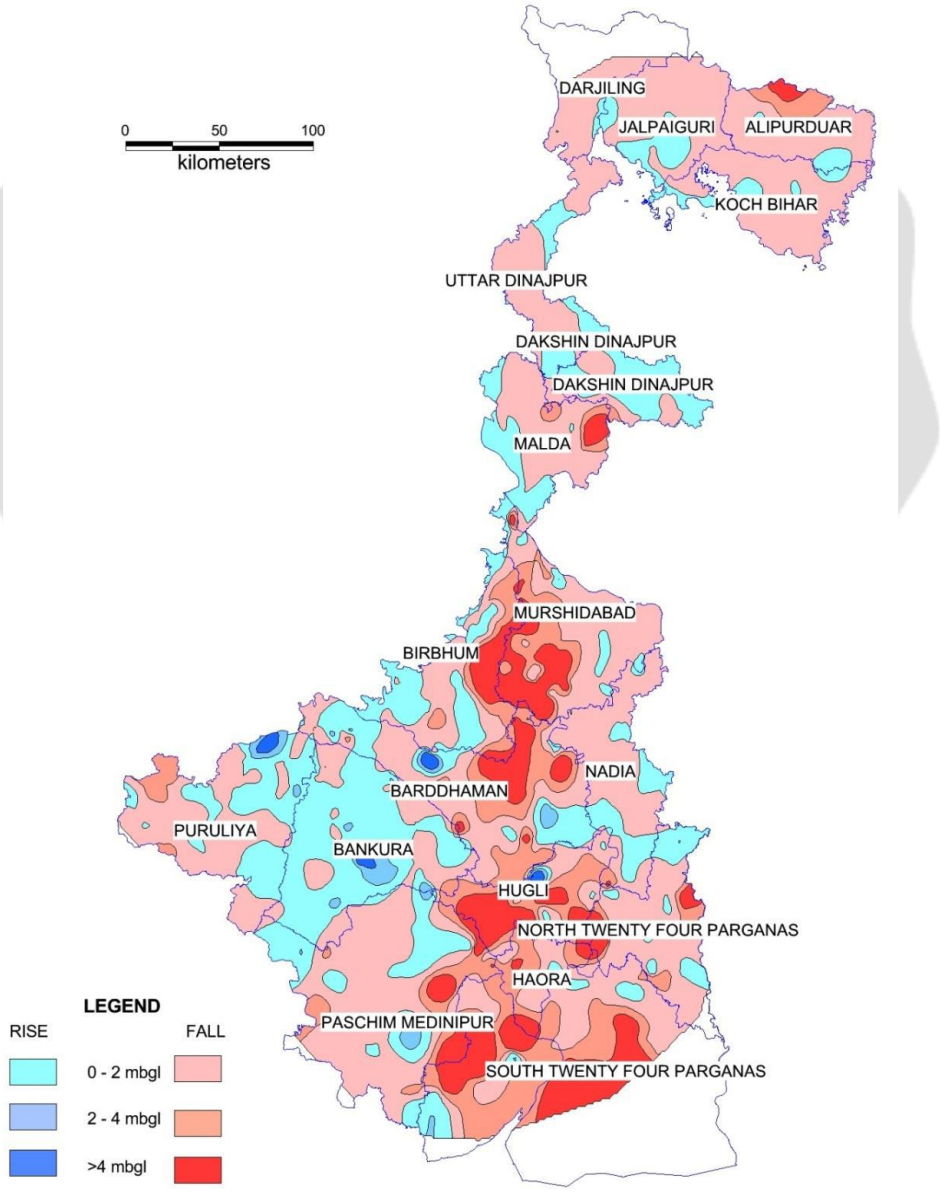

Fig-30: Water Level Fluctuation Map of West Bengal (Jan 2007 to Jan 2017)

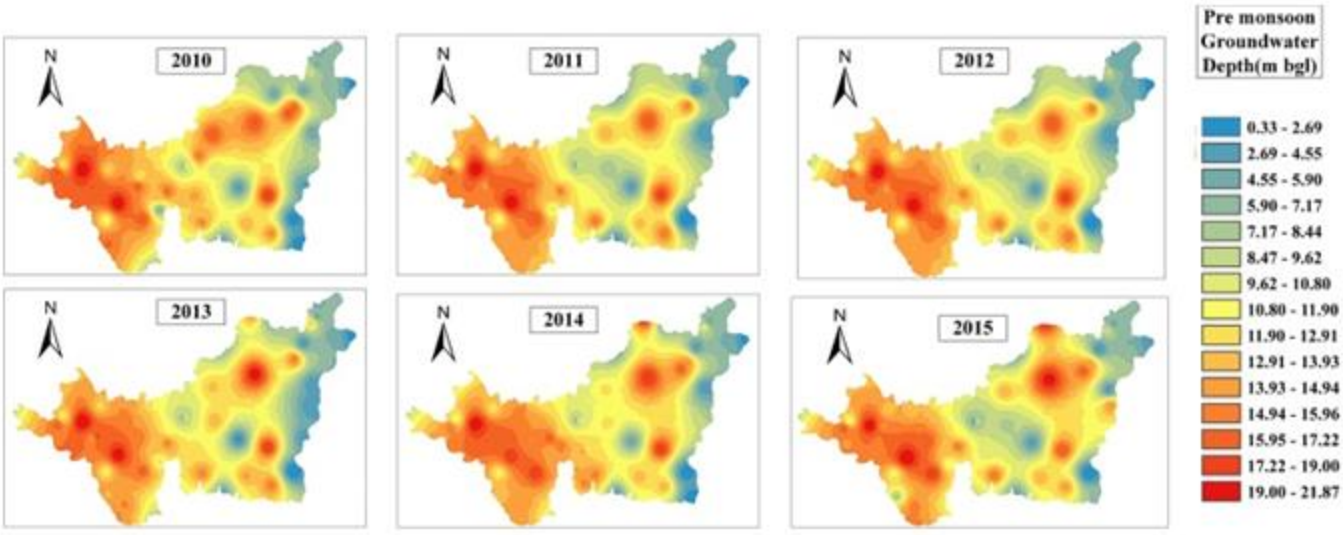

Fig-31: Pre Monsoon Ground Water Depth of Hooghly District (2010-2015)

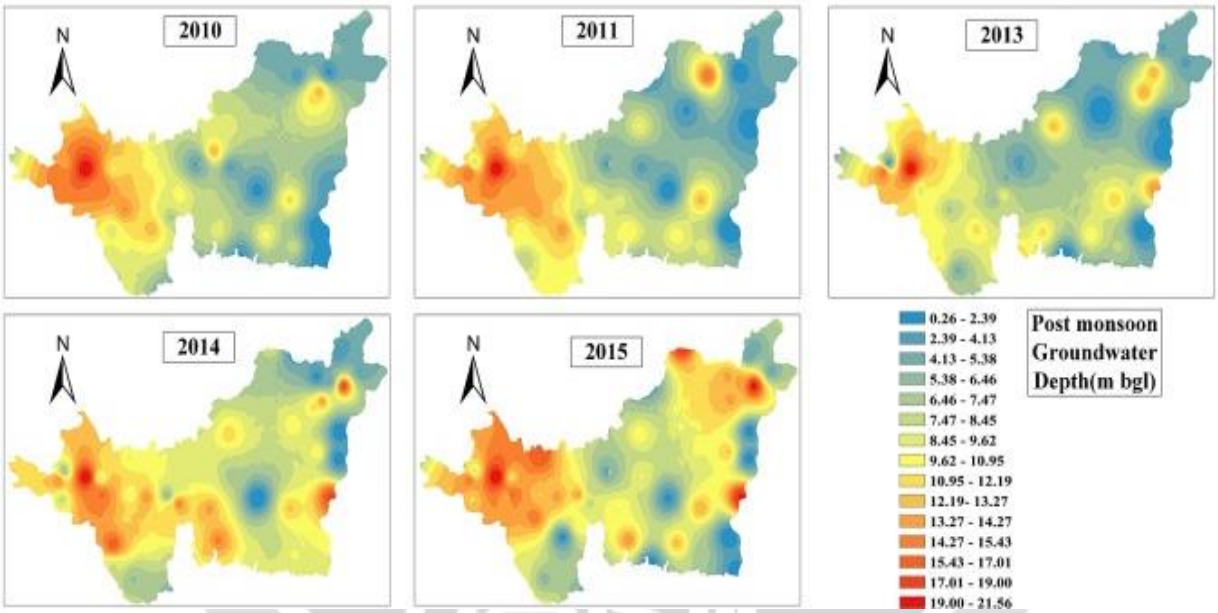

Fig-32: Post Monsoon Ground Water Depth of Hooghly District (2010-2015)

The water level (mbgl) at various blocks of Hooghly district does not stand at a very good and healthy position. Seven out of eighteen blocks (Goghat I, Goghat II, Arambag, Pursura, Chanditala I, Chanditala II, Singur) of the district show a low to medium groundwater level (varying from 10.3 to 14.6 mbgl) category, while the rest of the blocks fall under medium groundwater level (5.9 to 10.3 mbgl) category. From this information it is clear that higher depth of groundwater level of a location where the water is away from the ground surface and is less accessible. The erratic rainfall pattern; unplanned and rapid urbanization causing expansion of concrete landscape with the exchange of natural environment; structural and textural change of soil due to excessive use of chemical fertilizers resulting to reduction of infiltration rate by many times; and the poor groundwater recharge with in a spatiotemporal dimension are the probable reasons of the above. The study shows that all the blocks have a sharply declined trend of average groundwater level (mbgl) in pre-monsoon and post-monsoon condition.

It is further observed that, a considerable fluctuation in groundwater level took place in both pre-monsoon and post-monsoon readings resulting ultimately to falling of the SGWL. Generally post-monsoon readings indicate the amount of groundwater recharge from monsoonal rainfall annually, while the pre-monsoon reading gives an account of the groundwater discharge in the year. It is found that, in the case of Pandua, Balagarh and Singur, the pre monsoon readings of SGWL in 2007 was 5.095 mbgl, 4.815 mbgl, 15.65 mbgl respectively. In 2013 it was fallen down to 9.655 mbgl, 9.216 mbgl, and 18.55 mbgl respectively. The rate of falling is 4.56 mbgl, 4.401 mbgl, 2.9

mbgl respectively. Such fall of pre-monsoon SGWL in the above three blocks (Pandua, Balagarh and Singur) indicates that an amount of 15126, 12455 and 7170 ham volume of water had been actually lost from the system. Similarly, the post monsoon readings of SGWL in 2007for the three blocks were 1.605 mbgl, 3.526 mbgl, 11.490 mbgl and in 2013 those were recorded as 7.04 mbgl, 6.496 mbgl, and 12.2 mbgl resulting to the falling rates as 5.435 mbgl, 2.97 mbgl, and 0.71 mbgl respectively. The vertical fall of post-monsoon SGWL as 5.435 mbgl, 2.97 mbgl, 0.71 mbgl in the Pandua, Balagarh and Singur blocks in 6 years actually amounting to 18028, 84053 and 1755 ham volume of water had been lost from the system. A similar trend could be observed in the other three blocks namely, Chanditala I, Chanditala II and Tarakeswar in the district.

The major concern is that, the decline of post monsoon groundwater level reading indicates the gradual decrease in the amount of groundwater recharge from its successive year. On the other hand, gradual decline in pre-monsoon groundwater level also suggests that a high rate of groundwater withdrawal for domestic and agricultural and industrial purposes. So, an imbalance between groundwater recharge and discharge can be observed in these 6 blocks in Hooghly district. Based on the stage of groundwater development and long term pre and post monsoon water level trend, the blocks have been categorized as Safe, Semi-critical, Critical, and Overexploited. According to Groundwater Block Categorization Status in 2011 the 6 blocks namely, Goghat I, Pandua, Polba-Dadpur, Singur, Arambag and Chinsurah-Mogra of Hooghly district fall under semi-critical categorization. Whereas, during 1994-2004 only 2 blocks, Goghat I and Pandua of Hooghly district were fallen under semi-critical categorization. The figure indicates that there will be a demand of groundwater as high as more than 9376 ha-m designating the district as 'high' demand of groundwater by the year 2025.From the findings of the above investigation it is clear that the falling rate of static groundwater level (SGWL) of various blocks in Hooghly district is situated in an alarming position.

5. CONCLUSION

Groundwater can be considered as a natural asset. The value of such an asset resides in its ability to create flows of services over time. In the context of changing human activities there are two principal ways, which caused to threaten the quantity of groundwater. First and foremost is excessive abstraction, which is widely termed as aquifer overexploitation. Second, and far more subtly, insofar as climate change induced by greenhouse gas emissions alters recharge rates to aquifers, it is capable of leading to depletion of groundwater resources. However, from the above discussions it is clear that in a district like Hooghly and its various blocks, empirical evidences on the groundwater resources shows a sharply declined trend of average groundwater level (mbgl) as well as storage of groundwater in pre-monsoon and post-monsoon condition. It basically refers extraction in excess of net recharge in the considerable period and leads to reduce groundwater stocks rapidly and in the future too. So it's a high time that we understand and realize the importance of groundwater and its conservation and take every possible measure to sustain it for the future.

6. REFERENCES

[1] *Ground Water Year Book Of West Bengal (2013-2014),* Central Ground Water Board, Ministry Of Water Resources, Govt. Of India,

[2] *Ground Water Year Book Of West Bengal (2014-2015),* Central Ground Water Board, Ministry Of Water Resources, Govt. Of India,

[3] *Ground Water Year Book Of West Bengal (2015-2016),* Central Ground Water Board, Ministry Of Water Resources, Govt. Of India,

[4] *Ground Water Year Book Of West Bengal (2016-2017),* Central Ground Water Board, Ministry Of Water Resources, Govt. Of India,

[5] Patra S., Mahapatra S.C., Mishra P., Sahoo S. (2015), *A Quantitative Analysis Of Groundwater Status of Hooghly District, West Bengal, India,* International Journal Of Current Research (IJCR).

[6] Pal, S., Mazumdar, D., and Chakraborty, P.K., (2015), *District-wise trend analysis of rainfall pattern in last century (1901-2000) over Gangetic region in West Bengal, India,* Journal of Applied and Natural Science.