BEFORE THE NATIONAL GREEN TRIBUNAL

PRINCIPAL BENCH, NEW DELHI

ORIGINAL APPLICATION NO. 134/2015

IN THE MATTER OF:-

FRIENDS THROUGH ITS GENERAL SECRETARY **APPLICANT**

VS.

MINISTRY OF WATER RESOURCES **RESPONDENT**

INDEX

(DIVYA SINHA)
SCIENTIST 'E'
CENTRAL POLLUTION CONTROL BOARD
PARIVESH BHAWAN EAST ARJUN NAGAR
DELHI - 110032

PLACE: DELHI
DATED: 31.10.2019

STATUS OF AVAILABILITY OF GROUND WATER AND ITS USAGE IN 24 CITIES

AS PER DIRECTIONS OF

HON'BLE NATIONAL GREEN TRIBUNAL

(ORDER DATED 23TH SEPTEMBER, 2019)

IN THE MATTER OF

ORIGINAL APPLICATION NO. 134/2015

TITLED;

FRIEND THROUGH ITS GENERAL SECRETARY

V/S

MINISTRY OF WATER RESOURCES

REPORT IN COMPLIANCE TO THE HON'BLE NGT PRINCIPAL BENCH ORDER DATED 23.09.2019 IN THE MATTER OF O.A. NO. 134/2015 TITLED; FRIEND THROUGH ITS GENERAL SECRETARY V/S MINISTRY OF WATER RESOURCES

1.0 BACKGROUND

Hon'ble National Green Tribunal vide its Order dated 20.05.2019 in the aforesaid matter has directed as follows:

> *"The Expert Committee constituted by this Tribunal vide order dated 20.12.2018 along with Central Ground Water Authority may collect and provide data with regard to availability of ground water and its usage in 21 cities mentioned in the report of NITI Aayog and furnish a report to this Tribunal within one month by e-mail at judicial-ngt@gov.in."*

Hon'ble NGT further directed vide order dated 20.05.2019to collect and provide data with regard to availability of ground water and its usage in 21 cities mentioned in the report of NITI Aayog and furnish a report to this Tribunal within one month by e-mail at judicial-ngt@gov.in. Hon'ble NGT vide order dated 23.09.2019 has further directed as follows:

> *"With regard to the further direction requiring the Committee, along with Central Ground Water Authority (CGWA), to collect and provide data with regard to availability of groundwater and its usage in 21 cities mentioned in the report of NITI Aayog and furnish a report to this Tribunal, CPCB has, in their letter dated 01.08.2019, stated that CGWA is not furnishing the information in spite of being required to do so. Let the CGWA do the needful positively within one week failing which the Member Secretary of CGWA will be liable to pay Rs. 1 Lakh as costs. Further necessary report by the Expert Committee be furnished to this Tribunal within one month."*

2.0 COMPLIANCE TO DIRECTIONS

In compliance to directions issued by Hon'ble NGT vide order dated 23.09.2019, CGWA shared the required information with CPCB vide email dated 28.09.2019. Meeting of Expert Committee along with representative of CGWA was held on 17.10.2019. Expert Committee examined NITI Aayog report *"Composite Water*

Management Index: A tool for water Management" and find out that NITI Aayog has mentioned about 21 cities in report and source of which is findings of World bank report titled "*UN Water, 'Managing water under uncertainty and risk', 2010*and findings are published in Hindustan Times. Source reference in Niti Aayog report is attached at **Annexure-I**. Source reference given in NITI Aayog report is not verifiable, so expert Committee analysed CGWB report of 24 cities which was published by CGWB in response to NITI Aayog report. Detail report of CGWB attached at **Annexure –II**.

3.0 OBSERVATIONS

The information shared by CGWA was examined by the Expert Committee and following observations are made:

3.1 Status of Ground Water Extraction

a. Fourteen cities have Stage of Ground Water Extraction (SGE*) greater than 100 %; eight cities have SGE between 70-90% and only one city, namely Agra, has SGE between 90-100%. Details of SGE for 24 cities is given in Table 1.

*Stage of Ground Water Extraction (%) = $\frac{\text{Existing gross ground water extraction for all uses} \times 100}{\text{Annual Extractable Ground Water Resources}}$

Table 1: Details of Stage of Ground Water Extraction of 24 cities

S.no	Name of City	Stage of Ground Water Extraction
1.	Jalandhar	(472 %)
2.	Amritsar	(363 %)
3.	Delhi	(360%)
4.	Patiala	(312 %)
5.	Gurugram	(300 %)
6.	Hyderabad	(294 %)
7.	Ludhiana	(290%)
8.	Faridabad	(269%)
9.	Ghaziabad	(245%)
10.	Bikaner	(239%)
11.	Mohali	(212 %)
12.	Bengaluru	(141 %)

S.no	Name of City	Stage of Ground Water Extraction
13.	Chennai	(100%)
SGE between 90 and 100		
1	Agra	
SGE between 70 and 90		
1	Jaipur	(90%)
2	Gandhinagar	(88 %)
3	Jodhpur	(87%)
4	Indore	(84%)
5	Ratlam	(77%)
6	Jaisalmer	(74%)
7	Yamunanagar	(74%)
8	Ambala	(72%)

b. Only Velloreand Ajmer has less than 70 % stage of ground water extraction.

3.2 Status of Demand/Supply of Ground and Surface Water in 24 Cities

The demand for water supply has been assessed vis-à-vis the supply for water in the CGWA report and it has been fourteen cities in 2021 and 2041 shall have adequate water supply and their shall be no gap in demand vis-à-vis supply. The details of these cities is mentioned in table 2.

Table 2: Details of cities having no gap in demand vis-à-vis supply in 2021 and 2041

S. No	Cities having no Gap in Water Supply and demand in 2021	Cities having no Gap in Water Supply and demand in 2041
1	Gandhinagar	Gandhinagar
2	Ambala	Ambala
3	Faridabad	Faridabad
4	Yamunanagar	Yamunanagar
5	Indore	Indore
6	Ratlam	Ratlam
7	Amritsar	Amritsar

S. No	Cities having no Gap in Water Supply and demand in 2021	Cities having no Gap in Water Supply and demand in 2041
8	Jalandhar	Jalandhar
9	Ludhiana	Patiala
10	Bikaner	Ludhiana
11	Chennai	Chennai
12	Vellore	Vellore
13	Ajmer	Hyderabad- nil (2035)
14	Ghaziabad	Bikaner

Further ten cities shall face shortage in supply vis-à-vis demand of water in 2021 as well as 2041. The name of these cities as well as gap in the supply vis-à-vis demand is given in table 3.

Table 3: Details of cities having gap in demand vis-à-vis supply in 2021 and 2041

Sl. No	2021		2041	
	City	Gap (MCM)	City	Gap (MCM)
1	Delhi	370	Delhi	964
2	Bengaluru	217	Bengaluru	518
3	Gurugram	55	Ghaziabad	280
4	Agra	55	Agra	221
5	Jodhpur	45	Jaipur	186
6	Hyderabad	75	Jodhpur	113
7	Jaipur	35	Gurugram	55
8	Patiala	6	Mohali	14
9	Mohali	2	Ajmer	6
10	Jaisalmer	1	Jaisalmer	1

3.3 Cities dependencyon Ground and Surface Water

a. Ajmer is the only city which has been projected to be dependent on surface water in year 2021.However, in the year 2041 five cities, in addition to Ajmer namely Gurugram, Indore, Hyderabad, Amritsar and Bikaner shall be dependent on surface water

b. Six cities have been projected to be dependent on ground water in year 2021 However, only three cities have been projected to be dependent on ground water in year 2041. Details of these cities are mentioned in table 4.

Table 4: Details of cities having dependency on groundwater in year 2021 and 2041

S.no	Ground water dependent cities in year 2021	Ground water dependent cities in year 2041
1	Amritsar	Jalandhar
2	Jalandhar	Faridabad
3	Patiala	Yamuna Nagar
4	Ludhiana	
5	Faridabad	
6	Yamunanagar	

c. 13 Cities have been projected to be dependent on both (surface water and ground water) in the year 2021 and 15 Cities are projected to be dependent on both (surface water and ground water) in the year 2041. The name of these cities along with the percentage of surface water in the total water supply is given in the table 5

Table 5: Details of city having dependency on groundwater and surface water

S.no	2021		2041	
	City	% of Surface Water	City	% of Surface Water
1	Vellore	97	Vellore	97
2	Agra	96	Agra	96

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S.no	2021		2041	
	City	% of Surface Water	City	% of Surface Water
3	Bengaluru	94	Ludhiana	96
4	Jaisalmer	93	Bengaluru	94
5	Delhi	91	Ambala	94
6	Ratlam	91	Jaisalmer	93
7	Chennai	89	Delhi	To increase from 91
8	Jodhpur	88	Ratlam	91
9	Ambala	84	Chennai	89
10	Jaipur	83	Jodhpur	88
11	Gandhinagar	77	Gandhinagar	86
12	Mohali	60	Jaipur	83
13	Ghaziabad	29	Patiala	76
14			Mohali	60
15			Ghaziabad	27

It is observed that as per the information compiled in this section that dependency of the cities on surface water is increasing and at the same time the dependency of cities on Ground water is decreasing in the coming years possibly because of very high Stage of Ground Water Extraction(SGE) which is currently more than 70% in all 24 cities.

(Divya Sinha) Additional Director, CPCB	(P. Rajesh) Scientist 'E', Head FAD, BIS	(Y P Singh) Scientist E, MoEF&CC	(Pawan Labhasetwar) Principal Scientist, NEERI

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Annexure I

सत्यमेव जयते

NITI Aayog

COMPOSITE WATER MANAGEMENT INDEX

A TOOL FOR WATER MANAGEMENT

JUNE 2018

IN ASSOCIATION WITH

MINISTRY OF WATER RESOURCES
GOVERNMENT OF INDIA

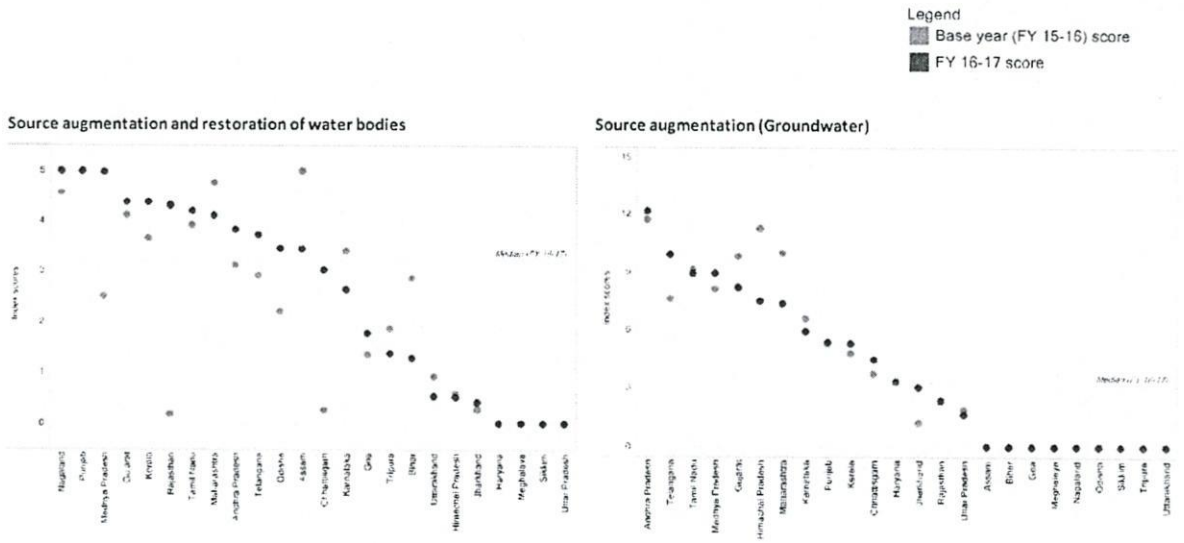
MINISTRY OF DRINKING WATER & SANITATION
GOVERNMENT OF INDIA

MINISTRY OF RURAL DEVELOPMENT
GOVERNMENT OF INDIA

(19)

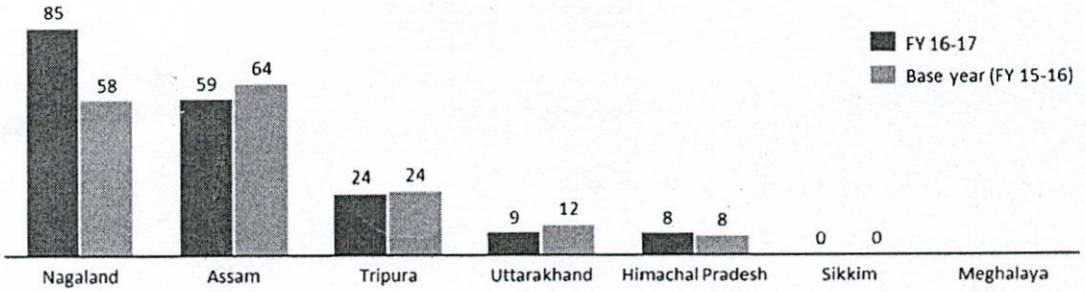
Significant improvements are required in states' performance across critical indicator themes. The performance of states has varied widely at the level of the nine indicator themes. Most of the states have done well in the infrastructure-heavy themes of 'Major and medium irrigation' and 'Watershed development' and have also enacted policies corresponding to the recommendations within the 'Policy and governance' theme. However, the critical themes of 'Source augmentation (Groundwater), 'Sustainable on-farm water use practices', and 'Rural drinking water' are lagging behind (*Figure 5*). Most states have achieved less than 50% of the total score in the augmentation of groundwater resources, highlighting the growing national crisis—54% of India's groundwater wells are declining, and 21 major cities are expected to run out of groundwater as soon as 2020, affecting ~100 million people[10]. Further, 70% of states have also achieved scores of less than 50% on managing on-farm water effectively. Given the fact that agriculture accounts for 80% of all water use[11], this underperformance, as discussed in the analysis of low performers above, poses significant water and food security risks for the country. Finally, states have also performed averagely on providing safe drinking water to rural areas. With 800 million people, or ~70% of the country's population, living in rural areas, and about two lakh people in the country dying each year due to a lack of access to safe water[12], this is one of the most critical service delivery challenges in the world. Performance across each of these themes, as well as indicator-level analyses, are explored further in the *'Results and commentary'* section of the report.

Figure 5: State performance across indicator themes
Index scores (Base year (FY 15-16), FY 16-17)



10 Source: WRI; World Bank (Hindustan Times, The Hindu)
11 Source: National Commission for integrated Water Resource Development, MoWR
12 Source: WHO Global Health Observatory; 2011 Census of India

Figure 40: Indicator 1: Area irrigated by water bodies restored during the given FY as compared to the irrigation potential area of total number of water bodies identified for restoration—North-Eastern and Himalayan states
In % (Base year (FY 15-16), FY 16-17)



Overall, states have displayed excellent performance on this indicator, with the median state restoring ~60% of the possible irrigation potential of identified water bodies. ~70% of Non-Himalayan states have restored more than 50% of the area, while several North-Eastern and Himalayan states are lagging behind. Punjab, Madhya Pradesh, Kerala, Gujarat, and Rajasthan have been the top performers, achieving more than 80%. Rajasthan has also experienced the largest improvement from base year (FY 15-16) to FY 16-17, increasing the percentage of area restored by a substantial amount, from 3% to 81%. The achievements on this theme, though, are dependent on the area covered by water bodies identified for restoration by states, and care needs to be taken that these are reported exhaustively.

State governments can boost restoration and irrigation potential by deeply engaging community organizations and NGOs in the restoration process and providing adequate financing. Madhya Pradesh and Rajasthan have benefited from community galvanization, led by local officers and NGOs, for the restoration of traditional water bodies such as farm ponds and tanks. Since 2006, farmers in the Dewas district of Madhya Pradesh have constructed 8000 ponds, thereby creating an irrigation potential of 40,000 hectares. These have been enabled by loans obtained through banks, such as NABARD, with the help of NGOs and government officers[61].

Theme: Source augmentation (Groundwater)

Indicator 2: Percentage of overexploited and critical assessment units that have experienced a rise in water table to total number of assessment units in pre-monsoon current FY in comparison to pre-monsoon previous FY

Indicator 2 measures the percentage of overexploited and critical groundwater units that have experienced a rise in water table levels as compared to the previous year. This indicator warrants special attention given the fact that 54% of India's groundwater wells are decreasing in levels and 21 major cities across the country are expected to run out of groundwater by 2020[62]. Eight states—Odisha, Bihar, Goa,

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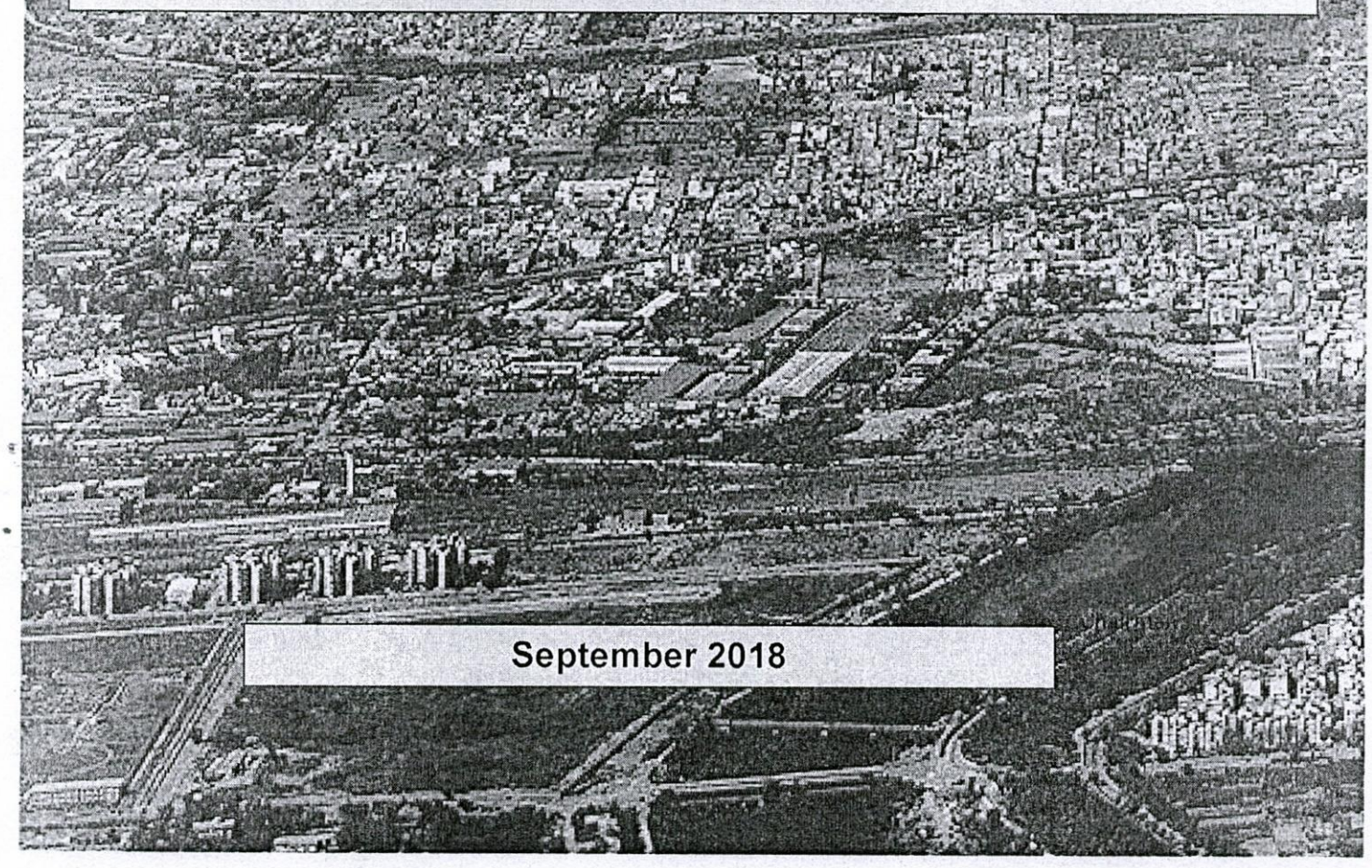
61 Source: A Decision Made 10 Years Ago by Farmers in a Small MP Village Is Helping Them Tackle Drought Today, Nivedita Khandekar, June 15, 2016, accessed at : http://www.thebetterindia.com/58237/farm-ponds-dewas-tackle-drought/

62 Source: UN Water, 'Managing water under uncertainty and risk', 2010; World Bank (Hindustan Times, The Hindu)

Annexure-II

Government of India
Ministry of Water Resources, RD & GR
Central Ground Water Board

GROUNDWATER RESOURCES vs DOMESTIC WATER DEMAND AND SUPPLY FOR SELECT CITIES IN INDIA



September 2018

Government of India
Ministry of Water Resources, RD & GR
Central Ground Water Board

GROUNDWATER RESOURCES vs DOMESTIC WATER DEMAND AND SUPPLY FOR SELECT CITIES IN INDIA

September 2018

GROUNDWATER RESOURCES vs DOMESTIC WATER DEMAND AND SUPPLY FOR SELECT CITIES IN INDIA

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GROUNDWATER RESOURCES VS DOMESTIC WATER DEMAND AND SUPPLY FOR SELECT CITIES IN INDIA

1.0 INTRODUCTION

In NITI Aayog report entitled "Composite Water management Index –A Tool for water management" it has been mentioned that 21 cities across India are expected to run out of water by 2020. In this connection, CGWB was entrusted to study the groundwater situation in 24 cities (Anenxure-1) and a committee was constituted vide L.NoNo.95/TC/Chmn/CGWB/2016-17-4533 dated 27.07.2018to study the groundwater situation and submit a report (Annexure-2).

The committee obtained information from the Regional Offices on groundwater situations along with demand vis-à-vis supply in 2018 and projected demand and supply for 2021, 2031 & 2041. The data on water demand and supply were collected by CGWB Regional offices from respective State agencies and the methodology adopted for the analysis of the same has been enumerated below.

1. The Demand & supply from surface water & groundwater sources in 2018 and projected Demand & supply from surface water & groundwater sources for 2021, 2031 & 2041 were obtained from the concerned State Agencies. In the absence of data on projected supply for the subsequent years, data for the year 2018 has also been considered for subsequent years.
2. The demand & supply data obtained for 2018, 2021, 2031 & 2041 have been linearly distributed for arriving at the demand and supply figures for the intervening years.
3. The groundwater resources as in 2017 was worked out for each city, using GEC-2015 methodology for determination of annual replenishable and in-storage resources in the aquifer. As the NITI Aayog report mentions about drying up of cities, an exercise has been made by CGWB to assess the in-storage resources of the aquifer (if dewatered) to find about the total availability. However, for any policy decision, annual replenishable resources are only to be considered. Use of in-storage resources, which means mining of ground water, may lead to serious, undesirable consequences and hence it is advocated not to use the in-storage resources.
4. The groundwater resources as assessed in 2017 has been considered as annual groundwater availability for subsequent years of projected demand.
5. The Gap between demand and total supply for domestic purposes has been worked out for each year
6. An attempt was initially made to find out the availability of groundwater to meet the proposed water supply from the annual replenishable resources and if found inadequate, the available in-storage resource has been considered. In case, the total in-storage resource is also found inadequate, the balance available replenishable resources is shown as only available resources every year for the subsequent years.
7. Subsequently, an attempt was made to find out the possibility of groundwater meeting the Gap between Demand and supply. In this attempt, initially only annual replenishable resources were considered and if found inadequate, the available in-storage resource has been considered. In case, the total in-storage is also found inadequate, the balance available replenishable resources will be the only available groundwater resources every year.

The location of 24 cities identified by NITI Aayog is presented as Fig.1. It has been observed that cities from Punjab, Haryana, Gujarat and some cities in Rajasthan have alluvial aquifer, while the cities in southern States have hard crystalline aquifers. In general alluvial aquifers have good yield potential and groundwater augmentation can be successful, while in crystalline aquifers, the presence of fracture pattern defines the yield potential and the success of groundwater augmentation is limited.

Vital Statistics, summary of groundwater system and Demand vis-à-vis Supply for each city has been described in succeeding sections.

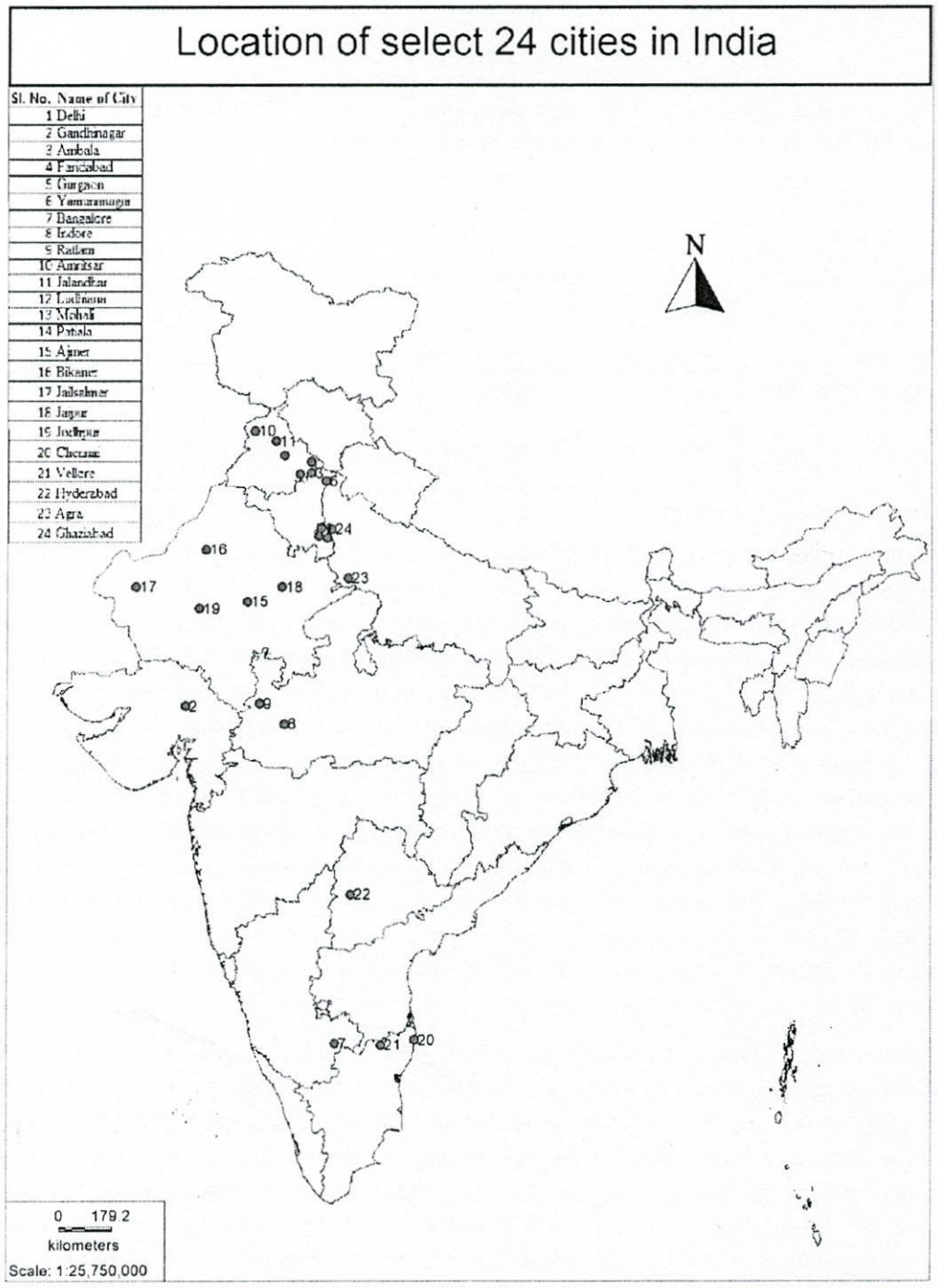

Fig 1

Groundwater Resources Vs Domestic Water Demand and Supply for select cities in India

2.0 CITY WISE DEMAND VIS-À-VIS SUPPLY

2.1 Delhi

The National Capital Territory (NCT) of Delhi, covering an area of 1483 sq.km, 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. NCT of Delhi is divided in 11 Revenue District and 1 non-revenue unit along river Yamuna. The 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.

2.1.1. Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	Population 2018	Population 2021	Population 2031	Population 2041	Normal Annual Rainfall (mm)
1483	16787941	2.12	19279271	20346984	23906028	27465071	747.1

2.1.2 Groundwater System

The shallow groundwater in the NCT Delhi originates from a combination of rainfall, river/canal water and irrigation return flows. Groundwater in the deeper aquifers is mostly recharged as a result of leakage from the upper unconfined aquifer and partly from lateral flow from the north. Its geology and physiography controls nature of occurrence and movement of groundwater. There are four main hydrogeological units i.e. (i) Wide spread alluvial plains to the west of the ridge covering almost $^{2}/_{3}^{rd}$ areas of NCT Delhi. The aquifer is under unconfined to semi-confined conditions. (ii) Narrow strips of areas on either side of Yamuna River, in forms of flood plain and river terrace deposit, which is invariably on east of the ridge, mainly between the ridge and the Yamuna River and east of the Yamuna river. The aquifers here are under both unconfined and semi-confined conditions but have high potential. (iii) Small alluvial basin of Chhattarpur in South district, which is enclosed within rocky surroundings of the Delhi ridge. The basin acts as a single aquifer under unconfined groundwater conditions. (iv) Weathered and dissected rocks of ridges, at places covered by highly permeable regolith and sandy soils. Groundwater occur mainly in unconfined conditions. At shallow depth it has moderate to high potential whereas deeper zones have poor potential.

The water table slopes away from the ridge on both sides. The water table is relatively shallower in northern and northwestern parts and deeper levels exist in the southern parts. The southwestern part of the NCT has a large groundwater trough at Najafgarh Block. The alignment of the Delhi Branch of the Western Yamuna Canal acts as a groundwater ridge diverting the flow of water to the south-west and east towards the Yamuna. In NCT Delhi, in general, the fresh water sediments, consisting predominantly sand with thin clay zones in between, have limited thickness and are followed by sediments predominant with clay and kankars, having saline groundwater. 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 upto the bedrock. The hard rock (quartzite) area is represented by weathered/ fractured/ jointed quartzite, which forms potential aquifer with potable water. At a few locations, saline ground water is present at a very shallow depth range.

In aquifer group I (older Alluvium), the discharge varies from 8 to 35 m^3/hr with a drawdown of 6 to 24 m. In aquifer group II (younger Alluvium), the discharge varies from 100 to 310 m^3/hr with a

drawdown of 5 to 11 m. In aquifer group III (Chhatarpur basin Alluvium), the discharge varies from 7 to 314 m^3/hr with a drawdown of 12 to 20m whereas in aquifer group IV (Quartzite-Ridge Rocks), the discharge varies from 4 to 31 m^3/hr with a drawdown of 2 to 20 m.

The groundwater resources has been assessed down to a depth of 75m bgl. The annual replenishable resources has been assessed as in 2017 as 340 M.Cu.m and in-storage as 1080 M.Cu.m and total storage as 1420 M.Cu.m.

The decadal water level fluctuation from 2008 to 2017 with respect to Premonsoon 2018 for 83 wells analysed in NCT Delhi shows that 44 wells have shown fall in water level in the range of 0-4 m and 19 well show fall of >4m. In 18 wells, there is a rise in water level within the range of 0-4 m and 2 wells show a rise of >4m.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
83	15	18	3	4	2	2	22	27	22	27	19	23	20	**24**	63	**76**

2.1.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	1892.00	1382.00	133.00	1515.00	9%	377.00
2021	2289.00	1747.00	173.00	1920.00	9%	369.00
2031	2665.00	1797.00	178.00	1975.00	9%	690.00
2041	2993.00	1847.00	183.00	2030.00	9%	963.00

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.1.1.

2.1.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 1892 M.Cum in 2018 to 2993 M.Cum in 2041, while there is an increase in surface water supply to meet the demand from 1382 to 1847M.Cum & groundwater supply from 133 to 183 M.Cu.m respectively from 2018 to 2041(Fig 2.1.1). The share of groundwater in water supply has been provided by State Government agency 09 % as in 2018. The total supply to meet the demand would be increased from 1515 to 2030 M.Cum from 2018 to 2041, there by resulting in a gap of 377 M.Cum in 2018 & increasing to 963 M.Cum in 2041

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is sufficient to meet the proposed water supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that even the in-

storage groundwater resources are likely to be used up by the year 2022 and thereafter only annual replenishable resources would be available every year.

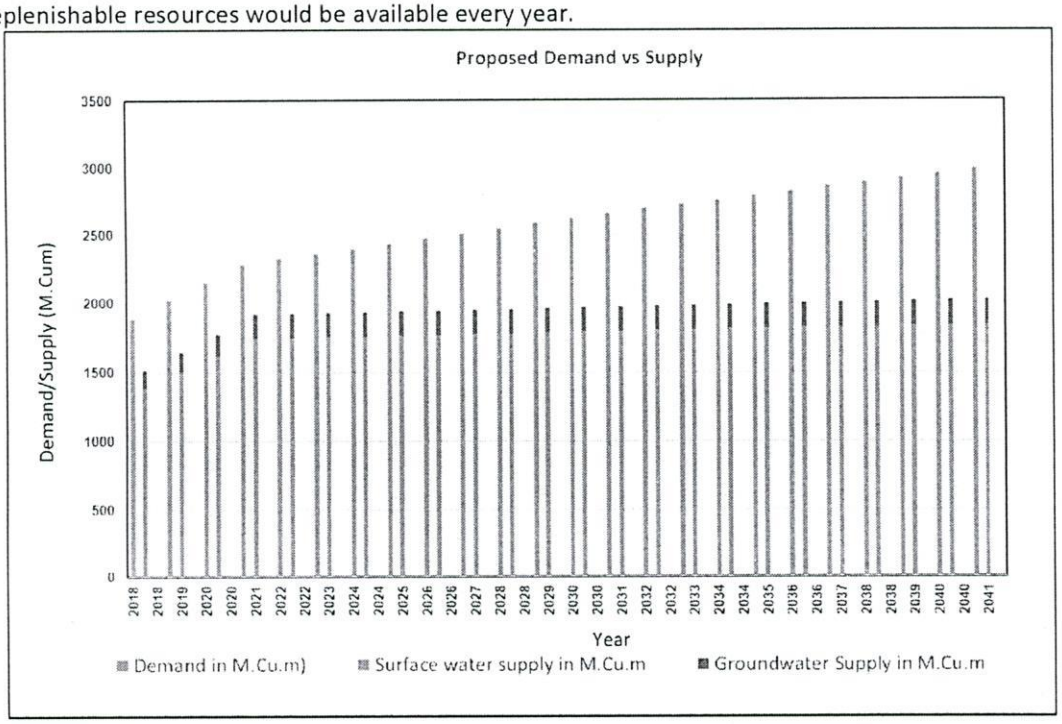

Fig 2.1.1

2.1.5 Conclusion

- **Demand**: Demand has been assessed as 1892 M.Cu.m in 2018, 2289 M.Cu.m in 2021, 2665 M.Cu.m in 2031 & 2993M.Cu.m in 2041
- **Total Supply:** Total Supply has been assessed as 1515 M.Cu.m in 2018, 1920 M.Cu.m in 2021, 1975 M.Cu.m in 2031 & 2030M.Cu.m in 2041 and the share of GW in water supply is 09%.
- **Gap:** The Gap has been assessed as 377 M.Cu.m in 2018, 369 M.Cu.m in 2021, 690 M.Cu.m in 2031 & 963M.Cu.m in 2041
- **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic)as in 2017 is 340 M.Cu.m and in-storage is 1080M.Cu.m with a total of 1420M.Cu.m
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 9% and it can be met from the annual replenishable resources.
    - If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2022 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
- **Recommendations:**
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.2 Gandhinagar

Gandhinagar the Capital City of Gujarat is situated on the western bank of river Sabarmati. The area of the city is 57.38 Sq Km. Gandhinagar has a tropical monsoon climate, which is hot and dry, except

in the rainy season. Summer days are very hot with mean maximum temperature of 41.3°C while, nights are pleasant. The mean maximum and minimum temperatures in winter are 30°C and 15.4°C respectively. The average annual rainfall of the area is 805 mm, although there is a considerable variation from year to year. It occurs generally during the months of June to September. The average relative humidity is 60% with a maximum of 80% to 90% during the rainy season.

The area as a whole, in general monotonously flat except few mildly undulating topography. The average elevation of the city area is about 81m a msl.

2.2.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	Population 2018	Population 2021	Population 2031	Population 2041	Normal Annual Rainfall (mm)
57.38	292797		3,26,013	3,40,547	4,87,606	5,95,356	805

2.2.2 Groundwater System

Gandhinagar is part of Cambay basin and North Gujarat alluvial Plain. The Quaternary Alluvium comprising silt, sand, clay, gravel and kankar occupy the area. The Tertiary sediments followed by Deccan trap and Himatnagar Sandstone underlie the quaternary alluvium. Based on the studies carried out by CGWB a multiple aquifer system has been delineated in the area.

Ground water exploration in the city has been carried out down to a depth 210m. Based on Exploration two main aquifers are identified. The shallow aquifer down to about 70mbgl depth is unconfined in nature and most of the dug wells and shallow tube wells tap this aquifer. The deeper aquifer occurring below 70mbgl is further subdivided into Semi-confined Aquifer (100 to 130 mbgl) and Confined Aquifer (145 to 210 mbgl) up to the explored depth of 210 mbgl.

The depth to water level during the Pre-monsoon period 2018 (May 2018) is about 50 mbgl in the unconfined aquifer, about 80 mbgl in the semi-confined aquifer and about 108 mbgl in the confined aquifer.

The decadal mean water level fluctuation in deeper aquifers from 2008 to 2017 with respect to Pre-monsoon 2018 for 2 wells in the city of Gandhinagar shows a fall in the range of 0.38m to 5.7m.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
2	-	-	-	-	-	-	1	50	-	-	1	50	-	-	2	100

The groundwater resources has been assessed down to a depth of 210m bgl. The annual replenishable resources has been assessed as in 2017 as 6.34 M.Cu.m and in-storage as 239.09M.Cu.m and total storage as 245.43 M.Cu.m.

2.2.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	23.00	16.43	5.11	21.54	24%	1.46
2021	24.18	21.90	8.03	29.93	27%	0.00
2031	30.70	32.85	0.00	32.85	0%	0.00
2041	37.48	40.15	0.00	40.15	0%	0.00

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.2.1.

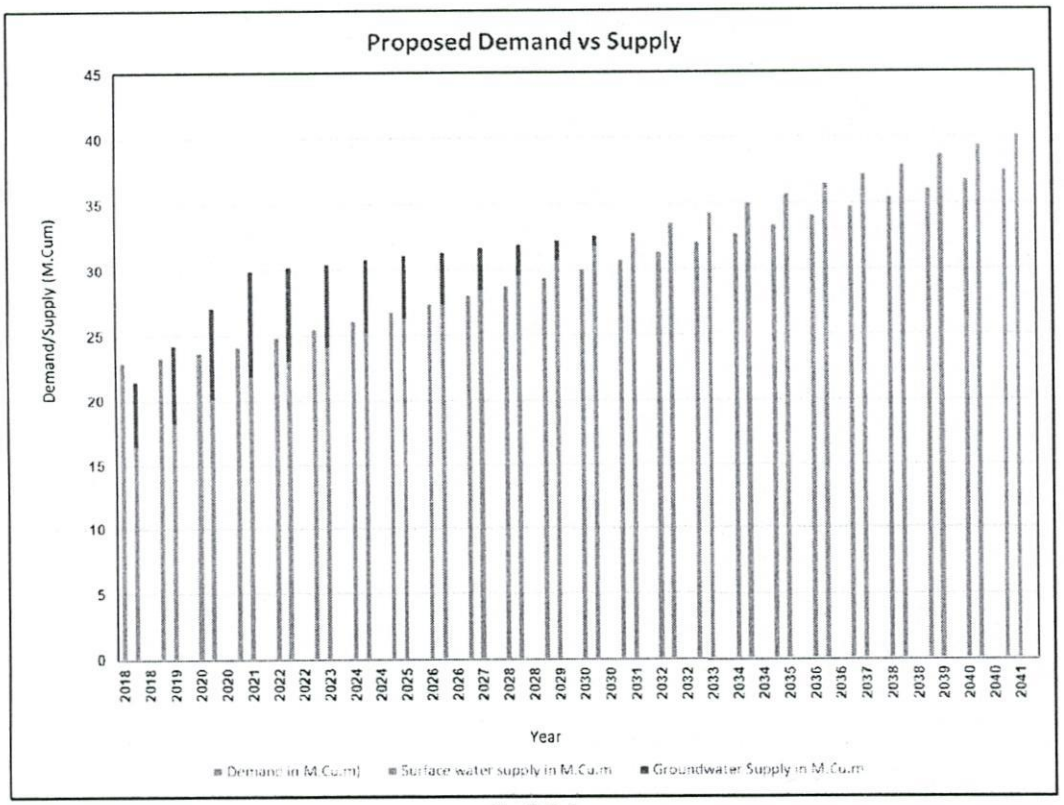

Fig 2.2.1

2.2.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 23 M.Cum in 2018 to 37.48 M.Cum in 2041 (Fig 2.2.1). There is an increase in surface water supply to meet the demand from 16.43 to 40.15 M.Cum in 2018 to 2041 & increase in groundwater supply from 5.11 to 8.03 M.Cu.m from 2018 to 2021. In 2031 and 2041 the entire proposed demand is to be met by surface water sources only. The share of groundwater in water supply has been provided by State Government agency as 24 % in 2018 and 27% in 2021 which reduces to nil in 2031 & 2041. The total supply to meet

the demand has increased from 21.54 to 40.15 M.Cum from 2018 to 2041, there by resulting in a gap of 1.46 M.Cum in 2018 only

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is sufficient to meet the proposed water supply in 2018 but not in 2021, where the in-storage would have to be utilised to meet the proposed supply from ground water sources. It is seen that after 2018 there will be no gap between demand and supply as the supply from surface water is proposed to increase as per the information received from the State Agencies.

2.2.5 Conclusion

- Demand: Demand has been assessed as 23 M.Cu.m in 2018, 24.18 M.Cu.m in 2021, 30.70 M.Cu.m in 2031 & 37.48 M.Cu.m in 2041.
- Total Supply: Total Supply has been assessed as 21.54 M.Cu.m in 2018, 29.93 M.Cu.m in 2021, 32.85 M.Cu.m in 2031 & 40.15 M.Cu.m in 2041 and the share of GW in water supply is 24% in 2018 and 27% in 2021 and becomes nil in 2031 & 2041.
- Gap: The Gap has been assessed, as 1.46 M.Cu.m in 2018and there is no gap afterwards.
- Groundwater Availability: The annual replenishable groundwater resources (Dynamic)as in 2017 is 6.34 M.Cu.m and in-storage is 239.09 M.Cu.m with a total of 245.43 M.Cu.m
    - As per the water supply plan of State Agencies, the share of GW in water supply is 24% in 2018 which can be met from replenishable groundwater resources but the share will be increased to 27% in 2021 which cannot be met solely from replenishable groundwater resources but to be supplemented from available ground water in-storage.
    - It is seen that after 2018 there will be no gap between demand and supply as the supply from surface water is subjected to increase as per the information received from the State Agencies.
- Recommendations:
- It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.3 Ambala

Ambala is a municipal corporation in Ambala district in the state of Haryana with a total geographical area of the Ambala town as 42.34 sq.km. It is located on Sher Shah Suri Marg (NH-I), around 45 km from the State capital Chandigarh. It is bordered with Patiala district of Punjab in its western side.

2.3.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	Population 2018	Populatio n 2021	Population 2031	Population 2041	Normal Annual Rainfall (mm)
42.34	355497	1.123	3,26,013	413118	440797	490299	946

2.3.2 Groundwater System

In the Ambala city area, the underlying sediments are dominantly unconsolidated in nature and constituted of fine to medium grained sands, clays, silts and kankar with occasional gravels. The clays are usually brown to yellowish in colour and sticky to silty in nature. The sands are mostly fine grained, hence it becomes very difficult to develop wells giving sand free water with conventional well design. Thick layers of clay occur at site Race Course (Ambala cantt.) and the maximum thickness of clay is

172m. The maximum thickness of sand is 82m at site Ambala (Premnagar). The principal ground water reservoir in the area is unconsolidated alluvial deposits of Quaternary age.
The ground water exploration carried out by the Central ground water Board in Ambala City and cantonment Board has revealed the presence of three Aquifer Groups down to a depth of 450m. The aquifer group I consisting of coarser sediments extending upto 167 m depth and is underlain by a10-15 m clay bed. The aquifer group II occurs at the depths ranging between 65 to 294 m with varying thickness of 26-152m. This aquifer group consist of comparatively less coarser material than first aquifer group and further characterized by presence of Kankar. Fine sandy beds alternating with thick clay beds exist between 180 and 205 m depth characterize the Aquifer Group III. There are about 7 major tappable zones encountered upto a depth of 350m. The shallow tubewells down to 40 m depth yield 1.6 to 10 lps for a moderate drawdown of 6m. Deep tubewells constructed to a depth of 150 m yield upto 33 to 50 lps for 6 to 10m drawdown. However, further deeper tubewells tapping aquifer zones between150 m to 400 m depth, yield ranges from 4.1 to 54 lps for a drawdown ranging from 2.84 to 12.93 m.

The groundwater resources has been assessed down to a depth of 300m bgl. The annual replenishable resources has been assessed as in 2017 as 7.68 M.Cu.m and in-storage as 329.38 M.Cu.m and total storage as 337.06 M.Cu.m.

The average depth to water levels in May 2018 is 2.39m bgl, while the depth to water level in Piezometer of CGWB tapping deeper aquifers has been recorded as 51.34 m gl at Ambala City during pre-monsoon 2017.The Mean [Pre monsoon) (2008 to 2017)] water level is of the order of 5.24 bgl. The water level fluctuation with respect to mean is given below.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
4	-	-	-	-	-	-	2	50	1	25	1	25			4	100

2.3.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	17.32	14.35	2.97	17.32	17%	0.00
2021	17.82	15.68	2.14	17.82	12%	0.00
2031	22.90	21.28	1.61	22.89	7%	0.01
2041	27.25	20.70	1.56	22.26	7%	4.99

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.3.1.

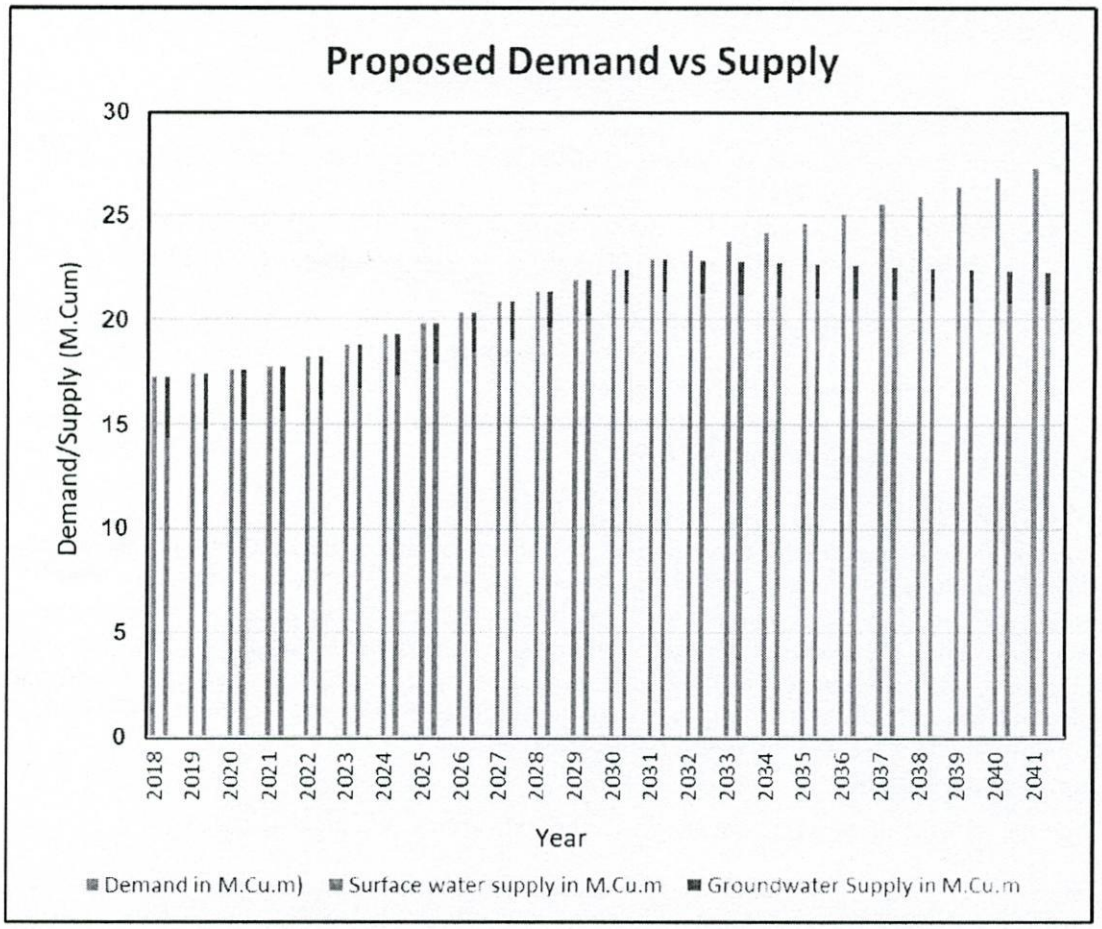

Fig 2.3.1

2.3.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 17.32 M.Cum in 2018 to 27.25 M.Cum in 2041 (Fig 2.3.1).There is an increase in surface water supply to meet the demand from 14.35 to 20.70 M.Cum from 2018 to 2041 & ground water supply decreases from 2.97 to 1.56 M.Cu.m from 2018 to 2041. The share of groundwater in water supply has been provided by State Government agency 17 % as in 2018 which reduces to 7% in 2041. The total supply to meet the demand has increased from 17.32 to 22.26 M.Cum from 2018 to 2041, there by resulting in an increase in gap from nil in 2018 to 4.99 M.Cu.m in 2041.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is sufficient to meet the proposed water supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the annual replenishable groundwater resources will be able to meet the gap.

2.3.5 Conclusion

- Demand: Demand has been assessed as 17.32 M.Cu.m in 2018, 17.82 M.Cu.m in 2021, 22.90 M.Cu.m in 2031 & 27.25 M.Cu.m in 2041.
- Total Supply: Total Supply has been assessed as 17.32 M.Cu.m in 2018, 17.82 M.Cu.m in 2021, 22.89 M.Cu.m in 2031 & 22.26 M.Cu.m in 2041.

- Gap: The Gap has been assessed as nil 2018 and 2021. It increases from 0.01 M.Cu.m in 2031 to 4.99 M.Cu.m in 2041.
- **Groundwater Availability** : The annual replenishable resources has been assessed as in 2017 as 7.68 M.Cu.m and in-storage as 329.38 M.Cu.m and total storage as 337.06 M.Cu.m.
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 17% in 2018 and decreased to 7 % and it can be met from the annual replenishable ground water resources.
    - The annual replenishable resources will be able to meet the envisaged gap between demand and supply in 2041.

2.4 Faridabad

Faridabad is located on south-eastern part of the state of Haryana. In the north, it is bordered by the Union Territory of Delhi, in the east by Uttar Pradesh, in the North West by Mewat and in the West by Gurgaon district. Total Geographical area of Faridabad district is 2151 sq. km, out of which Faridabad City cover about 208 sq.km area between the Aravali hills and River Yamuna of Haryana State. It is situated about 30 km south of Delhi .The city area has been divided into 3 zones namely NIT Faridabad, Old Faridabad and Ballabhgarh. Faridabad city is the headquarter of the district. There is rapid increase in industrialization in area surrounding Faridabad Urban area.

2.4.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2018	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
208	1438855	6.94	2137851	2438000	3886407	4703580	542

2.4.2 Groundwater System

Ground Water occurs in unconfined conditions in alluvium as well as in weathered and jointed quartzites. In alluvium, sand of various grades form the potential aquifer zones. In quartzite, it occurs in the weathered zones and inter spaces within interconnected joints and fractures.
The study in the area suggests the total thickness of unconfined aquifer is limited to about 50 m. The thickness of fresh aquifer is confined to 50m. Beyond 80m formations are mainly clayey and quality of water is marginal to saline. The depth to bedrock in the west as deciphered from the drilling data is within 170 m bgl while in the east near the River Yamuna it is more than 350 m bgl. The thickness of second aquifer is highly variable and increases from west to east. In general, 6-14 granular zones mainly comprise fine sand, silt, clay and kankar. The discharge of successful exploratory wells varies between 3.3 lps and 110 lps with draw down of 2-12m. It is observed that the discharge from the tube wells located closer to the canal is more in comparison to the rest. The water table has been found deeper along the National Highway No 2, indicating that ground water stressed area has been formed traversing North-South due to heavy pumping along the highway caused by dense network of tube wells due to concentration of habitation and industries.

The groundwater resources has been assessed down to a depth of 120m bgl. The annual replenishable resources has been assessed as in 2017 as 30.88 M.Cu.m and in-storage as 299.52 M.Cu.m and total storage as 330.40 M.Cu.m.

The average depth to water levels in May 2018 is 25.92m bgl. The long-term behaviour of ground water levels shows the declining trend in water levels. The mean [Pre monsoon) (2008 to 2017)]

water level is of the order of 26.98 m bgl. The water level fluctuation with respect to mean is given below.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
2	-	-	-	-	-	-	-	-	-	-	2	100	-	-	2	100

2.4.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	84.68	0.00	84.68	84.68	100%	0.00
2021	89.42	0.00	84.68	84.68	100%	4.74
2031	109.50	54.75	54.75	109.50	50%	0.00
2041	145.27	72.27	73.00	145.27	50%	0.00

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.4.1.

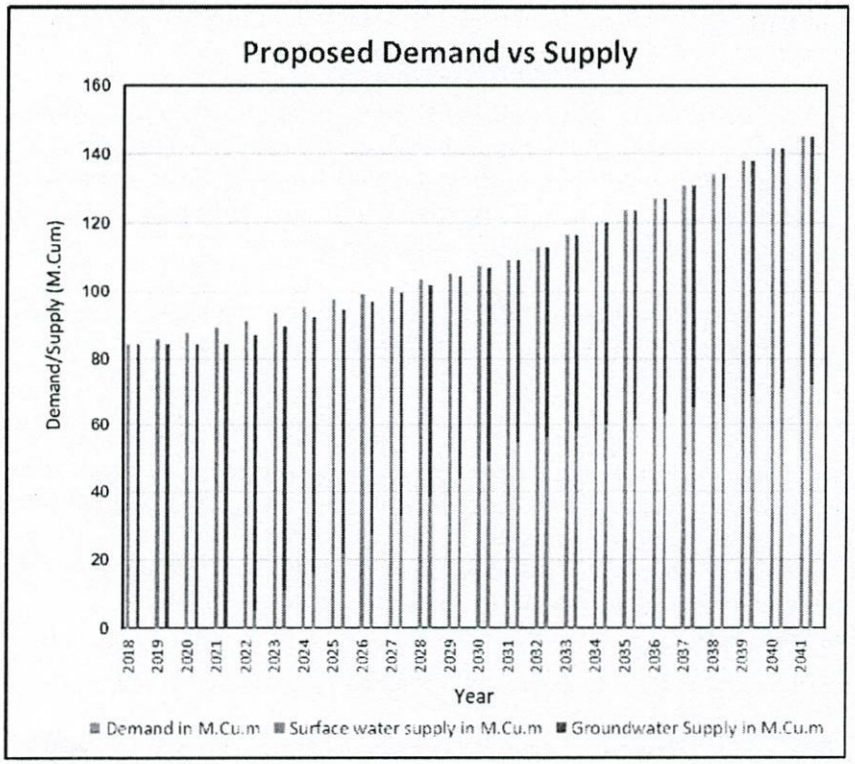

Fig 2.4.1

Groundwater Resources Vs Domestic Water Demand and Supply for select cities in India

2.4.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 84.68 M.Cum in 2018 to 145.27 M.Cum in 2041 (Fig 2.4.1). There is no surface water supply to meet the demand in 2018 & 2021, while it is of the order of 54.75 M.Cu.m in 2031 & 72.27 M.Cu.m in 2041. However, the ground water supply will decrease from 84.68 to 73.00 M.Cu.m from 2018 to 2041. The share of groundwater in water supply has been provided by State Government agency 100% as in 2018, which will become 50% by 2031. Overall, the total supply to meet the demand has increased from 84.68 to 145.27 M.Cum from 2018 to 2041, for all the years and the gap is nil, except for the year 2021, which is 4.74 M.Cu.m

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is not sufficient to meet the proposed water supply and even if available in-storage is used, the resources is likely to be used up by 2022 and thereafter only annual replenishable resource will be available every year.

2.4.5 Conclusion

- **Demand**: Demand has been assessed as 84.68 M.Cu.m in 2018, 89.42 M.Cu.m in 2021, 109.5 M.Cu.m in 2031 & 145.27 M.Cu.m in 2041
- **Total Supply:** Total Supply has been assessed as 84.68 M.Cu.m in 2018 & 2021, 109.5 M.Cu.m in 2031 & 145.27 M.Cu.m in 2041 and the share of GW in water supply is 100% in 2018 & 2021, while it has been envisaged to be reduced to 50% in 2031 & 2041.
- **Gap:** For all the years and the gap is nil, except for the year 2021, which is 4.74 M.Cu.m .
- **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic) as in 2017 is 30.88 M.Cu.m and in-storage resource is 299.52 M.Cu.m with a total of 330.40 M.Cu.m.
    - As per the water supply plan of State Agencies, the share of GW in water supply is 100% in 2018 & 2021, it has been envisaged to be reduced to 50% in 2031 & 2041 and it cannot be met from the annual replenishable resources and even if available in-storage is used, the resources is likely to be used up by 2022 and only annual replenishable resource will be available every year.
- **Recommendations:**
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.5 Gurugram

Gurugram is one of the industrial and financial city of Haryana state, which is located in the National Capital Region (NCR), very near to New Delhi and is an important centre of trade and commerce in Haryana State. It is the district head quarter of Gurugram district. Gurugram city covers an area of about 370 Sq.km. The rapid urbanization and population growth has resulted in the expansion of city boundaries. Gurugram is located around 20 miles south-west of New Delhi.

2.5.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2018	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
370	1514432	4.41	1981937	2183000	2852000	3520400	596

2.5.2 Groundwater System

The major part of Gurugram district is underlain by Quaternary alluvium consisting of sand, clay and silt. The quartzite ridge trending NNE-SSW is located about 7 km east of town in which ground water occurs in fractures, joints and crevices. Sandy layers at various depth form major water bearing horizons above the crystalline basement. Ground water in the Gurugram block occurs in unconfined and semiconfined condition. The upper zone of saturation consists of fine sand with silt varying from place to place.

As per studies carried out under NAQUIM Programme of CGWB, four aquifer groups has been delineated in Gurugram area. The Aquifer Group I, extends up to a depth of 120 m and is composed of relatively coarser sediments, and is subdivided into two subgroups at places by occurrence of a sub-regional clay. It is underlain by a regionally extensive clayey horizon (aquitard) of about 10 to 145 m thick in the Jhajjar-Rewari-Gurgaon Tract with its depth of occurrence between 23 and 176 m bgl in this area. This group occurs under unconfined to semi-confined conditions. The Aquifer Group II, consists of numerous sand and clay lenses occurring at variable depths ranging from 45 m to 186 m. The sediments of this group are coarse and are occasionally mixed with 'kankar'. Ground water occurs under semi-confined to confined conditions. Another regionally extensive clayey horizon (aquitard) of 7 to 114 m thick underlies this aquifer with its depth to occurrence between 76 and 250 m bgl. The Aquifer Group III comprises of thin sand layers alternating with thicker clay layers occurring at variable depths ranging from 101 to 217 m bgl. The granular material of this group is generally finer in texture with kankar. This aquifer is underlain by a thick clayey horizon (aquitard) of 9 to 76 m thick in this area with a depth of occurrence between 108 and 265 m bgl. In this aquifer group, ground water normally occurs under confined conditions. The Aquifer Group IV occurs between 168 to 282 m bgl under confined conditions with thick clayey layer occurring below this aquifer group. The groundwater resources has been assessed down to a depth of 300m bgl. The annual replenishable resources has been assessed as in 2017 as 34.81 M.Cu.m and in-storage resources as 2539.81 M.Cu.m and total storage as 2574.62 M.Cu.m.

The pre-monsoon depth to water level ranges from 11.35 mbgl to 40.98 m bgl. During May 2017.The deeper water level is observed at Gurugram Old city. The water level ranges between 20 to 40 m in major parts of Gurugram city. During post-monsoon season of 2017, it is observed that the water levels are deeper than the pre-monsoon water levels. The fall in water level is about 0.5 m to 1.6 m. The Mean [Pre monsoon) (2008 to 2017)] water level is of the order of 35.96 m bgl. The water level fluctuation with respect to mean is given below.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
4	1	25	-	-	-	-	1	25	1	25	1	25	1	25	3	75

2.5.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies is given below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	%of GW Share in Water Supply	Gap (M.Cum)
2018	210.97	118.26	92.71	210.97	44%	0.00
2021	220.82	118.26	92.71	210.97	44%	9.85
2031	310.25	118.26	92.71	210.97	44%	99.28

Groundwater Resources Vs Domestic Water Demand and Supply for select cities in India

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	%of GW Share in Water Supply	Gap (M.Cum)
2041	365.00	118.26	92.71	210.97	44%	154.03

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.5.1.

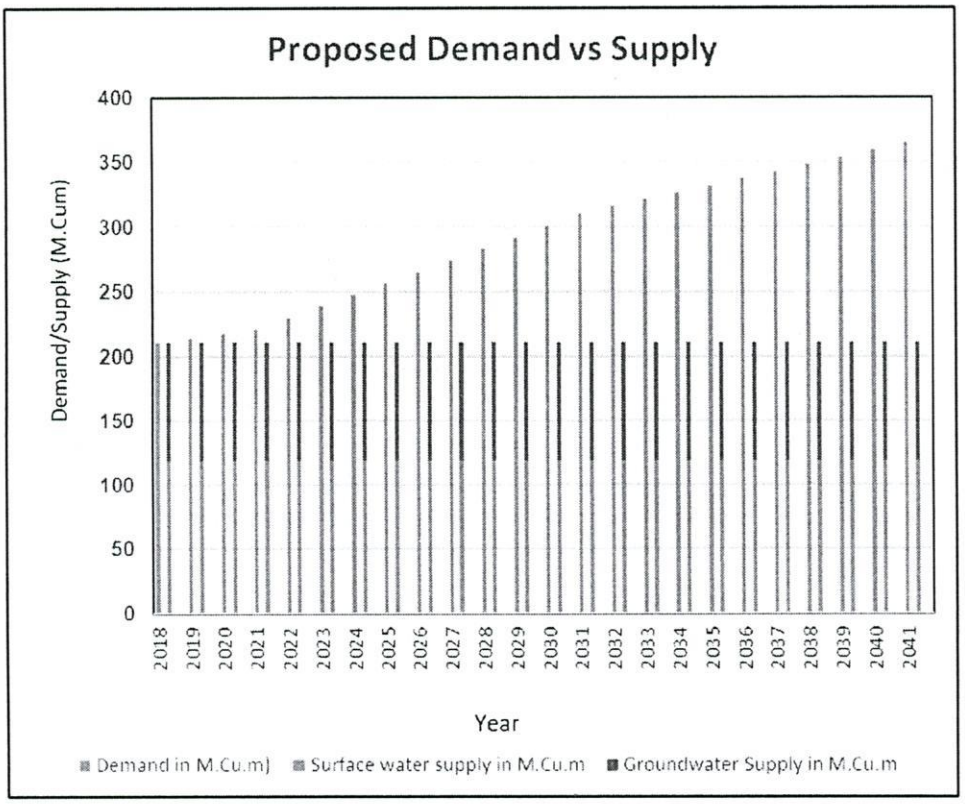

Fig 2.5.1

2.5.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 210.97 M.Cum in 2018 to 365 M.Cum in 2041, while the surface water supply & groundwater supply to meet the demand remains 118.26 and 92.71 M.Cum respectively from 2018 to 2041 (Fig 2.5.1). The share of groundwater in water supply has been provided by State Government agency as 44 % in 2018. The total supply to meet the demand remains 210.97 M.Cum from 2018 to 2041. However, the gap increases from 0 in 2018 to 154.03 M.Cum in 2041.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is not sufficient to meet the proposed water supply, the available in-storage would be able to meet the envisaged gap. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the in-storage groundwater resources are likely to be used up by the year 2038 and thereafter only annual replenishable resources would be available every year.

2.5.5 Conclusion

- **Demand:** Demand has been assessed as 210.97 M.Cu.m in 2018, 220.82 M.Cu.m in 2021, 310.25 M.Cu.m in 2031 & 365 M.Cu.m in 2041.
- **Total Supply:** Total Supply has been assessed as 210.97 M.Cu.m for 2018, 2021, 2031 & 2041 and the share of GW in water supply is 44%.
- **Gap:** The Gap has been assessed as nil in 2018, 9.85 M.Cu.m in 2021, 99.28 M.Cu.m in 2031 & 154.03 M.Cu.m in 2041.
- **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic) as in 2017 is 34.81 M.Cu.m and in-storage is 2539.81 M.Cu.m with a total of 2574.62 M.Cu.m
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 44% and it cannot be met from the annual replenishable resources. However, it can be met from the available in-storage.
    - If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2038 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
- **Recommendations:**
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.6 Yamunanagar

Yamunanagar city is the administrative headquarter of Yamunanagar district in the state of Haryana and governed by Municipal Corporation. It has the river Yamuna running through the district, and forming the eastern boundary with the neighboring district Saharanpur of Uttar Pradesh.

2.6.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2018	population 2021	populatio n 2031	population 2041	Normal Annual Rainfall (mm)
60	217000	1.36	237658	246000	281000	663000	952.2

2.6.2 Groundwater System

The major aquifer system of the Yamunanagar is alluvial deposit having older and younger alluvium, which mainly comprised of sand, silt and clay. The major lithological formations are sand & clay and silt is found admixed with gravels and kankars. Two aquifer groups have been delineated. The aquifer group I extends down to a depth of 180m bgl with a thickness of 95 to 110 m. The aquifer group II occurs at the depths of 178 to 300 m with thickness varying from 16 to 110 m .The first aquifer is water table aquifer and extends all over the area. The aquifers are mainly composed of fine to coarse-grained sand.

The groundwater resources has been assessed down to a depth of 300m bgl. The annual replenishable resources has been assessed as in 2017 as 12.04 M.Cu.m and in-storage as 964.92 M.Cu.m and total storage as 976.96 M.Cu.m.

Depth to ground water level of Yamunanagar city ranges from minimum 7.81 mbgl at Amdalpur near to the city and maximum 16.97 mbgl at Dhaurang near to the city during Pre monsoon 2018. The groundwater level is shallow in eastern part and moderately deeper in western parts of the city. The decadal fluctuation variations also replicated in the same directions. In general, the ground water table varies from 277 to 256 m amsl with ground water flow direction from northeast to southwest.

2.6.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	14.10	0.00	13.40	13.40	100%	0.70
2021	13.93	0.00	13.93	13.93	100%	Nil
2031	15.90	0.00	15.90	15.90	100%	Nil
2041	37.53	0.00	37.53	37.53	100%	Nil

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.6.1.

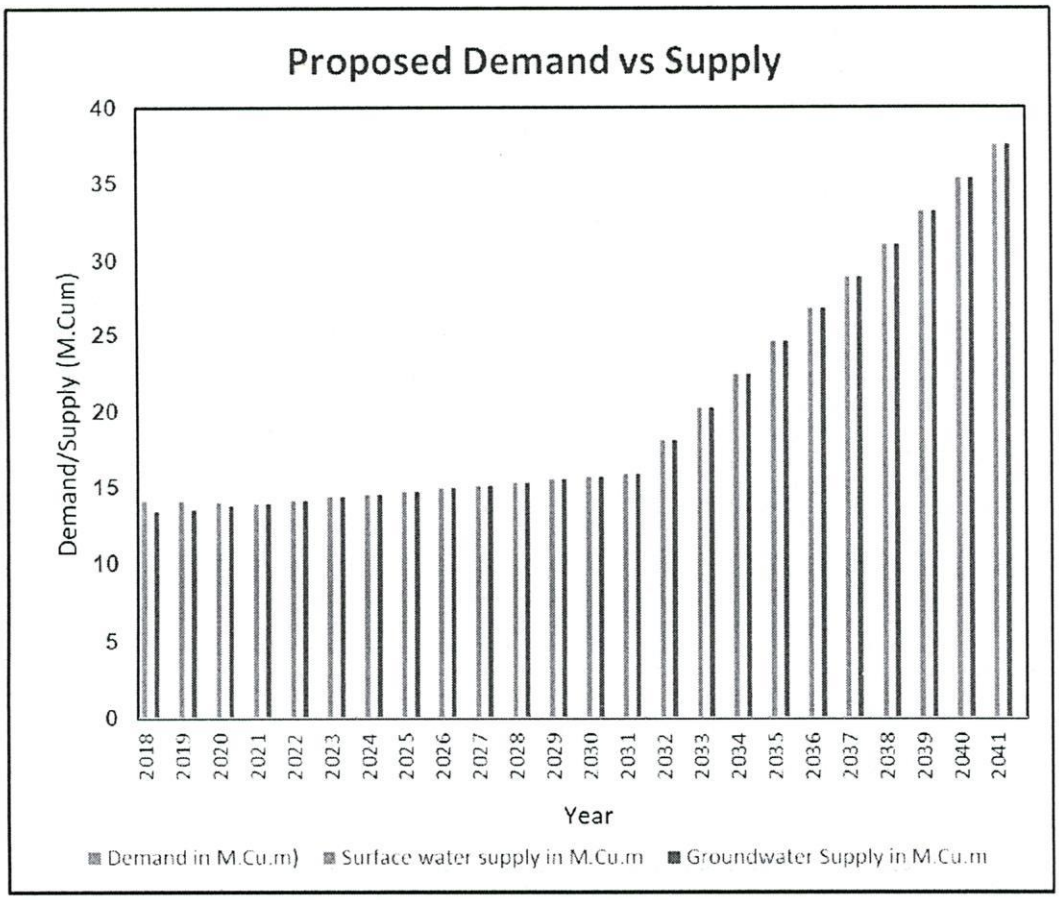

Fig 2.6.1

Groundwater Resources Vs Domestic Water Demand and Supply for select cities in India

2.6.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 14.10 M.Cum in 2018 to 37.53 M.Cum in 2041, while the surface water supply to meet the demand remains nil from 2018 to 2041(Fig 2.6.1). The share of groundwater in water supply has been provided by State Government agency 100 % as in 2018. The total supply to meet the demand increases from 13.40 M.Cum in 2018 to 37.53 M.Cum in 2041 which is only from groundwater. However, the gap decreases from 0.70 M.Cum in 2018 to nil in 2041.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is not sufficient to meet the proposed water supply , however the available in-storage can cater to the envisaged supply. Subsequently, an attempt was also made to find out whether the gap in demand and water supply can be met from available groundwater resources. It is seen that, the available ground water resources including the in-storage will be able to cater the gap.

2.6.5 Conclusion

- **Demand**: Demand has been assessed as 14.10 M.Cu.m in 2018, 13.93 M.Cu.m in 2021, 15.90 M.Cu.m in 2031 & 37.53 M.Cu.m in 2041.
- **Total Supply**: Total Supply has been assessed as 13.40 M.Cu.m in 2018, 13.93 M.Cu.m in 2021, 15.90 M.Cu.m in 2031 & 37.53 M.Cu.m in 2041 and the share of GW in water supply is 100%.
- **Gap**: The Gap has been assessed as 0.70 M.Cu.m in 2018 and is nil from 2021 to 2041.
- **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 12.04 M.Cu.m and in-storage is 964.92 M.Cu.m with a total of 976.96 M.Cu.m
  - As per the water supply plan of State Agencies, the share of groundwater in water supply is 100% and it cannot be met from the annual replenishable resources, however the available in-storage resources can meet the envisaged supply.
  - The total groundwater resources including in-storage resources will be able to meet the envisaged gap between demand and water supply.
- **Recommendations**:
  - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.7 Bangalore

Bengaluru is situated on a highland, forms a divide between the rivers Arkavathi on the west and South Pennar on the east. The local topography is characterized by a series of well defined valleys which radiate from a ridge of high ground to the north of the city and fall in a gradual manner towards wide belt of flat land extending beyond the limits of the metropolitan area to the South.The three principal valleys are known as Vrishabhavathi, Koramangala and Chellaghatta and the three valleys run generally in a north to the south direction and divide the greater part of the metropolitan area which lies to the south of the ridge into three separate and distinct drainage zones.

2.7.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	Population 2018	Population 2021	Population 2031	Population 2041	Normal Annual Rainfall (mm)
800	9621551	2.56	11345733	14241000	21080000	28330000	786-1033

Groundwater Resources Vs Domestic Water Demand and Supply for select cities in India

2.7.2 Groundwater System

In the city of Bengaluru, Granites and Gneisses of peninsular gneissic group constitute major aquifers. Ground water occurs in phreatic conditions or unconfined conditions in the weathered zone and under semi-confined to confined conditions in fractured and jointed rock formations. The occurrence of ground water, movement and recharge to aquifers are controlled by various factors like fracture pattern, degree of weathering, geomorphologic setup and amount of rainfall received. Generally, the depth of weathering varies, being more in the valley, often extending up to 30 m as observed in the dug wells. Yield of the bore wells, is found to be dependent upon factors like degree of weathering, presence of joints, fractures, and its connectivity and the presence of intrusive bodies. There are 18 monitoring wells in the city for monitoring groundwater levels. The depth to water level recorded in the Bengaluru city during pre-monsoon water level monitoring ranging from 0.56 m bgl to 16.81 m bgl for phreatic aquifers and 2.30 m bgl to 35.10 m bgl for deep aquifers.

The water level fluctuation with respect to mean is given below.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
18	4	22	1	5.5	0	0	10	56	2	11	1	5.5	5	**28**	13	**72**

The groundwater resources has been assessed down to a depth of 350m bgl. The annual replenishable resources has been assessed as in 2017 as 291.06 M.Cu.m and in-storage as 961.54M.Cu.m and total storage as 1252.60 M.Cu.m.

2.7.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	919.80	532.90	146.00	678.90	22%	240.90
2021	1029.30	815.78	109.50	925.28	12%	104.03
2031	1523.51	998.28	73.00	1071.28	7%	452.24
2041	2047.65	1279.33	36.50	1315.83	3%	731.83

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.7.1.

2.7.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 919.80 M.Cu.m in 2018 to 2047.65 M.Cu.m in 2041. The surface water supply to meet the demand is 532.90 M.Cu.m in 2018, 815.78 M.Cu.m in 2021,998.28 M.Cu.m in 2031 and 1279.33 M.Cum in 2041. However, the ground water supply will decrease from 146 to 36.50 M.Cu.m from 2018 to 2041(Fig 2.7.1). The share of groundwater in water supply has been provided by State Government agency as 22% in 2018, which

will reduce to 3% by 2041. Overall, the total supply to meet the demand has increased from 678.90 to 1315.83 M.Cu.m from 2018 to 2041. The gap is 240.9 M.Cu.m in 2018 which increases to 731.83 M.Cu.m in 2041.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is sufficient to meet the proposed water supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the in-storage groundwater resources are likely to be used up by the year 2031 and thereafter only annual replenishable resources would be available every year.

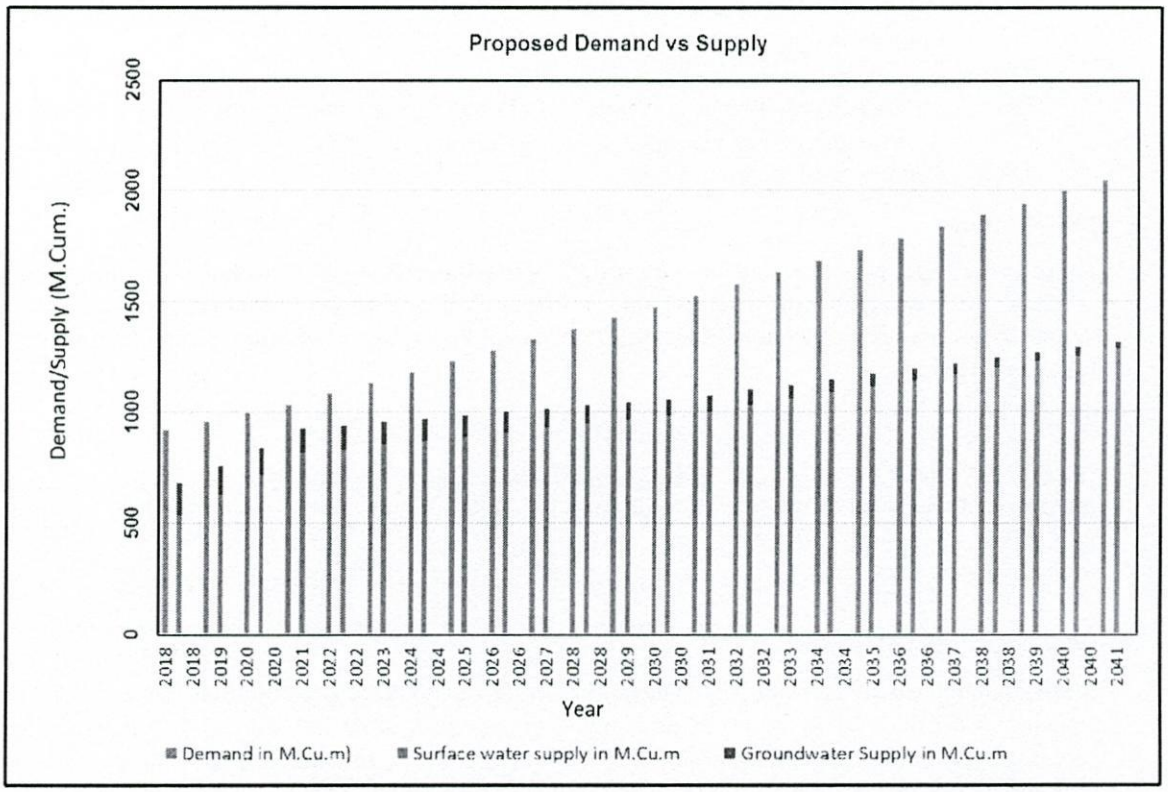

Fig 2.7.1

2.7.5 Conclusion

- **Demand**: Demand has been assessed as 919.80 M.Cu.m in 2018, 1029.30 M.Cu.m in 2021, 1523.51 M.Cu.m in 2031 & 2047.65 M.Cu.m in 2041
- Total Supply: Total Supply has been assessed as 678.90 M.Cu.m in 2018,925.28 M.Cu.m in 2021, 1071.28 M.Cu.m in 2031 & 1315.83 M.Cu.m in 2041 and the share of GW in water supply is 22% in 2018, while it has been envisaged to be reduced to 3% in 2041.
- **Gap**: The Gap has been assessed as 240.90 in 2018, 104.03 M.Cu.m in 2021, 452.24 M.Cu.m in 2031 and 731.83 M.Cu.m in 2041.
- **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 291.06 M.Cu.m and in-storage resources is 961.54 M.Cu.m with a total of 1252.60 M.Cu.m

- As per the water supply plan of State Agencies, the share of groundwater in water supply is 22% in 2018 & will be reduced to 3% in 2041 and it can be met from the annual replenishable resources.
- If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2031 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.

- **Recommendations:**
  - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.8. Indore

Indore is the most populous and the largest city in the state of Madhya Pradesh. It serves as the headquarters of both Indore District and Indore Division. It is located on the southern edge of Malwa Plateau at an average altitude of 550 m amsl. The city is 190 km west of the state capital of Bhopal.

2.8.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	Population 2018	Population 2021	Population 2031	Population 2041	Normal Annual Rainfall (mm)
276	2170295	4.02	2859807	3218750	4773707	7079853	929.1

2.8.2 Groundwater System

Three aquifers have been delineated in Indore city viz (i) Ist aquifer at a depth of 20-25 meter (ii) IInd aquifer at a depth of 60-65 meter (iii) IIIrd aquifer at the depth of 90-95 meter. The shallow aquifer occurs in weathered and jointed portion of the basalt. These form moderate to good aquifers where thickness of weathering and vesicular zones is adequate. The Deccan traps on weathering generally develop a top layer of black cotton soil. The underlying layer of weathered basalt forms a water-bearing horizon, which is tapped by most of the dugwells.

Ground water in Indore city occurs mostly under water table conditions. The extent and depth of weathering, distribution of secondary porosity in the form of fractures and joints, and the occurrence and disposition of vesicular units govern the movement of ground water. Most of the dugwell have a diameter of 2 to 10 meters and depth ranges from 4 to 20m. The yield is between 1 to 3 lps. The boreholes/tubewells are generally of 80 to 150 m depth and the potential fracture zones are very limited. In the southern, eastern and northern part of Indore City, the ground water level is around2-10 mbgl and towards the central and north-western part, the depth to water level increases from 10-15 and more than 15m bgl.

The groundwater resources has been assessed down to a depth of 150m bgl. The annual replenishable resources has been assessed as in 2017 as 46.69 M.Cu.m and in-storage as 23.85 M.Cu.m and total storage as 70.54 M.Cu.m.

There are 26 monitoring wells in the city for monitoring groundwater level. The Mean [Pre monsoon) (2008 to 2017)] water level is of the order of 10.54m bgl. The water level fluctuation with respect to mean is given below.

Groundwater Resources Vs Domestic Water Demand and Supply for select cities in India

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
26	5	19	0	0	1	4	14	54	2	8	4	15	6	23	20	77

2.8.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	167.01	65.70	14.60	80.30	18%	86.71
2021	234.97	73.95	16.43	90.38	18%	144.59
2031	348.48	109.67	24.37	134.04	18%	214.44
2041	516.83	162.65	36.14	198.79	18%	318.04

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.8.1.

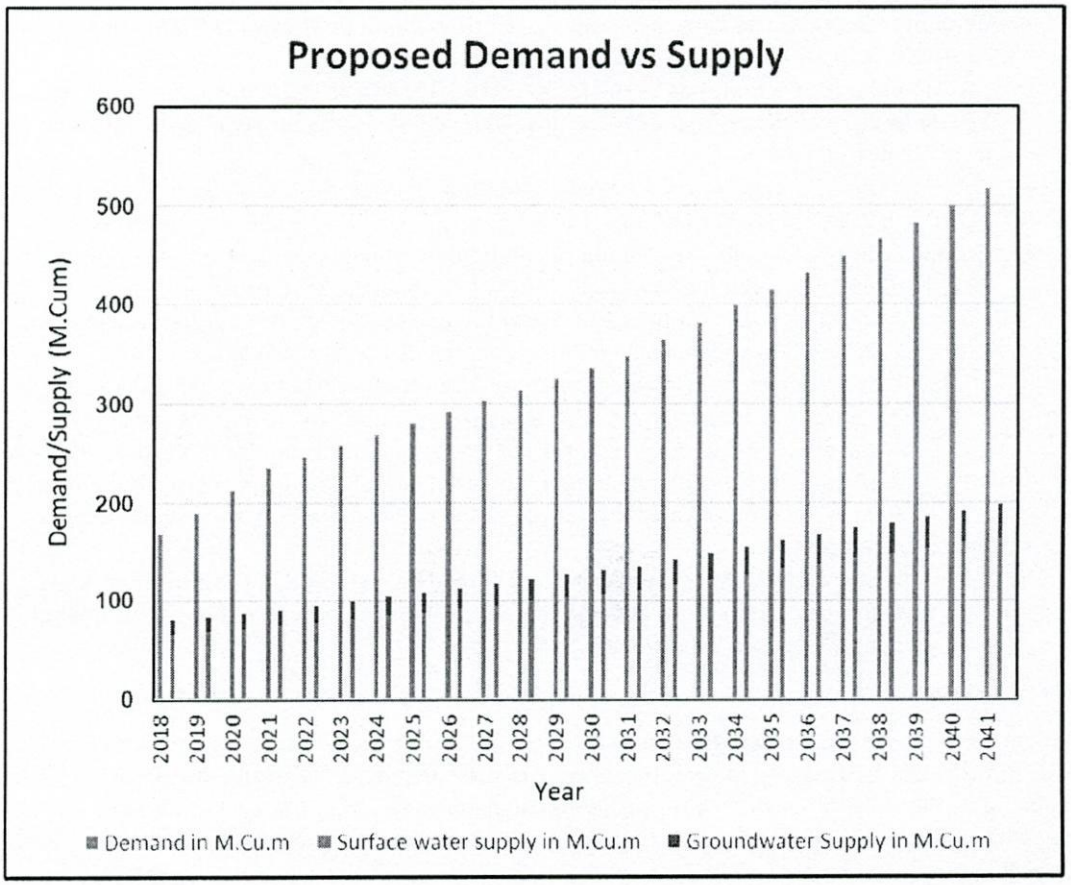

Fig 2.8.1

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2.8.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 167.01 M.Cu.m in 2018 to 516.83 M.Cum in 2041. The surface water supply to meet the demand also increases from 65.70 M.Cu.m in 2018 to 162.65 M.Cu.m in 2041. The ground water supply will increase from 14.60 to 36.14 M.Cu.m from 2018 to 2041(Fig 2.8.1). The share of groundwater in water supply has been provided by State Government agency 18% from 2018 to 2041. Overall, the total supply to meet the demand has increased from 80.30 to 198.79 M.Cum from 2018 to 2041, the gap increases from 86.71 to 318.04 M.Cu.m from 2018 to 2041.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is sufficient to meet the proposed water supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the available groundwater resources including the in-storage will not be able to cater the envisaged gap from 2018 onwards.

2.8.5 Conclusion

- **Demand**: Demand has been assessed as 167.01 M.Cu.m in 2018, 234.97 M.Cu.m in 2021, 348.48 M.Cu.m in 2031 & 516.83 M.Cu.m in 2041.
- **Total Supply**: Total Supply has been assessed as 80.30 M.Cu.m in 2018, 90.38 M.Cu.m in 2021, 134.04 M.Cu.m in 2031 & 198.79 M.Cu.m in 2041 and the share of GW in water supply is 18% from 2018 to 2041.
- **Gap**: The Gap has been assessed as 86.71 M.Cu.m in 2018, 144.59 M.Cu.m in 2021, 214.44 M.Cu.m in 2031 & 318.04 M.Cu.m.
- **Groundwater Availability** :The annual replenishable groundwater resources (Dynamic) as in 2017 is 46.69 M.Cu.m and in-storage is 23.85 M.Cu.m with a total of 70.54 M.Cu.m
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 18% and it can be met from the annual replenishable resources.
    - If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the available groundwater resources including the in-storage will not be able to cater the envisaged gap from 2018 onwards. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
- **Recommendations**:
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.9 Ratlam

Ratlam is the city headquarter of Ratlam district, located on northwest part of Madhya Pradesh which was known historically as Ratnapuri. The district is surrounded by Mandsaur district in the north, Jhabua and Dhar district in the south, Ujjain and Shajapur districts in the east, Banswara district of Rajasthan state in the west and Jhalawar district of Rajasthan state in the northeast bound the Ratlam District.

2.9.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	Population 2011	Growth rate per year (%)	Population				Normal Annual Rainfall (mm)
			2018	2021	2031	2041	
39.49	264914	1.02	303719	322043	391493	475919	1033.4

2.9.2 Groundwater System

The Deccan Traps are the predominant rock unit in the city and have wide variation in the water bearing properties. Individual lava flow generally consist of two unit viz., (i) the uppermost vesicular basalts with their weathered top portion and (ii) massive and compact basalt. The massive basalts with their weathered zones and secondary porosities and the vesicular basalts with their minutely connected and partly filled vesicles play an important role in determining the occurrence, movement and storage of water. The shallow aquifer occurs in weathered and jointed portion of the basalt. These form moderate to good aquifers where thickness of weathering and vesicular zones is adequate. The Deccan traps on weathering, generally develop a top layer of black cotton soil. The underlying layer of weathered basalt forms a water bearing horizon, which is tapped by most of the dugwells. Ground water in Ratlam city occurs mostly under water table conditions. The extent and depth of weathering, distribution of secondary porosity in the form of fractures and joints, and the occurrence and disposition of vesicular units govern the movement of ground water. Most of the dugwell have a diameter of 2 to 10 meters and depth ranges from 4 to 20m. The yield is between 1-3 lps. CGWB has drilled upto depth of 150 m but beyond the depth of 60 m , potential zones are very limited.
The groundwater resources has been assessed down to a depth of 60m bgl. The annual replenishable resources has been assessed as in 2017 as 4.30 M.Cu.m and in-storage as 7.43 M.Cu.m and total storage as 11.73 M.Cu.m.

There are 05 monitoring wells in the city for monitoring groundwater level and quality of which 03 wells are of CGWB and 02 wells are of State agency. The average water level in the city (May 2018) is of the order of 14.35mbgl and the Mean [Pre monsoon) (2008 to 2017)] water level is of the order of 10.93m bgl. The water level fluctuation with respect to mean is given below.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
2					1	50	1	50					1	50	1	50

2.9.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW share in Water Supply	Gap (M.Cum)
2018	17.74	8.28	1.5	9.78	15%	7.96
2021	18.81	8.79	1.59	10.38	15%	8.43
2031	22.86	10.68	1.93	12.61	15%	10.25
2041	27.79	12.98	2.35	15.33	15%	12.46

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The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.9.1.

2.9.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 17.74 M.Cum in 2018 to 27.79 M.Cum in 2041. While there is an increase in surface water supply from 8.28 to 12.98 M.Cum from 2018 to 2041 respectively. The ground water supply will increase from 1.50 to 2.35 M.Cu.m from 2018 to 2041. The share of groundwater in water supply has been provided by State Government agency 15% from 2018 to 2041. Overall, the total supply to meet the demand has increased from 9.78 to 15.33 M.Cum from 2018 to 2041, there by resulting in a gap of 7.96 M.Cum in 2018 & increasing to 12.46 M.Cum in 2041.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is sufficient to meet the proposed water supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the ground water resources including the in-storage groundwater are likely to be used up by the year 2018 and thereafter only annual replenishable resources would be available every year.

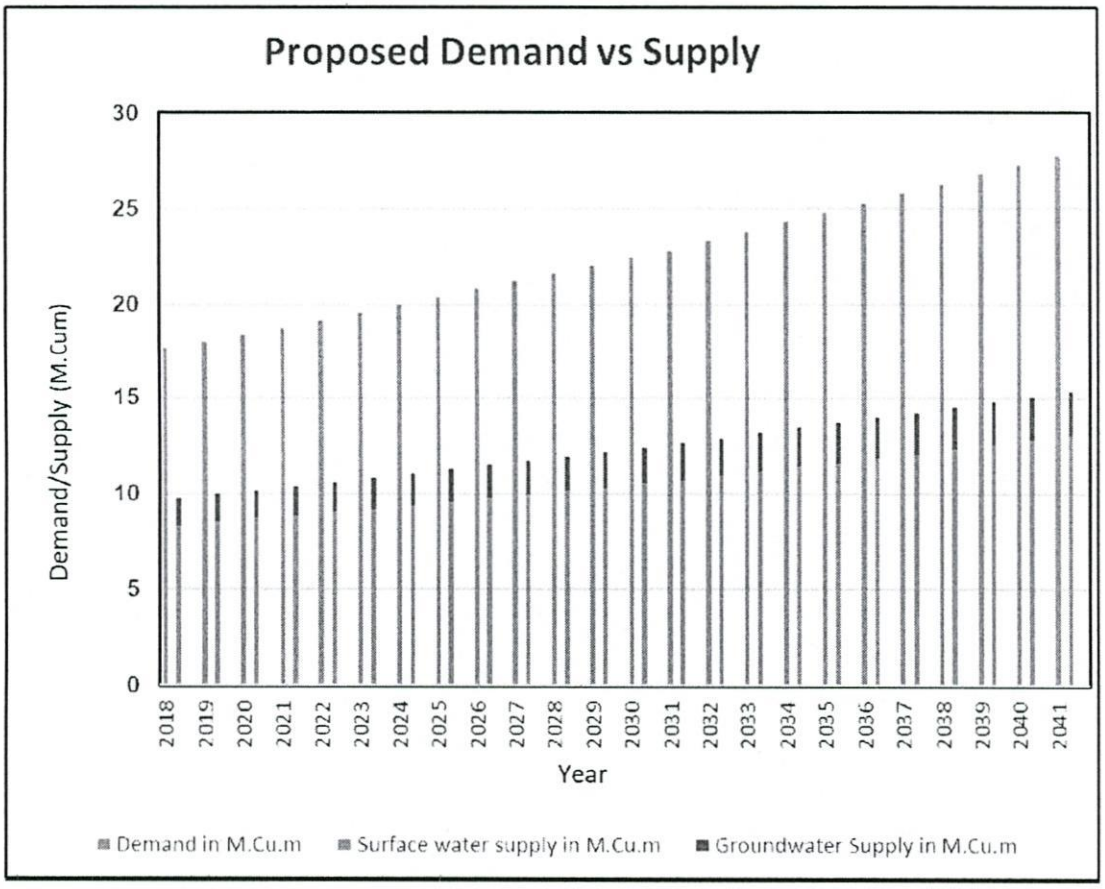

Fig 2.9.1

2.9.5 Conclusion

- **Demand:** Demand has been assessed as 17.74 M.Cu.m in 2018, 18.81 M.Cu.m in 2021, 22.86 M.Cu.m in 2031 & 27.79 M.Cu.m in 2041.
- **Total Supply:** Total Supply has been assessed as 9.78 M.Cu.m in 2018, 10.38 M.Cu.m in 2021, 12.61 M.Cu.m in 2031 &15.33 M.Cu.m in 2041 and the share of GW in water supply is 15% from 2018 to 2041.
- **Gap:** The Gap has been assessed as 7.96 M.Cu.m in 2018, 8.43 M.Cu.m in 2021, 10.25 M.Cu.m in 2031 & 12.46 M.Cu.m in2041.
- **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic) as in 2017 is 4.30 M.Cu.m and in-storage is 7.43 M.Cu.m with a total of 11.73 M.Cu.m.
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 15% from 2018 to 2041 and it can be met from the annual replenishable resources alone.
    - If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2018 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
- **Recommendations:**
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.10 Amritsar

Amritsar city is the administrative headquarter of Amritsar district in the state of Punjab, covering an area of 170.88 sq.km

2.10.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2018	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
170.88	1132761	1.54	1254873	1340000	1600000	1860000	546.1

2.10.2 Groundwater System

The city forms part of Uppar Bari Doab and is underlain by formations of Quaternary age comprising of alluvium deposits belonging to vast Indus alluvial plains. Sub surface geological formations comprise of fine to coarse grained sand, silt, clay and kankar. Gravel associated with sand beds occurs along left bank of Ravi. The beds of thin clay exists alternating with thick sand beds and pinches out at short distances against sand beds. Based on the available data, three Aquifer Systems has been delineated in the area. The aquifer group I occurs under unconfined condition and found between the depth of 17 and 114 m bgl with a thickness 79 m. The specific yields of the aquifer is 7.2%. The Transmissivity values ranges from 1450 to 2424 m^2/day. Aquifer is fresh and comprises of sand.

The aquifer group II and III occurs at a depth varying from 125 to 179m bgl and 185 to 300m bgl, with the thickness of 29 and 89m respectively. Depth to ground water level in the Amritsar city is 25.56mbgl (Verka) and 26.6 mbgl (Jandiala Guru Pz). Groundwater level is shallow in western part of

the city. Deeper groundwater levels ranging from 21 to 25 m bgl occurs in the central part of the city covering Golden Temple Complex, Ram Bagh and Bus stand areas.

The groundwater resources has been assessed down to a depth of 300m bgl. The annual replenishable resources has been assessed as in 2017 as 28.92 M.Cu.m and in-storage resources as 2385.57 M.Cu.m and total resources 2414.49 M.Cu.m.

The Mean [Pre monsoon) (2008 to 2017)] water level is of the order of 24.04 m bgl. The water level fluctuation with respect to mean is given below.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
1	-	-	-	-	-	-	1	100	-	-	-	-	-	-	1	100

2.10.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water	Gap (M.Cum)
2018	79.60	0.00	104.80	104.80	100%	0.00
2021	94.10	0.00	104.80	104.80	100%	0.00
2031	100.70	0.00	104.80	104.80	100%	0.00
2041	117.10	0.00	104.80	104.80	100%	12.30

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.10.1.

2.10.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 79.60 M.Cum in 2018 to 117.10 M.Cum in 2041. There is no surface water supply & groundwater supply to meet the demand from 2018 to 2041 is 104.80 M.Cu.m(Fig.2.10.1). The share of groundwater in water supply has been provided by State Government agency 100% from 2018 to 2041. Overall, the total supply to meet the demand is constant i.e. 104.80 M.Cum from 2018 to 2041, there by resulting in no gap between demand and supply from 2018 to 2031. However, there is a gap of 12.30 M.Cum in 2041.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is not sufficient to meet the proposed water supply. However available in-storage would be able to meet the envisaged supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the available groundwater resources including the in-storage will be able to meet the gap.

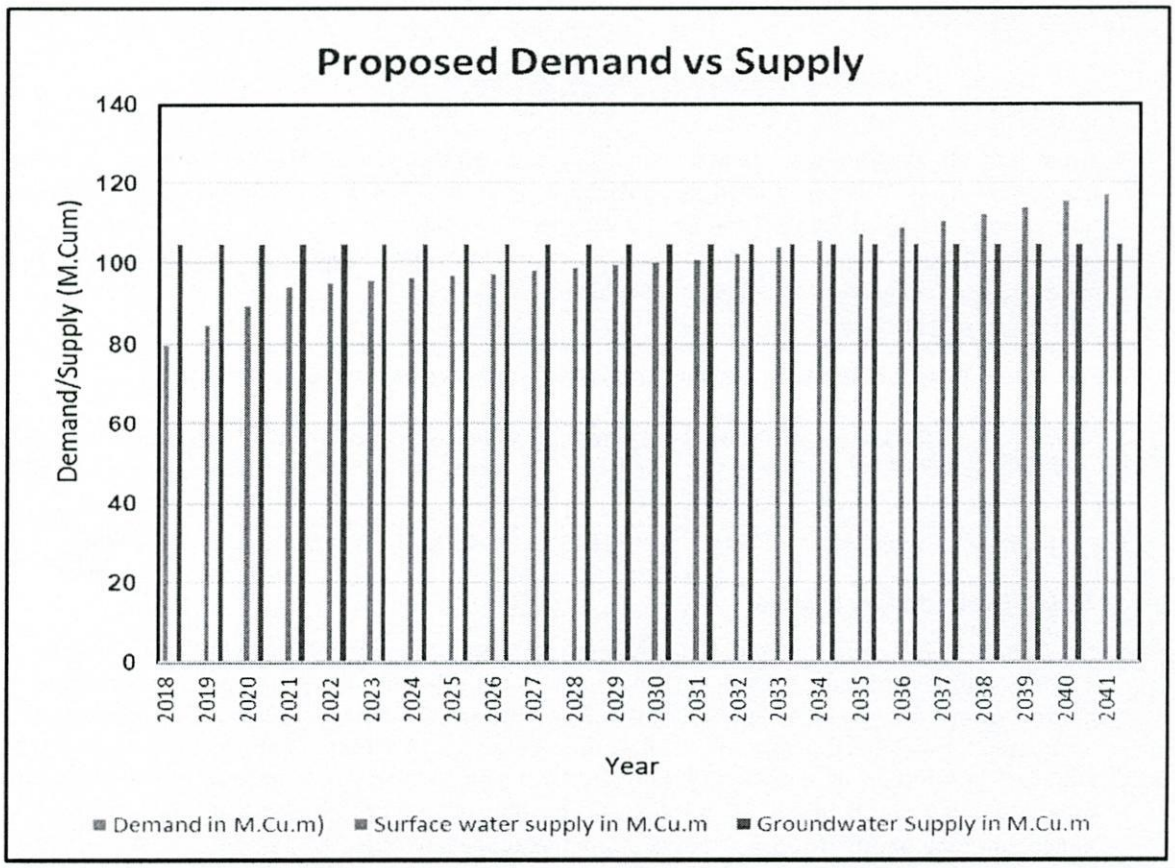

Fig.2.10.1

2.10.5 Conclusion

- **Demand**: Demand has been assessed as 79.60 M.Cu.m in 2018, 94.10 M.Cu.m in 2021, 100.70 M.Cu.m in 2031 & 117.10 M.Cu.m in 2041.
- **Total Supply**: Total Supply has been assessed as 104.80 M.Cu.m from 2018 to 2041 and the share of GW in water supply is 100% from 2018 to 2041.
- **Gap**: There is no gap in 2018, 2021 and 2031, however, it increases to 12.30 M.Cu.m in 2041.
- **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 28.92 M.Cu.m and in-storage is 2385.57 M.Cu.m with a total of 2414.49 M.Cu.m
  - As per the water supply plan of State Agencies, the share of groundwater in water supply is 100% and it cannot be met from the annual replenishable resources. However available in-storage would be able to meet the envisaged supply.
  - The groundwater resources including the in-storage will be able to meet the envisaged gap between demand and supply in 2041.
- Recommendations:
  - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.11 Jalandhar

The city, with has major road and rail connections, is a market for agricultural products. Manufacturing units include textiles, leather goods, wood products, and sporting goods. Jalandhar is situated at a

distance of 146 km from state capital Chandigarh. It is at a distance of 350 Km from Delhi on Delhi-Amritsar Highway. It is surrounded by Ludhiana district in East, Kapurthala in West, Hoshiarpur in North and Ferozpur in South. Total geographical area of Jalandhar Municipal Corporation and out growth is 101 km^2.Jalandhar city is spread over in parts of Tehsils, Jalandhar-I and Jalandhar-II and parts of Blocks Jalandhar west and Jalandhar East.

2.11.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2018	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
101.43	874412	2.05	999890	1053666	1232921	1412175	586.8

2.11.2 Groundwater System

The Jalandhar city is a part of Indo-Gangetic plain and Sutlej sub-basin of main Indus basin. The alluvial deposits comprise of sand, silt, clay and often associated with Kankar. Fine to medium grained sand horizon forms the potential aquifer in the area. The ground water from unconfined aquifer is abstracted through hand pumps and shallow tube wells up to the depth of 65 meters. Generally, the granular zones occurring between 29-35 m, 40-48 m and 56-68 m are tapped by shallow irrigation tube wells. However medium depth tube wells for the purpose of irrigation and drinking are being drilled up to the depth of 200 m. Three Piezometers tapping different aquifer groups have also been constructed up to a depth of 300 m in Jalandhar city. The exploratory drilling data have revealed the existence of about 16 to 18 granular zones down to the maximum depth of 350 m. The Mean [Pre monsoon) (2008 to 2017)] water level is of the order of 31.26m bgl. The water level fluctuation with respect to mean is given below.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
1	-	-	-	-	-	-	-	-	-	-	1	100	-	-	1	100

The groundwater resources has been assessed down to a depth of 300m bgl. The annual replenishable resources has been assessed as in 2017 as 26.41M.Cu.m and in-storage as 1174.43 M.Cu.m and total storage as 1200.84 M.Cu.m.

2.11.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	62.39	0.00	126.00	126.00	100%	0.00
2021	65.38	0.00	126.00	126.00	100%	0.00
2031	76.50	0.00	126.00	126.00	100%	0.00
2041	87.63	0.00	126.00	126.00	100%	0.00

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The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.11.1.

2.11.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 62.39 M.Cum in 2018 to 87.63 M.Cum in 2041. There is no surface water supply to meet the demand from 2018 to 2041. However, the ground water supply will be 126 M.Cu.m from 2018 to 2041(Fig 2.11.1) which is more than the demand. The share of groundwater in water supply has been provided by State Government agency 100% as in 2018. Overall, the total supply to meet the demand will be 126 M.Cum from 2018 to 2041, for all the years and the gap is nil. The supply is 200% of demand in 2018, 193% in 2021, 165% I 2031 & 126 % 2041, thereby indicating that groundwater development is more than the requirement. However it has been informed that due to losses during water supply, supply is kept more than demand.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is not sufficient to meet the proposed water supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that even the in-storage groundwater resources are likely to be used up by the year 2029 and thereafter only annual replenishable resources would be available every year.

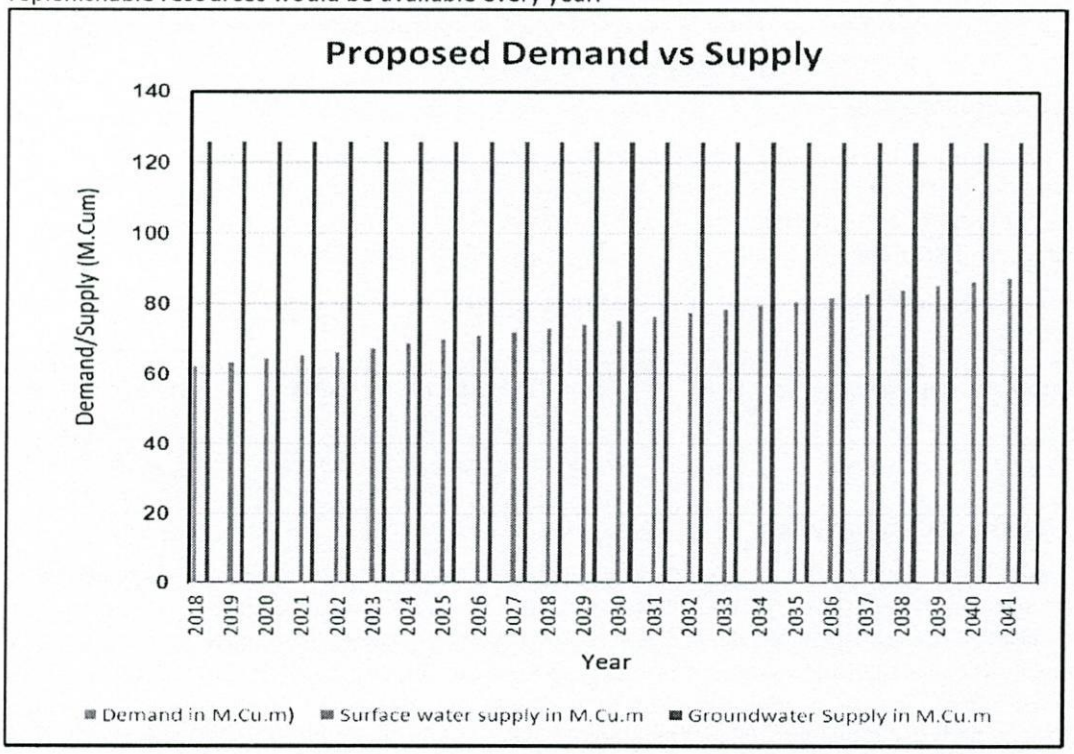

Fig 2.11.1

2.11.5 Conclusion

- **Demand**: Demand has been assessed as 62.39 M.Cu.m in 2018, 65.38 M.Cu.m in 2021, 76.50 M.Cu.m in 2031 & 87.63 M.Cu.m in 2041.

- **Total Supply**: Total Supply has been assessed as 126 M.Cu.m from 2018 to 2041, and the share of GW in water supply is 100%. Due to losses during water supply, supply is envisaged to be more than demand.
- **Gap**: There will be no gap between demand and supply from 2021 to 2041 as per data received from State agencies.
- **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 26.41 M.Cu.m and in-storage is 1174.43 M.Cu.m with a total of 1200.84 M.Cu.m
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 100% and it cannot be met from the annual replenishable resources.
    - If the groundwater resources are to be used for meeting the envisaged water supply, the in-storage groundwater resources are likely to be used up by the year 2029 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
- **Recommendations**:
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.12 Ludhiana City

Ludhiana city located in Ludhiana District of state of Punjab covers an area of 159.37 sq. Km. The city stands on the old bank of the Sutlej river about 13 km south of its present course. The city is 107 km west of the state capital Chandigarh.

2.12.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2018	populatio n 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
159.37	1618858	1.54	1793371	1949460	2285062	2620664	681

2.12.2 Groundwater System

The area is underlain by the Indo-Gangetic alluvium of Quaternary age. The alluvium is underlain by Pre-Cambrian basement rocks. The exploratory drilling carried out within Ludhiana City reveals that the thickness of unconsolidated alluvium is likely to be more than 373 m (Guruam Nagar). The alluvium is mainly of fluvial type and comprises of thick beds of fine to coarse grained unconsolidated sand, silt, clay, kankar etc, in various proportions. In the southern and eastern part, thick clay beds alternating with sand beds occur beyond 160 m. The lithological data of the area indicates the presence of many sand beds forming the principal aquifers separated by clay beds at various depths. The sand content in the aquifer in the area varies from 50 to 80%. Clay beds though thick at places occur mostly as lenses and pinch out laterally. The granular material becomes coarser with depth. In the shallow aquifer down to a depth of 50m, ground water occurs under unconfined/ semi-confined conditions, whereas in deeper aquifer, semi-confined/ confined conditions exist. This aquifer is tapped for domestic purpose by shallow tube wells and hand-pumps with a depth range of 40-60m. The tube wells constructed by Municipal Corporation and other agencies have tapped deeper aquifer down to depth of 200m. The deep tube wells constructed by CGWB tapped deeper aquifers below 150m, which are semi confined/ confined in nature. In the city area four aquifers groups have been delineated with thick clay layers separating each group. The thickness of these impervious horizons varies from 10 to 40m.In Ludhiana city, granular zone or potential aquifer of about 135 m thickness has been

encountered up to the depth of 360m. In western part, three to four thick aquifers exist down to the depth of 300m. These aquifers are extensive in nature and are separated by 5-10m thick clay beds. In northern part four granular zones ranging in thickness from 5-15m are present which are interspersed by clay beds of 3-7m thick. There are two monitoring stations in the city and the average water level during May 2018 was 35.70m bgl. The Mean [Pre monsoon) (2008 to 2017)] water level is of the order of 38.06 m bgl. The water level fluctuation with respect to mean is given below.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
1	-	-	-	-	-	-	1	100	-	-	-	-	-	-	1	100

The groundwater resources has been assessed down to a depth of 258m bgl. The annual replenishable resources has been assessed as in 2017 as 41.66 M.Cu.m and in-storage as 1447.44M.Cu.m and total storage as 1489.10 M.Cu.m.

2.12.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water	Gap (M.Cum)
2018	167.17	0.00	231.41	231.41	100%	0.00
2021	178.49	0.00	231.41	231.41	100%	0.00
2031	206.59	0.00	231.41	231.41	100%	0.00
2041	234.69	0.00	231.41	231.41	100%	3.28

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.12.1.

2.12.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 167.17 M.Cum in 2018 to 234.69 M.Cum in 2041. There is no surface water supply to meet the demand from 2018 to 2041. However, the ground water supply remains 231.41 M.Cu.m from 2018 to 2041 (Fig 2.12.1). The share of groundwater in water supply has been provided by State Government agency as 100%. The gap is nil, except for the year 2041, which is 3.28 M.Cu.m. The supply is more than the demand by 138% in 2018, 130% in 2021, 112% in 2031 and only 98% in 2041, resulting in gap only in 2041.The groundwater development is more than the requirement as it has been informed that supply has been kept higher than the demand due to losses during water supply.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is not sufficient to meet the proposed water supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the in-storage groundwater resources are likely to be used up by the year 2025 and thereafter only annual replenishable resources would be available every year.

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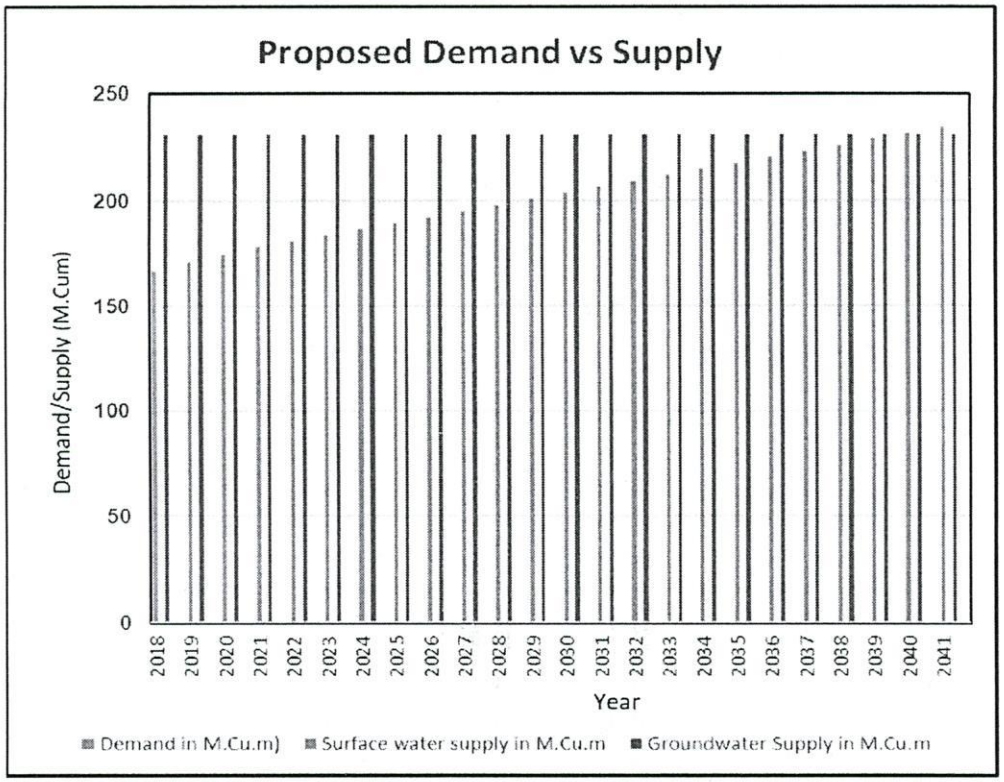

Fig 2.12.1

2.12.5 Conclusion

- **Demand**: Demand has been assessed as 167.17 M.Cu.m in 2018, 178.49 M.Cu.m in 2021, 206.59 M.Cu.m in 2031 & 234.69 M.Cu.m in 2041.
- **Total Supply**: Total Supply has been assessed as 231.41 M.Cu.m from 2018 to 2041 and the share of GW in water supply is 100% .The supply has been kept higher than the demand due to losses during water supply.
- **Gap**: There is no Gap between demand & supply except in 2041 which is 3.28 M.Cu.m.
- **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic)as in 2017 is 41.66 M.Cu.m and in-storage is 1447.44 M.Cu.m with a total of 1489.10 M.Cu.m
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 100% from 2018 to 2041 and it cannot be met from the annual replenishable resources.
    - If the groundwater resources are to be used for meeting the envisaged water supply, the in-storage groundwater resources are likely to be used up by the year 2025 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
- **Recommendations**:
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.13 Mohali City

Mohali also known as Ajitgarh or Sahibzada Ajit Singh Nagar is a city in the Sahibzada Ajit Singh Nagar district (SAS Nagar) in Punjab, India, which is a commercial hub lying south-west to the Union Territory of Chandigarh.

2.13.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
23.86	146000	1.84	146000	164000	200000	1027.7

2.13.2 Groundwater System

The S.A.S Nagar district is occupied by Quaternary Alluvial deposits belonging to the vast Indo-Gangetic alluvial plains, which forms the main aquifer system. Groundwater occurs under phreatic conditions in the shallow aquifers while leaky confined to confined conditions occur along the deeper aquifers of Quaternary alluvial deposits. CGWB has delineated three aquifer groups in the area. The aquifer group I occurs under unconfined to confined extending down to a depth of 9.89 to 108 m bgl and the thickness of granular zones is 34m. The aquifer group II, occurs at a depth of 130 to 201 m bgl and the thickness of granular zones is 24m. The aquifer group III occurs at a depth of 220 to 300m bgl with a thickness of 19 m for the granular zones. The transmissivity varies from 687 to 1395 m^2/day and a discharge rate of 2857 to 3466 m^3/day for aquifers underlying the area. Presently, there are 06 monitoring stations in the city. The average depth to water level during May 2018 in the city is of the order of 12.16m bgl. The water level fluctuation with respect decadal mean is given below.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
2	-	-	-	-	-	-	2	100	-	-	-	-	-	-	2	100

The groundwater resources has been assessed down to a depth of 300m bgl. The annual replenishable resources has been assessed as in 2017 as 7.51 M.Cu.m and in-storage as 140.69 M.Cu.m and total storage as 148.20 M.Cu.m.

2.13.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	25.77	15.46	10.31	25.77	40%	0.00
2021	26.75	15.46	10.31	25.77	40%	0.98
2031	29.69	15.46	10.31	25.77	40%	3.91
2041	32.63	15.46	10.31	25.77	40%	6.86

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.13.1.

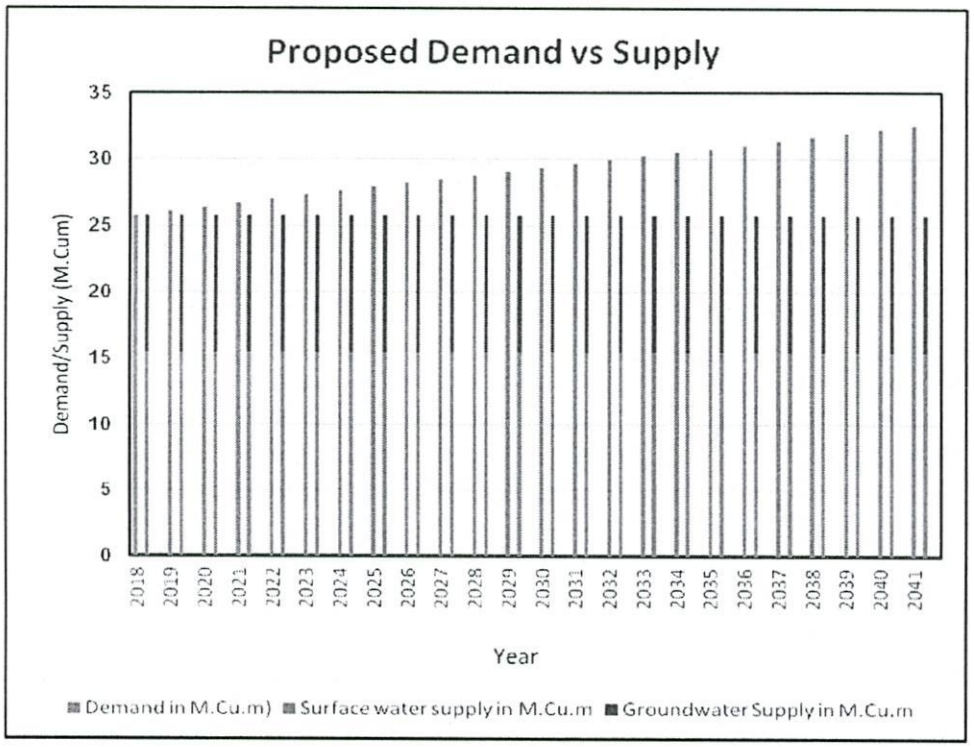

Fig 2.13.1

2.13.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 25.77M.Cum in 2018 to 32.63 M.Cum in 2041 and the supply is 15.46 M.Cum from surface water and 10.31 M.Cum from ground water resulting in a total supply of 25.77 M.Cum in 2018. There is no change in surface water supply & groundwater supply to meet the demand from 2018 to 2041(Fig 2.13.1). As a result the demand supply gap has been increased from nil in 2018 to 6.86 M.Cum in 2041. The share of groundwater in water supply has been provided by State Government agency, as 40%.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resource is not sufficient to meet the proposed water supply. However, the available in-storage will be able to cater to the proposed supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the in-storage groundwater resources are likely to be used up by the year 2039 and thereafter only annual replenishable resources would be available every year.

2.13.5 Conclusion

- **Demand**: Demand has been assessed as 25.77 M.Cu.m in 2018, 26.75M.Cu.m in 2021, 29.69 M.Cu.m in 2031 & 32.63M.Cu.m in 2041
- **Total Supply**: Total Supply has been assessed as 25.77 M.Cu.m from 2018 and the same is considered for the subsequent years. The share of GW in water supply is 40%.
- **Gap**: The Gap has been assessed as nil in 2018, 0.98 M.Cu.m in 2021, 3.91 M.Cu.m in 2031 & 6.86M.Cu.m in 2041

- **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic)as in 2017 is 7.51 M.Cu.m and in-storage is 140.69M.Cu.m with a total of 148.20M.Cu.m
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 40% and it cannot be met from the annual replenishable resources. However the available in-storage will be able to meet the envisaged supply.
    - If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2039 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence the groundwater resource is likely to last more than the estimated period.
- Recommendations:
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.14 Patiala City

Patiala is a city in south eastern Punjab. It is the fourth largest city in the state and is the administrative capital of Patiala district.

2.14.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2018	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
65	445000	1.15	480823	560500	676000	800000	632

2.14.2 Groundwater System

The city is occupied by Indo-Gangetic alluvial plain of Quaternary age, and falls in the Ghaggar basin. The groundwater occurs in alluvium formations comprising fine to coarse sand, which forms the potential aquifers. In the shallow aquifer, ground water occurs under unconfined/water table conditions, where as in deeper aquifer, semi-confined/confined conditions exist. Three aquifers have been demarcated down to 300 meter depth (Aquifer I- from 20.48 to 103mbgl, Aquifer II- from 130 to 185mbgl, Aquifer III- from 232 to 300mbgl). The average water level during May 2018 in the city is of the order of 30.88m bgl and the water level fluctuation with respect to decadal mean is given below.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
2	-	-	-	-	-	-	-	-	1	50	1	50	-	-	2	100

The groundwater resources has been assessed down to a depth of 300m bgl. The annual replenishable resources has been assessed as in 2017 as 8.08 M.Cu.m and in-storage as 445.33 M.Cu.m and total storage as 453.41 M.Cu.m.

2.14.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

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Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	29.20	0.00	25.19	25.19	100%	4.01
2021	31.39	6.21	25.19	31.40	80%	0.00
2031	38.33	13.14	25.19	38.33	66%	0.00
2041	45.63	20.44	25.19	45.63	55%	0.00

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.14.1.

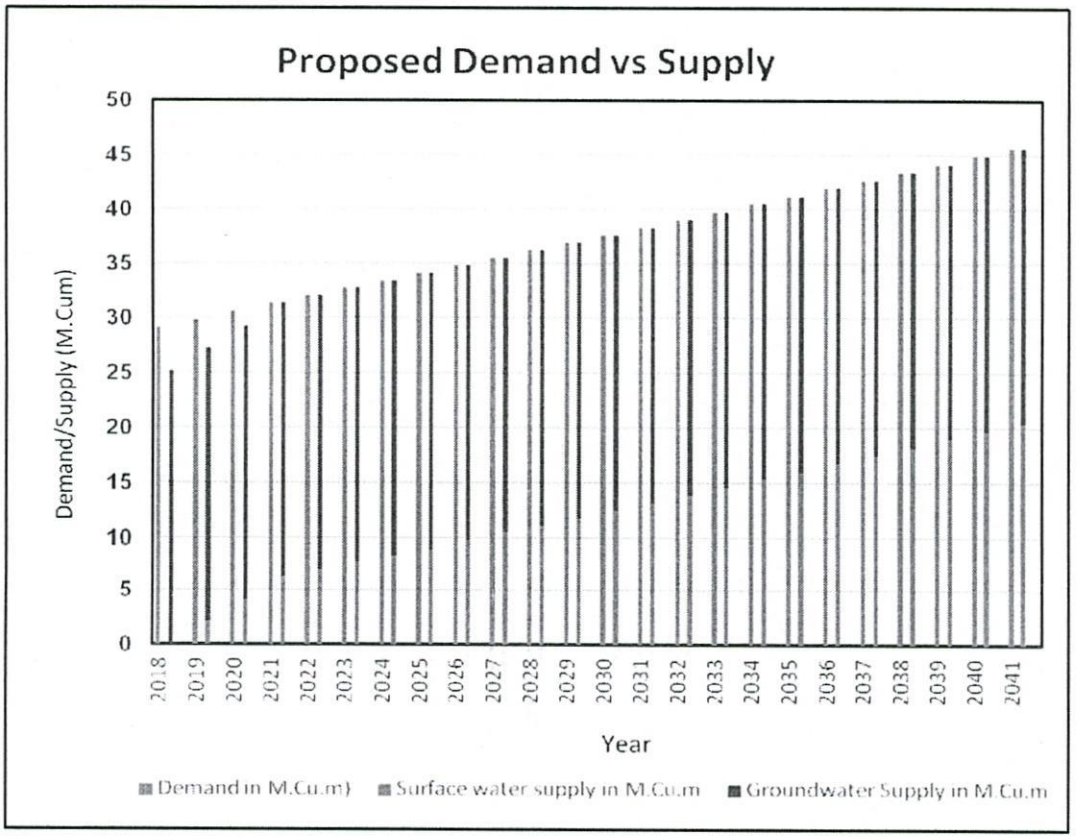

Fig 2.14.1

2.14.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 29.20M.Cum in 2018 to 45.63M.Cum in 2041, while there is a significant increase in surface water supply from nil to 20.44M.Cum respectively from 2018 to 2041 while the ground water supply is 25.19 M.Cum in 2018 & is retained till 2041 (Fig 2.14.1). The share of groundwater in water supply has been provided by State Government agency is decreasing from 100% in 2018 to 55% in 2041. The total supply to meet the demand has increased from 25.19 to 45.63 M.Cum from 2018 to 2041, there by resulting in a gap of 4.01M.Cum in 2018 and no gap in subsequent years.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resource is not sufficient to meet the proposed water supply. However, the available in-storage would be able to meet the envisaged supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the groundwater resources including the in-storage will be able to meet the demand in the projected years till 2041.

2.14.5 Conclusion

- **Demand**: Demand has been assessed as 29.2 M.Cu.m in 2018, 31.39 M.Cu.m in 2021, 38.33 M.Cu.m in 2031 & 45.63 M.Cu.m in 2041
- **Total Supply**: Total Supply has been assessed as 25.19 M.Cu.m in 2018, 31.4 M.Cu.m in 2021, 38.33 M.Cu.m in 2031 & 45.63 M.Cu.m in 2041 and the share of GW in water supply is 100% in 2018, 80% in 2021, 66% in 2031 & 55% in 2041.
- **Gap**: The Gap has been assessed as 4.01 M.Cu.m in 2018 and there is no gap in subsequent years.
- **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic)as in 2017 is 8.08 M.Cu.m and in-storage resources is 445.33 M.Cu.m with a total of 453.41M.Cu.m
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 100% in 2018 and it cannot be met from the annual replenishable resources alone. However, the available in-storage would be able to meet the envisaged supply.
    - The groundwater resources including the in-storage will be able to meet the demand in the projected years till 2041 .However there will be a huge depletion in in-storage groundwater resource which may trigger lateral inflow from surrounding areas.
- **Recommendations**:
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.15 Ajmer City

Ajmer is the 5th largest city in Rajasthan and being strategically located in its geographical centre, it is also known as the 'Heart of Rajasthan'. It is surrounded by the Aravalli Mountains and situated on the lower slopes of the Taragarh Hill range.

2.15.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2018	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
219.5	551100	1.17	596235	615579	680057	744536	550

2.15.2 Groundwater System

The Ajmer city is characterized by undulating topography, the city is surrounded by Aravalli hills. Hills and valleys in the area have been formed owing to differential erosion of isoclinal folds and steeply dipping rocks of Delhi Super Group. The valleys formed by erosion of less resistant schist and the resistant quartzite left out as hills. The main hydro-geological units in the Ajmer city are Schist(Sc) and Gneiss(Gn). The average discharge of wells with pump sets in zones Sc and Gn1 is 45,000 to 55,000 litres per day respectively. The chemical quality is potable with an exception of few scattered patches around city.

The groundwater resources has been assessed down to a depth of 90m bgl. The annual replenishable resources has been assessed as in 2017 as 3.93 M.Cu.m and in-storage as 1.08 M.Cu.m and total storage as 5.01 M.Cu.m.

There are 07 monitoring wells in the city for monitoring groundwater level and quality of which 06 wells are of CGWB and 01 well is of State agency. The depth to water ranges between 3.65m and 26.50m below ground level during pre-monsoon 2017 and from 4.30 m to 24.50m during post-monsoon 2017 period and the fluctuation ranges from 0.65 m to 2.00 m. The average water level in the city (May 2018) is of the order of 7.14m bgl. The Water Level Fluctuation with respect to mean (2012-17) shows fall of 1.27 m.

2.15.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	34.55	34.55	0.00	34.55	0%	0.00
2021	35.67	35.67	0.00	35.67	0%	0.00
2031	41.75	39.42	0.00	39.42	0%	2.33
2041	44.50	39.42	0.00	39.42	0%	5.08

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.15.1.

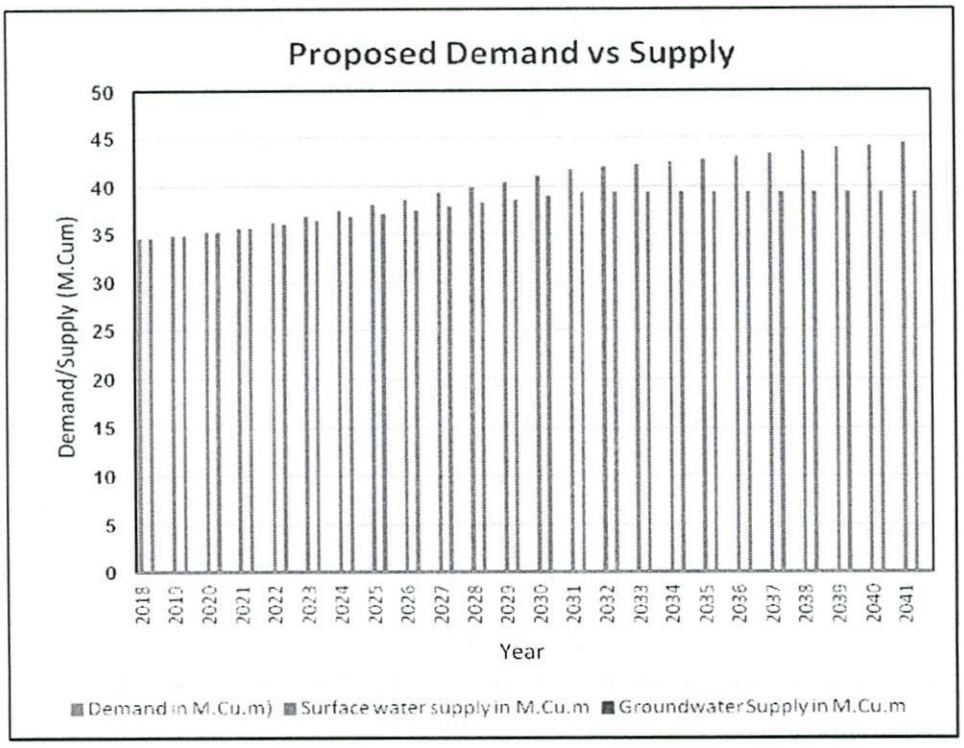

Fig 2.15.1

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2.15.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 34.55 M.Cum in 2018 to 44.50 M.Cum in 2041, while there is only marginal increase in surface water supply from 34.55 to 39.42 M.Cum respectively from 2018 to 2041. There is no groundwater supply in the city to cater the demand. The total supply to meet the demand will be increased from 34.55 to 39.42 M.Cum from 2018 to 2041, there by resulting no gap in 2018 to 5.08M.Cum in 2041 (Fig 2.15.1).

An attempt was made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the in-storage groundwater resources are likely to be used up by the year 2040 and thereafter only annual replenishable resources would be available every year.

2.15.5 Conclusion

- **Demand**: Demand has been assessed as 34.55 M.Cu.m in 2018, 35.67 M.Cu.m in 2021, 41.75 M.Cu.m in 2031 & 44.50 M.Cu.m in 2041
- **Total Supply**: Total Supply has been assessed as 34.55 M.Cu.m in 2018, 35.67 M.Cu.m in 2021, 39.42 M.Cu.m in 2031 & 2041 and share of GW in water supply is nil .
- **Gap**: The Gap has been assessed as nil in 2018 & 2021, 2.33 M.Cu.m in 2031 & 5.08M.Cu.m in 2041
- **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic)as in 2017 is 3.93 M.Cu.m and in-storage is 1.08M.Cu.m with a total of 5.01M.Cu.m
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is nil.
    - If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2040 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence the groundwater resources is likely to last more than the estimated period.
- **Recommendations**:
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.16 Bikaner City

The Bikaner City was founded by Rao Bikaji. It lies in the Western part of the Thar Desert and northwest of Rajasthan. Bikaner city is the administrative headquarters of Bikaner District.

2.16.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2018	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
155	644406	1.98	733721	771998	899591	1027183	260–440

2.16.2 Groundwater System

In the Bikaner city, the tertiary formation of Eocene age comprising medium to very coarse sand. The aquifer also comprises of loosely Cemented sandstone, clay and gravel with occasional occurrence of lignite lenses. The yield of the aquifer system varies from 1.38 to 5.0 lps. The depth to Water level in

the area varies from 75-81 mbgl in the area. There are 03 monitoring wells in the city for monitoring groundwater level and quality of which 01 well is of CGWB and 02 wells are of State agency. The average water level in the city (May 2018) is of the order of 78.4m bgl.

The groundwater resources has been assessed down to a depth of 165m bgl. The annual replenishable resources has been assessed as in 2017 as 1.53 M.Cu.m and in-storage as 45.57 M.Cu.m and total storage as 47.10 M.Cu.m. Water Level Fluctuation with respect to decadal mean shows rise of 2.29m.

2.16.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	16.06	14.45	1.61	16.06	10%	0.00
2021	16.90	15.22	1.61	16.83	10%	0.07
2031	19.71	17.70	1.61	19.31	8%	0.40
2041	22.48	22.48	1.61	24.09	7%	0.00

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.16.1.

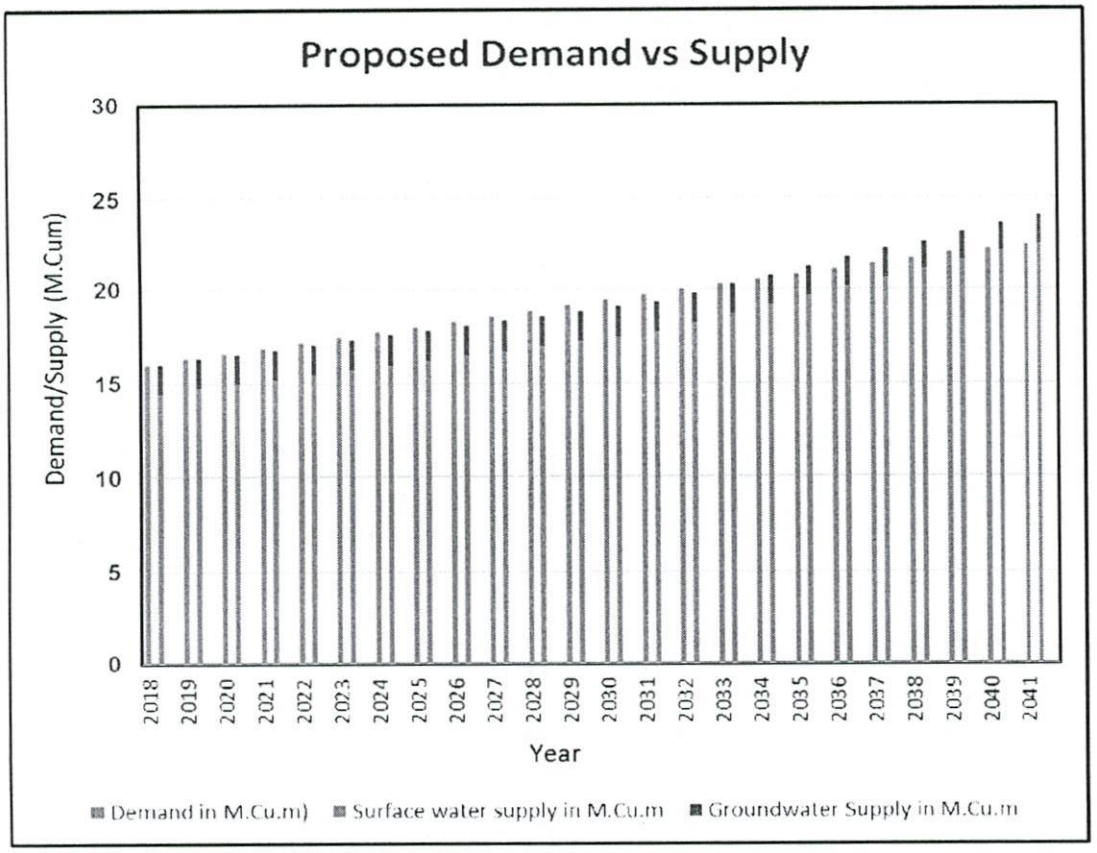

Fig 2.16.1

Groundwater Resources Vs Domestic Water Demand and Supply for select cities in India

2.16.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 16.06 M.Cum in 2018 to 22.48 M.Cum in 2041, while there is an increase in surface water supply from 14.45 to 22.48 M.Cum respectively from 2018 to 2041. The supply of groundwater is of the order of 1.61M.Cum and there is no change in groundwater supply in the city during the projected period (Fig 2.16.1). The share of groundwater in water supply has been provided by State Government agency as 10 % on 2018. The total supply to meet the demand has increased from 16.06 to 24.09 M.Cum from 2018 to 2041, there by resulting in no gap in 2018 & increasing to 0.40 M.Cum in 2031 and again becoming nil in 2041.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is not sufficient to meet the proposed water supply. However, the available in-storage will be able to meet the envisaged supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the available groundwater resources including the in-storage will be able to meet the envisaged gap.

2.16.5 Conclusion

- **Demand**: Demand has been assessed as 16.06 M.Cu.m in 2018 ,16.90 M.Cu.m in 2021, 19.71M.Cu.m in 2031 & 22.48 M.Cu.m in 2041
- **Total Supply**: Total Supply has been assessed as 16.06 M.Cu.m in 2018, 16.83M.Cu.m in 2021, 19.31M.Cu.m in 2031 & 24.09 M.Cu.m in 2041 .
- **Gap**: The Gap has been assessed as nil in 2018, 0.07 M.Cu.m in 2021, 0.40 M.Cu.m in 2031 & again nil in 2041
- **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic)as in 2017 is 1.53 M.Cu.m and in-storage is 45.57 M.Cu.m with a total of 47.10 M.Cu.m
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 10% in 2018 &2021, 8% in 2031 & 7% in 2041 and it cannot be met from the annual replenishable resources. However, the available in-storage will be able to meet the envisaged supply
    - The available groundwater resources including the in-storage will be able to meet the envisaged gap between demand and supply.
- **Recommendations**:
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.17 Jaisalmer City

The Jaisalmer city, nicknamed the golden city, is the district headquarter of Jaisalmer district which is a part of Thar desert. The city stands on a ridge of yellowish sandstone and is crowned by the ancient Jaisalmer fort.

2.17.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2018	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
62	58000	1.65	64699	67570	77140	86710	208

2.17.2 Groundwater System

The city of Jaisalmer is underlained by limestone and sandstones. Groundwater occurs under unconfined condition in the secondary porosity provided by the inter-connected opening of joints, bedding plane and fractures. Primary porosity of the limestone and sandstone is very low. It forms poor aquifer in the area. The average yield in the area varies from 5 to 15 m^3/day, depending upon the occurrence of secondary porosity. The Depth to water ranges from 25 to 40m bgl. Water levels in the city area have rising trend due to major water supply by IGNP canal. There are 04 monitoring wells in the city for monitoring groundwater level and quality of which 01 well is of CGWB and 03 wells are of State agency. The average water level in the city (May 2018) is of the order of 25 -40m bgl but long term water level data(2008-2017) of the city is not available.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
1	1	100	-	-	-	-	-	-	-	-	-	-	1	100	-	-

The groundwater resources has been assessed down to a depth of 160m bgl. The annual replenishable resources has been assessed as in 2017 as 0.04 M.Cu.m and in-storage as 1.59 M.Cu.m and total storage as 1.63 M.Cu.m.

2.17.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	4.75	4.75	0.37	5.11	7%	0.00
2021	5.11	4.75	0.37	5.11	7%	0.00
2031	5.48	4.75	0.37	5.11	7%	0.36
2041	6.21	4.75	0.37	5.11	7%	1.10

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.17.1.

2.17.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 4.75 M.Cum in 2018 to 6.21 M.Cum in 2041, while there is no change in surface & ground water supply from 2018 to 2041 (Fig 2.17.1). The share of groundwater in water supply has been provided by State Government agency 7 % as on 2018. The total supply to meet the demand is constant i.e. 5.11 M.Cum from 2018 to 2041, thereby resulting in no gap in 2018, increasing to 1.10 M.Cum in 2041.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is not sufficient to meet the proposed water supply and was seen that by 2021, the in storage also is likely to be used up and thereafter only annual replenishable resource will be available every year.

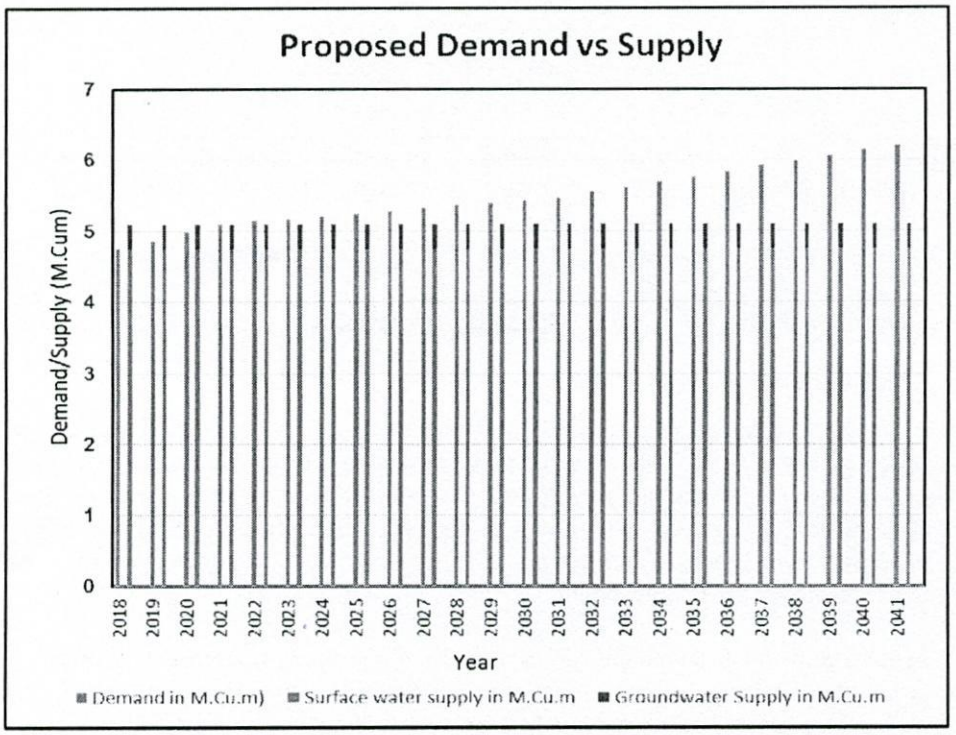

Fig 2.17.1

2.17.5 Conclusion

- **Demand**: Demand has been assessed as 4.75 M.Cu.m in 2018 5.11 M.Cu.m in 2021, 5.48 M.Cu.m in 2031 & 6.21 M.Cu.m in 2041
- **Total Supply**: Total Supply has been assessed as 5.11 M.Cu.m from 2018 to 2041
- Gap: The Gap has been assessed as nil in 2018 & 2021, 0.36 M.Cu.m in 2031, & 1.10 M.Cu.m in 2041
- **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic)as in 2017 is 0.04 M.Cu.m and in-storage is 1.59 M.Cu.m with a total of 1.63 M.Cu.m
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 7% and it cannot be met from the annual replenishable resources and available in-storage is also likely to be used up by 2021 & thereafter only annual replenishable resources will be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence the groundwater resources is likely to last more than the estimated period.
- **Recommendations**:
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.18 Jaipur City

Jaipur is the capital city of Rajasthan and it is one of the fastest growing cities in the country. The Jaipur Urban Cluster covers parts of Sanganer (45.5%), Jhotwara (42.5%) and Amer (12%) blocks .

2.18.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2018	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
470	3073350	4.5	4041455	4456358	5839365	7222373	656.5

2.18.2 Groundwater System

Quaternary Alluvium sediments comprising of sand, silt, clay and kankar cover the city of Jaipur. Gravel is found at depths in association with other sediment forms the principal potential aquifer in the area and mainly consists of fine sand and silt. However, at some places (e.g. Ambabari and Bajajnagar), gravel is also reported to occur in association with fine sand. It has been observed that kankar occurs within alluvium all over the area and the presence of secondary calcareous material reduces the porosity of the formations to a large extent.

Rocks of Alwar Group are predominantly arenaceous in composition and comprise of ortho-quartzite, micaceous quartzite and ferruginous quartzite with subordinate bands of quartz sericite schist and quartz biotite schist. Major part of Jaipur urban area is underlain by recent to sub-recent sediments with thickness ranging up to a maximum of 99 m. The depth to Water level in the area varies from 15-30m bgl for Hard Rock Formations and 35-70m bgl in the Alluvium Formations.

There are 15 monitoring wells in the city for monitoring groundwater level and quality of which 08 wells are of CGWB and 07 wells are of State agency. The average water level in the city (May 2018) is of the order of 43.17m bgl. The water level fluctuation with respect to mean is given below.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
14	0	0	4	29	3	21	1	7	3	21	3	21	7	50	7	50

The groundwater resources has been assessed down to a depth of 90m bgl. The annual replenishable resources has been assessed as in 2017 as 39.83 M.Cu.m and in-storage as 86.11 M.Cu.m and total storage as 125.94 M.Cu.m.

2.18.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	198.93	173.38	25.55	198.93	13%	0.00
2021	219.37	173.01	25.92	198.93	13%	20.44
2031	287.26	173.01	25.92	198.93	13%	88.33
2041	355.51	173.01	25.92	198.93	13%	156.59

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.18.1.

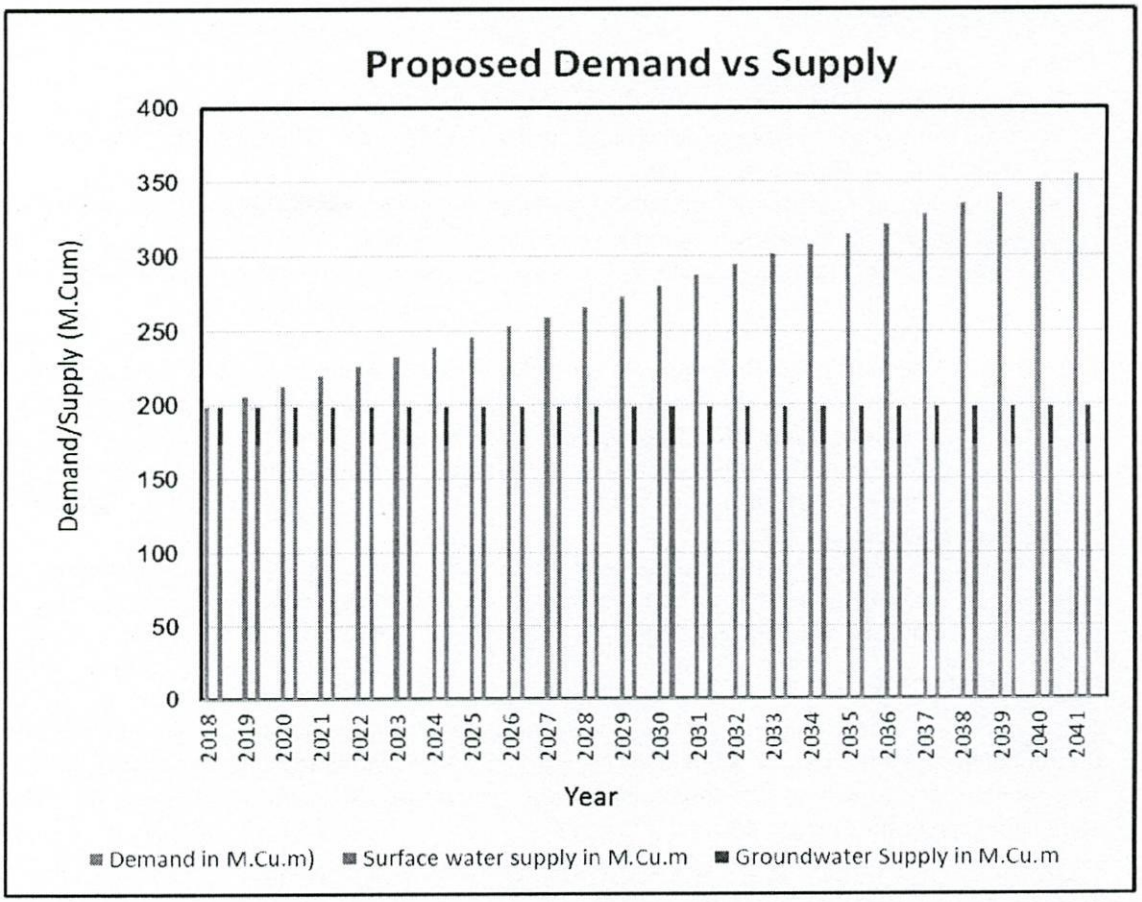

Fig 2.18.1

2.18.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 198.93M.Cum in 2018 to 355.51M.Cum in 2041 and supply from surface water sources as 173.38 M.Cum. & from groundwater as 25.55 M.Cum. in 2018. However, from 2021 to 2041 the surface water supply will be 173.01 M.Cum and ground water supply will be 25.92 M.Cum (Fig 2.18.1). The share of groundwater in water supply has been provided by State Government agency as 13% in 2018. The total supply to meet the demand is constant i.e. 198.93 M.Cum from 2018 to 2041, there by resulting in no gap in 2018 and increasing to 156.59M.Cum in 2041.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is sufficient to meet the proposed water supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the in-storage groundwater resources are likely to be used up by the year 2024 and thereafter only annual replenishable resources would be available every year.

2.18.5 Conclusion

- **Demand**: Demand has been assessed as 198.93 M.Cu.m in 2018, 219.37 M.Cu.m in 2021, 287.26 M.Cu.m in 2031 & 355.51 M.Cu.m in 2041.

- **Total Supply**: Total Supply has been assessed as 198.93 M.Cu.m from 2018 to 2041
- **Gap:** The Gap has been assessed as nil M.Cu.m in 2018 & 20.44 M.Cu.m in 2021, 88.33 M.Cu.m in 2031, & 156.59 M.Cu.m in 2041
- **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic)as in 2017 is 39.83 M.Cu.m and in-storage is 86.11 M.Cu.m with a total of 125.94 M.Cu.m.
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 13% and it can be met from the annual replenishable resources.
    - If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2024 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
- **Recommendations:**
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.19 Jodhpur City

Jodhpur is the second largest city in the Indian state of Rajasthan and officially the second metropolitan city of the state. It is popularly known as 'SUNCITY' and founded by Rao Jodhaji in 1459 A.D. Jodhpur is a popular tourist destination, featuring many palaces, forts and temples, set in the stark landscape of the Thar Desert.

2.19.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2018	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
208.31	1140000	2.92	1373016	1472880	1805760	2138640	350

2.19.2 Groundwater System

In the Jodhpur city, alluvial sediments, and Sandstone belonging to Jodhpur Group of Marwar Super Group forms the aquifer system underlying the city. Rhyolite forms moderately rugged basement of proterozoic Malani volcanics. Except in thin upper weathered and fractured zone, the Rhyolites are impervious, poorly jointed and massive and form very poor aquifer zones. Sandstone also does not form potential aquifer and its yield varies widely depending upon the extent of weathering and fracturing. The yield of the wells in sandstone generally varies from 10 to 50 m^3/day.

Depth to water level varies from 1m to 40m bgl. Shallow water level , less than 5m occurs in the old walled city area. Deeper water levels occur in south-western part of the area. Elevation of the water table ranges from about 283 m to less than 195 m above mean sea level. The flow of the ground water is from city area towards south. The ground water levels in the city have shown rising trend since 1997.This has caused serious problem of appearance of water in the basements of buildings and dampening of walls in some parts of the city.

There are 40 monitoring wells in the city for monitoring groundwater level and quality, of which 05 wells are of CGWB and 35 wells are of State agency. The average water level in the city (May 2018) is of the order of 3- 30m bgl. The water level fluctuation with respect to mean is given below.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
4	2	50	0	0	1	25	1	25	0	0	0	0	3	75	1	25

The groundwater resources has been assessed down to a depth of 150m bgl. The annual replenishable resources has been assessed as in 2017 as 14.61M.Cu.m and in-storage as 37.34 M.Cu.m and total storage as 51.95 M.Cu.m.

2.19.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	93.08	85.78	7.30	93.08	8%	0.00
2021	100.01	85.78	7.30	93.08	8%	6.94
2031	122.28	85.78	7.30	93.08	8%	29.20
2041	144.91	85.78	7.30	93.08	8%	51.83

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.19.1.

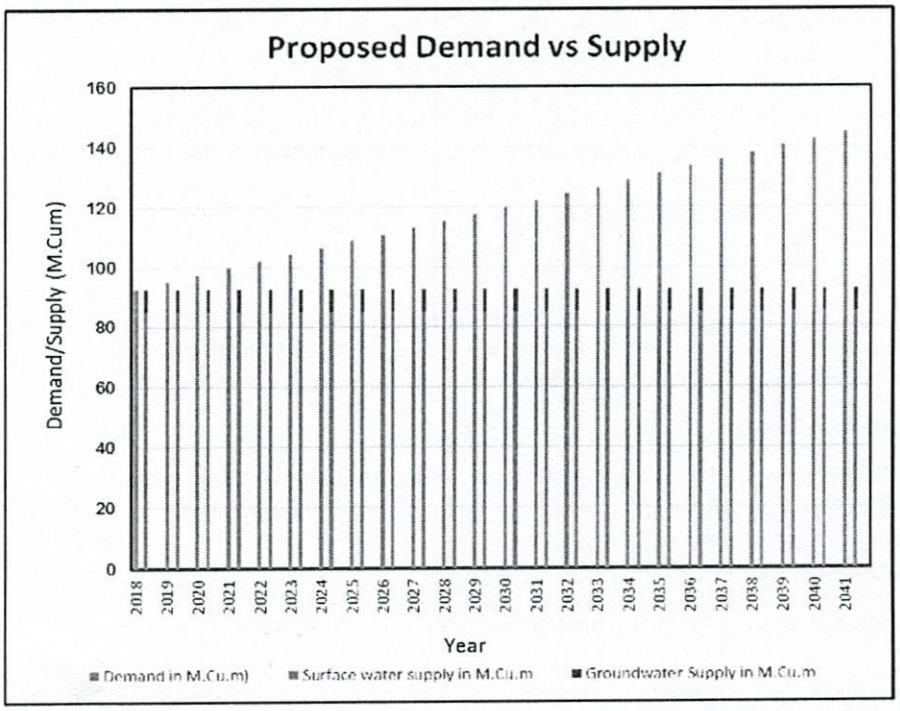

Fig 2.19.1

Groundwater Resources Vs Domestic Water Demand and Supply for select cities in India

2.19.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 93.08M.Cum in 2018 to 144.91M.Cum in 2041 and the supply from surface water & groundwater is 85.78 & 7.30 M.Cum. respectively. There is no change in surface water or ground water supply from 2018 to 2041(Fig 2.19.1). The share of groundwater in water supply has been provided by State Government agency as 8% in 2018. The total supply to meet the demand is constant i.e. 93.08 M.Cum from 2018 to 2041, there by resulting in no gap in 2018 and increasing to 51.83 M.Cum in 2041.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is sufficient to meet the proposed water supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the in-storage groundwater resources are likely to be used up by the year 2026 and thereafter only annual replenishable resources would be available every year.

2.19.5 Conclusion

- **Demand:** Demand has been assessed as 93.08M.Cu.m in 2018, 100.01 M.Cu.m in 2021, 122.28 M.Cu.m in 2031 & 144.91M.Cu.m in 2041
- **Total Supply**: Total Supply has been assessed as 93.08M.Cu.m from 2018 to 2041
- Gap: The Gap has been assessed nil in 2018 & 6.94 M.Cu.m in 2021, 29.20 M.Cu.m in 2031, & 51.83 M.Cu.m in 2041
- **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 14.61 M.Cu.m and in-storage is 37.34 M.Cu.m with a total of 51.95 M.Cu.m.
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 8% and it can be met from the annual replenishable resources.
    - If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2026 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
- Recommendations:
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.20 Chennai City

The Chennai city is located in the northeastern corner of the state and is also the capital of the State. It is bounded by the Bay of Bengal in the east, Tiruvallur district in the north and west and Kancheepuram district in the south.

2.20.1 Vital Statistics

The vital statistics of the city as obtained from Census 2011 is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	Population 2018	Population 2021	Population 2031	Population 2041	Normal Annual Rainfall (mm)
426	4646732	0.7	4873771	4971074	5295416	5619758	1200-1300

2.20.2 Groundwater System

Groundwater in Chennai city occurs in all the geological formations viz., the Archaean crystallines, Gondwanas, Tertiaries and alluvium and is developed by means of ring wells, dug wells, filter point wells, bore wells and tube wells. The geological formations of the district can be grouped into three units, namely i) the Archaean crystalline rocks ii) consolidated Gondwana and Tertiary sediments and iii) the Recent Alluvium. The Archaean crystalline rocks of the Metropolitan area comprise chiefly of Charnockites, gneisses and the associated basic and ultrabasic intrusives.

The crystalline rocks are weathered and jointed/fractured. The degree and depth of weathering varies from place to place and the thickness of weathered mantle varies from less than a metre to about 12 m in this city area. The successful borewells drilled tapping the deeper fractured aquifers revealed the existence of fracturing down to depth of 60m bgl. Crystallines are prominent in southern part of the city. The groundwater is essentially limited to the weathered mantle and fractures in the crystalline. Groundwater occurs under the unconfined condition in the weathered mantle and semi-confined to confined in fractures. The yield also is moderate to poor varying up to 3 lps. Dug wells tapping these overburden and shallow fractures get dried up during summer.

The Gondwana shales are black to dark grey in colour and are jointed / fractured. They are encountered in a number of bore holes and their thickness varies from 20 m in Ashok Nagar area through 24 m in Kilpauk area to more than 130 m in Koyembedu area. Gondwana Aquifer system is a semi-confined aquifer system. The yield of bore wells tapping the productive granular zones met within the Gondwana sediments were found to range from less than 1 to 4 lps for drawdowns varying between 8 to 9 m. The specific capacity ranged from 8 to 32 lpm/m of drawdown.

The alluvium covers the major part of the city. The alluvium forms unconfined aquifer in the city. The alluvium consists of sand, silts and clays. The thickness of alluvium varies from place to place and a maximum of 28 m is encountered in north Chennai near Perambur. Kilpauk water works area has 24 m thick alluvium. The yield of the wells at Kilpauk and Tirumangalam tapping the productive granular zones met within the alluvium is 25 lps and 6 lps for a drawdown of 7.21 and 0.22 m with a specific capacity of 206.35 and 40 lpm/m of drawdown respectively.

The groundwater resources has been assessed down to a depth of 100m bgl. The annual replenishable resources has been assessed as in 2017 as 46 M.Cu.m and in-storage as 13 M.Cu.m and total storage as 59 M.Cu.m.

There are 13 observation well in the city area being monitored for ground water levels. The analysis of May 2018 data shows that in 65% of the wells, the water level is in the range of 5 to 10 mbgl, in 31% of the wells it is in the range of 2 to 5 mbgl and in the remaining 4% of wells it is less than 2 mbgl. The water level fluctuation with respect to mean is given below:

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
13	2	15	0	0	0	0	8	62	2	15	1	8	2	15	11	85

2.20.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Groundwater Resources Vs Domestic Water Demand and Supply for select cities in India

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	407	163	73*	236	31%	171
2021	419	363**	73*	436	17%	0
2031	460	617**	73*	690	11%	0
2041	502	617**	73*	690	11%	0

* 27 M.Cu.m of groundwater being extracted from other basin.

** to be met from forthcoming desalination plant and availability of water in Stanley reservoir. There will not be any gap.

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.20.1.

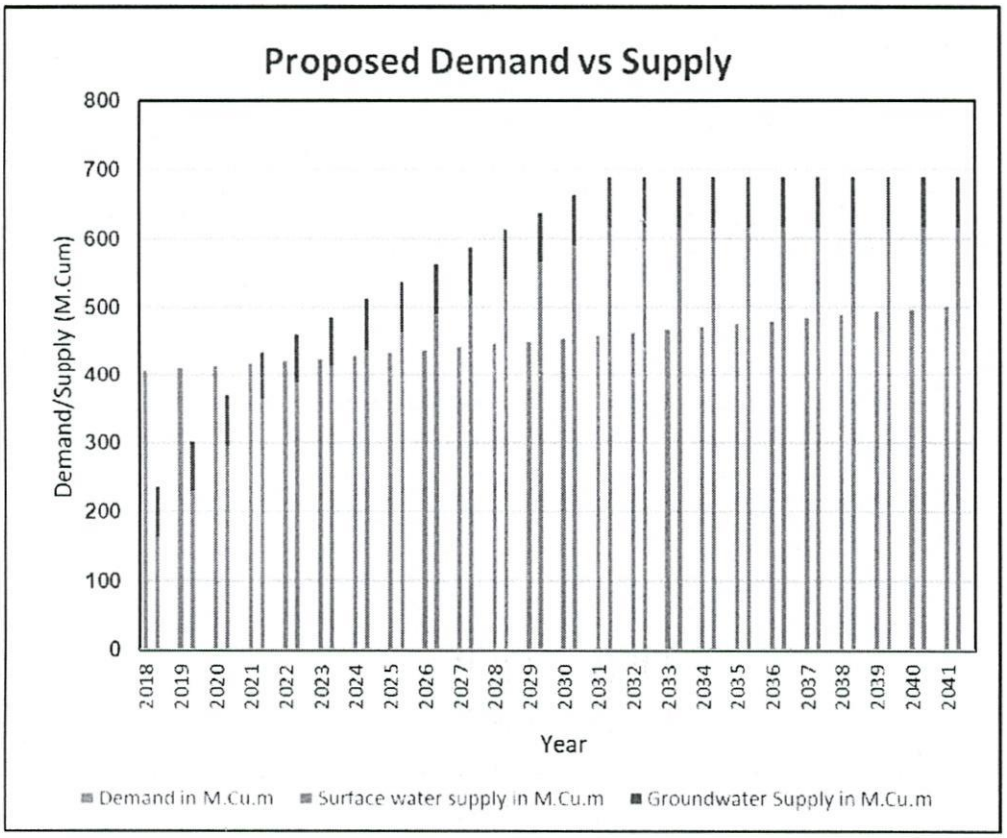

Fig 2.20.1

2.20.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 407.00 M.Cum in 2018 to 502.00 M.Cum in 2041 (Fig 2.20.1), while there is a significant increase in surface water supply

from 163.00 to 617.00 M.Cum respectively from 2018 to 2041 and no change in the groundwater supply. The share of groundwater is decreasing from 31% in 2018 to 11% in 2041. The total supply to meet the demand will be increased from 236 to 690 M.Cum respectively from 2018 to 2041, there by resulting in a gap of 171 M.Cum in 2018 to no gap in 2041. Out of 73 M.Cum of existing ground water supply, 27 M.Cu.m is extracted from outside the city. The increase in surface water supply is due to proposed desalination plants and additional supply from Stanley Reservoir. The proposal for additional water supply more than the demand is kept in view of availability of water in Stanley Reservoir (Cauvery River).

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is not sufficient to meet the proposed water supply. However, as 27 M.Cum is proposed to be extracted from outside the city, balance 46 M.Cum is equal to the annual replenishable resources and hence the supply can be achieved. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that though the ground water resources including in-storage will not be able to meet the gap in 2018, i.e. 171 M.Cum, but as the surface water supply is envisaged to be increased from the year 2021, there will be no gap between the demand and supply from 2021 onwards.

2.20.5 Conclusion

- **Demand:** Demand has been assessed as 407 M.Cu.m in 2018, 419 M.Cu.m in 2021, 460 M.Cu.m in 2031 & 502 M.Cu.m in 2041
- **Total Supply:** Total Supply has been assessed as 236 M.Cu.m in 2018, 436 M.Cu.m in 2021, 690 M.Cu.m in 2031 & 2041 and the share of GW in water supply is 31% in 2018, 17 % in 2021, 11 % in 2031 & 2041.
- **Gap:** The Gap has been assessed as 171 M.Cu.m in 2018. Due to proposed augmentation in the supply from the proposed desalination plant and Stanley Reservoir, there is no gap from 2021 to 2041.
- **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic) as in 2017 is 46 M.Cu.m and in-storage is 13M.Cu.m with a total of 59 M.Cu.m
    - As per the water supply plan of State Agencies, the share of GW in water supply is 31% in 2018, 17 % in 2021, 11 % in 2031 & 2041 and as 27 M.Cu.m is proposed to be extracted from outside the city, balance 46 M.Cu.m is equal to the annual replenishable resources and hence the supply can be achieved.
    - The ground water resources including in-storage will not be able to meet the gap in 2018, i.e. 171 M.Cum, but as the surface water supply is envisaged to be increased from the year 2021, there will be no gap between the demand and supply for subsequent years.
- **Recommendations:**
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.21 Vellore City

Vellore is the administrative headquarters of Vellore district in the state of Tamil Nadu. It is located about 135 kilometres west of Chennai and about 210 kilometres east of Bengaluru.

2.21.1 Vital Statistics

The vital statistics of the city as obtained from Census 2011 is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2018	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
87.915	484690	1.32	529475	548669	612648	676627	949.8

2.21.2 Groundwater System

The Vellore city is underlain by geological formations ranging in age from Archaean to Recent. The crystalline formations comprise charnockites, gneisses and granites. Groundwater occurs under phreatic conditions in the weathered zone and under semiconfined conditions in the fractures. The thickness of weathered zone varies from less than a metre to about 15 m in the area depending on the topography.

The thickness Alluvial Aquifer System along the course of the Palar River ranges from 8-20 m., which makes potential unconfined aquifer. Dug wells are the most common structures in recent alluvial formations too. The depth of dug wells tapping the Palar alluvium ranges from 4 to 18.70 meter below ground level (mbgl). These formations have moderate to good yield potential in the city and can sustain pumping for 3 to 4 hrs even during peak summer months and have yield up to 4.6 lps. Filter points of 10 to 15 m bgl depth are also being used in these formations for tapping groundwater for domestic purposes.

In the Crystalline Aquifers system, potential aquifer zones are also by fractures persisting to depths, particularly along lineaments and their inter sections. The depth of dug wells in crystalline formations varies from 8 to 19.5 mbgl. Fracture zones have been encountered in the well down to a depth of 116 mbgl in the borehole drilled by CGWB. The yield of dug wells is less than <1 lps in massive crystalline rocks whereas it is up to 2.3 lps in highly weathered gneisses. The yield of exploratory wells drilled in crystalline rock areas of the city ranged from 0.27 to 5.10 lps.

During the premonsoon 2018 the depth to water level in observation wells tapping shallow aquifer ranges from 3.4 to 8.60 m bgl. Shallow groundwater levels i.e. less than 5 mbgl were prominently observed in the southern area of the city. The long-term water level fluctuation for the period 2008 to 2017 indicates a fall of 0.51 (Abdullapuram) m to a rise of 3.39 m (Vellore).

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
2	-	-	2	100	-	-	-	-	-	-	-	-	2	100	-	-

The groundwater resources has been assessed down to a depth of 100 m bgl. The annual replenishable resources has been assessed as in 2017 as 9.9 M.Cu.m and in-storage as 4.10 M.Cu.m and total storage as 14 M.Cu.m.

2.21.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	22.00	11.00	3.00	14.00	21%	8.00

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Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2021	22.00	89.00*	3.00	92.00	-	0
2031	25.00	89.00*	3.00	92.00	-	0
2041	27.00	89.00*	3.00	92.00	-	0

* 78 M.Cu.m to be met from surface water resources from Mettur & Chekkanur Barrage and will be pumped for Vellore city and 11 municipalities. Hence there will not be any gap.

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.21.1.

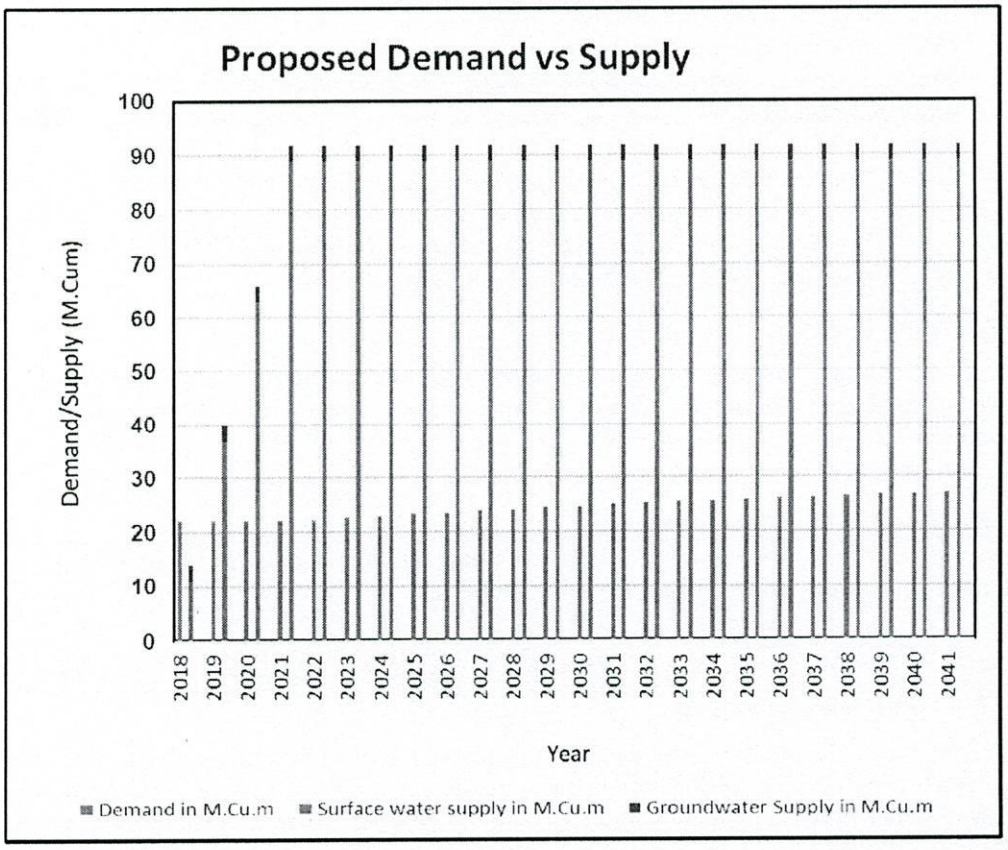

Fig 2.21.1

2.21.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 22 M.Cum in 2018 to 27 M.Cum in 2041 (Fig 2.21.1), while there is a significant increase in surface water supply from 11 to 89 M.Cum respectively from 2018 to 2041. The proposed additional 78 M.Cum from Mettur and Chekkanur Barrage includes the supply for Vellore City and 11 other Municipalities but the breakup is not provided. The groundwater supply i.e. 3.00 M.Cum, which 21 % of the total supply in 2018. The total supply to meet the demand will be increased from 14 to 92 M.Cum from 2018 to 2041, there by resulting in a gap of 8 M.Cum only in 2018.

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An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is sufficient to meet the proposed water supply.

2.1.5 Conclusion

- **Demand**: Demand has been assessed as 22 M.Cu.m in 2018 and 2021, 25 M.Cu.m in 2031 & 27 M.Cu.m in 2041.
- **Total Supply:** Total Supply has been assessed as 14 M.Cu.m in 2018, 92 M.Cu.m from 2021 to 2041 and the share of groundwater in water supply is 21% in 2018. The additional supply of 78 M.Cum includes the supply for Vellore City and 11 other Municipalities.
- **Gap:** The Gap has been assessed as 8 M.Cu.m in 2018, in subsequent years there is no gap.
- **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic) as in 2017 is 9.9 M.Cu.m and in-storage is 4.1 M.Cu.m with a total of 14 M.Cu.m.
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 21% in 2018 and it can be met from the annual replenishable resources.
    - The surface water supply is envisaged to be increased from 2021 hence there will be no gap between demand and water supply.

2.22 Hyderabad City

Hyderabad city was founded in the year of 1591 on the banks of the River Musi, had emerged as a strong industrial, commercial and technology centre and is the sixth largest urban agglomeration in the country.

2.22.1 Vital Statistics

The vital statistics of the city as obtained from the State agency are summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2018	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
778	7765000	2.45	9096698	9667425	11569850	13472275	884

2.22.2 Groundwater System

Hyderabad forms part of the Pre-Cambrian peninsular shield and is underlain by the Archaean crystalline complex, comprising pink and grey granites and granite gneisses. Numerous younger intrusive i.e quartz veins, pegmatite and dolerite dykes intrude granites along mega fractures and joints.

Ground water occurs under phreatic conditions in weathered zone and under semi-confined to confined conditions in the fractured zones. The aquifers are of anisotropic and non-homogenous type resulting in different hydrogeological conditions within shorter distances depending upon degree and intensity of fracture and recharge conditions. The thickness of the weathered zone varies from 5-25 m and discharges generally vary from negligible to 5 lps. High density of fractures are observed in the eastern, western and northern parts of the area while moderate to low density fractures are observed in central part in the main city area. Presently, ground water is being exploited through shallow and deep bore wells with depth ranging from 100-300 m. With groundwater development, the yield in productive shallow fractures is getting diminished. In general, the shallow fractures are more productive than the deeper ones. Central Ground Water Board (CGWB), under its exploration programme constructed 10 bore wells down to different depths ranging from 132 to 203. The discharges of these wells vary from 0.21 to 10 lps with drawdowns of 6 to 20.6 m.

The piezometric elevations in northern part vary from 500 to 563 m amsl with steep gradient in NE direction. In southern part, the piezometric elevation is between 470 and 520 m amsl with gentle gradient towards Musi River. The Piezometric levels from 44 Piezometers of CGWB and SGWD during

May-2018 ranges between 1.2 m bgl and 30 m bgl with an average of 11m.bgl. In 55% of the wells the Piezometric levels are < 10 m bgl, in 36% of the piezometers the water levels are between 10 to 20 m bgl and in 9% of the piezometers the water levels are more than 20 m bgl. Shallow water levels (< 5 m bgl) exist is southern parts, moderate water levels (5 to 15 m bgl) are noticed in major part of the area, extending in central, eastern and northern part of the area and deeper water levels (>20 m) are seen in southern and north-central part of Hyderabad urban area. The water level fluctuation with respect to mean is significant.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
27	8	42	5	26	6	32	3	38	2	24	3	38	19	70	8	30

The groundwater resources has been assessed down to a depth of 150m bgl. The annual replenishable resources has been assessed as in 2017 as 110.2M.Cu.m and in-storage resources as 372.26 M.Cu.m and total storage as 482.46 M.Cu.m.

2.22.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	1012	641	104	745	14%	268
2021	1389	969	104	1073	10%	315
2031	1995	1079	104	1183	9%	812
2041	-	-	-	-	-	-

The demand vs supply for the period from 2018 to 2041 has been provided as Fig 2.22.1.

2.22.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 1012 M.Cum in 2018 to 1995 M.Cum in 2031. While there is a significant increase in surface water supply from 641 to 1079 M.Cum), respectively from 2018 to 2031, there is no ground water based water supply by HMWS & SB in Hyderabad city(Fig 2.22.1) . The share of groundwater in water supply has been provided by State Government agency as 14% in 2018. The total supply to meet the demand increases from 745 M.Cum in 2018 to 1183 M.Cum in 2031, there by resulting in an increase in gap from 268 M.Cum in 2018 to 812 M.Cum in 2031.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is sufficient to meet the proposed water supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the in-storage groundwater resources are likely to be used up by the year 2019 and thereafter only annual replenishable resources would be available every year.

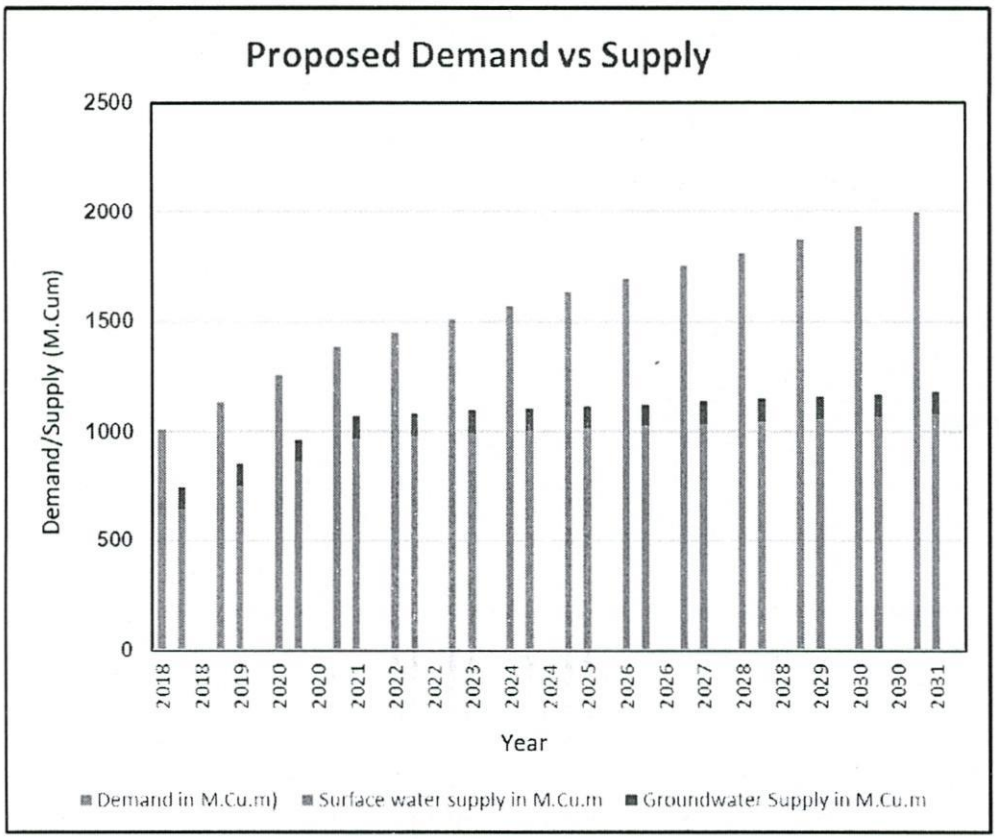

Fig 2.22.1

2.22.5 Conclusion

- **Demand**: Demand has been assessed as 1012M.Cu.m in 2018, 1389 M.Cu.m in 2021, 1995 M.Cu.m in 2031
- **Total Supply**: Total Supply has been assessed as 745 M.Cu.m from 2018, 1073 M.Cum in 2021 & 1183 M.Cum in 2031.
- **Gap**: The Gap has been assessed as 268 M.Cu.m in 2018 & 315 M.Cu.m in 2021 and 812 M.Cu.m in 2031
- **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 110.2 M.Cu.m and in-storage resources has been assessed as 372.26 M.Cu.m and total as 482.46 M.Cu.m
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 14% in 2018, 10% in 2021 & 9% in 2031 and it can be met from the annual replenishable resource.
    - If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2019 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
- **Recommendations**:
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.23 Agra City

The Agra city occupies the western part of the Uttar Pradesh.The city covers parts of the Bichpuri, Akola, Barauli Ahir, Khandauli, Etmadpur and Achnera blocks.

2.23.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
610.59	1600000	2.45	1934603	2360216	2879463	711

2.23.2 Groundwater System

The aquifer system underlying the city area is mainly covered by alluvium of quaternary age, which is moderately thick, regionally extensive and multilayered. These aquifers mainly comprise of fine to medium-grained sand & gravel of sandy facies in which ground water is occurring under unconfined to confined conditions. The yield prospects are on an average ranging from 4.1 to 13 lps. In the city, the pre-monsoon depth to water level in Shallow/Phreatic aquifers varies from 9.50 mbgl at Kankarpura to 44.36 mbgl at Dhaurra. During post-monsoon period, depth to water level varies from 9.05 mbgl (Kankarpura) to 45.43 m.bgl (Hajeepur Khera). The average water level in May 2017 is 27.52m bgl.

The groundwater resources has been assessed down to a depth of 123m bgl. The annual replenishable resources has been assessed as in 2017 as 11.38 M.Cu.m and in-storage resources as 898.56 M.Cu.m and total storage as 909.94 M.Cu.m.

2.23.3 Demand vis-à-vis Supply

The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	146.37	105.85	3.29	109.14	3%	37.23
2020	168.63	105.85	3.29	109.14	3%	59.49
2035	242.00	105.85	3.29	109.14	3%	132.86
2050	342.74	105.85	3.29	109.14	3%	233.60

The demand vs supply for the period from 2018 to 2050 has been provided as Fig 2.23.1.

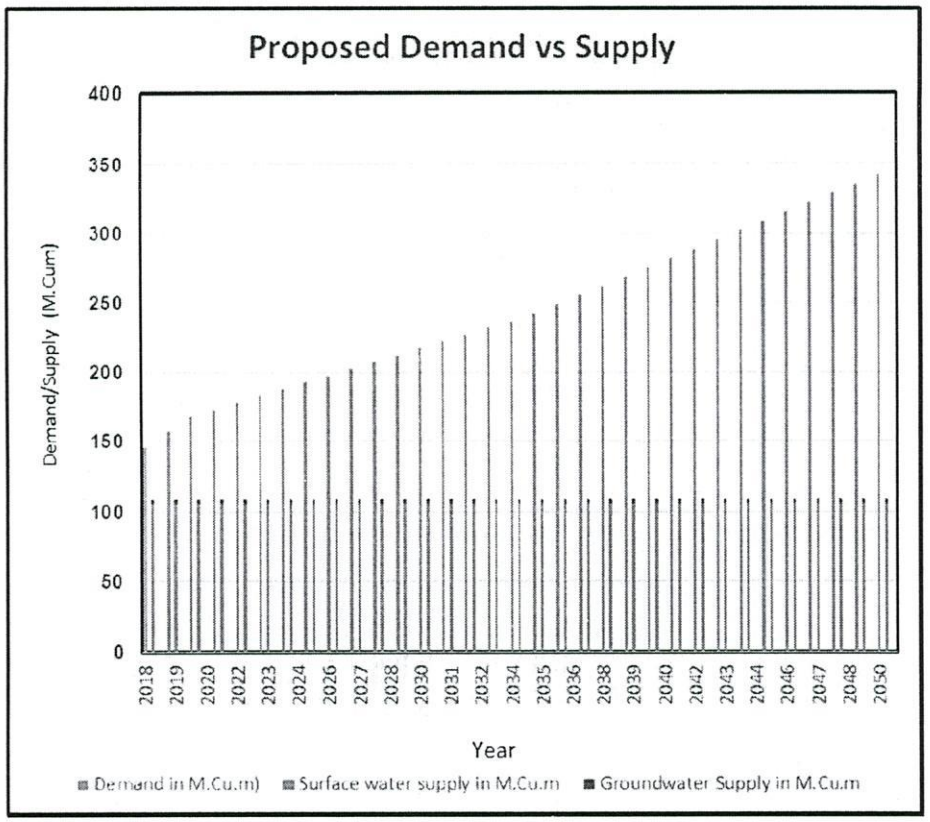

Fig 2.23.1

2.23.4 Analysis and Discussion

As per the data supplied by the State agencies, the demand would increase from 146.37M.Cum in 2018 to 342.74 M.Cum in 2050. The data on water supply for surface water sources and groundwater sources have been provided by State agencies for the year 2018 and in the absence of data on water supply, the same has been assumed for the year 2020, 2035 & 2050 and provided in Figure 2.23.1. The gap has increased from 37.23 M.Cum in 2018 to 233.60 M.Cum in 2050 against the total supply of 109.14 M.Cum.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is sufficient to meet the proposed water supply. Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that the in-storage groundwater resources are likely to be used up by the year 2029 and thereafter only annual replenishable resources would be available every year.

2.1.5 Conclusion

- **Demand**: Demand has been assessed as 146.37 M.Cu.m in 2018, 168.63 M.Cu.m in 2020, 242 M.Cu.m in 2035 & 342.74M.Cu.m in 2050
- **Total Supply:** Total Supply has been assessed as 109.14 M.Cu.m from 2018 to 2050.
- **Gap:** The Gap has been assessed as 37.23 M.Cu.m in 2018, 59.49 M.Cu.m in 2020, 132.86 M.Cu.m in 2035 & 233.60M.Cu.m in 2050
- **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic)as in 2017 is 11.38 M.Cu.m and in-storage is 898.56M.Cu.m with a total of 909.94M.Cu.m

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- As per the water supply plan of State Agencies, the share of groundwater in water supply is 3% and it can be met from the annual replenishable resources.
- If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2029 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence the groundwater resources is likely to last more than the estimated period.

- **Recommendations:**
  - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

2.24 Ghaziabad

Ghaziabad is an industrial city located in the western part of Uttar Pradesh adjacent to National Capital Territory of Delhi.

2.24.1 Vital Statistics

The vital statistics of the city as obtained from the State agency is summarised below.

Area (sq.km)	2011 Population	Growth rate per year (%)	population 2021	population 2031	population 2041	Normal Annual Rainfall (mm)
210	1700000	1.15	2800000	4700000	8100000	732

2.24.2 Groundwater System

In Ghaziabad, a vast sequence of Quaternary alluvial sediments consisting of mainly clay, silt, sand, gravel and kankar, which are grouped in younger and older alluvium, exist as aquifer materials. A three aquifer system has been demarcated based on groundwater exploration. The first aquifer system occurs between 70 and 125m bgl, while the second aquifer occurs at the depth of 140-250m bgl and third aquifer at the depth of 260-330m bgl. The third aquifer is absent west of Hindon River. The water quality in first aquifer is generally potable but with higher *in situ* salinity in Trans Hindon area, while in second aquifer, the quality is good in east of Hindon while saline in west of Hindon and in third aquifer it is fresh in east of Hindon and aquifer is not present west of Hindon.

Groundwater occurs in phreatic condition in shallow aquifer, which fulfills the major part of total ground water requirement of the city. The average water level in May 2018 is 25.0m bgl. The water level fluctuation with respect to mean is given below.

No. of wells Analysed	Rise						Fall						Rise		Fall	
	0-2 m		2-4 m		>4 m		0-2 m		2-4 m		>4 m					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	100

2.24.3 Demand vis-à-vis Supply

As informed by Water Supply agencies of Ghaziabad City verbally, most of the tube wells are now being constructed in the depth range of 100-160m. Thus, ground water contribution to water supply of Ghaziabad City is partly from Aquifer-I and partly from Aquifer-II. Since actual figures could not be

obtained from water supply agency, 30%-70% ratio has been assumed in respect of Aquifer-I and Aquifer-II. Accordingly, it is inferred that stage of ground water development from Aquifer-I has already reached around 300%. Present water supply scenario is graphically represented in **Fig.-2.24.1**.

Fig.-2.24.1: Existing Water Supply Scenario in Ghaziabad City, Ghaziabad District U.P.

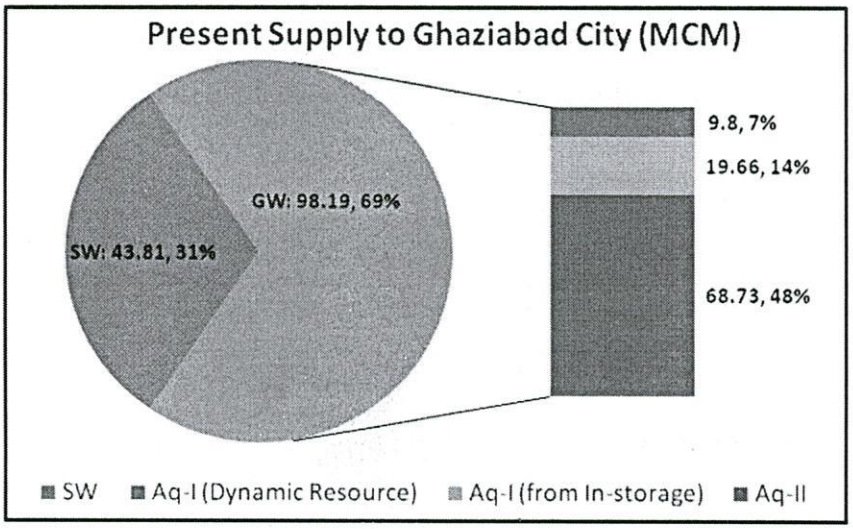

Table-2.24.1: Ground Water Resource in Aquifers in Ghaziabad City, Ghaziabad District U.P.

Formation water in Aquifer-II is suitable for drinking water, whereas it is of inferior quality in Aquifer-III. The information on demand vis-à-vis supply has been obtained from State agencies and a summary is furnished below.

Year	Demand (M.Cum)	Supply from SW (M.Cum)	Supply from GW (M.Cum)	Total supply (M.Cum)	% of GW Share in Water Supply	Gap (M.Cum)
2018	122.64	43.80	98.19	141.99	69%	0.00
2021	153.30	43.80	98.19	141.99	69%	11.31
2031	260.61	43.80	98.19	141.99	69%	118.62
2041	443.11	43.80	98.19	141.99	69%	301.12

The proposed demand vs supply has been graphically presented as Fig 2.24.2.

The groundwater resources has been assessed down to a depth of 330m bgl. The annual replenishable resources has been assessed as in 2017 as 9.80 M.Cu.m and in-storage as 1191.60 M.Cu.m and total storage as 1201.40 M.Cu.m.

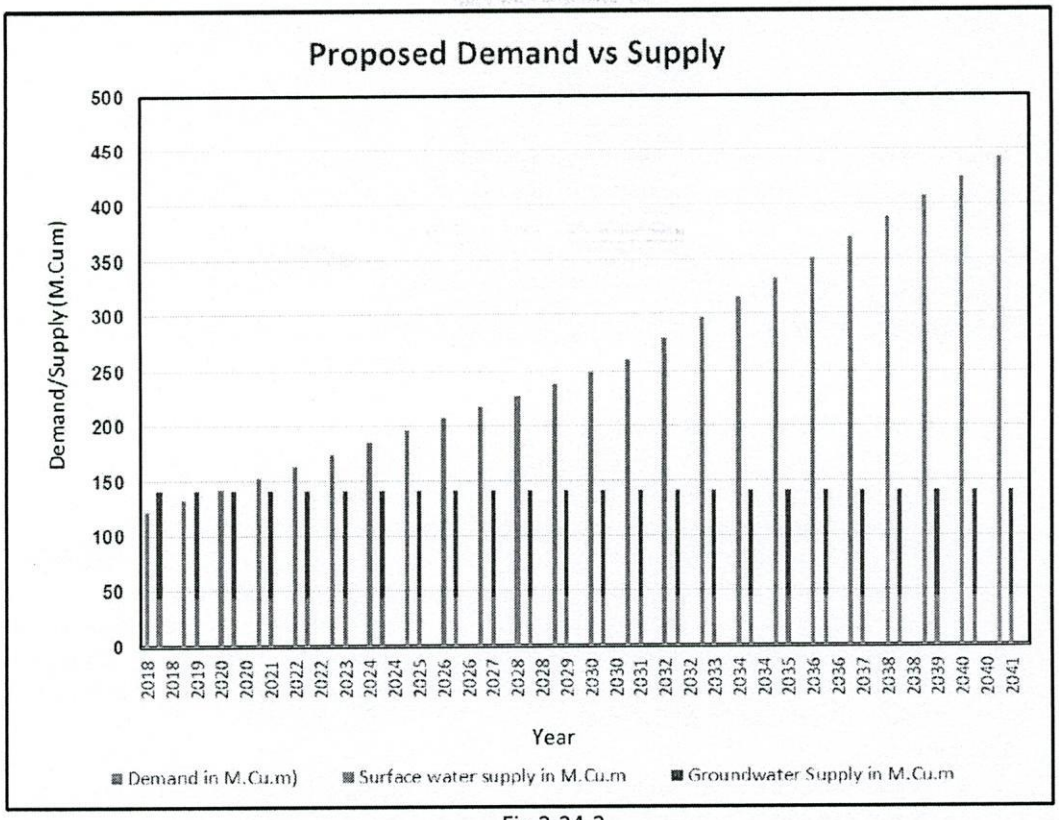

Fig 2.24.2

2.24.4 Analysis and Discussion

The supply to meet the demand was provided for only 2018, while the demand for 2018, 2021,2031 & 2041 was provided by the State agencies. It was also informed that there is no any proposal for new surface water scheme and proposes to use only groundwater to meet the demand but difficult to provide the quantity of groundwater contribution. Hence, the supply for 2018 was also assumed to be continued for 2021, 2031 & 2041 to calculate the Gap.

The demand has increased from 122.64 M.Cu.m in 2018 to 443.11 M.Cu.m in 2041. As the supply provide in 2018 has been assumed for subsequent years in the absence of data, the gap has increased from nil in 2018 to 301.12 M.Cu.m in 2041.

An attempt was made to find out the availability of groundwater to meet the proposed water supply from groundwater sources by the State Agencies. The annual replenishable resources is not sufficient to meet the proposed water supply and if in-storage resources was used for the envisaged supply, the in-storage groundwater resources are likely to be used up by the year 2030 and thereafter only annual replenishable resources would be available every year.

Subsequently, an attempt was also made to find out whether the gap in the water supply can be met from available groundwater resources. It is seen that even the in-storage groundwater resources are likely to be used up by the year 2027 and thereafter only annual replenishable resources would be available every year.

2.24.6 Conclusion

- **Demand**: Demand has been assessed as 122.64 M.Cu.m in 2018, 153.3 M.Cu.m in 2021, 260.61 M.Cu.m in 2031 & 443.11 M.Cu.m in 2041

- **Total Supply:** Total Supply has been assessed as 141.99 M.Cu.m in 2018 and has been retained for the subsequent years, as the data was not available and the share of GW in water supply is 69%.
- **Gap:** The Gap has been assessed as **Nil** in 2018, 11.31 M.Cu.m in 2021, 118.62 M.Cu.m in 2031 & 301.12 M.Cu.m in 2041
- **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic) as in 2017 is 9.80 M.Cu.m and in-storage is 1191.60 M.Cu.m with a total of 1201.40 M.Cu.m
    - As per the water supply plan of State Agencies, the share of groundwater in water supply is 69%. The annual replenishable resources is not sufficient to meet the proposed water supply and if in-storage resources was used for the envisaged supply, the in-storage groundwater resources are likely to be used up by the year 2030 and thereafter only annual replenishable resources would be available every year.
    - If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2027 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
- **Recommendations:**
    - It is advocated that groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository, quantity or quality wise can be avoided.

3.0 SUM UP

In NITI Aayog report entitled "Composite Water management Index –A Tool for water management", it has been mentioned that 21 cities across India are expected to run out of water by 2020. In this connection, CGWB was entrusted to study the groundwater situation in 24 cities of India. CGWB obtained information on demand and supply from State agencies and groundwater availability (both Dynamic and Static ground water resources) in these cities were computed by CGWB and has come up with the following generalizations. However, it is to mention that the static resources (in-storage) should be kept as a reserve in line with the global best practices and used for further scientific study only (as per decision taken in a meeting held on 19.06.2014, Chaired by Secretary, MoWR, RD & GR).

1. Groundwater use should be restricted to the annual replenishable resources so that any adverse impact on the groundwater repository (quantity or quality wise) can be avoided.
2. The vulnerability of groundwater situation deems that recycle and reuse of water should be promoted for uses other than drinking purposes in the city so that stress on fresh water resources can be avoided.
3. A summary of status on demand, supply and groundwater availability in 24 select cities has been tabulated below.

S.No	City	Position on projected water demand vis-à-vis water supply as in 2041
1	Delhi	• **Demand**: Demand has been assessed as 1892 M.Cu.m in 2018, 2289 M.Cu.m in 2021, 2665 M.Cu.m in 2031 & 2993M.Cu.m in 2041 • **Total Supply:** Total Supply has been assessed as 1515 M.Cu.m in 2018, 1920 M.Cu.m in 2021, 1975 M.Cu.m in 2031 & 2030M.Cu.m in 2041 and the share of GW in water supply is 09%. • **Gap:** The Gap has been assessed as 377 M.Cu.m in 2018, 369 M.Cu.m in 2021, 690 M.Cu.m in 2031 & 963M.Cu.m in 2041 • **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic)as in 2017 is 340 M.Cu.m and in-storage is 1080M.Cu.m with a total of 1420M.Cu.m o As per the water supply plan of State Agencies, the share of groundwater in water supply is 9% and it can be met from the annual replenishable resources. o If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2022 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
2	Gandhinagar	• **Demand:** Demand has been assessed as 23 M.Cu.m in 2018, 24.18 M.Cu.m in 2021, 30.70 M.Cu.m in 2031 & 37.48 M.Cu.m in 2041. • **Total Supply**: Total Supply has been assessed as 21.54 M.Cu.m in 2018, 29.93 M.Cu.m in 2021, 32.85 M.Cu.m in 2031 & 40.15 M.Cu.m in 2041 and the share of GW in water supply is 24% in 2018 and 27% in 2021 and becomes nil in 2031 & 2041. • **Gap:** The Gap has been assessed, as 1.46 M.Cu.m in 2018and there is no gap afterwards.

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S.No	City	Position on projected water demand vis-à-vis water supply as in 2041
		• **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic)as in 2017 is 6.34 M.Cu.m and in-storage is 239.09 M.Cu.m with a total of 245.43 M.Cu.m o As per the water supply plan of State Agencies, the share of GW in water supply is 24% in 2018 which can be met from replenishable groundwater resources but the share will be increased to 27% in 2021 which cannot be met from replenishable groundwater resources but to be supplemented from available in-storage ground water resources. o It is seen that after 2018 there will be no gap between demand and supply as the supply from surface water is subjected to increase as per the information received from the State Agencies.
3	Ambala	• **Demand:** Demand has been assessed as 17.32 M.Cu.m in 2018, 17.82 M.Cu.m in 2021, 22.90 M.Cu.m in 2031 & 27.25 M.Cu.m in 2041. • **Total Supply**: Total Supply has been assessed as 17.32 M.Cu.m in 2018, 17.82 M.Cu.m in 2021, 22.89 M.Cu.m in 2031 & 22.26 M.Cu.m in 2041. • **Gap**: The Gap has been assessed as nil 2018 and 2021. It increases from 0.01 M.Cu.m in 2031 to 4.99 M.Cu.m in 2041. • **Groundwater Availability**: The annual replenishable resources has been assessed as in 2017 as 7.68 M.Cu.m and in-storage as 329.38 M.Cu.m and total storage as 337.06 M.Cu.m. o As per the water supply plan of State Agencies, the share of groundwater in water supply is 17% in 2018 and decreased to 7 % and it can be met from the annual replenishable ground water resources. o The annual replenishable resources will be able to meet the envisaged gap between demand and supply in 2041.
4	Faridabad	• **Demand**: Demand has been assessed as 84.68 M.Cu.m in 2018, 89.42 M.Cu.m in 2021, 109.5 M.Cu.m in 2031 & 145.27 M.Cu.m in 2041 • **Total Supply:** Total Supply has been assessed as **84.68** M.Cu.m in 2018 & 2021, 109.5 M.Cu.m in 2031 & 145.27 M.Cu.m in 2041 and the share of GW in water supply is 100% in 2018 & 2021, while it has been envisaged to be reduced to 50% in 2031 & 2041. • **Gap:** For all the years and the gap is nil, except for the year 2021, which is 4.74 M.Cu.m. • **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic) as in 2017 is 30.88 M.Cu.m and in-storage resource is 299.52 M.Cu.m with 330.40 M.Cu.m. o As per the water supply plan of State Agencies, the share of GW in water supply is 100% in 2018 & 2021, it has been envisaged to be reduced to 50% in 2031 & 2041 and it cannot be met from the annual replenishable resources and even if available in-storage is used, the resources is likely to be used up by 2022 and only annual replenishable resource will be available every year.
5	Gurugram	• **Demand**: Demand has been assessed as 210.97 M.Cu.m in 2018, 220.82 M.Cu.m in 2021, 310.25 M.Cu.m in 2031 & 365 M.Cu.m in 2041. • **Total Supply**: Total Supply has been assessed as 210.97 M.Cu.m for 2018, 2021, 2031 & 2041 and the share of GW in water supply is 44%.

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S.No	City	Position on projected water demand vis-à-vis water supply as in 2041
		• **Gap**: The Gap has been assessed as nil in 2018, 9.85 M.Cu.m in 2021, 99.28 M.Cu.m in 2031 & 154.03 M.Cu.m in 2041. • **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 34.81 M.Cu.m and in-storage is 2539.81 M.Cu.m with a total of 2574.62 M.Cu.m o As per the water supply plan of State Agencies, the share of groundwater in water supply is 44% and it can not be met from the annual replenishable resources. However, it can be met from the available in-storage. o If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2038 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
6	Yamunanagar	• **Demand**: Demand has been assessed as 14.10 M.Cu.m in 2018, 13.93 M.Cu.m in 2021, 15.90 M.Cu.m in 2031 & 37.53 M.Cu.m in 2041. • **Total Supply**: Total Supply has been assessed as 13.40 M.Cu.m in 2018, 13.93 M.Cu.m in 2021, 15.90 M.Cu.m in 2031 & 37.53 M.Cu.m in 2041 and the share of GW in water supply is 100%. • **Gap**: The Gap has been assessed as 0.70 M.Cu.m in 2018 and is nil from 2021 to 2041. • **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 12.04 M.Cu.m and in-storage is 964.92 M.Cu.m with a total of 976.96 M.Cu.m o As per the water supply plan of State Agencies, the share of groundwater in water supply is 100% and it cannot be met from the annual replenishable resources, however the available in-storage resources can meet the envisaged supply. o The total groundwater resources including in-storage resources will be able to meet the envisaged gap between demand and water supply.
7	Bangalore	• **Demand**: Demand has been assessed as 919.80 M.Cu.m in 2018, 1029.30 M.Cu.m in 2021, 1523.51 M.Cu.m in 2031 & 2047.65 M.Cu.m in 2041 • **Total Supply:** Total Supply has been assessed as 678.90 M.Cu.m in 2018,925.28 M.Cu.m in 2021, 1071.28 M.Cu.m in 2031 & 1315.83 M.Cu.m in 2041 and the share of GW in water supply is 22% in 2018, while it has been envisaged to be reduced to 3% in 2041. • **Gap**: The Gap has been assessed as 240.90 in 2018, 104.03 M.Cu.m in 2021, 452.24 M.Cu.m in 2031 and 731.83 M.Cu.m in 2041. • **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 291.06 M.Cu.m and in-storage resources is 961.54 M.Cu.m with a total of 1252.60 M.Cu.m o As per the water supply plan of State Agencies, the share of groundwater in water supply is 22% in 2018 & will be reduced to

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S.No	City	Position on projected water demand vis-à-vis water supply as in 2041
		3% in 2041 and it can be met from the annual replenishable resources. o If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2031 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
8	Indore	• **Demand**: Demand has been assessed as 167.01 M.Cu.m in 2018, 234.97 M.Cu.m in 2021, 348.48 M.Cu.m in 2031 & 516.83 M.Cu.m in 2041. • **Total Supply**: Total Supply has been assessed as 80.30 M.Cu.m in 2018, 90.38 M.Cu.m in 2021, 134.04 M.Cu.m in 2031 & 198.79 M.Cu.m in 2041 and the share of GW in water supply is 18% from 2018 to 2041. • **Gap**: The Gap has been assessed as 86.71 M.Cu.m in 2018, 144.59 M.Cu.m in 2021, 214.44 M.Cu.m in 2031 & 318.04 M.Cu.m. • **Groundwater Availability** :The annual replenishable groundwater resources (Dynamic) as in 2017 is 46.69 M.Cu.m and in-storage is 23.85 M.Cu.m with a total of 70.54 M.Cu.m o As per the water supply plan of State Agencies, the share of groundwater in water supply is 18% and it can be met from the annual replenishable resources. o If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the available groundwater resources including the in-storage will not be able to cater the envisaged gap from 2018 onwards. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
9	Ratlam	• **Demand**: Demand has been assessed as 17.74 M.Cu.m in 2018, 18.81 M.Cu.m in 2021, 22.86 M.Cu.m in 2031 & 27.79 M.Cu.m in 2041. • **Total Supply**: Total Supply has been assessed as 9.78 M.Cu.m in 2018, 10.38 M.Cu.m in 2021, 12.61 M.Cu.m in 2031 &15.33 M.Cu.m in 2041 and the share of GW in water supply is 15% from 2018 to 2041. • **Gap**: The Gap has been assessed as 7.96 M.Cu.m in 2018, 8.43 M.Cu.m in 2021, 10.25 M.Cu.m in 2031 & 12.46 M.Cu.m in2041. • **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 4.30 M.Cu.m and in-storage is 7.43 M.Cu.m with a total of 11.73 M.Cu.m. o As per the water supply plan of State Agencies, the share of groundwater in water supply is 15% from 2018 to 2041 and it can be met from the annual replenishable resources alone. o If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2018 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger

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S.No	City	Position on projected water demand vis-à-vis water supply as in 2041
		increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
10	Amritsar	• **Demand**: Demand has been assessed as 79.60 M.Cu.m in 2018, 94.10 M.Cu.m in 2021, 100.70 M.Cu.m in 2031 & 117.10 M.Cu.m in 2041. • **Total Supply**: Total Supply has been assessed as 104.80 M.Cu.m from 2018 to 2041 and the share of GW in water supply is 100% from 2018 to 2041. • **Gap**: There is no gap in 2018, 2021 and 2031, however, it increases to 12.30 M.Cu.m in 2041. • **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 28.92 M.Cu.m and in-storage is 2385.57 M.Cu.m with a total of 2414.49 M.Cu.m o As per the water supply plan of State Agencies, the share of groundwater in water supply is 100% and it cannot be met from the annual replenishable resources. However available in-storage would be able to meet the envisaged supply. o The groundwater resources including the in-storage will be able to meet the envisaged gap between demand and supply in 2041.
11	Jalandhar	• **Demand**: Demand has been assessed as 62.39 M.Cu.m in 2018, 65.38 M.Cu.m in 2021, 76.50 M.Cu.m in 2031 & 87.63 M.Cu.m in 2041. • **Total Supply**: Total Supply has been assessed as 126 M.Cu.m from 2018 to 2041, and the share of GW in water supply is 100%. Due to losses during water supply, supply is envisaged to be more than demand. • **Gap**: There will be no gap between demand and supply from 2021 to 2041 as per data received from State agencies. • **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 26.41 M.Cu.m and in-storage is 1174.43 M.Cu.m with a total of 1200.84 M.Cu.m o As per the water supply plan of State Agencies, the share of groundwater in water supply is 100% and it cannot be met from the annual replenishable resources. o If the groundwater resources are to be used for meeting the envisaged water supply, the in-storage groundwater resources are likely to be used up by the year 2029 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
12	Ludhiana	• **Demand**: Demand has been assessed as 167.17 M.Cu.m in 2018, 178.49 M.Cu.m in 2021, 206.59 M.Cu.m in 2031 & 234.69 M.Cu.m in 2041. • **Total Supply**: Total Supply has been assessed as 231.41 M.Cu.m from 2018 to 2041 and the share of GW in water supply is 100% .The supply has been kept higher than the demand due to losses during water supply. • **Gap**: There is no Gap between demand & supply except in 2041 which is 3.28 M.Cu.m.

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S.No	City	Position on projected water demand vis-à-vis water supply as in 2041
		• **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic)as in 2017 is 41.66 M.Cu.m and in-storage is 1447.44 M.Cu.m with a total of 1489.10 M.Cu.m o As per the water supply plan of State Agencies, the share of groundwater in water supply is 100% from 2018 to 2041 and it cannot be met from the annual replenishable resources. o If the groundwater resources are to be used for meeting the envisaged water supply, the in-storage groundwater resources are likely to be used up by the year 2025 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
13	Mohali	• **Demand**: Demand has been assessed as 25.77 M.Cu.m in 2018, 26.75M.Cu.m in 2021, 29.69 M.Cu.m in 2031 & 32.63M.Cu.m in 2041 • **Total Supply**: Total Supply has been assessed as 25.77 M.Cu.m from 2018 and the same is considered for the subsequent years. The share of GW in water supply is 40%. • **Gap**: The Gap has been assessed as nil in 2018, 0.98 M.Cu.m in 2021, 3.91 M.Cu.m in 2031 & 6.86M.Cu.m in 2041 • **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic)as in 2017 is 7.51 M.Cu.m and in-storage is 140.69M.Cu.m with a total of 148.20M.Cu.m o As per the water supply plan of State Agencies, the share of groundwater in water supply is 40% and it cannot be met from the annual replenishable resources. However the available in-storage will be able to meet the envisaged supply. o If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2039 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence the groundwater resource is likely to last more than the estimated period.
14	Patiala	• **Demand**: Demand has been assessed as 29.2 M.Cu.m in 2018, 31.39 M.Cu.m in 2021, 38.33 M.Cu.m in 2031 & 45.63 M.Cu.m in 2041 • **Total Supply**: Total Supply has been assessed as 25.19 M.Cu.m in 2018, 31.4 M.Cu.m in 2021, 38.33 M.Cu.m in 2031 & 45.63 M.Cu.m in 2041 and the share of GW in water supply is 100% in 2018,80% in 2021,66% in 2031 & 55% in 2041. • **Gap**: The Gap has been assessed as 4.01 M.Cu.m in 2018 and there is no gap in subsequent years. • **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic)as in 2017 is 8.08 M.Cu.m and in-storage resources is 445.33 M.Cu.m with a total of 453.41M.Cu.m o As per the water supply plan of State Agencies, the share of groundwater in water supply is 100% in 2018 and it cannot be met

S.No	City	Position on projected water demand vis-à-vis water supply as in 2041
		from the annual replenishable resources alone. However, the available in-storage would be able to meet the envisaged supply. o The groundwater resources including the in-storage will be able to meet the demand in the projected years till 2041. However there will be a huge depletion in in-storage groundwater resource which may trigger lateral inflow from surrounding areas.
15	Ajmer	• **Demand**: Demand has been assessed as 34.55 M.Cu.m in 2018, 35.67 M.Cu.m in 2021, 41.75 M.Cu.m in 2031 & 44.50 M.Cu.m in 2041 • **Total Supply**: Total Supply has been assessed as 34.55 M.Cu.m in 2018, 35.67 M.Cu.m in 2021, 39.42 M.Cu.m in 2031 & 2041 and share of GW in water supply is nil . • **Gap**: The Gap has been assessed as nil in 2018 & 2021, 2.33 M.Cu.m in 2031 & 5.08M.Cu.m in 2041 • **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic)as in 2017 is 3.93 M.Cu.m and in-storage is 1.08M.Cu.m with a total of 5.01M.Cu.m o As per the water supply plan of State Agencies, the share of groundwater in water supply is nil. o If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2040 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence the groundwater resources is likely to last more than the estimated period.
16	Bikaner	• **Demand**: Demand has been assessed as 16.06 M.Cu.m in 2018 ,16.90 M.Cu.m in 2021, 19.71M.Cu.m in 2031 & 22.48 M.Cu.m in 2041 • **Total Supply**: Total Supply has been assessed as 16.06 M.Cu.m in 2018, 16.83M.Cu.m in 2021, 19.31M.Cu.m in 2031 & 24.09 M.Cu.m in 2041 . • **Gap**: The Gap has been assessed as nil in 2018, 0.07 M.Cu.m in 2021, 0.40 M.Cu.m in 2031 & again nil in 2041 • **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic)as in 2017 is 1.53 M.Cu.m and in-storage is 45.57 M.Cu.m with a total of 47.10 M.Cu.m. o As per the water supply plan of State Agencies, the share of groundwater in water supply is 10% in 2018 &2021, 8% in 2031 & 7% in 2041 and it cannot be met from the annual replenishable resources. However, the available in-storage will be able to meet the envisaged supply. o The available groundwater resources including the in-storage will be able to meet the envisaged gap between demand and supply.
17	Jaisalmer	• **Demand**: Demand has been assessed as 4.75 M.Cu.m in 2018 5.11 M.Cu.m in 2021, 5.48 M.Cu.m in 2031 & 6.21 M.Cu.m in 2041 • **Total Supply**: Total Supply has been assessed as 5.11 M.Cu.m from 2018 to 2041 • Gap: The Gap has been assessed as nil in 2018 & 2021, 0.36 M.Cu.m in 2031, & 1.10 M.Cu.m in 2041

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S.No	City	Position on projected water demand vis-à-vis water supply as in 2041
		• **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic)as in 2017 is 0.04 M.Cu.m and in-storage is 1.59 M.Cu.m with a total of 1.63 M.Cu.m o As per the water supply plan of State Agencies, the share of groundwater in water supply is 7% and it cannot be met from the annual replenishable resources and available in-storage is also likely to be used up by 2021& thereafter only annual replenishable resources will be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
18	Jaipur	• **Demand**: Demand has been assessed as 198.93 M.Cu.m in 2018, 219.37 M.Cu.m in 2021, 287.26 M.Cu.m in 2031 & 355.51 M.Cu.m in 2041. • **Total Supply**: Total Supply has been assessed as 198.93 M.Cu.m from 2018 to 2041 • **Gap:** The Gap has been assessed as nil in 2018 & 20.44 M.Cu.m in 2021, 88.33 M.Cu.m in 2031, & 156.59 M.Cu.m in 2041 • **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 39.83 M.Cu.m and in-storage is 86.11 M.Cu.m with a total of 125.94 M.Cu.m. o As per the water supply plan of State Agencies, the share of groundwater in water supply is 13% and it can be met from the annual replenishable resources. o If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2024 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
19	Jodhpur	• **Demand:** Demand has been assessed as 93.08M.Cu.m in 2018, 100.01 M.Cu.m in 2021, 122.28 M.Cu.m in 2031 & 144.91M.Cu.m in 2041 • **Total Supply**: Total Supply has been assessed as 93.08M.Cu.m from 2018 to 2041 • Gap: The Gap has been assessed nil in 2018 & 6.94 M.Cu.m in 2021, 29.20 M.Cu.m in 2031, & 51.83 M.Cu.m in 2041 • **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 14.61 M.Cu.m and in-storage is 37.34 M.Cu.m with a total of 51.95 M.Cu.m. o As per the water supply plan of State Agencies, the share of groundwater in water supply is 8% and it can be met from the annual replenishable resources. o If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2026 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger

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S.No	City	Position on projected water demand vis-à-vis water supply as in 2041
		increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
20	Chennai	• **Demand**: Demand has been assessed as 407 M.Cu.m in 2018, 419 M.Cu.m in 2021, 460 M.Cu.m in 2031 & 502 M.Cu.m in 2041 • **Total Supply:** Total Supply has been assessed as 236 M.Cu.m in 2018, 436 M.Cu.m in 2021, 690 M.Cu.m in 2031 & 2041 and the share of GW in water supply is 31% in 2018, 17 % in 2021, 11 % in 2031 & 2041. • **Gap:** The Gap has been assessed as 171 M.Cu.m in 2018. Due to proposed augmentation in the supply from the proposed desalination plant and Stanley Reservoir, there is no gap from 2021 to 2041. • **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic) as in 2017 is 46 M.Cu.m and in-storage is 13M.Cu.m with a total of 59 M.Cu.m o As per the water supply plan of State Agencies, the share of GW in water supply is 31% in 2018, 17 % in 2021, 11 % in 2031 & 2041 and as 27 M.Cu.m is proposed to be extracted from outside the city, balance 46 M.Cu.m is equal to the annual replenishable resources and hence the supply can be achieved. o The ground water resources including in-storage will not be able to meet the gap in 2018, i.e. 171 M.Cum, but as the surface water supply is envisaged to be increased from the year 2021, there will be no gap between the demand and supply for subsequent years.
21	Vellore	• **Demand**: Demand has been assessed as 22 M.Cu.m in 2018 and 2021, 25 M.Cu.m in 2031 & 27 M.Cu.m in 2041. • **Total Supply:** Total Supply has been assessed as 14 M.Cu.m in 2018, 92 M.Cu.m from 2021 to 2041 and the share of GW in water supply is 21% in 2018. The additional supply of 78 M.Cum includes the supply for Vellore City and 11 other Municipalities. • **Gap:** The Gap has been assessed as 8 M.Cu.m in 2018, in subsequent years there is no gap. • **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic) as in 2017 is 9.9 M.Cu.m and in-storage is 4.1 M.Cu.m with a total of 14 M.Cu.m. o As per the water supply plan of State Agencies, the share of groundwater in water supply is 21% in 2018 and it can be met from the annual replenishable resources. o The surface water supply is envisaged to be increased from 2021 hence there will be no gap between demand and water supply.
22	Hyderabad	• **Demand**: Demand has been assessed as 1012M.Cu.m in 2018, 1389 M.Cu.m in 2021, 1995 M.Cu.m in 2031 • **Total Supply**: Total Supply has been assessed as 745 M.Cu.m from 2018, 1073 M.Cum in 2021 & 1183 M.Cum in 2031. • **Gap**: The Gap has been assessed as 268 M.Cu.m in 2018 & 315 M.Cu.m in 2021 and 812 M.Cu.m in 2031 • **Groundwater Availability**: The annual replenishable groundwater resources (Dynamic) as in 2017 is 110.2 M.Cu.m and in-storage resources has been assessed as 372.26 M.Cu.m and total as 482.46 M.Cu.m

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S.No	City	Position on projected water demand vis-à-vis water supply as in 2041
		○ As per the water supply plan of State Agencies, the share of groundwater in water supply is 14% in 2018, 10% in 2021 & 9% in 2031 and it can be met from the annual replenishable resource. ○ If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2019 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.
23	Agra	• **Demand**: Demand has been assessed as 146.37 M.Cu.m in 2018, 168.63 M.Cu.m in 2020, 242 M.Cu.m in 2035 & 342.74M.Cu.m in 2050 • **Total Supply:** Total Supply has been assessed as 109.14 M.Cu.m from 2018 to 2050. • **Gap:** The Gap has been assessed as 37.23 M.Cu.m in 2018, 59.49 M.Cu.m in 2020, 132.86 M.Cu.m in 2035 & 233.60M.Cu.m in 2050 • **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic)as in 2017 is 11.38 M.Cu.m and in-storage is 898.56M.Cu.m with a total of 909.94M.Cu.m ○ As per the water supply plan of State Agencies, the share of groundwater in water supply is 3% and it can be met from the annual replenishable resources. ○ If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2029 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence the groundwater resources is likely to last more than the estimated period.
24	Ghaziabad	• **Demand**: Demand has been assessed as 122.64 M.Cu.m in 2018, 153.3 M.Cu.m in 2021, 260.61 M.Cu.m in 2031 & 443.11 M.Cu.m in 2041 • **Total Supply:** Total Supply has been assessed as 141.99 M.Cu.m in 2018 and has been retained for the subsequent years, as the data was not available and the share of GW in water supply is 69%. • **Gap:** The Gap has been assessed as **Nil** in 2018, 11.31 M.Cu.m in 2021, 118.62 M.Cu.m in 2031 & 301.12 M.Cu.m in 2041 • **Groundwater Availability:** The annual replenishable groundwater resources (Dynamic) as in 2017 is 9.80 M.Cu.m and in-storage is 1191.60 M.Cu.m with a total of 1201.40 M.Cu.m ○ As per the water supply plan of State Agencies, the share of groundwater in water supply is 69%. The annual replenishable resources is not sufficient to meet the proposed water supply and if in-storage resources was used for the envisaged supply, the in-storage groundwater resources are likely to be used up by the year 2030 and thereafter only annual replenishable resources would be available every year.

S.No	City	Position on projected water demand vis-à-vis water supply as in 2041
		○ If the groundwater resources are to be used for meeting the envisaged gap between demand and water supply, the in-storage groundwater resources are likely to be used up by the year 2027 and thereafter only annual replenishable resources would be available every year. However, depleting water level may trigger increased lateral flow from the surrounding areas. Hence, the groundwater resources is likely to last more than the estimated period.

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ANNEXURE

Groundwater Resources Vs Domestic Water Demand and Supply for select cities in India

Annexure-I

Minutes of the meeting to discuss the ground water situation in 21 identified cities held under the chairmanship of JS(IC&GW) on 24.7.2018 at 3:00 pm in his chamber

List of participants is annexed.

2. Welcoming the participants, Joint Secretary (IC&GW) remarked that recent articles in newspapers and report of NITI Aayog have created uneasiness among the public about ground water running out in 21 cities by 2021. There have been a number of Parliament Questions on this issue and Hon'ble Supreme Court had also made a reference in one of its order. It was informed that the thrust of the discussions in the meeting would be to formulate a comprehensive and credible response by CGWB on the ground water situation in the identified 21 cities.

3. Chairman, CGWB explained the dynamics of ground water flow within and between aquifers, both in soft rock and hard rock areas. The concept of in-storage resources and their difference with dynamic resources was also detailed. It was also underlined that as dynamic resources are replenished annually, the question of ground water running out does not arise. He also informed that a preliminary exercise for estimating the total ground water resources of the districts, in which the identified cities are situated, has been conducted. Tentative figures have also been worked out to estimate the total ground water extraction in the cities.

4. After detailed discussions, it was decided that a committee under Sh. G.C.Pati Member (East), CGWB be constituted to examine the issue in its entirety and arrive at realistic assessment of the ground water situation in cities, including cities identified by NITI Aayog. The Committee will submit its report to the Ministry within two months. A copy to be also submitted to the Committee constituted to assess the total water availability in cities. It was also decided that in view of the order of Hon'ble Supreme Court, the exercise in case of Delhi should be taken on priority.

Meeting ended with thanks to the Chair.

*****

List of participants

S.No.	Name and Designation
1	Sh. Akhil Kumar, Joint Secretary (IC&GW), MoWR, RD&GR – In Chair
2	Sh. K.C.Naik, Chairman CGWB
3	Sh. G.C.Pati, Member (East), CGWB
4	Sh. Avinash Mishra, Joint Advisor (WR, & LR), NITI Aayog
5.	Sh. Sujit Sinha, Suptd. Hydrologist, CGWB
6.	Sh. Pratul Saxena, Sr. Hydriogeologist
7.	Dr. Rajesh Chandra, Sr. Hydrogeologist

Annexure-II

Chairman's Technical Cell
No.95/TC/Chmn/CGWB/2016-17 4533
Government of India
Ministry of WR,RD&GR
Central Ground Water Board
BHUJAL BHAWAN
NH-IV, Faridabad
Dated: 27th July'2018

Office Copy

OFFICE ORDER 27 JUL 2018

NITI Aayog has brought out a report "Composite Water Management Index – A Tool for water management" in June 2018. It has been reported that 21 major cities in India are expected to run out of Ground water as soon as 2020, affecting about 100 million people.

In the light of above and as per decision taken in the meeting held with Joint Secretary (IC&GW), MoWR, RD&GR on 24th July'2018, the Chairman, CGWB has constituted a committee of following officers to examine the issue in its entirety and arrive at realistic assessment of the ground water situation in cities, including cities identified by NITI Aayog. :

1. Sri G.C.Pati, Member(East),CGWB, Faridabad
2. Sri Anoop Nagar, Regional Director, NWR, Chandigarh
3. Dr. S. Suresh, Sr.Hydrogeologist,Sc.D, CGWB, Faridabad

The Committee will submit its report within a period of **two weeks.**
Further, it is requested that in view of the order of Hon'ble Supreme Court, the report in **case of Delhi should be taken on priority.**

27/7/18
(S.K.Sinha)
Supdtg.Hydrologist & T.S. to Chairman

Distribution:
1. Sri G.C.Pati, Member(East),CGWB, Faridabad
2. Sri Anoop Nagar, Regional Director, NWR, Chandigarh
3. Dr. S. Suresh, Sr.Hydrogeologist,Sc.D,CGWB, Faridabad

Copy to:

1./2. Member (South)/ Member (N&W), CGWB ,Faridabad with a request to provide information required by the Committee on priority.
3. Sri Pratul Saxena, T.S. to the J.S.(IC&GW), MoWR,RD&GR, Shram Shakti Bhawan, New Delhi

Groundwater Resources Vs Domestic Water Demand and Supply for select cities in India

Annexure-III

Item No. 02 Court No. 1

BEFORE THE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH, NEW DELHI

Original Application No. 134/2015

Friends through its General Secretary Applicant(s)

Versus

Ministry of Water Resources Respondent(s)

Date of hearing: 23.09.2019

CORAM: **HON'BLE MR. JUSTICE ADARSH KUMAR GOEL, CHAIRPERSON**
HON'BLE MR. JUSTICE S.P WANGDI, JUDICIAL MEMBER
HON'BLE MR. JUSTICE K. RAMAKRISHNAN, JUDICIAL MEMBER
HON'BLE DR. NAGIN NANDA, EXPERT MEMBER

For Applicant(s): Mr. Rahul Choudhary, Advocate

For Respondent(s): Mr. Rajkumar, Advocate for CPCB
Mr. Attin Shankar Rastogi, Advocate for MoEF
Ms. Ruchi Mandal, Advocate for CGWA

ORDER

1. The issue for consideration is the permissibility of use of Reverse Osmosis (RO) system where Total Dissolved Solids (TDS) level is below a particular threshold and where RO system destroys minerals rendering use of RO treated water harmful for human health. Further question is preventing undue wastage of water rejected in the process.

2. The matter was considered by this Tribunal for more than four years. Finally, on 20.12.2018, having regard to the concern that the 80% of the potable water was being unnecessarily wasted and in absence of remineralization, use of RO system was resulting in adversely

affecting health, an Expert Committee with the representatives from Ministry of Environment, Forest and Climate Change (MoEF&CC), Central Pollution Control Board (CPCB), Bureau of Indian Standard, IIT Delhi and NEERI was constituted.

3. Based on the report dated 30.04.2019 by the said Expert Committee, this Tribunal held that where the TDS in the water was less than 500 mg/l, use of RO be prohibited. Wherever RO is to be permitted, condition of recovery of water to the extent of more than 60% be required. Further provision should be for enhancement of recovery of water upto 75% in phased manner in future and reuse thereof for permissible purposes. Vide order dated 20.05.2019, the Tribunal accepted the report and directed the MoEF&CC to issue appropriate notification and file an affidavit of compliance within one month, apart from other directions. The directions are as follows:

> *"(i) The MoEF&CC may issue appropriate notification prohibiting use of RO where TDS in water is less than 500 mg/l and wherever RO is permitted, a requirement is laid down for recovery of water be more than 60%. Further provision be laid down for recovery of water upto 75% and use of such RO reject water for purposes such as utensil washing, flushing, gardening, cleaning of vehicles and floor mopping.*
>
> *(ii) Appropriate directions in the matter may be issued. The Notification/Policy to be notified may also provide for a mechanism for public awareness about ill effects of demineralized water on public health and for effective enforcement requiring the concerned Local Bodies/Municipal Corporations/Municipalities/ Panchayats and institutions like Public Health Engineering Department (PHED)/ Jal Nigam / Jal Boards etc. be required to display water quality at regular intervals, particularly TDS concentration component by an appropriate mechanism.*
>
> *(iii) Above regulatory regime may ensure regulating consumption and use of low TDS water by requiring manufacturers to maintain minimum TDS concentration to 150 mg/l or the minimum levels of calcium and magnesium.*
>
> *(iv) Directions be issued for enforcement of Extended Producers Responsibility by the manufacturers for disposal of cartridges and membranes and requiring the manufacturers to provide proper labeling on the purifier specifying that the unit should be used if TDS is more than 500 mg/l.*

v) *MoEF&CC may file an affidavit of compliance by e-mail at judicial-ngt@gov.in within one month.*

(vi) *The Expert Committee constituted by this Tribunal vide order dated 20.12.2018 along with Central Ground Water Authority may collect and provide data with regard to availability of ground water and its usage in 21 cities mentioned in the report of NITI Aayog and furnish a report to this Tribunal within one month by e-mail at judicial-ngt@gov.in. The said report may be placed in the file of O.A. No. 176/2015 which is listed on 04.07.2019."*

4. The MoEF&CC has still not complied with the same and, instead, has filed an affidavit *inter-alia* as follows:

> *"It is humbly prayed that in order to delineate the appropriate provisions for effective compliance of the Hon'ble NGT directions 8 months time is required which includes 4 months for Inter-ministerial, stakeholders consultation and finalization of draft notification, 2 months for wide circulation of draft notification for inviting public comments and 2 months for incorporation of public comments and thereafter finalization of the notification. Accordingly, the Hon'ble Tribunal may kindly grant 8 months time."*

5. The above prayer appears to be unreasonable and delaying the matter to the detriment of public interest. Though the applicant suggests that delay will advance commercial interest of those benefitted by delay, we do not propose to go into such allegation in absence of any clear evidence. The fact remains that order of the Tribunal is based on report of Expert Committee which also comprised representative of MoEF&CC and is enforceable without permission of any other authority with penal consequences. Accordingly MoEF&CC may now issue the necessary notification in the light of direction already issued in accordance with the report of the Expert Committee and cover not only the subject of recovery of RO reject water in domestic and commercial use but also in industrial process.

6. With regard to the further direction requiring the Committee, along with Central Ground Water Authority (CGWA), to collect and provide data with regard to availability of groundwater and its usage in 21 cities mentioned in the report of NITI Aayog and furnish a report to this Tribunal, CPCB has, in their letter dated 01.08.2019, stated that CGWA is not furnishing the information inspite of being required to do so. Let the CGWA do the needful positively within one week failing which the Member Secretary of CGWA will be liable to pay Rs. 1 Lakh as costs. Further necessary report by the Expert Committee be furnished to this Tribunal within one month.

7. The Member Secretary, CGWA and the concerned Joint Secretary, MoEF&CC may remain present in person along with compliance reports on the next date.

List for further consideration on 04.11.2019.

Adarsh Kumar Goel, CP

S.P Wangdi, JM

K. Ramakrishnan, JM

Dr. Nagin Nanda, EM

September 23, 2019
Original Application No. 134/2015
DV