Ground Water Year Book
National Capital Territory, Delhi
2018-19


Rotary Rig

GOVERNMENT OF INDIA
CENTRAL GROUND WATER BOARD
STATE UNIT OFFICE, DELHI

DEPARTMENT OF WATER RESOURCES,
RIVER DEVELOPMENT & GANGA REJUVENATION
MINISTRY OF JAL SHAKTI

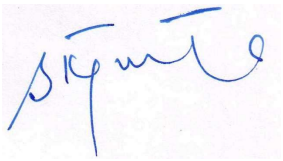
October - 2020

FOREWORD

Ground Water Year Book is based on the information generated through field studies. The data has been analyzed by Officers of Central Ground Water Board, State Unit Office, Delhi and presented in the report. The reports, annexure and maps have been generated using GEMS Software, Version-2.1, developed indigenously by Central Ground Water Board.

Depiction of ground water conditions in Delhi provides information on availability of groundwater in terms of quantity and quality, development prospects and management options. I am happy to note that the scientific information in this report is presented in a simplified form. I sincerely hope this report will be of immense help not only to planners, administrators, researchers and policy makers in formulating development and management strategy but also to the common man in need of such information to make himself aware of the ground situation in NCT Delhi.

The untiring efforts made by Sh. Faisal Abrar, Assistant Hydrogeologist, Sh. V Praveen Kumar, STA (Hydrogeology) & Sh. S Ashok Kumar, STA (Hydrogeology) for bringing out this report are highly appreciated.



(S K Juneja)
Officer in charge
Central Ground Water Board
State Unit Office, Delhi

EXECUTIVE SUMMARY

GROUND WATER YEAR BOOK 2018-19: NCT DELHI

National Capital Territory (NCT) of Delhi occupies an area of 1483 sq. km. and lies between 28° 24' 15'' to 28° 53' 00'' N latitudes and 76° 50' 24" to 77° 20' 30" E longitudes. The population of NCT Delhi, as per the census 2011 is 167.87 lakhs with a density of 11320 persons / sqkm area.

The normal annual rainfall of NCT Delhi is 611.8 mm. The rainfall increases from west to east. About 80% of the annual rainfall is received during the monsoon months July, August and September. The rest of the annual rainfall is received in the form of winter rain. Long- term rainfall data 1984 to 2017 shows that the rainfall in Delhi is highly variable and which in turn affects the natural recharge to ground water from year to year. The probability of rainfall exceeding normal rainfall of 611 mm is up to 62 % whereas there are 90 % chance that rainfall would limit to 450mm.

The ground water availability in NCT Delhi is controlled by the hydrogeological charactericts of its varied geological formations namely Delhi Quartzite, Older & Younger Alluvium. Central Ground Water Board (CGWB) is monitoring groundwater levels and quality through its monitoring stations spread over both Alluvial as well as quartzitic area of NCT of Delhi. Total 96 hydrograph monitoring stations data (2018-19) have been analyzed for this report, out of which 22 are dug wells and 74 are Piezometers.

District wise distribution of hydrograph network stations is highly uneven and varies from one monitoring station per 1.4 sq. km in New Delhi district to one monitoring station per 30 sq. km in North East district. Considering this unevenness in distribution of monitoring stations, Central Ground Water Board is striving to increase the number of stations for better monitoring of the ground water regime in the diverse Hydrogeological terrain.

An analysis for numbers of monitoring wells in the different categories of the water levels for all four monitoring periods of year 2018-19 reveals that water level depth up to 5 m varies considerably over two monitoring periods (May & other months) which shows that dynamic changes in ground water levels are conspicuously deciphered in shallow water zones. For depth range of 5 to 10 m and 10 to 20 m and more at few locations, changes in numbers of monitoring wells in August, November & January compared to May period not prominent. This may be interpreted as stressed water level conditions suppressing dynamic fluctuation in water levels. Whereas numbers of monitoring station showing water level below 40 m remain almost same in all four-monitoring period, indicate stressed water conditions in deep aquifers of NCT, Delhi.

The depth to water level recorded in NCT Delhi during 2018-19, in general varies from less than 2 m in areas of Yamuna Flood plain and parts of Northwest & West district to more than 65m, mainly in areas underlain by Ridges rocks in Central, New Delhi and South districts. Water level in **May-2018** range from 0.71 to 65 m and around 8% of area have shallow water level up to 5 m bgl while deep water levels of 20 to 60 m are observed in around 34% area. In rest of NCT Delhi, 58 % areas water level range from 5 to 20 m bgl. In **August-2018** water level range from 0.15 to 61.70 m bgl and around 17% of NCT Delhi areas have shallow water level up to 5 m bgl while deep water levels of 20 to 60 m observed in around 33% of NCT Delhi. In rest of NCT Delhi, 50 % areas have water level in range of 5 to 20 m bgl. In **November-2018** water level range from 1.02 to 65 m. bgl and around 15% of

NCT Delhi areas have shallow water level up to 5 m bgl while deep water levels of 20 to 60 m observed in around 33% of NCT Delhi. In rest of NCT Delhi, 52% areas have water level in range of 5 to 20 m bgl. In **January-2019** water level range from 0.80 to 65 m bgl and around 16% of NCT Delhi areas have shallow water level up to 5 m bgl while deep water levels of 20 to 60 m observed in around 30% of NCT Delhi. In rest of NCT Delhi, 54 % areas have water level in range of 5 to 20 m bgl.

Analysis of seasonal water level fluctuation comparing **May 2018** period show rise in range of 0 to 2 m in 62 % monitoring stations during **August 2018**, 52% in **November 2018** and 41% in **January 2019**. Very few monitoring stations, 10% to 27% show rise in range of 2 to 4 m. Whereas nearly 12% to 30% monitoring stations show decline in range of 0 to 2 m and rest 0% to 1% in range of 2 to 4m, which reflect overstress conditions.

The fluctuation of water level between **May-2017 and May-2018** of NCT Delhi show rise by 16 % of wells, up to 4 m while other 56 % of monitoring wells show fall in range of 0 to 2 m ; rest of 16% monitoring stations shows fall up to 4 m. Similarly, comparing **August-2017** water level with **August-2018** reveals that rise in the range of 0 to 2m in nearly 35% of the wells, while 42 % wells shows falls in range of 0 to 2 m. Fall of more than 4 m is observed in small pocket of South district (2 % wells). Comparing water level data of **November 2017** with **November 2018**, it is revealed that 17 % wells show rise in range of 0 to 2 m whereas 0% show rise more than 2 m. Rest 67 % wells shows fall, mostly in range of 0 to 2 m except small pockets of New Delhi & South district shows fall more than 2 m. Comparing water level data of **January 2018** with **January 2019**, it is revealed that 35 % wells shows rise, mostly in range of 0 to 2 m whereas small pockets in Southeast & South district has rise up to 5.6 m at Mehrauli area; whereas rest 51 % wells shows fall in range of 0 to 2m.

Long-term behaviour of water levels was studied by comparing water level data of May-2018 with 10 year mean water level of May (2008 to 2017) reveals change in water level range from -8.55 m to 12.97 m. Nearly 76 % of monitoring wells show increase in fall of water level whereas rest 24 % wells show increase in rise of water levels. Comparing water level data of August-2018 with 10 year mean water level of August (2008 to 2017) reveals change in water range from – 8.56 m to 10.82 m. Nearly 40 % of monitoring wells show increase in rise of water level whereas rest 60 % monitoring wells show increase in fall of water level. Comparing water level data of November-2018 with 10 year mean water level of November (2008 to 2017) reveals change in water level range from -13.16 m 11.64 m. Nearly 28% of monitoring wells show increase in rise of water level whereas rest 72 % monitoring wells show increase in fall of water level. Comparing water level data of January-2019 with 10 year mean water level of January(2009 to 2018) reveals change in water level range from – 13.58 m to 12.52 m. Nearly 32 % of monitoring wells show increase in rise whereas rest 68 % monitoring wells show increase in fall.

Most of eastern part of NCT Delhi, in areas around Yamuna flood plain and Delhi Quartzite Ridge zones has EC within permissible range of 0 to 2250 µS/cm at 25°C where as rest of NCT Delhi, except some pockets of Najafgarh and West District, has EC value of more than 3000 uS / cm at 25 °C. It is also observed that water from deeper aquifers have greater EC value than the water from shallow aquifer. The EC value increases with depth.

Chloride concentration in groundwater of NCT Delhi is related with EC content. It is observed that in areas having EC values within permissible limits (2250 to 3000 µS/cm), the chloride

content also lies within permissible limit of 250 mg/l. In areas having high EC more than 3000 µS/cm, chloride value is also high upto a maximum of 3000 mg/l.

Chemical analysis of ground water samples collected during May 2018 shows that nitrate content in groundwater is within permissible limit of 45 mg/l in most of the state and the concentration in Western parts of Delhi shows higher nitrate content. Similarly, except 9 locations in Central & Western half of NCT Delhi, all 61 locations show fluoride concentration within permissible limit of 1.5 mg /l.

Contents

PLATES / FIGURES:

TABLES

1. INTRODUCTION

The State Unit Office of Central Ground Water Board has jurisdiction over the National Capital Territory (NCT) of Delhi, covering an area of 1483 sq km and lies between 28°24'15'' & 28°53'00'' *North Latitudes* and 76°50'24" & 77°20'30" *East Longitudes*, covered under Survey of India Toposheet Nos. 53D and 53H. The NCT of Delhi is surrounded on three sides by two States, i.e., on North, West and South by Haryana and in the East across the river Yamuna by Uttar Pradesh.

1.1 Administrative Setup of NCT Delhi

NCT of Delhi is divided in 11 Revenue District and one non-revenue unit along river Yamuna, named as *Nazul Land*. Each district is headed by District Magistrate and assisted by 1 Additional District Magistrate & 3 Sub Divisional Magistrates. The District Administration in Delhi is the *de-facto* enforcement department for all kinds of Government Policies and exercises supervisory powers over numerous other functionaries of the Government of NCT, Delhi. As per District Census Hand Book[1], 11 districts of NCT of Delhi are further subdivided into 3 Tehsils for each district and there are total 33 Tehsils, with 112 villages, 110 Census Town and 3 Statutory Towns. Administrative map of NCT of Delhi is shown in figure 1 and list of districts, tehsils is presented in table 1 and detailed list of urban / rural areas given in annexure I.

Figure : 1

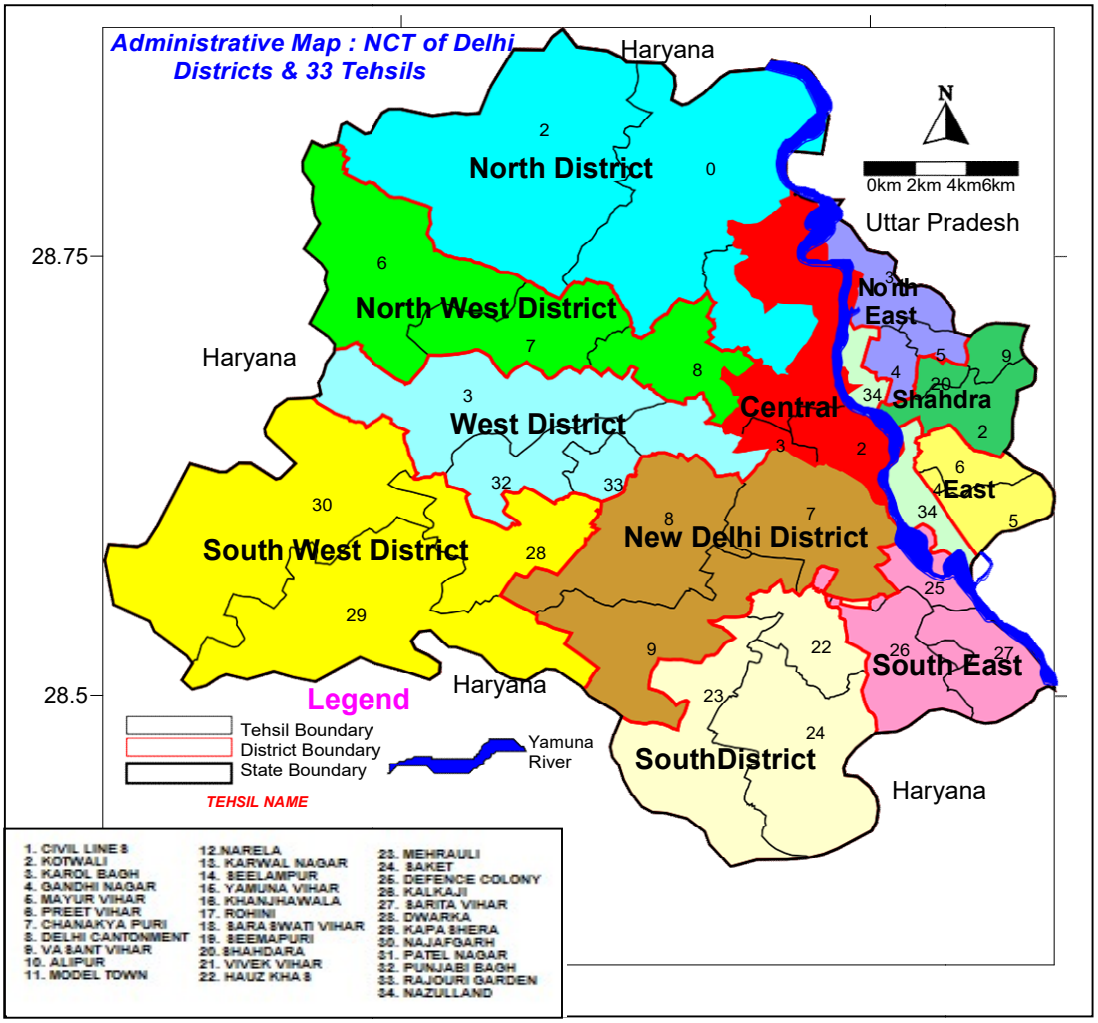


Table 1 : Details of Administrative Units - NCT of Delhi

Sr No.	District Name	Tehsil Name
1	CENTRAL	CIVIL LINES
		KOTWALI
		KAROL BAGH
2	EAST	GANDHI NAGAR
		MAYUR VIHAR
		PREET VIHAR
3	NEW DELHI	CHANAKYA PURI
		DELHI CANTONMENT
		VASANT VIHAR
4	NORTH	ALIPUR
		MODEL TOWN
		NARELA
5	NORTH EAST	KARAWAL NAGAR
		SEELAMPUR
		YAMUNA VIHAR
6	NORTH WEST	KHANJHAWALA
		ROHINI
		SARASWATI VIHAR
7	SHAHDARA	SEEMAPURI
		SHAHDARA
		VIVEK VIHAR
8	SOUTH	HAUZ KHAS
		MEHRAULI
		SAKET
9	SOUTH EAST	DEFENCE COLONY
		KALKA JI
		SARITA VIHAR
10	SOUTH WEST	DWARKA
		KAPASHERA
		NAJAFGARH
11	WEST	PATEL NAGAR
		PUNJAB BAGH
		RAJOURI GARDEN
Non Revenue Unit Area		NAZUL LAND

1.2 Population & Land Use

As per Census of India Report[2]total population of NCT of Delhi is 167,87,944 persons. Out of total 1483 sqkm areas, only 25 % constitutes rural areas spread in 112 villages, which is sparsely populated having population density of 1135 persons / sqkm, where as rest 75 % is urban areas spread in 110 Census Towns and 3 Statutory Towns and it is densely populated with population density of 14,698 persons / sqkm. Details of villages & towns and its area & populations and land use pattern is given in table 2a & 2b respectively.

Population of Delhi has increased at a rate of 2.1% per annum during the decade 2001-2011[2]. Considering the same growth rate for the present decade, it is estimated that the population of Delhi in 2019 will be about 184 lakhs and it would be about 188 lakhs in 2021, 208 lakhs by 2031. In order to evaluate the changes in ground water regime effect due to ever growing demand for ground water and the increasing numbers of abstraction

structures in the city, CGWB has been continuously monitoring the water level variation with its own network stations spread over the entire area of NCT Delhi.

Table 2a: Area , Population & Details of Towns and Villages : NCT of Delhi

Area & Population

Total Area 1483sqkm: **Total Population 167,87,941persons**

- Urban Area : 1114 sqkm(75 %) Urban Population 163,68,899 (98%)
- Rural Area: 369 sqkm(25%) Rural Population 4,19,042 (2%)

Details of Towns - Urban Area

- Statutory Towns :3
  - New Delhi Municipal Council : Area 42.74 sqkm: Population 2,57,803
  - Delhi Cantonment Board : Area 42.97 sqkm : Population1,10,351
  - Delhi Municipal Corporation : Trifurcated into
    - North Delhi Municipal Corporation (NDMC)
    - South Delhi Municipal Corporation(SDMC)
    - East Delhi Municipal Corporation (EDMC)
- Census Towns : 110 - (List – Details Annexure I)

  DMC & Census Town Area : 1028 sqkm : Population 160,00,745

Details of Villages - Rural Area

- Villages : 112 List – Details Annexure I)

  Village Area : 363.35 sqkm : Population 4,19,042

Source[2] : Delhi Statistical Handbook-2019 : www.delhigovt.nic.in

Land utilization data for year 2018-19 reveals that out of 1474.8 sqkm areas accounted for Land Records in NCT of Delhi, more than 65 % area is not available for cultivation where as only 92.70 sqkm is available for cultivation and nearly 34.75 sq km is gross cropped / agriculture areas. Nearly 6 % of total area is under forest, covering mostly notified ridge areas and other forest pockets under DDA & government forest land. Break up of land utilization is presented in table 2b and depicted graphically in figure 2a figure2b.

Table : 2b Utilisation of Land in Delhi (2018-19) Area in Hectares

Area according to Land use Records (Exclude Forest)		147488
Area not Available for Cultivation		92700
(a) Land Put to Non Agriculture Use -	76218	
(b) Barren and Uncultivated Land	16482	
Other Uncultivated Land		11124
(a) Permanent Pasture & Other Grazing Land	61	
(b) Land Use Under Miscellaneous Uses	1170	
(c) Cultivable Waste Land	9893	
Fallow Land		19225
Net Area Sown		22300
Area Sown more than once		11155
Total Cropped Area		33455
Area Under Forest		9453
(a) Forest Under DDA	1281	
(b) Notified Ridge Forest	7784	
(c) Other Forest Area	388	

Source: Joint Director of Agriculture, Govt of NCT,Delhi[2]

Table : 3 Sources of Irrigation and Irrigated Area 2018-19

Source		Area Irrigated (in Hectare)	
Canals			2236
Tanks			0
Wells	TWs	18647	19635
	Others	988	
Net Area Irrigated			21871
Area Irrigated More Than Once			7762
Gross Area Irrigated			29633

Source : Joint Director of Agriculture, Govt of NCT of Delhi[2]

Main source for irrigation in NCT of Delhi is groundwater whereas surface water is also available from Trans Yamuna Canal Network. Details about sources of irrigation and areas under irrigation is presented in table 3.

Figure : 2a

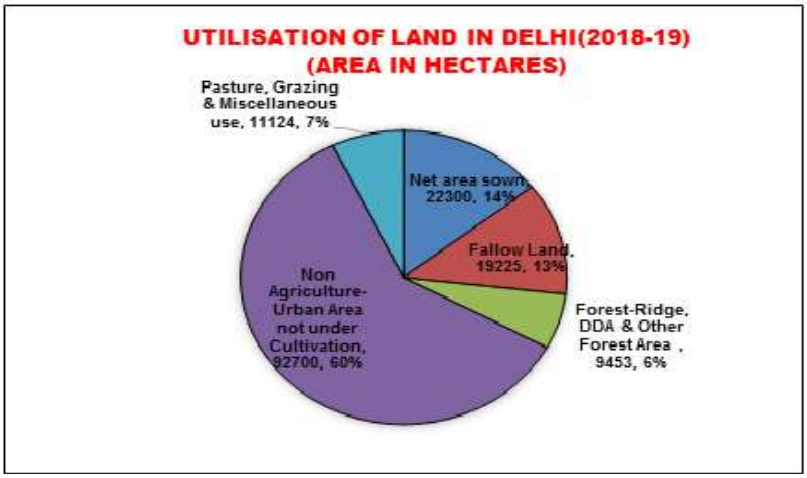
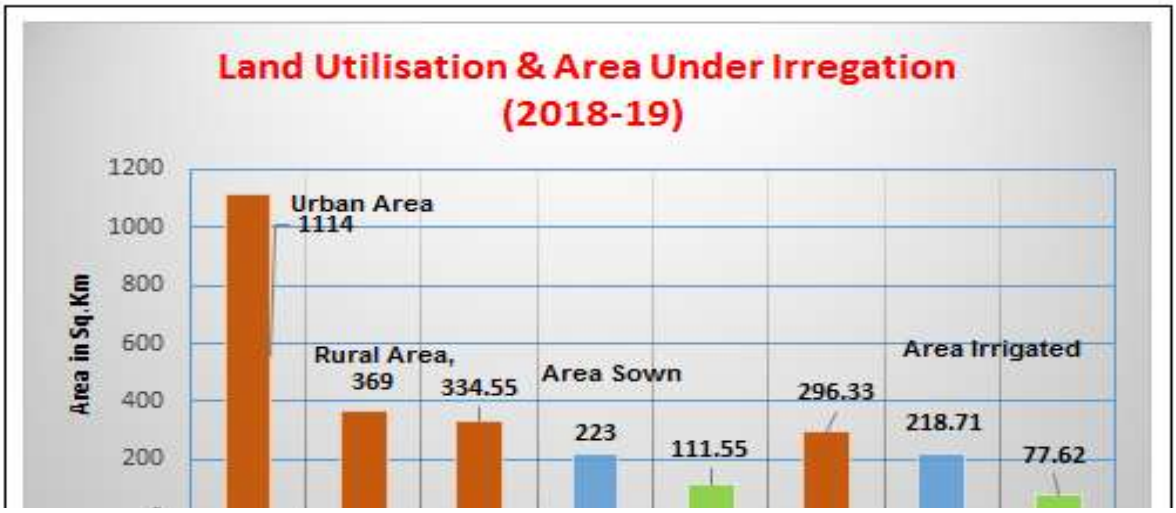


Figure : 2b



1.3 Climate and Rainfall

1.1.1. Climate

The climate of NCT Delhi is mainly influenced by its inland position and the prevalence of air of the continental type during the major part of the year. Extreme dryness with the intensely hot summer and cold winter are the characteristics of the climate. Only during the three-monsoon months July, August, and September does air of oceanic origin penetrate to this state and causes increased humidity, cloudiness and precipitation. The year can broadly be divided into three seasons (Table 4). Date on long-term average climatologic parameters covering monthly maximum / minimum temperature, relative humidity, evaporation and rainfall for NCT of Delhi is given in table 5 and presented graphically in figure 3.

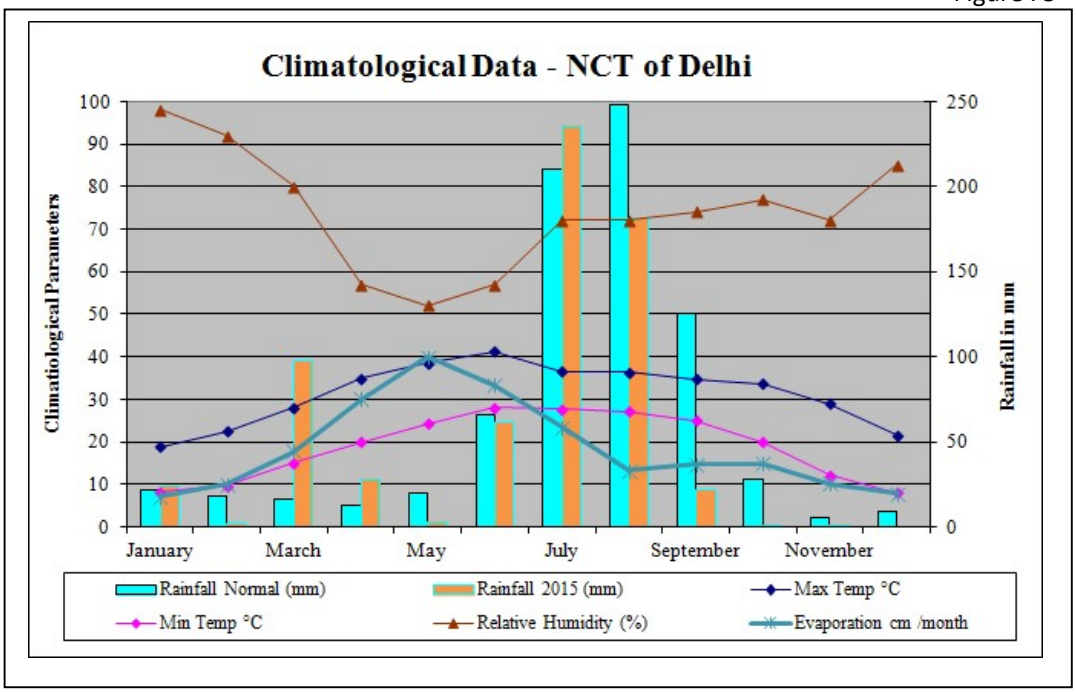
Table 4 : Climate Seasons in NCT of Delhi

Season	Begin	End
Cold/Winter	End of November	Middle of March
Summer	Middle/End of March	End of June
Rainy season	Early July	September

Table : 5 Climatological Parameters – NCT of Delhi (Source [2])

Month	Max Temp (°C)	Mini Temp (°C)	Relative Humidity (%)	Rainfall (mm) Normal	Rainfall (mm) 2015	Rainy Days	Eto (mm/d)
January	18.8	8.2	98.0	21.7	24.1	4.0	7.1
February	22.5	9.7	92.0	18.0	1.8	0.0	10.1
March	28.1	15.1	80.0	15.9	97.4	6.0	17.7
April	34.9	19.9	57.0	12.2	27.7	2.0	30.0
May	38.6	24.3	52.0	19.7	3.1	0.0	40.0
June	41.3	28.1	57.0	65.5	61.7	4.0	33.3
July	36.5	27.7	72.0	210.6	235.2	10.0	23.3
August	36.3	27.1	72.0	247.7	181.6	9.0	13.3
September	34.8	25.0	74.0	125.1	22.0	1.0	14.7
October	33.7	20.0	77.0	28.0	0.4	0.0	14.9
November	29.0	12.2	72.0	5.6	1.1	0.0	10.2
December	21.6	8.1	85.0	9.0	0.0	0.0	7.8
Total	**-**	**-**	**-**	**779.0**	**656.1**	**36.0**	**222.4**
Average	**31.3**	**18.8**	**74.0**				

Figure : 3



1.1.2. Rainfall

For calculation of normal rainfall of NCT Delhi, rainfall records from 1930-1980 for 13 stations (Table: 7) were considered. The normal annual rainfall in NCT Delhi is 611.8 mm. The rainfall in NCT Delhi increases from the southwest to the northwest (figure 4). About 81% of the annual rainfall is received during the monsoon months July, August and September. The rest of the annual rainfall is received as winter rains and as thunderstorm rain in the pre and post monsoon months. The variation of rainfall from year to year is large.

1.1.1. Rainfall Analysis

Rainfall analysis of 34 years annual rainfall of data and probability analysis date is plotted in figure 5 & 6 and its finding, about probability of occurrence of quantum of rainfall with various probability is presented in table 6. (data analyzed for probability graph Annexure II).

Figure :4

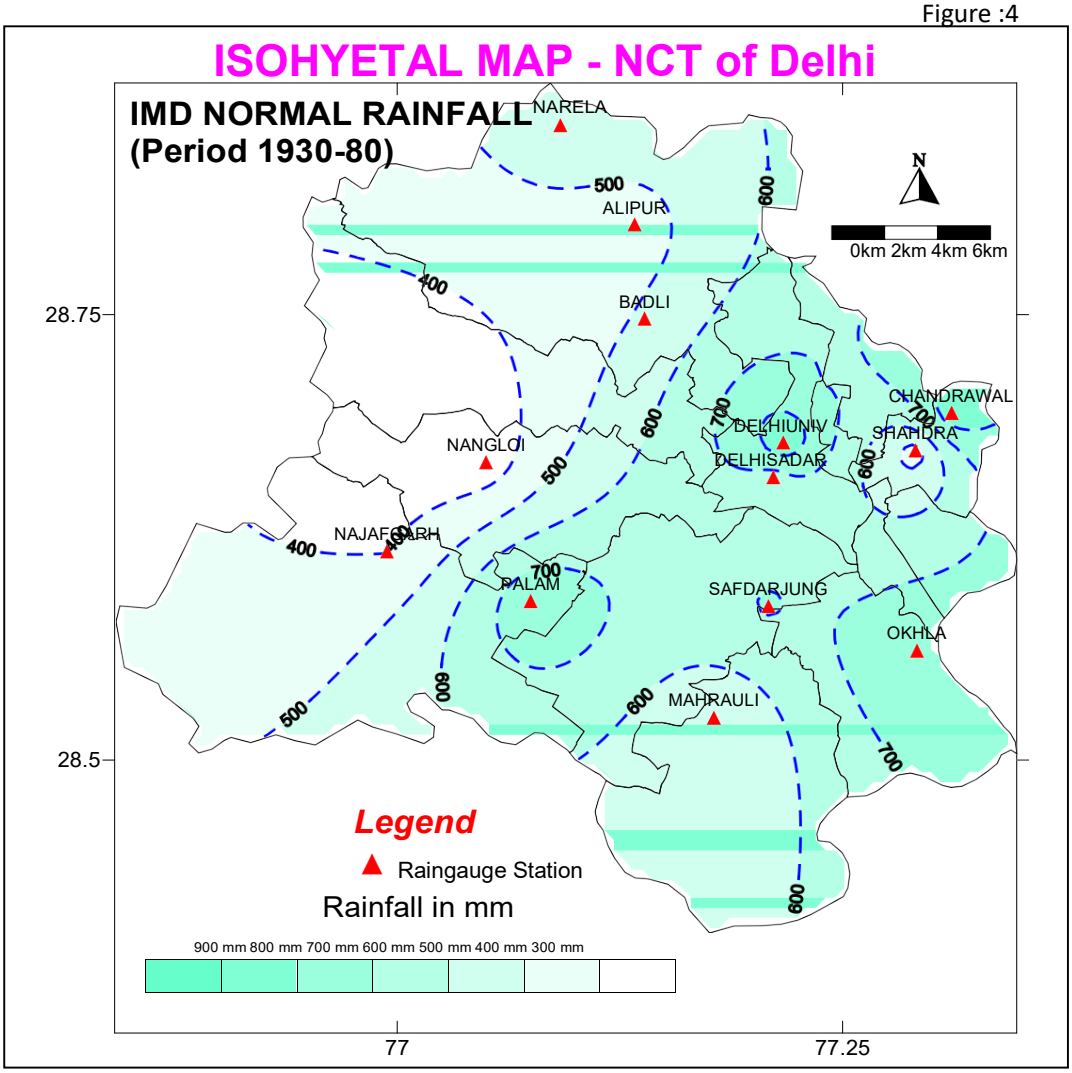


Figure :5

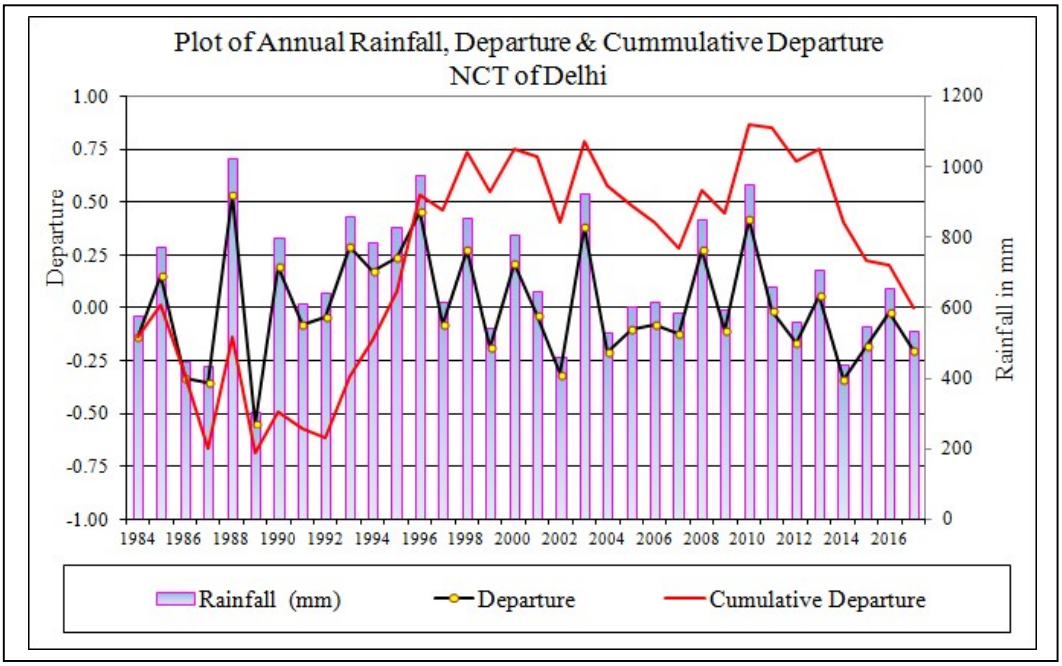


Figure : 6

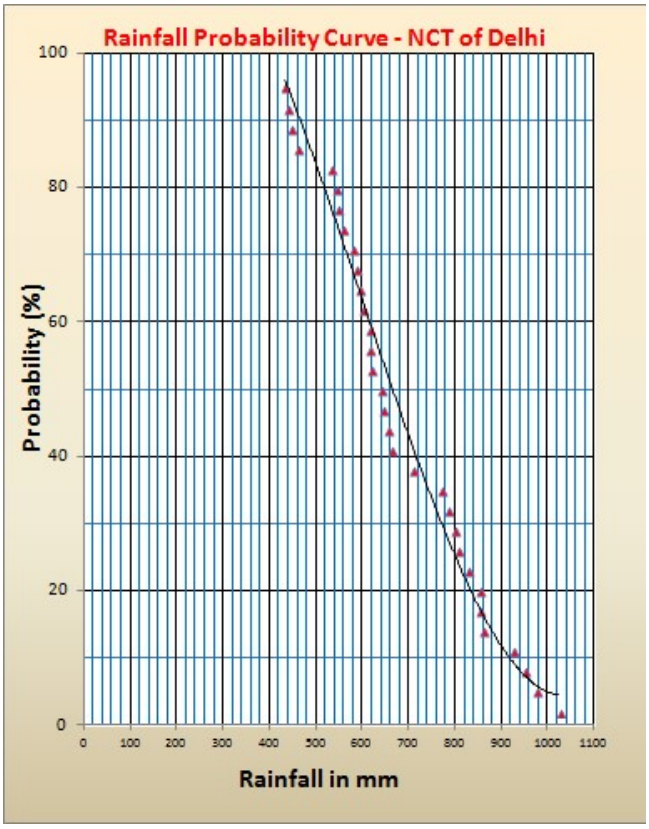


Table 6 : Rainfall Probability Analysis

Probability %	Annual Rainfall in mm
10%	922
20%	840
30%	778
40%	718
50%	664
60%	618
70%	562
80%	520
90%	476
Probability of exceeding of Normal RF	58%

A perusal of rainfall data from 1984 to 2017 shows that NCT Delhi received deficient rainfall during last 21 years corresponding to mild to severe drought conditions (Table 5 & Fig 5b and annexure). Severe drought with departure of 50 % was experience in 1989. Normal drought, departure 25 to 50 % was experienced during year 1986,1987, 2002 and recently during 2014. Whereas, Mild drought, departure up to 25 %, was experienced during the year 1984, 1991,1992, 1997, 1999, 2001, 2004 to 2007,2009,2010, 2012 and 2015 to 2017. The probability analysis shows that probability of rainfall exceeding normal rainfall of 669 mm is up to 48 % whereas there are 90 % chance that rainfall would limit to 476 mm.. Overall, thus the rainfall in Delhi is highly variable and which in turn affects the natural recharge to ground water from year to year.

1.1.2. Other Climatic Parameters

- Temperature:

The cold season starts after second week of November when both day and night temperature drop rapidly with the advance of the season. January is the coldest month with the mean daily maximum temperature at 21.3°C and the mean daily minimum at 7.3°C. In the winter months when western disturbances passes across north India, minimum temperatures may sometimes go down to the freezing point of water. From about the middle of March, temperature begins to rise fairly rapidly. May and June are the hottest months. While day temperature is higher in May the nights are warmer in June. From April the hot wind known locally as *'loo'* blows and the weather is unpleasant. In May and June maximum temperature may sometimes reach 46 or 47°C. With the advance of the monsoon

into the area towards the end of June or the beginning of July day temperatures drop appreciably while the night temperatures remain high. In October the day temperatures are as in the monsoon months but the nights are cooler.

- Humidity:

The air over Delhi is dry during the greater part of the year. Humidity is high in the monsoon months. April and May are the driest months with relative humidity of about 30% in the morning and less than 20% in the afternoons.

- Cloudiness:

During the monsoon especially in July and August skies are heavily clouded and often overcast. In the rest of the year skies are clear or lightly clouded. But in the months January, February and early March skies become cloudy by western disturbances.

- Winds:

Winds are generally light during the post monsoon and winter months. They strengthen during the summer and monsoon months. Except during the monsoon months, winds are predominantly from a westerly or northwesterly direction and tend to be more northerly in the afternoon. Easterly and southeasterly winds are more common in the monsoon months.

Table : 7 Normal and Extremes of Rainfall (Long Term 1930 to 1980 IMD Normal)

Stations	No. of Years of DATA		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL	HIGHEST ANNUAL RAINFALL AS % OF NORMAL &(YEARS)**	LOWEST ANNUAL RAINFALL AS % OF NORMAL &(YEARS)**	HEAVIEST RAINFALL In 24 HOURS * Amount (mm)	Date
Chandrawal (obsy)	20	a	8.5	15.3	16.7	5.5	18.2	47.6	329.8	308.4	102.3	14.4	8.2	11.6	886.5	163 (1977)	64 (1969)	171.0	1976 Aug 08
		b	0.6	1.2	1.2	0.5	1.5	2.2	10.5	10.4	3.9	0.9	0.2	0.8	33.9				
New Delhi (Safd)	79	a	20.5	20.1	13.3	7.8	12.5	62.2	203.2	202.2	137.6	21.7	3.1	8.0	712.2	215 (1933)	43 (1905)	495.3	1875 Sep 09
		b	1.8	1.5	1.2	0.8	1.4	3.6	9.2	9.5	5.1	1.0	0.2	0.7	36.0				
Delhi (University obsy)	29	a	20.7	18.3	19.1	5.1	16.4	62.2	281.6	263.5	147.4	41.6	4.1	7.6	887.6	209 (1957)	52 (1974)	250.0	1963 Sep 16
		b	1.6	1.4	1.5	0.7	1.5	2.8	10.3	10.5	5.2	1.6	0.2	0.8	38.1				
New Delhi Palam	22	a	14.7	14.1	9.3	6.1	18.9	54.2	241.1	284.3	119.4	16.8	6.4	8.6	793.9	164 (1967)	51 (1965)	265.8	1972 Jul 09
		b	1.3	1.5	1.0	0.6	1.5	3.5	10.9	10.7	4.9	1.4	0.2	0.6	38.3				
Okhala (obsy)	21	a	9.6	11.9	14.7	2.6	17.1	66.9	212.5	296.3	124.6	23.2	5.7	7.3	792.4	159 (1964)	66 (1974)	190.0	1967 Aug 26
		b	0.9	1.3	0.9	0.3	1.4	3.4	9.3	10.7	5.1	0.9	0.3	0.6	35.1				
Mahruali	33	a	13.9	10.1	7.3	9.4	3.6	28.3	159.9	152.5	98.7	11.5	1.5	2.3	499.0	197 (1944)	42 (1954)	177.8	1911 Sep 28
		b	1.1	0.7	0.6	0.6	0.3	1.5	5.8	5.9	3.0	0.3	0.2	0.3	20.3				
Delhi Sadaer	38	a	22.6	17.5	13.0	8.8	9.6	44.8	184.3	180.0	132.3	26.1	3.5	5.1	647.6	194 (1964)	42 (1903)	224.8	1942 Sep 05
		b	1.9	1.4	1.4	0.6	0.9	2.4	7.6	8.9	4.7	1.0	0.3	0.6	31.7				
Nangloi	25	a	8.5	4.6	1.1	4.0	2.4	19.8	100.3	121.6	69.0	5.0	0.4	0.5	337.2	246 (1964)	21 (1950)	120.0	1964 Aug 14
		b	0.8	0.3	0.2	0.2	0.3	1.1	4.6	5.4	3.1	0.4	0.0	0.0	16.4				
Sahadra	12	a	15.5	17.9	5.6	5.3	2.8	24.8	170.7	125.8	74.9	7.9	0.0	0.6	451.9	206 (1944)	42 (1948)	129.5	1944 Sep 04
		b	0.7	0.8	0.7	0.3	0.5	1.4	6.1	5.0	2.8	0.3	0.0	0.1	18.7				
Najafgarh	23	a	8.9	8.2	4.7	4.2	3.0	25.1	122.0	122.8	75.9	21.7	0.5	1.8	398.9	171 (1942)	10 (1959)	139.7	1954 Oct 01
		b	0.8	0.7	0.2	0.4	0.4	1.3	5.5	5.6	3.2	0.8	0.0	0.2	19.1				
Badli	23	a	13.7	8.6	9.6	3.6	1.4	21.8	154.2	181.3	88.2	32.9	0.8	0.0	516.1	257 (1961)	37 (1951)	205.7	1962 Jul 17
		b	1.0	0.7	0.6	0.4	0.2	1.1	5.8	6.4	3.7	0.8	0.0	0.0	20.7				
Alipur	21	a	11.7	10.6	3.3	3.6	6.0	26.7	146.1	137.1	87.7	13.7	1.3	1.1	448.9	202 (1961)	12 (1959)	162.1	1961 Jul 17
		b	1.3	0.7	0.4	0.4	0.4	1.5	4.7	6.0	2.9	0.7	0.1	0.1	19.3				
Narela	19	a	19.9	14.5	10.6	4.9	7.2	20.6	184.7	190.4	111.2	14.8	1.1	1.4	581.3	196 (1961)	29 (1965)	184.1	1947 Sep 15
		b	1.5	0.9	1.1	0.6	0.4	1.6	6.4	8.2	4.0	0.5	0.1	0.2	25.3				
Delhi (District)		a	14.5	13.2	9.9	5.5	9.2	38.8	191.6	197.4	105.3	19.3	2.8	4.3	611.8	251 (1933)	44 (1951)		
		b	1.2	1.0	0.8	0.5	0.8	2.1	7.4	7.9	4.0	0.8	0.1	0.4	27.0				

(a) Normal rainfall in mm.

(b) Average number of rainy days (i.e. days with rainfall of 2.5 mm or more)

* Based on all available data up to 1980.

** Years given in brackets.

2. GROUND WATER REGIME MONITORING

Monitoring of ground water regime is an effort to obtain information on variation in ground water levels and chemical quality through representative sampling, both in time and space. Systematic and regular monitoring of groundwater levels and quality brings out various information about the changes taking place in the groundwater regime.

2.1. Monitoring Objective and Method

Main objective is to record the response of ground water regime to the natural and artificial conditions of recharge and discharge with reference to geology, climate, physiography, land-use pattern and other hydrologic characteristics. The database generated, in forms of reports and maps, are of immense help for regional groundwater flow modeling which serves as a groundwater management tool to provide the necessary advance information to the user agencies to prepare contingency plans in case of unfavorable groundwater recharge situation. The data also has immense utility in deciding the legal issues arising out of conflicting interests of groundwater users and also form the basis for ground water development and management programme.

2.1.1. Monitoring Stations Status

Central Ground Water Board, as a part of its national programme, has established a network of observation wells in the NCT of Delhi with this objective. Number of wells monitored during 2018-19 in NCT of Delhi varied from 84 in May 2018 to 86 in January 2019. Details of monitoring wells, with district wise breakup and types of wells (dug wells / piezometers etc) is given in Table 8 and their distribution in NCT of Delhi shown in map in figure 7.

Table :8 Numbers of Stations Monitored by CGWB During 2018-19 – NCT Delhi

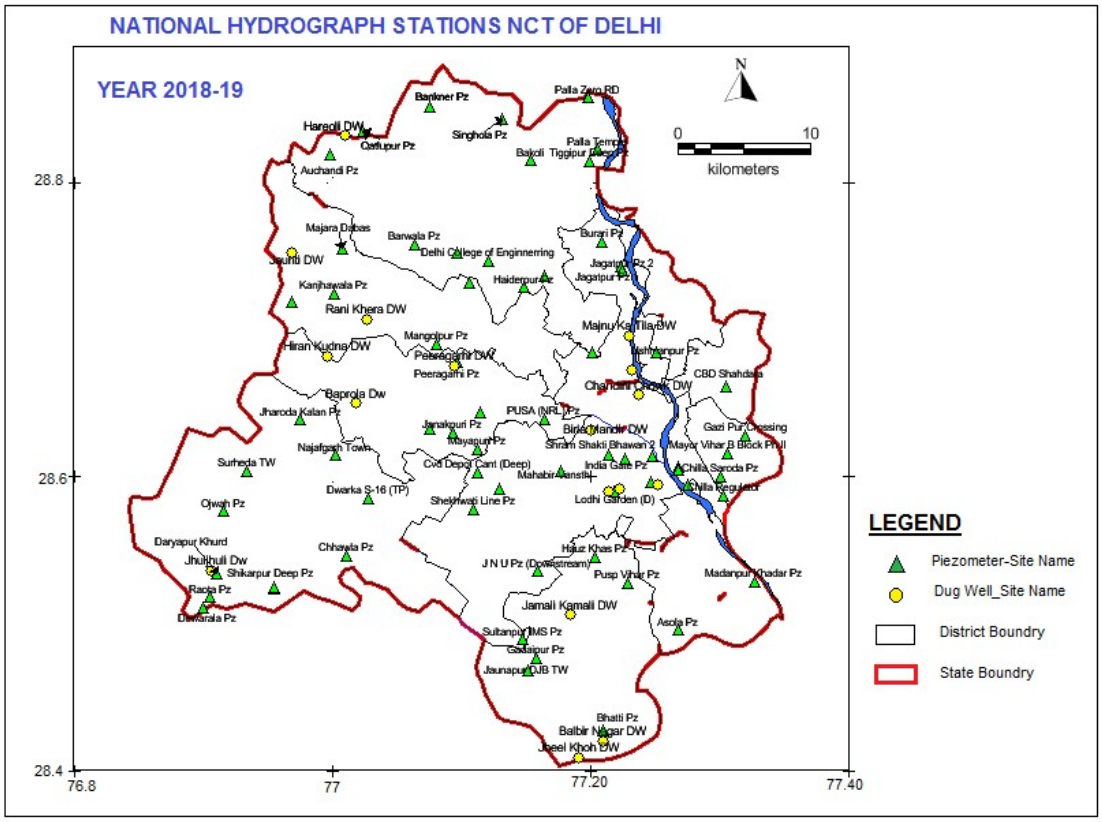
	May-18			Aug-18			Nov-18			Jan-19		
	Dw	Pz	Total	Dw	Pz	Total	Dw	Pz	Total	Dw	Pz	Total
North	1	16	**17**	1	14	**15**	2	16	**18**	2	16	**18**
North West	2	4	**6**	2	5	**7**	2	5	**7**	2	5	**7**
South	2	5	**7**	3	5	**8**	2	5	**7**	2	5	**7**
South West	1	10	**11**	1	11	**12**	1	11	**12**	1	12	**13**
South East	0	3	**3**	0	3	**3**	0	3	**3**	0	4	**4**
North East	0	1	**1**	0	0	**0**	0	1	**1**	0	1	**1**
East	0	3	**3**	0	3	**3**	0	4	**4**	0	4	**4**
West	3	6	**9**	3	6	**9**	3	6	**9**	3	4	**7**
New Delhi	4	14	**18**	4	14	**18**	4	12	**16**	4	13	**17**
Central	3	4	**7**	3	3	**6**	3	3	**6**	3	2	**5**
Shahdara	0	0	**0**	0	1	**1**	0	1	**1**	0	1	**1**
Nazulland *	0	2	**2**	0	0	**0**	0	2	**2**	0	2	**2**
Total	16	68	**84**	17	65	**82**	17	69	**86**	17	69	**86**

DW : Dug well & Pz : Piezometer ; * Non Revenue Land Area – Yamuna Flood Plain Area

It is observed that at present district wise distribution of monitoring network stations has became highly uneven. Over the period, mainly during last three years, numbers of monitoring stations became defunct largely due to corrosion of well assembly and at some places, destroyed / filled up due to other unavoidable urban development activities. During last two decade, at places, continuous decline in ground water level is observed. Such condition necessitates more attention and close monitoring at micro level. It is fact that establishing of new Peizometers or identifying new working dug wells in metropolitan city of Delhi is very difficult due to non-availability of space, although Central Ground Water Board is striving to increase the number of monitoring stations in NCT Delhi to have close observation in the diverse hydrogeological domain. To ensure optimum network density of monitoring station for scientific analysis of the dynamics of ground water regime, in exceedingly developing areas of NCT Delhi is most inevitable. CGWB has taken up groundwater exploration programme to drill and construct new piezometers to replace existing defunct piezometers in

NCT Delhi from the Annual Action Plan of year 2018-19 onwards. Map showing locations of existing monitoring stations of CGWB is presented in figure7.

Figure : 7



2.1.2. Distribution of Monitoring Stations

Central Ground Water Board has carried out extensive hydrogeological mapping and groundwater exploration in NCT of Delhi and its surrounding States. The information generated from these studies has helped to figure out the subsurface disposition and inter-relationship of the aquifers spatially and depth wise. This information has enabled to decide grouping of interrelated aquifers into one aquifer system for the purpose of monitoring.

In alluvial areas of NCT of Delhi, number of sand zones constituting individual local aquifers is grouped into major one main aquifer system and piezometers have been installed accordingly. Three distinct potential aquifer groups within the depth of 450 m below ground level, identified and grouped on basis of various hydrogeological mapping and ground water exploration, are asfollows.

1. Aquifer Group I - Down to 65 m below ground level(Un-confined)
2. Aquifer Group II- Between 65 to 200 m below ground level (Confined/Semi-Confined)
3. Aquifer Group III- Between 200 to >300 m below ground Level(Confined)

Separate piezometers are installed, tapping the two aquifer groups, the first one in the phreatic zone deep enough to accommodate long term fluctuation (i.e. up to 65 m deep) and the other one tapping

middle parts of the aquifer groups II, lying between 65 to 200 m. The Aquifer group III is not being monitored at present.

Similarly, hard rock area of NCT Delhi is being monitored through piezometric nests, which are installed in a single borehole tapping the weathered and fractured aquifers combined. Generally, the depth of the well goes up to 80 m, but in some cases it goes up to 140 m.

Besides piezometers, many numbers of dug wells, tapping phreatic aquifer zone are included in monitoring network. Over the period, numbers of dug wells are becoming defunct due to lack of their use and maintenance. Still, there are 17 dug wells integrated with monitoring network of NCT Delhi (figure 7).

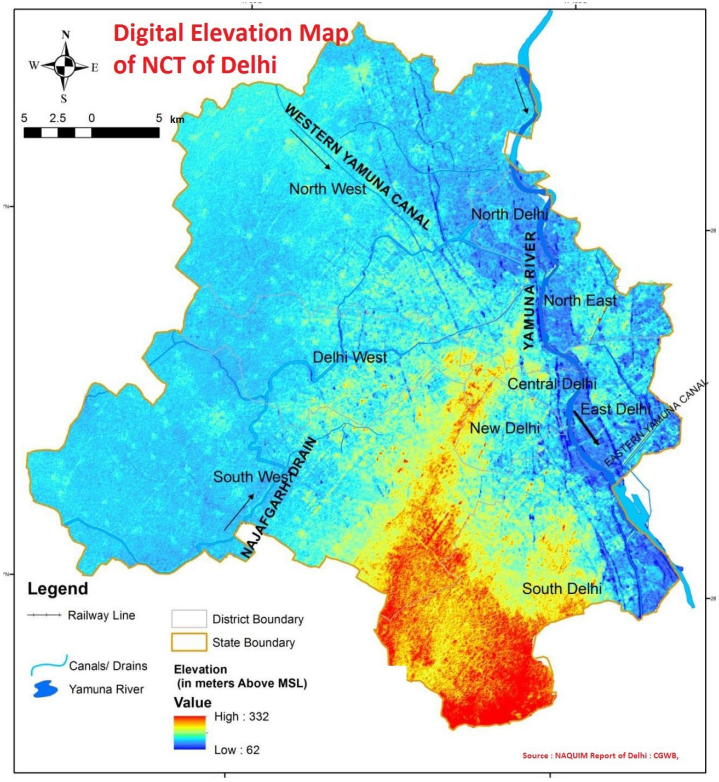
3. HYDROGEOLOGY

Occurrence and movement of groundwater in subsurface aquifer system depends upon topography, geology, climate, water yielding and water bearing properties of subsoils / rocks in the zones of aeration and saturation. The upper surface of the zone of saturation is the Water Table which is measured during water level monitoring. In case of wells penetrating confined aquifers, the water level represents the pressure or Piezometric Head at that point. For effective water level monitoring, it is essential to have a complete understanding of aquifer disposition and geometry in the area before establishing monitoring network.

3.1 Physiography &Drainage

NCT of Delhi represents a mature topography with vast, gently undulatory plains dominated by Yamuna River, low linear ridges and isolated hillocks. Physiography of Delhi is dominated by the Yamuna river, the Aravalli range, and the plains in between formed by alluvium deposits of Recent age. The SSW- NNE trending Aravalli Ranges are designated as *Delhi Ridge*, occupy the south central part of Delhi and extend up to western bank of Yamuna River near Okhla in the south and Wazirabad in the north-east. Ecologically, in western part of the India, the Aravalli Ridge acts as a barrier between the Thar desert and the plains and slows down the movement of dust and wind from the desert. In NCT Delhi, the ridge area are covered with forests, acts as city's lungs and help maintain its environment. This green belt, a natural forest, has a moderate influence on temperature, besides bestowing other known benefits to the people.

Figure : 8

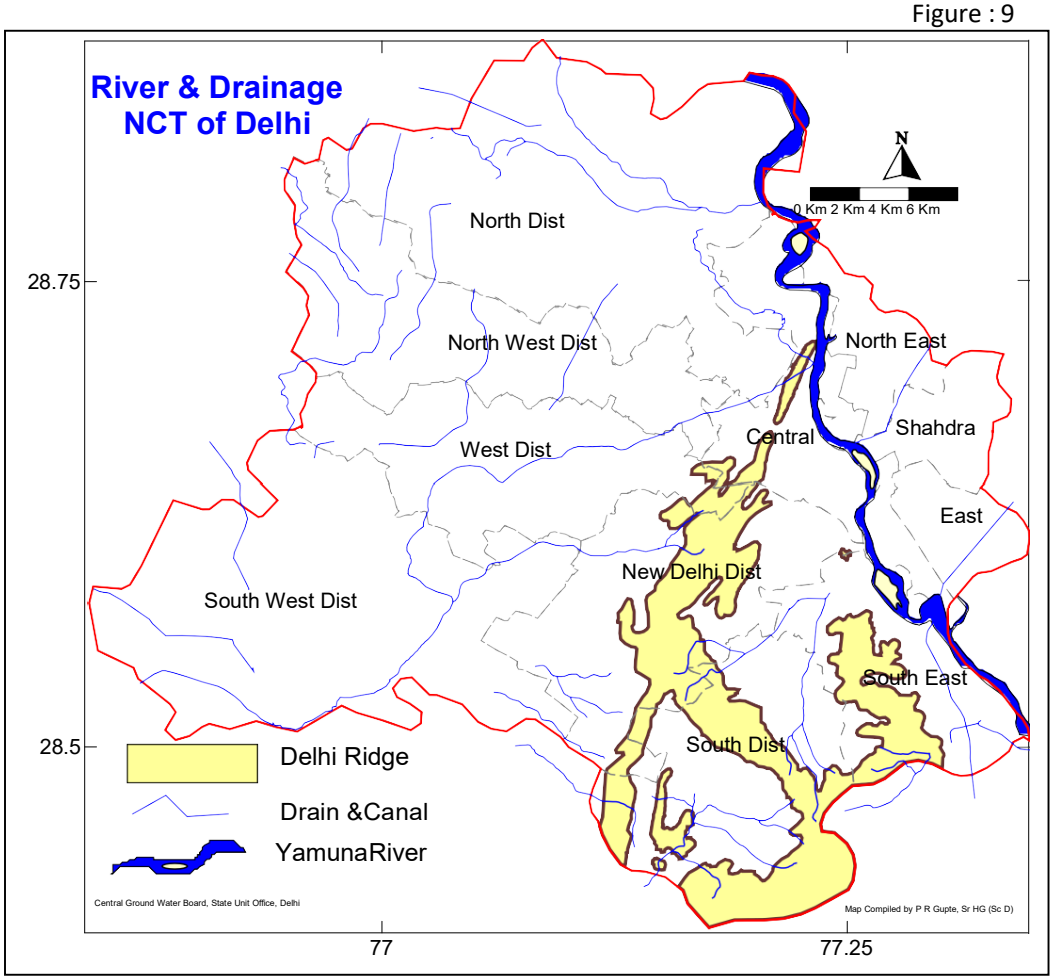


The area towards east of ridge has a gentle slope of 3.5 m/km towards Yamuna. The area towards west of ridge representing Older Alluvial Plain is mostly covered by sand dunes and has a westerly slope. Yamuna River flows across Delhi in a south-southeasterly direction with vast flood plain, marked by a bluff of 3 to 4 m on either bank. Digital Elevation Model Map of Delhi is presented in Fig. 8. Surface elevation varies from 332 m above mean sea level at the ridge to 62 m above mean sea level at river Yamuna. The low-lying Yamuna flood plains, with an elevation as low as 198 m amsl, provide fertile alluvial soil suitable for agriculture but are prone to recurrent floods.

The Yamuna river flowing in a southerly direction in the eastern part of the NCT of Delhi is the only perennial river in the area besides the number of micro watersheds originating from the quartzite ridge. The drainage on the East of the ridge enters river Yamuna, whereas on the West, it enters natural depressions located in Najafgarh Tehsil of South-West district. The NCT of Delhi can be

divided into seven sub basins, ultimately discharging into the Yamuna (figure 9), namely (I) The Najafgarh Drain is about 39 Km long, flows North-Easterly and joins Yamuna River at Wazirabad in North Delhi. (ii) Supplementary drain, (iii) Barapullah drain (iv) Wild life sanctuary area, (v) Drainage of Shahdara area, (vi) Bawana drain basin, (vii) Other drains directly out falling into river Yamuna on right bank. Swamp areas are common along the flood plains of Yamuna.

Figure : 9



3.2 Geomorphology

The ground water availability in NCT of Delhi indirectly relates with its distinct landforms units, which in turn represent underlying intrinsic geological features. Map showing these landforms of NCT of Delhi are presented in Fig. 10. All these landforms of NCT, Delhi can be grouped into three broad geomorphic units: namely Rocky surface, Older Alluvial Plain and Flood Plain of Yamuna River.

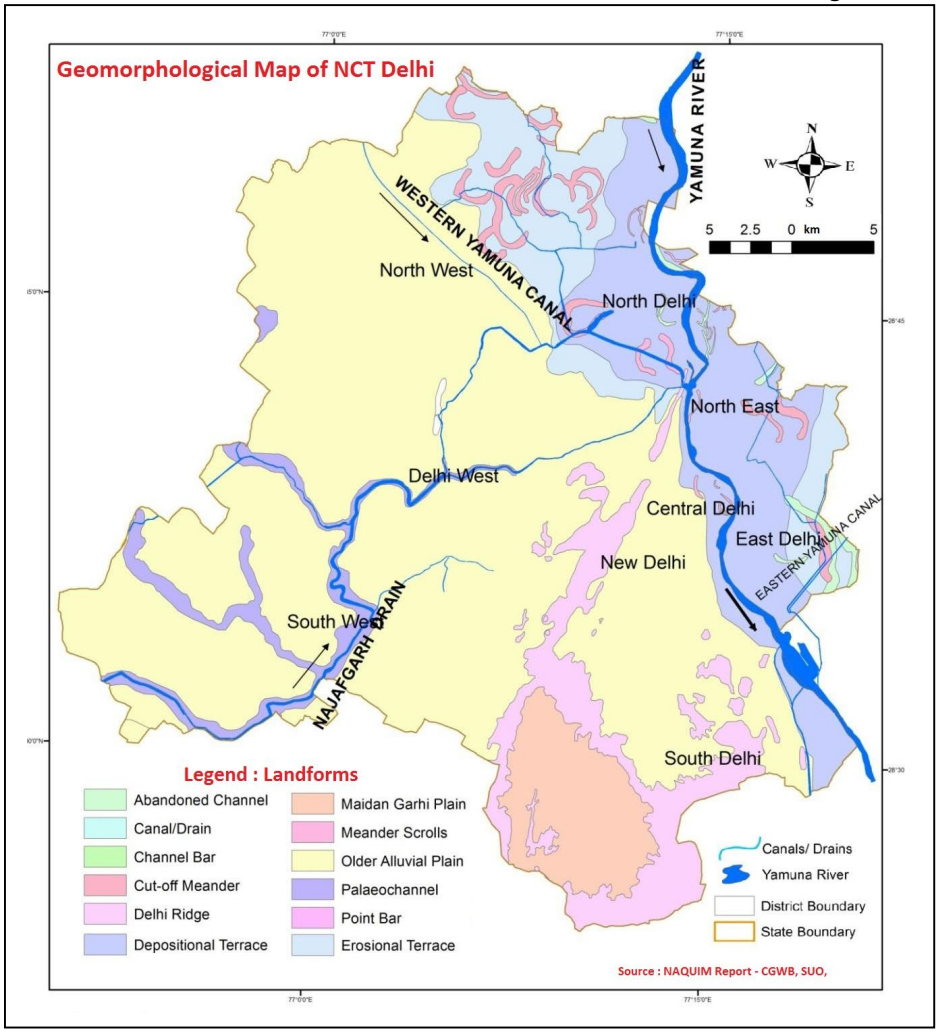
Rocky Surface : The rocky surface represents structurally controlled relict linear ridges and isolated hillocks comprising of rocks of Delhi Supergroup. This distinct landform comprising of isolated hills is most prominent in the south and south central parts, and extends from Mahipalpur to Wazirabad in the north. Towards south of Mahipalpur the ridge gets bifurcated, one arm extends towards Mandi and further south while the other arm takes a turn towards southeast and extends upto Tughlakabad-Greater Kailash-Nehru Place and Okhla. It attains a maximum elevation of 362 m amsl which gradually diminishes towards north where rocks are exposed on the western bank of Yamuna near Wazirabad.

Older Alluvial Plain: The gently undulatory terrain on either side of the rocky surface is described as Older Alluvial Plain. This surface is separated from the Yamuna Flood Plain by a bluff. Depending upon

the morphological expressions / features, this unit is further divided into different subunits: namely, (i) Najafgarh Older Alluvial Plain, (ii) Delhi Older Alluvial Plain and (iii) Maidan Garhi Plain. Najafgarh Older Alluvial Plain occupying western and southwestern part of the region is partly covered by sand dunes and sandy sheets. The gently sloping surface including the covered pediment along the eastern flank of the ridge represents the Delhi Older Alluvial Plain. Maidan Garhi Plain is a relatively higher plain surface and forms part of Chhatarpur Basin. A narrow zone of badland has formed mostly along the western margins of structural ridges due to intense development of gullies and rills.

Flood Plain of river Yamuna: The low-lying flat surface representing the Flood Plain of river Yamuna occupying northern, northeastern and eastern parts of the NCT is an important geomorphic unit. North of Narela, the width of flood plain varies from 15 to 17 km. The wider Older Yamuna flood plain indicates lateral migration of river Yamuna over large areas. This belt has good potential for ground water development and forms the erosional terrace. The Yamuna Active Flood Plain represents the wide belt bounded on both the sides by Eastern and Western bunds and is naturally prone to annual / periodic floods being in the flood way and flood fringe zone of river Yamuna. It forms depositional terrace and is characterized by abandoned channels, cut-off meanders, meander scrolls, point bars and channel bars. Presence of number of cut- off meanders in the Yamuna Flood Plain suggests oscillatory shifting of river. The lakes near Bhalsawa, Kondli and Khichdipur are remnants of large meanders.

Figure : 10



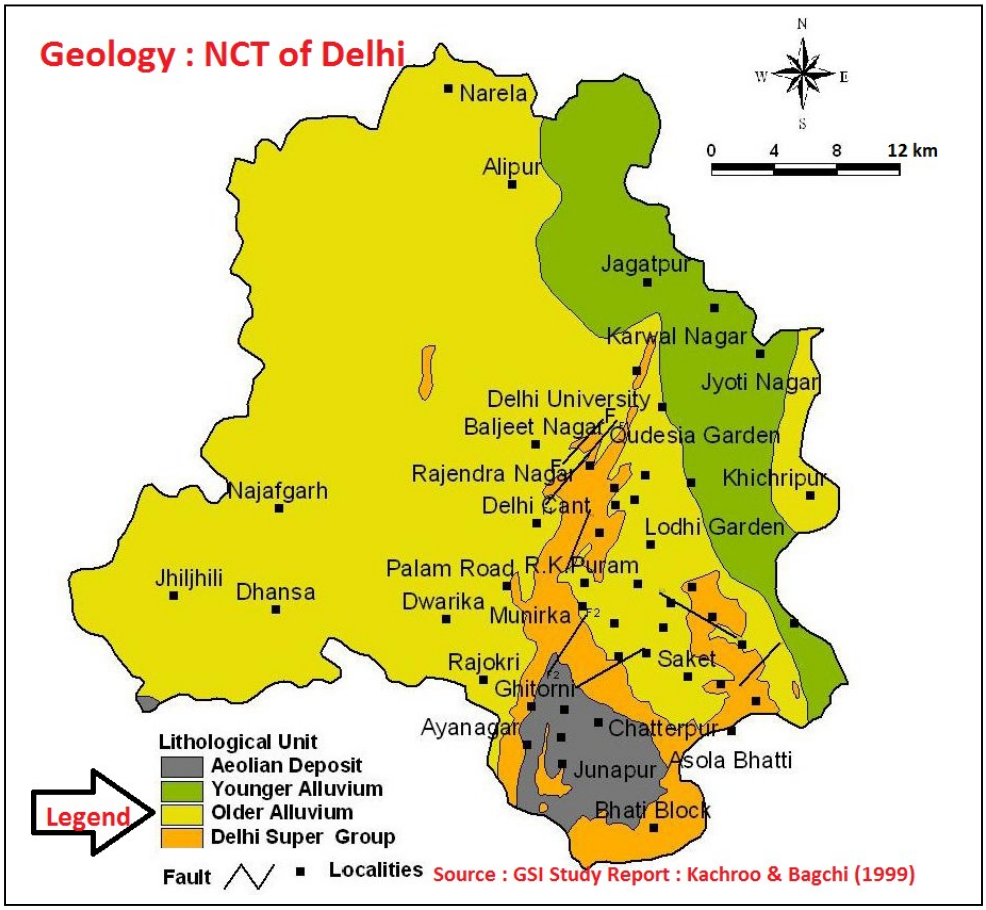
3.3 Geology

The rock formations exposed in the National Capital Territory of Delhi are mainly quartzite interbedded with thin bands of micaceous schist. These Proterozoic age rocks occur along the ridge, extending from Harchandpur (Haryana) in the South to Wazirabad (Delhi) in the North. Quaternary sediments consisting alluvium deposit directly overlie the Proterozoic rocks. Systematic geological and geomorphologic studies carried out by the Geologists of Geological Survey of India[3]has revealed three Stratigraphic horizons and underlying three distinct lithostratigraphic units of NCT Delhi. The highest of these is the erosional surface forming the top of denudational hills. The second surface is Older Alluvial plain and the third is depositional Younger Alluvial plain (Yamuna). All three lithostratigraphic units corresponding them have undergone changes due to widespread and uncontrolled urban activity over the period. The geological map of Delhi after Kachroo and Bagchi (1999)[3], showing these main units is shown in figure 11 and generalized stratigraphy of NCT of Delhi is presented in table9.

Table : 9 Generalized Stratigraphic Units of NCT Delhi (compiled after GSI Study[3])

Alluvium	Newer Alluvium	Unconsolidated, inter-bedded lenses of sand, silt gravel and clay confined to narrow flood plains of Yamuna river and Aeolian deposit of South Delhi.
	Older Alluvium	Unconsolidated thickness varies upto 300m. Interbedded, inter-fingering deposits of sand, clay and kankar, poor to moderately sorted.
Delhi Super Group	Alwar Quartzite	Well stratified, thick bedded, brown to buff colour, hard and compact, intruded locally by pegmatite and quartz veins interbedded with mica schist.

Figure : 11



3.3.1. Alluvium Deposits

In NCT Delhi region, exposures of the oldest lithostratigraphic unit, the Delhi Quartzite ridge acts as main recharge zone to subsurface aquifer system. The Quaternary deposits in the form of aeolian and alluvial deposits constitute the major repository of ground water in the area. In the East of the ridge, the thickness of unconsolidated sediments gradually increases away from the ridge, with the maximum reported thickness being 170 m. In the Southwestern, Western and Northern parts of the area, the thickness of sediments is more than 300 m except at Dhansa where the bedrock has been encountered at 297 m below land surface. In Chhattarpur basin, the maximum thickness of sediments is 116 m. The aeolian deposits of South Delhi are mainly comprised of loam, silty loam and sandy loam. The bedrock is overlain by these deposits. Older alluvial deposits consist mostly of interbedded, lenticular and inter fingering deposits of clay, silt, and sand along with kankar. These deposits are overlain by the newer alluvium, which occurs mostly in the flood plains of river Yamuna.

3.3.2. Hard Rock Formation

Quartzite is one of the most physically durable and chemically resistant rocks found in NCT of Delhi. The suits of quartzite and associated mica schist /phyllite bands of Delhi system have undergone multiple folding and different phases of metamorphism. When the mountain ranges are worn down by weathering and erosion, less-resistant and less-durable rocks are destroyed, but the quartzite remains. This is why Delhi Quartzite is so often the rock found as linear ridges ranges and covering their flanks as a litter of scree. One of the research study on weathering of Proterozoic quartzite in the semi-arid conditions around Delhi[4], it is suggested that Quartzite being a resistant rock, dissolution of small amount of pyrites presence, by moving water produced a sulphate-bearing acidic solution and ferrous iron which reacted with aluminosilicate minerals and quartz respectively which has made the Delhi Quartzite porous and friable. The coupled weathering mechanism, from the core outward and also proceeded initially from fractures towards the inside, produced weathering rinds and subsequent physical erosion of loose sand, produced during rind development in the outermost zones, thereby given rise to features like tors, spheroids, gullies, cavities and small-scale caves on these quartzites. Thus, the terrain has acquired ruggedness in semi-arid conditions.

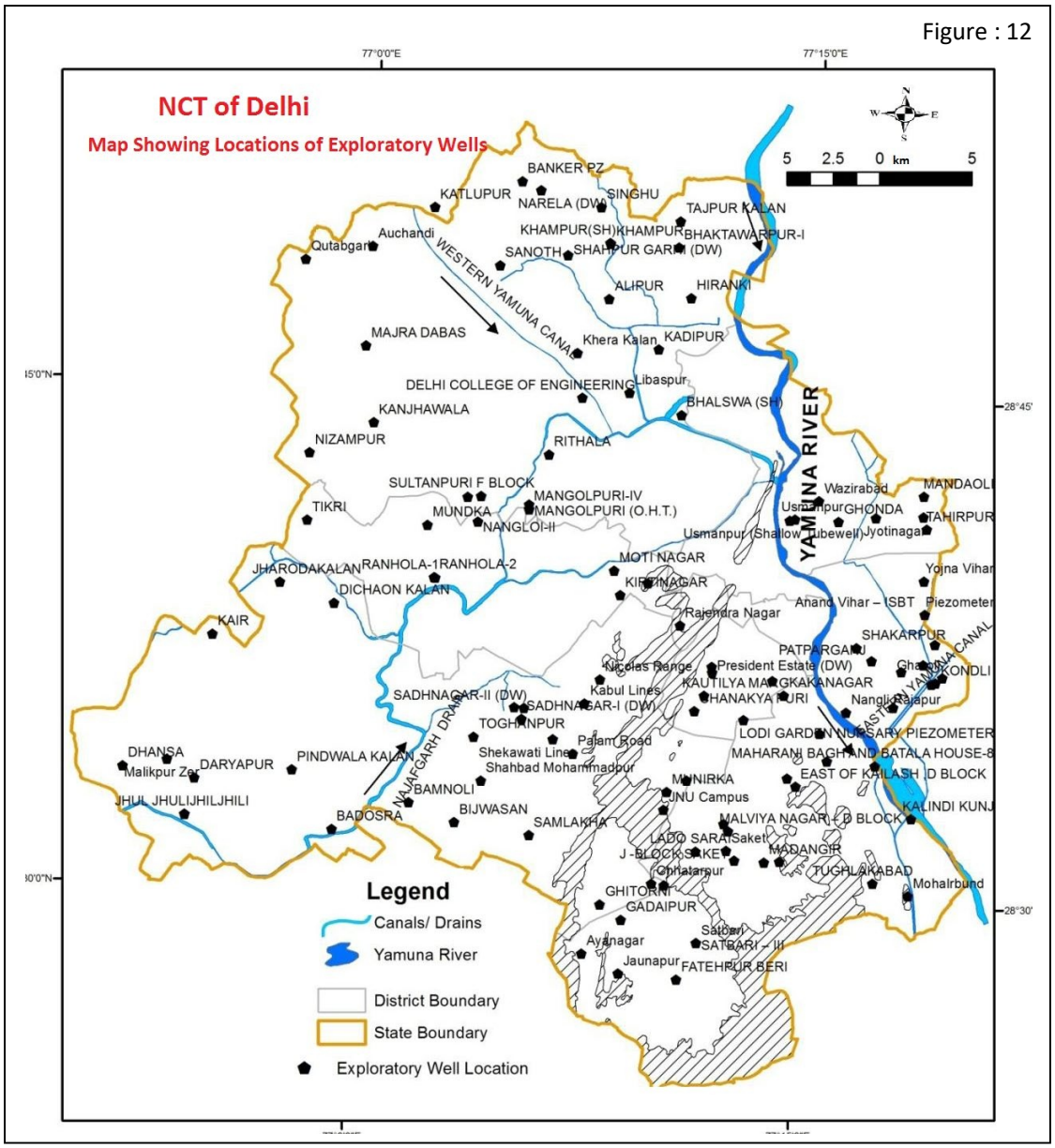
In one of the studies of GSI[5] it is reported three generations of folding in the rocks of Delhi. The fold axes of first generation folds follow the trend of main ridge i.e. NNE-SSW, the second generation folds trending NE-SW are observed at Tughlaqabad - Mehrauli area, and third generation fold trending NW-SE is observed at Anand Parbat. The rocks are highly jointed and two sets of conjugate vertical to sub-vertical joints have been reported [3]. Another study of GSI[6] has inferred a number of faults trending NNE-SSW, NE-SW and WNW-ESE.

3.3.3. Subsurface Aquifer Dispositions

Central Ground Water Board had been engaged in Ground Water Exploration in National Capital Territory of Delhi since its inception in 1972 and till date more than 327 boreholes are drilled out of which 151 are Exploratory Wells (EW), 176 are Observation Wells (OW) / Piezometers (Pz) / Slim holes[7]. Locations of exploratory boreholes are shown in figure 12. All these boreholes were electrically logged to identify granular zones with fresh ground water and other lithological characteristics of subsurface litho units. All these studies has revealed that there is distinct variations in sub-surface lithology characteristics and thickness of individual subunits of the main aquifer zone, within the Younger and Older alluvium deposits of NCT Delhi (refer Fig 11) which makes the aquifer geometry of Delhi complex. Younger Alluvium confined to the flood plains of Yamuna River and also along the courses of major streams, comprises of clay/silt mixed with small mica flakes, and medium to coarse-grained sand and gravel whereas Older Alluvium comprises interbedded and lenticular deposits of clay, silt and sand ranging from very fine to very coarse with occasional kankar. In general, the Younger alluvium, the disposition of different sediments particularly the pervious layer constituting the unconfined aquifer is well delineated in the Yamuna flood plain area while in the

older alluvium, the disposition of different lithological units is not well defined and they are heterogeneous in nature, making it difficult to identify the deep aquifer zones which are regionally extensive, both vertically and laterally. In the Yamuna flood plain, Younger Alluvium thickness is about 40m thick and underlain with silty clay with kankar whereas the thickness of the Older Alluvium, mainly west of Delhi Ridge is highly variable and is dependent mainly on the configuration of the basement; at Shahbad Mohammadpur near IGI airport the thickness of the older alluvium is 560 meters overlying the bed rock. Whereas in areas underlain by hard rock units, mainly South, South East, Parts of New Delhi and Central district of NCT of Delhi, the aquifers are defined by the presence of fractured zones at different depths. These fractured zones at places are locally well defined but not regionally extensive.

Figure : 12

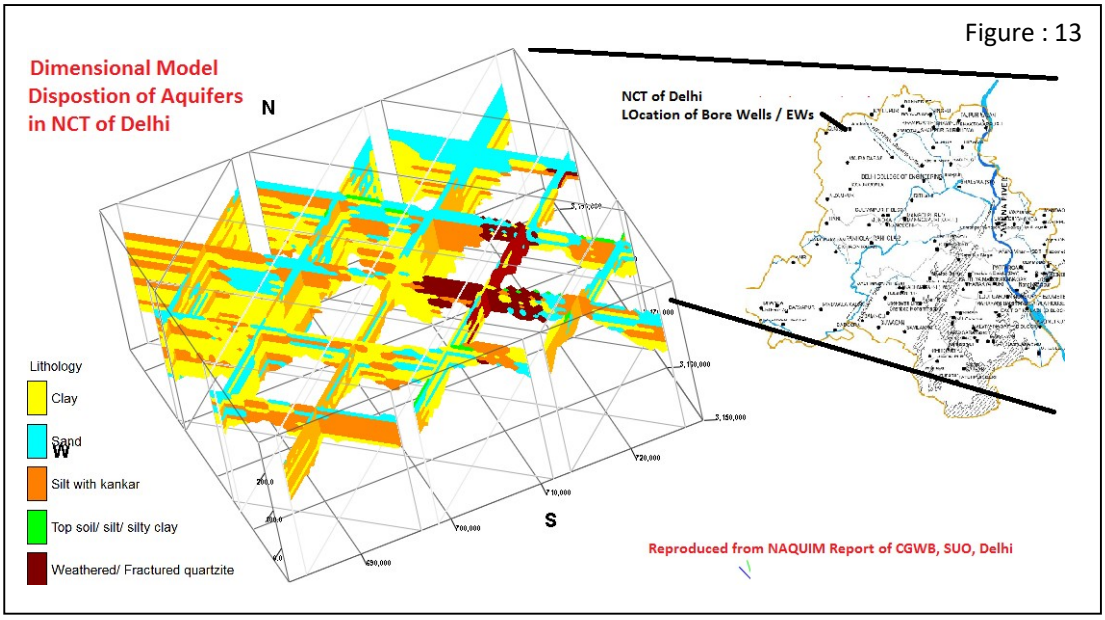


The subsurface configuration of aquifers, in entire NCT of Delhi has been deciphered on basis of available lithological and geophysical logs of exploratory wells drilled by Central Ground Water Board under the Ground Water Exploration Programme. To mark the aquifer geometry, on the basis of

these litholog data, the different sediments i.e. clay, silt, kankar and different grades of sand, and their admixture has been categorized as pervious (silt + kankar + sand) and impervious (mostly clay with some silt + kankar). In the areas underlain by hard rock formation, upper most wreathed regolith and quartzite with fractured zones at different depths and associated mica schist band constitutes unique hard rock aquifer system.

In recent report of CGWB taken up under NAQUIM, the detailed aquifer geometry on regional scale has been established in the NCT, Delhi. All available information about subsurface aquifer configuration, deciphered on basis lithological and geophysical logs of exploratory wells drilled by Central Ground Water Board under the Ground Water Exploration Programme along with interpreted records of various geophysical studies etc., are integrated to prepare the aquifer map. From the geological sections and fence diagrams prepared, principal aquifers in the area have been delineated by grouping the fine, medium, coarse sand and sand with gravels as sand. Top soil and silty clay or silt at the surface have been grouped together. Weathered and fractured quartzite and the massive quartzite/ bedrock have been grouped together as weathered/ fractured quartzite (Figure 13).

Figure : 13



3.3.4. Fresh –Saline Ground Water Interface

Various hydrogeological and groundwater exploration studies in NCT of Delhi by CGWB has revealed that thickness of fresh water in major part of the State varies from 20 to 40 m. It is also observed that no fresh water is available in a few pockets in Narela and Alipur tehsils of North District, Saraswati Vihar tehsil of Northwest district, Punjabi Bagh and Patel Nagar tehsils of West District, Najafgarh tehsil of Southwest district and Kalkaji tehsil of Southeast District. (Figure14).

In one of the recent study undertaken under NAQUIM projects by WAPCOS, the granular zones (the aquifers) with varied resistivity were picked up from the combined interpretations of electrical resistivity (64 inches Normal) and gamma radioactivity logs of the boreholes drilled in the area. It shows that resistivity values greater than 10 ohm m to 50 ohm m represents predominately sand with fresh ground water. Resistivity less than 10 ohm m indicates predominately clay and kankar with saline water. Further lowering of resistivity values to 1 ohm m indicates further deterioration of water quality with depth. Resistivity of the order of 50 to 500 ohm m in hard rock (quartzite) area is represented by weathered/ fractured/ jointed quartzite which forms potential aquifer with potable water. In general, it is clear that fresh water sediments are followed by the saline water sediments in

all over NCT of Delhi. The thickness of fresh water sediments is thin in major parts of NCT, Delhi. The depth to fresh – saline water interface varies from 10 m bgl to 80 m bgl. Ground water quality below fresh saline water interface is saline all through up to the bedrock. At a few locations like Dhansa, Qutabgarh and Bankner, saline ground water is present at a very shallow depth range. Panel diagram showing fresh – saline ground water interface in subsurface aquifer system of NCT of Delhi, from NAQUIM report of CGWB, is presented in figure 15.

Figure : 14

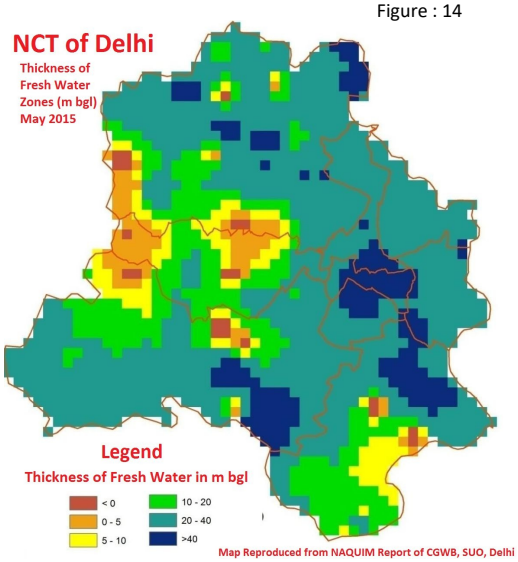
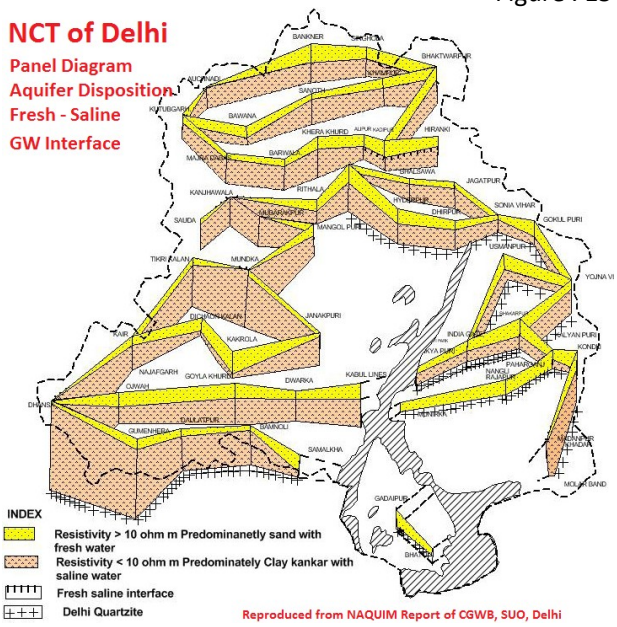


Figure : 15



Perusal of figure 15 shows that in the Southwest district of NCT Delhi, bedrock are encountered at many places i.e. in Dhansa, Samalkha, Kabul lines, Jhuljhuli where fresh/saline water interface also varies greatly in entire area. All along the Najafgarh Drain and two depressions i.e Gummanhera & Pindwalan Kalan, fresh water layer is somewhat deeper i.e. up to 35 m bgl but rest of the area is having thin layer of fresh water i.e. up to the depth 25 to 28 m bgl only. In the western parts of the district, the thickness of fresh water zone is limited. At a few locations like Dhansa, the saline ground water is present at a very shallow depth and as we move towards areas in the eastern part of the district, where hard rock is present, the thickness of fresh water aquifers is more and fresh/saline water interface occurs at deeper depth i.e. generally around 80 to 90 m bgl. At Rajolkri, the depth of fresh/ saline water interface has been observed to be 150 m bgl.

In West district, the depth of fresh/saline interface varies from 25 to 50 m bgl. The depth of fresh water zone varies from 10 to 45m. At places like Dichau Kalan and Kakrola, the thickness of fresh water aquifers is more and fresh/saline interface is at deeper depths while in the areas around Janakpuri, Mundka, the saline water is present at shallow depths.

In South district, depth of fresh/ saline water interface varies from 75 to 100 m. The thickness of fresh water zone varies from 30 to 85 m. At locations like Gadaipur, Bhatti and Munirka, fresh water aquifers are followed by hard rock (Delhi quartzite). In Southeast district, at places around Madanpur Khadar, the thickness of fresh water zones is limited. Here, fresh water aquifers are followed by saline water zone and bedrock is encountered at depth of around of 300 m.

In North West district, the depth of fresh/ saline water interface varies greatly. The thickness of fresh water aquifers is limited in this district. At locations like Auchandi, Qutabgarh & Bankner, the saline water is present at shallower depths. In areas along Yamuna Flood Plain fresh/ saline water interface is at deeper depth i.e around 40 to 70 m bgl, whereas in rest of the area it is 22 to 40 m. No bedrock has been observed up to the depth of 250 m.

In Northeast district, thickness of fresh water aquifers is more in areas around Yamuna Flood Plain. The depth of fresh/ saline water interface in Yamuna Flood Plain ranges between 32 and 50 mbgl whereas in rest of the area, it ranges from 25 to 38 m bgl.

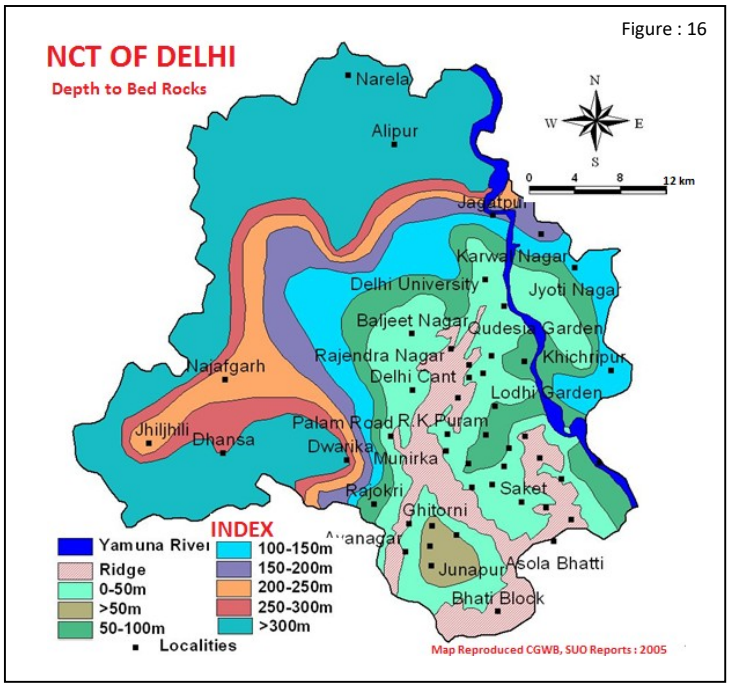
In New Delhi and Central Districts, fresh water sediments are followed by saline water and then by quartzites (Delhi Ridge). In East & Shahdara districts, thickness of fresh water aquifers is more at locations like Kalyanpuri, Kondli and Shakarpur up to 60 mbgl.

3.3.5. Basement Topography

The pre- Cambrian basement rocks are exposed in form of series of isolated hillocks with different dimension, usually termed as Ridge, trending almost in NNE- SSW direction in NCT of Delhi. Main exposures are Northern Ridge near Delhi University (0.87 Sq. Km), Central Ridge near Dhaula Kuan (8.69 Sq. Km), South Central Ridge near Vasant Kunj (6.26 Sq. Km) and Southern Ridge near Asola (62 Sq. Km). The strike of these rocks varies from north-east and south-west to north north-east and south south-west with steep dips towards east and south-east except for some local variation due to folding.

The Central Ground Water Board carried out a regular programme to drill exploratory wells in NCT Delhi and its surrounding States. So far, in NCT of Delhi alone, nearly 350 wells have been drilled in various parts of Delhi, which covers diverse terrain i.e. Yamuna flood plain , older alluvium area , Chattarpur Enclosed Basin and Delhi Quartzite terrain, for their aquifer evaluation and quality determination of ground water. Moreover, as a short term basis electrical resistivity survey was also carried out along Najafgarh Drain and , along Rajpath (India gate) as well as in different parts of south district. All these has helped to configure extension of basement rock topography, below variable thickness of alluvium, from the land surfaces of exposed ridge in all the stretches in& around NCT of Delhi. Earlier, during 2000, bed rock configuration map prepared on the basis of subsurface geological data generated from exploratory drilling and supplementary geophysical data input, indicated that the contour of the bed rock up to 200 m almost follows the Ridge alignment indicating the slope of the bed rock to be uniform. As such, taking into consideration of geological and tectonic processes undergone by basement rocks during the Pre-Cambrian and subsequent periods, the basement topography of NCT, Delhi is presumed to be highly uneven with the presence of sub-

Figure : 16



surface ridges and valleys. A simplified basement topography map, an abridged information derived by all available explorations & survey reports, mainly by using exploratory data of NCT Delhi, reproduced from old report of CGWB is shown in figure 16. Taking into account of thickness of alluvium overburden, the area of NCT Delhi has been classified into three zones Viz, A, B, C, which is shown in the table 10.

Table 10 Thickness of Alluvium overburden over Bed rock

Zone	Depth of Bed rockor overburden in mbgl	Area of NCT Delhi
Zone A	< 30	Lal Quila, Delhi Gate, Firoj Shah Kotla, Ramlila Ground, Azmeri Gate, Sdar Bazar, Dhir pur, Timarpur, Majanu Ka Tila, Gandhi Nagar (Rail Bridge) Nehrupark, Sbji Mandi, Chandani Chauk- Sadar Bazar, GreaterKailash-Kalakaji, North of Connaught Place & Moti Bagh.
Zone B	30 to 100	Usmanpur, Loni border, Metro rail Depot, Mayur Vihar Phase-II (Block BD), Geeta colony, Khajuri Khas, Shakarpur Khas, Gadaipur, Jaunapur, Ayanagar,Hauj Khas, Vayusena Bad.Jamia Univ. (Okhala), Arvindo Marg, Gulabi Bagh, Trilokpuri, Mayur Vihar-Ph-II, Ghazipur, Kondli (Loni Bdr).
Zone C	> 100	MdanPur Khadar, JagatPur, Jaitpur, WEST of Najafgarh Nala, Kirbi Place , Palam Village, Shastri Nagar , CBD Shahadara, Anada Vihar, Dilsad Garden, Bawan, Nangloi ,Tikri Kala.

4. GROUND WATER BEHAVIOUR DURING 2018-19

The monitoring of ground water levels has been carried out four times in a year simultaneously throughout the NCT of Delhi during following periods.

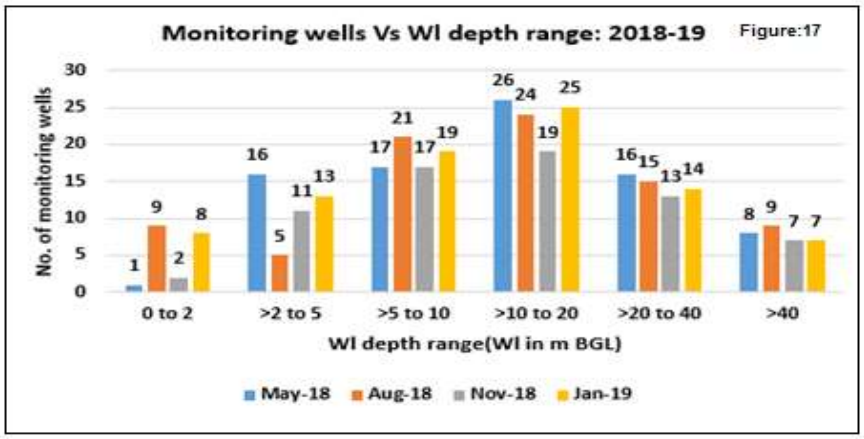
a) May - 20th to 30th (water level of pre-monsoon period)
b) August - 20th to 30th (peak monsoon water level)
c) November - 1st to 10th (water levels of post-monsoon period)
d) January - 1st to 10th (the recession stage of water level)

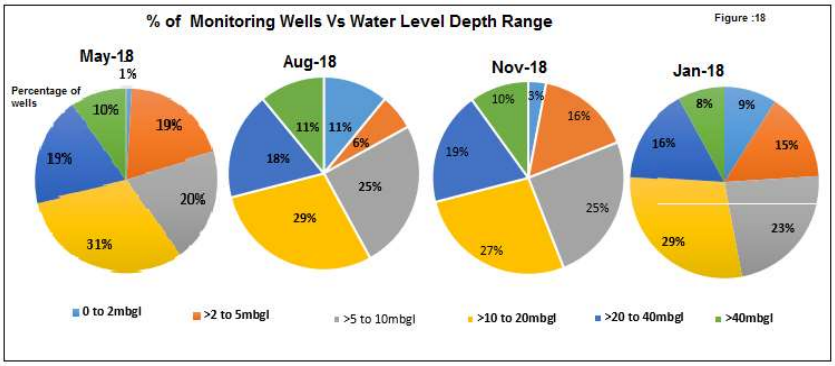
The data is analysed for each set of measurement, and report prepared which include following maps to understand the groundwater regime in NCT of Delhi.

a) Depth to water level – water level with reference to ground level.
b) Seasonal fluctuation - water level fluctuation in comparison to pre-monsoon.
c) Annual fluctuation - water level fluctuation in comparison to same month in the previous year.
d) Decadal fluctuation - water level fluctuation in the month of measurement with reference to the decadal average for the same month.
e) Ground Water Flow Net – water level with reference to mean sea level.

4.1 Depth to Water Level

The analysis of number of monitoring wells in the different categories of the water levels for all four monitoring periods of year 2018-19 reveals that water level depth up to 5 meters varies considerably over two monitoring periods (May &other months) which shows that dynamic changes in ground water levels are conspicuously deciphered in shallow water zones. For depth range of 5 to 0 m and 0 to 20 m and more at few locations, changes in numbers of monitoring wells in August, November & January compared to May period not prominent. This may be interpreted as stressed water level conditions suppressing dynamic fluctuation in water levels. Whereas numbers of monitoring station showing water level below 40 m remain almost same in all four-monitoring period, indicate stressed water conditions in deep aquifers of NCT Delhi.





4.1.1. May 2018

The Depth to water level recorded in NCT Delhi during **May-2018** ranges from 0.71 at Deorala to 65 m. bgl at Jheel Khoh. A map showing May 2018 ground water levels in NCT of Delhi is given in figure 19 and areas under various depth zones is presented in figure 20. Around 8 % of NCT Delhi areas, in parts of North, North West, South West & Central districts have shallow water level up to 5 m bgl. Deep water levels of 20 to 60 m observed in around 34% of NCT Delhi, in South, South East, New Delhi & South West districts. In rest of NCT Delhi, 58 % areas have water level in range of 5 to 20 mbgl.

Figure : 19

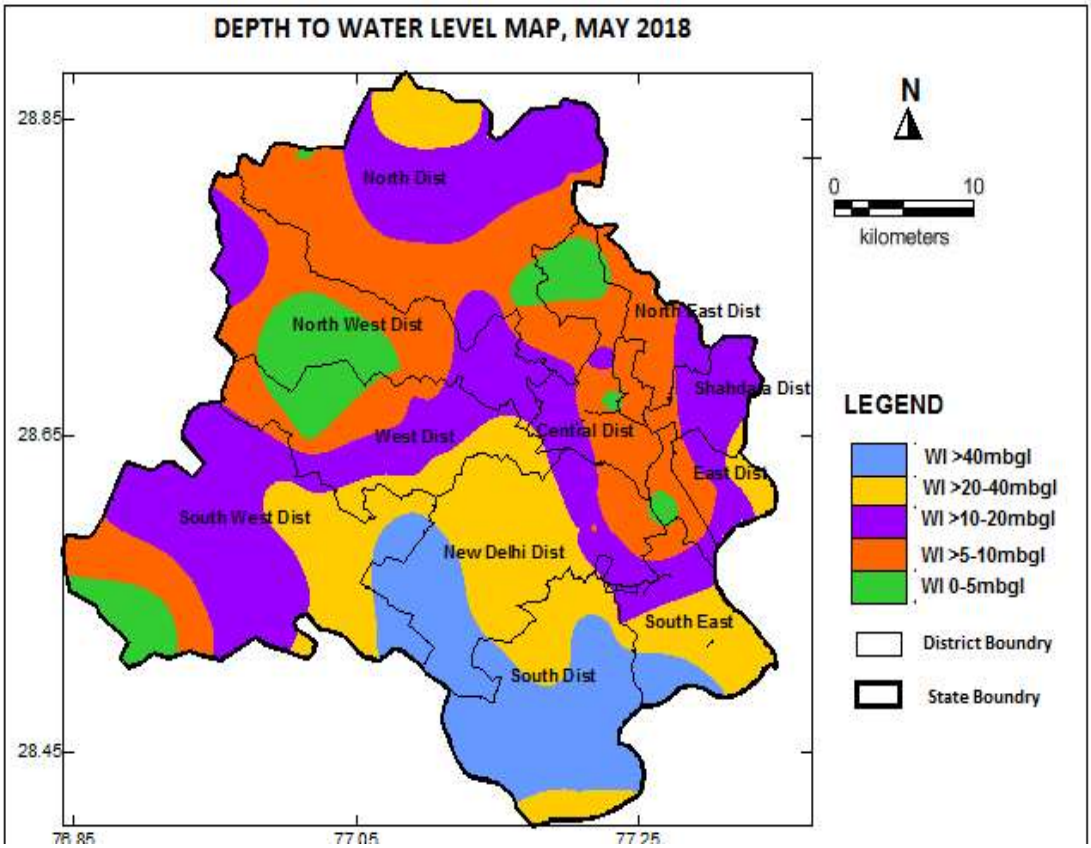
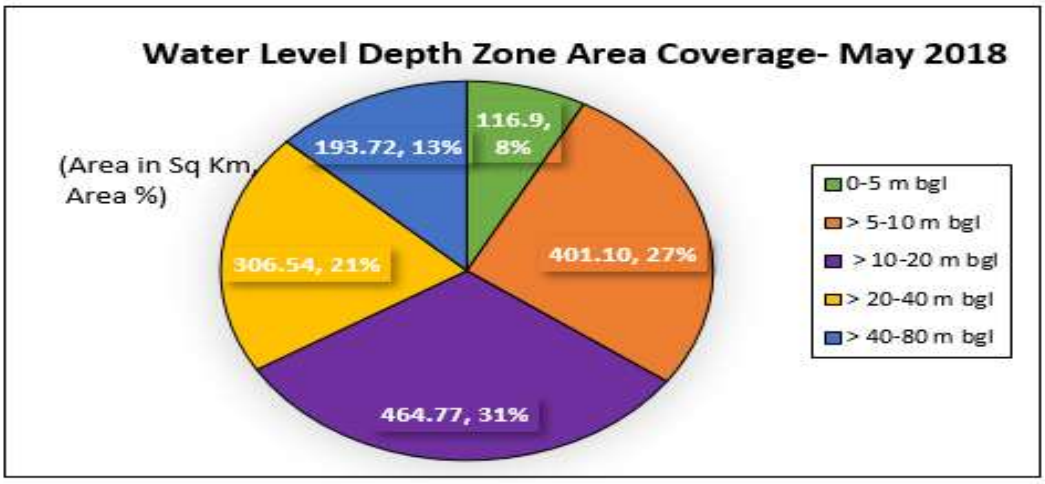


Figure : 20



4.1.2. August 2018

The Depth to water level recorded in NCT Delhi during **August-2018** ranges from 0.15 at Kanjhawala to 61.70 m.bgl at Gadaipur. A map showing August 2018 ground water levels in NCT of Delhi is given in figure 21 and areas under various depth zones presented in figure 22. Around 17% of NCT Delhi areas, in parts of North, North West, Northeast, Central and Southwest districts have shallow water level up to 5 m bgl. Deep water levels of 20 to 60 m observed in around 33% of NCT Delhi, in South, South East, New Delhi & South West districts. In rest of NCT Delhi, 50 % areas have water level in range of 5 to 20 mbgl.

Figure : 21

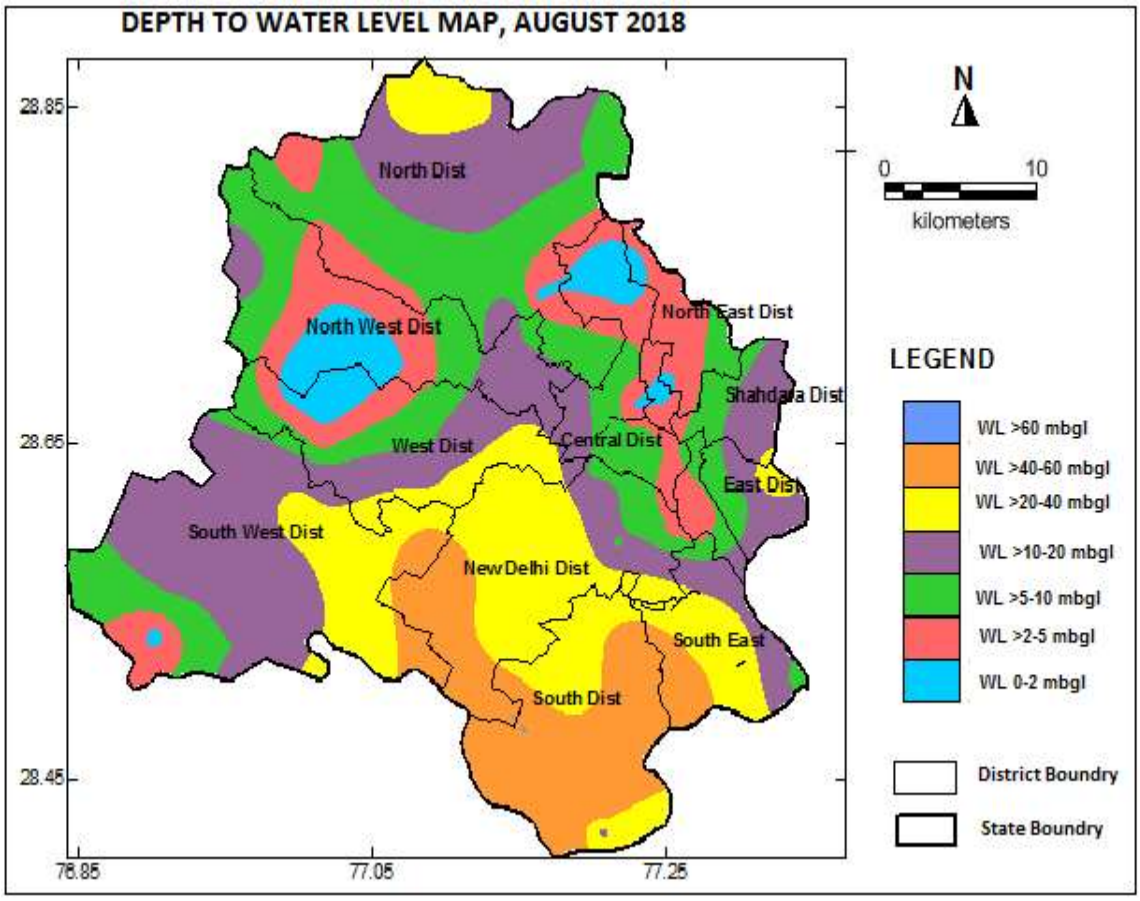
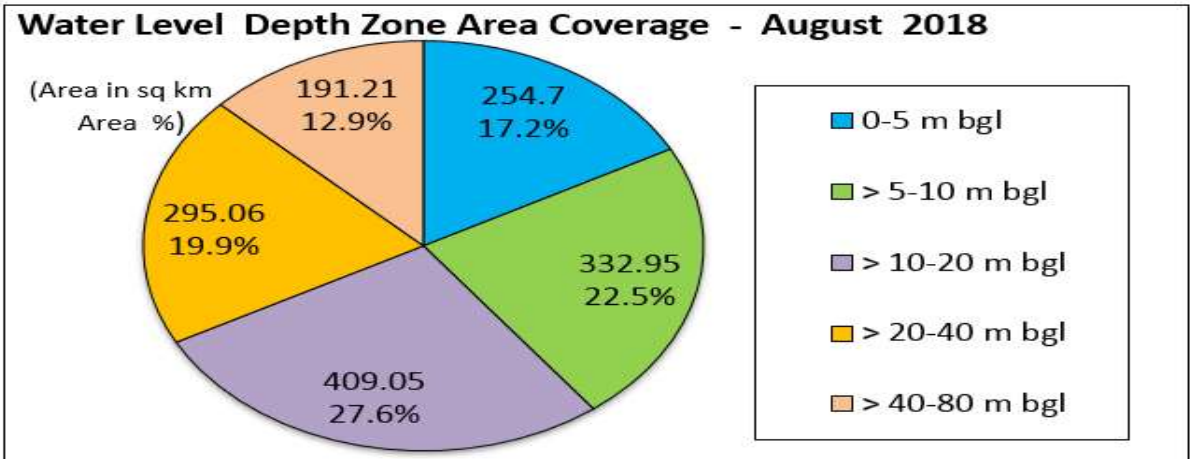


Figure : 22



4.1.3. November 2018

The Depth to water level recorded in NCT Delhi during **November-2018** ranges from 1.02 at Deorala to 65 mbgl at Jheel Khoh. A map showing November 2018 ground water levels in NCT of Delhi is given in figure 23 and areas under various depth zones presented in figure 24. Around 15% of NCT Delhi areas, in parts of North, North West, Northeast, East, Central, West and Southwest districts have shallow water level up to 5 m bgl. Deep water levels of 20 to 60 m observed in around 33% of NCT Delhi, in South, South East, New Delhi & South West districts. In rest of NCT Delhi, 52 % areas have water level in range of 5 to 20 mbgl.

Figure : 23

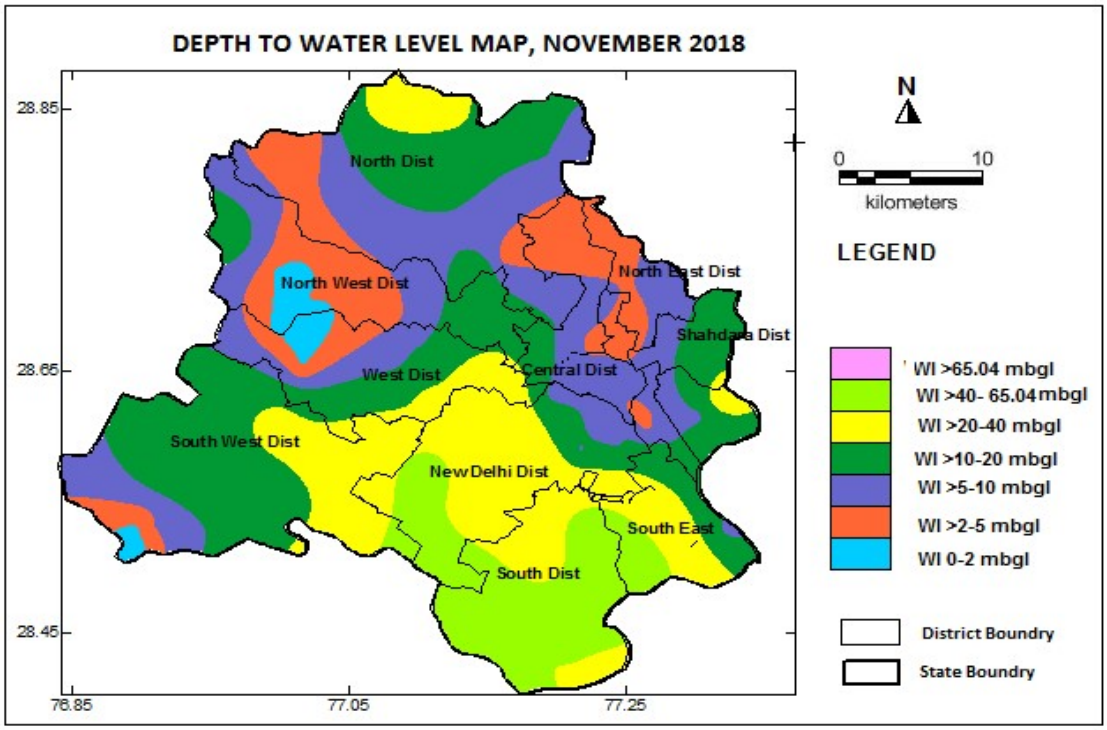
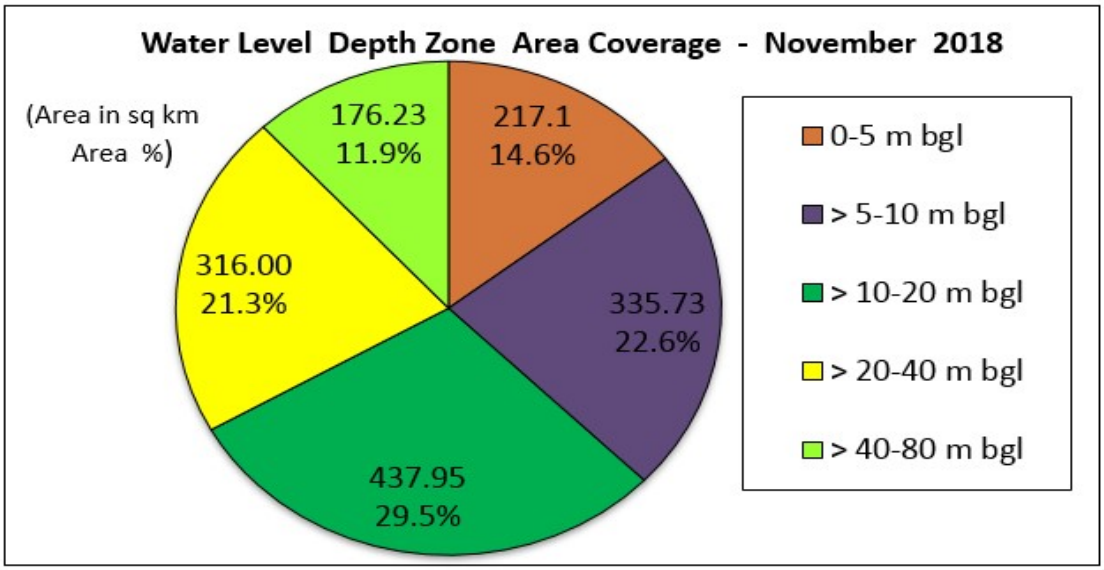


Figure:24



4.1.4. January 2019

The Depth to water level recorded in NCT Delhi during **January-2019** ranges from 0.80 at Deorala to 65 mbgl at Jheel Khoh . A map showing January 2018 ground water levels in NCT of Delhi is given in figure 25 and areas under various depth zones presented in figure 26. Around 16% of NCT Delhi areas, in parts of North, North West and some small pockets of Central & Southwest districts have shallow water level up to 5 m bgl. Deep water levels of 20 to 60 m observed in around 30% of NCT Delhi, in South, South East, New Delhi, West & South West districts. In rest of NCT Delhi, 54 % areas have water level in range of 5 to 20 m bgl.

Figure : 25

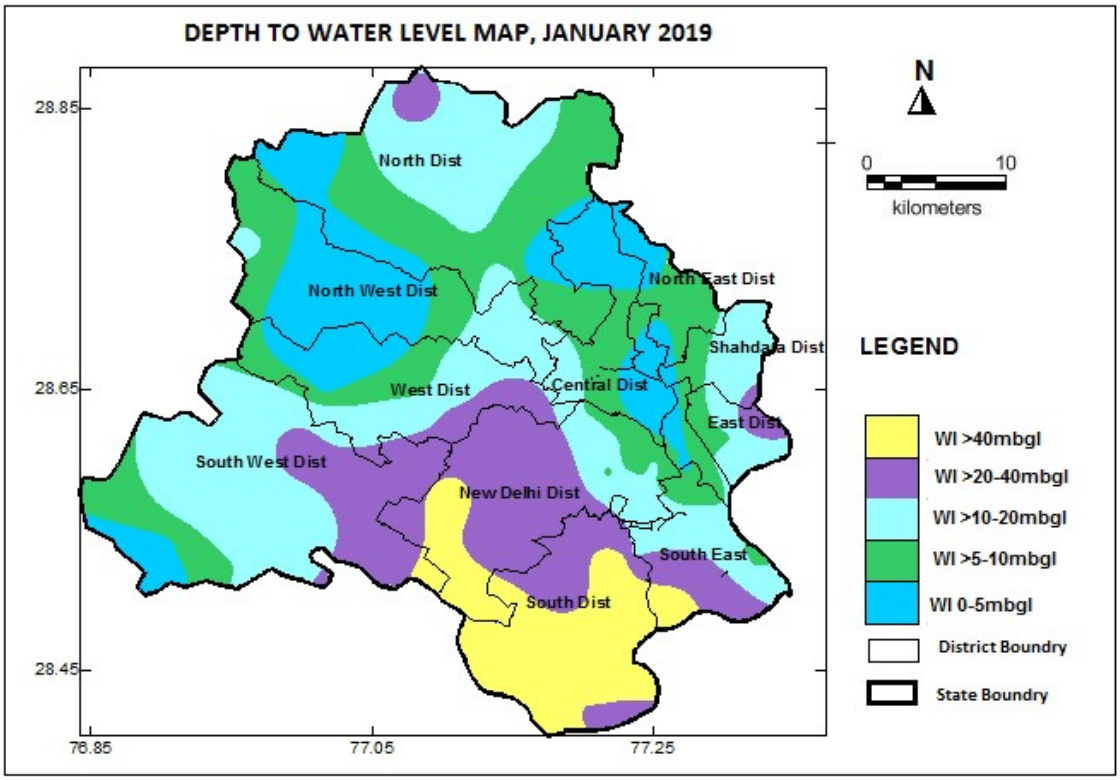
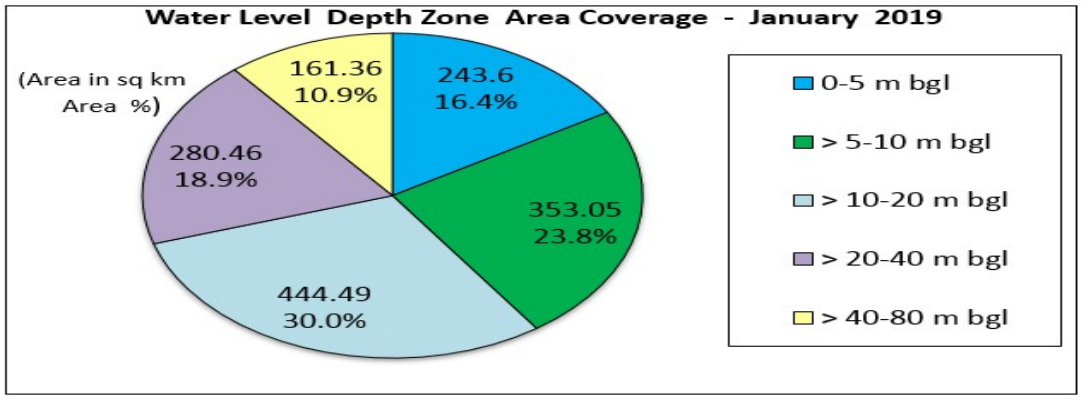


Figure : 26



4.2 Seasonal Water Level Fluctuation :2018-19

The seasonal water level fluctuation, i.e. the changes in depth of water levels of August 18, November 18 and January 19 with respect to May 18 water level reveals the effect of subsequent utilisation of groundwater for various needs like agriculture, irrigation, domestic etc., on overall groundwater regime of the area. Number of wells showing change in groundwater levels in the region over different periods is presented in figure 27 (a,b & c) and table11.

Figure : 27 a

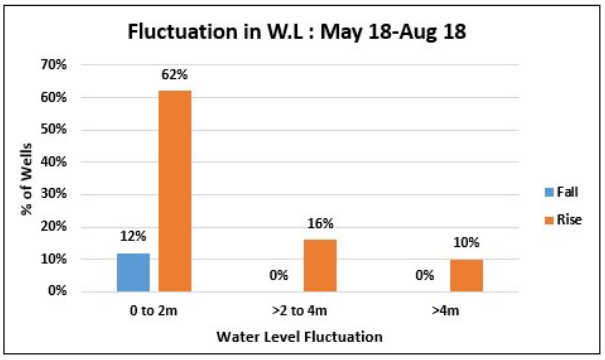


Figure : 27 b

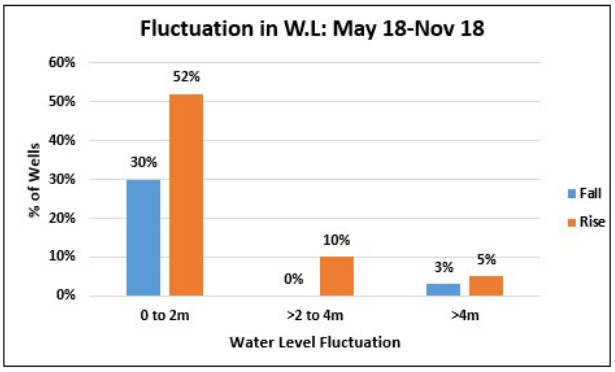


Figure : 27 c

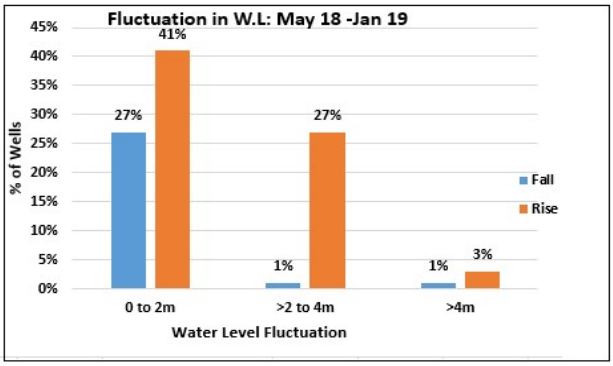


Table11: Monitoring wells showing seasonal fluctuation in water level

Water Level Fluctuation Range	May 18 -Aug 18		May 18-Nov 18		May 18 - Jan 19	
	Rise	Fall	Rise	Fall	Rise	Fall
0 to 2 m	47	9	40	23	31	20
> to 4 m	12	0	8	0	20	1
>4 m	8	0	4	2	2	1
Total	67	9	52	25	53	22
	76		77		75	

4.2.1. May 2018 to August 2018

A perusal of figure 27a and table 11 reveals that comparing water levels of May 18 to August 18, total 67 (88%) monitoring wells of the NCT of Delhi show a rise whereas rest shows decline. The extent of rise and decline in water levels is shown in map presented in figure 28 and also as pie chart in figure 29.

Figure : 28

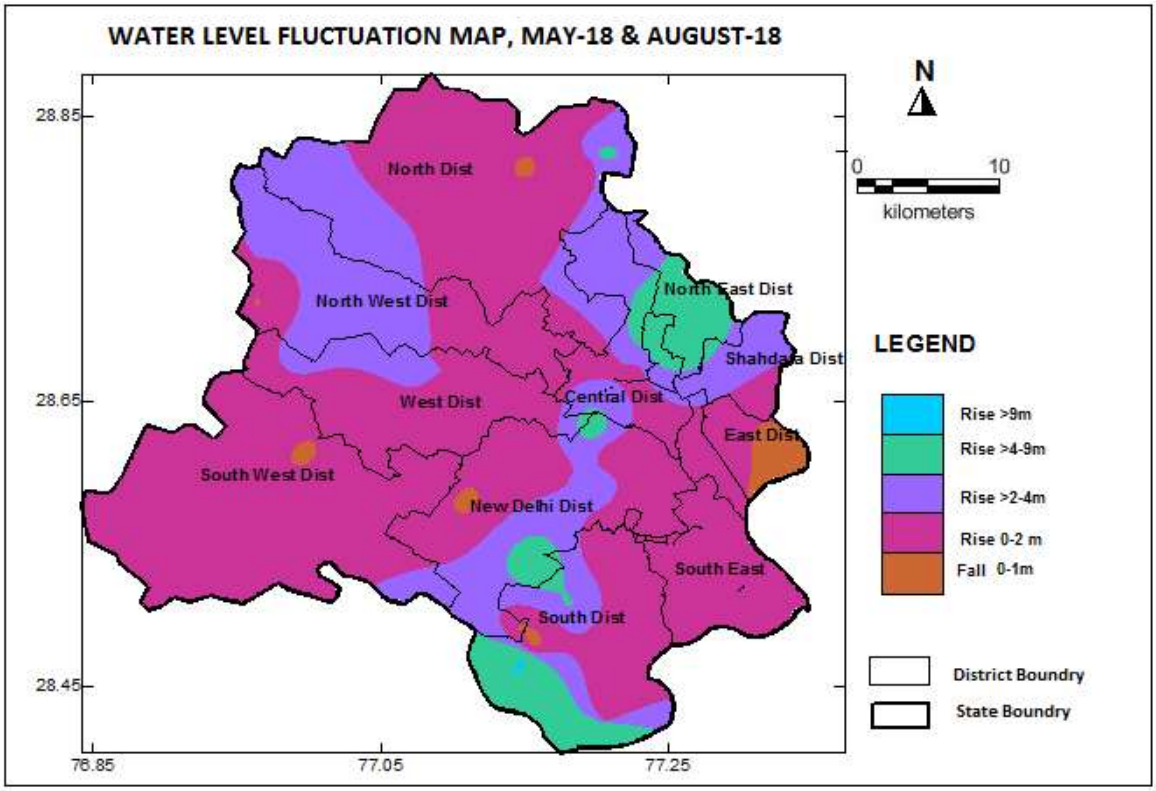
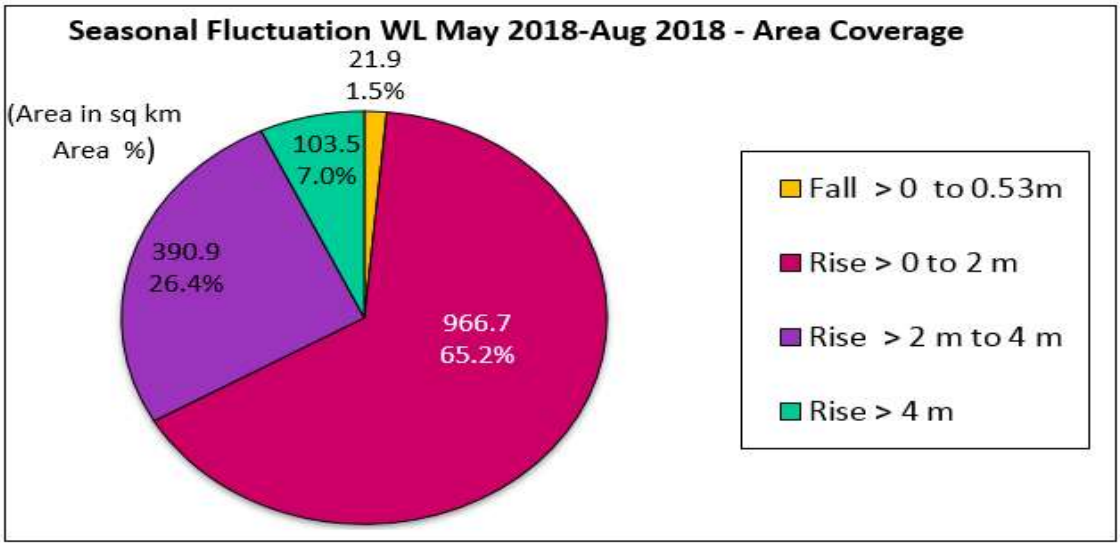


Figure : 29



4.2.2. May 2018 to November 2018 (Pre & Post Monsoon)

A perusal of figure 27(b) and table 11 reveals that comparing water levels of May 18 to November 18, total 52(67%) monitoring wells of the NCT of Delhi show a rise whereas rest shows decline. The extent of rise and decline in water levels is shown in map presented in figure 30 and also in pie chart in figure 31.

Figure : 30

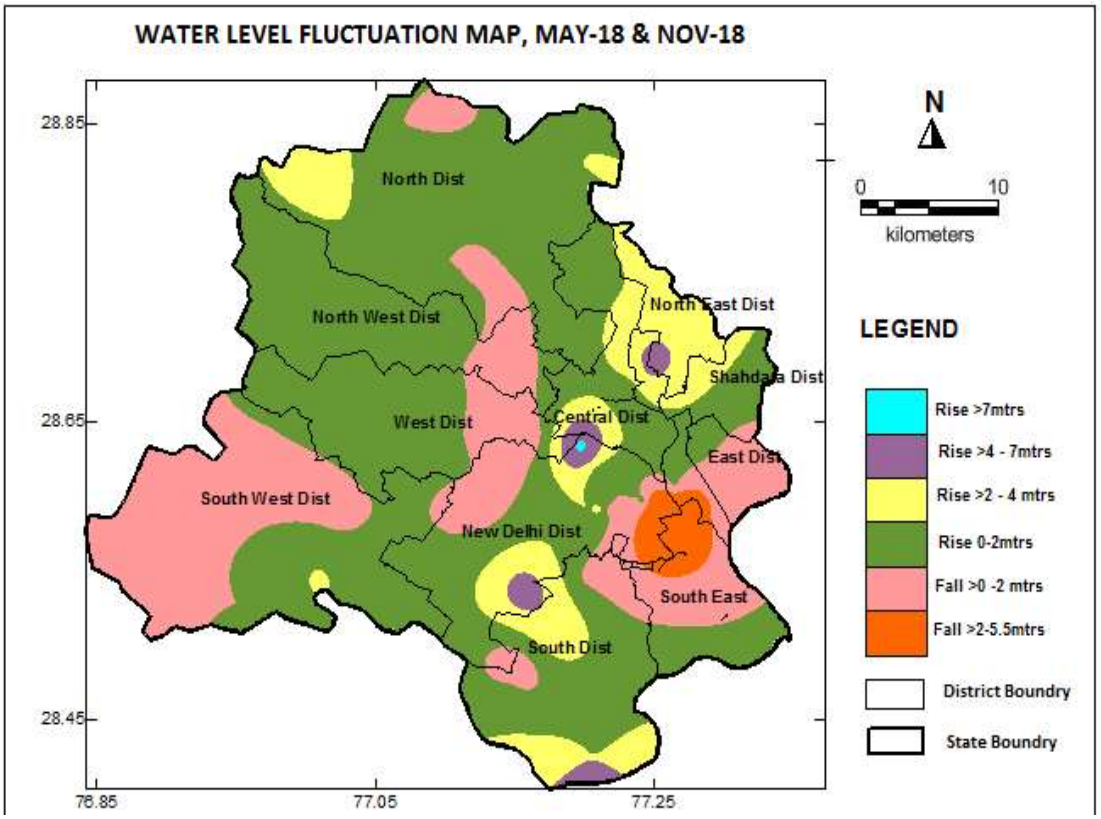
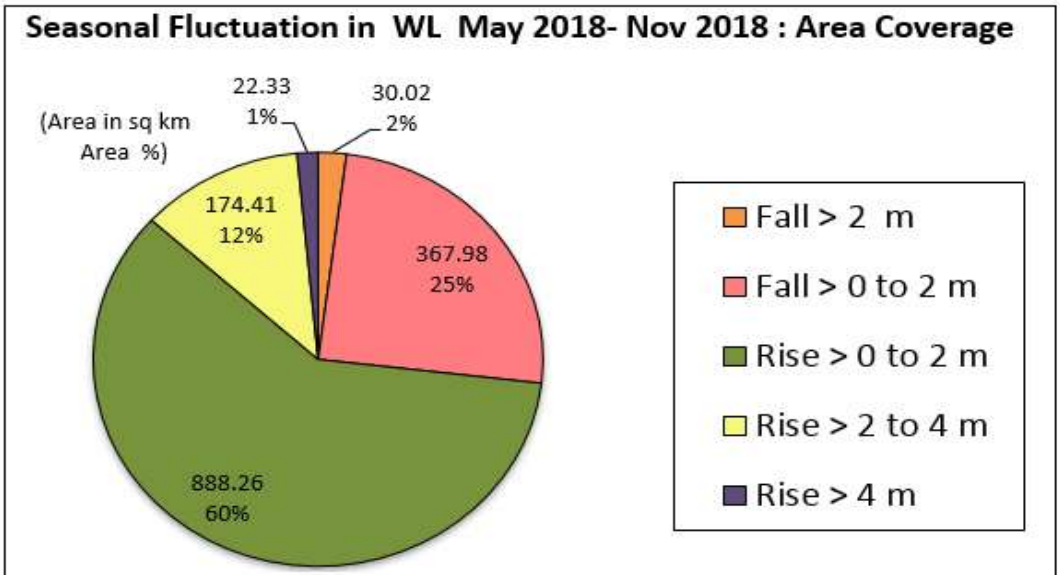


Figure : 31



4.2.3. May 2018 to January 2019

A perusal of figure 27(c) and table 11 reveals that comparing water levels of May 18 to January 19, total 53(71%) monitoring wells of the NCT of Delhi show a rise whereas rest shows decline. The extent of rise and decline in water levels is shown in map presented in figure32 and also in pie chart in figure33.

Figure : 32

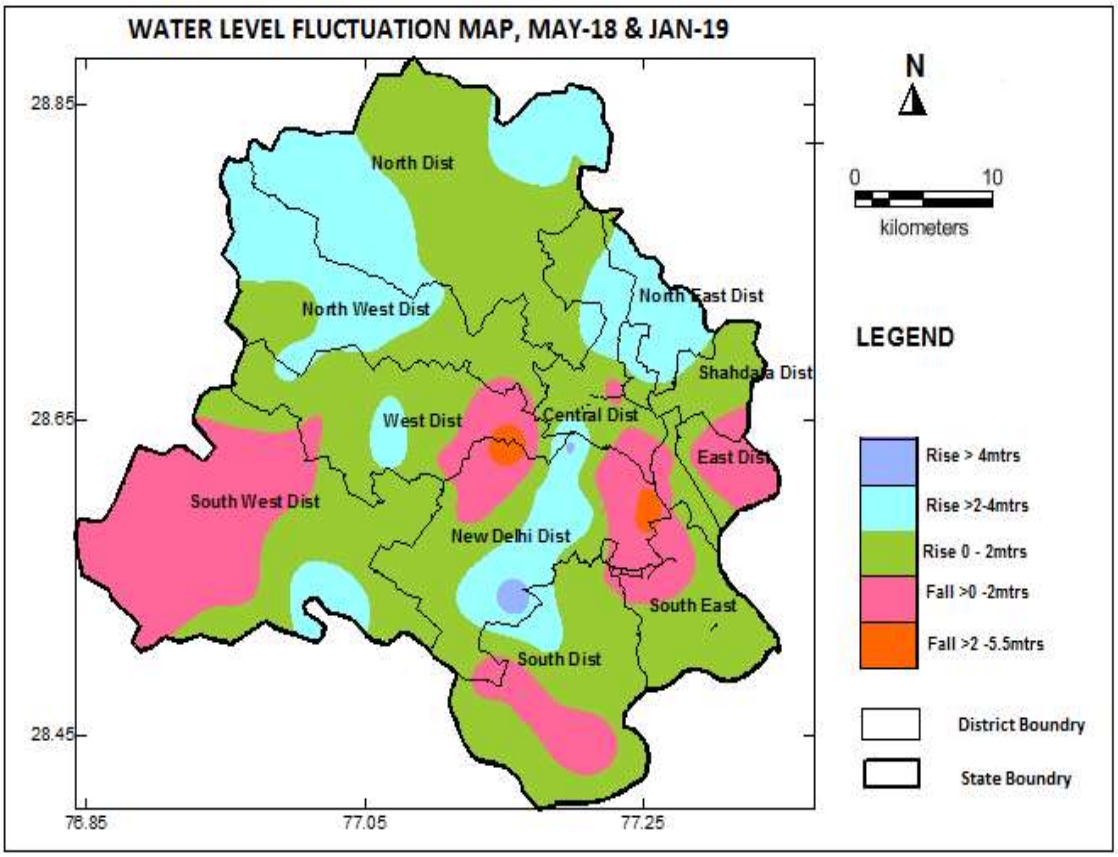
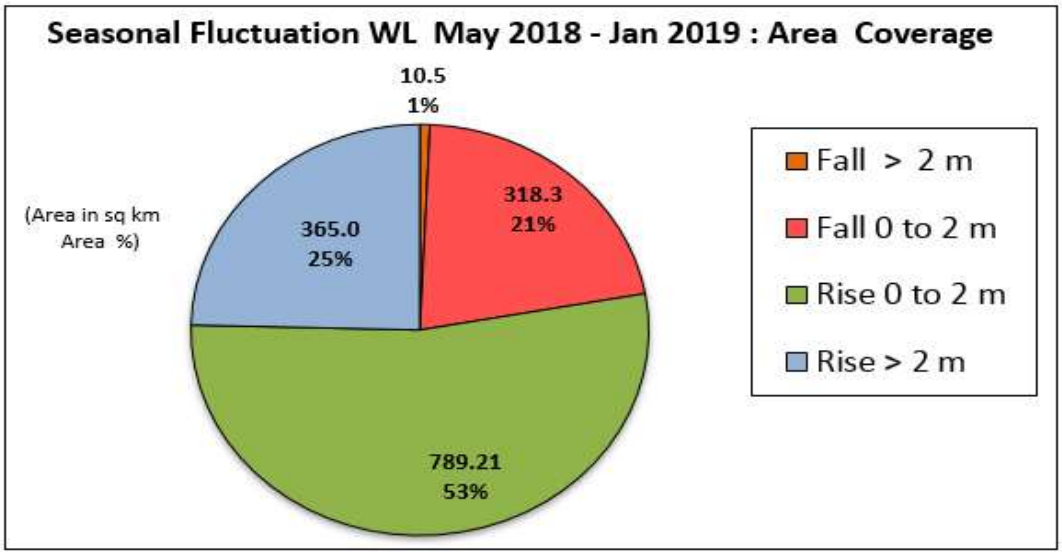


Figure : 33



4.3 Annual Water Level Fluctuation: 2018-19

Annual Fluctuation in the water levels of the ground water monitoring wells during 2018-19 for different monitoring periods were compared with same period of 2017-18 and wells showing change in groundwater levels over different periods is presented in figure 34 (a, b, c & d) and table 12.

Figure:34a

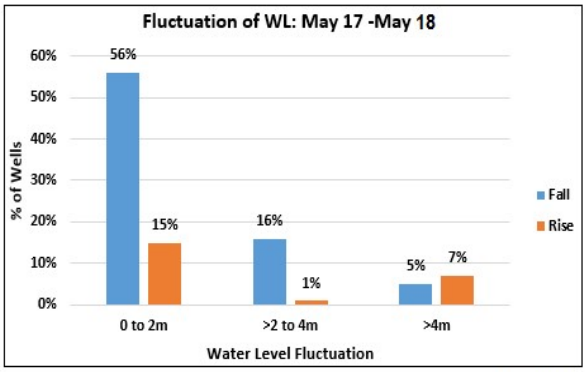


Figure: 34b

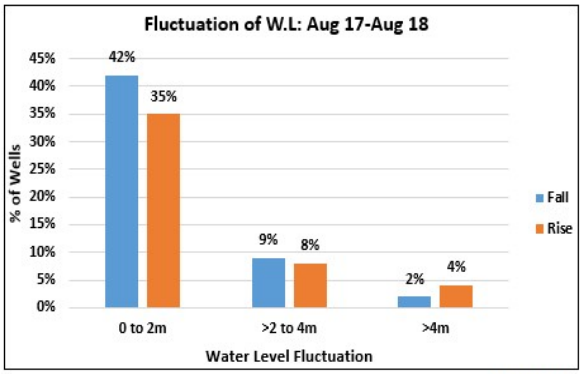


Figure: 34c

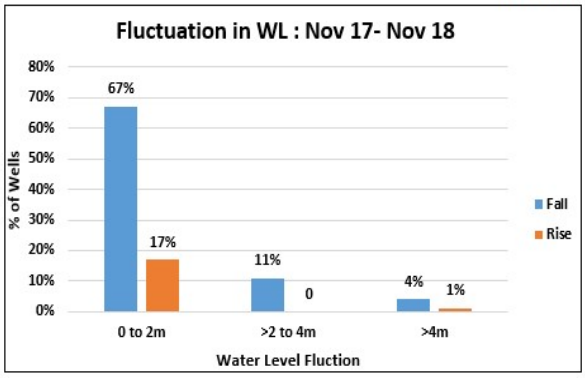


Figure: 34d

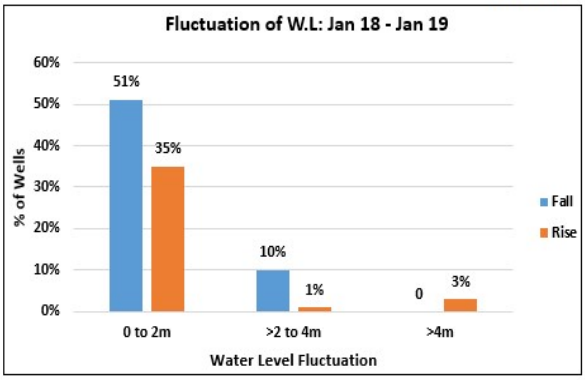


Table 12: Monitoring wells showing annual fluctuation in water level

WATER LEVEL FLUCTUATION	MAY 17-MAY 18		AUG 17- AUG 18		NOV 17-NOV 18		JAN 18-JAN 19	
	Rise	Fall	Rise	Fall	Rise	Fall	Rise	Fall
0 to 2 m	11	42	28	33	13	51	25	37
>2 to 4 m	1	12	6	7	0	8	1	7
>4 m	5	4	3	2	1	3	2	0
Total	17	58	37	42	14	62	28	44
	75		79		76		72	

4.3.1. Annual Fluctuation: May 2017 & May2018

The fluctuation of water level between **May-2017** and **May-2018** of NCT Delhi shows that except parts of North, North West, West and some pockets of South and South–West districts, represented by 8 % of wells show rise above 2m. 15% of wells show rise between 0-2m Rest of major parts of NCT Delhi areas represented by 56% of monitoring wells, show fall in range of 0 to 2 m while rest of 21% monitoring stations shows fall above 2m with respect to the previous year water level. Nearly 13% of area shows rise upto 2m while 54% of area shows fall in range of 0-2m, rest 22% of area shows fall more than 2m. 11% of areas show rise more than 2m (Figure 35)(Figure 36).

Figure :35

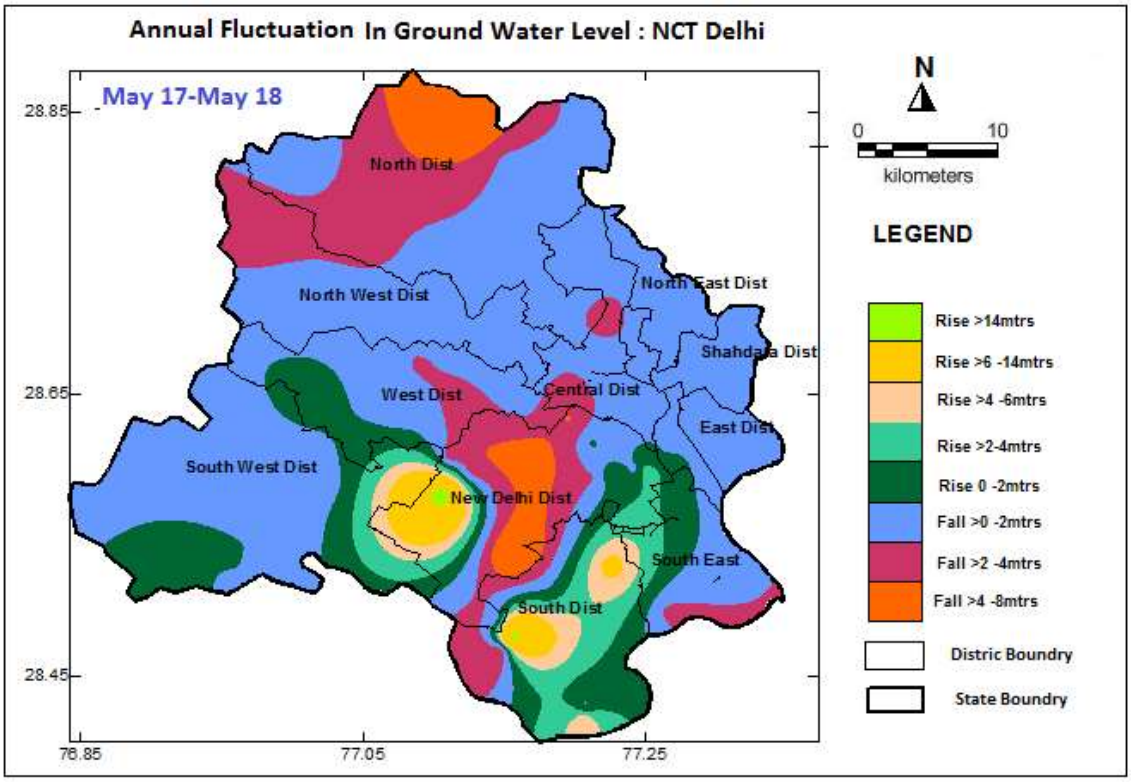
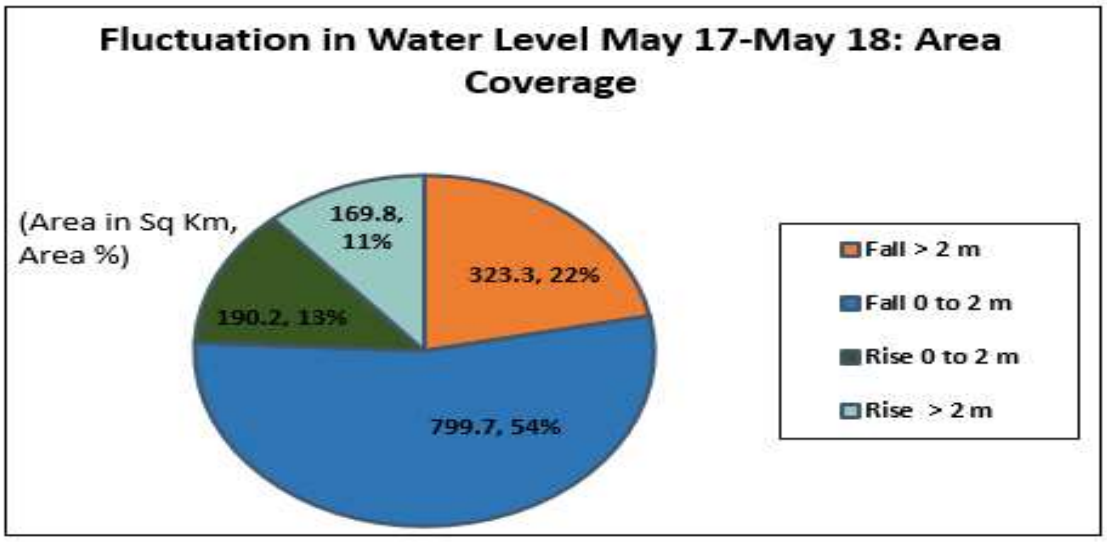


Figure :36



4.3.2. Annual Fluctuation: August 2017 & August 2018

The variation of water level from August-2017 and August-2018 reveals that there is a rise in the range of 0 to 2m in nearly 35% of the wells, while 51% wells shows falls in range of 0 to 4 m. Fall of more than 4m is observed in small pocket of New Delhi & North (2% wells). Nearly 38% of area shows rise upto 2m while 44% of area shows fall in range of 0-2m, rest 11% of area shows fall more than 2m. 7% of areas show rise more than 2m (Figure 37 & chart Figure 38).

Figure : 37

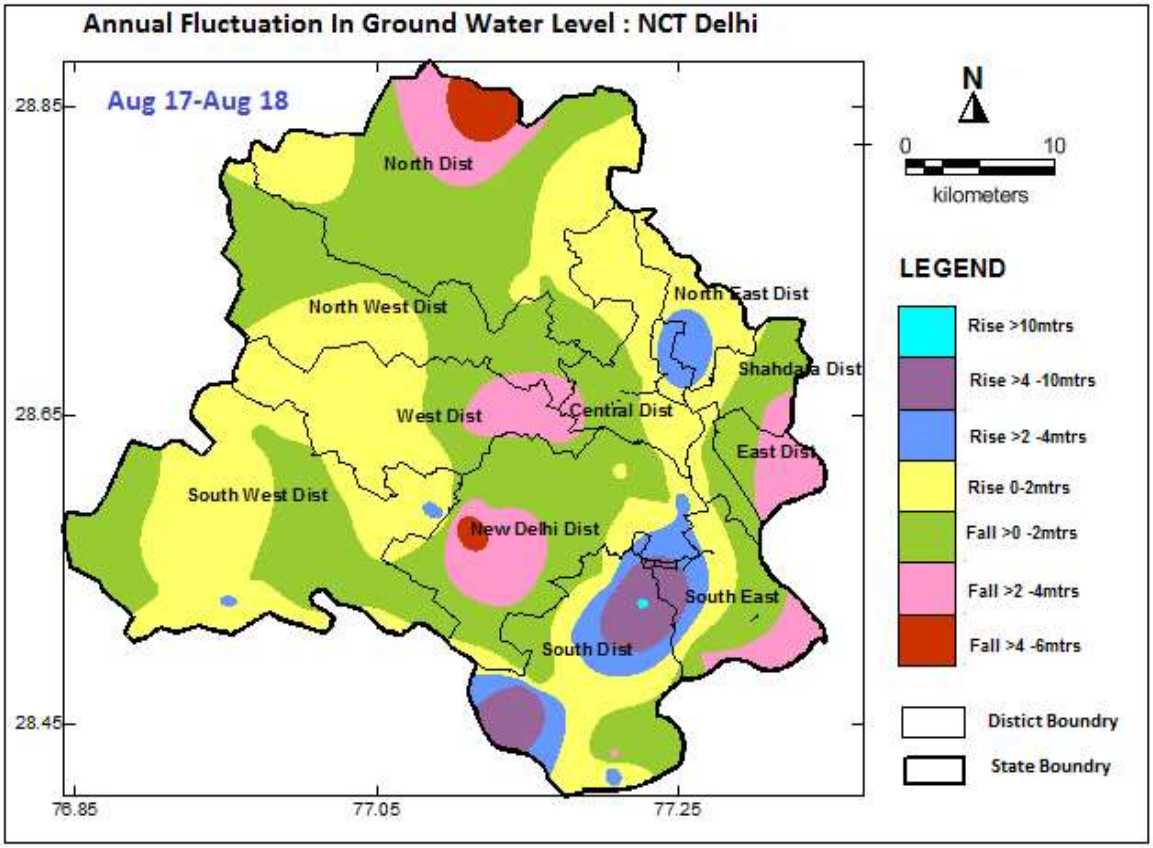
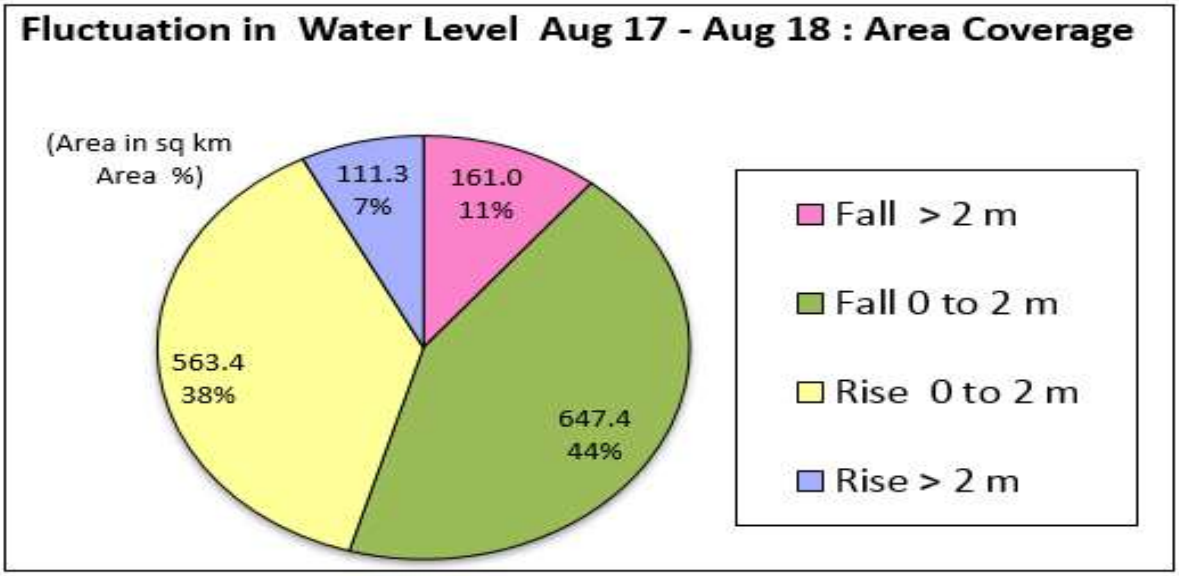


Figure : 38



4.3.3. Annual Fluctuation: November 2017 & November 2018

Comparing water level data of November 2017 to November 2018, it is revealed that 17% wells show rise in range of 0 to 2 m whereas, 1% wells shows rise more than 2m. Rest 67% wells shows fall, mostly in range of 0 to 2 m except small pockets of almost all districts shows fall more than 2m. (Figure 39) Nearly 10% of area shows rise upto 2m while 73% of area shows fall in range of 0-2m, rest 17% of area shows fall more than 2m (Figure40).

Figure : 39

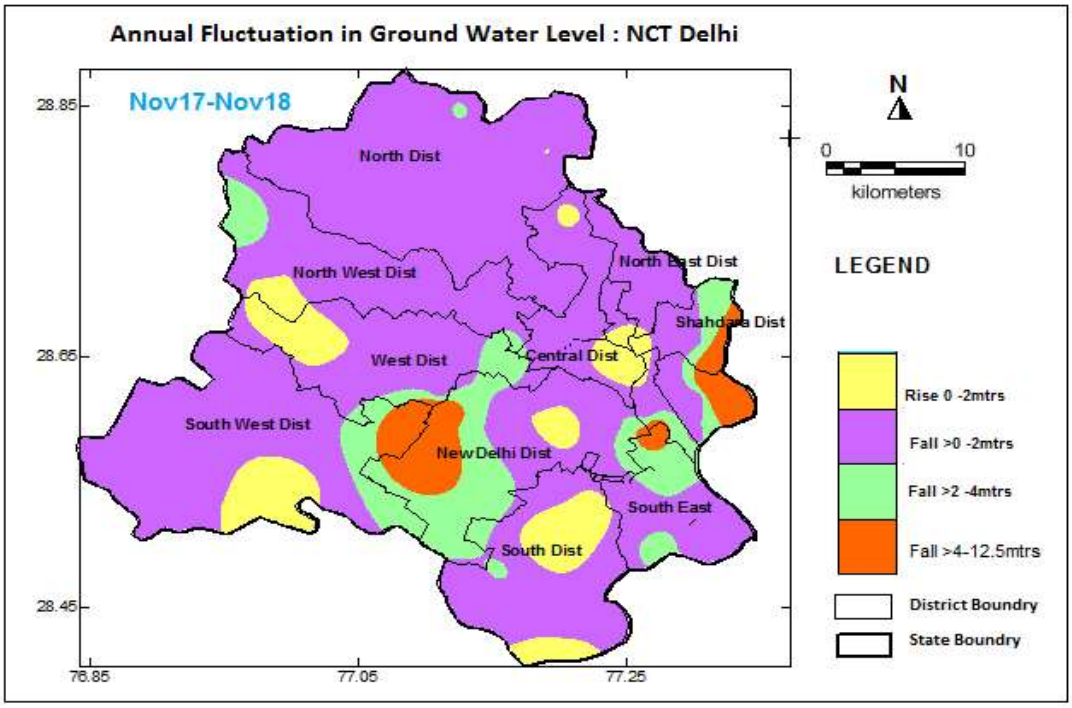
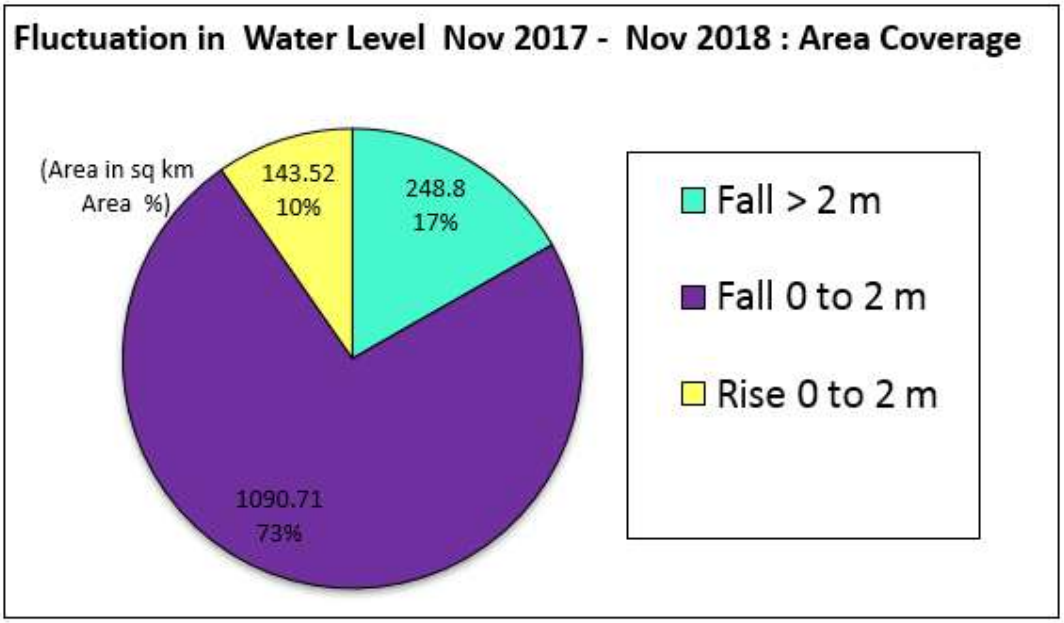


Figure : 40



4.3.4. Annual Fluctuation: January 2018 & January 2019

Comparing water level data of January 2018 to January 2019, it is revealed that 35 % wells shows rise, mostly in range of 0 to 2 m whereas small pockets in Southwest, West, North West, North, Central and Shahdra district has shown rise in Water Level; whereas rest 51 % wells shows fall in range of 0 to 2 m. Nearly 44% of areas show rise upto 2m, while rest 46% area shows fall in range of 0-2m, rest 3% area has fall more than 2m while 7% area has rise more than 2m(Figure 41) (Figure 42).

Figure : 41

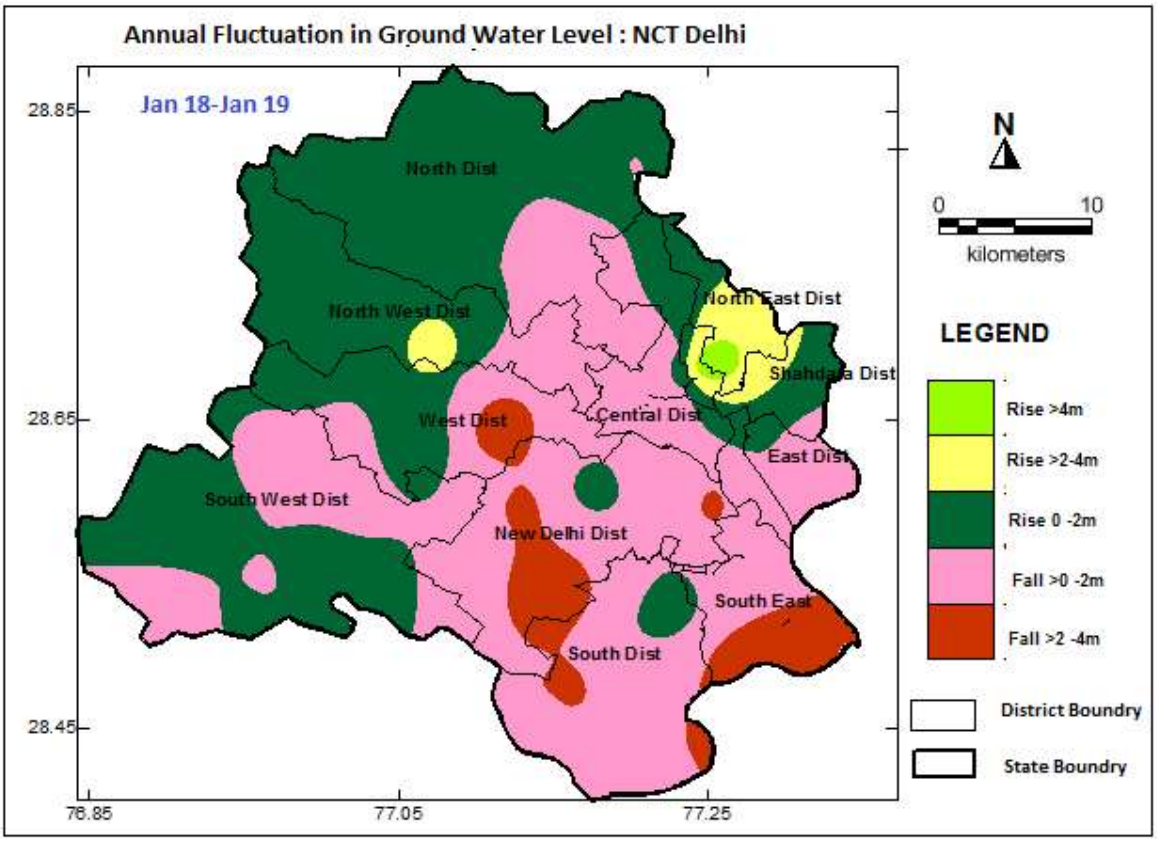
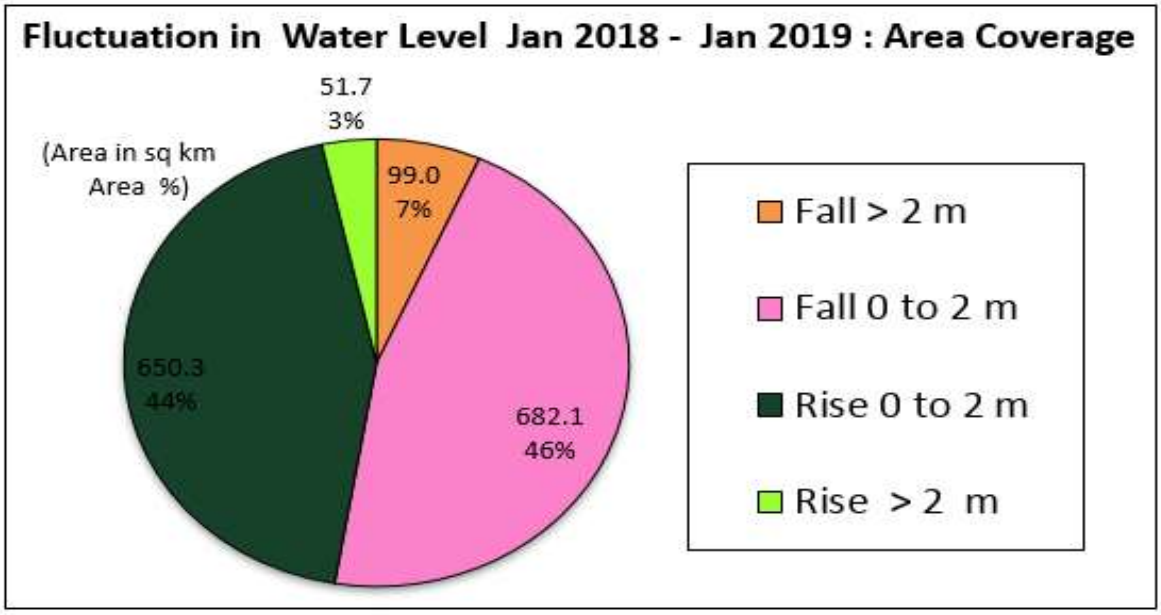


Figure : 42



4.4 Long Term Ground Water Scenario

Long-term behavior of water levels was studied by analysing water level change of decadal mean water levels data of 2008-17 for May, August & November and 2009-18 decade for January month with corresponding water level data of 2017-18. Statistical analysis of numbers of monitoring wells and range of water levels showing decadal change is presented as charts in figure 43 (a, b, c & d) and also in table 13.

Figure: 43a

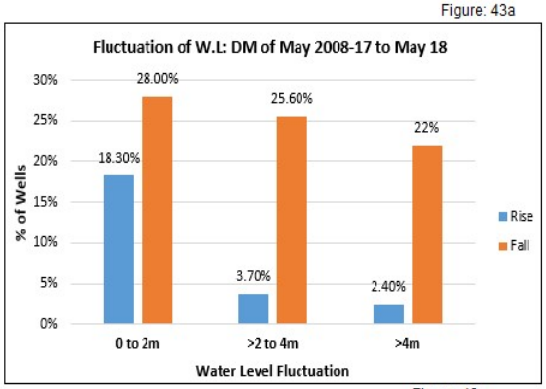


Figure: 43b

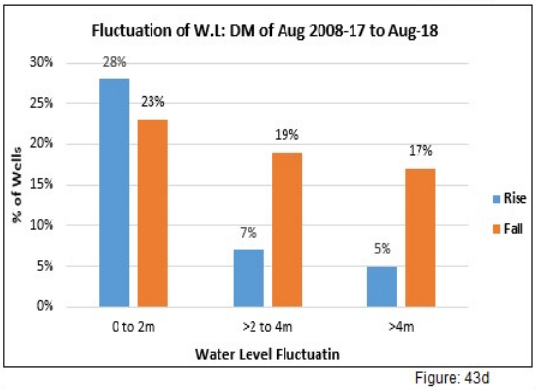


Figure: 43c

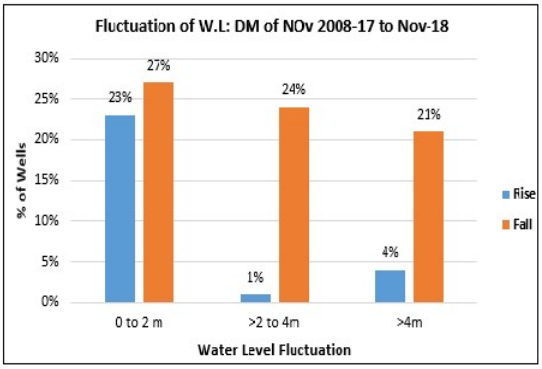


Figure: 43d

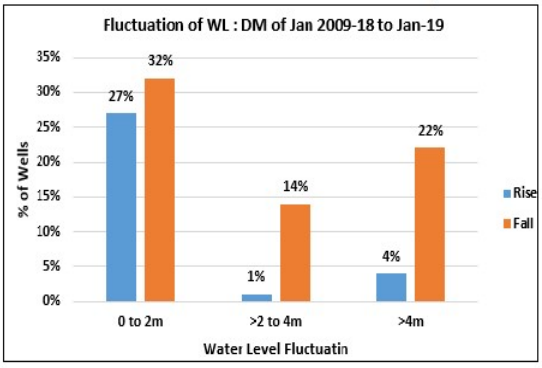


Table 13: Monitoring wells showing change in water level comparing Decadal mean

WATER LEVEL FLUCTUATION RANGE	DM of May 08-17 & May 18		DM of Aug 08-17 & Aug 18		DM of Nov 08-17 & Nov 18		DM of Jan 09-18 & Jan 19	
	Rise	Fall	Rise	Fall	Rise	Fall	Rise	Fall
0 to 2 m	15	23	23	19	19	23	23	27
>2 to 4 m	3	21	6	15	1	20	1	12
>4 m	2	18	4	14	3	18	3	19
Total	20	62	33	48	23	61	27	58
	82		81		84		85	

Maps showing change in water level scenario over May, August, November and January for year 2018-19 with decadal mean of May, August & November for 2008-17 and January 2009-18 respectively are presented in figure 44, 46, 48 and 50 and pie diagrams showing areas under different ranges of water level change are presented in figure 45, 47, 49 and 51 respectively for month corresponding May, August, November and January of 2018-19.

4.4.1. Decadal Fluctuation: (DM of May 2008-17 & May 2018)

Comparing water level data of May-2018 with 10 year mean water level of May (2008 to 2017), the change in water level ranges from -8.5 m to 12.97 m. Nearly 76 % of monitoring wells show increase in fall of water level of May 2018 when comparing decadal mean of May water level of 2008-17, whereas rest 24 % wells show increase in rise of water levels. This increase in rise mainly confined to east parts of Southwest & West districts, central part of New Delhi and South districts; entire northeast of NCR Delhi covering parts of Shahdra and East district and northern parts of North district. (figure 44). Nearly 27% areas shows increase in fall up to 2 m, 52% more than 2m. Similarly increase in rise up to 2m is recorded in 16% areas and 3% areas shows rise in range to 2 to 4 m. Chart showing extent of areas having change in rise and fall of water level, computed from map grid, is presented in figure45.

Figure: 44

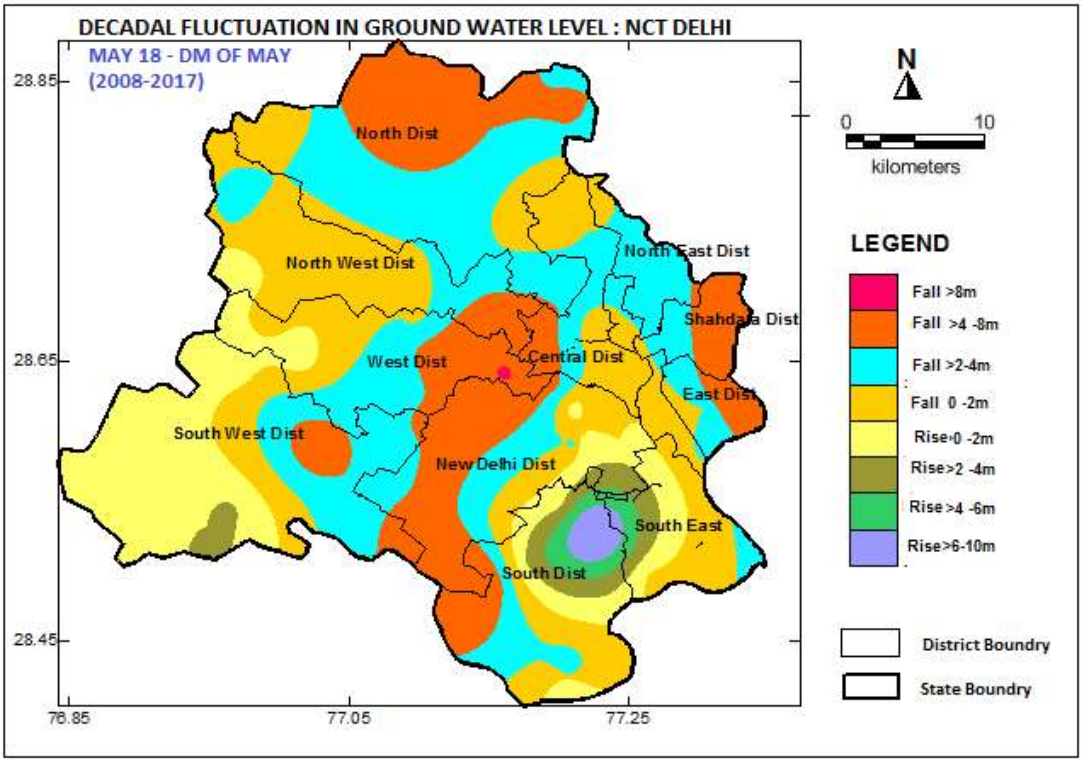
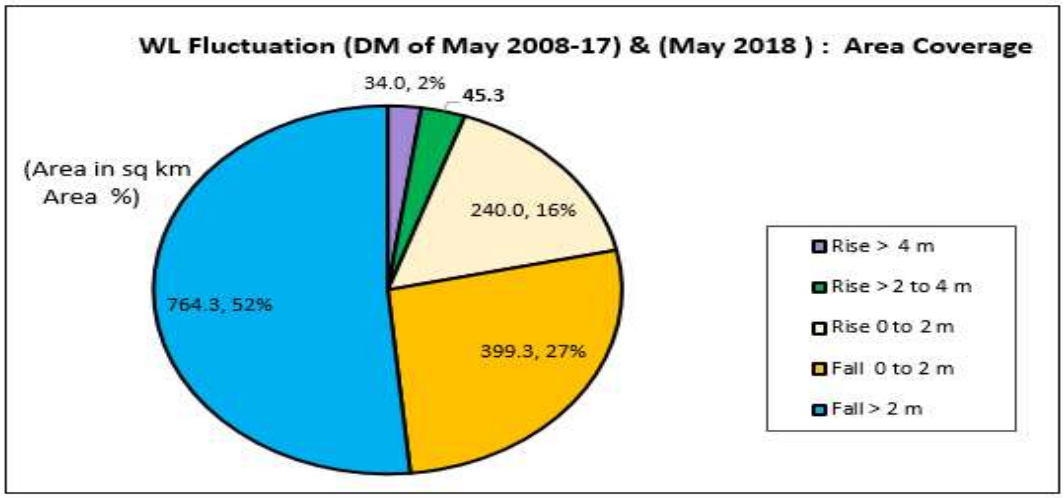


Figure : 45



4.4.2. Decadal Fluctuation: (DM of August 2008-17 & August2018)

Comparing water level data of August-2018 with 10 year mean water level of August (2008 to 2017), the change in water ranges from –8.56 m to 10.82 m. Nearly 40 % of monitoring wells show increase in rise of water level of August 2018, comparing decadal mean of August water level of 2008-17, whereas rest 60 % monitoring wells show increase in fall of water level. This rise mainly confined to central parts of NCT Delhi, covering parts of Northwest, West, Southwest and New Delhi district; south parts of South district; patches of North, North East, Shahdra and East districts (figure 46). Nearly 29% areas shows increase in rise up to 2 m, 6% from 2 to 10.6 m. Similarly increase in fall up 2 m is recorded in 29% areas and 36% in the areas above 2m. Chart showing extent of areas having change in rise and fall, computed from map grid, is presented in figure 47.

Figure : 46

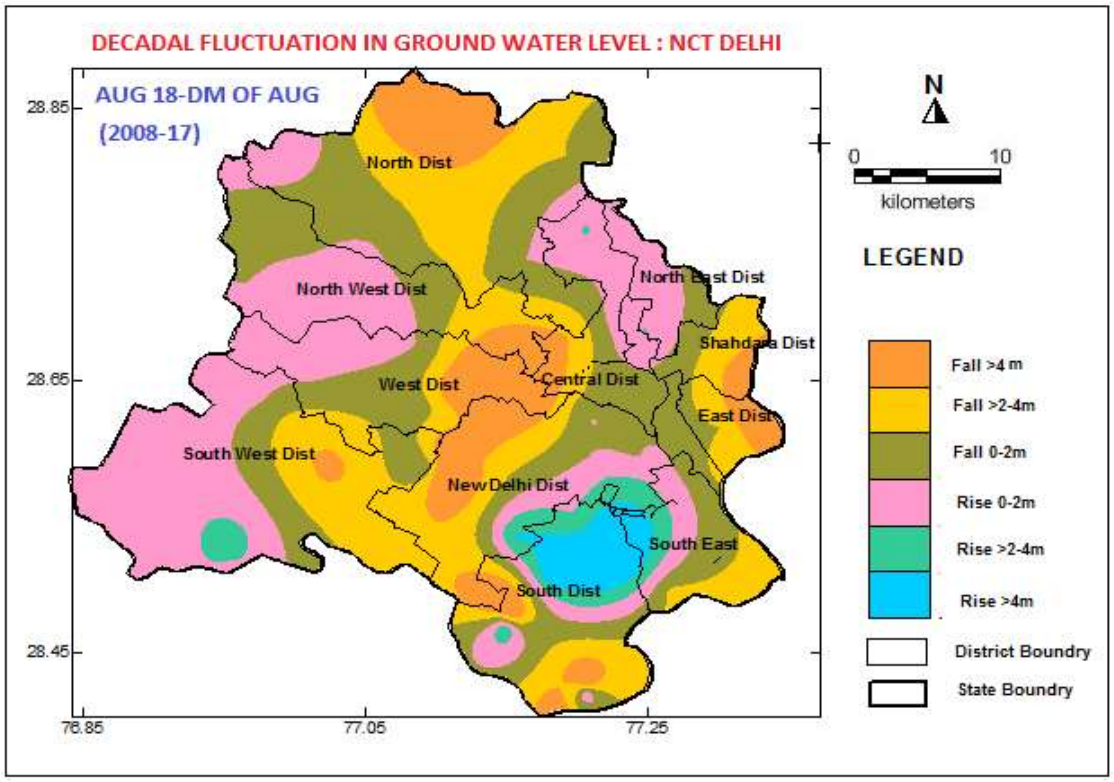
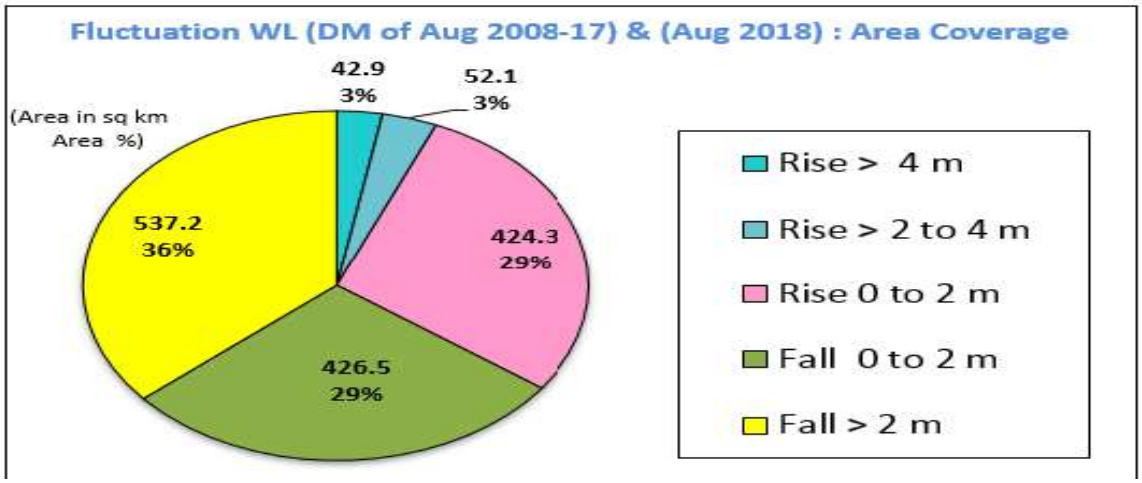


Figure: 47



4.4.3. Decadal Fluctuation: DM of Nov 2008-17 & Nov2018

Comparing water level data of November-2018 with 10 year mean water level of November (2008 to 2017), the change in water level ranges from -13.16 m to 11.64 m. Nearly 29% of monitoring wells show increase in rise of water level of November 2018, comparing decadal mean of November water level of 2008-17, whereas rest 71 % monitoring wells show increase in fall of water level. This rise mainly confined to two parts of NCT Delhi; i.e. in western part of Southwest, West and Northwest districts and in Southeast, South and New Delhi district of NCT Delhi (figure 48). Nearly 33 % areas shows increase in fall up to 2 m, 23% up to 4 m and rest 25% more than 4m. Similarly increase in rise up 2 m is recorded in 15% areas and 4 % areas shows rise more than 2m. Chart showing extent of areas having change in rise and fall, computed from map grid, is presented in figure 49.

Figure : 48

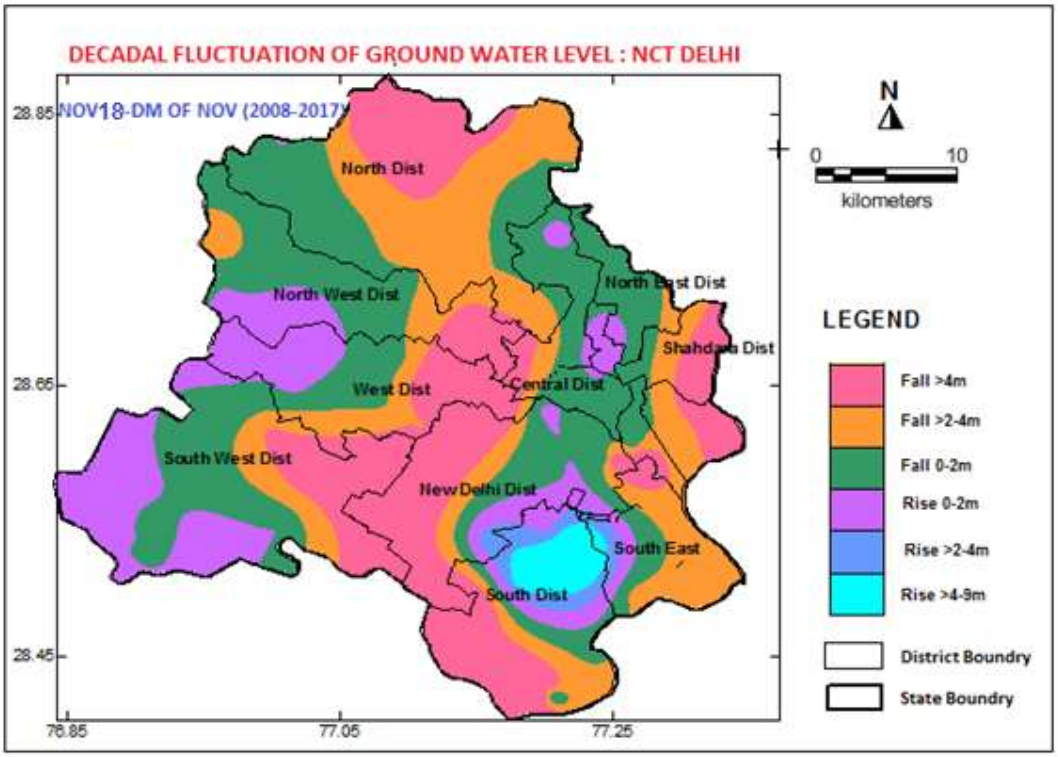
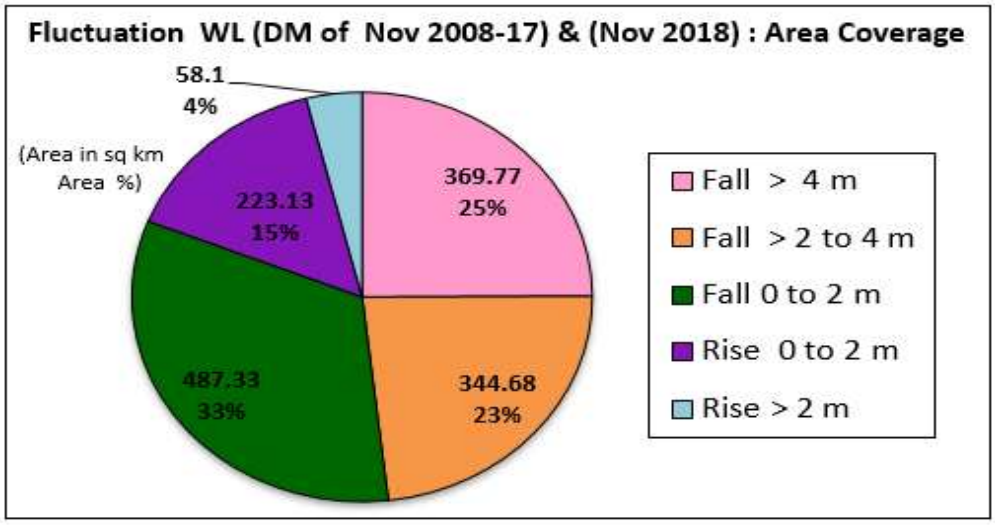


Figure : 49



4.4.4. Decadal Fluctuation: DM of January 2009–18 & January 2019

Comparing water level data of January-2019 with 10 year mean water level of January(2009 to 2018), the change in water level ranges from –13.58m to 12.52m. Nearly 32% of monitoring wells show increase in rise whereas rest 68% monitoring wells show increase in fall. This rise mainly confined to western half of NCT Delhi covering parts of Southwest, West, Northwest and North districts. Similarly parts of Southeast, South, New Delhi and Central districts also shows rise. (figure 50). Nearly 28% areas shows increase in fall up to 2 m, 40% more than 2m. Similarly increase in rise up 2 m is recorded in 28% areas and 42% areas shows rise more than 2m. Chart showing extent of areas having change in rise and fall, computed from map grid, is presented in figure 51.

Figure : 50

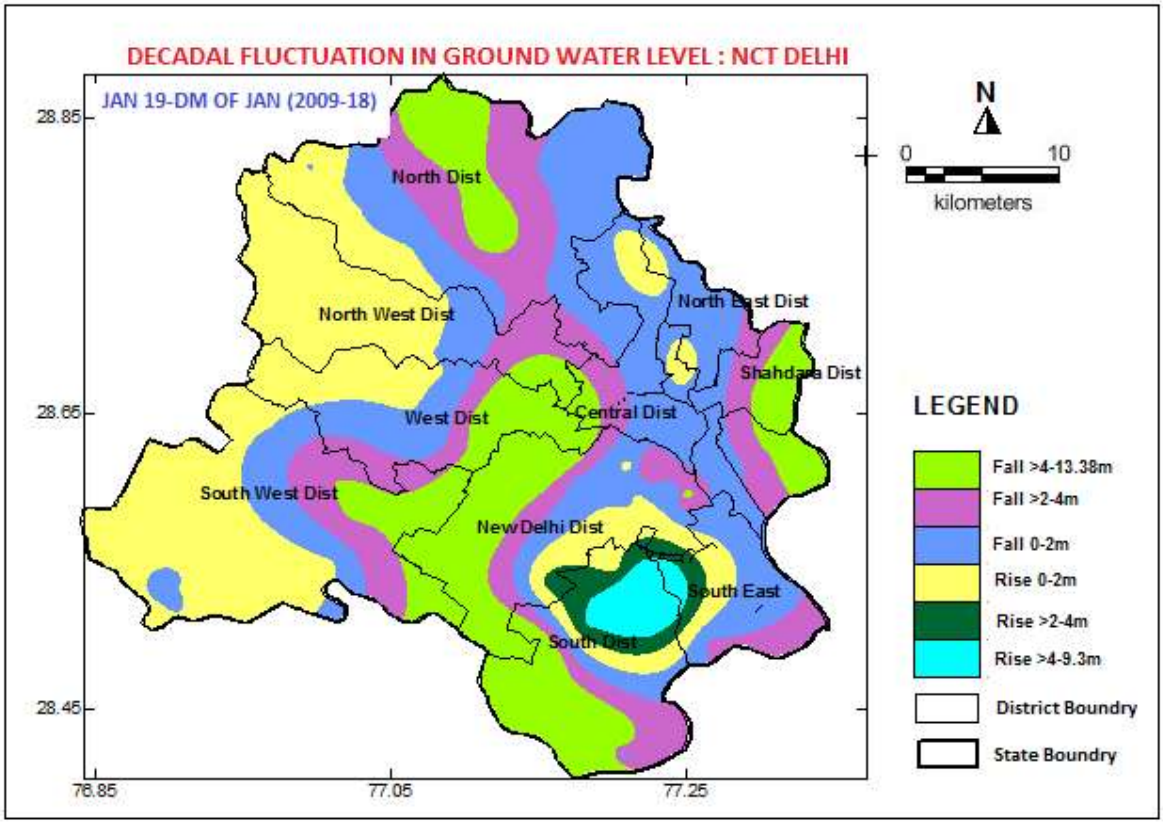
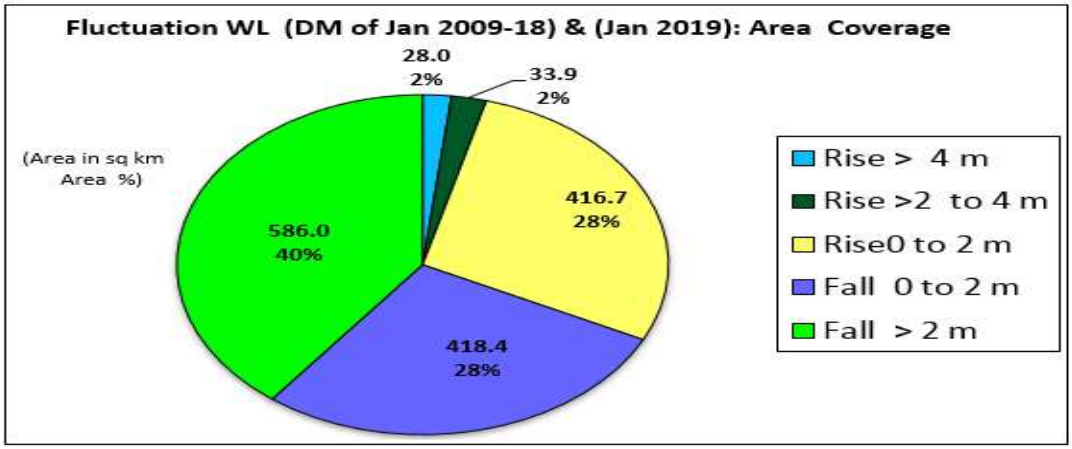


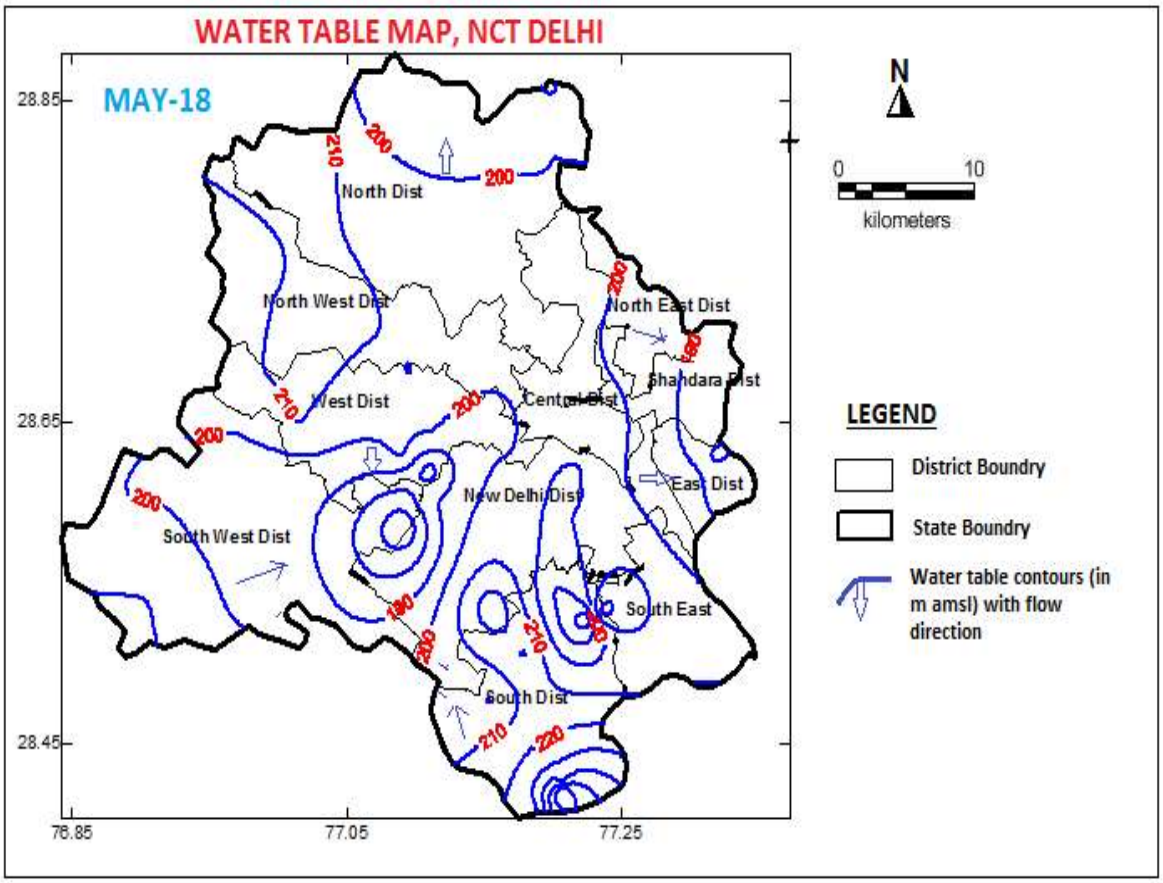
Figure : 51



4.5 Water Table Scenario

Water table contour map of May 2018 is presented in figure 52. The perusal of the map shows that the water table elevation ranges from 160m amsl at Palam Signal Camp in Dwarka Tehsil to 272m amsl at Balbir Nagar in Saket tehsil in south part of NCT Delhi. Aravalli Ridge areas is main recharge zones for NCT Delhi. In these areas water table ranges from 210 to 230 m amsl. Closely spaced contours on the eastern side of the ridge indicate steep gradient and high rate of flow of ground water, while widely spaced contours on the western side of the ridge indicate gentle gradient. Two trough of lowest water table observed indicate high development of groundwater; one is around Pusp Vihar in Hauz Khas tehsil and another is in Dwarka area of Dwarka tehsil. In rest part of NCT Delhi, water table counter follows general topography of the areas. Yamuna river flood zone shows water table in range of 185 to 198 m amsl. Major parts of Yamuna flood zone in NCT of Delhi, on either banks, water table configuration indicate influent nature of river Yamuna while in small section passing through South East district it shows effluent nature on right bank, in Southeast part of NCT Delhi whereas left bank area, in adjoin Uttar Pradesh it shows influent nature.

Figure : 52



5. HYDROGEOCHEMISTRY

The water that falls as rain and snow infiltrates into the subsurface soil and rock. Some water remains in the shallow soil layer whereas large portion infiltrate deeper and becomes part of groundwater system. The chemical characteristics of groundwater are mainly based on the surface and subsurface environment, such as the chemical composition of rain, composition of infiltrating surface water, properties of soil and rock in which the groundwater moves. It varies as per duration of contact time and contact surface between groundwater and geological material along its flow path, rate of geochemical (oxidation/reduction ion exchange, dissolution, evaporation, precipitation) process and microbiological process.

Hydrochemistry is an interdisciplinary science that deals with all these aspects responsible for the chemical composition of the groundwater and as such, it is helpful in knowing about residence time, flow path and aquifer characteristics, as the chemical reactions are time and space dependent. The classical use of chemical characteristics in hydrochemistry is to provide information about the regional distribution of water qualities. At the same time, hydrochemistry has a potential use for tracing the origin and history of water. The hydrochemistry can also be of immense help in yielding information about the environment through which water has circulated.

5.1 Hydrogeochemistry of NCT Delhi

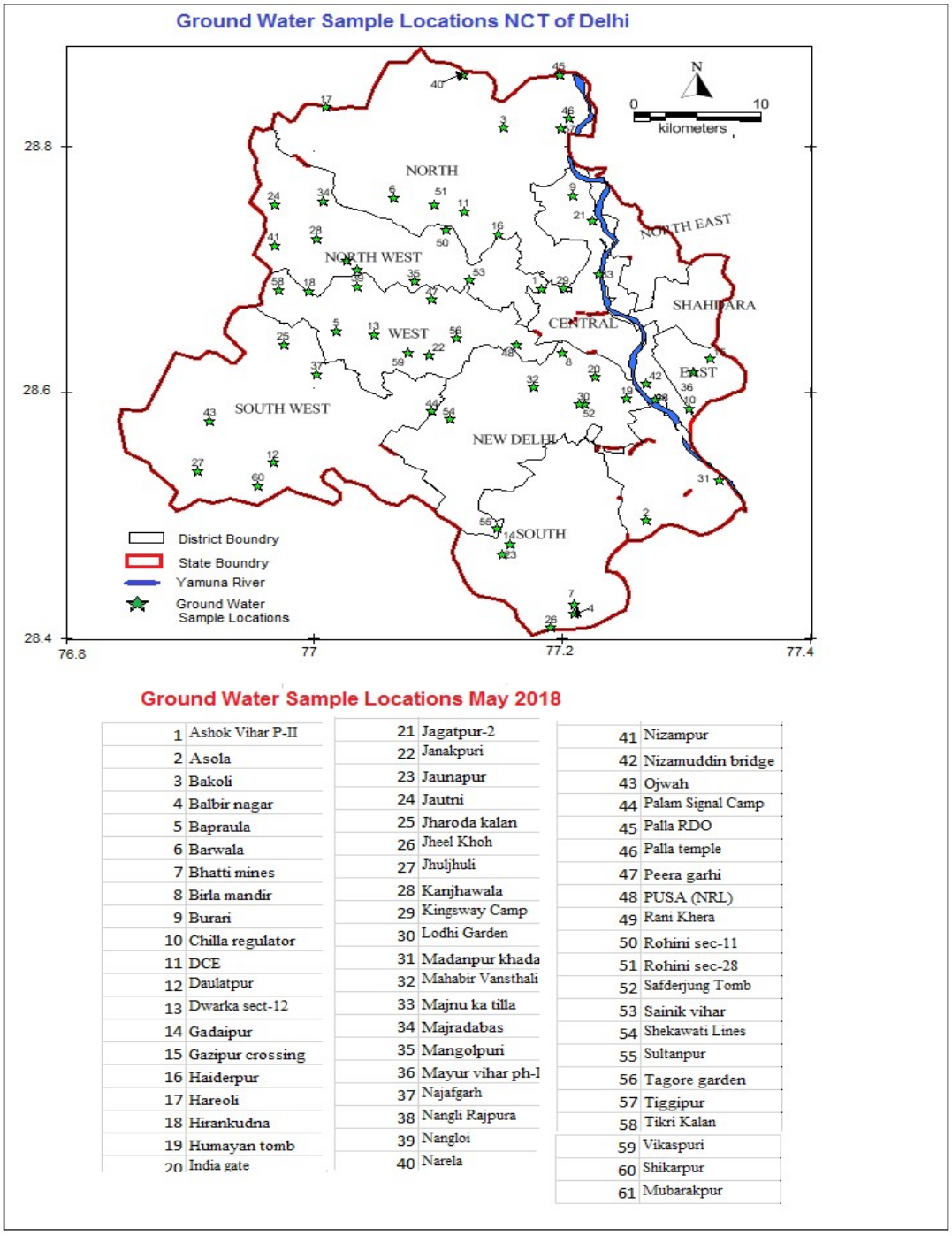
The diverse physiographic, topographic and geologic conditions have given rise to diversified groundwater situations and groundwater quality of NCT of Delhi and it varies with depth and space. It is mainly influenced by local geology and inherent salinity, and uneven development of groundwater.

In alluvial formations, in general, the quality of ground water deteriorates with depth, which is variable in different areas. The fresh ground water aquifers mainly exist up to a depth of 25 to 35 m in North West, West and parts of South west districts and in minor patches in North and Central districts. In South, Southeast & Southwest district, especially in Najafgarh *Jheel* area the fresh water occurs up to a depth of 30 to 45 m. A localized area located just north of Kamala Nehru Ridge (part of Delhi ridge falling in Central District) covering area of Dhirpur, Wazirabad and Jagatpur are characterized by shallow depth of fresh water aquifers that is in the range of 22 to 28m, regardless of proximity to River Yamuna. In the flood plains of Yamuna, in general, fresh water aquifers exist down to depth of 30-45m and especially in Palla it reaches to the depth of 60 to 75m below which brackish and saline water exists. The ground water is fresh at all depths in the areas around the ridge falling in Central, New Delhi, South and eastern part (Ridge Area) of South-West districts and also in Chattarpur basin. In the areas west of the ridge, in general, the thickness of fresh water aquifers decreases towards North-West, the thickness of fresh water zone is limited in most parts of west and southwest districts.

5.2 Groundwater Quality Monitoring

Monitoring of groundwater quality is an effort to obtain information on chemical quality through representative sampling in different parts of NCT Delhi. Groundwater is commonly tapped from phreatic aquifers through representative dug well / bore wells or hand pump located nearest to the monitoring station. A total number of 61 water samples were collected from NCT of Delhi, as part of groundwater quality monitoring work, during May 2018. List of locations and result of chemical analysis for its basic parameters such as pH, EC, TDS, CO_3, HCO_3, Cl, NO_3, SO_4, F, Ca, Mg, TH, is presented in annexure IV. Map showing locations of water sample locations is presented in figure 53.

Figure : 53



Ground Water Sample Locations May 2018

1	Ashok Vihar P-II
2	Asola
3	Bakoli
4	Balbir nagar
5	Bapraula
6	Barwala
7	Bhatti mines
8	Birla mandir
9	Burari
10	Chilla regulator
11	DCE
12	Daulatpur
13	Dwarka sect-12
14	Gadaipur
15	Gazipur crossing
16	Haiderpur
17	Hareoli
18	Hirankudna
19	Humayan tomb
20	India gate
21	Jagatpur-2
22	Janakpuri
23	Jaunapur
24	Jautni
25	Jharoda kalan
26	Jheel Khoh
27	Jhuljhuli
28	Kanjhawala
29	Kingsway Camp
30	Lodhi Garden
31	Madanpur khada
32	Mahabir Vansthali
33	Majnu ka tilla
34	Majradabas
35	Mangolpuri
36	Mayur vihar ph-I
37	Najafgarh
38	Nangli Rajpura
39	Nangloi
40	Narela
41	Nizampur
42	Nizamuddin bridge
43	Ojwah
44	Palam Signal Camp
45	Palla RDO
46	Palla temple
47	Peera garhi
48	PUSA (NRL)
49	Rani Khera
50	Rohini sec-11
51	Rohini sec-28
52	Safderjung Tomb
53	Sainik vihar
54	Shekawati Lines
55	Sultanpur
56	Tagore garden
57	Tiggipur
58	Tikri Kalan
59	Vikaspuri
60	Shikarpur
61	Mubarakpur

The overall results of hydro chemical analysis are attached in Annexure IV whereas distribution of major groundwater quality parameters in NCT of Delhi are described as under.

5.2.1. Electrical Conductance

Electrical conductivity represents total number of *cations* and *anions* present in groundwater, indicating ionic mobility of different ions, total dissolved solids and saline nature of water. Electrical Conductivity (EC)[8] is a measures of salinity of the groundwater in terms of saltiness, calculated as Micro Sieman / cm at 25°C. Similar expression is Total Dissolved Solid (TDS), a measure of total dissolved salt contents in mg / liter of groundwater. Different substances dissolve in groundwater giving it taste and odour. In fact, human beings have developed senses, which are able to evaluate

the potability of water. In general water having EC < 1500 uS/cm, is considered as fresh water, EC 1500 – 15000 uS/cm is considered as brackish water and EC > 15000 uS/cm is considered as saline water.

Map showing distribution of electrical conductance in groundwater of NCT Delhi is presented in figure 54. Most of eastern part of NCT Delhi, in areas around Yamuna in district of Central, North East, East, Shahdara, South East, New Delhi & South Delhi districts has EC within permissible range, upto to 2250 µS/cm at 25°C. The area of Najafgarh, Singhola, Bhalaswa and some pockets of south Delhi are showing exceptionally high EC Values, even in shallower depth. It is also observed that deeper aquifer water have greater EC value than the shallow aquifer, value increases with increase in depth. The major part of the area underlain by Delhi quartzite ridge have EC values in range of 600 µs/cm to 2000 µs/cm.

Figure : 54

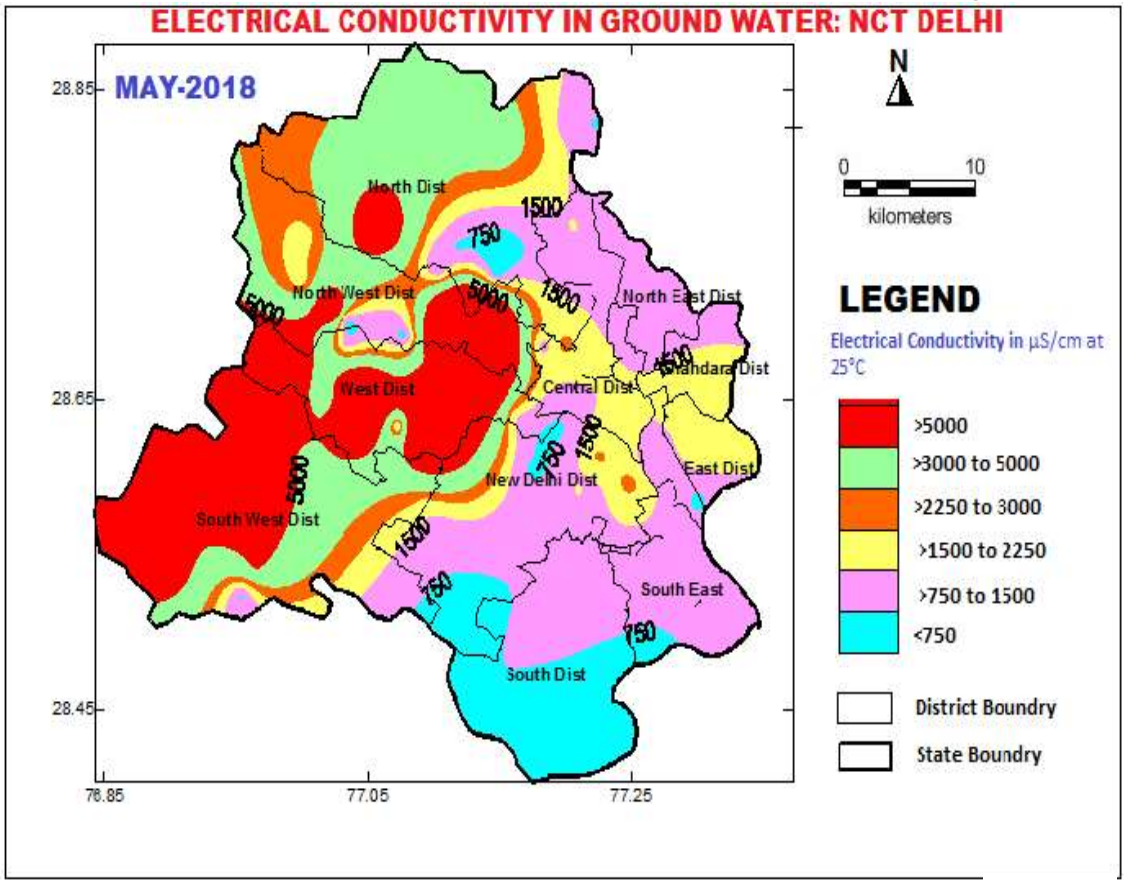
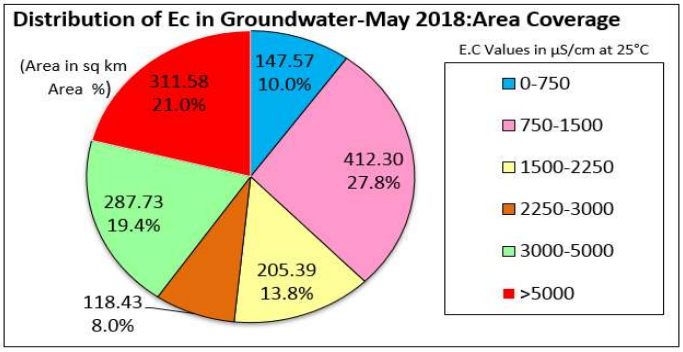


Figure: 55

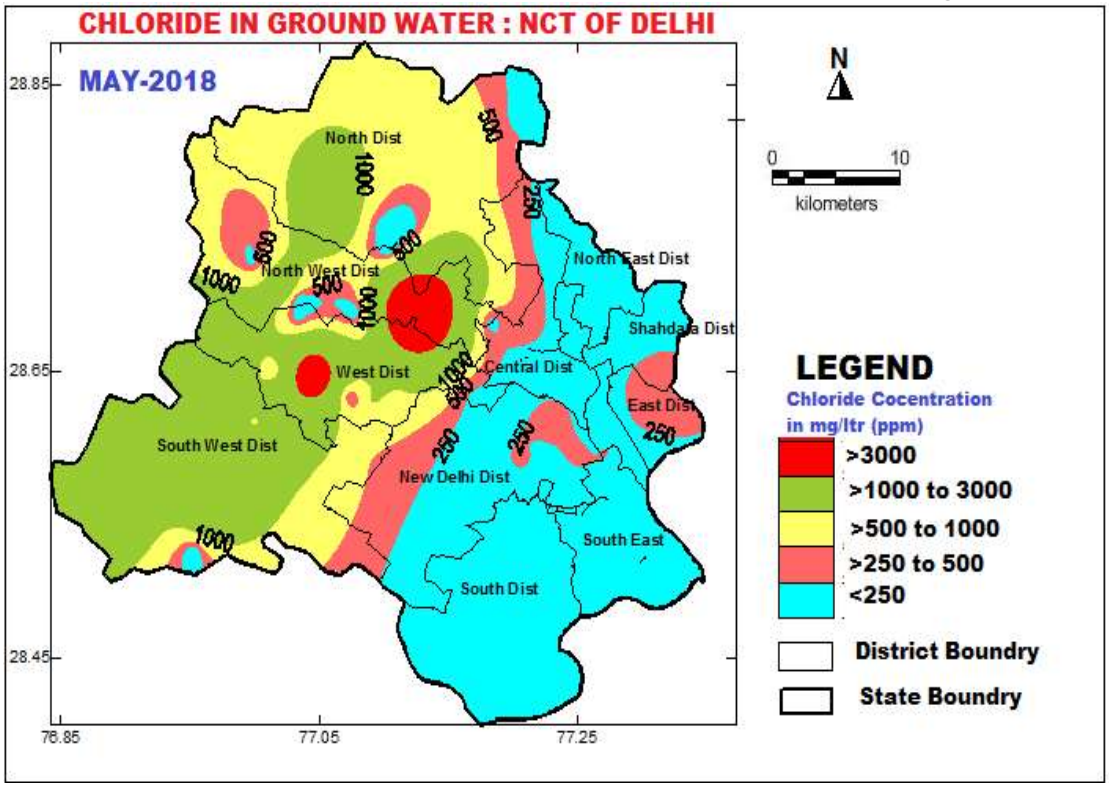
It is observed that nearly 40% areas of NCT Delhi falling in North, North West, West and South West districts show EC more than 3000 µS/cm at 25°C whereas rest 59 % area has EC in range from 0 to 3000 µS/cm at 25°C. Nearly 10% (147 sqkm) areas of North, New Delhi, South East & South district has EC of 0 to 750 µS/cm at 25°C (figure 55).



5.2.2. Chloride

Chloride is present in all natural waters being highly soluble and moves freely through soil and rock. In groundwater Chloride content is mostly below 250 mg/l except in cases where inland salinity is prevalent. BIS have recommended a desirable limit of 250mg/l of chloride in drinking water; this concentration limit can be extended to 1000 mg/l of chloride in cases where no alternative source of water with desired concentration is available. The map showing distribution of Chloride in NCT Delhi is presented in figure 56.

Figure : 56



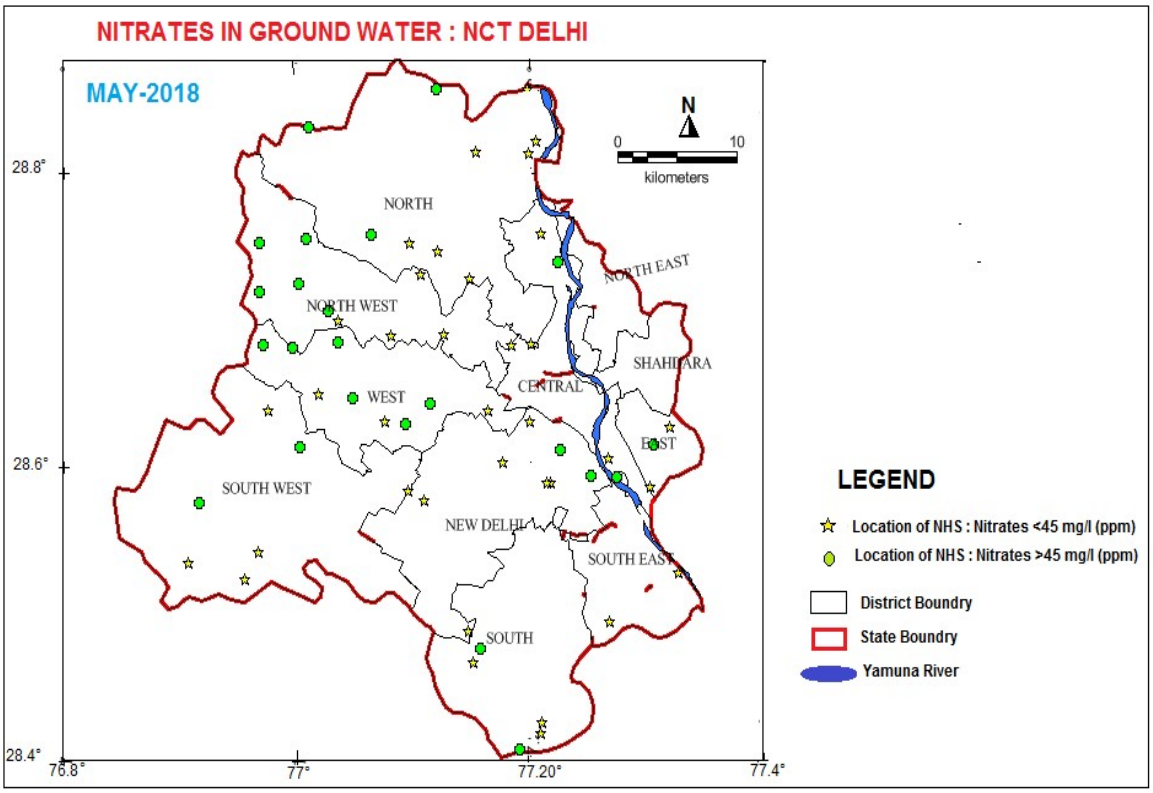
It is observed major part of NCT Delhi, in areas having EC with in permissible limits, up to 2250 to 3000 µS/cm, has chloride also within permissible limit of 250 mg/l. In areas having high EC more than 3000 µS/cm, chloride value is more than 1000 mg /l to high up to 3000 mg /l (figure56).

5.2.3. Nitrate

Nitrate is a naturally occurring compound that is formed in the soil when nitrogen and oxygen combine. The primary source of all nitrates is atmospheric nitrogen gas. This is converted into organic nitrogen by some plants by a process called nitrogen fixation. Dissolved nitrogen in the form of nitrate is the most common contaminant of groundwater. Nitrate in groundwater generally originates from non point sources such as leaching of chemical fertilizers and animal manure, groundwater pollution from septic and sewage discharges etc. It is difficult to identify the natural and man-made sources of nitrogen contamination of ground water. Some chemical and microbiological processes

such as nitrification and denitrification also influence the nitrate concentration in ground water. As per the BIS standard for drinking water the maximum desirable limit of nitrate concentration in groundwater is 45 mg/l. Though nitrate is considered relatively non-toxic, a high nitrate concentration in drinking water is an environmental health concern arising from increased risks of methaemoglobinemia particularly to infants.

Figure : 57



The map (figure 57) shows NHS having nitrates in ground water of Delhi, as point source of pollution, within permissible and beyond permissible limit of 45 mg /ltr.

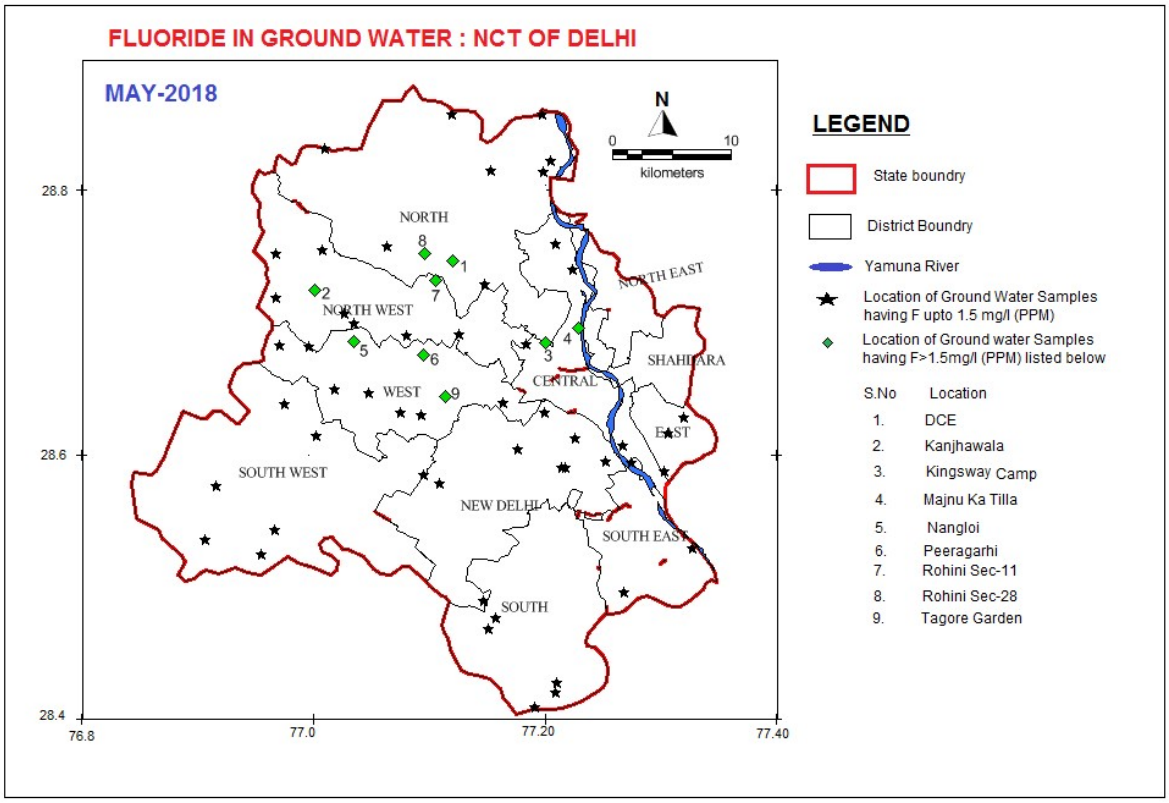
5.2.4. Fluoride

Fluorine is a fairly common element but it does not occur in the elemental state in nature because of its high reactivity. Fluorine is the most electronegative and reactive of all elements that occur naturally within many type of rocks. Most of the fluoride found in groundwater is naturally occurring from the breakdown of rocks and soils or weathering and deposition of atmospheric particles. Most of the fluorides are sparingly soluble and are present in groundwater in small amount. The map showing distribution of Fluoride in NCT Delhi is presented in figure 58.

It is well known that small amount of fluoride (>1.0 mg/l) have proven to be beneficial in reducing tooth decay. Community water supplies commonly are treated with sodium fluoride or fluorosilicates to maintain fluoride level ranging from 0.8 to 1.2 mg/l to reduce the incidents of dental carries. However, high concentrations (>1.5mg/l) have resulted in staining of tooth enamel while at still

higher levels of fluoride (> 5.0 mg/l) further critical problems such as stiffness of bones. BIS has recommended an upper desirable limit of 1.0 mg/l of fluoride concentration in drinking water, which can be extended to 1.5 mg/l in case no alternative source of drinking water is available. Water having fluoride concentration more than 1.5mg/l is not suitable for drinking purposes.

Figure : 58



The map (figure 58) shows NHS locations having fluoride in ground water of Delhi, within permissible limits & beyond permissible limit of 1.5 mg /litre.

ANNEXURE : I A LIST OF CENSUS TOWNS – NCT OF DELHI

District	Tehsil	Town Name Name
CENTRAL	Civil Lines	Burari (CT)
CENTRAL	Civil Lines	Jharoda Majra Burari (CT)
CENTRAL	Civil Lines	Kamal Pur Majra Burari (CT)
CENTRAL	Civil Lines	Mukund Pur (CT)
EAST	Gandhi Nagar	Shakar Pur Baramad (CT)
EAST	Mayur Vihar	Chilla Saroda Bangar (CT)
EAST	Mayur Vihar	Chilla Saroda Khadar (CT)
EAST	Mayur Vihar	Dallo Pura (CT)
EAST	Mayur Vihar	Gharoli (CT)
EAST	Mayur Vihar	Gharonda Neemka Bangar alias Patpar Ganj (CT)
EAST	Mayur Vihar	Kondli (CT)
NEW DELHI	Delhi Cantonment	Moradabad Pahari (CT)
NEW DELHI	Vasanat Vihar	Ghitorni (CT)
NEW DELHI	Vasanat Vihar	Kusum Pur (CT)
NEW DELHI	Vasanat Vihar	Malik Pur Kohi alias Rang Puri (CT)
NEW DELHI	Vasanat Vihar	Rajokri (CT)
NEW DELHI	Vasanat Vihar	Sambhalka (CT)
NORTH	Alipur	Ali Pur (CT)
NORTH	Alipur	Bakhtawar Pur (CT)
NORTH	Alipur	Bankauli (CT)
NORTH	Alipur	Ibrahim Pur (CT)
NORTH	Alipur	Khera Kalan (CT)
NORTH	Alipur	Libas Pur (CT)
NORTH	Alipur	Mukhmel Pur (CT)
NORTH	Alipur	Qadi Pur (CT)
NORTH	Alipur	Sahibabad Daulat Pur (CT)
NORTH	Alipur	Siras Pur (CT)
NORTH	Model Town	Bhalswa Jahangir Pur (CT)
NORTH	Narela	Bankaner (CT)
NORTH	Narela	Barwala (CT)
NORTH	Narela	Bawana (CT)
NORTH	Narela	Bhor Garh (CT)
NORTH	Narela	Darya Pur Kalan (CT)
NORTH	Narela	Khera Khurd (CT)
NORTH	Narela	Pehlad Pur Bangar (CT)
NORTH	Narela	POOTH KHURD
NORTH	Narela	Tikri Khurd (CT)
NORTH EAST	Karwal Nagar	Baqiabad (CT)
NORTH EAST	Karwal Nagar	Jiwan Pur alias Johri Pur (CT)
NORTH EAST	Karwal Nagar	Karawal Nagar (CT)
NORTH EAST	Karwal Nagar	Sadat Pur Gujran (CT)
NORTH EAST	Seelam Pur	Dayal Pur (CT)
NORTH EAST	Seelam Pur	Khajoori Khas (CT)
NORTH EAST	Seelam Pur	Khan Pur Dhani (CT)
NORTH EAST	Seelam Pur	Mir Pur Turk (CT)
NORTH EAST	Seelam Pur	Tukhmir Pur (CT)
NORTH EAST	Yamuna Vihar	Gokal Pur (CT)
NORTH EAST	Yamuna Vihar	Mustafabad (CT)
NORTH EAST	Yamuna Vihar	Ziauddin Pur (CT)
NORTH WEST	Kanjhawala	Gheora (CT)
NORTH WEST	Kanjhawala	Kanjhawala (CT)
NORTH WEST	Kanjhawala	Karala (CT)
NORTH WEST	Kanjhawala	Lad Pur (CT)
NORTH WEST	Kanjhawala	Mohammad Pur Majri (CT)
NORTH WEST	Kanjhawala	Qutab Garh (CT)
NORTH WEST	Rohini	Begum Pur (CT)

District	Tehsil	Town Name Name
SHAHDARA	Seema Puri	Mandoli (CT)
SHAHDARA	Shahdara	Babar Pur (CT)
SHAHDARA	Shahdara	Jaffrabad (CT)
SOUTH	Mehrauli	Aya Nagat (CT)
SOUTH	Mehrauli	Chandan Hola (CT)
SOUTH	Mehrauli	Dera Mandi (CT)
SOUTH	Mehrauli	Fateh Pur Beri (CT)
SOUTH	Mehrauli	Jona Pur (CT)
SOUTH	Mehrauli	Sultan Pur (CT)
SOUTH	Saket	Asola (CT)
SOUTH	Saket	Bhati (CT)
SOUTH	Saket	Chhatar Pur (CT)
SOUTH	Saket	Deoli (CT)
SOUTH	Saket	Maidan Garhi (CT)
SOUTH	Saket	Neb Sarai (CT)
SOUTH	Saket	Raj Pur Khurd (CT)
SOUTH	Saket	Saidul Azaib (CT)
SOUTH	Saket	Tigri (CT)
SOUTH EAST	Defence Colony	Saidabad (CT)
SOUTH EAST	Kalkaji	Pul Pehlad (CT)
SOUTH EAST	Sarita Vihar	Aali (CT)
SOUTH EAST	Sarita Vihar	Jaitpur (CT)
SOUTH EAST	Sarita Vihar	Kotla Mahigiran (CT)
SOUTH EAST	Sarita Vihar	Mithe Pur (CT)
SOUTH EAST	Sarita Vihar	Molar Band (CT)
SOUTH EAST	Sarita Vihar	Taj Pul (CT)
SOUTH WEST	Dwarka	Nangli Sakrawati (CT)
SOUTH WEST	Kapeshera	Chhawla (CT)
SOUTH WEST	Kapeshera	Dindar Pur (CT)
SOUTH WEST	Kapeshera	Kapas Hera (CT)
SOUTH WEST	Najafgarh	Jaffar Pur Kalan (CT)
SOUTH WEST	Najafgarh	Jharoda Kalan (CT)
SOUTH WEST	Najafgarh	Kair (CT)
SOUTH WEST	Najafgarh	Khera (CT)
SOUTH WEST	Najafgarh	Mitraon (CT)
SOUTH WEST	Najafgarh	Roshan Pura alias Dichaon Khurd (CT)
SOUTH WEST	Najafgarh	Ujwa (CT)
WEST	Patel Nagar	Hastsal (CT)
WEST	Patel Nagar	Raja Pur Khurd (CT)
WEST	Punjabi Bagh	Bakkar Wala (CT)
WEST	Punjabi Bagh	Bapraula (CT)
WEST	Punjabi Bagh	Mundaka (CT)
WEST	Punjabi Bagh	Nangloi Jat (CT)
WEST	Punjabi Bagh	Nilothi (CT)
WEST	Punjabi Bagh	Quammruddin Nagar (CT)
WEST	Punjabi Bagh	Shafi Pur Ranhola (CT)
WEST	Punjabi Bagh	Tikri Kalan (CT)
WEST	Punjabi Bagh	Tilang Pur Kotla (CT)
NORTH WEST	Rohini	Kirari Suleman Nagar (CT)
NORTH WEST	Rohini	Mubarak Pur Dabas (CT)
NORTH WEST	Rohini	Nithari (CT)
NORTH WEST	Rohini	Pooth Kalan (CT)
NORTH WEST	Rohini	Rani Khera (CT)
NORTH WEST	Rohini	Sultan Pur Majra (CT)

ANNEXURE : I B LIST OF VILLAGES – NCT OF DELHI

District	Tehsil	Village Name
CENTRAL	Civil Lines	Badar Pur Majra Burari
CENTRAL	Civil Lines	Jagat Pur ilaqa Delhi
CENTRAL	Civil Lines	Jagat Pur ilaqa Shahdara (un-inhabited)
CENTRAL	Civil Lines	Salem Pur Majra Burari
EAST	Mayur Vihar	Shamas Pur
NORTH	Alipur	Akbar Pur Majra
NORTH	Alipur	Bodh Pur Bija Pur
NORTH	Alipur	Fateh Pur Jat
NORTH	Alipur	Garhi Khasru
NORTH	Alipur	Hamid Pur
NORTH	Alipur	Hiranki
NORTH	Alipur	Jhangola
NORTH	Alipur	Kham Pur
NORTH	Alipur	Mohd. Pur Ramzan Pur
NORTH	Alipur	Nangli Poona
NORTH	Alipur	Palla
NORTH	Alipur	Qullak Pur
NORTH	Alipur	Singhola
NORTH	Alipur	Singhu
NORTH	Alipur	Sunger Pur Delhi
NORTH	Alipur	Sunger Pur Shahdara (un-inhabited)
NORTH	Alipur	Taj Pur Kalan
NORTH	Alipur	Tehri Daulat Pur (Un-inhabited)
NORTH	Alipur	Tigi Pur
NORTH	Alipur	Zind Pur
NORTH	Model Town	Shanjar Pur(un-inhabited)
NORTH	Narela	Bazid Pur Thakran
NORTH	Narela	Ghoga
NORTH	Narela	Hareoli
NORTH	Narela	Holambi Kalan
NORTH	Narela	Holambi Khurd
NORTH	Narela	Iradat Nagar alias Naya Bans
NORTH	Narela	Kankar Khera
NORTH	Narela	Katewara
NORTH	Narela	Kureni
NORTH	Narela	Lam Pur
NORTH	Narela	Mamoor Pur
NORTH	Narela	Mungesh Pur
NORTH	Narela	Ochandi
NORTH	Narela	Pansali
NORTH	Narela	Raja Pur Kalan (Un-inhabited)
NORTH	Narela	Sanoth
NORTH	Narela	Shah Pur Garhi
NORTH	Narela	Sultan Pur Dabas
NORTH EAST	Karwal Nagar	Badar Pur Khadar
NORTH EAST	Karwal Nagar	Bihari Pur
NORTH EAST	Karwal Nagar	Pur Delhi
NORTH EAST	Karwal Nagar	Pur Shahdara
NORTH EAST	Karwal Nagar	Saba Pur Delhi
NORTH EAST	Karwal Nagar	Saba Pur Shahdara
NORTH EAST	Karwal Nagar	Sadat Pur Musalmanan (un-inhabited)
NORTH EAST	Seelam Pur	Garhi Mendu
NORTH EAST	Seelam Pur	Sher Pur
NORTH WEST	Kanjhawala	Budhan Pur
NORTH WEST	Kanjhawala	Chand Pur
NORTH WEST	Kanjhawala	Chatesar
NORTH WEST	Kanjhawala	Garhi Rindhala
NORTH WEST	Kanjhawala	Jat Khor
NORTH WEST	Kanjhawala	Jonti
NORTH WEST	Kanjhawala	Nizam Pur Rashid Pur
NORTH WEST	Kanjhawala	Punjab Khor
NORTH WEST	Kanjhawala	Salah Pur Majra
NORTH WEST	Rohini	Madan Pur Dabas
NORTH WEST	Rohini	Rasool Pur
NORTH WEST	Saraswati Vihar	Saoda
SOUTH	Mehrauli	Gadai Pur
SOUTH	Saket	Satberi
SOUTH	Saket	Shahur Pur
SOUTH WEST	Kapeshera	Asalat Pur Khawad
SOUTH WEST	Kapeshera	Badhosra
SOUTH WEST	Kapeshera	Darya Pur Khurd
SOUTH WEST	Kapeshera	Daulat Pur
SOUTH WEST	Kapeshera	Deorala
SOUTH WEST	Kapeshera	Goela Khurd
SOUTH WEST	Kapeshera	Goman Hera
SOUTH WEST	Kapeshera	Hasan Pur
SOUTH WEST	Kapeshera	Jain Pur(Un-inhabited)
SOUTH WEST	Kapeshera	Jhatikra
SOUTH WEST	Kapeshera	Kangan Heri
SOUTH WEST	Kapeshera	Kharkhari Jatmal
SOUTH WEST	Kapeshera	Kharkhari Rond
SOUTH WEST	Kapeshera	Nanak Heri
SOUTH WEST	Kapeshera	Paprawat
SOUTH WEST	Kapeshera	Pindwala Kalan
SOUTH WEST	Kapeshera	Pindwala Khurd
SOUTH WEST	Kapeshera	Qutab Pur
SOUTH WEST	Kapeshera	Raghu Pur
SOUTH WEST	Kapeshera	Raota
SOUTH WEST	Kapeshera	Rewla Kham Pur
SOUTH WEST	Kapeshera	Salah Pur
SOUTH WEST	Kapeshera	Shikar Pur
SOUTH WEST	Kapeshera	Taj Pur Khurd
SOUTH WEST	Najafgarh	Baqar Garh
SOUTH WEST	Najafgarh	Dhansa
SOUTH WEST	Najafgarh	Dichaon Kalan
SOUTH WEST	Najafgarh	Ghalib Pur
SOUTH WEST	Najafgarh	Isa Pur
SOUTH WEST	Najafgarh	Jhuljhuli
SOUTH WEST	Najafgarh	Kharkhari Nahar
SOUTH WEST	Najafgarh	Khera Dabar
SOUTH WEST	Najafgarh	Malik Pur zer-Najafgarh
SOUTH WEST	Najafgarh	Mundhela Kalan
SOUTH WEST	Najafgarh	Mundhela Khurd
SOUTH WEST	Najafgarh	Qazi Pur
SOUTH WEST	Najafgarh	Samas Pur Khalsa
SOUTH WEST	Najafgarh	Sarang Pur
SOUTH WEST	Najafgarh	Sher Pur Deri
SOUTH WEST	Najafgarh	Surakh Pur
SOUTH WEST	Najafgarh	Surera
WEST	Punjabi Bagh	Jaffar Pur alias Hiran Kudna
WEST	Punjabi Bagh	Neel Wal

ANNEXURE : II RAINFALL DATA & PROBABILITY ANALYSIS

Rainfall, Departure and Cumulative Departure & Occurrence of Drought - NCT of Delhi

Year	Rainfall (mm)	Departure	Cumulative Departure	Typeof Drought
1984	579.2	-0.14	-0.14	Mild
1985	771.6	0.15	0.02	
1986	446.4	-0.33	-0.32	Normal
1987	434.2	-0.35	-0.67	Normal
1988	1025.2	0.53	-0.14	
1989	303.6	-0.55	-0.68	Severe
1990	800.6	0.20	-0.49	
1991	614.7	-0.08	-0.57	Mild
1992	641.6	-0.04	-0.61	Mild
1993	861.4	0.29	-0.33	
1994	784.6	0.17	-0.15	
1995	827.6	0.24	0.08	
1996	974.6	0.46	0.54	
1997	617.4	-0.08	0.46	Mild
1998	853.3	0.27	0.73	
1999	544.2	-0.19	0.55	Mild
2000	808.0	0.21	0.75	
2001	646.2	-0.04	0.72	Mild
2002	459.5	-0.31	0.40	Normal
2003	925.9	0.38	0.79	
2004	531.5	-0.21	0.58	Mild
2005	603.3	-0.10	0.48	Mild
2006	618.7	-0.08	0.40	Mild
2007	588.0	-0.12	0.28	Mild
2008	852.8	0.27	0.56	
2009	595.6	-0.11	0.44	Mild
2010	951.9	0.42	0.87	
2011	661.8	-0.01	0.85	Mild
2012	559.4	-0.16	0.69	Mild
2013	708.9	0.06	0.75	
2014	440.4	-0.34	0.41	Normal
2015	547.5	-0.18	0.22	Mild
2016	656.1	-0.02	0.20	Mild
2017	533.7	-0.20	0.00	Mild

Rank	Probability in %	ARF in decresing order
1	2.03	1025.2
2	5.09	974.6
3	8.08	951.9
4	11.08	925.9
5	14.07	861.4
6	17.07	853.3
7	20.06	852.8
8	23.05	827.6
9	26.05	808.0
10	29.04	800.6
11	32.04	784.6
12	35.03	771.6
13	38.02	708.9
14	41.02	661.8
15	44.01	656.1
16	47.01	646.2
17	50.00	641.6
18	52.99	618.7
19	55.99	617.4
20	58.98	614.7
21	61.98	603.3
22	64.97	595.6
23	67.96	588.0
24	70.96	579.2
25	73.95	559.4
26	76.95	547.5
27	79.94	544.2
28	82.93	533.7
29	85.93	531.5
30	88.92	459.5
31	91.92	446.4
32	94.91	440.4
33	97.90	434.2
34	100.90	303.6

ANNEXURE : IIIA WATER LEVEL MONITORING DATA : (2018-19)

List Of NHS / Monitoring Stations Monitored During 2018-19, NCT of Delhi (Wl in m bgl)							
District Name	**Tehsil Name**	**Site Name**	**May-18**	**Aug-18**	**Nov-18**	**Jan-19**	**Type Of Well**
South East	Kalkaji	Asola Pz	51.15	50.71	50.25	50.25	Pz
North	Narela	Auchandi Pz	5.10	NA	2.31	2.45	Pz
North	Alipur	Bakoli	13.48	13.72	12.74	11.25	Pz
North	Alipur	Bakoli Deep Pz	13.60	13.97	13.03	12.5	Pz
South	Saket	Balbir Nagar DW	22.67	14.26	17.47	21.51	DW
North	Narela	Bankner Pz	23.80	23.78	23.88	23.17	Pz
West	Punjabi Bagh	Baprola Dw	3.44	3.25	2.16	3.65	DW
North	Narela	Barwala Pz	8.55	5.96	6.62	5.56	Pz
North	Narela	Bawana DW New	NA	NA	NA	6.02	DW
North	Model Town	Bhalaswa Lake Pz	3.61	1.55	3.51	3.12	Pz
South	Saket	Bhatti Pz	50.95	51.06	49.61	51.86	Pz
New Delhi	Chanakyapuri	Birla Mandir DW	15.46	9.44	7.35	10.8	DW
Central	Civil Lines	Burari Augur Pz	4.30	NA	NA	3.01	Pz
Central	Civil Lines	Burari Pz	4.30	0.82	2.46	NA	Pz
Shahdara	Shahdara	CBD Shahdara	NA	13.13	14.17	14.4	Pz
Central	Kotwali	Chandini Chowk DW	7.54	6.03	6.51	NA	DW
South West	Kapeshera	Chhawla Pz	16.25	15.68	13.96	13.15	Pz
East	Mayur Vihar	Chilla Regulator	10.84	10.78	11.37	10.32	Pz
East	Mayur Vihar	Chilla Saroda Pz	NA	NA	11.66	11.6	Pz
New Delhi	Delhi Cantonment	Cvd Depot Cant (Deep)	28.52	27.91	28.93	27.91	Pz
South West	Najafgarh	Daryapur Khurd	NA	NA	5.12	4.65	DW
South West	Kapeshera	Daulatpur Pz	14.47	14.05	NA	15.21	Pz
North	Alipur	Delhi College of Enginnerring	8.63	8.62	8.77	8.05	Pz
South West	Kapeshera	Deorala Pz	0.71	NA	1.02	0.8	Pz
South West	Dwarka	Dwarka S-16 (TP)	23.12	22.56	23.7	22.74	Pz
South	Mehrauli	Gadaipur Pz	61.18	61.7	62.73	63.02	Pz
East	Preet Vihar	Gazi Pur Crossing	24.05	24.42	25.26	25.28	Pz
North	Alipur	Haiderpur Pz	13.30	11.65	13.55	12.48	Pz
North	Narela	Hareoli DW	5.19	2.7	2.62	1.95	DW
South	Hauz Khas	Hauz Khas Pz	33.28	32.98	33.72	33.35	Pz
West	Punjabi Bagh	Hiran Kudna DW	3.68	0.55	2.02	1	DW
New Delhi	Chanakyapuri	Humayu Tomb DW	5.76	5.16	11.38	11.28	DW
New Delhi	Chanakyapuri	India Gate Pz	8.71	7.66	8.42	10.43	Pz
Central	Civil Lines	ISBT (Kasmiri Gate) DW	3.16	1.45	2.17	3.85	DW
New Delhi	Vasant Vihar	J N U Pz (Downstream)	28.97	22.64	23.46	23.68	Pz
New Delhi	Vasant Vihar	J N U Pz (Upstream)	21.31	20.56	20.17	20.37	Pz
Central	Civil Lines	Jagatpur Pz 1	4.07	1.65	2.4	1.77	Pz
Central	Civil Lines	Jagatpur Pz 2	4.51	1.07	2.8	NA	Pz
South East	Kalkaji	Jahapana Park	17.01	NA	NA	16.97	DW
South East	Sarita Vihar	Jaitpur Khadar RD3500 Pz	NA	7.23	7.82	7.69	Pz
South	Mehrauli	Jamali Kamali DW	26.06	21.82	22.16	23.55	DW
West	Patel Nagar	Janakpuri Pz	13.61	12.15	13.21	13.44	Pz
South	Mehrauli	Jaunapur DJB TW	58.65	49.19	57.52	57.92	Pz
North West	Kanjhawarla	Jaunti DW	15.25	13.06	15.2	11.3	DW
South West	Najafgarh	Jharoda Kalan Pz	14.74	14.32	14.98	14.86	Pz
South	Mehrauli	Jheel Khoh DW	65.00	56.39	65	65	DW
South West	Najafgarh	Jhuljhuli Dw	2.20	1.11	2.26	2.67	DW
New Delhi	Delhi Cantonment	Kabul Line Pz	31.12	30.76	32.37	31.91	Pz
North West	Kanjhwaria	Kanjhawala Pz	2.83	0.15	1.37	1.4	Pz

North	Alipur	Khera Kalan Pz	NA	NA	NA	11.63	Pz
North	Narela	Kingsway Camp Police Ground Pz	10.75	9.83	10.1	9.16	Pz
New Delhi	Chanakyapuri	Lodhi Garden (D)	8.30	7.61	8.31	7.86	Pz
New Delhi	Chanakyapuri	Lodhi Garden.(SH)	8.71	7.54	7.85	7.37	Pz
New Delhi	Chanakyapuri	Lodhi Graden Dw	11.58	11.32	11.77	11.34	DW
New Delhi	Chanakyapuri	Mahabir Vansth.	29.58	28.23	28.38	27.45	Pz
North West	Saraswati Vihar	Majara Dabas	NA	3.39	3.5	3.05	Pz
Central	Civil Lines	Majnu Ka Tila DW	11.54	7.04	8.34	8.69	DW
South West	Najafgarh	Mandela Khurd Pz	13.24	12.51	NA	NA	Pz
North West	Rohini	Mangolpur Pz	4.91	2.44	3.75	3.19	Pz
West	Rajouri Garden	Mayapuri Pz	39.38	37.87	38.85	39.69	Pz
East	Mayur Vihar	Mayur Vihar B Block Ph II	8.73	8.57	9.15	9.26	Pz
South West	Najafgarh	Najafgarh Town	22.92	22.99	23.66	23.29	Pz
South East	Defence Colony	Nangli Rajapur Pz	4.50	3.44	9.75	4	Pz
North West	Kanjhwaria	Nizampur EW	7.29	7.41	7.15	7.37	Pz
Nazul Land	Nazul Land	Nizamuddin Bridge 1 Pz	4.59	NA	4.45	4.75	Pz
Nazul Land	Nazul Land	Nizamuddin Bridge 2 Pz	4.61	NA	5.08	5.35	Pz
South West	Najafgarh	Ojwah Pz	NA	15.04	15.8	14.97	Pz
South West	Dwarka	Palam Signal Camp Pz	56.92	55.61	NA	NA	Pz
North	Alipur	Palla Temple	11.64	7.15	9.37	8.48	Pz
North	Alipur	Palla Zero RD	11.56	11.02	11.13	8.98	Pz
West	Punjabi Bagh	Peeragarhi DW	10.76	8.64	9.02	8.99	DW
West	Punjabi Bagh	Peeragarhi Pz	6.51	5.75	6.32	NA	Pz
West	Patel Nagar	PUSA (NRL) Pz	28.65	28.5	30.36	NA	Pz
New Delhi	Delhi Cantonment	Pusa Institute (WTC)	26.43	25.6	NA	30.12	Pz
South	Hauz Khas	Pusp Vihar Pz	53.60	53.25	53.78	52.83	Pz
North	Narela	Qatlupur Pz	4.44	NA	2.05	1.78	Pz
Central	Kotwali	Rajghat Pz	NA	NA	NA	1.59	DW
North West	Rohini	Rani Khera DW	3.47	0.3	2.15	1.34	DW
South West	Kapeshera	Raota	NA	NA	2.2	2.59	DW
North West	Rohini	Rohini Sec 11 Pz	8.30	7.2	7.22	6.05	Pz
North	Alipur	Rohini Sector 28	7.94	6.65	7.94	6.2	Pz
New Delhi	Chanakyapuri	Safdarjung tomb	18.45	15	16.3	14.97	DW
New Delhi	Delhi Cantonment	Shekhwati Line Pz	47.32	48.07	47.53	46.97	Pz
South West	Kapeshera	Shikarpur Deep Pz	10.92	10.78	10.81	10.15	Pz
South West	Kapeshera	Shikarpur Shallow Pz	10.52	9.11	10.52	10.1	Pz
New Delhi	Chanakyapuri	Shram Shakti Bhawan 2	13.07	12.9	12.73	12.5	Pz
New Delhi	Chanakyapuri	Shram Shakti Bhawan 3	14.00	13.2	NA	NA	Pz
North	Alipur	Singhola Pz	21.58	20.2	21.51	NA	Pz
New Delhi	Vasant Vihar	Sultanpur IMS Pz	60.47	60.61	61.78	61.93	Pz
New Delhi	Chanakyapuri	Sunder Nursery Pz	8.11	7.79	8.15	8.24	Pz
South West	Najafgarh	Surheda TW	NA	11.19	13.13	13.02	Pz
West	Rajouri Garden	Tagore Garden Pz	15.72	15.51	15.68	15.22	Pz
North	Alipur	Tiggipur Deep Pz	11.55	10.35	10.1	8.62	Pz
North	Alipur	Tiggipur Shallow Pz	9.74	8.19	8.37	8.5	Pz
North East	Seelam Pur	Ushmanpur Pz	6.87	0.73	2.16	3.3	Pz
West	Patel Nagar	Vikashpuri Pz	16.41	14.73	15.22	13.27	Pz

ANNEXURE : IIIB - DECADAL MEAN WATER LEVEL DATA

List of NHS/ monitoring wells monitored during 2008-17 and Decadal mean				
	Decadal Mean Water Level in m bgl			
SITE_NAME	DM(2008-17)May	DM(2008-17)AUG	DM (2008-17)NOV	DM (2009-18)Jan
Asola Pz	50.81	48.48	47.56	48.09
Auchandi Pz	3.47	NA	1.85	2.37
Bakoli	9.49	10.7	9.51	9.41
Bakoli Deep Pz	9.54	10.95	9.6	9.54
Balbir Nagar DW	24.14	15.75	17.52	20.7
Bankner Pz	16.47	18.08	17.65	17.4
Baprola Dw	4.44	3.31	2.98	3.04
Barwala Pz	6.09	5.68	5.63	5.88
Bawana DW New	NA	NA	NA	6.05
Bhalaswa Lake Pz	2.14	1.5	1.48	1.51
Bhatti Pz	47.72	44.53	44.7	46.22
Birla Mandir DW	10.98	7.49	7.68	8.23
Burari Augur Pz	3.75	NA	NA	3.18
Burari Pz	3.94	3.04	2.88	NA
CBD Shahdara	NA	9.31	9.47	9.42
Chhawla Pz	15.1	13.96	13.92	13.63
Chilla Regulator	8.55	8.18	8.09	8.18
Chilla Saroda Pz	NA	NA	8.74	8.73
Cvd Depot Cant (Deep)	21.55	20.77	19.45	21.13
Daryapur Khurd	NA	NA	3.91	4.78
Daulatpur Pz	16.89	15.91	NA	16.77
Delhi College of Enginnerring	5.94	5.51	5.3	5.64
Dewarala Pz	2.35	NA	1.5	1.47
Dwarka S-16 (TP)	17.56	17.81	17.87	18
Gadaipur Pz	56.53	56	55.99	56
Gazi Pur Crossing	17.6	18.5	17.25	17.6
Haiderpur Pz	10.33	10.18	10	10
Hareoli DW	4.59	3.8	2.79	3.38
Hauz Khas Pz	35.15	35.18	34.88	34.73
Hiran Kudna DW	2.88	2.13	2.33	2.66
Humayu Tomb DW	6.87	6.25	6.2	6.33
India Gate Pz	7.1	5.96	6.22	6.35
ISBT (Kasmiri Gate) DW	2.99	1.62	2.45	NA
J N U Pz (Downstream)	27.9	26.85	26.49	26.34
J N U Pz (Upstream)	34.28	31.38	31.81	32.89
Jagatpur Pz 1	2.64	1.78	2.06	2.13
Jagatpur Pz 2	2.18	1.46	1.65	NA
Jaitpur Khadar RD3500 Pz	NA	4.7	5.3	5.97
Jamali Kamali DW	29.29	27.61	27.58	27.56
Janakpuri Pz	11.39	11.03	10.99	11.07
Jaunapur DJB TW	53.73	53.03	53.09	53.52
Jaunti DW	12.81	12.43	12.24	12.19
Jharoda Kalan Pz	15.21	14.83	14.64	14.69
Jheel Khoh DW	NA	50.86	51.84	51.42

Jhuljhuli Dw	2.61	1.26	2.2	2.25
Kabul Line Pz	26.38	26.4	26.27	26.52
Kanjhawala Pz	2.27	1	1.24	1.38
Khera Kalan Pz	NA	NA	NA	5.77
Kingsway Camp Police Ground	6.58	6.09	6.22	6.94
Lodhi Garden (D)	9.31	8.77	8.57	8.37
Lodhi Garden.(SH)	9.21	8.33	8.37	8.35
Lodhi Graden Dw	12.51	12.6	11.86	11.61
Mahabir Vansth.	25.63	25.49	25.91	25.83
Majara Dabas	NA	2.58	2.95	3.28
Majnu Ka Tila DW	9.03	7.82	8	7.97
Mandela Khurd Pz	13.79	13.97	NA	NA
Mangolpur Pz	3.91	3.09	2.91	3.18
Mayapuri Pz	34.78	34.87	35.09	34.8
Mayur Vihar B Block Ph II	6.73	6.49	6.87	6.83
Najafgarh Town	19.53	19.66	19.21	19.31
Nangli Rajapur Pz	3.7	2.56	2.87	3.03
Nizampur EW	8.45	7.44	7.32	7.59
Nizamuddin Bridge 1 Pz	4.44	NA	3.37	3.54
Nizamuddin Bridge 2 Pz	4.33	NA	3.23	3.42
Palam Signal Camp Pz	55.04	55.52	NA	NA
Ojwah Pz	NA	16.27	15.92	16.17
Palla Temple	6.9	5.98	6.17	6.43
Palla Zero RD	8.17	8.52	7.87	7.9
Peeragarhi DW	7.22	8.4	8.3	8.85
Peeragarhi Pz	5.64	4.79	4.73	NA
PUSA (NRL) Pz	20.1	19.99	20.19	20.43
Pusa Institute (WTC)	19.39	19.84	NA	19.14
Pusp Vihar Pz	63.81	63.86	63.14	62.54
Qatlupur Pz	2.45	NA	1.58	1.64
Rajghat Pz	NA	NA	NA	1.59
Rani Khera DW	3.11	2.14	2.35	2.69
Raota Pz	NA	NA	2.2	2.29
Rohini Sec 11 Pz	6.22	5.65	5.59	5.62
Rohini Sector 28	5.17	4.51	4.58	4.86
Safdarjung tomb	16.25	15.37	15.39	14.58
Shekhwati Line Pz	41.91	39.54	39.47	40.21
Shikarpur Deep Pz	13.56	13.12	12.37	12.13
Shikarpur Shallow Pz	12.5	12.81	11.76	11.39
Shram Shakti Bhawan 2	14.22	12.22	12.81	12.92
Shram Shakti Bhawan 3	15.22	14.15	NA	NA
Singhola Pz	13.68	13.86	13.66	NA
Sultanpur IMS Pz	52.23	52.05	52.71	52.98
Sunder Nursery Pz	7.88	7.43	7.29	7.31
Tagore Garden Pz	10.18	9.62	9.37	9.78
Tiggipur Deep Pz	8.08	8.37	7.92	7.9
Tiggipur Shallow Pz	7.41	7.33	7.11	6.95
Ushmanpur Pz	4.56	2.88	3.11	3.94
Vikashpuri Pz	12.93	12.99	13.24	13.05

ANNEXURE : IV LIST OF GROUNDWATER SAMPLES & CHEMICAL ANALYSIS : MAY 2018

Location	EC* in µS/cm at 25^0 C	CO_3	HCO_3	Cl^*	SO_4	NO_3^*	F^*	PO_4	Ca^*	Mg^*	Na*	K*	SiO_2	TH *as $CaCO_3$
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Ashok Vihar P-II	1118	62	276	104	156	20	1.10	<0.1	16	19	145	174	18	120
Asola	699	37	139	104	27	12	0.39	<0.1	20	24	103	1.30	18	150
Bakoli	4152	BDL	201	924	609	0.34	0.22	<0.1	116	126	615	24	21	811
Balbir nagar	285	38	63	20	BDL	4.90	0.23	<0.1	28	15	9	2	22	130
Bapraula	3267	50	390	702	229	28	1.00	<0.1	32	88	570	20	20	440
Barwala	7125	BDL	113	2279	208	102	0.08	<0.1	681	350	275	10	19	3145
Bhatti mines	638	BDL	377	69	0	15	0.45	<0.1	32	29	92	3	17	200
Birla mandir	667	25	113	83	106	0.59	0.33	<0.1	56	17	74	1.7	23	210
Burari	1547	BDL	151	334	197	5.80	0.16	<0.1	96	44	177	22	25	420
Chilla regulator	623	37	113	104	23	5.5	0.29	<0.1	24	24	79	7.6	21	160
Daulatpur	5540	BDL	239	1841	BDL	55	1.60	<0.1	281	326	320	5.50	27	2042
Delhi College of Eng.	678	50	113	21	141	3.10	0.51	<0.1	24	22	95	1.10	25	150
Dwarka sect-12	13520	BDL	126	5218	BDL	58	0.08	<0.1	581	579	1800	35	21	3833
Gadaipur	853	62	214	77	BDL	89	1.00	<0.1	20	20	152	4.60	20	133
Gazipur crossing	2130	37	76	389	397	22	0.33	<0.1	57	72	320	9	23	439
Haiderpur	560	BDL	151	94	BDL	6.30	1.00	<0.1	57	27	9	<1.0	24	255
Hareoli	2700	BDL	86	645	516	48	0.58	<0.1	86	132	355	10	27	756
Hirankudna	6550	BDL	352	1716	480	200	0.35	<0.1	180	203	950	21	22	1286
Humayan tomb	2550	86	440	299	325	84	1.40	<0.1	20	42	427	180	25	225
India gate	2390	49	189	368	371	155	1.50	<0.1	33	37	470	17	22	235

Location	EC* in µS/cm at 25^0 C	CO_3	HCO_3	Cl^*	SO_4	NO_3^*	F^*	PO_4	Ca^*	Mg^*	Na*	K*	SiO_2	TH *as $CaCO_3$
Jagatpur-2	903	BDL	176	160	BDL	195	0.26	<0.1	57	35	77	44	21	286
Janakpuri	12860	BDL	214	1091	4451	132	0.31	<0.1	262	399	1795	70	29	2297
Jaunapur	50	164	195	167	61	0.51	<0.05	<0.1	24	47	210	24	23	255
Jautni	3080	BDL	151	618	437	195	0.13	<0.1	139	104	370	72	23	776
Jharoda kalan	12600	BDL	151	1945	3326	27	0.51	<0.1	315	489	1735	20	21	2797
Jheel Khoh	685	37	189	69	49	48	1.10	<0.1	20	17	124	22	14	123
Jhuljhuli	6010	BDL	478	1500	516	7.50	1.30	<0.1	65	139	1085	50	23	735
Kanjhawala	1774	74	276	174	239	62	2.50	<0.1	16	50	115	320	19	245
Kingsway Camp	2580	50	164	521	299	38	3.10	<0.1	41	30	498	13	20	225
Lodhi Garden	653	BDL	113	90	72	43	0.32	<0.1	73	17	29	3.90	22	255
Madanpur khadar	1063	49	113	146	168	1.38	0.21	<0.1	45	27	154	2.80	18	225
Mahabir Vansthali	634	50	76	97	25	6.80	1.00	<0.1	24	12	92	1.70	26	112
Majnu ka tilla	1457	37	139	236	228	62	1.90	<0.1	41	25	270	18	21	204
Majradabas	2020	BDL	239	299	360	82	1.00	<0.1	74	60	287	35	22	429
Mangolpuri	576	BDL	176	77	41	4.40	0.93	<0.1	57	22	33	3	18	235
Mayur vihar ph-I	2200	99	201	299	253	217	1.20	<0.1	65	72	345	3	27	459
Najafgarh	4430	BDL	189	945	658	97	1.30	<0.1	78	181	640	<1.0	23	939
Nangli Rajpura	1392	BDL	264	264	74	77	0.61	<0.1	53	27	230	2.5	21	245
Nangloi	1072	37	139	153	139	45	1.70	<0.1	37	40	152	6	23	255
Narela	3340	BDL	139	716	380	200	0.44	<0.1	180	241	105	7	21	1439
Nizampur	4120	124	528	813	234	80	2.30	<0.1	24	129	710	25	24	592
Nizamuddin bridge	740	37	113	118	27	31	0.59	<0.1	24	25	90	9	23	163
Ojwah	5110	86	301	1244	350	56	1.20	<0.1	24	149	860	27	21	674

Location	EC* in µS/cm at 25^0 C	CO_3	HCO_3	Cl^*	SO_4	NO_3^*	F^*	PO_4	Ca^*	Mg^*	Na*	K*	SiO_2	TH *as $CaCO_3$
Palam Signal Camp	2060	62	264	465	69	6	0.45	<0.1	16	22	430	18	19	133
Palla RDO	1558	BDL	189	236	322	1.29	0.43	<0.1	45	42	255	13	25	286
Palla temple	761	BDL	139	132	99	<0.2	0.78	<0.1	61	32	53	1.20	21	286
Peera garhi	5010	BDL	226	1299	473	45	1.70	<0.1	127	233	619	15	18	1276
PUSA (NRL)	1650	62	251	382	BDL	11	0.62	<0.1	29	59	252	18	15	316
Rani Khera	7610	BDL	101	1932	856	194	0.27	<0.1	397	327	690	130	23	2338
Rohini sec-11	698	37	139	69	61	9.9	1.52	<0.1	41	25	57	6.30	14	204
Rohini sec-28	2180	74	314	257	333	5.60	2.04	<0.1	20	42	415	8	19	225
Safderjung Tomb	1642	BDL	189	354	171	24	0.39	<0.1	45	109	243	1.20	21	337
Sainik vihar	22600	BDL	139	7087	1167	28	1.17	<0.1	507	499	3703	2	25	3318
Shekawati Lines	1700	BDL	176	403	126	38	0.16	<0.1	45	47	260	4	26	306
Sultanpur	643	62	251	35	BDL	13	0.00	<0.1	8	27	101	2	22	133
Tagore garden	9270	BDL	126	1133	2723	140	2.20	<0.1	397	312	1168	20	16	2276
Tiggipur	1751	BDL	176	403	227	0.79	0.56	<0.1	65	30	305	5	24	286
Tikri Kalan	6780	37	25	2001	366	170	0.95	<0.1	298	213	880	12	22	1623
Vikaspuri	1124	37	201	160	84	39	1.34	<0.1	21	27	186	5	18	163
Shikarpur	620	50	251	42	BDL	12	0.27	<0.1	12	17	111	2	16	102
Mubarakpur	624	37	164	42	27	40	0.59	<0.1	24	35	50	<1.0	23	204

REFERENCE

[1] District Census Hand Book - 2019, Directorate of Economics & Statistics, Government of NCT, Delhi

[2] Census of India Report -2011; District Census Handbook, Directorate of Census Operations, Delhi

[3] GSI Study Report : Kachroo and Baghchi,1999.

[4] Jayant K. Tripathi & V. Rajmani : 'Weathering control over geomorphology of Supermature Proterozoic Delhi Quartzites of India' Earth Surface Processes & Landforms – Vol 28, Issue 13, Dec 2003.

[5] GSI Study Reports : Naha et.al 1944 & 1987; Roy 1988 ; Gangopadhyay and Sen, 1968)

[6] GSI Study Report : Srivastava et al. (1980)

[7] NAQUIM Report – "Aquifer Mapping and Groundwater Management Plan of Delhi", CGWB, SUO, New Delhi , 2016.

[8] Freeze R A & Cherry J A, "Groundwater", Textbook ; 1979 Prentice Hall Inc .