REPORT ON DYNAMIC GROUND WATER RESOURCES OF CHANDIGARH (UT) AS ON MARCH 2022
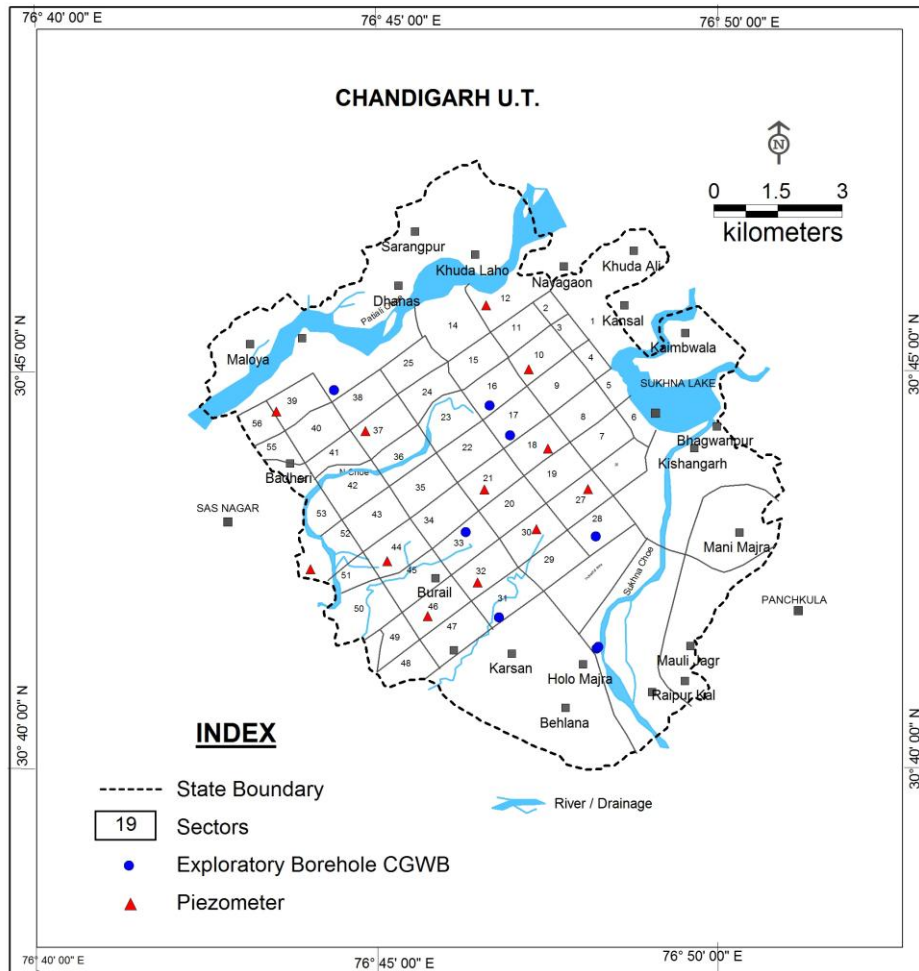

CHANDIGARH ADMINISTRATION & MUNICIPAL CORPORATION, CHANDIGARH
AND
CENTRAL GROUND WATER BOARD
NORTH WESTERN REGION
CHANDIGARH
JANUARY, 2023

REPORT ON DYNAMIC GROUND WATER RESOURCES OF CHANDIGARH UT AS ON MARCH 2022

Prepared by

CHANDIGARH ADMINISTRATION & MUNICIPAL CORPORATION, CHANDIGARH

AND

CENTRAL GROUND WATER BOARD

NORTH WESTERN REGION

CHANDIGARH

JANUARY, 2023

Faced with the challenges of Climate Change and rising demand for freshwater, makes it impending necessity to record accurate data and knowledge of existing water reservoirs, whether surface or underground for judicious use and development planning of water resources, Ground Water Resource, although replenishable, is not inexhaustible. The increasing demand on the resource over the years has led to water scarcity in many parts of the world. During past two decades increase in extraction and overexploitation of this resource has led to sharp decline in the availability of freshwater. Estimates for UT Chandigarh, project overall stage of Ground Water Development to be 81% (as on 31st March, 2022). The efforts towards enhancement of water supply efficiency and conservation measures have improved the ground water scenario in UT Chandigarh over the past years.

This report on Ground Water Resources Estimation, as on 31st March 2022, of UT Chandigarh has been prepared by the Central Ground Water Board, North Western Region, Chandigarh and Chandigarh Administration & Municipal Corporation, Chandigarh jointly. The report is prepared on guidelines by the Ground Water Resource Estimation Committee (GEC 2015) using IN-GRES web portal (http://ingres.iith.ac.in/) providing details regarding Total Annual Replenishable Ground Water Resources, present draft and scope for future development. The report indicates that UT Chandigarh has maintained its status same as "Semi Critical". The report provides valuable inputs for planning of aquifer rejuvenation instead of ground water developmental activities in the UT.

I would like to appreciate the efforts of each individual associated with data collection, analysis and preparation of this report by officers and officials of Central Ground Water Board, North-Western Region, Chandigarh and Chandigarh Administration & Municipal Corporation, Chandigarh. I personally feel that this report will be of immense value to the administrators, planners and agencies engaged in the development and regulation and management of ground water resources.

(Nitin Kumar Yadav, IAS)

अनुराग खन्ना
क्षेत्रीय निदेशक
Anurag Khanna
Regional Director

भारत सरकार
जल शक्ति मंत्रालय
केन्द्रीय भूमि जल बोर्ड
उत्तर पश्चिमी क्षेत्र चण्डीगढ़
Government of India
Ministry of Jal Shakti
Central Ground Water Board
North Western Region, Chandigarh

प्रस्तावना

केन्द्र शासित प्रदेश चंडीगढ़ के भूजल का सटीक आँकलन भारत सरकार की भूजल संसाधन आँकलन (GEC - 2015) संबंधी दिशा निर्देशो के आधार पर 31 मार्च 2022 तक क्रियाशील संसाधनों का आँकलन किया गया । यह आँकलन केंद्रीय भूमिजल बोर्ड, उत्तरी पश्चिमी क्षेत्र, चंडीगढ़ एवं चंडीगढ़ प्रशासन एवं नगर निगम, चंडीगढ़ के अधिकारियों ने संयुक्त रुप से किया है ।

इस अध्ययन के लिये भारतीय प्रोधोगिकी संस्थान, हैदराबाद द्वारा विकसित सॉफ्टवेयर (INGRES) का उपयोग किया गया है। सूचना प्रोधोगिकी के उपयोग से यह अध्ययन कम समय में एवं सटीक रूप से पूर्ण हो पाया है। प्रस्तुत रिपोर्ट में पुनर्भरण माध्यम से भूजल की वार्षिक उपलब्धता, भूजल के मौजूदा दोहन एवं भविष्य में भूजल की शेष उपलब्धता का ब्लाक स्तर पर किये गये विस्तृत आँकलन कर टेबल एवं ग्राफ के माध्यम से प्रस्तुत किया गया है । 2022 के अध्ययन में केंद्र शाषित प्रदेश चंडीगढ़ को आधार बना कर आँकड़े प्रस्तुत किये गये है । इस अध्ययन से यह ज्ञान हुआ है कि केंद्र शाषित प्रदेश चंडीगढ़ (एकमात्र ब्लॉक) ब्लॉक अर्ध विकट (Semi Critical) श्रेणी में है।

मैं श्री नितिन कुमार यादव, IAS , गृहसचिव, स्थानीय सरकार, चंडीगढ़ प्रशासन एवं अध्यक्ष आँकड़ा संशोधन समिति चंडीगढ़ यूटी (Committee for Estimation of Ground Water Resources Potential and Refinement of figures in UT of Chandigarh) के समय - समय पर दिये गये मार्गदर्शन एवं रिपोर्ट की स्वीकृति के लिये आभारी रहूँगा । मैं नगर निगम चंडीगढ़ से श्री एन. पी. शर्मा, मुख्य अभियंता एवं श्री विजय प्रेमी, अधीक्षण अभियंता तथा श्री जगदीश सिंघ, अधिशाषी अभियंता एवं श्री परविंदर पाल अधिशाषी अभियंता के इस रिपोर्ट के संकलन में दिये गये सहयोग के लिए आभार प्रकट करता हूँ ।

मैं केंद्रीय भूमिजल बोर्ड के डॉ. कृति मिश्रा (वैज्ञानिक बी) एवं श्री आदित्य शर्मा (स.भूजल मौसमविद) द्वारा इस रिपोर्ट को तैयार करने के लिए दिए गये उनके महत्वपूर्ण योगदान के लिए उनका आभार प्रकट करता हूँ । मैं साथ ही श्री दिनेश तिवारी (वैज्ञानिक ई) जिनके पर्यवेक्षण में यह रिपोर्ट तैयार की गयी है, का भी आभार व्यक्त करता हूँ । मैं उन सभी अधिकारियो का भी आभार व्यक्त करता हूँ, जिन्होंने इस रिपोर्ट के संकलन में महत्वपूर्ण भूमिका निभाई है । मेरा विश्वास है कि यह रिपोर्ट योजनाकारों, प्रशासकों एवं जल व्यवस्थापन से जुड़े सभी विषयों के लिए महत्वपूर्ण रहेंगी ।

(अनुराग खन्ना)
क्षेत्रीय निदेशक

भूजल भवन, प्लॉट नं. 3बी, सैक्टर - 27ए, मध्य मार्ग, चण्डीगढ़. 160019
Bhujal Bhawan, Plot No. 3B, Sector - 27A, Madhya Marg, Chandigarh-160019
Tel : 0172-2619500-01, E-mail : rdnwr-cgwb@nic.in

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CHAPTER-1: INTRODUCTION

1.1   INTRODUCTION

Chandigarh known, as "THE CITY BEAUTIFUL" is a Union Territory (U.T.) located at the foothills of the Siwaliks about 250 km north of Delhi. The city also has the distinction of being the joint capital of Punjab and Haryana states even though it does not form part of any of the two States. It lies between north latitudes $30^o40'$ and $30^o46'$ and east longitudes $76^o42'$ and $76^o51'$ and falls in Survey of India toposheet no. 53B/13 & 53B/14. Punjab state borders the UT in the south and southwestern sides and Haryana state on eastern side. UT of Chandigarh has an area of 114 sq. km, out of which 36 sq.km. is rural and remaining 78 Sq.km, is urban. The city is divided into 55 dwelling sectors. As per census 2011, total population of the city was 10,55,450 persons having a population density of 9258 persons/sq.km. Due to high urbanization, almost 79% of the total area is not available for cultivation. Main crops grown during Kharif are rice, maize and, potato while during Rabi season wheat, gram and oil seeds are grown.

There are 281 deep tube wells in the city for drinking & domestic use and out of them 277 are actual in use. 23 nos. of tube wells for commercial use / industrial use are permitted to withdraw ground water 217.65 ham/year and 30 nos. of tube wells are used for irrigation use and total draft of these wells are 5.73 MGD (950.80 ham/year).

The Urban Water Supply of the city is 88.89 MLD (Million liters per day) which includes Ground Water Supply 21.13 MGD and Surface Water Supply through canal is 67.76 MGD and water supply losses are 26.66 MLD (30% of total water supply).

There are no large natural surface water bodies in Chandigarh though small ponds do exist in the rural areas. The Sukhna Choe has been dammed in northeast side of the city, which has given rise to an artificial lake covering an area of about 1.99 sq. km. The lake, known as Sukhna, has a water holding capacity of 5 million cubic meters (MCM). UT of Chandigarh falls in the Ghaggar Basin. There are two major streams, Sukhna Choe and Patiali ki Rao that originate from Siwalik Hills ranges and forms the natural drainage of the city. The Sukhna Choe flows north to south, drains the eastern part and joins the Ghaggar River. The other important stream is Patiala-ki Rao, which flows northeast to southwest and drains the northern parts of the city. Both these streams are ephemeral in nature and carry high flows during monsoon. The N-Choe flows through the leisure

valley and drains major parts of the city. It flows from northeast to southwest direction and traverses north central part of the city. Another Choe, Choi Nala originates from Sector-31 and drains southern most part of the city.

1.2   Background for Re-Estimating the Ground Water Resources of the Union Territory

The first attempt to estimate the ground water resources of the country was made in the year 1979. A committee known as Ground Water Over-exploitation committee was constituted by Agriculture Refinance and Development Corporation (ARDC) of Govt. of India.   Based on the methodology and norms recommended by the above Committee, the ground water resources were assessed. Subsequently, the necessity was felt to refine the methodologies and the "Ground water Estimation Committee (GEC)" headed by the Chairman, CGWB came into existence. Based on the detailed surveys and studies by the various offices and projects of CGWB, the Committee recommended the revised methodology in 1984 (GEC-84) for estimation of ground water resources. Again in 1997, the Ground Water Estimation Committee reviewed the previous studies and work done in various states and suggested a modified methodology (GEC-97) for computation of ground water resources. Accordingly, the Dynamic Study of Ground Water Estimation in the Chandigarh UT in 2004, 2009, 2011 2013 has been carried out on the basis of GEC-97 Methodology.

In 2010, Ministry of Water Resources constituted a Central Level Expert Group (CLEG) for over all supervision of the reassessment of ground water resources in the entire country. The group finalized its report and the draft report was circulated to all the members of the Committee for their views. During the fourth meeting of the committee, held on 03-12-2015, the draft report of "Ground Water Resource Estimation Committee - 2015 (GEC 2015) was discussed in detail. The views expressed by the members for revised methodology were considered and necessary modifications were made and report of the Committee was finalized. As decided in the meeting held on 09.02.2016 at New Delhi on Revision of Ground water estimation Methodology-97, a workshop on "Ground Water Resource Estimation Methodology - 2015" was held on 24th January 2017 at CWPRS, Khadakwasla, Pune involving stakeholders and experts. The major changes proposed in the workshop were (i) to change the criteria for categorization of assessment units and (ii) to remove the potentiality tag.

The Ministry of Water Resources also requested all the State/UT Governments to constitute State Level Committees for over all supervision of assessment of ground water resources at the state

level. As per guidelines of Central Ground Water Board, Chandigarh UT Government, vide Endst. No. 16501-FII(9)-2020/12910 dated 01/11/2020, has notified a committee namely: "**State Level Evaluation Committee**" for estimation annual replenishable ground water resources in accordance with the Ground Water Resources Estimate Methodology.

1.3 Constitution of State-Level Committee for Ground Water Resources Estimation

In an attempt to re-assess the ground water resources of Chandigarh UT based on GEC-2015 methodology, Chandigarh UT administration has constituted a state level committee with the following members.

(Annexure I)

1.	Principal Secretary, Local Govt., Chandigarh Administration	**Chairman**
2.	Secretary Engineering Chandigarh Administration	**Member**
3.	Commissioner, Municipal Corporation, Chandigarh	**Member**
4.	Deputy Commissioner, UT Chandigarh	**Member**
5.	Chief Engineer, M. C Chandigarh	**Member**
6.	Chief Engineer, UT Chandigarh	**Member**
7.	S.E, Municipal Corporation, Chandigarh	**Member**
8.	S.E, Union Territory , Chandigarh	**Member**
9.	Director Industries	**Member**
10.	General Manager, NABARD	**Member**
11.	Regional Director, Central Ground Water Board (CGWB)	**Member Secretary**

CHAPTER-2

HYDROGEOLOGICAL CONDITIONS OF THE UNION TERRITORY

2.1 Hydrogeology

Four physiographic units are encountered in Chandigarh; **The Siwalik range** trending NW-SE forms the northeastern boundary of Chandigarh and is exposed in a small patch on the northeastern side. Southwestern slopes of the foothills are covered with loose talus material deposited by hill torrents forming alluvial fans. These alluvial fans coalesce to form piedmont **Kandi** formation running parallel to the hill ranges. The piedmont deposits comprise of cobble, pebble and boulder, associated with sand, silt and clay. The Kandi formations merge into **Sirowal** formations in south and southwest. The Sirowal merges with the main **Alluvial plain** towards south and southwest. The alluvial deposits belong to Quaternary age and comprise layers of fine sand and clay. Coarser sediments occur along the Sukhna Choe and Patiali ki Rao whereas relatively finer sediments, thus restricting the aquifer disposition laterally, underlie the area between these two streams. The typical Kandi formations comprising boulders-gravel- coarse sand are not prevalent in the area since the source formations are fine grained.

2.2 Hydrometeorology

Chandigarh (UT) has a humid subtropical climate characterized by a seasonal rhythm: very hot summers, mild winters, unreliable rainfall and great variation in temperature. The city also receives occasional winter rains from the western disturbance originating over the Mediterranean Sea. The western disturbances usually bring rain predominantly from mid-December to till end of April which can be heavier sometimes with strong winds and hails if the weather turns colder (during March–April months) which usually proves disastrous to the crops. Cold winds usually tend to come from the north near Shimla, and from the State of Jammu and Kashmir, both of which receive their share of snowfall during winter time.

Most of the year, the climate of Chandigarh (UT) is of a pronounced continental character, very hot in summer and markedly cold in winter. In between are the pleasant months of spring. There is extremely hot in summer at around 45 °C and mild in winter. The hottest months are May and June and the coldest are December and January. Normal minimum temperature ranges from 3°C to 9°C. Temperature dips to freezing point during the month of December/January. The air

over the entire UT is dry during the greater part of the year. Humidity is high in the monsoon months. April and May are the driest months with relative humidity of about 30% in the morning and less than 20% in the afternoons .Winds are generally light during the post monsoon and winter months. They strengthen during the summer and monsoon months. Except during the monsoon months, winds are predominantly from a westerly or north-westerly direction and tend to be more northerly in the afternoon. Easterly and south-easterly winds are more common in the monsoon months.

Rainfall

There are two seasons of rainfall in the UT. The south-west monsoon season, the principal source of ground water sets in last week of June and withdraws towards end of September and contributes about 80% of annual average rainfall. Another period of rainfall is winter rain from December to March is about 20% of total rainfall which is mostly absorbed into the soil. More than 50% of the annual rainfall received in the four rainy months for June to September, only there by leading to large variations on temporal scale. Rainfall is highly variable in time and space.

The Normal Rainfall for Chandigarh (UT) 1078 mm, but it has great spatial variations. The Actual annual rainfall since 2012 to 2021, of Chandigarh (UT) analyzed and compared to the normal rainfall, then it is observed that rainfall pattern is showing decline trend and continuously deficient rainfall 2012 (-7%), 2013 (-5%), 2014 (-24%), 2015 (-24%), 2016 (-47%), 2017 (-20%), 2018 (+1%), 2019 (-13%), 2020 (-20%) & in 2021 (-24%) observed in Chandigarh UT.

ITEM	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Normal Rainfall (mm)	1078	1078	1078	1078	1078	1078	1078	1078	1078	1078
Actual Rainfall (mm)	1004	1026	819	824	575	858	1086	940	867	819
% Departure From Normal	-7	-5	-24	-24	-47	-20	1	-13	-20	-24

Deviation in Actual Annual Rainfall from Normal Rainfall of Chandigarh UT
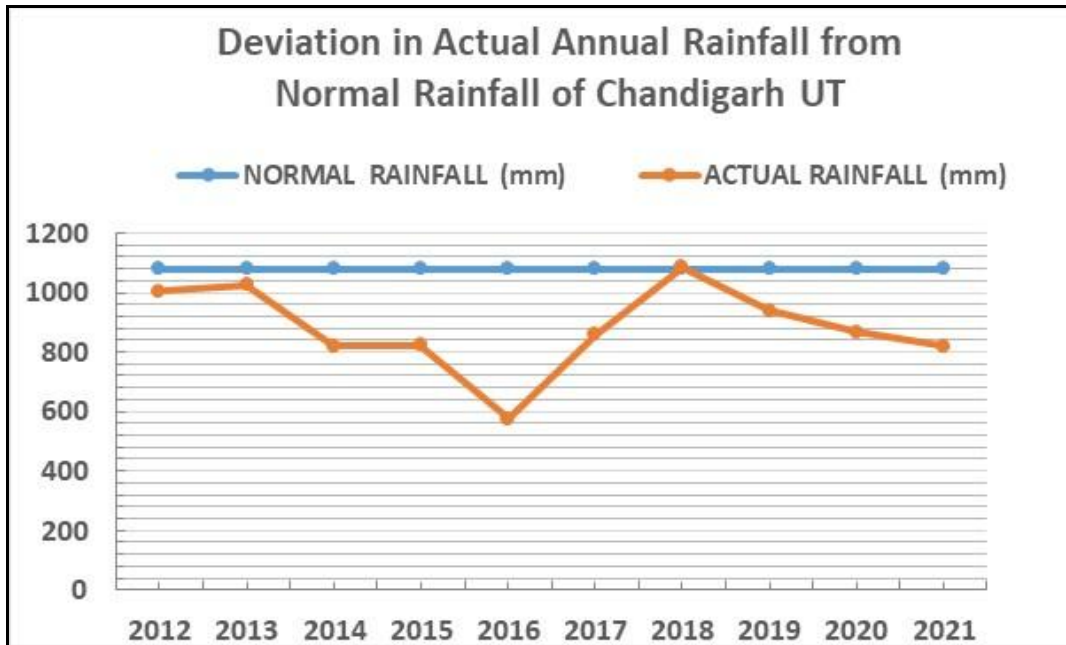
2.3 Aquifer Disposition and Characteristics

Based on the exploratory drilling carried out by Central Ground Water Board down to a depth of 450 mbgl, it can be concluded that fair to good aquifer horizons occur in most part of Chandigarh except in south-western parts near sectors 37, 38, 39, 40 and 41. A 20 meter thick aquifer at a depth of 160 mbgl, occurs in almost all of Chandigarh except around sector 38 which comprises of medium to coarse sand. It has also been inferred that the sediments are relatively coarse-grained down to a depth of 180 mbgl below which they become finer. The yield of the deeper aquifers is also lesser as compared to the shallower ones. The formations encountered in a borehole drilled down to 465 mbgl in sector 28 close to Sukhna Choe, are well-defined coarse sediments up to 240 mbgl. Below this depth the formations are finer grained. Whereas the shallow formations comprise coarse sand to gravel and pebbles intercalated with clays, the deeper ones are fine sands and silts. In sector 47, the aquifer material is coarse down to a depth of 174 mbgl below which it becomes finer. The aquifer material encountered at sector 33 is coarse down to 180 mbgl. This indicates that the thickness of coarser sediments is greater in northern parts of the city as compared to the southern parts. Along Sukhna Choe, three prominent sand beds occur (inter-bedded

with clay beds) within a depth of about 100 m. The upper sand beds are about 15 m thick and occur 8 m below land surface. Middle sand bed is about 18 m thick and occurs at depths varying from 21 to 38 mbgl. The deeper sand bed occurs at depth varying from 39 to 76 mbgl and is about 27 m thick. These beds are more persistent in the downstream direction of Sukhna Choe.

Ground water in the area occurs under water table, confined as well as semi-confined conditions. The pumping test data of the aquifers tested in the city clearly indicates that good confined aquifers occur around sector 10, 33, 38 and 47 while leaky are encountered around sector 28. One interesting feature is that the aquifers in the southern parts of the city are restricted in aerial extent due to lithological boundaries as deciphered from pumping test data. Ground water occurs under unconfined conditions down to about 80 m in Manimajra area. In other areas the semi-confined conditions prevail up to 20-30 m below land surface. Barring Manimajra area ground water below 20-30 m exist under confined conditions. The depth of the shallow aquifer system is less than 30 m below ground level whereas the depth of the deeper aquifer system ranges from 40 to 450 mbgl of explored depth while in Manimajra area, confined aquifers occur below 90 m. The transmissivity values for the deeper aquifer system ranged between 74 m^2/day at Sector 10 to 590 m^2/day at Sector 28. The storativity values ranged between $1.5x10^{-4}$ to $7.5x10^{-4}$ indicating confined nature of aquifer systems. A number of aquifer performance tests were also conducted on the existing shallow tubewells and only the recovery data was used to assess the aquifer parameters. The transmissivity values of shallow aquifers up to 100 m depth range obtained during these tests ranged between 70 and 466 m^2/day.

2.4   Groundwater level conditions

The depth to water level in the shallow aquifer system in pre-monsoon season varies from 3.84 m bgl (Sector 44) in the southern sectors to 17.11 m bgl (Sector 10) in the northern sectors. In the western and southwestern part of the city covering sectors 37 to 46 the water level is shallow i.e. less than five metres. This is due to fine nature of sediments and lithlogical boundaries. In the northern sectors, the water levels are more than 7.0 mbgl. During the post monsoon, the water level varies from 3.06 (Sector 44) in the southern part to 12.68 m bgl (Sector 10) in the northern part of the city.

The water level in the deeper aquifer system ranges between 15.69 (Sector 39) to 61.08 (Sector 46) m bgl during pre monsoon and 15.65 (Sector 39) to 62.66 (Sector 46) m bgl in post

monsoon. The long term water level fluctuation (decadal) of the deep aquifer system shows that in all part of city, there is significant decline trend in the range between 0.32 to 1.55 m/year. This fall in water level is attributed to heavy pumping from the deeper aquifer for domestic and agricultural purposes.
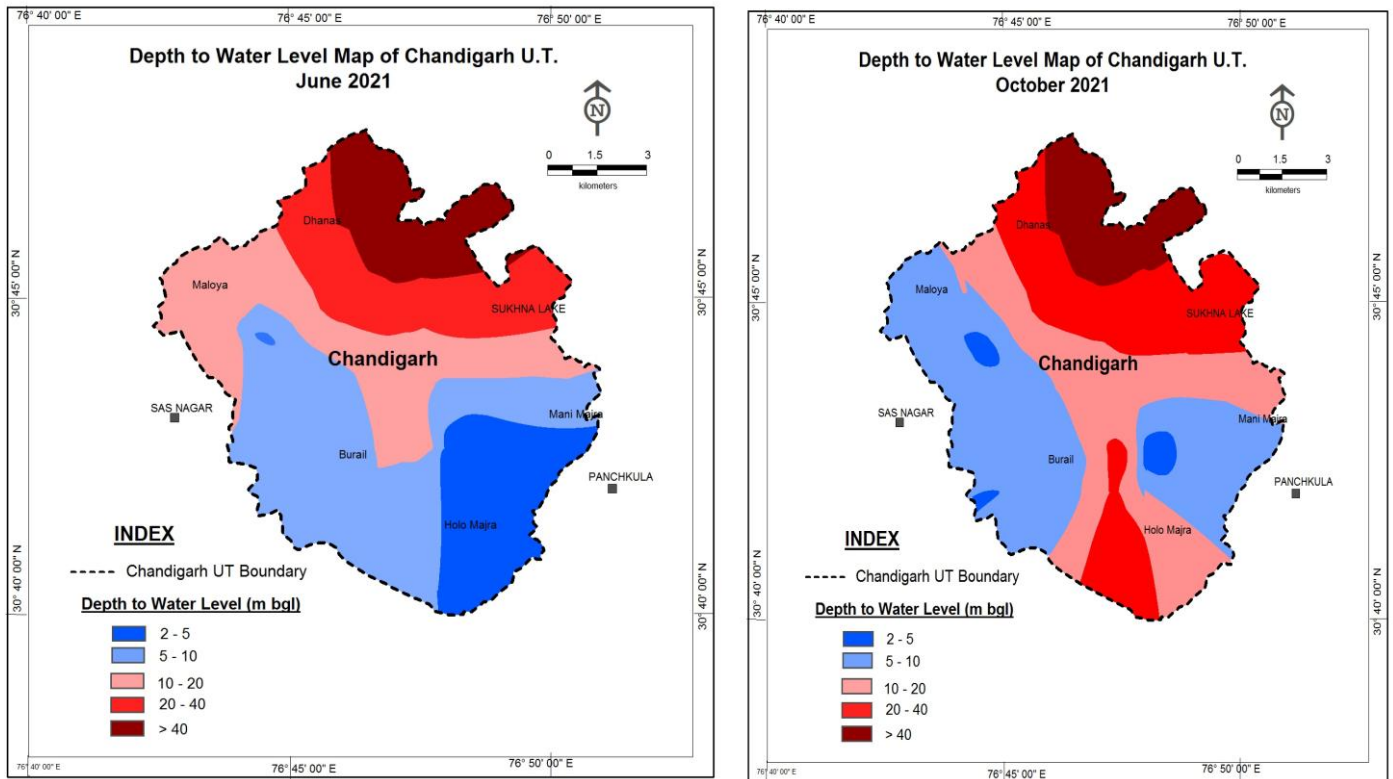
Depth to Water Level Map of Chandigarh in June, 2021 and October, 2021

2.5 Ground Water Quality

Based on the data generated from the analysis of ground water samples drawn from hand pump and tube wells, it is found that the ground water is fresh and suitable for drinking as well as irrigation purposes. Normally, the ground water drawn from the deeper aquifers is less mineralized as compared to water drawn from shallow aquifers. Geochemical facies evaluation of ground water indicates that most of the waters, both from shallow and deeper aquifer, are of Ca-HCO$_3$ type. Concentration of some of the vital quality indicators such as F, NO$_3$, salinity, and hardness is within permissible limits of drinking water standards (BIS -2012). Analysis of trace elements in ground water indicated that concentration of copper, iron and manganese in some of the shallow hand pump

waters is above maximum permissible limit for drinking waters. As far as deeper tubewell waters are concerned, none of the water sample registered higher concentration of any of the metal analyzed. It can be safely concluded that most of ground waters are free from heavy metal contamination.

Quality of shallow ground water of Chandigarh is evaluated through ten samples collected during June-2019. The water samples were analyzed for major cations (Ca, Mg, Na, K) and anions (CO_3, HCO_3, Cl, NO_3, SO_4, F,PO_4) in addition to pH, EC, SiO_2 and TH as $CaCO_3$ in the Regional Chemical Laboratory by following 'Standard analytical procedures' as given in APHA 2012.

COMPOSITION OF GROUND WATER

The results of chemical analysis of ground water sample (Appendix-I) reveals that it is alkaline in nature with pH from 8.05 to 8.75 and moderately mineralized with EC ranging from 254 to 582 µS/cm. at 250C. Among anions, carbonate ion is found to vary between 0 and 24 mg/l whereas bicarbonate concentration ranges from 24 to 293 mg/l. The chloride values range from 7 to 56 mg/l, while the Sulphate values vary from BDL to 95 mg/l. Nitrate concentrations are found to range between 0 to be 25 mg/l. The Fluoride content is 0.20 mg/l and maximum concentration is 0.60 mg/l which is below the desirable limit of 1.0 mg/l. The cations such as calcium and magnesium are present in low concentration and their highest values are 36 mg/l and 27 mg/l, respectively. The sodium concentration varies between 5.47 to 69 mg/l. The maximum potassium concentration reported is 14 mg/l. Total hardness of water sample expressed as CaCO3 is found to range between 70 and 170 mg/l.

Piper diagrame of ground water quality of UT Chandigarh

Diagram for interpreting the analysis of Irrigation water(USSL) UT Chandigarh-2021
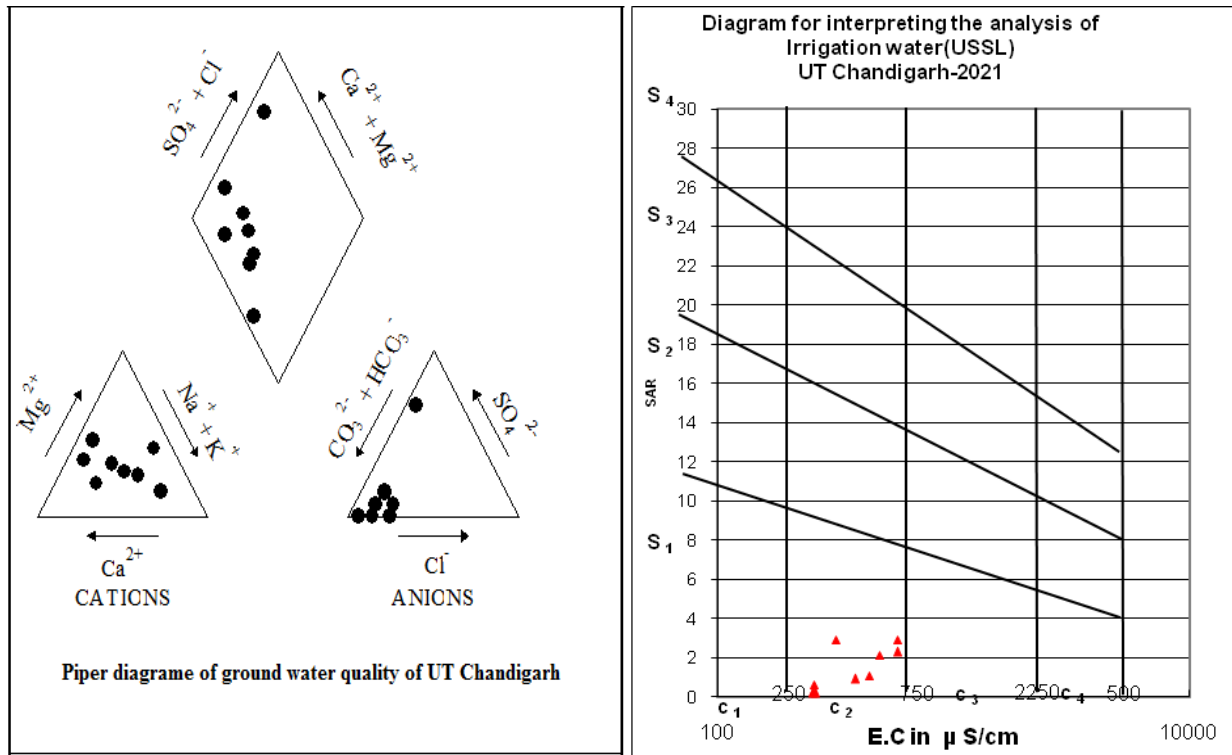
The perusal of Trilinear Plot of percentages of major ions represented on Piper Diagram (Plate 3), indicates that different types of water is found in the area, varying from Ca-Mg-HCO3. The suitability of groundwater for irrigational uses is determined by considering the values of salinity (EC), sodium adsorption ratio (SAR) and residual sodium carbonate (RSC). Based on highest reported values for EC (582 µS/cm.), SAR (2.91) and RSC (2.20), it can be concluded that groundwater of Chandigarh is suitable for irrigation. The USSL classification of irrigation waters (Plate 4) indicates that it falls in C2S1 class and can be used for customary irrigation. On comparison with chemical data of GWMS 2017, there is improvement in water quality in term of Salinity (with respect to EC), Nitrate and Fluoride during this period.

CONCLUSION & RECOMMENDATION

Conclusion drawn for quality evaluations of ground water and its suitability for various uses is based on macro level studies through monitoring stations sampled during 2021. It can be concluded that in Chandigarh ground water is generally suitable for drinking and groundwater is suitable for irrigation purposes.

Results of chemical analysis (mg/l) of ground water sample of Chandigarh UT:

State/UT	CHANDIGARH							
Parameters	Sector-46	IMD Sector 39	Sector 39-D	Maloya	Sector 10-C	Sector 31-D	New industrial Area (Karsan Camp)	Burail
Source	TW	TW	HP	TW	TW	TW	TW	DW
pH^*	8.50	8.40	8.45	8.05	8.35	8.75	8.70	8.52
EC^* in µS/cm at 25^0 C	257	259	385	582	254	486	319	440
CO_3	12	12	12	0	24	24	24	24
HCO_3	122	24	122	293	73	171	171	122
Cl^*	14	7	28	56	14	21	7	21
SO_4	0	95	12	0	20	15	0	28
NO_3^*	1.67	1.51	21	0.5	0	9.2	2.51	25
F^*	0.23	0.20	0.60	0.33	0.27	0.32	0.30	0.30
PO_4	0	0	0	0	0	0	0	0.12
Ca^*	32	28	32	36	32	12	16	32
Mg^*	7	17	15	19	12	27	7	15
Na	15	5.47	25	69	6.26	58	56	30
K	2.03	2.04	1.0	1.2	2.1	2.3	2.04	14
SiO_2	18	18	19	20	18	20	18	18
TH *as $CaCO_3$	110	140	140	170	130	140	70	140

CHAPTER-3

GROUND WATER RESOURCES ESTIMATION METHODOLOGY

The revised methodology GEC 2015 recommends aquifer wise ground water resource assessment. Ground water resources have two components – Replenishable ground water resources or Dynamic Ground Water Resources and In-storage Resources or Static Resources. GEC 2015 recommends estimation of Replenishable and in-storage ground water resources for both unconfined and confined aquifer. Wherever the aquifer geometry has not been firmly established for the unconfined aquifer, the in-storage ground water resources have to be assessed in the alluvial areas up to the depth of bed rock or 300 m whichever is less. In case of hard rock aquifers, the depth of assessment would be limited to 100 m. In case of confined aquifers, if it is known that ground water extraction is being taken place from this aquifer, the dynamic as well as in-storage resources are to be estimated. If it is firmly established that there is no ground water extraction from this confined aquifer, then only in-storage resources of that aquifer has to be estimated.

3.1   Periodicity of Assessment

Keeping in view of the rapid change in Ground Water Extraction, the committee recommends more frequent estimation of Ground Water Resources. As per recommendation of Committee, the resources are to be assessed every year from 2022 onwards. As per the present practice, there was a considerable time lag between assessment and publication of the results; however the introduction of INGRES has made it possible to reduce the time lag and the results can be reported within the successive water year.

3.2   Ground Water Assessment Unit

This methodology recommends aquifer wise ground water resource assessment. An essential requirement for this is to demarcate lateral as well as vertical extent and disposition of different aquifers. A watershed with well-defined hydrological boundaries is an appropriate unit for ground water resource estimation if the principal aquifer is other than alluvium. Ground water resources worked out on watershed as a unit, may be apportioned and presented on administrative units (block/ taluka/ mandal/ firka). This would facilitate local administration in planning of ground water management programmes. Areas occupied by unconsolidated sediments (alluvial deposits, aeolian deposits, coastal deposits etc.) usually have flat topography and demarcation of watershed

boundaries may not be possible in such areas. Until Aquifer Geometry is established on appropriate scale, the existing practice of using watershed in hard rock areas and blocks/ mandals/ firkas in soft rock areas may be continued.

The ground water resources assessment were carried out based on the guidelines of Ministry of Water Resources, RD & GR which broadly follows the methodology recommended by Ground Water Resources Estimation Committee, 2015. The salient features of the methodology are enumerated in the following paragraphs.

The ground water recharge is estimated season-wise both for monsoon season and non- monsoon season separately. The following recharge and discharge components are assessed in the resource assessment - recharge from rainfall, recharge from canal, return flow from irrigation, recharge from tanks and ponds and recharge from water conservation structures and discharge through ground water draft.

The ground water resources of any assessment unit is the sum of the total ground water availability in the principal aquifer (mostly unconfined aquifer) and the total ground water availability of semi-confined and confined aquifers existing in that assessment unit. The total ground water availability of any aquifer is the sum of Dynamic ground water resources and the In-storage or Static resources of the aquifer.

3.3 Ground Water Assessment of Unconfined Aquifer

As mentioned earlier, assessment of ground water includes assessment of dynamic and in- storage ground water resources. The development planning should mainly depend on dynamic resource only as it gets replenished every year. Changes in static or in-storage resources reflect impacts of ground water mining. Such resources may not be replenishable annually and may be allowed to be extracted only during exigencies with proper recharge planning in the succeeding excess rainfall years.

3.3.1 Dynamic Ground Water Resources

The methodology for ground water resources estimation is based on the principle of water balance as given below –

$$\text{Inflow – Outflow = Change in Storage (of an aquifer)} \qquad 1$$

Equation 1 can be further elaborated as -

$$\Delta S = R_{RF} + R_{STR} + R_C + R_{SWI} + R_{GWI} + R_{TP} + R_{WCS} \pm VF \pm LF - GE - T - E - B \qquad 2$$

Where,

ΔS – Change in storage

R_{RF} – Rainfall recharge

R_{STR}- Recharge from stream channels

R_C – Recharge from canals

R_{SWI} – Recharge from surface water irrigation

R_{GWI}- Recharge from ground water irrigation

R_{TP}- Recharge from Tanks and Ponds

R_{WCS} – Recharge from water conservation structures

VF – Vertical flow across the aquifer system

LF- Lateral flow along the aquifer system (through flow)

GE-Ground Water Extraction

T- Transpiration

E- Evaporation

B-Base flow

It is preferred that all the components of water balance equation should be estimated in an assessment unit. The present status of database available with Government and non- government agencies is not adequate to carry out detailed ground water budgeting in most of the assessment units. Therefore, it is proposed that at present the water budget may be restricted to the major components only taking into consideration certain reasonable assumptions. The estimation is to be carried out using lumped parameter estimation approach keeping in mind that data from many more sources if available may be used for refining the assessment.

3.3.2 Rainfall Recharge

It is recommended that ground water recharge should be estimated on ground water level fluctuation and specific yield approach since this method takes into account the response of ground water levels to ground water input and output components. This, however, requires adequately spaced representative water level measurement for a sufficiently long period. It is proposed that there should be at least three spatially well distributed observation wells in the assessment unit, or one observation well per 100 sq. Km. Water level data should also be available for a minimum

period of 5 years (preferably 10years), along with corresponding rainfall data. Regarding frequency of water level data, three water level readings during pre and post monsoon seasons and in the month of January/ May preferably in successive years, are the minimum requirements. It would be ideal to have monthly water level measurements to record the peak rise and maximum fall in the ground water levels. In units or subareas where adequate data on ground water level fluctuations are not available as specified above, ground water recharge may be estimated using rainfall infiltration factor method only. The rainfall recharge during non-monsoon season may be estimated using rainfall infiltration factor method only.

3.3.3 Ground water level fluctuation method

The ground water level fluctuation method is to be used for assessment of rainfall recharge in the monsoon season. The ground water balance equation in non-command areas is given by

$$\Delta S = R_{RF} + R_{STR} + R_{SWI} + R_{GWI} + R_{TP} + R_{WCS} \pm VF \pm LF - GE - T - E - B \qquad\qquad 3$$

Where,

ΔS – Change in storage

R_{RF} – Rainfall recharge

R_{STR} - Recharge from stream channels

R_{SWI} – Recharge from surface water irrigation (Lift Irrigation)

R_{GWI} - Recharge from ground water irrigation

R_{TP} - Recharge from tank and ponds

R_{WCS} – Recharge from water conservation structures

VF – Vertical flow across the aquifer system

LF- Lateral flow along the aquifer system (through flow)

GE-Ground water Extraction

T- Transpiration

E- Evaporation

B-Base flow

Whereas the water balance equation in command area will have another term Recharge due to canals (R_C) and the equation will be as follows:

$$\Delta S = R_{RF} + R_{STR} + R_C + R_{SWI} + R_{GWI} + R_T + R_{WCS} \pm VF \pm LF - GE - T - E - B \qquad\qquad 4$$

A couple of important observations in the context of water level measurement must be followed. It is important to bear in mind that while estimating the quantum of ground water extraction, the depth

from which ground water is being extracted should be considered, and certain limit should be fixed. First, by estimating recharge by Water Level Fluctuation method, rise in water level (pre to post monsoon Water Level observed in a dug well) is considered and in estimating the draft from dug wells and bore wells (shallow and deep) drop in water level is considered. One should consider only the draft from the same aquifer for which the resource is being estimated.

The change in storage can be estimated using the following equation:

$$\Delta S = \Delta h * A * S_Y \hspace{4cm} 5$$

Where

ΔS – Change in storage
Δh - rise in water level in the monsoon season A - area for computation of recharge
Sy - Specific Yield

Substituting the expression in equation 5 for storage increase ΔS in terms of water level fluctuation and specific yield, the equations 3 and 4 becomes,

$$R_{RF} = h \times Sy \times A - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B \hspace{1cm} 6$$

$$R_{RF} = h \times Sy \times A - R_C - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + \hspace{1cm} 7$$

The recharge calculated from equation 6 in case of non-command sub units and equation 7 in case of command sub units and poor ground water quality sub units gives the rainfall recharge for the particular monsoon season. However, it may be noted that in case base flow/ recharge from stream and through flow have not been estimated, the same may be assumed to be zero.

The rainfall recharge obtained by using equation 6 and equation 7 provides the recharge in any particular monsoon season for the associated monsoon season rainfall. This estimate is to be normalised for the normal monsoon season rainfall as per the procedure indicated below.

Normalization of Rainfall Recharge

Let Ri be the rainfall recharge and ri be the associated rainfall. The subscript i takes values 1 to N where N is number of years data is available which is at least 5. The rainfall recharge, Ri is obtained as per equation 6 and equation 7 depending on the sub unit for which the normalization is being done.

$$R_i = h \times Sy \times A - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B \hspace{1cm} 8$$

$$R_i = h \times Sy \times A - R_C - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B \hspace{1cm} 9$$

where,

Ri= Rainfall recharge estimated in the monsoon season for the ith particular year

h= Rise in ground water level in the monsoon season for the ith particular year

Sy   =Specific yield

A= Area for computation of recharge

GE = Ground water extraction in monsoon season for the ith particular year

B= Base flow the monsoon season for the ith particular year

R_C = Recharge from canals in the monsoon season for ith particular year

R_{STR}= Recharge from stream channels in the monsoon season for ith particular year

R_{SWI} = Recharge from surface water irrigation including lift irrigation in the monsoon season for the ith particular year

R_{GWI} = Recharge from groundwater irrigation in the monsoon season for the ith particular year

R_{WCS} =Recharge from water conservation structures in the monsoon season for the ith particular year

R_{TP}= Recharge from tanks and ponds in the monsoon season for the ith particular year

LF= Recharge through Lateral flow/ Through flow across assessment unit boundary in the monsoon season for the ith particular year

VF – Vertical flow across the aquifer system in the monsoon season for the ith particular year

T- Transpiration in the monsoon season for the ith particular year E- Evaporation in the monsoon season for the ith particular year

After the pairs of data on Ri and ri have been obtained as described above, a normalisation procedure is to be carried out for obtaining the rainfall recharge corresponding to the normal monsoon season rainfall. Let r(normal) be the normal monsoon season rainfall obtained on the basis of recent 30 to 50 years of monsoon season rainfall data. Two methods are possible for the normalization procedure.

The first method is based on a linear relationship between recharge and rainfall of the form

$$\mathbf{R = ar} \qquad\qquad \mathbf{10}$$

where,

R = Rainfall recharge during monsoon season

 r = Monsoon season rainfall

a = a constant

The computational procedure to be followed in the first method is as given below:

$$R_{rf}\,(normal) = \frac{\sum\limits_{i=1}^{N}\left[R_i \times \dfrac{r(normal)}{r_i}\right]}{N} \qquad \textbf{11}$$

Where,

R_{rf} (normal) - Normalized Rainfall Recharge in the monsoon season.

R_i - Rainfall Recharge in the monsoon season for the ith year.

r(normal) - Normal monsoon Season rainfall.

r_i - Rain fall in the monsoon season for the ith year.

N - No, of years data is available.

The second method is also based on a linear relation between recharge and rainfall.

However, this linear relationship is of the form,

$$\textbf{R = ar+b} \qquad \textbf{12}$$

where,

R = Rainfall recharge during monsoon season

 r = Monsoon season rainfall

a and b = constants.

The two constants 'a' and 'b' in the above equation are obtained through a linear regression analysis. The computational procedure to be followed in the second method is as given below:

$$a = \frac{NS_4 - S_1 S_2}{NS_3 - S_1^2} \qquad \textbf{13}$$

$$b = \frac{S_2 - aS_1}{N} \qquad \textbf{14}$$

Where

$$S_1 = \sum_{i=1}^{N} r_i \qquad S_2 = \sum_{i=1}^{N} R_i \qquad S_3 = \sum_{i=1}^{N} r_i^2 \qquad S_4 = \sum_{i=1}^{N} r_i R_i$$

The rainfall recharge during monsoon season for normal monsoon rainfall condition is computed as below:

$$R_{rf} \text{ (normal)} = a \ x \ r(normal) \ + \ b \qquad\qquad 15$$

3.3.4   Rainfall Infiltration Factor method

The rainfall recharge estimation based on Water level fluctuation method reflects actual field conditions since it takes into account the response of ground water level. However the ground water extraction estimation included in the computation of rainfall recharge using Water Level Fluctuation approach is often subject to uncertainties. Therefore, it is recommended to compare the rainfall recharge obtained from Water Level Fluctuation approach with that estimated using Rainfall Infiltration Factor Method.

Recharge from rainfall is estimated by using the following relationship -

$$R_{rf} = RFIF * A* (R - a)/1000 \qquad\qquad 16$$

Where,

R_{rf} = Rainfall recharge in ham A = Area in Hectares

RFIF = Rainfall Infiltration Factor R = Rainfall in mm

a = Minimum threshold value above which rainfall induces ground water recharge in mm

The relationship between rainfall and ground water recharge is a complex phenomenon depending on several factors like runoff coefficient, moisture balance, hydraulic conductivity and Storativity/ Specific yield of the aquifer etc. In this report, certain assumptions have been adopted for computation of Rainfall recharge factor. These assumptions may be replaced with actual data in case such area specific studies are available. At the same time, it is important to bring in elements of rainfall distribution and variability into sharpening the estimates of precipitation. Average rainfall data from nearby rain gauge stations may be considered for the Ground water assessment unit and the average rainfall may be estimated by the Theisen polygon or isohyet methods. Alternatively other advanced methods may also be used.

The threshold limit of minimum and maximum rainfall event which can induce recharge to the aquifer is to be considered while estimating ground water recharge using rainfall infiltration

factor. The minimum threshold limit is in accordance with the relation shown in equation 16 and the maximum threshold limit is based on the premise that after a certain limit, the rate of storm rains are too high to infiltrate the ground and they will only contribute to surface runoff. It is suggested that 10% of Normal annual rainfall be taken as Minimum Rainfall Threshold and 3000 mm as Maximum Rainfall limit. While computing the rainfall recharge, 10% of the normal annual rainfall is to be deducted from the monsoon rainfall and balance rainfall would be considered for computation of rainfall recharge. The same recharge factor may be used for both monsoon and non-monsoon rainfall, with the condition that the recharge due to non-monsoon rainfall may be taken as zero, if the normal rainfall during the non-monsoon season is less than 10% of normal annual rainfall. In using the method based on the specified norms, recharge due to both monsoon and non-monsoon rainfall may be estimated for normal rainfall, based on recent 30 to 50 years of data.

3.3.5 Percent Deviation

After computing the rainfall recharge for normal monsoon season rainfall using the water table fluctuation method and Rainfall Infiltration Factor method these two estimates have to be compared with each other. A term, Percent Deviation (PD) which is the difference between the two expressed as a percentage of the former is computed as

$$PD = \frac{R_{rf}\ (normal, wtfm) - R_{rf}\ (normal, rifm)}{R_{rf}\ (normal, wtfm)} \times 100 \qquad \mathbf{17}$$

where,

R_{rf} (normal, wlfm) = Rainfall recharge for normal monsoon season rainfall estimated by the water level fluctuation method

R_{rf} (normal, rifm) = Rainfall recharge for normal monsoon season rainfall estimated by the rainfall infiltration factor method

The rainfall recharge for normal monsoon season rainfall is finally adopted as per the criteria given below:

➢   If PD is greater than or equal to -20%, and less than or equal to +20%,Rrf (normal) is taken as the value estimated by the water level fluctuation method.

➢   If PD is less than -20%, Rrf (normal) is taken as equal to 0.8 times the value estimated by the rainfall infiltration factor method.

➢   If PD is greater than +20%, Rrf (normal) is taken as equal to 1.2 times the value estimated by

the rainfall infiltration factor method.

3.3.6   Recharge from other Sources

Recharge from other sources constitute recharges from canals, surface water irrigation, ground water irrigation, tanks and ponds and water conservation structures in command areas where as in non-command areas the recharge due to surface water irrigation, ground water irrigation, tanks and ponds and water conservation structures are possible.

Recharge from Canals: Recharge due to canals is to be estimated based on the following formula:

$$R_C = WA * SF * Days \qquad\qquad 18$$

Where:

R_C= Recharge from Canals WA=Wetted

Area

SF= Seepage Factor

Days= Number of Canal Running Days.

3.3.7   Recharge from Surface Water Irrigation:
Recharge due to applied surface water irrigation, either by means of canal outlets or by lift irrigation schemes is to be estimated based on the following formula:

$$R_{SWI} = AD * Days * RFF \qquad\qquad 19$$

Where:

R_{SWI} = Recharge due to applied surface water irrigation

AD= Average Discharge

Days=Number of days water is discharged to the Fields

RFF= Return Flow Factor

3.3.8   Recharge from Ground Water Irrigation:
Recharge due to applied ground water irrigation is to be estimated based on the following formula:

$$R_{GWI} = GE_{IRR} * RFF \qquad\qquad 20$$

Where:

R_{GWI} = Recharge due to applied ground water irrigation GE_{IRR}= Ground

Water Extraction for Irrigation

RFF= Return Flow Factor

3.3.9   **Recharge due to Tanks and Ponds:** Recharge due to Tanks and Ponds is to be estimated based on the following formula:

$$\textbf{R}_{\textbf{TP}} \textbf{=AWSA*RF} \qquad\qquad\qquad 21$$

Where:

R_{TP} = Recharge due to Tanks and Ponds

AWSA= Average Water Spread Area

RF= Recharge Factor

3.3.10   **Recharge due to Water Conservation Structures:** Recharge due to Water Conservation Structures is to be estimated based on the following formula:

$$\textbf{R}_{\textbf{WCS}} \textbf{=GS*RF} \qquad\qquad\qquad 22$$

Where:

R_{WCS} = Recharge due to Water Conservation Structures

GS= Gross Storage = Storage Capacity multiplied by number of fillings.

RF= Recharge Factor

3.4 Lateral flow along the aquifer system (Through flow)

In equations 6 and 7, if the area under consideration is a watershed, the lateral flow across boundaries can be considered as zero in case such estimates are not available. If there is inflow and outflow across the boundary, theoretically, the net inflow may be calculated using Darcy law, by delineating the inflow and outflow sections of the boundary. Besides such delineation, the calculation also requires estimate of transmissivity and hydraulic gradient across the inflow and outflow sections. These calculations are most conveniently done in a computer model. It is recommended to initiate regional scale modelling with well-defined flow boundaries. Once the modelling is complete, the lateral through flows (LF) across boundaries for any assessment unit can be obtained from the model. In case Lateral Flow is calculated using computer model, the same should be included in the water balance equation.

3.5   **Base flow and Stream Recharge**

If stream gauge stations are located in the assessment unit, the base flow and recharge from streams can be computed using Stream Hydrograph Separation method, Numerical Modelling and

Analytical solutions. If the assessment unit is a watershed, a single stream monitoring station at the mouth of the watershed can provide the required data for the calculation of base flow. Any other information on local-level base flows such as those collected by research centres, educational institutes or NGOs may also be used to improve the estimates on base flows.

Base flow separation methods can be divided into two main types: non-tracer-based and tracer-based separation methods. Non-tracer methods include Stream hydrograph analysis, water balance method and numerical ground water modelling techniques. Digital filters are available for separating base flow component of the stream hydrograph.

Hydro-chemical tracers and environmental isotope methods also use hydrograph separation techniques based on mass balance approach. Stream recharge can also be estimated using the above techniques.

Base flow assessment and Stream recharge should be carried out in consultation with Central Water Commission in order to avoid any duplicity in the estimation of total water availability in a river basin.

3.6   Vertical Flow from Hydraulically Connected Aquifers

This can be estimated provided aquifer geometry and aquifer parameters are known. This can be calculated using the Darcy's law if the hydraulic heads in both aquifers and the hydraulic conductivity and thickness of the aquitard separating both the aquifers are known. Ground water flow modelling is an important tool to estimate such flows. As envisaged in this report regional scale modelling studies will help in refining vertical flow estimates.

3.7   Evaporation and Transpiration

Evaporation can be estimated for the aquifer in the assessment unit if water levels in the aquifer are within the capillary zone. It is recommended to compute the evaporation through field studies. If field studies are not possible, for areas with water levels within 1.0 mbgl, evaporation can be estimated using the evaporation rates available for other adjoining areas. If depth to water level is more than 1.0m bgl, the evaporation losses from the aquifer should be taken as zero.

Transpiration through vegetation can be estimated if water levels in the aquifer are within the maximum root zone of the local vegetation. It is recommended to compute the transpiration through field studies. Even though it varies from place to place depending on type of soil and vegetation, in the absence of field studies the following estimation can be followed. If water levels

are within 3.5m bgl, transpiration can be estimated using the transpiration rates available for other areas. If it is greater than 3.5m bgl, the transpiration should be taken as zero.

For estimating evapotranspiration, field tools like Lysimeters can be used to estimate actual evapotranspiration. Usually agricultural universities and IMD carry out lysimeter experiments and archive the evapotranspiration data. Remote sensing based techniques like SEBAL (Surface Energy Balance Algorithm for Land) can be used for estimation of actual evapotranspiration. Assessing offices may apply available lysimeter data or other techniques for estimation of evapotranspiration. In case where such data is not available, evapotranspiration losses can be empirically estimated from PET data provided by IMD.

3.8   Recharge during Monsoon Season

The sum of normalized monsoon rainfall recharge and the recharge from other sources and lateral and vertical flows into the sub unit and stream inflows during monsoon season is the total recharge during monsoon season for the sub unit. Similarly this is to be computed for all the sub units available in the assessment unit.

3.9   Recharge during Non-Monsoon Season

The rainfall recharge during non-monsoon season is estimated using Rainfall Infiltration factor Method only when the non-monsoon season rainfall is more than 10% of normal annual rainfall. The sum of non-monsoon rainfall recharge and the recharge from other sources and lateral and vertical flows into the sub unit and stream inflows during non-monsoon season is the total recharge during non-monsoon season for the sub unit. Similarly this is to be computed for all the sub units available in the assessment unit.

3.10   Total Annual Ground Water Recharge

The sum of the recharge during monsoon and non-monsoon seasons is the total annual ground water recharge for the sub unit. Similarly this is to be computed for all the sub units available in the assessment unit.

3.11   Annual Extractable Ground Water Recharge (EGR)

The Total Annual Ground Water Recharge cannot be utilised for human consumption, since ecological commitments need to be fulfilled, before the extractable resources is defined. The National Water Policy, 2012 stresses that the ecological flow of rivers should be maintained. Therefore Ground water base flow contribution limited to the ecological flow of the river should be determined which will be deducted from Annual Ground Water Recharge to determine Annual

Extractable Ground Water Resources (EGR). The ecological flows of the rivers are to be determined in consultation with Central Water Commission and other concerned river basin agencies.

In case base flow contribution to the ecological flow of rivers is not determined then following assumption is to be followed. In the water level fluctuation method, a significant

portion of base flow is already accounted for by taking the post monsoon water level one month after the end of rainfall. The base flow in the remaining non-monsoon period is likely to be small, especially in hard rock areas. In the assessment units, where river stage data are not available and neither the detailed data for quantitative assessment of the natural discharge are available, present practice (GEC 1997) of allocation of unaccountable natural discharges to 5% or 10% of annual recharge may be retained. If the rainfall recharge is assessed using water level fluctuation method this will be 5% of the annual recharge and if it is assessed using rainfall infiltration factor method, it will be 10% of the annual recharge. The balance will account for Annual Extractable Ground Water Resources (EGR).

3.12 Estimation of Ground Water Extraction

Groundwater draft or extraction is to be assessed as follows.

$$GE_{ALL} = GE_{IRR} + GE_{DOM} + GE_{IND} \qquad\qquad 23$$

Where,

GE_{ALL}=Ground water extraction for all uses

GE_{IRR}=Ground water extraction for irrigation

GE_{DOM} =Ground water extraction for domestic uses

GE_{IND} = Ground water extraction for industrial uses

3.12.1 Ground Water Extraction for Irrigation (GE_{IRR}):

The single largest component of the groundwater balance equation in large regions of India is the groundwater extraction and, the precise estimation of ground water extraction is riddled with uncertainties. Therefore it is recommended that at least two of the three methods for estimation of ground water extraction may be employed in each assessment sub unit. The methods for estimation of ground water extraction are as follows.

Unit Draft Method: – In this method, season-wise unit draft of each type of well in an assessment unit is estimated. The unit draft of different types (eg. Dug well, Dug cum bore well, shallow tube well, deep tube well, bore well etc.) is multiplied with the number of wells of that particular type to

obtain season-wise ground water extraction by that particular structure. This method is being widely practiced in the country. There are several sources which maintain records on well census. These include Minor Irrigation Census conducted by MoWR, RD, GR, Government of India, and data maintained at the Tehsil level. It is recommended that a single source of well census should be maintained for resources computation at all India level. Minor Irrigation Census of MoWR, RD, GR would be the preferred option.

Crop Water Requirement Method: – For each crop, the season-wise net irrigation water requirement is determined. This is then multiplied with the area irrigated by ground water abstraction structures. The database on crop area is obtained from Revenue records in Tehsil office, Agriculture Census and also by using Remote Sensing techniques.

Power Consumption Method: – Ground water extraction for unit power consumption (electric) is determined. Extraction per unit power consumption is then multiplied with number of units of power consumed for agricultural pump sets to obtain total ground water extraction for irrigation. Direct metering of ground water draft in select irrigation and domestic wells and in all wells established for industrial purpose may be initiated. Enforcing fitting of water meters and recording draft in all govt. funded wells could also be a feasible option. The unit drafts obtained from these sample surveys can be used to assess ground water extraction. In addition to metering, dedicated field sample surveys (instantaneous discharge measurements) can also be taken up.

3.12.2 Ground Water Extraction for Domestic Use (GE$_{DOM}$):

There are several methods for estimation of extraction for domestic use (GE$_{DOM}$). Some of the commonly adopted methods are described here.

Unit Draft Method: – In this method, unit draft of each type of well is multiplied by the number of wells used for domestic purpose to obtain the domestic ground water draft.

Consumptive Use Method: – In this method, population is multiplied with per capita consumption usually expressed in litre per capita per day (lpcd). It can be expressed using following equation.

$\quad$ **GE$_{DOM}$= Population X Consumptive Requirement X Lg**

Where,

Lg = Fractional Load on Ground Water for Domestic Water Supply

The Load on Ground water can be obtained from the Information based on Civic water

supply agencies in urban areas.

3.12.3 Ground water Extraction for Industrial use (GE$_{IND}$): The commonly adopted methods for estimating the extraction for industrial use are as below:

Unit Draft Method: - In this method, unit draft of each type of well is multiplied by the number of wells used for industrial purpose to obtain the industrial ground water extraction.

Consumptive Use Pattern Method: – In this method, water consumption of different industrial units are determined. Number of Industrial units which are dependent on ground water are multiplied with unit water consumption to obtain ground water draft for industrial use.

$$\text{GE}_{IND}= \text{Number of industrial units X Unit Water Consumption X Lg} \qquad 25$$

Where,

Lg = Fractional load on ground water for industrial water supply

The load on Ground water for Industrial water supply can be obtained from water supply agencies in the Industrial belt. Other important sources of data on ground water extraction for industrial uses are - Central Ground Water Authority, State Ground Water Authority, National Green Tribunal and other Environmental Regulatory Authorities.

Ground water extraction obtained from different methods need to be compared and based on field checks, the seemingly best value may be adopted. At times, ground water extraction obtained by different methods may vary widely. In such cases, the value matching the field situation should be considered. The storage depletion during a season where other recharges are negligible can be taken as ground water extraction during that particular period.

3.13   Stage of Ground Water Extraction

The stage of ground water extraction is defined by,

$$\text{Stage of Ground Water Extraction}(\%) = \frac{\text{Existing gross ground water extraction for all uses}}{\text{Annual Extractable Ground water Resources}} \text{X 100} \quad \mathbf{26}$$

The existing gross ground water extraction for all uses refers to the total of existing gross ground water extraction for irrigation and all other purposes. The stage of ground water extraction should be obtained separately for command areas, non-command areas and poor ground water quality areas.

3.14   Validation of Stage of Ground Water Extraction

The assessment based on the stage of ground water extraction has inherent uncertainties. The estimation of ground water extraction is likely to be associated with considerable uncertainties as it is based on indirect assessment using factors such as electricity consumption, well census and area irrigated from ground water. The denominator in equation 26, namely Annual Extractable Ground Water Resources also has uncertainties due to limitations in the assessment methodology, as well as uncertainties in the data. In view of this, it is desirable to validate the „Stage of Ground Water Extraction‟ with long term trend of ground water levels.

Long term Water Level trends are to be prepared for a minimum period of 10 years for both pre-monsoon and post-monsoon period. The Water level Trend would be average water level trend as obtained from the different observation wells in the area.

In interpreting the long term trend of ground water levels, the following points may be kept in view. If the pre and post monsoon water levels show a fairly stable trend, it does not necessarily mean that there is no scope for further ground water development. Such a trend indicates that there is a balance between recharge, extraction and natural discharge in the unit. However, further ground water development may be possible, which may result in a new stable trend at a lower ground water level with associated reduced natural discharge.

If the ground water resource assessment and the trend of long term water levels contradict each other, this anomalous situation requires a review of the ground water resource computation, as well as the reliability of water level data. The mismatch conditions are enumerated below.

SOGWE	Ground Water level trend	Remarks
≤70%	Decline trend in both pre-monsoon and post-monsoon	Not acceptable and needs reassessment
>100%	No significant decline in both pre-monsoon and post-monsoon long term trend	Not acceptable and needs reassessment

In case, the category does not match with the water level trend given above, a 'reassessment‟ should be attempted. If the mismatch persists even after reassessment, the sub unit may be categorized based on Stage of Ground Water Extraction of the reassessment. However, the sub unit should be flagged for strengthening of observation well network and parameter estimation.

3.15   Categorization of Assessment Units

As emphasized in the National Water Policy, 2012, a convergence of Quantity and Quality of ground water resources is required while assessing the ground water status in an assessment unit. Therefore, it is recommended to separate estimation of resources where water quality is beyond permissible limits for the parameter salinity.

3.15.1 Categorization of Assessment Units Based on Quantity:

The categorization based on status of ground water quantity is defined by Stage of Ground Water extraction as given below:

Stage of Ground Water Extraction	Category
≤70%	Safe
> 70%and ≤90%	Semi-Critical
> 90%and ≤100%	Critical
> 100%	Over Exploited

In addition to this Category every assessment sub unit should be tagged with potentiality tag indicating its ground water potentiality viz. Poor Potential (Unit Recharge <0.025m), Moderately Potential (Unit Recharge in between 0.025 and 0.15m) and Highly Potential (Unit Recharge > 0.15m)

3.15.2 Categorization of Assessment Units Based on Quality

GEC 1997 proposed categorization of assessment units based on ground water extraction only. To adequately inform management decisions, quality of ground water is also an essential criterion. The Committee deliberated upon the possible ways of categorizing the assessment units based on ground water quality in the assessment units. It was realized that based on the available water quality monitoring mechanism and available database on ground water quality it may not be possible to categorize the assessment units in terms of the extent of quality hazard. As a trade-off, the Committee recommends that each assessment unit, in addition to the Quantity based categorization (safe, semi-critical, critical and over-exploited) should bear a quality hazard identifier. Such quality hazards are to be based on available ground water monitoring data of State Ground Water Departments and/or Central Ground Water Board. If any of the three quality hazards in terms of Arsenic, Fluoride and Salinity are encountered in the assessment sub unit in mappable units, the assessment sub unit may be tagged with the particular Quality hazard.

3.16 Allocation of Ground Water Resource for Utilization

The Annual Extractable Ground Water Resources are to be apportioned between domestic, industrial and irrigation uses. Among these, as per the National Water Policy, requirement for domestic water supply is to be accorded priority. This requirement has to be based on population as projected to the year 2025, per capita requirement of water for domestic use, and relative load on ground water for urban and rural water supply. The estimate of allocation for domestic water requirement may vary for one sub unit to the other in different states. In situations where adequate data is not available to make this estimate, the following empirical relation is recommended.

$$\text{Alloc} = 22 \text{ X N X } L_g \text{ mm per year} \qquad\qquad 27$$

Where

Alloc= Allocation for domestic water requirement

N = population density in the unit in thousands per sq. km.

L_g = fractional load on ground water for domestic and industrial water supply ($\leq$ 1.0)

In deriving equation 27, it is assumed that the requirement of water for domestic use is 60 lpd per head. The equation can be suitably modified in case per capita requirement is different. If by chance, the estimation of projected allocation for future domestic needs is less than the current domestic extraction due to any reason, the allocation must be equal to the present day extraction. It can never be less than the present day extraction as it is unrealistic.

3.17 Net Annual Ground Water Availability for Future Use

The water available for future use is obtained by deducting the allocation for domestic use and current extraction for Irrigation and Industrial uses from the Annual extractable Ground Water Recharge. The resulting ground water potential is termed as the net annual ground water availability for future use. The Net annual ground water availability for future use should be calculated separately for non-command areas and command areas. As per the recommendations of the R&D Advisory committee, the ground water available for future use can never be negative. If it becomes negative, the future allocation of Domestic needs can be reduced to current extraction for domestic use. Even then if it is still negative, then the ground water available for future uses will be zero.

3.18 Additional Potential Resources under Specific Conditions

3.18.1 Potential Resource Due to Spring Discharge: Spring discharge constitutes an additional

source of ground water in hilly areas which emerges at the places where ground water level cuts the surface topography. The spring discharge is equal to the ground water recharge minus the outflow through evaporation and evapotranspiration and vertical and lateral sub- surface flow. Thus Spring Discharge is a form of "Annual Extractable Ground Water Recharge". It is a renewable resource, though not to be used for Categorization. Spring discharge measurement is to be carried out by volumetric measurement of discharge of the springs. Spring discharges multiplied with time in days of each season will give the quantum of spring resources available during that season. The committee recommends that in hilly areas with substantial potential of spring discharges, the discharge measurement should be made at least 4 times a year in parity with the existing water level monitoring schedule.

Potential ground water resource due to springs = Q x No of days   28
Where

Q = Spring Discharge

No of days= No of days spring yields.

3.18.2 Potential Resource in Waterlogged and Shallow Water Table Areas:

The quantum of water available for development is usually restricted to long term average recharge or in other words "Dynamic Resources". But the resource calculated by water level fluctuation approach is likely to lead to under-estimation of recharge in areas with shallow water table, particularly in discharge areas of sub-basin/ watershed/ block/ taluka and waterlogged areas. In such cases rejected recharge may be substantial and water level fluctuations are subdued resulting in under- estimation of recharge component. It is therefore, desirable that the ground water reservoir should be drawn to optimum limit before the onset of monsoon, to provide adequate scope for its recharge during the following monsoon period.

In the area where the ground water level is less than 5m below ground level or in waterlogged areas, the resources up to 5m below ground level are potential and would be available for development in addition to the annual recharge in the area. It is therefore recommended that in such areas, ground water resources may be estimated up to 5m bgl only assuming that where water level is less than 5m bgl, the same could be depressed by pumping to create space to receive recharge from natural resources. It is further evident that these potential recharge would be available mostly in the shallow water table areas which would have to be demarcated in each sub-basin/ watershed/ block/ taluka/ mandal.

The computation of potential resource to ground water reservoir can be done by adopting the following equation:

Potential ground water resource in shallow water table areas = (5-D) x A x S_Y　　　　**29**

Where

D= Depth to water table below ground surface in pre-monsoon period in

shallow aquifers.

A= Area of shallow water table Zone

S_Y = Specific Yield

　　　The planning of future minor irrigation works in the waterlogged and shallow water table areas as indicated above should be done in such a way that there should be no long term adverse effects of lowering of water table up to 5m and the water level does not decline much below 5m in such areas. The behavior of water table in the adjoining area which is not water logged should be taken as a bench mark for development purposes.

This potential recharge to ground water is available only after depression of water level up to 5m bgl. This is not an annual resource and should be recommended for development on a very cautious approach so that it does not adversely affect the ground water potentials in the overall area.

3.18.3 Potential Resource in Flood Prone Areas: Ground water recharge from a flood plain is mainly the function of the following parameters-

> ➢　　　Areal extent of flood plain
> ➢　　　Retention period of flood
> ➢　　　Type of sub-soil strata and silt charge in the river water which gets deposited and controls seepage

Since collection of data on all these factors is time taking and difficult, in the meantime, the potential recharge from flood plain may be estimated on the same norms as for ponds, tanks and lakes. This has to be calculated over the water spread area and only for the retention period using the following formula.

Potential ground water resource in Flood Prone Areas = 1.4 x N x A/1000　　　　**30**

Where

N = No of Days Water is Retained in the Area A = Flood Prone Area

3.19 Apportioning of Ground Water Assessment from Watershed to Development Unit:

Where the assessment unit is a watershed, there is a need to convert the ground water assessment in terms of an administrative unit such as block/ taluka/ mandal. This may be done as follows.

A block may comprise of one or more watersheds, in part or full. First, the ground water assessment in the subareas, command, non-command and poor ground water quality areas of the watershed may be converted into depth unit (mm), by dividing the annual recharge by the respective area. The contribution of this subarea of the watershed to the block, is now calculated by multiplying this depth with the area in the block occupied by this sub-area. This procedure must be followed to calculate the contribution from the sub-areas of all watersheds occurring in the block, to work out the total ground water resource of the block.

The total ground water resource of the block should be presented separately for each type of sub-area, namely for command areas, non-command areas and poor ground water quality areas, as in the case of the individual watersheds.

3.20 Assessment of In-Storage Ground Water Resources or Static Ground Water Resources

The quantum of ground water available for development is usually restricted to long term average recharge or dynamic resources. Presently there is no fine demarcation to distinguish the dynamic resources from the static resources. While water table hydrograph could be an indicator to distinguish dynamic resources, at times it is difficult when water tables are deep. For sustainable ground water development, it is necessary to restrict it to the dynamic resources. Static or in-storage ground water resources could be considered for development during exigencies that also for drinking water purposes. It is also recommended that no irrigation development schemes based on static or in-storage ground water resources be taken up at this stage.

Assessment of In-storage ground water resources has assumed greater significance in the present context, when an estimation of Storage Depletion needs to be carried out in Over- exploited areas. Recently Remote Sensing techniques have been used in GRACE studies, to estimate the depletion of Ground Water Resources in North West India. Such estimation presents larger scale scenario. More precise estimation of ground water depletion in the over-exploited area based on actual field data can be obtained by estimating the Change in In-storage during successive assessments. Thus In-storage computation is necessary not only for estimation of emergency storage available for utilization in case of natural extremities (like drought) but also for an

assessment of storage depletion in over-exploited areas for sensitising stakeholders about the damage done to the environment.

The computation of the static or in-storage ground water resources may be done after delineating the aquifer thickness and specific yield of the aquifer material. The computations can be done as follows:-

$$SGWR = A * (Z_2 - Z_1) * S_Y \qquad\qquad 31$$

Where,

SGWR = Static or in-storage Ground Water Resources

A = Area of the Assessment Unit

Z_2 = Bottom of Unconfined Aquifer

Z_1 = Pre-monsoon water level

S_Y = Specific Yield in the In storage Zone

3.21 Assessment of Total Ground Water Availability in Unconfined Aquifer

The sum of Annual Exploitable Ground Water Recharge and the In storage ground water resources of an unconfined aquifer is the Total Ground Water Availability of that aquifer.

3.22 Ground Water Assessment of Confined Aquifer System

Assessment of ground water resources of confined aquifers assumes crucial importance, since over-exploitation of these aquifers may lead to far more detrimental consequences than to those of shallow unconfined aquifers. If the piezometric surface of the confined aquifer is lowered below the upper confining layer so that desaturation of the aquifer occurs, the coefficient of storage is no longer related to the elasticity of the aquifer but to its specific yield. In view of the small amounts of water released from storage in the confined aquifers, large scale pumpage from confined aquifers may cause decline in piezometric levels amounting to over a hundred meter and subsidence of land surface posing serious geotectonical problems.

It is recommended to use ground water storage approach to assess the ground water resources of the confined aquifers. The co-efficient of storage or storativity of an aquifer is defined as the volume of water it releases or takes into storage per unit surface area of the aquifer per unit change in head. Hence the quantity of water added to or released from the aquifer (V) can be calculated as follows

$$\Delta V = S\ \Delta h \qquad\qquad 32$$

If the areal extent of the confined aquifer is A then the total quantity of water added to or

released from the entire aquifer is

$$Q = A \, \Delta V = SA \, \Delta h \qquad\qquad 33$$

Where

Q = Quantity of water confined aquifer can release (m^3)

S = Storativity

A = Areal extent of the confined aquifer (m^2)

Δh = Change in Piezometric head (m)

Most of the storage in confined aquifer is associated with compressibility of the aquifer matrix and compressibility of water. Once the piezometric head reaches below the top confining bed, it behaves like an unconfined aquifer and directly dewaters the aquifer and there is a possibility of damage to the aquifer as well as topography. Hence ground water potential of a confined aquifer is nothing but the water available for use without damaging the aquifer. Hence the resources available under pressure are only considered as the ground water potential. The quantity of water released in confined aquifer due to change in pressure can be computed between piezometric head (h_t) at any given time 't' and the bottom of the top confining layer (h_o) by using the following equation.

$$Q_p = SA\Delta h = \ SA \, (h_t - h_0) \qquad\qquad 34$$

If any development activity is started in the confined aquifer, then there is a need to assess the dynamic as well as in storage resources of the confined aquifer. To assess the ground water resources of the confined aquifer, there is a need to have sufficient number of observation wells tapping exclusively that particular aquifer and proper monitoring of the piezometric heads is also needed.

3.22.1 Dynamic Ground Water Resources of Confined Aquifer

To assess the dynamic ground water resources the following equation can be used with the pre and post monsoon piezometric heads of the particular aquifer.

$$Q_D = SA\Delta h = \ SA \, (h_{POST} - h_{PRE}) \qquad\qquad 35$$

Where
Q_D = Dynamic Ground Water Resource of Confined Aquifer (m^3)
S = Storativity
A = Areal extent of the confined aquifer (m^2)

Δh = Change in Piezometric head (m)

h_{post} =Piezometric head during post-monsoon period(m amsl)

h_{PRE} = Piezometric head during pre-monsoon period(m amsl)

3.22.2 In storage Ground Water Resources of Confined Aquifer

For assessing the in storage ground water potential of a confined aquifer, one has to compute the resources between the pre monsoon piezometric head and bottom of the top confining layer. That can be assessed using the following formula:

$$\mathbf{Q_I= SA\Delta h = \quad SA \ (h_{PRE} - h_0)} \qquad\qquad \mathbf{36}$$

Where

Q_I =In storage Ground Water Resource of Confined Aquifer (m^3)

S = Storativity

A = Areal extent of the confined aquifer (m^2)

Δh = Change in Piezometric head (m)

h_0 = Bottom level of the top confining layer (m amsl)

h_{PRE} = Piezometric head during pre-monsoon period(m amsl)

If the confined aquifer is not being exploited for any purpose, the dynamic and static resources of the confined aquifer need not be estimated separately. Instead the in storage of the aquifer can be computed using the following formula.

$$\mathbf{Q_p = SA\Delta h = \quad SA \ (h_{POST} - h_0)} \qquad\qquad \mathbf{37}$$

Where

Q_p = In storage Ground Water Resource of the confined aquifer or the Quantity of water under pressure (m^3)

S = Storativity

A = Areal extent of the confined aquifer (m^2)

Δh = Change in Piezometric head (m)

H_{POST} =Piezometric head during post-monsoon period (m amsl) h_0 =

Bottom of the Top Confining Layer (m amsl)

The calculated resource includes small amount of dynamic resource of the confined aquifer also, which replenishes every year. But to make it simpler this was also computed as part of the static or in-storage resource of the confined aquifer.

CHAPTER-4

PROCEDURE FOLLOWED IN THE PRESENT ASSESSMENT

In the present assessment for the UT, the data source and collection for each of the data element required as per GEC 2015 methodology is detailed as under:

- The basic data including area, land use have been collected from Census handbook.
- Data on rainfall data has been collected from the Meteorological Department (IMD).
- The data pertaining to tube wells for agriculture, domestic and industries along with their draft has been collected from the Engineering Department, U T Administration and Municipal Cooperation, Chandigarh.
- Data for population and its projection has been taken from Census handbook. Domestic draft has been calculated on population basis. Population figures have been taken as person.
- The Agricultural data has been taken from the Department of Agriculture, Chandigarh UT.
- Data on Depth to water level, ground water quality, aquifer parameters have been availed from Central Groundwater Board.
- Data pertaining to Urban water supply and Tertiary treatment of STP provided by Municipal Cooperation, Chandigarh.
- Data on water conservation structure provided by U T Administration and CGWB.
- Data for ponds supplied by Municipal Cooperation, Chandigarh.

It is pertinent to note that INGRES software has been used for computation of data and no changes in the original methodology proposed by GEC have been made during the present assessment.

The norms used in the present assessment for computation of return flow factor for irrigation water by ground water irrigation, rainfall infiltration factor, specific yield etc have been taken as per GEC specified norms. As regards to the unit well draft, the figures used in computation are based on the actual field data.

CHAPTER-5

COMPUTATION OF GROUND WATER RESOURCES ESTIMATION

5.1   Salient Features of Dynamic Ground Water Resources Assessment

BRIEF SUMMARY OF DYNAMIC RESOURCES OF CHANDIGARH UT

Type of Assessment Units	Blocks
No. of Assessment Units (Blocks) taken for Study	01
Years of Collection of Data (10 years)	2012-2021
No. of Over-Exploited Blocks	Nil
No. of Critical Blocks	Nil
No. of Semi-Critical Blocks	**01**
No. of Safe Blocks	Nil

Chandigarh (UT) has very small area around 114 Sq. km and whole UT has been taken as an assessment unit. Groundwater level data of the period 2012-21 has been used for estimation and long term trends for categorization.

The depth to water level in shallow aquifers ranges from 6.29 to 9.3 mbgl during pre-monsoon of 2012-21 and 6.34 to 8.12 mbgl during post monsoon 2012-21. Specific yield in the zone of water table fluctuation has been taken as 12% and rainfall infiltration factor as 20% (as per norms). As per information available, there is no pumpage/ground water draft from shallow aquifers. Irrigation is being done by deep government tube wells only.

5.2   Method Adopted For Computing Rain Fall Recharge During Monsoon Season

The administrative block has been taken as assessment unit and for computing the block-wise rainfall recharge during monsoon season. Rainfall Infiltration Factor (RIF) Method has been mostly applied as the difference of computing this with Water Level Fluctuations (WLF) Method is more than 20%.

5.3   Ground Water Resource Assessment

The abstract of Dynamic Ground Water Assessment is as follows:-

DYNAMIC GROUND WATER RESOURCE IN SHALLOW AQUIFER

- Recharge from rainfall during monsoon   = 772.06 ham
- Recharge from rainfall during non- monsoon   = 313.0 ham
- Recharge from other source during monsoon   = 1424.78 ham
- Recharge from other source during non-monsoon   = 2694.85 ham
- Total annual ground water recharge   = 5204.69 ham
- Total Natural discharge   = 520.469 ham
- Annual Extractable Ground Water Resource (Ham)   = 4684.221 ham
- Ground water draft as on 31.03.2022   = 3793.76 ham
- Annual GW Allocation for Domestic Use as on 2025 (Ham) = 2625.72 ham
- Net annual ground water availability for future use   = 890.72 ham
- Stage of Ground Water development   = 80.99%
- Categorization for future ground water development   =Semi-Critical

Since, there is no draft from shallow aquifers; however the ground water is being abstracted from deeper aquifer to the tune of 3793.76 ham/year which places Chandigarh UT under **SEMI-CRITICAL** category.

S. N	DATA		QUANTITY (Ham/year)
1	Recharge from rainfall		1085.06
2	Recharge through Surface Water Irrigation	Recharge through Supply Leakages	2212.45
		Recharge through STP supply	1528.84
3	Ground Water Irrigation		205.77
4	Recharge through tanks & Ponds		105.77
5	Water Conservation Structures (RTRWH)		67.08
	TOTAL		**5204.97**

GROUND WATER DRAFT / EXTRACTION:

1. **Domestic Draft:** There are 281 tube wells for drinking / domestic water supply to the rural and urban population out of which total 277 tube wells are in use. These tube wells tap confined aquifers below 90 m from ground level. The depth of these wells ranges from 200-300 m. The average unit well draft of these wells is **12.27** ham/year. The annual draft from these tube wells is 3401.3Ham / year

2. **Industrial Draft:** There are 32 nos. of commercial tube wells for industrial water supply and out of which total 23 tube wells are actual in use. These tube wells tap confined aquifers below 90 m from ground level. The depth of these wells ranges from 200-300 m. The average unit well draft of these wells is **9.46** ham/year. The annual draft from these tube wells is 217.65 Ham / year.

3. **Agriculture Draft:** Total 30 nos. of irrigation tube wells in Chandigarh UT are actual in use. These tube wells tap confined aquifers below 90 m from ground level. The depth of these wells ranges from 200-300 m. The average unit well draft of these wells is **31.69** ham/year. The annual draft from these tube wells is 950.70 Ham / year.

S. N	ITEM	GWRE 2022 QUANTITY (Ham/Year)
1.	Annual Extractable Ground Water Resource	4684.21
2.	Existing GW Draft for Domestic Use	2625.71
3.	Existing GW Draft for Industrial	217.35
4.	Existing GW Draft for irrigation	950.70
5.	**Existing GW Draft for all Uses**	**3793.76**
6.	**Average Stage of GW Extraction of State**	**80.99%**
7.	**Category**	**Semi Critical**

5.4   Ground Water Assessment Comparison of Various Years

COMPARISON OF GROUNDWATER STATUS OF CHANDIGARH UT (SINCE 2004):

	YEAR OF GWR ESTIMATION						
	2004	**2009**	**2011**	**2013**	**2017**	**2020**	**2022**
Annual Extractable Ground Water Resource (Ham)	2030	1942	1940	1943	3794	5738.04	4684.21
Gross Ground Water Draft (Ham)	NIL	NIL	NIL	NIL	3378	4624.70	3793.76
Net GW Availability for Future Irrigation Development (Ham)	2030	1942	1940	1943	416	1113.34	890.72
Over Draft	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Stage of Ground water development in %	0 %	0 %	0 %	0 %	89%	81%	81%
Category	**SAFE**	**SAFE**	**SAFE**	**SAFE**	**SEMI CRITICAL**	**SEMI CRITICAL**	**SEMI CRITICAL**

5.5   Comparison in Dynamic Ground Water Resource in Shallow Aquifers of Chandigarh (UT) - 2020 V/S 2022

5.5.1   GROUND WATER RECHARGE:

DYNAMIC GROUND WATER RESOURCE IN SHALLOW AQUIFER				
S. N	RECHARGE	RECHARGE QUANTITY AS ON GWRE 2020 (HAM/YEAR)	RECHARGE QUANTITY AS ON GWRE 2022 (HAM/YEAR)	REMARKS
1	**Recharge from rainfall**	1669	1085	Urban area consideration and different filtration factors for paved and non paved area taken.
2	**Surface Water Irrigation (Supply Leakages + STP Supply)**	4343	3741	Actual Utilizable capacity of STP considered instead of installed capacity.
3	**Ground Water Irrigation**	206	206	Same as GWRA-2020
4	**Tanks and Ponds**	104	106	Number of ponds increased from 09 to 11 ponds.
5	**Water Conservation Structures**	54	67	No. of RTRWH increased from 202 to 516.
	TOTAL RECHARGE	**6376**	**5205**	

5.5.2 GROUND WATER EXTRACTION / DRAFT:

S.N	ITEM	GWRE 2020 QUANTITY (Ham/Year)	GWRE 2020 QUANTITY (Ham/Year)	Remarks
1.	**Annual Extractable Ground Water Resource / Net Annual Ground Water Availability**	5738	4684	GW recharge decreased in 2022.
2.	**Existing GW Draft for Domestic Use**	3483	2626	Draft decreased owing to surface supply.
3.	**Existing GW Draft for Industrial**	191	217	No. of industries with tube wells increases from 20 to 23.
4.	**Existing GW Draft for irrigation**	951	951	
5.	**Existing GW Draft for all Uses**	4625	3794	
6.	**Average Stage of GW Extraction of State**	80.66%	80.99 %	
7.	**Category**	Semi Critical	Semi Critical	

SUMMARY OF THE REPORT

Ground Water Extraction/Draft (Ham/Year)
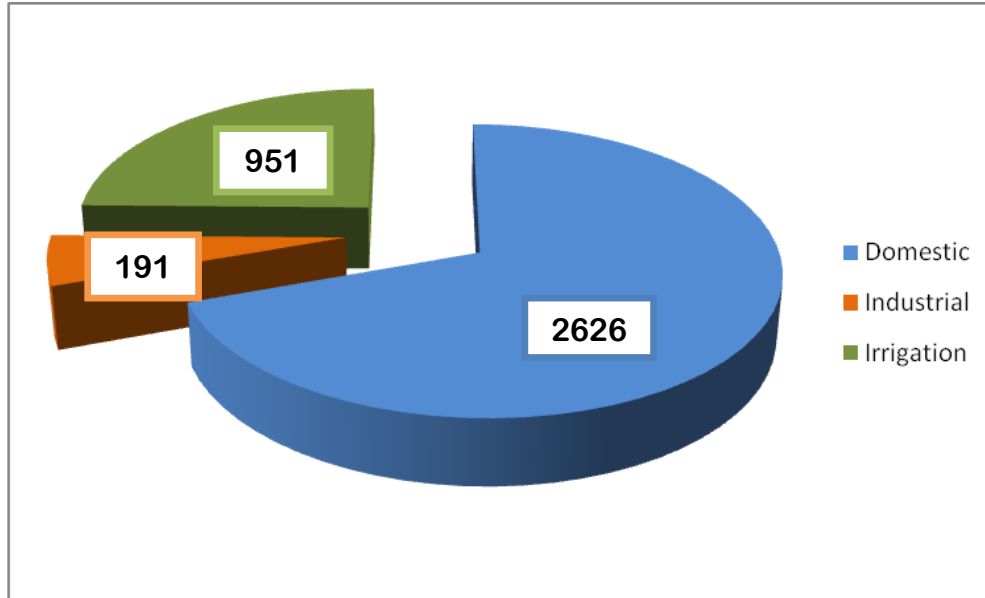
Dynamic Ground Water Resource & Draft of Chandigarh UT as on 31.03.2020 (Ham/Year)
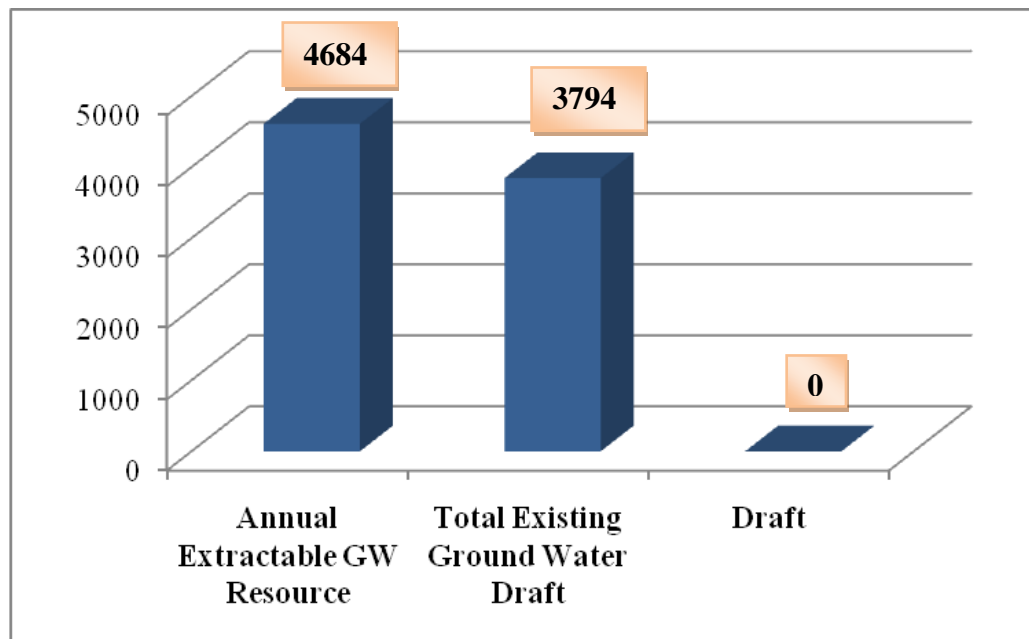
Ground Water Recharge 2020 vs 2022 (Ham/Year)

	Recharge from rainfall	Surface Water Irrigation (Supply Leakages + STP Supply)	Ground Water Irrigation	Tanks and Ponds	Water Conservation Structures
GWRE 2020	1669	4343	206	104	54
GWRE 2022	1085	3741	206	106	67
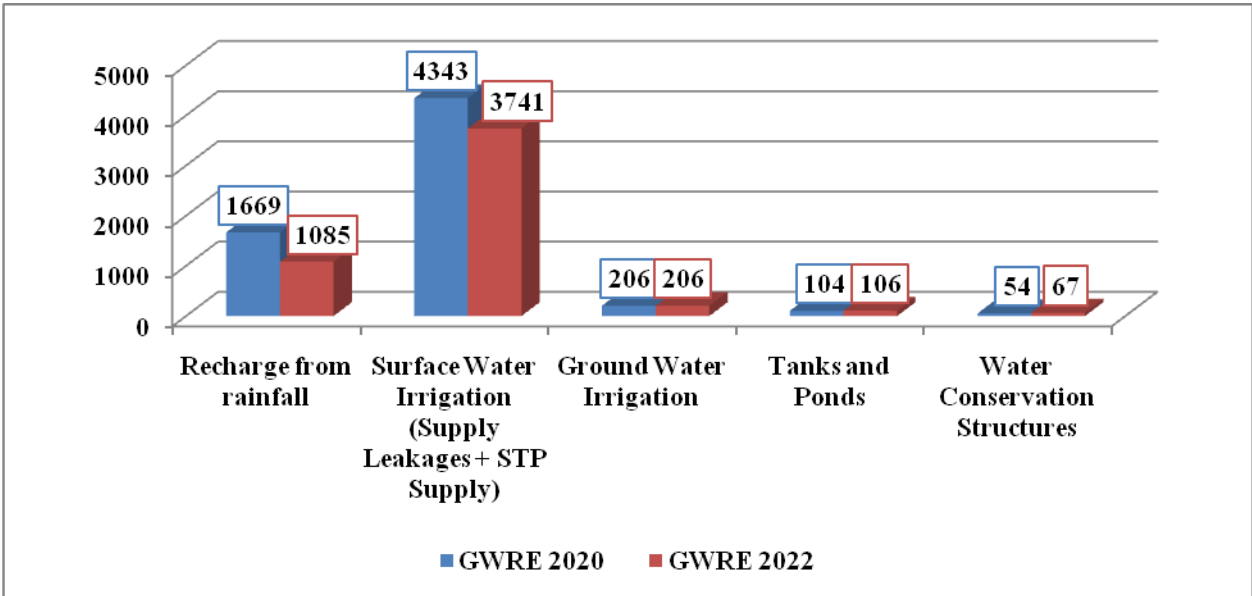
Ground Water Extraction 2020 vs 2022 (Ham/Year)

	Net Annual Ground Water Availability	Existing GW Draft for Domestic Use	Existing GW Draft for Industrial	Existing GW Draft for irrigation	Existing GW Draft for all Uses
GWRE 2020	5738	3483	191	951	4625
GWRE 2022	4684	2626	217	951	3794
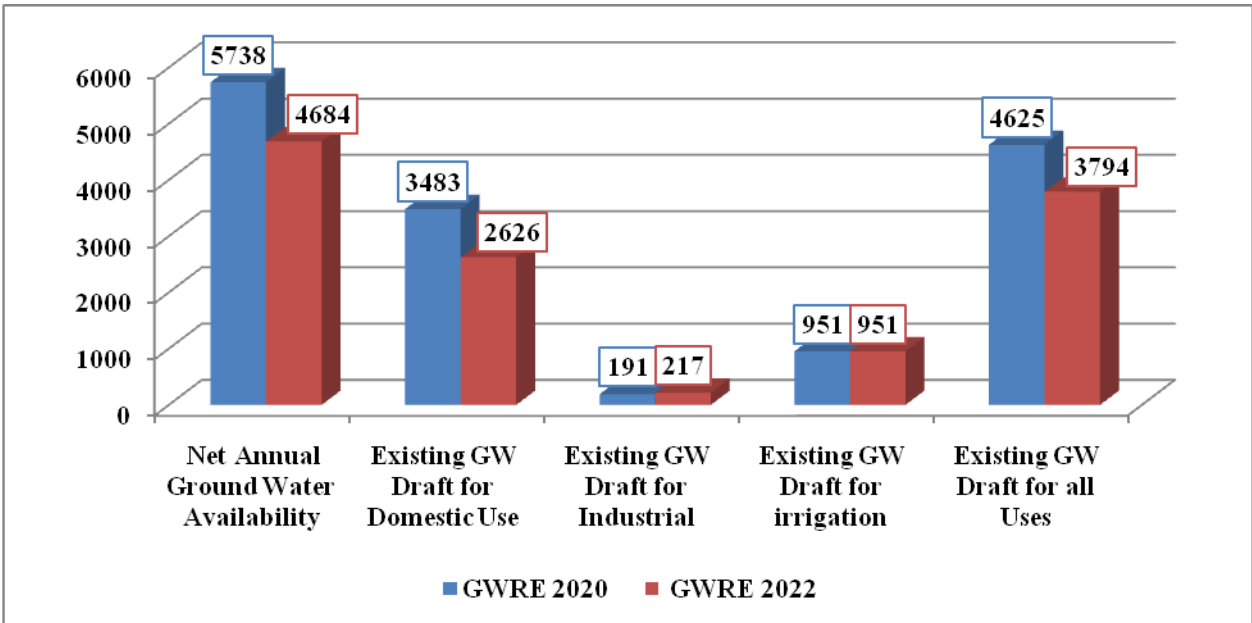
CONTRIBUTORS

Central Ground Water Board, North Western Region, Chandigarh:

1. Sh. Dinesh Tewari, Sc E

2. Dr. Kriti Mishra, Sc B

3. Sh. Aditya Sharma, AHM

Municipal Corporation & Chandigarh Administration:

1. Sh. N. P Sharma, Chief Engineer, Municipal Corporation, Chandigarh

2. Sh. Vijay Premi, SE(PH), MC, Chandigarh

3. Sh. Jagdish Singh, Executive Engineer, MC, Chandigarh

4. Sh. Parvinder Pal, Executive Engineer, MC, Chandigarh

Under supervision of:

Sh. Anurag Khanna, Regional Director, Central Ground Water Board

Chandigarh Administration
Local Government Department
Notification

Dated, 1 October, 2020

No. 16501-FII(9)-2020/12910   In pursuance of the guidelines vide No. T-13014/1/2019-GW Section MOWR dated 04.08.2020 of Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation, Govt. of India, New Delhi, the Administrator, Union Territory, Chandigarh is pleased to constitute the State Level Commtitee in Union Territory, Chandigarh, to re-assess ground water resources for the water year 2019-20, the State Level Govmmittee is constituted as under:-

i	Chairman	Principal Secretary Local Govt., Chandigarh Administration.
ii.	Member	Secretary Engineering Chandigarh Administration.
iii.	Member	Commissioner, Municipal Corporation, Chandigarh.
iv.	Member	Deputy Commissioner, UT Chandigarh.
v.	Member	Chief Engineer, M.C., Chandigarh.
vi.	Member	Chief Engineer, UT, Chandigarh
Vii	Member	S.E., Municipal Corporation, Chandigarh.
viii	Member	S.E., Union Territory, Chandigarh.
Ix	Member	Director Industries.
x.	Member	General Manager, NABARD -
xi.	Member Secretary	Regional Director, CGWB - Plot No. 3-B, Sector-27 A, Chandigarh.

Terms of Reference :   The broad terms of reference of the Committee would be as follows:-

i.   To re-assess annual ground water recharge of the state in accordance with the Ground Water Resources Estimation Methodology-2015.

ii.   To estimate the status of utilization of the annual extractable ground water resource.

Time frame: The Committee will submit its report on or before 28.02.2021.

Arun Kumar Gupta, IAS,
Principal Secretary Local Govt.,
Chandigarh Administration.

Endst.No. 38457- FII(9)-2020/ 12911   Dated, the 1-10-2020

     A copy is forwarded to the Controller, Printing and Stationery, U.T., Chandigarh, for publishing the above notification in the Chandigarh Administration Gazette(Extra-Ordinary). After the publication please supply 20 copies of the same to this Department for official use.

                                 Additional Secretary Local Govt.,
                                 For Pr. Secretary Local Govt.
                                 ChandigarhAdministration.

Endst.No.38457-FII(9)-2020/ 12912   Dated, the 1-10-2020

     A copy is forwarded to the Joint Secretary & Project Coordinator (Atal Jal), Govt. of India, Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation, Shram Shakti Bhawan, Rafi Marg, New Delhi w.r.t. his D.O No. T-13014/1/2019-GW Section MOWR dated 04.08.2020 for kind information.

                                 Additional Secretary Local Govt.,
                                 For Pr. Secretary Local Govt.
                                 ChandigarhAdministration.

Endst.No.38457-FII(9)-2020/ 12913   Dated, the 1-10-2020

     A copy is forwarded to the following for kind information and necessary action :-

1.   PA/Adviser to the Administrator, U.T., Chandigarh.
2.   PA/Secretary Local Govt. Chandigarh Administration.
3.   Commissioner, Municipal Corporation, Chandigarh.

                                 Additional Secretary Local Govt.,
                                 For Pr. Secretary Local Govt.
                                 ChandigarhAdministration.

Endst.No.38457-FII(9)-2020/ 12914   Dated, the 1-10-2020

     A copy is forwarded to the all concerned for information and necessary action.

                                 Additional Secretary Local Govt.,
                                 For Pr. Secretary Local Govt.
                                 ChandigarhAdministration.

Minutes of meeting related to Ground water Resource as on 2022 and Implementation of Master Plan for Artificial Recharge to Ground Water held on 31.05.2022 under the Chairmanship of the Secretary Engineering, U.T, Chandigarh at Secretariat Building, Chandigarh

A meeting was held regarding the formulation of State Level Committee (SLC) for Ground Water Resources of Chandigarh UT for 2022 and implementation of Master Plan for Artificial Recharge to Ground Water under the Chairmanship of Dr. Vijay Namdeorao Zade, Secretary Engineering, UT on 31.05.2022 at 14:45 Hrs. The List of Participants is attached as Annexure-I.

1. At the outset, Shri Dinesh Tewari Scientist-E, Central Ground Water Board (CGWB), NWR, Chandigarh welcomed all the members present in the meeting and appraised the Chairperson and other members about the role of SLC in Ground water Resource Assessment. He also briefed about the agenda points of the meeting. The agenda points for the meeting in specific were as follows:

   - *Formation of State Level Committee (SLC) for Ground Water Resource Assessment as in 2022.*
   - *Constitution of District Ground Water Coordination Committee (DGWCC).*
   - *Constitution of State Level Nodal Agency (SLNA) for implementation of Master Plan for AR to GW of Chandigarh UT.*
   - *Brief status on Ground Water Resources of Chandigarh UT (as on 31st March, 2020) and NAQUIM.*
   - *Release of GWRE 2020 report & NAQUIM report (CHD).*

2. Dr. Vijay Namdeorao Zade, Secretary Engineering, UT enquired about the various issues related to delay in the constitution of SLC for Chandigarh. He recommended that the SLC for the GWRE-2020 shall continue for the GWRE-22 and instructed the concerned officers that the reconstitution of SLC shall be expedited. It was followed by the presentation by Shri Aditya Sharma, AHM wherein he briefly explained the composition of the committee for the GWRE-

2020, mandate of the committee and briefed about the Dynamic Ground Water Resources of Chandigarh UT as on 31st March 2020, through power point presentation.

3. Dr. Vijay Namdeorao Zade, Secretary Engineering, UT proposed that the State Ground Water Coordination Committee (SGWCC) may be re-organized as District Ground water Co-ordination Committee for overall co-ordination of implementation of activities envisaged under NAQUIM.

4. Chairperson suggested that Haryana Water Resource Authority (HWRA) with co-opt from Municipal Co-operation, Chandigarh UT shall constitute State Level Nodal Agency (SLNA) for all water augmentation/conservation efforts in the UT so as to avoid overlapping of water conservation projects.

The meeting ended with vote of thanks to the Chair.

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List of participants in Meeting related to Ground water Resource as on 2022 and Implementation of Master Plan for Artificial Recharge to Ground Water held on 31.05.2022 under the Chairmanship of the Secretary Engineering, U.T, Chandigarh at Secretariat Building, Chandigarh

Sr. No.	Name	Designation & Department	Phone No.
1.	Smt. Anindita Mitra	Commissioner, MC	9463424848
2.	Sh. C.B. Ojha	CE	7508185419
3.	Sh. N.P. Sharma	CE, MCC	9781010000
4.	Dr. Rajesh Bansal	SE (PH)	9876607948
5.	Sh. Vijay Kumar Premi	SE, MC	9872511245
6.	Sh. Dinesh Tewari	Scientist 'E' CGWB, NWR, Chandigarh	7986629916
7.	Dr. Kriti Mishra	Scientist 'B' CGWB, NWR, Chandigarh	9415426179
8.	Sh. Aditya Sharma	AHM CGWB, NWR, Chandigarh	9785278115

Minutes of the State Level Committee for approval of Ground Water Resources Potential and Refinement of Figures in Chandigarh UT as on 31st March, 2022 held on 26.08.2022 under the chairmanship of worthy Home Secretary, Chandigarh

A meeting was held for approval of Ground Water Resources of Chandigarh UT as on 31st March, 2022 and refinement of figures under the chairmanship of Sh. Nitin Kumar Yadav, Local Government/Home Secretary, Chandigarh on 26.08.22 at 12:30 Hrs at Committee Room, UT Secretariat.

Shri Dinesh Tewari, Sc-E, CGWB, NWR, Chandigarh welcomed all the members of SLC and initiated the discussion and briefly explained the findings. Sh. Aditya Sharma, AHM presented brief about the Dynamic Ground Water Resources of Chandigarh UT as on 31st March 2022, through power point presentation. The Ground Water Resources had been worked out on the basis of the methodology recommended by Groundwater Estimation Committee-2015. The estimations were carried out based on the Data input provided by MC and Chandigarh Administration. The list of participant is attached in Annexure-I

After discussion with the Chairman and Members of the committee, the following recommendations have been made:

- Since the Chandigarh UT has been considered as Urban unit, significant decrease in natural recharge has been observed. It was suggested by Chairperson that methodology may be revised/revisited to mitigate such drastic changes.
- Since the domestic draft was observed to be on higher side, it was directed by Chairperson to recheck the Domestic Draft, as MC has supplemented the ground water supply with surface water supply.
- It was also directed to MC Chandigarh to provide the corrected data along with detailed report of 2 nos. of newly inducted ponds in village Dadumajra and Dhanas to CGWB at the earliest.

As per the directions from Chairperson the domestic draft was reduced and 02 nos. of pond was included for calculation of recharge. Based on the data provided the resources were recalculated and given as below:

➢ Annual Extractable Ground Water Resources is **46.84 MCM,**
➢ Existing GW Draft for irrigation is **9.50 MCM**,
➢ Existing GW Draft for Domestic use is **26.26 MCM**
➢ Industrial Use is **2.71 MCM**
➢ The Stage of Extraction for whole UT is estimated at **81%.**

As per the revised estimation, entire Chandigarh UT falls under Semi-Critical Category.

List of Participants

S.No.	Name	Department	Email & Phone No.
1.	Sh. Nitin Kumar Yadav	Home Secretary	In the Chair
2.	Smt. Anindita Mitra	Commissioner, MC, Chandigarh	9463424848
3.	Sh. N.P. Sharma	Chief Engineer, Municipal Cooperation	9781010000 npschandigarh@yahoo.com
4.	Sh. Sanjay Sahni	Executive Engineer, Public Health	7508185448 eeph3-chd@nic.in
5.	Sh. Vijay Kumar Premi	Superintending Engineer (Public Health), Municipal Cooperation	9872511245 vijaypremi64@gmail.com
6.	Sh. Joginder Kumar	S.D.E., Municipal Cooperation	987511350 joginderkumar98725@gmail.com
7.	Sh. Sumeet	Director, Department of Industries, Chandigarh UT	8901110100 dimsmevtchd@gmail.com
8.	Sh. Rajkiran Johri	NABARD	chandigarh@nabard.org,
9.	Sh. Dinesh Tewari	Sc-E, CGWB, NWR, Chandigarh	rdnwr-cgwb@nic.in,
10.	Sh. Aditya Sharma	AHM, CGWB, NWR, Chandigarh	6280378709 rdnwr-cgwb@nic.in,
11.	Sh. Sanjeev Chauhan	XEN (PH), MC	987251159 chausanju2002@gmail.com,

From

      The Executive Engineer,
      M.C. P.H.Divn.No.2,
      Chandigarh.

To

      The Regional Director,
      Central Ground Water Board,
      North Western Region,
      Plot No.3-B,Sector 27/A,
      Madhya Marg, Chandigarh.

      Memo No. 226
      Dated: 30/9/22

Sub: Approval of Ground Water Resources Potential and Refinement of Figures in Chandigarh UT as on 31st March,2022 held on 26.08.2022 under the chairmanship of worthy Home Secretary, Chandigarh.

Ref: Your office E-Mail dated 12.08.2022

      The presentation on Central Ground Water Resource Assessment (as on March, 2022) given by your office in the presence of State Level Committee(SLC) for Ground Water Resources of Chandigarh UT held on 26.8.2022 has been approved by the worthy Home Secretary, Local Government, Chandigarh vide memo no. P-202103 dated 29.09.2022, which is enclosed herewith.

      This is for your information and necessary action.

DA/As above.

                                Executive Engineer,
                                M.C.P.H.Divn. No.2,
                                Chandigarh

Endst No.   Dated:-

      A copy is forwarded to the Superintending Engineer, M.C.P.H.Circle, Chandigarh for his kind information please.

                                  -Sd-
                                Executive Engineer,
                                M.C.P.H.Divn. No.2,
                                Chandigarh

		DYNAMIC GROUND WATER RESOURCES OF INDIA, 2022													
		CHANDIGARH													
		Ground Water Recharge						Current Annual Ground Water Extraction					Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)
		Monsoon Season		Non-Monsoon Season		Total Annual Ground Water Recharge	Total Natural Discharges	Annual Extractable Ground Water Resource					Annual GW Allocation for Domestic use as on 2025		
S.NO	State/Union Territories	Recharge from rainfall	Recharge from other Sources	Recharge from Rainfall	Recharge from other Sources				Irrigation	Industrial	Domestic	Total			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	CHANDIGARH	772.06	1424.78	313	2695.13	5204.97	520.49	4684.48	950.7	217.35	2625.72	3793.76	2625.72	890.72	80.99
	Total (Ham)	772.06	1424.78	313	2695.13	5204.97	520.49	4684.48	950.7	217.35	2625.72	3793.76	2625.72	890.72	80.99
	Total (Bcm)	0.01	0.01	0.00	0.03	0.05	0.01	0.05	0.01	0.00	0.03	0.04	0.03	0.01	80.99

SUMMARY OF ASSESSMENT UNIT-WISE CATEGORIZATION (2022), as on 31.03.2022							
CHANDIGARH							
S. No.	Union Territory	Total Area (sq. km)	Over-exploited	Critical	Semi-critical	Safe	Poor Quality
1	2	3	4	5	6	7	8
	Chandigarh	114	-	-	SEMI CRITICAL	-	-

ANNUAL EXTRACTABLE RESOURCE OF ASSESSMENT UNITS UNDER DIFFERENT CATEGORIES, 2022													
CHANDIGARH													
		Total Annual Extractable Resource of Assessed Units (in mcm)	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
S.No	State/Union Territories		Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%
1	CHANDIGARH	46.84	-	-	46.84	100	-	-	-	-	-	-
	Total States	46.84	-	-	46.84	100	-	-	-	-	-	-
	Grand Total	46.84	-	-	46.84	100	-	-	-	-	-	-

				Safe		Semi-Critical		Critical		Over-Exploited		Saline	
S.No	States / Union Territories	Total Recharge Worthy Area of Assessed Units (in sq km)	Recharge Worthy Area (in sq km)	Recharge Worthy Area in sq km	%	Recharge Worthy Area in sq km	%	Recharge Worthy Area in sq km	%	Recharge Worthy Area in sq km	%	Recharge Worthy Area in sq km	%
1	CHANDIGARH	114	114	-	-	114	100	-	-	-	-	-	-
	Total States	114	114	-	-	114	100	-	-	-	-	-	-
	Grand Total	114	114	-	-	114	100	-	-	-	-	-	-

Table title (merged above):

RECHARGE WORTHY AREA UNDER DIFFERENT CATEGORIES, 2022
CHANDIGARH
AREA OF ASSESSMENT UNITS UNDER DIFFERENT CATEGORIES IN INDIA (2022)

QUALITY PROBLEMS IN ASSESSMENT UNITS, 2022			
CHANDIGARH			
ABSTRACT			
Total No. of Assessed Units	Number of Assessment Units affected by Fluoride	Number of Assessment Units affected by Arsenic	Number of Assessment Units affected by Salinity
0	0	0	0