GROUND WATER RESOURCES OF PUNJAB STATE

(As on 31st March, 2020)

CENTRAL GROUND WATER BOARD
NORTH WESTERN REGION
CHANDIGARH .

GROUND WATER MANAGEMENT CIRCLE
WATER RESOURCES DEPARTMENT, PUNJAB
S.A.S NAGAR.

OCTOBER, 2021

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Prepared by

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FOREWORD

Water is a scarce resource and it is essential for all form of life. Conservation and preservation of water is of utmost importance. Demand of ground water is increasing due to committed surface water resources and further raise of demand for irrigation, drinking & industry sectors. To keep pace with its growing demand regular monitoring and periodic assessment apart from its efficient use is a dire necessity. Assessment, Utilization and Monitoring of Natural Resources leads the path for their sustainability.

The present ground water assessment report has been computed by the officers & officials of the Ground Water Management Circle, Department of Water Resources Punjab, along with Department of Agriculture & Farmer's Welfare and Punjab Water Resources Management and Development Corporation Limited on the basis of latest guidelines by the Ground Water Resource Estimation Committee (GEC 2015), Government of India,. The report gives details on total annual recharge to ground water, its present draft and scope for future block-wise development.

The present ground water development in the state is 164% as on March 2020. Out of 150 blocks of the state taken for study, 117 blocks are "Over-exploited", 6 blocks are "Critical", 10 blocks are "Semi-critical" and 17 blocks are in "Safe" category. There is an urgent need to recharge ground water in the over-exploited blocks and develop available shallow ground water in the safe blocks to avoid water logging in the foreseeable future. The irrigation policy also needs review vis-a-vis prevailing hydrogeological scenario.

I would like to appreciate the efforts regarding excellent data collection by the officers/officials of Ground Water Management Circle, Mohali through their superb network and skilled manpower, which is the main support for this whole exercise especially Sh. Atul Kumar Sood, Senior Geophysicist, Sh. Suresh Narang, Senior Hydrologist, Sh. Sahil Thakur, Junior Geologist, Sh. Bhupinder Singh, Assistant Design Engineer, Sh. Sanjeev Bansal, STA and Sh. Bhola Singh, Draftsman under the able guidance of Sh. Bharat Bhushan Singla, Director, to complete the task in the most comprehensive and logical manner in a very short span of time.

I would like to place on record the commendable efforts of Sh. Rakesh Rana, Scientist 'D' and Sh. Arpan Banerjee, Scientist 'B' of the Central Ground Water Board for their contribution in preparation of this report.

I personally feel that this report will be of immense use to the planners, administrators and agencies engaged in the development and regulation of ground water resources of the state.

(Er. Kamal Kant)
Chief Engineer/ Ground Water cum
Project Coordinator NHP, WRD,
Government of Punjab.

September, 2021

कार्यालय प्रमुख
केन्द्रीय भूमिजल बोर्ड
उत्तरी पश्चिमी क्षेत्र, चंडीगढ़

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जल संसाधन, नदी विकास एवं गंगा संरक्षण विभाग, भारत सरकार

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Government of India

Dated: 27.10.2021

PREFACE

Punjab, a granary state of India, comprising 1.5 percent of the total geographical area of the country has been contributing around two third of wheat and half of rice to the central pool. Ground water is being used for irrigating 71% of total area irrigated in the state. This has led to over-exploitation of ground water resources, as the surface water fall short of the irrigation needs of the State. Punjab model of irrigation is characterized by excess demand of water for irrigation coupled with unconstrained mining of ground water for meeting the food bowl requirements of the country.

Ground water being a replenishable resource, requires realistic assessment for its proper management and economic development on sustainable basis. The complexities of the process governing occurrence and movement of ground water make the process of ground water assessment somewhat difficult not only because of enormous data that are to be analyzed but also a multidisciplinary approach that is adopted for computation of parameters regarding extraction and recharge. Moreover, the presence of saline aquifers in southwestern part of the state makes the estimation more complicated.

The estimation of ground water resources based on the recent methodology i.e. GEC, 2015 has been carried out with all precessions by the Water Resources & Environment Directorate (WRED), Punjab in collaboration with Central Ground Water Board (CGWB) is highly praiseworthy. For the first time, all computations for the assessment of ground water resources have been carried out through a web based application namely "INDIA GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES)" developed jointly by CGWB and IIT Hyderabad. The estimation has brought out clearly the grim situation regarding ground water resources scenario in Punjab state which needs to be developed in more scientific and sustainable development model. The large scale ground water conservation/recharge measures like on farm water management techniques, village pond revival for recharging to ground water, construction of check dams in Siwaliks and water harvesting in urban areas is also required to be promoted and encouraged in the state to arrest the over exploitation of precious ground water resources.

I would like to appreciate the sincere efforts made by the officers of CGWB and WRED, Punjab in preparing this report at a very short span of time.

S.kumar

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CHAPTER-1
INTRODUCTION

1.1 BACKGROUND

Punjab State, one of the smallest states of India having geographical area of 50,362 sq km (Only 1.5 percent of the geographical area of the country), is pre-dominantly an agrarian state contributing around two third of the food grains procured annually in the country and is devoid of any other mineral or natural resource except water. Agriculture in the State is highly intensive which needs heavy requirement of water. The economy of the State and well being of the farmers depend to a large extent on the availability of water. The hard work of the farmers has proudly earned the State the name of "Food Basket of Country".

In Punjab State, surface water resources are being fully utilized through well-organized canal irrigation system. The available surface water resources of the State are unable to meet the demand of agriculture as such there is an increasing pressure on ground water resources. The ground water is being over-exploited to meet ever increasing demands of water for diverse purposes i.e. for intensive irrigation, drinking, industry, power generation etc. With the introduction of Green Revolution in the State in mid-sixties, the number of tube-wells increased from a meager 50,000 in the early sixties to above 70,000 in early eighties, to about 10.70 lakhs in year 2001 to 11.80 lakhs in the year 2005-06 and to approx. 12.0 lakhs in the year 2012-13 as per the 5th Minor Irrigation Census Report. Now the figure stands at 14.50 lakhs.

The share of State's surface water resources is limited and decreasing with the effect of global warming and in ground water resources, the State is facing the dual phenomenon of rising water table (mostly in south-western parts, where water extraction is limited due to brackish/saline quality) and falling water table in north-western, central, southern and south-eastern parts of the state, where ground water is generally fresh and fit for irrigation.

To assess the irrigation potential from the ground water, an estimate of ground water resources was made in the year 1973 by the Ministry of Agriculture in consultation with State ground water and minor irrigation organization. Subsequently in early eighties, the ground water resource was re-estimated on the basis of Methodology proposed by the Ground Water Over Exploitation Committee-1977. In 1982, the Government of India had constituted a Ground Water Estimation Committee to improve the quantitative assessment of ground water and to suggest a methodology after considering all aspects of ground water estimation. This Committee recommended a methodology namely: Ground Water Estimation Committee Methodology–1984 (GEC-84). Since then, the Central Ground Water Board and State Ground Water Organization have adopted this GEC–1984 methodology and estimated the ground water resource in the Punjab State in the years 1984, 1986, 1989, 1992 and 1999.

However, some limitations were encountered in the estimation and this necessitated revision of methodology for more accurate assessment. Therefore, with a view to review GEC–84 and to look into all the related issues, a Committee on Ground Water Estimation was constituted vide GOI, MOWR Notification No. 3/9/93-GWII/2333 dated 13.11.1995, which had recommended a revised methodology namely: Ground Water Resource Estimation Methodology–1997 (GEC-97) for estimating the ground water resource for all the States in future. The Government of India also desired that a Working Group on the Estimation of Ground Water Resource and Irrigation potential from Ground Water should be constituted in each State for furnishing the relevant information to the Planning Commission and to review the GEC-97 and to suggest suitable modification, if any.

However, R and D Advisory Committee on Ground Water Estimation, Government of India, thought of refining the existing Methodology i.e. GEC-1997 and strengthening the norms for various parameters for resource estimation like specific yield, canal seepage factor, rainfall recharge factor, irrigation return flow factor etc. It was decided in the 11th Meeting of R and D Advisory Committee on Ground Water Estimation, held on 13.11.2009, to carry out the Ground Water Estimation in the alluvial areas as per the norms mentioned in the Methodology GEC-1997 with refinement of data. The Dynamic Study of Ground Water Estimation in the Punjab State in 2004, 2009, 2011 and in 2013 has been carried out on the basis of GEC-97 Methodology.

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

CWPRS, Khadakwasla, Pune involving stakeholders and experts. The major changes proposed in the workshop were (i) to change the criteria for categorization of assessment units and (ii) to remove the potentiality tag.

The Ministry of Water Resources also requested all the State Governments to constitute State Level Committees for over all supervision of assessment of ground water resources at the state level. As per guidelines of Central Ground Water Board, Punjab Government, vide Punjab Govt. Notification No. 1 / 5 / 2003 / IPJ (3) 24378-89 dated 11th Dec. 2004 **(Appendix –1.1),** has notified a committee namely: "***State Level Committee on Ground Water Resource Estimation***" for proper monitoring and Finalization of the Report. Also, vide Notification No. 1/5/2003/PJ (3)/3419 dated 9/10/2009 **(Appendix –1.2)**, Govt. of Punjab constituted a "***Sub-Committee for Ground Water Balance***" for Ground Water Resource Estimation as a standing forum for the purpose of finalization of Ground Water Assessment Report before putting up to State Level Committee .

Accordingly steps were taken to carry out the ground water resource assessment with data for the period 2004-08 for 2009, 2006-10 for 2011, 2008-12 for 2013 as per GEC-97 methodology, 2012-16 for 2017 and the data of 2015-19 for the present study as per GEC-2015. The recommendations of GEC-2015 have been suitably incorporated in the present report also.

Hydrological data observed from network created under HP-II (Aided by World Bank) has been used in this study. Under this Project a network of about 750 Ground Water observation Wells (GWOW) have been established recently in the state covering each block and this reliable data has been very useful to estimate the Ground Water Resources of each block of the state.

CHAPTER 2
HYDROGEOLOGICAL CONDITIONS OF PUNJAB

2.1 GENERAL FEATURES

Punjab is one of the North Western States of India and covers an area of 50,362 sq km falling between latitude 29º30' N to 32º32' N and longitude 73º55' E to 76º50'E. There are 22 Districts and 145 Blocks in the State. It is one of the most developed State of India where all villages are approachable by metalled roads and all the houses in villages have electricity.

The Punjab State is a flat alluvial plain except a thin belt along north eastern border, where it is mountainous and in the south western parts, where stable sand dunes are seen dotting the landscape. The slope of the plain is towards South and South West which seldom exceeds 0.4 m/km.

There are 3 perennial rivers namely Sutlej, Beas and Ravi and one non- perennial river Ghaggar in the State. These rivers feed a vast network of canal system in the State and even provide water to Haryana, Rajasthan and Jammu and Kashmir.

2.2 GEOLOGY

The alluvial deposits in the state comprise of sand, silt and clays often mixed with kankar. Sandy zones of varying grade constitute a vast ground water reservoir. The alluvial plain towards the hills is bordered by the piedmont deposits comprising Kandi and Sirowal. Immediately south-west of the hills, Kandi belt is 10 to 15 km wide followed by Sirowal which imperceptibly merges with the alluvial plain. Kandi deposit explored almost down to 450 m bgl show a gradation from boulders to clays, at places an admixture of various grades in different proportions. The Sirowal is essentially composed of finer sediments but occasional gravel beds are also encountered. The saturated sand, gravel or boulder beds constitute the aquifers. **(PLATE 1)**

2.3 HYDROMETEOROLOGY

2.3.1. Climate

The climate of the State is semi-humid to semi-arid in the North, arid in the South and southwest and semi-arid in the remaining part of the State. The state experiences four seasons in the year namely, cold season from November to March, hot season from April to June, southwest monsoon season from last week of June to mid of September and post monsoon season from September to beginning of November. During cold weather season, seasons of western disturbances affect the climate of the state and bring rainfall of light intensity.

The State has well-defined rainy period from July to September. There is about 80% rainfall during this period due to South-West Monsoon. Long dry spells are often experienced necessitating irrigation from man-made systems for agriculture.

2.3.2 Rainfall Distribution

There are two periods of rainfall in the state. The southwest monsoon season, the principal source of ground water sets in last week of June and withdraws towards end of September and constitutes about 80% of annual average rainfall. Another period of rainfall is winter rain from December to March is about 20% of total rainfall which is mostly absorbed into the soil.

The rainfall distribution in Punjab State is erratic both in time and space. The annual rainfall in the state varies from about 1000 mm in the northeast to less than 300 mm in the southwest. The areas to the north of Gurdaspur and near the Shivalik hills receive maximum amount of rainfall while the areas situated in the southwestern side of Punjab (Fazilka) receive minimum amount of rainfall. In the central part of the state, average long term rainfall varies from 400 mm to 600 mm. The highest and the lowest annual average rainfall in the state for the year 2019 are recorded in Gurdaspur and Ferozepur districts which are 1201 mm and 245 mm respectively. Isohyets for the year 2019 are attached as **FIG- 1.**

Average annual rainfall in recent past has been quite low as compared to that in the earlier years as is clear from data given below :-

YEAR	AVERAGE ANNUAL RAINFALL (in mm)
1970	672 mm
1980	739 mm
1990	754 mm
1997	710 mm
1998	477 mm
1999	392 mm
2000	392 mm
2001	463 mm
2002	315 mm
2003	460 mm
2004	375 mm
2005	448 mm
2006	418 mm
2007	438 mm

2008	529 mm
2009	385 mm
2010	472 mm
2011	480 mm
2012	366 mm
2013	620 mm
2014	385 mm
2015	547 mm
2016	427 mm
2017	493 mm
2018	598 mm
2019	579 mm

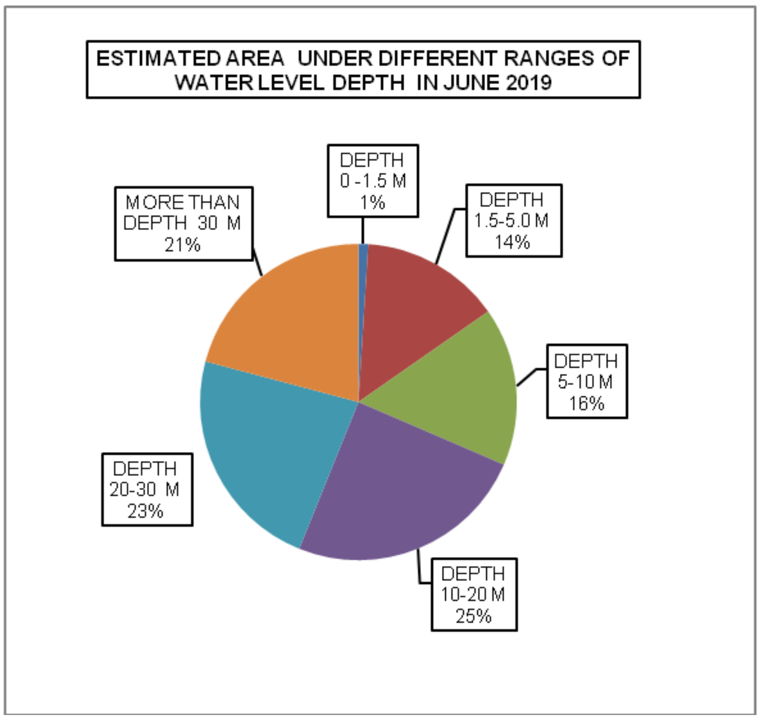
2.4 HYDROGEOLOGY

Ground water levels in Punjab State vary from almost near surface to about 60 m bgl. The deep water levels are recorded in Kandi belt. Water logging conditions exist in some parts of south-western districts. In the remaining part of Punjab the water table varies from 3 to 40 m bgl approximately. The master ground water slope is towards southwest. Most of the shallow tubewells have ground water draft per year varying from 0.5 to 2.921 Ham (electric) and 0.288 to 1.873 Ham (diesel) and are capable of commanding 1 to 3 Hectare of land per tube-well. There is significant variation in quality of ground water with depth, especially in the south western parts.

2.5 GROUND WATER LEVEL FLUCTUATIONS/ TRENDS

2.5.1 Depth to Ground Water Level – June 2019

Minimum water level depth of 0.79 mbgl has been observed in block Abohar of district Fazilka and maximum depth of 65.10 mbgl has been observed in block Sardulgarh of district Mansa. Water level up to 1.50 mbgl has been estimated in about 1% area of the State, mainly in districts Faridkot, Fazilka and Sri Muktsar Sahib. Shallow water level in range from 1.50 to 5.00 mbgl has been encountered in an area of about 14% of the State, mainly in districts Faridkot, Fazilka, Gurdaspur, Hoshiarpur, Pathankot, Muktsar & Ropar. Water levels in the range 5-10 mts has been encountered in about 16% area of the State, mainly in districts, Bathinda, Faridkot, Fazilka, Ferozepur, Gurdaspur, Hoshiarpur, Kapurthala, Mansa, Mohali and Ropar. Moderate water levels in the range 10 to 20m depth have been observed in an area of about 25% falling mainly in the districts of Amritsar, Bathinda, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, Mansa ,Nawan Shahr, and Tarn-Taran. Water level in the range of 20-30 m depth has been observed in about 23% area mainly in districts Barnala, Bathinda, Fatehgarh Sahib, Hoshiarpur, Jalandhar, Ludhiana, Kapurthala, Moga, Patiala and Sangrur. Water level more than 30 m has been noticed in about 21% area , mainly in districts Barnala, Hoshiarpur,Moga, Jalandhar, Patiala and Sangrur.

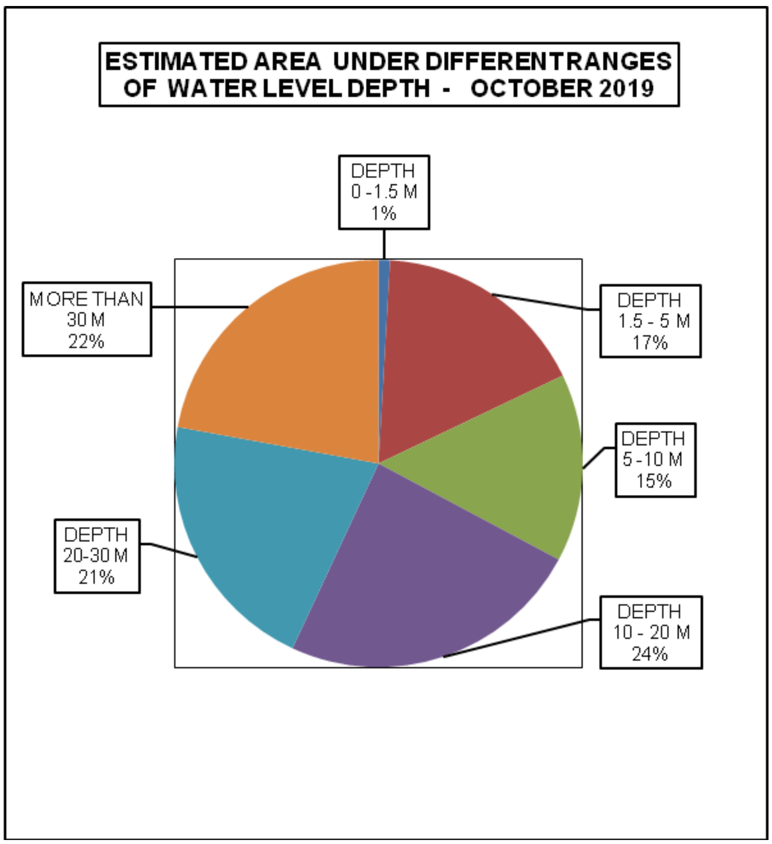


2.5.2 Depth to Ground Water Level – October 2019

The depth to ground water level during October 2019 varies from 0.53 m in Kot Bhai block of Sri Muktsar district to 67.27 m in Sardulgarh block of Mansa district. Data for this period reveals that water level upto 1.50 mbgl has been observed in about 1% estimated area of the states, mainly in districts Sri Muktsar Sahib, Ropar and Hoshiarpur, and in some pockets of districts Gurdaspur, Pathankot, and Patiala. Shallow water level in range from 1.50 to 5.00 mbgl has been encountered in about 17% estimated area mainly in districts Faridkot, Fazilka, Gurdaspur, Pathankot, Ropar , S.A.S. Nagar and Sri Muktsar Sahib and in some pockets of districts Ferozepur, Hoshiarpur, Ludhiana and Patiala.

Ground Water Level Depth in the range of 5-10 mbgl has been encountered in about 15% estimated area, mainly in districts Bathinda, Faridkot, Ferozepur, Gurdaspur, Mansa and Ropar. Ground Water Level Depth in the range of 10-20 mbgl has been encountered in about 2% estimated area, mainly in districts Amritsar, Bathinda, Ferozepur, Hoshiarpur, Kapurthala, Ludhiana, Mansa, S.B.S. Nagar (Nawan Shahr), Ropar and Tarn-Taran.

Deep water level of 20-30 mbgl been observed in about 21% estimated area of State mainly in parts of districts Barnala, Bathinda, Fatehgarh Sahib, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, Moga, Patiala and Tarn-Taran. Deeper water level of 30m or more has been estimated in about 22% estimated area of the state comprising parts of districts Barnala, Jalandhar, Moga, Patiala and Sangrur.

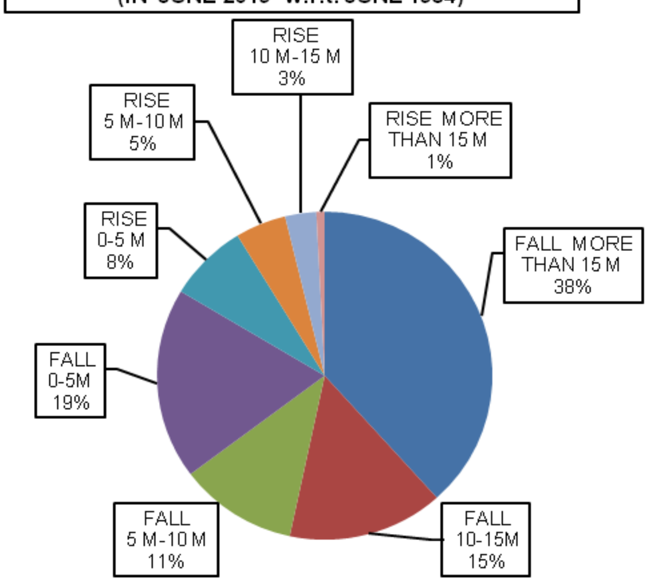


2.5.3 Ground Water Level Fluctuation In June 2019 W.R.T. June 1984

Minimum fall of 0.09 m has been noticed in block Bathinda of district Bathinda and maximum fall of 36.15 m has been noticed in block Rajpura of district Patiala, whereas minimun rise of 0.04 m has been noticed in block Gurdaspur of district Gurdaspur and maximum rise of 20.70 m has been noticed in block Talwara of district Hoshiarpur.

It is observed that fall of water level of more than 15m occurs in about 38 % area, mainly in parts of districts, Barnala, Bathinda, Fatehgarh Sahib, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, Moga, Patiala, Sangrur and Tarn-Taran. Fall of water level between 10m-15m is estimated in about 15% area mainly in parts of districts, Amritsar, Faridkot, Fatehgarh Sahib, Ferozepur, Jalandhar, Hoshiarpur, Ludhiana, Mansa, Nawan Shahr and Tarn-Taran. Fall of water level between 5m-10m is encountered in about 11 % area, mainly in parts of districts, Amritsar, Faridkot, Ferozepur, Gurdaspur, Hoshiarpur, Mansa, Nawan Shahr and Tarn-Taran. In about 19% area of the state fall of water level upto 5 m is estimated, mainly in parts of districts Faridkot, Fazilka, Ferozepur, Gurdaspur, Hoshiarpur, Kapurthala, Ludhiana, Mohali, Muktsar and Ropar. Rise of water level between 0-5m is estimated in about 8 % area, mainly in parts of districts Bathinda, Fazilka, Gurdaspur, Hoshiarpur, Ropar, Sri Muktsar Sahib and Pathankot. Rise of water level between 5m-10m is estimated in about 5 % area, mainly in parts of districts Bathinda, Fazilka, Muktsar, Gurdaspur and Pathankot and Mohali. Rise of water level between 10m-15m is estimated in about 3% area, mainly in parts of districts Fazilka, Bathinda, Muktsar and Pathankot. Rise of water level of more than 15m is encountered in about 1% area, mainly in parts of districts Muktsar and Hoshiarpur.

Fig.-3
ESTIMATED AREA UNDER DIFFERENT RANGES OF FALL / RISE OF GROUND WATER LEVEL (IN JUNE 2019 w.r.t. JUNE 1984)



2.5.4 Yearly Rate of Fall / Rise of Ground Water Level in June 2019 w.r.t. June 1984

Higher districtwise yearly rate of fall of ground water level, more than 0.50 m per year, has been noticed in districts Sangrur, Barnala, Patiala, Moga and Jalandhar. Moderate districtwise yearly rate of fall of ground water level has been found in districts Fatehgarh Sahib, Bathinda, Tarn-Taran, Kapurthala, Mansa, Hoshiarpu, Ludhiana, Ferozepur and S.B.S. Nagar. In some of the districts , namely Ropar, Gurdaspur, Pathankot, S.A.S.Nagar, Hoshiarpur, Mansa, Fazilka, Bathinda and Sri Muktsar Sahib fall of Ground Water Level in some area and rise of Ground Water Level in some other area of the respective district has been noticed.

Some blocks have recorded higher blockwise yearly rate of fall of ground water level, more than 0.70 m per year. These blokcs are, Barnala, Mahal Kalan & Sehna in district Barnala, Jalandhar-East and Jalandhar-West in district Jalandhar, Moga - I & Nihal Singh Wala in Moga district, Bhuner Heri, Patran, Samana and Sanaur in Patiala district, Andana, Bhawanigarh, Dhuri , Lehragaga, Sangrur, Sherpur and Sunam in district Sangrur. Few blocks have shown mixed trend in the block, fall in some area of the block and rise in some other area of the respective blocks. These blocks are, Bathinda and Maur of district Bathinda, Fazilka and Khuyian Sarwar of district Fazilka, Dhariwal, Dina Nagar ,Gurdaspur and Sri Hargobindpur of district Gurdaspur, Mukerian and Talwara of district Hoshiarpur, Jhunir of district Mansa, Pathankot of district Pathankot, Ghanaur of district Patiala, Anandpur Sahib and Morinda of district Ropar, Dera Bassi and Kharar of district S.A.S.Nagar, Malout of district Sri Muktsar Sahib.

2.6 GROUND WATER QUALITY

Increasing water pollution due to urbanization, industrialization and increased use of fertilizers and pesticides is causing water quality deterioration of surface and groundwater resources. Groundwater at Shallow depth is largely contaminated caused by surface water pollution. The physico-chemical characteristics of shallow groundwater in the State indicate wide variations in mineral contents. The quality of groundwater is classified as Fit, Marginal and Unfit on the basis of Electrical Conductivity (E.C.) and Residual Sodium Carbonate (R.S.C.) which is indicative of salinity and alkalinity effect. Nearly 50-60% of the groundwater up to 60 meters depth in the State is fresh and fit and generally found in North, Northeastern and Central parts of the State comprising of districts of Amritsar, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Nawanshahar, Ropar, Ludhiana, Fatehgarh Sahib and SAS Nagar. Nearly 20-30% of the groundwater generally found in

Northwestern and Central parts of the State comprising of districts of Tarn Taran, Patiala, Sangrur, Barnala and Moga is moderately saline and of marginal quality. About 15-25% of the groundwater is saline/alkaline and not fit for irrigation use and generally found in isolated patches in South and Southwestern parts of the State in districts of Muktsar, Bathinda, Mansa and Sangrur. Groundwater in South and Southwestern districts of the State namely Faridkot, Ferozepur, Muktsar, Bathinda, Mansa, Barnala and Sangrur contain varying concentration of soluble salts and its use for irrigation adversely effects agricultural production. Depth-wise study in South and Southwestern part of the State reveals that quality of native groundwater is largely fresh/fit at shallower depths and generally deteriorates with depth. The study shows that groundwater quality is fresh and fit in 60% of area at 10 metres depth which decreases to nearly 30% and 18% at 35 metres and 60 metres depth respectively. Similarly, groundwater quality is saline/ alkaline in nearly 17% of the area at depth of 10 metres which increases to 50% and 52% at the depth of 35 and 60 metres respectively. Ground water quality problem is more severe in terms of salinity in the districts of Muktsar, Mansa and Bathinda. Contaminations notably of Nitrate, Fluoride, heavy metals and radio-active element such as uranium in groundwater has been reported in significant proportion beyond the permissible limit in South and Southwestern part of the State by various agencies.

In general about 60% of ground water is fresh and of good quality mostly in districts of Amritsar, Fatehgarh Sahib, Nawan Shahr, Gurdaspur, Ropar, Hoshiarpur, Jalandhar, Ludhiana and Kapurthala, nearly 30% is saline/alkaline (marginal to moderate) in districts of Patiala, Moga, Ferozepur and Mansa and nearly 10% is saline/alkaline which is unsafe for all purposes mostly in districts of Faridkot, Muktsar, Bathinda and Sangrur.

CHAPTER 3

GROUND WATER RESOURCES ESTIMATION METHODOLOGY

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

3.1 PERIODICITY OF ASSESSMENT

Keeping in view of the rapid change in Ground Water Extraction, the committee recommends more frequent estimation of Ground Water Resources. The committee observes that the comprehensive assessment of Ground Water Resources is a time intensive exercise. Hence as a tradeoff, it recommends that the resources should be assessed once in every three years. As per the present practice, there is a considerable time lag between assessment and publication of the results. Hence the committee recommends to make all out efforts to reduce the time lag and the results may be reported with in the successive water year.

3.2 GROUND WATER ASSESSMENT UNIT

This methodology recommends aquifer wise ground water resource assessment. An essential requirement for this is to demarcate lateral as well as vertical extent and disposition of different aquifers. A watershed with well-defined hydrological boundaries is an appropriate unit for ground water resource estimation if the principal aquifer is other than alluvium. Ground water resources worked out on watershed as a unit, may be apportioned and presented on administrative units (block/ taluka/ mandal/ firka). This would facilitate local administration in planning of ground water management programmes. Areas occupied by unconsolidated sediments (alluvial deposits, aeolian deposits, coastal deposits etc.) usually have flat topography and demarcation of watershed boundaries may not be possible in such areas. Until Aquifer Geometry is established on appropriate scale, the existing practice of using watershed in hard rock areas and blocks/ mandals/ firkas in soft rock areas may be continued.

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

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

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

3.3 GROUND WATER ASSESSMENT OF UNCONFINED AQUIFER

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

3.3.1 Dynamic Ground Water Resources

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

Inflow – Outflow = Change in Storage (of an aquifer) **1**

Equation 1 can be further elaborated as -

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

Where,

ΔS – Change in storage

R_{RF} – Rainfall recharge

R_{STR}- Recharge from stream channels

Rc – Recharge from canals

R_{SWI} – Recharge from surface water irrigation

R_{GWI}- Recharge from ground water irrigation

R_{TP}- Recharge from Tanks and Ponds

R_{WCS} – Recharge from water conservation structures

VF – Vertical flow across the aquifer system

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

GE-Ground Water Extraction

T- Transpiration

E- Evaporation

B-Base flow

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

3.3.2 Rainfall Recharge

It is recommended that ground water recharge should be estimated on ground water level fluctuation and specific yield approach since this method takes into account the response of ground water levels to ground water input and output components. This, however, requires adequately spaced representative water level measurement for a sufficiently long period. It is proposed that there should be at least three spatially well distributed observation wells in the assessment unit, or one observation well per 100 sq. Km. Water level data should also be available for a minimum period of 5 years (preferably 10years), along with corresponding rainfall data. Regarding frequency of water level data, three water level readings during pre and post monsoon seasons and in the month of January/ May preferably in successive years, are the minimum requirements. It would be ideal to have monthly water level measurements to record the peak rise and maximum fall in the ground water levels. In units or subareas where adequate data on ground water level fluctuations are not available as specified above, ground water recharge may be estimated using rainfall infiltration factor method only. The rainfall recharge during non-monsoon season may be estimated using rainfall infiltration factor method only.

3.3.3 Ground water level fluctuation method

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

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

Where,

ΔS – Change in storage

R_{RF} – Rainfall recharge

R_{STR}- Recharge from stream channels

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

R_{GWI}- Recharge from ground water irrigation

R_{TP}- Recharge from tank and ponds

R_{WCS} – Recharge from water conservation structures

VF – Vertical flow across the aquifer system

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

GE-Ground water Extraction

T- Transpiration

E- Evaporation

B-Base flow

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

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

A couple of important observations in the context of water level measurement must be followed. It is important to bear in mind that while estimating the quantum of ground water extraction, the depth from which ground water is being extracted should be considered, and certain limit should be fixed. First, by estimating recharge by Water Level Fluctuation method, rise in water level (pre to post monsoon Water Level observed in a dug well) is considered and in estimating the draft from dug wells and bore wells (shallow and deep) drop in water level is considered. One should consider only the draft from the same aquifer for which the resource is being estimated.

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

$$\Delta S = \Delta h * A * S_Y \qquad 5$$

Where

ΔS – Change in storage

Δh - rise in water level in the monsoon season

A - area for computation of recharge

Sy - Specific Yield

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

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

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

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

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

Normalization of Rainfall Recharge

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

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

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

where,

Ri = Rainfall recharge estimated in the monsoon season for the i^{th} particular year

h = Rise in ground water level in the monsoon season for the i^{th} particular year

Sy =Specific yield

A = Area for computation of recharge

GE = Ground water extraction in monsoon season for the i^{th} particular year

B = Base flow the monsoon season for the i^{th} particular year

R_C = Recharge from canals in the monsoon season for i^{th} particular year

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

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

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

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

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

LF = Recharge through Lateral flow/ Through flow across assessment unit boundary in the monsoon season for the i^{th} particular year

VF – Vertical flow across the aquifer system in the monsoon season for the i^{th} particular year

T- Transpiration in the monsoon season for the i^{th} particular year

E- Evaporation in the monsoon season for the i^{th} particular year

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

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

$$R = ar \qquad 10$$

where,

R = Rainfall recharge during monsoon season

r = Monsoon season rainfall

a = a constant

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

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

Where,

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

R_i - Rainfall Recharge in the monsoon season for the i^{th} year.

r(normal) - Normal monsoon Season rainfall.

r_i - Rain fall in the monsoon season for the i^{th} year.

N - No, of years data is available.

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

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

where,

R = Rainfall recharge during monsoon season

r = Monsoon season rainfall

a and b = constants.

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

$$a = \frac{NS_4 - S_1S_2}{NS_3 - S_1^2} \qquad 13$$

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

Where

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

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

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

3.3.4 Rainfall Infiltration Factor method

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

Recharge from rainfall is estimated by using the following relationship -

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

Where,

R_{rf} = Rainfall recharge in ham

A = Area in Hectares

RFIF = Rainfall Infiltration Factor

R = Rainfall in mm

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

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

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

3.3.5 Percent Deviation

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

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

where,

Rrf (normal, wlfm) = Rainfall recharge for normal monsoon season rainfall estimated by the water level fluctuation method

Rrf (normal, rifm) = Rainfall recharge for normal monsoon season rainfall estimated by the rainfall infiltration factor method

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

- If PD is greater than or equal to -20%, and less than or equal to +20%,Rrf (normal) is taken as the value estimated by the water level fluctuation method.
- If PD is less than -20%, Rrf (normal) is taken as equal to 0.8 times the value estimated by the rainfall infiltration factor method.
- If PD is greater than +20%, Rrf (normal) is taken as equal to 1.2 times the value estimated by the rainfall infiltration factor method.

3.3.6 Recharge from other Sources

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

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

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

Where:

R_C= Recharge from Canals

WA=Wetted Area

SF= Seepage Factor

Days= Number of Canal Running Days.

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

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

Where:

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

AD= Average Discharge

Days=Number of days water is discharged to the Fields

RFF= Return Flow Factor

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

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

Where:

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

GE_{IRR}= Ground Water Extraction for Irrigation

RFF= Return Flow Factor

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

$$R_{TP} = AWSA * RF \quad 21$$

Where:

R_{TP} = Recharge due to Tanks and Ponds

AWSA= Average Water Spread Area

RF= Recharge Factor

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

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

Where:

R_{WCS} = Recharge due to Water Conservation Structures

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

RF= Recharge Factor

3.4 Lateral flow along the aquifer system (Through flow)

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

3.5 Base flow and Stream Recharge

If stream gauge stations are located in the assessment unit, the base flow and recharge from streams can be computed using Stream Hydrograph Separation method, Numerical Modelling and Analytical solutions. If the assessment unit is a watershed, a single stream monitoring station at the mouth of the watershed can provide the required data for the calculation of base flow. Any other information on local-level base flows such as those collected by research centres, educational institutes or NGOs may also be used to improve the estimates on base flows.

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

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

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

3.6 Vertical Flow from Hydraulically Connected Aquifers

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

3.7 Evaporation and Transpiration

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

Transpiration through vegetation can be estimated if water levels in the aquifer are within the maximum root zone of the local vegetation. It is recommended to compute the transpiration through field studies. Even though it varies from place to place depending on type of soil and vegetation, in the absence of field studies the following estimation can be followed. If water levels are within 3.5m bgl, transpiration can be estimated using the transpiration rates available for other areas. If it is greater than 3.5m bgl, the transpiration should be taken as zero.

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

3.8 Recharge during Monsoon Season

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

3.9 Recharge during Non-Monsoon Season

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

3.10 Total Annual Ground Water Recharge

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

3.11 Annual Extractable Ground Water Recharge (EGR)

The Total Annual Ground Water Recharge cannot be utilised for human consumption, since ecological commitments need to be fulfilled, before the extractable resources is defined. The National Water Policy, 2012 stresses that the ecological flow of rivers should be maintained. Therefore Ground water base flow contribution limited to the ecological flow of the river should be determined which will be deducted from Annual Ground Water Recharge to determine Annual Extractable Ground Water Resources (EGR). The ecological flows of the rivers are to be determined in consultation with Central Water Commission and other concerned river basin agencies.

In case base flow contribution to the ecological flow of rivers is not determined then following assumption is to be followed. In the water level fluctuation method, a significant portion of base flow is already accounted for by taking the post monsoon water level one month after the end of rainfall. The base flow in the remaining non-monsoon period is likely to be small, especially in hard rock areas. In the assessment units, where river stage data are not available and neither the detailed data for quantitative assessment of the natural discharge are available, present practice

(GEC 1997) of allocation of unaccountable natural discharges to 5% or 10% of annual recharge may be retained. If the rainfall recharge is assessed using water level fluctuation method this will be 5% of the annual recharge and if it is assessed using rainfall infiltration factor method, it will be 10% of the annual recharge. The balance will account for Annual Extractable Ground Water Resources (EGR).

3.12 Estimation of Ground Water Extraction

Groundwater draft or extraction is to be assessed as follows.

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

Where,

GE_{ALL}=Ground water extraction for all uses

GE_{IRR}=Ground water extraction for irrigation

GE_{DOM} =Ground water extraction for domestic uses

GE_{IND} = Ground water extraction for industrial uses

3.12.1 Ground Water Extraction for Irrigation (GE_{IRR}): The single largest component of the groundwater balance equation in large regions of India is the groundwater extraction and, the precise estimation of ground water extraction is riddled with uncertainties. Therefore it is recommended that at least two of the three methods for estimation of ground water extraction may be employed in each assessment sub unit. The methods for estimation of ground water extraction are as follows.

Unit Draft Method: – In this method, season-wise unit draft of each type of well in an assessment unit is estimated. The unit draft of different types (eg. Dug well, Dug cum bore well, shallow tube well, deep tube well, bore well etc.) is multiplied with the number of wells of that particular type to obtain season-wise ground water extraction by that particular structure. This method is being widely practiced in the country. There are several sources which maintain records on well census. These include Minor Irrigation Census conducted by MoWR, RD, GR, Government of India, and data maintained at the Tehsil level. It is recommended that a single source of well census should be maintained for resources computation at all India level. Minor Irrigation Census of MoWR, RD, GR would be the preferred option.

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

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

Direct metering of ground water draft in select irrigation and domestic wells and in all wells established for industrial purpose may be initiated. Enforcing fitting of water meters and recording draft in all govt. funded wells could also be a feasible option. The unit drafts obtained from these sample surveys can be used to assess ground water extraction. In addition to metering, dedicated field sample surveys (instantaneous discharge measurements) can also be taken up.

3.12.2 Ground Water Extraction for Domestic Use (GE_{DOM}): There are several methods for estimation of extraction for domestic use (GE_{DOM}). Some of the commonly adopted methods are described here.

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

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

$$GE_{DOM} = \text{Population} \times \text{Consumptive Requirement} \times Lg \qquad 24$$

Where,

Lg = Fractional Load on Ground Water for Domestic Water Supply

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

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

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

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

$$GE_{IND} = \text{Number of industrial units} \times \text{Unit Water Consumption} \times Lg \qquad 25$$

Where,

Lg = Fractional load on ground water for industrial water supply

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

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

3.13 Stage of Ground Water Extraction

The stage of ground water extraction is defined by,

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

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

3.14 Validation of Stage of Ground Water Extraction

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

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

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

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

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

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

3.15 Categorisation of Assessment Units

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

3.15.1 Categorization of Assessment Units Based on Quantity: The categorization based on status of ground water quantity is defined by Stage of Ground Water extraction as given below:

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

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

3.15.2 Categorization of Assessment Units Based on Quality

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

3.16 Allocation of Ground Water Resource for Utilisation

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

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

Where

Alloc= Allocation for domestic water requirement

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

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

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

3.17 Net Annual Ground Water Availability for Future Use

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

3.18 Additional Potential Resources under Specific Conditions

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

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

Where

Q = Spring Discharge

No of days= No of days spring yields.

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

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

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

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

Where

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

A = Area of shallow water table zone.

S_Y = Specific Yield

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

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

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

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

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

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

Where

N = No of Days Water is Retained in the Area

A = Flood Prone Area

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

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

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

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

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

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

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

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

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

Where,

SGWR = Static or in-storage Ground Water Resources

A = Area of the Assessment Unit

Z_2 = Bottom of Unconfined Aquifer

Z_1 = Pre-monsoon water level

S_Y = Specific Yield in the In storage Zone

3.21 Assessment of Total Ground Water Availability in Unconfined Aquifer

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

3.22 GROUND WATER ASSESSMENT OF CONFINED AQUIFER SYSTEM

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

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

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

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

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

Where

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

S = Storativity

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

Δh= Change in Piezometric head (m)

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

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

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

3.22.1 Dynamic Ground Water Resources of Confined Aquifer

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

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

Where

Q_D = Dynamic Ground Water Resource of Confined Aquifer (m^3)

S = Storativity

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

Δh = Change in Piezometric head (m)

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

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

3.22.2 In storage Ground Water Resources of Confined Aquifer

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

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

Where

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

S = Storativity

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

Δh = Change in Piezometric head (m)

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

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

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

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

Where

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

S = Storativity

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

Δh = Change in Piezometric head (m)

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

h_0 = Bottom of the Top Confining Layer (m amsl)

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

3.22.3 Assessment of Total Ground Water Availability of Confined Aquifer

If the confined aquifer is being exploited, the Total Ground Water Availability of the confined aquifer is the sum of Dynamic Ground Water Resources and the In storage ground water resources of that confined aquifer whereas if it is not being exploited, the Total Ground Water Availability of the confined aquifer comprises of only one component i.e. the In storage of the confined aquifer.

3.23 GROUND WATER ASSESSMENT OF SEMI-CONFINED AQUIFER SYSTEM

The Assessment of Ground Water Resources of a semi-confined aquifer has some more complications. Unless and until, it is well studied that the recharge to this is not computed either in the over lying unconfined aquifer or underlying/overlying semi confined aquifers, it should not be assessed separately. If it is assessed separately, there is a possibility of duplication of estimating the same resource by direct computation in one aquifer and as leakage in the other aquifer. As it is advisable to under estimate rather than to overestimate the resources, it is recommended not to assess these resources separately as long as there is no study indicating its non-estimation. If it is found through field studies that the resources are not assessed in any of the aquifers in the area, these resources are to be assessed following the methodology similar to that used in assessing the resources of Confined aquifers.

3.24 TOTAL GROUND WATER AVAILABILITY OF AN AREA

The Total Ground water availability in any area is the Sum of Dynamic Ground Water Resources, the total static/ in-storage ground water resources in the unconfined aquifer and the dynamic and In-storage resources of the Confined aquifers and semi confined aquifers in the area.

CHAPTER – 4

PROCEDURE FOLLOWED IN THE PRESENT ASSESSMENT INCLUDING ASSUMPTIONS

4.1 DYNAMIC GROUND WATER RESOURCES ESTIMATION

The Dynamic Ground Water Resource of Punjab State has been assessed as per GEC-2015 Methodology by taking Block as a Unit of Assessment. At present, there are total 150 Blocks in Punjab State which represents the entire geographical area of the state. The block boundaries and other technical details in respect of newly carved out 12 blocks have been provided by Central Ground Water Board, NWR, Chandigarh. The present assessment of Dynamic Ground Water Resource has been carried out for which the multidisciplinary data have been provided by the following Agencies:

1. Irrigation Department, Punjab.
2. Agriculture Department Punjab.
3. Public Health Department, Punjab.
4. Central Ground Water Board, North Western Region, Chandigarh.
5. Department of Industries, Punjab.
6. Indian Meteorological Department.
7. Census Department, Govt. of India, Sector 19, Chandigarh.

The water level data for the year 2016-20 has been used for calculation of average monsoon recharge which has been normalized as per GEC-2015 guidelines. The unit draft figures for the 150 blocks have been made available by Agriculture Department. The block wise figures of population provided by the Census Department GOI, has been used as per census 2011. The per capita consumption of water is taken as 100 lpd for assessing the domestic use requirement of ground water as per detailed deliberations held during various meetings. The percentage increase in district-wise population w.r.t. 2011 census has been applied for calculating the present and future domestic requirements. The block-wise water use requirement figures for Industry as supplied by Department of Industries, Punjab for the year 2003 have been used by projecting the data on pro-rata basis of population growth rate i.e. 1.5% per annum. As many new changes/modifications have been incorporated in the network of canals in the Punjab State, so the canal data has been procured from the various Canal Divisional Offices and has been updated and used in the calculations.

The value of Specific Yield for calculating the Dynamic Ground Water Resource of the State has been taken as 12% which is within the norms provided in the guidelines of GEC-2015 issued by Ministry of Water Resources, Govt. of India.

While calculating the ground water resources of the State, GEC -2015 methodology along with its amendments has been used with the following parameters/assumptions:-

1. In the primarily agrarian State of Punjab, it is not possible to differentiate between Command Area and Non-Command Area, so no separate computation of Command Area and Non-Command Area has been taken.
2. Even in the saline areas, there is canal and tube-well network and judicious mixing of the two sources of water is being done to raise different crops in these areas. No separate canal and Tubewell Irrigation data and its draft data figures are available for these areas. As such, these areas cannot be differentiated and has been clubbed for calculating the dynamic ground water recharge.
3. The various dependency factors for calculation of domestic ground water consumption have been taken from the GEC-2015 Methodology of CGWB.
4. The various modifications have been incorporated on the basis of the various inputs made available from CGWB, Agriculture Department of Punjab, Punjab Agricultural University, Ludhiana and other agencies associated with this estimation. The extracts of minutes of "*Meeting of Technical Sub Committee on Water balance of Punjab State*" **(Appendix 2.1 and 2.2)** concerning with present estimation are as follows:-

   i. A uniform value of Specific Yield and Rainfall Infiltration has been adopted instead of soil related value. The value of Sp. Yield and Rainfall Infiltration has been taken as 12% and 22% respectively for the Punjab State.

   ii. The canal seepage factor for un-lined canals may be taken as 17.5 ha m/day/million sq. mts. and 3.5 ha m/day/million sq. mts. for lined canals as recommended by GEC-2015.

   iii. For this Report, the Agriculture Department has supplied the block wise areas under Paddy/Non-Paddy crops and unit draft figures on pro-rata basis.

   iv. The Block-wise data of industrial draft figures was not supplied by the Department of Industries , so the industrial draft figure has not been taken in the present report.

v. Domestic draft has been calculated on population basis @ 100 lpd and also includes demand for next 25 years. The ground water dependency factor of 0.8 is taken into consideration for estimation of future requirement.

vi. G.E.C- 2015 requires that the average value of water level at 5 different points in a block be considered for calculation of seasonal fluctuation. The same condition has been applied in the present study.

vii. Whole of the geographical area of block, including saline area, has been taken as ground water worthy area in the Ground Water Estimation as surface water irrigation is being supplemented by the ground water in the State of Punjab even in the saline areas.

viii. Updated Canal data, as received from the Canal Circle / Division Offices during 2019-20 has been used in the estimation.

ix. Blocks where more than 50% of its geographical area is having groundwater level less than 5 m (below ground level) have been considered as "Safe".

x. Keeping in view the high ground water draft figures for agriculture and increasing domestic needs due to urbanization, the small size of the blocks and the agrarian character of the State, it is difficult to differentiate between command and non-command areas in the State as 97% of cultivated area is under irrigation either by tubewells or canal water or both and even in the saline areas, surface water irrigation is being supplemented by the ground water. Keeping this in view, it is decided to compute the ground water estimation by clubbing both command and non-command areas.

CHAPTER – 5

COMPUTATION OF GROUND WATER RESOURCES ESTIMATION IN PUNJAB

5.1 SALIENT FEATURES OF DYNAMIC GROUND WATER RESOURCES ASSESSMENT

Type of Assessment Units	Blocks
No. of Assessment Units (Blocks) taken for Study	150
Years of Collection of Data (5 years)	2015-19
Year of Projection of Report	2020
No. of Over-Exploited Blocks	117
No. of Critical Blocks	06
No. of Semi-Critical Blocks	10
No. of Safe Blocks	17

Out of total 150 Blocks taken for study, 117 Blocks (78%) are "Over-Exploited", 6 Blocks (4%) are "Critical", 10 Blocks (7%) are "Semi-Critical" and 17 Blocks (11%) are in "Safe" category. (**PLATE 3**) The percentage of blocks under different categories is represented as Pie Chart in **FIG-7.** The water level trends have been computed for last 10 years from 2009-2019 data.

5.2 METHOD ADOPTED FOR COMPUTING RAIN FALL RECHARGE DURING MONSOON SEASON

The administrative block has been taken as assessment unit and for computing the block-wise rainfall recharge during monsoon season. Rainfall Infiltration Factor (RIF) Method has been mostly applied as the difference of computing this with Water Level Fluctuations (WLF) Method is more than 20%. WLF Method has been applied only on 13 blocks out of total 150 blocks taken for study.

5.3 GROUND WATER RESOURCE ASSESSMENT

The ground water resource assessment of Punjab State has been computed as per GEC-2015 Methodology and the computations and its various details have been attached as **Annexure-1 to Annexure-5**. All the computations for the ground water resources Assessment have been carried out through a Web based application namely "India Ground water Resources Estimation System

(IN-GRES)” developed jointly by central Ground water Board and IIT Hyderabad. The abstract of Dynamic Ground Water Assessment is as follows:-

Net Annual Ground Water Availability	20, 59,011 Ham	16.68 MAF
Existing GW Draft for Irrigation	32, 80,208 Ham	26.57 MAF
Existing GW Draft for Domestic and Industrial Use	1,05,261 Ham	0.85 MAF
Existing GW Draft for All Uses	33, 85,476 Ham	27.43 MAF
Net GW Availability for Future Irrigation Development in Safe, Semi-critical, critical and Potential Resources in water logged areas	1,61,641 Ham	1.31 MAF
Average Stage of GW Extraction of State	164%	

- The Net Annual Ground Water Availability for the period 2016-20 works out to be 20, 59,011 Ham (16.68 MAF). The Average Normal Recharge figures for all the districts from rainfall and other sources have been calculated and indicated in **Table- 1 and FIG-8**.
- The gross ground water draft for all uses has been worked out to be 33, 85,476 Ham (27.43 MAF). The existing gross ground water draft for all Uses has been observed to be maximum in Ludhiana district as 3,46,729 Ham and minimum in Pathankot district as 19,872 Ham. The district-wise ground water draft for irrigation and for other uses (domestic and industrial use) is given in **Table- 2 and FIG- 9.** Domestic and Industrial water use demand for next 25 years have been taken in this estimation.
- The district-wise ground water availability of Punjab State vis-a-vis the ground water draft and net ground water availability for future irrigation Development have been depicted in **Table-2** and **FIG-10**. It has been observed that the net ground water availability for future irrigation development in the state is ‘NIL’ in over-exploited blocks of the State but in Safe, Semi-critical, critical and in water logged areas it has been assessed as 1,61,641 Ham (1.31 MAF) .
- The block-wise stage of ground water development varies from 27 % in Lambi Block of Muktsar district to maximum of 342 % in Dirba block of Sangrur district respectively (**Annexure-1**.).
- The district wise stage of ground water extraction has been computed and given in **Table-2** and shown in **FIG-11**. It varies from 43% in Muktsar district to 301 % in Sangrur district.

- Shallow water level area having depth to water table less than 5 m bgl in the State is about 5723 km^2 which is lying mainly in the south-western districts of the Punjab State.

5.4 GROUND WATER ASSESSMENT COMPARISON OF VARIOUS STUDIES

The number of Over-Exploited Blocks has increased with time as per various Ground Water Estimation Studies carried out from time to time, as shown below:

Study Year →	**1984**	**1986**	**1989**	**1992**	**1999**	**2004**	**2009**	**2011**	**2013**	**2017**	**2021**
Category of Blocks ↓											
Over-exploited	53	55	62	63	73	103	110	110	105	109	117
Critical	7	9	7	7	11	5	3	4	4	2	6
Semi Critical	22	18	20	15	16	4	2	2	3	5	10
Safe	36	36	29	33	38	25	23	22	26	22	17
Total	**118**	**118**	**118**	**118**	**138**	**137**	**138**	**138**	**138**	**138**	**150**

Net Annual Ground Water Availability for Irrigation Development comparison of various studies

Year	**Net Annual Ground Water Availability for Future Irrigation Development**	
	Ham	**MAF**
1984	301929	2.44
1989	67914	0.55
1992	103177	0.84
1999	27101	0.22
2004	(-) 988926	(-) 8.01
2009	(-) 1457475	(-) 11.81
2011	(-) 1483189	(-) 12.02
2013	(-) 1162414	(-) 9.42
2017	0	0
2021	0	0

5.5 SPATIAL VARIATION OF GROUND WATER RECHARGE AND DEVELOPMENT SCENARIO

The annual ground water recharge and the method adopted for computing monsoon recharge for previous 2017 study and for present 2021 study has been compared in **Table-IV.** Similarly, Categorization for Future Ground Water Development and the Stage of Ground Water development for each block and district of this study as a whole has also been compared with previous 2017 study as shown in **Table-3.**

5.6 COMPARISON WITH EARLIER GROUND WATER RESOURCE ESTIMATE

It has been observed that out of the total area of the State (50, 36,200 Ha) the area where ground water table is more than 10m deep has been continuously increasing. It was 7,49,600 Ha (14.9%) in June 1989; 10,23,400 Ha (20%) in June 1992; 14,15,100 Ha (28%) in June 1997; and 22,07,300 Ha (44%) in June 2002; ; 30,41,800 Ha (61%) in June 2008; 32,36,100 Ha (64%) in June 2010; 33,10,400 Ha (65%) in June 2012 ; 33,177,00 Ha (65%) in June 2016 and 34,246,00 Ha (68%) in June 2019. Water level as observed in June 2015 and June 2019 has gone down in general thereby showing decline of water levels. The present Ground Water Estimation shows a little improvement in ground water scenario in comparison to previous report as overall Stage of Ground Water Extraction has came down to 164% from 166 % (GWRE -2017).

CHAPTER – 6

WATER QUALITY TAG

GROUND WATER QUALITY IN PUNJAB

Evaluation of ground water quality through concentration of its physical, chemical and biological parameters is essential to determine its suitability for the intended use. It helps not only in finding its suitability; it also helps in taking effective remedial measures for its improvement on scientific lines. In most of rural and semi-urban areas of Punjab State, ground water is a major resource for drinking and irrigation uses especially in areas where surface water is inadequate or unavailable. Acknowledging the importance of this aspect of ground water, C.G.W.B., N.W.R., Chandigarh annually monitors the ground water quality through dedicated Ground Water Monitoring Stations consisting of dug wells and/or hand pumps of shallow depth.

6.1 Sampling & Analysis

During May 2019, 302 nos. ground water samples were collected from these structures spread uniformly over 22 districts of Punjab and no specific treatment such as acidification or filtration was given at the time of sampling. The water samples were analyzed for major cations (Ca, Mg, Na, K) and anions (CO_3, HCO_3, Cl, NO_3, SO_4) in addition to pH, EC, F, SiO_2, PO_4 and TH as $CaCO_3$ in Regional Chemical Laboratory by following 'Standard analytical procedures' as given in APHA 2017. Results of chemical analysis of water samples are placed in Annexure-I

6.2 Composition of Water

Chemical analysis shows that the ground water is slightly to moderately alkaline in nature. The pH values range from 7.51 at Bhikhi in Mansa district to 9.10 at Badru khan in Sangrur district. Salinity of ground water is measured in terms of EC. The ground water is found to have low to very high salt content as the EC of well water ranges from 195 μS/cm at Sarna in district Pathankot to 8320 μS/cm at Abohar in district Fazilka. Hardness reported in terms of $CaCO_3$ ranges from 20 to 1490 mg/l. The lowest hardness value is found at Sultanpur Lodi in district Kapurthala and highest at Issarpur in district SAS Nagar. The concentration of calcium ranges between 4 and 360 mg/l. Calcium below detection level has not been found in the State while the highest value is observed at Issarpur in district SAS Nagar. Magnesium concentration ranges between 0 mg/l at Sultanpur Lodhi district Kapurthala and 418 mg/l at Abohar in district Fazilka. In majority of ground water samples, calcium concentration is less than 100 mg/l (98%). Calcium is very low in some districts, though it is very essential element for drinking and irrigation purposes. However, magnesium is less than the desirable limit of 30 mg/l in 46% samples and less than the maximum permissible limit of 100 mg/l for drinking waters (BIS 1991) in 95% samples. In more than half of well waters examined, Ca + Mg are the dominant cations having their concentration almost 50% of the total cation determined.

Sodium is the dominant cation in majority of ground waters of districts Bathinda, Faridkot, Ferozepur, Mansa, Moga, Muktsar, Patiala, Sangrur, SAS Nagar and Tarantaran. Its concentration varies widely from 6.7 mg/l at Sidhwan Bet district Ludhiana to 1600 mg/l at Abohar in district Fazilka. Sodium concentration is less than 100 mg/l in more than half of well waters under consideration. Potassium is found to be present in low concentration. In majority of the samples analyzed, the potassium content is less than 10 mg/l (69%). It ranges from 0.63 mg/l at Dinanagar district Gurdaspur 620 mg/l at Sarawali district Mukatsar. High concentration of potassium (>100mg/l) is found in 5.96% samples. Its higher concentration indicates contamination of ground water from various point (industry, sewage) as well as non-point sources (agriculture).

Carbonate is found in a few samples and it varies from 0 to 263 mg/l at Kunde Balal in district Mukatsar. Bicarbonate is the dominant anions and it ranges from 70mg/l Bharampur at Ropar district to 1062 mg/l at Fatta Maluka district Mansa. The Chloride concentration in ground water varies between 7.1 mg/l at Bhadaur, district Barnala and 1432 mg/l at Abohar in district Fazilka. The Sulphate (SO_4) content in ground waters was found to be 0 at several places in the State. The highest value of 2005 mg/l of Sulphate has been observed at Sito Garhi in district Fazilka. In majority of ground water samples (77%), the concentration of sulphate is below 200 mg/l. Nitrate, an indicator of domestic, irrigation and industrial contamination, is found in significant number of samples. Its concentration in groundwater ranges from <0.20 mg/l a several places to 900 mg/l at Bhaliana, Mukatsar district. The fluoride (F) content in ground water of the State is generally less than 1.0 mg/l (84%). It ranges from <0.05 at Several places in the State to 8.00 mg/l at Amisha Khalra. Phosphate concentration varies from <0.10mg/l to 0.15 mg/l while Silica concentration, measured as SiO_2, ranged between 7.00 to 31 mg/l.

The district-wise concentration range of various chemical components in ground water is depicted in Table 1.

Map Showing the Sampling point of Punjab state in **Fig.1**

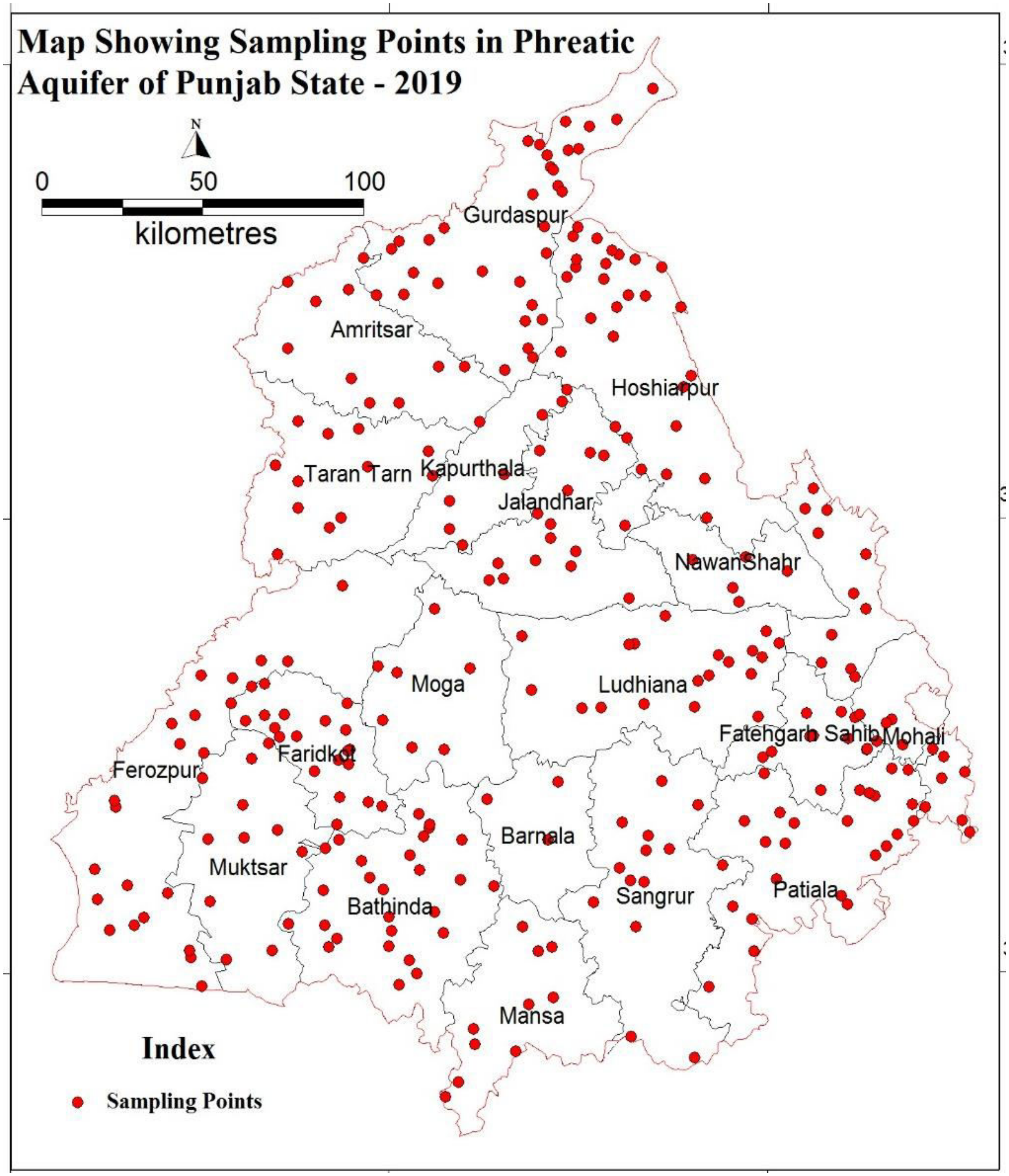


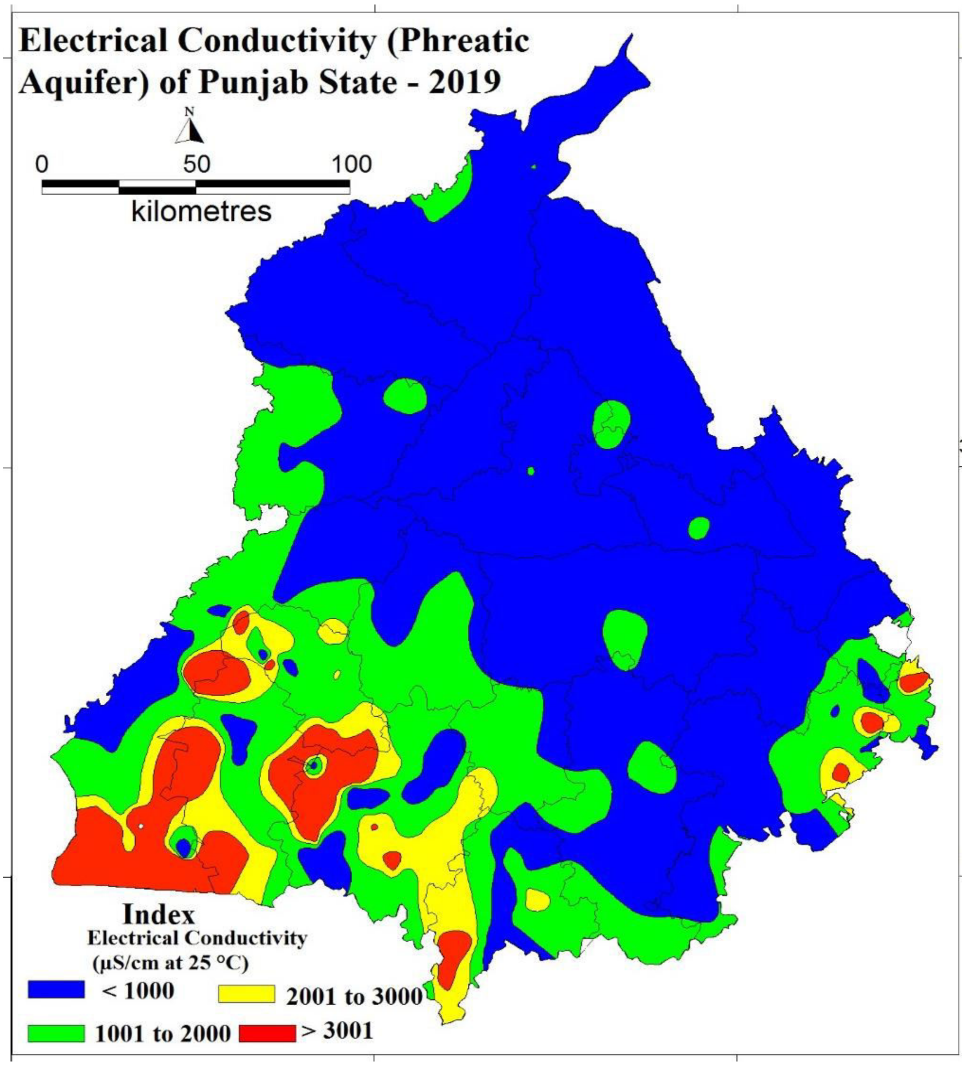
Table-1 : Range of Chemical Constituents in Groundwater of Punjab State

S. No.	District	No. of Samples	Min/Max	pH	EC* in µS/cm at 25^0C	CO3	HCO3	Cl	SO4	NO3	F	PO4	Ca	Mg	Na	K	SiO2	TH	SAR	RSC in meq/l
						mg/l														
1	Amritsar	11	Min	8.34	305	12	159	7.1	10	4	0.13	<0.10	8	2.4	30	2.2	23	60	2.39	2.41
			Max	8.90	915	72	317	78	80	48	0.57	<0.10	124	54	182	15	28	240	3.43	-3.03
2	Barnala	3	Min	8.34	305	12	159	7.1	10	4	0.13	<0.10	8	2.4	30	2.2	23	60	2.39	-3.03
			Max	8.90	915	72	317	78	80	48	0.57	<0.10	124	54	182	15	28	240	3.43	2.41
3	Bathinda	27	Min	7.90	258	0	85	11	12	1.46	0.08	<0.10	8	7.3	8.5	3.1	21	90	0.30	-22.39
			Max	8.98	6210	156	818	815	1200	554	3.8	<0.10	100	271	1120	500	28	1271	26.74	12.44
4	Faridkot	21	Min	8.14	410	0	104	35	70	3.9	0.14	<0.10	4	2.4	37	5	14	50	1.20	-9.45
			Max	8.95	4590	190	756	588	1045	180	4.6	<0.10	114	117	920	120	28	767	41.30	15.74
5	Fatehgarh Sahib	11	Min	8.15	470	0	168	21	0	2	0.19	<0.10	4.20	15	28	7	9	126	0.78	-0.75
			Max	8.77	1940	27	629	99	292	52	0.69	<0.10	42	72	361	26	15	315	10.79	6.97
6	Fazilka	15	Min	7.82	745	0	74	28	43	1.5	0.32	<0.10	8	5.1	110	2.8	17	74	3.03	-29.57
			Max	8.95	8320	240	574	1432	2005	253	3.1	<0.10	206	418	1600	180	24	911	35.00	14.38
7	Firozpur	7	Min	7.97	478	0	118	21	31	2.4	0.14	<0.10	13	13	37	4.3	18	105	1.03	-1.86
			Max	8.86	1641	102	370	106	305	172	1.21	<0.10	46	51	310	136	26	273	10.04	7.35
8	Gurdaspur	18	Min	8.35	220	12	98	7.1	8	0.2	0.14	<0.10	8	2.4	10	0.6	21	90	0.42	-0.80
			Max	8.95	1214	132	464	71	95	100	0.86	0.10	40	49	280	150	30	230	13.02	10.25
9	Hoshiarpur	26	Min	7.82	200	0	84	14	0	2	0.18	<0.10	4.2	5	9.5	0.8	7	84	0.33	-9.70
			Max	8.79	1750	14	377	184	407	48	0.67	<0.10	93	95	109	47	18	620	1.93	1.25
10	Jalandhar	15	Min	8.22	315	0	122	7	36	0.65	0.24	<0.10	4.0	12.0	14	1.3	21	100	0.51	-3.03
			Max	8.87	1070	132	378	142	145	138	4.00	<0.10	72	51	190	9.4	28	270	6.77	6.00
11	Kapurthala	8	Min	8.30	302	12	134	7.1	12	23	0.3	<0.10	8	0.0	40	1.2	19	20	1.43	-0.56
			Max	8.76	710	48	256	106	35	68	0.7	0.15	28	39	115	11	28	200	10.71	3.41
12	Ludhiana	9	Min	7.73	270	0	110	7	10	2.5	0.11	<0.10	8	10	6.7	2.4	18	90	0.23	-1.16
			Max	8.88	1220	96	696	64	82	78	1.62	<0.10	48	97	235	73	27	420	6.59	7.39

12	Mansa	10	Min	7.51	268	0	100	21.0	5	3.6	0.4	<0.10	12	2.4	43.0	2.1	16	50	1.14	-1.11
			Max	8.70	5140	204	1062	737	548	71	2	<0.10	60	77	1100	395	31	440	87.44	23.61
14	Moga	7	Min	8.50	465	36	134	14	0	0.4	0.36	<0.10	8	7.3	36	2.5	18	60	1.11	-0.21
			Max	8.92	1368	132	549	92	315	46	1.72	<0.10	20	54	260	9.4	25	240	14.16	9.63
15	Muktsar	10	Min	8.10	760	0	74	78	87	4	0.12	<0.10	12	22	34	9.5	17	179	1.35	-1.20
			Max	8.91	5840	263	816	610	1630	900	3.41	<0.10	72	170	1123	620	26	761	16.48	4.57
16	Nawashaher	6	Min	8.36	420	14	224	14	0	2	0.26	<0.10	8.4	13	38	5	9	84	1.23	-1.48
			Max	8.78	1220	25	363	121	222	48	0.79	<0.10	13	61	119	103	17	273	5.59	4.47
17	Pathankot	14	Min	8.05	195	0	98	7.1	5.0	2	0.08	<0.10	4	9.73	8	0.9	19	90	0.35	-2.59
			Max	8.85	1108	108	317	312	168	60	0.6	<0.10	40	78	135	9.7	28	330	3.23	2.18
18	Patiala	24	Min	7.55	355	0	171	7.1	5	0.35	0.19	<0.10	4.0	2	20	0.7	12	20	0.69	-13.23
			Max	8.88	4060	84	573	666	1022	358	4.12	<0.10	72	156	650	348	29	821	22.87	7.21
19	Roop Nagar	11	Min	7.92	300	0	70	14.0	0	2	0.1	<0.10	8	10	9.5	0.8	8	126	0.37	-5.09
			Max	8.74	900	27	409	78	226	52	0.98	<0.10	67	59	85	40	12	326	2.63	3.21
20	Sangrur	13	Min	7.68	329	0	150	14.0	12.0	5.7	0.15	<0.10	4.0	17.0	19	2.5	13.1	90	0.58	-3.22
			Max	9.10	1715	156	683	130	175	105	1.2	<0.10	48	106	385	69	28	560	17.84	14.01
21	SAS Nagar	14	Min	7.68	450	0	182	21	0	0.4	0.32	<0.10	8	14	30	1.0	8	95	0.93	-14.35
			Max	9.01	6480	14	699	432	880	407	1.52	<0.10	360	163	820	315	25	1490	11.54	8.73
22	Tarantaran	12	Min	8.24	362	0	134	7.1	20	0.28	0.2	<0.10	4	7.3	30	4.2	18.0	50	1.14	-3.17
			Max	9.02	1720	180	720	199	108	120	8	<0.10	48	61	420	15	30	360	25.84	16.80
			Min	7.51	195	0	70	7.1	0	0.2	0.080	<0.10	4.0	0.0	6.7	0.63	7	20	0.23	-29.57
	Grand Total		Max	9.10	8320	263	1062	1432	2005	900	8.00	0.15	360	418	1600	620	31	1490	87.44	23.61

6.3 Distribution of EC

The EC value of ground waters in the State varies from 195 to 8320 µS/cm at 25°C. Grouping water samples based on EC values, it is found that 47.68 % of them have EC less than 750, 44.37 % have between 750 and 3000 and the remaining 7.95 % of the samples have EC above 3000µS/cm. The Plate showing aerial distribution of EC with intervals corresponding to limits assigned for desirable, permissible and unsuitable classes of waters indicates that desirable class of waters occur in northern and central area of the State. The ground water occurring in the southern and southwestern parts comprising of Bhatinda, Faridkot, Fazilka, Muktsar and Mansa districts is mostly line and not suitable for drinking uses **(Fig -2).**



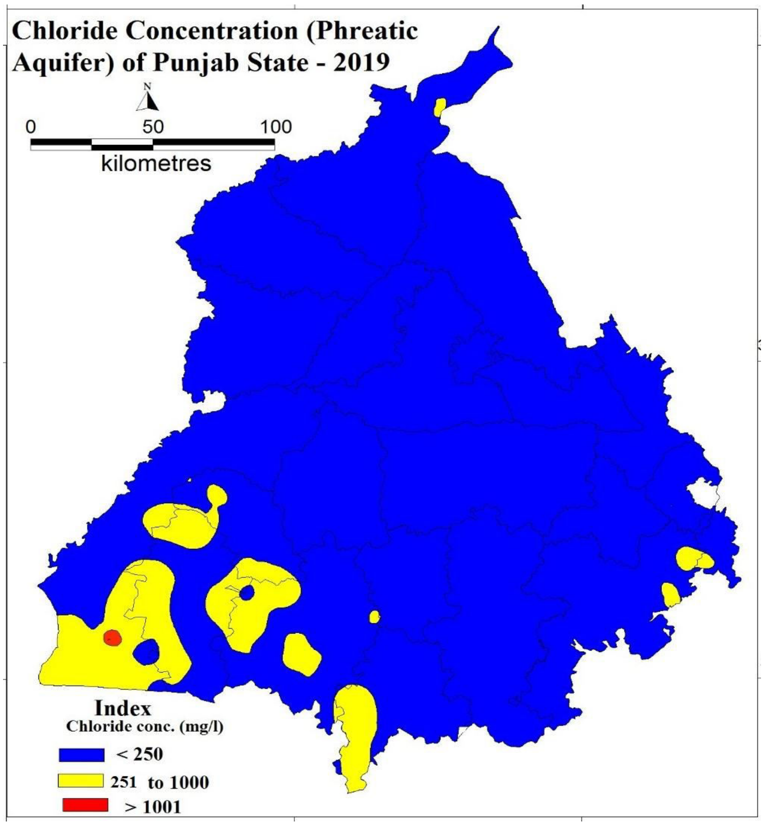
District wise distribution of Electrical Conductivity in shallow Ground water of Punjab State.

Table-2

E.C. <750 µS/cm	**E.C. 751-3000 µS/cm**	**E.C.>3000 µS/cm**
Amritsar	Amritsar	Bathinda
Bathinda	Barnala	Faridkot
Fatehgarh Sahib	Bathinda	Fazilka
Firozepur	Faridkot	Mansa
Gurdaspur	Fatehgarh Sahib	Muktsar
Hoshiarpur	Fazilka	Patiala
Jalandhar	Firozepur	SAS Nagar
Kapurthala	Gurdaspur	
Ludhiana	Hoshiarpur	
Mansa	Jalandhar	
Muktsar	Ludhiana	
Nawanshahr	Mansa	
Pathankot	Moga	
Patiala	Muktsar	
Ropar	Pathankot	
Sangrur	Patiala	
SAS Nagar	Ropar	
Tarantaran	Sangrur	
	SAS Nagar	
	Tarantaran	

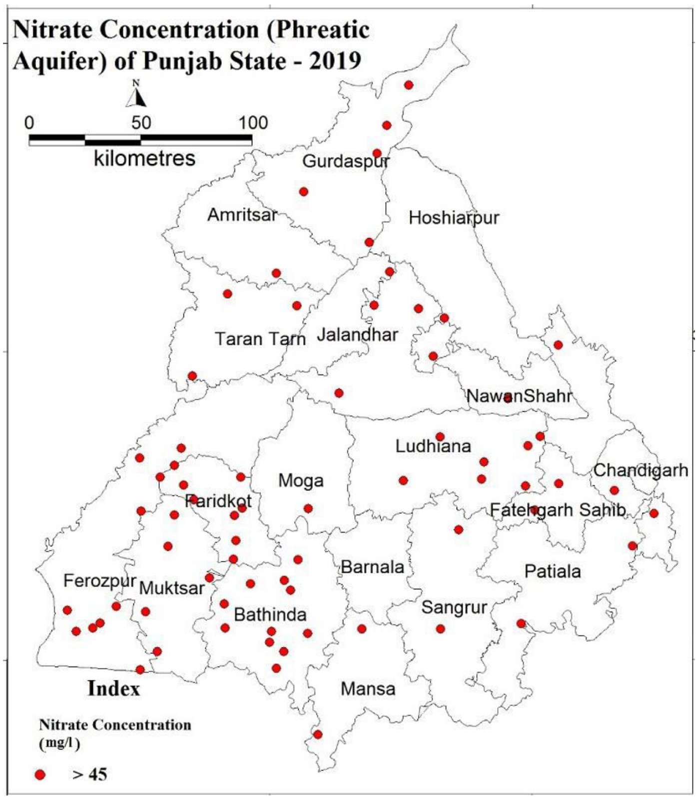
6.4 Distribution of Chloride (Cl)

Chloride content of ground water normally follows the distribution pattern of EC and it ranges from 7.1 mg/L to 1432 mg/L in the entire State. Chloride concentration above 400 mg/L gives salty taste to water and based on these aesthetic considerations, BIS has recommended a desirable limit of 250 mg/L for chloride in drinking water. This limit can be extended to 1000 mg/L in case of absence of a source with desirable concentration. Grouping of samples in these categories based on chloride content, it is found that Chloride is less than 250 mg/L in 88.74 % of the samples, between 250 and 1000 mg/L in 10.93 % samples and only 0.33 % of the samples are found to have Chloride above 1000 mg/L. Map showing spatial distribution of Cl contents in ground water (Fig 20) indicates that Cl is below 250 mg/L in most of the districts, it is between 250 and 1000 mg/L in Patiala , SAS Nagar and in southern and southwestern districts of the State. Cl is more than 1000 mg/L in isolated places in Fazilka district. (**Fig 3**).



6.5 Distribution of Nitrate (NO_3)

Occurrence of nitrate in ground water above 5.0 mg/L reflects contamination at some stage of its percolation and circulation. The probable sources of nitrate contamination of ground water are through excessive application of fertilizers, bacterial nitrification of organic nitrogen, and seepage from animal and human wastes and atmospheric inputs. In the State, nitrate in water samples varies from <0.20 to 900 mg/L. BIS permits a maximum concentration of 45 mg/L nitrate in drinking water. Considering this limit, it is found that 76.82 % of the samples, spread over the entire State, have nitrate below 45 and 23.18 % have more than 45 mg/L. Spatial distribution of nitrate indicates that ground water with permissible nitrate content generally occurs in the northern and central parts with a few isolated patches with nitrate above 45mg/L. A considerable area of the southern and southwestern part of the state have nitrate concentration exceeding 45 mg/L **(Fig-4)** Furthermore, quite a significant number water samples from, Bathinda, Faridkot, Fazilka, Ferozepur, , Muktsar and SAS Nagar districts are found to have nitrate above 100 mg/L.



District wise distribution of Nitrate in shallow Ground water of Punjab State.

Table-3

Nitrate <45mg/l	**Nitrate 45-100mg/l**	**Nitrate >100mg/l**
Amritsar	Amritsar	Bathinda
Barnala	Bathinda	Faridkot
Bathinda	Faridkot	Fazilka
Faridkot	Fatehgarh Sahib	Firozepur
Fatehgarh Sahib	Fazilka	Jalandhar
Fazilka	Gurdaspur	Muktsar
Firozepur	Hoshiarpur	SAS Nagar
Gurdaspur	Jalandhar	Tarantaran
Hoshiarpur	Kapurthala	
Jalandhar	Ludhiana	
Kapurthala	Mansa	
Ludhiana	Moga	
Mansa	Muktsar	
Moga	Nawanshahr	
Muktsar	Pathankot	
Nawanshahr	Patiala	
Pathankot	Ropar	
Patiala	Sangrur	
Ropar	SAS Nagar	
Sangrur	Tarantaran	
SAS Nagar		
Tarantaran		

6.6 Distribution of Fluoride (F)

Fluoride in small amounts in drinking water is beneficial while in large amounts it is injurious. The fluoride content in ground water ranges from <0.05 to 8.00 mg/L. BIS recommends that fluoride concentration up to 1.00 mg/L in drinking water is desirable, up to 1.50 mg/L is permitted and above 1.50 mg/L is injurious. Classification of samples based on this recommendation, it is found that 84.44 % samples have fluoride in desirable range, 5.30 % in the permissible and the remaining 10.26 % have fluoride above 1.50 mg/L. Map showing spatial distribution of fluoride contents in ground water (Fig- 5) indicates that ground water in most parts of the State has desirable concentration of fluoride. Ground waters with fluoride above 1.50 mg/L are found mainly in Bathinda, Faridkot, Fazilka, Muktsar, Patiala, SAS Nagar and Tarantaran districts of the State. It is worth mentioning that high fluoride waters are encountered in areas where agriculture activities are predominant. It indicates the possibility that fluoride has come from the phosphatic fertilizers, which have fluoride as impurity. **(Fig-5)**

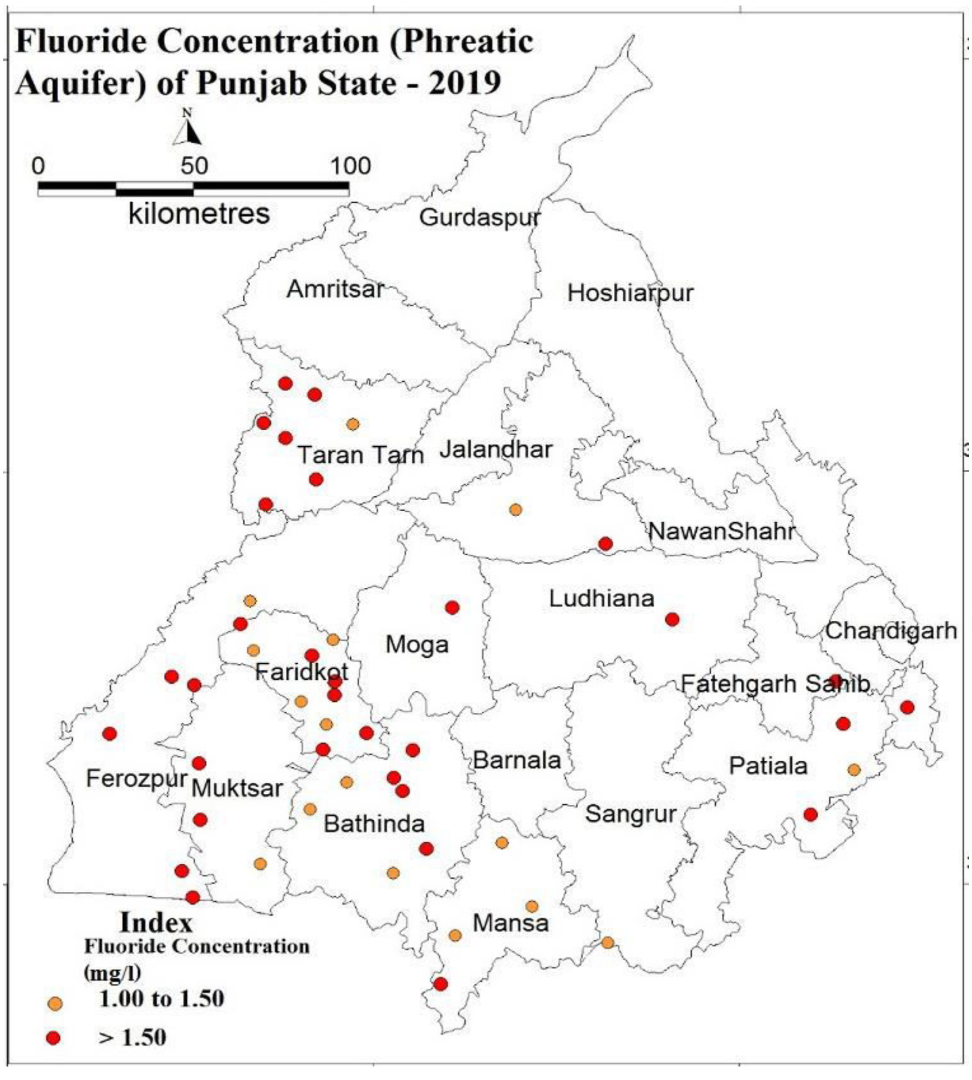


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Table-4

District wise distribution of Fluoride in shallow Ground water of Punjab State

Fluoride <1.00mg/l	Fluoride 1.00-1.50mg/l	Fluoride >1.50mg/l
Amritsar		Bathinda
Barnala	Bathinda	Faridkot
Bathinda	Faridkot	Fazilka
Faridkot	Firozepur	Jalandhar
Fatehgarh Sahib	Jalandhar	Ludhiana
Fazilka	Mansa	Mansa
Firozepur	Muktsar	Moga
Gurdaspur	Patiala	Muktsar
Hoshiarpur	Sangrur	Patiala
Jalandhar	Tarantaran	SAS Nagar
Kapurthala		Tarantaran
Ludhiana		
Mansa		
Moga		
Muktsar		
Nawanshahr		
Pathankot		
Patiala		
Ropar		
Sangrur		
SAS Nagar		
Tarantaran		

6.7 Type of Ground water

Considering the predominance of the cation and anion in the chemical composition of ground water, its type is determined and its relation with its occurrence in an area as well as with its salinity is studied. It is found that no discernible relationship between type of water and its occurrence in any particular area could be established. Nearly all types of waters are available in each district of the State. However, study of relation of water type with salinity of the water clearly indicates that nearly 47.68 % ground waters of the State are fresh, have low salinity and predominance of calcium + magnesium cations and bicarbonate as anion. About 52.32 % ground waters having intermediate salinity and are of mixed type. In these waters, mostly HCO_3 as anion dominates but no individual cation predominates. At some places HCO_3-type of waters with sodium as dominant cation are also encountered in low to moderately saline ground waters. This can be attributed either to precipitation of $CaCO_3$ due to loss of CO_2 or dissolution of Na-salts from the topsoil layers or to ion exchange reaction during the downward percolation of water. At some isolated locations, sulphate is found to be dominant anion. In the remaining ground waters, where salinity is high; mostly Na is the dominant cation and Cl or Cl + SO_4+NO_3 (Mixed anion) are dominant. Nevertheless, a few exceptions have also been found in these simple and well-defined types of ground waters.

6.8 Suitability of Groundwater for Drinking

Salinity, chloride, fluoride and nitrate are the important parameters that are normally considered for evaluating the suitability of ground water for drinking uses. Based on recommendations made for these parameters by BIS, it is found that ground water at quite a few places is not suitable for drinking uses because of either EC/Cl/F/NO_3 or all of them. It is observed that unsuitable quality of ground water occurs in the southern and southwestern regions, while in the northern and central areas ground water is of suitable quality for drinking uses. Table-5 below shows district-wise distribution of ground waters in different classes of suitability based upon EC, Cl, F and NO_3 contents.

Table-5:

Distribution of Well Waters of Punjab State in Different Classes of Drinking Water Suitability

S. N.	District	No. of Samples	Electrical Conductivity			Chloride			Nitrate			Fluoride		
			750	751-3000	3000	<250	251-1000	>1000	<45	46-100	>100	<1.00	1.00-1.50	>1.51
1	Amritsar	11	8	3	0	11	0	0	10	1	0	11	0	0
2	Barnala	3	0	3	0	3	0	0	3	0	0	3	0	0
3	Bathinda	27	5	17	5	18	9	0	16	4	7	20	3	4
4	Faridkot	21	1	17	3	17	4	0	12	5	4	11	4	6
5	Fatehgarh Sahib	11	9	2	0	11	0	0	8	3	0	11	0	0
6	Fazilka	15	1	8	6	8	6	1	8	1	6	10	0	5
7	Firozpur	7	2	5	0	7	0	0	6	0	1	6	1	0
8	Gurdaspur	18	13	5	0	18	0	0	15	3	0	18	0	0
9	Hoshiarpur	26	24	2	0	26	0	0	25	1	0	26	0	0
10	Jalandhar	15	10	5	0	15	0	0	12	2	1	13	1	1
11	Kapurthala	8	8	0	0	8	0	0	6	2	0	8	0	0
12	Ludhiana	19	15	4	0	19	0	0	12	7	0	18	0	1
13	Mansa	10	3	5	2	7	3	0	8	2	0	6	3	1
14	Moga	7	1	6	0	7	0	0	6	1	0	6	0	1
15	Muktsar	10	0	6	4	4	6	0	5	2	3	7	1	2
16	Nawashaher	6	5	1	0	6	0	0	5	1	0	6	0	0
17	Pathankot	14	12	2	0	13	1	0	12	2	0	14	0	0
18	Patiala	24	6	16	2	22	2	0	22	2	0	21	1	2
19	Rupnagar	11	8	3	0	11	0	0	10	1	0	11	0	0
20	Sangrur	13	5	8	0	13	0	0	11	2	0	12	1	0
21	SAS Nagar	14	4	8	2	12	2	0	11	1	2	12	0	2
22	Tarantaran	12	4	8	0	12	0	0	9	2	1	5	1	6
	Grand Total	302	144	134	24	268	33	1	232	45	25	255	16	31

The bar diagram clearly shows that most of the groundwater occurring in the districts Amritsar, Barnala, Fatehgarh Shahib,Gurdaspur, Hoshiarpur, Jallandhar, Kapurthala, Moga, Nawanshar, Sangrur, and Tarantaran occupy almost 75% length of the bar and has almost all the parameters within desirable limit for drinking purposes, thus can be considered as potable. Ground waters from the districts of Bhatinda, Firozpur, Faridkot, Fazilka , Mansa and Muktsar have bar length less than 50% indicating low potable rating. Fig,-6

District wise Distribution of Potable Waters in Punjab

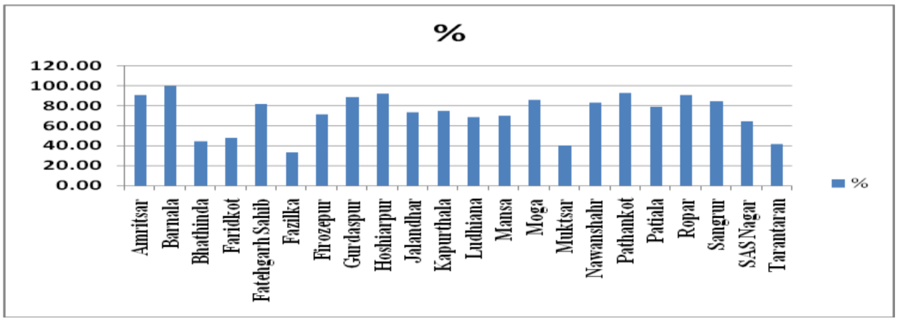

Table.6. Percentage wise classification chart for Potable water in Punjab state

Sr.No.	% wise classification	Name of the districts	Remarks
1.	>80	Amritsar,Barnala, Gurdaspur, Hosiarpur, Moga, Pathankot, Ropar & Sangrurr	It has been classified on the based of Salinity(EC,Cl,NO3 & F)
2.	50-80	Fatehgarh Shahib, Firozpur, Jalandhar, Kapurthala, Ludhiana, Mansa, Nawashehar, Patiala, SAS Nagar	
3.	<50	Bhatinda, Faridkot, Fazilka, Mukatsar, Tarrantarran	

6.9 Suitability of Groundwater for Irrigation

The suitability of ground water for irrigation is generally assessed considering salinity expressed as EC, sodium in relation to calcium and magnesium in terms of SAR, sodium in relation to carbonate in terms of RSC. EC and SAR range from 195 to 8320 µS/cm at 25^0C and 0.23 to 41.30 respectively. Waters having high values of EC and SAR causes salinity and sodium hazards respectively when used for customary irrigation.

USSL: Plot of USSL diagram based on EC and SAR, it is observed that ground water occurring in the northern and central parts of the State falls under C_2S_1 and C_3S_1 classes of irrigation waters. It indicates that most of these waters are suitable for irrigating semi-salt tolerant crops on all soils. Ground water mostly from the southern and southwestern parts comprising of

Bathinda, Faridkot, Fazilka, Ferozepur, Mansa, Muktsar , Patiala & Patiala districts falls under C_3S_2,C_3S_3, C_3S_4, C_4S_1, C_4S_2, C_4S_3 and C_4S_4 classes of irrigation classification. Such waters when used continuously for irrigation, they are likely to cause salinity hazards and lead to reduction in crop yields. They may also cause sodium hazards and lead to hardening of soils when used for irrigation without the addition of adequate quantity of gypsum.

RSC: Alkali hazards of irrigation ground waters are estimated through the computation of Residual Sodium Carbonate (RSC), also known as Eaton's Index. Waters with RSC value <1.25 meq/L are safe for irrigational uses, RSC between 1.25 and 2.5 are marginal and waters with RSC value >2.5 meq/L are unsafe. Based on RSC values of ground waters, it is found that 51.66% of the waters are safe, 14.57% marginal and the remaining 33.77 % are unfit for irrigational uses. RSC of ground waters are found to vary from below zero (-29.57) to 16.80 meq/l (Barwala,Tarantaran district). The district wise distribution of ground waters in different categories of suitability for irrigational uses based on USSL and RSC considerations is given in Table-7.

Table No. 7: Irrigation Rating of Well Waters of Punjab

(Based on Eaton's index and USSL Classification)

Sl.no.	District	No. of Samples	IRRIGATION SUITABILITY			
			EATON's INDEX (RSC in meq/L)			USSL Classification
			Safe	Marginal	Unsafe	
			<1.25	1.25-2.50	>2.50	
1	Amritsar	11	3	5	3	C2S1, C3S1
2	Barnala	3	0	0	3	C3S2, C3S1
3	Bathinda	27	14	3	10	C3S1, C4S2, C4S3, C2S1,C4S1, C4S4
4	Faridkot	21	10	1	10	C4S4, C4S3, C3S1, C3S2, C4S2, C2S1, C3S3
5	Fatehgarh Sahib	11	5	4	2	C2S1, C3S2, C3S1
6	Fazilka	15	8	0	7	C4S2, C4S3, C4S1, C3S1, C2S1, C3S2, C4S4
7	Firozepur	7	3	1	3	C3S1,C3S2, C2S1
8	Gurdaspur	18	11	3	4	C2S1, C1S1, C3S2, C3S1
9	Hoshiarpur	26	26	0	0	C2S1, C3S1, C1S1
10	Jalandhar	15	7	4	4	C2S1,C3S1
11	Kapurthala	8	3	3	2	C2S1, C2S2
12	Ludhiana	19	12	3	4	C2S1, C3S1
13	Mansa	10	3	2	5	C3S1, C2S1, C3S2, C4S4, C4S2
14	Moga	7	1	1	5	C3S2, C2S1, C3S1
15	Muktsar	10	5	1	5	C4S2, C3S1, C4S4, C4S1
16	Nawanshahr	6	4	0	2	C2S1, C3S1
17	Pathankot	14	13	1	0	C2S1, C3S1, C1S1
18	Patiala	24	9	7	8	C3S1, C2S1, C4S1, C4S2, C3S2, C3S3
19	Ropar	11	8	2	1	C3S1, C2S1
20	Sangrur	13	2	1	10	C3S1, C2S1, C3S2
21	SAS Nagar	14	6	2	6	C3S1, C2S1, C3S2, C4S2, C4S1
22	Tarantaran	12	4	0	8	C2S1, C3S1, C3S3, C3S2
	Total	302	156	44	102	

Most of ground waters from Amritsar, Fatehgarh Sahib, Gurdaspur, Hoshiarpur, Jallandhar, Kapurthala Ropar and Patiala are suitable for irrigation for semi-salt tolerant crops on adequately drained soils. The waters from districts of Bhatinda, Faridkot, Ferozepur, Mansa, Muktsar and Sangrur show wide variability in irrigation rating.

6.10 Suitability of Groundwater for Industries

Industries, in general, use water for variety of works depending upon the nature and size of the industry. As such specifications for suitability of water for industries vary widely depending upon the process in each industry. Therefore, chemical quality of water and its suitability could not be discussed due to diversified nature of industries.

6.11 Temporal Variation

The temporal changes in ground water quality are studied through percent of well water falling in different categories of suitability criteria based on concentration of important parameters such as salinity (EC), chloride, nitrate and fluoride contents. The percent well waters falling in desirable, permissible and unsuitable classes of BIS-1991 standards. During 2019 are compared with percent well waters in same classes during 2015, 2016 2017, 2018 & 2019. Table 8 shows both positive and negative change in percent well waters in different suitability classes based on above parameters and overall variation in % wells from 2015 to 2019.

On perusal of the Table-4, it is evident that there is deterioration in the quality of ground water from 2015 to 2019. It is observed that there is decrease in salinity and % of samples falling with EC below 750 µS/cm at 25^0C has decrease by 2.62 %. Whereas there is increase by 2.07 % samples falling in 750-3000 µS/cm at 25^0C . The % of Samples showing EC more than 3000 µS/cm at 25^0C.varies by +0.55%. Based on Fig.2 it can be clearly delineated that there is improvement of salinity in earlier saline patches in southern part of the State.

In respected to Chloride the % of water samples falling range below 250 mg/l has decrease by 0.66% whereas more increase is 1.73%of samples falling in 250-1000 mg/l. The percentage of samples showing Chloride >1000 mg/l decrease by 1.07%. A slight improvement in water quality is observed with respect to Chloride,.

Nitrate during the five years. in samples has been observed from Table -4 that there is increase in % of samples nitrate range <45mg/l has been increase by 7.42% .whereas there is decrease in samples above 45mg/l . Overall it is included that quality of ground water in respect to nitrate has been considerable improved and has came down with in the permissible limits as set by BIS(45mg/l).

In respect to Fluoride there is increase % of samples falling within 0-1.00mg/l. whereas there is decrease in % of samples fluoride within 1.0 -1.50mg/l. This indicates concentration of Fluoride has started coming down with in permissible limit set by BIS and there is improvement in ground water quality. Whereas % of samples falling Beyond permissible limits (>1.50mg/l) slightly increase 0.76%.it shows that the ground water quality deteriorated in respect to Fluoride.

Table 8: Periodic Variation in Suitability Classes of Well Waters of Punjab

Parameter	Class	% of Samples					Periodic Variation 2015-2019
		2015 (n=284)	2016 (n=289)	2017 (n=281)	2018 (n=278)	2019 (n=302)	
Salinity as EC	<750 µS/cm	50.3	43.3	36.7	48.9	47.68	-2.62
	750--3000	42.3	49.1	51.9	42.4	44.37	+2.07
	>3000	7.4	7.6	11.3	8.6	7.95	+0.55
Chloride as Cl	<250 mg/l	89.4	87.5	88.9	88.8	88.74	-0.66
	250 - 1000	9.2	10.4	9.6	9.0	10.93	+1.73
	>1000 mg/l	1.4	2.1	1.8	2.2	0.33	-1.07
Nitrate as NO_3	< 45 mg/l	69.4	77.2	75	82.0	76.82	+7.42
	> 45 mg/l	30.6	22.8	24.9	18.0	23.18	-7.42
Fluoride as F	<1.0 mg/l	82.4	84.4	81.8	88.1	84.43	+2.03
	1.0 - 1.50	8.1	4.8	7.5	4.7	5.30	-2.80
	>1.50 mg/l	9.5	10.7	10.7	7.2	10.26	+0.76

6.12 Conclusion & Recommendations on Groundwater Quality

Conclusion drawn for quality evaluations of ground water and its suitability for various uses is based on macro level studies through monitoring stations sampled during 2019. It can be concluded that in Punjab

- Ground water is generally suitable for drinking uses except at few places in the southern and south western parts where it is not suitable due to high EC or high fluoride or nitrate or combination of all.
- Almost all waters are suitable for irrigation on well-drained soils for growing salt tolerant crops like wheat, mustard, rice, barley and maize etc. However, at few places where EC of ground water goes beyond 5000 µS/cm and SAR is more than 10, such waters are not suitable for customary irrigation.
- It is recommended that areas identified with unsuitable or marginally suitable water quality should be monitored on micro level to effectively delineate such areas and use suitable management measures.

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CHAPTER – 7

CONCLUSIONS

1. The Dynamic Ground Water Estimation has been done as per GEC-2015 Methodology adopted by CGWB and based on data observed in the field for the last five years i.e. 2015-19.
2. There is overexploitation of Ground Water to meet the agriculture requirement of the state as surface water is limited and due to more draft of ground water the overall stage of ground water extraction of the state is 164 % as estimated in this report. As per this report about 78% area of the state is over-exploited. Out of 150 blocks, 117 blocks are “over-exploited” 06 blocks are “critical” 10 blocks are “semi-critical” and 17 blocks are in “safe” category.
3. In this report, Ground Water scenario has slightly improved in comparison to previous report. The Overall Stage of Ground water extraction has decreased from 166% (Report-2017) to 164%, due to the various modifications which have been incorporated on the basis of the various inputs made available from CGWB, Agriculture Department of Punjab, Punjab Agricultural University, Ludhiana and other agencies associated with this estimation.

APPENDIX – 1.1

Copy of Government of Punjab, Department of Irrigation (Project Branch) Notification No. 1 / 5 / 2003 / IPJ (3) 24378-89, Dated 11th Dec. 2004

The Governor of Punjab is pleased to constitute "State Level Committee on Ground Water Resource Estimation" with the following members:

1.	Principal Secretary, Government of Punjab, Irrigation Department Chandigarh.	Chairman
2.	Chief Engineer/Water Resources, Irrigation Works, Punjab, Chandigarh.	Member
3.	Chief Engineer/Canals, Irrigation Works, Punjab, Chandigarh.	Member
4.	Chief Engineer P.W.D (Public Health Branch), Punjab, Patiala.	Member
5.	Managing Director, Punjab Water Supply and Sewerage Board, Chandigarh.	Member
6	Director, Industries, Punjab, Chandigarh	Member
7.	Director Research, Punjab Agriculture University, Ludhiana	Member
8.	Director, Punjab Remote Sensing Center, (PAU Campus), Ludhiana.	Member
9.	Director of Agriculture, Punjab, Chandigarh.	Member
10.	Executive Director, Punjab State Council for Science and Technology, Chandigarh.	Member
11.	General Manager, NABARD, Chandigarh.	Member
12.	Regional Director, (North Western Region) Central Ground Water Board, Chd.	Member Secretary

The following shall be the Terms of Reference:-

i. To estimate ground water potential and Irrigation potential of Punjab State in accordance with the methodology recommended by Ground Water Estimation Committee set up by Government of India.

ii. To estimate the present level of development and utilization of this resource in State of Punjab.

iii. To estimate ground water recharge from rainfall and other resources separately in the State of Punjab.

iv. To assess the present and future requirement of ground water for Agriculture, Public Health, Industrial uses and other diverse purposes.

The headquarters of the Committee shall be at Chandigarh.

The Committee shall meet as often as may be considered necessary by the Chairman, but at least once every year. The Chairman may invite such persons and officers as he may considered necessary to be present at any meeting and participate in the deliberations.

The members shall draw TA/DA from their respective organizations.

Dated, Chandigarh
11th December, 2004

K.R. Lakhanpal
Principal Secretary to Govt. of Punjab
Department of Irrigation

APPENDIX- 1.2

Copy of Government of Punjab, Department of Irrigation (Project Branch) Notification No. 1 / 5 / 2003 / IPJ (3) 3419, Dated 9th October, 2009

The Governor of Punjab is pleased to constitute the Sub-Committee for Ground Water Balance of the State Level Committee on Ground Water Resources Estimation for the purpose of certification of finalization of Ground Water Assessment Report before putting up to State Level Committee and for the purpose of issuing Ground Water Assessment Certificate for any area of the State for installation of Tube-wells, both shallow and deep. The constitution of Sub-Committee is as follows:-

1.	Director, Water Resources and Environment, Punjab, Chandigarh	Chairman
2.	Director, Central Ground Water Board, Chandigarh	Member
3.	Representative of MD, PDWRDC Ltd., Chandigarh.	Member
4	Geologist/ Hydrologist, Ground Water Cell, Agriculture Department, Punjab, Chandigarh	Member Secretary

The Ground Water Assessment Certificate will be issued and signed by the Member Secretary, of Sub-Committee for Ground Water Balance. All the correspondence in the connection by various Departments /Agencies will be addressed to Geologist/ Hydrologist, Ground Water Cell, Agriculture Department, Punjab, Chandigarh.

Dated, Chandigarh the 4 Nov., 2009

Suresh Kumar,
Principal Secretary to Govt. of Punjab
Department of Irrigation

APPENDIX -2.1

Minutes of 1st Technical Sub-Committee on Water balance of Punjab State-2021 held under the Chairmanship of Director, Water Resources & Environment Directorate, Punjab cum- Chairman, Technical Sub Committee on Water balance of Punjab State, S.A.S. Nagar (Mohali) on 31" August, 2020 at 11:00AM.

The first meeting to discuss the modalities and time schedules for the preparation of Dynamic Ground Water Estimation study of Punjab State, 2021 was held under the Chairmanship of Director, Water Resources & Environment Directorate, Punjab–cum Chairman, Technical Sub Committee on Water balance of Punjab State, S.A.S. Nagar (Mohali) on 31st August, 2020 at 11:00 AM in the Committee Room of Water Resource Bhawan, Sector 68, SAS Nagar (Mohali).

2.0 The following participants attended the meeting:

1.	B.B Singla	-	Director, Water Resources & Environment Directorate, Punjab.
2.	Anoop Nagar	-	Regional Director, CGWB, Chandigarh.
3.	Jaswant Singh	-	Geologist/Hydrologist, Dept of Agriculture & Farmer Welfare, Punjab.
4.	Manpreet Singh	-	Dept of Agriculture & Farmer Welfare, Punjab.
5.	Rakesh Rana	-	Scientist D, CGWB, Chandigarh.
6.	S.K Mohiddin	-	Sr. Hyd. CGWB, NWR, Chandigarh.
7.	R.S Gupta	-	Sr. Hydrogeologist, PWRMDC Ltd., SAS Nagar.
8.	Neeraj Pandit	-	Dept of Agriculture & Farmer Welfare, Punjab.
9.	Suresh Narang	-	Water Resources & Environment Directorate, Punjab.
10.	Atul Kumar Sood	-	Water Resources & Environment Directorate, Punjab.

3.0 At the outset, the Chairman welcoming the Committee Members apprised all present that the work of preparation of Dynamic Ground Water Estimation study of Punjab State, 2021 (Study period 2016-2020) is to commence immediately within stipulated time period i.e. 31 March, 2021. He further informed that the aim of the meeting is to work out the modalities and time schedules for the preparation of Dynamic Ground Water Estimation study of Punjab State, 2021.

4.0 The house discussed that the work of preparation of Dynamic Ground Water Estimation study of Punjab State, 2021 involved collection of rainfall data from various sources/agencies. Like-wise, draft figures needs to be supplied by Department of Agriculture & Farmers Welfare, Punjab. Other factors like specific yield, rain infiltration and return flows etc., needs to be incorporated. Further, Regional Director, CGWB apprised the Chair that this time the Dynamic Ground Water Estimation study of Punjab State, 2021 needs to cater to all the 150 administrative blocks of the State instead of 138 blocks.

5.0 After detailed deliberations, it was unanimously decided that:

i. The rainfall data of Punjab State available with various agencies would be collected and analyzed by Water Resources & Environment Directorate, Punjab.

ii. Department of Agriculture & Farmers Welfare, Punjab will supply the block wise draft figures based on cropping pattern. For this, Water Resources & Environment Directorate, Punjab would first supply them the block wise canal water applied for irrigation. In blocks where cropping pattern is not available, the draft figures will be supplied on prorata basis.

iii. Punjab Agriculture University (PAU), Ludhiana may be approached by Water Resource & Environment Directorate, Punjab to explore the possibility of using their data of specific yield, rainfall infiltration and return flows etc. of different soil types.

iv. Punjab Remote Sensing Centre (PRSC), PAU Campus Ludhiana may be invited as special invitee In the next meeting to discuss the availability of GIS database/maps and explore the possibility of incorporation of the same in the report to be prepared.

v. Representative from Department of Industries may also be invited as special invitee to discuss the availability of data of Industries and water used by them.

vi. Representative of Chief Engineer, Canals may also be invited in the next meeting to appraise him regarding data required for the estimation study.

vii. The Dynamic Ground Water Estimation study of Punjab State, 2021 to be prepared would be of 150 administrative bocks of Punjab State.

viii. The Block map showing 150 blocks along with their administrative area is to be provided by Central Ground Water Board.

While concluding, the Chairman desired that all departments involved in the preparation of Dynamic Ground Water Estimation study of Punjab State, 2021 would extend full cooperation & work on the strategy discussed in the meeting so as to accomplish the task of preparation of Dynamic Ground Water Estimation study of Punjab State, 2021 (Study period 2016-2020) within stipulated time period i.e. 31 March, 2021.

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

APPENDIX -2.2

Minutes of 2nd Technical Sub-Committee on Water balance of Punjab State -2021 held under the Chairmanship of Director, Water Resources & Environment Directorate, Punjab - cum - Chairman, Technical Sub Committee on Water balance of Punjab State, S.A.S. Nagar (Mohali) on 22nd December, 2020 at 11:00AM.

The 2nd meeting to discuss the modalities and time schedules for the preparation of Dynamic Ground Water Estimation study of Punjab State, 2021 was held under the Chairmanship of Director, Water Resources & Environment Directorate, Punjab - cum-Chairman, Technical Sub Committee on Water balance of Punjab State, S.A.S. Nagar (Mohali) on 22nd December, 2020 at 11:00AM in the Committee Room of Central Ground Water Board, Sector 27-A, Chandigarh.

2.0 The following participants attended the meeting:

1. B.B Singla - Director, Water Resources & Environment Directorate, Punjab.
2. Anoop Nagar - Regional Director, CGWB, Chandigarh.
3. Jaswant Singh - Geologist/Hydrologist, Dept of Agriculture & Farmer Welfare, Punjab.
4. Manpreet Singh - Dept of Agriculture & Farmer Welfare, Punjab.
5. Rakesh Rana - Scientist D, CGWB, Chandigarh.
6. S.K Mohiddin - Sr. Hyd. CGWB, NWR, Chandigarh.
7. R.S Gupta - Sr. Hydrogeologist, PWRMDC Ltd., SAS Nagar.
8. Neeraj Pandit - Dept of Agriculture & Farmer Welfare, Punjab.
9. Suresh Narang - Water Resources & Environment Directorate, Punjab.
10. Atul Kumar Sood - Water Resources & Environment Directorate, Punjab.

3.0 At the outset, the Chairman while welcoming the Committee Members apprised all present that the work of preparation of Dynamic Ground Water Estimation study of Punjab State, 2021 (Study period 2015-2019) is undergoing and has to be completed within stipulated time period i.e. 31 March, 2021. He further informed that the aim of the meeting is to work out the modalities and time schedules of each stake holders for the preparation of Dynamic Ground Water Estimation study of Punjab State, 2021.

4.0 The house discussed that the work of preparation of Dynamic Ground Water Estimation study of Punjab State, 2021 is underway and **involved collection of data** of rainfall, Check Dams, Rooftop recharge, Village ponds etc. from various sources/agencies. Like-wise, draft figures needs to be supplied by Department of Agriculture & Farmers Welfare, Punjab. Other factors like specific yield, rain infiltration and return flows etc... needs to be incorporated. Further, Regional Director, CGWB apprised the Chair that this time the Dynamic Ground Water Estimation study of Punjab State, 2021 needs to cater to all the 150 administrative blocks of the State instead of 138 blocks. He further emphasized that the requisite data can be directly uploaded on the portal developed by IIT, Hyderabad. The password would be shared with all the members accordingly.

5.0 After detailed deliberations, it was unanimously decided that:

i. The Dynamic Ground Water Estimation study of Punjab State, 2021 to be prepared would be of 150 administrative blocks of Punjab State.

ii. The Block map showing 150 blocks along with their administrative area would be provided by Central Ground Water Board.

iii. Water Resources & Environment Directorate, Punjab would coordinate with IMD, GOI to gather rainfall data of Punjab State by 15th January,2021.

iv. Punjab Remote Sensing Centre (PRSC), PAU Campus Ludhiana would supply block wise Paved/Non-paved area by 15th January, 2021.

v. Department of Industries would write to PPCB regarding block wise groundwater usage by Industries and send report by 15th January, 2021.

vi. Punjab Water Resource Management & Development Corporation (PWRMDC), Punjab would supply 150 block wise deep tubewell data (study period 2015-19) by 15th January, 2021.

vii. Department of Agriculture & Farmers Welfare, Punjab will supply the block wise draft figures based on cropping pattern. For this, Water Resources & Environment Directorate, Punjab would first supply them the block wise canal water applied for irrigation during Monsoon/Non-Monsoon period and rainfall by **31 January, 2021**.

viii. Water Resources & Environment Directorate, Punjab would write to Department of Soil & Water Conservation, Punjab and Department of Rural Development & Panchayat, Punjab for information of 150 blocks regarding Check Dams, Rooftop recharge, Village ponds etc. & collect data by 15th January, 2021.

ix. Water Resources & Environment Directorate, Punjab would write to Department of Water Supply and Sanitation/ Drainage department to supply information of 150 blocks regarding Water logging, Flood area, and drinking water supply in urban / rural area by 15th January, 2021.

While concluding, the Chairman desired that all departments involved in the preparation of Dynamic Ground Water Estimation study of Punjab State, 2021 would extend full cooperation & work on the strategy discussed in the meeting so as to accomplish the task of preparation of Dynamic Ground Water Estimation study of Punjab State, 2021 (Study period 2015-2019) within stipulated time period i.e. 31 March, 2021.

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

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APPENDIX -2.3

Minutes of the State Level Committee for approval of Ground Water Resources Potential in Punjab State as on 31st March, 2020 held on 26.3.2021 under the chairmanship of Sh. Sarvjit Singh, IAS, Principal Secretary to Govt. of Punjab, Water Resources Department

A meeting was held for approval of Ground Water Resources of Punjab State as on 31st March, 2020 under the chairmanship of Sh. Sarvjit Singh, IAS, and Principal Secretary to Govt. of Punjab, Water Resources Department on 26.3.2021 at 11.30 Hrs through Video Conferencing. The List of Participants attached as Annexure-I.

At the onset of meeting, Shri Sarvjit Singh, Principal Secretary welcomed all the participants joined on VC. Shri Anoop Nagar, Regional Director, CGWB, NWR, Chandigarh initiated the discussion and briefly explained about the methodology and departments involved in preparation of ground water resources estimations of Punjab. Shri Rakesh Rana, Scientist-D, CGWB, NWR, Chandigarh presented and explained the salient features and findings of the estimations through power point presentation. The Ground Water Resources have been worked out on the basis of the methodology recommended by Groundwater Estimation Committee-2015 and by adopting fully automation through InGres software developed jointly by IITH and Central Ground Water Board. The Groundwater resources were estimated jointly by the CGWB, NWR, Chandigarh and WRED, SAS Nagar, Punjab based on the Data provided by all the departments. PRSC has shared the shape files for all the 150 blocks as per new configuration. These blocks were on the basis of estimation of ground water resources for the year 2020.

Shri Rakesh Rana, Scientist-D, CGWB, NWR, Chandigarh explained in detail about the calculations aspects and methodology applied for the Dynamic Ground Water Resources of Punjab State. The estimations were carried out based on the Data input provided by various departments like CGWB, IMD, WRED, Irrigation Department, PRSC, Department of Agriculture, PWD, Punjab Water Supply and Sewerage Board, PAU, Punjab State Council for Science and Technology, Industry department etc. Total Annual Groundwater Recharge of the State has been assessed as 22.79 bcm and Annual Extractable Ground Water Resource is 20.59 bcm. The Total Current Annual Ground Water extraction is 33.85 bcm and Stage of Ground Water extraction is 164%. Out of total 150 assessed blocks taken for study, 117 have been categorized as 'Over-exploited',6 as 'Critical', 10 as 'Semi Critical' and 17 as 'Safe'. Total Annual Groundwater Recharge has been reduced from 23.93 bcm to 22.79 bcm, annual extractable resources have decreased from 21.58 bcm to 20.59 bcm and the annual ground water extraction reduced from 35.78 bcm to 33.85 bcm. The state of ground water extraction has decreased from 166% to 164%. Adoption of threshold value at same rate for pre-monsoon and post monsoon seasons and re-organization of blocks and block boundaries also resulted in slight reduction in rainfall recharge. The decrease in draft is reduction in areas of paddy cultivation areas from 29.3 lakh hectares to 26.3 lakh hectares. In general about 60% of ground water is fresh and of good quality mostly in districts of Amritsar, Fatehgarh Sahib, Nawan Shahr, Gurdaspur, Ropar, Hoshiarpur, Jalandhar, Ludhiana and Kapurthala; nearly 30% is of marginal and moderately saline quality in districts of Patiala, Moga, Ferozepur and Faridkot and nearly 10% and is saline and not safe for drinking water in the districts of Fazilka, Muktsar, Bathinda and Mansa.

Quality tagging has also been made for such blocks. The additional potential of fresh ground water resources in shallow water level areas is estimated at 1.71 bcm.

With the above discussions and observations, the GWRE, 2020 for Punjab state have been approved by the SLC.

The meeting ended with the vote of thanks to the chair by Sh. Dinesh Tiwari, Scientist D, CGWB, NWR, Chandigarh.

22.4.21

Annexure I

1	Principal Secretary, Government of Punjab Water Resources Department, Punjab	Chairman
2	Chief Engineer Water Resources, Irrigation Works, Punjab	Member
3	Chief Engineer/ Canals Irrigation Works, Punjab	Member
4	Chief Engineer, P.W.D (Public Health Branch), Punjab , Patiala	Member
5	Managing Director, Punjab Water Supply and Sewerage Boar Chandigarh.	Member
6	Director, Industries, Punjab, Chandigarh	Member
7	Director Research, Punjab Agriculture University, Ludhiana.	Member
8	Director, Punjab Remote Sensing Center,(PAU Campus) Ludhiana.	Member
9	Director of Agriculture, Punjab, Chandigarh.	Member
10	Executive Director, Punjab State Council for Science and Technolog Chandigarh.	Member
11	General Manager, NABARD, Chandigarh	Member
12	Regional Director , CGWB, Chandigarh.	Member Secretary

ਨੰ:1/5/2003-ਪੀਜੇ(3)/

ਪੰਜਾਬ ਸਰਕਾਰ
ਜਲ ਸਰੋਤ ਵਿਭਾਗ
(ਪ੍ਰੋਜੈਕਟ ਸਾਖਾ)

ਸੇਵਾ ਵਿਖੇ,

Regional Director & Member Secretary,
Central Ground Water Board,
North Western Region,
Bhujal Bhawan, Plot-3-B,
Sector-27-A, Madhya Marg,
Chandigarh.
(email Id. rdnwr-cgwb@nic.in)

ਮੀਮੋ ਨੰ:1/5/2003-ਪੀਜੇ(3)/ 329
ਮਿਤੀ, ਚੰਡੀਗੜ 27-4-2021

Subject:- **Minutes of the State Level Committee for approval of Ground Water Resources Potential in Punjab State as on 31st March, 2020 held on 26.03.2021 under the Chairmanship of Sh. Sarvjit Singh, IAS, Principal Secretary to Govt. of Punjab Department Water Resources.**

ਉਪਰੋਕਤ ਵਿਸੇ ਤੇ ਆਪ ਦੀ ਈਮੇਲ ਮਿਤੀ 08.04.2021 ਦੇ ਹਵਾਲੇ ਵਿੱਚ।

2. ਵਿਸਾ ਅੰਕਿਤ ਮਾਮਲੇ ਸਬੰਧੀ ਹਵਾਲਾ ਅਧੀਨ ਈਮੇਲ ਰਾਹੀ ਆਪ ਵਲੋਂ ਪ੍ਰਾਪਤ ਮੀਟਿੰਗ ਦੀ ਕਾਰਵਾਈ ਰਿਪੋਰਟ (Minutes) ਪ੍ਰਮੁੱਖ ਸਕੱਤਰ, ਜਲ ਸਰੋਤ-ਕਮ-ਚੇਅਰਮੈਂਨ, ਸਟੇਟ ਲੈਵਲ ਕਮੇਟੀ ਫਾਰ ਐਸਟੀਮੇਸਨ ਆਫ ਗਰਾਊਂਡ ਵਾਟਰ ਰਿਸੋਰਜਿਸ ਜੀ ਵਲੋਂ ਪ੍ਰਵਾਨ ਕਰ ਦਿੱਤੇ ਹਨ, ਦੀ ਕਾਪੀ ਭੇਜਕੇ ਬੇਨਤੀ ਕੀਤੀ ਜਾਂਦੀ ਹੈ ਕਿ ਇਸ ਸਬੰਧੀ ਅਗਲੇਰੀ ਲੋੜੀਦੀ ਕਾਰਵਾਈ ਕਰਵਾਉਣ ਦੀ ਕ੍ਰਿਪਾਲਤਾ ਕੀਤੀ ਜਾਵੇ ਜੀ।

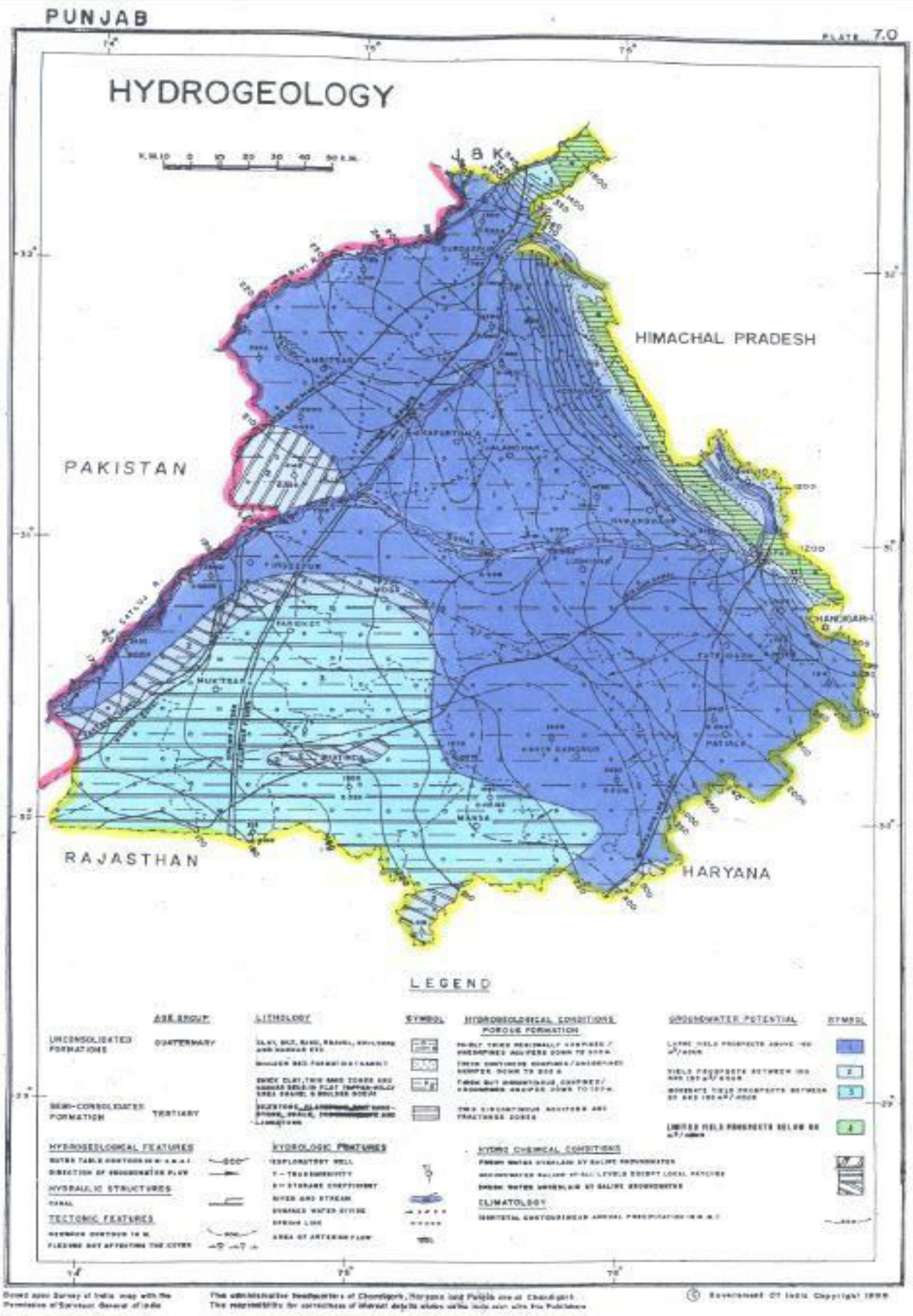
ਸੁਪਰਡੰਟ

ਪਿੱ.ਅੰ.ਨੰ:1/5/2003-ਪੀਜੇ(3)/ ਮਿਤੀ ਚੰਡੀਗੜ੍ਹ

ਉਪਰੋਕਤ ਦਾ ਇਕ ਉਤਾਰਾ ਮੁੱਖ ਇੰਜੀਨੀਅਰ/ਗਰਾਊਂਡ ਵਾਟਰ, ਜਲ ਸਰੋਤ ਵਿਭਾਗ, ਪੰਜਾਬ, ਜਲ ਸਰੋਤ ਭਵਨ, ਸੈਕਟਰ-68, ਐਸ.ਏ.ਐਸ. ਨਗਰ ਨੂੰ ਅਗਲੇਰੀ ਲੋੜੀਦੀ ਕਾਰਵਾਈ ਹਿੱਤ ਭੇਜਿਆ ਜਾਂਦਾ ਹੈ।

ਸੁਪਰਡੰਟ

PLATE 1



Source: CGWB, NWR, Chandigarh

PLATE-2 ADMINISTRATIVE BASE MAP

PLATE 3- CATEGORIZATION OF GROUND WATER ASSESSMENT UNITS IN PUNJAB STATE (2020)

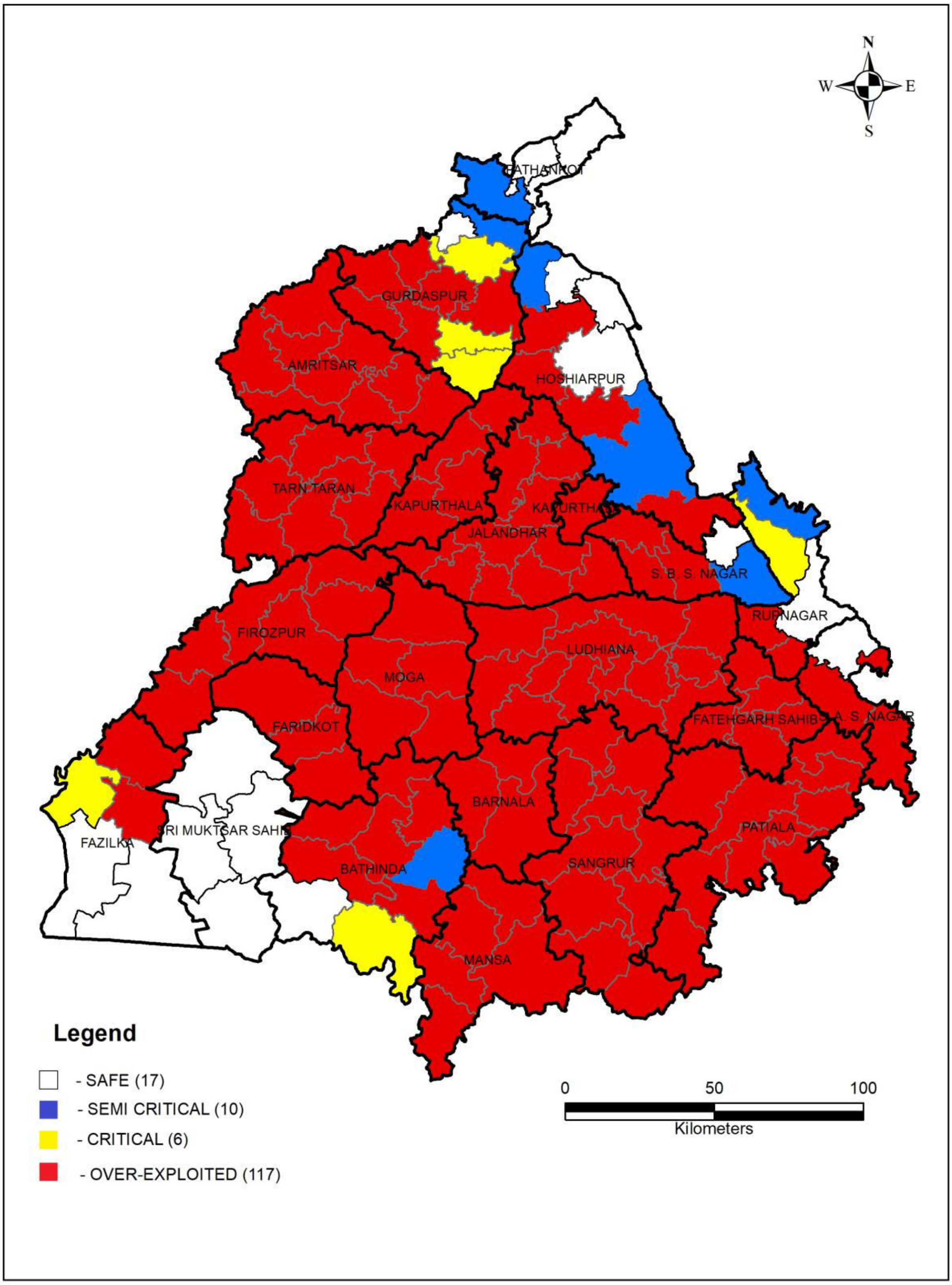


FIGURE-1- ISOHYETS FOR THE YEAR 2019

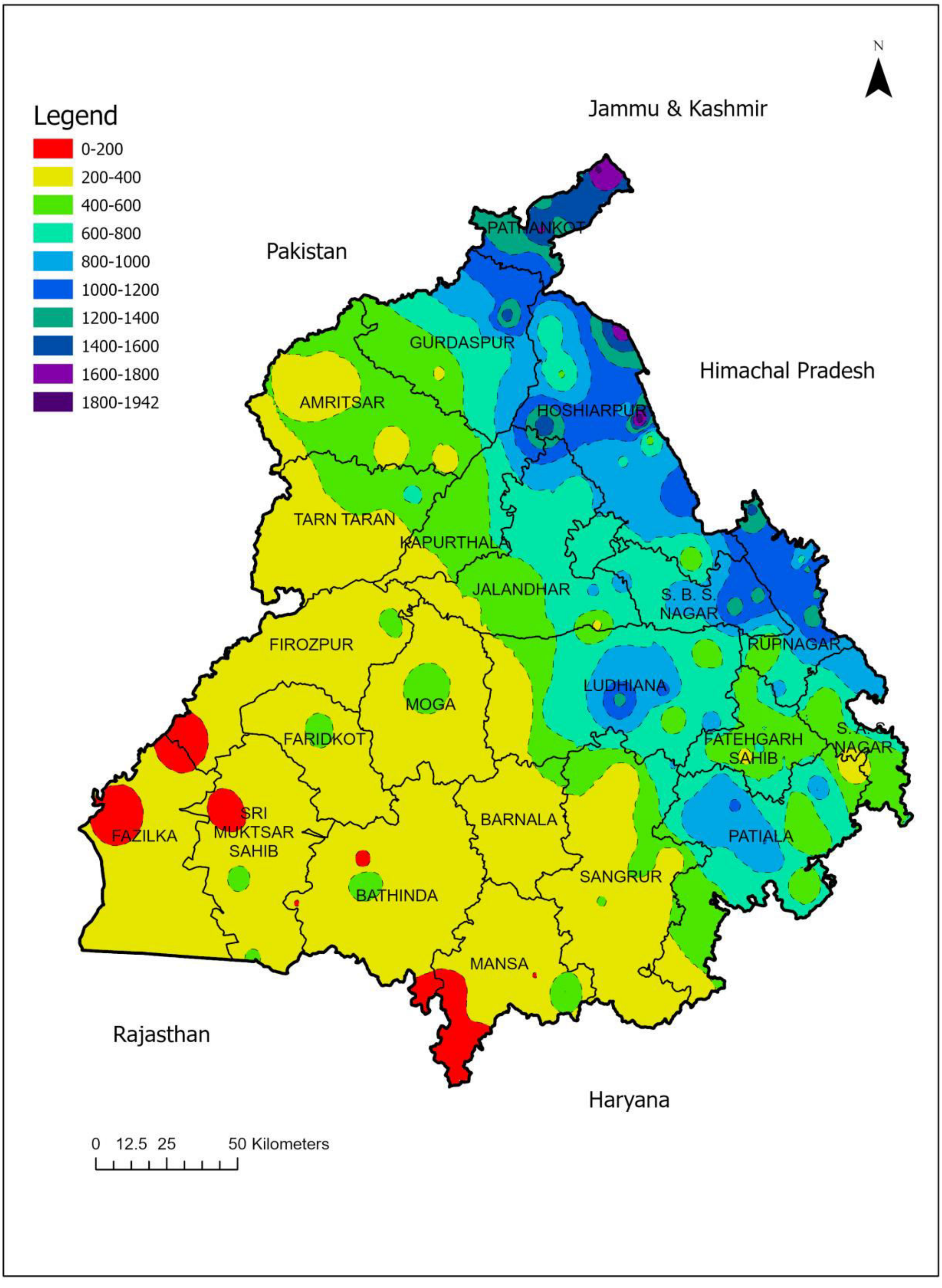


FIGURE-2 DEPTH TO WATER LEVEL, JUNE-2019

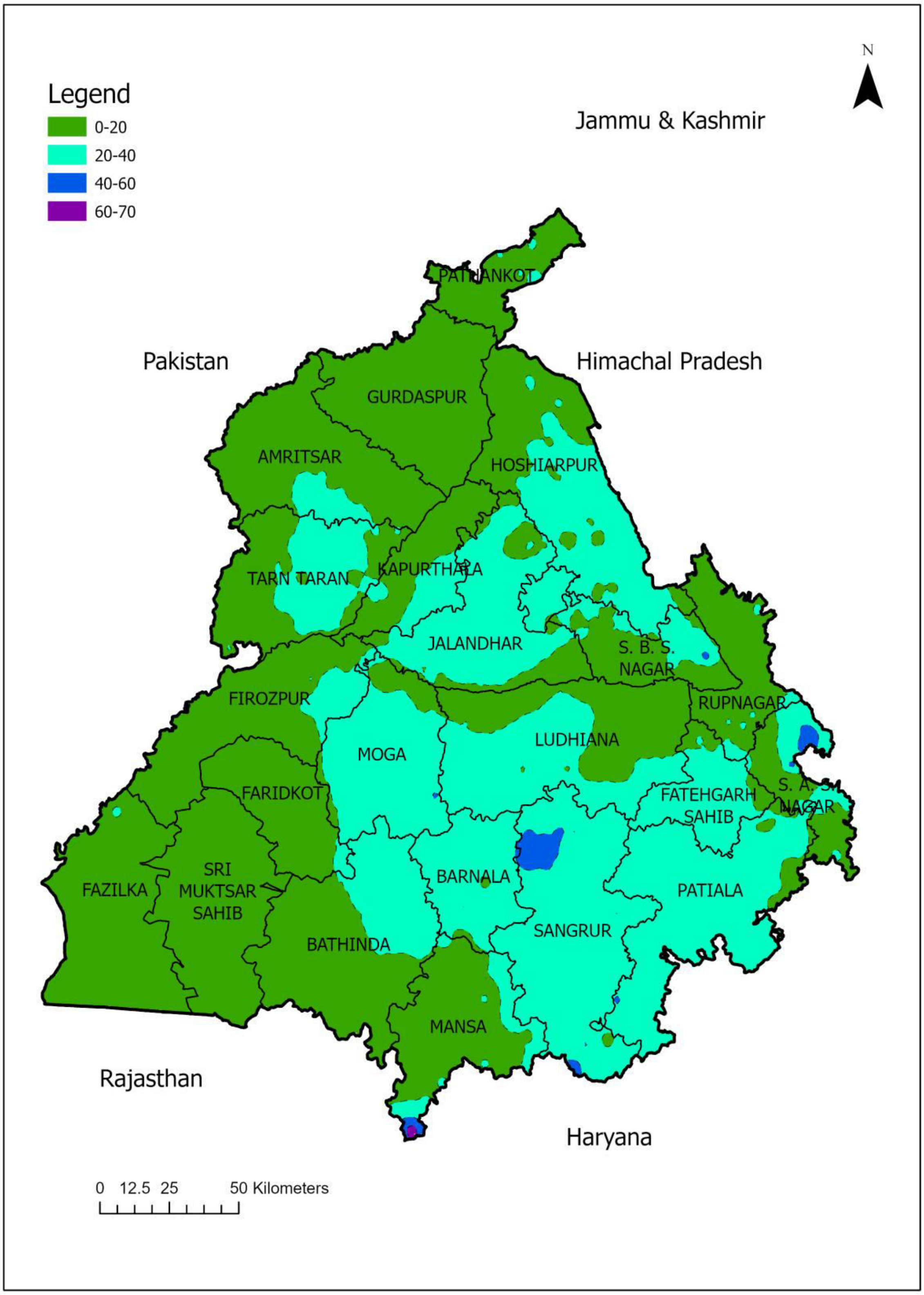


FIGURE-3 WATER TABLE CONTOURS, JUNE-2019

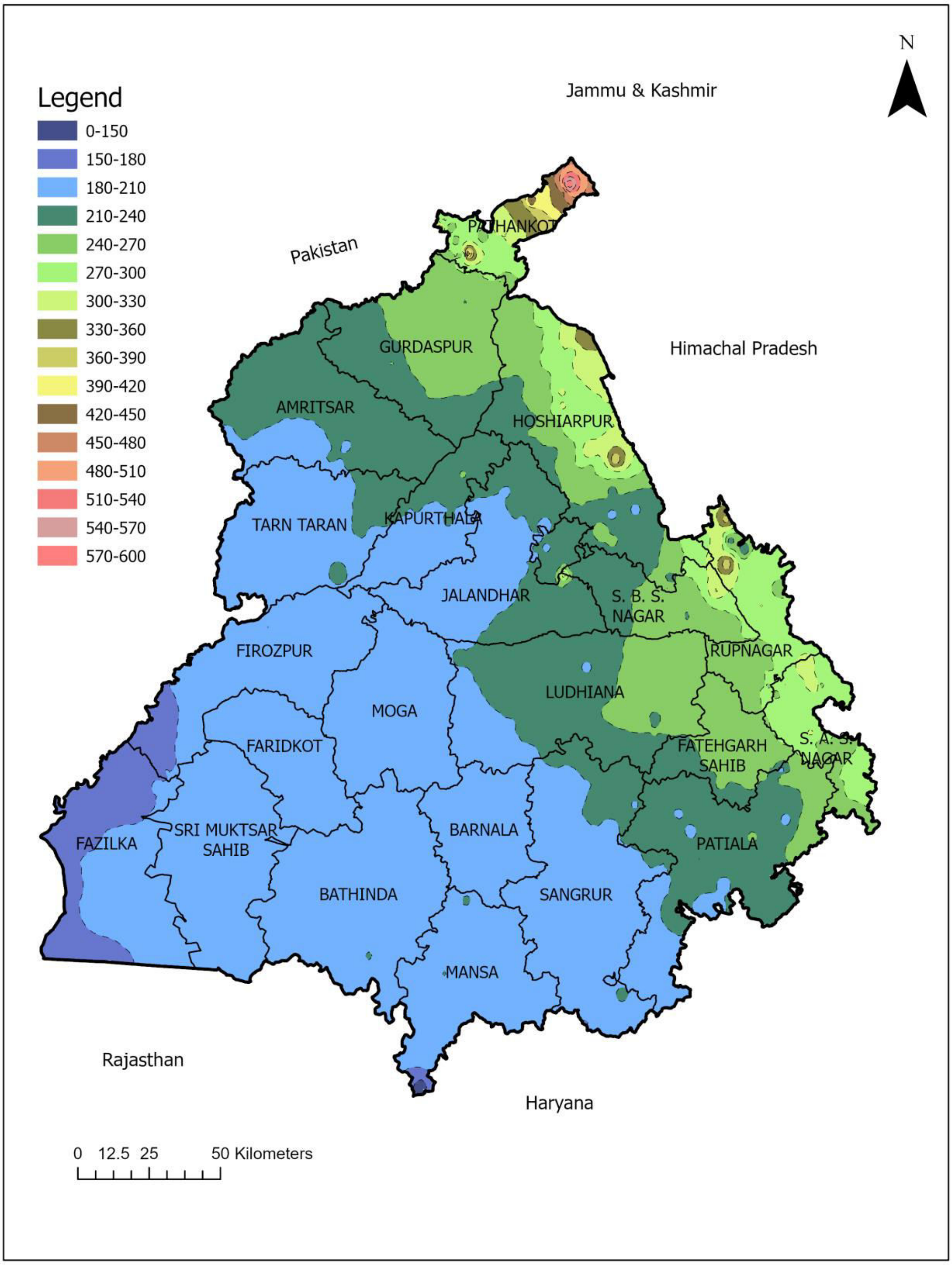


FIGURE 4 DEPTH TO WATER LEVEL, OCTOBER – 2019

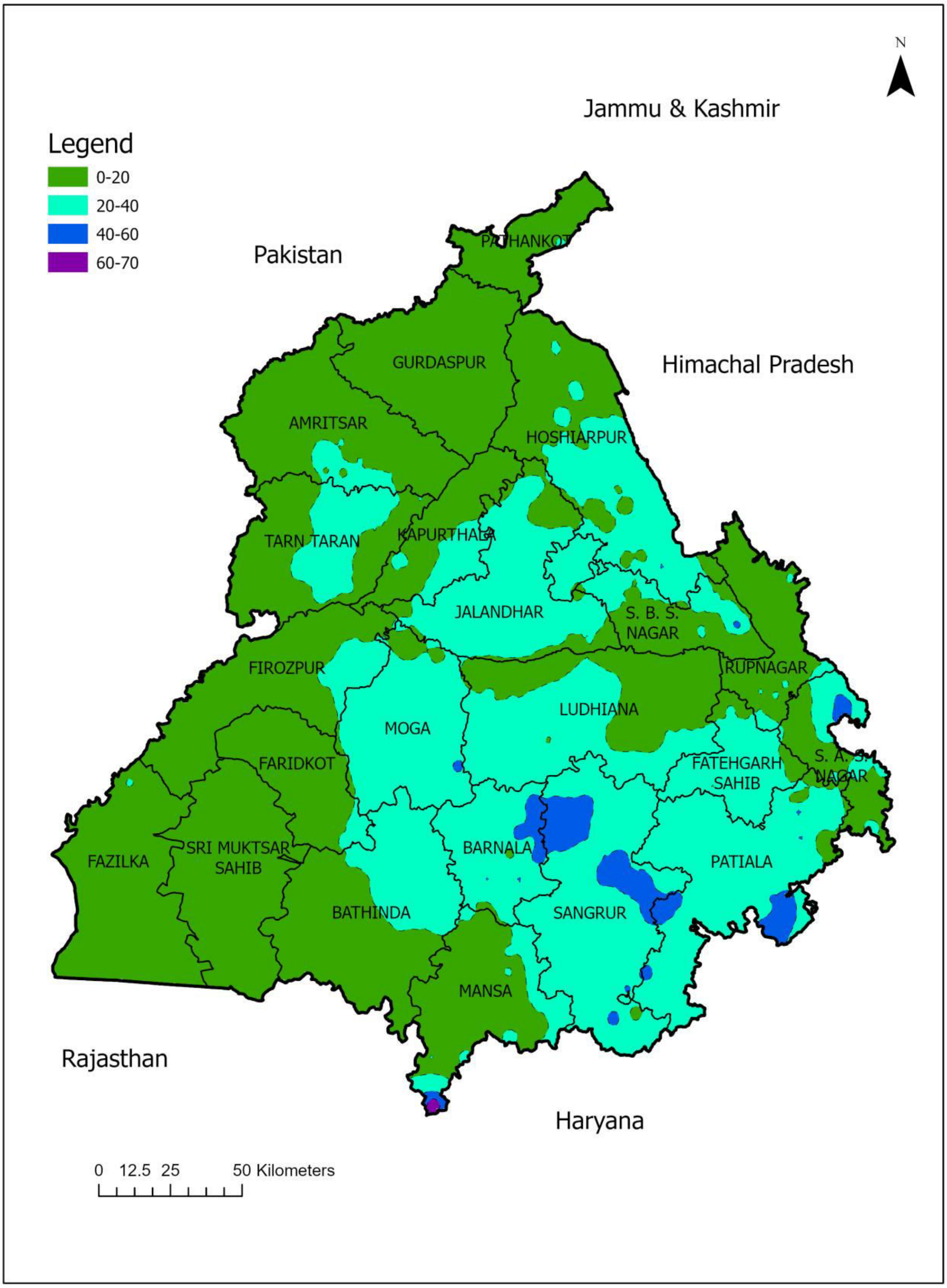


FIGURE 5 WATER TABLE CONTOURS, OCTOBER -2019

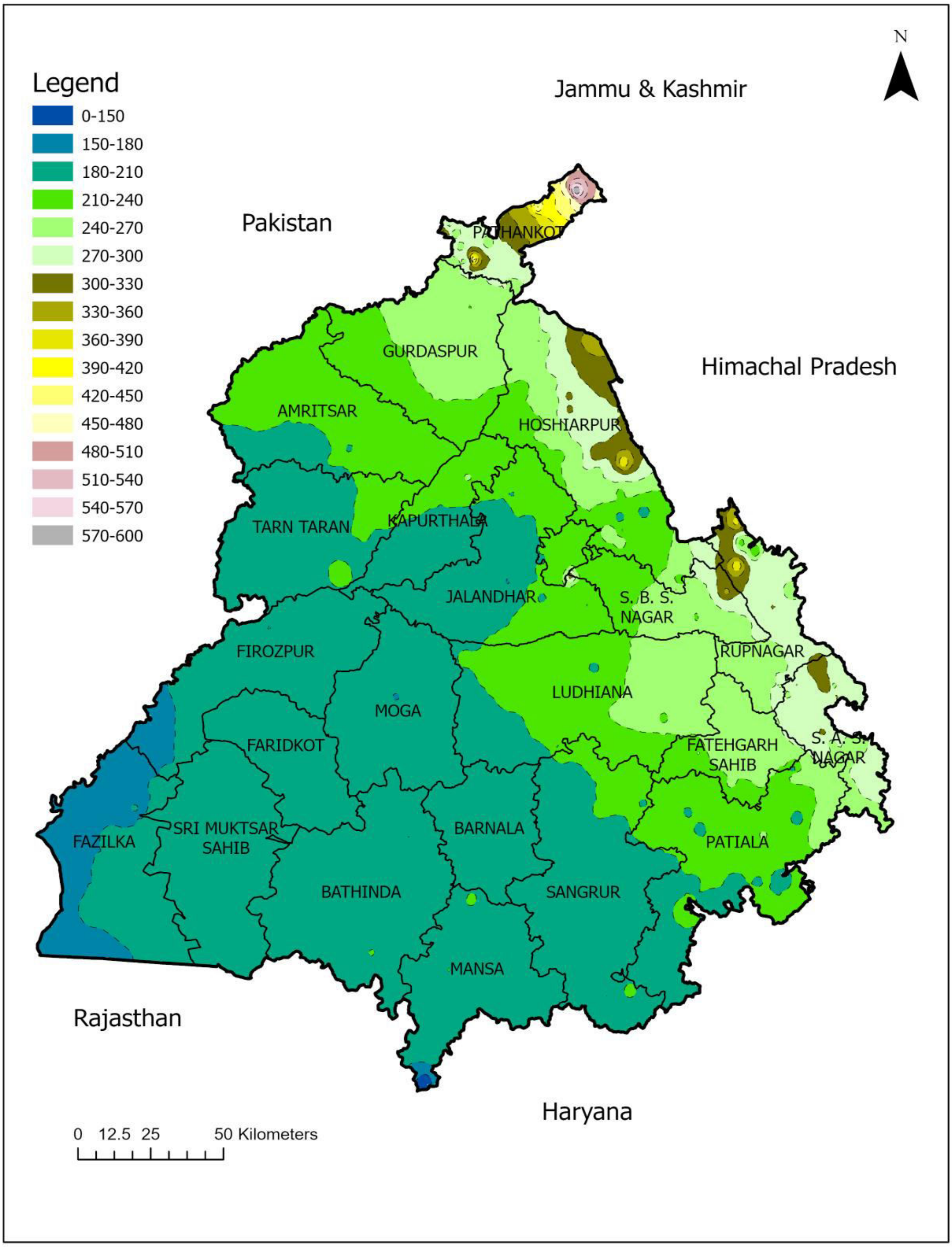


FIGURE 6 RISES and FALL OF WATER LEVEL, JUNE 1984- JUNE 2019

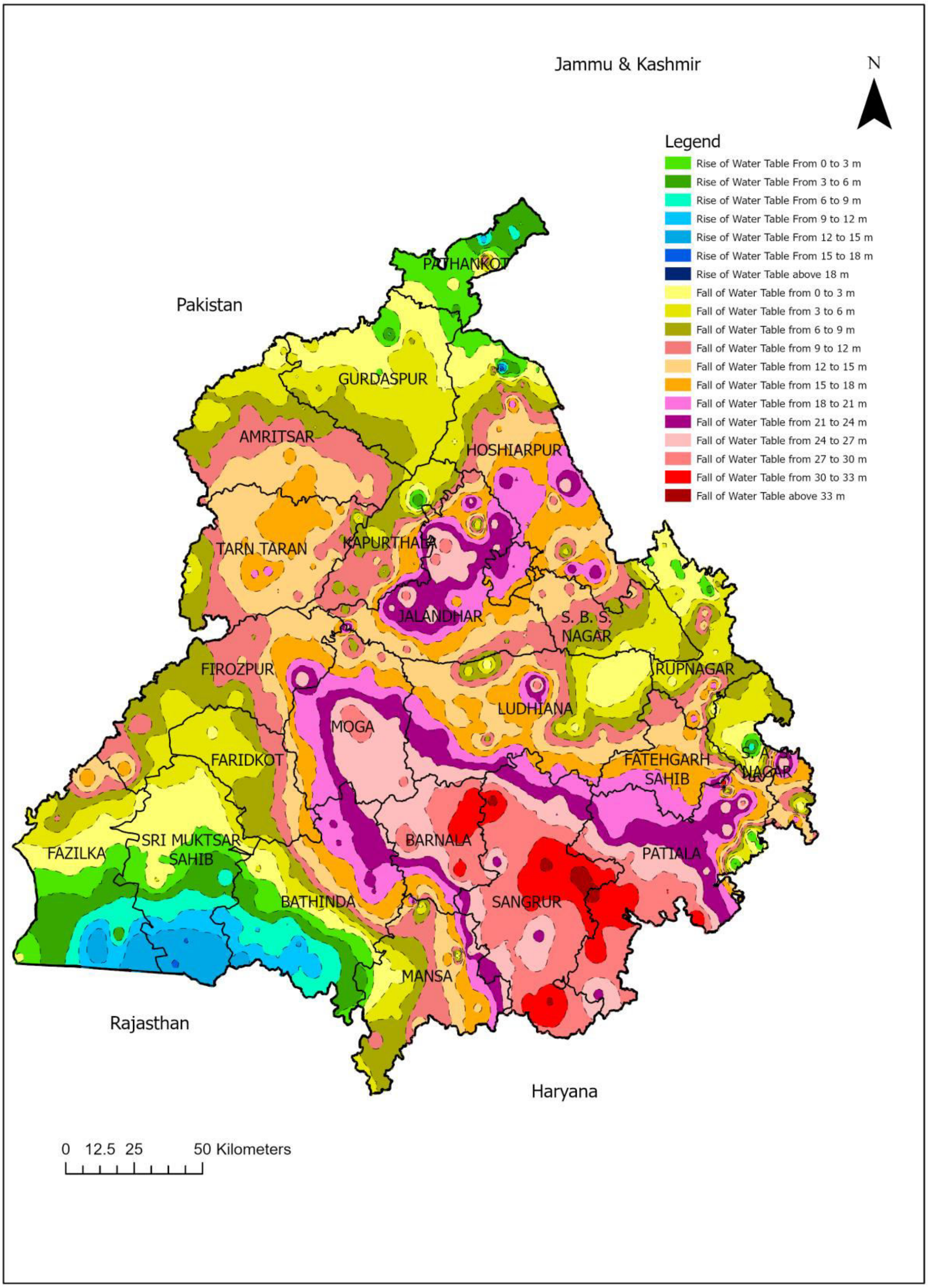


FIG. 7 PERCENTAGE OF BLOCKS UNDER DIFFERENT CATEGORIES

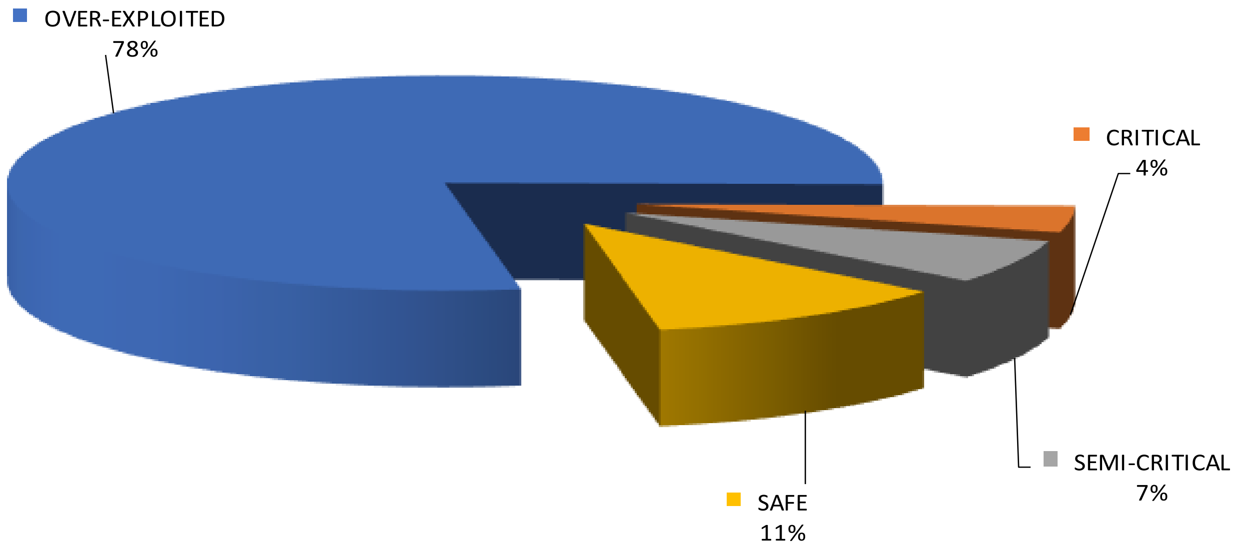


FIG. 8 DISTRICT-WISE RECHARGE FROM RAINFALL AND OTHER SOURCES,PUNJAB

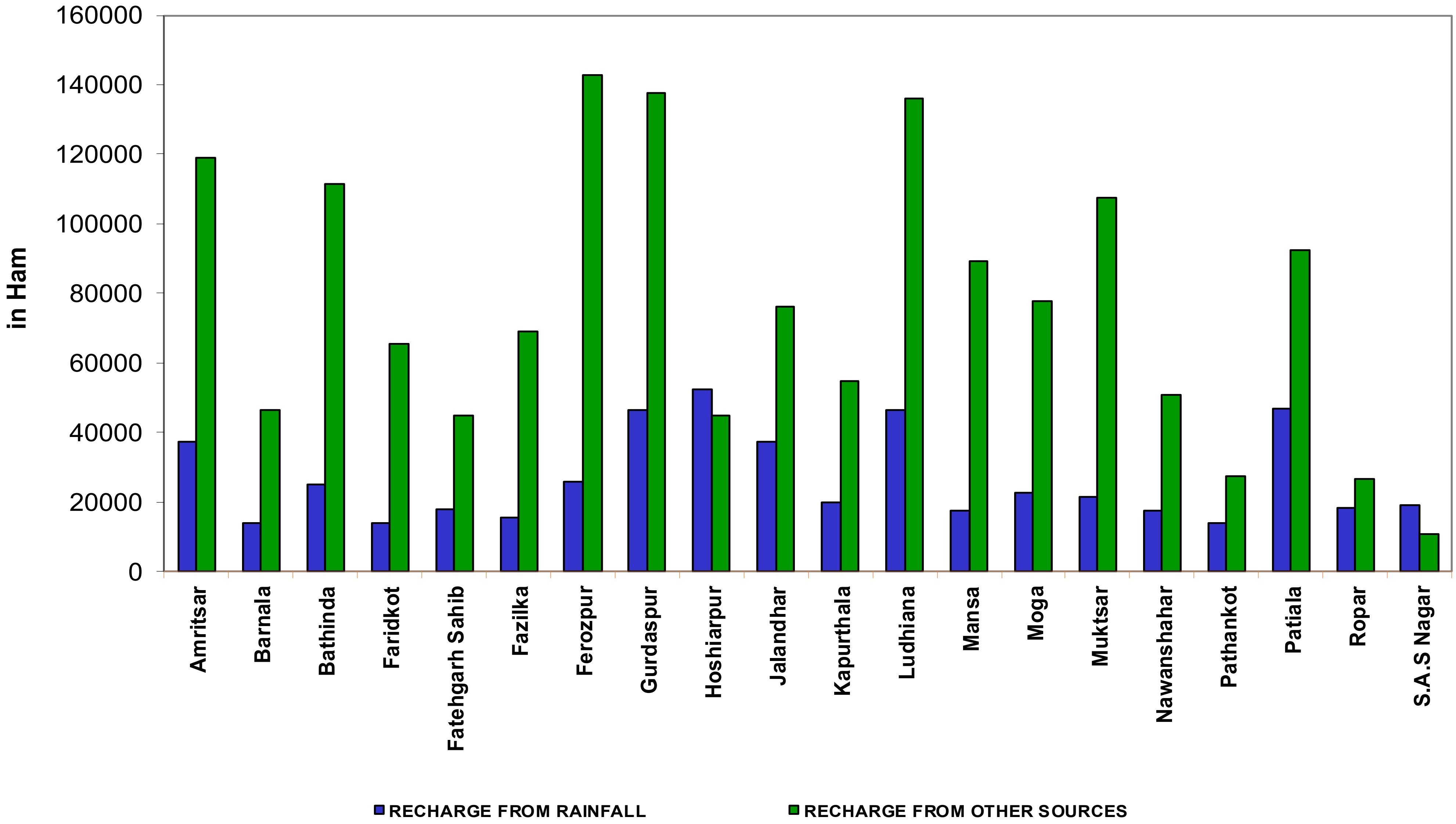


FIG. 9 DISTRICT-WISE GROUND WATER DRAFT, PUNJAB

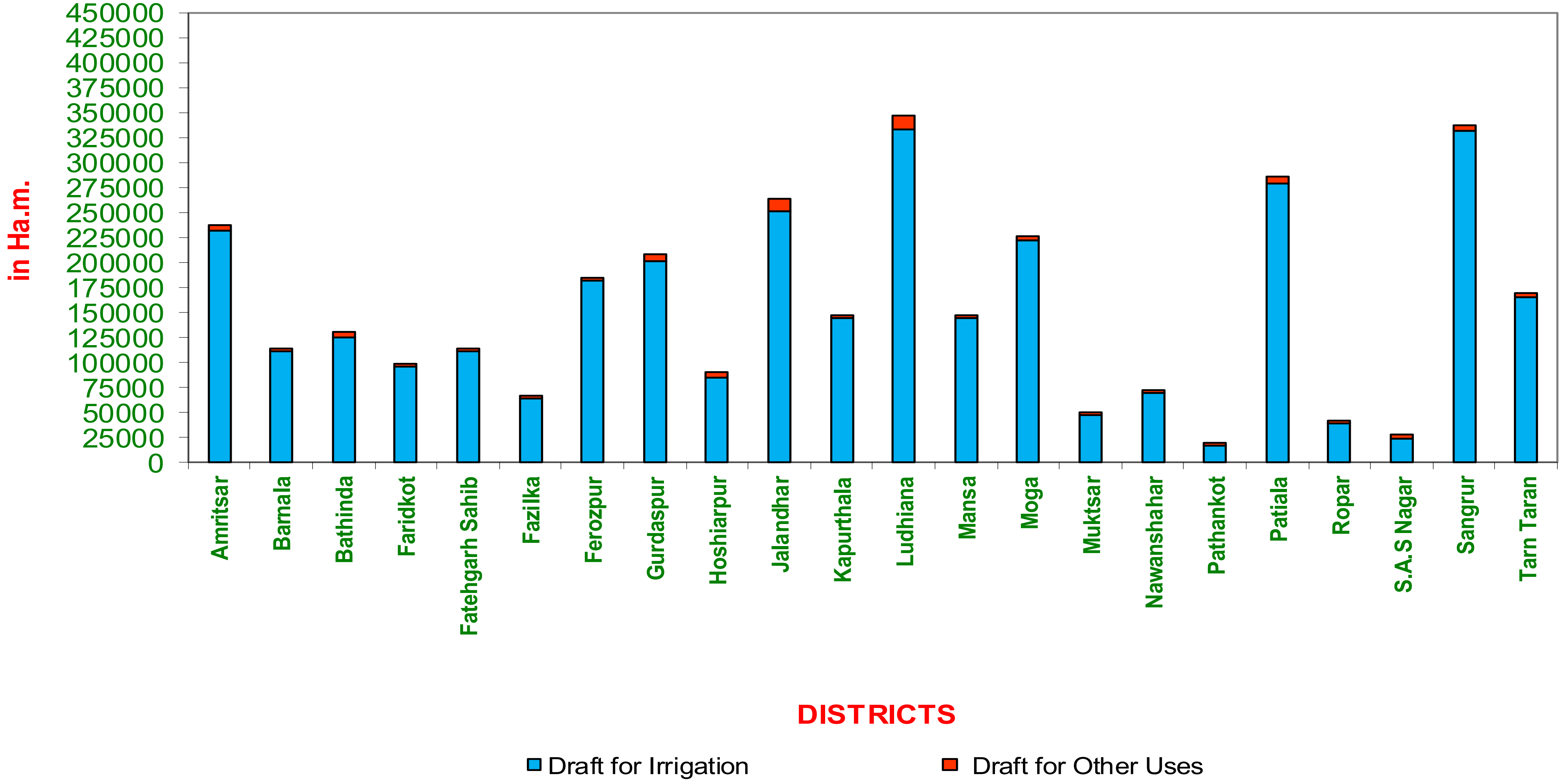


FIG.10 DISTRICT-WISE GROUND WATER AVAILABILITY, GROUND WATER DRAFT, NET GROUND WATER AVAILABILITY FOR FUTURE IRRIGATION PUNJAB

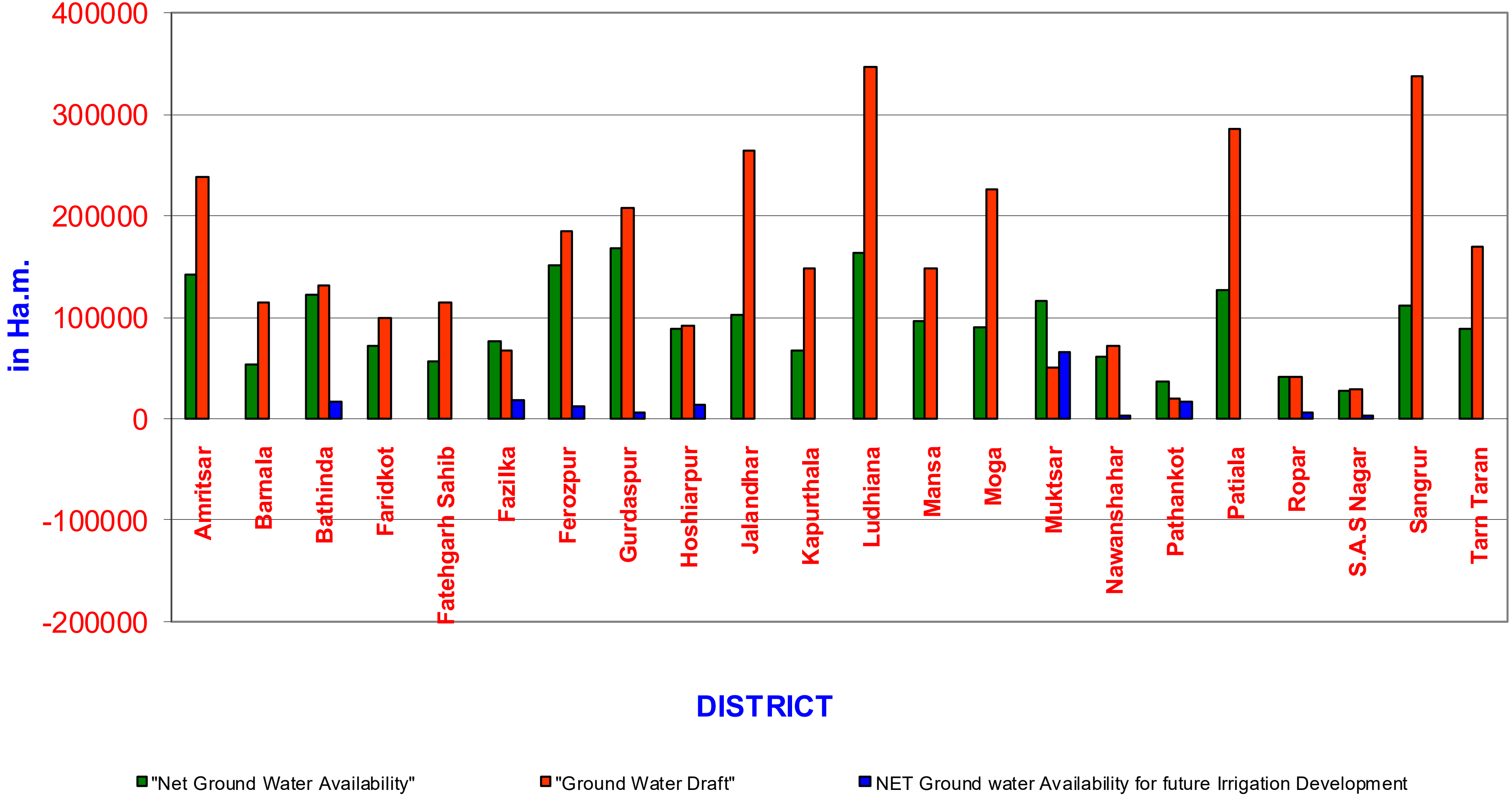
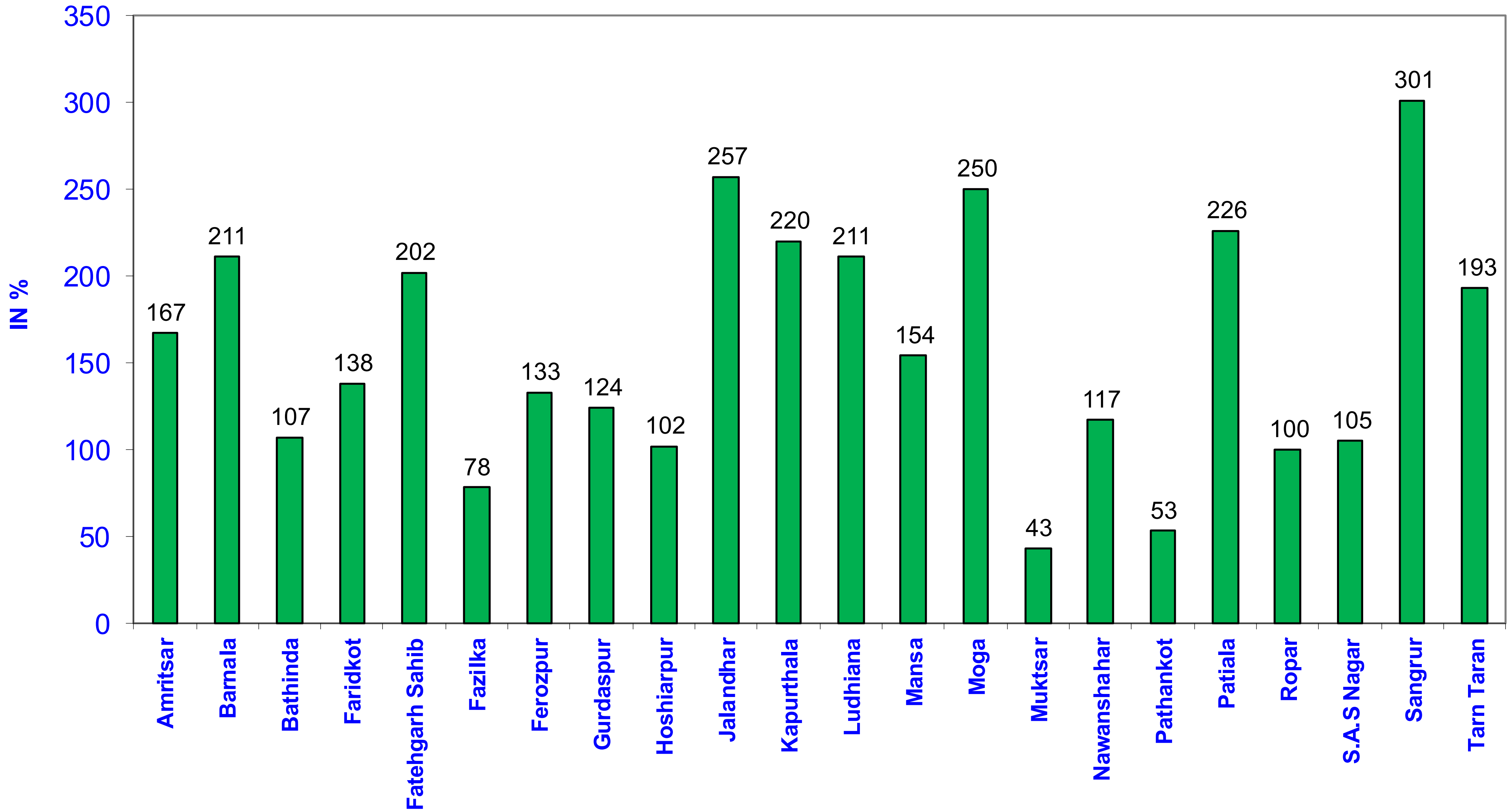


FIG.11 DISTRICT-WISE STAGE OF GROUND WATER DEVELOPMENT, PUNJAB



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ANNEXURE-1

DYNAMIC GROUND WATER RESOURCES OF PUNJAB, 2020

Sl. No	District	Assessment Unit Name BLOCK	Total Area of Assessment Unit (Ha)	Recharge Worthy Area (Ha)	Recharge from Rainfall-Monsoon Season (Ham)	Recharge from Other Sources-Monsoon Season (Ham)	Recharge from Rainfall-Non Monsoon Season (Ham)	Recharge from Other Sources-Non Monsoon Season (Ham)	Total Annual Ground Water Recharge (Ham)	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization (Over-Exploited/ Critical/Semi-critical/Safe/ Saline)
1	AMRITSAR	AJNALA	45610	45610	4949	15017	1054	6048	27067	2707	24360	36642	0	913	37555	981	0	154	OVER-EXPLOITED
2		ATTARI	26277	26277	2367	4793	642	2770	10572	529	10043	15923	0	586	16509	630	0	164	OVER-EXPLOITED
3		CHOGAWAN	42158	42158	5008	14831	1345	7004	28188	2819	25369	33847	0	867	34714	932	0	137	OVER-EXPLOITED
4		HARSHA CHINA	23162	23162	2568	7071	510	3902	14051	1405	12646	21340	0	390	21730	397	0	172	OVER-EXPLOITED
5		JANDIALA	23264	23264	2580	6505	527	3105	12717	1272	11445	24747	0	495	25242	532	0	221	OVER-EXPLOITED
6		MAJITHA	26159	26159	2258	11869	702	5148	19978	999	18979	28719	0	610	29329	656	0	155	OVER-EXPLOITED
7		RAYYA	32251	32251	4419	8885	1078	3677	18059	1806	16254	27362	0	1095	28457	1177	0	175	OVER-EXPLOITED
8		TARSIKA	23578	23578	3013	7673	571	3212	14468	1447	13021	24251	0	614	24865	660	0	191	OVER-EXPLOITED
9		VERKA	25181	25181	3085	4527	654	2867	11132	1113	10019	18921	0	548	19469	589	0	194	OVER-EXPLOITED
10	BARNALA	BARNALA	68971	68971	6176	9877	531	5236	21819	2182	19637	56684	0	1375	58059	1477	0	296	OVER-EXPLOITED
11		MAHAL KALAN	30275	30275	2897	8120	719	6798	18535	1853	16681	19142	0	567	19709	610	0	118	OVER-EXPLOITED
12		SEHNA	42055	42055	2951	9039	416	7306	19713	1971	17741	36102	0	479	36581	515	0	206	OVER-EXPLOITED
13	BATHINDA	BATHINDA	44559	44559	3411	10415	490	4870	19186	1919	17267	17068	0	1361	18429	1462	0	107	OVER-EXPLOITED
14		BHAGTA BHAI KA	26696	26696	1686	2051	341	1674	5751	575	5176	13331	0	181	13512	184	0	261	OVER-EXPLOITED
15		GONIANA MANDI	31977	31977	1531	2699	352	1837	6419	642	5777	10537	0	907	11444	975	0	198	OVER-EXPLOITED
16		MAUR	29581	29581	2265	5007	410	2932	10613	1061	9552	13324	0	340	13664	365	0	143	OVER-EXPLOITED
17		NATHANA	37558	37558	2479	7112	603	4088	14282	1428	12854	13397	0	602	13999	647	0	109	OVER-EXPLOITED
18		PHUL	28221	28221	1937	5675	186	6743	14541	1454	13087	17360	0	240	17601	258	0	134	OVER-EXPLOITED
19		RAMPURA	33258	33258	798	12142	263	5834	19037	1904	17133	13211	0	593	13804	637	3285	81	SEMI-CRITICAL
20		SANGAT	48201	48201	3213	12690	785	5306	21993	2199	19794	7355	0	512	7867	550	11889	40	SAFE
21		TALWANDI SABOO	57373	57373	3547	11434	858	8828	24667	2467	22201	20069	0	888	20957	954	1178	94	CRITICAL
22	FARIDKOT	FARIDKOT	72753	72753	6127	25001	1088	12002	44219	4422	39797	53590	0	1856	55446	1994	0	139	OVER-EXPLOITED
23		JAITON	42490	42490	3208	7691	477	3722	15097	1510	13588	22150	0	312	22462	318	0	165	OVER-EXPLOITED
24		KOT KAPURA	32355	32355	2486	10962	370	5940	19758	1976	17782	20448	0	314	20762	337	0	117	OVER-EXPLOITED
25	FATEHGARH SAHIB	AMLOH	25765	25765	3211	4499	550	3640	11900	1190	10710	24319	0	826	25145	888	0	235	OVER-EXPLOITED
26		BASSI PATHANA	18098	18098	2628	3190	541	2937	9296	930	8367	18031	0	322	18352	346	0	219	OVER-EXPLOITED
27		KHAMANON	19670	19670	2830	5873	476	3624	12804	1280	11523	18969	0	371	19340	399	0	168	OVER-EXPLOITED
28		KHERA	20212	20212	3074	4539	663	3452	11727	1173	10554	19537	0	292	19829	313	0	188	OVER-EXPLOITED
29		SIRHIND	30501	30501	3768	7059	262	5905	16993	1699	15294	30938	0	625	31562	671	0	206	OVER-EXPLOITED
30	FAZILKA	ABOHAR	86719	86719	5609	13173	1259	9182	29222	2922	26300	6970	0	1573	8544	1601	17729	32	SAFE
31		ARNIWALA SHEIKH SUBANPUR	32837	32837	1929	6762	484	4114	13288	1329	11959	14303	0	558	14861	568	0	124	OVER-EXPLOITED
32		FAZILKA	37610	37610	1774	12053	323	6409	20559	2056	18503	17033	0	682	17715	694	776	96	CRITICAL
33		JALALABAD	47807	47807	3584	11343	547	5852	21327	2133	19194	25258	0	1106	26365	1126	0	137	OVER-EXPLOITED
34		KHUYIAN SARWAR	68981	68981	4264	10050	941	4436	19691	1969	17722	5643	0	565	6208	575	11505	35	SAFE
35	FEROZPUR	FEROZPUR	45410	45410	3227	16957	480	8972	29635	2964	26672	25930	0	1181	27111	1202	0	102	OVER-EXPLOITED
36		GHALL KHURD	51840	51840	3535	21740	479	12064	37818	3782	34036	41090	0	451	41541	459	0	122	OVER-EXPLOITED
37		GURU HAR SAHAI	47053	47053	2671	15058	538	8737	27004	2700	24304	25482	0	343	25824	349	0	106	OVER-EXPLOITED
38		MAKHU	33406	33406	2017	13446	544	9454	25461	2546	22915	29965	0	208	30173	212	0	132	OVER-EXPLOITED
39		MAMDOT	33040	33040	2608	8151	523	3577	14860	1486	13374	22441	0	303	22745	309	0	170	OVER-EXPLOITED
40		ZIRA	41204	41204	3350	5895	499	4335	14079	1408	12671	31175	0	593	31768	603	0	251	OVER-EXPLOITED
41	GURDASPUR	BATALA	25611	25611	3766	10278	693	5081	19819	1982	17837	25789	0	1334	27123	1357	0	152	OVER-EXPLOITED
42		DERA BABA NANAK	28954	28954	4036	8775	892	3852	17555	1756	15799	24811	0	488	25300	497	0	160	OVER-EXPLOITED
43		DHARIWAL	23414	23414	3598	9259	695	4123	17676	1768	15908	23583	0	487	24070	496	0	151	OVER-EXPLOITED
44		DINA NAGAR	19734	19734	2555	5657	838	2813	11863	593	11270	7982	0	404	8387	411	2876	74	SEMI-CRITICAL
45		DORANGALA	10920	10920	1718	1951	392	1613	5674	284	5390	3420	0	193	3613	196	1774	67	SAFE
46		FATEHGARH CHURIAN	23070	23070	3015	10005	640	4718	18377	1838	16539	24861	0	408	25269	415	0	153	OVER-EXPLOITED
47		GURDASPUR	28902	28902	4631	8786	1036	3965	18419	1842	16577	15131	0	1340	16471	1364	82	99	CRITICAL
48		KAHNUWAN	33691	33691	5479	10012	1164	6201	22855	2286	20570	25598	0	494	26092	503	0	127	OVER-EXPLOITED
49		KALANAUR	19269	19269	3037	6219	627	2952	12835	1284	11552	17627	0	298	17925	303	0	155	OVER-EXPLOITED
50		QADIAN	20372	20372	2698	8354	731	5895	17678	1768	15910	15398	0	367	15766	374	138	99	CRITICAL
51		SRI HARGOBINDPUR	27488	27488	3069	11806	962	5154	20990	1050	19941	17751	0	441	18192	449	1741	91	CRITICAL

52	HOSHIARPUR	BHUNGA	42159	42159	6934	1617	1753	1673	11976	599	11378	6135	0	508	6642	516	4727	58	SAFE
53		DASUYA	32398	32398	5979	4509	1340	2217	14044	1404	12640	14018	0	642	14660	654	0	116	OVER-EXPLOITED
54		GARHSAHNKAR	28883	28883	3820	3701	458	1981	9960	996	8964	13977	0	693	14669	705	0	164	OVER-EXPLOITED
55		HAZIPUR	17944	17944	2800	3913	726	2138	9578	479	9099	5639	0	310	5950	316	3144	65	SAFE
56		HOSHIARPUR-II	35411	35411	5394	1553	1215	1317	9479	948	8531	10696	0	1292	11989	1315	0	141	OVER-EXPLOITED
57		HOSHIARPUR-II	36091	36091	4120	1178	969	1544	7811	391	7420	5194	0	561	5755	571	1655	78	SEMI-CRITICAL
58		MAHILPUR	33304	33304	4449	1114	659	1441	7664	766	6898	5037	0	526	5563	535	1325	81	SEMI-CRITICAL
59		MUKERIAN	23162	23162	4262	3547	892	2591	11292	1129	10162	7769	0	665	8434	676	1717	83	SEMI-CRITICAL
60		TALWARA	5698	5698	1073	495	262	317	2147	215	1932	723	0	297	1020	302	907	53	SAFE
61		TANDA	27371	27371	4502	5340	891	2492	13225	1323	11903	15894	0	414	16308	421	0	137	OVER-EXPLOITED
62	JALANDHAR	ADAMPUR	21894	21894	2850	4352	631	3421	11254	1125	10128	20238	0	364	20602	370	0	203	OVER-EXPLOITED
63		BHOGPUR	18255	18255	2487	5016	361	4738	12602	1260	11342	26423	0	260	26683	265	0	235	OVER-EXPLOITED
64		JALANDHAR-EAST	26710	26710	3441	2275	717	2184	8618	862	7756	20664	0	4814	25478	4898	0	329	OVER-EXPLOITED
65		JALANDHAR-WEST	34045	34045	4072	2998	464	2713	10247	1025	9222	20851	0	1599	22450	1627	0	243	OVER-EXPLOITED
66		LOHIAN	19004	19004	1997	3467	397	3537	9398	940	8458	21785	0	217	22002	221	0	260	OVER-EXPLOITED
67		MEHATPUR	17754	17754	1983	2853	355	2262	7453	745	6708	16007	0	417	16424	424	0	245	OVER-EXPLOITED
68		NAKODAR	28349	28349	3248	3293	667	3142	10350	1035	9315	26759	0	775	27534	788	0	296	OVER-EXPLOITED
69		NUR MAHAL	26121	26121	3142	4308	506	4069	12024	601	11423	24960	0	307	25267	312	0	221	OVER-EXPLOITED
70		PHILLAUR	29146	29146	3593	4980	911	4099	13582	1358	12224	30930	0	1965	32895	2000	0	269	OVER-EXPLOITED
71		RURKA KALAN	19307	19307	1784	3988	454	3931	10158	1016	9142	23568	0	321	23889	327	0	261	OVER-EXPLOITED
72		SHAHKOT	22414	22414	2521	2157	587	2200	7465	747	6719	19727	0	915	20642	931	0	307	OVER-EXPLOITED
73	KAPURTHALA	DHILWAN	27232	27232	3027	9630	461	3865	16983	1698	15285	28412	0	414	28827	422	0	189	OVER-EXPLOITED
74		KAPURTHALA	37167	37167	3699	4174	392	2439	10704	1070	9634	24188	0	943	25131	959	0	261	OVER-EXPLOITED
75		NADALA	24377	24377	3102	7562	445	3302	14412	1441	12970	21328	0	328	21656	334	0	167	OVER-EXPLOITED
76		PHAGWARA	29635	29635	3137	4625	385	3961	12108	1211	10897	29615	0	908	30523	924	0	280	OVER-EXPLOITED
77		SULTANPUR LODHI	44464	44464	4496	11052	626	3977	20151	2015	18136	41052	0	458	41509	466	0	229	OVER-EXPLOITED
78	LUDHIANA	DEHLON	14040	14040	1397	4340	0	2454	8192	819	7373	16659	0	510	17169	519	0	233	OVER-EXPLOITED
79		DORAHA	20269	20269	2231	10561	125	7196	20113	2011	18102	27690	0	486	28176	494	0	156	OVER-EXPLOITED
80		JAGRAON	37126	37126	3685	8904	702	6962	20254	2025	18228	27526	0	866	28391	881	0	156	OVER-EXPLOITED
81		KHANNA	27469	27469	3285	5455	508	3033	12280	1228	11052	33409	0	877	34287	892	0	310	OVER-EXPLOITED
82		LUDHIANA - I	38233	38233	4431	4826	639	2770	12666	1267	11400	26786	0	6894	33680	7014	0	295	OVER-EXPLOITED
83		LUDHIANA - II	49250	49250	6540	9633	1268	4550	21991	2199	19792	34969	0	1101	36071	1120	0	182	OVER-EXPLOITED
84		MACHHIWARA	33303	33303	1248	10457	1004	6491	19201	1920	17280	25283	0	304	25587	309	0	148	OVER-EXPLOITED
85		MALOUD	20188	20188	2079	5821	213	3601	11713	1171	10542	22644	0	288	22932	309	0	218	OVER-EXPLOITED
86		PAKHOWAL	24087	24087	2722	4020	254	2415	9411	941	8470	21866	0	321	22186	326	0	262	OVER-EXPLOITED
87		RAIKOT	30304	30304	3240	4348	520	2966	11074	1107	9966	26786	0	481	27267	490	0	274	OVER-EXPLOITED
88		SAMRALA	18016	18016	2245	5574	270	2626	10715	1071	9643	20154	0	453	20607	461	0	214	OVER-EXPLOITED
89		SIDHWAN BET	44370	44370	4838	7691	986	3758	17273	1727	15546	35507	0	259	35766	263	0	230	OVER-EXPLOITED
90		SUDHAR	14060	14060	1630	3390	312	2233	7565	757	6809	14146	0	467	14612	475	0	215	OVER-EXPLOITED
91	MANSA	BHIKHI	36834	36834	3228	7211	527	5005	15971	1597	14374	27226	0	369	27595	375	0	192	OVER-EXPLOITED
92		BUDHLADA	72590	72590	4101	20916	926	9331	35274	3527	31747	44721	0	939	45661	956	0	144	OVER-EXPLOITED
93		JHUNIR	32601	32601	1635	8660	531	9042	19869	1987	17882	21065	0	346	21410	352	0	120	OVER-EXPLOITED
94		MANSA	39177	39177	2793	10928	396	6791	20908	2091	18818	29965	0	800	30765	814	0	163	OVER-EXPLOITED
95		SARDULGARH	35660	35660	2843	5710	635	5464	14652	1465	13187	22026	0	416	22442	423	0	170	OVER-EXPLOITED
96	MOGA	BAGHA PURANA	55866	55866	4882	13406	750	7651	26689	2669	24020	52309	0	833	53142	847	0	221	OVER-EXPLOITED
97		DHARAMKOT (KOT ISA KHAN)	56234	56234	4330	20173	990	7381	32874	3287	29587	53024	0	671	53695	683	0	181	OVER-EXPLOITED
98		MOGA I	40872	40872	3604	7338	845	3670	15458	1546	13912	45923	0	1254	47177	1276	0	339	OVER-EXPLOITED
99		MOGA II	30930	30930	2629	5670	415	2844	11558	1156	10402	34508	0	404	34912	411	0	336	OVER-EXPLOITED
100		NIHAL SINGH WALA	39194	39194	3601	6213	612	3251	13676	1368	12309	36496	0	517	37013	526	0	301	OVER-EXPLOITED
101	S.A.S. NAGAR	DERA BASSI	39044	39044	6020	3813	1374	1959	13166	1317	11849	14033	0	1747	15780	1877	0	133	OVER-EXPLOITED
102		KHARAR	42275	42275	6105	1761	1116	1439	10421	1042	9379	7552	0	1880	9432	2020	0	101	OVER-EXPLOITED
103		SIALBA MAJRI	28064	28064	3573	758	685	926	5943	297	5646	2682	0	377	3060	406	2558	54	SAFE
104	MUKTSAR	GIDDERBAHA/ (KOT BHAI)	65681	65681	5011	10664	910	9972	26557	2656	23902	14222	0	813	15035	827	8853	63	SAFE
105		LAMBI	58733	58733	3773	15904	969	12952	33598	3360	30238	7518	0	559	8077	568	22152	27	SAFE
106		MALOUT	56233	56233	3427	10061	841	7699	22029	2203	19826	8595	0	824	9419	838	10393	48	SAFE
107		MUKTSAR	82781	82781	5245	25254	1147	15118	46765	4676	42088	16769	0	1174	17943	1194	24125	43	SAFE

108	NAWAN SHAHR	AUR	23037	23037	2818	17923	694	5381	26816	2682	24134	24023	0	340	24363	346	0	101	OVER-EXPLOITED
109		BALACHAUR	32464	32464	3068	3811	414	4074	11367	1137	10231	8526	0	469	8995	477	1228	88	SEMI-CRITICAL
110		BANGA	26066	26066	3331	3561	562	2266	9720	972	8748	14018	0	498	14515	506	0	166	OVER-EXPLOITED
111		NAWAN SHAHR	27592	27592	4385	6033	613	4850	15882	1588	14294	21806	0	751	22557	764	0	158	OVER-EXPLOITED
112		SAROYA	13677	13677	1360	1217	361	1749	4687	469	4218	1611	0	236	1847	240	2367	44	SAFE
113	PATHANKOT	BAMYAL	4641	4641	973	471	238	177	1859	186	1673	1221	0	162	1383	165	288	83	SEMI-CRITICAL
114		DHAR KALAN	4982	4982	1067	1338	231	562	3197	320	2877	823	0	395	1218	402	1653	42	SAFE
115		GHAROTA	11638	11638	2240	1244	463	633	4581	458	4123	2471	0	416	2887	423	1229	70	SEMI-CRITICAL
116		NAROT JAIMAL SINGH	19651	19651	2528	2927	752	1102	7310	731	6579	5142	0	421	5562	428	1009	85	SEMI-CRITICAL
117		PATHANKOT	14428	14428	1793	4589	257	2266	8904	890	8014	3796	0	570	4366	580	3638	54	SAFE
118		SUJANPUR	15720	15720	2815	7166	667	5001	15649	1565	14084	3903	0	554	4457	564	9618	32	SAFE
119	PATIALA	BHUNER HERI	36316	36316	5283	5376	927	4009	15595	1560	14036	38220	0	455	38676	463	0	276	OVER-EXPLOITED
120		GHANAUR	24174	24174	2815	4977	729	3953	12474	624	11850	12243	0	273	12517	278	0	106	OVER-EXPLOITED
121		NABHA	61803	61803	6657	9292	653	7890	24491	2449	22042	50591	0	1060	51650	1078	0	234	OVER-EXPLOITED
122		PATIALA	41740	41740	5466	6559	441	6688	19153	1915	17238	34948	0	2267	37215	2307	0	216	OVER-EXPLOITED
123		PATRAN	41841	41841	3954	6539	874	5012	16379	1638	14741	46023	0	656	46679	667	0	317	OVER-EXPLOITED
124		RAJPURA	26352	26352	4007	2936	441	3295	10679	1068	9611	16322	0	633	16954	644	0	176	OVER-EXPLOITED
125		SAMANA	39231	39231	4226	4728	863	5264	15080	1508	13572	27086	0	668	27753	679	0	204	OVER-EXPLOITED
126		SANAUR	37045	37045	4782	5690	766	3953	15191	1519	13672	34267	0	493	34760	501	0	254	OVER-EXPLOITED
127		SHAMBU KALAN	23345	23345	3605	3187	395	3222	10411	1041	9370	18838	0	559	19397	568	0	207	OVER-EXPLOITED
128	ROPAR	ANANDPUR SAHIB	25331	25331	3410	1987	535	1758	7691	385	7306	5154	0	642	5796	653	1499	79	SEMI-CRITICAL
129		CHAMKAUR SAHIB	19223	19223	2847	5839	406	5040	14132	1413	12719	15624	0	442	16066	449	0	126	OVER-EXPLOITED
130		MORINDA	13971	13971	2084	2901	363	2098	7445	745	6701	9597	0	244	9840	248	0	147	OVER-EXPLOITED
131		NURPUR BEDI	18872	18872	1863	1693	340	1527	5425	542	4882	4106	0	372	4478	379	397	92	CRITICAL
132		ROPAR	33856	33856	5249	1840	1080	1695	9863	493	9370	4317	0	851	5168	865	4187	55	SAFE
133	SANGRUR	ANDANA	32794	32794	2713	4477	657	3713	11559	1156	10403	24925	0	479	25404	487	0	244	OVER-EXPLOITED
134		BHIWANIGARH	33158	33158	3326	4883	518	3046	11773	1177	10596	31680	0	434	32114	442	0	303	OVER-EXPLOITED
135		DHURI	23337	23337	2255	5539	0	2961	10755	1076	9680	31550	0	559	32109	569	0	332	OVER-EXPLOITED
136		DIRBA	30716	30716	2765	3803	277	2724	9569	957	8612	29047	0	370	29418	377	0	342	OVER-EXPLOITED
137		LEHRAGHAGA	40808	40808	2736	4832	844	3037	11449	1145	10305	28987	0	576	29563	586	0	287	OVER-EXPLOITED
138		MALER KOTLA	42287	42287	4588	5323	772	4338	15022	1502	13520	38970	0	1211	40181	1232	0	297	OVER-EXPLOITED
139		MALERKOTLA-2	32242	32242	3601	5505	681	3296	13082	1308	11774	32143	0	0	32143	0	0	273	OVER-EXPLOITED
140		SANGRUR	47418	47418	3918	7996	355	3973	16241	1624	14617	46369	0	1012	47381	1029	0	324	OVER-EXPLOITED
141		SHERPUR	28584	28584	3645	3590	704	2501	10441	1044	9397	24928	0	421	25349	428	0	270	OVER-EXPLOITED
142		SUNAM	48981	48981	4164	6550	517	3069	14300	1430	12870	42915	0	555	43470	565	0	338	OVER-EXPLOITED
143	TARN TARAN	BHIKHIWIND	32937	32937	3243	5390	746	3581	12961	1296	11665	22207	0	455	22662	463	0	194	OVER-EXPLOITED
144		CHOLA SAHIB	28817	28817	1973	3583	520	2680	8756	876	7880	16731	0	443	17174	451	0	218	OVER-EXPLOITED
145		GANDIWIND	20990	20990	2427	5449	554	4064	12494	1249	11245	13029	0	277	13306	282	0	118	OVER-EXPLOITED
146		KHADUR SAHIB	28654	28654	3192	6297	599	3830	13918	1392	12526	26004	0	503	26507	512	0	212	OVER-EXPLOITED
147		NAUSHEHRA PANUAN	17247	17247	1762	3675	387	2848	8672	867	7805	16464	0	349	16813	355	0	215	OVER-EXPLOITED
148		PATTI	39482	39482	3992	4972	886	3304	13155	1315	11839	25774	0	810	26584	824	0	225	OVER-EXPLOITED
149		TARN TARAN	36094	36094	3535	4771	746	3239	12291	1229	11062	23920	0	970	24891	987	0	225	OVER-EXPLOITED
150		VALTOHA	37614	37614	3654	6763	811	4200	15428	1543	13885	21683	0	372	22055	378	0	159	OVER-EXPLOITED
			4926476	**4926476**	**501036**	**1042355**	**95388**	**640874**	**2279654**	**220644**	**2059011**	**3280207**	**0**	**105261**	**3385469**	**108378**	**161641**		

ANNEXURE-2

DYNAMIC GROUND WATER RESOURCES OF PUNJAB, 2020															(in Ham)
S. No.	Name of District	Ground Water Recharge					Total Natural Discharges	Annual Extractable Ground Water Resource	Current Annual Ground Water Extraction				Annual GW Allocation for for Domestic Use as on 2025	Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)
		Monsoon Season		Non-monsoon Season		Total Annual Ground Water Recharge			Irrigation	Industrial	Domestic	Total			
		Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other sources										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Amritsar	30246	81171	7082	37732	156231	14096	142136	231753	0	6118	237871	6552	0	167
2	Barnala	12024	27036	1667	19339	60066	6007	54060	111928	0	2421	114350	2602	0	211
3	Bathinda	20866	69223	4288	42112	136489	13649	122840	125653	0	5624	131276	6032	16352	107
4	Faridkot	11821	43654	1935	21663	79074	7907	71166	96187	0	2482	98669	2649	0	138
5	Fatehgarh Sahib	15510	25160	2492	19558	62720	6272	56448	111794	0	2436	114230	2617	0	202
6	Fazilka	12896	43330	2613	25557	84396	8440	75956	63564	0	3920	67485	3989	18505	78
7	Ferozpur	21672	91297	4003	51576	168548	16855	151694	181726	0	3644	185371	3708	11505	133
8	Gurdaspur	37602	91103	8669	46367	183742	16448	167293	201952	0	6255	208207	6364	6612	124
9	Hoshiarpur	43332	26967	9165	17712	97176	8249	88926	85083	0	5907	90990	6010	13475	102
10	Jalandhar	31117	39687	6051	36295	113150	10714	102437	251911	0	11955	263865	12163	0	257
11	Kapurthala	17461	37043	2310	17545	74358	7436	66922	144595	0	3052	147646	3105	0	220
12	Ludhiana	39571	85019	6801	51055	182446	18245	164202	333423	0	13306	346729	13554	0	211
13	Mansa	14600	53425	3016	35634	106675	10667	96007	145003	0	2869	147872	2919	0	154
14	Moga	19046	52800	3612	24797	100255	10026	90230	222261	0	3678	225939	3742	0	250
15	Muktsar	17456	61883	3868	45742	128949	12895	116054	47104	0	3369	50473	3428	65522	43
16	Nawanshahar	14962	32545	2645	18320	68472	6847	61625	69985	0	2293	72278	2333	3595	117
17	Pathankot	11415	17734	2609	9741	41500	4150	37350	17355	0	2518	19872	2562	17434	53
18	Patiala	40796	49284	6089	43285	139453	13322	126132	278538	0	7062	285601	7185	0	226
19	Ropar	15453	14260	2724	12118	44556	3578	40978	38798	0	2550	41348	2595	6083	100
20	S.A.S Nagar	15698	6333	3176	4324	29531	2656	26874	24268	0	4004	28272	4303	2558	105
21	Sangrur	33711	52499	5325	32658	124193	12419	111774	331514	0	5617	337131	5715	0	301
22	Tarn Taran	23779	40901	5250	27745	97676	9768	87908	165812	0	4180	169992	4253	0	193
	Total (Ham)	**501036**	**1042355**	**95391**	**640874**	**2279657**	**220644**	**2059011**	**3280208**	**0**	**105261**	**3385482**	**108378**	**161641**	**164**

ANNEXURE-3

DYNAMIC GROUND WATER RESOURCES OF PUNJAB, 2020

SUMMARY OF ASSESSMENT UNIT WISE CATEGORIZATION

S.No	Name of District	Total No. of Assessed	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
			No.	%	No.	%	No.	%	No.	%	No.	%
1	Amritsar	9							9	100	0	0
2	Barnala	3							3	100	0	0
3	Bathinda	9	1	11	1	11	1	11	6	67	2	22
4	Faridkot	3							3	100	2	67
5	Fateh Garh Sahib	5							5	100		0
6	Fazilka	5	2	40			1	20	2	40	3	60
7	Ferozpur	6							6	100	0	0
8	Gurdaspur	11	1	9	1	9	3	27	6	55		0
9	Hoshiarpur	10	3	30	3	30			4	40		0
10	Jalandhar	11							11	100		0
11	Kapurthala	5							5	100		0
12	Ludhiana	13							13	100		0
13	Mansa	5							5	100	2	40
14	Moga	5							5	100	0	0
15	Mohali	3	1	33					2	67	1	33
16	Muktsar	4	4	100							2	50
17	Nawanshahar	5	1	20	1	20			3	60		0
18	Pathankot	6	3	50	3	50						0
19	Patiala	9							9	100	2	22
20	Ropar	5	1	20	1	20	1	20	2	40		0
21	Sangrur	10							10	100		0
22	Tarn Taran	8							8	100		0
		150	17		10		6		117		14	

ANNEXURE-4

DYNAMIC GROUND WATER RESOURCES OF PUNJAB, 2020

ANNUAL EXTRACTABLE GROUND WATER RESOURCES

S.No	Name of District	Total Annual Extractable Ground Water Resource of Assessed Units (in mcm)	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
			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)	%	Annual Extractable Ground Water Resource (in mcm)	%
1	Amritsar	1421	0	0	0		0	0	1421	100	0	0
2	Barnala	541	0	0	0		0	0	541	100	0	0
3	Bathinda	1228	198	16	171	14	222	18	637	52	395	32
4	Faridkot	712	0	0	0		0	0	712	100	576	81
5	Fatehgarh Sahib	564	0	0	0		0	0	564	100	0	0
6	Fazilka	760	440	58	0		185	24	312	41	632	83
7	Ferozpur	1517	0	0	0		0	0	1340	88	0	0
8	Gurdaspur	1673	54	3	113	7	524	31	982	59	0	0
9	Hoshiarpur	889	224	25	245	28	0	0	420	47	0	0
10	Jalandhar	1024	0	0	0	0	0	0	1024	100	0	0
11	Kapurthala	669	0	0	0	0	0	0	669	100	0	0
12	Ludhiana	1642	0	0	0	0	0	0	1642	100	0	0
13	Mansa	960	0	0	0	0	0	0	960	100	311	32
14	Moga	902	0	0	0	0	0	0	902	100	0	0
15	Muktsar	1161	1161	100	0	0	0	0		0	619	53
16	Nawanshahar	616	42	7	102	17	0	0	472	77	0	0
17	Pathankot	374	250	67	124	33	0	0		0	0	0
18	Patiala	1261	0	0	0	0	0	0	1261	100	215	17
19	Ropar	410	94	23	73	18	49	12	194	47	0	0
20	S.A.S Nagar	269	56	21	0		0	0	212	79	118	44
21	Sangrur	1118	0	0	0		0	0	1118	100	0	0
22	Tarn Taran	879	0	0	0		0	0	879	100	0	0

ANNEXURE-5

DYNAMIC GROUND WATER RESOURCES OF PUNJAB, 2020
RECHARGE WORTHY AREA

S.No	Name of District	Total Recharge Worthy Area of Assessed Units (in sq.km)	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
			Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%
1	Amritsar	2676		0		0		0	2676	100	0	0
2	Barnala	1413		0		0		0	1413	100	0	0
3	Bathinda	3374	482	14	333	10	574	17	1986	59	1019	30
4	Faridkot	1476		0		0		0	1476	100	1051	71
5	Fatehgarh Sahib	1142		0		0		0	1142	100	0	0
6	Fazilka	2740	1557	57		14	376	14	806	29	2035	74
7	Ferozpur	2520	0	0		0		0	2520	100	0	0
8	Gurdaspur	2614	109	4	197	8	768	29	1540	59	0	0
9	Hoshiarpur	2824	658	23	926	33		0	1241	44	0	0
10	Jalandhar	2630		0		0		0	2630	100	0	0
11	Kapurthala	1629		0		0		0	1629	100	0	0
12	Ludhiana	3707		0		0		0	3707	100	0	0
13	Mansa	2169		0		0		0	2169	100	683	31
14	Moga	2231		0		0		0	2231	100	0	0
15	Muktsar	2634	2634	100		0		0		0	1390	53
16	Nawanshahar	1228	137	11	325	26		0	767	62	0	0
17	Pathankot	711	351	49	359	51		0		0	0	0
18	Patiala	3318		0		0		0	3318	100	505	15
19	Ropar	1113	339	30	253	23	189	17	332	30	0	0
20	S.A.S Nagar	1094	281	26		0		0	813	74	390	36
21	Sangrur	3603		0		0		0	3603	100	0	0
22	Tarn Taran	2418		0		0		0	2418	100	0	0
		49265	**6548**		**2393**		**1906**		**38418**		**7074**	

TABLE-1

DYNAMIC GROUND WATER RESOURCES OF PUNJAB, AS ON 31.03.2020

S. No.	Name of District	Ground Water Recharge					Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)
		Monsoon Season (Ham)		Non-monsoon Season (Ham)		Total Annual Ground Water Recharge (Ham)		
		Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other sources			
1	2	3	4	5	6	7	8	9
1	Amritsar	30246	81171	7082	37732	156231	14096	142136
2	Barnala	12024	27036	1667	19339	60066	6007	54060
3	Bathinda	20866	69223	4288	42112	136489	13649	122840
4	Faridkot	11821	43654	1935	21663	79074	7907	71166
5	Fatehgarh Sahib	15510	25160	2492	19558	62720	6272	56448
6	Fazilka	12896	43330	2613	25557	84396	8440	75956
7	Ferozpur	21672	91297	4003	51576	168548	16855	151694
8	Gurdaspur	37602	91103	8669	46367	183742	16448	167293
9	Hoshiarpur	43332	26967	9165	17712	97176	8249	88926
10	Jalandhar	31117	39687	6051	36295	113150	10714	102437
11	Kapurthala	17461	37043	2310	17545	74358	7436	66922
12	Ludhiana	39571	85019	6801	51055	182446	18245	164202
13	Mansa	14600	53425	3016	35634	106675	10667	96007
14	Moga	19046	52800	3612	24797	100255	10026	90230
15	Muktsar	17456	61883	3868	45742	128949	12895	116054
16	Nawanshahar	14962	32545	2645	18320	68472	6847	61625
17	Pathankot	11415	17734	2609	9741	41500	4150	37350
18	Patiala	40796	49284	6089	43285	139453	13322	126132
19	Ropar	15453	14260	2724	12118	44556	3578	40978
20	S.A.S Nagar	15698	6333	3176	4324	29531	2656	26874
21	Sangrur	33711	52499	5325	32658	124193	12419	111774
22	Tarn Taran	23779	40901	5250	27745	97676	9768	87908
	Total (Ham)	**501036**	**1042355**	**95391**	**640874**	**2279657**	**220644**	**2059011**

TABLE-2

DYNAMIC GROUND WATER RESOURCES OF PUNJAB, AS ON 31.03.2020

S. No.	Name of District	Annual Extractable Ground Water Resource (Ham)	Current Annual Ground Water Extraction (Ham)				Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)
			Irrigation	Industrial	Domestic	Total			
1	2	3	4	5	6	7	8	9	10
1	Amritsar	142136	231753	0	6118	237871	6552	0	167
2	Barnala	54060	111928	0	2421	114350	2602	0	211
3	Bathinda	122840	125653	0	5624	131276	6032	16352	107
4	Faridkot	71166	96187	0	2482	98669	2649	0	138
5	Fatehgarh Sahib	56448	111794	0	2436	114230	2617	0	202
6	Fazilka	75956	63564	0	3920	67485	3989	18505	78
7	Ferozpur	151694	181726	0	3644	185371	3708	11505	133
8	Gurdaspur	167293	201952	0	6255	208207	6364	6612	124
9	Hoshiarpur	88926	85083	0	5907	90990	6010	13475	102
10	Jalandhar	102437	251911	0	11955	263865	12163	0	257
11	Kapurthala	66922	144595	0	3052	147646	3105	0	220
12	Ludhiana	164202	333423	0	13306	346729	13554	0	211
13	Mansa	96007	145003	0	2869	147872	2919	0	154
14	Moga	90230	222261	0	3678	225939	3742	0	250
15	Muktsar	116054	47104	0	3369	50473	3428	65522	43
16	Nawanshahar	61625	69985	0	2293	72278	2333	3595	117
17	Pathankot	37350	17355	0	2518	19872	2562	17434	53
18	Patiala	126132	278538	0	7062	285601	7185	0	226
19	Ropar	40978	38798	0	2550	41348	2595	6083	100
20	S.A.S Nagar	26874	24268	0	4004	28272	4303	2558	105
21	Sangrur	111774	331514	0	5617	337131	5715	0	301
22	Tarn Taran	87908	165812	0	4180	169992	4253	0	193
	Total (Ham)	**2059011**	**3280208**	**0**	**105261**	**3385476**	**108378**	**161641**	**164**
	FIG. IN MAF	**16.68**	**26.57**	**0**	**0.85**	**27.43**	**0.88**	**1.31**	
	FIG IN BCM	**20.59**	**32.80**	**0**	**1.05**	**33.85**	**1.08**	**1.62**	

TABLE-3

DYNAMIC GROUND WATER RESOURCES OF PUNJAB, AS ON 31.03.2020

Comparison of Stage of Ground Water Extraction & Categorization of Previous and Present Study

Sr. No	Assessment Unit (Block)/ District	2017		Remarks	2020	
		Stage of Ground Water Development (%)	Categorization for future ground water development (Safe/semi-critical /critcal/ over-exploited		Stage of Ground Water Development (%)	Categorization for future ground water development (Safe/semi-critical /critcal/ over-exploited)
	AMRITSAR					
1	AJNALA	178	OVER-EXPLOITED		154	OVER-EXPLOITED
2	ATTARI			**NEW BLOCK IN 2019-20**	164	OVER-EXPLOITED
3	CHOGAWAN	133	OVER-EXPLOITED		137	OVER-EXPLOITED
4	HARSHA CHINA	124	OVER-EXPLOITED		172	OVER-EXPLOITED
5	JANDIALA	196	OVER-EXPLOITED		221	OVER-EXPLOITED
6	MAJITHA	120	OVER-EXPLOITED		155	OVER-EXPLOITED
7	RAYYA	168	OVER-EXPLOITED		174	OVER-EXPLOITED
8	TARSIKA	174	OVER-EXPLOITED		191	OVER-EXPLOITED
9	VERKA	123	OVER-EXPLOITED		194	OVER-EXPLOITED
	BARNALA					
1	BARNALA	255	OVER-EXPLOITED		296	OVER-EXPLOITED
2	MAHAL KALAN	177	OVER-EXPLOITED		118	OVER-EXPLOITED
3	SEHNA	185	OVER-EXPLOITED		206	OVER-EXPLOITED
	BATHINDA					
1	PHUL	184	OVER-EXPLOITED		135	OVER-EXPLOITED
2	NATHANA	73	SEMI-CRITICAL	**Stage of Development Increased**	109	OVER-EXPLOITED
3	MAUR	127	OVER-EXPLOITED		143	OVER-EXPLOITED
4	BATHINDA	103	OVER-EXPLOITED		107	OVER-EXPLOITED
5	TALWANDI SABOO	65	SAFE		94	CRITICAL
6	SANGAT	67	SAFE		40	SAFE
7	RAMPURA	69	SAFE		81	SEMI-CRITICAL
8	BHAGTA BHAI KA			**NEW BLOCK IN 2019-20**	261	OVER-EXPLOITED
9	GONIANA MANDI			**NEW BLOCK IN 2019-20**	198	OVER-EXPLOITED
	FARIDKOT					
1	FARIDKOT	169	OVER-EXPLOITED		139	OVER-EXPLOITED
2	KOT KAPURA	165	OVER-EXPLOITED		117	OVER-EXPLOITED
3	JAITON			**NEW BLOCK IN 2019-20**	165	OVER-EXPLOITED
	FATEHGARH SAHIB					
1	KHERA	210	OVER-EXPLOITED		188	OVER-EXPLOITED
2	SIRHIND	213	OVER-EXPLOITED		206	OVER-EXPLOITED
3	AMLOH	206	OVER-EXPLOITED		235	OVER-EXPLOITED
4	BASSI PATHANA	207	OVER-EXPLOITED		219	OVER-EXPLOITED
5	KHAMANON	199	OVER-EXPLOITED		168	OVER-EXPLOITED
	FAZILKA					
1	ABOHAR	38	SAFE		32	SAFE
2	FAZILKA	155	SAFE	**> 50% area under 5 mts depth**	96	CRITICAL
3	JALALABAD	150	OVER-EXPLOITED		137	OVER-EXPLOITED
4	KHUYIAN SARWAR	56	SAFE		35	SAFE
5	ARNIWALA SHEIKH SUBANPUR			**NEW BLOCK IN 2019-20**	124	OVER-EXPLOITED

Sr. No	Assessment Unit (Block)/ District	2017		Remarks	2020	
		Stage of Ground Water Development (%)	Categorization for future ground water development (Safe/semi-critical /critcal/over-exploited		Stage of Ground Water Development (%)	Categorization for future ground water development (Safe/semi-critical /critcal/over-exploited)
1	FEROZPUR	132	OVER-EXPLOITED		102	OVER-EXPLOITED
2	GHALL KHURD	198	OVER-EXPLOITED		122	OVER-EXPLOITED
3	GURU HAR SAHAI	117	OVER-EXPLOITED		106	OVER-EXPLOITED
4	MAKHU	149	OVER-EXPLOITED		132	OVER-EXPLOITED
5	MAMDOT	154	OVER-EXPLOITED		170	OVER-EXPLOITED
6	ZIRA	259	OVER-EXPLOITED		251	OVER-EXPLOITED
	GURDASPUR					
1	BATALA	171	OVER-EXPLOITED		152	OVER-EXPLOITED
2	DINA NAGAR	101	SAFE		74	SEMI-CRITICAL
3	FATEHGARH CHURIAN	144	OVER-EXPLOITED		153	OVER-EXPLOITED
4	GURDASPUR	93	CRITICAL		99	CRITICAL
5	KAHNUWAN	137	OVER-EXPLOITED		127	OVER-EXPLOITED
6	KALANAUR	141	OVER-EXPLOITED		155	OVER-EXPLOITED
7	QADIAN	143	OVER-EXPLOITED		99	CRITICAL
8	SRI HARGOBINDPUR	129	OVER-EXPLOITED		91	CRITICAL
9	DERA BABA NANAK	151	OVER-EXPLOITED		160	OVER-EXPLOITED
10	DHARIWAL	130	OVER-EXPLOITED		151	OVER-EXPLOITED
11	DORANGALA			**NEW BLOCK IN 2019-20**	67	SAFE
	HOSHIARPUR					
1	HOSHIARPUR-II	68	SAFE		78	SEMI-CRITICAL
2	BHUNGA	70	SAFE		58	SAFE
3	DASUYA	123	OVER-EXPLOITED		116	OVER-EXPLOITED
4	GARHSAHNKAR	131	OVER-EXPLOITED		164	OVER-EXPLOITED
5	HAZIPUR	69	SAFE		65	SAFE
6	HOSHIARPUR-1	147	OVER-EXPLOITED		141	OVER-EXPLOITED
7	MAHILPUR	70	SAFE		81	SEMI-CRITICAL
8	MUKERIAN	86	SEMI-CRITICAL		83	SEMI-CRITICAL
9	TALWARA	81	SEMI-CRITICAL		53	SAFE
10	TANDA	183	OVER-EXPLOITED		137	OVER-EXPLOITED
	JALANDHAR					
1	ADAMPUR	190	OVER-EXPLOITED		203	OVER-EXPLOITED
2	BHOGPUR	279	OVER-EXPLOITED		235	OVER-EXPLOITED
3	RURKA KALAN	211	OVER-EXPLOITED		261	OVER-EXPLOITED
4	JALANDHAR-EAST	316	OVER-EXPLOITED		329	OVER-EXPLOITED
5	JALANDHAR-WEST	213	OVER-EXPLOITED		243	OVER-EXPLOITED
6	LOHIAN	266	OVER-EXPLOITED		260	OVER-EXPLOITED
7	NAKODAR	277	OVER-EXPLOITED		296	OVER-EXPLOITED
8	NUR MAHAL	218	OVER-EXPLOITED		221	OVER-EXPLOITED
9	PHILLAUR	206	OVER-EXPLOITED		269	OVER-EXPLOITED
10	SHAHKOT	266	OVER-EXPLOITED		307	OVER-EXPLOITED
11	MEHATPUR			**NEW BLOCK IN 2019-20**	245	OVER-EXPLOITED
	KAPURTHALA					
1	NADALA	198	OVER-EXPLOITED		167	OVER-EXPLOITED
2	DHILWAN	217	OVER-EXPLOITED		189	OVER-EXPLOITED
3	KAPURTHALA	201	OVER-EXPLOITED		261	OVER-EXPLOITED
4	PHAGWARA	281	OVER-EXPLOITED		280	OVER-EXPLOITED
5	SULTANPUR LODHI	223	OVER-EXPLOITED		229	OVER-EXPLOITED

Sr. No	Assessment Unit (Block)/ District	2017		Remarks	2020	
		Stage of Ground Water Development (%)	Categorization for future ground water development (Safe/semi-critical /critcal/over-exploited		Stage of Ground Water Development (%)	Categorization for future ground water development (Safe/semi-critical /critcal/over-exploited)
1	DEHLON	208	OVER-EXPLOITED		233	OVER-EXPLOITED
2	DORAHA	121	OVER-EXPLOITED		156	OVER-EXPLOITED
3	JAGRAON	156	OVER-EXPLOITED		156	OVER-EXPLOITED
4	KHANNA	251	OVER-EXPLOITED		310	OVER-EXPLOITED
5	LUDHIANA	275	OVER-EXPLOITED		295	OVER-EXPLOITED
6	MACHHIWARA	119	OVER-EXPLOITED		148	OVER-EXPLOITED
7	MANGAT	174	OVER-EXPLOITED		182	OVER-EXPLOITED
8	PAKHOWAL	210	OVER-EXPLOITED		262	OVER-EXPLOITED
9	RAIKOT	256	OVER-EXPLOITED		274	OVER-EXPLOITED
10	SAMRALA	225	OVER-EXPLOITED		214	OVER-EXPLOITED
11	SIDHWAN BET	185	OVER-EXPLOITED		230	OVER-EXPLOITED
12	SUDHAR	163	OVER-EXPLOITED		215	OVER-EXPLOITED
13	MALOUD			**NEW BLOCK IN 2019-20**	218	OVER-EXPLOITED
	MANSA					
1	BHIKHI	125	OVER-EXPLOITED		192	OVER-EXPLOITED
2	BUDHLADA	188	OVER-EXPLOITED		144	OVER-EXPLOITED
3	JHUNIR	99	CRITICAL		120	OVER-EXPLOITED
4	MANSA	123	OVER-EXPLOITED		163	OVER-EXPLOITED
5	SARDULGARH	193	OVER-EXPLOITED		170	OVER-EXPLOITED
	MOGA					
1	BAGHA PURANA	178	OVER-EXPLOITED		221	OVER-EXPLOITED
2	DHARAMKOT (KOT ISA KHAN)	210	OVER-EXPLOITED		181	OVER-EXPLOITED
3	MOGA I	282	OVER-EXPLOITED		339	OVER-EXPLOITED
4	MOGA II	285	OVER-EXPLOITED		336	OVER-EXPLOITED
5	NIHAL SINGH WALA	276	OVER-EXPLOITED		301	OVER-EXPLOITED
	MUKTSAR					
1	GIDDERBAHA/ (KOT BHAI)	105	SAFE		63	SAFE
2	LAMBI	45	SAFE		27	SAFE
3	MALOUT	64	SAFE		48	SAFE
4	MUKTSAR	85	SAFE		43	SAFE
	NAWAN SHAHR					
1	AUR	177	OVER-EXPLOITED		101	OVER-EXPLOITED
2	BALACHAUR	63	SAFE		88	SEMI-CRITICAL
3	BANGA	150	OVER-EXPLOITED		166	OVER-EXPLOITED
4	NAWAN SHAHR	108	OVER-EXPLOITED		158	OVER-EXPLOITED
5	SAROYA	66	SAFE		44	SAFE
	PATHANKOT					
1	BAMYAL	105	SAFE		83	SEMI-CRITICAL
2	DHAR KALAN	24	SAFE		42	SAFE
3	PATHANKOT	81	SEMI-CRITICAL		54	SAFE
4	NAROT JAIMAL SINGH	107	SAFE		85	SEMI-CRITICAL
5	GHAROTA			**NEW BLOCK IN 2019-20**	70	SEMI-CRITICAL
6	SUJANPUR			**NEW BLOCK IN 2019-20**	32	SAFE

Sr. No	Assessment Unit (Block)/ District	2017		Remarks	2020	
		Stage of Ground Water Development (%)	Categorization for future ground water development (Safe/semi-critical /critcal/over-exploited		Stage of Ground Water Development (%)	Categorization for future ground water development (Safe/semi-critical /critcal/over-exploited)
1	BHUNER HERI	231	OVER-EXPLOITED		276	OVER-EXPLOITED
2	GHANAUR	160	OVER-EXPLOITED		106	OVER-EXPLOITED
3	NABHA	160	OVER-EXPLOITED		234	OVER-EXPLOITED
4	PATIALA	228	OVER-EXPLOITED		216	OVER-EXPLOITED
5	RAJPURA	211	OVER-EXPLOITED		176	OVER-EXPLOITED
6	SAMANA	248	OVER-EXPLOITED		204	OVER-EXPLOITED
7	SANAUR	250	OVER-EXPLOITED		254	OVER-EXPLOITED
8	PATRAN	368	OVER-EXPLOITED		317	OVER-EXPLOITED
9	SHAMBHU KALAN			**NEW BLOCK IN 2019-20**	207	OVER-EXPLOITED
	ROPAR					
1	ANANDPUR SAHIB	80	SEMI-CRITICAL		79	SEMI-CRITICAL
2	CHAMKAUR SAHIB	212	OVER-EXPLOITED		126	OVER-EXPLOITED
3	MORINDA	178	OVER-EXPLOITED		147	OVER-EXPLOITED
4	NURPUR BEDI	109	OVER-EXPLOITED		92	CRITICAL
5	ROPAR	47	SAFE		55	SAFE
	S.A.S. NAGAR					
1	DERA BASSI	147	OVER-EXPLOITED		133	OVER-EXPLOITED
2	KHARAR	117	OVER-EXPLOITED		101	OVER-EXPLOITED
3	SIALBA MAJRI	58	SAFE		54	SAFE
	SANGRUR					
1	AHMEDGARH	275	OVER-EXPLOITED		273	OVER-EXPLOITED
2	ANDANA	271	OVER-EXPLOITED		244	OVER-EXPLOITED
3	BHIWANIGARH	251	OVER-EXPLOITED		303	OVER-EXPLOITED
4	DHURI	320	OVER-EXPLOITED		332	OVER-EXPLOITED
5	LEHRAGHAGA	222	OVER-EXPLOITED		287	OVER-EXPLOITED
6	MALER KOTLA	198	OVER-EXPLOITED		297	OVER-EXPLOITED
7	SANGRUR	285	OVER-EXPLOITED		324	OVER-EXPLOITED
8	SHERPUR	254	OVER-EXPLOITED		270	OVER-EXPLOITED
9	SUNAM	299	OVER-EXPLOITED		338	OVER-EXPLOITED
10	DIRBA			**NEW BLOCK IN 2019-20**	342	OVER-EXPLOITED
	TARN TARAN					
1	BHIKHIWIND	139	OVER-EXPLOITED		194	OVER-EXPLOITED
2	CHOLA SAHIB	141	OVER-EXPLOITED		218	OVER-EXPLOITED
3	GANDIWIND	134	OVER-EXPLOITED		118	OVER-EXPLOITED
4	KHADUR SAHIB	164	OVER-EXPLOITED		212	OVER-EXPLOITED
5	NAUSHEHRA PANUAN	177	OVER-EXPLOITED		215	OVER-EXPLOITED
6	PATTI	177	OVER-EXPLOITED		225	OVER-EXPLOITED
7	TARN TARAN	147	OVER-EXPLOITED		225	OVER-EXPLOITED
8	VALTOHA	163	OVER-EXPLOITED		159	OVER-EXPLOITED