

State of Groundwater in Uttar Pradesh

A Situation Analysis with Critical
Overview and Sustainable Solutions

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Ravindra Swaroop Sinha

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Ground Water
Action Group

State of Groundwater in Uttar Pradesh

*-A Situation Analysis with Critical Overview
and Sustainable Solutions*

Ravindra Swaroop Sinha

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Lucknow, Uttar Pradesh, India

GRATITUDE

The report on 'State of Groundwater in Uttar Pradesh' is a comprehensive technical document that has been prepared with great support from WaterAid India and Ground Water Action Group. The required data and the related technical information, gathered from different platforms, and consultations with experts along with extracting useful information from different publications, are highly acknowledged.

I would like to express my special gratitude to Mr. Farrukh Rahman Khan, Regional Manager, WaterAid India, Lucknow, for his inputs & continuous support during preparation of this elaborate document on groundwater resources of Uttar Pradesh, covering almost all the dimensions and aspects related to groundwater.

I sincerely acknowledge the support of Mr. B.B. Trivedi, former Senior Scientist, CGWB, for providing useful technical inputs for this manuscript. I am thankful to Mr. Naveen Shukla, Scientist, U.P. Jal Nigam for providing relevant publications. I also acknowledge the support of Dr. Shishir Chandra of WaterAid India for providing inputs on Banda water campaign. My sincere thanks are also due to Mr. Y.B. Kaushik, former Regional Director, CGWB for his technical advice and suggestions. Various data gathered from published reports & online platforms of different departments like Ground Water Department, CGWB, UP Jal Nigam, SWaRA, UPPCB is also gratefully acknowledged.

I feel pleasure in thanking Mrs. Priya Srivastava and Mr. Aditya Agrawal, IT experts, SWaRA and Mr. Shakti Verma for providing co-operation and help during preparation of this document. I also wish to sincerely thank all the fellow members of Ground Water Action Group and WaterAid India for their motivation and support.

R.S. Sinha

Author,

Convenor - Ground Water Action Group

FOREWORD



**Chairman, Uttar Pradesh
Water Management and
Regulatory Commission,
Lucknow**

It is a matter of immense pleasure that Ground Water Action Group and WaterAid India are bringing out a very useful and informative document on "State of Ground Water in Uttar Pradesh-A Situation Analysis with Critical Overview and Sustainable Solutions".

We are fortunate that the state of Uttar Pradesh is blessed with a very rich river system of Ganga, Yamuna and their tributaries, along with vast groundwater resources potential stored in multi-layered alluvial aquifers, known to be one of the largest aquifer systems in the world.

However, over-exploitation of groundwater, erratic & decreasing rainfall, increased water contamination and reduced ecological flows have put the State into a critical and challenging situation. Depleting ground water levels across the State both in rural and urban segments have emerged as a major policy concern. The threat of climate change is likely to affect the State's water security.

It is important to realize that groundwater has largely contributed to economic development of the State by providing major support to irrigation, drinking water and industrial sectors. But with increased dependency on groundwater, the resource has been extensively exploited, putting the aquifers under high stress. As per the Ground Water Assessment Report- 2017, 280 blocks and 10 cities are reported as stressed.

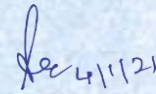
Diversity of groundwater problems has raised many concerns and it is high time the experts, planners and administrators evolved an efficient mechanism with focused and achievable plans to achieve significant improvement in groundwater condition.

It is appreciated that at a time when the State is seriously thinking to resolve the overall crisis of water resources, this report on the state of ground water in Uttar Pradesh has come out with a thoughtful and robust mechanism for sustainable groundwater management in the State, covering almost all the management aspects and focusing majorly towards restoration of depleted aquifers through new technological approaches. The report highlights the need to have more practical and targeted actions for agriculture, industrial and urban sectors suggesting the need to strengthen and refine data analysis, its management and resource assessment process, need to conduct extensive groundwater quality mapping and develop quality protocols, and to adopt large scale recharging methods, need to undertake aquifer

mapping on 1: 10000 scale for aquifer wise management. The report is a comprehensive document on groundwater resources of the State, providing all possible scenarios as a pathway for ground water management reforms. The new areas of virtual water assessment, consumptive water use and dual roster system for simultaneous use of surface water & groundwater, as envisaged in the report, may give new dimensions to groundwater studies.

It is heartening to note that WaterAid India, a leading International NGO, has been working across seven districts of the State in close collaboration with concerned departments, administration and panchayats contributing towards safe water and sanitation to people, specially marginalized communities and also supporting ground water conservation activities. The contribution of Mr. R.S. Sinha, a well experienced ground water expert in preparing this elaborate document on groundwater, is praiseworthy. I hope this report will prove to be a useful document for groundwater resource planning and management process in the State.

Date: 4th January 2021



(Susheel Kumar)

Chairman

Uttar Pradesh Water Management
and Regulatory Commission,
Lucknow

COMMENTS OF EXPERTS

- I. I have gone through the executive summary and table of contents of the important document titled “STATE OF GROUNDWATER IN UTTAR PRADESH -A Situation Analysis with Critical Overview and Sustainable Solutions, prepared by Sri R. S. Sinha, an eminent groundwater expert, with the support of WaterAid India. The document includes some basics of groundwater along with international and national perspective of groundwater usage with detailed overview of groundwater availability and various associated problems in different parts of Uttar Pradesh state. The decreasing trend of rainfall pattern and possible impact of climate change on groundwater are also highlighted. The current central and state government regulatory policies and implantation status are also discussed with possible management strategies. This document will be very useful for those who are associated with the groundwater investigations, monitoring, policy planning and implementation including experts working in associated areas, agriculturists, industrialists, other users and those who want to understand the status of current availability of groundwater in different parts of the Uttar Pradesh state and various water quality problems.

Dr. Bhishm Kumar

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- II. The document on State of Groundwater in Uttar Pradesh provides a comprehensive insight on different aspects of groundwater resources of this agrarian state and highlights diversified issues and the related management concerns. This is important that the document has come out with host of solutions for overall reform of groundwater sector in the state. The vast Ganga plain, a part of Ganges – Brahmaputra basin, have always been recognised all the world over, as most prolific reserve of groundwater. For this reason, only, the area earmarks highest population density of India with population touching almost 50 crores. Known to all that the states of Punjab, Haryana and Uttar Pradesh were harbinger in ushering Green Revolution in 1964 -67 period, when groundwater revolution leaped up the irrigation potential by 80%, transforming the country into food surplus category. But almost 50 years down the line groundwater came to be savagely hounded upon for agriculture as well for drinking needs simulated irreversible damage to worthy aquifer system. Starting from common man to water professional, bureaucrat, political hegemony, all tended to forget that life elixir though in abundance, but not infinite. The situation of impoverished resource now stands smitten by impaired top (phreatic) aquifer through savage mining, once perennial rivers starved off even base flow in non-monsoon months, shrinking of river flood plains, hazardous pollution of both surface and groundwater. The complicity of all in such criminal indifference towards the resource has resulted into mindless extraction from same depth intervals at say micro-basin level for

every day swelling urban agglomerates with practically a blind eye towards conservation aspect in form Rain /Storm water harvesting, conversion of age-old ponds into housing colonies, concretisation all around even pavements and highly subsidized drinking water. Water professionals among themselves do not see eye to eye in coming out with effective measures in time-to-time resource estimation and accordingly re-visit relatively worthy area as well depth interval more appropriate for withdrawals with changing dynamics of aquifer systems. Planners are in practise of taking a leaf out of the mayhem and act whimsical to comply with contemporary political wishes. Time had already arrived for us all to earnestly come together for parenting the severely damaged resource for coming generation.

The present document by Sri. R.S. Sinha is an in-depth analysis of basic bottlenecks together prioritising the issues in order of merit. The everlasting zeal of the author exhorts many of us to become more responsive for the cause of water and he always deserve high commendations for giving a lead to professionals and planners alike. The effort of WaterAid India to bring out this elaborate report on groundwater is praiseworthy.

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- III. Uttar Pradesh has nine agro-climatic regions, eight major river basins, and diversified hydro-geological setup mostly dominated by alluvial aquifers of the Gangetic plain and discontinuous aquifer system of Bundelkhand and Vindhya. It has one of the world's most extensive groundwater reserves. Ironically, it is also the most groundwater exploited region of the world. In this important volume, the author has presented the detailed scenario of groundwater in the state of Uttar Pradesh. As a result of unscientific exploitation of groundwater in many rural and urban areas, a grim scenario of over exploited and stressed blocks has emerged which is leading to severe threats of pollution, resource depletion and ecological imbalance. It has been observed that reduced base flows are impacting groundwater dependent ecological flows as well the surface storages. Western UP has been categorized as one of the most depleted aquifer systems of the state. The author also highlights the importance of micro level aquifer mapping and aquifer-based groundwater management plan. Overall, this volume is must for those who are interested to know groundwater from a regional perspective, and for scholars who are engaged in natural resource management and policy studies.

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BACKGROUND NOTE

Depletion of groundwater resources has emerged as a policy concern both at national and state level, which requires to be addressed through an integrated approach.

In Uttar Pradesh, groundwater is the most preferred resource for augmenting supplies in all the sectors. However, the resource management in the state poses both qualitative and quantitative challenges. Therefore, for groundwater resource sustainability, it is important to make balance between utilisation/ extraction and recharge, recycle and reuse of water. Addressing groundwater issues would also require change of perceptions and practices at different levels, where civil society organisations will have an important role in sensitizing relevant stakeholder groups.

It is heartening to note that the State Government is working on both policy and regulation side of water sector. At this point of time, the effort of Lucknow regional office, WaterAid India for bringing out a comprehensive report on “State of Ground Water in Uttar Pradesh” will go a long way in the planning and management process of groundwater resources in the state. The report covers almost all the relevant aspects of groundwater resources in Uttar Pradesh, effectively summarising the current scenario with criticality of situation and the status of existing policies. The report signifies the importance of data management, resources assessment, including need of restoration of aquifers. A set of ground water reforms and integrated solutions, as envisaged in the report, may surely provide a sustainable pathway for futuristic planning, management and conservation of groundwater in the state.

Farrukh Rahman Khan
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STATE OF GROUNDWATER

IN UTTAR PRADESH

-A Situation Analysis with Critical Overview and Sustainable Solutions

EXECUTIVE SUMMARY

Groundwater is the country's most extracted resource with withdrawal rates currently in the estimated range of about 250 bcm per year, thereby putting India on the top of World's biggest groundwater exploiting nations, being responsible for 25 percent of total global abstraction.

Different states in the country are over-pumping groundwater for years, especially after the advent of Green Revolution in eighties, and amongst them, Uttar Pradesh is the largest extractor state taking out billion of litres of groundwater from the aquifers every year equal to almost one-fifth of country's total annual withdrawal.

In Uttar Pradesh, 70% of irrigated agriculture is groundwater dependent, while it also provides majority of supplies for drinking water, industrial, commercial, infrastructural, mining and horticultural uses. Groundwater has, thus, become a dominant and crucial source of water for most of the development activities of the state, thereby contributing largely to the growth of state's economy.

Consequently, large scale unabated extraction has put various rural and urban areas of the state under heavy groundwater depletion to an extent that potential aquifers of Ganga basin are taking their last breaths. In addition to this crisis, groundwater pollution has emerged as a much greater threat for water security in different parts of the state. Furthermore, due to huge withdrawal from aquifers, the resultant rapid decline of water levels has severely impacted groundwater fed rivers of the state, because natural discharges / base flows from groundwater system to rivers & wetlands have significantly reduced or almost vanished. Moreover, large-scale encroachment of water bodies and their catchments has added miseries.

However, to bring groundwater out of prevailing crisis, various proactive measures and policy initiatives have been started in the state during the last 20 years, but, the overall outcome is not visible on the ground. Since the resource is invisible, it is being neglected, underestimated, undervalued and inadequately managed. At this point, it also becomes

important to look back and critically review groundwater related policies, programmes and schemes in the state towards the resource management to ensure optimal and sustainable impact.

In this context, to look forward for ensuring sustainable and adequate water supplies, groundwater management in the state is becoming a formidable challenge as well as the foremost priority. Hence, it is imperatively needed to have a critical overview of different groundwater dimensions, including past and current scenarios, and integrate & analyse them for evolving sustainable solutions for effective management and restoration of depleted groundwater sources in the state.

Purpose:

With above perspective, the purpose of bringing out a comprehensive report on "State of Groundwater in Uttar Pradesh" is to document for the first time almost all the aspects and dimensions of groundwater resources and its management requirements by suggesting an implementable robust mechanism integrated with efficient, sustainable & more practical policy interventions.

The idea is to showcase all the past and current scenarios of different aspects of groundwater and implementation status of existing policies, which have been thoroughly discussed, analysed & consolidated in this document in **nine elaborate chapters**.

The main points are -

- *The document describes and analyses diversity of groundwater problems in the state with a critical overview of groundwater resources, both its availability and quality as well as the resource changing situation in urban & rural segments.*
- *It envisages an exhaustive prescription suggesting possible management approaches and pathways to achieve sustainability of groundwater resources for meeting future demands of the state through honest implementation of a composite management mechanism, based on critical analysis of resource availability, related stresses and various policies, plans and practices by converting them into most efficient and actionable solutions.*
- *The document is expected to be a way forward towards overall reform of groundwater sector in Uttar Pradesh.*

The key features of the document include changing scenario, general basics and scientific facts, new perspective for per capita availability, changes in rainfall pattern, hydrogeological set-up, new classification for aquifer system, key groundwater problems, status of groundwater resource availability and extraction - both rural, urban perspectives, river basin scenarios and crisis of groundwater fed rivers, water scarcity in Bundelkhand-Vindhyans, extent & threats of groundwater pollution, scenario of sub-surface waterlogging, role of new technologies, existing policies & initiatives, actions & practices, regulatory regime, management issues & concerns, inherent gaps in resource assessment methodology, shortcomings in policy implementation, suggested reforms through robust mechanism including data management, refinement of assessment methodology, micro level studies, national regulatory framework, extractive and restorative policies, aquifer mapping on 1:10000 scale, composite strategy for restoration of aquifers, including new practices for recharging, urban groundwater management, specific solutions for efficient water uses in agriculture and horticulture sectors, integrated quality assessment and mapping, management mechanism for groundwater uses in industrial, infrastructural, commercial & mining sectors, assessment of consumptive uses and virtual water, watershed geomorphology for Bundelkhand-Vindhayan, groundwater protection charges, community and stakeholders participation in conservation campaigns & water budgeting and creation of an integrated & effective awareness mechanism.

Country's Overview:

Total Precipitation:	4000 bcm
Annual water availability:	1869 bcm
Utilizable water:	1122 bcm (about 60%)
	Surface water -- 690 bcm
	Groundwater -- 432 bcm

Per Capita Water Availability - New Perspective:

The per capita water availability is determined on the basis of country's total water availability and population, using Falkenmark Water Stress Indicator. But for all practical purposes, the utilizable water, taken as 60% of total water availability, is primarily considered for the overall water resources planning. Hence, it would be rather more realistic to determine per capita availability and relative water stresses on the basis of utilizable water.

The projected scenario, using utilizable water component, has been developed for different time periods, as given in the following table. Though, it appears highly challenging and critical, a paradigm shift would be needed from current overview of per capita water availability to the probable projections calculated by using utilizable water, with the objective to formulate more realistic long-term plans for ensuring futuristic water demands and supplies, especially keeping in mind the reality of future water stresses and related management challenges.

**-Per Capita Water Availability: Projected Scenario
(Using Utilizable Water)**

Year	Per Capita Water Availability Scenario (m ³ /capita/year)	
	Based on Annual Water Availability (as reported)	Probable Projection based on Utilizable Water
1951	5177	3107
1981	2960	1640
2001	1820	1047
2011	1545	900
2021	1341 (projected)	808 (likely projection)
2051	1140 (projected)	656 (likely projection)

(Source: Sinha, R.S., 2019)

Water Stress -1700 m³/capita/year,

Water Scarcity- 1000 m³/capita/year

Groundwater Resources - U.P. Scenario:

A relative scenario of groundwater resources in India and Uttar Pradesh is presented as follows -

Groundwater Resources --A Relative Scenario

Status of Groundwater	India	Uttar Pradesh
Annual Extractable Groundwater	392.70 bcm	65.32 bcm
Annual Groundwater Extraction	248.69 bcm	45.84 bcm
1. Irrigation/agriculture use	221.45 bcm	40.89 bcm
2. Domestic use	24.86 bcm	4.95 bcm
3. Industrial use	2.38 bcm	Not reported
Net Availability for Future Use	144.01 bcm	19.48 bcm
Stage of Groundwater Extraction	63.33 %	70.18 %
OCS Units (Over-exploited, Critical and Semi-critical)	2471 nos.	290 nos.

Key Highlights:

1. Groundwater has made significant contribution to the socio-economic development of Uttar Pradesh. In the process, it has emerged as a groundwater dominant state, as far as security of irrigation, drinking water, industries, horticultural and infrastructural projects is concerned.
2. It is also significant that Uttar Pradesh alone covers about 28.68% area of entire Ganga basin, which extends over 11 states of the country and comprises most fertile and productive land, known to have vast water resource potential.
3. The state is characterised by a highly diversified hydrogeological set up, mostly dominated by thick pile of alluvial deposits and is known to have the richest repository of groundwater underneath. But there are some hydrogeological constraints also, the state is largely overlain by Older Alluvium with prevalence of silty sand, having relatively low to moderate yield and a prominent saline belt extending through a major part at variable depths, whereas, Bundelkhand-Vindhyan is dominated by discontinuous aquifers.
4. Presently, groundwater caters about 70% irrigated agriculture in the state, besides fulfilling about 90% of rural domestic needs and more than 75% of urban water demand as well as providing about 95% industrial, infrastructural and commercial supplies.
5. Uttar Pradesh is one of the states in India where after independence, enormous water development has taken place for large scale expansion of irrigation facilities, besides meeting other sectoral demands. The most crucial change in the use of irrigation facilities has been witnessed with Green Revolution era in early eighties, when low-cost pump set technology has accelerated the tube well construction activity in the entire country and the Uttar Pradesh, in particular, has emerged as the biggest centre for irrigation tube well activity.
6. Amongst all the users, irrigation supplies in the state are largely groundwater dependent with more than 37 lakh shallow tube wells extracting about 41 bcm of groundwater annually, which is about 90% of total groundwater abstraction in the state. This becomes more important that 35-40% of total irrigation wells in the country are located in this state.
7. Statistics reveal that there has been a significant increase in the net irrigated area in the state from 3.2 million hectare to about 14.4 million hectares after the independence. In last 30-40 years, ground water contribution in increasing net

irrigated area in the state is about 70-80 %. At present, the total irrigated area in the state is about 87%, while the National average is only 49%. As a result, the state is now one of highly irrigated states of the country.

8. Before five-year plan period, irrigation potential created in the state was only 5.4 million hectares, which has increased by about 6 times that is approximately 36 million hectares. With significant increase in groundwater dependent irrigation facilities and having one of the largest canal networks, crop productivity and also the food production has increased manifold, making the state as one of the major contributors to the food basket of the country. However, widespread cultivation of sugarcane, a highly water sucker crop, has aggravated the problem of groundwater depletion.
9. There has also been remarkable rise in the demand and consumption of groundwater sources in other sectors of the state, especially drinking water, industries, commercial uses, infrastructural activities, horticultural uses, fisheries development and mining. However, the realistic assessment of groundwater abstraction in these user sectors requires urgent attention.
10. In past decades, marked changes have been noticed in the land use from agricultural land to urban, industrial, and infrastructural activities and with such land use changes, the dependency on ground water sources has gradually increased. According to the survey of 2014-15, about 16.6-million-hectare (68.5%) land in the state is used for cultivation. But due to land use changes, about 3 lakh hectare cultivable land in the state has decreased between 2002-03 and 2013-14, which mostly converted into non-agricultural uses. With increase in demand of urbanisation and industrial as well as infrastructural development, land use of the state is continuously changing and as a result, pattern of water usage and its development is also changing significantly.
11. **Resource underestimated** - In the last Ground Water Resource Assessment - 2017, stage of groundwater extraction in the state is estimated as 70.18 %, which is slightly above the threshold of safe limit i.e., 70%. But in this assessment exercise, groundwater extraction for industrial uses has not been estimated, leaving an important component of groundwater uses/extraction. Consequently, the reported stage of extraction is significantly underreported. However, it is pertinent that if groundwater extraction for industrial and other uses, including infrastructural & commercial, is reliably assessed and subsequently added to the above reported figure

of gross abstraction in the state, the overall stage of groundwater extraction will distinctly change with significant increase.

Likely change in Stage of Groundwater Extraction in U.P.

	Total Extraction (bcm)	Stage of Extraction (%)
As per Assessment report - 2017	45.84	70.18
Assessment based on Analysed figures for Domestic, Industrial, and other uses.	55.68	85.24

The above table demonstrates how the stage of groundwater extraction would change drastically, when withdrawal from industrial, commercial & other users, which have been unreported so far, are estimated and added to the previous assessment. The Assessment report - 2017 does not include the abstraction for industrial and other uses, therefore, an attempt is made to find out groundwater extraction in industries (including MSMEs), commercial and infrastructural activities along with reassessment of actual withdrawal in domestic uses. The conservative estimation approach is adopted for this endeavour and as a result, additional extraction in these user sectors has been figured out as 9.84 bcm. This figure is added to previously assessed extraction of 45.84 bcm and the scenario has changed with stage of extraction increasing from 70.18% to 85.24%. The purpose of carrying out this exercise is primarily to find out more realistic picture of groundwater extraction in the state, so that the current methodology of assessment GEC Methodology - 2015 could be reviewed for refining the resource estimation procedure. This would also lead to new management processes.

12. The issue of groundwater estimation, hence, becomes quite important from resource management perspective as well as for the regulatory instrument presently operational in the state. It also raises serious concern on the procedure recommended in the new GEC methodology - 2015 for estimating recharge and extraction components, because the estimation process envisages inherent uncertainties and also the limitation of adopting adhoc norms.
13. **Situation of Overdraft by year 2028** - With rising trend of groundwater extraction in almost all the user sectors, **the future groundwater scenario of the state appears very grim.** With current rate of abstraction, the projected gross extraction in the state may reach up to 70 bcm or more around 2028 and is expected to cross over the

recharge/extractable resource **that might put the entire state in a stage of overdraft. Furthermore, the declining rainfall, impacting the natural recharging of aquifers, is making the situation worse.**

Changes in Groundwater Resources Status between 1975--2017

Year	1975	1986	1990	1995	2000	2004	2009	2011	2013	2017
Groundwater Recharge (bcm)	70.5	76.9	64.1	71.6	80.8	70.1	68.6	71.6	71.5	65.3
Groundwater Extraction(bcm)	26.3	26.2	26.4	26.9	42.2	48.8	49.6	52.4	52.8	45.8
Net Groundwater Availability (bcm)	44.2	50.7	57.7	44.7	38.6	21.3	19	19.2	18.7	20.36

14. Groundwater contamination - The issue of groundwater pollution has also emerged as a new threat for water security and potable water supplies in the state. About 35 districts are reported to have been found variously affected with Arsenic toxicity. Besides, salinity, fluoride, nitrate pollution, heavy metal toxicity, bacteriological contamination in ground water is also a serious concern for potable and irrigation water supplies in the state.

Occurrence of salinity in groundwater of Central Ganga plains at varying depth intervals has come up as a difficult situation for resource sustainability, as this extends from north west to south east all across the state, covering 700 kms stretch from Ghaziabad-Agra to Pratapgarh-Jaunpur, and encompassing 70000 sqkm area (Trivedi, B.B.).

Districts Affected with Groundwater Pollution

Contaminants	Districts Affected (Nos)
Salinity (EC>3000µS/cm at 25°C)	14
Fluoride (>1.5 mg/l)	16
Iron (>1.0 mg/l)	29
Nitrate (>45 mg/l)	49
Arsenic	35
Lead	10
Cadmium	2
Chromium	4
Manganese, Zinc, Nickel, Copper	Industrial/urban areas

15. Sub-surface waterlogging in Canal commands has converted large areas unproductive. In the state, the area affected with sub-surface water logging (0-3m) is variously reported from 8 lakh ham to about 32 lakh ham, so correct mapping of shallow water levels / sub-surface water logging is needed.
16. **Industrial clusters - Groundwater abstraction not yet estimated** - There are 13 polluted industrial clusters located in the state. Amongst them, nine clusters are critically polluted, and four clusters are severely polluted. These industrial clusters as well as other major industries are mostly groundwater dependent, but ground water situation in these clusters has not been evaluated so far. Further, there is also no official estimate on groundwater extraction in the industrial sector of the state, as in the periodic resource assessments being carried out since the year 2000, groundwater abstraction in industrial uses has never been computed, despite clear cut provision in the methodology. Furthermore, there are about 90 lakhs MSMEs (Micro, Small and Medium Enterprises) in the state, which are mostly groundwater dependent. Though, the actual quantity of groundwater being pumped out by MSMEs is not yet assessed, but the expected abstraction might be around 2.8 bcm. This is noteworthy that both the central and state regulatory regimes have exempted those MSMEs from the ambit of regulation, which are extracting groundwater up to 10 cum per day.

Groundwater Stresses and Key Challenges:

Various groundwater stresses are reported from different parts of the state-

- i. With high activity of groundwater abstraction and consumption by large set of users, both in rural and urban areas of the state, **the prolific aquifer system**, especially the Ist Aquifer Group, **is in peril, as unabated pumping and continuously declining water levels have led to almost irreparable damage to dynamic aquifers.**
- ii. **Urban Areas Highly Stressed** - The cities like Lucknow, Ghaziabad, G.B. Nagar, Meerut, Agra, Kanpur, Bareilly, Prayagraj, Varanasi are experiencing large scale groundwater mining, which is expected to cause grave environmental implications in near future as groundwater in such places is depleting at much faster pace because of ruthless ground water exploitation. In about **95% municipal bodies of the state, drinking water supplies are groundwater dependent.**
- iii. Most of the prominent cities are facing widespread groundwater level decline from 0.5 to 1 m per year during the last 15-20 years, surpassing the threshold of significant annual decline of more than 20 cm. In most of the cities, groundwater levels have

reached to much deeper depths beyond 20 m and even more, which would be, more likely, difficult to get back.

- iv. The major cities are gradually becoming hub of extensive groundwater withdrawal, but the actual level of extraction in different user sectors is not known. However, groundwater abstraction in Lucknow city has been variously assessed/reported by different agencies with vast variance, as shown below-

Lucknow city: Variously Assessed Groundwater Extraction (mld)

Lucknow Jal Sansthan	CGWB	Analysis based Assessment	TERI/GWD, UP
356	264	1391	350

The large variations in groundwater extraction figures require field based extensive survey & its evaluation and authenticity of various data for evolving a clear picture of groundwater withdrawal not only in Lucknow city, but also in other urban areas.

- v. Western Uttar Pradesh has been categorised as one of the most depleted aquifer systems of the state, where extensive and indiscriminate groundwater exploitation has now spread to almost all the rural and urban segments.
- vi. **Groundwater Mining in 74 Blocks**
In Resource Assessment - 2017, a most critical situation of groundwater mining has been observed in 74 over-exploited blocks, which have been continuously reported as overdraft areas in all the previous assessments since 2004. The alarming side of this indiscriminate exploitation is that the huge quantity of ground water has been pumped out much more than what is being annually replenished.
- vii. About 70% blocks and majority of urban centres are witnessing decline in groundwater levels. In the last assessment of 2017, 82 blocks are categorised as over-exploited, 47 as critical and 151 semi critical.
- viii. For the first time, 10 major cities, out of total 653 urban bodies, were assessed for groundwater resource availability. Nine cities were categorized as over-exploited and one city (Agra) as critical.
- ix. The 290 OCS blocks, including 10 cities, have increased by 33% from 217 blocks categorised in 2013- assessment, while during the same period, there has been a rise of only 25% at the national level where OCS areas have increased from 1968 to 2471. Overall, the OCS areas are continuously increasing in the state, as revealed by various assessments carried out since the year 2000.

This scenario is a clear indication that groundwater situation of Uttar Pradesh is gradually becoming more & more critical.

Relative Increase in OCS Areas

Place	Over-exploited, Critical and Semi-critical areas - OCS (nos.)	
	2013	2017
India	1968	2471
Uttar Pradesh	217	290

- x. Alluvial aquifers of the state are considered to have huge groundwater storages, but at the same time, due to excessive groundwater abstraction and utilization, these aquifers have reached to a state of irreversible over-exploitation.
- xi. The prime concern for water resources overall planning and management in the state is the huge gap between the potential created for canal irrigation and the potential utilized. Therefore, this issue needs to be addressed on priority, as significant increase in canal-based irrigation would gradually reduce dependency on ground water.
- xii. **Quality Mapping, a bigger challenge** - Overall scenario of groundwater quality in the state is yet to be mapped, while large population is exposed to various diseases like fluorosis, arsenicosis, heavy metal related toxicity, gastro-intestinal problem and other health related problems.
- xiii. For decades, Bundelkhand-Vindhyan region is facing severe water crisis, where locating and exploiting ground water has always been a challenging task due to diverse geological & geomorphological set up and un-supportive economic yield of the aquifers. Though, the watershed geomorphology-based interventions can enhance the resource availability, but this concept has never been properly understood and implemented.
- xiv. This is important that groundwater feeds river, lakes, wetlands and if it is hugely pumped to an amount more than the recharge, the whole eco-system would be adversely impacted. Reduced base flows are impacting groundwater dependent rivers and their ecological flows as well as the surface storages. Gomti river and its tributaries and several other rivers in the state are groundwater fed, but heavy extraction and subsequent groundwater depletion in the river catchment have severely impacted the e-flows of these rivers because of reduction in base flows / natural

discharges from groundwater system into the stream. Groundwater fed rivers, therefore, would require entirely different management interventions.

- xv. **Decline in Rainfall** - Another disturbing situation, the state is facing, is the deficient rainfall and its highly erratic pattern with extreme events, which has more or less triggered the prevailing groundwater crisis. During 1991-2000, the overall decline in rainfall was 8%, while the data of last two decades depict that the rate of rainfall decline has been much faster with deficit of more than 20%. Overall, the state is receiving deficit rains almost every year with reduced rainy days and heavy, short duration events of downpour. This has affected the surface storages, soil moisture and groundwater recharge. Districts like Ghaziabad, G.B. Nagar, Baghpat, Bulandsahar, Agra, Kanpur Dehat are highly rain deficient, where even less than 40 % of normal rainfall has been received in past years, directly impacting replenishable groundwater recharge.

Decadal Changes in Average Annual Rainfall in Uttar Pradesh

Decade	1971-1980	1981-1990	1991-2000	2001-2010	2011-2019
Average Annual rainfall (mm)	1280.1 (135%)	923.8 (97.5%)	872.9 (92.10%)	737.4 (77.8%)	732.47 (77.31%)
Normal Annual Rainfall in U.P.: 947.4 mm					
(Figure in percentage with respect to normal rainfall)					

- xvi. Loss of enormous quantities of groundwater, as a result of **consumptive uses** in agriculture, mining, manufacturing & industry, dewatering and construction activities in infrastructure projects as well as the **virtual water trade** (hidden water behind a product), is a newly emerged area of great concern, because this portion of water is not returning to water system and invariably this lost component from groundwater regime within the hydrologic cycle is neither included in the methodology nor yet recognised in the estimation process of groundwater resources.
- xvii. **Treated water to replace groundwater-based supplies** - huge sewage pollution load of river Ganga, Yamuna and their tributaries have tremendous indirect potential for providing large amount of treated wastewater, which could be utilized as alternative supplies for irrigation, industrial uses, construction activities and other such uses. As per the official estimates, the currently available amount of **treated water, being produced by the Sewage Treatment Plants in the state, is about 2240 million litre per day**. Obviously, if this amount of treated water is utilized fully, extraction from

groundwater sources could be reduced significantly at least for industrial, infrastructural uses.

Management Concerns and Issues: In the present perspective of groundwater depletion and contamination, impacting different areas of the state, the management concerns and the related groundwater issues have come to the forefront. The issue primarily moves from how to simply get back the depleted resource availability to how can we manage and achieve the resource sustainability for future generations, future demands, future economies and future ecosystem. The focus on groundwater governance then becomes imperative how we move to identify and understand the major concerns and issues and find out integrated solutions.

Large scale groundwater extraction has emerged as the most crucial issue across the state and it is greatly posing a formidable challenge for policy makers, and the state administration at large, to sustainably manage and regulate groundwater resources.

<i>Unreported Extraction in Uttar Pradesh</i>	
<i>In following areas, groundwater extraction is either unreported or underreported in Groundwater Resources Assessments</i>	
User areas	Expected Extraction (bcm)
Sugarcane Cultivation	20.80
Drinking/Domestic uses	5.49
Major/Large Industries	2.5
MSMEs	2.8
Commercial Uses	2.2
Infrastructural Uses	1.0
Institutional Uses	0.8
<i>In above mentioned user areas, conservative estimation approach is used to find out probable groundwater extraction. More likely, the actual extraction might be relatively higher or less, hence, it is required to have a systematic assessment & validation to come out with a correct picture of extraction in these user areas.</i>	

The broader issues and concerns, inter-related with groundwater management, are discussed in the document for effective solutions. Some of the important issues are -

1. Inadequate management of vast groundwater data.
2. Insufficient knowledge and understanding of aquifers amongst stakeholders.

3. No comprehensive & integrated regulatory mechanism to overall control and reduce indiscriminate groundwater withdrawal.
4. Variance and data gaps in groundwater resource estimation.
5. Ambiguity in important norms such as specific yield, unit draft; need validation.
6. Hugely extracted groundwater underestimated, groundwater abstraction in certain areas still unrecognised.
7. Review and reframing Urban groundwater norms.
8. Tagging groundwater quality in resource assessment process.
9. Restoring equilibrium and wholesomeness to stressed aquifers.
10. Alarming trends of groundwater contamination and lack of integration in quality assessment.
11. Lack of comprehensiveness in existing regulatory regimes.
12. Guidelines for implementation and enforcement of rain water harvesting and groundwater recharge techniques are not followed.
13. Water efficient practices, water saving devices, change in cropping pattern, adoption of low water consuming species in agriculture sector are not getting momentum.
14. Watershed geomorphology-based mapping and management in Bundelkhand not yet imagined and initiated.
15. Conjunctive water use management method not practised in the field.
16. Inadequate participation of stakeholders and communities in field level management/conservation practices, water budgeting and awareness campaigns.
17. Integrated water resource management concept yet to be evolved & implemented.

In view of widely spread groundwater crisis in Uttar Pradesh, an overall concrete management & regulatory regime along with a robust mechanism for efficient implementation and enforcement of policies is most needed to get back the heavily depleted aquifers. Though, the new U.P. Ground Water Act- 2019 is being looked as a way forward, but the major chunk of groundwater exploitation in larger user sectors, especially agriculture and urban consumers would remain unregulated. Further, the implementation/enforcement infrastructure is needed for this Act, that urgently demands technical scale up through extensive technical arrangements and large-scale expertise.

However, with a recent Notification dated 24-9-2020 issued by Ministry of Jal Shakti, Government of India, notifying the Guidelines to regulate and control of ground water extraction in the country, there arises a state of conflict for Uttar Pradesh, as two regulatory

regimes with certain contradictory provisions have put the users into state of dilemma. As per CGWA guidelines, it has a pan India applicability and the guidelines also states that where there is inconsistency in guidelines of the State having their own regulatory mechanism, the guidelines of CGWA will prevail. **In this background, the urgent need is to review existing legal instruments with contradictory provisions and come out with a National legal framework for a central groundwater law in the entire country.**

How to make Groundwater Visible - Need for an Overall Reform:

These are some critical situations that groundwater domain of the state is currently facing. Groundwater is a quasi-invisible resource and perhaps this is the major hurdle in its management. Hence, it becomes most important how groundwater and the issues can be made more visible. Since, groundwater data management requires adequate and thoughtful policy interventions in the state, foremost need is to develop scientific knowledge and understanding on groundwater with change in perception, diagnose the problems with their prognosis, share this knowledge with stakeholders and identify amongst them who should be included in knowledge development and preparation of process management for framing resource protection policy.

In fact, **any single ground water management strategy cannot be adopted** for the entire state due to varying factors that include varied hydrogeological conditions and the aquifer systems, non-uniform pattern of extraction and usage, issues of rising water levels and water logging in canal commands, widespread groundwater contamination, prevailing groundwater crisis in rocky terrain of Bundelkhand and Vindhya and reduced flows of ground water fed rivers.

Besides the extensive groundwater exploitation for agriculture uses, **urbanization in the state is also becoming more crucial and challenging as it modifies underlying groundwater systems** that often leads to adverse hydrogeology, quality, ecology and socio-economic effects, jeopardizing resource sustainability. For many heavily depleted urban aquifers, to get back their sustainability has now emerged as a critical issue.

Urban population are expanding rapidly, and therefore, urban water supply issues are important and becoming increasingly important. **The need is to provide serious insight into urban groundwater issues due to anthropogenic changes in urban groundwater condition.** Therefore, sustainable development and management of urban groundwater system is urgently required.

Existing Groundwater Policy and Implementation:

With proactive role of state government, number of policy initiatives and flagship programmes have been started in the state to protect and save groundwater, but these efforts could not be efficiently translated on the ground due to inadequate implementation. Though, Uttar Pradesh is the first state to have an independent Ground Water Policy-2013, but due to the huge gap between the policy framing and the policy execution at the level of responsible departments, this policy instrument, so far, could not deliver the desired outcome. However, this is the right time to review what has gone wrong with the design and execution of conservation schemes. Regarding over abstraction, the major flaw is that we continue to extract groundwater indiscriminately and on the same time large scale efforts and investment are made to recharge the aquifers without finding its effective impact. The reason being that we do not have hydrogeology based extractive and restorative policies.

For urban areas, **roof top rain water harvesting has already been mandated** in government and private buildings way back in 2001 and necessary provisions have also been made in building by-laws by the U.P. Housing department. Similarly, other provisions such as combined recharge system, keeping open areas in new housing colonies, restoration of ponds and construction of new water bodies have also been mandated. The scientific guidelines are already in place, but are not being followed. However, effective implementation and enforcement of these provisions need review.

The fact remains that depletion of aquifers by intensive agriculture or urbanisation and other processes cannot be checked in the state, unless a meaningful and focused policy is made and implemented rigorously. **With grim scenario of groundwater in Uttar Pradesh, this is the high time to realise that groundwater is not a resource that could be exploited and utilized indiscriminately, and furthermore, groundwater based domestic water supplies cannot always be treated as potable & safe due to widespread contamination.**

It is important that Uttar Pradesh is characterised by a diversified hydrogeological set up mostly dominated by alluvial aquifers in Gangetic plain and discontinuous aquifer system of Bundelkhand & Vindhya and the hydrogeological, lithological and geomorphic characteristics are variable and complex, which are governed by varied geological formations and the tectonic history of the area. **Hence, this geotectonic aspect, pertaining to Ganga basin and influencing likely changes in hydrogeological/groundwater domain, needs to**

be carefully studied for determining future probabilities of groundwater explorations from deeper/alternate aquifers.

Suggested Policy Actions and Key Solutions:

In above situation, groundwater management regime in Uttar Pradesh requires a paradigm shift in the current management approaches by framing and implementation of host of interventions for long scientific and technical policy evolution and overall reform of groundwater management process through a robust mechanism. Therefore, **the concept of RRR- Retrospection, Reimagination, Redesigning** has been considered in the present document to strengthen groundwater management process. The major policy interventions and key solutions suggested for implementation in an integrated and composite manner are -

- i. Data consolidation, analysis, and management.
- ii. Reconcile the discrepancies in groundwater resources data along with review of groundwater assessment methodology, tagging quality hazards in resource assessment.
- iii. Single centralised groundwater law with national regulatory framework and constitution of state groundwater authorities.
- iv. Extractive policy and setting of sustainable abstraction limits.
- v. Paradigm shift from groundwater recharge to restoration of aquifers using composite interventions of RRR envisaging different dimensions - Reduce demand/consumption, Reduce extraction, and Recharge groundwater.
- vi. Preparation and implementation of groundwater security plans, as per regulatory provisions under the Act-2019.
- vii. Demarcation of groundwater quality protection zones and integrated quality assessment and mapping.
- viii. Integrated efforts to increase ecological flows.
- ix. Balanced use of surface water and groundwater through conjunctive water use management.
- x. Different solutions for urban areas and Bundelkhand-Vindhyans, having different hydrogeological characteristics and diverse groundwater problems.
- xi. Specific interventions for agriculture sector.
- xii. Separate mechanism for industrial- infrastructural- commercial- bulk users.
- xiii. Groundwater protection charges for resource abstraction.
- xiv. Mechanism for ensuring stakeholders and community participation.

Different aspects of groundwater resources in the state, as discussed above, are summarised in total Nine Chapters, which include 1.Introduction; 2. Hydrogeological set up and Aquifer systems - key features; 3. Groundwater resources in Uttar Pradesh - a critical overview; 4. Groundwater contamination - an overview; 5. Scenario of sub surface waterlogging; 6. Role of New technologies; 7. Policies, Initiatives and Actions; 8. Groundwater management - Issues and Concerns; 9. Robust mechanism for Groundwater management - a situational need for overall reform.

All the issues and aspects of groundwater and the prevalent crisis, with sustainable solutions, are analysed, discussed & extensively covered and systematically documented, which could be of great use for resource planning, management and policy making. The document proposes a set of more practical, effective, and implementable management actions and interventions with the targeted goal to achieve long term sustainability of groundwater resources in the State of Uttar Pradesh. It is suggested that various interventions and solutions should be integrated for implementation in a composite way, with special focus for adopting authentic groundwater assessment process, centralised groundwater law, framing and implementing groundwater extractive and restorative policy, translating RRR concept for restoration of aquifers, implementing practically feasible water efficient methods in agriculture sector with farmers acceptability, extensively mapping groundwater quality for aquifers of variable depths, solving Bundelkhand crisis through watershed geomorphology and involving community and stakeholders participation from planning to implementation phase. Groundwater uses in horticulture, fish ponds and mining areas, which are yet to be officially estimated, need to be identified, assessed and suitably regulated in the state.

CHAPTER-1

INTRODUCTION

Experts believe that India is fast moving towards a crisis of groundwater overdraw, overuse and contamination resulting in its extensive depletion, deteriorating quality and consequent stress on competing water uses. Groundwater overdraft or overexploitation is defined as a situation when, over a period, average extraction rate from aquifers is greater than the average recharge rate. This situation of over extraction is reflected by declining groundwater levels and subsequent failures of tube wells. In India, the availability of surface water is greater than groundwater, but owing to the decentralized availability and easy accessibility, groundwater holds the largest share in India's agriculture and drinking water supplies. The emerging concern is that with increased utilization, the loss of groundwater from the hydrologic system due to Consumptive use and Virtual water trade is neither monitored nor assessed.

Uttar Pradesh, covering a part of Ganga basin, is known as a most fertile and productive state because of its rich water resources. The major part of the state is covered with thick alluvial deposits, which hold huge repository of groundwater. Over the years, the importance of groundwater has gradually increased and it has become the most preferred source of water supply in almost all the user sectors, mainly including agriculture, drinking water, industries and infrastructure.

With increase in groundwater-based irrigation facilities, crop productivity and food production have also increased in multiple proportion in the state. After independence, net irrigated area has increased from 3.2 mha to 14.4 mha. Now, it has attained a vital position in the overall economic development of the state. At the same time, it has been indiscriminately exploited, but being an invisible resource, it is perhaps the most neglected, unregulated, undervalued and under assessed resource in the state. The agriculture sector remains the major consumer of groundwater in the state and those alone accounts to almost 90% of total groundwater extraction, which is reported as about 46 bcm, about one-fifth of country's total extraction. This is reasoning that Uttar Pradesh has emerged as the biggest exploiter amongst all the states of the country, but to prevent and control its exploitation and excessive consumption, an overall management framework is yet to be evolved.

It is important that the state is having huge network of canals with adequate irrigation potential, but the share of these canals in providing irrigation is relatively quite less. This is one reason that the dependence on groundwater, as a reliable source of water, has extensively increased and this over-dependency has opened the path for its indiscriminate extraction in various part of the state without understanding the replenishing capacities of the alluvial aquifers at large and other environmental factors such as changing behaviour and natural dynamics of groundwater dependant ecosystem.

Groundwater abstraction is rapidly increasing and more areas are getting highly stressed. Overall, the state of groundwater in Uttar Pradesh is extremely critical due to over-exploitation, contamination and other related factors as well as the poor policy implementation and therefore, the situation needs to be critically analysed and reviewed why the various management efforts and initiatives could not succeed on ground. The groundwater resource assessment is the key for the resource planning and management, but the allocations made in the resource assessment for natural discharges as 4.6 bcm and for domestic uses as 5.96 bcm for the entire state need clarification as their field extensions are yet to be evolved for computing and validating base flows/ natural discharges to particular rivers/streams, especially groundwater fed rivers and also to evaluate augmentation of drinking water supplies from the allocated groundwater component.

However, on the other side, despite reduced availability, groundwater would, more likely, remain the main preference as a source water for providing huge supplies under the piped water supply scheme of the State Government's ambitious project "Jal Jeevan Mission" launched by the Government of India.

Formidable Challenge: The major concern and the formidable challenge would be to achieve the sustainability of groundwater in the state, as its management becomes an extreme complex proposition, especially in context of heavily depleted alluvial aquifers and rising cases of pollution from different parts of the state. The diverse hydrogeology, non-uniform extraction of groundwater, uneven pattern of its usage and the quality deteriorations **makes it rather impossible to have a single management mechanism for the entire state.** Primarily, any strategy for scientific management of groundwater should involve combination of area specific and implementable measures depending upon the regional hydrogeological settings.

At this point, **importance of different data sets required for overall management of groundwater should have to be looked upon. The correctness of the data forms the**

baseline for the success of all the plans, projects and in case of groundwater, if the data is efficiently and correctly gathered, analysed and understood, area specific problems could be suitably identified, diagnosed and most appropriate measures with robust Decision Support System, guided by strong policy initiatives, executive decisions and regulatory provisions, could be efficiently implemented for reaching at least somewhere close to the ultimate goal of getting back the depleted aquifers of Ganga basin, otherwise achieving groundwater sustainability would remain a distant dream.

Furthermore, for Uttar Pradesh, other **important thrust areas would be** to bring Bundelkhand-Vindhyan out of water crisis, to identify, assess and map groundwater pollution and related health risks for mitigation and ensuring potable supplies and also to resolve the much-neglected issue of sub-surface water logging in canal commands and growing urban water crisis through conjunctive water use management.

1.1 Context

In recent decades, since increasing dependency on groundwater resource has led to its indiscriminate exploitation, billions of litres of groundwater have been pumped out much more than what is being annually replenished from rainfall and other sources.

As groundwater levels have been continuously depleting at much faster rate, serious groundwater crisis prevails due to excessive overdraft in various states of the country, including Uttar Pradesh, where huge groundwater depletion due to over-exploitation has now become the most critical issue for the state's overall water sector in both the urban and rural areas. On the other side, groundwater contamination has also emerged as a most vulnerable issue for water security.

In Uttar Pradesh, due to uncontrolled and unregulated extraction, groundwater levels are rapidly declining in about 70% blocks and majority of urban centres. The growing demand and the mind set of people to extract groundwater as much possible have worsened groundwater conditions, and further, various initiatives to protect and conserve the resource could not yield the desired results.

This is irony that groundwater crisis remains a reality and instead of showing any improvement, it has further deteriorated even after passing of about 23 years, when in compliance of the judgment of the Hon'ble Supreme Court, the Central Ground Water Authority, constituted in 1997 by the Government of India under the Environment Protection Act, 1986 in order to protect, manage and regulate groundwater in the entire country, could

not achieve the targeted goal of controlling groundwater abstraction. In this regard, Hon'ble National Green Tribunal's observation in a petition is quite pertinent and significant, which has mentioned that the situation of falling groundwater level, instead of showing any improvement during these years, has worsen further. **This observation is an eye opening for all those initiatives and efforts taken up in the past, that could not succeed** in managing and preventing continuous falling of groundwater levels in the country. This primarily demands the need to find out the reason of failures of these past initiatives & actions as a learning for future reforms in groundwater management.

During the last two decades, number of policies to manage groundwater were framed both at the state and national level and also various new technological approaches and practices were adopted, similarly number of programmes and schemes were also initiated for resource management and conservation, but we have lacked to comply the scientific guideline and the prescribed designs for the implementation, and therefore, the expected outcome could not be achieved.

It would be more relevant that all the existing groundwater management policies and ongoing plans and programmes **are reassessed and reviewed. This is the right time to look back into the shortcomings, gaps and failures as well as the achievements, if any, should be identified as a positive way for moving forward to come out with an integrated and efficient management framework embracing focused and implementable interventions.**

At this point, the concern of National Green Tribunal regarding indiscriminate extraction and falling groundwater level is very much detailed in its recent order by which the Government of India has been asked to take step for preventing ground water depletion and illegal extraction through a robust mechanism.

This situation calls for preparing dedicated plans and schemes to scientifically manage this depleting resource. Over-exploited and critical areas are more like hotspots and therefore, demand a combination of strong policy actions to effectively control extraction and make changes in groundwater usage pattern and promoting surface water measures as well as large-scale demand side applications through water efficient devices.

Simultaneously, groundwater research and studies should also be the integral part of such management actions to have updated knowledge along with new technological applications and impact assessment of various ongoing activities in order to take-up effective steps towards timely improvements in groundwater conditions

1.2 Changing Scenario and Challenges

Alluvial aquifers, occupying the larger part of Uttar Pradesh, have vast groundwater potential and therefore, are considered as a valuable source of fresh water. But at the same time, these alluvial aquifers, comprising the "largest groundwater reservoir," are at the higher risk of irreversible over-exploitation due to excessive withdrawal and declining recharge rates.

- i. The critical state of groundwater depletion is distinctly visible in various parts of the state and the situation is very well evident in 74 over exploited blocks, which are suffering from continuous heavy withdrawal and marked depletion since the year 2004, as revealed by groundwater assessment data analysis.
- ii. Studies suggest that over the last three decades, groundwater scenario in the state has completely changed and it is continuously changing, because of widespread exploitation, uncontrolled utilization, improper management and human influenced anthropogenic actions causing aquifer deteriorations, quality hazards and rainfall depletion. **The change is clearly noticeable that the geo-scientifically known characteristics of alluvial formations of Uttar Pradesh have changed over the time, especially aquifer storages and the yield of the wells have drastically reduced.**
- iii. Overall, groundwater situation in Uttar Pradesh is extremely critical and diversified problems related to the resource domain have been identified in different parts of the state. The problems can be very well visualised by: -
 - a) the obvious impact of unregulated and indiscriminate extraction on declining groundwater levels in both urban and rural segments,
 - b) improper water use practices in canal commands causing sub-surface water logging and salt encrustation, which have rendered large areas unproductive for the crops,
 - c) reported high occurrence of various chemical contaminants and heavy metals making groundwater highly polluted at different places.
- iv. Looking at the regional scenarios of the state, all the four administrative regions have altogether different groundwater issues with varying situations -
 - a. Western U.P. is mainly impacted with highly depleted aquifers and lowering of water levels along with occurrence of high salinity and mostly anthropogenic pollutants.

- b. In Eastern U.P., waterlogging has affected the agricultural productivity, while arsenic toxicity in groundwater, with related health issues, is also dominating different areas
 - c. Lack of understanding of watershed geomorphology and high rainfall runoff in Bundelkhand-Vindhyan region has led to severe groundwater crisis.
- v. **Increasing Demand:** Although, these are very important issues, which demand immediate actions at policy/administrative level, but, on the other side, there are more challenges to cater the increasing water needs for sustainable supplies. In view of growing population, there is an increasing demand for more crop production, for that, it is required to bring more agricultural area under irrigation. Besides, the demand of water for industrial and drinking purpose is also increasing in multiple proportion.
- vi. **Reducing Water Availability:** The decadal rate of growth of population of the state is about 25 percent. With this trend of population growth, there is a likely competition in demand of water in various user sectors, particularly in drinking/domestic use and industrial sector as well as the urban development. In this situation, water availability for irrigated agriculture is likely to get reduced. Tube wells are the major source of irrigation followed by canals, ponds and lakes and the dependency upon groundwater is also larger than the surface water. This situation, therefore, needs to be addressed on priority.
- vii. An integrated approach is, therefore, required for planning, development and management of both the surface water and groundwater, the two major sources for irrigation, which would certainly improve the performance efficiency of the system in a sustainable manner. The declining pattern of rainfall should also be taken into consideration, while evaluating the future availability and demand of overall water resources.
- viii. **Future Scenario More Alarming:** It is estimated that for the domestic, industrial and irrigation needs of growing population in the state, the stage of groundwater exploitation is expected to rise from the present stage of 45.84 bcm (as per 2017 assessment) to more or less 70.00 bcm by 2028. And, if the current level of rainfall reduces further, the annual groundwater recharge would also get reduced by that time. As a result, the projected stage of groundwater extraction would surpass the recharge component, meaning thereby that **the dynamic groundwater availability would become negative**. The annual replenishable recharge in 2017 is estimated as 69.92 bcm, while extractable resource is 65.32 bcm. **Since rainfall is continuously**

declining, the recharge component is not expected to increase further. Hence, the projected extraction of about 70 bcm may cross the projected figure of groundwater recharge around the year 2028. With this probable situation, if arises, **the whole state may likely reach to a stage of overdraft.** This scenario should, therefore, be taken as a warning signal for the water planners and managers. The impacts of climate change may also aggravate this critical situation and would act as an additional stressor.

1.3 Purpose

The purpose of bringing out this document is to show casing the "State of Groundwater in Uttar Pradesh" with a critical analysis of prevailing situation of groundwater and related management concerns, at a time when the resource has become the dominant player of overall economic development of the state. The document is aimed to cover comprehensively the present status of groundwater resources in the state that would critically discuss and highlight all the possible aspects and related issues and suggesting actionable solutions for achieving goal of sustainable management -

- Changes occurring in resource availability and usage pattern due to unsustainable rising demand.
- Rise in unabated groundwater extraction.
- The growing issue of decline in rainfall impacting groundwater recharge process.
- Review of groundwater assessment methodology, data discrepancies, norms validation.
- Threats of groundwater pollution and other environmental issues like waterlogging and reduced base flows to the river ecosystem.
- The urban groundwater issues.
- Water scarcity in Bundelkhand- Vindhyaans.
- Existing national and state policies & their implementation status, initiatives and actions taken, new groundwater legislation for the state.
- Critical overview and situation analysis of management plans and practices.

Overall, different groundwater dimensions and scenarios, gaps in resource assessment are analysed and evaluated to have a correct assessment of present situation. As a solution to overcome the groundwater crisis in the state, a comprehensive management mechanism, covering most appropriate and practical measures for all the aspects and issues of

groundwater, including data management, validation of resource assessment norms, agriculture, urban and industrial water use pattern & management, pollution control measures, is suggested for the overall protection of groundwater resources with a critical overview of all the related problems and also highlighting probable potential reforms.

The present document also describes and analyses the current situation, and diversity of groundwater problems prevailing in the state and possible management approaches and pathways to achieve sustainability of groundwater resources for meeting future demands through an honest implementation of a robust mechanism, based on critical analysis of various policies, plans and practices by converting them into most efficient strategies and sustainable solutions.

1.4 General Basics & Facts about Groundwater

Invisible Resource... how to make it Visible:

A polymath & a great artist Leonardo Da Vinci has rightly visualized that *“the greatest river of earth flows underground”*, which signifies his imaginativeness about the magnitude of the invisible groundwater resource some 600 years before. This resource is a distinguished and vital component of the Water Cycle. **Since it is not visible, the biggest challenge is how to make it visible, therefore, scientific approach is needed for its comprehensive understanding.**

The major challenge for framing a strong management mechanism is the proper understanding of the dynamics of groundwater flow under different hydrogeological conditions. There are certain important characteristics of groundwater, which requires proper understanding for carrying out the management processes. Following key features of groundwater are discussed from management perspective.

- i. In contrast to rivers and lakes, groundwater systems are hidden from direct observation and measurement.
- ii. This is an invisible resource, in that we cannot visually observe its movement, storage, extent and dimensions.
- iii. Information on groundwater is obtained by water level measurements on the wells and by indirect methods like surface geophysics, remote sensing, geological and geomorphological mapping, drilling/ exploration, parameter tests, yield tests etc.
- iv. These data are used to infer the occurrence and movement of groundwater to develop a conceptual model of the groundwater system. This model can never be exact and is

subject to uncertainty and error because of indirect nature of the measurement methods and the complexities of the subsurface system and the geomorphological & geological controls on groundwater regime.

- v. Groundwater systems store and transmit water, but this characteristic is variable under different hydrogeological settings.
- vi. Understanding the movement of water through the groundwater system and understanding the lateral and vertical limits of aquifers are the key aspects for the groundwater availability assessment. Also, characteristics of aquifer systems are not the same at all places.

1.4.1 Understanding Dynamics of Groundwater Levels

Two main processes of groundwater systems are important for understanding the dynamics-

- i. The time that takes water levels to respond changes in stress (like pumping) on the groundwater system.
- ii. The time it takes the water to travel through the groundwater system.

The time frame of changes in water levels depends on how quickly the change in water levels propagates through the system after water is removed from the storage. The time of travel of water flowing through the system depends on the velocity of the water and the distance between the recharge and discharges boundaries. These two-time scenarios are very different for most groundwater systems.

The volume of groundwater in storage decreases in response to withdrawals and this reflected as water level declines. **And if water level declines are sustained over time, the effect is described as groundwater depletion.** The consequences of groundwater level decline are increased pumping costs, deterioration of water quality, reduction of flows to rivers and lakes and further prolonged and progressive decrease in the resource availability leads to groundwater mining, that may cause land subsidence.

Groundwater moves slowly:

The most distinctive characteristic of many groundwater systems is their vast storages. In consequence, groundwater moves continuously but slowly from areas of natural aquifer recharge to areas of aquifer discharge (springs, seepages to water courses, wetlands). Major aquifers under semi-arid climatic regimes are characterised by varying groundwater residence times from decades to centuries and even sometimes in millennia, with large volumes of so-

called fossil water still being held in storage. Studies reveal that groundwater in deeper aquifers of Uttar Pradesh are reported to be as old as 25000 to 50000 years and even more.

1.4.2 Water levels respond slowly to Recharge

Groundwater possesses some unique features--

It travels slowly with velocity of horizontal flow may be 30-60m/year in alluvial formations, while vertical recharge/percolation rate is relatively faster depending upon the soil type.

Studies have suggested that **groundwater levels respond slowly** to the changes in the weather and can take months or years once the aquifer is pumped for irrigation or other uses. The question arises why groundwater levels respond slowly to the changes in weather? The logic given is the layer of unsaturated soil that acts as a buffer between the atmosphere and the aquifer.

When it rains, the surface soil becomes wetter and surface water bodies increase in volume, **but it takes time to percolate to the aquifers. If the amount of rain is small, it may not replenish the aquifer.**

Scientifically, it is believed that **it can take long time, even months or years for the aquifers to recover, depending upon various parameters, how much the aquifer has depleted, what is the rate of groundwater flow.** It appears relevant for Ganga basin, where the artificial recharge process may likely be governed by these factors.

1.4.3 Specific Yield: Important parameter for resource assessment

Specific yield of aquifer is an important parameter used in groundwater resource assessment. For the accuracy of resource assessment, the factor of specific yield should be determined through field studies/long duration parameter test.

Since sufficient data on specific yield is not available, the Central Ground Water Board (CGWB) has assumed and assigned 'specific yield values' for all the Major Aquifer Units, including alluvial and hard rock aquifers, which are recommended in the GEC-2015, Methodology for groundwater resource assessment.

In hydrogeological terms, the specific yield normally denotes the volume of water that a groundwater system (aquifer) releases and it represents the water yielding capacity of the saturated sediment. It is defined as "the ratio of the volume of water that a saturated soil or

rock will yield by gravity to the total volume of soil or rock." Specific yield is usually expressed as a percentage and it is also known as effective porosity.

Specific Yield Influences Rainfall Recharge: In groundwater resource assessment, the Specific yield is the dominant parameter for computing rainfall recharge. If higher values of specific yield are taken without validation, instead of taking recommended/assigned values for aquifer formation, the figure of rainfall recharge, thus, estimated would be excessively on higher side and might impact the correctness of resource availability as well as the categorisation of assessment unit.

1.4.4 Overdraft / Groundwater Mining

The term "groundwater mining" typically refers to a prolonged and progressive decrease in the amount of water stored in a groundwater system, as may occur, for example, in heavily pumped aquifers in semiarid regions like that of Uttar Pradesh. Groundwater mining is a hydrologic term without connotations about water management practices. The term "overdraft" refers to withdrawals of groundwater from an aquifer at rates considered to be excessive, and therefore, carries the seriousness of over-development. Thus, **overdraft may refer to groundwater mining** that may have undesirable effects of groundwater withdrawals.

Stage of Extraction: The stage of groundwater extraction is computed as ratio of groundwater extraction to total extractable groundwater resource. Following formula is applied to derive the stage of extraction-

$$\text{Stage of Extraction (\%)} = \text{Ground Water Extraction} / \text{Extractable Resource} \times 100$$

Appropriate Definition of Overexploitation: When can an aquifer be said to be "overexploited"? The most appropriate definition will be economic one that "the overall cost of the negative impacts of groundwater exploitation exceed the net benefits of groundwater use." However, these impacts can be equally difficult to predict & assess and to determine the cost.

1.4.5 Scientific Aspects of Artificial Recharge

Natural recharge to ground water occurs as precipitation/rainfall falls on the land surface, infiltrates into soils and moves through pore spaces down the water table. Natural recharge can also occur as seepages from rivers, streams, lakes, ponds, wetlands.

In stressed areas, **groundwater can be artificially recharged from surplus rainwater by redirecting water storages on the land surface through infiltration basins, ponds, canals and through pits, trenches, shafts, abandoned wells, injection/recharge wells.** Surface water run-off in many river basins is controlled due to aquifer recharge through artificial measures, especially injection well method, but ensuring that the pollution risk to aquifers do not occur.

To ensure the effective and efficient operation of an artificial recharge system, a thorough and detailed hydrogeological study must be conducted before selecting the site and recharge method. The factors such as location of geologic boundary, depth of aquifer and lithology, storage capacity, porosity, permeability, availability of land, quality and quantity of rainwater to be recharged, economic and legal aspects concerning the recharge, public acceptance should be taken into consideration.

If suspended solids are present in source water, surface spreading applications and storage techniques will be more effective and safer than the recharge well methods that may result in clogging of such well and possible risk of contamination.

Disadvantages of Injection well:

There are certain disadvantages if water from open catchments/fields is directly recharged into aquifers through injection well or recharge wells. **There is a greater risk of groundwater contamination from injected surface water run-off, especially from agricultural fields, open areas and road surfaces.**

There is also probability of discharge of micro pollutants that may negatively affect the receiving soil and the aquifer. The concern is that the pollutants if reaches to aquifers, they may have long residence impacts. There is all risk that recharge can degrade the aquifer unless quality control of injected water is highly adequate and protective.

Therefore, careful analysis of various quality factors should precede any recharge projects. **The recharge water must be chemically compatible with the naturally occurring ground water** and the aquifer material that it flows through and **should also comply the drinking water quality standards.**

Recharge/ injection wells methods are always prone to clogging because of suspended solids or chemical impurities. However, use of injection well should only be considered on experimental basis.

Impact:

Studies in southern states dominated by peninsular hard rock terrain have evaluated the impact of aquifer recharge structures from a hydrological and hydrogeological perspective, raising issues of water quality, storage, clogging maintenance. Various studies indicated that run-off harvesting in scarce regions does not offer any potential for groundwater recharge. It is also observed that this does not provide any sustainable solution and may not always solve the depletion problems. Studies also indicate concerns from economic and social perspectives.

Hence, impact assessment should essentially be the integral part of all the artificial recharge schemes in different hydrogeological settings, especially in alluvial aquifers.

1.4.6 Consumptive Water Use / Virtual Water Trade

Consumptive water use is part of that water, which is removed from available supplies without return to a water resource system / water cycle. It broadly means the part of water that cannot be recovered because it is lost to various activities, such as agriculture, manufacturing, construction, food preparation. Crop consumptive water use is the total seasonal loss from an area of land due to transpiration during plant growth and evaporation from soil surface and foliage in the crop area. This is important to find out how much of groundwater withdrawal is lost to Consumptive Use and as Virtual Water and also how much water ends up as return flow. The magnitude of consumptive use of groundwater withdrawals is substantial, but difficult to quantify. Therefore, in all user sectors, consumptive use of the withdrawals and virtual water needs to be monitored, assessed and quantified.

1.4.7 Some Basic Principles

- i. Groundwater is the water that seeps through rocks and soil and is stored below the ground. The rocks in which groundwater is stored are called aquifers. "Aquifers" are typically made up of gravel, sand, sandstone, or limestone. Water moves through these rocks/sediments because they have large, connected spaces that make them permeable. The area where water fills the aquifer is called the saturated zone. The depth from the surface at which groundwater is found is called the water table.
- ii. Permeability refers to the ability of a rock to transmit water.
- iii. Heavy rains can cause the water table to rise and conversely, continuous extraction of groundwater can cause the level to fall.

- iv. In hard rock terrains, rocks give rise to a complex and extensive low-storage aquifer system, where in the water level tends to drop very rapidly once the water table falls appreciably. These aquifers have poor permeability, which limits their recharge through rainfall. This implies that water in these aquifers is non-replenishable and will eventually dry out due to continuous usage.
- v. Aquifers of Gangetic Plains have significant storage spaces, and hence, are a valuable source of fresh water supply. However, due to excessive groundwater extraction and low recharge rates, these aquifers are at the risk of irreversible damage.
- vi. Natural discharge occurs as seepage to water bodies, streams and as transpiration by plants whose roots extend up to the water table.
- vii. Geogenic contaminants occur as a result of geological processes that happen within the crust of the earth.

1.5 Water Crisis: A National Concern

The looming danger of increasing water crisis has become an area of National Concern.

World Bank, in its report, (*India's Water Economy: Bracing for a Turbulent Future, 2005*) has warned that India's water future is very grim, as the country faces a turbulent future of its water resources. Some of the key observations are -

- i. Report predicted a serious crisis in the country in coming years "due to inadequate water supplies and poor management of Groundwater Resource".
- ii. Report states "Unless Water Management practices are changed and changed soon.... India will face a severe water crisis within the next two decades and will have neither the cash to build new infrastructure nor the adequate water required for its growing economy and rising population."
- iii. Bank has also sounded an alert about further projections of climate change, likely to worsen India's water problems. If such climate changes occur, more rain is expected to fall only in fewer days and monsoon may likely become erratic.
- iv. As such, rainfall deficits may cause droughts when continuous over-pumping of ground water takes place causing water tables to fall further and the consequent critical depletion of aquifers.
- v. NASA and recently NGRI have reported major groundwater crisis in North India. Report states that huge groundwater resource has vanished from the aquifers of northern states during last few years.

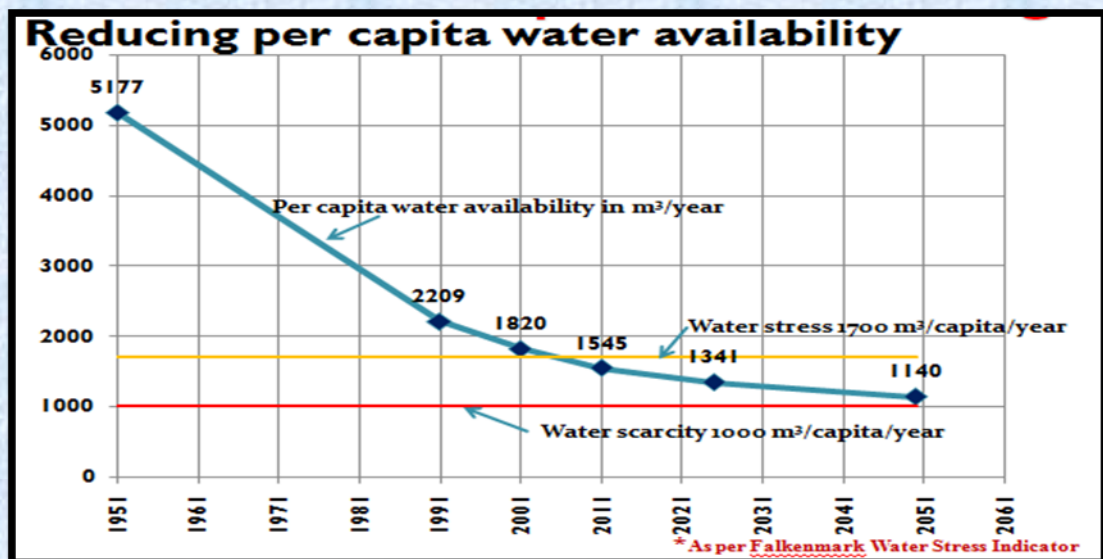
After almost 15 years, World Bank's concern about impending water crisis in India is proving a reality. Groundwater situation is continuously deteriorating and widespread groundwater depletion has been noticed across Uttar Pradesh as well as in others states also.

1.6 Per Capita Water Availability: New Perspective

- ❖ Total precipitation: 4000 bcm
- ❖ Annual water availability: 1869 bcm
- ❖ Utilizable water: 1122 bcm (about 60%)
 - Surface water: 690 bcm
 - Groundwater: 432 bcm
 - GW Utilization: 249 bcm

The per capita water availability has been assessed since 1951, which is computed based on total water availability in the country, using "Falkenmark Water Stress Indicator". The per capita availability has reduced over the years due to growing population and this is represented in the following graph (Figure-1).

Figure-1: Per Capita Water Availability



(Source : R.C. Jain, 2018)

Observations are -

- i. The graph shows per capita water availability at the National level for different time intervals since 1951. It is evident that the per capita availability has reduced significantly during the last 60 years and now we have already crossed the threshold limit laid down for the Water Stress, which is kept as 1700 m³ /capita /year. Since

overall demand is increasing in multiple proportion, this declining per capita availability is becoming a serious concern.

- ii. The data clearly reveal that we are already 'water stressed' since 2004 and now the water crisis across the country has emerged as a major challenge for meeting the ever-growing demand of agriculture, domestic, industrial and infrastructural sectors.
- iii. In the year 2019, the per capita water availability has already touched a mark of 1364 m³ /year, moving towards a much greater critical phase. The threshold limit for water scarcity is kept as 1000 m³ /capita/year, indicating that we are moving fast toward this most alarming situation.
- iv. Since the present per capita water availability scenario has been derived on the basis of country's Total Annual Water Availability, which is reported as 1869 bcm. **But, for all practical purposes, the Utilizable Water assumed as 60% of the total available water, which is 1122 bcm, is primarily considered in the planning process** for all the sectoral water demands and supplies in the entire country.
- v. **New Perspective - More challenging:** It would be more realistic if we determine the per capita availability and the relative water stress on the basis of the Utilizable Water component using the Falkenmark Water Stress Indicator, the scenario would emerge as more challenging. The projected scenario using Utilizable Water component is developed as given in the Table-1. The projected figures for different time periods are found more critical, when compared with the existing per capita water availability scenario, being currently utilized for the planning purposes.

Table - 1: Per Capita Water Availability: Projected Scenario

Year	Per Capita Water Availability Scenario (m ³ /capita/year)	
	Based on Annual Water Availability (as reported)	Probable Projection based on Utilizable Water
1951	5177	3107
1971	3785	2044
1981	2960	1640
1991	2209	1263
2001	1820	1047
2011	1545	900
2018	1380	829
2021	1341 (projected)	808 (likely projection)
2051	1140 (projected)	656 (likely projection)

(Source: Sinha, R.S., 2019)

Water Scarcity -1000 m³/capita/year; **Water Stress**- 1700 m³/capita/year

Concern:

If per capita water availability is projected on the basis of utilizable water, as shown in the above table, its scenario would entirely change with more alarming situation. Presently, the threshold for Water Scarcity is kept as 1000 m³/capita/year, which is expected to occur somewhere around the year 2050.

But, with the projected scenario, using utilisable water, this stage of water scarcity would have been occurred way back in the year 2001. This appears to be an extremely grave situation and **the expected per capita water availability in the current year 2020 might be somewhere 815 m³/capita/year.**

Since the utilizable water is practically considered for the planning purposes at the field level, the above projected scenario, therefore, requires immediate attention and review at the level of Government of India and Niti Aayog.

In various states all across the country, water crisis is already visible, where people are facing high to extreme water stress. Hence, this new scenario of per capita water availability, derived by using a different set of data of Utilizable Water, **needs to be addressed on priority for future perspectives.**

1.7 Overview of Rainfall - Changing Pattern

Rain is a major component of the water cycle and it is responsible for providing most of the fresh water on the Earth. It replenishes aquifers/groundwater resources and contributes flows and storage in stream, rivers, lakes and ponds. For various crops including paddy, rain water is the dominant source of irrigation. Therefore, the rains are extremely important for the survival of mankind as well as for our ecosystem on the Earth.

As per the IMD (Indian Meteorological Department) data, the average annual normal rainfall in India is 1190 mm, but during the last 20-25 years, the country is receiving low rains than the long-term average. During 2001-2018, India received deficit monsoon in 13 of last 18 years below the normal rains, though the year 2013 was surplus year. Further with climate change, monsoon has become erratic and the monsoon days & duration have reduced with extreme rainfall events and deficit rains, flash floods.

Generally, the monsoon accounts for 70% of total replenishment of groundwater resources, but this deficit in rains has impacted the annual recharging of aquifers. Urban areas have

suffered the most due to concrete, which affected the natural percolation, thereby heavily reducing natural process of groundwater recharge.

The annual rainfall and the distribution of rainwater under different soil, topographic & hydrogeological situations have direct impact on the dynamic resource of groundwater regimen in any area. So, the role of rainfall/rain water is most significant while estimating ground water resource availability.

Rainfall pattern of Uttar Pradesh based on the average annual normal rainfall, region wise average rainfall and expected volume of rain water ideally received in different region/zones is given in Table - 2.

Table- 2
Region-wise Average Rainfall and Expected Volume of Rain Water (U.P.)

Region	Area (Lakh ha)	Volume of rain water (lakh ham)	Average rainfall (mm)
Eastern Region (Including Vindhyan)	110.06	100	950
Central Plains	44.68	42.3	930
Western Plains	74.85	82.9	1110
Bundelkhand	11.33	10.2	900
Total	240.92	235.4	947.4

1.7.1 Decadal Changes

In Uttar Pradesh, during the last 3 decades, significant drop in rainfall has been witnessed, especially the monsoon, and this has impacted overall i.e., the surface storages, groundwater recharge, stream flows and soil moisture.

Therefore, it becomes imperative that the rainwater-based management and conservation plans need to be prepared on the basis of actual rainfall being received.

This changing rain pattern with deficit in rainfall is primarily attributed to climate change. Decadal changes in the rainfall trend of the state since 1970 show a gradual negative deviation and as such continuous decrease in quantum of annual rainfall is clearly visible, as briefed in the Table- 3.

Table- 3: Decadal Changes in Average Annual Rainfall in Uttar Pradesh

Decade	1971-1980	1981-1990	1991-2000	2001-2010	2011-2019
Average Annual rainfall (mm)	1280.1 (135%)	923.8 (97.5%)	872.9 (92.10%)	737.4 (77.8%)	732.47 (77.31%)
Normal Annual Rainfall in U.P.: 947.4 mm (Figure in percentage with respect to normal rainfall)					

The above table clearly shows that the rainfall is continuously declining and during last 2 decades negative deviation is more than 20%. The state is receiving deficit rains almost every year and this has impacted the surface storages and ground water recharge.

1.7.2 Distribution Pattern of Rain Water

If we assume that Uttar Pradesh is receiving normal annual rainfall of about 950 mm, ideally the total rainwater available annually in the state would be around 235.4 lakh hectare meter. For the state, distribution of above volume of rainwater in different components of ecosystem is already illustrated in the pie diagram (Figure- 2). This shows that apart from 15.45% of rainwater which replenishes groundwater, there is about 37.5% rain water available as run-off, contributing flows to drains and rivers.

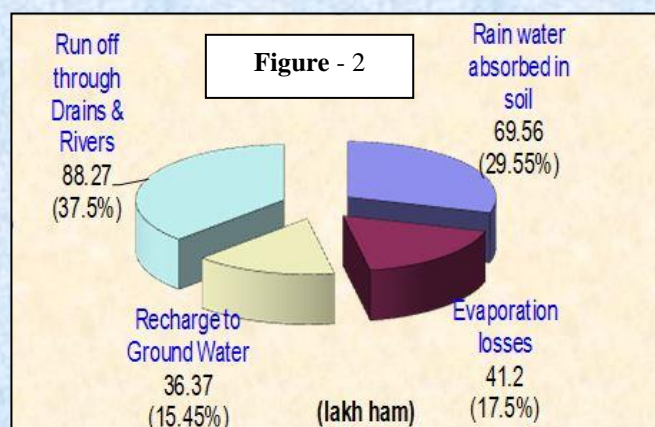


Table-4: Distribution Pattern of Rain water in Uttar Pradesh

Distribution	Rain Water (lakh ham)	Rain Water (%)
Rain water absorbed in soil	69.56	29.55
Loss due to evaporation	41.20	17.50
Recharge to Groundwater	36.37	15.45
Run of through Drains & River	88.27	37.50
Total Estimated Rain Water	235.40	100.00

1.7.3 Key Observations on Deficient Rainfall

- i. This ideal situation of rainfall is not being witnessed since last 03 decades, as the rainfall is continuously declining and the rainwater quantum has also decreased

appreciably. Since 2011, the average annual decrease in rainfall is about 23% with respect to long term normal rain fall (as evident from the above table showing Decadal changes.). Obviously, now only the reduced quantum of rainwater would be available for various management purposes, including the rainwater harvesting programme. Further, erratic monsoon and reduced rainy days and duration are also affecting the conservation programmes.

- ii. With this scenario, the run-off component of rainwater (storm water) is an important area, which needs to be managed carefully. After allowing the desired run-off for protecting Environmental / Ecological Flows (e-flows) for the streams/rivers, **the surplus monsoon run-off should be assessed as per the changing rainfall scenario for each watershed / micro basin covering both urban and rural segments**, which could be suitably managed and conserved through area-specific rainwater harvesting and recharge interventions.
- iii. In most of the urban sprawls, the quantum of available surplus monsoon run-off / storm water would be relatively much more, as natural recharging becomes very low due to concrete urban environment and most of the rain water from roof tops, roads, pavements go waste down the drains, which is required to be tapped through scientifically appropriate harvesting techniques.
- iv. **Rainfall Deficit districts:**

CGWB has assessed district-wise rainfall pattern on basis of 2016 rainfall data, used in the Resource Assessment-2017. The data shows that out of 75 districts, 44 have received deficient rainfall with a minimum of 20% deficit in district Agra and Jalaun (Orai) to a maximum of 66% deficit/negative deviation in district Farrukhabad. A total of 19 districts had a deficit rainfall of 40% or more i.e., departure from normal rainfall. There are also 14 districts, which have received 1% to 19% below the normal rainfall, but they have been categorised as normal rainfall districts. Overall, the state has received 20% deficit rainfall.

However, 6 districts namely Banda, Bareilly, Chitakoot, Mirzapur, Sonbhadra, Varanasi have received excess rainfall.

- v. Since rainfall influences monsoon and non-monsoon recharge, the deficit rainfall and the excess rainfall should have impacted these recharge components in the resource assessment and that might have been reflected in the recharge estimation.

- vi. The rainfall data of IMD shows that the state is not receiving normal rains for most of the years since 2000-01.
- vii. The last four years data also shows that rainfall has been deficient and that would be impacting the overall groundwater availability by influencing rainfall recharge especially in stressed areas. In the year 2017-18, the percentage of rainfall to normal rainfall is recorded lowest as 65.5%.

Table-5: Rainfall in U.P. 2016 to 2020 (State Average)

Year (June - May)	Normal Rainfall (mm)	Actual Rainfall (mm)	Percentage to Normal Rainfall
2016-17	947.5	746.2	78.86
2017-18		620.2	65.5
2018-19		793.2	83.7
2019-20		877.4	92.6

Overall, the pattern of monsoon rainfall in the state is showing a negative deviation as shown in the following table-6.

**Table 6: Monsoon Rainfall in U.P.
June to September**

Year	Normal Monsoon (mm)	Actual Rainfall (mm)	Percentage (%)
2019	823.9	699.1	84.2
2020		640.2	77.7

As per the rainfall data of IMD for monsoon period recorded between June to September for the year 2019 and the year 2020, majority of districts have received deficient, highly deficient and scanty monsoon rainfall.

In the year 2019, there are 21 districts, including Aligarh, Hapur, Etawah, Baghpat, Sambhal, Amroha, Badaun, which have received deficient rainfall between 60-80 %. In the year 2020, such deficient districts are reported as 22, including Kanpur Nagar, Mirzapur, Meerut, Lalitpur, Mainpuri, Aligarh, Moradabad, Etah, Hapur.

Similarly, there were 9 highly deficient districts with rainfall ranging between between 40-60% in the year 2019, while 18 districts are reported highly deficient. In the year 2020, including Shamli, Bhagpat, Mahoba, Agra, Lucknow, Hathras, Sambhal, Amroha.

Importantly, majority of these districts are already groundwater stressed.

There are also several other districts, which have received scanty rainfall below 40% and most of these districts, as shown in the following table-7, are also highly stressed from groundwater point of view. These districts are Rampur, Bulandshahr, Kanpur Dehat, Mathura, Kaushambi, Ghaziabad and G.B.Nagar. Amongst them, G.B.Nagar and Ghaziabad districts are the worst affected, as these districts had received the lowest rainfall in both the years which would have greatly impacted the groundwater recharge and effecting resource availability. This is noteworthy that G.B.Nagar, in the monsoon period of year 2020, has received only 11.2% rainfall of the normal monsoon rainfall, which is an extremely critical situation. Similarly, in Ghaziabad also, extremely low monsoon rainfall has been recorded.

Table - 7: Districts Affected with Scanty Rainfall (Less than 40 %) June to September (in percentage)

S. No.	Year2020	Year2019
1	Rampur (39.6)	Shamli (26.6)
2	Bulandshahr(38.8)	Pilibhit (34.8)
3	Kanpur Dehat (37.5)	Kanpur Dehat (38.4)
4	Mathura (35.2)	--
5	Kaushambi (30.4)	--
6	Ghaziabad (29.1)	Ghaziabad (24.1)
7	G.B. Nagar (11.2)	--

1.8 Climate Change Impact on Groundwater : Adaptation Strategies

Adaptation strategies are proposed to mitigate increasing stresses on groundwater resources due to impending crisis of climate change--

- i. Implementation of IWRM concept (Integrated Water Resource Management) by consolidating, analysing and utilizing available potential of rainwater, surface water and groundwater sources from the lowest unit in the field adopting Bottom-up Approach from gram panchayat in rural areas and the smallest municipal units of urban bodies.
- ii. Understandable and implementable aquifer maps should be prepared at micro scale for public use.
- iii. Restoration of aquifers by reducing groundwater demand, extraction and use through supply side interventions, optimizing water use efficiency and large-scale rainwater harvesting and groundwater recharge measures in an integrated and holistic manner by saturating micro watersheds to obtain desired outcome.
- iv. Effective implementation of conjunctive water use management in irrigation supplies as well as in urban areas to overcome the water stress.
- v. For deficit rainfall areas, micro water management plans should be prepared and implemented.
- vi. Feasibility for promoting Micro irrigation schemes should be assessed for different agro climatic zones and ground water situation.
- vii. Groundwater fed rivers in the state should be mapped with demarcation of their catchments, morphometric analysis of steams, finding the existing river flows, pollution source and load, analyse the reduction in base flows in all the river basins / sub-basin, map the water bodies, consolidate and delineate management issues for specific interventions for rejuvenation and restoration of respective ecosystem in all the river basins.
- viii. Bundelkhand and Vindhyan region requires different set of planning and management, integrating geomorphological and geological mapping of all the watersheds.
- ix. Development of Micro forests in all the villages and Micro Green climates in Urban Areas.

- x. Extensive ground water quality mapping for all parameters including heavy metals, bacteriological contamination should be taken up for the entire state and identify quality affected areas for mitigation.
- xi. Controlled piped water supplies should be planned and implemented for all the industrial clusters.
- xii. Groundwater regulation/governance in stressed/notified areas for all user sectors through implementation of micro level groundwater security plans.

CHAPTER - 2

HYDROGEOLOGY AND AQUIFER SYSTEM

- KEY FEATURES

Water has always been an integral part of the developmental activities of the human society as it is essential for sustaining all forms of life. But this very precious resource, and groundwater in particular, has become a rare commodity in different parts of the country, including many parts of Uttar Pradesh. Out of total water available on earth amounting to 1370 million cubic kilometres, only 8.2 million cubic kilometres is available as fresh water, most of which is groundwater.

2.1 Overview: National Context

The rapid expansion in the development of groundwater resources for various usages has contributed to significant growth of irrigated agriculture with overall economic development and in improving the quality of life in India. Last three decades have seen an exponential growth in number of groundwater structures and more than 20 million wells all over the country are presently providing water to more than 60% of irrigated area. The substantial increase in agricultural output has also been from groundwater irrigation, as it provides higher yield due to sustained and controlled supplies.

This resource has also become an important source of drinking water and food security for millions of people. It provides an extremely high share of water for domestic use in rural areas as well as urban areas along with meeting major industrial demands all across the country. As a most reliable resource for irrigation and drinking water supplies during drought years has further strengthened the people's faith in utilization of groundwater as dependable source.

2.1.1 India : Globally Largest Exploiter

With growing dependency on groundwater in almost all user sectors, India has become the largest ground water exploiter globally, being responsible for 25% of World's total groundwater exploitation. The stage of groundwater extraction is extremely high in the states of Delhi, Haryana, Punjab and Rajasthan, where the abstraction is more than 100%. This implies that in these states, the annual groundwater extraction is more than the annual ground water recharge and all these states are in a critical state of groundwater mining, **whereas, in**

the states of Himachal Pradesh, Tamil Nadu and Uttar Pradesh, the stage of groundwater development is above 70% and thereby crossing the threshold of safe limit for abstraction, that is kept as 70%. In rest of the states, the level of groundwater development is below 70%.

Over the years, usage of groundwater has increased in areas where the resource was readily available for exploitation. This has resulted in an increase in overall groundwater extraction in the country from 58% in 2004 to 63.33% in 2017.

2.1.2 Key Information

❖ India is the largest user of groundwater in the World.

❖ Groundwater Resources in India, as on 31 March,2017:

i.	Total Annual Groundwater Recharge:	431.86 bcm
ii.	Total Natural Discharges:	39.16 bcm
iii.	Annual Extractable Groundwater (i-ii):	392.70 bcm
iv.	Annual Groundwater Extraction :	248.69 bcm

User Sector:

	• Agriculture sector -	221.46 bcm
	• Domestic/Drinking water-	24.87 bcm
	• Industrial sector -	2.38bcm
v.	Annual Allocation for domestic use as on 2025:	31.62 bcm
vi.	Net Groundwater Availability for future use:	173.25 bcm
vii.	Stage of Groundwater Extraction	: 63.33%

❖ In last 40 years, groundwater has contributed more than 80% in increasing the total irrigated area of the country.

❖ It is anticipated that groundwater share in GDP may be around 9%.

In National context, the overall economic development and expansion of irrigated agriculture has led to large scale rise in extraction and use of groundwater resource. Due to significant growth in the number of irrigation wells during last 30 years, groundwater has contributed about two- third of irrigated agriculture in the country.

- The different sectoral water demands need to be analysed in respect to available utilizable water and if the per capita availability data is projected on the basis of utilizable water, as discussed in Chapter- I to get the future water scenario, the picture appears very alarming and grim.
- On the basis of per capita water availability data, projected figures of water demand in year 2025 shall come closer to total water availability, whereas in year 2050 water demand shall exceed the total available utilizable water. This is certainly an eye-opening water scenario for the planners. If utilizable water is worked out for determining per capita availability, the situation would be much more alarming.
- About 89% of total groundwater extracted is used in irrigation sector, making it the biggest groundwater user category in the country.
- Groundwater use in domestic and drinking water sector is 7% of the total extracted groundwater, while industrial use of groundwater is only 4%.
- The main sources of irrigation in the country are canals, tanks and wells, including tube-wells. Of all these sources, groundwater constitutes the largest share.
- At the national level, different wells, including dug wells, shallow tube wells and deep tube wells provide about 60 % of water for irrigation, followed by canals with only 24.5%.
- Overall, 60% of urban water requirements and 85% of rural domestic water requirements are fulfilled by groundwater.

2.1.3 Hydrogeological Set up of India

India is a vast country with varied hydrogeological situations, resulting from diversified geological, climatological and topographic set ups. The rock formations and varied geological settings of Archaean to Recent age primarily control the occurrence and movement of ground water.

Physiography varies from rugged mountainous terrain of Himalayas, Eastern and Western Ghats and Deccan plateau to the flat alluvial plains of the river valleys and coastal tracts and the Aeolian deserts in western part.

Based on groundwater bearing properties, the geological formations of the country are broadly classified into following two major categories-

- i. Porous rock formations

- (a) Unconsolidated formations
- (b) Semi - consolidated formations
- ii. Hard rock/consolidated formations

2.1.4 Aquifer System of India

An aquifer is geologically a formation, a group of formations or a part of formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. The areal and vertical location of major aquifers is fundamental to the determination of groundwater availability for the entire country. Hence, various geological formations with distinctive hydrogeological characteristics constitute different aquifer systems of various dimensions.

Based on the various major rock formations and geological units extending over different parts of the country, 14 Principal Aquifer Systems, comprising different hydrogeological properties, are categorized for the overall groundwater resource assessment and management process.

2.1.5 Principal Aquifer Systems

The Principal Aquifer Systems, as identified and mapped by the Central Ground Water Board under the National Aquifer Mapping Project, are shown in Figure 3. These Aquifer Systems are categorized as follows-

Principal Aquifer Systems in India

1. Alluvium	2. Laterite
3. Basalt	4. Sandstone
5. Shale	6. Schist
7. Quartzite	8. Charnockite
9. Khondalite	10. Lime stone
11. Granite	12. Gneiss
13. Banded gneissic complex	14. Intrusive

All these aquifer systems have different properties and therefore, movement and occurrence of groundwater in these aquifers differ widely. Hence, the process of groundwater resource

planning, management, its assessment, protection and conservation would be entirely different in all the aquifer systems, depending upon the type of geological formations, lithology and respective hydrogeological conditions. Therefore, **any standard set of interventions will not work for managing and regulating groundwater in different hydrogeological settings.**

2.1.6 Major Aquifers

The Principal Aquifers are further divided into 42 Major Aquifers, as depicted in Figure 4. These major aquifers, shown in Table-8, are mapped and classified on the basis of their distinctive hydrogeological characteristics, geological formations and their spatial distribution.

The maps of Major Aquifers are available with the Regional Offices of CGWB.

Table-8: Major Aquifers in India

S. No	Major Aquifer	S. No	Major Aquifer
1	Younger Alluvium	22	Shale or/ with limestone
2	Pebble Gravel	23	Miliolitic Limestone
3	Older Alluvium	24	Limestone/Dolomite
4	Aeolian Alluvium	25	Limestone -Dolomite
5	Coastal Alluvium	26	Limestone with Shale
6	Valley Fills	27	Marble
7	Glacial Deposits	28	Acid Rocks -Granite
8	Laterite	29	Acid Rocks -Pegmatite
9	Basalt Basic Rock	30	Schist
10	Basalt- Ultra Basics	31	Phyllite
11	Sandstone	32	Slate
12	Sandstone with Shale	33	Quartzite
13	Sandstone with shale/coal beds	34	Quartzite
14	Sandstone with clay	35	Charnockite
15	Sandstone/Conglomerate	36	Khondalite
16	Sandstone and Shale	37	Banded Gneissic Complex
17	Shale with Limestone	38	Gneiss - meta sedimentary
18	Shale with Sandstone	39	Gneiss Weathered/Massive
19	Shale, Limestone and Sandstone	40	Migmatite Gneiss
20	Shale	41	Intrusive-Dolerite
21	Shale/Shale with Limestone	42	Intrusive-Ultrabasic

(Source: CGWB)

Figure-3: Principal Aquifer Systems in India

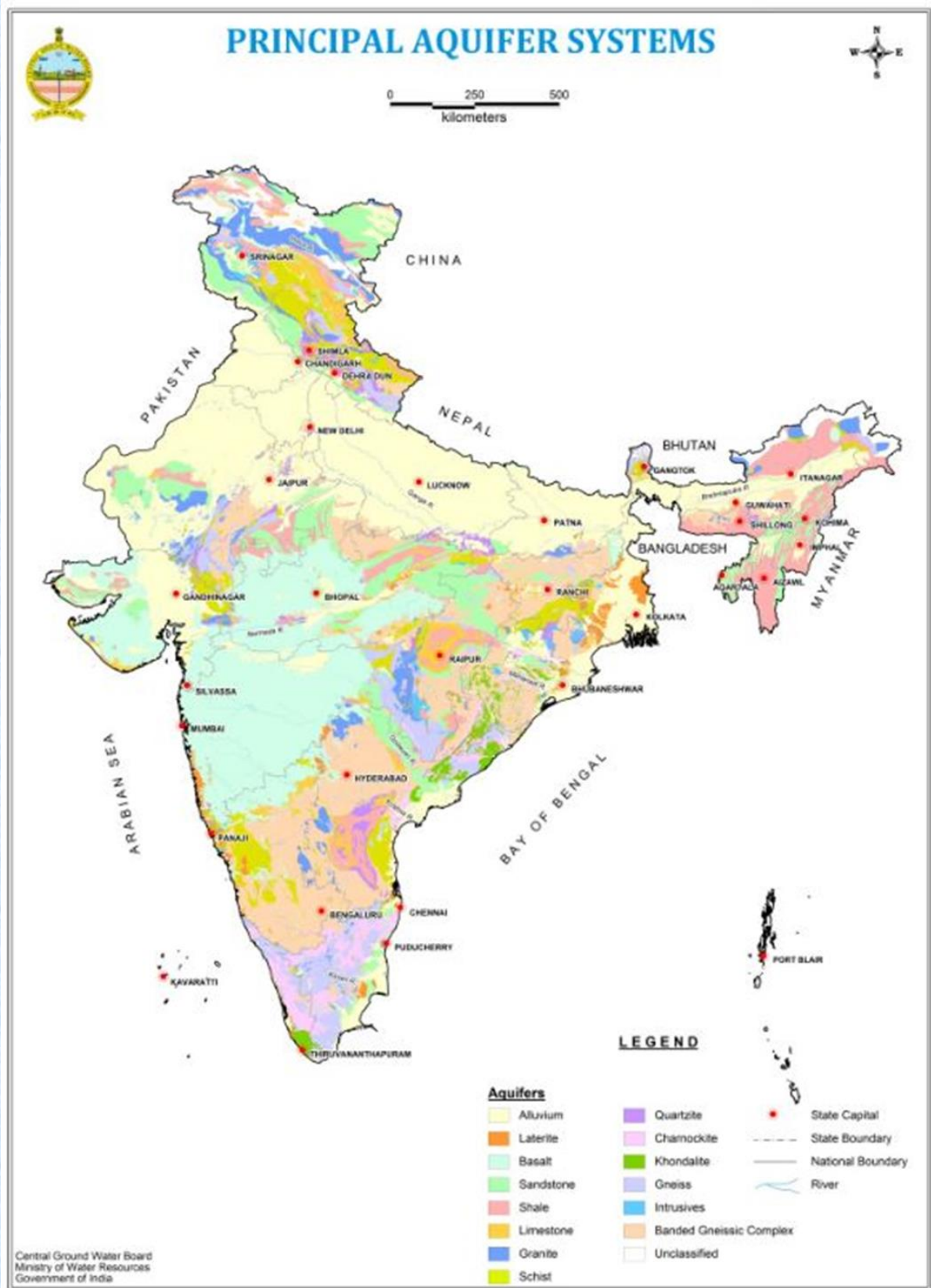
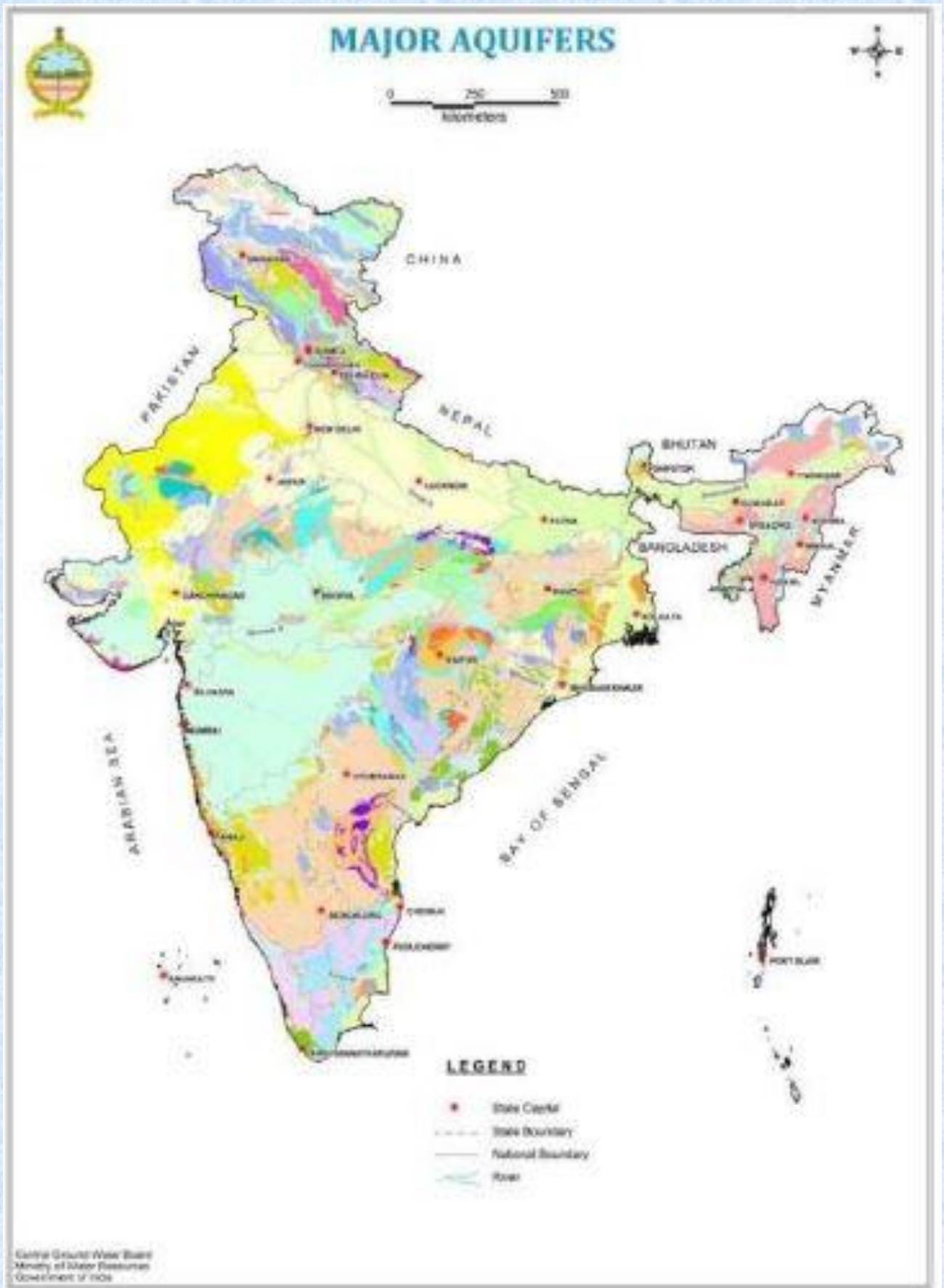


Figure- 4: Major Aquifers in India



2.2 Overview: U.P. Context

The state of Uttar Pradesh (UP) is known to be endowed with rich natural resource potential, lying in the fertile Indo Gangetic plain with high natural soil fertility, abundant rainfall and huge potential of surface and ground water resources. Five major rivers, the Ganga, Yamuna, Ramganga, Gomti and Ghaghara, flow through the state. All the rivers are part of Ganga Basin. Physio-graphically, the state is broadly divided into two regions, the southern hills/plateau and the vast Gangetic alluvial plain.

For the planning purposes, the state is divided into four major regions viz. southern part (Bundelkhand), western region, central region and eastern region (including Vindhya). All these 4 regions have variable groundwater availability, rainfall and diversified issues. Administratively, there are 75 districts in the state, comprising 822 development blocks, 653 urban bodies and 97941 villages.

Uttar Pradesh has always been considered a potentially most productive state and comprises one of the largest aquifer systems in the World, with huge resources occurring within the alluvial deposits. Over the time, due to its easy and assured availability, groundwater has attained the position of a 'democratic resource' in major part of the state covering alluvial region. This is the prime reason that despite much greater availability of surface water resources estimated as 128 bcm in the state, groundwater resources, with total extractable component as only 65.32 bcm, is the most utilized and preferred resource amongst all the water user sectors.

It was around eighties, with the start of Green Revolution, the importance of groundwater has come to the forefront. Since then, the tube well construction has gained significant momentum and Uttar Pradesh became the centre of "Irrigation Tube Well Revolution" in the entire country. It is noteworthy that more than 30% of private minor irrigation tube wells in the country i.e., about 37 lakhs are located in the state, extracting huge bulk of groundwater for agriculture use. The number of these private tube wells has increased to 44 lakhs by March, 2020, while 16.5 borings without pump sets are adding fuel to groundwater exploitation.

The data reveal that more than two-third of irrigated agriculture in the state is dependent on groundwater. Besides, most of drinking water and almost all industrial demands in the state are also fulfilled by groundwater, resulting into its continuous escalated abstraction and declining water levels all across the state in both rural and urban segments. About 70%

blocks and more than 80% urban bodies are witnessing decline in groundwater levels. This has eventually affected the resource sustainability in many areas, where groundwater availability is rapidly diminishing. Apart from this, the continuous deficient rains have added to the crisis of groundwater by impacting the rainfall recharge, which has reduced significantly over the years. On the other hand, non-conjunctive and unplanned use of surface water (canal water) and groundwater, mostly in canal commands, has led to various geo-environmental problems like sub-surface water logging, rising water levels and soil sodicity.

Looking at the Bundelkhand region, covering seven districts of the state along with the Vindhyan, there has been a challenge for decades for providing even minimal required water supplies due to poor availability of groundwater and the inability of various conservation schemes to check and hold huge monsoon run-off for surface storages for meeting the local water needs. The other sources of water are also inadequate making this hard rock terrain almost a water scarce region. **As watershed geomorphology of this rocky terrain is never recognised and understood, most of the rain water flows away down the sloping terrain and due to this high run-off, natural recharging to groundwater normally gets hampered and only partial replenishment of aquifers occurs.** This is one of the reason ground water availability in Bundelkhand-Vindhyan region remains very poor. Other factor is unscientific execution of rainwater conservation measures, which are not guided by local geological and geomorphological settings. Further, the concept of saturating every single watershed is entirely missing. Both these rocky terrains are characterised by various **geomorphic features like valley fills, buried pediments, colluvial deposits, which are potential sites for both groundwater development and rainwater conservation, and hence, these features need special attention.**

The state is also facing the emerging crisis of groundwater pollution. The reported occurrence of Arsenic in groundwater of various districts in the state has come-up as a new challenge for ensuring safe drinking water supplies and also the possible risk of arsenic contamination reaching to the people through food chain and exposing them for various health problems. Other water quality threats like pollution of fluoride, iron, nitrate, chromium, manganese and also the bacteriological contamination as well as the salinity in groundwater have overall posed big challenges for ensuring potable water supplies in the state.

These varied situations of groundwater resources in the state indicate that **due to its multi-sectoral demand and use, it is totally neglected, poorly recognised, misunderstood and**

underestimated from management perspective and as a result, the resource in the state is leading towards an invisible crisis.

2.2.1 Hydrogeology of Uttar Pradesh

The State of Uttar Pradesh, predominantly covered with Indo-Gangetic alluvium, is characterized by varied hydrogeological formations, ranging in geological age from Archean to Recent, that have resulted from diversified geological, geomorphological, climatological and topographic actions / events occurred during the geological past. These formations, along with space-time variable annual water cycle, govern groundwater repositories in respective river basins of the state. The major portion of the state is covered by Ganga basin, comprising Yamuna, Ramganga, Gomti, Ghaghara, Gandak, Rapti and Son sub basins, including rocky terrain of Bundelkhand. **The mountain chain of the Himalayas in the north, with high run-off, plays an important role in passive recharging of the vast Ganga basin through horizontal flows.**

Diverse set up: The state comprises two major geomorphic units,

- 1) Gangetic alluvial plain,
- 2) Bundelkhand-Vindhyan plateau.

Due to diverse hydrogeological and geomorphological set ups, spatial and temporal distributions of groundwater resources and its availability in the state are non-uniform and range from plenty in alluvial plain to scarce in Bundelkhand-Vindhyan.

The hydrogeological framework of the state consists of both porous and fractured formations. The alluvial region comprises the porous formations, while the fractured/weathered formations are found in Bundelkhand-Vindhyan.

The larger part of the state, covering alluvial plain, is underlain by the fluvial sediments, which were laid down in the fore deep between plateau region in the south and Himalayas in the north, during the Quaternary period by the Indus-Ganga system of drainage over the Precambrian topography existing during geological past. These deposits owe their origin to riverine activity.

The southern part of the state, covering Bundelkhand-Vindhyan and part of peninsular plateau, is characterised by entirely different geological conditions being underlain by hard rocks of Precambrian formations under a thin cover of marginal alluvium. The sediment deposits in Bundelkhand and Vindhyan are entirely different because these sediments were

carried by northwardly flowing rivers originating from peninsular region and subsequently laid down over the hard rock basement and characterised by different ground water systems.

Thus, Uttar Pradesh can be broadly divided into two hydrogeological formations shown in the following Table-9.

1. Unconsolidated, alluvial sediments
2. Consolidated, hard rock formations

The formation wise different hydrogeological units and the respective lithology are shown in the Table-9, clearly depicting that the hydrogeological properties and groundwater conditions of above two formations differ widely.

Table - 9: Hydrogeological Framework in Uttar Pradesh

Hydrogeological formations	Hydrogeological units	Area (sq km)	Lithology
Unconsolidated Formation	Bhabhar	1,400	Assorted sediments constituting boulder, cobbles, pebbles and sand
	Tarai	11,500	Alluvium (predominantly fine sediments with intercalation of clay or silt with sands)
	Central Ganga Plain	1,98,372	Alluvium (predominantly sand with intercalation of clay or silt)
	Marginal Alluvial Plain	8,688	Alluvium (sand with intercalation of clay or silt)
Consolidated formation (Hard Rock)	Southern Peninsular Area	21,750	Archean /Pre- Cambrian crystalline and Vindhyan sediments

(Source: CGWB)

2.2.1.1 Unconsolidated formation

The hydrogeological unit comprising unconsolidated formation covers more than 85% of the state's total geographical area. Such formations have been deposited through mighty rivers originating from great Himalayan Mountains. These are primarily alluvial sediments that comprise an admixture of pebble, gravel, sand, silt, clay and kankar. The sediments are generally coarser in the north and gradually become finer in south eastward along downstream of the drainage, which is a typical feature of fluvial deposits.

Unconsolidated formation is further divided into four hydrogeological units as shown in the above table. The hydrogeological properties of these four units are briefly discussed in the following text. The exploratory drilling conducted by CGWB in these units down to the depth of 600-700m revealed a multi-layered aquifer system, which comprises alluvial sediments and promises to hold large groundwater resources.

a). Bhabhar Zone

The Bhabhar zone, represented by piedmont deposits, consists of numerous coalescent alluvial fans, occupying a narrow tract of 10 to 20 km. in width along the foot hill region south of Sub Himalayan zone. This belt is a south sloping plain (10-20 m/km) merging with Tarai belt in the south and extends from Saharanpur in the west to Bijnor in the east. It gradually narrows down eastward.

The alluvial fans have been formed by accumulation of debris brought down by heavily charged streams on their emergence from the hills. The fans consist of poorly sorted material with boulders and pebbles of all sizes. The percentage of granular material is much higher. The presence of thick clay layer over coarser sediment, with abrupt reduction of slope, marks the southern limit of Bhabhar. The groundwater occurs under unconfined state and depth to water level is deep, which goes down as deep as 130 mbgl. The elevation of water table varies from 250 m to 300 m above mean sea level. The yield potential of tube wells up to a depth of 250m is found moderate.

b). Tarai Zone

The Tarai zone occupies a narrow belt south of Bhabhar and its contact with Bhabhar is well marked by a spring line. Its southern boundary is not pronounced, and it gradually merges with Central Ganga plain. It is characterised by moist, waterlogged, swampy area which is gently sloping south-ward (2.5 m/km). Luxuriant growth of dense forest is the characteristic feature.

The Tarai deposits are dominantly fine sediments with well sorted material. In this belt, ground water occurs under unconfined, confined and semi- confined conditions. The depth to water level in shallow aquifer ranges between 2 to 6 m below ground. The water table slopes southward. In deeper aquifer (below 50 m depth), groundwater occurs in confined state. The yield potential of tube wells has been reported as 1000-2000 lpm (litre per minute). The autoflow (self-flowing) conditions are the known characteristics in this belt. This flowing condition is said to be associated with nature and size of fan deposits. **However, with large**

scale exploitation over the years, the artesian/self-flowing conditions have markedly reduced.

c). Central Ganga Plain

The vast alluvial tract for Central Ganga Plain, covering nearly two third of the state, occupies the area south of Tarai and can further be divided in two sub units - Younger Alluvium and Older Alluvium with dominance of older alluvial sediments. This Central Ganga Plain is known for having the richest groundwater repository in the World.

It is characterized by topographic plain of low relief and numerous fluvial geomorphological features such as abandoned channel, natural levee and meander scars. The presence of different erosional and depositional fluvial features indicates shifting and meandering nature of the rivers. In the process of shifting of the river course, older flood plains were left-off as extensive high lands that act as present-day interfluves. The rivers have degraded their alluvial plain and carved new meander belts at lower elevation, where younger flood plain deposition took place. Thus, this region presents two distinct subunits, the high land or composite flood plain area and low meander flood plains. The low-lying riparian area occupied by the present-day meander belts forms the meander flood plain. Such meander flood plains are usually underlain by coarser sediments.

- The **Younger alluvium** occurs mostly along the present-day flood plain area. The continuous shifting of the drainage network gave rise to the younger alluvium.
- The **Older alluvium, occupying** comparatively high land, covers major part of the Central Alluvial Plain in the state. A typical characteristic of older alluvium is formation of kankar within itself due to leaching of calcium carbonate under favourable climatic conditions. The kankar occasionally forms pans restricting downward movement of water. The thickness of older alluvial sediment is variable and generally goes up to 600 m below or even more and beyond that occurs stratigraphic elongated features in isolated areas, known as "Basement highs.
- "This unconsolidated zone is porous and permeable with primary inter-granular porosity and has good ground water potential occurring under unconfined, semi-confined and confined conditions. Water levels were originally shallow to moderate in major part of the Central Ganga plain, but **with continuous withdrawals, water levels in most of the parts have gone down much deeper even to irreversible depths.**

Based on the hydrogeological characteristics, the Younger alluvial deposits are expected to have relatively higher yield potential than the older alluvium.

d). Marginal Alluvial Plain

The transition zone between Ganga plain in the north and Bundelkhand plateau region in the south forms the Marginal Alluvial Plain. This zone is characterized by gently north- east sloping plain, comprising abandoned channel, meander scars and ravines. The fluvial sediments present in this belt have been deposited partly by the fluvial action of the river Yamuna and partly by the Ganga River. The average thickness of alluvial material varies from 70 to 200m, overlying Pre Cambrian basement.

Lithologically, the Marginal Alluvium consists of clay and silt interbedded with sand lenses of variable thickness and extension. While in Mathura- Agra area the sandy horizons are thin and persist over short distances, these have wider subsurface extension in Jalaun. The subsurface data for Jalaun area indicate 10 to 50m thick sandy horizon lying between 30 to 100m depth. The sediments are poorly sorted comprising sands of different grade inter bedded with clays.

Groundwater occurs mostly in unconfined state, but occasionally under semi confined to rarely in confined state. The water table is generally shallow in southern part and gradually deepens close to Yamuna rivers. The yield potential of tube wells of 150-200m depth has been reported as 1000-2000 lpm. **But with increased exploitation, the discharges have reduced and water levels have gone down.**

2.2.1.2 Consolidated formation

The Southern plateau region of Uttar Pradesh, covering about 10% of the state's geographical area, comprises Bundelkhand and Vindhyan formations. The area has a rugged topography, with undulating and northward sloping terrain. All the main rivers flow towards north and finally merges in Ganga.

The plateau like terrain of Kaimur range and Bundelkhand Massif forms the Southern Peninsular region. The region is characterised by rocky formations such as granites, gneisses, shale, sandstone, limestone punctuated with quartz reef, dykes and variety of land forms such as mesas, buttes, residual hillocks, inselberg, pediments, valley fills etc. Isolated patches of residual soil and laterites of varying thickness and extension are also present. **The peninsular**

shield of Bundelkhand and Vindhyan comprises discontinuous aquifers of limited potential in weathered and fissured formations.

Bundelkhand Formation: The crystalline rocks of Bundelkhand Granite Complex group occupy Jhansi, Jalaun, Lalitpur, Mahoba and Banda districts. The groundwater occurs within the secondary porosity (joints, fractures) as well as in the weathered residuum of the rocks under water table conditions. The weathered residuum (colluvium) may be granular or sandy clay depending upon texture and composition of parent rock. Hydrogeologically, this colluvium is similar to alluvial sediments. The vertical and lateral extension of weathered zone varies from place to place. The depth to water level varies between 2 to 16 mbgl.

Vindhyan Formation: The Vindhyan sandstone/shale occupies considerable area of Peninsular region. Generally, the sandstones are compact except for Shankargarh sandstone occurring in Prayagraj, Mirzapur, Sonbhadra and Chitrakoot area. The groundwater occurs in the joints and fractures of sandstone under water table condition. The depth to water table depends on the geomorphology and varies between 2 to 25 mbgl. More or fewer confining conditions are found in that part of Vindhyaachal area, where flowing condition is present. The Vindhyan limestone, exposed in central part of Mirzapur and southern part of Banda and Lalitpur districts, forms ground water repository of low to moderate yield. The cavernous limestone of Chitrakoot has been found yielding reasonably moderate discharge. **However, the limestone terrain needs to be extensively explored.**

2.2.2 Aquifer Systems of Uttar Pradesh

Uttar Pradesh is characterised by diverse hydrogeological situations, where unconsolidated sediments and various rock formations having different geological, geomorphological, and hydrological properties have developed varied aquifer systems that comprise aquifers of different dimensions.

These aquifers may be moderate to extensive both laterally and vertically in the alluvial region and they may be unconfined to semiconfined or confined, while in the rocky terrain of Bundelkhand and Vindhyan, the aquifer systems are largely fissured, weathered and discontinuous.

The potentiality of alluvial and fissured/weathered aquifers as well the occurrence and movement of groundwater within these aquifers also differ widely from place to place. Therefore, different aquifers have their unique characteristics. Accordingly, the aquifer systems have been identified and classified. At this point, it would be relevant to mention that

without understanding and studying the dynamics and nature of the aquifers, any management action, if initiated, will not succeed and this is the reason the groundwater problems are not getting resolved.

A brief description of broad Aquifer Systems of the state is given below:

2.2.2.1 Artesian Aquifer

Artesian aquifer belt in the state, situating in front of the foot hill region, extends from Maharajganj district in the east to close to Saharanpur district in the west passing through Lakhimpur kheri, Bijnor and other districts. This is a potential aquifer system (auto flowing) may provide water supplies for various uses which does not need energy to lift water from different depths. **However, the recharge area of artesian aquifer belt needs conservation and protection measures, since pressure 'heads' of artesian aquifer have decreased with the time, due to increased exploitation of groundwater.**

2.2.2.2 Regionally Extensive Porous Aquifer

In Uttar Pradesh, a multi- layered alluvial aquifer system extends over Central Ganga Plain, which largely covers rural areas. The aquifers are usually porous with varying granularity. Dimensions of aquifers may be regionally extensive, crossing administrative boundaries. The sub- surface correlation of formation sediments in alluvial region of the state has shown presence of several aquifers down to a depth of 600 m or beyond beneath the ground, broadly comprising four Aquifer Groups at different depth ranges, but these depth ranges are variable in different parts of state. Each aquifer group comprises varying set of aquifers, having different properties. Based on the exploratory data of CGWB, these aquifers of Central Ganga Plain have been grouped on the basis of lithological characters as well as based on interpretation of electrical logs of boreholes drilled.

These are summarised in Table-10.

Table-10
Different Aquifer Groups in Central Ganga Plain

S. No.	Aquifer Group	Depth Range (mbgl)
1.	First aquifer	0-150
2.	Second aquifer	100 -210
3.	Third aquifer	225- 360
4.	Fourth aquifer	360 - 600 or beyond

(Mbgl denotes metre below ground level)

Observations:

- i. The granularity of these aquifers controls the yield and flows of groundwater. Coarser the material, higher will be the yield and the storage will also be more.
- ii. **The upper part of first aquifer down to 50 mbgl is the main source of drinking water through hand pumps and dug wells and is unconfined in nature. Shallow private minor irrigation tube wells are also constructed in this zone.** The first aquifer as a whole, is mostly unconfined to semi-confined at places. **This is the most preferred aquifer group as it is used as the main source of groundwater in the state, being extensively exploited** through private as well as government tube wells to meet the drinking water, irrigation and other requirements.
- iii. Overall, the shallow and phreatic aquifers are **under 'high stress'** due to extensive exploitation.
- iv. The second aquifer group, mostly dominated by saline water, covers larger part of Central Ganga Plain. While, in the northern fringe of this Central Ganga Plain, salinity is not reported. The granularity of aquifers is fine with low to moderate yield.
- v. The third and fourth aquifer groups, are also characterised by fine sand and the yield is low to moderate. The aquifers are mostly semi-confined to confined in nature.
- vi. The **deeper aquifers** are semi confined to confined in nature and generally have **static resource storage**, which are mostly not replenished by the rainfall and get passive recharging from the Himalayas. But **due to lack of regulatory provisions, these aquifers are also being exploited by both private and government users at their will.** This suggests the 'mining' of groundwater has almost become a common practise in ground water development, but scientifically this should not be permitted in any case, without having detailed studies.
- vii. The depth ranges of all the aquifer groups are highly variable all across the state. The minimum and maximum depth of these aquifer groups of Central Ganga Plain may vary from west to east and north to south. **The granularity and corresponding potential of aquifers is also quite variable.**
- viii. Towards **Agra, Mathura, Firozabad, normally third and fourth aquifer groups are not encountered**, and the bed rock is usually encountered at a depth of 150-200 mbgl.
- ix. For the planning purpose, **area-specific aquifer system should be taken into consideration.**

2.2.2.3 Urban Aquifer System

Though most of the major, medium and small towns of the state are located over the Central Ganga Plain Aquifer system, it needs special mention as **"separate urban area aquifer system"** because the urban land use, groundwater development, yield potential, extraction pattern and the recharge process differ entirely from those of rural area aquifers. Study shows that the urban aquifer illustrations, as prepared for some urban areas, depict in general, a multi layered aquifer system, distinguishable with four aquifer groups at different depths and covered with thick clay layers up to 20m. Various urban aquifer groups mostly encountered in the state are shown in the Table -11.

Table-11: Urban Aquifer System of U. P.

Aquifer Group	Depth Range (mbgl)
First aquifer	up to 100
Second aquifer	130 - 255
Third aquifer	200 - 460
Fourth aquifer	500 - 753

(Source: Sharma S.K.)

Observations:

- i. The above depth ranges of various aquifer groups are simply a general depiction of urban aquifer system, which vary from area to area and therefore, different cities of the state are characterized by different aquifer systems of variable depth ranges. Hence, every city should have separate aquifer mapping for future planning.
- ii. The urban aquifers are highly variable in thickness, lateral extent, granularity and quality. For any management process, the area specific aquifer disposition should be taken into consideration.
- iii. The aquifers up to 100m are generally unconfined in nature, while the aquifer groups beyond 100m are semi-confined to confined.
- iv. It has been observed that the tube well yields are continuously reducing due to indiscriminate groundwater pumping thereby putting urban aquifer under stress.
- v. **The first aquifer group is already under stress and needs its sustainable yield level to be fixed and regulated for longevity of aquifer.**
- vi. **Groundwater mapping and modelling of urban aquifers on 1:10000 scale, therefore, should receive priority in view of greater use of groundwater for domestic and other consumption.**

2.2.2.4 Discontinuous Aquifer System in Rocky terrain

The southern peninsular region of Bundelkhand and Vindhyan comprises discontinuous aquifers, having limited resource potential in the weathered and fissured/fractured system. The weathered mantle, overlying the rocks, envisages phreatic aquifers of unconfining nature. **The fissured aquifers, comprising fissures, fractures, cracks, joints within the rock formations, contain groundwater under unconfining to often semi-confining state and the storage in such aquifers may be moderately good where intensity of fractures/fissures is high.** Here the network of fissures and fractures serves as a permeable conduit yielding water to the wells. The flow of such groundwater remains limited within the respective watershed unit.

2.2.3 New Set up of Aquifer Systems of Uttar Pradesh

The above aquifer systems have been grouped and classified on the basis of conventional knowledge base of hydrogeological conditions and these are usually quoted and referred, so far, in various groundwater studies, technical deliberations and related documents.

In 2012, CGWB, in reference to National Aquifer Mapping Programme, has further classified and rearranged the above aquifer systems relatively in a more focussed and scientific manner. As discussed previously, the new set up of aquifer system at the National level has been classified into 14 Principal Aquifer Systems, which are further sub classified into 42 Major Aquifers. For this aquifer-based classification, different geological and geomorphological formations with distinctive hydrogeological characteristics and parameters have been considered.

Based on the above classification and the diverse hydrogeological set up, **Uttar Pradesh is broadly grouped into following Principal aquifer systems** for the Alluvial region and Bundelkhand-Vindhyan terrain.

2.2.3.1 Principal Alluvial Aquifer System

Alluvial Aquifers constitute the Principal Aquifer system that covers major part of Uttar Pradesh. The general hydrogeological characteristics are already discussed under the description for the aquifer system of Central Ganga Plain. Two Major Aquifers are identified under this aquifer system -

- (a) **Older Alluvial Aquifer:** It covers major part of the state, comprising older alluvium sediments. **The GEC-2015 methodology, issued by CGWB, has recommended**

specific yield for this aquifer as 6% with a range of 4 to 8 %. This is an important parameter for groundwater resource assessment, which is already discussed under the sub-chapter "General Basics of Groundwater" of Chapter-I.

(b) Younger Alluvial Aquifer: It usually extends over present-day flood plain area and comprises newer alluvium material. The higher value of **specific yield for this aquifer is recommended as 10% with a range of 8 to 12%.**

The hydrogeological features of both the older and younger alluvial sediments are discussed in this chapter under the text "Hydrogeology of Uttar Pradesh".

2.2.3.2 Principal Aquifer Systems in Bundelkhand and Vindhyan

Based on the geological formations and occurrence of rock types, five broad Principal aquifer systems are identified in Bundelkhand and Vindhyan region of the state-

- (i) Sandstone aquifer
- (ii) Shale aquifer
- (iii) Limestone aquifer
- (iv) Granite aquifer
- (v) Gneissic aquifer

These principal aquifers are further classified into different major aquifers on basis of distinctive geological formations and their hydrogeological characteristics. All the major aquifers are coded by the CGWB for the Southern Peninsular Plateau of Uttar Pradesh. These major aquifers are mostly discontinuous and localised and vary from place to place. The prevailing groundwater conditions are already discussed in the previous text.

2.3 Key Groundwater Problems

With vast potential, groundwater resource in Uttar Pradesh has emerged as primary source of water for almost all the user sectors, but the management neglect of the resource along with its unplanned development and unscientific utilization has put it under various critical situations in the entire state. Different data sets depict that **the state is facing diversified groundwater problems related to resource occurrence, availability, its quality and environmental degradation, which are reported from different districts.**

Four major groundwater problems have been identified and consolidated across the state, which need to be addressed on priority if effective improvement in prevailing groundwater situations is to be achieved –

1. Over-exploitation / indiscriminate extraction of groundwater in both urban and rural areas, causing significant decline in water levels

- Groundwater resources are rapidly depleting due to uncontrolled and indiscriminate exploitation in many areas of the state both in rural and urban segments, resulting into widespread decline of groundwater levels and irreversible depletion of aquifers in different parts.

2. Water logging / shallow water levels affecting the agricultural productivity

- In canal command areas, crop productivity is largely affected due to sub-surface waterlogged conditions, which has emerged in the areas where groundwater levels are very shallow (0-3m). Here conjunctive water use practices are not being applied, causing problem of rising groundwater levels and soil sodicity.

3. High run off, Low Recharge, Poor resource availability in Bundelkhand-Vindhyan

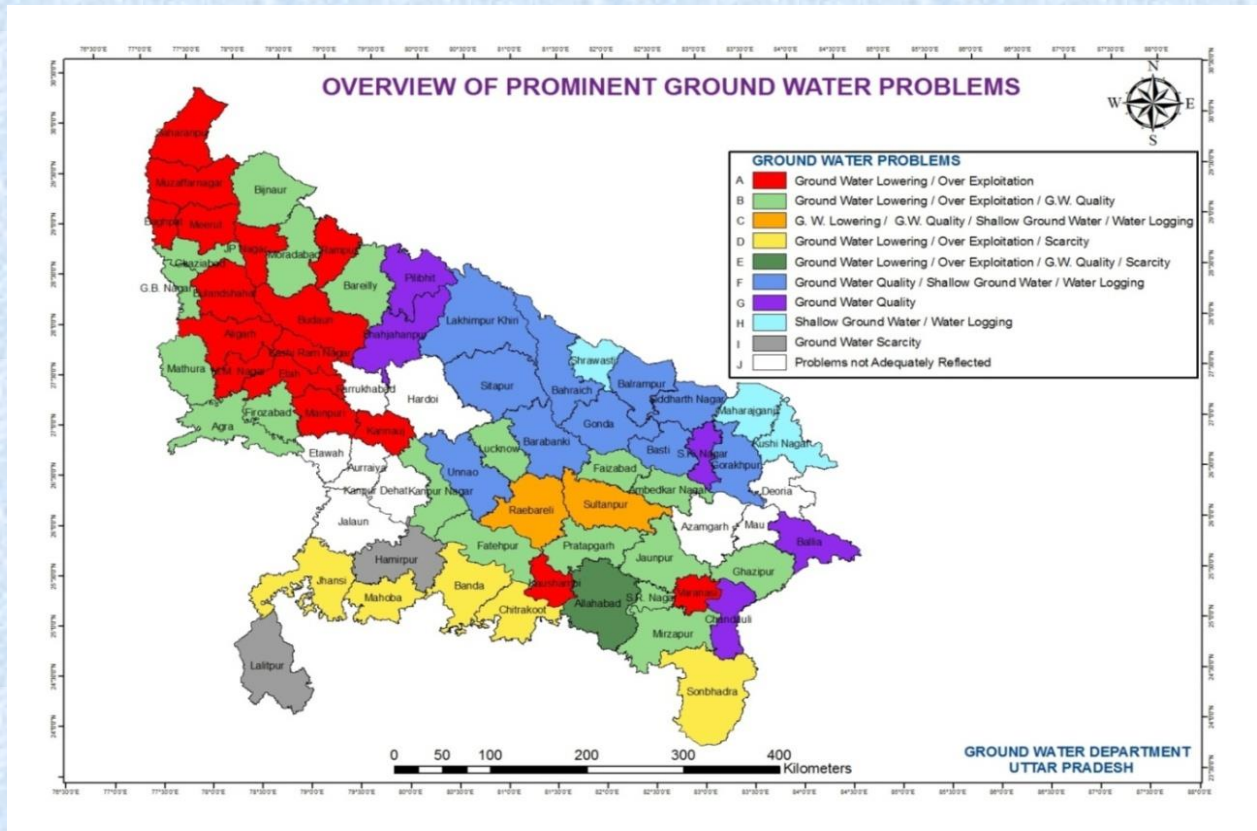
- Groundwater development in Bundelkhand-Vindhyan region is hampered due to high run-off of rainwater, resulting into less recharge, poor resource availability and localised occurrence. Neglect of watershed geomorphology in the implementation of different plans and interventions is the prime reason for the prevailing serious groundwater crisis in this rocky terrain.

4. Groundwater Contamination / Pollution hazards

- Problem of groundwater pollution, both natural and anthropogenic, is reported from various districts of the state. Groundwater dependent potable and safe supplies for drinking water and irrigation use in many rural and urban areas are severely affected due to chemical, metal and bacteriological pollution in ground water sources. Human health is also at risk due to highly contaminated groundwater sources, causing serious health issues in many areas.

It has been found that the majority of districts are affected either singly or with set of multiple problems. Accordingly, these groundwater problems have been identified and grouped district-wise and a composite map of the state, showing the affected districts, with different set of problems has been prepared. The following map (Figure-5) presents an overview of prominent groundwater problems in the state. It can be easily visualized from the map the problem / set of problems the districts are facing, which would help in finding out the broad strategies for groundwater management.

Figure - 5: Key Groundwater Problems in Uttar Pradesh.



(Source: Sinha, R.S. - 2008)

The above map, showing an overview of various prominent groundwater problems surrounding almost the whole Uttar Pradesh, **demand a robust management plan** for subsequent implementation to overcome the prevailing groundwater crisis in the state.

2.3.1 Incidence of Land Subsidence

The state has witnessed two major incidences of land subsidence. In early 90's, potato belt of district Farrukhabad, which has been heavily groundwater dependent, has witnessed massive land subsidence due to collapse of cavity borewells, because of depletion of ground water and drying up of cavities. The dried cavities had converted into mega cavity, which collapsed due to heavy rainfall and as a result huge land cracks developed in the area.

In June 2008, land subsidence has occurred in village Jigni of district Hamirpur, where due to continuous droughts, soil moisture had almost dried up causing loosening of top soil cover and groundwater levels had gone down quite deep. As a result, extensive deep cracks of 20 - 30 cm width, extending up to 500 m, have developed causing damage to local habitation.

CHAPTER -3

GROUNDWATER RESOURCES IN UTTAR PRADESH

-A CRITICAL OVERVIEW

Groundwater resources in Uttar Pradesh has attained a vital position in the overall development and economic growth of the state. The resource has slowly become the mainstay of state's agriculture and drinking water security. It also plays a dominant role in industrial and infrastructural development of the state. The state is the most populous state of the country currently with approximately 233 million people and therefore, to meet the rising demand of growing population, high pressure has been exerted on groundwater resources especially during last 3 decades. The increasing crop production, growing urbanization, industrialisation and further non-uniform extraction have accelerated widespread depletion of groundwater resources in most parts of the state. This situation is well reflected in falling groundwater levels and increasing contamination of aquifers.

It, therefore, becomes important to realize that groundwater is not a resource that could be utilized indiscriminately in the state. Even for protecting ecology and environment, groundwater has an important role for keeping water level and flows in the rivers, lakes and wetlands through natural discharges & base flows.

3.1 Significance of Groundwater in Economic Development

In Uttar Pradesh, groundwater has become an integral component of almost all development programmes, which directly determine and govern the economic growth of the state. Following are the salient points-

- i. It provides drinking water to about 85 percent rural and urban population of the state.
- ii. In irrigation sector of the state, in spite of huge network of canals, groundwater remains the key source of irrigation and holds the major share, where more than 70% of irrigated agriculture is dependent on supplies from minor irrigation tube wells. Hence, its contribution in agriculture sector of the state is most crucial.
- iii. Groundwater is also the major source of industrial sector of the state, which is the backbone of state's economy. Almost all water needs of industries are fulfilled from groundwater sources.

- iv. Infrastructural development, construction activities and their operational demands in the state, including multi-storey buildings, residential colonies, hotels, malls, hospitals, swimming pools, recreational parks & gardens, are entirely dependent on supplies from tube wells for their water requirements.
- v. Even the commercial activities are getting their supplies from groundwater.
- vi. The ecosystem of the state is largely dependent on groundwater, which has ecologically become important for the survival of wetlands. It contributes natural discharges as base flow to the rivers, including Ganga, Gomti, Sai and others.

Since, groundwater is a reliable resource and easily accessible in the alluvial plain of the state, it has been heavily exploited with the mind-set that it is unlimited and freely available. In many parts, it has become critical to scarce, even then its uncontrolled abstraction is continuously increasing.

This is the reason that **Uttar Pradesh tops in groundwater exploitation in the country**. As per assessment report, out of the total extraction of groundwater in the country, **18.4% (45.85 bcm) is being extracted alone in Uttar Pradesh**.

3.1.1 Share of Groundwater in various User Sectors

Groundwater holds a major contribution in state's development and its share in different user sectors is unmatched.

Following is the reported share of groundwater in different sectors (Table-12).

Table- 12: Contribution of Groundwater in Different Sectors

User Sector	Share of Groundwater
Irrigation supplies/Irrigated Agriculture	70%
Drinking Water Domestic Supplies	Urban: 75-80% Rural :90-95%
Industrial Water Demand	95 %
Infrastructural, Commercial Activities and bulk Uses	>95%

However, the importance and contribution of groundwater resource in the overall development of the state is never recognised and it remained neglected from management and governance perspective.

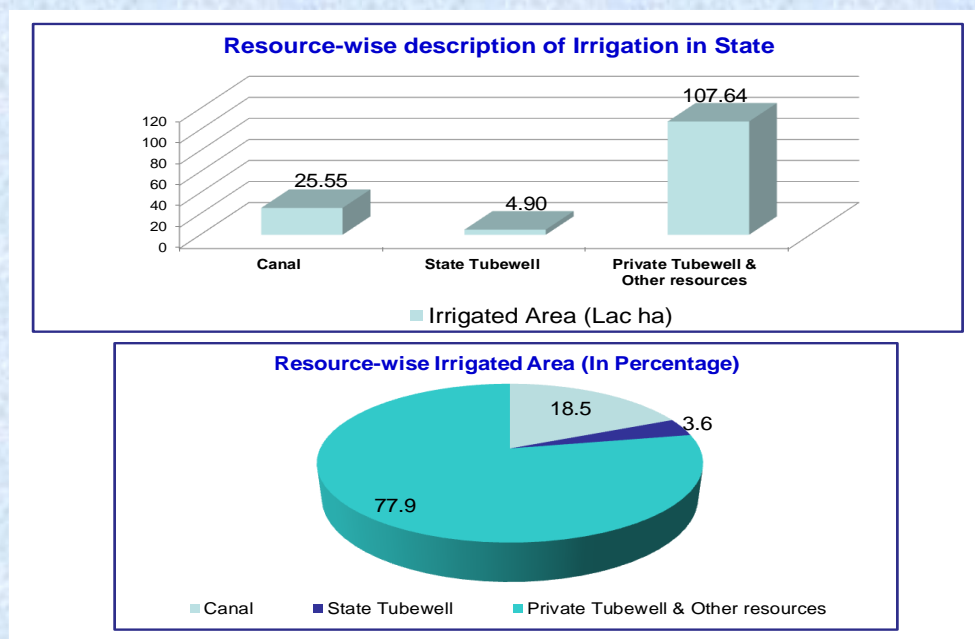
3.1.2 Irrigation Sources: Largest Consumer of Groundwater in the State

The state has an extensive canal network of about 75,000 km with a huge infrastructure, but its share in overall irrigated agriculture is very less. Based on the data of 2011-12, the resource wise description of irrigated area in the statant contribution of irrigation supplies from canal, tube wells and other sources is summarised as follows-

- i. The total irrigated area reported from different sources is 138.09 lakh hectare.
- ii. Irrigated area from canals is reported as 25.55 lakh hectare, contributing 18.5 % to the total irrigated area.
- iii. As reported, state tube wells irrigate 4.90 lakh hectare area, with total contribution as only 3.6%.
- iv. Irrigated area from private tube wells and other sources is reported as 107.64 lakh hectare, that contributes 77.9% to the total irrigated area. This includes the share of private tube wells as 70%, which irrigate 96.71 lakh hectare area of the state. The above data clearly reflects that the irrigated agriculture is mainly dependent on groundwater sources.

Following bar chart and pie diagram (Figure- 6) depict the resource wise description of irrigated area and contribution of canals, state tube wells, private tube wells and other sources.

Figure-6: Resources-wise Irrigation in U.P. (2011-12)



However, according to the data of 2014-15, relative change has been observed in the source wise irrigated area (Table - 13). Area irrigated by canals and state tube wells has gradually reduced, while irrigated area through private tube wells and other sources have relatively increased. From 2011-12 to 2014-15, total irrigated area has increased from 138.09 lakh hectare to 143.89 lakh hectare. Overall, the contribution of private tube wells and state tube wells is more than 70% of total irrigated area. It is also important that the area irrigated through private tube wells has almost doubled from 50.86 lakh hectare in 1984-85 to 97.39 lakh hectare in 2014-15 in a span of 30 years, that indicates how groundwater usage has increased in agriculture sector over the years.

Table - 13: Relative Change in Source-wise Irrigated area

Source	Irrigated area (lakh hectare)	
	2011-12	2014-15
Canal	25.55 (18.5%)	24.82 (17.3%)
State tube well	4.9 (3.6%)	4.44 (3%)
Private tube wells	96.7 (70%)	97.39 (67.7%)
Other sources	10.93 (7.9%)	17.24 (12%)
Total	138.09	143.89

(Source: Statistical Diary, Uttar Pradesh, 2018)

3.1.3 Status of Minor Irrigation Wells in U.P.

As per 5th Minor Irrigation (M.I.) Census (2013-2014), 37 lakhs minor irrigation wells including shallow, medium and deep tube wells are located in Uttar Pradesh, spreading all over the state. With more than 33 lakhs shallow tube wells, the minor irrigation programme has become the lifeline for the agriculture sector of the state, by providing decentralized groundwater supplies to the farms. Following is the statistics of minor irrigation wells as per the census 2013-14 (Table-14). This is used as the base line data for the assessment of groundwater extraction in irrigation sector.

Table- 14: Status of Minor Irrigation Wells - 5th M.I. Census

Minor Irrigation wells	India (no's)	Uttar Pradesh (no's)
Dug wells	8785599	108688
Shallow tube wells	5940701	3332304
Medium tube wells	3176792	250101
Deep tube wells	2618792	87249
Total	20521884	3778342

Observations:

- i. The above table shows that in Uttar Pradesh, there are 36.69 lakhs irrigation tube wells, which are about 31 % of the country's total 117.36 lakh irrigation tube wells.
- ii. Main source of irrigation in the state is shallow tube wells, which comprises about 56% of country's total shallow tube wells. Apart from the tube wells, more than 1 lakh dug wells are also reported from the state.
- iii. In other states, dug wells provide the prominent source of irrigation. In the entire country, there are more than 87 lakhs dug wells as per the census data, while in Uttar Pradesh, there are only 1.08 lakhs dug wells, irrigating about 14.73 lakh hectare of irrigated area.
- iv. **Ban on energization lifted:** Currently, the above number of tube wells might have increased since the above M.I. Census was done for the base year 2013-14. In the meantime, new tube wells would have also been constructed under different government schemes. Furthermore, the ban on energization of private tube wells has already been lifted in the year 2017, it is expected that a large number of private tube wells getting pending clearances for energization and the borings constructed privately by the farmers would, by default, have raised the number of wells as reported in the M.I. census. Obviously, by now the total number of irrigation tube wells in the state would have increased significantly and that would eventually influence the increase in groundwater extraction.

Significant increase in MI wells as on 31 March, 2020

Since 5th MI census was conducted for the year 2013-14, there has been a significant increase in the number of irrigation tube wells in Uttar Pradesh by March, 2020, as evident from the data of Minor Irrigation department--

(i) The MI census reported 36.69 lakh tube wells for the year 2013-14, which **rose to 44.05 lakhs in the year 2019-20** as consolidated by Minor Irrigation Department on 31 March 2020. During the period of 7 years between 2013-14 & 2019-20, the rise in number of irrigation tube wells is about 20%, which is definitely quite high. This rise in number of private tube wells is expected to have increased the overall quantum of groundwater extraction by more than 10% for irrigation uses, suggesting that the Current Stage of groundwater extraction in the state would have gone up quite significantly, if compared with the figure of 2017.

(ii) These lifting of ban on energization in 2017 would have raised at least 2 lakh tube wells in the state.

(iii) The latest minor irrigation data also reveal that there are also about 16.5 lakh Borings without pump set in the state, which are probably going unnoticed in the assessment of extraction for irrigation uses. Further, 2735 Community Wells are also reported in the state.

(iv) It is anticipated that with above changed scenario of tube wells and corresponding rise in groundwater extraction, which might get reflected in the next Resource Assessment, 2020.

3.1.4 Tube wells in other sectors

As per the available information, there are more than **13800 drinking water tube wells** and more than 30 lakhs India Mark II handpumps, operating under different government run water supply schemes, that are providing drinking water supplies in both urban and rural areas. The U.P. Jal Nigam data reveal that these water supply tube wells and handpumps are reportedly extracting around **5.49 bcm** of ground water annually.

- i. Besides, there are also innumerable and **countless tube wells** running in government/private establishments, industries, commercial sectors, hotels, housing & infrastructural sectors, hospitals, educational institutions and other areas. The well census has never been done and groundwater extraction / pumping data is nowhere recorded / available for these user sectors.
- ii. There are millions of domestic/private borings in urban and rural areas, but there is no proof count of such borings.
- iii. As such, there is no official record/data available with responsible organisations. Even in GEC-2015 methodology, appropriate provisions to compute such abstraction are neither included nor given any recognition. The irony is that true picture of overall groundwater extraction in the state for domestic industrial, infrastructural, commercial and other such sectors are never assessed in any of the resource estimation. As such, **large scale groundwater extraction is going unnoticed for decades** and that suggests groundwater extraction figure are underreported for the entire state.

In view of above facts, it would be appropriate that the groundwater extraction figures estimated for different user sectors should be reviewed and reassessed for deriving correct abstraction scenario.

3.2 Dynamic Resource Assessment in Uttar Pradesh (as on 31.03.2017)

For competing the rising water demand of increasing population, growing urbanization, rapid industrialization, infrastructural development and to fulfil the future water requirements and raising the agricultural production, groundwater in the present scenario has emerged as a most dependable source. Since it is replenished annually and rainfall being the dominant source, its availability in space and time remains non-uniform, because of varied hydrogeological and other factors. Hence, the sustainable utilization of groundwater resources demands a realistic quantitative assessment based on the scientific norms.

The findings of dynamic groundwater resource estimation basically provide a base line input to planners and stakeholders to formulate their respective strategies and programmes for

utilizing groundwater for irrigation and drinking water supplies as well as to support water demands of industries and infrastructural sectors. Based on these findings, steps for taking up water conservation measures and other management interventions are also suggested for the stressed areas.

In Uttar Pradesh, previous resource assessments were carried out in 1975, 1986, 1990, 1995, 2000 and later on, based on the methodology of Ground Water Estimation Committee-1997(GEC-97), it was done periodically for 2004, 2009, 2011 and 2013.

The GEC- 97 Methodology is now revised as GEC- 2015 Methodology with more inputs and recommending revised values for specific yield and an initial assessment procedure for urban groundwater estimation. Based on this recent methodology, the dynamic ground water resources assessment using the data as on 31 March, 2017 was carried out by CGWB and Ground Water Department. This resource assessment is done block wise covering 820 blocks located in 75 districts.

Apart from this, the highlight of the present assessment is urban groundwater resource estimation. For the first time, CGWB& GWD, UP, have jointly carried out groundwater resource estimation for 10 prominent cities of the state having population more than 10 lakhs. The cities included are Lucknow, Kanpur, Agra, Varanasi, Praygraj, Ghaziabad, G.B. Nagar, Bareilly, Moradabad and Meerut. Until now, urban areas were not covered in the ground water assessment process. This urban assessment exercise is done entirely by assuming very generalised adhoc norms, due to unavailability of field data and validated norms/parameters.

The above ground water resource assessment-2017 broadly includes estimation of dynamic groundwater resources, which get replenished every year largely through rainfall and also from irrigation fields as well as other sources like water bodies, ponds etc. Therefore, **this periodic exercise is termed as Dynamic Ground Water Resource Assessment of Unconfined Aquifer.** However, this assessment does not include the other component of the groundwater system called Static resource, which is relatively quite vast and occurs beyond the dynamic resource at deeper depths.

Static Resource: Yet to be Assessed -

The other part of groundwater, called "Static or In- storage resources", is found in deeper aquifers, which get passive recharging from Himalayas. This resource may be described as the groundwater volume available at deeper depth in alluvial sediments or rock formations stored over thousands of years.

The Static resource is treated as a future reserve and since it is not replenished annually, it should not be allowed to be extracted. Basically, the static resource is not an active part of the water cycle.

As per the past data of CGWB, Uttar Pradesh is considered as the largest repository of Static Ground Water Reserve in the country. The initial estimates reveal that 3470 bcm of static resource is stored in alluvial aquifers, which is 33% of country total static resource, while the hard rocks hold 30 bcm of static resource. These tentative figures pertain to alluvial aquifers up to 450-600m and 100m in hard rock area. But for future perspectives, this resource is required to be systematically assessed.

Unbated groundwater mining-

There are no policy provisions for the extraction and use of static resource. As per the laid down scientific principle, this static resource should not be abstracted for being the future reserve. Experts believe that any extraction of static reserves can only be allowed for a very limited period during exigencies only or in case of any extreme situation of water crisis, but that should only be done after thorough assessment of possible environmental risks and aquifer deteriorations with all caution and there must be a mandatory provision to obtain necessary permission from a competent authority, as may be prescribed.

Since, there is no such mandatory clause to prevent groundwater extraction from static reserve, unreported exploitation of this reserve is going on unabated leading to indiscriminate mining causing irreversible loss of static/in-storage groundwater, which would certainly have long term environmental implications.

3.2.1 Broad Findings of Assessment - 2017

The broad findings of Ground Water Dynamic Resource Assessment - 2017 is given in the following table. The whole exercise of groundwater estimation is quite comprehensive requiring vast data sets from almost all water related sectors including rainfall with. In the process, broadly two major components i.e., Recharge and Extraction are assessed with different scenarios to derive the resource availability along with other outputs.

As per the report of CGWB and Ground Water Department (GWD, UP) on Dynamic Ground Water Resources of Uttar Pradesh-2017, main findings with state figures are tabulated in Table-15

Table- 15: Ground Water Resources Assessment (31-03-2017) for Uttar Pradesh

A) Ground Water Recharge		
Monsoon Season	i) Recharge from Rainfall	37.73 bcm
	ii) Recharge from other sources	11.67 bcm
Non-Monsoon Season	iii) Recharge from Rainfall	1.59 bcm
	iv) Recharge from other sources	18.93 bcm
A1) Total Annual Ground Water Recharge(i+ii+iii+iv)		69.92 bcm
A2) Total Natural Discharge		4.60 bcm
A3) Annual Extractable Ground Water (A1-A2)		65.32 bcm
B) Annual Ground Water Extraction	i) Irrigation	40.89 bcm
	ii) Domestic	4.95 bcm
	iii) Industrial	--
B1) Total Annual Ground Water Extraction (i+ii+iii)		45.84bcm
(C) Net Ground Water Availability for Future Use		20.36bcm
(D) Stage of Ground Water Extraction		70.18%

Observations:

- i. Groundwater extraction for industrial uses has not been estimated, hence this important component is treated as nil.
- ii. An annual allocation of 5.96 bcm groundwater for domestic uses as on 2025 has also been made in the present assessment.
- iii. A slight variation is observed in the figure of net groundwater availability, which is reported as 20.36 bcm, but with simple mathematical factor, it should come out as 19.48 bcm, if total groundwater extraction is subtracted from annual extractable resource. However, there seems to be some technical or procedural limitation in computation of resource assessment, which further requires some justification.
- iv. **Provision for base flow:**

Out of total annual replenishable groundwater recharge of 69.92 bcm, provision of 4.6 bcm as natural discharges to contribute base flow for the rivers has been made in this resource assessment.

The district wise details of annual extractable groundwater resources, current annual groundwater extraction and net groundwater availability for the future use with stage of groundwater extraction based on ground water resource assessment as on 31 March 2017 are given in the Table-16-

Table-16: District wise Dynamic Ground Water Resources of Uttar Pradesh, 2017

DISTRICTWISE DYNAMIC GROUND WATER RESOURCES OF UTTAR-PRADESH (31.03. 2017)							
Unit of assessment: ham							
S. No.	District	Annual Extractable Ground Water Resources	Current Annual Ground Water Extraction			Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)
			Irrigation	Domestic & Industrial	Total		
1	2	3	4	5	6	7	8
1	Agra	84758.50	83464.26	7654.20	91118.45	8384.66	107.50
2	Aligarh	89024.52	51082.36	10220.91	61303.27	29381.42	68.86
3	Ambedkar Nagar	74702.33	50783.94	5534.13	56318.07	16528.64	75.39
4	Amethi	75090.37	43561.74	4437.78	47999.52	26334.50	63.92
5	Amroha	47037.04	44832.01	4357.04	49189.05	2671.09	104.58
6	Auraiya	63284.49	28326.20	3224.37	31550.57	31411.54	49.86
7	Ayodhya	86299.96	50701.60	6328.90	57030.50	27936.56	66.08
8	Azamgarh	121709.84	66875.61	12123.66	78999.27	40274.16	64.91
9	Bagpat	37773.55	32572.10	2495.67	35067.77	3767.36	92.84
10	Bahraich	114444.88	51267.29	8747.66	60014.95	52858.97	52.44
11	Ballia	83422.96	45675.11	7339.63	53014.74	29101.36	63.55
12	Balrampur	90538.81	40778.51	5488.45	46266.96	43142.89	51.10
13	Banda	59608.51	36116.28	4037.47	40153.75	17304.30	67.36
14	Barabanki	165383.56	101396.20	8130.32	109526.52	54457.15	66.23
15	Bareilly	127520.48	71803.57	13565.18	85368.75	43777.07	66.95
16	Basti	71621.34	41045.45	5990.56	47036.01	23754.84	65.67
17	Bijnor	136350.76	86514.45	7299.21	93813.66	42652.39	68.80
18	Budaun	73955.42	52041.70	7754.47	59796.17	14540.14	80.85
19	Bulandshahar	158312.47	135089.69	6574.67	141664.36	21867.06	89.48
20	Chandauli	53081.05	22462.29	4283.15	26745.44	25762.47	50.39
21	Chitrakoot	36652.78	27475.14	2502.40	29977.54	5202.74	81.79
22	Deoria	72679.53	39430.31	7668.38	47098.68	24193.96	64.80
23	Etah	57189.46	41770.55	4283.97	46054.52	10604.68	80.53
24	Etawah	79080.93	27552.56	3215.51	30768.07	47848.95	38.91
25	Farrukhabad	50609.47	34226.52	3809.61	38036.13	11972.71	75.16
26	Fatehpur	148504.76	97567.50	6615.37	104182.87	43823.48	70.15
27	Firozabad	70630.98	72524.96	6154.17	78679.13	9227.10	111.39
28	G.B.Nagar	60546.55	62501.84	3893.42	66395.26	1646.99	109.66
29	Ghaziabad	37028.97	35693.32	11837.44	47530.76	1339.60	128.36
30	Ghazipur	91141.91	50062.00	8272.48	58334.48	31529.04	64.00
31	Gonda	90330.41	47157.64	8722.89	55880.53	32720.27	61.86
32	Gorakhpur	104716.15	56120.27	10870.09	66990.36	36127.16	63.97
33	Hamirpur	42944.22	28369.07	2571.54	30940.61	11518.21	72.05
34	Hapur	45780.67	45976.10	3165.06	49141.16	1300.77	107.34
35	Hardoi	171280.33	95005.91	8745.11	103751.02	66192.41	60.57
36	Hathras	55110.17	52158.42	3773.39	55931.81	6492.45	101.49
37	Jalaun	106082.82	48282.60	4039.72	52322.32	52359.23	49.32
38	Jaunpur	145569.78	99366.93	12067.34	111434.27	35310.72	76.55
39	Jhansi	84908.30	39230.56	2926.59	42157.15	42215.07	49.65
40	Kannauj	65808.21	39762.58	4021.25	43783.83	26764.71	66.53
41	Kanpur Dehat	89083.05	58668.52	3995.08	62663.60	26042.20	70.34
42	Kanpur Nagar	85015.55	59126.97	8238.31	67365.28	18108.75	79.24
43	Kasganj	58476.45	38406.88	3611.03	42017.91	15807.90	71.85
44	Kaushambi	59146.64	38065.54	4033.64	42099.18	16554.35	71.18
45	Kushi Nagar	131108.59	60855.26	16997.71	77852.97	49973.88	59.38
46	Lakhimpur Kheri	223926.75	115738.38	10605.16	126343.54	94897.16	56.42
47	Lalitpur	40019.77	28703.37	2645.49	31348.86	6295.53	78.33
48	Lucknow	75575.86	35690.03	13691.67	49381.70	29458.24	65.34

49	Mahoba	21742.14	17674.50	1409.29	19083.79	2934.78	87.77
50	Mahrajganj	96731.42	53160.56	6069.70	59230.26	36351.01	61.23
51	Mainpuri	86255.34	55983.23	4191.23	60174.46	27738.59	69.76
52	Mathura	105152.63	75651.09	5911.71	81562.80	26381.65	77.57
53	MaunathBhanjan	52983.09	27563.71	5657.89	33221.60	18538.21	62.70
54	Meerut	71928.34	49980.17	10448.40	60428.57	15185.07	84.01
55	Mirzapur	50055.58	24703.63	6083.17	30786.80	18300.46	61.51
56	Moradabad	65617.15	48160.81	10462.85	58623.66	8496.81	89.34
57	Muzaffarnagar	107510.36	70542.00	6353.51	76895.51	30817.63	71.52
58	Pilibhit	126909.71	57893.86	4952.60	62846.46	63373.60	49.52
59	Pratapgarh	128693.44	95709.82	7554.16	103263.98	29417.57	80.24
60	Prayagraj	146102.76	86809.93	15266.54	102076.47	43692.61	69.87
61	Raibareli	112741.13	60950.30	6415.82	67366.13	44222.00	59.75
62	Rampur	71375.19	48930.24	4711.65	53641.89	19063.37	75.15
63	Saharanpur	120495.84	137850.68	6727.41	144578.09	6992.94	119.99
64	Sambhal	41999.33	33338.43	5121.15	38459.58	3596.46	91.57
65	Sant Kabir Nagar	46173.76	23768.03	7443.55	31211.58	11153.35	67.60
66	Sant Ravidas Nagar	33245.66	24716.29	3737.09	28453.38	4356.39	85.59
67	Shahjahanpur	120578.94	65481.86	7660.66	73142.52	45895.79	60.66
68	Shamli	40389.58	40899.32	3229.34	44128.66	2146.67	109.26
69	Shrawasti	47859.41	24258.46	2860.64	27119.10	20139.71	56.66
70	Siddharth Nagar	87259.34	47404.43	6559.72	53964.15	31934.71	61.84
71	Sitapur	196914.28	107818.20	10106.98	117925.18	77037.82	59.89
72	Sonbhadra	23197.19	9190.83	3768.39	12959.22	9460.48	55.87
73	Sultanpur	111858.56	49392.88	5736.97	55129.85	55868.10	49.29
74	Unnao	176693.76	100951.63	7760.66	108712.29	66518.66	61.53
75	Varanasi	48745.91	38544.60	10075.51	48620.11	5198.09	99.74
State Total (ham)		6532079.71	4089209.58	494837.81	4584047.39	2036249.37	70.18
State Total (bcm)		65.32	40.89	4.95	45.84	20.36	70.18

(Source : CGWB & GWDUP)

The observations on above assessment are:

- i. In Resource Assessment - 2017, nine districts namely Agra, Amroha, Firozabad, G.B.Nagar, Ghaziabad, Hapur, Hathras, Sambhal and Shamli are found as highly exploited with stage of groundwater extraction more than 100%. Maximum exploitation of 128% is reported from district Ghaziabad.
- ii. **Groundwater surplus zone :** District **Lakhimpur kheri holds the largest potential of extractable groundwater in the state as 2.24 lakh ham**, while adjacent district Sitapur is the 2nd richest with 1.97 lakh ham extractable groundwater. The other adjacent districts Hardoi, Unnao and Raebareli also holds large potential as 1.71, 1.76 and 1.12 lakh ham respectively. These findings reported from Central U.P. districts located in Lucknow Revenue Division are quite interesting for exploring them as a potential hub of surplus water for future groundwater development through water efficient practices.
- iii. **Areas of Huge Extraction:** From management perspective, another interesting feature of this resource assessment is that **out of total groundwater extraction of 45.84 bcm in the state, 27% (12.69bcm) is reported only from 11 districts namely**

Saharanpur, Bulandshahar, Lakhimpur kheri, Sitapur, Jaunpur, Barabanki, Unnao, Fatehpur, Pratapgarh, Hardoi and Prayagraj, each with quantum of extraction more than one lakh ham/ one bcm, where Saharanpur and Bulandshahar are the top exploiter districts.

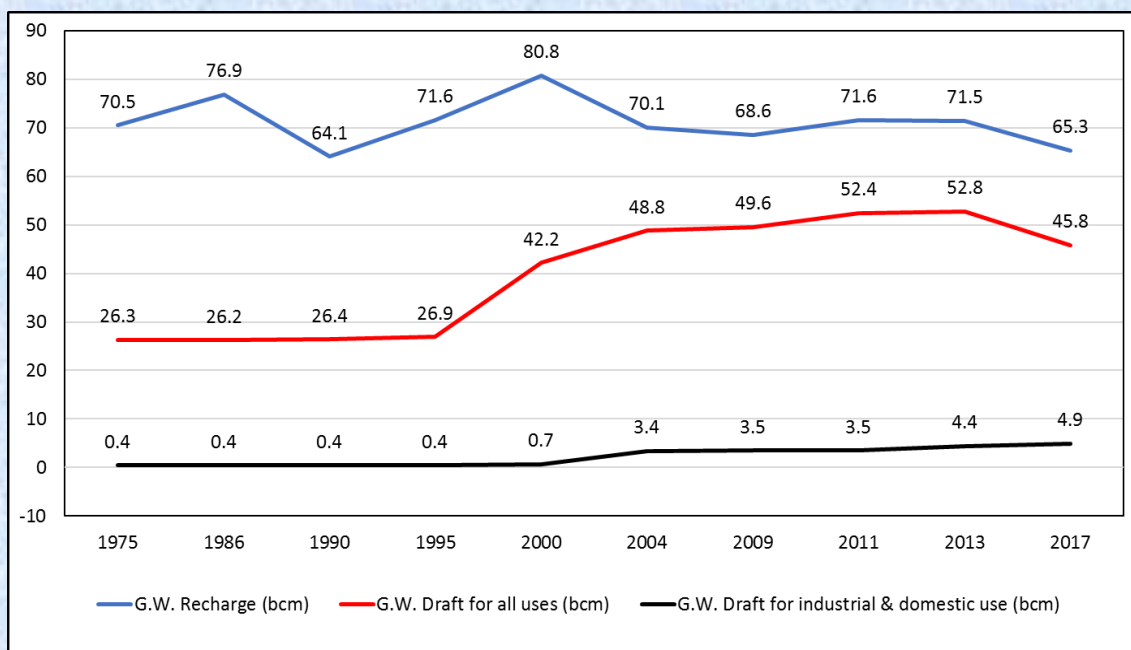
- iv. This situation analysis appears quite interesting and thought provoking and therefore, requires scientific explanation through further data checks and validation.

3.2.2 Significant Changes in Groundwater Resources over Last Four Decades

Groundwater resources data, gathered from last 10 periodic estimations carried out from 1975 upto 2017, have been consolidated and analysed. Overall, significant changes have been observed both in groundwater recharge and draft (extraction) components.

- A marked increase in groundwater extraction, especially during last 2 decades, is found.
- This increased extraction is mainly attributed to extensive development of minor irrigation programme in the state for meeting the growing demand of irrigation supplies in agriculture sector.
- Data further shows that for providing drinking water supplies in urban as well as rural areas, groundwater has again emerged as a main source.

Figure-7 : Changing Pattern of Ground Water Recharge and Extraction



(Data Source : GWDUP)

- The data of past assessments is well presented in the above graph (Figure-7), which clearly shows the changing pattern of groundwater recharge (extractable resource) and extraction (draft) since the year 1975.
- The periodic resource assessment data of recharge and draft components have been shown in this graphical representation.
- The graph depicts how the recharge, abstraction and relative availability of groundwater resources has changed over the years.
- Various factors influencing recharge and draft could be analysed and indentified.

Observations:

- i. It is observed that the recharge, which is mainly influenced by the rainfall, shows a periodic variation of around 10 to 15%. A very clear change has been observed in the recharge component after year 2000, as GEC - 1997 Methodology has been adopted for resource assessment. It can be noticed that the recharge component has decreased sharply from 80.8 bcm in 2000 to 65.32 bcm in 2017, that might be due to significant decline in rainfall during the period.
- ii. The most obvious change is noticed in ground water extraction that has critically increased almost two times since 1995.
- iii. The above graph clearly shows that in 2017 assessment, there is an overall relative reduction in the recharge and abstraction components. Both the annual recharge and the annual extraction have significantly reduced in 2017 assessment by 8.7% and 13.2% respectively, when compared with the respective data of previous assessment for the year 2013.
- iv. One reason for decrease in annual recharge may be due to declining rainfall, but relative reduction of 8.7% in the recharge component also raises a question on the large-scale rainwater harvesting & recharge activities reportedly implemented in the state during past 10-15 years, suggesting that these activities could not deliver any impact on groundwater.
- v. Further, the reduction in groundwater abstraction is contrary to the general perception that uncontrolled abstraction is rising in all the user sectors and as a consequence of that, groundwater levels are also rapidly declining, which is well represented by the monitoring data.
- vi. Both the above **figures of recharge and abstraction in Assessment- 2017 are not corresponding to ground realities and therefore needs proper review.**

- vii. The graph shows, a slight increase of 0.5 bcm in extraction for domestic uses between 2013 and 2017, but in totality this figure is still on the lower side when compared to actual abstraction in domestic sector. Moreover, the groundwater extraction from industrial sector has not been computed in this assessment. This evidently suggests that the extraction figure for domestic and industrial uses shown in the assessment is under estimated, that would obviously impact the stage of groundwater extraction.

3.2.3 Decreasing Availability : Dismal Scenario

The past assessments of groundwater resources markedly indicate that the resource availability is gradually declining over the years due to rising groundwater withdrawals. A comparative picture of net groundwater availability from 1975 to 2017 is evolved on the basis of previous assessments, as given in the Table-17.

Table- 17: Changes in Net Ground Water Availability between 1975--2017

Net Ground Water Availability (bcm)	1975	1986	1990	1995	2000	2004	2009	2011	2013	2017
	44.2	50.7	57.7	44.7	38.6	21.3	19	19.2	18.7	20.36

Observations :

- i. Since 1975, net groundwater availability is reducing continuously as evident from the above table.
- ii. **The future scenario appears quite dismal, as it would be undoubtedly difficult to meet the future sectoral demands from groundwater sources.**
- iii. One most crucial factor for the gradual decrease in the groundwater availability is the deficit in rainfall witnessed over last 20 years, as the rainfall recharge is continuously reducing.
- iv. If the values of Specific Yield, taken in the Resource Assessment-2017, are modified and replaced, as recommended by GEC-2015 Methodology, the reported figure of groundwater availability will go down drastically due to reduction in rainfall recharge.

3.2.4 Categorization of Blocks

As per the Assessment- 2017, all the 820 blocks as well 10 cities, having population more than 10 lakhs are categorized into safe, semi-critical, critical and over-exploited categories. In GEC-2015 methodology, the criteria for categorization of different assessment units are defined and governed by the Stage of Ground Water Extraction. The long-term groundwater level trends for both pre-monsoon and post-monsoon period are not considered for

categorisation in the Resource Assessment- 2017, as this criterion has been dropped in new methodology without giving any scientific logic. On the other hand, the methodology also put a rider by highlighting that the validation of stage of groundwater extraction should be the pre-requisite of resource assessment because assessment based on the stage of ground water extraction has inherent uncertainties. So, the methodology becomes questionable. Therefore, it becomes imperative to validate the stage of groundwater extraction with long term trends of groundwater levels for categorization of blocks/cities. However, the norms and the criteria adopted for assessment -2017 is given in the Table-18.

Table- 18: Norms for Categorization of Assessment Units

Stage of Ground Water Extraction	Category
Less than or upto 70%	Safe
More than 70% up to 90%	Semi- critical
More than 90% up to 100%	Critical
More than 100%	Over-exploited

(Source: CGWB)

Computation of Stage of Extraction:

The stage of groundwater extraction is computed as ratio of groundwater extraction to total extractable resource, as per the following formula-

$$\text{Stage of Groundwater Extraction (\%)} = \frac{\text{Annual Groundwater Extraction}}{\text{Annual Extractable Groundwater Resource}} \times 100$$

Here, extractable groundwater resource denotes recharge from rainfall and other sources, while groundwater extraction is computed by consolidating withdrawals in irrigation, domestic and industrial uses.

Based on the above criteria of categorization, of assessment units (blocks/cities), the district wise list of over-exploited, critical and semi-critical blocks, along with 10 stressed cities of the state, prepared by CGWB and GWDUP, is given in the Table- 19.

Table-19: Over-exploited, Critical and Semi-critical Blocks and Stressed Cities

CATEGORIZATION OF ASSESSMENT UNITS-2017; UTTAR PRADESH							
S. No	District	S. No	Semi-Critical	S. No	Critical	S. No	Over-Exploited
1	Agra	1	Bah	1	Achhnera	1	Barauli Ahir
		2	Jagner	2	Akola	2	Bichpuri
		3	Kheragarh			3	Etmadpur
						4	Fatehabad
						5	Fatehpur Sikri
						6	Khandauli

						7	Saiya
						8	Shamsabad
2	Aligarh-City	1	Chandaus	1	Iglas		
		2	Gangiri				
		3	Jawan				
		4	Khair				
		5	Lodha				
3	AmbedkarNagar	1	Baskhari				
		2	Bhiti				
		3	Jahangirganj				
		4	Jalalpur				
		5	Katehari				
4	Amethi	1	Sangrampur				
5	Amroha	1	Amroha			1	Dhanora
		2	Gangeshwari			2	Gajraula
						3	Hasanpur
						4	Joya
6	Ayodhya	1	Bikapur				
		2	Milkipur				
7	Azamgarh	1	Sathiaon				
8	Baghpat	1	Baraut	1	Baghpat	1	Binauli
		2	Chaprauli			2	Khekra
						3	Pilana
9	Banda	1	Bareru				
		2	Jaspura				
		3	Naraini				
		4	Tindwari				
10	Barabanki	1	Banikodar				
11	Bareilly	1	AlampurZafarabad				
		2	Fatehganj				
		3	RamNagar				
12	Bijnor	1	AakuNehtaur	1	Noorpur	1	Jalilpur
		2	BudhanpurSeohara				
13	Budaun	1	Bisauli	1	Asafpur	1	Ambiapur
		2	Jagat			2	Islamnagar
		3	Mion				
		4	Quadarchowk				
		5	Sahaswan				
		6	Salarpur				
		7	Ujhani				
14	Bulandshahar	1	Anupshahar	1	B.B.Nagar	1	Bulandshahar
		2	ArniaKhurd	2	Khurja	2	Danpur
		3	Jahangirabad	3	Shikarpur	3	Gulaoti
		4	Lakhaoti	4	Unchagaon	4	Sikandrabad
		5	Pahasu			5	Siyana
15	Chitrakoot	1	Manikpur	1	Karwi		
		2	Mau				
		3	Pahari				
		4	RamNagar				
16	Etah	1	Ali ganj	1	Jalesar		
		2	Awagarh				
		3	Jaitara				
		4	Nidholikalan				
		5	Sheetalpur				
17	Farrukhabad	1	Barhpur				
		2	Kamalganj				
		3	Mohammadabad				
		4	Nawabganj				
		5	Shamsabad				
18	Fatehpur	1	Airayan	1	Amauli	1	Bhitora
		2	Bahua				
		3	Dhata				
		4	Haswa				
		5	Hathgaon				
		6	Malwan				
		7	Teliyani				
19	Firozabad	1	Madanpur	1	Araon	1	Firozabad
						2	Khairgarh(Hathwant)
						3	Narkhi
						4	Shikohabad
						5	Tundla
20	G.B.Nagar	1	Dadri	1	Dankaur	1	Bisrakh
						2	Jewar
21	Ghaziabad	1	Muradnagar			1	Bhojpur
						2	Loni
						3	Razapur

22	Ghazipur	1	Barachawar				
		2	Muhammadabad				
		3	Saidpur				
23	Hamirpur	1	Gohand				
		2	Maudaha				
		3	Rath				
		4	Sarila				
		5	Sumerpur				
24	Hapur	1	Dhaulana			1	Grahmukteshwar
						2	Hapur
						3	Simbhaoli
25	Hathras	1	Sadabad	1	Hathras	1	Mursan
		2	Sikandrarao			2	Sahpau
						3	Sasni
26	Jaunpur	1	Barasathi	1	Buxa	1	Badalapur
		2	Dharamapur	2	Muftiganj	2	Karanjakalan
		3	Dobhi			3	Kerakat
		4	Ramnagar			4	Mahrajganj
		5	Rampur			5	Sikarara
						6	Sirkoni
27	Jhansi	1	Babina				
		2	Bangra				
		3	Baragaon				
		4	Mauranipur				
28	Kannauj	1	Chibramau			1	Jalalabad
		2	Gugrapur			2	Talgram
		3	Kannauj				
29	Kanpur Dehat	1	Akbarpur				
		2	Malasa				
		3	Rasoolabad				
		4	SarvanKhera				
30	Kanpur Nagar	1	Bidhnoo	1	Ghatampur	1	Chaubeypur
		2	Bilhaur	2	Sarsaul		
		3	Patara				
		4	Shivrajpur				
31	Kasganj	1	G.Dhundwara	1	Kasganj		
		2	Sahawar				
32	Kaushambi	1	Kara			1	Chail
		2	Manjhanpur			2	MooratGanj
		3	Newada				
		4	Sirathu				
33	Lalitpur	1	Bar				
		2	Birdha				
		3	Jakhaura				
		4	Madaora				
		5	Mehrauni				
		6	Talbehat				
34	Mahoba	1	Charkhari			1	Jaitpur
		2	Kabrai			2	Panwari
35	Mainpuri	1	Jageer			1	Barnahal
		2	Mainpuri				
36	Mathura	1	Farah			1	Baldeo
						2	Nohjhil
						3	Raya
37	Meerut	1	Hastinapur	1	Meerut	1	Kharkhoda
		2	Mawana	2	Parichhatgarh	2	Machhra
		3	Sarurpur			3	Rajpura
38	Mirzapur	1	Sikhar	1	Chanbey		
				2	City		
				3	Kon		
				4	Majhawan		
39	Moradabad	1	Chhijlet	1	BhagatpurTanda		
		2	Dingerpur	2	Bilari		
		3	MundaPandey	3	Dilari		
		4	Moradabad				
40	Muzaffarnagar	1	MuzaffarNagar	1	Charhawal	1	Baghara
		2	Shahpur			2	Budhana
41	Pratapgarh	1	AspurDeosara	1	Mangraura	1	Mandhata
		2	Baba Belkherath	2	Patti	2	PratapgarhSadar
		3	Gaura			3	SandwaChandrika
		4	Lakshmanpur			4	Shivgarh
		5	Lalganj				
		6	RampurSangramgarh	-			
42	Prayagraj	1	Holagarh	1	Bahadurpur	1	Chaka
		2	Mau-Aima	2	Baheria		
		3	Saidabad	3	Dhanupur		

				4	Pratappur		
43	Raibareli	1	Sareni				
44	Rampur	1	Said Nagar			1	Chamraua
		2	Shahabad				
		3	Swar				
		4	Baliakheri				
45	Saharanpur			1	Deoband	1	Gangoh
				2	Muzafarabad	2	Nagal
				3	Nanauta	3	Nakur
				4	Rampur	4	SaduliQudim
						5	Sarsawa
46	Sambhal	1	Junawai	1	Asmoli	1	Bahjoi
				2	Gunnaur	2	Baniakhera
				3	Sambhal	3	Pawansa
47	SantRavidasNagar	1	Abholi	1	Bhadohi		
		2	Aurai	2	Gyanpur		
		3	Deegh				
		4	Suriyawan				
48	District-Shamli	1	ThanaBhawan			1	Kairana
						2	Kandhala
						3	Shamli
						4	Un
49	Sonbhadra	1	Duddhi				
50	Varanasi	1	Baragaon	1	Pindara	1	Araziline
		2	Chiraigaon			2	Harhua
		3	Cholapur				
		4	KashiViddyapeeth				
		5	Sewapuri				
Cities							
				1	Agra-City	1	Aligarh-City
						2	Bareilly-City
						3	Ghaziabad-City
						4	Kanpur-City
						5	Lucknow-City
						6	Meerut-City
						7	Moradabad-City
						8	Prayagraj-City
						9	Varanasi-City
ABSTRACT							
Total No. of Assessed Units			Semi-critical	Critical		Over-Exploited	
830			151	48		91	

Figure - 8: Bar Diagram showing Changing Pattern of Over-exploited Blocks in U.P.

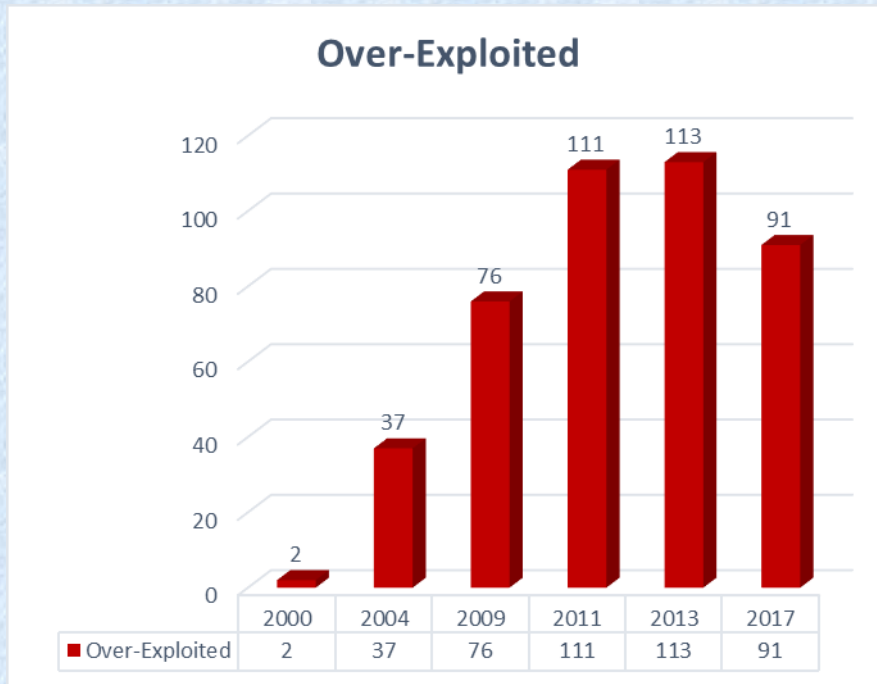


Figure-9: Ground Water Stressed Blocks in U.P.

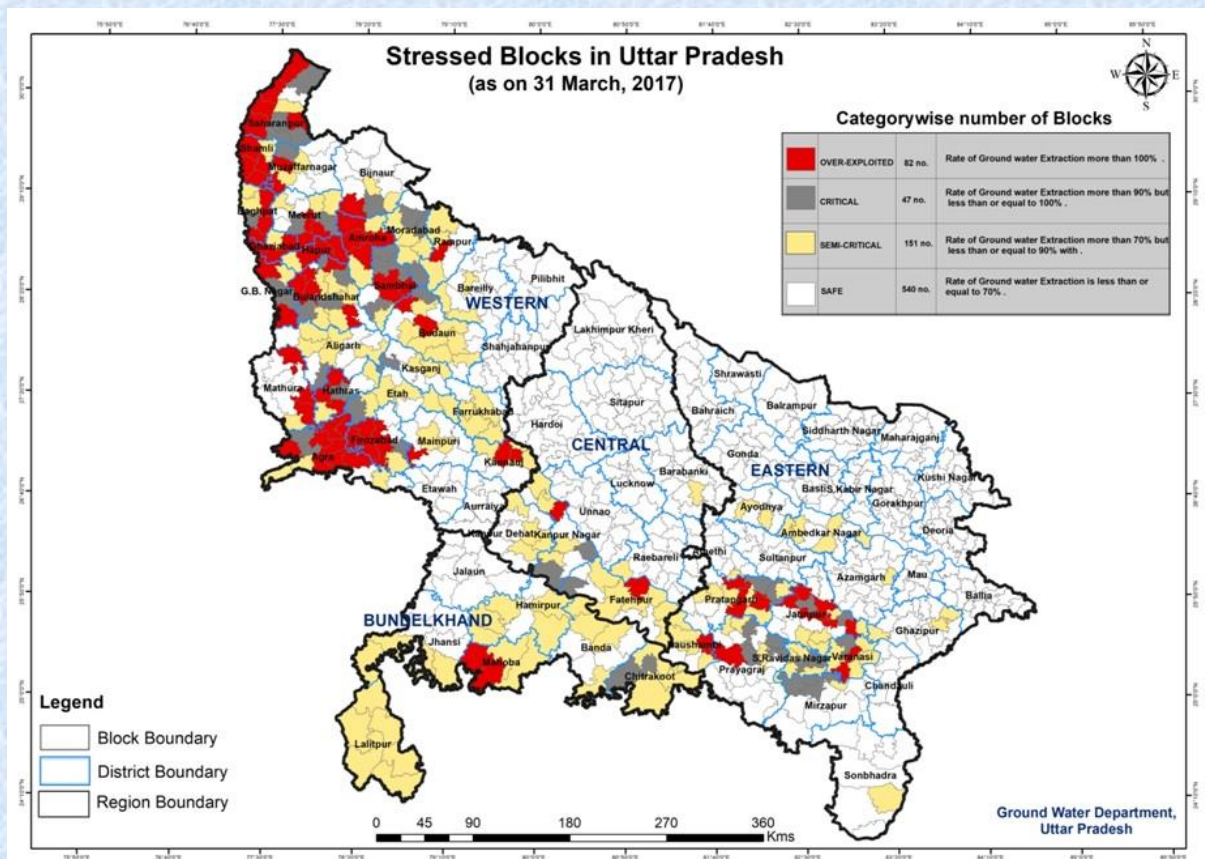


Figure -10: Bar Diagram showing Changing Pattern of Critical Blocks in U.P.

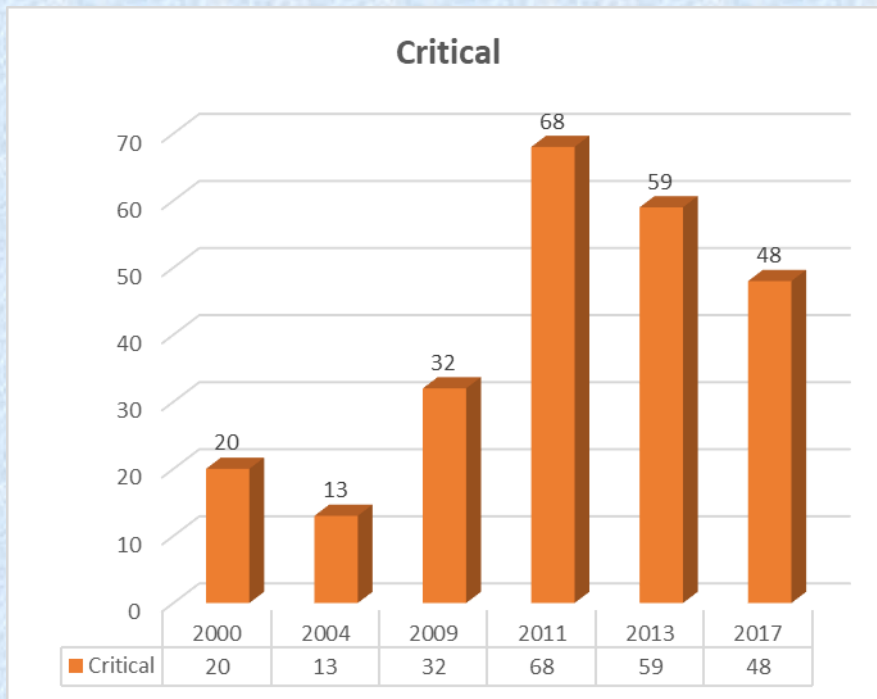


Figure - 11: Bar diagram showing Changing Pattern of Semi-critical Blocks in U.P.

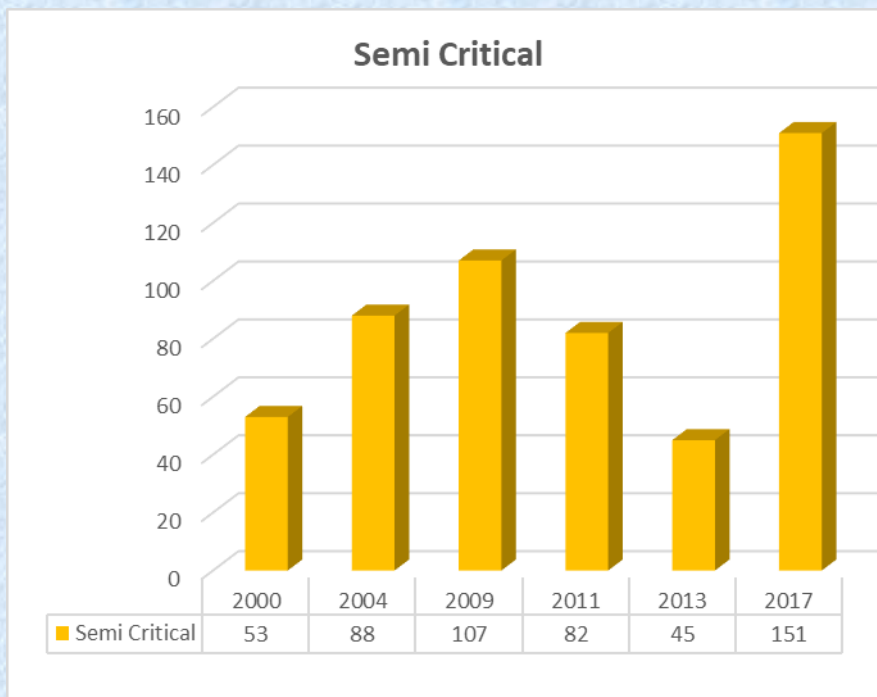


Figure - 12: Bar Diagram showing Changing Pattern of Safe Blocks in U.P.



3.2.5 Increasing Stressed Areas

The impact of indiscriminate extraction of groundwater is visible in the state both in rural and urban areas. The past resource assessments distinctly indicate that the stress on groundwater resources is continuously increasing, which is well reflected by groundwater level decline in various parts of the state.

As per the methodology of Ground Water Estimation Committee, now GEC- 2015, ground water assessment unit (block/city/watershed) is categorised as Safe, Semi-critical, Critical or Over-exploited, based on the Stage of Ground Water Extraction.

It is observed that the total stressed blocks in 2017 assessment when compared with the resource's assessment of the year 2000, the number of over-exploited, critical and semi-critical blocks (termed OCS blocks) has significantly increased from 75 in the year 2000 to almost 4 times i.e., 280 in the year 2017, as shown in the Table- 20 -

Table-20: Comparative Scenario of Different Categories of the Blocks in U.P.

(As per the Periodic Ground Water Resources Assessments)

CATEGORY	BLOCKS FALLING IN DIFFERENT CATEGORIES (nos.)						
	2000	2004	2009	2011	2013	2017	
						Block	Cities
Over-Exploited	2	37	76	111	113	82	9
Critical	20	13	32	68	59	47	1
Semi Critical	53	88	107	82	45	151	
OCS	75	138	215	261	217	280	
Safe	745	682	605	559	603	540	
TOTAL	820	820	820	820	820	820	10

Observations:

A relative decrease is observed in over- exploited and critical blocks between 2013 and 2017, while the number of semi-critical blocks have sharply increased, as depicted in the table. The change may be attributed to reported relative decrease in both recharge and extraction. But, this overall decrease in both recharge and extraction component requires scientific validation.

In 2017 assessment, total 830 assessment units were assessed for dynamic ground water resources availability based on GEC-2015 methodology. It includes 10 cities /urban bodies, where population is more than 10 lakhs.

The above 290 OCS units as per 2017 assessment, including 280 blocks (rural U.P.) and 10 cities, are primarily located in 51 districts of the state. The majority are located in Western U.P., which is known as a major contributor to the food basket of the state.

The above table also shows remarkable variations in different assessments, especially in the number of OCS areas.

The number of over-exploited and semi-critical areas are variably changing, influenced by the pattern of groundwater recharge and extraction, which is mostly non-uniform. This variable pattern of recharge and extraction is primarily dependent on different types of data as well the assumed adhoc norms. However, any change in such data/values may greatly influence the categorization of blocks/cities, hence, reassessment and review of certain parameters and data validation would change the resource overall scenario.

3.2.6 Relative Increase in OCS Areas

An overall increase in over-exploited, critical and semi critical (OCS) areas has been observed in the Assessment-2017 both at national and state level, when compared to the figure's of 2013 assessment. The data, given in the Table-21, depict that in the year 2013 there were 1968 OCS areas in the country, which increased to 2471 in the year 2017 with a rise of 25%, while in Uttar Pradesh, an increase of 33% has been found in OCS areas, which rose from 217 to 290 during the same period.

Table-21: Relative Increase in OCS Areas

Place	Over-exploited, Critical and Semi-critical areas - OCS (nos.)	
	2013	2017
India	1968	2471
Uttar Pradesh	217	290

3.2.7 Distinctive Analysis of Past Assessments - Unchanged status of OE Blocks

The relative analysis of past assessments shows that the status of 74 over-exploited blocks remained unchanged since 2004. A distinctive analysis is made to observe the changes in the pattern of over- exploited blocks over the last five Ground Water Assessments between 2004 and 2017. **The idea of this exercise is to find out whether there is any improvement in the stressed condition of the over-exploited blocks over the years due to implementation of various supply side and demand side interventions and other important policy initiatives and administrative decisions including imposing ban on construction of new irrigation tube wells in these blocks.**

In the Assessment-2017, total 82 blocks are categorised as over-exploited. In the present analysis, out of these 82 blocks, 74 over- exploited blocks are identified, whose category has either not changed or their ground water condition has further deteriorated in corresponding previous assessments of 2004, 2009, 2011, 2013 till the latest assessment of 2017. The categorization of blocks in the Assessment-2017 is taken as a Base line data for the relative analysis of 74 over-exploited blocks located in 27 districts.

A relative overview, showing critical depiction of 74 over-exploited blocks and their categorization status in past assessments, is given in Table-22.

Table- 22: Critical Depiction of Over-exploited Blocks: A Relative Overview
(As per Resource Assessments: 2004, 2009, 2011 ,2013& 2017)

District	Block	Assessment Year				
		2004	2009	2011	2013	2017
Agra	BarauliAhir	OE	OE	OE	OE	OE
	Bitchpuri	SC	OE	OE	OE	OE
	Etmadpur	SC	S	OE	OE	OE
	Fatehabad	SC	S	OE	OE	OE
	Fatehpur Sikri	S	OE	OE	OE	OE
	Khandauli	SC	OE	OE	OE	OE
	Saiyan	S	C	OE	OE	OE
	Shamshabad	OE	OE	OE	OE	OE
Amroha	Dhanora	S	C	OE	OE	OE
	Gajraula	OE	OE	SC	OE	OE
	Hasanpur	OE	OE	S	OE	OE
	Joya	SC	OE	C	OE	OE
Baghpat	Binauli	OE	OE	OE	OE	OE
	Pilana	OE	OE	OE	OE	OE
	Khekra	C	OE	C	C	OE
Bijnor	Jalilpur	OE	SC	OE	OE	OE
Budaun	Ambiapur	OE	OE	OE	OE	OE
	Islamnagar	C	OE	OE	C	OE
Bulandshahar	Gulaothi	SC	C	OE	OE	OE
	Sikandrabad	S	SC	OE	OE	OE
Fatehpur	Bhitaura	S	S	OE	OE	OE
Firozabad	Firozabad	C	OE	OE	OE	OE
	Khairgharh	S	S	OE	OE	OE
	Narkhi	S	OE	OE	OE	OE
	Shikohabad	SC	S	OE	OE	OE
	Tundla	SC	OE	OE	OE	OE
G.B. Nagar	Bisrakh	S	SC	OE	OE	OE
	Jewar	S	OE	OE	OE	OE
Ghaziabad	Bhojpur	S	C	OE	OE	OE
	Loni	SC	OE	OE	OE	OE
	Rajapur	S	S	OE	OE	OE
Hapur	Garhmukteshwar	S	S	OE	OE	OE
	Hapur	SC	SC	OE	OE	OE
	Simbhaoli	S	SC	OE	OE	OE
Hathras	Mursan	S	OE	OE	OE	OE
	Sahpau	OE	OE	SC	OE	OE
	Sasni	OE	OE	OE	OE	OE
Jaunpur	Badalapur	S	C	OE	OE	OE
	Karanjakalan	S	OE	OE	OE	OE
	Kerakat	SC	OE	OE	OE	OE
	Maharajganj	S	C	OE	OE	OE
	Sirkoni	S	OE	OE	OE	OE
Kannauj	Jalalabad	SC	OE	OE	OE	OE
	Talgram	SC	OE	OE	OE	OE
Kaushambi	Chail	SC	OE	OE	OE	OE
	Mooratganj	S	C	OE	OE	OE
Mahoba	Jaitpur	S	OE	OE	OE	OE
	Panwari	S	OE	OE	OE	OE
Mainpuri	Barnahal	SC	OE	OE	OE	OE
Mathura	Baldeo	SC	OE	OE	OE	OE
	Nohjhil	OE	OE	OE	OE	OE
	Raya	SC	OE	OE	OE	OE
Meerut	Kharkhoda	S	OE	C	OE	OE
	Rajpura	S	OE	OE	OE	OE

Muzaffarnagar	Baghara	S	OE	OE	OE	OE
	Budhana	S	OE	OE	OE	OE
Pratapgarh	Mandhata	S	S	OE	OE	OE
	PratapgarhSadar	S	OE	OE	OE	OE
	Sandwa Chandrika	S	C	OE	OE	OE
	Shivgarh	S	C	OE	OE	OE
Prayagraj	Chaka	S	S	OE	OE	OE
Rampur	Chamrauha	OE	OE	OE	OE	OE
Saharanpur	Gangoh	OE	OE	OE	OE	OE
	Nakur	OE	OE	OE	OE	OE
	Nagal	SC	OE	OE	OE	OE
	SaduliQudim	S	S	OE	OE	OE
	Sarsawan	S	OE	OE	OE	OE
Sambhal	Bahjoi	OE	OE	OE	OE	OE
	Baniakhera	S	OE	OE	OE	OE
	Panwasa	SC	OE	OE	OE	OE
Shamli	Kairana	SC	OE	OE	OE	OE
	Kandhala	SC	OE	OE	OE	OE
	Un	OE	OE	OE	OE	OE
Varanasi	Araziline	S	C	OE	OE	OE

(Data Source: CGWB & GWDUP) (OE: **Over-Exploited**; C: Critical, SC: **Semi Critical**; Safe)

Following critical observations are drawn from the above table-

- i. **The situation in 12 blocks is most alarming**, which are categorised as over-exploited in all the five resources assessments. These blocks are BarauliAhir and Shamshabad (district Agra), Binauli and Pilana (district Baghpat), Ambiapur (district Budaun), Sasni (district Hathras), Nohjeel (district Mathura), Chamrauha (district Rampur), Gangoh and Nakur (district Saharanpur), Bahjoi (district Shambhal) and Un (district Shamli), The situation is also very serious in 30 blocks, where the over-exploited category has not changed in last four assessments-2009, 2011, 2013 and 2017.
- ii. In last 3 assessments of 2011, 2013 and 2017, 25 blocks have been continuously categorised as over-exploited, which is also a critical situation.
- iii. In remaining 7 blocks, namely Gajraula, Hasanpur, Joya (district Amroha), Khekra (district Baghpat), Islamnagar (district Budaun), Sahpau (district Hathras) and Kharkhoda (district Meerut), the ground water condition has deteriorated and reached to over-exploited category.
- iv. It is inferred that overall, there is no improvement in the criticality of the situation of overdraft. In some blocks, the situation has greatly deteriorated.

A Crucial Case for Urgency of Restorative Measures -

The above observations on 74 over-exploited blocks suggest that the prevailing situation in these blocks is a crucial issue and urgently requires focused and composite interventions for

the protection, restoration and management of heavily depleted ground water resources in all the blocks, where groundwater conditions have become worse to worst. This is obviously a visible example of Groundwater Mining, an extreme situation of irreversible damage to aquifers.

It is clearly evident from the above observations that all the efforts made over the years for the management and conservation of groundwater resources in these blocks with heavy investments could not give the positive results and rather have failed to provide any respite to heavily depleted aquifers. It now becomes necessary that this situation should be critically reviewed to find out the reasons and the technical shortcomings.

The foremost need is to immediately declare these 74 blocks of the state as the "Hotspots", **as the situation calls for some urgent restorative measures and strong regulatory actions.**

3.3 Basin wise Status of Groundwater Resources in U.P.

Based on the data of resource assessment- 2017, an endeavour has been made to find out the scenario of groundwater resources in the major river basins of the state. The State Water Resources Agency (SWaRA) has delineated the whole state into 08 river basins namely Ganga, Yamuna, Ram Ganga, Gomti, Ghaghra, Gandak, Sone and Rapti.

Basin wise Reallocation of Assessment Units:

Accordingly, an exercise has been done by reallocating all the assessment units within different river basins to get the basin-wise overview of replenishable groundwater recharge, extractable groundwater, gross groundwater extraction and also the stage of extraction.

Though, the basin wise reallocated figures of groundwater resources may be further refined, validated and computed more accurately through GIS technique and data analysis, but this initial exercise gives a broad idea of basin wise scenario of groundwater resources that can be used for the overall planning of groundwater resources specially to determine resource availability and future demands of various user sectors in different river basins.

The basin wise status of groundwater resources, based on the Resource Assessment-2017, is given in the Table-23. However, this exercise needs further refinement.

Table-23: Status of Ground Water Resource in Different River Basins of U.P.

Basin	Replenishable Annual Ground Water Recharge(bcm)	Extractable Ground Water (bcm)	Ground Water Extraction (bcm)	Stage of GW Extraction (%)
Ganga	18.82	17.4	13.14	75.5
Yamuna	16.36	15.5	12.3	79.35
Ram Ganga	5.45	5.12	3.6	70.31
Gomti	10.84	10.05	6.72	66.86
Ghaghra	8.67	8.1	4.73	58.39
Gandak	4.28	4.0	2.22	55.5
Sone	1.10	1.05	0.54	51.43
Rapti	4.40	4.1	2.23	54.39
Total	69.92	65.32	45.84	70.18

(Using the data of Resource Assessment - 2017)

Following are some important observations :-

- i. The basin wise groundwater resources data could be suitably used for river basin planning and assessing future water demands and its allocation for different sectors.
- ii. In three river basin - Ganga, Yamuna and Ram Ganga, covering the major part of the state, **the stage of groundwater extraction has crossed the threshold of safe limit of 70%**. Hence, for any future water resource allocation in these river basins, groundwater resource availability has to be carefully evaluated.
- iii. Since groundwater is depleting fast in major river basins, there is an urgent need to shift groundwater based demands to surface water resources and accordingly future plans should be formulated.

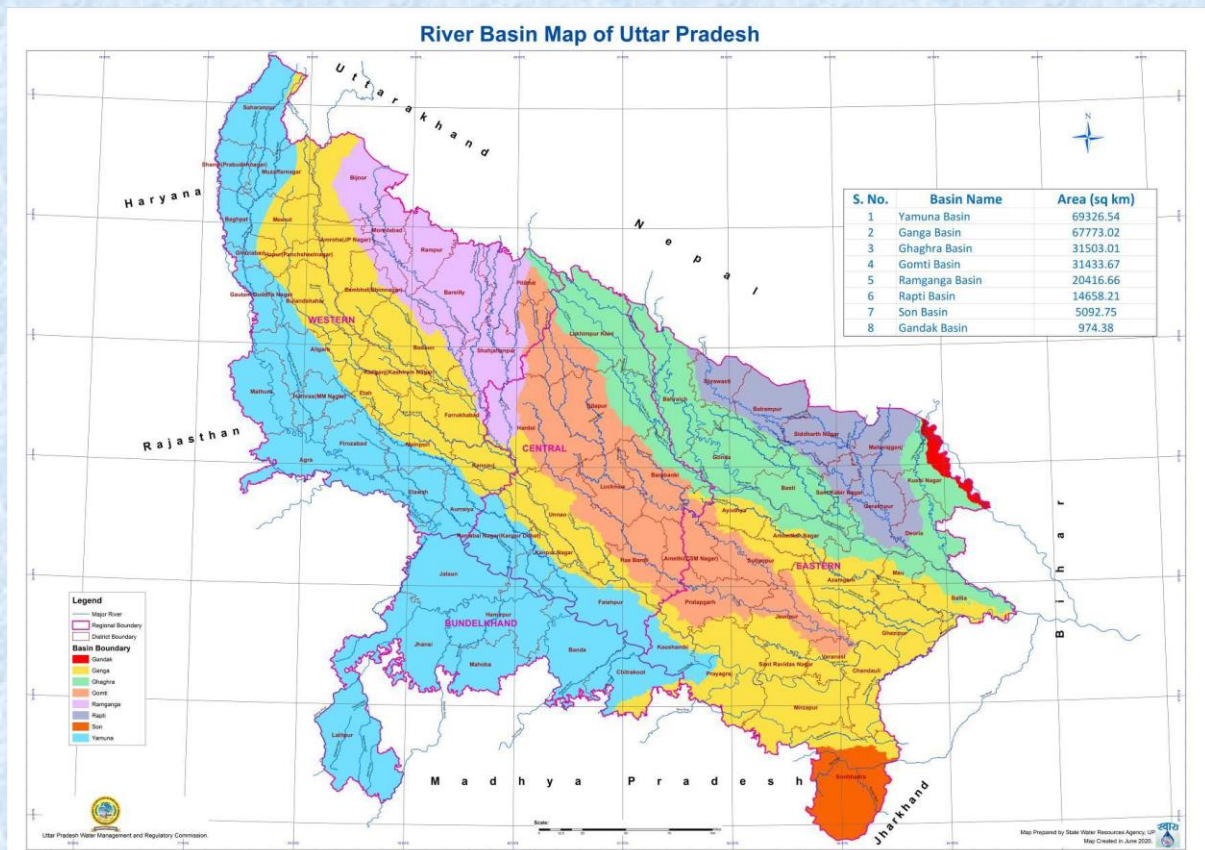
3.3.1 Groundwater Fed Rivers : Reduced E - Flows due to Groundwater Depletion

There are number of rivers in Uttar Pradesh which are groundwater fed, originated from lakes/ wetlands. Groundwater assumes a crucial position in the protection of whole ecosystem as it feeds rivers, wetlands, ponds, but due to continuous groundwater depletion, the natural discharges, as base flow, from groundwater system into the river system has drastically reduced, leading to significant reduction in the environmental flows of such groundwater fed rivers. As a consequence, **the symbiotic relationship between groundwater and the rivers is under threat and the inter connectivity between these two systems has almost reached to a broken state at various places in the state.**

With growing abstraction and resultant decline in groundwater levels all along different river courses of the state, following rivers/tributaries, being groundwater fed, have been found to have either highly reduced flows or they have gradually lost their water flows at places all along the stream course. Some of these rivers have even dried up at various places.

- i. **Gomti river:** The Gomti river, a tributary of Ganga, originates from Gomat Taal (Phullar Lake) at Madhotanda in Pilibhit. Similarly, small tributaries of Gomti river namely Kathina, Bhainsi, Sarayan, Behta, Kalyani, Reth are all ground water fed, originating from local wetlands.
Studies reveal that marked reduction of about 40% in the ecological flows of Gomti river have been witnessed during last three decades.
- ii. **Sai river:** The Sai River, an important tributary of Gomti, originates from a pond at Parsoi village, Hardoi.
- iii. **Varuna river :** TheVaruna river, a tributary of Ganga, also originates from Maelhun lake located at the confluence of Jaunpur, Allahabad and Pratapgarh.
- iv. Similarly, the tributaries of **Saryu**, such as Tedhi, Manorama and other small rivers a namely Pandu, Ishan, Arind, Sengar, Bakulahi are also ground water fed streams, originating from local wetlands/lakes, springs.

Figure- 13: Major River Basins in U.P.



(Source: State Water Resources Agency, UP)

3.4 Status of Groundwater Level Monitoring in Uttar Pradesh

Monitoring and measurement of groundwater levels is the basic mandate of State Ground Water Department to obtain fundamental information and knowledge about groundwater system. The department has established an extensive network of more than 9500 hydrograph stations (piezometers and observation wells) in both rural and urban areas.

In rural areas, groundwater levels are being monitored on hydrograph stations/observation wells since the year 1973. This monitoring network was later extensively strengthened from the year 2006-07 onwards on a concept of one piezometer or observation well in each grid of 5 x 5 km. Under this new plan scheme of the Ground Water Department, **urban areas in the state** have been included for the first time for monitoring of groundwater levels and about 1200 piezometers have been installed, each in a grid of 2 x 2 km.

In rural areas, the manual measurements are taken 4 times in a year, including pre-monsoon and post-monsoon season, while in urban areas, monthly monitoring is done. Whereas, CGWB also monitors and measures groundwater levels separately on a network of 1198 piezometers in the state.

3.4.1 Ground Water Level Measurements in Rural U.P : Decadal Changes

The pre-monsoon data of groundwater level for the year 2009 to 2018 has been analysed by the Ground Water Department block wise to observe the relative decadal changes (rise and fall) in the water level regime, recorded on the hydrograph stations/monitoring wells. The average yearly changes in groundwater levels have been consolidated block wise by the department. The block-wise overall decline in groundwater levels has been grouped in different ranges for computing yearly decline. **The yearly decline of 20 cm or more is considered as a critical/significant decline.** It has been found that 287 blocks are affected with decline of more than 20 cm. per year, where 100 blocks depict a highly critical yearly decline of 50 cm or more. Overall, 572 blocks are affected with yearly decline from one cm and more up to 60 cm and even beyond.

However, 248 blocks are reported to have either stable or rising trend, but these blocks are required to **be evaluated for assessing and integrating the problem of subsurface water-logging, which is already reported from different areas.** If the blocks are affected with very shallow water levels or are water logged (water level between 0-3 mbgl), then the **separate management interventions would be required to overcome the problem of**

waterlogging. The affected blocks with groundwater level decline of different ranges in pre-monsoon season are grouped as shown in the Table- 24.

**Table- 24: Blocks Affected with Yearly Groundwater Level Decline
(Based on pre monsoon ground water level data year 2009-2018)**

Yearly Decline Range (cm.)	Blocks Affected(nos.)
1 - 10	147
>10 - 20	138
>20 - 30	83
>30 - 40	59
>40 - 50	45
>50 - 60	23
> 60	77
No Decline	248
Total	820

(Source : Ground Water Department U.P.)

3.5 Scenario: Urban Groundwater

Rapid, unplanned and indiscriminate growth of urban settlements in total disregard to the ecology and environment (carrying capacity) has almost reached to a state of ‘hydrological poverty’ in most of the urban areas of Uttar Pradesh, where availability of fresh groundwater, is fast depleting. It is a matter of concern that urbanization modifies underlying groundwater system induced by land use changes that often leads to adverse hydrogeological situation, quality deterioration, geotechnical and even socio-economic effects, which may hamper resource sustainability.

Uttar Pradesh is also urbanizing at a faster pace and so the urban drinking water demand is also escalating with increasing population. Since surface water supplies are inadequate in the state to meet the rising demand of drinking water in majority of the cities, groundwater has gradually become the main contributor and backbone of urban water supplies. Hence, there is a tremendous pressure on groundwater resources to fulfil the drinking water and other requirements of most of the cities. Impact of increasing urbanization is mostly reflected as indiscriminate pumping, lowering of groundwater table, less recharge to groundwater regime, high storm water run-off from the urban catchments as well as the water quality deteriorations.

Sustainable groundwater management calls for “the management of groundwater in such a manner that meets the needs of eco-system and mankind in present generations without compromising the need of future generation”. But it is becoming difficult to achieve this goal of groundwater sustainability in urban areas of the state, where unscientific and unregulated groundwater extraction has reached to unsustainable levels.

The situation has emerged as very critical and in absence of effective management plans and interventions, the impact could be extremely grave for the urban environment of the state. There are all probabilities that due to extensive depletion, urban aquifers in major cities might have reached to an irreversible stage. Lucknow, Ghaziabad and Meerut have almost crossed the critical stage of extraction.

Currently, **there are no authentic studies on groundwater resources of urban areas of the state.** Hence, the imperative need is to undertake extensive studies for assessing the resource availability, the recharging capacities of depleted urban aquifers as well the magnitude of exploitation, so that some useful plans and strategies could be evolved for suitably managing, protecting and conserving these highly stressed aquifers in order to make them sustainable (at least to a desirable stage) for groundwater uses.

3.5.1 Increasing Urban Population and Rising Drinking Water Demand

The urbanisation trend suggests that Rural-Urban migration and demographic increase in the cities will further raise the respective percentage of urban population. Presently, groundwater sources are being mostly tapped even to undesirable levels to meet the rising demand of the urban populace. Thus, continuous withdrawal will surely put long term geo-environmental implications on the urban groundwater reserves. The darker side of rapid and haphazard urbanisation is that the urban land is either being paved or concretized due to intensive construction activities, which, consequently, is hampering the natural percolation of rainwater. Moreover, the vertical urban growth is aggravating groundwater crisis in most of the cities -

- i. **The vertical urban growth and the high-rise constructions have added fuel to groundwater crisis** by increasing the resource demand in extreme proportion on every such piece of land.
- ii. In most of the urban areas, it is visible that the land, which once used to cater only small water needs because of a small dwelling unit with usually 5-6 persons, is now bearing **the burden of huge resource demands due to high rise constructions with large number of inhabitants.** Obviously, the water supply demand would have

automatically grown in multiple proportion on the same piece of land and in case the source of supply is groundwater, the resource extraction would have undoubtedly crossed the threshold, reaching to a stage of adverse situations.

- iii. Uttar Pradesh is the most populated state in the country, where its 22.27 % population as per 2011 census, reside in cities and towns. The table-25 serves as a pointer to the fact that the size of urban population is continuously rising putting simultaneous pressure on water supplies.

Table-25: Growth of Urban Population in Uttar Pradesh

Census Year	Population(million)		Percentage urbanization total population
	Total	Urban	
1971	88.34	12.38	14.02
1981	110.86	19.90	17.95
1991	139.10	27.60	19.84
2001	166.05	34.50	20.77
2011	199.8	44.50	22.27

3.5.2 Mushrooming of Tube wells in Cities

In most of the urban centres, majority of the drinking water demand is being met through tube wells & hand pumps, making groundwater a predominant source for urban water supplies. Groundwater is also meeting the rising demands of infrastructural and industrial sectors. This reflects the vital position groundwater has attained in urban water system, in spite of the fact that this resource is rapidly depleting within a transforming concrete urban environment, which is largely affecting the natural replenishment of groundwater regime.

There are overall 653 major and small townships in Uttar Pradesh and majority are located on alluvial aquifers of Indo-Gangetic plain. Due to easy availability and access to exploit groundwater, private tube well construction activity is going on unchecked. As a result, **private tube wells and submersible borings have mushroomed in housing colonies and multi-storey buildings.** Therefore, the exploitation and use of groundwater in big cities, has tremendously increased.

The reason for this increasing over-dependency on groundwater to meet the overall urban water demand may be the shortage in municipal water supplies, which are not adequate to meet the ever-growing demands of domestic as well as industrial/ infrastructural and other allied sectors. Secondly, **there has been no regulation to ban tube well constructions, which is going on indiscriminately**

Groundwater Dependent Municipal Supplies:

As per the U.P. Jal Nigam data (September, 2018), groundwater based municipal supply is almost providing 75-80% of total drinking water demand in majority of the 653 urban bodies. Based on the data, groundwater dependent supply in urban areas of the state is estimated as 5975mld (million litres per day), which is annually assessed as 2180 billion litres (2.18 bcm). The data also reveal that out of 653 urban bodies, 622 are entirely dependent on groundwater, while only 31 mostly depends on surface water-based supplies.

3.5.3 Declining Urban Groundwater Levels

The monitoring of hydrological regime by measuring groundwater levels is of utmost importance for scientific and planned management of the resource, particularly in urban segments, where indirect measurement techniques could not be suitably applied due to concrete land use.

Almost all the prominent urban centres like Lucknow, Kanpur, Meerut, Ghaziabad, Agra, Noida and Varanasi are severely affected with groundwater depletion. In these areas, **groundwater is likely to become a critically scarce resource, as the mining of static groundwater reserves has already started**, which is a serious concern and needs urgent attention.

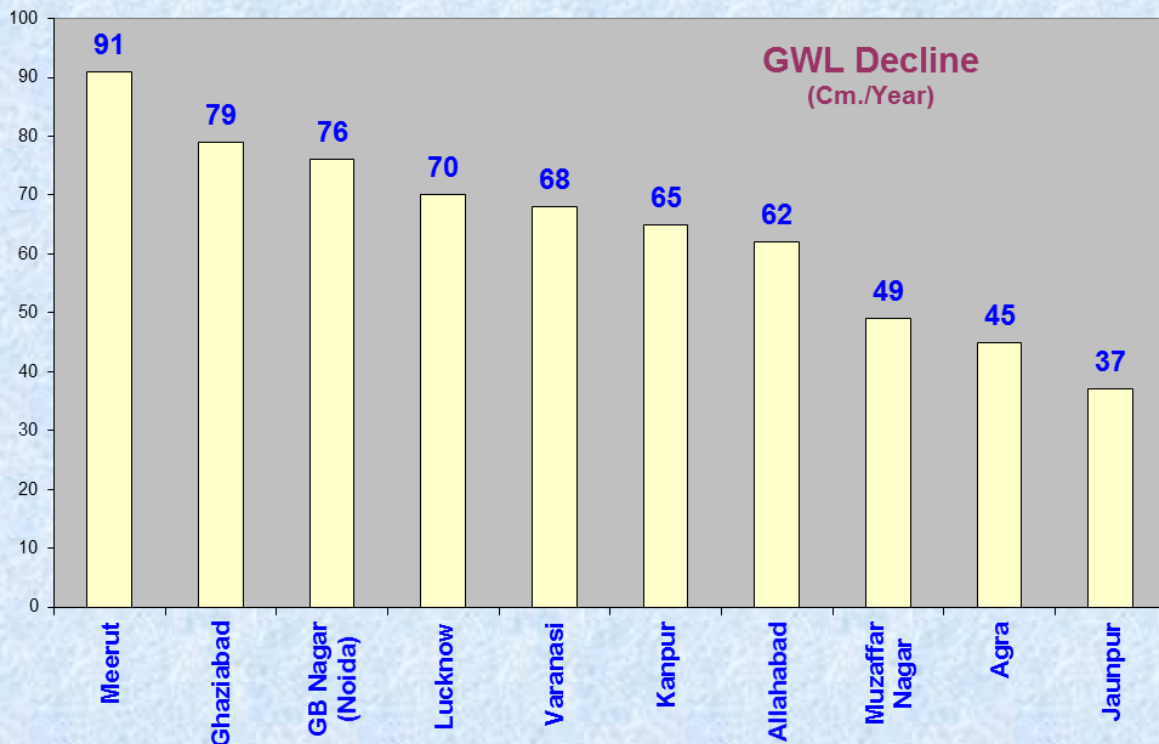
Urban Monitoring of groundwater levels:

Monitoring of groundwater levels in urban areas of the state has been started from 2006-07 on a close network of piezometers. Based on the groundwater level data of last 10-12 years measured on the piezometers of urban areas, an alarming condition of rapidly declining water levels has been observed in most of the cities.

In about 20 prominent cities, groundwater situation has become extremely critical. The groundwater level is declining at a rate of 0.5 m to more than 1.0 m every year in the cities like Lucknow, Kanpur, Agra, Aligarh, Meerut, G.B.Nagar and Ghaziabad.

Based on the past trend of groundwater level decline in some cities, a pictorial view of average yearly decline for prominent cities is given in Figure-14.

Figure- 14 : Average Yearly Decline in Major Cities



(The above graphical depiction is fast changing with continuous extensive decline)

This is obvious that with rapid decline of groundwater levels and excessive depletion of aquifers, it would more likely be difficult to ensure future drinking water supplies in most of the urban areas.

It is most likely expected that urban annual water supply would reach to a level of about 2500 billion litres or more by the year 2025, apart from the demands of other sectors rising at a faster pace.

3.5.4 Groundwater Depletion in Major Cities

Based on groundwater level monitoring data, marked depletion in groundwater regime of major cities (Kanpur Nagar, Agra, Lucknow, Ghaziabad, G.B. Nagar and Aligarh) has been observed between post monsoon 2006 and 2015.

Due to continuous decline, the zone of groundwater level beyond the depth of 25 m has expanded to larger areas in respective cities within a span of 10 years, highlighting the criticality of the situation. Groundwater depletion is shown in the Table-26

Table-26: Groundwater Depletion in Major Cities

City	Zone of depth to groundwater level more than 25 m (sq. km)	
	2006 (post monsoon)	2015 (post monsoon)
Kanpur Nagar	16.6	52.9
Agra	29.2	113.82
Lucknow	30.2	127
Ghaziabad	0.4	38.76
G.B. Nagar	Nil	71.45
Aligarh	Nil	28.21

- i. Apart from these cities, in Varanasi city also, zone of groundwater level between >15 to 25m has increased from 36.84 sq. km in post monsoon 2006 to 87.95 sq. km in post monsoon season of 2015.
- ii. The overall trend of groundwater level decline in most of the cities is worsening and groundwater levels are going down to much deeper depths.

3.5.5 Groundwater Assessment in Urban Areas

For the first time, the provision is included in GEC- 2015 methodology for the assessment of groundwater resources in urban areas, However, **this arrangement is made only on very initial adhoc norms, so findings may not be conclusive.** In the Assessment of 2017, ten cities, having population more than 10 lakhs, were selected. These are Lucknow, Kanpur Nagar, Aligarh, Agra, Ghaziabad, Meerut, Moradabad, Bareilly, Prayagraj and Varanasi.

Methodology of GEC-2015 states that since urban areas are concrete jungle, 30% of the rainfall infiltration factor is considered for the estimation of recharge component as an adhoc arrangement till field studies are done. For recharge from other sources, seepages from pipe line leakages, sewage, flash floods are recommended for estimation purpose. Methodology also states that in absence of any well census, the available extraction data will not be accurate. Therefore, it is recommended in the methodology to take the difference of the actual demand and the supply by surface water sources as the withdrawal from groundwater resources.

But, in Uttar Pradesh, the urban water supply scenario is entirely different, **where surface water sources are not available in most of the urban bodies and majority of supplies are dependent on groundwater.** Therefore, in urban groundwater resource assessment, extraction data of water supply tube wells should have been used, but that has been

overlooked in this estimation exercise. Hence, the estimation in 10 cities needs review and reassessment. The city wise resource estimation, as per GEC-2015, is given in the Table- 27.

Table-27: Urban Ground Water Resource Estimation 2017

S No.	City	Area (sq. km)	Extractable Ground Water Resource (ham)	Ground water Extraction (ham)	Stage of Extraction (%)	Decline/Year (cm)		Category
						Pre-mon.	Post-mon.	
1	Agra	141.97	1402	1309	93	43	13	C
2	Aligarh	68.5	1040	3572	343	32	39	OE
3	Bareilly	134	2197	5111	232	15	52	OE
4	Ghaziabad	210	3461	9115	263	97	110	OE
5	Kanpur Nagar	278	4212	4311	102	51	47	OE
6	Lucknow	340	5451	9656	177	44	54	OE
7	Meerut	141	2136	5262	246	27	47	OE
8	Moradabad	91	1759	5414	308	27	34	OE
9	Prayagraj	82	2562	3810	149	Rising	Rising	OE
10	Varanasi	68	2445	4913	201	15	Rising	OE

(OE: Over-exploited; C: Critical)

In the above Assessment-2017, only Agra city is classified as critical, while remaining nine cities are categorised as over-exploited.

Some key observations are as follows-

- i. For all the cities, natural discharges are assumed as 10% of total annual groundwater recharge for calculating the extractable groundwater resources.
- ii. The quantum of annual extraction is reported highest from Lucknow as 9656 ham, means 264 million litres per day, but this figure is underestimated when the data of Lucknow Jal Sansthan's tube well based supply is compared.
- iii. The stage of groundwater extraction is estimated highest in Aligarh city as 343%, while the lowest stage of extraction of 93% is computed in Agra city.
- iv. **Need to review Recharge from other sources:** In the assessment of annual groundwater recharge in these cities, **the quantum of recharge from other sources is found extremely high when compared to the recharge from annual rainfall.** Lowest rainfall recharge is assessed in Varanasi city as only 16%, while the maximum rainfall recharge is reported as 44% from Bareilly city. This shows that in all the 10 cities, the recharge component assumed from the other sources is distinctly very high.

The recharge component computed from other sources like **seepages from pipe line leakages, sewage leakages, flash floods does not appear valid**, as these sources as suggested in the methodology, are rather more hypothetical and impractical in urban context without only support data from field. Therefore, for the resource assessment reliability, the component of recharge from other sources, as recommended in the methodology, needs to be critically reviewed with field validation.

- v. The Prayagraj city is categorized as over-exploited, but it is interesting that groundwater level is not declining in both pre & post monsoon seasons. Similarly, in the over - exploited Varanasi city also, post monsoon water level shows no decline, while pre monsoon level depicts a decline of only 15cm/year, which is less than the threshold of yearly decline of 20 cm. **The categorisation of both the cities needs clarification in light of GEC-2015 methodology**, because when water levels are not showing any decline, how these cities can be categorised as over- exploited.
- vi. The above observations clearly suggest that the results of this Assessment-2017 along with the norms taken for estimation would remain questionable as various figures are contradictory & not correct. Therefore, it would be appropriate that the findings of this assessment should only be considered for any management intervention after reframing the norms with field validation and reassessment.

The municipal water supply data shows that except Agra city remaining nine cities are predominantly dependent on tube well based supply and there is a marked difference in the figure of groundwater extraction reported in the municipal water supply data and the Assessment report-2017. An overview of municipal water supply and reported extraction in the assessment report is depicted in the Table - 28.

Table- 28: Tube well based supplies in Major Cities

City	Municipal Water Supply		Resource Assessment-2017
	Tube well (no)	Ground Water extraction (mld)	Ground Water Extraction (mld)
Aligarh	109	125	98
Bareilly	65	125	140
Ghaziabad	151	180	249
Kanpur Nagar	159	166	118
Lucknow	630	390	265
Meerut	155	257	144
Moradabad	80	165	148
Prayagraj	242	208	109
Varanasi	135	135	134
Agra	NR	NR	36

(Source: Municipal supply data: UP Jal Nigam, September, 2018) (NR: Not reported)

The above table depicts-

- i. It is revealed that the figures of groundwater extraction computed for 10 cities in the resource assessment - 2017 do not correspond with the respective figures reported in municipal water supply data.
- ii. In Aligarh, Kanpur Nagar, Lucknow, Meerut, Moradabad, Prayagraj cities, the groundwater extraction for municipal supplies is much more than the extraction reported in the Assessment - 2017.
- iii. In Bareilly and Ghaziabad cities, the extraction for municipal water supplies is relatively less than that reported in Assessment-2017.
- iv. In Agra city, tube well based supply is not reported. Here water supplies are being augmented from surface water sources and there is also a deficit in overall supply. More than 7600 India Mark Hand Pumps are also used in Agra city. There is also a proposal for construction of 693 tube wells in Agra city to meet the deficit in water supply. However, as per the monitoring data, Agra city is witnessing significant decline. So, Agra city needs clarity on the water supply issue

3.5.6 Groundwater in Lucknow city: A Case Study

Lucknow city, resting on a rich alluvial aquifer system of Central Ganga Plain, is a glaring example of 'Hydrogeological Stress', where pressure on groundwater for augmenting drinking water supplies has increased manifold and this has resulted into continuous and excessive withdrawal of groundwater. In the capital city, river Gomti has been the main source for drinking water supplies, but with growing urbanization and rising population, the dependence of municipal water supplies on groundwater has increased manifold, making it a predominant source to meet the city's escalated water supply demand. Jal Sansthan's data shows that the water supply tube wells have significantly increased from 45 in 1975 to 630 in 2019, showing a rise of 15 times in the number of tube wells (Table-29). This rise in tube wells has accelerated extensive exploitation of groundwater.

Table-29: Growing Tube wells, Reducing Yields, Increasing Extraction in Lucknow City

Year	1975	1985	2005	2009	2019
Growing Tube wells (nos.)	45	70	300	490	630
Reducing Yields (LPM)	< -----1500-1200 ----- 1100-600 ----->				
Increasing withdrawals (MLD)	50	70	190	300	356

(Source: Sinha R.S.)

As per the present estimates, 45 to 50% of municipal water supplies in the city are dependent on groundwater. Besides meeting the drinking water demand, groundwater is also being largely exploited to meet the ever-increasing demands of housing, institutional, infrastructural, industrial, commercial, horticulture and other sectors operating in this capital city of the state.

Lucknow Jal Sansthan manages the municipal water supplies in the city and further to augment and maintain the supplies, **the city is divided into 8 water supply zones**. Apart from tube well based supply to meet the city's drinking water demand, about 400 mld (million litre per day) of water supply is being provided by three water works.

Aishbagh water works is the oldest, which gets raw water from the Gomti river for the water supply. The second is Balaganj water works, which also takes water from the river Gomti, while the third water works gets the water from Kathauta Jheel located in Gomtinagar, which in turn gets water from Sharda Sahayak canal. In water supply zone 1 to 4 and 6 & 7, water supplies are augmented from both the Gomti/Kathauta Jheel and the tubewells, while water supply zone 5 & 8 as well as Vikas Nagar area are totally tube well fed.

The zone-wise and source-wise supply status of Lucknow city is given in the Table-30.

Table- 30
Zone-wise and Source-wise Water Supply Status in Lucknow City

Water Supply Zone	Source-wise Water Supply		
	Surface Water		Ground Water
	Supply from Gomti River	Tube well (nos.)	Tube well supply (mld)
	/KathautaJheel(mld)		
Zone-1	60	65	38
Zone-2	110	55	32
Zone-3	40	122	68
Zone-4	35	85	46
Zone-5	-	60	35
Zone-6	110	48	28
Zone-7	45	56	32
Zone-8	-	114	62
Vikasnagar	-	25	15
Total	400	630	356

(Source: Lucknow Jal Sansthan)

□ Depleting Groundwater

During the last 02 decades, since the demand of groundwater has increased in multiple proportion, there has been large scale exploitation of this resource almost in the entire city. This has led to **widespread depletion of aquifers in the city beyond critical levels from where the situation reversal appears quite challenging.**

- i. The monitoring of groundwater levels in Lucknow city since 2006 has provided clear evidence of continuous groundwater level decline in different parts of city.
- ii. The data shows that groundwater levels are declining rapidly reaching to deeper depths. This has resulted in decrease of tube well yield and also the widespread drying up of wells/tube wells.
- iii. For the larger part of the city, groundwater levels are mostly declining at an average rate of 70 cm to 1.0 m per year and even more. The prominent affected localities are Mahanagar, Aliganj, Gomti Nagar, Indiranagar, Chowk, New Hyderabad, Lalbagh, Cantonment, Hazratganj, Alambagh, Vrindavan colony alongwith other parts of the city.
- iv. **Tube well yield reduced:** It has been observed that due to heavy groundwater depletion, the tube well yields have also reduced significantly from 1200 litres/minute to about 600 litres/minute or even less in a span of 20-30 years, as shown in the Table- 25.
- v. This has happened mainly because of the decreased aquifer storage capacity as well as drying up of aquifers, which is caused by continuous exploitation over a period of time.

□ Piezometers to Monitor Groundwater Level

Ground Water Department, in the year 2006, has established a network of piezometers in the entire city, under the Urban groundwater level monitoring programme. The urban piezometers are being monitored monthly.

Under the World Bank Project, some of the piezometers have been installed with automatic monitoring system of Digital Water level Recorders for daily monitoring of groundwater levels.

Table- 31: Decline in Groundwater Level in Lucknow City (Source: GWDUP)

Decline in Ground Water Levels in Lucknow City (Some Locations)					
Sl No	Location of Piezometer	Ground Water Level (mbgl)		Decline (m) Pre 2006 - Pre 2019	
		Pre 2006	Pre 2019	Total	Per Year
1	Mahanagar, Post Office	24.5	39.1	14.6	1.12
2	Faizulahganj	8.93	29.71	20.78	1.6
3	Remote Sensing Application Center, Kursi Rd	15.1	26.06	10.96	0.84
4	LDA Lal Bagh	30.29	40.43	10.14	0.78
5	Naubasta	26.06	35.82	9.76	0.75
6	Victoria Park, Chowk	18.19	27.75	9.56	0.73
7	Airport, Amausi	14.85	20.38	5.53	0.42
		Pre 2014	Pre 2019	Pre 2014 - Pre 2019	
1	Gomti Nagar, Viram Khand	19.7	27.8	8.1	1.62
2	Indira Nagar	26.15	35.25	9.1	1.82
3	Walmi, Vrindavan Colony	14.2	22.4	8.2	1.64

The groundwater levels in pre-monsoon 2006 and 2019 are compared for some locations as given in the Table-31. The comparative data shows a huge decline of 20.78 m at Faizulahganj, with an average yearly decline of 1.6 m within a period of 13 years. This is followed by another major decline of 14.6 m at Mahanagar post-office with an annual declining rate of 1.12 m. At Lalbagh, Naubasta, Chowk, Kursi road also, groundwater levels are going down at a faster pace. Even at Amausi Airport, the annual decline is quite significant.

No positive outcome of Recharge project:

The other scenario of groundwater level decline from Gomti Nagar and Indiranagar is of much concern, because **a mega project of artificial recharge has been executed in about 70 parks of these localities during 2010-12** for the purpose of improving and arresting groundwater depletion, but the monitoring data from the piezometers installed at these locations for the Impact Assessment depict rather more alarming picture. The digitally measured water level data of piezometers at two locations of Indiranagar and Gomitnagar is quite noticeable, where huge decline of 9.1 m and 8.1 m has been recorded respectively in a period of 5 years from pre-monsoon 2014 to pre-monsoon, 2019. The average yearly decline is also quite high, which is found as 1.82 m and 1.62 m respectively at both these locations.

This suggests that there is no positive impact as such of this mega artificial recharge project executed in these areas.

Concerns

Most of the city area is paved and concretised and apart from large scale exploitation, there is continuous deficit in monsoon rainfall especially during the last 2 decades. This situation has hampered natural groundwater percolation, thereby aggravating groundwater depletion in the city.

As per the IMD data, average annual rainfall recorded between 2011-2018 for district Lucknow is 733 mm against normal rainfall of 963 mm, showing an annual average deficit of about 24% in the rainfall.

Main reasons for groundwater crisis in Lucknow city are attributed to-

- i. Granularity of aquifers is moderate, mostly **dominated by fine sand, which holds low yield and reduced recharge capacity.** Hence, the resource potential of aquifers is also moderate.
- ii. Natural recharging is not happening due to concrete urban sprawl, impacting the replenishment of aquifers.
- iii. Indiscriminate extraction of groundwater in excess of the resource potential through huge number of tube wells and borings has caused the aquifer deterioration by large scale groundwater mining.
- iv. The main concern is to get back sustainability of the top aquifers (< 100 mbgl), which have almost gone dry and now, we have started exploiting the future reserves from Static groundwater resource, occurring beyond the depth of 150-200m or more.
- v. **Consequently, a 'Trough' has developed within the city, with multiple local depressions, and that has become a potential risk to the sustainability of Lucknow's eco-system.**
- vi. Since **groundwater resource is not visible and the overall situation is gradually worsening in the city, any possible threat to geo-environment domain with likely events of land subsidence/cracks cannot be overlooked.** This is well discussed in the succeeding text with more scientific facts and reasons.
- vii. **Salinity in deeper groundwater :** Studies have pointed out that at various places across the city including Raj Bhawan area, deeper extraction may encounter poor quality (saline) water, as granular zones with marginally deteriorated/poor quality water are encountered at depths. This is also an area to be looked at seriously for ensuring future potable supplies in this state's capital city.

□ Groundwater Extraction- A Tentative Assessment

At present, there is no scientific methodology available to assess the quantum of groundwater abstraction in urban centres. **The measurement of groundwater levels is the only tool to find out and visualize the impact of large-scale extraction and that can be ascertained by evaluating declining trends of water levels.** The decrease in yield of tube wells can also indicate the trend of extraction. The piezometers/monitoring stations, installed in Lucknow city, are the only devices presently available to monitor groundwater levels and to assess and analyse the extent of groundwater depletion.

Since there is no official system and scientific mechanism for periodic estimation of groundwater withdrawals in urban areas, an endeavour has been made to determine Groundwater Extraction/drawls within the Lucknow city by consolidating the data gathered from the different users and available field data, which is summarised in the Table- 32.

In the present exercise, the preliminary data on groundwater extraction is analysed and figured out as 1391 mld and, that is indicative of very high groundwater withdrawals. This is an extremely critical situation for the Lucknow city as the analysed figure of groundwater abstraction is almost four times of what is being presented by Jal Sansthan or CGWB.

As per the tentative estimate, it is found that in one sq. km area of the city, on an average about 3.2 million or 32 lakh litre of groundwater is being extracted every day, and this unabated and uncontrolled pumping might jeopardize city's geo-environment.

The following tabulated data indicate that out of the total expected extraction of 1391 mld, only 356 mld is extracted by water supply tube wells as per the data of Jal Sansthan, while the rest of the abstraction, about 1035 mld, is from other sources, which have never been recognised as potential sources of groundwater exploitation.

The findings of above preliminary assessment are, surely, an eye opening for the organisations responsible for groundwater management. This is quite an alarming situation that groundwater depletion in Lucknow city has crossed unsustainable levels, but still complete well census has not yet been attempted for the realistic assessment of groundwater extraction. This is irony that despite critical urban scenarios, no scientific mechanism/arrangement is yet developed for well censuses and to measure and monitor groundwater abstraction in urban areas of the state.

Table- 32: Tentative Groundwater Extraction in Lucknow City by Different Users

Institution/Activities	Tube wells (nos.)	Tentative Ground Water Extraction (mld)
Lucknow Jal Sansthan	630	356
Railways & Govt. Establishments (Central & State) *	380	145
Multistoried Flats/Apartments, private residential colonies. *	930	315
Commercial establishments, Hotels, Hospital, Malls. *	260	130
Tankers, Bottling Units, Water Parks, Swimming pools *	----	38
Industries *with MSMEs	----	178
Construction Activities. *	----	24
Recreation Grounds, Public Parks, Gardens, Horticulture	----	10
Submersible Domestic Borings *	1.5 Lakh or more	195
(*These estimates are based on survey and consolidation)		Total: 1391 mld

(Source: Sinha, R.S., 2019)

Methodology adopted:

The figures of tube wells and respective groundwater withdrawals given in the above table are assumed on the basis of pattern of growth of housing, institutional, infrastructural and commercial sectors and also the prevailing pattern of water usage within the city limits. To arrive at the above assessment, data and related information about borings and tube wells were collected from drillers, builders, bottling units/tankers, government & private establishments and all the data was then consolidated and analysed to broadly estimate the overall abstraction in Lucknow city.

However, the given figures require further validation and refinement through sector wise extensive and dedicated door to door surveys and well-census to come-out with a well-documented data on groundwater extraction.

Observation: It has been found that in multi storied residential complexes, for every two high rise towers, on an average one tube wells is usually constructed for augmenting in-house water supply and this is a clear pointer of massive extraction in Lucknow city, where countless multi storeyed residences/colonies have been constructed, which are continuously sucking huge quantity of groundwater. Similarly, most of government and private

establishment and their housing facilities are having own tube well based supply system, which are pumping groundwater indiscriminately.

Impact:

The impact of this extraction of high magnitude, as tentatively analysed, is clearly visible on groundwater levels of Lucknow city, which have been heavily depleted all across the city and are continuously going down beyond the unsustainable depths. Further, the significant drop in tubewell yield also validates the current state of excessive groundwater withdrawals in the city.

Ground Water Auditing:

A Special study for Sustainable Groundwater Management and Ground Water Auditing in Stressed urban area of Lucknow city under the World Bank Project, UPWSRP-2, is undertaken in the year 2019 by the Ground Water Department with an objective to find out the quantum of groundwater extraction and pattern of its usage in different user sectors located in the city. The consultancy study was awarded to TERI (The Energy and Resources Institute). It has been proposed in the consultancy **to undertake sample size of 50-60 thousand questionnaire-based surveys in the entire city, covering domestic borings, government tube wells, commercial borings and tube wells in residential complexes/flats, multi storied buildings, hotels, malls, hospitals, institutional establishments, industries and other users**, to analyse and assess ground water situation and current extraction and usage pattern. In Lucknow city, there are about 6.5 lakhs dwelling units, besides huge number of different establishments in all the sectors as stated above and majority of them are dependent on groundwater resources.

This consultancy study involves a multi task approach and therefore, it should have come out with focussed findings on the situation of groundwater withdrawal and pattern of usage in all the user sectors in the city.

The Executive Summary of the Project Study - Key Findings:

i) TERI has recently released the Executive Summary of the consultancy study, which reveal that central parts of city have very high levels of groundwater abstraction, assessed as 200 mld with average abstraction as >1750 cum/day/sqkm, while in other part of city covering west and south Lucknow, area around Kathauta jheel, peripheral area in north and

area towards south-east of Saheed path, current groundwater abstraction is about 150 mld with average withdrawal between 1050 - 1470 cum/day/sqm.

ii) The findings suggest that the current gross extraction in Lucknow city is only 350 mld. But, this figure, reported by TERI, is under estimated and it is not matching with ground situation of groundwater withdrawals as tabulated above. Even the zone wise findings of TERI do not correspond with the tube well pumping data and the surface water supplies in Jal Sansthan's water supply zones.

iii) Overall, critical state of groundwater depletion in Lucknow city, including the pattern of groundwater consumption and groundwater quality aspects, are not adequately reflected in the study report.

iv) It is suggested to refine and strengthen the study report with scientific field inputs from the experts and stakeholders for a useful and implementable document towards restoration of extensively depleted aquifers of this capital city.

Critical Observations on Groundwater Depletion:

- i. In 1970's, the pre-monsoon depth to water table in Lucknow city was less than 10 mbgl (below ground level) for the most part, which was **even shallower along the flood plain of Gomti river.**
- ii. With continuous large-scale withdrawals, groundwater table has depleted widely beyond the depth of 20 mbgl and even it has crossed much deeper levels i.e., 30 mbgl or more in some areas, including Lalbagh, Cantonment, HAL, Indiranagar, Alambagh, Jail Road, Puraniya.
- iii. A comparative study of groundwater depletion data shows that groundwater zone of 8-15 mbgl was covering 132 sq. km area of the city in pre-monsoon, 2006, but within a span of 10 years i.e., in pre-monsoon, 2015, this zone has reduced to 63.6 sqkm, while deeper groundwater zone of 25-35 mbgl has relatively increased from 62.5 to 101.4 sqkm. in the same corresponding period, because groundwater levels have gone much deeper during this period.
- iv. Likewise, the zone beyond 35 mbgl has also expanded from 2.9 to 34.3 sq.km between 2006-2015, i.e., more than 10 times. It is anticipated that currently, these deeper groundwater zones might have been expanding / increasing further to more critical levels, due to continuous and unabated drawl / mining of deeper groundwater sources.

- v. **Classic example :** Aminabad, a densely populated area, is located in central part of the city, where an open well, having a total depth of 24 mbgl and situated within the premises of police station, was selected by the CGWB for water level measurements in the year 1976. The initial groundwater level was measured as 6.72 mbgl, which recorded continuous decline and later had dried-up in the 2001. Some of the measured values of groundwater levels in this monitoring well at different time period are -

Changing Groundwater Level in Aminabad Area

1976	1988	1999	2001
6.72 m	10.35 m	21.60 m	23.70 m

- vi. **Reversal seems difficult:**

The above data reveal that with continuous indiscriminate extraction, groundwater levels are rapidly going down much deeper to almost unsustainable level and it appears difficult to be get back the original water levels, **unless some strong and mega policy interventions are implemented and translated on the ground.** However, if the extraction is reduced heavily at least by 40% or more, the current trend of groundwater level decline could be arrested and with continued efforts, some significant improvement may be achieved.

- vii. **Critical state - lost 2800 billion litre of groundwater :**

The scenario is certainly very alarming. The **data analysis suggests that the granular zones of dynamic/top aquifers are expected to have lost some 2800 billion litre of ground water during the last 10-12 years.** This situation, more likely, appears to be an irreversible loss to groundwater resources of Lucknow city.

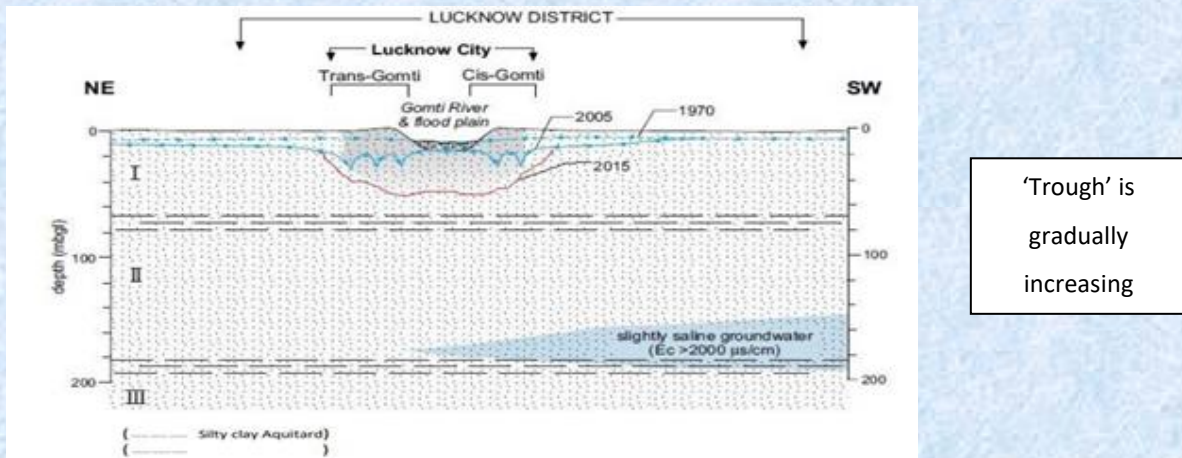
❑ Gomti lost Seepage/Inflows from Groundwater

Gomti is a groundwater fed river (Gaining stream), but during the last 3-4 decades due to excessive exploitation in the Gomti basin, groundwater levels have gone down drastically and this has impacted natural inflows of groundwater to river Gomti.

Studies reveal that the stream flows (e-flows) of Gomti have reduced appreciably by at least 35-40% over the years, because the river is not receiving inflows from groundwater resource, which has extensively depleted.

The river has almost dried-up at many places all along its course from Pilibhit to Jaunpur. The groundwater depletion is very much visible along the Gomti watershed in Lucknow city, which is well depicted in the following sectional view (Figure- 11).

Figure-11: Ground Water Trough in Lucknow City



Alarming facts

a) Groundwater Trough due to rapid depletion

"Groundwater Trough" has developed within the Lucknow city and as a result, interaction and inter connectivity between river Gomti and groundwater regime has broken as depicted in figure - 11. The data suggest that multiple small troughs have gradually developed in and around Lalbagh/Hazratganj, Cantonment, Jail road, Vrindavan colony, Alambagh, Aliganj, Mahanagar, Indiranagar areas of the city, which indicate a potential environmental risk.

b) Drying up of granular zone: Probable Risk of Land Cracks

- i. There is a possible threat that such situations along with changes in lithological characteristic may lead to events like land-subsidence/cracks.
- ii. A groundwater study (Trivedi, B.B., 2009) revealed that due to drying up of the groundwater resources and subsequent depletion of aquifers, loss of elasticity in the dried-up granular zone would have occurred, followed by drying up of the succeeding clay layer. Such clay layers in due course of time are likely to become plastic.
- iii. The study has pointed out that the prevailing elasticity on account of both the surface tension and the adhesive forces between formation grains and water molecules has almost vanished. The plasticity is expected to be more at locations underlying relatively thicker and also more finer clays. By virtue of finer grains, the inter grain

distance has become very less, which led to increase in the plastic character of clay layers. As a result, **heavy rains would increase the weight i.e., the pressure of rainwater in the intermediate zone of aeration leading to probabilities of surface cracks**, because the elastic change in volume of formation would become negligible and it may lead to cracking of layer.

Impact of Roof Top Rain Water Harvesting in Lucknow city

Installation of Roof Top rain water harvesting and recharge system in government and private buildings has been mandated in the year 2001 and subsequently various directions have been issued by the Housing and Urban Planning Department from time to time.

As per available information, roof top recharging structures are reported to have been installed in more than 250 government buildings (both old and new) and number of new private buildings (constructed on plot size of 300 sq. m or more) as well as in residential complexes and multi-storeyed buildings located in Lucknow city, The impact of these initiatives on groundwater resources is not yet determined, despite putting piezometers in the premises of various recharge sites. Since no mechanism has been evolved so far, in spite of very specific guidelines and executive provisions for monitoring, enforcement and impact assessment of roof top rain water harvesting structures, techno-economic benefit of these recharge systems on groundwater resources of this capital city has not been assessed, despite making huge investments on the installation of roof top rain water harvesting and recharge structures, especially on government buildings.

- i. **The impact of various efforts made both at the level of government and private stakeholders, establishments, is nowhere visible on groundwater levels of the city, which are continuously depleting. The current rate of decline is also not showing any improvement.**
- ii. **Monitoring Recharge Mounds:** When rain water gets recharged into groundwater through sub surface artificial measures, a Recharge Mound is normally formed during recharging process, which should be monitored to find the impact efficiency of the recharge structure. But this important impact monitoring method is not being used.
- iii. **Lack of Maintenance:** Due to lack of regular maintenance, a large number of recharge structures, mainly installed on government buildings, are reportedly not properly functional. Therefore, the utility of such structures should be evaluated and usefulness of other water conservation measures should be explored.

Lucknow city - categorized as Over exploited

CGWB has carried out Ground Water Resource Assessment-2017 in 10 prominent cities of Uttar Pradesh including Lucknow, as discussed in the previous text.

This is the first exercise conducted for urban groundwater resource estimation. In this assessment, Lucknow city has been categorized as ‘over exploited’ with stage of groundwater extraction reported as 177%. This **figure clearly reflects that the static ground water reserves of Lucknow city are under heavy exploitation**. This is an extreme situation reflecting mining of the future reserves of groundwater. The principle of sustainable groundwater management does not permit to withdraw this static reserve unless some policy is framed and regulated and therefore, only dynamic/replenishable resource should be extracted for the long-term security of groundwater resource.

However, the reported figure of extraction needs reassessment as only 264 mld of ground water extraction is taken in the assessment which is relatively quite less than the reported withdrawal by Lucknow Jal Sansthan. The actual extraction, as already discussed above, is expected to be around 1400 mld. It suggests that in case the current unregulated practice of groundwater pumping/mining is not stopped, the recovery of groundwater resources will never be possible and further any environmental crisis will be inevitable.

Lucknow city: Various Assessed Groundwater Extraction (mld)

Lucknow Jal Sansthan	CGWB	Analysis based Assessment	TERI/GWD, UP
356	264	1391	350

Need to identify groundwater usages

Lucknow city is divided into a network of eight water supply zones with Vikas Nagar as independent supply region, but the pattern of groundwater extraction and its usages are different in all water supply zones. Beside drinking water supplies, all supply zones are also abstracting and using ground water for commercial, industrial, infrastructural and other activities. It becomes important to determine the realistic quantum of groundwater abstraction and identify the pattern of its usages in all the major user sectors.

Therefore, a well-thought and meaningful plan for groundwater management of the over-exploited Lucknow city through strong policy actions/interventions with effective reduction in groundwater extraction is urgently needed for implementation to overcome the prevailing crisis of groundwater depletion.

CHAPTER- 4

GROUNDWATER CONTAMINATION

- AN OVERALL SCENARIO

The quality scenario of groundwater resources in the state of Uttar Pradesh has significantly changed over the last 2–3 decades. The findings of various quality studies reveal that critical situations related to groundwater quality and pollution hazards are emerging very fast in different parts of the state, which were once known as safe groundwater areas.

4.1 Quality Scenario

Lakhs of hand pumps and tube wells have been installed all over the state to provide safe & potable water supplies for various uses. The quality reports have shown that the groundwater supplies are now at the risk of contamination. The reports have indicated that the groundwater quality in several areas has deteriorated to alarming levels and as a result the human health is now exposed to critical diseases like fluorosis, arsenicosis, heavy metal related toxicity, gastro-intentional problem and others health issues.

India Mark-II Handpumps, tube wells and piped water supply schemes mostly cater the drinking water needs of rural and urban habitations in the state. Under the “National Drinking Water Mission”, large scale groundwater quality assessment of India Mark II Handpumps has been taken-up in the past in different parts of the state. Studies for groundwater quality assessment have also been taken-up in different areas of the state by different agencies and institutions. These studies indicate that the dynamic shallow groundwater in different parts is variously affected with different quality hazards, but the magnitude of groundwater pollution, however, varies from area to area.

4.2 Concerns

The chemical quality of groundwater determines and affects its suitability for different uses. Natural chemical reactions between water and the sediments/ rock, it flows through, add dissolved substances and compound to the water and in the process its quality gets impacted. Manmade/anthropogenic contaminants on the surface can also percolate into groundwater sources and affect its quality.

Important issues related to quality concerns are summarised as follows-

- i. **Source of Pollution:** The sources of groundwater contamination in the state are numerous and of diverse origin that include point and non-point (dispersed) sources. Contamination from point sources is extremely variable with distance and depth and is difficult to characterize from a regional perspective. Likewise, contamination from non-point sources is relatively local and varies with depth. While natural chemicals like arsenic, fluoride, iron are associated with geological formations.
- ii. It is also pertinent to mention that in a reported poor-quality area, all the handpumps/ borewells might not yield contaminated groundwater, as it would depend upon the vulnerability of aquifer system and in-situ mobilization of pollutants. For example, in a village if any handpump is yielding high fluoride water, the nearby handpump may give good water quality without fluoride toxicity. This is mainly observed in those areas where the cause of groundwater pollution is natural/geogenic and therefore, requires extensive quality mapping.
- iii. **Genesis:** The studies have also pointed out that the chemical contaminants affecting the quality of ground water in various parts of the state may be of anthropogenic or geogenic origin. However, the scientific genesis of various contaminants is not yet established
- iv. **Physical manifestation of Pollutants:** Various groundwater contaminants affect human health even to larger extent in the form of different diseases. It is important that in quality affected areas, the physical manifestation of pollutants impacting health of the local inhabitants need to be find out.

4.3 Existing Quality Monitoring Arrangements in the State

U.P. Jal Nigam

For drinking water quality assessment, UP Jal Nigam (UPJN) has been given the responsibility to monitor and analyse groundwater source for drinking water quality parameters, including TDS, nitrate, iron, arsenic, fluoride under National Drinking Water Mission. A dedicated project to analyse and map the sources, including 28 lakh India Mark II handpumps, was already completed in 2016 in co-ordination with Water and Sanitation Support Organisation (WSSO). Under its normal programme, UPJN also carries out groundwater quality assessment for water supply tube wells and handpumps. UNICEF has also supported in the past various quality analysis programmes of UPJN. For water sample analysis, regional and state level quality labs have also been established in UPJN as in-house

facilities. So far, UPJN has massive groundwater quality data, which requires to be consolidated on district level GIS platform

Central Ground Water Board

Central Ground Water Board has been involved with regular groundwater quality testing. The Board normally collects pre-monsoon and post-monsoon samples from its 1198 piezometers and analysis various physio-chemical parameters as well heavy metals. The Board is also having a dedicated team with NABL Chemical Lab for taking up water quality monitoring in quality affected. CGWB also takes up various quality assessment programmes every year.

Ground Water Department, U.P.

The department is carrying out a dedicated scheme for Ground Water Quality Monitoring and Mapping in the state, since 2014. Under the scheme, **600 monitoring stations are selected in 50 districts for periodic analysis of physio-chemical parameters and heavy metals during both pre and post monsoon periods.** The original idea of this dedicated scheme is to evolve a scientific assessment of any qualitative changes at selected locations over a period of time.

However, from 2019-20, the mandate of scheme has been modified for ground water quality checking in selected river basins along with previously decided programme of quality assessment on 600 monitoring stations. The department is also having 3 chemical labs for quality testing, which are working since the year 1980.

Observation : These organisations, including UP Pollution Control Board and Central Pollution Control Board have, so far, generated huge data on ground water quality, which need to be integrated for overall quality mapping and management in the state and also to support and provide technical inputs to the Regulatory authority of the state.

4.4 Key Findings

The high levels/ excessive concentration of the various quality parameters in groundwater like TDS, Fluoride, Iron, Nitrate have been found in critical levels beyond the permissible limit prescribed by BIS and WHO, affecting groundwater quality in several parts of the state. The generalised quality situations, based on variously reported quality data from different parts of the state, are summarised below-

- i. The saline ground water tract extending from Ghaziabad-Agra up to Pratapgarh-Jaunpur is a well-known poor-quality area. This is a naturally occurring/ geogenic problem.
- ii. Excess of Fluoride concentration in groundwater of district Unnao has affected the local people with “Fluorosis”, which causes skeletal deformity or tooth decay. This fluoride pollution is also reported from other districts like Agra, Firozabad, Raibareli, Lucknow, Sonbhadra, Prayagraj and other districts.
- iii. Prevalence of heavy metals like chromium, cadmium, manganese, lead, nickel have also been reported in groundwater from the industrial places like Kanpur, Ghaziabad, Moradabad and various other districts.
- iv. Besides the chemical pollution of groundwater, bacteriological/ faecal contamination in groundwater resources, a much larger and serious issue for human health, is also reported from rural & urban centres. In a UNICEF survey conducted few years back and in a recent study of UP Jal Nigam, bacteriological contamination in groundwater has been widely reported from the state.
- v. In an analysis of ground water samples from submersible borings in Gomti Nagar area of Lucknow city conducted by IITR under the Artificial Recharge Project in Parks of the city during 2011-12, Faecal coliforms have been reported beyond permissible limit. This finding contradicts the general perception that groundwater of domestic borings is safe.

4.4.1 Urban Quality Issues

In almost all the towns of the state, unscientific urbanisation practices have led to the contamination of groundwater.

- i. Studies have revealed that the soak pits, inadequate sewerage system, unplanned landfills and the waste dumping sites as well as the industrial activities might be continuously causing pollution of groundwater, as pollutants like nitrate, iron, manganese, zinc, coliforms from such areas gradually percolate down into the aquifers and subsequently contaminate groundwater, which render it unfit for human consumption.
- ii. In urban areas of the state, more than 20,000 metric ton of municipal solid waste is generated every day, but majority of the towns do not have scientifically safe

dumping sites. The solid waste is being dumped in unplanned and unscientific way in and around urban areas and due to gradual leaching of contaminants, groundwater sources are getting polluted.

- iii. The damaged and non-functional sewer lines and unscientifically developed soak pits also pose high risk of groundwater pollution, because the civic facilities for sewage disposal in the urban settlements are not adequate. Out the total 653 townships, only 10-15% urban bodies are said to have sewerage system, but that too is either partial or not adequate. Remaining towns do not have any proper system and soak pits are being largely used, which are potential source for groundwater pollution.

4.4.2 Arsenic Contamination in Uttar Pradesh

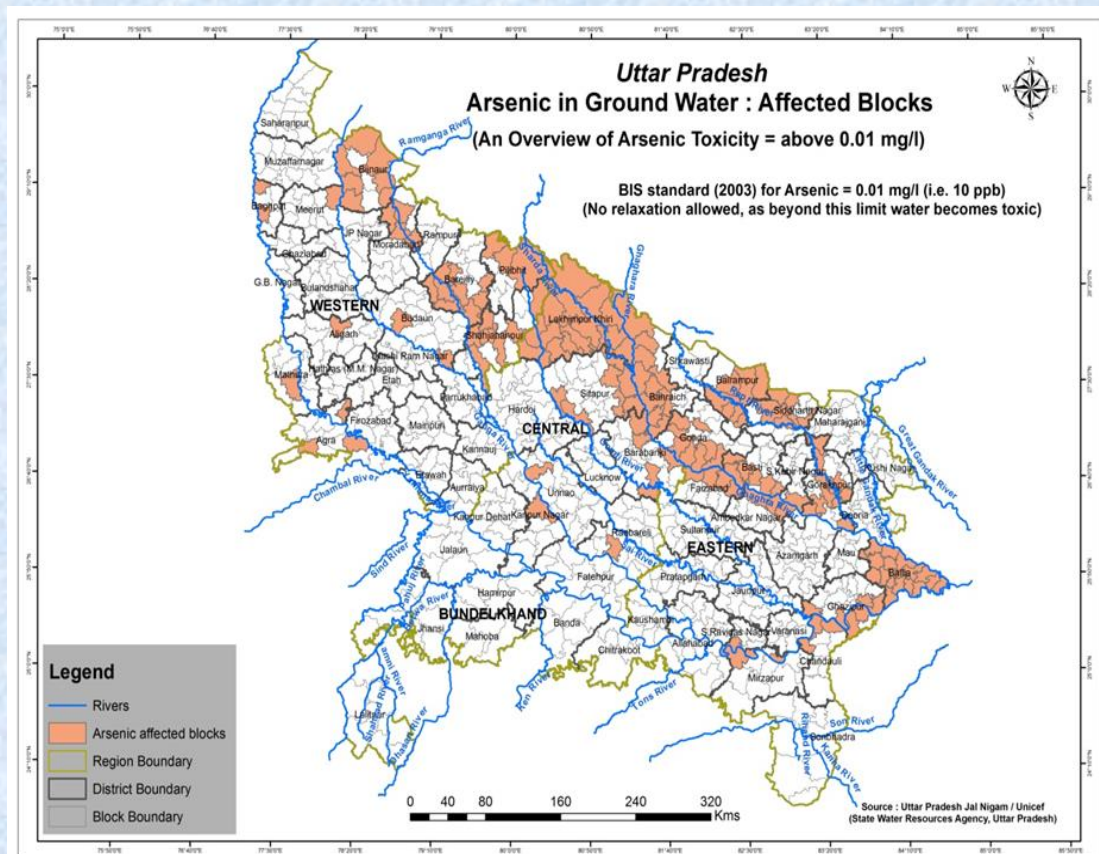
Various findings reveal that the Arsenic toxicity in groundwater, mostly geogenic (natural), is emerging very fast in different parts of the state.

- i. It was in the year 2003, when the issue of Arsenic contamination in groundwater was first reported from district Ballia, where High Arsenic levels were found in a study of the Jadhavpur University and the Centre of Science and Environment. These findings were largely publicized and were well taken by the government and subsequently, the UP Jal Nigam has initiated the work of Arsenic testing in different parts of Ganga and Ghaghra basins, which were considered as probable vulnerable areas.
- ii. Presently, the quality analysis for Arsenic in groundwater is being carried out by different agencies under different schemes, but the complete and consolidated scenario for the whole state is yet to emerge.
- iii. The primary analysis of available data of UNICEF, U.P. Jal Nigam and CGWB reveal that the harmful concentration of Arsenic in groundwater, exceeding 0.01 mg/l (permissible limit: B.I.S.), is critically spread over 144 blocks of the state located in 28 districts. In subsequent studies by different organizations, more new districts are identified as Arsenic affected.
- iv. Cause of Arsenic in groundwater is geogenic, and several mechanisms have, so far, been suggested for the release and occurrence of Arsenic in groundwater, but the actual mechanism and the cause is yet to be ascertained scientifically.
- v. **Two types of Arsenic**, Tetravalent and Pentavalent, are reported to be occurring in groundwater sources of different districts. Both the types of arsenic contamination

have distinctive features and variable toxicity. But, any such study to find out the type of arsenic **is not being done by the concerned departments.**

This aspect, therefore, needs detailed analysis and scientific explanation. Separate mitigation measures would also be required. More studies on Arsenic toxicity are suggested to be taken up in different districts of the state.

Figure-12: Arsenic Affected Blocks in U.P.



(Source: Sinha R.S., 2010-11)

- vi. To have an overview of Arsenic toxicity in various districts of the state, an attempt is made for the first time in the year 2010-11 at the State Water Resources Agency (SWaRA) by consolidating all the related data and information available with different organization and institutions. The report 'An Overview of Arsenic Toxicity in Uttar Pradesh' highlights the extent of the problems being faced by the state in 28 districts. Important findings of the study are-
 - a. Different GIS scenarios of Arsenic contamination in groundwater clearly indicate the alarming situation and the magnitude of the problem.

- b. Ballia & Lakhimpur Kheri are the worst affected districts with Arsenic in groundwater. Reoti, Belhari & Dubhand blocks in Ballia district and block Nighasan, Isanagar, Palia & Ramia Behar of district Lakhimpur Kheri are found to be the '**most critically contaminated areas**'.
- c. Ghaghra basin is the most severely Arsenic affected region of the state. The contamination levels of Arsenic in groundwater of Bahraich has made this district a 'HOTSPOT' for Arsenic toxicity.
- d. In UPJN-UNICEF study, groundwater sources in 20 districts, including Allahabad (now Prayagraj), G.B. Nagar, Ghaziabad, Bulandshahar, Rampur were found free from Arsenic contamination. But, with new quality monitoring and more testing, extension of Arsenic contamination is expanding in other districts, as discussed in following text.
- e. On the urban side, Arsenic in some groundwater samples has been reported from Kanpur Nagar, Lucknow and Shuklaganj area of Unnao. Shuklaganj has been found the 'most critically contaminated area' for the Arsenic. In the affected areas, Arsenic pollution is largely reported from shallow aquifers.

4.4.3 Heavy Metal pollution in Uttar Pradesh

The quality studies conducted by CGWB indicate presence of high levels of different heavy metals in groundwater of different areas. Some of the findings are briefed below-

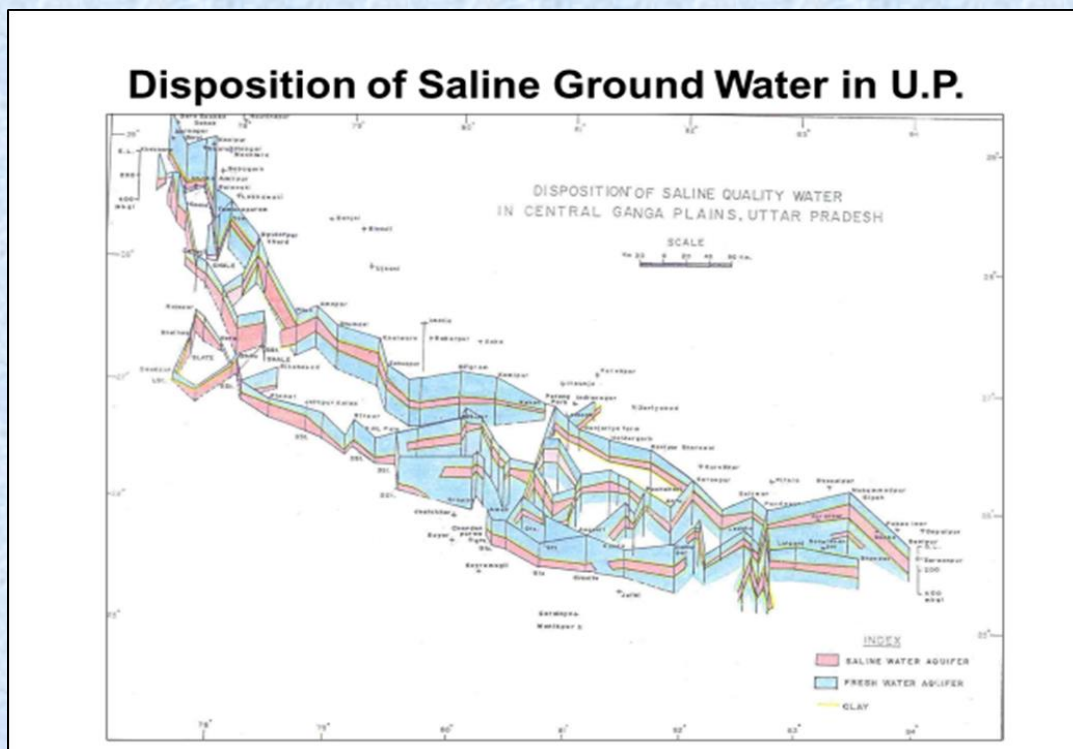
- i. In Ghaziabad city, groundwater from hand pumps is found **contaminated with manganese, zinc, iron and chromium**.
- ii. In Mathura - Vrindavan area, groundwater is found polluted with toxic heavy metals like **copper, iron, cobalt, lead and zinc**.
- iii. In Raina industrial area of Kanpur, metallic pollution of copper, chromium, nickel, zinc, lead, iron and manganese is reported from groundwater.
- iv. Heavy metals in groundwater have also been reported from other urban and industrial townships of the state.
- v. The analysed quality data and the reports prepared by the Ground Water Department also show the presence of various heavy metals beyond permissible limit in groundwater sources at different locations in different districts.

4.4.4 Occurrence of Saline Groundwater

Salinity in groundwater has been reported all across the Central Ganga plains of Uttar Pradesh, extending over a stretch of 700 km in NW-SE direction from Ghaziabad/ Agra-Mathura to Pratapgarh - Jaunpur and encompassing 70000 sq km area of the state. Various quality studies and borehole logging surveys have shown that the problem of In-land Salinity in groundwater resources. However, **the problem of salinity in groundwater is geogenic, occurring in shallow to deep aquifers.**

Various districts of the state are facing acute water crisis due to variable salinity in groundwater resources, the salinity has affected the drinking water and irrigation supplies in many parts. In salinity affected areas, it becomes challenging to provide potable water supplies and, therefore, the surface water schemes are the suitable option. Agra, Mathura, Firozabad districts are severely affected with this problem. Other districts like Aligarh, Ghaziabad, Kasganj, Kanpur Nagar, Unnao, Raebareli, Pratapgarh, Jaunpur are also reported to have moderate to high salinity in groundwater. The scientists of CGWB (Trivedi B.B. and others) have consolidated and analysed the borehole logging and quality data and come out with a distinct disposition of saline groundwater at varying depth intervals from western to eastern region of the state, as depicted in the following map (Figure- 13)

Figure-13 : Inland Salinity and Its Disposition in Ground Water of U.P.



(Source: Trivedi B.B.)

However, the information so far available on the inland salinity in the state provides only a generalised idea as to where salinity and its extent can be an issue. The depth to saline water at any particular place can be substantially different from what is available on the regional maps prepared with well logs or analysed quality data, which needs to be further updated.

4.4.5 An Overview of Quality Affected Districts

Based on the findings of different groundwater quality studies carried out by various organisations, as discussed above, rural/urban segments in different districts of the state are found partly or majorly affected with salinity and pollution of nitrate, fluoride, iron, arsenic and various heavy metals like arsenic, lead, cadmium, chromium, manganese, copper, nickel. An overview of the districts affected with different ground water contamination/pollution is summarised in the Table- 33.

Table-33: Overview of Quality Affected Districts in U.P.

Contaminants	Districts Affected (in part)	Nos
Salinity (EC>3000µS/cm)	Agra, Aligarh, Firozabad, Ghaziabad, G.B. Nagar, Hamirpur, Kasganj, Kanpur Nagar, Mathura, Raebareli, Unnao, Lucknow, Pratapgarh, Jaunpur	14
Fluoride (>1.5 mg/l)	Agra, Aligarh, Etawah, Firozabad, Hamirpur, Jaunpur, Kasganj, Lucknow, Mathura, Mainpuri, Mau, Raebareli, Unnao, Prayagraj, Mirzapur, Sonbhadra, Varanasi	16
Iron (>1.0 mg/l)	Agra, Azamgarh, Ballia, Balrampur, Budaun, Bulandshahar, Chandauli, Etawah, Fatehpur, Firozabad, Ghazipur, Gonda, G.B. Nagar, Ghaziabad, Jaunpur, Kanpur Nagar, Kanpur Dehat, Kannauj, Lalitpur, Lakhimpur kheri, Hardoi, Mainpuri, Mathura, Mau, Mirzapur, S.Ravidas Nagar, Siddharthnagar, Varanasi, Unnao	29
Nitrate (>45 mg/l)	Agra, Aligarh, Prayagraj, AmbedkarNagar, Auraiya, Azamgarh, Budaun, Bagpat, Balrampur, Banda, Barabanki, Bareilly, Basti, Bijnor, Bulandshahar, Chitrakoot, Etawah, Etawah, Fatehpur, Firozabad, G.B. Nagar, Ghaziabad, Ghazipur, Hamirpur, Hardoi, Hathras, Jaunpur, Jhansi, Kannauj, Kanpur Dehat, Lakhimpurkheri, Unnao, Lucknow, Mahoba, Mathura, Meerut, Mau, Moradabad, Muzaffarnagar, Mirzapur, Raebareli, Rampur, S.R.Nagar, Shahjahanpur, Sitapur, Sonbhadra, Sultanpur, Shravasti, Sidharthnagar.	49
Arsenic (Above 0.01 mg/l)	AmbedkarNagar, Ayodhya, Bahraich, Ballia, Balrampur, Barabanki, Bareilly, Basti, Baghpat, Bijnor, Budaun, Chandauli, Ghazipur, Gonda, Gorakhpur, Kanpur Nagar, Lakhimpur kheri, Lucknow City, Meerut, Mirzapur Moradabad, Pilibhit, Raibareli, S.KabirNagar, Sahjahanpur, Siddharthnagar, Sitapur, S. Ravidas Nagar, Unnao	29
Lead (Above 0.01 mg/l)	Muzzafarnagar, Mathura, Moradabad, Prayagraj, Bhadohi, Ghaziabad, Jaunpur, Kanpur Nagar, Raibareli, Sonbhadra	10

Cadmium (Above .003 mg/l)	Varanasi City, Unnao	2
Chromium (Above 0.05 mg/l)	Kanpur Nagar, Unnao, Ghaziabad, Varanasi	4
Manganese, Zinc, Nickel, Copper	High level of these toxic metals are reported from various industrial and urban areas.	

(Source : CGWB & UP Jal Nigam)

The above scenario of affected districts is based on the available information related to various past studies taken separately by different agencies. **This scenario may likely change if more quality data, given in the following text, is added and more extensive groundwater quality mapping is conducted on periodic basis.**

The new districts found affected with various contaminants in the quality testing carried out by UP Jal Nigam covering groundwater sources from 75 districts and by GWD-IITR in Hindon river basin, as briefed in the following paras (4.4.6 and 4.4.7) **are not included in the above Table - 33.**

4.4.6 Recent Findings on Groundwater Quality: UPJN

U.P. Jal Nigam partially carries out analysis of various parameters of groundwater sources from India Mark - II Hand pumps, under its Groundwater Quality Testing Program. The parameters analyzed include arsenic, fluoride, nitrate, salinity, iron and bacteriological contamination. The report of 2018-19, covering chemical testing of 25102 sample and bacteriological testing of 18184 samples from 75 districts of the state.

Following are the findings of different parameters (Table- 34).

Table- 34: Groundwater Sources Found Contaminated (UPJN:2018-19)

Parameter	Contaminated Sources (nos.) (Above permissible limit)	District affected (nos.)
Arsenic	268	13
Fluoride	326	19
Nitrate	277	19
Salinity	148	9
Iron	378	30
Bacteriological	6128	22

Prominent findings are-

- i. Arsenic contamination is largely reported from **129 sources of Sambhal** district followed by 67 sources from Bahraich, 19 from Gonda, 16 from **Bareilly**, 8 from Gorakhpur and 7 each from **Amroha, Bijnor & Ballia**. This is important that **3 groundwater sources of Meerut and 2 sources of Lucknow are also found Arsenic contaminated, which are relatively considered safe areas.**
- ii. Maximum sources with **fluoride pollution** are reported from Unnao district with 185 numbers, followed by 81 from Kanpur Dehat, 9 from Agra and 5 from Rai Bareli are found polluted with excess fluoride.
- iii. Maximum sources found affected with **nitrate contamination** are 188 from Unnao, while 16 sources from Mathura, 13 from Varanasi, 11 each from Kannauj and Kanpur Dehat are also reported to have high nitrate.
- iv. The salinity is reported mainly from 64 sources of Mathura, 33 of Unnao, 23 of Kanpur Dehat and 19 of Etah.
- v. The **iron pollution** is mainly reported from 59 sources of Siddharthnagar, 53 of Balrampur, 35 of Ghazipur, 36 of Sambhal, 31 of Bahraich, 24 of Gorakhpur, 23 of Kannauj, 19 from Varanasi and 17 from Amroha.
- vi. The **bacteriological contamination** from sources of 22 districts is a matter of concern for potable supplies. About 34% of tested sources are found affected with bacteriological contamination. Maximum sources 716 are reported from Bahraich, followed by 573 from Balrampur, Deoria, 415 from Kanpur Dehat 369 from Sultanpur, 362 from Gorakhpur.
- vii. Overall, 6523 habitations from 50 districts are found affected with different contamination in this quality testing.
- viii. In above quality analysis, sources from 25 districts have not shown any contamination.

4.4.7 Groundwater Quality : Hindon River Basin

(GWD, UP & CSIR- IITR)

Ground Water Department, under its annual scheme of "Ground Water Quality Monitoring and Mapping", has carried out a special quality testing in Hindon River Basin of U.P. during

the year 2019-20 in collaboration with India Institute of Toxicological Research, Lucknow (CSIR-IITR).

Total 388 samples from groundwater sources of nine districts namely Saharanpur, Shamli, Baghpat, Muzaffarnagar, Meerut, Ghaziabad, G.B. Nagar, Agra and Firozabad for were analysed for heavy metals (Arsenic, Manganese, Iron), fluoride, nitrate, coliforms along with physio-chemical parameters including calcium, magnesium, hardness as well as the temperature.

**Table-35: Quality affected Groundwater Sources in Hindon River Basin
(GWD & IITR: 2019-20)**

Districts	Contaminated Groundwater Sources (above prescribed limit)				
	Arsenic	Manganese	Iron	Fluoride	Coliforms
1. Saharanpur	4	39	23	--	57
2. Shamli	--	2	10	--	9
3. Baghpat	--	7	16	2	4
4. Muzaffarnagar	1	12	12	--	21
5. Meerut	--	6	12	26	11
6. Ghaziabad	3	3	6	1	12
7. G.B. Nagar	1	4	7	2	10
8. Agra	--	4	14	25	22
9. Firozabad	--	1	8	13	8
Total	9	78	108	69	154

Major findings are :

- i. **Eye opening finding of this study** is the presence of **Arsenic contamination in nine groundwater sources of Saharanpur, Muzaffarnagar, Ghaziabad and G.B.Nagar districts**, where Arsenic pollution in groundwater has never been reported till now by any agency. This finding demands more extensive groundwater testing in these areas.
- ii. Another toxic contaminant Manganese (Mn) is reported from 78 sources located in all 9 districts beyond the permissible limit. In some of the sources, the concentration of manganese is 7 to 9 times higher than the prescribed limit.
- iii. Iron contamination, more than the prescribed limit of 1.0 mg/l, is found in 108 samples from all 9 districts. In Agra, Ghaziabad, G.B. Nagar, Baghpat & Meerut, the concentration of iron is reported very high from 4 to 15 times of the prescribed limit in certain samples.

- iv. The concentration of fluoride in 69 samples is reported higher than the desirable limit of 1.0 mg/l. The important finding is that in Meerut, Agra and Firozabad, all the tested sources have fluoride concentration above 1.0 mg/l. Hence, such locations should have a continuous monitoring mechanism for such a situation.
- v. Presence of coliforms has also been confirmed in the above ground water quality testing. As per BIS norms, in groundwater sources total and faecal coliforms should be nil. But in 154 sources from all the 9 districts have reported the presence of coliforms in groundwater. In Agra city 11 out of 12 sample are found contaminated with coliform.

Obviously, such drinking water sources, having coliforms, are not fit for drinking water use. Therefore, such areas should have periodic monitoring arrangement and also need to share this information with the local people as well to the administration for prevention of health risk.

Other pollutants like arsenic, manganese, iron, fluoride also pose health risk. Higher values of nitrate, calcium, magnesium found in different sources also need scientific evaluation for potable water supplies.

4.4.8 Analysis of Environmental Parameters in Groundwater (UPPCB)

Apart from physiochemical and other quality parameters being analysed by UP Jal Nigam, Ground Water Department, CGWB and other agencies, the U.P. Pollution Control Board (UPPCB) has also started ground water quality monitoring for a different set of parameters of environmental significance on 40 sites including industrial areas since 2017, covering districts Unnao, Gorakhpur, Lucknow, Raebareli, Kanpur, Meerut, Ghaziabad, Varanasi, Prayagraj, Jhansi, Moradabad, Muzzafarnagar and Saharanpur.

The findings of above ground water quality monitoring conducted by UPPCB is of greater importance as **some specific chemical parameters such as Boron, Ammonia, Total Suspended solids, BOD, COD, phosphate, Faecal and total coliform along with other parameters may provide new aspects and dimensions of groundwater chemistry**, which could be utilised for understanding the quality dynamics.

Most significantly, the temperature of groundwater is also being monitored by UPPCB. All such quality data may be utilized by CGWB and GWD, UP for overall groundwater quality understanding.

4.5 Risk to Human Health

People are at larger risk of consuming polluted water and such pollutants in groundwater might also be reaching to the public from irrigation fields to crops, vegetables through the food chain, which may be a potential threat for the human health.

Therefore, health risk assessment along with detailed groundwater quality mapping in the entire state with focus on quality vulnerable areas is the need of the hour.

CHAPTER-5

STATUS OF SUB-SURFACE WATERLOGGING

The problem of sub-surface waterlogging (very shallow groundwater levels) is mainly prominent in canal command areas of Uttar Pradesh, mostly predominant in the eastern part. The cause of this problem is attributed to improper water use due to canal irrigation practices. Though the most practical and potent solution for such water issues is the use of **conjunctive water use management**, but for last 40 years, it could not take-off in any of the canal commands of the state, because no organisation is interested to take the ownership. Some efforts were attempted in the past, but that could succeed. Even **initiatives of UPWSRP-phase-1 could not sustain in the field. In UPWSRP-phase2 also, a consultancy study was taken up for development of conjunctive water use management plan for Fatehpur district.** The issue is quite important for the agricultural sustainability and development for the state and therefore, needs attention.

As per the assessment of the National Commission on Agriculture (1976), total sub- surface waterlogged area in the state is 8.10 lakh ha and out of this, about 4.3 lakh ha area falls under eight major canal commands spreading over 32 districts. **This problem is primarily impacting the agricultural productivity due to very shallow groundwater levels, which are non-conducive for the growth of crops.** The co-existence of problem of soil sodicity is adding miseries to the farmers, as the land becomes unproductive for the crops. **The severity of the twin problem-** waterlogging and soil salinity/sodicity in different irrigation commands is not similar and varies from one project to another due to variation in slope, soil type, water distribution and water use practices, cropping patterns, farm water management, drainage etc. **In general, the problem of water logging is more serious in middle/lower reaches of the commands of the various irrigation projects** such as Sharda Sahayak, Gandak and Saryu, because they pass through low surface gradient area, whereas the problem of salinity/sodicity is relatively more serious in commands of old irrigation projects such as Ramganga and Sharda canal as the long-term effect of water logging causes soil sodicity. Even in Sharda Sahayak canal command, the problem of soil sodicity (sodic land) is reported from various places.

Problem of Water Logging: Water logging is a phenomenal problem caused by the increased inflow to a groundwater body due to excessive water seepage from surface water system.

- Due to increased irrigation & seepage through canals, the water table rises almost so high as to adversely affect the soil productivity and restrict the air circulation to plant root zone.
- The soil under such condition is said to be Waterlogged. Waterlogging is of two types normally developed under different set of conditions.
 - (a) Surface Waterlogging
 - (b) Sub-surface Waterlogging
- **Sub-surface waterlogging** is a direct impact of groundwater level fluctuation and rising water levels due to capillary rise. In the affected areas, such problem not only impact the crop productivity, but also hampers the infrastructural projects.

5.1 Classification of Waterlogging

The National Commission on Agriculture (1976) defined an area to be waterlogged when the water table rises to an extent that the soil pores in the root zone of a crop become saturated, resulting in restriction of normal circulation of air, decline in the level of oxygen and increase in the level of carbon dioxide due to decomposition of organic matters. A special committee of the Central Board of Irrigation and Power (CBIP) was set up in 1991 to come out with a more practical definition of water logging. These were perhaps the first attempt to delineate scientifically the areas under water logging. The issue of sub-surface water logging falls in a different category that also need to be tackled with suitable management interventions.

The Special Committee of the Central Board of Irrigation & Power (CBIP) has, however, defined '**waterlogging**' as follows:

“An area is said to be waterlogged when the water table rises to an extent that the soil pores in the root zone of a crop become saturated, resulting in restriction of the normal circulation of air, decline in the level of oxygen and increase in the level of carbon dioxide.” The high-water table, which is considered harmful, would depend upon the type of crop, type of soil and the quality of water.

- The actual depth of water table, when it starts affecting the yield of the crop adversely, may vary over a wide range from zero for the rice to about 1.5 metre for other crops.
- Wheat and sugarcane are affected when the depth to water level is within 0.6 metre.

- Maize & Bajra are sensitive to water table within 1.2 metre and Gram and Barley are affected with water level within 0.9 metre.

An "Expert Group" constituted by Ministry of Water Resources, G.o.I. (1986) classified following standards for waterlogging in Sharda Sahayak Project, U.P.-

Table- 36: Classification of Waterlogging (MoWR)

Level of Waterlogging	Depth of Water Level below ground level
(1) Worst Zone	Less than 1m
(2) Bad Zone	1-2 m
(3) Alarming Zone	2-3 m
(4) Safe Zone	More than 3 m

CBIP Special Committee, 1991, suggested the following norms for sub-surface water logging, a phenomenon controlled by rise in groundwater levels (Table - 37).

Table-37: CBIP Norms for Sub-surface Waterlogging

Critically waterlogged	0-2 mbgl
Potential area for waterlogging	2-3 mbgl
Safe for crops	> 3 mbgl

The U.P. Council of Agricultural Research constituted a high-level committee in 1994 on the balanced use of ground water, which has categorized waterlogged areas into 3 categories as follows-

- (i) Worst affected areas where the water table is from 0-2m below the ground level. These are characterized by low yields, some becoming barren due to salt accumulation.
- (ii) Water level falls within 2-5 m below the ground level, where partial waterlogged conditions are visible and crop yields are poor to medium.
- (iii) Water table is 5-10 m below ground level, here waterlogged conditions may occur only in heavy clay loam soils.

It is well known that the surface waterlogging is not a menace, as the sub-surface waterlogging. It aggravates sub-surface waterlogging conditions. However, it appears that authorities concerned with agricultural development are emphasizing on surface waterlogging, although the need to resolve sub-surface waterlogging problems seems to be more urgent. A lot of confusion subsists about the definition and scope to the term

‘waterlogged’ area. Hence, **it is necessary to clarify this issue**, if a realistic plan of action is to be put in place. Probably, a more holistic definition of the term water logging is required which could include:

- (i) Surface waterlogging with respect to irrigation works and damage to soil capability.
- (ii) Sub-surface waterlogging linked to-
 - (a) agriculture crops including vegetables,
 - (b) fruit trees,
 - (c) timber and fuel,
 - (d) infrastructural development.

5.2 Assessment of Waterlogging

A still baffling problem is that of assessment of waterlogged areas. The water-logged areas in Uttar Pradesh have been variously assessed as given in the Table -38.

Table- 38: Different Assessments of Waterlogging in U.P.

Assessing authority/source	Water logged area in lakh ha.
State’s Tenth Plan Document	7.30
Irrigation Commission (1972) and the National Commission on Agriculture (1976)	8.10
U.P. Land Use Board Seminar (1992), Estimates of the waterlogged area in three important canals command areas of Gandak, Sarda Sahayak and Ram Ganaga	7.10
Wasteland Atlas of India (GoI), 2000, based on satellite imagery	4.98
NCAER Report (quoted in Planning Commission’s Report on Integrated Management of Water Resources in U.P. (2000)	20.00
Planning Commission (GoI)	8.10
U.P. Irrigation Department Vision Document 2025 (excluding Bundelkhand & Vindhayans)	
(a) Waterlogged 0-2 mbgl	32.77
(b) Semi waterlogged area 2-3 mbgl	46.86

- i. The various agencies have thrown up figures which cannot be reconciled unless there is unanimity about the definition of waterlogged area and the methodology of estimating the area. It appears that serious efforts are needed on priority to scientifically and precisely map the waterlogged areas in the state. While flood

induced surface, waterlogged areas should be surveyed and a near correct assessment is made each year.

- ii. The water level below the ground is a changing phenomenon in the context of seasonal precipitation, type of soil, slope of the land, seepage of water into the soil (other than precipitation), drawl from the groundwater sources etc., so its dynamics should be mapped for future planning process and to utilize such areas for agricultural development in the state.

5.2.1 Monitoring Data- Subsurface waterlogging in Eastern U.P.

In Eastern Uttar Pradesh, shallower groundwater levels up to a depth of 3 mbgl are recorded in about 57% of monitoring wells, which are located in 18 districts, including Ayodhya, Sultanpur, Amethi, Gorakhpur, Gonda, Mirzapur, Chandauli during post-monsoon, 2020. As per data of the Ground Water Department, out of 1259 monitoring wells, 720 wells depict groundwater level ranging within a depth of 3 m, which clearly indicate subsurface waterlogged condition in these areas. The monitoring data also indicate such condition at about 12% locations, where groundwater level has been recorded within 3 m depth even in pre-monsoon period. The data suggest that periodic analysis of groundwater levels should be carried out in the entire state for delineating such shallower water level/subsurface waterlogged zones for the purpose of indentifying area specific separate management interventions.

5.3 Issues need to be resolved

There are some important issues related to water logging which are to be looked into seriously -

- i. Waterlogged areas in U.P. has so far been variously assessed by different agencies.
- ii. Some reported 8 lakh ha or more, while some put more than 36 lakh ha area under waterlogging.
- iii. Waterlogging is yet to be correctly mapped.
- iv. Lot of confusion relates to its definition and the term 'waterlogged'.
- v. Confusion is also prevailing between the term surface waterlogging & sub-surface waterlogging.

- vi. Sub-surface waterlogging is causing loss to agriculture economy and damage to soil, but no department/agency owns the responsibility for its mapping, monitoring and management.

5.4 Land Degradation and Sodic Land

Sodic land is the most adverse situation of land degradation-

- The formation of salt-affected/sodic lands, locally termed USAR, usually a resultant factor of waterlogging.
- With rising water levels, evaporation takes place and salts get precipitated on the land, thereby developing the salt-affected land and the fertility of soil is also affected.

Field Photograph: Severity of water logging & salt- encrustation on left bank of ShardaSahayak Main Feeder (Figure -14)



The severity of waterlogging and sodic land in the areas adjacent to Sharda Sahayak main feeder is clearly visible in the above photograph, as found during the study carried- out in Sai-Gomti basin.

CHAPTER-6

ROLE OF NEW TECHNOLOGIES

6.1 Real Time Groundwater Level Monitoring–A way forward under World Bank Project

Groundwater resources are under increasing stress as there is a rapid growth in their usage. Hydrogeologists and ground water planners need more quick and accurate data to assess the prevailing groundwater crisis for timely management actions.

The groundwater conditions have direct impact on groundwater levels, therefore, groundwater level measurements from observation wells/piezometers are the principal source of information about the seasonal fluctuation and the hydrologic stresses acting on aquifers and these stresses with water level changes affect groundwater recharge, storage and discharge within a hydrological regime.

6.1.1 Significance of Groundwater Level Monitoring

In the present scenario of groundwater crisis, significance of groundwater level data has increased manifold, especially to evaluate changes in the resource over the time for developing groundwater models, future trends and monitoring effectiveness of groundwater management interventions. However, in dynamically changing geo environment, impacted with widespread groundwater depletion, timely monitoring of groundwater levels has become a critical issue and therefore, the necessity of groundwater level measurements for gathering real time data through Digital Water Level Recorder, using telemetry system, have come to the forefront.

6.1.2 Infrastructure for Automated Data

The need for real time data suggests the development of an infrastructure for acquiring, transferring and analysing the automated data, which can be accurately captured through Digital water level recorders for different time intervals as per the requirement.

Digital water level recorders fitted on Piezometers are designed with automatic data logger along with sensor cable. Data logger is capable to record variations/changes in groundwater levels. The equipment is enabled with telemetry system, where real time data on water levels is captured & stored in GPS enabled sim and is transmitted on server for such time intervals as prescribed for onward data retrieval and management.

6.1.3 Upgradation of Monitoring Network: Real Time Measurements

In Uttar Pradesh, groundwater levels are being monitored by the Ground Water Department on a network of nearly 9000 hydrograph stations, located both in rural and urban areas. With the support of World Bank Project, real time monitoring through Digital Water level Recorders in selected piezometers has been started phase wise since 2015 in different basins of the state.

As a normal practice, groundwater levels are being monitored manually through hand held steel tapes or sounders for 04 times in a year, including pre monsoon and post monsoon periods. Such data is primarily used to assess the periodic water level fluctuations and trend analysis for resource assessment.

Under the World Bank funded Uttar Pradesh Water Sector Restructuring Project (Phase-2), a separate Ground Water Component was approved for the State of Uttar Pradesh with the prime objective to strengthen the existing groundwater monitoring network, to establish data storage system with analysis and management, groundwater information system and to develop aquifer and conjunctive water use management plan along with capacity building and institutional development of Ground Water Department.

One of the main activities under groundwater component is aimed to strengthen and upgrade the existing water level monitoring network, which included the development of real time groundwater level monitoring system through installation of digital water level recorders on piezometers, which are so far being used for manual measurements.

Under the project, it is proposed to install 1050 DWLRs with Telemetry on existing piezometers located in different river sub basins, covering part of Yamuna, Gomti, Ganga, Ramganga basins. Installation of DWLRs has started since 2015 in a phased manner. These DWLRs have been installed at different locations of the state and groundwater level data is being received daily at an interval of 12 hours (6 am & 6 pm). Twelve Revenue Divisions of the state, which are covered by real time monitoring network through DWLRs, include Agra, Aligarh, Lucknow, Kanpur, Allahabad, Varanasi, Moradabad, Saharanpur, Meerut, Bareilly, Banda and Jhansi.

6.1.4 Key Wells

Apart from this, under the National Hydrology Project, key piezometers with digital water level recorders have been installed by the Ground Water Department in 149 problematic

blocks and 22 stressed cities of the state. Key wells are constructed at deeper depths beyond shallow aquifers to monitor the changes in behaviour of groundwater levels and to observe the influence of piezometric pressure on water level.

6.2 Multiple Monitoring Stations

As a mandate for dynamic groundwater resource assessment, groundwater level measurements are done on shallow/dynamic aquifers through shallow monitoring wells. In present context, as groundwater extraction has already started from deeper aquifers, there is a need to install deep piezometers to find out the changes in their piezometric levels and also to assess the impact of deeper extraction.

Under the World Bank Project UPWSRP-2, **100 Multiple Monitoring Stations** have been installed in the state. Each multiple monitoring station is designed to have 3 piezometers of varying depths - Deep (up to 250m), Medium (up to 150 m) and shallow piezometers (up to 80) to tap the different aquifers.

With the help of multiple monitoring wells, the changes in groundwater level fluctuation for varying depths can be easily evaluated. This information will also be useful in determining the aquifer characteristics as well in the assessment of in- storage/static groundwater resource. These multiple monitoring stations are equipped with DWLRs for real time monitoring of groundwater levels providing daily observation on the piezometric levels in the piezometers of different depths.

Apart from this, under the National Hydrology Project, also key piezometers with digital water level recorders have recently been installed in 149 problematic blocks and 22 stressed cities of the state.

Developing interface between shallow & deeper groundwater system:

The real time groundwater level data obtained from multiple monitoring wells and key wells will provide an interface between shallow and deeper groundwater systems. This is for the first time that apart from existing monitoring network of shallow piezometers, the piezometric levels representing deeper aquifers will be measured in real time mode at different places of the state and that offers opportunity for use of state of art for more focussed hydrologic analysis of groundwater levels of different piezometric heads and determining possible inter relationship between groundwater systems of different dynamics for future management of both shallow and deep aquifers and framing actionable strategies.

Decision Support System: Ground Water Department, UP, **requires necessary infrastructure, capacity and robust expertise to consolidate, manage and analyse such huge daily data, develop different scenarios and use all such advanced analysed data in a decision-making process,** as Decision Support System (DSS) would be the future groundwater management needs. **Without DSS, real time monitoring data cannot be fully utilized for groundwater management process.**

CHAPTER-7

POLICIES, INITIATIVES AND ACTIONS

7.1 Existing Policies

Salient features of major water policies, formulated so far, are mentioned below:

7.1.1 Uttar Pradesh State Water Policy-1999

Planning and development of water resources of the state need to be governed by the development perception of the state. With this principle in mind, the state has formulated U.P. State Water Policy in 1999, with the broad objective to ensure preservation of the scarce water resources and to optimize the utilization of the available resources and also to ensure self-sustainability in water resource development.

Some important strategies proposed in the policy document are-

- ❖ Qualitative improvement in overall water resource management through stakeholder's participation and decentralization of power.
- ❖ Preserve water quality by establishing norms and protocols.
- ❖ Treating surface water and groundwater as a unitary resource for integrated management of water resources.
- ❖ Ensure equity among users in resource allocation and management. However, drinking water is kept as top priority.
- ❖ Establish legal frame work for water resource management and regulation.
- ❖ Promote awareness, research and training in water resource sector.

New Draft Document - Uttar Pradesh State Water Policy-2021: The State Government has prepared a draft document for new State water policy-2021 for Uttar Pradesh.

7.1.2 National Water Policy 2012

The basic principles for driving policies on water resources given in the National Water Policy-2012 are: -

- Water needs to be managed as a common pool community resource held by the state under public trust doctrine to achieve food security, support livelihood and ensure equitable and sustainable development for all.
- Water is essential for sustenance of eco-system.

- Available water should be allocated in a manner to promote its conservation and efficient use.
- Planning, development and management of water resources need to be governed by common integrated perspective.
- Principles of equity and social justice must guide use and allocation of water.
- Good governance through transparent informed decision-making is crucial to the objectives of equity, social justice and sustainability.
- Given the limits on enhancing the availability of utilizable water resources and increased variability in supplies due to climate change, meeting the future needs will depend more on demand management, and hence, this area needs to be given priority.
- All the elements of the water cycle, i.e., evapo-transpiration, precipitation, run-off, river, lakes, soil moisture, groundwater, sea, etc. are inter-dependent and the basic hydrological unit is the river basin, which should be considered as the basic hydrological unit for planning.
- The impact of climate change on water resources availability must be guided by water management related decisions.
- Water quality and quantity are interlinked and need to be managed in an integrated manner.

7.1.3 Policy for Ground Water Management, Rain Water Harvesting and Ground Water Recharge in the State of Uttar Pradesh- 2013

Since groundwater development is the foremost need of the state, long term management and planning of groundwater resources becomes imperative. With this goal in mind, the State Government has come out with a comprehensive policy document in February, 2013 for overall groundwater management. This document named 'Overall Policy for Ground Water Management, Rain Water Harvesting and Ground Water Recharge in Uttar Pradesh' covers almost all important aspects of groundwater resource management, including focus on its regulated development/extraction, optimum use and conservation as well as detailed mapping of aquifers. The priority areas emphasised in the policy document are-

Aquifer mapping and aquifer-based groundwater management.

Optimum use of groundwater and planned management of its exploitation.

Rain water harvesting and groundwater recharge in an integrated manner.

Setting groundwater regulation process.

- Monitoring and mapping of groundwater quality for environment protection.
- Promoting groundwater data management with a State Ground Water Informatics Centre.
- Preparation of district wise water management plans.
- Training, publicity, extension and public awareness.
- Strengthening existing institutional system.

Uttar Pradesh is the first state in the country to have a Policy for Ground Water Management, Rain Water Harvesting and Ground Water Recharge in Uttar Pradesh (February, 2013). This is a very comprehensive policy document, envisaging diversified groundwater management strategies. Therefore, **the Ground Water Policy needs dedicated efforts for its implementation and to have overall reform of groundwater sector in the state.**

7.2 Initiatives and Actions

In Uttar Pradesh, the State Government has always been proactive and felt the need of "Rain Water Harvesting & Ground Water Recharge" (RWH & GWR) in the stressed areas of the state to rejuvenate the depleting aquifers and improve critical groundwater conditions. However, due to inadequate institutional mechanism, technical expertise and infrastructure, the various line departments have not shown any serious commitment so far to carry out the rainwater harvesting programme as per the geo-scientific norms and the prescribed guidelines. For last 20 years, basic recharges models, designs are still in practice, without assessing their efficacy and efficiency. **These designs are neither technologically updated nor any new more efficient and innovative methods and integrated modules for large scale recharge interventions are yet designed and attempted in the state.**

Moreover, the concept of groundwater conservation has been initiated in the state in late nineties and especially during the last 15 to 20 years, various schemes and projects on rain water harvesting and groundwater recharge have been started and implemented. Various programmes and schemes are still being carried out by different departments. But any impact on depleting aquifers or any improvement in prevailing groundwater conditions is not visible. Even its usefulness and efficacy on scientific parameters is yet to be established, especially in the alluvial aquifers of the state.

Policy Decisions: Looking back at the executive actions of the state government, various important initiatives and policy decisions, envisaging suitable provisions for rain water harvesting and water conservation, have been taken in the state over past 20 years. The main

initiatives include various provisions for roof top rain water harvesting, renovation of ponds, check dams, on-farm activities, water use efficient applications for both the rural and urban areas, besides making provisions for monitoring, co-ordination and implementation. Elaborate government orders have been issued from time to time with detailed technical guidelines and executive provisions for compliance and execution.

7.2.1 Key Initiatives

- i. Provisions have been made for rain water harvesting and groundwater recharge in urban areas way back in 2001, which are being amended from time to time. **These provisions are included in the Building Construction and Development By-Laws, 2000.**
- ii. A high level "Executive Committee", under the chairmanship of the Chief Secretary of Uttar Pradesh, was constituted in the year 2004 to periodically review the rain water harvesting schemes in the state and issue necessary directives.
- iii. Ground Water Department has been declared “**Nodal Agency**” in the year 2004 for the management and planning of groundwater resources and monitoring of rain water harvesting schemes in the entire state.
- iv. Technical Co-ordination Committee (TCC) under the chairmanship of District Magistrate has been constituted in the year 2005 all the districts for implementation and monitoring of Rain Water Harvesting projects.

7.2.2 Guidelines Mandated for Rain Water Harvesting

Rain water harvesting and groundwater recharge techniques are **site specific** and should be implemented in only those areas where groundwater resources have significantly depleted, so that sufficient space in the aquifers could be available for augmenting the resource.

Feasible Areas : Based on the hydrogeological conditions of the state, the **Ground Water Department has formulated detailed Guidelines for rain water harvesting and ground water recharge. These guidelines** have been mandated in the state in 2005-06 **for demarcation of feasible areas for taking up rainwater harvesting and groundwater recharge programmes. The key points of the Guidelines are-**

- a. Areas that witness continuous groundwater level decline shall be taken up for rain water harvesting and recharging with following criteria -

- i. **In Alluvial region**, the areas, where **depth to groundwater level is more than 8 mbgl in post-monsoon period** and the **long-term annual decline of groundwater level is 20 cm or more in pre-monsoon period** shall be considered as feasible areas for the rain water harvesting and groundwater recharge activities. **For the identification of feasible areas, both the conditions shall apply.**
- ii. In hard rock region of **Bundelkhand - Vindhya**s, the depth to water level shall be taken as **more than 5 mbgl in post monsoon**, while the condition for annual water level decline shall remain the same.
- b. **Over-exploited/critical blocks** shall be considered for rain water harvesting and recharge schemes.
- c. **Stressed urban areas with long term yearly decline of more than 20 cm** shall be taken up for such interventions.
- d. **Surface storages:** The areas, **which do not fall in above categories**, should only be considered for surface storage schemes for conserving rain water. This provision is also included in the building by laws of Housing and Urban Planning Department, Uttar Pradesh.

7.2.3 Mandatory Provisions for Rain Water Harvesting in Urban Areas

- i. Various executive decisions have been taken for rain water harvesting and recharging in urban areas. The initial decision in this regard was taken in the year 2001 and subsequently various provisions have been included, modified and amended as and when required.
- ii. Rain water harvesting has been made mandatory for all new housing as well as group housing schemes in the urban areas of the state.
- iii. Roof top rain water harvesting is mandatory for plot size 300 sqm or more. The provision has been included in the building by- laws of Housing and Urban Planning Department.
- iv. For all the government buildings (both new & old), installation of Rooftop rain water harvesting system is mandatory since 2001.
- v. Provision of **Combined Recharge System** is made mandatory for all the group housing schemes and the plots below 300 sqm in all the new housing schemes. The collective/combined system of recharge is a most suitable, easy and cost-effective method for roof top rain water harvesting in urban areas. This system envisages installation of separate rain water pipeline for all the group houses in the new housing

schemes. The RWH pipelines would be joined to a common recharge/storage facility for the purpose of rain water harvesting and groundwater recharge.

- vi. **Direct recharging** of rain water to aquifers from open/paved/unpaved areas is not allowed, due to risk of pollution/contamination as per the provision made in the G.O dated 25 April, 2006. This provision has also been included in the U.P. Ground Water Act-2019, under the Prevention of Ground Water Pollution with strict penal provisions.
- vii. Conservation of existing water bodies with catchment restoration in all urban areas is mandatory.
- viii. Provision for allocating 5% land for the development of water body is mandatory in all the new housing schemes.
- ix. Depth of ponds should be kept up to 3 metres. Identification of natural catchment & feasibility assessment should be the integral part of pond development/rejuvenation.
- x. Recharge shaft should not to be constructed in ponds as risk of industrial/other pollution may occur.
- xi. In parks, only 5% area is allowed to be covered with concrete / pavements.
- xii. Road side pavements should be kept kaccha (unpaved) as far as possible with perforated brick on edge/loose stone tiles to allow maximum natural percolation for groundwater recharging.
- xiii. In shallow water level areas, rainwater from roof catchments should be conserved as surface storages.
- xiv. Area specific hydrogeological parameters and feasibility assessment should be adopted for the design and implementation.
- xv. **Maintenance and upkeep** of the recharge structures should be the integral part of all the recharge schemes. In this context, arrangements for maintenance of recharge structures have been issued by the Ground Water Department way back in 2004.
- xvi. Arrangement for **Impact Assessment** should be ensured by the Nodal Agency (Ground Water Department). Ground Water Department has already circulated methodology for Impact Assessment in 2004.

All the above provisions are clearly made in the respective executive orders. The Technical guidelines for rain water harvesting and groundwater recharge, 2005, issued by the Ground Water Department, provides elaborate methodology for preparation, designing, implementation of recharge schemes in stressed areas as per the area-specific

hydrogeological feasibility and also for the impact assessment and maintenance of recharge structures and it is mandated to be followed strictly by all the stakeholders.

7.3 Other Major Initiatives

7.3.1 Ban on Irrigation Tube well

To control ground water exploitation in over-exploited and critical blocks in the state, there is a complete ban on the new government irrigation schemes, such as minor irrigation tube wells, state tube wells and other related schemes.

7.3.2 Observance of Groundwater Week

In view of the impending water crisis and deteriorating groundwater conditions, Ground Water Week is observed every year from 16-22 July since 2012 to create public awareness and make the people sensitize for groundwater conservation and management in the entire state from block to district and at the state headquarter.

During the Groundwater week, various awareness programmes like poster, slogan writing, debate competitions are proposed to be organised for the students. Besides, rallies, workshops, seminars and exhibitions are also the part of the week to be conducted throughout the state with the participation of all the departments. In the week-long programme, it is directed to ensure participation of schools, colleges, Bhujal Sena, all academic institutions, NGOs, industrial establishments, Confederation of Indian Industries, public representatives, resident welfare associations, district science clubs, Krishi vigyan Kendra, architect associations, Nehru yuva Kendra, Yuva mangal dal, water user associations and other stakeholders. The details of all the proposed programmes are given in the respective Government order dated 5 June, 2012.

It is important to mention that Uttar Pradesh is the only state in the country, where Ground Water Week is celebrated for creating the awareness amongst the people.

Earlier, from the year 2005 to 2011, **Ground Water Day** on 10th June every year was observed for the same cause, which was later converted to a week-long programme with the idea to involve the students and teachers at large.

7.3.3 Rain Water Harvesting in Syllabus

In order to sensitize and educate the students about the importance of water conservation and management, the State Government has introduced the rain water harvesting as a chapter in

the syllabus of 6th to 12th class. The chapter includes introduction, concept, benefit and importance of rainwater harvesting and groundwater recharge in conservation and management of water resources. The suitable techniques and simple methods of rain water harvesting and groundwater recharge are also discussed in the chapter.

7.3.4 Bhujal Sena at District level

The State Government has taken a decision in the year 2016-17 to constitute Bhujal Sena, as an independent and dedicated group, in all the districts of the state, with the sole aim to create and launch a public awareness campaign for carrying out continuous awareness activities on groundwater management and conservation in the entire state. Representatives of NGO's, students, teachers, environmentalists, social workers, scientists are proposed to be included in this group.

Fifty such members are proposed to be nominated in each district level Bhujal Sena by the respective District Magistrates. For the purpose of carrying out this activity, the State Government has started in 2016-17, a **dedicated annual scheme** named "**Ground Water Public Awareness and Publicity Programme**".

- i. The **district level Bhujal Sena is an innovative initiative of the State Government.** With a total strength of 3750 Bhujal Sainiks in the state, the Bhujal Sena could be successfully utilized for awareness programmes.
- ii. The Bhujal Sena aims to work as per the 'Action Plan' prepared annually by the Ground Water Department to be monitored through District Magistrates.
- iii. This is an ambitious public campaign of the State Government and needs special attention for planning and executing area specific groundwater awareness programmes round the year in a phased manner.
- iv. Stressed areas may be prioritised for such campaigns.
- v. It is provided in U.P. Ground Water Act-2019 also that the representative of Bhujal Sena may be nominated in village & block level committees.

Due to the lack of infrastructure and motivation of implementing agencies, this program, however, could not take-off as have been planned at the time of inception.

7.3.5 State Ground Water Conservation Mission

With the aim to effectively improve groundwater conditions in stressed areas, the State Ground Water Conservation Mission has been started in 2017-18. This is an ambitious five

years programme of the state, conceived with the targeted goal to bring the stressed areas into safe category. **Under the Mission, 271 blocks**, covering 113 over-exploited, 59 critical, 45 semi critical blocks **as per 2013-Assessment** and 54 blocks from Bundelkhand and Vindhyan region and 22 stressed urban areas have been selected with the objective to enhance the resource availability for improving the stressed conditions and also to arrest decline of groundwater levels.

The guidelines of the Mission and the methodology proposed are very comprehensive, which include preparation of **Implementable Action Plan by the Ground Water Department** for each block/urban area selected under the Mission, based on the exhaustive field-based studies, mapping and validation of norms for evolving realistic groundwater situation and deriving targeted actions.

As per the Mission guideline, various field studies, comprehensive data analysis and resources mapping along with the gaps identification would be incorporated to prepare each action plan, so that the suitable interventions could be identified, integrated and scientifically implemented for achieving the desired results of improvement in groundwater condition. It would be pertinent to mention that the earlier such activities under other programmes were not taken up in an integrated and targeted manner and hence desired outcome could not be achieved. In view of this, it becomes **a challenging task for the State Mission** to achieve the targeted goal of making significant improvement in stressed groundwater conditions of identified blocks and cities through dedicated Action Plans.

It, therefore, becomes relevant to find out the implementation status of this flagship, ambitious Mission of the state and assess the achievements and impact on the ground as far as achieving the targeted goal of de-stressing the depleted aquifers matters.

7.4 Major Campaigns for Rain Water Harvesting and Groundwater Management

The State Government has always been proactive for resolving groundwater issues in the state. During the last two decades, number of campaigns at state and regional levels have been undertaken for rain water harvesting, groundwater recharge and for sustainable management of groundwater resources. The prominent campaigns and various programmes are being listed as follows-

- i. In 2001, rain water harvesting and groundwater recharge programme in **urban areas** has been launched in a big way.

- ii. In 2004, for all the industrial development sectors in the state, rain water harvesting programme was started by Industrial Development Department.
- iii. For revival and rejuvenation of ponds, a dedicated scheme called '**Adarsh Jalsaya Yozna**' has been launched.
- iv. In 2006-07, an exhaustive '**Master Plan for rain water harvesting and groundwater recharge in problematic areas of Uttar Pradesh**' has been prepared covering 141 blocks of 36 districts and 431 urban bodies. The activities in the Master Plan were proposed to be covered through convergence of various scheme during 2007-12.
- v. In 2009, a **major programme** of rain water harvesting and recharging was started in **130 stressed blocks of the state**, with the objective to bring stressed block into safe category.
- vi. An **integrated programme** for rain water harvesting, groundwater recharge and water conservation was launched in year 2012, covering 108 over-exploited and critical blocks of the state.
- vii. In 2015, a mega campaign for water conservation named '**Mukhya Mantri Jal Bachao Abhiyan**' was launched in the state.
- viii. The State Planning Commission has undertaken a **special study on 'Unplanned Ground Water Extraction'** in the year 2015 and recommendations on actionable strategies have been submitted to state government for implementation.
- ix. In **2017**, the state government has launched a five-year programme called as "**State Ground Water Conservation Mission**" for revival of groundwater stressed rural and urban areas of the state.
- x. **Atal Bhujal Yozna:** In order to improve the management of groundwater resources through community participation, an ambitious scheme of Government of India with the support from World bank has been launched in April, 2020, covering 550-gram panchayats, falling in 20 blocks of Bundelkhand region and 6 blocks of western U.P.
- xi. **Regional Campaigns:**
 - a. A community-based approach in **Jakhni village**, the water scarce area of Bundelkhand, has revived the village ponds by undertaking traditional water conservation methods and made the village free from water scarcity
 - b. **Banda Campaign:** With the efforts of district administration, the people of Banda district in Bundelkhand have taken-up large-scale water conservation

measures in 2019 through construction of contour trenches, well restoration and Jal Chaupals. The campaign is discussed as a case study below-

Case Study: Bhujal Badhao Peyjal Bachao Abhiyaan, District Banda

Context

Most of the hand pumps, ponds and wells in district Banda were lying in a state of neglect as the community connect to preservation and upkeep of these community water sources has been lost culturally. Also, groundwater depletion rates are high in Banda resulting in seasonal acute water scarcity in most parts of the district. The unreliable hand pumps, dried ponds and wells particularly during summer months adding more water stress for household and community needs. As per Ground Water Year Book published by Central Ground Water Board (2015-16), there are 14 observation wells in district Banda, one of the districts in Bundelkhand region of Uttar Pradesh in India. The maximum range of fluctuation is 3.20 m (Rise) and 5.26m (Fall) annually indicating high seasonal variability in availability of water in wells. Overall, about 71% of the wells are showing groundwater depletion with 50% wells showing 0-2 m, 7% showing 2-4m and 15% showing more than 4 m depletion annually.

Thus, the situation related to groundwater is truly alarming in Banda and requires a massive awareness, campaign and interventions for groundwater recharge to reduce the threats to groundwater security. In district Banda, groundwater is a basic source of water supply to most of its citizens in rural and urban areas. This means that realization of this right for the people of Banda hinges crucially on perennial and sustainable availability of groundwater for all our water sources namely India Mark II Hand Pumps, wells and tube wells in district Banda.

Another big challenge pre-intervention was that rural communities were not aware about their Water Budget for the Gram Panchayat so as to make informed choices for long term plans for household water security and collective community action for water conservation and groundwater recharge using rain water harvesting.

Work done under the water conservation campaign-

A structured tool of Water Budgeting using *Jal Chaupal* model towards democratization of water developed by WaterAid India, an international not for profit organization, was included for support under the campaign by District Administration. In Phase -1 of the campaign between January to March 2019 namely *Bhujal Badhao Payjal Bachao Abhiyaan*, 34732 people who participated in *Jal Chaupal* in 469 Gram Panchayats directly are aware about

their water budget (demand and supply), rates of groundwater depletion of various strata and changes in rainfall patterns observed by community over period of last 20 years. This also triggered the community action towards *shramdaan* for digging contour trenches for groundwater recharge around wells and Hand Pumps as per technical designs prepared under the phase -1 of the campaign.

Phase I Campaign

Result of one month long first phase of the campaign named 'BhujalBadhaoPeyjalbachaoAbhiyaan', (Enhance Ground Water, Protect Drinking Water Campaign) - 2605 contour trenches have been constructed by community members around 260 wells and 2183 hand pumps across 8 blocks and 470 Gram Panchayats in District Banda. These contour trenches are expected to retard the current depletion rate of water levels in drinking water sources contributing to enhanced water security. These contour trenches are expected to have created additional 110001 cubic meters (or kilo litre) per annum of recharge capacity around 2443 drinking water sources (Hand Pumps and Wells) in entire rural Banda.

The district administration of Banda under the leadership of DM, Banda made giant efforts to upscale the campaign, buoyed by success of phase-1 of the campaign. Therefore, Phase-2 of the Campaign which was conducted between April to November 2019 namely '*Kuan, Talab Jiao Abhiyaan*' (Bring Life back to Ponds and Wells Campaign) started targeting massive campaign and *Jal Chaupals* around wells and Ponds by DM Banda and team of district Administration. In the phase-2, 244 *Jal chaupals* were conducted again, community action towards digging of ponds and wells was triggered by reviving culture of respect towards water bodies in rural masses, which was part of long cultural history of Bundelkhand and Banda. Technical models for construction of contour trenches, rain water harvesting in wells and rehabilitation of ponds were developed and disseminated through public campaigns, booklets and posters extensively in simple Hindi Language that can be understood by rural masses.

Like Phase-1, in Phase-2 of Campaign also, a large number of people participated in *Jal*

*The second phase of the campaign named as **Kuan Taalab Jiao Abhiyaan**, resulted in rehabilitation and digging of 49 minor irrigation Ponds, 249 gram panchayat's ponds (under MGNREGA), 274 gram panchayat's ponds (under Gram Nidhi), construction of 840 Farm Ponds (Khet Taalaab), 82 Roof Top Rain Water Harvesting cum recharge pit structures at different government buildings, 29 trench/recharge pits at degree college buildings, 1507 trench/recharge pits at primary/upper primary school buildings, 1311 Medbandi related work at agriculture land. All this construction/rehabilitation work is expected to create sufficient **recharge capacity in district Banda** till 15th of November, 2019. It was observed that due to this campaign in Banda, massive targets were set under different government programmes (Khet TaalabYojna, MGNREGA etc.) and were achieved with proactive support from different departments under district administration and rural communities triggered by *Jal chaupals* to take action.*

Chaupal and in total 244 panchayats *Jal Chaupal* was organized where 16448 people, men and women were directly triggered for taking action towards protection, upkeep and revival of Ponds and Wells. The focus of the campaign was the involvement of people of Banda with district administration and the model of *Jal Chaupal* resulted in triggering community action and self-action in many cases for restoration of pond and wells, digging of community trenches and rain water harvesting structures as is evident from results obtained from this campaign.

The campaign created massive water potential in district using ponds, wells, recharge tranches, rain water harvesting structures, *medbandi* in farms, farm Ponds etc. and retarded depletion rates for groundwater and exacerbating ground water / Drinking water crisis.

Sustainability of the work-

Since the initiative of digging trenches was undertaken completely by communities based on triggers towards community action in *Jal Chaupal* around drinking water sources, the upkeep and ensuring that trenches are in place to recharge groundwater rests with local rural communities living in villages and therefore, ensuring sustainability. Similarly, the wells cleaned up during the campaign and converted in recharge well by roof top rain water harvesting have been protected and will be used as source of drinking water only by converting them into low-cost water drinking water selling points after adequate chlorination

at minimum costs by village entrepreneurs authorized by Gram Panchayat and making them responsible for its after care and sustainability.

The idea of holding *Jal Chaupal* was to embed the democratic water dialogues at village level by holding a *Gram Sabha / UP Gram Sabha* at least twice a year on issue of water security. We are hoping that Panchayati Raj Department of Government of UP will be able to issue guidelines for holding *Jal Chaupal* every six months through *Gram Sabha* and *UP Gram Sabha* to make plans for water conservation and also monitor progress every six months particularly in all those districts which are under Jal Shakti Abhiyaan.

Scalability of work

Given the demonstrated leadership at district level, the model is scalable to conduct *Jal Chaupal* and digging of contour trenches around drinking water sources in Banda and in other districts too with meagre resources and full public participation. The model does not require heavy funds to implement the campaign and is aligned with local self- governance processes in India using the route of *Jal Chaupal*. In fact, in very short time this model has spread in new villages in Banda in Phase-2 of Campaign, in district Fatehpur and Bhadohi under Jal Shakti Abhiyaan and so on.

We do hope that this model of *Jal Chaupal* for triggering peoples demand for water conservation will be integrated in implementation plan of Jal Shakti Abhiyaan in all districts of India using the institutional set up of *Gram Sabhas* and *UP Gram Sabhas*.

Cost effectiveness

The model of the campaign is very cost effective as based on voluntary action of communities to dig recharge trenches after being triggered to conserve groundwater and make efforts to recharge it and *Jal Chaupal* does not take more than Rs. 5-10 per capita overall in areas where it has been implemented by agencies promoting it. The model is hugely cost efficient and more impactful as compared to other approaches tried out for Gram Panchayat/ Village Water Security.

Transparency

The model is completely transparent as no public funds were spent in this campaign for actual construction of Contour trenches for recharging groundwater around drinking water sources. The involvement of all concerned departments and communities ensured that every step of the campaign is executed in completely transparent manner.

Accountability

The campaign called for people to be accountable for current groundwater stress situation based on how their practices (of mismanaging water) and take action for its recharge by providing community contribution towards digging of contour trenches for rain water harvesting. Therefore, the public accountability was the concept that was built up in core of the *Jal Chaupal* model that was applied in this campaign.

7.5 Initiatives for Industries

In all the industries, for the regular groundwater level and quality monitoring, installation of piezometers has been mandated in the year 2004 by the Environment Department, GoUP, for all the industries of the state, under the provision of Section-18 of the Water (Pollution, Prevention and Control) Act -1974.

The Executive Order (G.O. dated 26.12.2004) directs following actions for compliance: -

- i. Piezometer shall be installed within the premises for regular water level measurements.
- ii. Groundwater quality assessment shall be done through water sample analysis from IITR or equivalent institutions.
- iii. Industries shall take future steps on the basis of groundwater quality and ground water level data.
- iv. All the industries, which are drawing groundwater, shall mandatorily undertake rain water harvesting measures as per the hydrogeological principles and the prescribed guidelines.

7.6 Rain Water Harvesting Activities in Uttar Pradesh

From the year 1999 - 2000, the government organisations have started discussing and deliberating the need of rain water harvesting at different levels as a potential solution for impending groundwater crisis in several parts of the state. Various efforts have started taking shape. The departments have started framing policies, guideline, plans for carrying out field activities. As per the available information, following rain water harvesting and water conservation measures have been executed by the different departments in the state. It is now an ongoing programme in the state, involving multiple activities being implemented by several departments such as Minor Irrigation, Ground Water, Agriculture, Horticulture,

Irrigation and Water Resources, UP Jal Nigam, Panchayati Raj, Rural Development, Housing and Urban Planning, Urban Development under different Central and State schemes.

Table- 39: Activity-wise status of Rainwater Harvesting

S No.	Activity	Achievement
1.	Check Dams	7255 number's
2.	Renovation of Ponds	1,40,000 number's
3.	Farm Ponds	14000 number's
4.	On-Farm Harvesting	> 3.7 lakh ha
5.	Water Conservation Work (IWMP)	> 36.50 lakh ha
6.	Roof Top Rain Water Harvesting on Government Buildings	815 number's
7.	Drip & Sprinkler Irrigation System	Ongoing schemes of Horticulture and Agriculture Department in different districts
8.	Pipe Irrigation System	Implementation by Minor Irrigation Department

(The above data may be updated by adding the latest progress under State Ground Water Mission and other ongoing water conservation schemes)

For the construction of rainwater harvesting and recharge structures and to implement micro irrigation programme, the concerned departments have also issued their separate guidelines for formulation and execution of respective projects.

7.7 Ground Water Regulation Instruments

7.7.1 The Uttar Pradesh Ground Water (Management and Regulation) Act, 2019

- One Step Forward

The Government of Uttar Pradesh has recently enacted 'The Uttar Pradesh Ground Water (Management and Regulation) Act, 2019' in order to provide for protecting, conserving, controlling and regulating groundwater to ensure its sustainable management in the State, both quantitatively and qualitatively, especially in stressed rural and urban areas.

The State Government, in order to deal with situation of serious groundwater crisis and groundwater contamination, has brought this new legal framework in the public interest to manage and regulate the extraction and use of groundwater judiciously in any form and also to conserve and protect groundwater in the stressed rural and urban areas of the state.

The rules under this Act have also been framed as the Uttar Pradesh Ground Water (Management and Regulation) Rules, 2020.

7.7.2 Key Points / Provisions

- i. Under the act, the user sectors to be regulated are industrial, commercial, infrastructural and bulk users.
- ii. However, the major user sectors, agriculture and domestic, have been kept out of the regulatory provisions of the act. Domestic and agricultural users shall get the registration of their wells only (on line or direct). Further, no penal provision shall be applicable on domestic and agricultural users of groundwater.

iii. **Institutional Framework**

To carry out the functions under the act, following Institutional Framework shall work-

- Gram Panchayat Ground Water Sub-committee in every Gram Panchayat shall be the lowest unit in the rural areas. It shall prepare Gram Panchayat Groundwater Security Plan.
- Block Panchayat Ground Water Management Committee shall work at block level. The committee shall prepare Block Level Groundwater Security Plan by consolidating gram panchayat level plans. The committee shall monitor the implementation of Groundwater Security Plan. The Block Committee shall register all the wells except those of existing commercial, industrial, infrastructural and bulk users.
- In Urban area, Municipal Water Management Committee shall be the lowest public unit for managing water. The committee shall prepare an overall Municipal Groundwater Security Plan and monitor its implementation. The committee shall register all the wells other than those of existing commercial, industrial, infrastructural and bulk users.
- At district level, District Ground Water Management Council shall be an overall unit for management of groundwater resources. The District Council shall consolidate district level Groundwater Security Plan and ensure its implementation. The council shall register all the existing commercial, industrial, infrastructural and bulk users and grant No-objection certificate for groundwater abstraction.

- The State Ground Water Management and Regulatory Authority shall be the apex institution under the chairmanship of the Chief Secretary, Government of Uttar Pradesh. The State Authority shall notify and de-notify the areas, fix groundwater abstraction limits and take ground water pollution control measures.
- iv. In rural areas, over-exploited and critical blocks, whereas stressed municipal / urban areas where significant decline of groundwater levels, i.e., more than 20cm/year recorded during last five years shall be designated as Notified Areas for the purpose of the regulation.
- v. Groundwater Abstraction limit shall be fixed for the notified and non-notified areas for all the existing and new Commercial, Industrial, Infrastructural or Bulk users of groundwater, based on the hydrogeological conditions and the resource potential of the area concerned.
- vi. Fee on groundwater extraction for commercial, industrial, infrastructural or bulk users shall be charged annually on the basis of quantity of groundwater extracted. An annual groundwater audit shall be conducted to check the actual extracted water against quantity of groundwater allowed/authorized for extraction.
- vii. Extraction, sale and supply of raw/unprocessed/untreated groundwater in Notified areas for the purpose of commercial/bulk uses will not be allowed.
- viii. **Prevention of Ground Water Pollution**
 - Ground Water Quality Sensitive Zones shall be declared for the purpose of prevention and protection of ground water pollution.
 - Prohibition on disposal of polluting matter into the well.
 - Ban on direct recharging from open areas into the aquifers.
 - Prohibition on polluting ponds, rivers, wells.
- ix. Process of self-regulation shall be adopted to protect, conserve and regulate groundwater resources in the stressed areas. Rain Water Harvesting shall be the integral part of water security plans. Roof top rain water harvesting and combined recharge system in municipal areas shall be enforced as per provisions of existing Building by- laws.
- x. Recycling and reuse of groundwater shall be encouraged.
- xi. Ground Water Security Plans shall be prepared for systematic implementation to ensure and achieve sustainability of groundwater resources in Notified areas.
- xii. Impact assessment and transparency shall be ensured.

- xiii. Penal provisions shall be enforced for offences.
- xiv. Ground water fund shall be created to be utilized for groundwater management activities.

7.7.3 The Uttar Pradesh Ground Water (Management and Regulation) Rules, 2020

To enforce the provision of Ground Water Act - 2019, the State Government has made the following Rules - 2020 by Notification, dated 25-2-2020.

- i. Terms of office and qualification of non-official members.
- ii. Meetings of Appropriate Authorities.'
- iii. Procedure for application for Registration of well.
- iv. Procedure for modification or alteration in registered well.
- v. Registers for certificate of registration.
- vi. Process for registration of drilling agencies.
- vii. Grant of No Objection certificate.
- viii. Fee for ground water extraction drawl.
- ix. Identification and demarcation of Notified areas.
- x. Fixing limit of abstraction of ground water.
- xi. Demarcation and declaration of Ground Water Quality Sensitive zones.
- xii. Process for fixing standards of Treated waste water and installation of treatment plant.
- xiii. Process of imposing provisions for rain water harvesting.
- xiv. Compounding offences, grievance redressal and miscellaneous.

7.7.4 Notification for Fee structure

The State Government, vide notification dated 3-7-2020, has prescribed fee structure for following provisions--

- i. Fee for registration of wells
- ii. Fee for registration of drilling agencies.
- iii. Fee for NOCs.
- iv. Water conservation fee for groundwater drawl for different users.
- v.

7.7.5 Declaration of Notified Areas:

The State Government, vide notification dated 17-6-2020, has notified areas in rural and urban segments for regulation purposes.

7.7.6 CGWA Guidelines to regulate and control groundwater extraction in India

The Central Ground Water Authority, under the Ministry of Jal Shakti, Government of India, in compliance of Hon'ble NGT orders, has issued "Guidelines to regulate and control groundwater extraction in India" vide Notification dated 24-9-2020. The aforesaid CGWA guidelines has pan India applicability. Its main features are-

- i. NOC shall not be granted to new industries and commercial entities in over-exploited area.
- ii. There shall be **no ban on issuance of NOC in Critical and semi-critical blocks.**
- iii. For Infrastructure and Mining projects, there will be **no ban on grant of NOCs in over-exploited blocks.**
- iv. Micro, Small and Medium Enterprises (MSME) drawing ground water less than 10 cum / day, individual domestic consumer, rural drinking water supply schemes, armed forces establishments, agricultural activities are **exempted from seeking NOC for ground water extraction.**
- v. Registration of drilling rigs.
- vi. Ground water abstraction/restoration charges are enforced.
- vii. Environmental compensation shall be charged from those extracting ground water without NOC.
- viii. Imposing penalties

The provisions of above guidelines will prevail over the guidelines of those states/UTs, which are inconsistent with CGWA guidelines.

CHAPTER-8

GROUND WATER MANAGEMENT

- ISSUES AND CONCERNS

8.1 Resource Management in U.P. - *A long journey ahead*

An action without efficient and suitable mechanism is a failure, so the case is with the management scenario of groundwater resources in Uttar Pradesh, which is facing diversified groundwater problems, as discussed in the previous chapters. The present pace of groundwater management reforms in the state is very slow and it implies that the state has to go a long way to manage its groundwater resources effectively. The state requires meaningful management interventions to tackle and overcome these problems. Therefore, the importance of an overall reform for groundwater management in the state, covering and addressing all the issues, should be suitably recognized and understood.

Located in Ganga Basin, the state of Uttar Pradesh holds huge groundwater storage. With this background in mind, the user departments, organizations and institutions of the state have indiscriminately extracted and utilized groundwater under various development schemes, especially during last 25-30 years, without giving a thought that the resource is not infinite and its overuse may have adverse impacts on sustainability of the resource. The uncontrolled exploitation and utilization of the resource still continues, which is a growing concern.

This is the high time to give serious thought for managing the prevailing groundwater crisis by integrating series of steps involving various measures and prognosis that would include identification and diagnosis of problem, data management and analysis, review of resource assessment, urban issues, quality mapping, waterlogging, water efficient practices and eco-system restoration. During the last two decades, groundwater has drawn much attention both at the State and National level. On different platforms, a series of discussions and deliberations were held on various aspects of management, conservation and regulation of groundwater resources and, in the process, number of policies were framed.

At state level, several policy statements and number of initiatives have, so far, been taken since 2000, which clearly signify the concern and the proactive approach of State Government towards development and governance of groundwater and its judicious use along with the necessity of effective implementation of conservation plans in problem areas. But, at the same time at implementation level, nothing concrete could have come out. The

concerned departments and organisations, responsible for carrying out such activities, could not translate the policy initiatives and plans on the ground. Importantly, **there is a huge gap in policy framing and policy execution**. As a result, groundwater conditions in the state have not improved and instead the situation has worsened over the time, raising doubts whether it would be possible to get back the original groundwater conditions both qualitatively and quantitatively in the state, which was once considered the richest repository of groundwater.

The broader issues and concerns, inter-related with groundwater management, are discussed in the document for effective solutions. Some of the important issues are -

1. Inadequate management of vast groundwater data.
2. Insufficient knowledge and understanding of aquifers amongst stakeholders.
3. No comprehensive & integrated regulatory mechanism to overall control and reduce indiscriminate groundwater withdrawal.
4. Variance and data gaps in groundwater resource estimation.
5. Ambiguity in important norms such as specific yield, unit draft, need validation.
6. Hugely extracted groundwater under estimated, groundwater abstraction in certain areas still unrecognised.
7. Review and reframing Urban groundwater norms.
8. Tagging groundwater quality in resource assessment process.
9. Restoring equilibrium to stressed aquifers.
10. Alarming trends of groundwater contamination and lack of integration in quality assessment.
11. Lack of comprehensiveness in existing regulatory regimes.
12. Guidelines for implementation and enforcement of rain water harvesting and groundwater recharge techniques are not followed.
13. Water efficient practices, water saving devices, change in cropping pattern, adoption of low water consuming species in agriculture sector are not getting momentum.
14. Watershed geomorphology-based mapping and management in Bundelkhand not yet initiated.
15. Conjunctive water use management method not practised in the field.
16. Inadequate participation of stakeholders and communities in field level management/conservation practices, water budgeting and awareness campaign.
17. Integrated water resource management concept yet to be implemented.

Although, groundwater issues, related concerns and their dimensions in the state are numerous, but **some major issues need elaborate discussion and analysis for evolving probable interventions towards effectively managing groundwater resources in a holistic way.** Following prominent issues are identified for detailed discussion in the present chapter -

- i. Lack of comprehensiveness in existing regulatory regimes
- ii. Lack of integration and co-ordination in groundwater management process.
- iii. Huge diversity and discrepancy in resource assessment.
- iv. Challenges & gaps in implementation of rain water harvesting.
- v. Quality monitoring and mapping - under sheer neglect.

8.2 Lack of Comprehensiveness in Existing Regulatory Regimes

Groundwater depletion and the deteriorating quality have emerged as major policy concerns both at national and state level, but there is no central law for management and regulation of groundwater resources in the country. Central Ground Water Authority was established way back in the year 1997, but it could not manage groundwater in the entire country. The CGWA guidelines have very limited mandate and only industries and infrastructural users are kept under the ambit of these guidelines in only those states where independent regulatory authority do not exist. Whereas in Uttar Pradesh, though efforts were initiated since 2002 to enact groundwater law, it was in the year 2019, the U.P. Ground Water (Management and Regulation) Act was enacted, but that too has limited regulatory ambit. It is noteworthy that the provisions in these two legal instruments are variously different.

It would be relevant to look back into the decision taken by the Government of India in the year 1997 for establishing Central Ground Water Authority in compliance of the Hon'ble Supreme Court judgment in the matter of falling groundwater level due to its indiscriminate extraction.

In the background of above, the issue was taken up by the Hon'ble Supreme Court on the basis of news item published in Indian Express on 18-3-1996 under the caption "Falling Ground Water Level threatens city" vide its order dated 5-12-1996 and judgement dated 10-12-1996. In this context the Central Ground Water Board has apprised the Hon'ble Supreme Court through an affidavit that from 1962 onwards, the water levels were declining on account of enhanced pumpage. Ministry of Water Resources (MoWR) has also informed the

apex court on 24-10-1996 that there was over exploitation of groundwater in certain areas. The MoWR (now Ministry of Jal Shakti) has further suggested that it was for the states to take further steps as Water is a state subject, informing the Hon'ble Supreme Court that a Model Bill was circulated to states way back in the year 1970. Meanwhile, NEERI, on the direction of the apex court has examined the matter and recommended an Authority be constituted.

The Hon'ble Supreme Court overturned the MoWR/MoJS stand that the groundwater is a State Subject and has found it necessary that the matter is regulated by a statutory authority to develop a constant mechanism of groundwater planning and management. The constitution states that water is a state subject, while National Water Policy suggests it as a national resource.

1. The Environment Protection Act, 1986, a central act (treated as mother act), also covers water subject.
2. **The Easement Act:** The Easement Act, 1882 says that the owner of the land is the owner of water beneath it. This is the one reason that groundwater is exploited freely.

The Hon'ble Apex Court has observed that matter needed to be dealt with under the Environment (Protection) Act, 1986 (EP Act, 1986) by the Central Government referable to Entry 13, List 1 of seventh schedule read with Article 253 of the Constitution. Thereafter, Central Ground Water Authority (CGWA) was accordingly constituted in compliance of the above direction of the Hon'ble Supreme Court, under the EP Act, 1986, under section 3(3) of this Act.

The mandate of CGWA has been to exercise all the powers under the EP Act necessary for the purpose of regulation and control of groundwater management and development in the entire country, but the said Authority could not take adequate steps, even after a long period of 23 years, to bring out an effective legal mechanism both at the National and state level for the overall management and regulation of groundwater resources, to be conceptually controlled by diversified hydrogeological set ups.

The current groundwater situation pointed out that the CGWA could not make any impact to control indiscriminate extraction of groundwater resources in the country and Hon'ble NGT has to interfere time and again. Hon'ble National Green Tribunal, hearing various petitions on groundwater issues since 2012, has **recently made its eye-opening observations that the**

situation of declining groundwater levels has not improved during these years and instead the situation has turned highly critical.

8.2.1 No Policy for Ground Water Extraction:

The crux of groundwater depletion is its indiscriminate exploitation. This is the irony that for years groundwater resources are being ruthlessly pumped out and despite Hon'ble Supreme Court's directives, **we could not frame any Groundwater Extractive Policy** at national or state level for allowing/fixing limits of groundwater abstraction for different user segments in diverse hydrogeological set ups characterised by distinct aquifer systems. As a result, whole groundwater extraction activity is going on unabated, because the resource is treated as freely available commodity. It has never been given the status of a Natural Resource.

This could be the reason that Uttar Pradesh has become the biggest exploiter state in the country. There is also no clarity about how much dynamic replenishable resource remains available for future needs while granting groundwater drawl permission for different usages or we are allowing pumping from our Static resource.

This is also the reason why groundwater extraction is going on unchecked in all the user sectors and no significant effort is yet made for reducing or controlling the resource over abstraction. Past resource assessments clearly show that groundwater availability as well recharge component has been quite variable and inconsistent over the years.

The present situation also demands review of the GEC-2015 Methodology and reassessment of whole groundwater estimation exercise to get true picture of groundwater resources both in rural and urban areas, because there are valid reasons pointing towards the gaps and discrepancies in the data used and the norms taken, as discussed previously. **It is, therefore, important to have right prescription of interventions for efficient groundwater management and for that correct resource assessment is the basic requisite.** That way the directions of Hon'ble Apex Court / Tribunal could be complied.

Although the CGWA has made some efforts to control and regulate groundwater abstraction in industrial, infrastructural and commercial sectors by granting conditional permissions, but the indiscriminate groundwater drawls could not be checked and over the time, resource extraction has crossed all the thresholds, putting groundwater under high stress in Uttar Pradesh and other states.

8.2.2 Absolute Regulation- A Distant Dream

For the agriculture and domestic sectors, being the largest extractor, currently there is no regulatory and management mechanism, whereas industrial and allied sectors have been put under the ambit of CGWA, which are extracting only 4- 6% of entire groundwater drawls. The Uttar Pradesh Ground Water (Management and Regulation) Act, 2019 also envisages regulatory provision only for the industrial, commercial, infrastructural and bulk users. Though the regulatory provisions under the CGWA and the State Act can be seen as moving a step forward for groundwater resource management and regulation, but without putting into action a strong regulatory mechanism for agriculture and domestic users, absolute management to bring back the depleted groundwater resources would remain a distant dream.

8.2.3 Hon'ble NGT's Order for pan India compliance!

In continuation of mandate of law laid down by Hon'ble Supreme Court in 1996 for pan India regulation and control of groundwater development and management by giving directions to the Central Government for constituting Central Ground Water Authority (CGWA) under EP Act- 1986, the grievances of widespread illegal drawl of groundwater for commercial purposes with no effective control by the CGWA have been raised before Hon'ble NGT by filing petitions from time to time since 2012.

The Hon'ble Tribunal is hearing and disposing such matters of illegal extraction with series of directions in different petitions. The important directions of Hon'ble Tribunal vide its order dated 20 July, 2020, are -

- i. CGWA and MoJS should comply with the directions of Tribunal's previous orders dated 3-1-2019, 7-5-2019 and 11-9-2019 to have a meaningful regulatory regime and robust monitoring mechanism for ensuring prevention of groundwater depletion and unauthorised extraction of groundwater for the sustainable management in over-exploited, critical and semi-critical (OCS) areas.
- ii. Regard must be had to water availability and safe levels to which its drawl can be allowed especially for commercial purpose, based on available and assessed data in each 'Assessment Unit'.
- iii. Undertaking an impact study in light of projected data for the next 50 years, in phased manner with action plan decade-wise.
- iv. No general permission for groundwater withdrawal be given, particularly to any commercial entity, without environment impact assessment of such activity on

individual assessment units in cumulative term covering carrying capacity aspects by an expert committee.

- Such permission should be as per water management plans to be prepared based on mapping of individual assessment units.
 - Any permission should be for specified times and for specified quantity of water.
 - An annual review by independent and expert evaluation must audit and record groundwater levels as well as compliance with the conditions of the permission.
 - Such audits must be published online for transparency and to track compliance and year to year change in groundwater levels and swift action taken against those who fail audit including withdrawal of permission and initiation of prosecution and recovery of deterrent environmental compensation as per CPCB regime.
- v. All OCS units must undergo water mapping. Water management plans need to be prepared for all OCS assessment units in the country based on the mapping data, starting with over-exploited blocks. The water management plans, data on water availability or scarcity and policy of CGWA must be uploaded on its website for transparency.

In pursuance of the directions of Hon'ble NGT and the powers conferred under EP Act-1986, the Department of Water Resources, River Development and Ganga Rejuvenation, Government of India has notified the guidelines on 24-9-2020, as briefly discussed under chapter -7. But, the overall compliance of NGT's directions is still to be done.

8.2.4 Model Bill for State Groundwater Regulation: Long Journey of 15 years

The CGWB has circulated model bill for enactment of ground water regulation for all the states in 2002, 2005 and 2016. Based on these model bills, the Ground Water Department has prepared five draft acts so far in 2005, 2011, 2014 and 2017. The previous draft acts could not get the requisite approvals, but the draft Act prepared in 2017 finally got enacted in October, 2019 as Uttar Pradesh Ground Water (Management & Regulation) Act - 2019.

8.2.5 Two Regulatory Regimes: Variance in Provisions

CGWA guidelines, 2020 clearly stated ---

- i. Its guidelines will have pan India applicability.
- ii. The CGWA shall regulate ground water abstraction in 22 States and 2 Union territories, which are not regulating ground water.

- iii. The States/UT's that have come out with their own abstraction guidelines, but are inconsistent with the CGWA guidelines, the provisions of CGWA guidelines will prevail.
- iv. In case, the guidelines of States/UT's contain some more stringent provisions than CGWA guidelines, such provision may also be given effect to by the respective State/UT's Authorities in addition to those contained in the CGWA guidelines.

The above directions, as given in the CGWA guidelines, clearly specified that the states despite having their own regulatory mechanism, shall have to comply with the provisions of CGWA guidelines, while the provisions of State Act, which are considered more stringent, may also be enforced by the respective state authorities in addition to those provisions envisaged in CGWA guidelines.

With this new pan India regulatory arrangement, it is obvious that in Uttar Pradesh, technically there would be two regulatory regimes in place, one guided by CGWA guidelines and the other of state's own mechanism. And with such dual regulatory instruments having variance in provisions within a single state, a conflicting and ambiguous situation is bound to arise, putting the users in dilemma. In such a contrast state, compliance of the Tribunal's directions would be more challenging.

However, CGWA has later clarified that State Act will operate in Uttar Pradesh, but this decision of CGWA may not be in line with the NGT orders. An effort is made here to identify the possible inconsistencies, conflicts and confusions, as explained in Table - 40.

Table- 40: Contradictory Provisions of Two Regulatory Regimes

CGWA Guidelines 24 Sept, 2020		U.P. Ground Water (Management Regulation) Act, 2019	
1.	MSMEs drawing ground water less than 10 cum/day exempted from seeking NOC.	1.	Micro & small enterprises drawing ground water less than 10 cum/day exempted from seeking NOC.
2a.	No 'NOC' for new industry, commercial entity in over-exploited (OE) block, but it shall be granted in Critical blocks/areas.	2a.	All O.E & critical blocks and stressed Urban areas shall be 'Notified Areas', where ban shall be imposed on construction of new wells for industrial, commercial, infrastructural and bulk users.
b.	New MSMEs, Mining and Infrastructure projects shall be granted NOC in OE blocks.	b.	No such exemption/provision.
c.	Expansion of industries with increase in quantum of ground water abstraction in OE blocks shall not be permitted.	c.	Modification or alteration in a registered well of such user in notified area is allowed.
d.	Drinking & Domestic use for residential apartments/ Group housing societies in Urban areas shall be granted NOC for new wells with specific conditions.	d.	Such users shall fall in the category of Bulk users, so the restrictions for stressed urban areas shall apply.

e.	Two set of charges- Ground water abstraction and Ground water restoration shall apply on users with variable structure.	e.	Water conservation fee shall have to be paid with variable structure. The rate of fee structure is relatively quiet less, if compared to provisions CGWA guidelines.
f.	Private tankers as bulk suppliers shall be granted NOC in all the categories and shall have to pay ground water abstraction charges.	f.	Extraction sale and supply of raw/unprocessed/untreated ground water in Notified Areas for bulk/commercial users shall not be allowed and will be punishable.
g.	Abstraction of saline ground water would be encouraged.	g.	No such provision in known Saline ground water areas.
h.	Environmental compensation shall be levied for illegal abstraction without NOC by industries, infrastructure units and mining projects as per the rates prescribed for different users.	h.	No such provision.
i.	No provision for fixing ground water extraction limit as per hydrogeological condition, for example for over-exploited aquifers.	i.	Provision made for fixing ground water extraction charges as per hydrogeological condition/resource availability.
j.	Water Management plan of each assessment unit shall be prepared by the concerned state.	j.	Ground Water security plans for notified areas shall be prepared and implemented.

Moreover, in both the above regimes, it is not clarified that while allowing no-objection for the construction of new well, what should be the scientific criteria for the depth of the new well under different hydrogeological conditions, as the assessment units are assessed on the basis of only dynamic resource availability, while the aquifer depth is variable and no divide is drawn between shallow /dynamic and static/deeper aquifers in different hydrogeological setups.

Secondly, in over-exploited blocks, since there is no resource availability for further withdrawal, any renewal of permission for existing wells or permission for constructing new well for the exempted categories would be a difficult perspective and it could not be technically allowed due to non-availability of resource. The provision of artificial recharge to groundwater is also not a potential option in proportion to heavy quantum of extracted water and simultaneously inadequate availability of source water because of deficit rainfall at places, particularly the districts in western UP, while in shallow water level areas, as per the guidelines, recharge is scientifically not feasible except surface storages. This is most important that rainfall in the state has depleted over the years, impacting the adequate availability of source water for recharge/rain water harvesting. Another area of concern is that in case deeper wells are permitted in Static Reserve, without knowing the resource

availability, that would be in disregard to hydrogeological assessment norms and resource sustainability.

In view of the above as well as in the interest of users, it becomes imperative to clarify and evaluate various contradictory provisions and related aspects. Both CGWA and GWD, UP should come out with suitable explanations and suggest practical path way for long term sustainability of groundwater through a robust mechanism in accordance with the directions of Hon'ble NGT and Hon'ble Supreme Court.

8.2.6 Notifying Stressed Urban Areas - Criteria needs clarity

According to the mandate of U.P. Ground Water Act-2019, the State Government, on the advice of Ground Water Department, has notified 26 urban areas as Notified Areas in the state through Notification dated 17.6.2020 for taking up appropriate measures under the provisions of the act. It is provided in the Act under **section 8(3) "Identification of areas for the purpose of regulating ground water" that the stressed Municipal/Urban areas, where significant decline of ground water levels i.e., more than 20 cm/year during last five years, are to be notified for the purpose of regulation through notification.**

The usual scientific practice for determining and assessing the declining situation in an area allows that more than 80% of regularly measured monitoring wells / piezometers should have witnessed the prescribed ground water level decline of more than 20cm every year continuously for a period of 5 or 10 years as specified. Furthermore, it would also be scientifically more appropriate to include in the Act a simultaneous mandatory provision for the depth of ground water level to be kept more than 8 mbgl in post-monsoon season for alluvial region and more than 5 mbgl for Bundelkhand-Vindhyan region.

Such stressed areas, as notified, should be regularly monitored for measuring ground water level changes during the regulatory regime.

- The notified areas should not have shallower ground water level situations, i.e., less than 8 m in alluvial region & less than 5 m in Bundelkhand-Vindhyan during post-monsoon period.
- In Uttar Pradesh, the Guideline of the year 2005, prepared by Ground Water Department, clearly stated that the **critical threshold for depth to ground water level must be kept as more than 8 m below ground level in post monsoon period for alluvial region, while for Bundelkhand-Vindhyan terrain, it is prescribed as more than 5 m.**

8.2.7 Stressed Urban Areas in U.P.: Different Scenarios

It is noticeable that currently 3 scenarios, depicting different sets of different stressed urban areas, are being managed in the state for separate purposes and interventions. These scenarios are briefly discussed as follows--

- i. As per the Report of Dynamic Groundwater resources of U.P. (as on 31.3.2017), CGWB/GWD, November, 2019, 10 cities of the state are categorised as Over-exploited / Critical. The general scientific perception assumes over-exploited and critical areas as highly stressed and should be prioritised from regulation perspective.
- ii. The Ground Water Department has identified 22 urban areas as Stressed, on the basis of significant ground water decline data. These are included in the five-year State Ground Water Conservation Mission, started in 2017 for taking up appropriate management and conservation measures to de-stress these urban areas.
- iii. Under the provisions of U.P. Ground Water Act-2019, 26 stressed urban areas are notified as per prescribed groundwater conditions.

In these three different scenarios for stressed urban areas, it has been observed that certain urban areas do not correspond, which are listed in one scenario but missing in other or vice-versa. In the list of Notified Urban Areas under the Act, Moradabad, Bareilly, Varanasi, Agra cities are not included, while these stressed cities are already categorised as over-exploited/critical in the Resource Assessment-2017. Contrary to this, over-exploited Prayagraj city, though showing rising trend in the assessment report, is included as notified urban area. On the other side, some urban / municipal areas like Gonda, Mau, Gorakhpur, Shajahanpur, having relatively shallower ground water levels are notified for the purpose of regulation. In view of the above, it would be advisable to revisit and review these different scenarios of urban areas.

Groundwater level trend in Gonda City in Pre-monsoon (mbgl)

(Notified as stressed Urban area under U.P. Ground Water Act, 2019)

Location	2015	2016	2017	2018	2019	2020
Khaira Mandir	5.05	5.75	5.42	5.65	6.60	5.15
FCI Godown, Sahabganj	5.60	6.30	5.97	5.20	6.75	5.70
PWD Inspection House	6.00	6.55	6.47	6.95	7.05	6.60
Mahila Hospital	5.55	6.30	5.93	6.60	6.65	4.75
Zigar Inter College	5.65	6.45	6.25	6.70	7.10	6.15

(Source: GWD, UP)

Groundwater level data of Gonda city, as depicted in the above table, signifies shallower water level depths in pre-monsoon period, while post monsoon water levels fluctuate from minimum 2.20 m in 2019 at Mahila Hospital to the maximum recorded level of 6.65 in 2017 at Zigar Inter College: Out of 10 monitoring locations in Gonda city, continuous recorded data for last five years, from 2015-2020 is available only for above five locations. The perusal of the data clearly reveals that the prescribed criteria of annual decline of more than 20 cm during last five years for identifying stressed urban areas as per the provision of Act-2019 is not consistently visible in any of the above locations. Instead of consistent annual decline of more than 20 cm, a mix of declining & rising water levels has been recorded at these monitoring locations/piezometers. Secondly, the recorded water levels are quite shallower than the threshold limit of depth to water level of more than 8 m in post monsoon period, as provided in the guidelines for rain water harvesting and groundwater recharge, 2005, issued by GWD, UP.

In continuation of above observations on Gonda city, the respective groundwater level data of 3 more cities Gorakhpur, Mau and Jhansi, declared as Notified areas under the provision of Ground Water Act, 2019 have been analysed, as per the criteria laid down for the purpose of notification, and it has been found that groundwater level trend between 2015-2000 does not correspond to the above criteria. Therefore, the notified cities need to be reassessed as per the criteria provided in the Act.

Some critical features of variously identified stressed urban areas, representing different scenarios and the status of groundwater-based supply, are being summarised in the following Table-41.

Table - 41: Three Different Scenarios of Urban Areas, U.P.

Over-exploited/ Critical cities (GWD/ CGWB: as on 31-3-2017)				Stressed Urban areas as per State Ground Water Conservation Mission (2017-22) *	Urban Water	Notified Urban Areas Notification Dated, 17-6-2020 Govt. of U.P. **	Status of Municipal Tube well Supply (Source: UP Jal Nigam/Local Bodies)		
Category	Extraction (mld)	Decline/Yr. Pre/Post (cm)	W/S Tube wells				Ground Water Supply (mld)		
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	Lucknow (OE)	264.5	44/54	1.	Lucknow	1.	Lucknow	630	356
2.	Kanpur (OE)	118	51/47	2.	Kanpur	2.	Kanpur	166	159
3.	Agra(C)	37	43/13	3.	Agra		--	--	--
4.	Aligarh (OE)	97	32/39	4.	Aligarh	3.	Aligarh	109	125
5.	Meerut (OE)	144	27/47	5.	Meerut	4.	Meerut	155	257
6.	Ghaziabad (OE)	249	97/110	6.	Ghaziabad	5.	Ghaziabad	109	130
7.	Moradabad (OE)	148	27/34	7.	Moradabad		--	80	165

8.	Bareilly (OE)	140	15/52	8.	Bareilly	--	65	125
9.	Prayagraj (OE)	104	Rising	9.	Prayagraj	6.	Prayagraj	242
10.	Varanasi (OE)	134.6	15/Rising	10.	Varanasi	--	135	135
				11.	Ayodhya	--	56	56
				12.	Bhadohi	--	7	7
				13.	G.B. Nagar	7.	G.B. Nagar 1. Noida 2. Greater Noida	2
				14.	Bulandsahar	--	33	43
				15.	Muzzafarnagar	8.	Muzzafarnagar	49
				16.	Saharanpur	9.	Saharanpur	115
				17.	Bijnor	--	22	17
				18.	Jhansi	10.	Jhansi	29
				19.	Raebareli	--	15	11
				20.	Pratapgarh	--	1	1
				21.	Jaunpur	--	30	27
				22.	Sultanpur	--	18	15
						11.	Firozabad	164
						12.	Auraiya	31
						13.	Akbarpur	6
						14.	Kaushambi	--
						15.	Buduan	21
						16.	Fatehpur	47
						17.	Sahjahanpur	22
						18.	Mau	35
						19.	Gorakhpur	97
						20.	Hathras	8
						21.	Kannauj	32
						22.	Sambhal	17
						23.	Gonda	28
						24.	Farrukhabad	59
						25.	Amroha	12
						26.	Mainpuri	21

* Significant decline of groundwater levels more than 20 cm/year during last 10 years.

** Significant decline of groundwater levels more than 20 cm/year during last 5 years.

8.3 Lack of Integration and Co-ordination in Groundwater Management

One of the reasons for the inadequate groundwater management is the lack of planning and coordination among various water institutions/stake holders, which are dealing with groundwater in isolated manner. In spite of policy commitments, there is no organisation yet in the state for integrated planning and management. As a result, there is no integration amongst the concerned institutions related to water sector in the state. **Overall, the real problem is lack of efficient water governance**, both on technical and administrative front.

The need of integration and co-ordination is highlighted in State Water Policy-1999 as well as in Ground Water Policy-2013, but the **concerned departments have not recognised its importance and are working in isolation**. Even there is no integration and co-ordination between different departments in ongoing World Bank projects. **There are about 15 departments in the state**, which are fully or partially related to water resources development

and management, **but in spite of various policy instruments and executive provisions, there is no coherence, co-ordination and integration between these departments.**

8.3.1 Implementation of IWRM - A long way to go

The ultimate goal of World Bank funded UPWSRP is to implement and bring the concept of Integrated Water Resource Management (IWRM) on the ground. Phase-1 was already completed in 2010 and now the phase-2 will be over by the end of this year 2020, but this IWRM is nowhere visible in any activity/scheme of the project. It is a well-known fact that surface water and groundwater are physically and conceptually inseparable, but on the ground, both are always considered separate systems.

There is also no showcasing of conjunctive water use management in the field, which has always been the most talked issue in both phase-1 and phase-2. Model for conjunctive use of surface water and groundwater and Decision Support System (DSS) for Jaunpur branch sub basin under Sharda Sahayak command were developed in UPWSRP phase-1 for implementation in the field and to subsequently replicate the DSS to other canal commands of the state, but this DSS could not be operationalised in the field.

In World Bank assisted **National Hydrology Project** also, both the components- surface water and groundwater are being dealt separately in all the states. There is no integration of various activities such as water resources data acquisition, information system, operation and planning, which are being taken up with entirely different mandate in the state. It appears that convergence of these activities towards achieving overall water resource management goal at the state level will be quite challenging.

However, the recent initiative of State Government for constituting a **new Jal Shakti Ministry** is a step forward for bringing whole water sector under one umbrella. The Irrigation and Water Resources Department, NamamiGange, Rural Water Supply, Minor Irrigation and Ground Water Department have been brought under the ambit of this Ministry. With the new ministry in place, though the concerned departments are still working in isolation, it is expected that the state may now have an Integrated Water Resource Management Framework in near future, if water resources are to be managed on a right path.

8.3.2 Neglect of Conjunctive Water use Management

Scientifically, the conjunctive use management of surface water and groundwater within the ambit of IWRM, if applied effectively and honestly, it would certainly prove as a key

prognosis for the prevailing water crisis in the state. This management approach of conjunctive water use, involving simultaneous use of surface water & ground water and being the most efficient and potential measure, is totally neglected in the state. This has never been given any serious consideration, particularly in canal commands.

In this background, it would be pertinent to mention that most of the canal commands, due to improper management practices, are facing various geo-environmental problems, like water-logging, rising water levels, soil sodicity in the upper reaches, while due to over draft in lower reaches, groundwater resources have extensively depleted. Stressed districts Fatehpur, Jaunpur, Pratapgarh, falling in Sharda Shayak canal command, are the critical examples.

8.4 Huge Diversity & Discrepancy in Groundwater Resource Assessment - Need to Relook the Estimation Procedure

Groundwater resource assessment is done periodically to provide basic data on recharge, abstraction and availability and to subsequently classify the assessment units into safe, semi critical, critical and over-exploited categories with the mandate to provide baseline inputs for overall planning and management to sustainably augment supplies for different users as a key contributor to all the major development and economic activities of the state. Therefore, the accuracy of such data would primarily help in identifying the most appropriate interventions and area-specific activities to be undertaken for groundwater development and its conservation and management in different areas. Obviously, this requires scientific estimation of both recharge and extraction components with greater accuracy and caution.

The whole exercise of resource assessment is entirely based on variety of data sets and various assumed norms, but in case of any variation, deviation, gap or inconsistency in any data that might lead to distortion of resource assessment figures. As a consequence, groundwater management and planning process will be certainly impacted because a slight variation or incorrectness in the data and the norms assumed will change the recharge & extraction figures and overall resource scenario would also get changed. This would most likely result into faulty ground water assessment and as such any block or assessment unit might be wrongly categorised from safe to critical or semi-critical to over-exploited or vice versa. Hence, looking at the imperative need for the reliability of groundwater resource potential, it is observed that groundwater resource if not estimated correctly, the situation would certainly affect the implementation of various development and conservation schemes, plans and practices.

The background of discussing above issues is the **huge variations observed in groundwater assessment figures of last two resource estimations carried out for the year 2013 and 2017**. A relative analysis is taken up on the basis of the data incorporated in the district wise comparison of extractable groundwater, annual groundwater abstraction and the stage of extraction, which is given in the Report of CGWB & GWD, UP on **Dynamic Ground Water Resources of Uttar Pradesh (as on 31-3-2017)**, November, 2019. **The analysis shows distinct variations in the district wise figures of recharge and extraction in the above two assessments and that requires to be closely studied for critical reappraisal.**

The following observations on this comparative analysis signify and suggest the need to scientifically re-examine the various district wise assessment figures for the overall reliability of groundwater resource estimation data for getting a more reliable picture of the resource.

8.4.1 Large Variations in Groundwater Recharge Component

In the resource assessments of 2013 and 2017, a relative reduction of 8.7% in the overall extractable groundwater resource (representing recharge component) has been observed in the state. But, **district wise figures of extractable groundwater indicate relatively large variations in the assessments of 2013 and 2017**. The observation is-

- i. In 23 districts, the extractable resource in 2017 has considerably decreased beyond state average by 20% or more and even up to 40% in Jalaun, Gorakhpur and Siddharthnagar. This comparative decrease is quite large and appears unusual, when various recharge parameters are assumed. The other districts are Ambedkar nagar, Amethi, Amroha, Bagpat, Barabanki, Bareilly, Basti, Budaun, Chandauli, Deoria, Ghazipur, Gonda, Hamirpur, Kushinagar, Lakhimpur Kheri, Lalitpur, Meerut, Moradabad, Sambhal and S. Kabirnagar.
- ii. On the contrary, there are 10 districts, namely Ayodhya, Chitrakoot, Fatehpur, G.B.Nagar, Ghaziabad, Mahoba, Prayagraj, Kaushambi, Raibareli and Jhansi that have witnessed substantial comparative increase in the extractable resource in the assessment of 2017 with about 18% increase in Ayodhya to a maximum of 49% in Chitrakoot and this relative rise in extractable resource appears very high, when the state, as a whole, has shown comparative reduction in extractable resource. Furthermore, there are 24 more districts, where extractable resource has also increased.
- iii. It is also pertinent to mention that the rainfall, being considered as a major source of groundwater recharge, is gradually declining over the years. Even in the year 2016,

prior to the Assessment 2017, about 55 districts have received deficient rainfall. In the assessment-2017, the rainfall contribution to the total groundwater recharge is estimated as 56% in comparison to National figure of 65%, while recharge from other resources is computed as 44%, which seems to be on the higher side and requires further analysis. In various assessment units/blocks, the quantum of recharge from other sources has been computed as very high and that requires to be relooked.

- iv. In above context, it would also be desirable to have a look at those 7 districts namely Ayodhya, Fatehpur, G.B.Nagar, Ghaziabad, Kaushambi, Raibareli and Jhansi, which are assessed to have more than 18% relative rise in extractable groundwater, but the rainfall in 2016 have been highly deficient.

8.4.1.1 Specific Yield: Adhoc Values Assumed - Need Authentication

The usual practice adopted to estimate groundwater recharge from monsoon rainfall is based on water level fluctuation and specific yield approach, as this method takes into account the response of groundwater levels to groundwater input and output components. **The specific yield, therefore, becomes a key parameter in computing the change in storage of an aquifer or assessment unit.** This change in the storage is considered most important component for determining Rainfall Recharge.

It can be well explained by the following equation-

Inflow (Recharge) - Outflow (Discharge) = Change in Storage

And this change in storage is estimated by the following equation-

Change in storage = Rise in Water level in Monsoon Season x Area x Specific yield

The above observations clearly highlight the greater significance of specific yield in the overall computation of Monsoon Rainfall Recharge in an assessment unit. It is always recommended in the GEC methodology to determine the norm of specific yield for each assessment unit by conducting field based appropriate studies and procedures. But, for all the previous assessments since the year 2000, the specific yield has never been validated through field methods and therefore, various assumed values of specific yield have been adopted for the computation of rainfall recharge. Obviously, with adhoc or assumed values, the true picture of recharge component may not be obtained and that might influence and alter the outcome of the assessment as well the categorization.

Since sufficient field data on specific yield is not available for different hydrogeological units of Uttar Pradesh, it is recommended in **GEC-2015 methodology that the values of specific yield**, assigned for different hydrogeological units of the state such as **older alluvium, younger alluvium, sandstone, granite, scists, limestone, shale etc, should be adopted for estimating the rainfall recharge**. The larger **part of the state is covered with Older Alluvium**, for that the average value of specific yield is **recommended in the methodology as 6% with minimum of 4% and maximum as 8%**, while for the less occupied areas of **younger alluvium**, the average specific yield is assigned as 10% with minimum value of 8% and maximum as 12 %. Accordingly, different geological units of the hard rock terrain are also assigned with different values of specific yield.

But in the Resource Assessment-2017, the specific values were assumed differently. It is stated in the report on Dynamic Ground Water Resources of Uttar Pradesh that in case the recommended specific yield values of 6% and 10 % are taken for the older and younger alluvium respectively, **there would be drastic change in groundwater resources as well as in the categorisation of blocks**. It was, therefore, decided by the sub-committee of CGWB & GWD, UP to **continue with three different specific yield values of 16%, 12% and 10%** for the rainfall recharge computation in the older alluvial formations for the above assessment.

In this backdrop, it becomes clear that the findings of Resource Assessment-2017 do not reflect the true picture of groundwater resources in the state, because in case reduced values of specific yield, as suggested in methodology, would have been adopted in the above Assessment, the rainfall recharge potential would have also decreased exorbitantly and, that might have led to more distinguished and marked changes in the categories of the blocks, making groundwater situation of the state relatively very alarming with more new blocks might be reaching to critical or over-exploited category.

Furthermore, the above specific yield values, taken for the resource assessment, have also been assumed differently for various districts/assessment units, that **requires scientific logic and clarification for the reliability of resource assessment exercise**. The various observation is -

- i. In district Kanpur Dehat, Auraiya and Fatehpur, the specific yield value is taken as 10%.

- ii. In district Kanpur Nagar, Farrukhabad, Azamgarh, Ballia, Chandauli, Ghazipur, Jaunpur, Pratapgarh, Prayagraj, Mau, S. Ravidasnagar, Varansi, the value is assumed as 12%.
- iii. On the contrary, in district Agra, Mathura, Firozabad, G.B.Nagar, the specific yield value is taken as 16%.
- iv. In some blocks of district Meerut, Amroha, much higher values of 18-20% have been assumed in the resource assessment.

It appears that the specific yield values considered in the assessment might not be corresponding to respective groundwater systems and **that should be critically reviewed for future assessments**. It would be rather appropriate that generalised assumption of specific yield should be avoided in the resource assessment for making the findings more authentic.

8.4.2 Distinct Changes in Annual Groundwater Extraction

The abstraction of groundwater directly influences the resources availability as well as the fluctuation in groundwater levels. **This parameter is very important as it provides key contribution in the overall assessment of groundwater resources in any area.** Hence, **the abstraction should be carefully and precisely determined in all the user sectors that include irrigation, domestic and industrial uses.**

Accurate estimation of groundwater abstraction in any area would, therefore, require complete well data with unit discharges of wells for all the user sectors and also finding the quantum of extracted groundwater. This involves an exhaustive and in-depth exercise through a scientific mechanism, which appears to be missing in all the past periodic resource assessments done so far on the basis of assumed or adhoc norms for unit draft.

The above report of CGWB, under discussion, gives a comparative overview of district wise groundwater extraction as computed in 2013 and 2017 assessments. The comparison of data, however, shows distinct variations in groundwater extraction figures in both the above assessments for most of the districts of the state. Though an overall average reduction of 13.2% in the resource extraction in state has been observed in 2017 assessment, when compared to 2013 assessment figures. The significant observations are-

- i. Though the state as a whole has witnessed an overall decrease in groundwater abstraction, but **in 11 districts, substantial increase in groundwater extraction has been noticed** that include Lucknow with 11 % increase, Bulandsahar 14 %, Hathras 15%, Varanasi 16%, Muzaffarnagar 18 %, Ayodhya 26%, Hapur 38 %,

District	Percentage Increase
Lucknow	11 %
Bulandsahar	14 %
Hathras	15 %
Varanasi	16 %
Muzaffarnagar	18 %
Ayodhya	26 %
Hapur	38 %

Sonbhadra 42%, Ghaziabad 50% and G.B. Nagar with 55% rise. While in Balrampur, Raibareli and Prayagraj districts, the relative increase has been found as 9, 8 and 7 percent respectively. In Bundelkhand also, there has been an overall rise in resource abstraction.

- ii. In another scenario, **24 districts are found to have relatively high percentage of decrease in groundwater extraction** where reduction in abstraction is observed as more than 20 %, much greater than the state's figure.
- iii. In the comparative analysis of these 24 districts, Bagpat district has shown a relative decrease of 21% in resource abstraction, while the highest relative reduction of 45%, has been noted in district Sambhal. The other districts, where the relative decrease has been found in the range of 21 to 45%, are Amethi, Amroha, Auraiya, Basti, Budaun, Deoria, Farrukhabad, Ghazipur, Gonda, Gorakhpur, Kasganj, Lakhimpur Kheri, Manपुरi, Meerut, Pilibhit, Pratapgarh, S. Kabir Nagar, S. Ravidas Nagar, Shamli, Siddharthnagar, Sitapur and Sultanpur.

8.4.2.1 Extraction for Industrial Uses: Not Assessed

There are huge numbers of Micro, Small and Medium Enterprises (MSME) in Uttar Pradesh, tentatively around 90 lakhs, with 40-50% units are groundwater dependent. There are also large number of major industries such as chemical, food, engineering, steel, tannery, sugar, beverages, Agri food, dying, carpet, pulp and paper industries. As per the available information, more than 90% of these industrial units are dependent on groundwater sources for their water requirements. GEC Methodology-2015 clearly states that in the resource assessment exercise, groundwater extraction for industrial uses should also be computed for estimating the gross annual groundwater extraction.

The above figures of industries clearly indicate that the share of groundwater in industrial uses in the state is most significant, but **in the Resource Assessment-2017, ground water extraction for industrial uses is not estimated.** This suggests that the gross extraction figure computed for all uses in the above assessment is not correct and is under reported. Undoubtedly, in such a situation, if groundwater abstraction for industrial uses is assessed and added to the annual extraction figure, **the stage of extraction for almost all the assessment units would surely change and that would greatly influence and modify the current scenario of categorization of blocks and cities in the state, as per 2017 assessment. The assessment of groundwater resources is being carried out periodically since the year 2000, using GEC methodology, but the estimation of groundwater**

extraction in industrial sector has never been taken up in any of the assessments, thereby leaving a major chunk of extracted groundwater from being assessed.

It is not clarified why this important component is left out in the resource assessment, while the industrial users are considered responsible for 5 to 8 % of total groundwater withdrawal. This is a critical gap in the Assessment-2017 and, therefore, requires logical clarification.

8.4.2.2 Infrastructural and Commercial Users - Not Recognised

In addition to industries, MSMEs, groundwater extraction is also reported from other user sectors like infrastructure, commercial, private and government institutions and, bulk users. But these sectors are not included in GEC methodology and because of this obvious reason, a significant portion of groundwater extraction is always left out from being estimated and that lead to under reporting of groundwater withdrawal.

The pattern of groundwater extraction and its usage has extensively changed over the years and it is still changing, but the **large number of ground water users are neither identified not defined in the GEC- methodology. Question arises why these key groundwater users are not considered for resource estimation?**

This is surely a prime issue and in view of this, it becomes imperative to modify the Assessment methodology, make changes in estimation procedure and add these users for correctly assessing groundwater extraction eventually for reliable resource estimation.

8.4.2.3 Extraction for Domestic & Other Uses : Underestimated/unreported

In the GEC-2015 Methodology, the procedure prescribed for groundwater resource assessment includes estimation of groundwater extraction in irrigation, domestic and industrial uses to assess the gross extraction.

Extraction for domestic uses underestimated:

Data analysis of Assessment-2017 reveal that the extraction figure reported jointly for domestic and industrial uses pertains only to domestic sector, which is given as 4.95 bcm. While most of the drinking water supplies in the state are groundwater dependent in both urban and rural areas, attempt has been made to study and analyse UP Jal Nigam data, which revealed relatively higher figure of groundwater extraction for drinking water use, estimated as 5.49 bcm, almost 11% greater than the figure assessed in Assessment - 2017 (Table-42).

Analysing Industrial Extraction:

Since the extraction for industrial uses, including MSMEs, has not been estimated and the figure is reported as nil in the assessment report, the available data with UPPCB and related agencies on groundwater demand and its usages in industrial activities has been analysed to consolidate and tentatively estimate the overall pattern of groundwater withdrawal in industrial segment. The groundwater extraction consolidated for major, large industries and MSMEs has been tentatively figured out as 5.3 bcm, as given in Table-42.

The issue also becomes relevant in view of the recent U.P. Ground Water (Management and Regulation) Act-2019, which is enacted to regulate the industrial, commercial, infrastructural and bulk users. The question simply arises how these users would be regulated when there is no official estimate of ground water withdrawals in these user sectors.

However, an attempt is made to consolidate and analyse the available data of UP Jal Nigam and UP Pollution Control Board related to extraction of groundwater for meeting water supplies in urban and rural areas and industrial demands.

Consolidating other Groundwater Withdrawals:

Attempt is also made to consolidate and analyse abstraction related data of other groundwater users, such as infrastructural, institutional, commercial and bulk users to have an overview of tentative groundwater withdrawal in these sectors, which is analysed as 4.0 bcm (Table-42). The segment wise analysed annual ground water utilization/ abstraction, using conservative assessment approach, is mentioned in the Table - 42.

Table - 42: Segment wise Annual Ground Water Extraction (as consolidated)

S.N.	Segment	Annual Ground Water Extraction (Tentative as per UP Jal Nigam/Data Analysis)		As per Assessment Report- 2017
		Daily (mld)	Annual (bcm)	Annual (bcm)
1.	Urban supplies	5975	2.18	--
2.	Rural supplies	9065	3.31	--
3.	Gross Domestic uses (1+2)		5.49	4.95
4.	Major/Large Industries	--	2.5	Not estimated
5.	MSMEs Groundwater dependent (40%)	--	2.8	Not estimated
6.	Commercial uses	--	2.2	Not estimated
7.	Infrastructural uses	--	1.0	Not estimated
8.	Institutional drawls & Bulk uses	--	0.8	Not estimated
	Total		14.79	

(Extraction data generated and consolidated, using conservative estimation approach, is based on preliminary exercise, needs validation)

From the above exercise, it is coherent that the actual annual extraction for domestic, industrial and other uses is tentatively assessed as 14.79 bcm, which is much higher than the reported figure of 4.95 bcm shown in the Resource Assessment-2017. **The analysed figure is a pointer for reviewing and making changes in resource estimation procedure by including these users as potential groundwater extractors. The issue, in a larger perspective of groundwater management, demands a policy intervention.**

The state figure of annual groundwater extraction for irrigation uses is taken as 40.89 bcm as per the Assessment report - 2017 and analysed figure of withdrawal for domestic, industrial and other uses is taken as 14.79 bcm and the likely change in the scenario of stage of groundwater extraction will emerge as given in Table-43. For determining this probable changed scenario of stage of groundwater extraction, the figure of extractable groundwater (65.32 bcm) reported in the Assessment report - 2017 has been considered for computation.

Table 43: Likely change in Stage of Extraction in U.P.

	Total Annual Extraction (bcm)	Stage of Extraction (%)
As per Assessment report - 2017	45.84	70.18
Adding Analysed Extraction figure for Domestic, Industrial & other uses to Irrigation uses	55.68	85.24

The above analysis indicates a marked change and suggests that by adding the extraction of industrial, MSMEs, infrastructural, commercial and bulk user sectors would entirely change the present scenario and the stage of groundwater extraction would, more likely, reach to highly critical levels. It is clearly evident that correct assessment of extraction will change the entire picture of groundwater status in the state.

8.4.2.4 Unit Draft - Key input requires field validation

Based on the GEC methodology, estimation of groundwater extraction for irrigation is mainly done using unit draft method. The unit draft denotes the quantum of groundwater drawl from a particular type of tube well or ground water structure, which may be shallow tube well, deep well, pumping set, state tube well or open well. Therefore, in this method, the unit draft of a particular structure should be estimated on the basis of field studies for groundwater drawl in different seasons. This unit draft figure is then multiplied with the total number of

that particular type of wells in an assessment unit (block) to obtain season wise groundwater extraction by that particular structure. The computation of groundwater draft in each assessment unit/block for irrigation can be explained as follows-

$$\text{Groundwater Extraction} = \text{Unit draft (season wise)} \times \text{total number of particular types of well located in each block or assessment unit}$$

Suppose, in a block, if there are 100 shallow private tube wells used for irrigation purposes and the unit draft is taken as 0.5 ham for monsoon season and 1 ham for non- monsoon season, the total ground water extraction (GWE) from shallow private tube wells will be computed as follows-

$$\text{GWE in Monsoon Season (100x0.5)} = 50$$

$$\text{GWE in Non-Monsoon Season(100x1)} = 100$$

$$\text{Total Ground Water Extraction} = 150 \text{ ham}$$

Likewise, groundwater extraction for other wells is estimated, based on the unit draft taken/assumed for different types of wells in an assessment unit/block.

This highlights the **importance of unit draft as a key parameter in the estimation of groundwater extraction**, hence, instead of taking assumed values, precise determination of unit draft through well documented field studies for all types of wells in each block is essentially needed as even slight variation or any erroneous value for this norm might result into incorrect estimation of groundwater extraction.

Significant changes in Stage of Extraction. The comparative large variation in the figures of extractable groundwater resource and its extraction has resulted into significant changes in the stage of ground water extraction in 21 districts, as observed from assessments of 2013 and 2017 (Table- 44).

Table-44: Significant changes in Stage of Extraction

S. No	District	Stage of Ground Water Extraction (%)	
		2013	2017
1	Aligarh	82.13	68.86
2	Ambedkarnagar	56.89	75.39
3	Basti	78.55	65.57
4	Chitrakoot	66.13	81.79
5	Fatehpur	95.21	70.15
6	G.B. Nagar	93.07	109.66

7	Hapur	89.04	107.34
8	Hathras	84.52	101.49
9	Jalaun	28.61	49.32
10	Kashganj	99.51	71.85
11	Lalitpur	61.62	78.33
12	Mahoba	112.17	87.77
13	Mainpuri	85.76	69.76
14	Mathura	91.96	77.57
15	Meerut	70.18	84.01
16	Pratapgarh	140.89	80.24
17	Prayagraj	80.94	69.87
18	Rampur	106.63	75.15
19	Sambhal	108.97	91.57
20	Sultanpur	72.79	49.29
21	Varanasi	86.28	99.74

The relative variation in stage of extraction is **quite large** in above 21 districts. These changes / variations may be reviewed.

8.4.2.5 Ambiguity in Unit Draft norms - A Sample Analysis

In district Sambhal, the comparative figures of both the annual extractable groundwater resources and annual groundwater extraction in the Resource Assessments 2013 & 2017 have shown large variations. Following are the important observations-

- i. The extractable resource in the district has significantly decreased by about 34%. In the assessment-2013, it is estimated as 63992 ham which has reduced to 41999 ham in 2017 assessment, showing that the extractable resource has relatively decreased by 21993 ham.
- ii. The assessment data of 2017 shows that the rainfall has contributed about 80 % to the total ground water recharge, while remaining 20% is the recharge from other sources. Both the figures are showing huge change in the usual pattern of recharge in alluvial formations.
- iii. Though on overall substantial reduction of 34% has been computed in recharge component in district Sambhal, but the rainfall data of 2016 shows that the district has received the annual rainfall of 960 mm with a very marginal deficit of only 3%. Therefore, this significant change in recharge therefore requires explanation.

- iv. Similarly, the annual groundwater extraction has relatively shown much greater reduction of 45%. In 2013 assessment, this extraction figure was estimated as 69731 ham but in 2017 assessment, it has decreased to 38459 ham, showing the total extraction has reduced by 30912 ham, which is a highly significant reduction.
- v. Although the reason for overall reduction of 13% in groundwater extraction in the state has been attributed to changes Minor Irrigation (M.I) census data of 2013-14. But, the comparative decrease of 45% in extraction figure of district Sambhal is seemingly much more and therefore needs scientific evaluation.
- vi. The stage of extraction has also shown sharp reduction from 108.97% in 2013 assessment to 91.57% in 2017 assessment.

There is possibility that the figures of various irrigation tube wells might have relatively reduced or changed while considering the M.I. Census data in the resource estimation. But such a **huge difference in the extraction figures of two corresponding assessments of 2013 & 2017 appears inconsistent**, as the M.I. well data might not be the sole reason for this exceptionally reduced figure of extraction.

In district Sambhal, there **appears ambiguity in the unit draft norms adopted** for different wells for the computation of groundwater extraction in the 2017 assessment. Most of the unit draft figures are relatively on the lower side, which might be the reason for the marked decrease in the extraction figure.

The comparative values of unit draft for private tube wells (deep) and state tube wells for district Sambhal and adjoining districts of Amroha and Rampur are given in Table-45 for logical understanding of the situation.

Table- 45: Comparative Values of Unit Draft

District	Season wise Unit Draft (ham)			
	PTW (deep)		STW	
	Monsoon Season	Non-Monsoon Season	Monsoon Season	Non-Monsoon Season
Sambhal	0.3	1.5	0.47-1.76	1.4-5.26
Amroha	1.5	4.5	1.19-4.5	3.57-13.5
Rampur	1.5	4.5	0.58-2.22	1.5-5.97

The above table clearly indicates **much greater variations in the unit draft figures in almost similar hydrogeological situations**. In district Sambhal, relatively lower values of unit draft might have influenced the reduction in groundwater extraction, which need to be

re-examined. GEC-2015 methodology has already highlighted the significance of determining accurate unit draft through well documented detailed field studies.

Moreover, this becomes important in view of the large variations in the assumed values of unit draft even for the similar type of wells. The reported values of unit draft for private tube wells both shallow and deep, pumping sets, deep wells, open wells and dug wells located in different blocks and districts appear quite inconsistent, as can be observed in district Agra, Unnao, G.B.Nagar, Budaun, Mathura, Mainpuri, Saharanpur, Meerut, Etah, Lucknow, Baharaich etc.

Apart from this, **much higher values of unit draft** for private tube wells (deep & shallow), dug wells have been assumed for hard rock **district Chitrakoot and Banda**, as compared to districts of alluvial region (Table- 46).

Table- 46: Unit Draft Adopted in Hard Rock Areas

District	Season wise Unit Draft (ham)			
	PTW (Deep)		Dug well/open well	
	Monsoon Season	Non-Monsoon Season	Monsoon Season	Non-Monsoon Season
Chitrakoot	1-2.5	3-8.5	0.25-0.5	0.75-1.50
Bauda	2	6-8.6	0.13-0.35	0.39-1.05

8.4.2.6 Geographical Area of Assessment Units requires validation

The geographical area of assessment units/ blocks and district provides an important input in estimation of recharge component and any change or variation in the figure will alter the output. In view of this, geographical area of certain districts given in the Report on Dynamic Ground Water Resources has been cross-checked with the figures of District NIC data. **Some variation/change in the figures of geographical area of the district Azamgarh, Bagpat, Bahraich, Basti, Bijnor, Badaun, Etawah, Fatehpur has been noted.** As only few districts were checked and change in the area has been noticed, it would be appropriate to validate the geographical area of all the blocks and districts so that the results of resource assessment may not get affected.

The above analyses of different aspects of groundwater assessment clearly explain and suggest that various norms and parameters especially specific yield and unit draft have larger significance in computation of recharge and extraction components. It is also

clearly noticed that if any data deviate from the logical value, incorrect assessment is figured out. Obviously, this exercise to analyse various parameter and data will be helpful for onward resource assessment and necessary improvement in the estimation of ground water resource can be easily made. In view of above analysis and discussion, it would be useful that the resource assessment can be reviewed and re-examined for finding more reliable results.

8.4.3 Urban Groundwater Estimation: Are GEC Norms Valid?

The practice for estimating the groundwater resource is based upon a methodology evolved by a committee (Ground Water Estimation Committee- GEC-97) set up by the Government of India in 1996. This GEC-97 methodology has been considered till the Assessment-2013. This is now modified as GEC-2015, which is used in the Resource Assessment-2017. In rural agricultural areas, that total vertical recharge may indeed be overwhelmingly large in comparison to the Horizontal flows (HO), because of large open, unpaved areas and significant contribution to recharge from applied irrigation/canal seepage. Hence the GEC norms, in practice, are quite well applicable for the rural- agricultural areas.

In urban areas the vertical components may be very small and as such, the role of the horizontal flows would, therefore, be important. **The horizontal flows are very sensitive to groundwater levels within a target area.** Thus, it is necessary to envisage such values of the horizontal flows in the resource calculations of rural areas also, as horizontal flows are consistent with the desired groundwater scenario. The GEC-97 norms and now GEC-2015 norms are deficit in handling the HO in respect of the monsoon as well as the non-monsoon periods. This could inevitably lead to a distortion in the resource estimates. Hence, GEC-2015 methodology should include this HO factor.

8.4.3.1 Horizontal Flows in Urban Areas

In Urban areas, the total vertical recharge gets severely curtailed on account of large concrete paved areas and almost complete absence of the recharge from applied irrigation/canal seepage a major source of recharge in rural areas. Thus, the contribution of HO in determining the urban resource may be quite significant and this HO has to be treated differently.

8.4.3.2 Adhoc Urban Norms GEC - 2015: Not Sustainable

As previously discussed, 30% of the rainfall infiltration factor is proposed in the GEC-2015 Methodology for recharge estimation in urban areas as an adhoc arrangement till field studies

are done. For the major cities of Uttar Pradesh, it appears inappropriate to consider 30% factor in view of the concretised land use. Similarly, the factors recommended for estimation of urban recharge from other sources, such as losses during seepages from pipelines, seepages from sewages and flash floods, should also be authenticated through field studies due to underlying urban complexities. **The urban recharge factor is scientifically questionable without evolving validated norms.**

Similarly, for estimation of extraction, the difference of the actual demand and the supply by surface water sources as the withdrawal from groundwater sources is recommended. But, this method for estimation of extraction is not appropriate in case of Uttar Pradesh, where more than 75% urban supplies are tube well based catering majority of the towns. Secondly, there are most of urban bodies, where surface water supplies are not available, while in some urban bodies, available supplies are less than the actual demand.

In Assessment-2017, urban groundwater assessment is done only for those cities where population is more than 10 lakhs, while 643 urban bodies are still un-assessed. It means overall urban groundwater picture will remain unclear. Secondly, the estimation of groundwater extraction in all the 10 cities is not matching with the reported tube well based water supplies. Since, well census is not done, the extraction in other user sectors is also not considered. This suggests that extraction figure of cities in Assessment-2017 is under reported. Therefore, **in view of the U.P. Ground Water Act-2019, scientifically validated urban groundwater norms should be framed** and procedure given in GEC-2015 methodology should be accordingly modified for correct urban estimation.

8.4.3.3 Declining Trend Criteria Dropped: Mismatched Scenarios in Semi critical areas

GEC-1997 methodology envisages a broad approach for the categorization of assessment units/blocks, which is based on dual criteria envisaging (1). Stage of ground water extraction, and, (2). Declining ground water level trend.

The basic concept of keeping dual criteria is to correlate the stage of extraction with decline in ground water levels in both pre & post monsoon periods, because the impact of increased extraction should have been visible on groundwater levels as significant falling trend over the past years. Therefore, the threshold for significant yearly decline in groundwater levels for a long period of at least 10 years has been recommended as 20 cm or more for the purpose of categorization of assessment units.

In case of Uttar Pradesh, this dual criterion has been adopted in the resource assessments of 2004, 2009, 2011 & 2013 by matching the stage of extraction with declining trend and found quite reasonable for the categorization of blocks. Since the state is extensively covered with a dense network of more than 9000 piezometers in both urban and rural areas, it would more precisely provide sufficient groundwater level data that could be suitably used in resource assessment.

In view of the above contradictory provisions of the GEC-2015 for the categorisation of assessment units, the data sheets provided in the CGWB report on Resource Assessment - 2017 (November,2019) reveal following observations--

- i. Fifty blocks, located in 32 districts, are categorized as semi critical with stage of extraction ranging from more than 70% to 90%, but the corresponding yearly falling trend is relatively much higher than the threshold of significant decline of more than 20 cm in both pre & post monsoon seasons.
- ii. The above situation of falling water levels in both the seasons demands re-estimation & validation of stage of groundwater extraction in these blocks.
- iii. Especially, the blocks namely Gangeswari (Amroha), Bisauli & Jagat (Budaun), Jalalpur & Bhati (Ambedkarnagar), Milkipur (Ayodhya), Mohammadabad (Farrukhabad), Dhaulana (Hapur), Sikandara Rao (Hathras), Dharampur (Jaunpur), Mawana (Meerut), Dingerpur & Munnapandey (Moradabad), Shahpur (Muzzaffarnagar), Duddhi (Mirzapur), showing declining trend of more than 20 cm/ year in both the seasons, are reported to have stage of extraction as 85% or more even close to 90%, should be re-examined for validation of stage of extraction. Since, increased abstraction of groundwater directly influences decline in water levels, this aspect requires to be correlated & matched in the 2017 assessment for evolving an authentic picture.

The criteria of declining trend have been dropped in the modified methodology of GEC-2015 and the categorization has been proposed only on the basis of stage of extraction, that primarily involves a quantitative approach.

Contrary to this new modification, it has also been categorically mentioned in the Methodology-2015 under the para "**Validation of stage of extraction**" that the assessment based on the stage of extraction has inherent uncertainties. This a pointer to the fact the provisions in the new methodology lack clarity and because of such ambiguity, the assessment findings would not be realistic and need to be reviewed.

8.4.3.4 Sugarcane- A huge sucker of groundwater and a growing challenge

Sugarcane cultivation in U.P. is growing rapidly and emerged as a huge sucker of groundwater as most of irrigation for Sugarcane crop is from groundwater sources. The sown area, as recorded in 2019-20, is 26.79 hectare. Sugarcane is expected to consume 18000 cum water per hectare per crop and about 70% of the sown area is irrigated by tube wells. Based on this, the conservative assessment of total annual ground water extraction for irrigation use in sugarcane crop comes out to be around 20.80 bcm. This extraction in sugarcane cultivation is quite enormous a proportionately very high, approximately 50% of the current annual gross extraction in irrigation uses which is reported as 40.89 bcm. Obviously, this aspect of groundwater extraction needs to be evaluated comprehensively to find out the realistic estimate of gross extraction in irrigation uses, especially the overall use of ground water in paddy, rabi other crops is to be figured out.

Therefore, sugarcane cultivation needs special attention of policy makers and planners, because huge amount of groundwater consumed in sugar production, that is estimated as 1750 litre for one kilogram of sugar. A report of Dr. Ashok Gulati, the eminent Indian agriculture economist shows that India exported 7.5 million tons of sugarcane in last financial year, consuming hugely 15 bcm of groundwater, which as virtual water will never return to the hydrologic cycle. This data is a matter of concern for Uttar Pradesh, which contributes around 40% of total sugarcane grown in India.

8.5 Challenges & Gaps in Implementation of Rain Water Harvesting Policies

The State Government has made rain water harvesting mandatory for new plots, housing constructions and all the new and old government buildings. It has been found that the technology of rain water harvesting and groundwater recharge alone cannot be a solution. In this backdrop, a general observation is that in over-driving rain water harvesting, huge number of recharge / injection wells are being drilled all across the state, without any scientific logic. **The probabilities of long-term implications of injection well method need to be seriously evaluated, as groundwater once contaminated may turn irreversible.** Further, the lack of maintenance and upkeep of such recharge structures are over-weighting their usefulness. **It has been the general observation that the low cost and relatively sustainable recharge pit, trench methods are not being recognised.**

Some of the issues related to existing policies are-

- i. For **the existing houses and residential colonies**, rainwater harvesting has not been mandated, leaving a major chunk in all the urban areas where surplus monsoon run-

off could not be utilised for recharging and that goes away down the drains. **A policy intervention is, therefore, needed for this.**

- ii. The **Combined Recharge System** is mandatory for all the new housing schemes, but it is yet to take-off.
- iii. Since **no department owns the responsibility for conducting the impact assessment** of installed rain water harvesting and recharging structures, the real benefit of such scheme could not be assessed.
- iv. In major cities, roof top rain water harvesting structures have been installed in various government buildings having large roof catchments, but the impact of recharging on groundwater is not visible as water levels are rapidly declining.
- v. Hydrogeological parameters are being neglected and the pre-project hydrogeological surveys in mega housing schemes are usually not conducted.
- vi. In rain water harvesting programmes in both rural and urban areas, area specific feasibility assessment based on the geo-scientific guidelines is mostly not taken up.
- vii. In spite of the **ban**, rain water from paved/unpaved area, parks, open fields are reportedly allowed for **direct recharging of aquifers though injection wells** in various scheme. This is a serious issue because of pollution risk, but there is no such surveillance mechanism to enforce the provisions. In view of the risk of contamination, this provision is also envisaged in the Ground Water Act-2019.
- viii. **Maintenance** of recharge well structure, storage and filter chambers in the roof top harvesting systems, is being totally ignored. In most of the government buildings, where such rooftop recharging system is installed, arrangement for regular maintenance is not envisaged, in spite of several directives issued by the government. Such negligence may lead to clogging of structure with pollution risk and the structure may also become defunct.
- ix. Organising programs & campaigns for people's sensitization/awareness and engaging communities is missing in the recharge programmes.
- x. No dedicated mechanism is yet developed in the concerned departments, where suitable technical advice could be provided to the people, who are willing to install the recharging system.
- xi. Overall, the **monitoring and enforcement mechanism** for the rain water harvesting is missing in the state. Enforcement arrangement is almost lacking to ensure the implementation of various provisions under building by-laws.

- xii. After 2001, roof top rain water harvesting system has been installed in large number of government buildings with huge investment, but there is no such documentation whether they are functional or lying defunct.

8.6 Quality Monitoring and Mapping: Under Sheer Neglect

In on- going programmes of ground water quality assessment carried out by different organisations, identification of sources of contamination/pollution and the risk on human health are never given due importance. The sources of groundwater contamination may be anthropogenic, point or non-point source or the cause may be geogenic. But, these crucial aspects of ground water quality have not been recognised. Obviously, if the causes and genesis of various quality contaminants in groundwater are not determined, the suitable and effective measures could not be evolved. Unless the issue of groundwater quality is taken seriously in light of its magnitude of severity and related health risk, the quality hazards would become a much bigger issue in future.

The sources found contaminated with pollutants are not tagged as polluted source and, in most cases, they are being used locally for drinking purposes posing greater risk for the local population.

8.6.1 Tagging Quality Hazards in Resource Assessment: Not Envisaged

Since groundwater quality analysis is done in isolation, the overall and integrated picture of groundwater pollution in the state is not distinctly known and groundwater quality zones in the state could not be delineated and mapped. The studies have already shown greater concern as number of districts in Uttar Pradesh are quality affected in terms of Arsenic, Fluoride, Nitrate, Salinity, heavy metals and even the bacteriological contamination.

The GEC-2015 methodology states that in addition to quantity-based categorisation, each block/ city should be tagged with the particular quality hazard, but despite this specific guideline, the quality hazards are not shown in the resource assessment of 2017. Any management process in such districts will surely be impacted, if quality hazards and related health risks are not recognised.

8.6.2 No Co-ordination / Integration for State's Overall Quality Mapping

Several prominent organisations in the state are carrying out groundwater quality analysis and huge quality data is generated at different platforms, but the data could not be utilized for integrating and developing an overall scenario of groundwater quality of the state.

There is no co-ordination mechanism for groundwater quality assessment. The main departments, engaged in ground water quality analysis, are U.P. Jal Nigam, Ground Water Department (GWD, UP), Central Ground Water Board (CGWB) and Pollution Control Board (UPPCB).

In U.P. Jal Nigam, there is a state level chemical lab, accredited by NABL, and 75 regional/district level labs, 5 mobile water quality testing labs. The Ground Water Department is having 3 labs, each at Lucknow, Agra and Saharanpur and is carrying out groundwater quality analysis for all important parameters including heavy metals since 2014-15 through a dedicated Ground Water Quality mapping scheme with 600 monitoring stations located in 50 districts for pre-monsoon & post-monsoon quality analysis. River basin wise quality testing has also been started by GWD, UP. Besides, Water and Sanitation Support Organisation under Sate Water and Sanitation Mission has completed groundwater quality testing on all 28 lakh handpumps of the state with large quality data of different parameters. There are also other agencies, academic institutes, which are also doing groundwater quality analysis.

But, despite generation of massive groundwater quality data by above organisations, no such initiative for integrating vast quality data for ultimate overall mapping of different dimensions of groundwater pollution and identifying safe zones in the state is yet to take-off and this is the reason, the adequate and integrated measures for prevention and management of quality issues could not be evolved. Certainly, if such huge data is compiled and analysed for different scenarios, the state could get a more useful data base and information on groundwater quality for onward quality management.

CHAPTER-9

ROBUST MECHANISM FOR GROUNDWATER MANAGEMENT

- A Situational Need for Overall Reform

9.1 Key Action Points for Deriving Sustainable Solutions

In view of the severity and urgency of the problems impacting groundwater management process in Uttar Pradesh, there arises immediate need of an "Effective Groundwater Management Mechanism" to be framed and implemented on priority. **Unless the state changes the ways and practices for managing its groundwater resources, it would be rather difficult to meet the future water demands.**

The impacts of over abstraction and resultant water level declines and also emerging threats of groundwater pollution have been reported widely in the state. Deficient rainfall is also a matter of concern. Therefore, with such grim scenario, this is the high time to realise that groundwater is not a resource that could be exploited and utilized indiscriminately. Other groundwater issues such as pollution (both anthropogenic and natural), agricultural toxins, salinity, waterlogging and industrial discharges need to be looked upon.

Ground reality suggests that there has not been adequate thoughtfulness amongst the stakeholders in the state for controlled & regulated extraction of groundwater, resource conservation, efficient use of groundwater, its reuse, recycle & recharge and ecosystem protection for increasing the base flows into the rivers. Therefore, the impending groundwater crisis demands a dedicated mechanism in the state to ensure implementation of focussed management measures to get back the sustainability of depleted groundwater resources as well as the prevention and protection of its deteriorating quality. It would be pertinent that the measures, to address groundwater problems, should be designed within the specific context of the varied hydrogeological settings of the state and particularly the hydrodynamics of the aquifer systems, otherwise it will continue to result in ineffective management responses and undesired outcomes.

The Uttar Pradesh Ground Water Policy-2013 envisages broad actions and strategies for overall resource management and its conservation & protection, which may guide and show the pathway for framing efficient and targeted groundwater management plans for the state. In view of deteriorating groundwater situation, various corresponding issues that

are fast emerging and the challenges of implementing the existing policies and achieving the targeted goal of sustainability from ongoing activities, a Robust Mechanism is imperatively needed to effectively overcome the prevailing crisis of groundwater management and also to have overall reform of groundwater sector in Uttar Pradesh is designed & documented in this Chapter with long term perspective by consolidating specific and focused actions for efficient implementation.

9.1.1 Suggested Management Actions and Sustainable Solutions

In above situation, groundwater management regime in Uttar Pradesh requires a paradigm shift in the current management approaches by framing and implementing host of interventions for long scientific and technical policy evolution and overall reform of groundwater management process through a well designed and meaningful mechanism. The major policy interventions and key solutions suggested for implementation in an integrated and composite manner are -

- i. Data consolidation, analysis and management.
- ii. Reconcile the discrepancies in groundwater resources data along with review of groundwater assessment methodology, tagging quality hazards in resource assessment.
- iii. Single centralised groundwater law with national regulatory framework and constituting state groundwater authorities.
- iv. Extractive policy and setting of sustainable abstraction limits.
- v. Paradigm shift from groundwater recharge to restoration of aquifers using composite interventions of RRR envisaging different dimensions - reduce demand, reduce extraction and recharge groundwater.
- vi. Preparation and implementation of groundwater security plans, as per regulatory provisions.
- vii. Demarcation of groundwater quality protection zones and integrated quality assessment and mapping.
- viii. Integrated efforts to increase ecological flows.
- ix. Balanced use of surface water and groundwater through conjunctive water use.
- x. Different solutions for urban areas and Bundelkhand-Vindhya, having different hydrogeological characteristics and diverse groundwater problems.
- xi. Specific interventions for agriculture sector.
- xii. Separate mechanism for industrial- infrastructural- commercial- bulk users.

- xiii. Groundwater protection charges for resource abstraction.
- xiv. Mechanism for ensuring stakeholders and community participation.

1. Groundwater Data Management: The First & Foremost Step

Management of any resource requires accurate, reliable and timely information and to generate such information, correct and validated data is needed. Therefore, for management of groundwater resource, data becomes the key factor. As groundwater is an invisible resource, finding its movement, availability and status would require large data sets for indirect measurement of the resource from both quality and quantity perspective. There are so many factors that govern & influence groundwater flows, its occurrence and quality, therefore, efficient data management and analysis is the foremost need for the resource precise assessment.

In the process of groundwater data management, number of data sets and information would be required to be generated, and that need to be gathered, compiled and analysed for developing different groundwater and related scenarios. If data is not correct and reliable, it may lead to wrong planning and execution of unrealistic & undesirable interventions. Currently, there is no integrated information system for groundwater in the state and therefore, it is almost difficult to get a realistic scenario of groundwater resources. The existing constraints for data management include large data gaps on one side, while adequate and authentic data on groundwater is also not available. In such a scenario, it appears challenging to identify & diagnose issues and suggests prognosis for ultimate management solutions.

The dimension of ground water data is quite vast and listing of department wise available data is a huge task. In Uttar Pradesh, there are more than 15 government departments and number of research institutes and universities, which are generating, collecting and analysing variety of groundwater data sets, but presently, there is no consolidated system for gathering, management, analysis and utilization of such data. **The Ground Water Department is the Nodal Agency for groundwater management in the state, however, there is as such no arrangement for centralised collection and consolidation of huge data lying unused with different departments and organisations. Even the huge data available with nodal agency require systematic consolidation and analysis for much needed analysis and management of diversified groundwater data.**

Since groundwater data and related information are always a much needed pre-requisite for the overall resource assessment, monitoring, planning, protection and regulation. Hence, its efficient management becomes the need of the hour. Following steps are required for ensuring overall groundwater data management in the state. It also becomes imperative to identify all data types, data sources and uses/applications related to groundwater domain. For ensuring effective data management, following action points are suggested for implementation-

- i. Evolve an organised mechanism to collect, store and organise data on GIS platform.
- ii. Identify and list out all departments, institutions and non-government stakeholders, which are expected to provide useful groundwater and related data / information.
- iii. Develop benchmarking and protocols for data gathering, validation and correctness of data.
- iv. Need to take policy actions for developing a co-ordination mechanism amongst all the organisations, departments, user sectors and other related stakeholders for smooth flow and dissemination of required information & data.
- v. Develop an IT based digital framework for Groundwater Data Analysis and Management.
- vi. Establish a Web based "State Groundwater Informatics Centre" with all advanced capabilities of data storage, analysis and management.

2. Ensuring Accuracy in Groundwater Assessment: Need to Validate Norms

Assessment of groundwater resources forms the basis for overall water resource planning in order to meet different sectoral demands. The periodic assessment of dynamic resources involves variety of data sets and their analysis. Therefore, **data and its correctness play the key role for reliable assessment of groundwater resources.**

The Ground Water Resource Assessment-2017 is guided by revised GEC Methodology-2015, which **recommends to conduct field studies to validate norms and strengthen the database for the reliability of the assessment.** The accuracy of various parameters, used in assessment, is, therefore, required to be evaluated through field validation & scientific tests, as the values of all these parameters may differ even within a similar hydrogeological domain and therefore, without field studies & validation of such parameters, the assessment output will not be reliable.

In all the resource assessments, as a practice, adhoc / assumed parameters and various data has been used without filter & validation. **Large variations and inconsistency in various estimation figures of Groundwater Assessment-2017 have been analysed and discussed in Chapter-8.** Hence, groundwater resource assessment requires validation and review of various norms **for the reliability and accuracy in the output.**

Following actions are suggested for reliable resource assessment and refinement/changes in GEC-2015 Methodology --

- i. The **current practice of groundwater estimation on adhoc parameters should be discouraged** and actual validated field norms and values and also the authentic data, as emphasised in GEC-2015 Methodology, should be used for reliable groundwater assessment in order to get a true picture of groundwater availability and stage of extraction for onward planning and management.
- ii. **Need for Validation of Norms:** Different parameters like recharge estimation factors, specific yield, unit draft, infiltration factor, groundwater level fluctuation, base flow/natural discharge etc are usually assessed by adhoc / assumed values, which raise a question on the reliability of assessment output. Specific yield and unit draft are the most important parameters for resource estimation. Any change made in the values of these parameters beyond the laid down principles, the recharge and extraction figures will get distorted and wrong picture of resource assessment would emerge. In Assessment -2017, much higher values of specific yield were assumed that raised the rainfall recharge figures contrary to field realities. Likewise, the adopted unit draft values were also not consistent with field conditions. Therefore, **future estimations should strictly be done only after the norms and parameters are properly validated by field studies** and suitably documented separately for different hydrogeological settings along with data refinement. **There should also be a reasonable explanation for data gaps, inconsistency in data and changes observed in various set of figures considered for computation of recharge and extraction.**
- iii. **Ensuring Data Correctness and Refinement :** Canal and land use data, water levels, prevailing cropping pattern, return flow from applied water, seepages from canal, tanks, ponds, check dams and other recharge structures, lithological properties, quality data, changes in urban dynamics contribute significant role in resource assessment. The CGWB and the GWD,UP should undertake **the needful exercise** and such

data/information should be collected, refined and analysed with greater accuracy for the reliability of the data as well as the resource assessment. **A slight change/deviation in the data from field reality may change the entire groundwater scenario.**

- iv. **Assess Well wise Fluctuation and Declining Trend :** In the past resource assessments, it has been a practice to assume lump average of groundwater level fluctuation and declining trend for each Block (Assessment unit) by consolidating groundwater levels of all piezometers/monitoring wells into a single average figure for the entire block for pre-monsoon and post monsoon seasons. From hydrogeological perspective, this approach would give incorrect and distorted figures of groundwater levels and the fluctuation and corresponding declining trend. It is strongly suggested that in rainfall recharge estimation, block's average of water level fluctuation and declining trend should not be taken and instead figures of well wise fluctuation and declining trend should only be considered for estimation purpose.

Statistical Data Analysis using Mean, Regression & Integration methods, best suited to the requirement, may be used for getting authentic results.

- v. **Declining Rainfall - Need to Relook Criteria:** Rainwater is the main source to replenish groundwater, but during last 2-3 decades, rainfall pattern mostly shows negative deviation/declining trend, hence the rainfall factor should be studied carefully while estimating the recharge component. With climate change scenario, **it becomes imperative that the GEC-2015 Methodology should be relooked for its recommendations and guiding criteria on rainfall recharge for more realistic computation.**
- vi. **Develop Strong Mechanism for Estimating Abstraction:** Mechanism should be evolved on priority for accurately estimating groundwater abstraction in all the user sectors, to avoid the probabilities of any under reporting. Hence, a periodic well census is required, so that **a robust data base of groundwater extraction is all user sectors, including agriculture, industrial, commercial, bulk and infrastructural could be generated with numbers of wells and their discharges in each user sector to get sector-wise realistic picture of abstraction.**
- vii. **Reinclusion of Parameter of Significant Water level Decline:** As per the modified criteria laid down in GEC-2015 Methodology, categorization of blocks/units is carried out only on the basis of stage of groundwater extraction, while dropping the most valid & measurable dual criteria/condition of significant water level decline observed

in pre and post monsoon seasons. As pointed out in Chapter-8, noticeable ambiguity and certain discrepancies in Assessment-2017 have been observed in the categorisation of blocks, because of excluding the most significant criteria of groundwater level decline. As a matter of concern, rise in groundwater level has been reported even in over-exploited units, which is against the geoscientific principle. This needs review and extensive deliberations, **as groundwater level is the only dependable parameter that provides directly measured information on rather invisible ground water levels.**

This criterion, therefore, cannot be dropped & ignored in the resource assessment. Hence, the above change in the methodology needs urgent review and **the dual criteria of analysing long term groundwater level trend to determine the significant decline should be reincluded in the Methodology-2015 as a mandatory provision for the purpose of categorisation.** Any assessment done on the basis of only single criteria of stage of extraction would surely give an incorrect picture of Categorisation of Assessment Units and that would also hamper the whole process of groundwater planning and management in the state.

- viii. **Refine & Improve Urban Groundwater Assessment Methodology:** The provisions in GEC-2015 Methodology for urban groundwater resource assessment are more hypothetical and adhoc and, therefore, need to be reviewed and revisited in the light of certain relevant observations already pointed out in the Chapter-8 for the accuracy of assessment.

The above points clearly suggest that correctness & refinement of groundwater data & validation of different norms & parameters are of utmost importance for realistic assessment of groundwater resource. Sincere efforts are, therefore, needed at the level of responsible organisations as the accurate estimation would lead to move on towards the sustainable path for achieving goal of efficient groundwater management and also ensuring future demands and supplies.

Furthermore, to strengthen and effectively improve groundwater resource assessment process, following points need to be given immediate attention for inclusion in the Methodology- 2015: -

- i. **Identify Surplus and Deficient zones:** Micro level studies have shown that within an assessment unit, groundwater occurrence and pattern of water levels may be variable

from place to place. It is always not necessary that stressed block/city as a whole is groundwater deficient / stressed. Some of the areas within such stressed unit may be water surplus due to resource variability. **With changing management demands, groundwater surplus and deficient areas should be identified, demarcated & mapped from block / city to district and up to state level.**

If we look at the state level, **eastern region is mostly ground water surplus**, while **western region is a water scarce area** and, therefore, **the management strategies would also be different**. Since the state is focussing on new groundwater programmes, **it is suggested that this study / mapping should be envisaged in the resource assessment methodology for greater accuracy and more refined output**, which would help in targeting the problem area for more specific & focussed management interventions. In the process of resource estimation, each assessment unit/ block/city should have been delineated into groundwater surplus and deficient areas. This point needs to be integrated in the Methodology-2015.

- ii. **Remote Sensing based Hydro geomorphological Studies:** Geomorphology/ Landforms have direct bearing on groundwater occurrence and movement; hence it is suggested that for better understanding, assessment and management of groundwater resources and demarcating recharge / discharge areas, remote sensing based hydro geomorphological mapping on 1: 10,000 scale should be carried out for entire state in a phased manner. Findings of this mapping should be integrated with the suggested most desired activity of Aquifer mapping discussed in the following text.
- iii. **Assessing Consumptive use of Groundwater and Virtual Water:** Consumptive water use is a very significant factor in a water resource system. The portion of groundwater which is consumed or lost during the process of utilization such as crop water use, dewatering & construction activities in infrastructure projects, manufacturing & industry, food making and as a Virtual water in the plant/crops never returns to water cycle.

Virtual water means a hidden water behind a product that is embedded in food or other products needed for its production. Various studies have found virtual water content (cum/ metric tonne) in different crop produce, for example - water footprint for rice is 3000 and for wheat 1350, potatoes 160, milk 900, poultry 2800, cheese 5300. However, these water footprints need to be evaluated for agro climatic conditions of Uttar Pradesh for further planning process. A study indicated that for chillies, 6 million litre of water was measured under flood irrigation, while for

tomatoes, it is reported as 2.5 million litre per hectare. In groundwater assessment - 2017, this vital aspect has not been touched, because guideline and procedure for computation of consumptive use/virtual water or groundwater footprints have not been included in the Methodology-2015.

In changing scenario, norms to determine and assess this unaccounted portion, which is either getting lost or going out of water cycle system, be framed and included in the methodology. This would help in bringing out the hidden myths and facts about consumptive use and the virtual water, which are heavily consuming in different activities or hugely exporting big quantity of groundwater in the form of products. It is obvious that the virtual water trade is pushing economic growth, but simultaneously there is almost permanent loss of groundwater from the hydrologic system, an unaccounted invisible loss.

- iv. **Assessing conflicting demands:** The issue of competing water demands may also be resolved as conflict of demands, supply and allocation for various users is arising in different regions, where using generalised groundwater availability data is resulting into conflicting demands.
- v. **GPS Mapping of Well Monitoring & Data Keeping in Public Domains:** This is the high time that GPS mapping of all the piezometers and observations wells should be carried-out in the entire state for quick mapping of groundwater level data using GIS technique and refining resource assessment process. Different groundwater scenarios should be generated using modelling tools and putting the data and maps in real time **as well as in understandable mode in public domain** for the larger use of such data for field level planning.

It is emphasized in **Atal Bhujal Yozna** also for public disclosure of groundwater related information. With this initiative, site specific **groundwater quality data can also be made available in public domain through GPS technology.** The information, thus, generated would be utilized for groundwater resource assessment and development of DSS.

- vi. **GPS Mapping of Recharge structures:** Development of different GIS based scenarios for rain water harvesting & groundwater recharge programmes under different schemes and **GPS mapping** of all existing rain water harvesting and recharge structures as well as all groundwater structures should be done for impact assessment and refinement of groundwater estimation output.

- vii. **DSS based Planning and Management:** With Web based technology in place, the present scenario demands for development of DSS (Decision Support System) based groundwater planning and management in the state. The technical team of the Ground Water Department at the state level may be geared up and extensively trained to take-up such advanced technologies, keeping in view the future challenges of groundwater management in the state.
- viii. **Use of Information Technology & Modelling system:** With advancement in technology, new modelling systems like Artificial Neural Network (ANN) should be adopted as forecasting models for predicting groundwater level changes based on temporal data inputs that would include historic groundwater level data, weather data and forecasts, land use, groundwater withdrawal and other anthropogenic data.

3. Aquifer Mapping on 1:10,000 -- Futuristic Need

Under the National Aquifer Mapping Programme, Central Ground Water Board is currently conducting aquifer mapping on 1:50000 scale in the state in a phased manner. This mapping is expected to provide a baseline information on the aquifer systems and initial aquifer management plans for regional planning, but these maps would not be helpful in area specific planning and management. Ground Water Policy, 2013 has also strongly pointed out imperative need of aquifer mapping in the entire state on 1:10000 scale. **This is pertinent to mention that the aquifers should be the core unit for groundwater management**, because groundwater movement and its availability is entirely dependent on an aquifer system and not the administrative boundary.

- i. In view of the prevailing crisis and challenges of groundwater management in the state, it would be more scientific to have Aquifer Mapping on 1:10000, which would be more understandable and implementable for micro level management at district level and also usable for community and stakeholders at large. Hence, the urgent need is to have a policy intervention for preparing micro level aquifer maps (1:10,000) to formulate aquifer-wise robust management plans and their subsequent implementation. This is undoubtedly a mega activity and a most desirable management action that would give deeper understanding of aquifer's hydrological and environmental properties. Such maps would also provide relevant information for the taking up regulatory measures as provided in the U.P. Ground Water Act-2019.

- ii. Aquifer mapping on 1:10000 scale for each watershed of at least 1000 hectare should also be carried out for developing workable plans for aquifer-wise management.
- iii. **Need to Upload Aquifer Maps on District Website:** The aquifer maps and the validated watershed integrated with the hydro geomorphological maps on 1:10000 scale along with real time groundwater levels should be kept in public domain for decision-making, timely actions in case of groundwater crisis and also to apprise and sensitise the public about current ground water situations. Meanwhile, the Aquifer Maps and the Management Plans on 1:50000 scale prepared by CGWB should be uploaded on the website of respective districts for needful actions. The Aquifer Maps on 1:50000 scale prepared by the Ground Water Department for Lucknow city, Kanpur city, Agra city and Chitrakoot area should also kept on the respective district's website as base line data for preparing plans and resolving groundwater management issues at local level.

4. Assessment and Management of Static Resource: A Future Perspective

Presently, entire groundwater-based planning process in the state is dependent on replenishable dynamic groundwater resources, located in first aquifer group of alluvial formations, which is severely under stress both on quality and quantity aspects. In Uttar Pradesh, minor irrigation programmes are also dependent on dynamic replenishable groundwater resources occurring in first aquifer group. The deeper aquifers extend over different depths ranging in second to fourth aquifer group, which may extend even beyond 600 m. The deeper aquifers have in storage/static groundwater resource of varying dimensions, which normally get passive recharging from Himalayas.

However, for future perspective, there is a need to accurately assess the In- storage and Static part of groundwater resource. As a policy, the **static resource** should not be extracted (except any situation of extreme urgency), as it is **considered future reserve of groundwater** or otherwise, **there should be a separate well defined, scientifically validated Extractive Policy for static groundwater**. Since, dynamic resource is in a critical state of irreversible over-exploitation, **this is high time that there should be well prepared extraction plan for meeting future demands**. Therefore, the accurate assessment of static resource becomes a need of hour.

For future perspective, following steps are required to be taken up on priority-

- i. GEC- 2015 methodology has emphasised for computation of In- storage and Static resource. Therefore, in view of future challenges, **the state should take up the assessment of In- storage and Static resource on priority**, so that exact potential of static resource could be evaluated and futuristic plans and strategies, based on strong policy decisions and regulatory arrangements, could be prepared. The interim methodology given in GEC-2015 may be used for the estimation with refinement of norms.
- ii. It is suggested that extensive studies should be taken up in the entire state for reliable assessment of static groundwater resource with aquifer mapping on 1:10000 scale **to find out the realistic picture of aquifer domain both in alluvial region and hard rock terrain of Bundelkhand-Vindhyans.**
- iii. It is also important **to delineate the vertical and horizontal extensions of both the dynamic and static resources within each assessment unit**, in order to prevent groundwater mining and to evolve prospects and risk assessment of deeper groundwater exploration and possible environmental consequences in light of future demands.
- iv. The data of Deep piezometers, based on Multiple Monitoring Stations and Key wells, constructed by the Ground Water Department under World Bank projects, should be intensively monitored and analysed **for observing the changes/fluctuations in the ground water regime of In-storage/Static resource. Such data will form a baseline information for groundwater studies regarding static resource.** However, it will be pertinent to come out with a well-defined methodology for the analysis of water level data from deeper wells and relative assessment of water levels from shallower wells as well **evaluation of inter relationship between aquifers tapped at different depth ranges.**
- v. **Potential in Deep Aquifers:** Exploratory studies carried out by ONGC in collaboration with CGWB in the Gangetic alluvium indicated existence of auto flowing fresh groundwater at more than 1000 m depth. Similarly, free flow of ground water has been reported at deeper depths from some areas like Terai and Sub-Terai belt of Uttar Pradesh. As no energy is required for **extraction of ground water from such auto flowing aquifers, development of groundwater from these auto flow zones may be economically viable and eco-friendly.** Hence, detailed studies are required for authentication of above findings.

- vi. It is scientifically an established fact that **the vast water resources of Uttar Pradesh including river systems have developed in the foreland of Himalayas** that lap on Vindhyan and Granite system of Indian Peninsular region, due to various depositional activities occurred during formation of Ganga basin. **The studies revealed that this foreland is in dynamic state due to plate-tectonic activity** and ONGC has seismic data of Ganga basin which can reveal the depth to basement as well as the changing dynamics of aquifers at different depths with their spatial and temporal distributions and the geological changes occurring overtime.
- vii. **It is suggested that a collaborative study with ONGC should be taken up to derive an in-depth hydrogeological scenario of entire Uttar Pradesh. This study may prove to be a mile stone for ensuring sustainability of groundwater resources in the state.**

5. Need of Central Law for National Groundwater Regulatory Framework

Ground water should be given an independent entity like other natural resources- mineral, oil, forest in the country, instead of treating it as common pool resource. Therefore, the urgent need is to have a National Ground Water Management and Regulatory Framework. At this point, review of Indian **Easement Act of 1882** becomes imperative, since it allows rights to the owner of a piece of land for having the right to the water beneath his/her land and the use of water located beneath the land. Therefore, for an overall effective and single legal framework, the provision in question needs to be abolished. The central law for groundwater management and regulation should have a unitary regulatory mechanism for more efficient and uniform implementation/enforcement--

- i. Currently, only six States out of 28 States, including Uttar Pradesh and two Union territories have their own State regulatory mechanism and rest are regulated by CGWA. The latest CGWA guidelines issued by Notification dated 24.9.2020 are applicable for whole India. In view of this, it would be more appropriate to have a single regulatory mechanism for the entire country, that should have very specific provisions according to the hydrogeological situations prevailing under different aquifer systems/geological terrains.
- ii. Central Ground Water Authority should be given the responsibility as **National Nodal Advisory Body** with State Ground Water Authorities to be constituted in all

- the states/union territories under the E.P. Act- 1986 for a uniform, single regulatory and management process for an overall systematic execution in the entire country.
- iii. The current legal set ups, constituted in some states/UTs, having their own separate mandates, need to be brought under the umbrella of central law and should be accordingly restructured for bringing unitary regulatory system.
 - iv. For managing the overall regulation process in the country, groundwater management rules and policies need to be framed taking into account all the 42 major aquifers characterized by different hydrogeological set-ups and different geological/geomorphological formations. These major aquifers are already coded and mapped by CGWB.

6. National Groundwater Extraction Policy: An Immediate Need

Unless the current level of groundwater extraction is adequately reduced in all the user segments by implementing set of composite actions/interventions, including reduction in groundwater consumption, augmenting large scale surface water-based supplies and mandatory use of water- efficient methods, the crisis of groundwater will not improve. Experts are of the view that for sustainably managing depleted groundwater system, the potential option is to reduce withdrawals by 40 - 50%.

Hence, **framing and implementing a robust, systematically designed, scientifically well-defined Groundwater Extraction Policy should be the utmost priority at the national level to fix, allow and regulate the withdrawals** separately for different areas under different hydrogeological situations based on current state of aquifer storages. As a proactive measure, **strong policy intervention is, therefore, urgently needed both at central and state level.**

a) Ground Water Extraction Policy

- i. Ground Water Extraction policy should be urgently framed both at national and state level with separate extraction norms for different hydrogeological formations, so as to scientifically assess, allow fixed and regulated withdrawal with strong enforcement. Such norms should have clarity whether the extraction be done from dynamic or static resources.
- ii. These extraction norms should have separate implementing guidelines for urban areas, agriculture, industrial, commercial and infrastructural uses and that should be formulated on the basis of different hydrogeological set-ups/the major aquifer systems.

- iii. **Fixing of abstraction limit:** Permission to allowable quantum of extraction from a ground water system/aquifer should have clarity on the actual resource availability in that particular system, the future needs and the quality. Though the **provision has been made in the State Act,2019 under Section-15 for Fixing of limit for Abstraction of Groundwater**, depending upon the hydrogeological conditions and resource potential of the area concerned, **but scientific clarity is imperatively required as the criteria of resource potential will not sustain due to dynamic state of resource**. It is also important that **there should be specific norms for allowing extraction limit for different category of users within a single aquifer system**.
- iv. Provision of drinking water is a basic necessity, but need based regulatory and controlled withdrawal and consumption should be applied when energized means of groundwater extraction is allowed to individual households.
- v. **District-wise Water Balance:** Under the new Act of the state, District Ground Water Management Council is responsible for carrying out regulatory measures. **Every district should, therefore, immediately proceed to prepare its overall water balance** showing the resources availability at the district level, the water supply commitments, groundwater quality status as well as the carrying capacity of groundwater sources that could sustain the growing population pressure. It is also suggested **to evolve criteria for micro-zonation of OCS units by delineating stressed & unstressed areas** within such units on the basis of determining carrying capacity of aquifers, current groundwater status, declining water level trend and, other factors primarily for the purpose of regulation.
- vi. **Groundwater Security Plans:** This would be pertinent to mention that **Hon'ble NGT has directed for the preparation of water management plans for OCS areas**. There are provisions in the **U.P. Ground Water Act, 2019 to prepare Groundwater Security plans** in all the notified areas for implementation, **as incorporated under section-13. This regulatory provision is very ambitious, but requires dedicated efforts to prepare and implement these plans**. Moreover, the objective of finding water balance, preparing water management plan or groundwater security plan is almost identical. Obviously, the goal is to improve groundwater condition to have sustainable supplies in future. However, **the immediate need is to prepare water management plans / groundwater security plans for OCS areas /**

notified areas on priority for time bound implementation. The over-exploited 74 blocks, as discussed in Chapter - 3, should be on the top of priority list.

- vii. **Guidelines for Dewatering:** Dewatering for basement excavations and its use should be scientifically managed and regulated. **This water should not be drained out but should be gainfully utilized to augment water needs of nearby areas for irrigation** and other uses. In the **CGWA guidelines some provisions are included, which can be elaborated and further extended to state act.**
- viii. **Heavily dewatered aquifer zone should not be permitted for pumping** and information about such zone should be disclosed and put in public domain for awareness.
- ix. During registration, information about extraction of groundwater from deeper aquifers/ In-storage and Static reserves should essentially be gathered and analysed for regulation purposes.
- x. The extraction policy should also cover **groundwater pumping in Fisheries and Mining areas.** As per available information, there are more than 1000 fishery ponds, where groundwater is being pumped out for filling ponds. Similarly, in mining activities also, groundwater is extracted heavily.

b) Registration of all wells

- i. First and foremost, need is the well census through registration of all groundwater structures, which are, so far, countless. In order to develop a realistic data base of groundwater extraction and pattern of usage, process of on-line registration of bore wells/tube wells owned by all groundwater users including all the users from the government sector should be mandated. **The format prescribed for registration should be elaborate, covering all the information of the well including design, depth, diameter, water level, discharge, daily extraction, quality, year of construction, geo-referenced location** etc, as it would help in developing actual scenario of sector-wise groundwater extraction and usage in the entire state as well as in the country. This would also help in more refined and accurate assessment of groundwater resources. With geo-referenced locations, all these wells could be mapped and tagged on GPS/GIS platform to get an overview and pattern of well density.
- ii. Registration of wells for all the user sectors in the state has been mandated by provision in Uttar Pradesh Ground Water (Management and Regulation) Act, 2019. However, **it is suggested that this provision of registration should also be**

extended for all the government tube wells by making necessary amendment in the Act, so that the clarity on groundwater withdrawal by government tube wells could emerge with better inputs that can be obtained by the process of registration. The major chunk of groundwater withdrawal is reported from the tube wells constructed under different government schemes.

- iii. **Consumptive Water use in construction phase:** In the process of registration, information should also be gathered about groundwater usage during construction phase of any building or infrastructure development and also in the construction of tube wells and borings. This is the area, where groundwater extraction is never given any attention and it is left out in the estimations process, while it can be well visualised that huge extraction would have been done during construction phase of different activities and that portion of abstraction remained un-estimated. This is a major concern that the extracted portion of ground water for consumptive uses gradually vanishes and would never return to the water cycle. Similarly, the non-measured Virtual water, which goes away with the product in huge amounts, is also not returning to the hydrological system. This is, obviously, a permanent and irreversible loss to ground water system. It is, therefore, suggested that during the registration process of wells, information on consumption of groundwater in construction and other such activities should also be gather for onward analysis.

Incorporating the above suggestions on registration of wells would strengthen the data base and also the regulatory process.

7. Need for Paradigm Shift from Recharge to Restoration of Aquifers : Time to Act

Artificial recharge in the aquifer and rain water harvesting is often said to be viable alternatives to overcome groundwater crisis in stressed areas. But, **are they really potent enough to solve the problem of groundwater depletion especially in alluvial aquifers! This requires scientific explanation.**

Hence, the best and proven recharge designs and practices for alluvial deposits and rocky terrain of the state should be identified, benchmarked and piloted for experiencing the real benefit of recharging for onward execution and replication in hydro geologically similar areas. This is important because hydrogeology is complex as wide variation occurs in geological formations, physical properties of aquifers and tectonic history of an area, even in alluvial formations having varied sediment characteristics.

The **source water for recharging is primarily rainfall**, but it is now erratic and scanty in time and space. So, with changing rainfall pattern, potential and availability of rain water as source water for recharging needs to be determined.

Existing policies, practices and execution of rain water harvesting and groundwater recharge schemes, a flagship programme to harvest surface water storages and conserve groundwater, could not deliver encouraging results so far in Uttar Pradesh because of weaknesses in project designing, implementation, enforcement as well as neglecting the prescribed guidelines.

Secondly, the lack of **maintenance and upkeep of recharge structures** are outweighing their usefulness.

The other aspect is the isolated approaches of rain water harvesting and recharging, being currently adopted in the state, are scientifically and environmentally not very promising for alluvial deposits. However, in Bundelkhand-Vindhyan region, **technologically viable water conservation measures, based on micro and macro watershed approach, can potentially revive and enhance water storages including large scale augmentation of groundwater sources**. But, the current trend of isolated implementation of traditional conservation activities in hard rock terrain of the state could not achieve the desired results.

RRR Approach for Restoration of Aquifers :

Now, this is the high time for retrospection of ongoing rain water harvesting and groundwater recharge programmes as well as looking back at the respective policies. The outcome is not promising and, hence, future of groundwater sustainability is not with recharge measures and, therefore, rain water harvesting alone cannot be relied upon as a potential solution for restoring aquifers. Rainfall is declining, so supply side methods are also not very much feasible to augment depleting groundwater resources and the situation now calls for more emphasis on demand side initiatives and other management interventions.

Implementing Composite Aquifer Restoration Package :

It is most reasonably required to take up a composite management process envisaging rain water harvesting and groundwater recharge activities combined with host of water efficient measures to arrest the rate of decline, by significantly reducing groundwater abstraction and integrating with strong regulatory actions. The need of the hour is **to initiate a new more practical and doable policy intervention for Restoration of Aquifers through a**

composite aquifer restoration package termed as 'RRR' with different dimensions (reduce demand, reduce abstraction, recharge ground water) for achieving ultimate goal of significant improvement in ground water conditions. RRR is basically a targeted strategy for scientific management of ground water resources combining broadly supply side and demand side measures with appropriate regulatory interventions depending on the regional hydrogeological setting.

Interestingly, the above newly designed composite groundwater management process of RRR has been conceptualized by **using another RRR concept based on three elements- Retrospection, Reimagination, Redesign.**

This RRR management process will envisage following steps to be implemented in a composite way-

- i. **Reduce groundwater demands and consumption** in all user sectors by reorienting and redesigning existing groundwater-based usage pattern in stressed areas. Its increasing use and rising demand should be strictly rationalised for the good of environment and sustainability of groundwater. The reduction in demand and consumption will certainly reduce the stress on groundwater resources.
- ii. **Reduce and regulate groundwater abstraction -**
By effectively reducing and regulating groundwater withdrawal through a mix of dedicated measures/interventions, declining trend in stressed areas could be gradually arrested and as a consequence, there are all probabilities of significant improvement in groundwater situation over the time. Following activities are identified for composite action as per area specific needs -
 - a. **Reduce groundwater extraction** efficiently from tube wells in all the user sectors by fixing allowable abstraction limit and making water meter mandatory. As a principle, declining rate would significantly improve by effectively controlling and reducing groundwater abstraction.
 - b. **Recycle** groundwater supplies, especially in industrial and manufacturing processes.
 - c. **Reuse** treated water in agricultural fields, gardening, toilets, vehicle washing and other non-domestic uses including construction activities.
 - d. **Use of water efficient methods** including micro-irrigation, pipe irrigation, regulating irrigation watering, ridge & furrow irrigation, crop diversification, crop

rotation, low water requiring crops in agriculture sector through sustainable irrigation plans (discussed in detail under action point-8 of this chapter).

- iii. **Recharge** stressed aquifers through a mix of traditional methods and new innovative techniques for large scale recharging.

The suggested management approach of RRR, using Best Practices, may prove to be a holistic solution for bringing out groundwater resources from prevailing crisis as well restoration of stressed aquifers. The RRR approach would surely work efficiently in stressed areas by implementing all the feasible methods as a composite aquifer restoration package. Therefore, strong policy initiatives would be required and modalities for all the components need to be worked out.

7.1 Review Existing Recharge Practices and Scope of New innovations

During past 15-20 years, large number of rain water harvesting and groundwater recharge programmes have been implemented in the state. Various schemes are still ongoing, but much impact is not visible on depleted groundwater resources. The criticality of situation is well reflected in 74 over-exploited blocks of the state, which have not shown any improvement and change in the stressed groundwater conditions over the years, since resource assessment of 2004. It is a matter of concern, because during this period, large number of water conservation and rain water harvesting activities have been executed in these blocks, but nothing significant could be achieved

Such situation demands that existing practices of rain water harvesting and recharging should be critically reviewed, redesigned and restructured with new technological ideas and innovative methods, guided by strong policy actions, robust monitoring and enforcement. Following interventions, based on site specific feasibility, are suggested-

- i. The investment on rain water harvesting and groundwater recharge interventions should be **performance linked** with techno-economical assessment.
- ii. In any stressed area, the recharge activities should be implemented in an integrated manner with a dedicated and targeted plan for restoration of aquifer, as suggested above, and to saturate any selected hydrological unit/watershed by such feasible water conservation activities. It should not be done in isolation, which is currently a common practice in the state.
- iii. The techniques of rain water harvesting and recharge should be **site specific** and need based with feasibility assessment and projected out comes.

- iv. **With past learning and experiences** about various traditional practices of rain water conservation and recharge, **the time demands for designing and developing modern and more efficient techniques for recharge and water conservation either with appropriate modifications in existing methods or coming up with new innovative designs of much larger dimensions for both rural and urban segments and also for industrial sector.** Accordingly, new guidelines will have to be formulated.
- v. **Certain scientific explanations and implications** about sub-surface and surface application for artificial recharge are discussed in Chapter - I, under sub head 'General Basics of Groundwater', which should be considered while preparing such guidelines.
- vi. The traditional approaches of groundwater recharge alone could not make any visible change to de-stress the aquifers. Uttar Pradesh is characterised by two different hydrogeological scenarios, the alluvial formations and the rocky terrain of Bundelkhand & Vindhya, therefore, **new innovations based on some field driven projects and scientific principles**, such as Managed Aquifer Recharge, Recharge basin, Radial wells, Infiltration gallery, large pressure head recharge wells should be taken up on pilot basis in both the hydrogeological domains, along with construction of small structures for recharge and storage, such as recharge trenches, farm ponds, in-situ soil conservation measures, gabion structures, peripheral bunds, nala bunds, check dams for finding and evaluating the relative impact of new innovative methods and traditional structures on groundwater regime. However, this suggestion would require some policy initiative at government level.
- vii. **Impact assessment as well as the maintenance** of recharge structures should be the integral part of all such projects to find out the technical and economic benefits of such investments as well in terms of improvement in groundwater conditions.
- viii. The method and procedure for impact assessment and maintenance of recharge structures have already been circulated by the Ground Water Department to all the concerned departments way back in 2004. However, the methodology may be reviewed and modified in current scenario.

7.2 Actions / Interventions for Urban Areas

The increasing urbanisation with uncontrolled vertical growth of urban areas in the state has put tremendous pressure on groundwater resources in every single unit area, where water demand has increased in multiple proportion. The 1st urban aquifer group has heavily

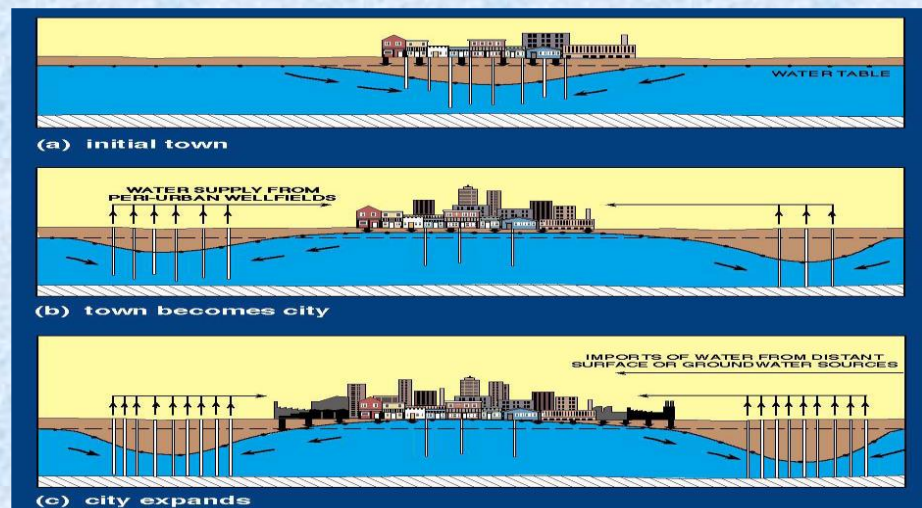
depleted due to overdraft of groundwater, while the 2nd aquifer group has been subjected to unregulated groundwater mining, which may, more likely, result into serious geo-environmental threat. The current situation of over exploited aquifers in urban sprawls of the state is very alarming, which appears to be a most challenging task to revive the depleted resource. Therefore, concrete policy interventions are needed to rejuvenate heavily extracted urban aquifers of Uttar Pradesh. **In continuation of RRR approach discussed above, following policy actions are suggested for the urban areas for systematic execution.**

- i. **Reduce Extraction-** Immediate regulatory interventions are needed for all the urban users for effective reduction in the current trend of groundwater extraction. The resource is in a critical state and effectively reducing groundwater withdrawals has become an imperative need, hence, some robust and strict measures need to be evolved urgently to bring down the present stage of abstraction by at least 40%. Such policy interventions would certainly give respite to depleted urban aquifers from heavy withdrawals and with this effort the aquifers might subsequently revive. Over the time, the resource potential would gradually increase and may notably improve groundwater levels.
- ii. **Develop Peri-Urban Well Fields having Prolific Aquifers -** In stressed urban areas, municipal water supply tube wells should be gradually phased out and shifted to peri-urban areas for giving respite to starved aquifers from continuous pumping. As a policy action, potential well fields in peri-urban areas, having high yielding prolific aquifers, are required to be explored for constructing new tube wells to augment sustainable supplies for catering the drinking water demand of urban population.
- iii. In Lucknow city, potential aquifers have been identified in peri-urban limits on Sitapur road and Chinhata area. The capital city is highly exploited and, therefore, to restrain further exploitation from already depleted aquifers, it is strongly suggested to steadily phase out the existing tube wells located within the city and subsequently augment and maintain continuous water supply to the city from peri urban tube wells.

The prospects and scope of such intervention, how it could be planned and how the groundwater levels would possibly recover over a period of time are highlighted in the schematic picture (Figure - 15).

(Potential intervention
for Urban Ground Water
Management)

Figure -15



- iv. **All roof tops to be tapped** - Hydrogeologically, rain water harvesting and recharging may be useful in those cities (alluvial areas in particular) where ground water is under critical state, such as Lucknow, Kanpur, Meerut, Ghaziabad, Noida, Varanasi where groundwater levels are rapidly declining. In all stressed cities systematic and planned implementation of Roof Top Rain Water Harvesting should cover all the houses located within the city limits through simple and low-cost feasible methods, mostly recharge pits, trenches, to capture maximum rain water as much as possible for subsequent sub surface percolation. Roof top catchments are relatively safe for groundwater recharge.
- v. It is important that since **urban areas have different issues, they would require different solutions**. The rainfall collection centres are mainly roof tops, surface pavements, open spaces, lawns, parks, so different strategies need to be undertaken.
- vi. **Combined Recharge System** - This system is mandated by Housing department for new housing schemes in the year 2006. It is a promising technique for groundwater recharge/rain water harvesting for group of houses. In this system, a separate line for rain water harvesting shall be provided in all the houses, which will be joined to a common RWH line connected to a Common Recharge system. In existing colonies also, feasibility of combined RWH system can be explored with the participation of local residents/resident welfare associations.
- vii. The citizens need to be motivated for groundwater conservation through effective social communication and local workshops.

- viii. **Keeping lawns unpaved (kaccha)** - This could be a good option for allowing natural percolation of rain water and with this small effort, the cities would be able to capture a huge amount of rain water for indirect recharge as a natural process.
- ix. In urban areas, apart from roof top, road side pavements are good catchments for storage or recharging. Possibilities of Pavement storm water harvesting need to be explored for execution. This a very potential option for groundwater recharge. The **concrete/tiled pavements should be redesigned for more natural percolation** as per the local hydrogeological feasibility that would prove to be a promising method for large scale natural recharging. It is expected that a redesigned pavement of 100x2m size, having larger unpaved space for natural percolation, may recharge around 10000 litre of monsoon run-off into the sub-surface strata by adding to soil moisture and subsequently augmenting groundwater sources. Such practice if adopted in all the stressed cities, a huge amount of storm water could be suitably recharged through the natural process.
- x. Further, feasible locations for **Storm water storages** through reservoirs, ponds, recharge basins should also be identified in all the cities for storing surplus monsoon run-off. However, this requires a pilot for evaluating the feasibility of such method in urban areas including economic & social assessment.
- xi. Water efficient methods such as **Recycling and Reuse** of extracted water should be mandated and enforced for institutional, housing & commercial establishments. This would reduce groundwater extraction also. The RRR approach has been discussed in the previous text.
- xii. **Developing Urban Micro Climate** -
Micro climate zones through dense plantation of trees should be developed in groundwater stressed urban areas. Such climate zones will check the rainfall run-off that might spread on land surface, percolate and augment groundwater sources. It is also important that the local temperature may also get improved around the micro climatic zone.

Some Precautions:

1. Rain Water Harvesting structure is a self-choking/clogging system, therefore, it needs regular maintenance.
2. Sandy soil layer is most responsive to groundwater recharge, while the clayey soil lowers down the percolation rate.

3. The RWH system should be designed as per area specific soil, hydrogeology, rain water availability and other parameters.
4. The risk of any contamination/pollution should also be taken care of and it should be pre- assessed before installing the recharge structures.

7.3 Development of Simple Prototypes for Urban Recharging

Low-cost simple prototypes for urban rain water harvesting and recharging should be developed to allow maximum sub surface percolation of rainfall.

Hydrogeology, lithology, rainfall pattern, quantum of run-off should be taken into consideration for developing the prototypes, because these factors differ widely in the state. Therefore, the urgent need is to develop simple, innovative prototypes for rain water harvesting and groundwater recharge, water saving devices for recycle and reuse of water, efficient water uses for the industries, and also for the infrastructural, commercial and bulk users.

The significance of these prototypes and water saving devices becomes important in light of the U.P. Ground Water Act, 2019, because all these users shall adhere to related provisions prescribed under the said act

Recharge Conduits and Multiple Pits:

In urban areas, with limitation of open fields, it is suggested to artificially create more recharge spaces, which could be done by increasing surface area through recharge conduits and pits to hold more rain water for subsequent groundwater recharge and increase in soil moisture. The recharge conduits and pits up to maximum depth of 3.0 m can be made in multiple numbers in parks, open/unpaved fields, lawn area, roadside pavements.

7.4 Need for Strict Policy / Regulatory Measures

i. Discourage Injection Well for Ground Water Recharging

In roof- top rain water harvesting technique, injection well, bore well or recharge well methods are usually in practice for direct recharging of rain water into the aquifers. Geo-scientifically, this method should be precisely adopted with all necessary precautions in light of probabilities of pollution risks. **It has been a general observation that the use of injection well has become a common practice without following the specified norms which might contaminate aquifers.** There are reports from various places that the injection/bore wells are also constructed in the

ponds for the purpose of recharging. This is not permitted because there is all possibility of direct recharging of pond water, which might be contaminated and may pollute the aquifers. Even the rain water from paved/unpaved catchments is not allowed for direct recharging into the aquifers through injection/recharge wells.

In general, the injection/recharge well structures are not being maintained and most of them are in bad condition do to clogging and also there are chances of contaminants percolating directly into the aquifers.

Therefore, for ensuring long term protection of aquifers, **strict measure by putting blanket ban on recharge/injection well method** in all the rain water harvesting and groundwater recharge programmes of the state need to be taken on priority.

- ii. In any case, recycled water, treated waste water and rain water from paved/unpaved open fields, waste disposal, overflows should not be allowed for direct recharging into the aquifers through injection well, shafts, abandoned bore wells/hand pumps. (Penal provisions are envisaged in the U.P. Ground Water Act-2019). A large number of such structures already constructed should be identified and penalised as per the provision of the U.P. Ground Water Act-2019.
- iii. **Ensure Enforcement:** Implementation and enforcement of groundwater recharge provisions prescribed for the urban areas especially rooftop rainwater harvesting, combined recharge system and also the other provisions should be ensured. **Single department should be made responsible for the purpose of enforcement.**
- iv. The major part of almost all the urban areas is not covered with the provisions of rain water harvesting, which is applicable to new housing schemes and new constructions on plots of 300 m and above. Hence, in order to tap most of the rain water for groundwater recharging, **policy provisions for promoting rain water harvesting and recharge in existing colonies** and establishment are required through executive decision and the simple feasible designs for recharging should be developed for citizens acceptability.
- v. **Recharging Flood Plain Aquifers:**
Flood banks of rivers should be protected as environmental zones for natural flood recharge. **Aquifer of flood plain are good repositories of groundwater, where controlled withdrawal of groundwater during non-monsoon season can be taken up to create ample additional space in unsaturated zone** of flood plain for subsequent recharge/infiltration during rainy flood season. In absence of such created

space the flood water may overflow. This method of **Induced Recharging in flood plain aquifer of Uttar Pradesh** can be experimented on the pilot basis for subsequent implementation on large scale. If this method gets succeeded, it may be a boon for both stressed areas and flood affected regions

7.5 Rainfall Assessment for Project Formulation

There is an overall deficit in rainfall in the past years, hence it becomes imperative to evaluate whether the rain water harvesting/recharging projects implemented with huge investments could achieve the targeted goal of recharge, because the deficient rainfall factor is never considered in the project formulation. Therefore, it becomes imperative to assess rainfall pattern of past years and accordingly quantum of rain water for purpose of rain water harvesting and groundwater recharge should be properly determined for formulating appropriate project. This aspect needs to be thoroughly reviewed in respect of techno-economic benefits of such projects.

8. Ensuring Specific Mechanism for Agriculture Sector

Effective initiatives need to be taken for managing the abstraction of groundwater by the farmers owning private wells. Presently, there is no proof count of all irrigation wells, but that could be around three million or more in India. Same is the case with other groundwater wells, being used in households/domestic, industrial, commercial sectors and other bulk users.

Agriculture sector needs complete reform in irrigation water use:

Groundwater use in agriculture sector is of utmost importance, hence strong regulation over irrigation water (groundwater) is the need of the hour. In U.P. scenario, it becomes imperative to formulate norms for the use of groundwater for different crops, so the present extraction rate could be effectively regulated and reduced to save and protect it.

- i. Bench-marking for optimum number of irrigation (**Crop watering**) needs to be developed for different crops, seasons and agro-climatic zones. The number of watering required for different crops should be identified and regulated. It is important that dichotomy in water uses in agriculture sector needs to be looked into and scientifically addressed.
- ii. **Less water consuming crops** should be **regulated and notified** for stressed areas for sowing as per the availability and need of ground water. For this intervention, farmers should be incentivized.

- iii. Promotion and adoption of **efficient water use techniques** should be encouraged. **and farmers should also be incentivized** for adopting such water efficient methods. Water use efficiency by micro irrigation including drip irrigation is as high as 80 to 90% in comparison to only 30 to 40% in conventional flood irrigation, resulting in saving of considerable amount of irrigation water, especially groundwater withdrawal, under drip irrigation.
- iv. Micro Irrigation (drip/sprinkler) should be extensively promoted in the state, as it is a potential area and efficient technology for controlling and reducing groundwater draws in agriculture sector. However, **feasibility of such schemes for different crops and for the small holding size farmers need to be determined.**
 - The important crops suitable for micro irrigation system, under different agroclimatic zones, should be notified for adoption.
 - About 90% farmers are small and marginal with land holding size less than 1 hectare, therefore this aspect is quite significant while promoting drip and sprinkler irrigation, because for the farmers, the maintenance and running cost on such devices will be difficult to manage.
- v. The impact of implementation of micro irrigation schemes needs to be reviewed. In Uttar Pradesh, having about 37 lakhs private irrigation wells, only 0.25% are covered with micro irrigation, which is very less if compared to the National coverage of 5%.
- vi. **Feasibility Assessment of Micro-irrigation:** In context of Uttar Pradesh, it is important to conduct district wise feasibility assessment of micro-irrigation system so that the details of village level agricultural fields, crops and willingness of farmers could be worked out separately for drip and sprinkler methods. With this exercise, the quantum of micro irrigation for each district may be assessed for future management actions.
- vii. **Community / Group based centralized drip irrigation system** should be encouraged for small / marginal farmers to easily manage annual maintenance and running cost more efficiently.
- viii. To evaluate the feasibility of sprinkler system on state tube well, canals and reservoirs, pilot studies may be carried out at 4-5 places for onward implementation.
- ix. In light of above suggested interventions, **crop diversification and crop rotation** should be adequately addressed and regulated for different agro-climatic zones and groundwater stressed areas, **but farmers acceptability needs to be determined. The**

farmers are ready for crop diversification and other practices, they can be provided with some incentive.

- x. **Optimization of cropping pattern** is meaningful, but replacement of rice crop is not the right alternative. **The need is to give economically viable options to farmers.** Integrated approaches including soil, water and crop productivity as well water use efficiency should be adopted.
- xi. **Sugarcane is a highly water intensive crop and in Uttar Pradesh, cultivating sugarcane has become the first choice of farmers.** As per field estimates, sugarcane crop consumes about 15-18 million litre water per hectare. This is very high consumption and requires regulated management through water efficient methods.
- xii. Farm ponds and farm management interventions, including ridge and furrow irrigation should be extensively promoted.
- xiii. Agriculture sector is single largest consumer of groundwater and wasteful, excessive use of groundwater by farmers is already in the notice of concerned organization. NGT has already advised to regulate agriculture use through state interventions. It is suggested that **individual land holdings of more than 3 ha may be asked to provide rain water harvesting structures as per the size of holding and volume of extracted groundwater.** This will help in storing and harvesting rain water which could be used for irrigation and livestock.
- xiv. There should be some incentive for using treated effluents for irrigation as it would exert lesser pressures on groundwater irrigation. Industries authorized by the Pollution Control Board should encourage and incentivise farmers for using their treated effluent for agriculture.
- xv. **Sustainable irrigation plans:**
In view of **regulatory provisions of implementing groundwater security plans in notified areas**, the need is to make it mandatory the preparation of sustainable irrigation plans and promote farmers participation in proactive demand and supply side measures specially reduction in conveyance losses, development of irrigation plans, adoption of water efficiency measures for water intensive crops etc.
- xvi. **Training of Farmers:** Farmers need to be trained for adopting and implementing demand side management practices. Innovations may reduce groundwater pumping through mix of several approaches and that may also improve economic returns. However, **farmer's overall acceptability needs to be assessed for the proposed reforms in agriculture sector.**

- xvii. **Integration of Local Groups:** In water sector, there are so many groups like Water User Association (WUA), Village Water & Sanitation Committee, Bhujal Sena, Ground Water User Groups, Pain Panchayat, Jal Saheli, but there is no integration amongst them at the field level and, therefore, full potential of these groups could not be utilized so far for promoting water conservation measures. **These groups with support from stakeholders active in this area should be integrated at district level to make use of their potential in various field level agricultural reform activities** from collecting field information to creating awareness about various proposed reforms. These activities can also be co-ordinated with organising **Jal Chaupals** for communicating with farmers.
- xviii. **Task for Saving Water:** Efficient agriculture practices as well use of irrigation water can save water up to 30-40 percent without compromising crop yield. This should be the focus area.
- xix. **Treated grey water for agriculture:**
The treated water from Sewage Treatment Plants has huge potential for its use in agriculture and allied sector. It would reduce the burden on existing irrigation supplies. **So efficient and best practices for use of treated water need to be evolved and implemented.**

9. Policy Actions for Industrial - Commercial -Infrastructural Users

In the U.P. Ground Water (Management and Regulation) Act-2019, the user sectors, which have been brought in the ambit of various regulatory measures, are industries, commercial users, infrastructural sector and bulk users. But, for carrying out these regulatory measures, required data and information, especially on groundwater availability and utilization, are not available with the responsible organisations for these users. So, question arises how these sectors could be managed and regulated without having adequate scientific knowledge and requisite database on groundwater resources availability, extraction, demand, pattern of usages and trend of groundwater levels.

In view of this, certain specific studies need to take up for generating such information which would essentially be required for the purpose of regulation of these users. Following interventions are needed-

- i. District wise inventory of industries (**MSMEs and large industries**), commercial, infrastructural and bulk users should be prepared.

- ii. Commercial, infrastructural and bulk users should be clearly defined **with their specific names, types or category for distinct identification of such users.**
- iii. Currently, there is no official estimate of ground water extraction and pattern of its usage in industrial, commercial, infrastructural and bulk user sectors. Therefore, **all such information for each district is required to be determined on priority by the Ground Water Department through data gathering, specific surveys and data analysis.**
- iv. In Resource Assessment-2017, groundwater estimation for industrial uses is not done. This has been in practice in past ground water estimations also. This data gap is a major challenge for achieving sustainable groundwater management in these critical user sectors. Therefore, this part of **estimation of groundwater extraction for industrial uses, including the abstraction in the infrastructural, commercial, bulk sectors, should essentially be carried out and the present assessment findings should be modified and corrected accordingly**, as estimating this portion of groundwater abstraction is quite crucial for the purpose of regulation of these user sectors.
- v. Groundwater assessment should be carried out in all the industrial clusters of state, including 13 most polluted clusters.
- vi. Moreover, information on groundwater levels in these user sectors is a basic requisite to have a long-term overview on groundwater situation, but since such focused information on groundwater levels for these sectors is currently not available with Ground Water Department and CGWB, that **would certainly influence the impact assessment of present regulatory actions.**
- vii. The urgent need is to develop and consolidate groundwater level monitoring system (along with quality analysis) in all these user sectors for obtaining required information in a time bound manner for subsequent analyses and to develop probable scenarios. This activity can be strengthened by the data being collected by various industries through previously established piezometers for monitoring of groundwater level and its quality, mandated by the Environment Department, Government of U.P. in 2004. This activity is also proposed in the state Act as well in CGWA guidelines. Hence, data consolidation and analysis become important and challenging for management of these user sectors, as collecting previously monitored/past groundwater related data and information would remain a large data gap, while they are the most targeted users in the state for groundwater regulation. In fact, **their true**

share in groundwater extraction and consumption is scientifically never deciphered, raising valid question on the resource assessment findings.

- viii.** All the units under these user sectors, industrial-infrastructural-commercial, should be classified on the basis of groundwater withdrawals, on the similar lines industries have been classified for the purpose of control of pollution under the Water Act-1974.

It is suggested that **different user units may be classified as -**

- 1. Highly water intensive,**
- 2. Critically water intensive,**
- 3. Moderately water intensive, and,**
- 4. Less water intensive.**

10. Micro level studies for 'Notified Areas'

In view of the U.P. Ground Water (Management and Regulation) Act, 2019, and its respective Rules, various blocks and urban areas are 'Notified' for regulation purposes. The GEC-2015 methodology suggests the need of **Micro level studies in the Notified areas for the reassessment of recharge and extraction in order to find out accurate groundwater figures.** The **suggested approach for micro level studies** may be-

- i. The area may be sub-divided into different hydrogeological sub-areas such as recharge area, discharge area, transition zone and also for quality.
- ii. The number of observation/monitoring wells should be increased in a way to represent each sub areas with continuous water level monitoring. Digital Water level recorders should be used.
- iii. Groundwater level data of at least last 10-15 year should be analysed periodically and changes should be documented for each sub-area.
- iv. Hydrological and hydrogeological parameters particularly the **specific yield** should be collected for different formations in each sub area. Long duration pump test data would be reliable.
- v. The data for other parameters like seepage from canals, check dams, ponds, reservoirs should be collected after field studies, instead of adopting recommended norms. Details of lined canals in sub area should also be collected
- vi. Base flows should also be estimated based on stream gauge measurement.
- vii. For each sub-area (urban and rural), land use pattern map should be prepared for the purpose of groundwater management.

- viii. Data of number of existing structures/well and unit draft should be reassessed after fresh surveys and should match the ground reality of extraction and declining trend. Well census in each sub-area should be done including industries, commercial, infrastructural and bulk users. All structures should be geo-referenced for GIS based location map of each sub area.
- ix. For each sub-area, aquifer profiling based on strata charts of existing tube wells should be done to understand the dynamics of aquifers for purpose of regulatory measures.
- x. Information regarding all the recharge and rain water harvesting structures and also on micro irrigation schemes/water efficient methods should be collected and consolidated for each sub-area for the assessment of supply side and demand side interventions.
- xi. For each sub-area, groundwater quality/ pollution data should be collected along with the information on health issues for overall quality and health risk mapping and analysis. The information about sources of pollution should also be collected and compiled for the purpose of regulation.
- xii. All the available groundwater data for watershed and sub areas should be collected from all respective agencies, institutes, universities for reassessment purpose.
- xiii. Reassessment should be carried out as per the recommended methodology using freshly collected data and validated values of parameters.
- xiv. The reassessment results may be cross-checked with the behaviour of groundwater levels and both should match. If any anomaly is found, revised assessment should be re- examined.
- xv. Based on the finding of micro level studies, **such area can be re-categorised.**
- xvi. Other groundwater issues should also be identified in each sub area.
- xvii. Groundwater security plans can be easily developed, using such information.
- xviii. **Urban Groundwater Mapping:** Urban areas with yearly decline of more than 20 cm for last 05 years are to be declared as stressed areas for the purpose of management and regulation, as recently envisaged in the U.P. Ground Water (Management and Regulation) Act-2019. Therefore, in stressed cities, periodic ground water level mapping with intensive real time monitoring should be started on priority and this information should be kept in public domain.
- xix. **Micro level study in notified areas is most relevant and valid** in reference to U.P. Ground (Management & Regulation) Act, 2019.

xx. **Specific Tasks for Management:**

In the State Act, **three important tasks** (a)- Preparation and implementation of groundwater security plans for notified areas, (b) -Demarcation of groundwater quality sensitive zones, and (c) Fixing of groundwater extraction limits are envisaged. **All the three tasks have significant role in carrying out the provisions of Act.** Hence, it would be pertinent that for implementing these tasks, efficient interventions based on geo-scientific understanding should be prioritised and evolved for timely actions.

- The groundwater security plans should have targeted goal of achieving and maintaining groundwater harmony at village or watershed level.
- Delineation of groundwater quality sensitive zones is complex exercise, hence needs to be carefully demarcated based on the consolidation and analysis of all existing data available with different departments.
- The third task of fixing abstraction limit implies the need to carry out detailed micro level resource assessment as the recharge potential is variable and dynamic and it can be different at different places within an assessment unit (block or city) and also the prevailing hydrogeological conditions. So, the procedure of estimating ground water extraction limit need to be carefully defined.

11. Need of Extensive Groundwater Quality Mapping and Assessment

The Comptroller and Auditor General (CAG) of India in its **Performance Audit of Water Pollution in India, 2011-12** observed that despite increasing pollution of groundwater sources and presence of contaminants like arsenic, nitrate, fluoride, etc., no programme at the central or state level is being implemented for control of pollution and restoration of groundwater. CAG has also pointed out that the Central Pollution Control Board and the CGWB do not carry out real-time monitoring of water pollution in rivers, lakes and groundwater sources. However, real-time monitoring for certain quality parameters to measure river water pollution has been started sometime back, but real time monitoring for groundwater quality has not started yet.

The CAG has made following recommendations with regard to the prevention and control of pollution of groundwater:

- i. the Ministry of Environment, Forest and Climate Change needs to establish enforceable water quality standards for lakes, rivers and groundwater to help protecting ecosystem and human health,
- ii. penalties need to be levied for violations of water quality standards, and,
- iii. States need to take measures for control of source of pollutants through sewage and agriculture run-off entering water bodies in the projects for conservation and restoration of lakes.

Despite of above recommendations of CAG, **groundwater quality issue remained neglected in the state. Contamination/pollution hazards are widely reported from different districts of the state.** The quality issues are emerging fast as a new crisis, but the **state still does not have realistic and consolidated scenario of groundwater quality both at regional and local levels.** The magnitude of groundwater pollution is gradually increasing as a future threat for resource sustainability. **This is the high time that the seriousness of groundwater pollution should be understood** at the state level for timely actions.

Therefore, **a comprehensive groundwater quality study and mapping of different pollutants in groundwater foe entire state is urgently required, for the purpose of maintaining and restoring wholesomeness of groundwater quality and prevention of groundwater pollution.**

With increasing ground water quality issues in the state, the need is to develop long-term consistent and periodic information on the overall quality of this hidden resource, so that appropriate decisions for groundwater quality management with time bound policy interventions could be suitably taken up. Several important key actions are, hence, suggested for groundwater quality mapping and assessment in the state.

State Groundwater Quality Assessment: Need for a Dedicated Programme

Urgent Need for a Uniform Policy

In the state, new trends of groundwater pollution would be the biggest futuristic threat for resource sustainability and people at large. It is seen as much larger issue than the over-exploitation. In this background, **Uttar Pradesh requires a dedicated State Groundwater Quality Assessment Programme to be designed with a target to have a long-term consistent information and data base** on groundwater chemistry, periodic quality changes assessment and mapping, baseline understanding of different quality parameters prescribed

for drinking water and irrigation supply as well as **identifying uniform methods for quality sampling and analysis with development of respective protocols.**

This programme would envisage following activities as discussed -

- i. **Documentation of ongoing programmes:** As a first step, understand and document the on-going quality assessment programmes of all the concerned organisations, that include UP Jal Nigam, GWD, UP, CGWB, UPPCB, CPCB. The document should envisage method of sample collection, transportation, quality analysis, equipment's used, parameters analysed and NABL status for the quality labs.
- ii. **Consolidation and Integration of Existing Data for Baseline Scenario:** Huge groundwater quality data for all important parameters, including heavy metals, is lying isolated with U.P. Jal Nigam, Ground Water Department, Central Ground Water Board, UPPCB, CPCB and other organisations, academic institutes, but such important data and reports, primarily of public health concerns, have never been integrated and utilized, especially at planning and execution stage to ensure and augment safe water supplies. This is irony, that the local administration as well as the stakeholders are also not aware of such situation. Hence, it is utmost needed that compilation, consolidation and data analysis of all the past and current groundwater quality data available with the above departments should be taken up on priority to evolve a baseline quality scenario of the state. This should include broader findings as well as the data gaps and also focus on probable hotspots as well as demarcating safe areas.
- iii. **Identify Single Department for Organised Quality Assessment:** The imperative need is to have an Organised Assessment of groundwater quality for all the parameters including heavy metals, pesticides and bacteriological contamination. Presently, isolated quality assessments are done by U.P Jal Nigam, CGWB, Ground Water Department, U.P. Pollution Control Board and other institutes such as IITR, CPCB, IITs and different Universities. But it is quite surprising that no department takes the ownership for dedicated quality assessment of both the drinking water and irrigation supplies. The departments are working on different groundwater quality schemes, but neither the findings are shared nor the concerned departments show any co-ordination for taking up integrated quality assessment in order to ensure potable supplies in the affected areas.

Therefore, **one department at the state level should be made responsible for overall quality assessment along with establishing NABL accredited labs in all the problem districts for periodic quality assessments.**

- iv. **Prepare Quality Assessment Protocols and identity Parameters:** The state should also formulate quality protocols for ground water sample collection and its analysis.
- v. **Establishing Permanent Quality Monitoring Stations:** Permanent groundwater quality monitoring stations both on shallow and deep wells should be established/strengthened on a definite grid pattern. The purpose is to have periodic quality checks both in pre-monsoon and post-monsoon seasons as well as in other seasons. The existing permanent quality monitoring network established in 2014 by the Ground Water Department requires to be adequately strengthened in view of new perspectives.
- vi. **Periodic Quality Assessment and Quality Mapping:**
Initiatives/actions are required to-
 - Analyse quality data for all the parameters and assess periodic changes,
 - Identify sources and causes of pollution,
 - Prepare district wise GIS based quality maps, develop different scenarios and models, demarcate groundwater polluted areas to identify Hotspots.
 - Prepare detailed district quality reports with mitigation and preventive measures.
 - Upload major findings on district website for remedial actions.
 - a) These maps should be periodically updated to assess dynamic changes in the quality and to take appropriate measures for potable supplies, both domestic and irrigation.
 - b) The maps should clearly show whether the quality issue is natural (geogenic) or it is due to man-made/anthropogenic activities for taking up suitable quality management interventions.
 - c) The quality affected groundwater sources should be regulated as "**Ground Water Quality Sensitive Zones**" for ensuring potable water supplies and prevention of quality. Such provision is made in the U.P. Ground Water Act- 2019 and needs to be accorded priority for implementation and enforcement.
 - d) A "Technical Task Force" should be formed at state level for guiding and monitoring groundwater quality related activities. The issue is important and requires regular updating of available quality information for taking up necessary remedial measures in polluted zones.

vii. **Delineate Inland Salinity boundary:**

Since a large Inland Salinity tract extends across many districts from western region to eastern part, the boundary between fresh water and salt water needs to be demarcated at micro basin level through combination of studies for identifying safe areas and ensuring potable water supplies.

viii. Reject water from Profiler should be scientifically analysed to study the concentration of different chemicals, as it may be possibly highly toxic and accordingly suitable measures should be adopted.

ix. **Health Risk Assessment and Management:**

A large population of the state is reported to have been affected with various health issues like fluorosis, arenicolids, gastro intestinal and other ailments. Safe and potable supplies in quality affected areas are severely hampered. Secondly, due to excessive use of groundwater for the irrigation in these contaminated areas, risk of contaminants reaching to people through Food Chain is already reported in various studies, therefore, requires needful action.

a) The quality issue in irrigation supplies is gradually becoming an emerging concern all across the state, because in groundwater based minor irrigation programmes, the problem of water quality has never been recognised in the state and contaminants accumulation in the crops has also not been investigated.

b) The issue is, therefore, required to be addressed for extensive mapping of groundwater quality in agricultural farms/ irrigation fields as well as for its mitigation and prevention.

c) The health **risk assessment** due to groundwater pollution should also be carried out in the state for the documentation and mapping of different diseases and affected population, so that the timely measures as well as developing protocols for mitigating human health risk could be initiated on priority.

Meanwhile, till the decision is taken for a Uniform Policy on groundwater quality assessment programme, as suggested for the state, the **above action points should be included in the on-going programmes of quality assessments**, being carried out by U.P. Jal Nigam, Ground Water Department, U.P. Pollution Control Board, CGWB for improvement in overall quality assessment through a co-ordination mechanism.

12. Groundwater Protection Charges: Need of Differential Pricing

Most important part of groundwater management is to implement effective pricing for groundwater usage by all user sectors. Pricing is precisely a dominant tool to encourage people for self-regulation and to stop misuse of resource. It is recommended to introduce Groundwater Protection Charges to regulate the uncontrolled groundwater extraction and its misuse.

- i. Irrigation water should be charged at the minimal rates as per the land holding and multiplicity of crop sowing. Minimal charges will change the attitude of the farmers for improper use and excessively exploiting the resource.
- ii. Groundwater based municipal water supply may be metered and charged on the pattern of electricity to make the people water-wise. However, the charges may be prescribed according to the plot size.
- iii. Group housing societies should be charged for withdrawing water from their own tube wells.
- iv. Likewise, dwelling units should also be charged for withdrawals from their own tube wells/ submersible borings. The charges can be categorised as per the plot area and the quantity of groundwater draws.
- v. Groundwater economy valuation should be carried out in the state for future perspective of resource allocation in different user sectors.

13. Conjunctive Water Use Management: Need to Translate on Ground

For efficient water conservation, conjunctive management of surface water and groundwater requires attention of policy makers for adopting this method to overcome the problems of sub-surface water logging in canal command, over-exploitation in stressed areas and water supply issues in urban areas.

It is a well-known fact that conjunctive water use management is the most potential method for protection and sustainability of water resources as a whole by maintaining the hydrological harmony of both surface water and groundwater systems, especially in stressed areas of alluvial region of the state, but **the concept is still a distant dream because of lack of governance in ownership of this proven technology by the concerned departments for implementation in the field, mostly in canal command areas.**

This is the reason that last four decades have seen various efforts for conjunctive water use, but could not succeed due to lack of continuity in implementation phase. The conjunctive use

plans prepared in World Bank funded UPWSRP - Phase 1 could not be implemented in the Project area of Jaunpur Branch Sub-basin.

In view of above, it is suggested-

- i.** The concept should be seriously taken up as a mandatory policy intervention for implementation in water projects to ensure sustainability of both the surface and groundwater and also to overcome future crisis. Till date, no department is willing to own and implement conjunctive water use.
- ii.** As a conjunctive use measure, sub-surface waterlogged areas offer good scope for groundwater development as the shallow groundwater level can be lower down up to 6 m easily without any undesirable environment consequence.
- iii.** Conjunctive water use should be mandated through regulation in the agriculture sector for the balanced use of surface water and groundwater, especially in over-exploited and critical blocks. The dual roster for conjunctive use of canal water and groundwater supplies is a well experimented application and it should be promoted for balance use of water resources.
- iv.** In urban areas where both sources are available, it would be the most potential method. Major cities like Lucknow, Kanpur, Varanasi, Allahabad, Agra should take up the conjunctive water use in urban water supplies to reduce pressure on groundwater resources.

The conjunctive water use management method should be considered as very promising intervention at policy level, as it can efficiently control over-exploitation and can also manage water scarce areas as well as the water issues of urban bodies.

There are numerous extensions of this approach for water resource management.

Therefore, the need is to pilot this method in the field for subsequent replication in canal commands as well as in stressed areas.

Study for Aquifer management and Conjunctive use management:

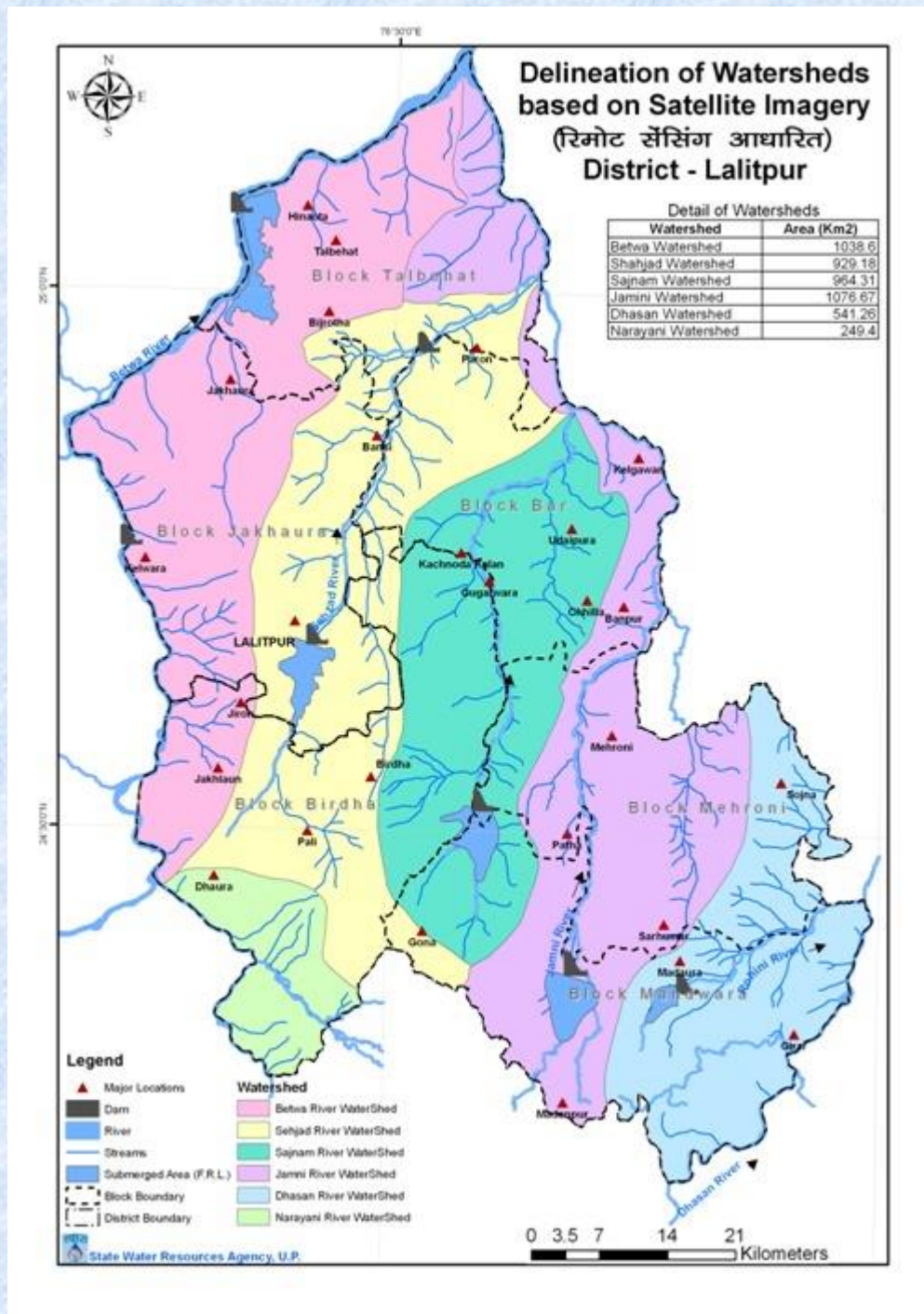
Under the World Bank Project, UPWSRP-2, a special study is undertaken for aquifer management and conjunctive use management in part of stressed Fatehpur district. The highlight of this study would be aquifer mapping on 1: 10000 scale and aquifer management plan and implementable Dual Roster for conjunctive use of canal and ground water. If the desired outcomes as per the targeted goal are achieved, it is hoped that findings would go a long way for replication in other parts of the state.

14. Watershed Geomorphology based Interventions for Bundelkhand-Vindhyan

In rocky terrain like Bundelkhand, watershed plays an important role for resource management. Watershed is a natural hydrologic land, where flow of rain water is controlled by the existing drainage network and geomorphic features. Every watershed behaves differently to flow of the rainwater, being dependant on the drainage and its hydrologic characteristics, largely controlled by geomorphology of the area. The geomorphology, in conjunction with geological setting, is characterised by various fluvial and denudational land forms, which comprise recharge and non-recharge areas.

The understanding of watershed geomorphology and based on this, the derived water conservation measures, if suitably implemented, would prove to be a potential technological intervention for complex terrain of Bundelkhand and Vindhyan. Watershed geomorphology-based approach in such rocky terrain would certainly achieve desired results. Following suggested actions may deliver promising results in improving ground water condition in Bundelkhand - Vindhyan region.

- i. Remote sensing-based mapping of watershed geomorphology on 1:10000 scale should be done for the entire Bundelkhand along with the rocky terrain of Vindhyan.
- ii. All denudational and fluvial landforms/geomorphic features, drainage system having different groundwater significances, should be mapped within each selected watershed.
- iii. Based on these maps, recharge and non- recharge areas in each watershed should be delineated for deriving suitable area-specific water conservation structures.
- iv. The **buried pediments, valley fill deposits, colluvial deposits and flood plain deposits**, including paleo-channels would be the potential areas for both groundwater recharge and its extraction.
- v. The second to fifth order streams of drainage systems, controlled by fluvial geomorphology, should be mapped for identifying suitable rainwater conservation measures, in order to augment maximum rainwater for surface spreading and subsequent recharge. The 1st order stream should not be considered for any water conservation measure due to its unstable geomorphic characteristic.
- vi. **Micro Village Forests:**
The plantation should be done on barren residual hillocks and pediplain landforms to check the runoff within the watershed. Similarly, "**Micro Village Forests**" should be developed in every village of Bundelkhand-Vindhyan for enhancing recharge



and control of excessive monsoon run-off. This concept of 'Micro Forest', having an area of at least of 0.5 to 1 ha each, can also be suitably replicated in alluvial rural areas of the state. The sites for such micro forest should be identified at a place, where surplus run-off could be checked for subsequent surface spreading and recharge.

15. Mechanism for Ensuring Stakeholders and Community Participation

In Uttar Pradesh, a lot has to be done for community participation and creating public awareness in the field of groundwater conservation and management. The experience of

water conservation in Jakhni village, water campaign in Banda district, on farm harvesting in Andhao village, Baberu and successful concept of Jal Chaupal should be scaled up and restructured with more innovative project designs for implementation in the field.

- i. Bhujal Sena is already in place in all the districts of the state along with various social groups like Pani Panchayat, Jal Saheli, WUA. These groups should be integrated and assigned with the responsibility of taking up different awareness campaigns at the local level.
- ii. In urban areas awareness and sensitization campaigns may be started from school to school and in rural areas from panchayat to panchayat in a chain form, so that the message of groundwater conservation and management could reach to the masses. These groups may also contribute a proactive role in motivating the communities for their participation in groundwater conservation measures at large.
- iii. With change in perceptions and practices, communities should be engaged and given important role in water conservation activities. Civil society organisations should have their role in sensitizing relevant stakeholder groups to address groundwater issues.
- iv. Develop an interface between government and stakeholders/community, involving them from planning to execution.
- v. Mechanism needs to be evolved for community level water budgeting, groundwater level measurements and documenting various water related conservation and management activities carried out by stakeholders, NGOs and aligning them with government plans and programmes as field inputs for future perspective.
- vi. **People involvement in Ground Water Budgeting:** The paradigm shift is needed in current groundwater assessment process. The local groups should also be involved in gathering groundwater level data, ground water usage data, rain water conservation data for preparing / estimating water budget at village panchayat / municipal level.
- vii. Groundwater awareness / sensitization programme should be carried out round the year with large scale involvement of community and stakeholders in a way that the message of groundwater protection & conservation could reach to every citizen of the state within a span of 3-5 years.
- viii. The stakeholder groups, communities and local awareness groups should have regular interactions by organising Jal chaupals and Groundwater dialogues.
- ix. Information- Education- Communication (IEC) can be an important tool for sensitizing the community. However, for carrying out IEC activities, material should

be prepared as per the local language and it should be easy to understand for the local people.

16. Preparation and Implementation of Integrated Water Resources Management Plans

Integrated Water Resources Management (IWRM) is a much-talked term, that holds the potential to provide ultimate solution for the prevailing water crisis in the state, but it has never been included in any water resources planning process.

This is the right time that this concept should now be translated on the ground. **Bottom-up approach should, therefore, be adopted for implementing IWRM in the state.**

Following key points are suggested for its implementation -

- ❖ The smallest unit for IWRM should be either gram panchayat /block or micro basin 'micro watershed for rural areas and municipality / water supply zones for urban areas.
- ❖ The provisions for preparation and implementation of Ground Water Security Plans for the notified areas, as mandated in UP Ground Water (Management and Regulation) Act ,2019. can be expanded to formulate overall water management plans plans by envisaging the concept of IWRM.

CONCLUDING REMARKS

Groundwater depletion has emerged as a policy concern both at national and state level, which needs to be addressed through an integrated and holistic approach. The resource management in Uttar Pradesh poses both quantitative and qualitative challenges, which requires efficient policy interventions for restoration of aquifers so as to achieve balance between extraction, utilisation and replenishment of groundwater sources,

The document on "State of Groundwater in Uttar Pradesh" covers an exhaustive overview of groundwater resources in Uttar Pradesh. The issues of ground water in the state are quite diversified and therefore, the attempt has been made to cover almost all the aspects of ground water resources including its availability and resource changing pattern, growing ground water stresses, quality scenario, environmental issues and management concerns.

Different policy initiatives and government decisions have been discussed at large. Various scenarios are critically analysed and relevant observation are made to suggest scientific improvement in different procedures and methods.

Importance of data management and digital technology in ground water governance is highlighted. In the alluvial aquifers, where multi aquifer system exists there is a need to concretize methodologies for assessment of extractable potential of deeper aquifers.

To suggest different reforms in ground water sectors, a robust mechanism for sustainable and efficient groundwater management through a set of actionable solutions are recommended, which include innovative practices and programmes for ensuring long term sustainability of groundwater systems of the entire state facing diversified ground water problems. Suitable suggestions and interventions are envisaged for resolving various issues pertaining to all groundwater users.

A road map by combining and integrating various activities would, therefore, be required for a holistic and sustainable solution to gradually overcome ground water crisis in the state. There is an urgent need for coordinated efforts from various Central and State agencies, social service and non-governmental organisations, academic institutions and the stakeholders for successfully implementing the much-needed strategies.

Community involvement and people participation should be envisaged on priority and conducting round the year public awareness programmes for creating sensitization amongst

the people and stakeholders at large would be greatly helpful in translating ground water plans on the ground.

The report, envisaging set of groundwater reforms and integrated solutions, may provide a sustainable pathway for futuristic planning and sustainable groundwater management with a new concept of "RRR" for achieving restoration of aquifers as ultimate goal.

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Ravindra Swaroop Sinha, having more than 40 years of experience in diversified fields of ground water sector, did Master's in Geology in 1977 from Lucknow University and is trained in Remote Sensing from IIT, Mumbai and IIRS (Indian Institute of Remote Sensing) Dehradun. Joined Ground Water Department, Govt. of UP as Hydrogeologist in July, 1979 and retired as "Senior Hydrogeologist" in the capacity of technical staff officer at Ground Water Directorate in June 2016. He was reappointed as "Officer on Special Duty" by the Government of UP and after that worked as "Senior Advisor (Ground Water)" in the World Bank Project (UPWSRP-II) in the Ground Water Department, till Oct, 2019. He has also worked for 4 years in the U.P. Jal Nigam as Senior Hydrogeologist covering urban/rural water supply related activities and also assigned the task of Rain Water Harvesting as its "Nodal Officer". He has served in SWaRA (State Water Resources Agency), U.P. for about 4 years as Ground Water Expert, under UPWSRP-I.

He was majorly involved with Policy, Regulation & Management related matters pertaining to Groundwater resources of Uttar Pradesh. He was also involved in the drafting of "Uttar Pradesh Ground Water (Management and Regulation) Act, 2019." Recently he has been nominated as Co-member in the Drafting Committee for the new State Water Policy. He possesses 15 years of active experience in the field of Remote sensing and watershed geomorphology. He has covered areas of Bundelkhand, Vindhyan and canal commands for ground water studies. He was instrumental in initiating the technology of rain water harvesting and groundwater recharging in the state of UP since the year 2000 and developed, designed various rain water harvesting/recharge models presently under practice in the state. He was also actively involved in the formulation of guidelines and policies related to rain water harvesting and groundwater management in the state. He has a large number of technical publications and scientific papers published in journals and Seminar proceedings. He is a regular writer on ground water subject and has been guest speaker at different forums. Co-edited book on Sustainable Groundwater Management, 2010 and Co-author, Water Development and Management in Uttar Pradesh. Currently involved with advisory, advocacy and awareness related activities in ground water field as Convener of the Ground Water Action Group.

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WaterAid India (www.wateraidindia.in): Established in 1981, WaterAid is leading international non-governmental organization focused exclusively on improving poor people's access to safe water, improved sanitation and hygiene (WASH) in developing countries. WaterAid India is part of the global federation registered as Jal Sewa Charitable Foundation. Across India, WAI's presence is in six states including Uttar Pradesh, covering 18 districts. While WAI's goal is universal access to WASH, its work is prioritised from the locations of the excluded and most marginalized communities. WAI works on themes such as drinking water security, sanitation, WASH in health and nutrition, WASH in schools and anganwadi, in rural areas and in urban locations.

Ground Water Action Group: is a voluntary collective of water sector experts, policy planners, researchers, civil society organisations and practitioners to promote sustainable and integrated water management practices & support state's efforts towards developing sustainable water management policies, plans and regulatory frameworks.
