DYNAMIC GROUND WATER RESOURCES OF MADHYA PRADESH

(As on March, 2020)

CENTRAL GROUND WATER BOARD
North Central Region
Ministry of Jal Shakti
Government of India

GROUND WATER SURVEY
Water Resources Department
Government of Madhya Pradesh

BHOPAL
MARCH 2020

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भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
केन्द्रीय भूमि जल बोर्ड, उत्तर मध्य क्षेत्र

Government of India
Ministry of Jal Shakti
Department of Water Resources, R D & G R
Central Ground Water Board, North Central Region

PREFACE

The state of Madhya Pradesh is in the process of an accelerated development in the fields of irrigation and industrial activities and ground water occupies a key position in the developmental activities of the state. Although, ground water is a replenishable resource, over extraction of ground water, recurrent droughts, varied monsoon pattern etc., are leading to situation on which several blocks of the state have been categorized as over exploited to Semi-critical.

Assessment of Ground Water Resources of Madhya Pradesh is being done jointly by Central Ground Water Board, North Central Region, Bhopal and Ground Water Survey, Water Resources Department, Government of Madhya Pradesh as per the methodology recommended by the Ground Water Resource Estimation Committee 2015(GEC-2015). For the first time, all computations for the assessment of ground water resources have been done by a web based application "INDIA-GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES) developed by CGWB in collaboration with IIT-Hyderabad.

The report titled 'Dynamic Ground Water Resources of Madhya Pradesh, 2020' summarizes the results of the assessment, primarily in terms of resource availability, utilization and categorization of assessment units duly approved by the State Level Committee (SLC) constituted for the purpose. The report briefly describes salient features of previous assessments, ground water estimation methodology, rainfall distribution, physiography, geomorphology, land use land cover, drainage, hydrogeology, ground water level scenario and hydrochemistry of the state in the first three chapters before describing various components of the ground water resource assessment, 2020 in detail.

I am indebted to Shri S. N. Misra, Additional Chief Secretary, Water Resources Department, Government of Madhya Pradesh and Chairman of State Level Technical Coordination committee for Ground Water Resource Estimation for his inspiration. I express my sincere thanks to members of committee for approval of the report on "Dynamic Ground Water Resources of Madhya Pradesh (As on March'2020)". I am obliged to Sh. M. S. Dabar, Engineer in Chief, Water Resource Department, under his supervision the entire work was accomplished. Thanks to Sh. G. P. Soni, Chief Engineer, Water Resources Department, and Dr Jitendra Jain, Superintending Engineer, Ground Water Survey, Water Resources Department, Government of Madhya Pradesh for co-coordinating the work at state level. I would like to express my sincere gratitude to Sh. M. M. Rao Sonkusare, Scientist-D, CGWB, NCR, Bhopal for his contribution.

A deep sense of gratitude is expressed to Sh Bijendra Baghel, Scientific Officer and all the Officers of Ground Water Survey, Water Resources Department, Government of Madhya Pradesh, who was associated with this work at one stage or the other.

I wish to place on record my appreciation of the untiring efforts of Sh Chitta Ranjan Biswal, Scientist-B and the team of officers of Central Ground Water Board, North Central Region, Bhopal for completing the challenging task of resource assessment and compiling this informative report.

I hope that, this report will be useful to all the user agencies engaged in planning and development of ground water in the state.

PK Jain

P K Jain
Regional Director

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DYNAMIC GROUND WATER RESOURCES OF MADHYA PRADESH, 2020

AT A GLANCE

1. Total Annual Ground Water Recharge (BCM)	: 36.16
2. Annual Extractable Ground Water Resource (BCM)	: 33.38
3. Annual Ground Water Extraction (BCM)	: 18.97
4. Stage of Ground Water Extraction (%)	: 56.82

CATEGORISATION OF ASSESSMENT UNITS

(Blocks/ Urban Areas)

Sl. No.	Category	Assessment Units		Annual Extractable Ground Water Resource	
		Number	%	in MCM	%
1	Safe	233	73.5 %	24254.07	72.66 %
2	Semi-Critical	50	15.77 %	5021.66	15.04 %
3	Critical	8	2.52 %	754.83	2.26 %
4	Over-Exploited	26	8.20 %	3349.83	10.04%
5	Saline	0	0 %	0	0 %
Total		**317**		**33383.40**	

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EXECUTIVE SUMMARY

Dynamic Ground Water Resources Assessment is carried out at periodical intervals jointly by Central Ground Water Board, North Central Region, Bhopal and Ground Water Survey, Water Resource Department, Govt. of Madhya Pradesh under the guidance of State Level Committee and under the overall supervision of Central Level Expert Group. Such joint exercises have been taken up earlier in 1980, 1995, 2004, 2009, 2011, 2013 and 2017.

The assessment involves computation of Dynamic Ground Water Resources or Annual Extractable Ground Water Resource, total Current Annual Ground Water Extraction (utilization) and the percentage of utilization with respect to annual extractable resources (Stage of Ground Water Extraction). The assessment units (Blocks/ Urban areas) are categorized based on Stage of Ground Water Extraction, which are then validated with long-term water level trends. The assessment prior to that of year 2017 were carried out following Ground Water Estimation Committee (GEC) 97 Methodology, whereas 2017 as well as the present assessment are based on norms and guidelines of the GEC 2015 Methodology.

The main source of replenishable ground water resources is recharge from rainfall, which contributes to nearly 77 % of the total annual ground water recharge. A major part of the state receives rainfall mainly during SW Monsoon season spread over the months of mid-June to September. Over 99 % of the annual rainfall is received in the four rainy months for June to September only thereby leading to large variations on temporal scale.

Type of rock formations and their storage and transmission characteristics have a significant influence on ground water recharge. Ground water occurrence in the Hard rock formations which are occupying nearly 80% of the total geographical area of the state, are forming poor aquifers. Porous formations such as the alluvial formations in the Bhind (Chambal basin), Hoshangabad and Narsimhapur districts (Narmada basin) and also in Sheopur, Morena, Datia, Chhatarpur, Jabalpur, Katni, Khandwa, Burhanpur, Raisen, Sidhi and Balaghat districts and along rivers in some other districts on the other hand generally have high specific yields and are good repositories of ground water.

In the present assessment, the total annual ground water recharge has been assessed as 36.16 bcm. Keeping an allocation for natural discharge, the annual extractable ground water resource works outas 33.38 bcm. The total annual ground water extraction (as in 2020) has been assessed as 18.97 bcm. The average stage of ground water extraction for the state as a whole works out to be about 56.82%. The extraction of ground water for various uses in different parts of the state is not uniform. Out of the total 317 assessment units (Blocks/ Urban areas) in the state, 26 units (8.20 %) have been categorized as 'Over-Exploited' indicating GroundWater extraction exceeding the total Annual Extractable Resources. A total of 8 (2.52 %) assessment units have been categorized as 'Critical', where the stage of ground water extraction is between 90-100 % of annual extractable resources available. There are 50 'Semi-Critical' units (15.77%), where the stage of ground water extraction is between 70 % and 90 % and 233 (73.51%) assessment units have been categorized as 'Safe ', where the stage of Ground water extraction is lessthan 70 %. Out of 33383.40 mcm of total Annual Extractable Resources of the state, 3349.83 (10.04 %) are under 'Over-Exploited', 754.83 mcm (2.26 %) are under 'Critical', 5021.66 mcm (15.04 %) are under 'Semi-Critical', 24254.07 mcm (72.66 %) are under 'Safe' category assessment units.

In comparison to 2017 assessment, the total numbers of assessment units in the state have increased from 313 to 317 as the four urban areas of the state namely Bhopal, Indore, Gwalior and Jabalpur are added in this year assessment. The total annual ground water recharge has decreased from 36.42 to 36.16 bcm. The changes are attributed mainly to changes in recharge from 'Other Sources'. Accordingly, the annual extractable resource of Ground Water Resource Assessment, 2020 on comparison Ground Water Resource Assessment, 2017 shows a decrease from 34.47 to 33.38 bcm. The groundwater extraction has marginally increased from 18.88 to 18.97 bcm and the changes are attributed mainly to due to increase in the abstraction structures and increase in population. The overall stage of groundwater extraction has increased from 54.76 % to 56.82 %.

Almost all over-exploited assessment units falling in western part of Madhya Pradesh, which is known as "MALWA AREA" where ground water extraction has increased many folds during past decades. District wise analysis of data of annual extractable resource and annual ground water extraction indicate that four districts namely

Indore, Mandsaur, Ratlam & Shajapur are districts where stage of ground water extraction is more than 100% as a whole.

CHAPTER-1

1.0 INTRODUCTION

Water is a fundamental resource for life. Sustainable development and efficient management of this scarce resource has become a challenge in Madhya Pradesh. Increasing population, growing urbanization and rapid industrialization combined with the need for raising agricultural production generates competing demands for water. Ground water has steadily emerged as the backbone of Madhya Pradesh's agriculture and drinking water security. Ground water is an annually replenishable resource but its availability is non- uniform in space and time. Ground water available in the zone of water level fluctuation is replenished annually with rainfall being the dominant contributor. Hence, the sustainable utilization of ground water resources demands a realistic quantitative assessment of ground water availability in this zone based on reasonably valid scientific principles.

Agriculture is the main stay of the people of Madhya Pradesh. Water is essential for irrigation purposes, but its indiscriminate use can lead not only to shortages, but also to the deterioration of crop yields and soils. The impact of over extraction on dynamic resources of ground water resources is noticed in many places in Madhya Pradesh especially in western part called Malwa region. In these areas depletion of water levels, drying of wells and ground water quality problems are reported. The State has varied hydrogeological characteristics due to which ground water potential varies from place to place. Increasing urbanization and growing dependence on ground water for irrigation in the state has called for judicious and planned uses of ground water resources.

The dynamic ground water refers to the quantity of ground water available in the zone of water level fluctuation, which is active recharge zone and replenished annually. In addition to the dynamic ground water resource, there exists a limited ground water reservoir in the deeper zones below the active recharge zone and in the confined aquifers in Madhya Pradesh. The ground water exploitation primarily confines in the shallow aquifer. The sustainability of shallow aquifers plays an important role for the development of ground water structures. The sustainable development of ground water resources, therefore, warrants precise quantitative assessment of dynamic ground water resources based on the reasonably valid scientific principles.

1.1 PREVIOUS ASSESSMENTS

Ground Water Resources Estimation of the country was done for the first time in the year 1979. A committee known as Ground Water Exploitation Committee was constituted by Agriculture Refinance and Development Corporation (ARDC) of Government of India Based on

the methodology and norms recommended by the above committee ground water resources were assessed. Subsequently, necessity was felt to refine the methodologies and the "Ground Water Estimation Committee (GEC)" headed by the Chairman, CGWB came into existence. Based on the detailed Surveys and Studies carried out by the different Regions and Projects of CGWB, the committee recommended the revised methodology in 1984 (GEC- 84) for estimation of ground water resources.

Again in year 1997, Ground Water Estimation Committee revised its methodology and suggested the modified methodology for computation of ground water resource estimation, which was refined on the basis of studies of State Government agencies and CGWB. Based on GEC 1997, the dynamic ground water resources of Madhya Pradesh have been estimated for the state considering 2004, 2009, 2011 and 2013 as base years. The methodology underwent comprehensive revisions again in 2015 and a revised methodology, namely GEC 2015 methodology has been prescribed for ground water assessment. This methodology is being followed for assessment carried out from 2017 onwards. Salient details of status of ground water resources and categorization of assessment units in 2004, 2009, 2011, 2013, 2017 and 2020 are shown in **Table 1.1** and **Table1.2** respectively.

Table.1.0: Ground water Resources assessment 2009 to 2020

Sl. No.	Ground WaterResources Assessment	2009	2011	2013	2017	2020
1	Annual Ground Water Recharge (BCM)	33.95	35.04	35.98	36.42	36.16
2	Annual Extractable Ground Water Resource (BCM)	32.25	33.29	34.16	34.47	33.38
3	Annual Ground Water Extraction for Irrigation,Domestic & Industrial uses (BCM)	17.99	18.83	19.36	18.88	18.97
4	Stage of Ground Water Extraction (%)	55.7	57	56.68	54.76	56.82

Table.1.1: Categorization of assessment units from 2009 to 2020

Sl. No.	Categorization of Assessment units	2009	2011	2013	2017	2020
1	Total Assessed units	313	313	313	313	317
2	Safe	224	218	228	240	233
3	Semi-critical	61	67	58	44	50

Sl. No.	Categorization of Assessment units	2009	2011	2013	2017	2020
4	Critical	04	04	02	07	08
5	Over-Exploited	24	24	25	22	26
6	Saline	00	00	00	00	00

1.2 RE-ASSESSMENT OF GROUND WATER RESOURCES, 2020

The assessment of Ground water resources is carried out to determine the prevailing status of ground water resources in the state. It also helps assess the impact of the on-going ground water management practices on the groundwater resources. In 2020, Department of Water Resources, River Development & Ganga Rejuvenation, Ministry of Jal Shakti constituted a Central Level Expert Group (CLEG) for over-all supervision of the re-assessment of ground water resources in the entire country as in 2020. The terms of reference of the committee include supervision of assessment of annual replenish able ground water resources and the status of utilization for reference year 2020. A copy of the Government Resolution is in **Appendix A**.

Ground water resources assessment for reference year 2020 in Madhya Pradesh have been carried out jointly by Central Ground Water Board (CGWB), North Central Region, Bhopal in association with Ground Water Survey, Water Resources Department, Government of M.P. under the supervision of State Level Committee (**Appendix B**), with technical guidance from Central Level Expert Group. The assessment carried out was approved by the State Level Committee (**Appendix D**). Based on the assessments the Report titled "Dynamic Ground Water Resources of Madhya Pradesh-2020" has been compiled. The report briefly describes salient features of previous assessments, ground water estimation methodology, rainfall distribution, physiography, geomorphology, land use land cover, drainage and basins hydrogeology, aquifer systems of Madhya Pradesh, ground water level and ground water quality scenario, and various components of the ground water resource assessment, 2020 in detail.

The report was reviewed and deliberated upon during the meeting of CLEG held on 31.03.2021, and was approved as mentioned in **Appendix E**.

1.3 CONSTITUTION OF STATE LEVEL COMMITTEE FOR GROUND WATERRESOURCE ESTIMATION

The reassessment of dynamic ground water resources of Madhya Pradesh for the base year 2019-20, has been presently estimated. A State Level Technical Committee was constituted for Re-Estimation of Ground Water Resources of Madhya Pradesh under the Chairmanship of the Additional Chief Secretary, Water Resources Department, Government of M.P. vide Memo No.

F-15/21/2016/Minor/31/1244 dated 23.09.2020 for the assessment 2019-20 (**Appendix B**). The structure of Committee was with following nominees of different departments:

1. Additional Chief Secretary,
   Water Resources Department, Government of M.P. - Chairman
2. Commissioner, Urban Development and Housing Department - Member
3. Engineer -in - Chief, Water Resources Department - Member
4. Engineer -in - Chief, Public Health Engineering Department - Member
5. Engineers -in - Chief, RES - Member
6. Director, Agriculture, Government of M.P. - Member
7. Director, Industries, Government of M.P. - Member
8. General Manager, NABARD, Bhopal - Member
9. Director, Rajeev Gandhi Watershed Mission, Government of M.P. - Member
10. Chief Engineer, BODHI, Water Resources Department - Member
11. Superintending Geo Hydrologist, GWSC, Circle Bhopal - Member
12. Resource Scientist, State GW Data Centre, Bhopal - Member
13. Regional Director, CGWB, NCR, Bhopal - Member Secretary

1.4 PROCEEDINGS OF THE RESOURCE ESTIMATION

First State level meeting was held on 04.12.2020 under the Chairmanship of Sh. S N Mishra, Additional Chief Secretary, Water Resources Department, Govt. of Madhya Pradesh. In the meeting Sh. M. S. Sonkusare, Head of office, CGWB, NCR, Bhopal explained the planning of assessment of Dynamic Groundwater Resource of Madhya Pradesh (As on March' 2020). It was decided in the meeting that all data will be provided by all the line departments by 31st January, 2021 and all attempts will be made to complete the Dynamic Groundwater resource estimation by the end of February 2021. The minutes of the meeting and the list of participants is enclosed as **Appendix C**.

Thereafter, the Groundwater resource estimation work was taken up jointly by CGWB, NCR, Bhopal and State Groundwater Survey, WRD under the supervision of Sh. G P Soni, Chief Engineer, BODHI, Water Resource Department and Sh. P.K. Jain, Regional Director, CGWB, NCR, Bhopal. For the first time exercise was done through IN-GRES (India-Groundwater Resource Estimation System), a software solution developed by CGWB in collaboration with IIT-Hyderabad for the purpose of Resource Estimation Automation. Virtual as well as hands on training programs were conducted by CGWB showcasing INGRES features, data upload, trigger computations and approve the results. Sh. Chitta Ranjan Biswal, Scientist 'B', CGWB, NCR,

Bhopal provided necessary guidance for computation of Groundwater Resource works and reconciliation of the entire exercises. Dr. Jitendra Jain, Superintending Engineer and Sh. Bijendra Baghel, Scientific Officer from Ground Water Survey, Water Resource Department coordinated and monitored the progress of the works done by officers of Ground Water Survey. The data uploaded in INGRES software by Officers of State Ground Water Survey were checked, validated and discrepancies noticed were corrected under the direction of Sh. Chitta Ranjan Biswal, Scientist 'B', CGWB, NCR, Bhopal.

Second State level meeting was held virtually on 07.04.2021 under the Chairmanship of Sh. S N Mishra, Additional Chief Secretary, Water Resources Department, Govt. of Madhya Pradesh. Sh. Chitta Ranjan Biswal, Scientist 'B', CGWB, NCR, Bhopal presented the gist on Dynamic Ground Water Resource Assessment (As on March' 2020). The resources were discussed thoroughly by the members of the committee and after discussion the Dynamic Ground Water Resource of Madhya Pradesh as on March' 2020 was approved. The minutes of the meeting and the list of participants is enclosed as **Appendix D**.

After approval from the state level committee the Dynamic Groundwater Resource got approved from the competent authority, Ministry of Jal Shakti, Govt. of India on 15.06.2020. (**Appendix G**). After approval from the Ministry Dynamic Groundwater Resource of Madhya Pradesh (As on March' 2020) was prepared by Sh. Chitta Ranjan Biswal, Scientist 'B', CGWB, NCR, Bhopal under the guidance of Sh. P K Jain, Regional Director, CGWB, NCR, Bhopal.

CHAPTER-2

2.0 GROUND WATER RESOURCE ESTIMATION METHODOLOGY

Ground water resource as in 2020 have been estimated following the guidelines mentioned in the GEC 2015 methodology using appropriate assumptions depending on data availability. The principal attributes of GEC 2015 methodology are given below:

The methodology recommends aquifer wise ground water resource assessment of both the Groundwater resources components, i.e., Replenish able ground water resources or Dynamic Ground Water Resources and In-storage Resources or Static Resources. Wherever the aquifer geometry has not been firmly established for the unconfined aquifer, the in-storage ground water resources have to be assessed in the alluvial areas down to the depth of bed rock or 300 m, whichever is less. In case of hard rock aquifers, the depth of assessment would be limited to 100 m. In case of confined aquifers, if it is known that groundwater extraction is being done from this aquifer, the dynamic as well as in-storage resources are to be estimated. If it is firmly established that there is no ground water extraction from this confined aquifer, then only in-storage resources of that aquifer has to be estimated. Until aquifer geometry is established on appropriate scale, the existing practice of using watershed in hard rock areas and blocks/mandals/ firkas in soft rock areas may be continued.

It is also pertinent to add that as it is advisable to restrict the groundwater development as far as possible to annual replenish able resources, the categorization also takes into account the relation between the annual replenishment and groundwater development. An area devoid of ground water potential may not be considered for development and may remain safe whereas an area with good groundwater potential may be developed and may become over exploited over a period of time. Thus, water augmentation efforts can be successful in such areas, where the groundwater potential is high and there is scope for augmentation.

2.1 GROUND WATER ASSESSMENT OF UNCONFINED AQUIFER

Though the assessment of ground water resources includes assessment of dynamic and in-storage resources, the development planning should mainly focus on dynamic resource as it gets replenished on an annual basis. Changes in static or in-storage resources normally reflect long-term impacts of ground water mining. Such resources may not be replenishable annually and may be allowed to be extracted only during exigencies with proper planning for augmentation in the succeeding excess rainfall years.

2.1.1 Assessment of Annually Replenish able or Dynamic Ground Water Resources

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

$$Inflow - Outflow = Change\ in\ Storage\ (of\ an\ aquifer) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Equation (1) can be further elaborated as –

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

Where,

ΔS - Change in storage

RRF –Rainfall Recharge

R_{STR} - Recharge from stream channels

R_C - Recharge from canals

R_{SWI} - Recharge from surface water irrigation

R_{GWI} - Recharge from ground water irrigation

RTP - Recharge from Tanks & Ponds

R_{WCS} - Recharge from water conservation structures

VF - Vertical flow across the aquifer system

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

GE - Ground Water Extraction

T -Transpiration

E – Evaporation

B - Base flow

It is preferred that all the components of water balance equation should be estimated in an assessment unit. Due to lack of data for all the components in most of the assessment units, it is proposed that at present the water budget may be restricted to the major components only, taking into consideration certain reasonable assumptions. The estimation is to be carried out using lumped parameter estimation approach keeping in mind that data from many more sources if available may be used for refining the assessment.

2.1.2 Rainfall Recharge

It is recommended that ground water recharge should be estimated on ground water level fluctuation and specific yield approach since this method takes into account the response of ground water levels to ground water input and output components. This, however, requires adequately spaced representative water level measurement for a sufficiently long period. It is proposed that

there should be at least three spatially well distributed observation wells in the assessment unit, or one observation well per 100 sq. Km. Water level data should also be available for a minimum period of 5 years (preferably 10years), along with corresponding rainfall data. Regarding frequency of waterlevel data, two water level readings, during pre and post monsoon seasons, are the minimum requirement. It would be ideal to have monthly water level measurements to record the peak rise and maximum fall in the ground water levels. In units or subareas where adequate data on ground water level fluctuations are not available as specified above, ground water recharge may be estimated using rainfall infiltration factor method only. The rainfall recharge during non-monsoon season may be estimated using rainfall infiltration factor method only.

2.1.2.1 Ground Water Level Fluctuation Method

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

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

Where,

ΔS - Change is storage

R_{RF} - Rainfall recharge

R_{STR} - Recharge from stream channels

R_{SWI} - Recharge from surface water irrigation

R_{GWI}-Recharge from ground water irrigation

RTP - Recharge from Tanks & Ponds

R_{WCS} - Recharge from water conservation structures

VF - Vertical flow across the aquifer system

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

GE - Ground water extraction

T-Transpiration

E - Evaporation

B - Base flow

Whereas the water balance equation in command area will have another term i.e., Recharge due tocanals (R_C) and the equation will be as follows:

$$\Delta S = R_{RF} + R_{STR} + R_C + R_{SWI} + R_{GWI} + R_{TP} + R_{WCS} \pm VF \pm LF - GE - T - E - B \quad \text{..... (4)}$$

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

extraction, the depth from which ground water is being extracted should be considered. One should consider only the draft from the same aquifer for which the resource is being estimated.

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

$$\Delta S = \Delta h \times A \times SY \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where,

ΔS - Change is storage

Δh - rise in water level in the monsoon season

A - Area for computation of recharge

S_Y - Specific Yield

Substituting the expression in equation (5) for storage increase ΔS in terms of water level fluctuationand specific yield, the equations (3) & (4) becomes (6) & (7) for non-command and command sub- units,

$$\boldsymbol{R_R = \Delta h \times A \times S_Y - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B} \ldots\ldots\ldots (\mathbf{6})$$

$$\boldsymbol{R_R = \Delta h \times A \times S_Y - R_{STR} - R_{SWI} - R_C - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B} \ldots\ldots\ldots (\mathbf{7})$$

Where base flow/ recharge to/from streams have not been estimated, the same is assumed to be zero. The rainfall recharge obtained by using equation (6) and (7) provides the recharge in any particular monsoon season for the associated monsoon season rainfall. This estimate is to be normalized for the normal monsoon season rainfall as per the procedure indicated below.

2.1.2.2 Normalization of Rainfall Recharge

Let R_i be the rainfall recharge and r_i be the associated rainfall. The subscript "i" takes values 1 to N where N is the number of years for which data is available. This should be at least 5. The rainfall recharge, R_i is obtained as per equation (6) & equation (7) depending on the sub-unit for which the normalization is being done.

After the pairs of data on R_i and r_i have been obtained as described above, a normalization procedure is to be carried out for obtaining the rainfall recharge corresponding to the normal monsoon season rainfall. Let r(normal) be the normal monsoon season rainfall obtained as the average of recent 30 to 50 years of monsoon season rainfall. Two methods are possible for the normalization procedure. The first method is based on a linear relationship between recharge and rainfall of the form

$$R = ar \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

` Where,

R =Rainfall recharge during monsoon season

r = Monsoon season rainfall

a = a constant

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

$$R_{RF}(Normal) = \frac{\sum_{i=1}^{N}[R_i \frac{r\ (Normal)}{ri}]}{N} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Where,

R_{RF} (normal) - Normalized Rainfall Recharge in the monsoon season,

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

r(normal) - Normal monsoon season rainfall,

ri - Rainfall in the monsoon season for the ith year,

N - No. of years for which data is available.

The second method is also based on a linear relation between recharge and rainfall. However, thislinear relationship is of the form,

$$R_{RF}(normal) = a \times r(normal) + b \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\

The rainfall recharge estimation based on Water level fluctuation method reflects actual field conditions since it takes into account the response of ground water level. However, the ground waterextraction estimation included in the computation of rainfall recharge using water level fluctuation approach is often subject to uncertainties. Therefore, it is recommended to compare the rainfall recharge obtained from water level fluctuation approach with that estimated using rainfall infiltration factor method. Recharge from rainfall is estimated by using the following relationship –

$$R_{RF} = RFIF \times A \times \frac{\mathrm{R-a}}{1000} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 13$$

Where,

A - Area in hectares

R_{RF} - Rainfall recharge in ham

RFIF - Rainfall Infiltration Factor

R - Rainfall in mm

a - Minimum threshold value above which rainfall induces ground Water recharge in mm

The threshold limit of minimum and maximum rainfall event which can induce recharge to the aquifer is to be considered while estimating ground water recharge using rainfall infiltration factor method. The minimum threshold limit is in accordance with the relation shown in equation (13) and the maximum threshold limit is based on the premise that after a certain limit, the rate of storm rain is too high to contribute to infiltration and they will only contribute to surface runoff. It is suggested that 10% of Normal annual rainfall may be taken as minimum rainfall threshold and 3000 mm as maximum rainfall limit. While computing the rainfall recharge, 10% of the normal annual rainfall is tobe deducted from the monsoon rainfall and balance rainfall would be considered for computation of rainfall recharge. The same recharge factor may be used for both monsoon and non-monsoon rainfall, with the condition that the recharge due to non-monsoon rainfall may be taken as zero, if the normal rainfall during the non-monsoon season is less than 10% of normal annual rainfall. In using the method based on the specified norms, recharge due to both monsoon and non-monsoon rainfall may be estimated for normal rainfall, based on recent 30 to 50 years of data.

2.1.2.4 Percent Deviation

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

$$PD = \frac{R_R(\text{normal,wtfm}) - R_{RF}(\text{normal,rif m})}{R_{RF}(\text{normal,rif m})} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Where,

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

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

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

- If PD is greater than or equal to -20%, and less than or equal to +20%, R_{RF} (normal) is takenas the value estimated by the ground water level fluctuation method.
- If PD is less than -20%, R_{RF} (normal) is taken as equal to 0.8 times the value estimated by therainfall infiltration factor method.
- If PD is greater than +20%, R_{RF} (normal) is taken as equal to 1.2 times the value estimated bythe rainfall infiltration factor method.

2.1.3 Recharge from Other Sources

Recharge from other sources constitutes recharges from canals, surface water irrigation, ground water irrigation, tanks & ponds and water conservation structures in command areas where as in non-command areas it constitutes the recharge due to surface water irrigation, ground water irrigation, tanks & ponds and water conservation structures. The methods of estimation of recharge from different sources are as follows.

Table.2.1: Methods of estimation of recharge from different sources

Sl. No.	Source	Estimation Formula	Parameters
1	Recharge from	$R_C = WA \times SF \times Days$	R_C = Recharge from CanalsWA = Wetted Area SF = Seepage Factor Days = Number of Canal Running Days

Sl. No.	Source	Estimation Formula	Parameters
	Canals		
2	Recharge from Surface Water Irrigation	$R_{SWI} = AD \times Days \times RFF$	R_{SWI} = Recharge due to applied surface water irrigation AD = Average Discharge Days = Number of days' water is discharged to the Fields RFF = Return Flow Factor
3	Recharge from Ground Water Irrigation	$R_{GWI} = GE_{IRR} \times RFF$	R_{GWI} = Recharge due to applied ground water irrigation GE_{IRR} = Ground Water Extraction for Irrigation RFF = Return Flow Factor
4	Recharge dueto Tanks & Ponds	$R_{TP} = AWSA \times N \times RF$	R_{TP} = Recharge due to Tanks & Ponds AWSA = Average Water Spread Area N = Number of days Water is available in the Tank/Pond RF = Recharge Factor
5	Recharge dueto Water Conservation Structures	$R_{WCS} = GS \times RF$	RWCS = Recharge due to Water Conservation Structures GS = Gross Storage = Storage Capacitymultiplied by number of fillings. RF = Recharge Factor

2.1.4 Evaporation and Transpiration

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

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

&vegetation, in the absence of field studies the following estimation can be followed. If water levels are within 3.5m bgl, transpiration can be estimated using the transpiration rates available for other areas. If it is greater than 3.5m bgl, the transpiration should be taken as zero.

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

2.1.5 Recharge During Monsoon Season

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

2.1.6 Recharge During Non-Monsoon Season

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

2.1.7 Total Annual Ground Water Recharge

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

2.1.8 Annual Extractable Ground Water Resource (EGR)

The Annual Extractable Ground Water Resource (EGR) is computed by deducting the Total Annual Natural Discharge from Total Annual Ground Water Recharge.

The ground water base flow contribution limited to the ecological flow of the river should be determined which will be deducted from Annual Ground Water Recharge to determine Annual Extractable Ground Water Resources (EGR). The ecological flows of the rivers are to be determined in consultation with Central Water Commission and other concerned river basin

agencies. In case base flow contribution to the ecological flow of rivers is not determined then following assumptionis to be followed.

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

2.1.9 Estimation of Ground Water Extraction

Ground water draft or extraction is to be assessed as follows.

$$GE_{ALL} = GE_{IRR} + GE_{DO} + GE_{IND} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (15)$$

Where,

GE_{ALL} = Ground water extraction for all uses

GE_{IRR} = Ground water extraction for irrigation

GE_{DOM} = Ground water extraction for domestic uses

GE_{IND} = Ground water extraction for industrial uses

2.1.9.1 Ground Water Extraction for Irrigation (GE_{IRR})

The methods for estimation of ground water extraction are as follows.

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

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

Power Consumption Method: **–**Ground water extraction for unit power consumption (electric) is determined. Extraction per unit power consumption is then multiplied with number of units of power consumed for agricultural pump sets to obtain total ground water extraction for irrigation.

2.1.9.2 Ground Water Extraction for Domestic Use (GEDOM)

There are several methods for estimation of extraction for domestic use(GEDOM). Some of the commonly adopted methods are described here.

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

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

$$G_{DO} = Population \times Consumptive\ Requirement \times L_g \quad (16)$$

Where,

L_g = Fractional Load on Ground Water for Domestic Water Supply.

The Load on Ground water can be obtained from the Information based on Civic water supply agencies in urban areas.

2.1.9.3 Ground Water Extraction for Industrial Use (GEIND)

The commonly adopted methods for estimating the extraction for industrial use are as below:

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

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

$$GE_{IND} = Number\ of\ Industrial\ Units \times Unit\ Water\ Consumption \times L_g \quad (17)$$

Where,

L_g = Fractional load on ground water for industrial water supply.

The load on ground water for industrial water supply can be obtained from water supply agencies in the Industrial belt.

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

2.1.10 Stage of Ground Water Extraction

The stage of ground water extraction is defined by.

$$\text{Stage of GW Extraction} = \frac{\text{Existing Gross GW Extraction for all Uses}}{\text{Annual Extractable GW Resources}} \times 100 \ldots\ldots\ldots (18)$$

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

2.1.11 Validation of Stage of Ground Water Extraction

The assessment based on the stage of ground water extraction has inherent uncertainties. In view ofthis, it is desirable to validate the 'Stage of Ground Water Extraction' with long term trend of ground water levels.

Long term Water Level trends are prepared for a minimum period of 10 years for both pre-monsoon and post-monsoon period. If the ground water resource assessment and the trend of long term water levels contradict each other, this anomalous situation requires a review of the ground water resource computation, as well as the reliability of water level data. The mismatch conditions are enumerated below.

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

2.1.12 Categorization of Assessment Unit

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

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

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

2.1.13 Allocation of Ground Water Resource for Utilization

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

$$Alloc = 22 \times N \times L_g \; mm\ per\ year \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (19)$$

Where,

Alloc = Allocation for domestic water requirement

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

L_g = fractional load on ground water for domestic water supply (≤ 1.0)

In deriving equation (19), it is assumed that the requirement of water for domestic use is 60 lpd per head. The equation can be suitably modified in case per capita requirement is different. If by chance,the estimation of projected allocation for future domestic needs is less than the current domestic extraction due to any reason, the allocation must be equal to the present day extraction. It cannever be less than the present day extraction as it is unrealistic.

2.1.13 Net Annual Ground Water Availability for Future Use

The water available for future use is obtained by deducting the allocation for domestic use and current extraction for Irrigation and Industrial uses from the Annual Extractable Ground Water Recharge. The resulting ground water potential is termed as the net annual ground water availability for future use. The Net annual ground water availability for future use should be

calculated separately for non-command areas and command areas. As per the recommendations of the R&D Advisory committee, the ground water available for future use can never be negative. If it becomes negative, the future allocation of Domestic needs can be reduced to current extraction for domestic use. Even then if it is still negative, then the ground water available for future uses will be zero.

2.1.14 Ground Water Assessment Urban Areas

The Assessment of Ground Water Resources in urban areas is similar to that of rural areas. Because of the availability of draft data and slightly different infiltration process and recharge due to other sources, the following few points are to be considered.

- Even though the data on existing ground water abstraction structures are available, accuracyis somewhat doubtful and individuals cannot even enumerate the well census in urban areas. Hence it is recommended to use the difference of the actual demand and the supply by surface water sources as the withdrawal from the ground water resources.
- The urban areas are sometimes concrete jungles and rainfall infiltration is not equal to that of rural areas unless and until special measures are taken in the construction of roads and pavements. Hence, it is proposed to use 30% of the rainfall infiltration factor proposed for urban areas as an adhoc arrangement till field studies in these areas are done and documented field studies are available.
- Because of the water supply schemes, there are many pipelines available in the urban areas and the seepages from these channels or pipes are huge in some areas. Hence this component is also to be included in the other resources and the recharge may be estimated. The percent losses may be collected from the individual water supply agencies, 50% of whichcan be taken as recharge to the ground water system.
- In the urban areas in India, normally, there is no separate channels either open or sub surface for the drainage and flash floods. These channels also recharge to some extent the ground water reservoir. As on today, there is no documented field study to assess the recharge. The seepages from the sewerages, which normally contaminate the ground water resources with nitrate also contribute to the quantity of resources and hence same percent as in the case of water supply pipes may be taken as norm for the recharge on the quantity of sewerage when there is sub surface drainage system. If estimated flash flood data is available, the same percent can be used on the quantum of flash floods to estimate the recharge from the flash floods. Even when the drainage system is open channels, till further documented field studies are done same procedure may be followed.

- It is proposed to have a separate ground water assessment for urban areas with population more than 10 lakhs.
- Wherever, the pre monsoon and post monsoon water levels are above mean sea level the dynamic component of the estimation will be same as other areas.
- If both these water levels are below sea level, the dynamic component should be taken as zero.
- Wherever, the post monsoon water table is above sea level and pre monsoon water table is below sea level the pre monsoon water table should be taken as at sea level and fluctuation is to be computed.
- The static or in storage resources are to be restricted to the minimum of 40 times the pre monsoon water table or the bottom of the aquifer.

2.2 NORMS TO BE USED IN THE ASSESSMENT

The committee recommends that the state agencies should be encouraged to conduct field studies and use these computed norms in the assessment. For conducting field studies, it is recommended to follow the field-tested procedures for computing the norms. There is the possibility of error creeping in at various levels in the field study and hence the committee is of the opinion to give a maximum and minimum values for all the norms used in the estimation. The committee can foresee the handicap of the state agencies which are not able to compute the norms by their own field study. In such cases, it suggests an average of the range of norms to be used as the recommended value for the norm.

2.2.1 Specific Yield

Recently under Aquifer Mapping Project, Central Ground Water Board has classified all the aquifers into 16 Principal Aquifers which in turn were divided into 42 Major Aquifers. Hence, it is required to assign Specific Yield values to all these aquifer units. The values recommended in the **Table 2.1** may be followed in the future assessments. The Major aquifer map can be obtained from Regional officesof Central Ground Water Board.

The recommended Specific Yield values are to be used for assessment, unless sufficient data based on field studies are available to justify the minimum, maximum or other intermediate values. The Norms suggested below are nothing but the redistribution of norms suggested by GEC-1997 methodology and hence people are encouraged to conduct field studies and strengthen the Norms database.

Table.2.2: Norms Recommended for Specific Yield

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	Quaternary	10	8	12
2	Alluvium	AL02	Pebble / Gravel/ Bazada/ Kandi	Quaternary	16	12	20
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	Quaternary	6	4	8
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	16	12	20
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay)	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	16	12	20
7	Alluvium	AL07	Glacial Deposits	Quaternary	16	12	20
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	2.5	2	3
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
11	Basalt	BS02	Ultra Basic - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
12	Basalt	BS02	Ultra Basic - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
13	Sandstone	ST01	Sandstone/Conglomerate	Upper Palaeozoic to Cenozoic	3	1	5
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic to Cenozoic	3	1	5
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	3	1	5
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	3	1	5
17	Sandstone	ST05	Sandstone/Conglomerate	Proterozoic to Cenozoic	3	1	5
18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	3	1	5
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	1.5	1	2
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
21	Shale	SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
22	Shale	SH04	Shale	Upper Palaeozoic to Cenozoic	1.5	1	2
23	Shale	SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic	1.5	1	2

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
24	Shale	SH06	Shale with Limestone	Proterozoic to Cenozoic	1.5	1	2
25	Limestone	LS01	Miliolitic Limestone	Quarternary	2	1	3
26	Limestone	LS01	Karstified Miliolitic Limestone	Quarternary	10	5	15
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	2	1	3
28	Limestone	LS02	Karstified Limestone / Dolomite	Upper Palaeozoic to Cenozoic	10	5	15
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	2	1	3
30	Limestone	LS03	Karstified Limestone/Dolomite	Proterozoic	10	5	15
31	Limestone	LS04	Limestone with Shale	Proterozoic	2	1	3
32	Limestone	LS04	Karstified Limestone with Shale	Proterozoic	10	5	15
33	Limestone	LS05	Marble	Azoic to Proterozoic	2	1	3
34	Limestone	LS05	Karstified Marble	Azoic to Proterozoic	10	5	15
35	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.) - Weathered , Jointed	Mesozoic to Cenozoic	1.5	1	2
36	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.)-Massive or Poorly Fractured	Mesozoic to Cenozoic	0.35	0.2	0.5
37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	3	2	4
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	0.35	0.2	0.5
41	Schist	SC02	Phyllite	Azoic to Proterozoic	1.5	1	2
42	Schist	SC03	Slate	Azoic to Proterozoic	1.5	1	2
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	1.5	1	2
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.3	0.2	0.4
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
46	Quartzite	QZ02	Quartzite- Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	3	2	4
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	1.5	1	2

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
50	Khondalite	KH01	Khondalites, Granulites - Mssive, Poorly Fractured	Azoic	0.3	0.2	0.4
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	1.5	1	2
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
54	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	3	2	4
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	1.5	1	2
58	Gneiss	GN03	Migmatitic Gneiss - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
59	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
61	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
62	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5

2.2.2 Rainfall Infiltration Factor

It is recommended that to assign Rainfall Infiltration Factor values to all the aquifer units recently classified by the Central Ground Water Board. The values recommended in **Table 2.2** may be followed in the future assessments. The recommended Rainfall Infiltration Factor values are to be used for assessment, unless sufficient data based on field studies are available to justify the minimum, maximum or other intermediate values.

An additional 2% of rainfall recharge factor may be used in such areas or parts of the areas where watershed development with associated soil conservation measures are implemented. This additional factor is subjective and is separate from the contribution due to the water conservation structures such as check dams, nalla bunds, percolation tanks etc.

The norms for the estimation of recharge due to these structures are provided separately. This additional factor of 2% is at this stage, only provisional, and will need revision based on pilot studies.

The Norms suggested below are nothing but the redistribution of norms suggested by GEC-1997 methodology and hence people are encouraged to conduct field studies and strengthen the Norms database.

Table.2.3: Norms Recommended for Rainfall Infiltration Factor

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	Quaternary	22	20	24
2	Alluvium	AL02	Pebble / Gravel/ Bazada/ Kandi	Quaternary	22	20	24
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	Quaternary	22	20	24
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	22	20	24
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay) -East Coast	Quaternary	16	14	18
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay) - West Coast	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	22	20	24
7	Alluvium	AL07	Glacial Deposits	Quaternary	22	20	24
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	7	6	8
9	Basalt	BS01	Basic Rocks (Basalt) - Vesicular or Jointed	Mesozoic to Cenozoic	13	12	14
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered	Mesozoic to Cenozoic	7	6	8
10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	2	1	3
11	Basalt	BS02	Ultra Basic - Vesicular or Jointed	Mesozoic to Cenozoic	13	12	14
11	Basalt	BS02	Ultra Basic - Weathered	Mesozoic to Cenozoic	7	6	8
12	Basalt	BS02	Ultra Basic - Massive Poorly Jointed	Mesozoic to Cenozoic	2	1	3
13	Sandstone	ST01	Sandstone/Conglomerate	Upper Palaeozoic to Cenozoic	12	10	14
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic to Cenozoic	12	10	14
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	12	10	14
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	12	10	14
17	Sandstone	ST05	Sandstone/Conglomerate	Proterozoic to Cenozoic	6	5	7
18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	6	5	7

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	4	3	5
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	4	3	5
21	Shale	SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic	4	3	5
22	Shale	SH04	Shale	Upper Palaeozoic to Cenozoic	4	3	5
23	Shale	SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic	4	3	5
24	Shale	SH06	Shale with Limestone	Proterozoic to Cenozoic	4	3	5
25	Limestone	LS01	Miliolitic Limestone	Quarternary	6	5	7
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	6	5	7
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	6	5	7
31	Limestone	LS04	Limestone with Shale	Proterozoic	6	5	7
33	Limestone	LS05	Marble	Azoic to Proterozoic	6	5	7
35	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.) - Weathered , Jointed	Mesozoic to Cenozoic	7	5	9
36	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.)-Massive or Poorly Fractured	Mesozoic to Cenozoic	2	1	3
37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	11	10	12
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	7	5	9
40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
41	Schist	SC02	Phyllite	Azoic to Proterozoic	4	3	5
42	Schist	SC03	Slate	Azoic to Proterozoic	4	3	5
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	6	5	7
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	6	5	7
46	Quartzite	QZ02	Quartzite- Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	5	4	6
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	2	1	3
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	7	5	9

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
50	Khondalite	KH01	Khondalites, Granulites - Mssive, Poorly Fractured	Azoic	2	1	3
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	7	5	9
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Massive, Poorly Fractured	Azoic	2	1	3
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoic	7	5	9
54	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	11	10	12
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	7	5	9
58	Gneiss	GN03	Migmatitic Gneiss - Massive, Poorly Fractured	Azoic	2	1	3
59	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	7	6	8
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
61	Intrusive	IN02	Ulrta Basics (Epidiorite, Granophyre etc.) - Weathered, Jointed	Proterozoic to Cenozoic	7	6	8
62	Intrusive	IN02	Ulrta Basics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3

2.2.3 Norms for Canal Recharge

Unlike other norms, the Recharge factor for calculating recharge due to canals is given in two units viz. ham/million m^2 of wetted area/day and cumecs per million m^2 of wetted area. As all other norms are in ham, the committee recommends the norm in ham/million m^2 of wetted area for computing the recharge due to canals.

There is a wide variation in the values of the recharge norms proposed by GEC 1997.The Canal seepage norm is approximately 150 times the other recharge norms. In the absence of any field studies to refine the norms it is decided by the committee to continue with the same norms. The committee strongly recommends that each state agency must conduct one filed study at least one ineach district before completing the first assessment using this methodology. The committee

also suggests a recommended value and minimum and maximum values as in the case of other norms. Where specific results are available from case studies in some states, the adhoc norms are to be replaced by norms evolved from these results.

The Norms suggested in **Table.2.3** below are nothing but the rationalization and redistribution of norms suggested by GEC-1997 methodology and hence people are encouraged to conduct field studies and strengthen the Norms database.

Table.2.4: Norms Recommended for Recharge due to Canals

Formation	Canal Seepage factor (ham/day/million square meters of wetted area)		
	Recommended	**Minimum**	**Maximum**
Unlined canals in normal soils with some clay content along with sand	17.5	15	20
Unlined canals in sandy soil with some silt content	27.5	25	30
Lined canals in normal soils with some clay content along with sand	3.5	3	4
Lined canals in sandy soil with some silt content	5.5	5	6
All canals in hard rock area	3.5	3	4

2.2.4 Norms for Recharge Due to Irrigation

The Norms Suggested by GEC-1997 gives for only three ranges of water levels and it creates a problem in the boundary conditions. For instance, as a result of the variation in water level from 24.9 to 25.1m bgl in the adjoining blocks, change occurs in the return flow from irrigation in the range of 10% to 15%. Hence to reduce the discrepancy it is recommended to have linear relationship of the norms in between 10m bgl water level and 25m bgl water level. It is proposed to have the same norm of 10m bgl zone for all the water levels less than 10m. Similarly, the norm recommended for 25m may be used for the water levels more than 25m as well. The Recommended Norms are presented in **Table 2.4**.

For surface water, the recharge is to be estimated based on water released at the outlet. For ground water, the recharge is to be estimated based on gross draft. Where continuous supply is used instead of rotational supply, an additional recharge of 5% of application may be used. Where specific results are available from case studies in some states, the adhoc norms are to be replaced by norms evolved from these results.

Table.2.5: Norms Recommended for Recharge from Irrigation

DTW m bgl	Ground Water		Surface Water	
	Paddy	Non-paddy	Paddy	Non-paddy
≤ 10	45.0	25.0	50.0	30.0
11	43.3	23.7	48.3	28.7
12	40.4	22.1	45.1	26.8
13	37.7	20.6	42.1	25.0
14	35.2	19.2	39.3	23.3
15	32.9	17.9	36.7	21.7
16	30.7	16.7	34.3	20.3
17	28.7	15.6	32.0	18.9
18	26.8	14.6	29.9	17.6
19	25.0	13.6	27.9	16.4
20	23.3	12.7	26.0	15.3
21	21.7	11.9	24.3	14.3
22	20.3	11.1	22.7	13.3
23	18.9	10.4	21.2	12.4
24	17.6	9.7	19.8	11.6
≥ 25	20.0	5.0	25.0	10.0

2.2.5 Norms for Recharge due to Tanks & Ponds

As the data on the field studies for computing recharge from Tanks & Ponds are very limited, it is recommended to follow the same norm as followed in GEC 1997 in future assessments also. Hence the norm recommended by GEC-2015 for Seepage from Tanks & Ponds is 1.4 mm / day.

2.2.6 Norms for Recharge due to Water Conservation Structures

Even though the data on the field studies for computing recharge from Water Conservation Structures are very limited, it is recommended that the Recharge from the water conservation structures is 40% of the Gross Storage based on the field studies by Non-Government Organizations. Hence, the norm recommended by GEC-2015 for the seepage from Water Conservation Structures is40% of gross storage during a year which means 20% during monsoon season and 20% during non- monsoon Season.

2.2.7 Norm for Per Capita Requirement

As the option is given to use the actual requirement for domestic needs, the Requirement Norm recommended by the committee is 60 lpcd for domestic needs. This can be modified if the actual requirement is known.

2.2.8 Norm for Natural Discharges

The Discharge Norm used in computing Unaccounted Natural Discharge is 5% if water table fluctuation method is used or 10% if rainfall infiltration factor method is used for assessing the Rainfall recharge. This committee recommends to compute the base flow for each assessment unit. Wherever, there is no assessment of base flow, earlier norms recommended by GEC 1997 i.e. 5% or 10% of the Total Annual Ground Water Recharge as the Natural Discharges may be continued.

2.2.9 Unit Draft

GEC-1997 methodology recommends to use well census method for computing the ground water draft. The norm used for computing ground water draft is the unit draft. The unit draft can be computed by field studies. This method involves selecting representative abstraction structure and calculating the discharge from that particular type of structure and collecting the information onhow many hours of pumping is being done in various seasons and number of such days during each season. The Unit Draft during a particular season can be computed using the following equation:

$$Unit\ Draft = Discharge\ in\ m^3/hr \times No.\ of\ pumping\ hours\ in\ a\ day \times No.\ of\ days \ldots\ldots (29)$$

One basic drawback in the methodology of computing unit draft is that there is no normalization procedure for the same. As per GEC-1997 guidelines, the recharge from rainfall is normalized for a normal rainfall. It means that even though the resources are estimated in a surplus rainfall year or in a deficit rainfall year, the assessment is normalised for a normal rainfall which is required for planning. For recharge from other sources, average figures/ values are taken. If the average figures are not available for any reason, 60% of the design figures are taken. This procedure is very much essential as the planning should be for average resources rather than for the recharge due to excess rainfall or deficit rainfall. But the procedure that is being followed for computing unit draft does not have any normalization procedure. Normally, if the year in which one collects the draft data in the field is an excess rainfall year, the abstraction from ground water will be less. Similarly, if the year of the computation of unit draft is a drought year the unit draft will be high. Hence, there is a requirement to devise a methodology that can be used for the normalization of unit draft figures. The following are the two simple techniques, which can be followed. If the unit draft values for one rainfall cycle are available for at least 10 years second method shown in equation 31 is to be followed or else the first method shown in equation 30 may be used.

$$Normalised\ Unit\ Draft = \frac{\text{Unit Draft} \times \text{Rainfall for the year}}{\text{Normal Rainfall}} \ldots\ldots\ldots\ldots\ldots (30)$$

$$\text{Normalised Unit Draft} = \frac{-b\sum_{i=1}^{n}\text{Unit Draft}_i}{Number\ of\ Years} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (31)$$

Although GEC-1997 methodology recommends a default value for the unit drafts, each State is using its own values, generally after conducting field studies, even though without a documentation. Hence, it is felt that this norm may be computed by the state agency, which is going to assess the norms before commencement of the assessment. But it is strongly recommended that the field studies should be documented and submitted along with the results of the assessment.

2.3 INDIA -GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES)

"INDIA-GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES) is a Software/Web-based Application developed by CGWB in collaboration with IIT-Hyderabad. It will provide common and standardized platform for Ground Water Resource Estimation for the entire country and its pan- India operationalization (Central and State Governments). The system will take 'Data Input' through Excel as well as Forms, compute various ground water components (recharge, extraction etc.) and classify assessment units into appropriate categories (safe, semi-critical, critical and over-exploited). The Software uses GEC 2015 Methodology for estimation and calculation of Groundwater resources. It allows for unique and homogeneous representation of groundwater fluxes as well as categories for all the assessment units (AU) of the country.

URL of IN-GRES http://ingres.iith.ac.in

The detailed description about IN-GRES Software is given in **Appendix-H**.

CHAPTER-3

3.0 BACKGROUND

Madhya Pradesh is located in the central part of India or metaphorically, the heart of India. The State of Madhya Pradesh is a land-locked State, bordered on the west by Gujarat, on the northwest by Rajasthan, on the northeast by Uttar Pradesh, on the east by Chhattisgarh, and on the south by Maharashtra **(Fig 3.1)**. It has a geographical area of 3,08,252 Sq. km. and is situated between north latitudes 21° 04' and 26° 54' and east longitudes 74° 00' and 82° 50'. There are 52 districts and 313 Community Development blocks in Madhya Pradesh. The population of state as per census 2011 is 7.27 crores with a population density of 236 persons per sq.km area. Out of total population, 72.37% is rural. The important urban areas in the State are Bhopal, Indore, Jabalpur, and Gwalior.

Madhya Pradesh comprises several linguistically and culturally distinct regions, of which the major regions are:

- Malwa - A plateau region in the northwest of the state, north of the Vindhya Range, with its distinct language and culture. Indore is the major city of the region, while Ujjain is a town of historical importance. Bhopal, the capital city, lies on the extension of Malwa Region and on the edge of Bundelkhand region.
- Nimar (Nemar): The western portion of the Narmada River valley, lying south of the Vindhyas in the southwest portion of the state. This region comprises Khandwa, Khargone, Burhanpur and Barwani districts.
- Bundelkhand: A region of rolling hills and fertile valleys in the northern part of the state, which slopes down toward the Indo-Gangetic plain to the north. Gwalior is an historic center of the region. This region encompasses Datia, Sagar, Damoh, Panna, Chhatarpur and Tikamgarh Districts.
- Chambal: The north-western region. A mountainous region rich in red, soft, and fragile sandstone. The climate is harsh, and the area is known for murderous pirates who were active in hundreds in the late 1900s. This region comprises Sheopur, Morena and Bhind districts.
- Baghelkhand: A hilly region in the northeast of the state, which includes the eastern end of the Vindhya Range. Satna, Rewa and Sidhi districts lie in this Region.

- Mahakoshal (Mahakaushal): The southeastern portion of the state, which includes the eastern end of the Narmada river valley and the eastern Satpuras. Jabalpur is the most important city in the region. Katni and Jabalpur districts lie in this Region.
- Central Vindhya and Satpura region: Occupy most of the central Narmada river valley. Hoshangabad, Harda, Narsinghpur districts lie in this Region.

Fig 3.1: Administrative Map/ Assessment units of Madhya Pradesh

Central Ground Water Board (CGWB), North Central Region, Bhopal in association with Ground Water Survey Department, Water Resources Department, Government of M.P. has assessed dynamic ground water resources of Madhya Pradesh in 317 assessment units (313 blocks and 4 urban areas i.e. Bhopal, Indore, Jabalpur, Gwalior) **(Fig-3.1)** according to the methodology recommended by the Ground Water Estimation Committee constituted by Government of India (GEC 2015). The Present report quantifies the dynamic ground water resources of Madhya Pradesh State for the base year 2019-20.

3.1 RAINFALL OF MADHYA PRADESH

Madhya Pradesh experiences a tropical climate with wide variation in temperature. There are four seasons during the year. The summer season from March to Mid-June, the monsoon season from Mid-June to September, the post monsoon season in October-November, and the winter season from December to February, May is the hottest month, while January is the coldest.

Rainfall is the main source of recharge to ground water which contributes to nearly 77 % of the total annual ground water recharge, so rainfall pattern has an important impact on groundwater levels in the phreatic aquifer. A major part of the country receives rainfall mainly during SW Monsoon season spread over the months of June to September. Over 99 % of the annual rainfall is received in the four rainy months for June to September. August is the wettest month.

The district wise seasonal and annual rainfall observed during the year 2019 for the districts is given in **Table 3.1**. The district-wise observed monthly rainfall is given in **Table 3.2**. Annually, the Mandsaur District received the highest rainfall of 2144.5 mm where as Datia District received the lowest rainfall of 787.2 mm.

Table.3.1: District-wise seasonal and annual Rainfall (mm) - Year 2019 (Source: IMD)

Sl No.	Districts	Winter	Pre-Monsoon	SW-Monsoon	Post-Monsoon	Annual
1	**Agar-Malwa**	0	12	1855	62.2	1929.2
2	**Alirajpur**	0	2.9	1394.5	123.5	1520.9
3	**Anuppur**	44.1	60.1	1342.3	29.2	1475.7
4	**Ashoknagar**	15.8	10.8	1366.5	63.5	1456.5
5	**Balaghat**	46.6	18.3	1284.1	29.2	1378.2
6	**Barwani**	0	0.1	1138.2	62.4	1200.7
7	**Betul**	0.5	10.2	1250.9	127.3	1388.9
8	**Bhind**	31.8	7.4	734.2	19.8	793.1
9	**Bhopal**	0.4	15.2	1756.5	154.8	1926.9
10	**Burhanpur**	0	3.3	1206.3	127.2	1336.7
11	**Chhatarpur**	12.2	16.4	1205.1	62.3	1295.9
12	**Chhindwara**	29.5	25	1275.3	84.9	1414.7
13	**Damoh**	4	5.5	1489	35	1533.5
14	**Datia**	29.7	14.8	719.9	22.7	787.2
15	**Dewas**	0	1.2	1465.2	39.7	1506
16	**Dhar**	0.3	5.7	1217.2	68	1291.1
17	**Dindori**	17.2	24.8	1453.4	114.7	1610.1

Sl No.	Districts	Winter	Pre-Monsoon	SW-Monsoon	Post-Monsoon	Annual
18	**Guna**	7.1	16.8	1557.2	35.4	1616.5
19	**Gwalior**	34.8	25.1	823	12	894.9
20	**Harda**	10.5	13.7	1591.5	101.9	1717.6
21	**Hoshangabad**	7.4	45.9	1934.1	88.5	2075.9
22	**Indore**	2.5	0.9	1434.6	63.6	1501.5
23	**Jabalpur**	12.5	20.5	1587	39.4	1659.3
24	**Jhabua**	1.8	2.4	1424.7	120.4	1549.3
25	**Katni**	25	41.8	1283	66.4	1416.2
26	**Khandwa**	0	0	1311.3	90.8	1402.1
27	**Khargone**	0	0	1016.5	47.3	1063.7
28	**Mandla**	29.1	31.2	1747.2	67	1874.5
29	**Mandsaur**	1.2	41.3	2018.6	83.5	2144.5
30	**Morena**	42.3	24.8	731.1	38.9	837
31	**Narsinghpur**	0.2	8.6	1719.4	14.4	1742.6
32	**Neemuch**	3	19.7	1711.7	70	1804.4
33	**Panna**	4.3	0	1115.5	81.6	1201.3
34	**Raisen**	6.2	8.8	1863.2	61	1939.2
35	**Rajgarh**	0	8.4	1631	85.6	1725
36	**Ratlam**	0	16.9	1563.5	80.7	1661
37	**Rewa**	37.8	35.1	1199.2	71	1343.2
38	**Sagar**	0.7	17	1519.9	19.5	1557.2
39	**Satna**	33.9	29.7	903	24.1	990.6
40	**Sehore**	3.2	10	1774.4	55.2	1842.8
41	**Seoni**	22.2	20.3	1474.7	90.9	1608.1
42	**Shahdol**	15	38	869	55	977
43	**Shajapur**	0	6	1712.9	88.1	1807
44	**Sheopur**	13.6	22.5	849.2	25	910.3
45	**Shivpuri**	12.8	23.4	895	44.4	975.5
46	**Sidhi**	22.2	26.2	916	96.4	1060.8
47	**Singrauli**	26.4	66.3	1211.3	91	1395
48	**Tikamgarh**	4.5	14.5	1053	108.7	1180.7
49	**Ujjain**	4	11.8	1477.3	90.1	1583.2
50	**Umaria**	18.9	28.2	1334.2	31.3	1412.6
51	**Vidisha**	1.6	17.8	1603.8	47	1670.2

Table.3.2: District wise monthly Rainfall-Year-2019 (Source: IMD)

DISTRICTS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Agar-Malwa	0	0	0	12	0	69.6	314.4	688.4	782.6	60.2	2	0
Alirajpur	0	0	0	2.9	0	84	338.1	686.4	286	83.4	40.1	0
Anuppur	27.5	16.5	42.6	8.6	8.9	123	324.6	447.2	447.6	20.1	0	9.2
Ashoknagar	0	15.8	0.8	10	0	38.5	345.8	566	416.3	58.8	4.3	0.5
Balaghat	28.6	18	17.9	0.4	0	35.1	353.6	447.1	448.4	20.4	1.5	7.3
Barwani	0	0	0	0.1	0.1	60.9	309.1	458.1	310.1	57	5.3	0
Betul	0	0.5	0.3	9.9	0	90.1	372.9	487.2	300.7	115.6	3.3	8.3
Bhind	0	31.8	0	1.5	5.9	66.3	263	210.7	194.3	12.2	7.6	0
Bhopal	0	0.4	0	14.2	1	101.1	641.9	493.2	520.3	132.6	0.6	21.6
Burhanpur	0	0	0	1.8	1.5	109.3	347.7	441.9	307.4	85.6	40.2	1.4
Chhatarpur	2.6	9.5	1.3	11.6	3.4	47.5	264.7	476	416.9	38.8	0	23.5
Chhindwara	23.5	6	14.3	10.7	0	63.6	219.1	454.5	538.2	61.2	1.7	22
Damoh	1.5	2.5	1	4	0.5	56.5	453	543	436.5	21.5	0	13.5
Datia	0.7	29	0	7.7	7.2	52.7	301.3	155.4	210.6	15.1	0	7.7
Dewas	0	0	0	1.2	0	69	393.8	417.8	584.5	38.5	1.2	0
Dhar	0	0.3	0	5.7	0	105.4	302.5	461.3	348	63.6	4.3	0.1
Dindori	7	10.2	19.6	5.2	0	119.6	453.8	416.2	463.8	85	0	29.7
Guna	1	6.1	0.3	16.1	0.4	32	324.5	730	470.8	30.9	3.5	1
Gwalior	2.2	32.6	1.3	9.7	14.2	61.8	249.1	210.7	301.5	9.6	0.4	2.1
Harda	0	10.5	13.2	0.5	0	42.4	446.3	410.3	692.6	67.8	26.7	7.4
Hoshangabad	3.5	3.9	30.3	12.3	3.3	52.7	505.8	771.5	604.1	67.4	2.9	18.2
Indore	0	2.5	0	0.5	0.4	120.7	387.8	400.3	525.8	50.4	13.1	0
Jabalpur	3.1	9.4	3.1	17.1	0.3	64.5	393.5	734.3	394.8	24.7	0	14.7
Jhabua	0	1.8	0	2.4	0	143.1	302.9	598.7	379.9	103.1	15.9	1.3
Katni	12	13	28.6	13.2	0	102.8	278	313.6	588.6	13.6	0	52.8
Khandwa	0	0	0	0	0	100.6	436.7	378	396	70.5	15	5.3
Khargone	0	0	0	0	0	48.8	293.9	393.8	280	46.2	1	0
Mandla	18.7	10.3	25.6	5.6	0	83.4	493.6	559.8	610.5	53.2	0	13.8
Mandsaur	0	1.2	0	41.3	0	84.2	455.3	891	588.1	75.1	8.4	0
Morena	25	17.4	0.6	16.5	7.7	79.8	235.2	227.3	188.8	18.7	10.6	9.7
Narsinghpur	0	0.2	0.6	8	0	82.6	442	581	613.8	1.8	3.2	9.4
Neemuch	0	3	0.3	19.3	0	116.9	379.5	674.6	540.7	47.3	21	1.7
Panna	2.2	2.1	0	0	0	30.7	277.4	439	368.5	57	0	24.6

DISTRICTS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Raisen	0	6.2	0	6.8	2.1	71.6	475.9	667.3	648.4	29	12	20
Rajgarh	0	0	0	8.4	0	80.2	349.8	638.9	562.1	65.2	18.2	2.3
Ratlam	0	0	0	15.5	1.3	179.3	453.2	480.1	450.8	79.3	0.3	1
Rewa	25.2	12.6	23.2	10.3	1.6	29.3	355.7	426.4	387.8	55.4	0	15.6
Sagar	0	0.7	0	15.3	1.7	70.4	334	612.8	502.6	6.1	2.6	10.8
Satna	11.3	22.6	11.8	6.2	11.7	51.1	301.1	350.3	200.4	8.5	0	15.6
Sehore	0	3.2	3.2	0	6.8	92.8	564.5	493.7	623.4	46.6	0.6	8
Seoni	19.7	2.5	15.7	3.6	1.1	72.2	333.5	422.6	646.5	71.5	0	19.4
Shahdol	7	8	18	20	0	38	243	347	241	26	0	29
Shajapur	0	0	0	6	0	71.5	520.2	527	594.2	76.6	11.5	0
Sheopur	3.5	10.1	0	22.5	0	76.7	355	294.2	123.4	19.5	0	5.5
Shivpuri	1.3	11.5	0.3	21	2.1	50.1	319.3	271.6	254	36.6	6.5	1.3
Sidhi	17.4	4.8	22.6	3.6	0	9.4	201.6	328	377	35.4	0	61
Singrauli	13.4	13	37.1	21.8	7.4	68.8	334.5	407.7	400.3	33.8	0	57.2
Tikamgarh	0	4.5	0	2.5	12	21.5	339	405.5	287	93	0	15.7
Ujjain	0	4	0	8.6	3.2	132	330.9	517.2	497.2	69.2	20.8	0.1
Umaria	4.6	14.3	11.8	16.4	0	52.3	503	402.4	376.5	10.8	0	20.5
Vidisha	0	1.6	0	17.5	0.3	33	345.1	689.3	536.3	32.1	7.5	7.4

Fig. 3.2: Rainfall Distribution - SW Monsoon 2019, Madhya Pradesh

Daily observed rainfall distributions for Madhya Pradesh along with their daily rainfall normal have been depicted in Fig 3.2. The normal annual rainfall for Madhya Pradesh is 1088 mm. The variation in normal annual rainfall is between 742.5 mm and 1471.6 mm. The rainfall decreases as we move from East to West and south to North. The highest normal annual rainfall occurs in Balaghat district (1471.6 mm) followed by Mandla, Annupur and Dindori districts, which are in southern and south eastern parts of State whereas lowest normal annual rainfall is recorded in 742.5 mm in Barwani district in the western part of Madhya Pradesh. The Normal annual rainfall map of Madhya Pradesh in shown in the

Table.3.3: District wise Normal Annual Rainfall-Year-2019

S.No	District	Normal Annual Rainfall (mm)	S.No	District	Normal Annual Rainfall (mm)
1	**Agar Malwa**	1036.1	27	**Khargone**	950.3
2	**Alirajpur**	912.8	28	**Mandla**	1427.7
3	**Anuppur**	1423.6	29	**Mandsaur**	753.7
4	**Ashoknagar**	926	30	**Morena**	753
5	**Balaghat**	1471.6	31	**Narsinghpur**	1191
6	**Barwani**	742.5	32	**Neemuch**	854.9
7	**Betul**	1145.55	33	**Panna**	1183
8	**Bhind**	951	34	**Raisen**	1207.3
9	**Bhopal**	1126.65	35	**Rajgarh**	972
10	**Burhanpur**	883.8	36	**Ratlam**	992.85
11	**Chhatarpur**	1092.7	37	**Rewa**	1141.5
12	**Chhindwara**	1139.25	38	**Sagar**	1205
13	**Damoh**	1176	39	**Satna**	1075.5
14	**Datia**	963.8	40	**Sehore**	1067.5
15	**Dewas**	1069	41	**Seoni**	1322

S.No	District	Normal Annual Rainfall (mm)	S.No	District	Normal Annual Rainfall (mm)
16	**Dhar**	856.5	42	**Shahdol**	1131.4
17	**Dindori**	1376.3	43	**Shajapur**	1036.1
18	**Guna**	1082	44	**Sheopur**	799.2
19	**Gwalior**	870	45	**Shivpuri**	994.9
20	**Harda**	1374	46	**Sidhi**	1154
21	**Hoshangabad**	1324.5	47	**Singrauli**	1120.2
22	**Indore**	976.8	48	**Tikamgarh**	943.6
23	**Jabalpur**	1279.45	49	**Ujjain**	861.5
24	**Jhabua**	865.4	50	**Umaria**	1242
25	**Katni**	1171.4	51	**Vidisha**	1135.3
26	**Khandwa**	951.65			

Fig.3.3: Annual Normal Rainfall Map, Madhya Pradesh

3.2 PHYSIOGRAPHY

The State exhibits six distinct physiographic units as follows:

- The Malwa Plateau
- The Satpura Range

- The Vindhyan Range
- The Mahakoshal Range
- The Bundelkhand Region and
- The River valleys.

Fig.3.4: Physiography Map, Madhya Pradesh

The Malwa Plateau marks the northern span of the Deccan Plateau and this region forms a part of the vast Deccan Plateau of Central India. The hill ranges run across the plateau. The Satpura Range located in the southern part of the State is E-W trending. It has an average elevation of 600 m amsl and highest elevation of 1350 m amsl. The Vindhyan range occupies in the northern and central part of the region and has ENE-WSW trend. The Mahakoshal Range also has a similar trend. The Vindhyan Range extends into the Malwa Plateau and Bundelkhand Region. The Vindhyan Range and Mahakoshal Range are separated from the Satpura Range by the Narmada River and vast tract of its basin area. The river valleys, other than the Narmada alluvial plain and Chambal alluvial plain, are very limited and form narrow belts along the rivers. Dhupgarh in Pachmarhi is on 1350 m amsl which is the highest elevation point in the state. The Physiography map of Madhya Pradesh is shown in the **Fig 3.4**.

3.3 GEOMORPHOLOGY

Major part of the state is occupied by pediment pediplain complex, dissected plateaus and dissected hills and valleys. Pediment Pediplain complex is the major landform covering about 180762 km^2 (nearly 59%), presently mostly in the western and northeastern side sparcely distributed in all other sides. The other major landform observed is moderate dissected plateau covering about 43709 km^2 (14.2%), highly dissected plateau in 11090 km^2 (3.5%), low dissected plateau in 8520 km^2 (2.8%), moderately dissected hills and valleys in 22012 km^2 (7.35%), low dissected hills and valleys in 6363 km^2 (2%). Dissected hills and valleys, flood plain and alluvial plain landforms are occupied very small part of the state. The geomorphology map of Madhya Pradesh is shown in the **Fig 3.5.**

Fig.3.5: Geomorphology, Madhya Pradesh

3.4 LAND USE LAND COVER

Agriculture and forest are the prominent land use aspects in the state and forms 55 % and 28 % of total area respectively followed by the shrub land and water bodies. The spatial distribution of land use is presented in **Fig 3.6.** (as per Land Use Land cover data, NASA, USA).

Fig3.6: Land use Land Cover, Madhya Pradesh

3.5 DRAINAGE AND BASINS

Madhya Pradesh State represents great river basins and the watershed of a number of rivers. Catchments of many rivers of India lie in Madhya Pradesh. There are six river basins in Madhya Pradesh namely 1. Ganga Basin (1.1 Yamuna sub basin - Chambal sub-sub basin, Kunwari sindh sub-sub basin, Jamni sub-sub basin, Betwa sub-sub basin, Dhasan sub-sub basin, Ken sub-sub basin, Paisuni and Baidhan sub sub basin 1.2 Tons sub basin, 1.3 Sone sub basin), 2. Narmada Basin, 3. Godavari Basin, 4. Tapti Basin, 5. Mahi Basin and 6. Mahanadi Basin. The basins of Madhya Pradesh are shown in the **Fig 3.7**. As Madhya Pradesh is located in the center of India, most of the rivers are interstate rivers. The rivers namely, Chambal, Sindh, Betwa, Ken flows northward and meet with Yamuna, whereas the Sone River falls directly into Ganga. Narmada, Tapti and Mahi Rivers flow westward and meet Arabian Sea whereas Wainganga and Pench Rivers meet Godavari in the south. The Narmada (originating from Amarkantak) and Tapti (originating from Multai in Betul District) Rivers and their basins divide the state in two, with the northern part draining largely into the Ganga basin and the southern part into the Godavari and Mahanadi systems. The Vindhyas form the southern

boundary of the Ganga basin, with the western part of the Ganga basin draining into the Yamuna and the eastern part directly into the Ganga itself. All the rivers, which drain into the Ganga, flow from south to north, with the Chambal, Kshipra, Kalisindh, Parbati, Kuno, Sind, Betwa, Dhasan and Ken Rivers being the main tributaries of the Yamuna. The land drained by these rivers is agriculturally rich, with the natural vegetation largely consisting of grass and dry deciduous forest types. The eastern part of the Ganga basin consists of the Son, the Tons and the Rihand Rivers, with the Son being the major tributary. This is also the junction point of the Satpura and the Vindhya Ranges, with the Maikal and Kaimur Hills being the fulcrum. The forests here are much richer than the thorn forests of the northwestern part of Madhya Pradesh. The Son River is of great significance in that it is the largest tributary going into the Ganga on the south bank and arising out of the hills of Madhya Pradesh rather than from the Himalayas. This river and its tributaries contribute the bulk of the monsoon flow into Ganga, because the north bank tributaries are all snow fed. The major tributary of the Ganga, the Son River, arises in one of the most important watersheds in India, the Maikal hills around Amarkantak. Three of the great rivers of India, Narmada, Mahanadi and Son, are given birth to by these hills. This is also one of the few ranges in the state having a north south configuration. The Mahanadi itself, together with its tributaries such as Hasdeo, Mand and Kharun flows southeast into Chhattisgarh and converts that state into a green rice bowl. The upper Mahanadi catchment contains some of the finest forests in the state, ranging from mixed deciduous to teak, bamboo and sal. Just as the Mahanadi flows east from the Maikal hills and the Son flows north, the mighty Narmada charts a westerly course from these very hills. The Narmada flows through a rift valley, with the Vindhyas marching along its northern bank and the Satpuras along the southern. Its tributaries include Banjar, Tawa, Machna, Denwa and Sonbhardra Rivers. Taken in combination with its parallel sister river, the Tapti, which also flows through a rift valley, the Narmada - Tapti systems carry and enormous volume of water and provide drainage for almost a quarter of the land area of Madhya Pradesh.

The Satpuras, in the Gawligarh and Mahadeo hills, also contain a watershed, which is south facing. The Indrawati, Wainganga, Wardha, Pench, Kanhan and Penganga Rivers, discharge an enormous volume of water into the Godavari system. The Godavari is the lifeline of Andhra Pradesh, but the water which feeds it is a gift of the central India watershed.

Fig.3.7: Basins and Major Rivers, Madhya Pradesh

3.6 HYDROGEOLOGICAL UNITS AND AQUIFER PARAMETERS

The State of Madhya Pradesh has varied hydrogeological characteristics due to which ground water potential differs from place to place. The area is underlain by various geological formations ranging in age from the Archaean to the Recent. Hard rock areas cover more than 80% of total land area of the State. These hard-rock areas show wide variations and complexities in nature and composition of rocks, geological structures, geomorphological set up and hydro meteorological conditions. The crystalline rocks of Archaean age like granite, gneiss, granulites, schist, quartzite and granitoids occupy about 14.7% of geographical area of the State. The basaltic rocks of Deccan lava flows are the predominant formations and occupy nearly 44.5% of total geographical area. The consolidated sedimentary rocks of Vindhyan Super Group and Mahakoshal (Cuddapah) Super Group of Proterozoic age occupy about 19.1% of total geographical area and the semi consolidated (Gondwana Formation) occupies about 6.7%. Recent unconsolidated alluvial sediments occupy about 14.4% of total geographical area. The Principal aquifer system of Madhya Pradesh is shown in the **Fig 3.8.** The Hydrogeological units of the state and their potential is described in **Table 3.4** and shown in **Fig 3.9**

Fig.3.8: Principal aquifer system, Madhya Pradesh

Table.3.4: Hydro geological Units, their Potential and Groundwater Scenario, Madhya Pradesh

Geological Age	Group	Rock Formation	Surface Exposure Area (Approx.)	Occurrence and Hydrogeological Characters.
Pleistocene to Recent	Alluvial plains (older and Newer Alluvium)	Unconsolidated clays and silts, gravels and sands of different mix. Lenses of Peat and organic matter carbonate and siliceous concretions (Kankars)	38,000 Sq.Km.	Occur widespread in Bhind (Chambal basin), Hoshangabad and Narsimhapur districts (Narmada basin) and also in Sheopur, Morena, Datia, Chhatarpur, Jabalpur, Katni, Khandwa, Burhanpur, Raisen, Sidhi and Balaghat districts and along rivers in some other districts. Form very potential ground water reservoirs with a thick sequence of sandy aquifers down to great depths (>300 m.bgl). The aquifers are unconfined, semi-confined (leaky confined) or confined.
Cretaceous to Eocene	Deccan Trap	Basalts	1,43,300 Sq.Km.	Occupy the Malwa plateau covering Nimuch, Mandsaur, Indore, Dhar, Ratlam, Shajapur, Sagar, Rajgarh, Sehore, Badwani, Khargone, Khandwa and Burhanpur districts and parts of Jhabua, Raisen, Guna, Ashoknagar, Vidisha, Bhopal, Sehore, Betul, Jabalpur, Katni, Hoshangabad, Harda, Narsimhapur, Chhindwara, Seoni, Dindori, Mandla, Shahdol and Anuppur districts.
	Bagh and Lameta Groups	Sandstones cherty limestone	8,500 Sq.Km.	Infra Trappean formation of Bagh&Lametas occurs in Dhar, Jhabua& Jabalpur districts and small patches in Sagar, Hoshangabad and Narsimhapur districts. Weathered, Fractured and vesicular basaltic layers of Traps, inter-trappeans and infratrappeans form productive unconfined hallow aquifers and leaky confined/confined deeper aquifers and yield upto 5 lips. (Infra trappeans are less productive). Sp.Yield 1 to 4% Hydraulic conductivity 5-15 m/day.
Palaezoic to Cretaceous	Gondwana super Group. Jabalpur, Mahadeva, Panchet, Raniganj, Barakars and Talchir Groups	Boulder beds Sand-stones, shales, clays, limestone, coal seams	28,000 Sq.Km.	Occur in Betul, Chhindwara, Narsimhapur, Hoshangabad, Jabalpur, Katni, Sidhi, Umaria, Shahdol and Anuppur districts. Possess moderate primary porosity. Groundwater occurs under phreatic as well as semi-confined to confined conditions. Free flowing conditions with free flow discharge of 150 to 200 lpm have been recorded in North-eastern part of Jabalpur district.
	Vindhyan Super Group. Bhander,			Occur in Gwalior, Morena, Sheopur, Shivpuri, Guna, Ashoknagar, Rewa, Panna, Satna, Jabalpur, Katni, Damoh, Sagar, Chhatarpur, Raisen, Bhopal, Vidisha, Nimuch, Mandsaur and Dewas districts. Generally, devoid of any

Geological Age	Group	Rock Formation	Surface Exposure Area (Approx.)	Occurrence and Hydrogeological Characters.
Precambrian (Proteozoic)	Rewa, Kaimur and Semri Groups. Mahakoshal (Cuddaph) Super Group Bijawar and Gwalior Groups.	Shales, Sandstones and limestones	58,700 Sq.Km.	primary porosity. Weathering and denudation, structurally weak planes and fractures impart porosity and permeability in the rock mass. Solution cavities (Cavernous) in carbonate rocks, at places give rise to large groundwater storage/circulation. Sp. Yield value of unconfined aquifer is generally low (0.2% to 3%). Hydraulic conductivity varies widely depending upon fracture incidence (2 to 10 m/day.)
Archaeans	Older MetamorphicsSausar, Sakoli and Chilpi Groups. &Bundelkhand Granites.	Granitoid gneisses, schists, gneisses, quartzites and granites	31,500 Sq.Km.	Occur in Seoni, Balaghat, Shahdol, Anuppur, Mandla, Dindori, Sidhi, Rewa, Panna, Datia, Tikamgarh, Gwalior, Chhatarpur, Jabalpur, Katni, Jhabua and Shivpuri districts, as also parts of Chhindwara, Harda, Hoshangabad, Narsimhapur and Dewas districts. Do not posses primary porosity. Weathering, fracturing, jointing impart secondary porosity. Groundwater mostly occurs under phreatic conditions and at some places also under confined/semi confined conditions.

3.6.1 Archaeans

Archaeans comprise old metamorphic, granites, gneisses and schist. They are hard and compact formations with low primary permeability, forming poor aquifers. Ground water occurs in these only in the weathered mantle and underlying fractured zone. Dug wells in this formation have depths of 5-30 m with water levels between 3-17 m bgl. Where thickness of aquifer is considerable. Specific capacity ranges from 20-200 lpm/m of draw down. Hydraulic conductivity is generally less than 1 m/d and specific yield less than 3%. The yield of open wells ranges between 40-135 m^3/d.

3.6.2 Vindhyans

These are composed of sandstone, shale and limestone. The sandstone and shale are hard and compact and form poor aquifers. Ground water occurs in these in the weathered mantle and fractured zone. The limestone is different in its hydrogeological properties having large solution cavities, which give rise to immense secondary permeability. The wells in limestone formations yield 100-500 m^3/day for 3m draw down. Specific capacity ranges from 100-300 lpm/m of draw down, hydraulic conductivity varies between 5-15 m/d and specific yield ranges from 1-3 % in good karstic zones.

3.6.3 Gondwana

The Gondwanas are sedimentary formations rich in granular zones and form good aquifers. They support both dugwells and tubewells, capable of yielding 100-500 m^3/d for the drawdown of 6-10 m. the specific capacity ranges between 75-250 lpm/m of drawdown, hydraulic conductivity varies between 10-25 m/d and specific yield is from 1-3 %.

3.6.4 Infra Trappeans

The Bagh and Lameta beds and Nimar sandstone are also sedimentary formations but have a limited extent and poor to moderate permeability. The limestone and calcareous clays when karstified form productive aquifers. The corralling limestone, the marls and nodular limestone are hard and compact having poor permeability. The Nimar sandstone has intergranular porosity, joints, fracture, bedding planes, which give moderate scope for ground water movement. The depth of wells varies from 3 to 13 m and depth to water level between 2 to 12 m bgl.

3.6.5 Deccan Traps

These form the most important aquifers in the region. Being the most extensive. The weathered, fractured, jointed and vesicular units of basalts form moderate to good aquifers. These formations have highly variable yields ranging from 10 to 750 m^3/d. Dug wells range in depth from 4 to 20 m with water levels varying between 2 and 14 m bgl. The specific capacity ranges from 50 to 150 lpm/m of drawdown, hydraulic conductivity varies between 5 and 15 m/d and the specific yield is 1-3%. The Deccan Traps formations can be tapped by dug well, dug-cum-bore

and bore wells. It is observed that the yield increases by 5-10 times when 10-15 m bores wells extending down to the lower vesicular and bore well are drilled at the base of dug wells. Yields of 400-600 m^3/d can be obtained in this way. In some areas the control of doleritic dykes on occurrence of ground water is observed. Wells located on the upstream side of these dykes produce yields. Also wells located on tectonic lineaments gave better yields.

3.6.6 Alluvium

It consists of unconsolidated gravel, sand, silt, clay in various proportions and has primary inter-granular porosity and permeability. Hence it is the most promising formation for ground water development. The thickness of alluvium varies from 10 to 318 m with aquifer thickness from 10 to 160 m being more in the Ganga basin than in the Narmada basin. The depth to water ranges from 5 to 30 m bgl. The transmissivity is high in the Ganga basin being upto 3000 m^2/d. In the Narmada basin transmissivity ranges between 83-283 m^2/d. the yields vary from 30 to 50 m^3/hr for shallow wells and 30-200 m^3/hr for deep wells in the Ganga basin. In the Narmada basin the yields are of the order of 15-30 m^3/hr in the phreatic zone and 70-200 m^3/hr in the deeper zone. In the Waingangā sub basin, the wells yield 60-600 m^3/d. In the Tapi basin, the yields are 25-95 m^3/d.

Fig.3.9: Hydrogeology Map, Madhya Pradesh

3.7 GROUND WATER LEVELS SCENARIO

3.7.1 Depth to Water Level

Groundwater level refers to underground surface below which the ground is wholly saturated with water. The upper surface of the zone of saturation is the water table. In case of wells penetrating confined aquifers, the water level represents the pressure or piezometric head at the point. The configuration of the water table depends upon topography, geology, climate water yielding and water bearing of rocks in the zones of aeration and saturation which control ground water recharge.

During the water year 2019-20, the existing monitoring wells (**Fig 3.10**) were monitored four times, i.e., during May 2019, August 2019, November 2019 and January 2020. With the field data, maps were prepared for visual interpretation of the behaviors of the ground water levels. Depth to ground water levels were demarcated into various zones in the ranges of less than 2 m, 2-5 m, 5-10 m, 10-20 m, 20-40 m and more than 40 m. The description of the depth to water levels during pre-monsoon (May) and post monsoon (November) monitoring seasons is as follows:

Fig.3.10: Location of Groundwater Monitoring Wells, Madhya Pradesh

3.7.1.1 Depth to Water Level: Pre-Monsoon (May- 2019)

Depth to Water levels ranges from 0.72 in Jhoteshwar monitoring station, Narsinghpur district to 37 m bgl in Lalpura monitoring station of Neemuch district of Madhya Pradesh. Very shallow water levels up to 2 m bgl are very few. Only 0.58% of wells in Madhya Pradesh State fall in this category. About 13.40% of wells spreading all over Madhya Pradesh State has recorded

a water level in depth range of 2-5 m bgl. Depth to water levels ranging 5-10 m bgl is spread in most parts of the State. About 48.10% of wells fall under this category. Deeper ground water levels ranging 10-20 m bgl are seen mostly in northern western parts of the state and in isolated patches in the northern and southern parts of the state. About 35.79 % of wells in the State fall in this category. Ground water levels of more the 20 m bgl are found in about 2.13 % of the wells and occur mainly in are seen mostly in northern western parts of the state and in isolated patches in the northern and southern parts of the state. The depth to water level map of Madhya Pradesh State for May 2019 is shown in **Fig 3.11**.

Fig 3.11: Pre monsoon Water level (May-2019), Madhya Pradesh

3.7.2 Depth to Water Level: Post-Monsoon (November-2019)

Depth to Water levels ranges from ground level to 32.35 m bgl in Madhya Pradesh state. During this year the state has received excess rainfall and many of the districts are in rainfall large excess category. Very shallow water levels up to 2 m bgl are seen in many districts as patches. About 25.37 % of monitoring wells recorded water level less than 2 m bgl category. About 44.91% of monitoring wells spreading all over Madhya Pradesh state has recorded a water level in the depth range of 2-5 m bgl. Depth to water levels ranging 5-10 m bgl is noticed in about 23.14% of wells. Deeper ground water levels ranging 10-20 m bgl are seen in about 5.60% of wells in the state. Ground water levels of more than 20 m are found in about 0.98% of the wells and are seen

in of the state. The depth to water level map of Madhya Pradesh State for November 2019 is shown in **Fig 3.12**.

Fig.3.12: Post monsoon Water level (Nov-2019), Madhya Pradesh

3.7.3 Water Level Fluctuation

Ground water is a dynamic system. The ground water level or head is subject to change both due to natural and manmade causes. The zones of aeration and saturation play important roles in ground water recharge and ground water level fluctuation. Groundwater level is an important indicator for the recharge of the aquifer, groundwater abstraction and the discharge from the aquifer to surface waters and to some extent groundwater quantity. Groundwater level can vary significantly over time and seasons. Decline in groundwater levels can occur as a result of natural climatic conditions (low rainfall), changes in land use, or as a result of over abstraction. Rise in groundwater levels can occur as a result of natural climatic conditions (heavy rainfall), changes in land use, or as a result of artificial recharge to groundwater by rainwater harvesting.

Water level fluctuations were analysed and maps were prepared after every water level measurement comparing the current water levels with that of the same season of the previous year, preceding season, pre-monsoon season and the decadal seasonal mean. These fluctuations were carefully examined to observe the ground water situation with respect to time.

3.7.4 Annual Water Level Fluctuation

3.7.4.1 Water level Fluctuation (May-2018 to May-2019)

The ground water levels of monitoring wells during May 2019 were compared with those of May 2018 to decipher the changes that took place in the ground water regime. In Madhya Pradesh, 52% of the wells show a rise and the rest 48% wells show a decline in water levels. About 24.19 % of the wells show a rise in water level up to 2 m spreading in patches in many parts of the state. About 11.06 % of the wells show a rise in water level between 2 to 4 m and, 16.73% of the wells shows rise more than 4 m. The rise in water level in the range of 2-4 m and more than 4 m are mainly found in districts towards the eastern and northern parts of the state.

About 18.66 % of the wells show a decline in water level up to 2 m and covering almost all district of the state. About 12.48 % of the wells show a decline in water level between 2 to 4 m and occur in sporadic patches of the state. About 16.88 % of the wells shows decline more than 4 m. In general, this year there is a rise in water level in the state as compared to last year. The annual water level fluctuation map (May 2018-May 2019) is shown in the **Fig 3.13.**

Fig.3.13: Annual Water Level Fluctuation (May 2018- May 2019), Madhya Pradesh

3.7.4.2 Water level Fluctuation (November 2018 to November 2019)

About 87.90 % of wells show rise and 12.09 % decline in water levels in November 2019 compared to those in November 2018. The state has received excess rainfall during the month of September and October and many districts are in large excess category which leads to rise in water level all over the state. About 37.53 % of wells in Madhya Pradesh state, shows rise in water levels

up to 2 m and seen almost all part of the state. Rise of 2-4 m has occurred in 25.86 % of wells. About 24.5% of wells shows rise in water levels more than 4 m and most prominently seen as patches in the westernmost part of the state.

Decline in water levels up to 2 m are seen in about 9.56 % of wells. Decline in water level between 2-4 m is observed in 1.36 % of wells of the state. Decline in water level more than 4 m is observed by 1.15 % monitoring wells located in Balaghat, Narsingpur, Hoshangabad, Chhindwara, Gwalior, Bind, Morena Districts and in many other districts in small pockets. The annual water level fluctuation map (November 2018-November 2019) is shown in the **Fig 3.14.**

Fig.3.14: Annual Water Level Fluctuation (Nov 2018- Nov 2019), Madhya Pradesh

3.7.4.3 Seasonal Water Level Fluctuations (May-2019 to November-2019)

Water levels have shown a general rise in 96.23 % of the wells. Such a rise is a normal phenomenon in the hydrological cycle since the monsoon rainfall forms the sole source of natural recharge to ground water regime in the state. The state has received excess rainfall during the month of September and October and many of the districts fall in large excess category. Rise in the order of 0 to 2 m bgl is seen in 17.67 % of wells of the state. About 29.13% of the wells have shown a rise of 2-4 m bgl and are seen in almost all parts of the state except the northern and southeastern part of the state. Significant rise of more than 4 m bgl is found in 49.42 % of wells that is, in entire parts of the state except the northern parts of the state.

About 3.77% of the wells in Madhya Pradesh state show a marginal decline in water level up to 2 m bgl. Decline in water level between 2-4 m bgl is observed in 0.33 % of wells and mostly in the northern and southeastern part of the state. About 0.16 % wells shows a decline in water level more than 4 m bgl and are seen in northern and southeastern part of the state. The seasonal water level fluctuation map (May 2019-November 2019) is shown in the **Fig 3.15.**

Fig.3.15: Seasonal Water Level Fluctuation (May 2019- Nov 2019), Madhya Pradesh

3.7.4 Long-Term Ground Water Level Trend

Groundwater is replenished from precipitation and from surface water, but the rate of abstraction (withdrawal by humans) may exceed the rate of natural recharge, leading to reduction of the resource indicated by declining trend of water level. Rising trend in groundwater levels can occur as a result of natural climatic conditions (heavy rainfall), changes in land use, construction of pond or reservoir or as a result of artificial recharge to groundwater by rainwater harvesting.

The trend analysis of depth to ground water levels (time series analysis) using the data from the hydrograph network stations for the past one decade 2010-19 was carried out using the least square method. Based on this analysis, maps are prepared demarcating various zones of rising and declining trends for the decade 2010-19.

3.7.4.1 Ground water Level Trend Pre-Monsoon (May 2010 to May 2019)

Ground water levels trend map of pre-monsoon period (May 2010 to May 2019) in Madhya Pradesh state has been depicted in Fig 24. The Map shows that there is a general declining trend up to 0.10 m/year of ground water levels during the past decade in the almost all the districts of the State. The rising trend more than 0.20 m/year has been observed only in Sheopur district. Declining trend at a rate up to (-0.10 m/year) is observed in a small pocket mainly in central and southern parts of the state and declining trend at a rate (-0.10 to -0.20 m/year) has been observed mainly in Damoh, Narsinghpur, Chhindwara, Indore, Dhar, Ratlam and Raisen District of the state. The declining trend at a higher rate (>0.2m/year) has seen in Dhar, Chhindwara, Bind, Morena, Guna and Ratlam Districts of the state. The declining trend of pre-monsoon water levels reflects the ground water developmental activities in an area, whereas the rising trend indicates that either the developmental activities have reduced, or that, recharge due to sources other than the rainfall, such as applied irrigation has increased. Around 52.2% of monitoring wells are showing declining water levels trend while 47.8 % monitoring wells are showing rising ground water level trend.

Fig 3.16: Pre-monsoon Water Level Trend, Madhya Pradesh

3.7.4.2 Ground water Level Trend Post-Monsoon (November 2010 to November 2019)

Ground water levels trend map of post-monsoon period (Nov 2010 to Nov 2019) in Madhya Pradesh state has been depicted in Fig 25. The Map shows that there is a general declining trend up to 0.10 m/year of ground water levels during the past decade in almost all the districts of the state. Declining trend at a rate (-0.10 to -0.20 m/year) has been observed mainly in Rajgarh, Vidisha, Betul, Sheopur Districts of the state. Rising trend at a rate 0.10 m/year is observed in northeastern parts of the state. Declining trend at a rate 0.10 to 0.20 m/yearhas been observed in Chhindwara (part), Narsingpur(part), Damoh (part), Panna (part), Sheopur (part) & Datia (part) Districts of the state. Declining trend at a rate (0.10 to 0.20 m/year) has been observed in Vidisha, Rajgarh and Betul Districts.The declining trend in post-monsoon water levels suggests that a part of the aquifer is being dewatered every year, due either to deficient rainfall or to developmental activities. The rising post-monsoon trend, on the other hand, shows that additional water is being stored in the aquifer due to either increased rainfall or to seepage through applied irrigation.

Fig.3.17: Post-monsoon Water Level Trend, Madhya Pradesh

3.8 HYDROCHEMISTRY OF GROUNDWATER (2019-20)

Water samples were collected from 1194 Ground Water Monitoring Wells during May 2019 and monitored for chemical quality of ground water (phreatic aquifer) and their location is given in **Fig 3.18**. Detailed analysis of the chemical samples was carried out parameters namely: pH, Electrical Conductivity (EC), Carbonate, Bi-carbonate, Chloride, Fluoride, Nitrate, Sulphate, Phosphate, Total hardness, Calcium, Magnesium, Sodium and Potassium.

Fig.3.18: National Hydrographic Station for Groundwater Collection

3.8.1 Salinity

The salinity of water is represented by electrical conductivity. Electrical conductivity is a numerical expression of the ability of water to conduct an electric current. It depends on the total concentration of the ionized substances dissolved in water and the temperature at which the measurement is made. Electrical conductivity increases by about 2% per degree Celsius rise in temperature. The mobility of the dissolved ions, their valencies and their concentration affect conductivity. As electrical conductivity is an index of salinity in water, high electrical conductivity means high salinity. High salinity not only imparts bad taste to drinking water but such water is not suitable for irrigation purposes as it leads to deposition of salt content in the soil and affects the fertility of soil in the absence of adequate soil management practices.

The water having electrical conductivity up to 1000 µS/cm at 25°C may be considered fresh & suitable for drinking purpose. The Ground water quality of Madhya Pradesh is generally good as 58.71% wells have electrical conductivity below 1000 µS/cm at 25°C. The salinity tolerant crop may be grown in the area where electrical conductivity is more than 2000 µS/cm 25°C.

The chemical quality of ground water of Madhya Pradesh is generally good as the perusal of the frequency distribution of electrical conductivity in phreatic aquifer. Table 3.5 shows that 86.85% wells fall in the range of 0-1500 µS/cm at 25°C and only 1.01% wells have electrical conductivity more than 3000 µS/cm at 25°C.

Table.3.5: Frequency distribution of electrical conductivity in phreatic aquifer range

EC Range (µS/cm at 25°C)	**No. of Samples**	**%**
0-1500	1037	86.85
1501-3000	145	12.14
>3001	12	1.01

Fig.3.19: Electrical Conductivity in shallow aquifer, Madhya Pradesh

The distribution of major ions indicates that in Madhya Pradesh in ground water with low to medium salinity (EC 1000 µs/cm) bicarbonate is the predominant anion but there is conspicuous increase in Chloride, Sulphate and Nitrate ion concentration with increase in salinity which indicates that the leaching of minerals of these constituents or human activity is contributing towards salinity in ground water of the area. Generally, the ground water in Madhya Pradesh is alkaline earth bicarbonate type. In Madhya Pradesh, the electrical conductivity of water in shallow aquifer occurs more than 3000 µs/cm at 25°C in Agar Malwa, Alirajpur, Bhind, Indore, Neemuch, Ratlam, Sagar and Sehore districts. The distribution of Electrical Conductivity in Madhya Pradesh is given in the **Fig 3.19**.

3.8.2 Fluoride

Generally, fluoride is present in low concentration in natural water. The presence of fluoride in ground water is very important from health point of view for human consumption as in low concentration; it prevents dental caries (up to 1.0 mg/l). However, the high concentration of fluoride above the permissible limit of 1.5 mg/l in drinking water (IS: 10500 Drinking water standards) is harmful for human consumption as it causes mottling of teeth and skeletal fluorosis. Its accumulation leads not only to high skeletal concentration, but also has crippling ill effects.

In Madhya Pradesh fluoride rich water in shallow aquifer occurs in Alirajpur, Anuppur, Bhind, Chhindwara, Datia, Dewas, Dhar, Dindori, Harda, Jabalpur, Mandla, Neemuch, Raisen, Rajgarh, Ratlam, Singrauli, Tikamgarh, Ujjain and Umaria districts. The distribution of fluoride in the State is shown in Fig 28. Flouride analysis reveals that there is no specific trend observed for distribution of Fluoride in the State. The maximum fluoride concentration has been observed at Fatta (4.00 mg/l) of Alirajpur district. The frequency distribution of Fluoride is given in the **Table 3.6** shows that in 89.61% (1070 nos.) wells Fluoride concentration is within the desirable limit of 1.0 mg/l where as 3.18% (38 nos.) wells show Fluoride concentration above the maximum permissible limit of 1.5 mg/l.

Table.3.6: Frequency Distribution of Fluoride in Phreatic Aquifer

Fluoride Conc. Range (mg/l)	No. of Samples	%
0-1	1070	89.61
1-1.5	86	7.20
>1.5	38	3.18

Fig.3.20: Fluoride Concentration in shallow aquifer, Madhya Pradesh

3.8.3 Nitrate

Undesirable changes in the natural quality of ground water due to anthropogenic activities of man are a matter of great concern. The contribution of atmospheric and geological sources for Nitrate in ground water is small in comparison to the sources related to pollution as a result of activities of man. Sewage and animal waste contain considerable amount of Nitrate and its discharge on land & subsequent leaching by rainfall causes enrichment of Nitrate in ground water. Similarly, agricultural sources such as excessive use of fertilizers, irrigation with wastewaters, legumes and farm yard wastes contribute nitrate to ground water.

Concentration of nitrate in excess of 45mg/l in water is harmful for human consumption, particularly for infants as it may cause blue baby disease. The highest desirable and maximum permissible limit of nitrate is 45mg/l (IS: 10500 Drinking water standards). The locations of wells in Madhya Pradesh, where concentration of nitrate ion was more than 45mg/l in ground water are shown in Fig 29. Perusal of frequency distribution of nitrate in ground water reveals that 69.18% (826 nos.) wells have nitrate concentration within the permissible limit of 45mg/l while 30.82% (368 nos.) well water contain nitrate in excess of 45 mg/l (**Table 3.7**).

Table.3.7: Frequency distribution of Nitrate in shallow aquifer

Nitrate Conc. Range (mg/l)	No. of Samples	%
0-45	826	69.18
46-100	282	23.62
>100	86	7.20

Fig.3.21: Nitrate Concentration in shallow aquifer, Madhya Pradesh

In Madhya Pradesh, nitrate concentration in shallow aquifer occurs in Agar Malwa, Alirajpur, Anuppur, Ashok Nagar, Balaghat, Barwani, Betul, Bhind, Bhopal, Burhanpur, Chhatarpur, Chhindwara, Damoh, Datia, Dewas, Dhar, Dindori, Gwalior, Harda, Hoshangabad, Indore, Jabalpur, Jhabua, Katni, Khandwa, Khargone, Mandla, Mandsaur, Morena, Narsinghpur, Neemuch, Panna, Raisen, Rajgarh, Ratlam, Rewa, Sagar, Satna, Sehore, Seoni, Shahdol, Shajapur, Sheopur, Shivpuri, Sidhi, Singrauli, Tikamgarh, Ujjain, Umaria and Vidisha districts. The distribution of nitrate concentration in the State is shown in Fig 29. Very high nitrate concentration of 458 mg/l was found in the ground water sample from Palar of Damoh district.

3.8.4 Total Hardness

Hardness is mainly caused by the presence of Calcium and Magnesium Bicarbonate, Sulphate and Chloride ions. As per Bureau of Indian Standard IS:10500: 2012 (Drinking water), the desirable limit of total hardness is 200 mg/l and permissible limit is 600 mg/l. Total Hardness

in the shallow ground water in Madhya Pradesh ranges between 10 to 1480 mg/l (1480 mg/l in Sanwer, Indore district). Most of the waters are calcium bicarbonate type attributing to temporary hardness of water. Permanent hardness of water caused by Calcium and Magnesium, Sulphate and Chloride can be removed by ion exchange.

Table.3.8: Frequency distribution of Total Hardness in shallow aquifer

Total Hardness Range (mg/l)	No. of Samples	%
<200	246	20.60
200-600	863	72.28
>600	85	7.12

The study of Total Hardness in ground water reveals that 85 nos. (7.12%) of well waters contain hardness more than the permissible limit of 600 mg/l and 863 nos. (72.28%) of well waters has total hardness above the desirable limit of 200 mg/l but below the permissible limit of 600 mg/l (Table 3.8).

3.8.5 Suitability for Irrigation

The crop productivity depends on the quality of the water used for irrigation. Water suitability for irrigation needs to be evaluated on the basis of hazards it can create in the soil, affecting yield & quality of crops. The potential hazards to crop growth are salinity, sodicity, alkalinity and toxicity.

3.8.6 Sodium absorption Ratio

Sodium Adsorption Ratio (SAR) is an estimate of the degree to which Sodium will be absorbed by soil from water. Sodium in irrigation, waters adversely affects soil structure and permissibility by replacing Ca and Mg ions.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

Where: Na+, Ca+2 and Mg+2 is expressed in meq/l

Table.3.9: Quality of Water on the basis of SAR values

S.No.	Range of SAR	No. of Sample	% of Samples	Quality of Water
1.	<10	1184	99.16	Low Sodium hazard good quality
2.	10-18	9	0.75	Medium Sodium hazard medium quality
3.	18-26	1	0.08	High Sodium hazard bad quality
4.	>26	0	0	Very High Sodium hazard very bad

Table 3.9 shows that the quality of water samples as per SAR is good as 99.16% (1184 nos.) wells have SAR value below 10.

3.8.7 Residual Sodium Carbonate

Residual Sodium Carbonate (RSC): Equals the sum of bicarbonate and Carbonate ion concentration minus the sum of Calcium & Magnesium ions, when all the ions are expressed in meq/l.

$$RSC = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

According to Eaton (1950) and USSL (1954), irrigation waters containing residual sodium carbonate (RSC) above 2.5 meq/l are not suitable for irrigation purpose. Water containing 1.25 to 2.5 meq/l of RSC is marginally suitable & those containing less than 1.25 meq/l of RSC are safe. The water quality of Madhya Pradesh has been evaluated on the basis of RSC in **Table 3.10**.

Table.3.10: Number of wells falling in different RSC ranges

S.No.	RSC Range in meq/l	No. of wells	% of wells	Suitability
1.	< 1.25	1081	90.54	Suitable
2.	1.25 – 2.5	56	4.69	Marginally suitable
3.	>2.5	57	4.77	Unsuitable

Nearly 95.23% (1137 Nos.) of dug well waters of Madhya Pradesh were found to have RSC values below 2.5meq/l, which infers that the water is free from alkalinity hazards. However, 4.17% (49 Nos.) of wells have RSC more than 2.5 meq/l. Excessive use of these high RSC waters for irrigation can adversely affect fertility of the soil in the area by making it alkaline, resulting at times in hardening of the soil due to deposition of sodium carbonate. For safe use of such waters gypsum requirement for different soils needs to be evaluated.

Maximum and minimum values and values exceeding desirable and permissible limit for drinking use of different parameters is shown in the **Table 3.11**.

Table3.11: Showing maximum and minimum values and values exceeding desirable and permissible limit for drinking use of different parameters

	pH	**TH**	**Ca**	**Mg**	**Na**	**K**	**CO_3**	**HCO_3**	**Cl**	**SO_4**	**NO_3**	**F**	**EC**	
		m											**µS/cm at 25°C**	
Range of values	6.48	20	4	1	4	0.1	0	25	5	0	1	0.01	Minimum	138
Range of values	8.43	1480	421	206	610	165	32	1197	1151	1100	458	4.00	Maximum	4875
IS:10500 drinking water (desirable	6.5-8.5	200	75	30				Bicarbonate alkalinity 200	250	200	45	1	Range of EC	% of samples
IS: 10500 drinking water (permissibl	6.5-8.5	600	200	100				600	1000	400	45	1.5	<1500	86.85
% samples exceeding desirable	Nil	72.28	42.80	38.53				78.73	7.12	0.92	30.82	7.20	1501-3000	12.14
% samples exceeding permissible	Nil	7.12	3.26	1.17				3.93	0.17	0.25	30.82	3.18	>3000	1.01

CHAPTER-4

4.0 COMPUTATION OF GROUND WATER RESOURCE

The Dynamic ground water resources (as in 2020) of Madhya Pradesh have been assessed jointly by Central Ground Water Board, North Central Region, Bhopal and Ground Water Survey, Water Resource Department, Govt. Of Madhya Pradesh under the supervision of the State Level Committee. The dynamic ground water resources are also known as Annual Ground Water Recharge, since it gets recharged every year from rainfall and other sources (secondary sources) such as applied irrigation water, surface water bodies, water conservation structures, etc. Methodology adopted for the assessment has been outlined in Chapter 2 of this report. This section provides a summary of the Ground Water Resources Assessment 2020 (GWRA-2020) made for the state. Data of rainfall, ground water structures, canal, tanks ponds etc. are collected of five years from 2015 to 2019. The water level data are used from 2010 to 2019.

4.1 ASSESSMENT UNITS

In the earlier assessment years, the resource was estimated for all 313 administrative blocks as the assessment units. In the assessment year 2019-20, four urban areas of Madhya Pradesh namely Bhopal, Indore, Gwalior and Jabalpur were added to estimate separately. The ground water resources have been computed for all 317 assessment units (313 administrative blocks and 4 urban areas) of Madhya Pradesh.

The following sub-units are taken into account for the computation of various figures in the methodology and have been considered as given below: -

4.1.1 Hilly Area

This sub-unit comprises of all portions of ground water assessment unit which have slopes greater than 20%. This sub-unit is characterized by more runoff and less ground water recharge, and hence has been excluded for ground water recharge computation.

4.1.2 Poor Ground Water Quality Area

There is no clear cut demarcated area of poor quality in the State for computation of ground water resources. Apart from this, statistical data of ground water structure is also not available. Hence this unit has not been considered for resource estimation.

4.1.3 Command and Non-Command Area

In the methodology, it is recommended that dynamic ground water resources estimation should be carried out for command area and non-command area separately. This has been followed. For computation of ground water resources of command area only medium and major command areas have been considered.

Block-wise total geographical areas, hilly area, command area, non-command area and area worthy for ground recharge are given in **Annexure IVA**, whereas district-wise geographical areas, hilly area, command area, non-command area and area worthy for ground recharge are shown in **Table 4.1**

Table.4.1: District wise Area Details

District	Total Geographical Area (Hectare)				
	Recharge Worthy Area			Hilly Area	Total
	Command area	Non-command area	Total		
Alirajpur	0	305440	305440	26400	331840
Agar	11375	240201	251576	20617	272193
Anupur	0	294200	294200	78200	372400
Ashoknagar	20650	441594	462244	5150	467394
Balaghat	101503	790290	891793	31107	922900
Badwani	66689	300142	366831	175369	542200
Bhind	179891	266009	445900	0	445900
Bhopal	0	264800	264800	12437	277237
Betul	29248	827202	856450	147850	1004300
Burhanpur	11289	245761	257050	66250	323300
Chhatarpur	116640	673794	790434	78302	868736
Chhindwara	12476	872301	884777	296723	1181500
Datia	132097	134103	266200	2900	269100
Damoh	57667	416952	474619	255981	730600
Dewas	18544	558538	577082	125002	702084
Dhar	149070	663570	812640	2660	815300
Dindori	0	456000	456000	116500	572500
Guna	37209	580305	617514	21486	639000
Gwalior	131133	297167	428300	28100	456400
Harda	79150	190940	270090	62910	333000
Hoshangabad	253623	304729	558352	112048	670400
Indore	5376	376521	381897	7903	389800
Jabalpur	80876	362992	443868	78225	522093
Jhabua	17018	294235	311253	34747	346000
Katni	33404	433244	466648	22752	489400
Khargone	172061	484836	656897	146103	803000
Khandwa	92560	488886	581446	171004	752450
Mandla	31070	542920	573990	180410	754400
Mandsaur	0	499048	499048	54470	553518
Morena	224789	213700	438489	60400	498889
Neemuch	0	375744	375744	44300	420044

District	Total Geographical Area (Hectare)				
	Recharge Worthy Area			Hilly Area	Total
	Command area	Non-command area	Total		
Narsinghpur	50569	428531	479100	34200	513300
Panna	32712	629763	662475	52375	713500
Raisen	58600	602340	660940	185700	846640
Rajgarh	0	615498	615498	0	615498
Ratlam	8614	452986	461600	24500	486100
Rewa	75446	517470	592916	38444	631360
Satna	47108	624998	672106	78128	750234
Sagar	47073	878345	925418	99782	1025200
Sehore	95559	368413	463972	193828	657800
Seoni	71956	733064	805020	70780	875800
Shahdol	5047	492753	497800	86300	584100
Shajapur	0	339617	339617	7708	347325
Sheopur	71150	462330	533480	127120	660600
Shivpuri	69421	907628	977049	50751	1027800
Sidhi	48890	311515	360405	124995	485400
Singrauli	6602	444658	451260	115940	567200
Tikamgarh	39692	448408	488100	16700	504800
Umaria	0	421900	421900	32000	453900
Ujjain	0	593933	593933	19090	613023
Vidisha	76287	594483	670770	66330	737100
State Total	**2870134**	**24064797**	**26934931**	**3889627**	**30824558**

4.2 GROUND WATER RESOURCES OF MADHYA PRADESH

Groundwater resources of Madhya Pradesh State have been computed according to Methodology and norms described in Chapter-2. The assessment wise details have been provided in **Annexure (IV B to IV H)**. The Salient features of the computations are given below.

4.2.1 Recharge from Rainfall

Recharge from rainfall has been computed separately for monsoon and non-monsoon periods as well as for command and non-command areas. Recharge from rainfall is mainly a function of geographical area of the district, normal monsoon rainfall and lithology of the area.

The recharge from rainfall during monsoon season has been computed using mainly Water Level Fluctuation Method, whereas recharge from rainfall during non-monsoon period has been computed using Rainfall Infiltration Factor Method. Details of the block-wise monsoon and non-

monsoon Rainfall recharge have been given in **Annexure IV B**. District-wise recharge from rainfall is given in **Table-4.2**.

Non-monsoon rainfall recharge is taken into account in Annupur, Balaghat, Burhanpur, Chhindwara, Dindori, Mandla, Rewa, Satna, Seoni, Shahdol, Sidhi and Umaria districts, where non monsoon rainfall is more than 10% of the total annual rainfall. Total recharge from rainfall in the State is of the order of 2787259.71 ham (27.87 bcm) which is approximately 76.75% of the total annual ground water recharge (**Fig 4.1**) with Hoshangabad district having the highest recharge of 129279.3 ham and Alirajpur district has minimum recharge of the order of 19981.86 ham.

4.2.2 Recharge from Other Sources

Total Recharge to ground water has several components, rainfall being the major one. The other component include seepage from canals, return flow from surface water irrigation, return flow from ground water irrigation, seepage from Tanks and Ponds etc. for command area. For non–command area seepage from canals and return flow from surface water irrigation is not applicable. Assessment wise recharge from other sources has been given in **Annexure IV B**. District- wise recharge from other sources is given **Table 4.2**. Component of recharge from other sources is highest in Hoshangabad district (77814.08 ham) followed by Khargone district (50420.74 ham) where maximum canal irrigation facility is available. Lowest value of recharge from other source is recorded in Dindori (641.44 ham) and Anuppur (1565.94 ham) being tribal districts where use of ground water as well surface water for irrigation purpose is very low. Total recharge from rainfall is 2787259.71 ham (27.87 bcm) whereas from other sources is 828873.53 ham (8.29 bcm). Assessment wise recharge from canals, surface water irrigation, ground water irrigation, seepage from Tanks and Ponds, water conservation structures and pipelines has been given in **Annexure IV C**. District- wise recharge from canals, surface water irrigation, ground water irrigation, seepage from Tanks and Ponds, water conservation structures and pipelines is given **Table 4.3**.

4.2.3 Recharge from All Sources

The overall contribution of rainfall (both monsoon & non-monsoon) recharge to state's total annual ground water recharge is 77 % and the share of recharge from 'Other sources' viz. canal seepage, return flow from irrigation, recharge from tanks, ponds and water conservation structures taken together is 23 % (**Fig 4.1**). Total replenishable ground water resources including rainfall recharge and recharge from other sources have been computed on assessment- wise and by adding up assessment wise figures of the respective districts which is presented in **Annexure**

IV B and **Table-4.2**. Total annual recharge from all sources in the State is of the order of 3616133.15 ham, (36.16 bcm), with Hoshangabad district having the highest recharge of 207093.39 ham and Alirajpur district has minimum recharge of the order of 23103.53 ham. Volumetric estimates are dependent on the areal extent of the assessment units. In order to compare the ground water resource of different assessment units, the volumetric estimates of annual ground water recharge have been converted to depth units (m) by dividing the annual ground water recharge by the area of the respective assessment units (km2). Spatial variation in annual ground water recharge (m) is shown in **Fig 4.2**.

4.2.4 Unaccounted Natural Discharge and Annual Extractable Ground Water Resource

The total annual ground water recharge of the area is the sum of monsoon and non-monsoon recharge. An allowance of 5% of total annual ground water recharge has been kept for natural discharge in the non-monsoon season, recharge is considered of WLF method is employed to compute rainfall recharge during monsoon season otherwise 10%. The balance ground water available accounts for existing net ground water availability for various uses and potential for future development. Assessment wise unaccounted natural discharge and Annual Extractable Ground Water Resource is given in **Annexure IV B** whereas district wise unaccounted natural discharge and Annual Extractable Ground Water Resource is given in **Table 4.2**. Total unaccounted natural discharge in the State is of the order of 278093.45 ham (2.78 bcm) with Hoshangabad district having the highest discharge of 12074.2 ham and Jhabua with lowest of 1703.56 ham. The total natural discharge in the state is about 8% of the total annual Groundwater recharge (**Fig 4.1**). The Annual Extractable Ground Water Resource in the state is 3338039.67 ham (33.38 bcm) with Hoshangabad district having the highest Annual Extractable Ground Water Resource of 195019.19 ham and Alirajpur with lowest of 21327.31 ham. The Annual Extractable Ground Water Resource in the state which is 92% of the total annual Groundwater recharge (**Fig 4.1**)

Fig.4.1: Ground Water Resources and Extraction Scenario, Madhya Pradesh, 2020

Table.4.2: District wise Recharge, Madhya Pradesh

S. No.	District	Monsoon Season		Non-monsoon Season		Total Annual Ground Water Recharge (Ham)	Total Natural discharges (Ham)	Annual Extractable Ground Water Resource (Ham)
		Recharge from rainfall (Ham)	Recharge from other sources (Ham)	Recharge from rainfall (Ham)	Recharge from other sources (Ham)			
1	**Agar Malwa**	33138.64	2590.2	0	9681.3	45410.14	4382.3	41027.84
2	**Alirajpur**	19981.86	1058.6	0	2063.07	23103.53	1776.22	21327.31
3	**Anuppur**	36011.33	319.95	2853.65	1245.99	40430.92	2695.93	37734.99
4	**Ashoknagar**	28905.41	2075.65	0	7824.77	38805.83	3103.98	35701.85
5	**Balaghat**	81686.5	1957.93	290.51	2791.18	86726.12	8672.64	78053.48
6	**Barwani**	34944.34	3415.72	0	18550.63	56910.69	5165.15	51745.54
7	**Betul**	102040.17	3612.4	0	16046.71	121699.28	8221.47	113477.81
8	**Bhind**	80922.82	1574.22	0	15453.78	97950.82	9204.22	88746.59
9	**Bhopal**	30342.01	2622.81	0	6942.84	39907.66	3042.37	36865.29
10	**Burhanpur**	30054.26	2541.78	264.63	7412.93	40273.6	2929.68	37343.92
11	**Chhatarpur**	65844.51	4269.32	0	16628.35	86742.18	6288.59	80453.59
12	**Chhindwara**	87803.07	3866.38	600.33	12436.85	104706.63	5919.69	98786.94
13	**Damoh**	31619.92	2050.39	0	9173.22	42843.53	3545.25	39298.28
14	**Datia**	36352.9	730.38	0	6722.3	43805.58	3037.44	40768.14
15	**Dewas**	66496.05	4935.92	0	15466.15	86898.12	6096.06	80802.06
16	**Dhar**	84490.43	7124.47	0	22699.4	114314.3	9401.24	104913.07
17	**Dindori**	40499.2	141.01	301.21	500.43	41441.85	2604.84	38837.01
18	**Guna**	60581.42	4283.83	0	14725.3	79590.55	4324.69	75265.86
19	**Gwalior**	53338.95	8182.71	0	18809.43	80331.09	6641.99	73689.1
20	**Harda**	33125.19	2883.56	0	15865.43	51874.18	5187.43	46686.75
21	**Hoshangabad**	129279.31	11449.3	0	66364.78	207093.39	12074.2	195019.19
22	**Indore**	37119.3	7338.55	0	15632.8	60090.65	5476.51	54614.14
23	**Jabalpur**	51628.17	3265.54	0	8922.5	63816.21	4819	58997.21
24	**Jhabua**	21206.45	1494.72	0	5236.23	27937.4	1703.56	26233.84

S. No.	District	Monsoon Season		Non-monsoon Season		Total Annual Ground Water Recharge (Ham)	Total Natural discharges (Ham)	Annual Extractable Ground Water Resource (Ham)
		Recharge from rainfall (Ham)	Recharge from other sources (Ham)	Recharge from rainfall (Ham)	Recharge from other sources (Ham)			
25	**Katni**	33856.39	1363.44	0	4594.03	39813.86	3136.6	36677.26
26	**Khandwa**	56167.03	4407.81	0	37510.11	98084.95	8047.93	90037.02
27	**Khargone**	63404.27	5658.22	0	44762.52	113825.01	7863.59	105961.41
28	**Mandla**	56699.37	871.29	1095.53	4003.84	62670.03	3425.88	59244.15
29	**Mandsaur**	47803.06	4507.38	0	14756.06	67066.5	6706.65	60359.85
30	**Morena**	47301.71	1017.7	0	20826.71	69146.12	5361.48	63784.63
31	**Narsinghpur**	102628.63	3571.16	0	15637.83	121837.62	8296.36	113541.26
32	**Neemuch**	29881.06	4282.92	0	8391.84	42555.82	4255.57	38300.25
33	**Panna**	57402.37	1283.65	0	6047.5	64733.52	6473.35	58260.17
34	**Raisen**	76289.29	3279.07	0	9587.61	89155.97	7206.76	81949.21
35	**Rajgarh**	65411.49	3848.31	0	13198.21	82458.01	4954.26	77503.75
36	**Ratlam**	54572.43	7036.13	0	22822.5	84431.06	8108.4	76322.66
37	**Rewa**	42008.7	1835.61	273.82	8259.36	52377.49	4009.86	48367.63
38	**Sagar**	91071.07	3614.96	0	14072.96	108758.99	8828.73	99930.26
39	**Satna**	51079.31	2498.19	1006.14	10349	64932.64	5640.78	59291.86
40	**Sehore**	54332.97	3470.08	0	11992.9	69795.95	4608.14	65187.81
41	**Seoni**	62350.77	1951.24	2242.88	5957.79	72502.68	4252.85	68249.83
42	**Shahdol**	45582.48	368.6	1595.85	1329.18	48876.11	4887.61	43988.5
43	**Shajapur**	42405.42	3246.09	0	11150.46	56801.97	3551.76	53250.21
44	**Sheopur**	35918.59	963.24	0	19248.01	56129.84	4957.24	51172.6
45	**Shivpuri**	62089.34	3662.39	0	14689.65	80441.38	5712.34	74729.04
46	**Sidhi**	47076.52	795.32	667.28	2711.05	51250.17	3756.37	47493.79
47	**Singrauli**	33344.8	790.04	0	2636.16	36771	2717.35	34053.65
48	**Tikamgarh**	47166.79	3180.52	0	11632.9	61980.21	5618.82	56361.39
49	**Ujjain**	73764.02	5627.8	0	20805.98	100197.8	8396.96	91800.84

S. No.	District	Monsoon Season		Non-monsoon Season		Total Annual Ground Water Recharge (Ham)	Total Natural discharges (Ham)	Annual Extractable Ground Water Resource (Ham)
		Recharge from rainfall (Ham)	Recharge from other sources (Ham)	Recharge from rainfall (Ham)	Recharge from other sources (Ham)			
50	**Umaria**	42947.39	559.13	811.73	1768.1	46086.35	4608.62	41477.73
51	**Vidisha**	75288.67	2711.94	0	12747.24	90747.85	6394.74	84353.11
	Total(Ham)	**2775256.2**	**160187.57**	**12003.56**	**668685.87**	**3616133.15**	**278093.45**	**3338039.67**
	Total(BCM)	**27.753**	**1.602**	**0.12**	**6.687**	**36.161**	**2.781**	**33.38**

Table 4.3: District wise Recharge from other source components

S.No	District	Recharge from Canals (in Ham)	Recharge from Surface Water Irrigation (in Ham)	Recharge from Ground Water Irrigation (in Ham)	Recharge Due to Tanks and Ponds (in Ham)	Recharge due to Water Conservation Structures (in Ham)	Recharge Due to Pipelines (in Ham)	Total Recharge from Other Sources (in Ham)
1	**Agar Malwa**	822.45	575.21	9510.33	884.71	478.8	0	12271.5
2	**Alirajpur**	0	0	1576.64	486.63	1058.408	0	3121.678
3	**Anuppur**	0	0	1509.74	47.8	8.4	0	1565.94
4	**Ashoknagar**	1065.65	2912.64	5170.39	404.34	347.4	0	9900.42
5	**Balaghat**	601.11	563.69	2683.92	306.21	594.18	0	4749.11
6	**Barwani**	1067.34	9536.29	8041.96	1402.6	1918.182	0	21966.372
7	**Betul**	2579.49	3097.02	11786.88	1899.26	296.46	0	19659.11
8	**Bhind**	6027.16	5897.31	5011.63	37.3	54.6	0	17028
9	**Bhopal**	0	0	5859.22	957.57	279.644	2469.225	9565.659
10	**Burhanpur**	89.15	1383.85	5072.76	634.35	2774.604	0	9954.714
11	**Chhatarpur**	3858.06	2191.32	12708.11	2039.58	100.596	0	20897.666
12	**Chhindwara**	323.43	1196.14	13287.86	782.47	713.34	0	16303.24
13	**Damoh**	1403.38	3311.6	4860.83	1568.61	79.2	0	11223.62
14	**Datia**	1081.84	3177.9	2980.92	26.34	185.68	0	7452.68
15	**Dewas**	351.1	884.88	15138.68	452.5	3574.92	0	20402.08
16	**Dhar**	3624.05	2498.58	19212.62	2826.52	1662.14	0	29823.91
17	**Dindori**	0	0	594.4	0	47.04	0	641.44
18	**Guna**	2153.48	3640.06	11821.66	1066.35	327.55	0	19009.1
19	**Gwalior**	4984.5	15623.83	4488.97	1165.43	72.42	657	26992.15
20	**Harda**	7578.09	7456.05	3603.8	53.03	58.02	0	18748.99
21	**Hoshangabad**	47900.87	20157.26	9583.56	122.46	49.92	0	77814.07
22	**Indore**	53.17	224.85	14795	1518.02	6380.32	0	22971.36
23	**Jabalpur**	291.37	2915.4	7073	326.86	1033.92	547.5	12188.05

S.No	District	Recharge from Canals (in Ham)	Recharge from Surface Water Irrigation (in Ham)	Recharge from Ground Water Irrigation (in Ham)	Recharge Due to Tanks and Ponds (in Ham)	Recharge due to Water Conservation Structures (in Ham)	Recharge Due to Pipelines (in Ham)	Total Recharge from Other Sources (in Ham)
24	**Jhabua**	138.7	2064.42	2585.97	1266.34	675.504	0	6730.934
25	**Katni**	818.99	1162.49	3344.73	523.27	108	0	5957.48
26	**Khandwa**	1306.54	24904.72	10005.09	3336.37	2365.188	0	41917.908
27	**Khargone**	3702.27	28246.99	10358.47	3290.52	4822.496	0	50420.746
28	**Mandla**	1789.44	588.06	1727.04	706.37	64.224	0	4875.134
29	**Mandsaur**	0	0	15359.41	463.63	3440.4	0	19263.44
30	**Morena**	13914.63	3795.66	3661.65	389.19	83.28	0	21844.41
31	**Narsinghpur**	1390.29	585	17184.98	5.22	43.5	0	19208.99
32	**Neemuch**	0	0	8374.27	3574.49	726	0	12674.76
33	**Panna**	678.79	1828.76	3888.25	870.13	65.22	0	7331.15
34	**Raisen**	320.25	91.09	9704.18	2412.93	338.22	0	12866.67
35	**Rajgarh**	0	0	15386.64	735.88	924	0	17046.52
36	**Ratlam**	162.87	19.44	25879.92	773.6	3022.8	0	29858.63
37	**Rewa**	3212.94	934.91	5480.83	367.35	98.94	0	10094.97
38	**Sagar**	889.62	1061.16	14222.49	1363.95	150.69	0	17687.91
39	**Satna**	362.68	3960.65	8308.49	136.41	78.96	0	12847.19
40	**Sehore**	1116	3124.33	9645.1	1504.37	73.2	0	15463
41	**Seoni**	1013.96	237.6	5435.39	1184.4	37.68	0	7909.03
42	**Shahdol**	310.94	0	1211.11	149.56	26.16	0	1697.77
43	**Shajapur**	0	0	13519.96	571.79	304.8	0	14396.55
44	**Sheopur**	12744.8	3259.29	3650.51	395.05	161.6	0	20211.25
45	**Shivpuri**	1760.69	2851.83	12023.37	1351.98	364.18	0	18352.05
46	**Sidhi**	848.13	0	2116.92	275.52	265.8	0	3506.37
47	**Singrauli**	102.14	0	2697.44	356.86	269.76	0	3426.2

S.No	District	Recharge from Canals (in Ham)	Recharge from Surface Water Irrigation (in Ham)	Recharge from Ground Water Irrigation (in Ham)	Recharge Due to Tanks and Ponds (in Ham)	Recharge due to Water Conservation Structures (in Ham)	Recharge Due to Pipelines (in Ham)	Total Recharge from Other Sources (in Ham)
48	**Tikamgarh**	1269.5	2109.89	9187.41	2169.1	77.52	0	14813.42
49	**Ujjain**	0	0	23047.85	2355.37	1030.56	0	26433.78
50	**Umaria**	0	0	2147.83	162.6	16.8	0	2327.23
51	**Vidisha**	2182.2	687.27	12081.65	421.02	87.038	0	15459.178
District Total (Ham)		**135892.1**	**168757.44**	**428609.8**	**50122.21**	**41818.264**	**3673.725**	**828873.529**
District Total (bcm)		**1.36**	**1.69**	**4.29**	**0.50**	**0.42**	**0.04**	**8.29**

Fig.4.2: Annual Groundwater Recharge per unit area, Madhya Pradesh

4.3 GROUND WATER EXTRACTION FOR ALL USES (DOMESTIC, IRRIGATION AND INDUSTRIAL)

Ground water extraction for various uses has been calculated separately for command and non-command areas. Details of assessment-wise groundwater extraction for various uses are given in **Annexure – IV D**. District-wise ground water extraction figures are also compiled and given in **Table 4.4**

Total extraction of ground water for all uses in state is calculated as 1896752.9 ham (18.97 bcm). From the **Table 4.4**, it is seen that maximum ground water extraction for all uses is 107741.87 ham in Ratlam district and minimum extraction of ground water for all uses is 4131.95 ham in Dindori district. Comparison of ground water extraction for various uses reveals that extraction for irrigation accounts for more than 91% of total ground water extraction, whereas extraction for domestic & industrial supply accounts for meager 9% of the total ground water extraction in the state. (**Fig 4.1**). Volumetric estimates are dependent on the areal extent of the assessment units. In order to compare the total ground water extraction of different assessment units, the volumetric estimates of total ground water extraction have been converted to depth units

(m) by dividing the total ground water extraction by the area of the respective assessment units (km2). Spatial variation in total extraction (m) is shown in **Fig 4.3**.

Fig.4.3: Total Groundwater Extraction per unit area, Madhya Pradesh

Table.4.4: District -wise Ground Water Extraction for Various Uses and Stage of Ground Water Development

S N	District	Existing Gross Ground Water Extraction for Irrigation (Ham)	Existing Gross Ground Water Extraction for Industrial Water Supply (Ham)	Existing Gross Ground Water Extraction for Domestic Water Supply (Ham)	Existing Gross Ground Water Extraction for All Uses (Ham)	Annual GW Allocation for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for Future use (Ham)	Stage of Ground Water Extraction (%)
1	**Agar Malwa**	**38041.29**	0	1593.66	39634.97	1766.32	4711.45	96.61
2	**Alirajpur**	**6306.57**	0	2189.07	8495.65	2548.66	12472.07	39.83
3	**Anuppur**	**6038.97**	0	1512.23	7551.2	1623.03	30072.99	20.01
4	**Ashoknagar**	**20681.54**	0	1746.69	22428.24	1927.85	13092.45	62.82
5	**Balaghat**	**12464.29**	0	3597.17	16061.44	3889.78	61699.41	20.58
6	**Barwani**	**33147.22**	0	3491.24	36638.47	3939.54	19221.59	70.81
7	**Betul**	**46816.25**	0	3753.32	50569.58	4105.82	62555.74	44.56
8	**Bhind**	**25344.54**	0	3414.4	28758.94	3758.17	59643.88	32.41
9	**Bhopal**	**23436.86**	0	3579.55	27016.42+9	4087.34	9341.08	73.28
10	**Burhanpur**	**22112.22**	0	1469.58	23581.82	1665.18	13566.5	63.15
11	**Chhatarpur**	**50832.41**	0	2952.35	53784.73	3323.15	26298.06	66.85
12	**Chhindwara**	**53283.55**	0	5792.71	59076.21	6149.52	39353.93	59.8
13	**Damoh**	**19443.36**	0	2988.54	22431.87	3295.52	16559.44	57.08
14	**Datia**	**12664.84**	0	1678.34	14343.2	1894.54	26208.75	35.18
15	**Dewas**	**60554.71**	25.35	4104.7	64684.74	4579.59	16963.5	80.05
16	**Dhar**	**77390.91**	0	5739.37	83130.27	6648.4	32426.91	79.24
17	**Dindori**	**2377.6**	0	1754.34	4131.95	1986.42	34472.98	10.64

S N	District	Existing Gross Ground Water Extraction for Irrigation (Ham)	Existing Gross Ground Water Extraction for Industrial Water Supply (Ham)	Existing Gross Ground Water Extraction for Domestic Water Supply (Ham)	Existing Gross Ground Water Extraction for All Uses (Ham)	Annual GW Allocation for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for Future use (Ham)	Stage of Ground Water Extraction (%)
18	**Guna**	**47286.67**	0	2408.17	49694.84	2715.98	25263.21	66.03
19	**Gwalior**	**17955.82**	0	3756.7	21712.52	4376.51	51729.54	29.47
20	**Harda**	**14704.63**	0	1183.32	15887.95	1330.85	30651.27	34.03
21	**Hoshangabad**	**39144.71**	0	2168.49	41313.17	2355.8	153518.7	21.18
22	**Indore**	**59179.95**	1471.4	8146.08	68797.42	10002.61	2539.19	125.97
23	**Jabalpur**	**25507.4**	6.48	3536.67	29050.55	3956.94	29689.42	49.24
24	**Jhabua**	**10246.94**	0	2993.56	13240.51	3548.42	12438.46	50.47
25	**Katni**	**13378.93**	0	2624.73	16003.69	2973.79	20324.5	43.63
26	**Khandwa**	**40020.29**	45.92	2881.48	42947.69	3243.92	46726.88	47.7
27	**Khargone**	**41433.83**	0	4293.5	45727.33	4743.84	59783.75	43.15
28	**Mandla**	**6908.22**	0	2425.78	9334	2690.49	49645.45	15.76
29	**Mandsaur**	**61437.69**	0	3311.25	64748.93	3604.9	2412.5	107.27
30	**Morena**	**19819.3**	0	5581.4	25400.69	6348.42	37719.42	39.82
31	**Narsinghpur**	**70217.32**	0	2263.17	72480.48	2452.96	40870.98	63.84
32	**Neemuch**	**33497.06**	0	1893.07	35390.12	2063.71	3215.25	92.4
33	**Panna**	**15444.08**	0	2363.99	17808.08	2635.57	40180.52	30.57
34	**Raisen**	**39617.81**	650	3227.11	43494.9	3646.89	38034.53	53.08
35	**Rajgarh**	**61546.56**	0	3873.19	65419.73	4534.9	11422.31	84.41
36	**Ratlam**	**103519.66**	208	4014.22	107741.87	6066.1	1491.06	141.17

S N	District	Existing Gross Ground Water Extraction for Irrigation (Ham)	Existing Gross Ground Water Extraction for Industrial Water Supply (Ham)	Existing Gross Ground Water Extraction for Domestic Water Supply (Ham)	Existing Gross Ground Water Extraction for All Uses (Ham)	Annual GW Allocation for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for Future use (Ham)	Stage of Ground Water Extraction (%)
37	**Rewa**	**21032.59**	173.74	5346.46	26552.8	6185.05	20976.23	54.9
38	**Sagar**	**56586.75**	0	3645.88	60232.63	4089.76	39253.76	60.27
39	**Satna**	**33693.62**	0	4544.75	38238.38	5077.31	23649.88	64.49
40	**Sehore**	**38035.12**	0	2365.6	40400.72	2605.78	24992.51	61.98
41	**Seoni**	**22485.01**	0	3136.8	25621.81	3485.41	42279.41	37.54
42	**Shahdol**	**4944.24**	0	2157.66	7101.91	2384.54	36659.72	16.14
43	**Shajapur**	**54079.84**	0	2098.73	56178.57	2288.53	2798.52	105.5
44	**Sheopur**	**17631.34**	0	1719.3	19350.64	1968.51	31572.74	37.81
45	**Shivpuri**	**48093.48**	0	4394.96	52488.42	5022.47	21613.11	70.24
46	**Sidhi**	**8506.79**	0	2518.87	11025.68	2894.9	36092.08	23.21
47	**Singrauli**	**10858.41**	0	2174.35	13032.75	2568.08	20627.17	38.27
48	**Tikamgarh**	**36393.46**	0	3841.62	40235.06	5083.16	14884.79	71.39
49	**Ujjain**	**92923.58**	28.84	3517.88	96470.3	3859.19	9505.3	105.09
50	**Umaria**	**8591.38**	0	1480.99	10072.37	1714.96	31171.39	24.28
51	**Vidisha**	**47660.09**	0	3576.55	51236.64	4027.89	32665.13	60.74
	Total(Ham)	**1733319.68**	**2609.73**	**160823.56**	**1896752.9**	**183736.97**	**1525059.41**	**56.82**
	Total(BCM)	**17.333**	**0.026**	**1.608**	**18.968**	**1.837**	**15.251**	**56.82**

4.4 STAGE OF GROUND WATER EXTRACTION

The overall stage of groundwater extraction in the state is 56.82 %. The stage of ground water extraction is very high in the districts of Indore, Mandsaur, Ratlam and Shajapur where it is more than 100%, which implies that in these districts the annual ground water consumption is more than annual extractable ground water resources. In the districts of Ashoknagar, Barwani, Bhopal, Burhanpur, Chhatarpur, Dewas, Dhar, Guna, Narsinghpur, Rajgarh, Sagar, Satna, Sehore, Shivpuri, Tikamgarh and Vidisha the stage of ground water Extraction is between 60-90%. Agar and Neemuch districts have stage of ground water extraction between 90 to 100 %. In rest of the districts, the stage of ground water extraction is below 60 %. The Ratlam (141.17%), Indore (125.97%), Mandsaur (107.27%), Shajapur (105.5%) and Ujjain (105.09%) districts reached at highest ground water extraction and Dindori with 10.64% is lowest stage of extraction district in state.

4.5 CATEGORIZATION OF ASSESSMENT UNITS

The distributions of various categorized assessment units are shown in the **Fig 4.4**. 233 blocks are falling under safe category, 50 blocks are falling in semi-critical category, 8 blocks of in critical category, and 26 blocks of the state are categorized as over-exploited. List of safe, semi-critical, critical and over-exploited area is given in **Annexure IV E** and in **Annexure IV D**. Almost all over-exploited blocks are falling in western part of Madhya Pradesh, which is known as “MALWA AREA” where ground water extraction has increased many folds during past decades.

The percentage of Over-exploited, Critical and Semi-critical administrative units are approximately 27% of the total units in the state (Fig. 4.5). Out of 33380.40 mcm of Total Annual Extractable Resources of the state, 3349.83 mcm (10.04 %) are under ‘Over-Exploited’, 754.83 mcm (2.26 %) are under ‘Critical’, 5021.66 mcm (15.04 %) are under ’Semi-Critical’, 24254.07 mcm (72.66 %) are under ‘Safe’ category assessment units. District-wise details are given in **Table 4.5**.

4.6 GROUND WATER AVAILABLE FOR FUTURE USE

Assessment wise, data of Ground Water Available for future use is given in **Annexure-IV D** and district wise are shown in **Table 4.4**. From **Table 4.4**, it is seen that in Madhya Pradesh 1525059.41 ham (15.25 bcm) ground water is estimated to be available for future use.

Figure.4.4: Categorisation of Assessment units in Madhya Pradesh

Figure.4.5: Categorisation of Assessment units

Table.4.5: Category wise Annual Extractable Ground Water Resource

S.No	District	Total Annual Extractable Ground Water Resource of Assessed Units (in mcm)	Safe		Semi-Critical		Critical		Over-Exploited	
			Annual Extractable Ground Water Resource (in mcm)	%	Annual Extractable Ground Water Resource (in mcm)	%	Annual Extractable Ground Water Resource (in mcm)	%	Annual Extractable Ground Water Resource (in mcm)	%
1	**Agar Malwa**	410.28	111.64	27.21	106.19	25.88	-	-	192.46	46.91
2	**Alirajpur**	213.27	213.27	100.00	-	-	-	-	-	-
3	**Anuppur**	377.35	377.35	100.00	-	-	-	-	-	-
4	**Ashoknagar**	357.02	283.47	79.40	73.55	20.60	-	-	-	-
5	**Balaghat**	780.53	780.53	100.00	-	-	-	-	-	-
6	**Barwani**	517.46	354.96	68.60	103.68	20.04	-	-	58.81	11.36
7	**Betul**	1134.78	823.52	72.57	311.26	27.43	-	-	-	-
8	**Bhind**	887.47	887.47	100.00	-	-	-	-	-	-
9	**Bhopal**	368.65	206.30	55.96	162.35	44.04	-	-	-	-
10	**Burhanpur**	373.44	373.44	100.00	-	-	-	-	-	-
11	**Chhatarpur**	804.54	438.95	54.56	365.58	45.44	-	-	-	-
12	**Chhindwara**	987.87	671.36	67.96	218.60	22.13	97.91	9.91	-	-
13	**Damoh**	392.98	338.45	86.12	54.53	13.88	-	-	-	-
14	**Datia**	407.68	407.68	100.00	-	-	-	-	-	-
15	**Dewas**	808.02	427.58	52.92	114.76	14.20	-	-	265.68	32.88
16	**Dhar**	1049.13	623.22	59.40	-	-	76.18	7.26	349.73	33.34
17	**Dindori**	388.37	388.37	100.00	-	-	-	-	-	-
18	**Guna**	752.66	752.66	100.00	-	-	-	-	-	-
19	**Gwalior**	736.89	712.21	96.65	24.68	3.35	-	-	-	-
20	**Harda**	466.87	466.87	100.00	-	-	-	-	-	-
21	**Hoshangabad**	1950.19	1749.06	89.69	201.14	10.31	-	-	-	-
22	**Indore**	546.14	-	-	107.28	19.64	-	-	438.86	80.36
23	**Jabalpur**	589.97	582.55	98.74	-	-	7.42	1.26	-	-

S.No	District	Total Annual Extractable Ground Water Resource of Assessed Units (in mcm)	Safe		Semi-Critical		Critical		Over-Exploited	
			Annual Extractable Ground Water Resource (in mcm)	%	Annual Extractable Ground Water Resource (in mcm)	%	Annual Extractable Ground Water Resource (in mcm)	%	Annual Extractable Ground Water Resource (in mcm)	%
24	**Jhabua**	262.34	238.59	90.95	23.75	9.05	-	-	-	-
25	**Katni**	366.77	366.77	100.00	-	-	-	-	-	-
26	**Khandwa**	900.37	781.31	86.78	119.06	13.22	-	-	-	-
27	**Khargone**	1059.61	998.02	94.19	61.60	5.81	-	-	-	-
28	**Mandla**	592.44	592.44	100.00	-	-	-	-	-	-
29	**Mandsaur**	603.60	-	-	136.36	22.59	161.97	26.83	305.27	50.57
30	**Morena**	637.85	637.85	100.00	-	-	-	-	-	-
31	**Narsinghpur**	1135.41	931.36	82.03	204.05	17.97	-	-	-	-
32	**Neemuch**	383.00	-	-	139.58	36.44	-	-	243.42	63.56
33	**Panna**	582.60	582.60	100.00	-	-	-	-	-	-
34	**Raisen**	819.49	725.29	88.51	94.20	11.49	-	-	-	-
35	**Rajgarh**	775.04	149.65	19.31	330.79	42.68	294.60	38.01	-	-
36	**Ratlam**	763.23	-	-	103.28	13.53	-	-	659.94	86.47
37	**Rewa**	483.68	449.39	92.91	34.29	7.09	-	-	-	-
38	**Sagar**	999.30	999.30	100.00	-	-	-	-	-	-
39	**Satna**	592.92	382.62	64.53	210.30	35.47	-	-	-	-
40	**Sehore**	651.88	535.13	82.09	-	-	116.75	17.91	-	-
41	**Seoni**	682.50	682.50	100.00	-	-	-	-	-	-
42	**Shahdol**	439.89	439.89	100.00	-	-	-	-	-	-
43	**Shajapur**	532.50	-	-	129.10	24.24	-	-	403.40	75.76
44	**Sheopur**	511.73	511.73	100.00	-	-	-	-	-	-
45	**Shivpuri**	747.29	300.26	40.18	447.04	59.82	-	-	-	-
46	**Sidhi**	474.94	474.94	100.00	-	-	-	-	-	-
47	**Singrauli**	340.54	340.54	100.00	-	-	-	-	-	-

S.No	District	Total Annual Extractable Ground Water Resource of Assessed Units (in mcm)	Safe		Semi-Critical		Critical		Over-Exploited	
			Annual Extractable Ground Water Resource (in mcm)	%	Annual Extractable Ground Water Resource (in mcm)	%	Annual Extractable Ground Water Resource (in mcm)	%	Annual Extractable Ground Water Resource (in mcm)	%
48	**Tikamgarh**	563.61	101.62	18.03	461.99	81.97	-	-	-	-
49	**Ujjain**	918.01	-	-	485.74	52.91	-	-	432.26	47.09
50	**Umaria**	414.78	414.78	100.00	-	-	-	-	-	-
51	**Vidisha**	843.53	646.61	76.66	196.92	23.34	-	-	-	-
	Total States	**33380.40**	**24254.07**	**72.66**	**5021.66**	**15.04**	**754.83**	**2.26**	**3349.83**	**10.04**

4.7 COMPARISON OF RESOURCE OF 2016-17 WITH BASE YEAR 2019-20

The total assessment units in the year 2016-17 was 313 (all the blocks), but in the year 2019-20 four urban areas namely Bhopal, Indore, Jabalpur and Gwalior are added separately for estimation. So in the year 2019-20 the resource is estimated for total 317 assessment units (313 blocks and 4 urban areas).

The annual extractable resource in the state computed in 2016-17 was 3447359 ham (34.47 bcm) which is almost same as compared to current data of 3338039.67 ham (33.38 bcm). In general, the reasons for slight changes are attributed to decrease in recharge from other sources.

The total groundwater extraction in the state for the year 2016-17 was 1887866 ham (18.88 bcm), but in the year 2019-20 total groundwater extraction is slightly increased to 1896753 ham (18.97 bcm) due to the revision of well census data and population.

The stage of ground water extraction has reached to 56.82% as compared to 54.76% in assessment year 2016-17. In the assessment year-2016-17, 240 blocks falling in safe category has decreased to 233 in 2019-20, 44 blocks falling in semi-critical category has increased to 50 in 2019-20, 07 blocks falling in Critical category has increased to 08 in 2019-20 whereas blocks under over-exploited category has 22 in the year 2016-17 reached to 26 in the assessment year 2019-20.

The ground water resources of the individual block /assessment unit show wide variation in the resource available and stage of ground water extraction. In Madhya Pradesh, the high ground water extraction concentrates mainly in the western (Malwa Region) and part of Bagkhelkhand Region of the State. The other part of the state has very low extraction of ground water. Twelve districts in the state have stage of extraction between 60% and 90 %, whereas two districts have stage of ground water extraction between 90 to 100 %. The Indore (116.63%), Mandsaur (103.22%), Ratlam (126.63%) and Shajapur (102.52%) districts reached at highest ground water extraction and Anuppur with 7.87% of extraction is lowest stage of extraction district in state. The overall stage of extraction of Madhya Pradesh in ground water point of view is 56.82 %.

The assessment units improved or deteriorated from 2017 to 2020 assessment are given in **Table 4.6.** For comparison of ground water resources data computed using GEC'2015 analysis of district wise figures is made for year 2016-17 and 2019-20, which is given in **Table 4.7**.

Table.4.6: Comparison of Categorization of Improved and Deteriorated Assessment Units (2020 And 2017)

S. No	Name of District	Name of Assessment Unit	Stage of Ground Water Extraction (%) in 2017	Categorization in 2017	Stage of Ground Water Extraction (%) in 2020	Categorization in 2020
Improved Assessment Units						
1	**Raisen**	**Sanchi**	73.15	Semi-Critical	63.49	Safe
2	**Damoh**	**Batiyagarh**	73.37	Semi-Critical	65.34	Safe
3	**Sagar**	**Banda**	70.38	Semi-Critical	57.92	Safe
Deteriorated Assessment Units						
4	**Sehore**	**Ashta**	77.36	Semi-Critical	99.67	Critical
5	**Hoshangabad**	**Bankhedi**	68.56	Safe	72.96	Semi-Critical
6	**Narsinghpur**	**Narsinghpur**	67.48	Safe	74.25	Semi-Critical
7	**Chhindwara**	**Chhindwara**	88.5	Semi-Critical	96.55	Critical
8	**Chhindwara**	**Mohkhed**	67.73	Safe	70.83	Semi-Critical
9	**Neemuch**	**Jawad**	96.1	Critical	100.3	Over-Exploited
10	**Neemuch**	**Neemuch**	94.64	Critical	102.25	Over-Exploited
11	**Ashoknagar**	**Ishagarh**	67.06	Safe	77.74	Semi-Critical
12	**Shajapur**	**Kalapipal**	97.33	Critical	108.83	Over-Exploited
13	**Jhabua**	**Jhabua**	67.74	Safe	77.13	Semi-Critical
14	**Shivpuri**	**Kolaras**	69.56	Safe	78.97	Semi-Critical
15	**Rewa**	**Mauganj**	65.62	Safe	72	Semi-Critical
16	**Vidisha**	**Gyraspur**	67.58	Safe	71.96	Semi-Critical
17	**Vidisha**	**Kurwai**	69.26	Safe	71.06	Semi-Critical
18	**Dhar**	**Tirla**	87.6	Semi-Critical	94.44	Critical
19	**Chhatarpur**	**Bijawar**	66.91	Safe	76.28	Semi-Critical

Table.4.7: District -wise comparison of resource between 2016-17 and 2019-20

S. No.	District	Annual Extractable Groundwater Resource (ham)		Total Ground Water Extraction (ham)		Stage of Ground Water Extraction (%)	
		2016-17	**2019-20**	**2016-17**	**2019-20**	**2016-17**	**2019-20**
1	**Agar Malwa**	42166.88	41027.84	39149.51	39634.97	92.84	96.61
2	**Alirajpur**	18279.15	21327.31	8227.54	8495.65	45.01	39.83
3	**Anuppur**	34549.47	37734.99	2754.3	7551.2	7.97	20.01
4	**Ashoknagar**	39821.99	35701.85	21865.91	22428.24	54.91	62.82
5	**Balaghat**	89518.11	78053.48	15288.99	16061.44	17.08	20.58
6	**Barwani**	70775.53	51745.54	38993.26	36638.47	55.09	70.81
7	**Betul**	119671.8	113477.8	68986.65	50569.58	57.65	44.56
8	**Bhind**	72318.86	88746.59	26026.74	28758.94	35.99	32.41

S. No.	District	Annual Extractable Groundwater Resource (ham)		Total Ground Water Extraction (ham)		Stage of Ground Water Extraction (%)	
		2016-17	2019-20	2016-17	2019-20	2016-17	2019-20
9	**Bhopal**	37001	36865.29	25955	27016.42	70.15	73.28
10	**Burhanpur**	36013.37	37343.92	24202.6	23581.82	67.2	63.15
11	**Chhatarpur**	98493.03	80453.59	60773.92	53784.73	61.7	66.85
12	**Chhindwara**	113351.8	98786.94	62575	59076.21	55.2	59.8
13	**Damoh**	38283.47	39298.28	22279.32	22431.87	58.2	57.08
14	**Datia**	34747.76	40768.14	13955.1	14343.2	40.16	35.18
15	**Dewas**	78745.17	80802.06	66325.6	64684.74	84.23	80.05
16	**Dhar**	113217.6	104913.1	77988.57	83130.27	68.88	79.24
17	**Dindori**	36408.05	38837.01	3709	4131.95	10.19	10.64
18	**Guna**	83413.77	75265.86	46124.79	49694.84	55.3	66.03
19	**Gwalior**	74837	73689.1	22348.18	21712.52	29.86	29.47
20	**Harda**	48132	46686.75	14902	15887.95	30.96	34.03
21	**Hoshangabad**	186782	195019.2	41680	41313.17	22.31	21.18
22	**Indore**	54997	54614.14	64140.6	68797.42	116.63	125.97
23	**Jabalpur**	66823	58997.21	28380	29050.55	42.47	49.24
24	**Jhabua**	22230.96	26233.84	12722.26	13240.51	57.23	50.47
25	**Katni**	35385	36677.26	16464	16003.69	46.53	43.63
26	**Khandwa**	101065.5	90037.02	43364.22	42947.69	42.01	47.7
27	**Khargone**	126703.9	105961.4	46185.25	45727.33	36.45	43.15
28	**Mandla**	49909.92	59244.15	8867.3	9334	17.77	15.76
29	**Mandsaur**	58367.69	60359.85	60244.7	64748.93	103.22	107.27
30	**Morena**	68113.96	63784.63	24224	25400.69	35.56	39.82
31	**Narsinghpur**	117630.2	113541.3	74501.75	72480.48	63.34	63.84
32	**Neemuch**	40882.44	38300.25	35748.54	35390.12	87.44	92.4
33	**Panna**	44965.39	58260.17	16410.86	17808.08	36.5	30.57
34	**Raisen**	84863.65	81949.21	44396.28	43494.9	52.31	53.08
35	**Rajgarh**	84511.21	77503.75	70539.68	65419.73	83.47	84.41
36	**Ratlam**	80882.77	76322.66	102423.2	107741.9	126.63	141.17
37	**Rewa**	59043.14	48367.63	26582.62	26552.8	45.02	54.9
38	**Sagar**	103446.3	99930.26	60315.75	60232.63	58.31	60.27
39	**Satna**	61419.25	59291.86	41860.17	38238.38	68.15	64.49
40	**Sehore**	70844.86	65187.81	43865.18	40400.72	61.92	61.98
41	**Seoni**	74391.7	68249.83	28669	25621.81	38.54	37.54
42	**Shahdol**	52728.41	43988.5	4763	7101.91	9.03	16.14
43	**Shajapur**	55658.04	53250.21	57061.03	56178.57	102.52	105.5
44	**Sheopur**	48321.65	51172.6	17376.34	19350.64	35.96	37.81
45	**Shivpuri**	73451.36	74729.04	50831.63	52488.42	69.2	70.24
46	**Sidhi**	32259.48	47493.79	9464	11025.68	29.34	23.21
47	**Singrauli**	37232.04	34053.65	10472.9	13032.75	28.13	38.27

S. No.	District	Annual Extractable Groundwater Resource (ham)		Total Ground Water Extraction (ham)		Stage of Ground Water Extraction (%)	
		2016-17	2019-20	2016-17	2019-20	2016-17	2019-20
48	**Tikamgarh**	51286.71	56361.39	37413.48	40235.06	72.95	71.39
49	**Ujjain**	90065.7	91800.84	88575.88	96470.3	98.35	105.09
50	**Umaria**	44810.56	41477.73	5425.8	10072.37	12.11	24.28
51	**Vidisha**	88556.95	84353.11	52464.67	51236.64	59.24	60.74
TOTAL (ham)		**3447359**	**3338040**	**1887866**	**1896753**	**54.76**	**56.82**
TOTAL (bcm)		**34.47**	**33.38**	**18.87**	**18.97**	**54.76**	**56.82**

CHAPTER-5

5.0 DISTRICT WISE GROUND WATER SCENARIO

The ground water conditions, its availability and utilization scenario and categorization of assessment units in different states are discussed in the previous chapter. District wise summaries are given below.

5.1 ALIRAJPUR

Alirajpur district is underlain by Archaean Granite-gneisses, phyllite Basaltic lava flows of Deccan trap and Bagh Bed. Dynamic Ground water resources of the district have been estimated for base year-2019-20, on block wise basis. Out of 334900 ha of geographical area, 305400 ha (91%) is ground water recharge worthy area and 29500 ha (9%) is hilly area. There are six number of assessment units (block) in the district which fall under non-command category, there are no major irrigation projects in the district, and medium irrigation project for irrigation. All blocks of the district are categorized as safe blocks, and highest stage of ground water development is computed as 68.77 % for Bhabra Block. The annual extractable groundwater resource in the district is 21327.31 ham and total ground water extraction for all uses is 8495.65 ham, making stage of ground water development 39.83% (45.01% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 12472.07 ham.

5.2 AGAR

Agar district is underlain by mainly Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 270243 ha of geographical area, 251576 ha (93%) is ground water recharge worthy area and 18667 ha (7%) is hilly area. There are four number of assessment units (block) in the district out of which Barod (Semi Critical in 2016-17) block falls under Semi Critical category and Nalkhera (Over Exploited in 2016-17) & Susner (Over Exploited in 2016-17) fall in over exploited category. The highest stage of ground water development is computed as 126.05 % in Nalkhera block. The annual extractable groundwater resource in the district is 42167 ham and net ground water extraction for all uses is 39634.97 ham, making stage of ground water development 96.61% (92.84% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 4711.45 ham.

5.3 ANUPPUR

Anuppur district is underlain by Archaean Granite-gneisses, Gondwanas sandstone-clays, Lametas and Deccan trap basalts. Dynamic ground water resources of Anuppur district have been

estimated for base year -2019-20, on block- wise basis. Out of 372400 ha of geographical area, 294200 ha (79%) is ground water recharge worthy area and 78,200 ha (21%) is hilly area. There are four number of assessment units (block) in the district which fall under non-command sub-unit, as there are no major & medium irrigation projects in the district. All blocks of the district are categorized as safe blocks, and highest stage of ground water development is computed as 33% for Jaitahri Block. The annual extractable groundwater resource in the district is 37734.99 ham and ground water extraction for all uses is 7551.2 ham, making stage of ground water development 20.01% (7.97 % in 2019-20) as a whole for district. After making allocation for future domestic for year 2025, balance available ground water for future use would be 30072.99 ham.

5.4 ASHOKNAGAR

Ashoknagar district is underlain by Deccan trap basalts, Vindhyan sandstone and Archaean granite-gneisses. Dynamic Ground water resources of the district have been estimated for base year -2019-20, on block- wise basis. Out of 4,67,394 ha of geographical area, 4, 62,244 (98%) ha is ground water recharge worthy area and 5,150 (2%) is hilly area. There are four numbers of assessment units (block) in the district having command area (4.46 %) and non-command area (95.54%). Out of 4 blocks of the district, 3 blocks are categorized as safe and Ishagarh block fall under semi-critical category (Safe in 2016-17). Highest stage of ground water extraction, is computed as 77.74% (67.06% in 2016-17) in Ishagarh block. The annual extractable resource in the district is 35701.85 ham and gross ground water extraction for all uses is 22428.24 ham, making stage of ground water extraction 62.82% (54.91 % in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 13092.45 ham.

5.5 BALAGHAT

Balaghat district is underlain by Archaean Granite, gneisses and phyllites. Dynamic Ground water resources of the district have been estimated for base year -2019-20, on block wise basis. Out of 922900 ha of geographical area, 891793 ha (97 %) is ground water recharge worthy area and 31107 ha (3%) is hilly area. There are ten numbers of assessment units (block) in the district which fall under command (11%) and non-command (89%) sub units. All blocks of the district are categorized as safe blocks, and highest stage of ground water development is computed as 52.57% (35.30% in 2016-17) for Khairilangi Block. The annual extractable ground water resource in the district is 78053.48 ham and ground water extraction for all uses is 16061.44 ham, making stage of ground water extraction 20.58% (17.08% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 61699.41 ham.

5.6 BARWANI

Barwani district is underlain by, Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year-2019-20, on block-wise basis. Out of 5,42,200 ha of geographical area, 3,66,831 (68%) ha is ground water recharge worthy area and 1,75,369 ha (32%) is hilly area. There are seven number of assessment units (block) in the district which fall under command and non-command sub-unit. Barwani, Niwali, Pati, Thikari and Sendhwa blocks of the district are categorized as safe blocks, Rajpur as semi critical, and Pansemal as over exploited with highest stage of ground water development which is computed as 143.60% (100.03% in 2016-17). The annual extractable ground water resource in the district is 51745.54 ham and ground water extraction for all uses is 36638.47 ham, making stage of ground water extraction 70.81% (55.09% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 19221.59 ham.

5.7 BETUL

Betul district is underlain by Archaeans Granite-gneisses, Gondwanas sandstone-clays, Lametas and Deccan trap basalts. Dynamic ground water resources of the district have been estimated for base year -2019-20, on block-wise basis. Out of 10,04,300 ha of geographical area, 8,56,450 ha (85%) is ground water recharge worthy area and 1,47,850 ha (15%) is hilly area. There are ten numbers of assessment units (block) in the district which fall under command (3.41 %) and non-command (96.59%) sub units. All blocks of the district are categorized as safe blocks except Betul and Multa block. Betul block having highest stage of ground water extraction which is computed as 44.56% (79.10% in 2016-17) and categorized as Semi Critical. The annual extractable ground water resource in the district is 113477.81 ham and ground water extraction for all uses is 50569.58 ham, making stage of ground water development 46.56% (57.65% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 62555.74 ham.

5.8 BHIND

Bhind district is characterized by alluvial formation,Vindhyan Formation, and Gwalior Series. Dynamic Ground water resources of the district have been estimated for base year -2019-20, on block-wise basis. Out of 4,45,900 ha of geographical area, 445900 ha (100%) is ground water recharge worthy area. There are six numbers of assessment units (block) in the district which fall under command (40%) and non-command (60%) sub units. All blocks of the district are categorized as safe blocks, and highest stage of ground water development is computed as 35.82%(45.63% in 2016-17) for Ater Block. The annual extractable ground water resource in the district 88746.59 ham and ground water extraction for all uses is 28758.94 ham, making stage of ground water development 32.41% (35.99% in 2016-17) as a whole

for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 59643.88 ham.

5.9 BHOPAL

Bhopal district is underlain by Deccan trap basalts and Vindhyan sandstone. Dynamic ground water resources of the district have been estimated for base year -2019-20, on block wise basis. Out of 2, 77,237 ha of geographical area, 2, 64,800 ha (96%) is ground water recharge worthy area and 12,437 ha (4%) is hilly area. There are three number of assessment units (two blocks and one urban area) in the district which fall under non-command sub unit. The assessment of Bhopal Urban area done this year separately. Berasia block of the district is categorized as safe block (same in 2016-17) and the Phanda block and Bhopal Urban area fall under Semi-critical category. Highest stage of ground water extraction is computed as 79.46% for Bhopal Urban. The annual extractable ground water resource in the district is 36865.29 ham and ground water extraction for all uses is 27016.42 ham, making stage of Ground water extraction 73.28% (70.15% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 9341.08 ham.

5.10 BURHANPUR

Burhanpur district is underlain by, Basaltic lava flows of Deccan trap and Tapi alluvium. Dynamic Ground water resources of the district have been estimated for base year -2019-20, on block-wise basis. Out of 3,23,300 ha of geographical area, 2,57,050 ha (80%) is ground water recharge worthy area and 66,250 ha (20%) is hilly area. There are two number of assessment units (block) in the district which fall under command (4%) and non-command (96%) sub units. Both the blocks of the district are categorized as safe blocks with highest stage of ground water development is computed as 68.56% for Burhanpur block. The annual extractable ground water resource in the district is 37343.92 ham and ground water etraction for all uses is 23581.82 ham, making stage of ground water extraction 63.15% (67.20% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 13566.5 ham.

5.11 CHHATARPUR

About 65% of the district is occupied by Bundelkhand granite in northern & north central part with a thin soil cover. The exposure of Bijawars triangular in shape and constitute about 15% of the south eastern part of the district. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 861549 ha of geographical area, 790434 ha (92%) is ground water recharge worthy area and 71115 ha (8%) is hilly area. There are eight number of assessment units (block) in the district which fall under non-command (86%) and command (14%) sub units. Badamalhara, Gaurihar, Loundi and Rajnagar blocks are in safe. Buxwaha, Chhatarpur, Nowgaon and

Bijawar (Safe in 2016-17) are under semi critical. Highest stage of ground water development is computed as 87.33 % for Buxwaha Block. annual extractable ground water resource in the district 80453.59 ham and ground water extraction for all uses is 53784.73 ham, making stage of ground water extraction 66.85% (61.70% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 26298.06 ham.

5.12 CHHINDWARA

Chhindwara district is underlain by Deccan trap basalts, Archaean granite-gneisses and Gondwanas sandstone-clays. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 1176024 ha of geographical area, 879301 ha (75%) is ground water recharge worthy area and 296723 ha (25%) is hilly area. There are eleven number of assessment units (block) in the district which fall under non-command (99 %) and command (1 % Morkhed and Sauser) sub units. Amarwara, Bichhua, Chourai, Harrai, Jamai, Sausar, Parasia and Tamia blocks of the district are categorized as safe blocks, Mohkhed (safe in 2016-17), Pandurna (Same in 2016-17) are as semi critical, Chhindwada (Semi-critical in 2016-17) is categorized as critical. Highest stage of ground water extraction is computed as 96.55 (88.50%in 2016-17) for Chhindwara block. The annual extractable ground water resource in the district is 98786.94 ham and ground water extraction for all uses is 59076.21 ham, making stage of ground water extraction 59.80% (55.20% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 39353.93 ham.

5.13 DAMOH

Damoh district is underlain mainly by Vindhyan Shale, Limestone and Sandstone. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 730600 ha of geographical area, 474619 ha (65%) is ground water recharge worthy area and 255981 ha (35%) is hilly area. There are seven number of assessment units (block) in the district which fall under non-command (88 %) and command (12%) sub units. Damoh, Hatta, Jabera, Patera, Tedukheda, Batiyagarh (Semi-critical in 2016-17) blocks of the district are categorized as safe blocks, and Pathariya as semi critical (same in 2016-17). The highest stage of ground water extration is computed as 81.20% (81.83% in 2016-17) in Pathariya block. The annual extractable ground water resource in the district is 39298.28 ham and ground water extraction for all uses is 22431.87 ham, making stage of ground water development 57.08% (58.20 % in 2012/13) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 16559.44 ham.

5.14 DATIA

Datia district is characterized by alluvial formation, Bundelkhand Granite gneiss, and Gwalior Series Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 269100 ha of geographical area, 266200 ha (99%) is ground water recharge worthy area and 2900 (1%) is hilly area. There are three numbers of assessment units (block) in the district which fall under command (49%) and non-command (51%) sub units. All blocks of the district are categorized as safe blocks with highest stage of ground water development of 48.16 % in Datia block. The annual extractable ground water resource in the district 40768.14 ham and ground water extraction for all uses is 14343.2 ham, making stage of ground water extraction 35.18**%** (40.16 % in 2016-17) as a whole for district. After making allocation for future domestic and industrial supply for year 2025, balance available ground water for future irrigation would be 26208.75 ham.

5.15 DEWAS

Dewas district is underlain by Deccan trap basalts, Archaeans granite-gneisses and Vindhyan sandstone. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out 718744 ha of geographical area, 577082 ha (79 %) is ground water recharge worthy area and 141662 ha (21%) is hilly area. There are six number of assessment units (block) in the district which fall under non-command (97 %) and command (3% Bagli and Kannod) sub units. Bagli, Kannod and Tonkkhurd blocks of the district are categorized as safe blocks. Kategaon block of the district is categorized as semi critical block (same in 2016-17), Dewas and Sonkatch (same in 2016-17) blocks as over exploited with highest stage of ground water development of 104.83% in Dewas block. The annual extractable ground water resource in the district is 80802.06 ham and ground water extraction for all uses is 64684.74 ham, making stage of ground water development 80.05% (84.23% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 16963.5 ham.

5.16 DHAR

Dhar district is underlain by mainly Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 815300 ha of geographical area, 812640 ha (almost 100%) is ground water recharge worthy area and 2660 ha (less than 1%) is hilly area. There are thirteen number of assessment units (block) in the district which fall under non-command (82 %) and command (18 %) sub units. Bagh, Dahi, Dharampuri, Gondwana, Kukshi, Manawar, Nisarpur, Sardarpur and Umraban blocks of the district are categorized as safe blocks. Tirla are categorized as critical (semi critical in 2016-17) and Badnawar, Dhar and Nalchha are categorized as over exploited (same in 2016-17) with highest stage of ground water development is

computed as 155.40 % in Dhar block. annual extractable ground water resource in the district is 104913.07 ham and ground water extraction for all uses is 83130.27 ham, making stage of ground water development 79.24% (68.88 % in 2012/13) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 32426.91 ham.

5.17 DINDORI

Dindori district is underlain by Deccan trap basalts. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 612800 ha of geographical area, 4,96,300 ha (81%) is ground water recharge worthy area and 1,16,500 ha (19%) is hilly area. There are seven number of assessment units (block) in the district which fall under non-command sub units. All blocks of the district are categorized as safe blocks, and highest stage of ground water development is computed as 16.10% for Shahpura Block. The annual extractable ground water resource in the district is 38837.01 ham and Ground Water extraction for all uses is 4131.95 ham, making stage of ground water extraction 10.64%(10.19 % in 2012/13) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 34472.98 ham.

5.18 GUNA

Guna district is underlain by Deccan trap basalts, Vindhyan sandstone and laterites. Dynamic ground water resources of the district have been estimated for base year-2019-20 on block-wise basis. Out of 6,39,000 ha of geographical area, 6,17,514 ha (97%) is ground water recharge worthy area and 21,486 ha (3%) is hilly area. There are five number of assessment units in the district which fall under non-command (94%) and command (6%) units. Presently all the blocks of the district are categorized as safe blocks. The highest stage of ground water development is computed as 69.90% (63.43% in 2016-17) in Guna block. The annual extractable ground water resource in the district is 75265.86 ham and ground water extraction for all uses is 49694.84 ham, making stage of ground water extraction 66.03% (55.30% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 25263.21 ham.

5.19 GWALIOR

Gwalior district is characterized by Gwalior Series, Bundelkhand granite gneiss, Vindhyan sandstone and alluvial formations. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 4,75,660 ha of geographical area, 4,47,560 ha (94%) is ground water recharge worthy area and 28,100 ha (6%) is hilly area. In the district there are total five number of assessment units (four blocks and one urban area), out of which three numbers of assessment units (Bhitarwar, Dabra and Ghatigaon) in the district fall under command (30%) and all five assessment

units (Bhitarwar, Dabra, Ghatigaon and Morar) fall under non-command (70%) sub units. The assessment of Gwalior_Urban area done this year separetaely. All assessment units of the district are categorized as safe blocks except the Gwalior_Urban area which comes under semi critical category with highest stage of ground water extraction of 85.47%. The annual extractable ground water resource in the district is 75265.86 ham and ground water extraction for all uses is 21712.52 ham, making stage of ground water extraction 29.47 % (29.86% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 51729.54 ham.

5.20 HARDA

Harda district is characterized by alluvial formations and Deccan trap basaltic lava flow. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 3,33,000 ha of geographical area, 2,70,090 ha (81%) is ground water recharge worthy area and 62,910 ha (19%) is hilly area. There are three numbers of assessment units in the district which fall under command (29%) and non-command (71%) categories sub units. All blocks of the district are categorized as safe blocks, with highest stage of ground water development of 51.30% in Harda block. The annual extractable ground water resource in the district 46686.75 ham and ground water extraction for all uses is 15887.95 ham, making Stage of Ground water extraction 34.03% (30.96% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 30651.27 ham.

5.21 HOSHANGABAD

Hoshangabad district is characterized by alluvial formations, Gondwana, Archaean and Deccan trap basaltic lava flow. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 6,65,453 ha of geographical area, 5,58,352 ha (83%) is ground water recharge worthy area and 1,07,101 ha (17%) is hilly area. There are seven number of assessment units in the district which fall under command (45%) and non-command (55%) sub units. All blocks of the district are categorized as safe blocks, except Bankhedi, which is categorized as semi-critical (safe in 2016-17) with the highest stage of ground water extraction of 72.96%(68.56% in 2016-17). The annual extractable ground water resource in the district 195019.19 ham and ground water extraction for all uses is 41313.17 ham, making stage of ground water extraction 21.18% (22.31% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 153518.7 ham.

5.22 INDORE

Indore district is underlain by mainly Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 3,89,800

ha of geographical area, 3,81,897 ha (98%) is ground water recharge worthy area and 7,903 ha (2%) is hilly area. There are five number of assessment units (Depalpur, Indore, Mhow, Sanwer and Indore_Urban) in the district which fall under non-command (99 %) and command (1% Mhow and Depalpur) sub units. The assessment of Indore_Urban done separately this year. Mhow block of the district is categorized as semi critical (same in 2016-17) and Depalpur, Indore and Sanwer as over exploited (same in 2019-20) and the Indore_Urban also categorized as over exploited. The command sub units of Depalpur and Mhow blocks are safe. The highest sage of ground water extraction is computed as 176.55% in Indore block. The annual extractable ground water resource in the district is 54614.14 ham and ground water extraction for all uses is 68797.42 ham, making stage of ground water extraction 125.67 % (116.63 % in 2019-20) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 2539.19 ham.

5.23 JABALPUR

Jabalpur district is underlain by Alluvium, Archaean granite, Basaltic lava flows of Deccan trap Bijawar and Vindhyan sandstone. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 5,45,365 ha of geographical area, 4,50,538 ha (83%) is ground water recharge worthy area and 94,827 ha (17%) is hilly area. There are eight number of assessment units (seven blocks and one urban area) in the district which fall under non-command (82%-Kundam and Majholi) and command (18%) sub units. All the assessment units are categorized as safe except the Jabalpur_Urban area, which assessed first time this year and is categorized as critical. The highest stage of ground water extraction is computed as 90.66% in Jabalpur_Urban. The annual extractable ground water resource in the district is 58997.21 ham and ground water extraction for all uses is 28380 ham, making stage of ground water development 49.24% (42.47% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 29689.42 ham.

5.24 JHABUA

Jhabua district is underlain by Archaeans granite-gneisses, phyllite and Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 344300 ha of geographical area, 311200 ha (90%) is ground water recharge worthy area and 33100 ha (10%) is hilly area. There are six number of assessment units (block) in the district which fall under non-command (95%) & command (5%) (Petlawad) categories. All blocks of the district are categorized as safe blocks, except Jhabua, which is categorized as semi critical (safe in 2016-17) and highest stage of ground water development is computed as 77.13% (67.74% in 2016-17)

for Jhabua Block. The annual extractable ground water resource in the district is 26233.84 ham and ground water extraction for all uses is 13240.51 ham, making stage of ground water extraction 50.47% (57.23% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 12438.46 ham.

5.25 KATNI

Katni district is underlain by Vindhyan sandstone, Bijawar Alluvium and Basaltic lava flows of Deccan trap and. Dynamic ground water resources of the district have been estimated for base year - 2019-20 on block-wise basis. Out of 489400 ha of geographical area, 466648 ha (95 %) is ground water recharge worthy area and 22752 ha (5%) is hilly area. There are six number of assessment units (block) in the district which fall under non-command (93 %) and command (7 %) sub units. All the blocks of the district are categorized as safe. Highest stage of ground water extractoion is computed as 62.95% (60.72 % in 2016-17) for Vijayraghogarh. The annual extractable ground water resource in the district is 36677.26 ham and ground Water extraction for all uses is 16003.69 ham, making stage of ground water extraction 43.63 % (46.53 % in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 20324.5 ham.

5.26 KHANDWA

Khandwa district is underlain by mainly Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 751550 ha of geographical area, 581446 ha (77%) is ground water recharge worthy area and 170104 ha (23%) is hilly area. There are seven number of assessment units (block) in the district which fall under non-command (85%) and command (15%, Chhegaon Makhan, Khandwa, Punasa and Pandhana) sub units. All the blocks except, Chhegaon Makhan are categorized as safe. Chhegaon Makhan block of the district is categorized as semi critical (semi critical in 2016-17). The highest stage of ground water development is computed as 82.96%(78.89% IN 2016-17) in Chhegaon Makhan. The annual extractable ground water resource in the district is 90037.02 ham and ground water extraction for all uses is 42947.69 ham, making Stage of Ground water extraction 47.70% (42.91% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 46726.88 ham**.**

5.27 KHARGONE

Khargone district is underlain by mainly Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 803000 ha of geographical area, 656897 ha (82 %) is ground water recharge worthy area and 146103 ha (18 %) is hilly area. There are nine number of assessment units (block) in the district which fall under

non-command (74%) and command (26%) sub units. All the blocks are categorized as safe except Khargone. Khargone block of the district are categorized as semi-critical (same in 2016-17). The highest stage of ground water extraction is computed as 76.53 % in Khargone. The annual extractable ground water resource in the district is 105961.41 ham and ground water extraction for all uses is 45727.33 ham, making stage of ground water extraction 43.15% (36.45% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 59783.75 ham.

5.28 MANDLA

Mandla district is underlain by Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 877100 ha of geographical area, 726910 ha (83%) is ground water recharge worthy area and 150190 ha (17%) is hilly area. There are nine number of assessment units (block) in the district which fall under non-command (95 %) and command (5 %- Bichhiya, Mandla and Nainpur) sub units. All blocks of the district are categorized as safe blocks, and highest stage of ground water extraction is computed as 47.78 %(55.01% in 2016-17) for Mohgaon Block. The annual extractable ground water resource in the district is 59244.15 ham and ground water extraction for all uses is 9334 ham, making Stage of Ground water extraction 15.76 % (17.77 % in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 49645.45 ham.

5.29 MANDSAUR

Mandsaur district is underlain by mainly Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 552330 ha of geographical area, 499047 ha (90%) is ground water recharge worthy area and 53283 ha (10 %) is hilly area. There are five number of assessment units (block) in the district which fall under non-command. Garoth block of the district are categorized as semi critical (same in 2016-17), Malhargarh and Bhanpra block of the district are categorized as critical (same in 2016-17), Mandsaur and Sitamua (same in 2016-17) as over exploited. The highest stage of ground water extraction is computed as 135.16% in Sitamau block. The annual extractable ground water resource in the district is 60359.85 ham and ground water extraction for all uses is 64748.93 ham, making stage of ground water extraction 107.27 % (103.22 % in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 2412.5 ham.

5.30 MORENA

Morena district is characterized by alluvial formation,Vindhyan Formation and Gwalior Series. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-

wise basis. Out of 496889 ha of geographical area, 438489 ha (88 %) is ground water recharge worthy area and 58400 ha (12%) is hilly area. There are seven numbers of assessment units (block) in the district which fall under command (51 %) and non-command (49 %) sub units. All the seven blocks- ambah, Jaura, Kailaras ,Morena, Pahadgarh, Porsa and Sabalgarh blocks are safe. The highest stage of ground water extraction is computed as 59.93% in Ambah block. The annual extractable ground water resource in the district 63784.63 ham and ground water extraction for all uses is 25400.69 ham, making stage of ground water extraction 39.82% (35.56% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 37719.42 ham.

5.31 NARSINGHPUR

Narsinghpur district is underlain by Alluvium, Gondwana sandstone, Bijawar and Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 513300 ha of geographical area, 479100 ha (89%) is ground water recharge worthy area and 34200 ha (11%) is hilly area. There are six number of assessment units (block) in the district which fall under non-command (90%) and command (10%) sub units. Except Narsinghpur block, which is categorized as semi critical (safe in 2016-17), all other blocks are categorized as Safe. The highest stage of ground water extraction is computed 74.25 %(69.74 % in 2016-17) in Narsinghpur block. The annual extractable ground water resource in the district is 113541.26 ham and Ground Water extraction for all uses is 72480.48 ham, making stage of ground water extraction 63.84% (63.34 % in 2016-17) as a whole for district. After making allocation for future domestic for year 2025, balance available ground water for future use would be 40870.98 ham.

5.32 NEEMUCH

Neemuch district is underlain by mainly Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 4, 20,044 ha of geographical area, 3,75,744 ha (89%) is ground water recharge worthy area and 44,300 ha (11 %) is hilly area. There are three number of assessment units (block) in the district which fall under non-command. Jawad block (critical in 2016-17) of the district is categorized as over exploited. Neemuch (critical in 2016-17) is ver exploited and Manasa (same in 2016-17) as semi critical. The highest stage of ground water extraction is computed as 102.25% in Neemuch block. The annual extractable ground water resource in the district is 38300.25 ham and ground water extraction for all uses is 35390.12 ham, making stage of ground water extraction 92.40 % (87.44 % in 2016-17) as a whole for district. After making

allocation for future domestic supply for year 2025, balance available ground water for future use would be 3215.25 ham.

5.33 PANNA

Panna district is underlain by Vindhyan Shale, Limestone and Sandstone and Alluvium. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 7,13,500 ha of geographical area, 6,82,425 ha (96%) is ground water recharge worthy area and 31,025 ha (4 %) is hilly area. There are five number of assessment units (block) in the district which fall under non-command (95 %) and command (5 % Panna) sub units. All the blocks of the district are categorized as safe blocks. The highest stage of ground water extraction is computed as 42.30% (61.96% in 2016-17) in Ajaygarh block. The annual extractable ground water resource in the district 58260.17 ham and ground water extraction for all uses is 17808.08 ham, making stage of ground water extraction 30.57% (36.50 % in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 38034.53 ham.

5.34 RAISEN

Raisen district is underlain by Basaltic lava flows of Deccan trap Vindhyan Sandstone and Alluvium. Dynamic Ground water resource estimation of the district has been computed for Base Year-2019-20, on block wise basis. Out of 8,46,539 ha of geographical area, 6,60,939 (78%) ha is ground water recharge worthy area and 1,85,600 (22 %) is hilly area. There are seven number of assessment units (block) in the district which fall under non-command (92%) and command (8%- Badi) sub units. All blocks of the district are categorized as safe except Obedullaganj which fall in semi critical category. The highest stage of ground water extraction is computed as 71.62 % in Obedullaganj block. The annual extractable ground water resource in the district 81949.21 ham and ground water extraction for all uses is 43494.9 ham, making stage of ground water extraction 53.08% (52.31% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 38034.53 ham.

5.35 RAJGARH

Rajgarh district is underlain by mainly Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 6,15,498 ha of geographical area, 6,15,498 ha (100 %) is ground water recharge worthy area. There are six number of assessment units (block) in the district which fall under non-command. Biora, Khilchipur and Zeerapur blocks of the district are categorized as semi critical (same in 2016-17), Narsinghgarh and Sarangpur blocks of the district are categorized as critical (semi critical in 2016-17), Rajgarh categorized as safe (same in 2016-17). The highest stage of ground water extraction is computed as 98.18% (95.39 % in

2016-17) in Sarangpur block. The annual extractable ground water resource in the district is 77503.75 ham and ground water extraction for all uses is 65419.73 ham, making stage of ground water extraction 84.41 % (83.47% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 13335.61 ham.

5.36 RATLAM

Ratlam district is underlain by Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 4, 86,100 ha of geographical area, 4, 61,600 ha (95 %) is ground water recharge worthy area and 24,500 ha (5 %) is hilly area. There are seven number of assessment units (block) in the district which fall under non-command (98 %) and command (2% Bajna block) sub units. Alote, Jaora, Piploda and Ratlam blocks of the district are categorized as over exploited (same as in 2016-17), Sailana and Bajna as semi critical (same as in 2016-17). The highest stage of ground water extraction is computed as 167.50 % in Jaora block. The annual extractable ground water resource in the district 76322.66 ham and ground water extraction for all uses is 107741.87 ham, making stage of ground water extraction 141.47% (126.63 % in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 1491.06 ham.

5.37 REWA

Rewa district is underlain by Vindhyan Shale, Limestone and Sandstone and Alluvium. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 628736 ha of geographical area, 591136 ha (93%) is ground water recharge worthy area and 37600 ha (7%) hilly area. All blocks, of the district are categorized as safe, except Mauganj which is categorized as semi critical (safe in 2016-17). The highest stage of ground water extraction is computed as 72% in Mauganj block. The annual extractable ground water resource in the district is 48367.63 ham and ground water extraction for all uses is 26552.8 ham, making stage of ground water extraction 54.90% (45.02% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for futureuse would be 20976.23 ham.

5.38 SAGAR

Sagar district is underlain by Basaltic lava flows of Deccan trap Vindhyan Sandstone and Alluvium. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 1,025,200 ha of geographical area, 925418 ha (90 %) is ground water recharge worthy area and 99782 ha (10 %) is hilly area. There are eleven number of assessment units (block) in the district which fall under non-command (95 %) and command (5 %) sub units. All the blocks are categorized as safe. Banda block of the district is categorized as safe which was categorized as semi

critical in 2016-17. The highest stage of ground water extraction is computed as 69.82% in Bina block. The annual extractable ground water resource in the district 99930.26 ham and ground water extraction for all uses is 60232.63 ham, making stage of ground water extraction 60.27% (58.31 % in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 39253.76 ham.

5.39 SATNA

Satna district is underlain by Vindhyan Shale, Limestone and Sandstone and Alluvium. Dynamic ground water resources of the district have been estimated for base year -2016/17 on block-wise basis. Out of 752016 ha of geographical area, 672106 ha (89%) is ground water recharge worthy area and 779910 ha (11%) hilly area. There are nine number of assessment units (block) in the district which fall under non-command & command (Amarpatan, Nagod, Rampur baghelon, Sohawal, Uchehra blocks). Amarpatan, Majhgawan, Nagod, Ramnagar and Unchehra blocks of the district are categorized as safe (safe in 2016-17). Maihar, Rampur Baghelon and Sohawal blocks (same in 2016-17) as semi critical. The highest stage of ground water development is computed as 89.21% in Rampur Baghelon. The annual extractable ground water resource in the district is 59291.86 ham and ground water extraction for all uses is 38238.38 ham, making stage of ground water development 64.49% (68.15% in 2012/13) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 23649.88 ham.

5.40 SEHORE

Sehore district is underlain by Basaltic lava flows of Deccan trap, Vindhyan Sandstone and Alluvium. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis. Out of 656544 ha of geographical area, 462716 ha (70%) is ground water recharge worthy area and 193828ha (30%) is hilly area. There are five number of assessment units (block) in the district which fall under non-command (80%) and command (20% Ashta, Budhni, Ichawar, Nasrullahganj & Sehore) sub units. Ashta block of the district are categorized as critical (semi critical in 2016-17) and rest of the blocks are safe. The highest stage of ground water development is computed as 99.37% (77.36% in 2016-17) Ashta block. The annual extractable ground water resource in the district 65187.81 ham and ground water extraction for all uses is 40400.72 ham, making stage of ground water extraction 61.98% (61.92% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 24992.51 ham.

5.41 SEONI

Seoni district is underlain by Deccan trap basalts and Archaeans granite-gneisses. Dynamic ground water resources of the district have been estimated for base year -2019-20 on block-wise basis.

Out of 8,75,800 ha of geographical area, 8,05,020 ha (92%) is ground water recharge worthy area and 70,780 ha (8 %) is hilly area. There are eight number of assessment units (block) in the district which fall under non-command (91%) and command (9% Barghat, Dhanora, Keolari and Seoni) sub units. All the blocks of the district are categorized as safe blocks. Chhapara is with highest stage of ground water development is computed as 57.10% (66.15% in 2016-17). The annual extractable ground water resource in the district is 68249.83 ham and ground water extraction for all uses is 25621.81 ham, making stage of ground water extraction 37.54 % (38.54% in 2016-17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 42279.41 ham.

5.42 SHAHDOL

Shahdol district is underlain by Archaeans granite-gneisses, Gondwanas sandstone-clays, Lametas and Deccan trap basalts. Dynamic ground water resources of the district have been estimated for base year -2019/20 on block-wise basis. Out of 5, 84,100 ha of geographical area, 4, 97,800 ha (85%) is ground water recharge worthy area and 86,300 ha (15%) is hilly area. There are five number of assessment units (block) in the district which fall under non-command & command (Beohari) category. All blocks of the district are categorized as safe blocks, and highest stage of ground water extraction is computed as 22.39 % for Sohagpur Block. The annual extractable ground water resource in the district is 56801.97 ham and ground water extraction for all uses is 7101.91 ham, making stage of ground water extraction 16.14% as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 43988.5 ham.

5.43 SHAJAPUR

Shajapur district is underlain by mainly Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year -2019/20 on block-wise basis. Out of 3,44,325 ha of geographical area, 3,39,617 ha (98%) is ground water recharge worthy area and 4,708 ha (2%) is hilly area. There are four number of assessment units (blocks) in the district which fall under non-command. Mohan Berodia (same in 2016/17) and Shujalpur block (same in 2016/17) and Kalapipal unit are categorized as over-exploited, whereas Shajapur unit is categorized as semi-critical of the district. The highest stage of ground water extraction is computed as 126.34% in Mohan Berodia block. The annual extractable ground water availability in the district is 56801.97 ham and ground water extraction for all uses is 56178.57 ham, making stage of ground water extraction 105.50% (102.52% in 2016/17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 53250.21 ham**.**

5.44 SHEOPUR

Sheopur district is underlain by Vindhyan Sandstone and Alluvium. Dynamic ground water resources of the district have been estimated for base year -2019/20 on block-wise basis. Out of 6,60,600 ha of geographical area, 5,33,480 ha (81%) is ground water recharge worthy area and 1,27,120 ha (19%) is hilly area. There are three number of assessment units (blocks) in the district which fall under non-command (87%) and two (Sheopur and Vijaypur) under command (13%) sub units. All blocks of the district are categorized as safe. The highest stage of ground water extraction is computed as 68.96% in Vijaypur block. The annual extractable ground water availability in the district 51172.6 ham and ground water extraction for all uses is 19350.64 ham, making stage of ground water extraction 37.81% (35.96 % in 2016/17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 53250.21 ham.

5.45 SHIVPURI

Shivpuri district is underlain by Budelkhand granite, Basaltic lava flows of Deccan trap Vindhyan Sandstone and Alluvium. Dynamic ground water resources of the district have been estimated for base year -2019/20 on block-wise basis. Out of 10,27,800 ha of geographical area, 9,77,049 ha (95%) is ground water recharge worthy area and 50,751 ha (5%) is hilly area. There are eight number of assessment units (block) in the district which fall under non-command (93%) and seven also under command (7%) sub units. Karera, Shivpuri and Pohri blocks are categorized as safe whereas Badarwas, Khaniyadhana, Kolaras, Narwar and Pichor blocks of the district are categorized as semi critical. The highest stage of ground water extraction is computed as 83.82% in Khaniyadhana block. The annual extractable ground water availability in the district 74729.04 ham and ground water extraction for all uses is 52488.42 ham, making stage of ground water extraction 70.24 % (69.2% in 2016/17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 21613.11 ham.

5.46 SIDHI

Sidhi district is underlain by Vindhyan limestone sandstone, Archaean granite Gondwana sandstone and Alluvium Dynamic ground water resources of the district have been estimated for base year-2019/20 on block-wise basis. Out of 4,85,380 ha of geographical area, 3,60,385 ha (74%) is ground water recharge worthy area and 1,24,995 ha (26%) is hilly area. There are five number of assessment units (block) in the district which fall under non-command (87%) and three under command (13%) sub units. All blocks of the district are categorized as safe. The highest stage of ground water development is computed as 43.56% in Sidhi block. The annual extractable ground water availability in the district 47493.79 ham and ground water extraction for all uses is 11025.68 ham, making stage of ground water

extraction 23.21% (29.34% in 2016/17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 36092.08 ham.

5.47 SINGRAULI

Singrauli district is underlain by Archaean granite and Gondwana sandstone. Dynamic ground water resources of the district have been estimated for base year -2019/20 on block-wise basis. Out of 5,67,200 ha of geographical area, 4,51,260 ha (80%) is ground water recharge worthy area and 1,15,940 ha (20%) is hilly area. There are three number of assessment units (block) in the district which fall under non-command (86%) and two under command (14% -Deosar, Waidhan) sub units. All the blocks of the district are categorized as safe. The highest stage of ground water extration is computed as 32.02% in Chitrangi block. The annual extractable water availability in the district 56361.39 ham and ground water extraction for all uses is 13032.75 ham, making stage of ground water extraction 38.27% (28.13% in 2016/17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 20627.17 ham.

5.48 TIKAMGARH

Tikamgarh district is occupied by Bundelkhand granite with a thin soil cover. Dynamic ground water resources of the district have been estimated for base year-2019/20 on block-wise basis. Out of 5,04,864 ha of geographical area 4,88,164 ha (97%) is ground water recharge worthy area and 16,700 ha (3%) is hilly area. There are six number of assessment units (blocks) in the district which fall under non-command (92%) and command (8%) sub units. All blocks of the district in command and non-command area are categorized as semi critical except Prathivipur which fall in safe category. Highest stage of ground water extraction is computed as 81.26% for Jatara block. The annual extractable ground water availability in the district 56361.39 ham and ground water extraction for all uses is 40235.06 ham, making stage of ground water extraction 71.39% (72.95% in 2016/17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 14884.79 ham.

5.49 UJJAIN

Ujjain district is underlain by mainly Basaltic lava flows of Deccan trap. Dynamic ground water resources of the district have been estimated for base year-2019/20 on block-wise basis. Out of 6,13,023 ha of geographical area, 5,93,933 ha (97%) is ground water recharge worthy area and 19,090 ha (3%) is hilly area. There are six number of assessment units (blocks) in the district which fall under non-command (100 %). Mahidpur, Tarana and Khachrod blocks of the district are categorized as semi critical. Badnagar, Ghatia and Ujjain blocks are categorized as over exploited. The highest stage of ground water

extraction is computed as 142.70% in Ujjain block. The annual extractable ground water resource in the district is 91800.84 ham and ground water extraction for all uses is 96470.3 ham, making stage of ground water extraction 105.09% (98.35% in 2019/20) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 9505.3 ham.

5.50 UMARIA

Umaria district is underlain by Gondwana sandstone, Archaeans granite-gneisses, -clays, Lametas and Deccan trap basalts. Dynamic ground water resources of the district have been estimated for base year-2019/20 on block-wise basis. Out of 4,53,900 ha of geographical area, 4,21,900 ha (93%) is ground water recharge worthy area and 32,000 ha (7%) is hilly area. There are three number of assessment units (blocks) in the district which fall under non-command category. All blocks of the district are categorized as safe blocks, and highest stage of ground water extraction is computed as 31.48% for Karkeli Block. The annual extractable ground water resource in the district is 41477.73 ham and ground water extraction for all uses is 10072.37 ham, making stage of ground water extraction 24.28% (12.11% in 2019/20) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future irrigation use be 31171.39 ham.

5.51 VIDISHA

Vidisha district is underlain by Basaltic lava flows of Deccan trap and Vindhyan Sandstone. Dynamic ground water resources of the district have been estimated for base year-2019/20 on block-wise basis Out of 7,37,100 ha of geographical area, 6,80,770 ha (92%) is ground water recharge worthy area and 56,330 ha (8%) is hilly area. There are seven number of assessment units (block) in the district which fall under non-command (89%) and command (11%) sub units. Five blocks of the district are under safe category whereas two blocks are falling in Semi-Critical Category. The highest stage of ground water extraction is computed as 71.964 % in Gyraspur block. The annual extractable ground water resource in the district 84353.11 ham and ground water extraction for all uses is 51236.64 ham, making stage of ground water extraction 60.74% (59.24% in 2016/17) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 32665.13 ham.

CHAPTER 6

6.0 CONCLUSIONS

- Total Annual Ground Water Recharge in the state (2020) has been assessed as 36.16 billion cubic meters (bcm). Ground water resources are replenished through rainfall and other sources like return flow from irrigation, canal seepage, recharge from water bodies, water conservation structures etc. The main source of annual ground water recharge is rainfall, which contributes nearly 77% of the Total Annual Ground Water Recharge.
- The Total Annual Extractable Ground Water Resource of the country has been assessed as 33.38 billion cubic meters (bcm), after keeping a provision for natural discharge.
- The Annual Ground Water Extraction of the state (2020) is 18.97 billion cubic meters (bcm), the largest user being irrigation sector.
- The Stage of ground water extraction for the entire state, which is the percentage of ground water extraction with respect to Annual Extractable Ground Water Recharge, has been computed as 56.82 %. The extraction pattern of ground water is not uniform across the state, resulting in ground water stressed conditions in some parts of the state while in some other areas; ground water extraction has been sub- optimal.
- Out of the total 317 assessment units (Blocks/ Urban areas) in the state, 26 units (8.20 %) have been categorized as 'Over- Exploited', 8 units (2.52 %) have been categorized as 'Critical', 50 units (15.77 %) have been categorized as 'Semi-Critical' and 233 units (73.51 %) have been categorized as 'Safe.'
- Out of 33383.40 mcm of total Annual Extractable Resources of the state, 3349.83 (10.04 %) are under 'Over-Exploited', 754.83 mcm (2.26 %) are under 'Critical', 5021.66 mcm (15.04 %) are under 'Semi-Critical', 24254.07 mcm (72.66 %) are under 'Safe' category assessment units.
- Almost all over-exploited assessment units falling in western part of Madhya Pradesh, which is known as "MALWA AREA" where ground water extraction has increased many folds during past decades.
- The total Annual Ground Water Recharge for the entire state, as in 2020 has decreased by 0.26 bcmas compared to the last assessment (2017). The total Annual Extractable GW Resources has also decreased by 1.09 bcm. The Annual Ground Water Extraction for irrigation, domestic and Industrial uses increased by 0.09 bcm during this period. These variations are attributed mainly

to refinement of parameters, refinement in well census and population data, and changing ground water regime.

- It is also pertinent to add that as it is advisable to restrict the ground water extraction as far as possible to annual replenishable resources, the categorization also reflects the relation between the annual replenishment and ground water extraction. An area with low groundwater potential may not be considered for ground water extraction and may remain safe and an area with good ground water potential may be heavily used for ground water extraction and may become over exploited over a period of time. Thus, water augmentation efforts can be successful in such areas, where the groundwater potential is high and there is scope for augmentation.

- GEC-2015 methodology has been developed for prevalent Indian conditions, on the basis of terrain characteristics and data availability. INDIA-GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN- GRES) is a Software/Web-based Application developed by CGWB in collaboration with IIT-Hyderabadfor assessment of ground water resources using GEC 2015 Methodology. Constraints in data availability have been overcome through realistic assumptions based on experience in the state.

- A conscious effort is required on the parts of the State/ Central agencies to acquire the requisite realistic data to map the changing groundwater scenario in the state.

6.1 INFERENCES FROM GROUND WATER RESOURCE ASSESSMENT

An analysis of assessment results leads us to the following inferences as the way forward in the assessment of Ground water resources.

6.1.1 Water balance Studies

Ground water is one of the several components of the Hydrologic Cycle, other important components being rainfall, surface water, soil moisture and evapotranspiration. Holistic water resources management interventions require proper understanding of the interactions between the different components of the hydrosphere. Studies for determining the Base flow and lateral flow components in the Water Balance equation need to be taken up to bring more accuracy to the Ground Water Resources Assessment.

6.1.2 Aquifer Charactersation and Parameter Estimation

One of the key elements that determine the accuracy of ground water resources assessment is the realistic estimation of the recharge and discharge parameters. It is recommended that more experimental studies be taken up for refining the norms of RIF, return flow from irrigation based on soil types and

agro-climatic zone, recharge from water conservation and water bodies and more field studies for evaluation of specific yield values as well as its variation with depth.

6.1.3 Case Studies Linking Assessment with Management

It is recommended to take up case studies in various assessment units wherein quantitative evaluation of the ground water management interventions and consequent changes in the assessment results could be analysed. Such studies would help bring out the efficacy of various management interventions on the ground water regime.

6.1.4 Temporal availability of Ground Water Resources

Even though the GEC 2015 methodology advocates season-wise resource assessment, the estimation of recharge during monsoon and non-monsoon seasons may not be sufficient. Temporal variations in groundwater availability, particularly in hard rock terrain are not reflected in present practices. Hence, the assessment of temporal availability of ground water resources on the basis of available water columns can be attempted by considering the water levels measured frequently using Digital Water Level Recorders (DWLRs).

6.1.5 Creation of Database for Ground Water Resources Assessment and its Regular Updating

GEC 2015 has devised the data structure of all the data elements (like water level, rainfall etc.) and norms (like Specific Yield, Rainfall Infiltration Factor etc.) with its name, type of data and its precision. The templates (excel sheets) for data collection/compilation for assessment through IN-GRES using GEC 2015 has also been devised. However, major challenges are lack of dedicated manpower as well as presence of State GW/Nodal Departments (in majority of States) at Districtlevel for understanding/analysis of data/information to be collected/compiled from different State Departments (like Agriculture, Irrigation, Water Supply, Industries, Water Conservation etc.). Of particular importance in this regard are data/information related to recharge from water bodies, water conservation/harvesting structures, return flow from applied irrigation and details of ground water extraction structures in use for irrigation, domestic and industrial purpose. These need to be collected/compiled and regularly updated at district/block level so that more realistic assessment of ground water resources could be accomplished.

6.1.6 Aquifer- Stream Interactions

Additional studies on aquifer-stream interactions are required to understand the contribution of ground water to streams and the requirement of environmental flows for sustainability of water resources and surrounding ecosystem.\

6.1.7 Ground Water Modelling and Predictive Simulation

Besides the assessment of the dynamic ground water resources using norms prescribed in GEC 2015 methodology through automation, the concept of Ground water modelling must be included where predictive simulation can also be done. This would give an idea of the future availability of Ground water resources with respect to the changing climate and extraction patterns.

6.2 RECCOMENDATIONS

The dependency on groundwater has increased many folds during the recent years and the groundwater extraction for irrigation, domestic and industries have resulted in lowering of water levels, long-term water level declining trend and even drying up of wells. The best option lies in improving the recharge component in any well-defined administrative or natural boundary (Block/ Water shed) by an integrated scientific approach with people participatory program. Such program also needs to include cost effective structures and best practices possible without deteriorating the existing surface and ground water resources in terms of quantity and quality. In order to regulate the groundwater extraction, Central Ground Water Board in association with Ground Water Survey, Water Resource Department has computed Dynamic Groundwater Resources and categorized blocks as Over Exploited, Critical, Semi Critical and Safe.

Hence, there is an urgent need to implement artificial recharge schemes to augment ground water so that artificial recharge would be a part of Sustainable Management of ground water. The guidelines which can be used in the formulation of scheme proposal can be enumerated as follows.

Criteria for selection of priority area

1. Area characterized by significant declining post monsoon long term water level trend
2. Area characterized by deeper post monsoon water level.
3. The area having high stage of groundwater extraction & categorized as Over Exploited, Critical ground water assessment units.
4. The aquifer under stress needs to be considered for artificial recharge & priority to be given for recharging at the recharge area of the confined aquifer, viz., crystalline-sedimentary contacts, palaeo-channels, beach terraces, upstream side of fractures/lineaments.

Appendix-A

Government Resolution on constitution of Central Level Expert Group for overall re-assessment of Ground Water Resources of the country, 2020

Shram Shakti Bhavan, Rafi Marg,
New Delhi, Dated: 24/06/2020

RESOLUTION

Sub: Constitution of Central Level Expert Group (CLEG) for overall re-assessment of ground water resources of the country as on 31 Mar 2020.

The last assessment of state-wise annual ground water recharge for the entire country has been made as on 31st March 2017 based on the methodology finalized by Ground Water Resources Estimation Committee (GEC) - 2015. Since then there have been changes in ground water scenario in many places of the country and accordingly, a Central Level Expert Group (CLEG) is hereby constituted for over-all supervision of the re-assessment of ground water resources (as on 31st March 2020) in the entire country. The composition and terms of reference of the Expert Group are as follows:-

1. Composition:

S.No.	Names/Designation	Committee
1.	Chairman, CGWB	Chairman
2.	Member(RM),CWC	Member
3.	Member (WP & P), CWC or, representative	Member
4.	Member (CGWA), CGWB	Member
5.	Member(HQ), CGWB	Member
6.	Member (ED & MM), CGWB	Member
7.	Member (RGI), CGWB	Member
8.	Additional Director General (Stat), DoWR,RD & GR	Member
9.	Chief General Manager, NABARD	Member
10.	Director, NIH, Roorkee or representative	Member

11.	Representative of NITI Aayog	Member
12.	Joint Secretary, Ministry of Agriculture & Farmer Welfare	Member
13.	Joint Secretary, Ministry of Environment, Forests & Climate Change	Member
14. (a)	Joint Secretary, Ministry of Rural Development (Watershed Development Programme)	Member
14 . (b)	Joint Secretary, Ministry of Rural Development (MGNREGS)	Member
15.	Joint Secretary, Department of Drinking Water Supply & Sanitation, Ministry of Jal Shakti	Member
16.	Joint Secretary, Ministry of Housing & Urban Affairs	Member
17.	Representative of IIT, Delhi (Water Resources Section), Civil Engineering Department	Member
18.	Chief Engineer (HQ), NWDA or representative	Member
19.	Technical Expert (WM), NRAA, Ministry of Agriculture & Farmer Welfare	Member
20.	Representative of India Meteorological Department, Ministry of Earth Sciences	Member
21.	Representative of Geological Survey of India, Ministry of Mines	Member
22.	Secretary In-Charge, Water Resources Department, Uttar Pradesh	Member
23.	Secretary In-Charge, Water Resources Department, Punjab	Member
24.	Secretary In-Charge, Water Resources Department, Maharashtra	Member
25.	Secretary In-Charge, Water Resources Department, Andhra Pradesh	Member
26.	Secretary In-Charge, Water Resources Department, Rajasthan	Member
27.	Secretary In- Charge, Water Resources Department, Madhya Pradesh	Member
28.	Secretary In- Charge, Water Resources Department, Gujarat	Member

29.	Secretary In- Charge, Water Resources Department, West Bengal	Member
30.	Secretary In- Charge, Water Resources Department, Tamil Nadu	Member
31.	Secretary In- Charge, Water Resources Department, Haryana	Member
32.	Secretary In- Charge, Water Resources Department, Karnataka	Member
33.	Secretary In- Charge, Water Resources Department, Telangana	Member
34.	Representative of Department of Civil Engg., Indian Institute of Science (IISc), Bangalore	Member
35.	Representative of Department of Civil Engg., Indian Institute of Technology-Hyderabad	Member
36.	Member (WQ & TT), CGWB	Member Secretary

The committee may co-opt any other Member(s), if necessary.

2. **Terms of Reference: –**

i. To ensure the assessment of annual ground water recharge of the States/UTs in coordination with the respective state level committees for the reference year 2020. The Committee will work on ground water assessments in accordance with the methodology and will adopt improved procedures and practices wherever possible for the sake of achieving greater accuracy of assessment(s).

ii. To supervise the estimation of status of utilization of the annual extractable ground water resource as on 31st March 2020 of the States/UTs to be carried by the respective State/UT level committees.

iii. To supervise compilation of a National level report on assessment of ground water resources and status of its utilization as on 31st March, 2020.

iv. To work towards integration of ground water and surface water data with a view to facilitate planning for conjunctive use of water resources.

v. Any other aspect relevant to the terms referred to above.

3. **Time frame:-**

The Committee will submit its report on or before 31.03.2021.

4. **Expenditure**

Expenditure on account of TA/DA to official Members of the Expert Group will be met from the source from which they draw their salaries and that of non-official Members (if any), will be borne by the Central Ground Water Board as per Govt. norms.

This issues with the approval of competent authority.

(Mukesh Kumar)
Deputy Secretary (EA&IC)
email: dirgw-mowr@nic.in

मुकेश कुमार/MUKESH KUMAR
उप सचिव/Deputy Secretary
जल शक्ति मंत्रालय/Ministry of Jal Shakti
जल संसाधन, नदी विकास एवं गंगा संरक्षण विभाग
Deptt. of Water Resources, River Developmen
and Ganga Rejuvanation
भारत सरकार/Government of India
नई दिल्ली/New Delhi-110001

ORDER

Ordered that the Resolution be published in the Gazette of India for general information.

Ordered that a copy of the Resolution published be communicated to this Ministry for record.

(Mukesh Kumar)
Deputy Secretary (EA&IC)
email: dirgw-mowr@nic.in

मुकेश कुमार/MUKESH KUMAR
उप सचिव/Deputy Secretary
जल शक्ति मंत्रालय/Ministry of Jal Shakti
जल संसाधन, नदी विकास एवं गंगा संरक्षण विभाग
Deptt. of Water Resources, River Development
and Ganga Rejuvanation
भारत सरकार/Government of India
नई दिल्ली/New Delhi-110001

To

The Manager,

Government of India Press,

Faridabad (Haryana).

Copy to:

1. PS to Minister (JAL SHAKTI)
2. PS to MoS (JAL SHAKTI)
3. Sr PPS to Secretary (DoWR, RD & GR)
4. PPS to Joint Secretary (IC & GW)
5. All members concerned.
6. Chairman, CGWB, Faridabad.
7. Member (WQ & TT) and Member Secretary of the CLEG-2020, CGWB, Faridabad for information and necessary action.

Copy also to:
NIC for uploading the Resolution on Ministry's website.

Appendix-B

Constitution of State Level Committee

(as in 2020)

Government of Madhya Pradesh
Water Resources Department
Mantralaya
Vallabh Bhawan, Bhopal

ORDER

Memo No. F-15/21/2016/Minor/31/1244 Bhopal dated 23/09/2020

Subject:-Assessment of annual Ground water recharge-constitution of State Level Committee for re-assessment of ground water resources for the water year 2019-20.

The last assessment of state-wise annual ground water Recharge for the state was made in the year 2016-17 base on the Methodology adopted by the Ground Water Resources Estimation Committee-2015. With a view to re-assessed ground water resources for the year 2019-20, the State Level Committee is constituted as under :-

i.	Additional Chief Secretary / Principal Secretary, Water Resources Department	Chairman
ii.	Commissioner, Urban Development and Housing Department	Member
iii.	Engineer-in-Chief, Water Resources Department	Member
iv.	Engineer-in-Chief, Public Health & Engineering Department	Member
v.	Engineer-in-Chief, RES	Member
vi.	Director, Agriculture	Member
vii.	Director, Industries	Member
viii.	General Manager, NABARD	Member
ix.	Director, Rajeev Gandhi Water Shed Mission	Member
x.	Chief Engineer, BODHI, Water Resources Department	Member
xi.	Superintending Geo Hydrologist, GWSC, Circle Bhopal	Member
xii.	Resources Scientist, State GW Data Center, Bhopal	Member
xiii.	Regional Director, CGWB	Member Secretary

The Committee may co-opt any other Member (s)/ special invitee(s), if necessary. The broad terms of reference of the Committee would be as follow :-

i. To estimate annual replenish able ground water resources of the state in accordance with the Ground Water Resources Estimation Methodology- 2016-17.
ii. To estimate the status of utilization of the annual replenish able ground water resources.

The Committee will submit its report within six months from the date of its constitution. Expenditure on account of TA/DA to official Members of the Committee will be met from the source from which they draw their salaries and that of non-official Members, will be borne by the Water Resources Department.

23/9/2020

(V.S.Tekam)
Deputy Secretary,
Govt. of M.P.Water Resources Deptt.

Endt. No. F-15/21/2016/Minor/31/1245 Bhopal, Dated 23 /09/2020

Copy forward to:-

1. OSD, Hon'ble Minister / State Minister, GoMP, Water Resources Department, Bhopal.
2. P.A. to Additional Chief Secretary, GoMP, Water Resources Department, Bhopal.
3. Commissioner, Urban Development and Housing Department, Bhopal.
4. Engineer-in-Chief, Water Resources Department, Bhopal.
5. Engineer-in-Chief, Public Health & Engineering Department, Bhopal.
6. Engineer-in-Chief, RES, Bhopal.
7. Director, Agriculture, GoMP, Bhopal.
8. Director, Industries, GoMP, Bhopal.
9. General Manager, NABARD
10. Director, Rajeev Gandhi Water Shed Mission, Bhopal.
11. Chief Engineer, BODHI, Water Resources Department, Bhopal.
12. Superintending Geo Hydrologist. SWARA, GWSC, Circle Bhopal.
13. Resources Scientist, State Ground Water Data Center, Bhopal.
14. Regional Director, CGWB, Paryawas Bhawan, Bhopal.

for information and necessary action.

23/9/2020

Deputy Secretary,
Govt. of M.P.Water Resources Deptt.

Appendix-C

Minutes of First SCL meeting

(as in 2020)

Minutes of the First Meeting of State Level Committee for Ground Water Resource Estimation held on 04.12.2020

The first meeting of the State Level Committee for Groundwater Resource Estimation 2020 was held in the Meeting room D-103, First floor, Vallabh bhawan-3 on 04.12.2020 at 15:30. The meeting was chaired by Sh. S N Mishra, Additional Chief Secretary, Water Resources Department, Govt of Madhya Pradesh. The meeting was attended by committee members from Water Resources Department, Public Health Engineering Department, Department of Agriculture & Central Ground Water Board. The list of participants who attended the meeting is enclosed in Annexure-I.

Dr Sarita Tiwari, Scientist B welcomed the participants of the meeting. With the permission of the chair, Sh M M Rao Sonkusare gave an introduction of the National Aquifer Mapping Programme being carried out by Central Ground Water Board. He informed the committee that CGWB, NCR, Bhopal has prepared Aquifer Maps & Management plan for an area of 21454 sq km of Hoshangabad, Agar, Betul & Narsinghpur districts. Following presentations of Aquifer Maps & Management plan were made by officers of CGWB, NCR, Bhopal:

1. Sh N K Jatav, Scientist B: Hoshangabad district
2. Ms Lata Udsaiya, Scientist B: Agar district
3. Sh Chittaranjan Biswal, Scientist B: Betul district
4. Dr K Paramasivam, AHG: Narsinghpur district

Chairman of the committee appreciated the work being carried out by Central Ground Water Board, Govt of India under National Aquifer Mapping Programme in Madhya Pradesh. The intervention of recharge & Draft Management Plan to improve the Stage of Extraction was also agreeable. The chair mentioned that the reports may also be shared with the district administration & disseminated to the general public in simple language. The committee approved the work done by CGWB under National Aquifer Mapping Programme in Madhya Pradesh state.

Sh M M Rao Sonkusare, Member Secretary briefed about the progress & timeline of data collection for Ground water Resource Estimation 2020. He stressed about the data acquisition from various line departments such as Water Resources Department, Department of Industries, Department of Urban Development & Housing and Department of Panchayat & Rural Development. It was agreeable that all the data will be provided by all the line departments by 31st January, 2021. All attempts will be made to complete Ground water resource estimation 2020 by the end of February 2021.

Further he explained that as per GEC 2015, area having more than 100 ha under surface water irrigation projects is to be considered command area for GWRE 2020. Annual draft of industries may be provided to have an actual resource estimation.

The meeting ended with a vote of thanks to the chair.

9/12/2020

Put up for approval

(M M Rao Sonkusare)
Member Secretary of SLC

Approved

member Secy

15/12/2020

Annexure-I

List of participants of Meeting of State Level Committee for "Ground water Resource Estimation"

S no.	Name	Designation & Department
1.	Sh M. S. Dabur	Engineer-in-chief, Water Resources Department
2.	Sh K K Songaria	Engineer-in-chief, Public Health Engineering Department
3.	Dr J K Jain	Superintending Engineer, Water Resources Department
4.	Sh B M Sahve	Additional Director, Department of Agriculture
5..	Sh R K Rajak	AGH, Water Resources Department
6.	Dr Bijendra Baghel	DBA, Water Resources Department
7.	Sh M M Rao Sonkusare	Head of Office, CGWB, NCR, Bhopal
8.	Dr Rakesh Singh	Scientist D, CGWB, NCR, Bhopal
9.	Sh N K Jatav	Scientist B, CGWB, NCR, Bhopal
10.	Ms Lata Udsaiya	Scientist B, CGWB, NCR, Bhopal
11.	Ms Gargi Walia	Scientist B, CGWB, NCR, Bhopal
12.	Sh Chittaranjan Biswal	Scientist B, CGWB, NCR, Bhopal
13.	Dr Sarita Tiwari	Scientist B, CGWB, NCR, Bhopal
14.	Dr K Paramasivam	AHG. CGWB, NCR, Bhopal
15.	Dr Seraj Khan	Scientist D (Retd.), CGWB, NCR, Bhopal

Appendix-D

Minutes of Second SCL meeting and approval of Resource from SLC (as in 2020)

Minutes of meeting of State Level Committee for "Ground Water Resources Estimation" held on 07.04.2021

The meeting of State Level Committee for Ground Water Resources Estimation was held virtually on 07.04.2021, 15:00 hrs. The meeting was chaired by Sh. S N Mishra, IAS, Additional Chief Secretary, Water Resources Department, Govt. of Madhya Pradesh. The list of officers attended the meeting is enclosed in Annexure-1.

Sh. M M Rao Sonkusare, Head of the Office, CGWB, NCR, Bhopal welcomed the participants of meeting. With permission of chair, Sh. Chitta Ranjan Biswal, SC B, CGWB, NCR, Bhopal made presentation on "Ground Water Resources Estimation of Madhya Pradesh as on March 2020". The gist of Ground Water Resource Estimation 2020 is given below:

1	Area of State	308525 Sq.Km
2	Total Number of Districts	51
3	Total Number of Assessment Units	317 (313 blocks+ 4 urban Areas
4	Annual Extractable Groundwater Resource (Dynamic)	3338039 Ham
5	Existing Gross Groundwater Extraction for Irrigation	1733319.6 Ham
6	Existing Gross Groundwater Extraction for Domestic and Industrial Water Supply	163433.29 Ham
7	Existing Gross Groundwater Extraction for all uses	1896999.9 Ham
8	Provision for future domestic utilization	183736.97 Ham
9	Net Groundwater Availability for future use	1525059.41 Ham
10	Stage of Groundwater Extraction	56.82 %
11	Number of Safe Blocks	233
12	Number of Semi-Critical Blocks	50
13	Number of Critical Blocks	8
14	Number of Over-Exploited Blocks	26

The groundwater resources were discussed thoroughly by the members of the committee and after discussions, the report of Ground Water Resources Estimation of Madhya Pradesh as on March 2020 was approved.

The meeting ended with a vote of thanks to the chair.

Approved

12/4/2021

M M Rao Sonkusare
Head of the Office and
Member Secretary of SLC

16/04/2021
(एस. एन. मिश्रा)
अ.मु.स. म.प्र. शासन
जल संसाधन एवं परिवहन विभाग

3370 16/07/2021

Annexure-1

List of Participants of Meeting of State Level Committee for Ground Water Resource Estimation	
Si No.	Participants
1	Sh.S N Mishra, Additional Chef Secretary, Water Resources Department
2	Commissioner, Urban Development and Housing Department
3	Engineer-in-Chief, Water Resources Department
4	Engineer-in-Chief, Public Health and Engineering Department
5	Engineer-in-Chief, Rural Engineering Services
6	Director, Farmer Welfare and Agriculture Development Department
7	Managing Director, MP Industrial Development Corporation Limited
8	General Manager, NABARD, Madhya Pradesh
9	Director, Rajiv Gandhi National Water Shed Mission
10	Engineer-in-Chief, BODHI, Water Resources Department
11	Superintending Geo Hydrologist, GWSC, Water Resources Department
12	Resource Scientist, State Groundwater Data Center, Bhopal
13	Sh. M M Rao Sonkusare, Head of Office and Member Secretary of SLC, CGWB, NCR, Bhopal
14	Sh. N K Jatav, Sc.B, CGWB, NCR, Bhopal
15	Sh. Chitta Ranjan Biswal, Sc.B, CGWB, NCR, Bhopal
16	Dr. Seraj Khan, Retired Sc. D, CGWB, NCR, Bhopal

Appendix-E

First Minutes of the meeting of the Central Level Expert Group for overall re- assessment of Ground water resources of country, 2020

Minutes of 1st Meeting of Central Level Expert Group for Re-assessment of Ground WaterResources of India as in 2020

Date: 19.01.2021

The 1st meeting of the Central Level Expert Group (CLEG) for re-assessment of the Ground Water Resources of India as in 2020 was held through Video Conferencing on 19.01.2021 at 10.30 Hrs. Shri G. C. Pati, Chairman, Central Ground Water Board & CLEGchaired the meeting. The list of participants is annexed.

Dr P. Nandakumaran, Member (South), CGWB & Member Secretary, CLEG, welcomedall the Members of Central Level Expert Group and participants. He briefed the participants on the Ground Water Resource Assessment process and roles and responsibilities of CLEG and State Level Committees (SLCs) for ensuring timely completion the whole process by the end of March, 2021. The Chairman, in his opening remarks, emphasized the need for timely completion of GWRA-2020 by using the Webbased application ''INDIA-GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES)''developed by CGWB in association with IIT-Hyderabad.

A presentation on 'Status of various activities related to Ground Water Resource Assessment-2020' was made by Dr. Ratikanta Nayak, Scientist-D, CGWB, CHQ, Faridabad. It was followed by Presentation by Prof K. B. V.N. Phanidra, Dept. of Civil Engg., IIT-Hyderabad on ''INDIA-GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES)''. The presentations were followed by detailed discussions on various aspects of the resource assessment.

Important action points emerged from the discussions are listed below:

Minor refinements in 'IN-GRES' suggested by Members based on the online and physical trainings shall be incorporated in the software. (Action: CGWB & IIT, Hyderabad)

1. Feasibility of incorporating a provision in the software for computation of distributed values of water level fluctuation over the assessment unit throughinterpolation of water level fluctuation in the individual observation points-maybe explored during future refinement to overcome the shortcomings of using arithmetic average as is in practice at present.
(Action: CGWB & IIT, Hyderabad)

2. Request of some of the members to have login credentials of the IN-GRES software to have hands-on experience and to suggest improvements shall be considered after firming up the software and data entry by

States. (Action: CGWB & IIT, Hyderabad)

3. Possibility to aggregating groundwater availability at basin level, as is being donein the case of surface water resources may be considered in future.

(Action: CGWB & IIT, Hyderabad) Possibility of considering block level data availability in Tamil Nadu (Firkas of TamilNadu within a block can be arithmetically added and block level assessment bemade and included in the report) could be considered to bring in uniformity.(Action: CGWB & IIT, Hyderabad)

The following decisions were taken during the meeting: -

1. The whole process of Re-assessment of Ground Water Resources of the countryas in 2020 will be carried out through 'INDIA-GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES)'.

2. The States (**Punjab, Madhya Pradesh, West Bengal, Rajasthan, Uttar Pradesh**) where re-organization /changes in number and boundary of assessment unitshave taken place (2020 as compared to 2017) shall provide the **shape file of assessment unit boundaries without further delay**. ***State Groundwater/Nodal Departments are requested to provide the shape filefor commencement of data upload for the States in 'IN-GRES'.***

3. Data collection/compilation of **GW Extraction** (for domestic, irrigation and industrial uses) and **Recharge from 'Others Sources'** (canal seepage, return flow from SW/GW irrigation, tanks/ponds, water conservation structures) **for majority of States have not been completed**. ***State Groundwater/Nodal Departments are requested to expedite data collection in this regard, as these data are available exclusively with State Departments.***

4. Progress of work to be monitored on a regular basis by States/Regional offices of CGWB as well as the Working Group at CGWB, CHQ, Faridabad to ensure completion of **re-assessment of ground water resources of the State and approval by State Level Committees by the end of February, 2021**.

The meeting ended with thanks to the Chair.

List of participants of the 1st meeting of Central Level Expert Group (CLEG) on 19.01.2021

S.No	Participants
1.	Shri. G. C. Pati, Chairman, Central Ground Water Board
2.	Dr. P. Nandakumaran, Member (South), Central Ground Water Board
3.	Shri. Sunil Kumar, Member (CGWA), Central Ground Water Board
4.	Shri. Sanjay Marwah, Member (HQ), Central Ground Water Board
5.	Shri. G. L. Meena, Member (N&W), Central Ground Water Board
6.	Shri S.K. Tripathi, DDG & RMH-IV, Southern Region, Geological Survey of India
7.	Dr. Anupma Sharma, Scientist 'F', National Institute of Hydrology, Roorkee
8.	Dr. Pulak Guhathakurta, Scientist F & Head, Climate Research Division, IMD, Pune
9.	Shri Sunil Kumar, Director, Basin Planning-1, Directorate, Basin PlanningManagement Organization, Central Water Commission
10.	Smt. Soumya P Kumar, Director, MI-Stat.Wing, D/o Water Resources, RD & GR, M/o Jal Shakti
11.	Shri A. Murlidharan , Deputy Adviser (PHE), Department of Drinking Water Supply & Sanitation, Ministry of Jal Shakti
12.	Shri. B Rath, Technical Expert (WM), NRAA, Ministry of Agriculture & Farmer Welfare
13.	Shri. Sekhar M, Professor, Department of Civil Engg., Indian Institute of Science (IISc), Bangalore
14.	Shri. K B V N Phanindra, Professor, Department of Civil Engg., Indian Institute of Technology-Hyderabad
15.	C. Mruthyunjaya Swamy, K.E.S, Secretary to Government, Minor Irrigation & Ground Water Development Department, Govt of Karnataka
16.	Shri V S Patel, Managing Director, Gujarat Water Resources DevelopmentCorporation Ltd., Gandhinagar, Gujarat
17.	Er. Debashish Roy, Engineer in Chief & Ex-Officio Secretary, Water ResourcesInvestigation Department, Government of West Bengal
18.	Dr. Pandith Madhnure, Director, Ground Water Department , Govt. of Telengana
19.	Shri. Gopal Sharma, Superintending Hydrogeologist, Ground Water Department, Government of Rajasthan
20.	Shri. B.B Singla, Superintending Engineer, Ground Water Management Circle , S.A.SNagar, Government of Punjab
21.	Er. S.Raja, Deputy Director, Officer of the Chief Engineer, State Ground andSurface Water Resources Data Centre, Govt. of Tamil Nadu
22.	Shri. N. Srinivasu, Deputy Director, Ground Water & Water Audit Department, Govt.of Andhra Pradesh
23.	Dr. Vijay Pakmode, Deputy Director, GSDA, Pune, Govt. of Maharastra
24.	Dr. Bijendra Baghel, GW Data Center, WRD, Bhopal, Government of MadhyaPradesh
25.	Shri Awdhesh Kumar, Executive Engineer, Ground Water Department, UttarPradesh
26.	Shri. Pankaj Mahala, Hydrologist, Ambala, Government of Haryana
27.	Shri.Paul Prabhakar, Regional Director, CGWB, SECR, Chennai
28.	Shri.V.Kunhambu, Regional Director, CGWB, SWR, Bangalore
29.	Dr.S.K.Samanta, Regional Director, CGWB, ER, Kolkata
30.	Dr.P.K.Jain, Regional Director, CGWB, CR, Nagpur
31.	Er. Hirak Dey, Director, State Water Investigation Directorate, West Bengal
32.	Shri. P. Jyoti Kumar, Deputy Director, Ground Water Department, Telengana

S.No	Participants
33.	Dr. R C Jain, Advisor (GW), Gujarat Water Resources Development CorporationLtd., Gandhinagar, Gujarat

34.	Shri. Mahavir, TA, Office of Hydrologist, Karnal, Government of Haryana
35.	Dr. Poonam Sharma, Scientist-D, CGWB, CHQ, Faridabad
36.	Shri. A. K. Madhukar, Scientist-D, CGWB, CHQ, Faridabad
37.	Shri. Anurag Khanna, Scientist-D, CGWB, CHQ, Faridabad
38.	Shri. M. K. Sharma, Scientist-D, CGWB, WR, Jaipur
39.	Dr. Ratikanta Nayak, Scientist-D, CGWB, CHQ, Faridabad
40.	Dr. Ranjan Ray , Scientist-D,CGWB, CHQ, Faridabad
41.	Dr. S. Subramanian, Scientist-D, CGWB, SECR, Chennai
42.	Smt. Sandhya Yadav, Scientist-D, CGWB, ER, Kolkata
43.	Shri. M.L.Angurala, Scientist-D, CGWB, NWHR, Jammu
44.	Shri. Sanjeev Mehrota, Scientist-D, CGWB, WCR, Ahmedabad
45.	Shri. A. V. S. S. Anand, Scientist-D, CGWB, Rajiv Gandhi National Ground WaterTraining & Research Institute, Raipur
46.	Shri. D. Venkateshwar, Scientist-D, CGWB, CR, , Nagpur
47.	Dr. M. Senthil Kumar, Scientist-C, CGWB, CHQ, Faridabad
48.	Smt. Rumi Mukherjee, Scientist-C, CGWB, CHQ, Faridabad
49.	Shri. Chittaranjan Biswal, Scientist-B, CGWB, NCR, Bhopal
50.	Miss. Subhra Satapathy, Scientist-B, CGWB, CHQ, Faridabad
51.	Rayees Ahmad Pir, Assistant Hydrogeologist, CGWB, NWHR, Jammu
52.	Shri. Yogesh Bhandari, Vassar Labs, Hyderabad
53.	Shri. Nikhilesh Kumar, Vassar Labs, Hyderabad
54.	Smt. Baljinder Kaur, Vassar Labs, Hyderabad

Appendix-F

Second Minutes of the meeting of the Central Level Expert Group for overall re- assessment of Ground water resources of country, 2020

Minutes of 2nd Meeting of Central Level Expert Group for Re-assessment of Ground Water Resources of India for 2020 (held through Video Conferencing)

Date: 31.03.2021

The 2nd meeting of the Central Level Expert Group (CLEG) for re-assessment of the Ground Water Resources of India for 2020 was held under the Chairmanship of Shri G.C. Pati, Chairman, Central Ground Water Board (CGWB) through Video Conferencingon 31.03.2021 at 10.30Hrs. The list of participants is attached (Annexure).Dr P. Nandakumaran, Member (South), CGWB & Member Secretary, CLEG, welcomedall the Members of Central Level Expert Group and participants. He briefed the participants about the Ground Water Resource Assessment 2020 and requested Chairman, CGWB to address the participants. Chairman, Central Ground Water Board, congratulated all Officers of State GW/Nodal Departments, Regional offices of CGWBand IIT Hyderabad for their sincere efforts for completion of GW Resource Assessment for 2020 through web based application ''INDIA-GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES)''. He also appreciated the CLEG members for their valuable inputs which have helped in the realistic assessment of ground water resources in the country. He also intimated the members about the directions of the DoWR, RD & GR, Ministry of Jal Shakti regarding the need to complete the assessment and to publish the report without further delay. He then requested the Member Secretary to take up the Agenda items:

Agenda 2.1: Confirmation of Minutes of 1st CLEG Meeting & Action Taken on Decisions:

As no comments were received from any of the members, minutes of the 1st meeting of CLEG held on 19.01.2021 were confirmed.

Dr P. Nandakumaran, Member Secretary, CLEG mentioned that various actions for improvements in the IN-GRES software, as discussed during the previous meeting have been initiated in consultation with IIT Hyderabad and that all such improvements will becarried out over the next couple of years in a phased manner.

Agenda 2.2: Status of Ground Water Resource Assessment 2020:

A brief presentation on status of 'Ground Water Resource Assessment-2020 (GWRA-2020)' as in 2020 was made by Dr. Ratikanta Nayak, Scientist-D, CGWB, CHQ, Faridabad. It was informed that all the States/UTs (except Telangana, Tamil Nadu andWest Bengal) have already assessed their ground water resources jointly with CGWB.State Level Committees (SLCs) of 28 States/UTs have approved the GW Resource Assessment for their respective States/UTs.

Salient features of the national scenario of dynamic ground water resources of India, based on the outputs of assessment as in 2020 in respect of 33 States and outputs of assessment as in 2017 in respect of Tamil Nadu, Telangana and West Bengal were presented and discussed. The members appreciated the work done by CGWB, StateDepartments and IIT Hyderabad and expressed their agreement with the whole process of assessment.

The presentations were followed by detailed discussions, during which the following requests were made

1. State GW/Nodal Department of Telangana and Tamil Nadu requested for 15 days more time for completing GWRA-2020.
2. State GW/Nodal Department of West Bengal requested for 3 months more timefor completing GWRA-2020.

The following decisions were taken during the meeting after the discussions: -

1. In view of the fact that incorporation of ground water resources Tamil Nadu, Telangana and West Bengal as in 2020 are not considered to cause any significant change in the national scenario, members of CLEG gave their consent/approval for the results of GWRA-2020 as finalized, subject to incorporation of final results of the remaining States/UTs.
2. The national report on Dynamic GW Resources of India, 2020 will be prepared by CGWB based on the assessment carried out jointly by State GW/Nodaldepartments and CGWB.
3. It was decided by the CLEG that 15 days time will be given to the three States(Telangana, Tamil Nadu and West Bengal) to submit their assessment results as in2020 (with the approval of State Level Committee) so that the assessment resultsfor 2020 can be included in national compilation report. In case data in respectof these States are not made available by the prescribed date, CGWB may proceed with finalization and publication of the national report by incorporatingresults of the previous assessment results for these States.
4. It was also decided to request the States for which assessment is yet to be approved by their respective SLCs to get the same approved at the earliest andlatest by 15.04.2021 positively.

The meeting ended with thanks to the Chair.

List of participants of the 2nd meeting of Central Level Expert Group (CLEG) on 31.03.2021

S.No	Participants
1.	Shri. G. C. Pati, Chairman, Central Ground Water Board
2.	Dr. P. Nandakumaran, Member (South), Central Ground Water Board
3.	Shri. Sunil Kumar, Member (CGWA), Central Ground Water Board
4.	Shri. Sanjay Marwaha, Member (HQ), Central Ground Water Board
5.	Shri. G. L. Meena, Member (N&W), Central Ground Water Board
6.	Shri. Rohit Kumar, Joint Secretary, Ministry of Rural development(MGNREGS),Govt. of India
7.	Ms. Veditha Reddy, IAS, Secretary (PWD), Andaman & Nicobar Administration
8.	Shri. C. Mruthyunjaya Swamy, K.E.S, Secretary to Government, Minor Irrigation & Ground Water Development Department, Govt. of Karnataka
9.	Shri. Suren Karkidholi, PCE-cum-Secretary, Water Resource Department, Govt. of Sikkim
10.	Shri S.K. Tripathi, DDG & RMH-IV, Southern Region, Geological Survey of India
11.	Dr. Pulak Guhathakurta, Scientist F & Head, Climate Research Division, IMD, Pune
12.	Dr. Anupma Sharma, Scientist 'F', National Institute of Hydrology, Roorkee
13.	Dr. Sekhar M, Professor, Department of Civil Engg., Indian Institute of Science (IISc), Bangalore
14.	Dr.B.R.Chahar, Professor, Department of Civil Engineering, Indian Institute of Technology -Delhi
15.	Dr. Mallinath Kalshetti, IAS , Director, Ground Water Survey and Development Agency (GSDA), Govt. of Maharashtra
16.	Dr. K B V N Phanindra, Associate Professor, Department of Civil Engg., Indian Institute of Technology-Hyderabad
17.	Shri Sunil Kumar, Director, Basin Planning-1, Directorate, Basin Planning Management Organization, Central Water Commission
18.	Smt. Soumya P Kumar, Director, MI-Stat. Wing, D/o Water Resources, RD & GR, M/o Jal Shakti, Govt. of India
19.	Shri. B Rath, Technical Expert (WM), NRAA, Ministry of Agriculture & Farmer Welfare
20.	Shri.Avinash Mishra, Joint Advisor (WR&LR), NITI Aayog, New Delhi
21.	Shri. V S Patel, Managing Director, Gujarat Water Resources Development Corporation Ltd., Gandhinagar, Govt. of Gujarat
22.	Dr. Pandith Madhnure, Director, Ground Water Department , Govt. of Telangana
23.	Shri. A Varaprasad Rao, Director, State Ground Water & Water Audit Department, Govt. of Andhra Pradesh
24.	Er. Hirak Dey, Director, State Water Investigation Directorate, Govt. of West Bengal
25.	Shri. Narinder Kumar Garg, Chief Engineer, Ground Water Cum Project Co-ordination-NHP, Department of Water Resources, Govt. of Punjab
26.	Shri Gopal Prasad Sharma, Superintending Hydrogeologist, Ground Water Department, Government of Rajasthan, Jaipur.
27.	Dr. Bijendra Baghel, GW Data Center, WRD, Bhopal, Government of Madhya Pradesh
28.	Shri. Rakesh Ku. Gupta, Chief Hydrogeolgist, Office of Hydrologist, Karnal, Governmentof Haryana
29.	Dr. R C Jain, Advisor (GW), Gujarat Water Resources Development Corporation Ltd., Gandhinagar, Govt. of Gujarat
30.	Shri. B. S. Nirola, Additional Chief Engineer, Water Resource Department, Govt. of Sikkim
31.	Dr. S. Raja, Executive Engineer, SG&SWRDC, Govt. of Tamil Nadu
32.	Shri. P. Jyoti Kumar, Deputy Director, Ground Water Department, Govt. of Telangana
33.	Shri. N. Srinivasu, Deputy Director, Ground Water & Water Audit Department, Govt. of Andhra Pradesh

34.	Ms. Debatri Bagchi, Sr. Geologist, State Water Investigation Directorate, Govt. of West Bengal
35.	Shri. S. S. Timsina, SE, Water Resource Department, Govt. of Sikkim
36.	Ms. A. Lahiri, Geologist, State Water Investigation Directorate, Govt. of West Bengal
37.	Shri. S. Haldar, EE, State Water Investigation Directorate, Govt. of West Bengal
38.	Shri. R. K. Banshiwal, Senior Hydrogeologist, (DSPC), Ground Water Department, Jodhpur.
39.	Shri. Arun Kumar, EE, APWD, Andaman & Nicobar Administration
40.	Shri. Mahavir, TA, Office of Hydrologist, Karnal, Government of Haryana
41.	Shri. Paul Prabhakar, Regional Director, CGWB, SECR, Chennai
42.	Shri. Anand Kumar Agrawal, Regional Director, CGWB, MER, Patna
43.	Shri. V. Kunhambu, Regional Director, CGWB, SWR, Bangalore
44.	Dr. S .K. Samanta, Regional Director, CGWB, ER, Kolkata
45.	Dr .P. K. Jain, Regional Director, CGWB, CR, Nagpur
46.	Shri. Sanjeev Mehrota, Scientist-D & HOO, CGWB, WCR, Ahmedabad
47.	Dr. Poonam Sharma, Scientist-D, CGWB, CHQ, Faridabad
48.	Shri. Rana Chatarjee, Scientist-D & HOO, CGWB, SUO, Delhi
49.	Shri.Pramod Kr.Tripathi, Scientist-D & HOO, CGWB, NR, Lucknow
50.	Dr. Prabir Ku.Naik, Scientist-D, CGWA, Delhi
51.	Dr. Ratikanta Nayak, Scientist-D, CGWB, CHQ, Faridabad
52.	Shri. Prashant Rai, Scientist-D, CGWB, UR, Dehradun
53.	Dr. Ranjan Ray , Scientist-D,CGWB, CHQ, Faridabad
54.	Smt. Sandhya Yadav, Scientist-D, CGWB, ER, Kolkata
55.	Shri. M.L.Angurala, Scientist-D, CGWB, NWHR, Jammu
56.	Dr. A. V. S. S. Anand, Scientist-D, CGWB, Rajiv Gandhi National Ground Water Training & Research Institute, Raipur
57.	Dr. M. Senthil Kumar, Scientist-C, CGWB, CHQ, Faridabad
58.	Smt. Rumi Mukherjee, Scientist-C, CGWB, CHQ, Faridabad
59.	Smt. Rani.V.R, Scientist-C, CGWB, KR, Kerala
60.	Shri. Biswarup Mohapatra, Scientist-C, CGWB, WCR, Ahmedabad
61.	Shri. Vipin Mallick, Scientist-B, CGWB, NHR, Dharamsala
62.	Shri. Uddesya Kumar, Scientist-B, CGWB,NCCR, Raipur
63.	Miss. Chandreyee Dey, Scientist-B, CGWB, UR, Dehradun
64.	Shri. Chittaranjan Biswal, Scientist-B, CGWB, NCR, Bhopal
65.	Miss. Subhra Satapathy, Scientist-B, CGWB, CHQ, Faridabad
66.	Shri.A.K.Sinha, Assistant Geophysicist, CGWB, ER, Kolkata
67.	Dr. Fakhre Alam, AHG, CGWB, MER, Patna
68.	Shri. Yogesh Bhandari, Vassar Labs, Hyderabad

Appendix-G

Approval Letter of Dynamic Ground Water Resource -2020 By Ministry

Email **North Central Region Bhopal**

Approval of National Compilation on Dynamic Ground Water Resources of India, 2020

From : ratikanta nayak <tsmsouth-cgwb@gov.in> Fri, Jun 18, 2021 11:51 AM

Subject : Approval of National Compilation on Dynamic Ground Water Resources of India, 2020

To : Regional Director CR <rdcr-cgwb@nic.in>, RDSR <rdsr-cgwb@nic.in>, RDSWR <rdswr-cgwb@nic.in>, Regional Director, CGWB,Tvm. <rdkr-cgwb@nic.in>, Subramanian Sudaramorthy <rdsecr-cgwb@nic.in>, RD NWR CGWB <rdnwr-cgwb@nic.in>, A K Agrawal <rdmer-cgwb@nic.in>, Santanu Kumar Samanta <rder-cgwb@nic.in>, Regional Director, WCR <rdwcr-cgwb@nic.in>, Regional Director <rdwr-cgwb@nic.in>, RDNER <rdner-cgwb@nic.in>, RD-CGWB-NHR-DSALA <rdnhr-cgwb@nic.in>, RD CGWB, NR, Lucknow <rdnr-cgwb@nic.in>, regional director, NCCR <rdnccr-cgwb@nic.in>, Rdur-cgwb <rdur-cgwb@nic.in>, RD, CGWB, Jammu <rdnwhr-cgwb@nic.in>, RD SER CGWB <rdser-cgwb@nic.in>, North Central Region Bhopal <rdncr-cgwb@nic.in>, Officer Incharge SUO Delhi <oicnd-cgwb@nic.in>

Cc : Ground Water Resources Assessment Cell CGWB, MoWR <res-cgwb@nic.in>, P Nandakumaran <msouth-cgwb@gov.in>, Member N and W <mnorth-cgwb@gov.in>, Member(E), CGWB <meast-cgwb@gov.in>, Member (CGWA) <mcgwa-cgwb@gov.in>, Member HQ CGWB <mhq-cgwb@gov.in>, Member(RGI),CGWB,Faridabad <mrgi-cgwb@nic.in>, T.S.to Chairman Cell <tschmn-cgwb@nic.in>, TS to Member HQ <tsmsam-cgwb@nic.in>, anurag khanna <a.khanna-cgwb@gov.in>, Dr.S.Suresh <gisndc-cgwb@nic.in>, Dr Prabir <prabir.naik-cgwb@gov.in>

Sir,
It is to inform that the competent authority, Ministry of Jal Shakti, Government of India has accepted the "National Compilation on Dynamic Ground Water Resources of India, 2020". The soft copy of the report will be shared soon. All Regions may finalise & publish their respective State/UT Reports on Dynamic Ground Water Resources, 2020 latest by 15th July, 2021.
with regards
Dr Ratikanta Nayak
Scientist-D
& TS to Member (South)

Appendix-H

IN-GRES (INDIA GROUND WATER RESOURCE ESTIMATION SYSTEM)

URL: https://ingres.iith.ac.in

A. Objectives of IN-GRES

- IN-GRES allows for unique and homogeneous representation of groundwater fluxes as well as categories for all the assessment units (AU) of the country.
- The visibility dashboards and System allows user to view data in both MIS (tabular) as well as GIS (map) formats, and to download reports.
- Removes the hurdles associated with manual data entry, computations, representation, report generation, approvals, and visualization
- Improves accuracy, efficiency and minimizes time in groundwater (GW) resource computation.
- Helps the district / state level GW scientists in effective planning and management of GW resources of their region, and draw regulations on GW withdrawals.
- Create awareness among the public through access, visualize, and compare the status of GW resources to the level of a mandal/district

Figure 1: Overview of Ground Water Resource Estimation Platform – GEC 2015

B. Modules

IN-GRES is divided into 3 modules namely: Input, Computation and Output.

1. **Input module**– Input Module refers to the Data Entry module at an Assessment Unit (AU)level. Data Input is done via 2 methods i.e.

a. **Excel based input**– In this, the user needs to download district level data sheet template where he/she can fill the data at an Assessment Unit level. User then needs to upload their fully filled excel sheet into the system.

"Basic Data" input sheet for [District], [State] for year [Year]

Note:
(1) Grayed out column headers should not be changed. They are taken from the shapefile.
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	*Total Geographical Area (ha)	*Hilly Area (ha)	*Total Recharge Worthy Area (ha)				Static/In-Storage Unconfined Ground Water Resources		If Assessment Unit is Urban						Deep Water Level ? (Default: False)
						*Command	*Non Command	*Poor Quality	Total	Bottom of the Unconfined aquifer (m)	Specific Yield in Static/In-Storage zone	Command		Non Command		Poor Quality		
												Paved	UnPaved	Paved	UnPaved	Paved	UnPaved	

Figure 2: Basic Data Template

b. **Form based input** – In this, the user is shown a form and he/she can fill/edit the data in data sheet in an online mode. Once user is done with editing online, he/she can submit the data file.

- A User needs to upload a State **shape file** with Assessment unit, hierarchy and geometry. This information needs to be embedded into the shape file's attribute table. The shape file should be in .shp format consisting of 6 associated files with extensions:. cpg, .dbf, prj, qpj,.shp, .shx.

Figure 3: Basic Data Form Input

2. **Computation module**– Computation Module refers to the ground water level calculationsfor an assessment unit. These computations are based on GEC 2015 methodology and are used to calculate Annual Extractable Ground Water Resource, Total Current Annual Ground Water Extraction (utilization) and the percentage of ground water utilization with respect to recharge (stage of Ground Water Extraction) for an assessment unit. Based onthese percentages an assessment unit is categorized into one of the SAFE, SEMI- CRITICAL, CRITICAL, and OVEREXPLOITED categories.

3. **Output module -** Once categorized, the results are shown in two views:

   a. **MIS Dashboard** – MIS dashboard shows the results of the assessment for the entire India, and also for each state State in a tabular form. The MIS dashboard shows all type of recharges, extractions, inflows and outflows computed for both monsoon and non-monsoon periods of the year and then reflect the overall stage of extraction at the selected Geo-Zoom Level. User can see the calculations for each component by drilling down to the Assessment Unit level.

S No	STATE	Rainfall (mm)			Total Geographical Area(ha)					Ground Water Recharge (ham) +			Natural Discharges (ham) +			Annual Extractable Ground water Resource (ham)			Ground Water Extrac (ham) +	
					Recharge Worthy			Hilly Area	Total											
		C	NC	Total	C	NC	Total			C	NC	Total	C	NC	Total	C	NC	Total	C	NC
1	CHANDIGARH	-	1,061	1,061	-	11,400	11,400	-	11,400	0	2,343.94	2,343.94	0	234.39	234.39	0	2,109.54	2,109.54	0	3.6
2	CHHATTISGARH	1,309	1,346	1,341	1,320,334	9,287,537	10,607,871	2,911,282	13,519,153	2,40,020	9,57,832.82	11,97,852.82	23,455.04	89,660	1,13,115.04	2,16,564.96	8,68,172.82	10,84,737.78	1,13,465.53	4,83.6
3	DAMAN AND DIU	342	-	338	10,516	-	11,090	110	11,200	283.01	0	283.01	28.3	0	28.3	254.71	0	254.71	18,690.55	
4	GOA	3,453	3,408	3,373	21,919	156,008	220,960	149,239	370,199	13,310.76	34,794.94	54,815.21	1,325.62	3,479.49	5,476.07	11,985.14	31,315.45	49,339.14	4,003.21	4.8
5	HARYANA	500	-	509	3,775,374	-	3,775,374	354,103	4,129,477	8,20,978.65	0	8,20,978.65	80,778.88	0	80,778.88	7,40,199.76	0	7,40,199.76	11,56,736.08	
6	JAMMU AND KASHMIR	-	690	660	-	1,677,406	1,677,406	8,464,294	10,141,700	0	2,33,964.63	2,33,964.63	0	23,396.47	23,396.47	0	2,10,568.17	2,10,568.17	0	1.9
7	NAGALAND	-	399	389	-	1,409,148	1,409,148	248,752	1,657,900	0	50,027.11	50,027.11	0	5,002.71	5,002.71	0	45,024.4	45,024.4	0	1.9
TOTAL		727	1,177	1,052	5,128,143	12,541,499	17,713,249	12,127,780	29,841,029	10,74,592.42	12,78,963.44	23,60,265.37	1,05,587.85	1,21,773.07	2,26,031.86	9,69,004.57	11,57,190.38	21,32,233.5	12,92,895.37	4,76.0

Figure 4: MIS View

   b. **GIS Dashboard**– GIS dashboard shows the data in Web Geo-Server format, implemented in interactive GIS platform allowing user to all GEC related information in the map itself. GIS view represents the data on India map and color codes each District/Assessment unit based on the categorization.

Figure 5: GIS View

C. Excel Download and Upload Templates

To compute data in IN-GRES, 11 excel templates are provided for the user to fill and submit the datain the system for an Assessment Unit. These include:

i. Basic Data File (with 2 internal sub-sheets)

"Basic Data" input sheet for [District], [State] for year [Year]

Note:
(1) Grayed out column headers should not be changed. They are taken from the shapefile.
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	*Total Geographical Area (ha)	*Hilly Area (ha)	*Total Recharge Worthy Area (ha)				Static/In-Storage Unconfined Ground Water Resources		If Assessment Unit is Urban						Deep Water Level ? (Default: False)
						*Command	*Non Command	*Poor Quality	Total	Bottom of the Unconfined aquifer (m)	Specific Yield in Static/In-Storage zone	Command		Non Command		Poor Quality		
												Paved	UnPaved	Paved	UnPaved	Paved	UnPaved	

Figure 6: Basic Data Template

"Aquifer Data" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers should not be changed. They are taken from the shapefile.
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Principal Aquifer	Major Aquifer	*Major Aquifer Code	Command			Non Command			Poor Quality		
							*Percentage of geographical area	* Recommended Specific Yield for assessment (%)	* Recommended Infiltration Factor for assessment (%)	*Percentage of geographical area	* Recommended Specific Yield for assessment (%)	Recommended Infiltration Factor for assessment (%)	*Percentage of geographical area	Recommended Specific Yield for assessment (%)	* Recommended Infiltration Factor for assessment (%)

Figure 7: Aquifer Data Template

ii. Rainfall Data File (with 5 internal sub-sheets)

"Rainfall Data at Assessment unit level" input sheet for [District], [State] for year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	*Year	Monsoon		Non-Monsoon	
						*Actual (mm)	*Normal (mm)	*Actual (mm)	*Normal (mm)

Figure 8: Rainfall – Assessment Unit Data Template

"Rainfall Data at Rain Gauge level" input sheet for [District], [State] for year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) Only the raingauge station data of the state are considered to compute rainfall values.Neighbouring state's rainguage data is not considered in the interpolation method.
(4) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Name of Raingauge	*Latitude	*Longitude	*Year	Monsoon		Non-Monsoon	
					*Actual (mm)	*Normal (mm)	*Actual (mm)	*Normal (mm)

Figure 9: Rainfall – Rain Gauge Data Template

"Rainfall Data at IMD Grid level" input sheet for [District], [State] for year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) Only the IMD Grid in the state are considered to compute rainfall values. Neighbouring state's grid data is not considered in the interpolation method.
(4) All columns will be pre-populated from the values entered in the previous assessment year

S.No	GRID ID	*Latitude	*Longitude	*Year	Monsoon		Non-Monsoon	
					*Actual (mm)	*Normal (mm)	*Actual (mm)	*Normal (mm)

Figure 10: Rainfall – IMD Grid Data Template

"Rainfall Data at Time Series level" input sheet for [District], [State] for year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year
(4) This data can be given via an API

S.No	Station Name	Station ID	*Latitude	*Longitude	Date	Time	Value (mm)

Figure 11: Rainfall – Time Series Data Template

"Rainfall Data Threshold Value" input sheet for [District], [State] for year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	Threshold Value (mm)	
					Minimum	Maximum

Figure 12: Rainfall – Threshold Data Template

iii. **Ground Water Well Data File (**with 3 internal sub-sheets**)**

"Ground Water Well - Assessment Unit Level" input sheet for [District], [State] for year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed if rainguage station data for the state is not uploaded into the system
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	* Year	Level (m)	
						*Pre-monsoon	*Post-Monsoon

Figure 13: Ground Water Well – Assessment Unit Data Template

"Ground Water Well - Well Level Data" input sheet for [District], [State] for year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed if rainguage station data for the state is not uploaded into the system
(2) * Marked column headers are mandatory
(3) Only the Ground water observation well data of the state are considered to compute Ground water level values.
Neighbouring state's Ground water observation well data is not considered in the interpolation method.
(4) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Name of the observation well	*Longitude (degree decimal)	*Latitude (degree decimal)	*Year	Level (mbgl)		Dry (Yes/No)
					*Pre-monsoon	*Post-Monsoon	

Figure 14: Ground Water Well – Well Level Data Template

"Ground Water Well - Time Series Data" input sheet for [District], [State] for year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed if rainguage station data for the state is not uploaded into the system
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year
(4) This data can be given via an API

S.No	Station ID	*Longitude (degree decimal)	*Latitude (degree decimal)	*Date (DD-MM-YYYY)	Time	Level (mbgl)

Figure 15: Ground Water Well – Time Series Data Template

iv. **Recharge Data File (**with 6 internal sub-sheets**)**

"Recharge from Other Sources - Surface Water Irrigation" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Source Type	* Distributory in which it is located	* Design discharge (ha.m/day)	Average discharge (ha.m/day)	Command																							
								Paddy								Non Paddy															
								Continous Water Supply (Yes/No)	Area under Paddy (ha)		RFF Factor				Continous Water Supply (Yes/No)	Crop name	Area under Non Paddy (ha)		RFF Factor				Weighted RFF				* No of days water released			
									Kharif	Rabi	Monsoon	Non - Monsoon					Kharif	Rabi	Monsoon	Non - Monsoon			Monsoon	Non - Monsoon			Monsoon	Non - Monsoon		
								Non Command																							
								Paddy								Non Paddy															
								Continous Water Supply (Yes/No)	Area under Paddy (ha)		RFF Factor				Continous Water Supply (Yes/No)	Crop name	Area under Non Paddy (ha)		RFF Factor				Weighted RFF				* No of days water released			
									Kharif	Rabi	Monsoon	Non - Monsoon					Kharif	Rabi	Monsoon	Non - Monsoon			Monsoon	Non - Monsoon			Monsoon	Non - Monsoon		
								Poor GW Quality																							
								Paddy								Non Paddy															
								Continous Water Supply (Yes/No)	Area under Paddy (ha)		RFF Factor				Continous Water Supply (Yes/No)	Crop name	Area under Non Paddy (ha)		RFF Factor				Weighted RFF				No of days water released			
									Kharif	Rabi	Monsoon	Non - Monsoon					Kharif	Rabi	Monsoon	Non - Monsoon			Monsoon	Non - Monsoon			Monsoon	Non - Monsoon		

Figure 16: Recharge – Surface Water Irrigation – Canal Outlet Template

"Recharge from Other Sources - Surface Water Irrigation" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Command Area															
				Paddy							Non-Paddy								
				Continous Water Supply (Yes/No)	* Estimated Crop Water Requirement (mm)		* Area under crop (ha)		RFF Factor		us Water Supply (Yes/No	* Crop Name	* Estimated Crop Water Requirement		* Area under crop (ha)		RFF Factor		
					Kharif	Rabi	Kharif	Rabi	Monsoon	Non - Monsoon			Kharif	Rabi	Kharif	Rabi	Monsoon	Non - Monsoon	
				Non-Command Area															
				Paddy							Non-Paddy								
				Continous Water Supply (Yes/No)	* Estimated Crop Water Requirement (mm)		* Area under crop (ha)		RFF Factor		us Water Supply (Yes/No	* Crop Name	* Estimated Crop Water Requirement (mm)		* Area under crop (ha)		RFF Factor		
					Kharif	Rabi	Kharif	Rabi	Monsoon	Non - Monsoon			Kharif	Rabi	Kharif	Rabi	Monsoon	Non - Monsoon	
				Poor GW Quality Area															
				Paddy							Non-Paddy								
				Continous Water Supply (Yes/No)	* Estimated Crop Water		* Area under crop		RFF Factor		us Water Supply	* Crop Name	* Estimated Crop		* Area under crop		RFF Factor		
					Kharif	Rabi	Kharif	Rabi	Monsoon	Non - Monsoon			Kharif	Rabi	Kharif	Rabi	Monsoon	Non - Monsoon	

Figure 17: Recharge – Surface Water Irrigation– Crop Water Requirement Template

"Recharge from Other Sources - Canal Seepage" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year
(4) It is mandatory to fill either (J or K , L & M) or N
(5) It is mandatory to enter I or O

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Poor Quality)	* Name of the canal Segement	Canal Type (Main/Minor)	Type (Lined/Unlined)	Length of Canal (m)	Design depth of flow (m)	Average Supply Depth (m)	Bed width (m)	Side Slope (degrees)	Wetted Perimeter (m)	Wetted Area (million sq m)	Canal seepage factor (ha.m/d/million sq.m)		* No.of canal running days	
															Monsoon	Non-Monsoon	Monsoon	Non-Monsoon

Figure 18: Recharge – Canal Seepage Template

"Recharge from Other Sources - Tanks & Ponds" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year
(4) Either Design Water Spead Area or Average Water Spread Area or Both Should be given

S.No	Location Code	District	Assessment Unit	*Name of Tank/Pond	Command area						
					Number of Tanks/Ponds	Recharge Factor (mm/day)	Design water spread area of single tank (ha)	Average Water Spread area of single tank (ha)		* No. of days water is available	
								Monsoon	Non monsoon	Monsoon	Non monsoon
					Non Command area						
					Number of Tanks/Ponds	Recharge Factor (mm/day)	Design water spread area of single tank (ha)	* Average Water Spread area of single tank (ha)		* No. of days water is available	
								Monsoon	Non monsoon	Monsoon	Non monsoon
					Poor GW Quality area						
					Number of Tanks/Ponds	Recharge Factor (mm/day)	Design water spread area of single tank (ha)	* Average Water Spread area of single tank (ha)		* No. of days water is available	
								Monsoon	Non monsoon	Monsoon	Non monsoon

Figure 19: Recharge – Tanks and Ponds Template

"Recharge from Other Sources - Water Conservation Structures" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	* Name of the Structure	Recharge Factor of Structure		Structure information								
							Command			Non Command			Poor Quality		
					Monsoon	Non-Monsoon	* Number of Structures	* Storage Capacity (ha.m)	* No. of Fillings	* Number of Structures	* Storage Capacity (ha.m)	* No. of Fillings	* Number of Structures	* Storage Capacity (ha.m)	* No. of Fillings

Figure 20: Recharge – Water Conservation Structure Template

"Recharge from Other Sources - Ground Irrigation " input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Command														
				Paddy					Non Paddy						Weighted RFF		* No of days water released	
				Continous Water Supply (Yes/No)	Area under Paddy (ha)		RFF Factor		Continous Water Supply (Yes/No)	Crop name	Area under Non Paddy (ha)		RFF Factor					
					Kharif	Rabi	Monsoon	Non - Monsoon			Kharif	Rabi	Monsoon	Non - Monsoon	Monsoon	Non - Monsoon	Monsoon	Non - Monsoon
				Non Command														
				Paddy					Non Paddy						Weighted RFF		* No of days water released	
				Continous Water Supply (Yes/No)	Area under Paddy (ha)		RFF Factor		Continous Water Supply (Yes/No)	Crop name	Area under Non Paddy (ha)		RFF Factor					
					Kharif	Rabi	Monsoon	Non - Monsoon			Kharif	Rabi	Monsoon	Non - Monsoon	Monsoon	Non - Monsoon	Monsoon	Non - Monsoon
				Poor GW Quality														
				Paddy					Non Paddy						Weighted RFF		No of days water released	
				Continous Water Supply (Yes/No)	Area under Paddy (ha)		RFF Factor		Continous Water Supply (Yes/No)	Crop name	Area under Non Paddy (ha)		RFF Factor					
					Kharif	Rabi	Monsoon	Non - Monsoon			Kharif	Rabi	Monsoon	Non - Monsoon	Monsoon	Non - Monsoon	Monsoon	Non - Monsoon

Figure 21: Recharge – Ground Water Irrigation Template

v. Draft Data File (with 6 internal sub-sheets)

"Domestic (Unit Draft)" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year
(4) Actual number of wells in use (column H) is considered to be 80% of number of wells (column G)

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	* Type of Structure	* No. of wells in assessment year	Actual No. of wells in use	* Estimated draft per well (ha.m)	
								Monsoon	Non-Monsoon

Figure 22: Draft – Domestic Unit Draft Template

"Domestic (Consumptive Use)" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Command											
				Population Details						* Per capita Requirement (lpcd - litres per capita per day)		* Fractional load on ground water Lg		No. of Days	
				* Reference Year	* Population as on Reference Year		* Growth Rate (%)							Monsoon	Non Monsoon
					Rural	Urban	Rural	Urban		Rural	Urban	Rural	Urban		
				Non Command											
				Population Details						Per capita Requirement (lpcd - litres per capita per day)		* Fractional load on ground water Lg		No. of Days	
				* Reference Year	* Population as on Reference Year		* Growth Rate (%)							Monsoon	Non Monsoon
					Rural	Urban	Rural	Urban		Rural	Urban	Rural	Urban		
				Poor GW Quality											
				Population Details						Per capita Requirement (lpcd - litres per capita per day)		* Fractional load on ground water Lg		No. of Days	
				* Reference Year	* Population as on Reference Year		* Growth Rate (%)							Monsoon	Non Monsoon
					Rural	Urban	Rural	Urban		Rural	Urban	Rural	Urban		

Figure 23: Draft – Domestic Consumptive Use Template

"Irrigation (Unit Draft)" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	* Type of Structure	* No. of wells in assessment year	Actual No. of wells in use	* Estimated draft per well (ha.m)	
								Monsoon	Non-Monsoon

Figure 24: Draft – Irrigation Unit Draft Template

"Irrigation (Power Consumption)" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Command Area			
				Monsoon		Non Monsoon	
				* Estimated power requirement For 1 ham of water lift (kilo watt hours kWh)	* Total power consumed (kilo watt hours kWh)	* Estimated power requirement For 1 ham of water lift (kilo watt hours kWh)	* Total power consumed (kilo watt hours kWh)
				Non-Command Area			
				Monsoon		Non Monsoon	
				* Estimated power requirement For 1 ham of water lift (kilo watt hours kWh)	* Total power consumed (kilo watt hours kWh)	* Estimated power requirement For 1 ham of water lift (kilo watt hours kWh)	* Total power consumed (kilo watt hours kWh)
				Poor GW Quality Area			
				Monsoon		Non Monsoon	
				* Estimated power requirement For 1 ham of water lift (kilo watt hours kWh)	* Total power consumed (kilo watt hours kWh)	* Estimated power requirement For 1 ham of water lift (kilo watt hours kWh)	* Total power consumed (kilo watt hours kWh)

Figure 25: Draft – Irrigation Power Consumption Template

"Industrial (Unit Draft)" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	* Type of Industries	* Type of Structure	* No. of wells in assessment year	Actual No. of wells in use	* Estimated draft per well (ha.m)	
									Monsoon	Non-Monsoon

Figure 26: Draft – Industrial Unit Draft Template

"Industrial (Consumptive Use Pattern)" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Command Area					
				* Type of Industry	* No of Such Industries	* Estimated Consumptive Requirement (ha.m/day)	* Fractional load on ground water Lg	No. of days water is being extracted	
								Monsoon	Non Monsoon
				Non Command Area					
				* Type of Industry	* No of Such Industries	* Estimated Consumptive Requirement (ha.m/day)	* Fractional load on ground water Lg	No. of days water is being extracted	
								Monsoon	Non Monsoon
				Poor Quality Area					
				* Type of Industry	* No of Such Industries	* Estimated Consumptive Requirement (ha.m/day)	* Fractional load on ground water Lg	No. of days water is being extracted	
								Monsoon	Non Monsoon

Figure 27: Draft – Industrial Consumptive Use Template

vi. **Inflow and Outflow Data File (**with 8 internal sub-sheets**)**

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	River Gauge name	Day	Average Stream Discharge (cumecs)	Direct Runoff Spells					
								Spell No.	Start day	End Day	Day Number in the Spell	Discharge at Start Day (cumecs)	Discharge at End Day (cumecs)

Figure 28: Environmental Flows – Base Flow Template

"Fluxes : Additional Base Flow" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	No. of stream gauges	Name of up stream river gauge	Catchment area of upstream river gauge	Name of down stream river gauge	Catchment area of downstream river gauge

Figure 29: Environmental Flows – Base Flow Template

"Fluxes : Vertical Inter Aquifer Flow" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	Zone No	Hydraulic Conductivity of the Aquitard	Thickness of Aquitard (m)	Monsoon		Non Monsoon	
								Average Change in Head (m)	Area of the Zone (ha)	Average Change in Head (m)	Area of the Zone (ha)

Figure 30: Environmental Flows – Vertical Inter Aquifer Flow Template

"Fluxes : Lateral Aquifer Flow" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	Section No.	Transmissivity	Monsoon					Non Monsoon				
							Length of the section (m)	Up Contour (m)	Down Contour (m)	Distance between two contours on ground in (m)	InFlow/ OutFlow	Length of the section (m)	Up Contour (m)	Down Contour (m)	Distance between two contours on ground in (m)	InFlow/ OutFlow

Figure 31: Environmental Flows – Lateral Aquifer Flow Template

"Fluxes : Evapotranspiration" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	Zone Number	Zone Description	Evapotranspiration rate in mm/day	Average Root Depth in m	Capillary rise in m	Area in hectare		Average ground water level in the zone in m		No of days Evapotranspiration takes place	
										Monsoo	Non	Monsoo	Non	Monsoo	Non
						0.0-0.5						0.25	0.25		
						0.5-1.0						0.75	0.75		
						1.0-1.5						1.25	1.25		
						1.5-2.0						1.75	1.75		
						2.0-2.5						2.25	2.25		
						2.5-3.0						2.75	2.75		
						3.0-3.5						3.25	3.25		
						3.5-4.0						3.75	3.75		
						4.0-4.5						4.25	4.25		
						4.5-5.0						4.75	4.75		

Figure 32: Environmental Flows – Evapotranspiration Template

"Fluxes : Evaporation" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	Zone Number	Zone Description	Evaporation rate in mm/day	Capillary rise in m	Area in hectare (ha)		Average ground water level in the zone in m		No of days Evaporation takes place	
									Monsoon	Non Monsoon	Monsoon	Non Monsoon	Monsoon	Non Monsoon
						0.0-0.5					0.25	0.25		
						0.5-1.0					0.75	0.75		
						1.0-1.5					1.25	1.25		
						1.5-2.0					1.75	1.75		

Figure 33: Environmental Flows –Evaporation Template

"Fluxes : Transpiration" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	Zone Number	Zone Description	Transpiration rate in mm/day	Average Root Depth in m	Capillary rise in m	Area in hectare		Average ground water level in the zone in m		No of days Transpiration takes place	
										Monsoo	Non	Monsoo	Non	Monsoo	Non
						0.0-0.5						0.25	0.25		
						0.5-1.0						0.75	0.75		
						1.0-1.5						1.25	1.25		
						1.5-2.0						1.75	1.75		
						2.0-2.5						2.25	2.25		
						2.5-3.0						2.75	2.75		
						3.0-3.5						3.25	3.25		
						3.5-4.0						3.75	3.75		
						4.0-4.5						4.25	4.25		
						4.5-5.0						4.75	4.75		

Figure 34: Environmental Flows – Transpiration Tem

"Recharge from Other Sources - Stream Recharges" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	Section No.	Transmissivity	Monsoon				Non Monsoon			
							Length of the section (m)	Up Contour h2 (m)	Down Contour h1 (m)	Distance between two contours on ground in (m)	Length of the section (m)	Up Contour h2 (m)	Down Contour h1 (m)	Distance between two contours on ground in (m)

Figure 35: Environmental Flows – Stream Channels Template

vii. Additional Potential Resources Data File (with 3 internal sub-sheets)

"Shallow Water Table Zone" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Shallow Water Table Zone	
				* Pre-Monsoon DTWL (m bgl)	* Area (ha)
				0.0-0.5	
				0.5-1.0	
				1.0-1.5	
				1.5-2.0	
				2.0 -2.5	
				2.5 -3.0	
				3.0 -3.5	
				3.5-4.0	
				4.0-4.5	
				4.5 -5.0	

Figure 36: Additional Potential Resources – Shallow Water Area Template

"Flood Prone Area" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Flood Prone Area		
				* Flood Prone Area (ha)	* Flood Impound Days in a year	Seepage Factor (m)

Figure 37: Additional Potential Resources – Flood Prone Area Template

"Spring Discharge" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Name of Spring	Spring Discharge (lph)		Number of Days Spring	
					* Monsoon	* Non-Monsoon	* Monsoon	* Non-Monsoon

Figure 38: Additional Potential Resources – Spring Discharge Template

viii. Resources of Confined and Semi-Confined Aquifer Data File (with 2 internalsub-sheets)

"Confined Aquifer Piezometer Data" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	* Name of the Confined Aquifer	* Area of Confined Aquifer (Sq. m)	* Storativity (Fraction)	* Bottom of top confining layer (m)	Being Extracted or Not (Yes/No)	* Average Piezometric head (m amsl)	
									Pre-Monsoon	Post-Monsoon

Figure 39: Resources of Confined and Semi-Confined Aquifer – Confined Aquifer Template

"Semi-Confined Aquifer Piezometer Data" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	* Name of the Semi-Confined Aquifer	Recommended Specific Yield for assessment (%)	* Area of Semi-Confined Aquifer (Sq. m)	* Storativity (Fraction)	* Bottom of top confining layer (m)	Being Extracted or Not (Yes/No)	* Average Piezometric head (m amsl)	
										Pre-Monsoon	Post-Monsoon

Figure 40: Resources of Confined and Semi-Confined Aquifer – Semi-Confined Aquifer Template

ix. Urban Area Resource – Pipelines and Sewages (with 1 internal sub-sheet)

"Pipelines and Sewages" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	Per capita water requirement (lpcd)	Pipelines				Sepage through Sewages/Flash floods				
						Water Supply (ham/day)	(%) Loss	No. of days of flow		Wetted Perimeter (m)	Length (m)	No of days of flow		Seepage factor
								Monsoon	Non-monsoon			Monsoon	Non-monsoon	

Figure 41: Urban Area Resource –Pipelines & Sewage Template

x. Unconfined Dynamic Aquifer Other Details (with 1 internal sub-sheet)

"Unconfined Dynamic and Other Detail" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed if Monitoring station data for the state is not uploaded into the system
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	Quality Tagging		Environmental Flows in ham/year	Population Details						* Per capita Requirement (lpcd - litres per capita per day)		* Fractional load on ground water Lg	
					Major parameter present in mappable areas (Salinity/Fluoride/Arsenic)	Other Parameters present in mappable areas		* Reference Year	* Population as on Reference Year		* Growth Rate (%)						
									Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban

Figure 42: Unconfined Dynamic Aquifer Other Details Template

xi. Coastal Areas (with 1 internal sub-sheet)

"Coastal Areas" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment y

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor Quality)	Name of the Coastal Area	* Area of Coastal Area(ha)	* Specific Yield (Fraction)	* Bottom of the Aquifer (m above MSL)	* Reduced Level of Ground Level	Pre-Monsoon Water Level (mbgl)	Post-Monsoon Water Level (mbgl)

Figure 43: Coastal Areas Template

xii. **Water Depletion Zones (**with 1 internal sub-sheet**)**

"Water Depleted Zones" input sheet for [District],[State] for assessment year [Year]

Note:
(1) Grayed out column headers are populated from shapefile and should not be changed
(2) * Marked column headers are mandatory
(3) All columns will be pre-populated from the values entered in the previous assessment year

S.No	Location Code	District	Assessment Unit	Assessment Sub-Unit (Command, Non Command, Poor	Name of the Water Depleted Zone	* Area of Water Depleted Zone(ha)	* Specific Yield (Fraction)	Pre-Monsoon Water Level (mbgl)	Post-Monsoon Water Level (mbgl)

Figure 44: Water Depletion Zones Template

D. Approval Levels

The data is uploaded at the root Level by the District/State Level Experts. After data entry, the datasets are TRIGGERED and sent for approval by Higher Authorities. There are 6 stages of approvals in IN-GRES. The hierarchies of data approvals are shown in **Fig 45.**

Fig 45: Approval Levels

E. Report and Annexure

The download option in MIS View allows the user to download reports in 6 formats:

Central Level Report option allows user to download the state-wise district level data for an assessment year, computation type and view.

State Report option allows user to download the Assessment Unit-wise data for the selectedstate for an assessment year, computation type and view.

Annexure 1 – State-wise Resources

Annexure 2 – District-wise Resources

Annexure 3 – Categorization

Annexure 4 – List of Categorization

Custom Report - Custom reports allow user to generate report for a specific assessment unit which fall under a certain criterion. User has an option to define ranges for Recharge Worthy Area, Annual Rainfall, Ground Water Recharge, Ground Water Extraction and Stage of Extraction. User also has an option to choose to download the report for a specific Category.

Note: -The above 4 Annexures are as per standard CGWB formats.

F. Other System Features-

1. Live Ground Water Dashboard

Live Ground Water Dashboard shows the live Change in Ground Water Storage for a specific assessment unit. The live ground water level is fetched from the India WRIS website via an API. Change in Ground Water Storage can be expressed as follows:

$$\Delta S = A * (Pre - Current) * SY$$

Where,

ΔS = Change in Ground Water Storage

A = Area of Water Depletion Zones

Pre = Pre - monsoon Ground water level

Current = Current Ground water level

SY = Specific Yield

2. Map comparison

Map comparison allows user to compare the Ground water estimation done for two years. The GIS view shows the categorization at an assessment unit level. The MIS View table will show the data foryear 1, year 2 and also the percentage difference in the value between these two years.

S.No.	Asessment Year	Ground Water Recharge from (ham)				Total Natural Discharges(ham)	Annual Extractable Ground Water Resource (ham)	Current Annual Ground Water Extraction(ham)				Annual Ground Water Allocation for Domestic Use as on 2025(ham)	Net Ground Water Availbility For Future Use(ham)	Stage of Ground Water Extraction(%)
		Monsoon Season		Non Monsoon Season				Irrigation	Domestic	Industrial	Total			
		Recharge From Rainfall	Recharge From OtherSources	Recharge From Rainfall	Recharge From OtherSources									
1	2016-2017	2,00,46,563.76	6,72,47,038.2	20,16,229.84	15,60,55,226.48	2,56,06,866.06	23,43,37,722.16	3,68,00,648.08	48,82,62,136.93	3,37,57,807.48	55,88,20,591.26	56,35,982.28	20,43,07,765.64	238.47
2	2019-2020	2,33,20,010.32	59,05,217.25	25,69,465.46	70,95,451.91	32,51,397.9	3,53,63,882.91	2,00,54,912.97	25,02,252.68	2,51,833.3	2,28,08,999.46	1,22,04,466.55	1,59,24,728.16	64.5
3	Difference	32,73,446.56	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Fig 46: Map Comparison

3. Heat Maps

Allows to visualize geospatial view of the output data based on different parameters which include:

- Categorization for future Ground Water development
- Annual Normal Rainfall
- Annual Ground water recharge
- Annual Ground water extraction
- Aquifer

4. Computational Popup

Provide an overview of the summary of the computations.

Rainfall Recharge Summary

Season : Monsoon

Recharge using Rainfall Infiltration Method (RFIFM)

S. No	Description	Quantity
1	Area in hectares	28,212
2	Normal Annual Rainfall in mm	774.6
2.a	Normal Rainfall during monsoon in mm (max:3000 mm)	687.2
2.b	Rainfall threshold (10% of annual rainfall, max:300 mm) in mm	77.46
2.c	Rainfall left for recharge computation (2.a - 2.b) in mm	609.74
3	Is rainfall recharge possible in this area ?	Yes
4	Rainfall infiltration factor	0.16
(1 * 2.c * 4) / 1000		
	Rainfall recharge in command area by RF infiltration factor method (ha.m)	2,752.32

Recharge using Water table fluctuation method (WTFM)

S. No	Description	Quantity

Fig 47: Computation Popup

5. Map Download

Provision to download Map.

ABBREVIATIONS

bcm	Billion Cubic Meter
C	Command
CGWB	Central Ground Water Board
CLEG	Central Level Expert Group for overall reassessment of ground water resource of the country
cm	Centimeter
DOWR, RD & GR	Department of Water Resources, River Development & GangaRejuvenation, Ministry of Jal Shakti, Govt. of India
GEC-1984	Ground Water Estimation Committee, 1984
GEC-1997	Ground Water Resources Estimation Committee, 1997
GWRA- 2015	Ground Water Resources Estimation Committee, 2015
GWS	Ground Water Survey
ham	Hectare meter
IMD	India Meteorological Department
LPA	Long Period Average
lps	Litres per second
m	Meter
m bgl	Meter below ground level
mcm	Million cubic Meter
m ham	Million hectare meter
mm	Millimeter
NABARD	National Bank for Agricultural and Rural Development
NC	Non Command
NCR	North Central Region
Sq. m	Square Meter
WRD	Water Resource Department

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