GROUND WATER RESOURCES OF PUNJAB STATE

(As on 31st March, 2022)

CENTRAL GROUND WATER BOARD
NORTH WESTERN REGION
CHANDIGARH .

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

DECEMBER, 2022

GROUND WATER RESOURCES OF PUNJAB STATE
(As on 31st March, 2022)

Prepared by

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

and

CENTRAL GROUND WATER BOARD
NORTH WESTERN REGION
CHANDIGARH.

DECEMBER, 2022

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 2022. Out of 150 blocks of the state taken for study, 114 blocks are "Over-exploited", 4 blocks are "Critical", 15 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 and Sh. Bhola Singh, Draftsman under the able guidance of Sh. Hardeep Singh Mendiratta, Superintending Engineer, 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' 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.

December, 2022

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

अनुराग खन्ना
क्षेत्रीय निदेशक
Anurag Khanna
Regional Director

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

PREFACE

Punjab a granary state of India, comprising 1.5% of the total geographical area of the country has been contributing two third of the wheat and half of the rice to the central pool. Ground water is being used is being used for irrigating 71% of the total area of the state. This has led to over exploitation of ground water resources as surface water falls short of Irrigation needs of the state. Punjab model of Irrigation is characterized by excess demand of irrigation coupled with unconstrained mining of ground water for meeting the food bowl requirement of 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 multi disciplinary approach that is adopted for computation of parameters regarding extraction and recharge. Moreover, the presence of saline aquifers in south-western 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 and Environment Directorate (WRED) Punjab in collaboration with Central Ground Water Board (CGWB) is highly praiseworthy. All the computations for the assessment of ground water resources have been carried out through a web based application namely "INDIA GROUND WATER RESOURCE ESTIMATION SYSTEM (IN-GRES) developed jointly by CGWB and IIT Hyderabad. The estimation has brought out the situation regarding ground water resources scenario in Punjab state which needs to be developed in more scientific and sustainable model. The large scale ground water conservation recharge measures like on farm water management techniques, village pond revival for recharging of 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 place on records my appreciation for sincere efforts made by the officers of CGWB and WRED, Punjab in bringing out this report at a very short span of time.

अनुराग खन्ना

Anurag Khanna
Regional Director

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

CONTENTS

LIST OF APPENDICES

LIST OF PLATES

LIST OF FIGURES

LIST OF ANNEXURES

LIST OF TABLES

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, 2015-19 for 2020 and the data of 2012-21 for the present study of 2022 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 830 Ground Water observation Wells (GWOW) have been established in the state covering each block and the data obtained from these has been used and is 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 23 Districts and 150 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
2020	603 mm
2021	528 mm

2.4 HYDROGEOLOGY

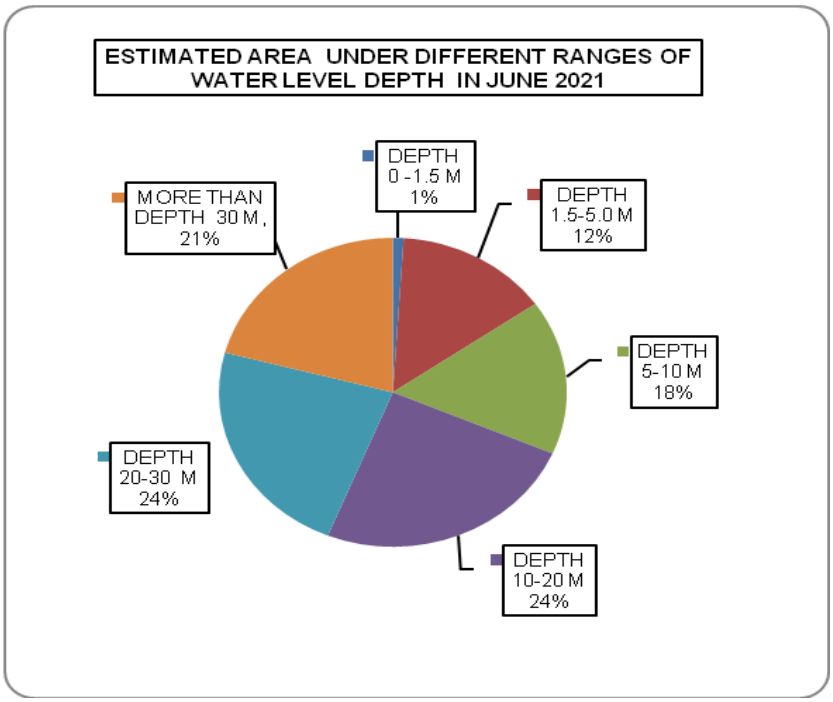
Ground water levels in Punjab State in general vary from almost near surface to about 60 m bgl. The deep water levels are recorded in Kandi belt. Water logging conditions exist in some parts of south-western districts. In the remaining part of Punjab the water table generally varies from 3 to 40 m bgl approximately. The master ground water slope is towards southwest. Most of the shallow tubewells have ground water draft per year varying from 0.27 to 2.59 Ham (electric) and 0.21 to 2.30 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 2021

Minimum water level depth of 1.10 mbgl has been observed in block Kotbhai of district Sri Muktsar Sahib and maximum depth of 68 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 Gurdaspur, 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 12% 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 18% area of the State, mainly in districts, Bathinda, Amritsar, Ludhiana, Ferozepur, Gurdaspur, Hoshiarpur, Kapurthala, Mansa, Mohali, Ropar and Pathankot.. Moderate water levels in the range 10 to 20m depth have been observed in an area of about 24% falling mainly in the districts of Amritsar, Bathinda, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, Mansa ,Mohali Nawan Shahr, Tarn-Taran, Faridkot and Ferozpur. Water level in the range of 20-30 m depth has been observed in about 24% area mainly in districts Mansa, Bathinda, Fatehgarh Sahib, Hoshiarpur, Jalandhar, Ludhiana, Kapurthala, Moga, Patiala, Nawanshahr, Taran Taran and Sangrur. Water level more than 30 m has been noticed in about 21% area , mainly in districts Barnala, Ludhiana, Mohali , Bathinda, Hoshiarpur,Moga, Jalandhar, Patiala and Sangrur.



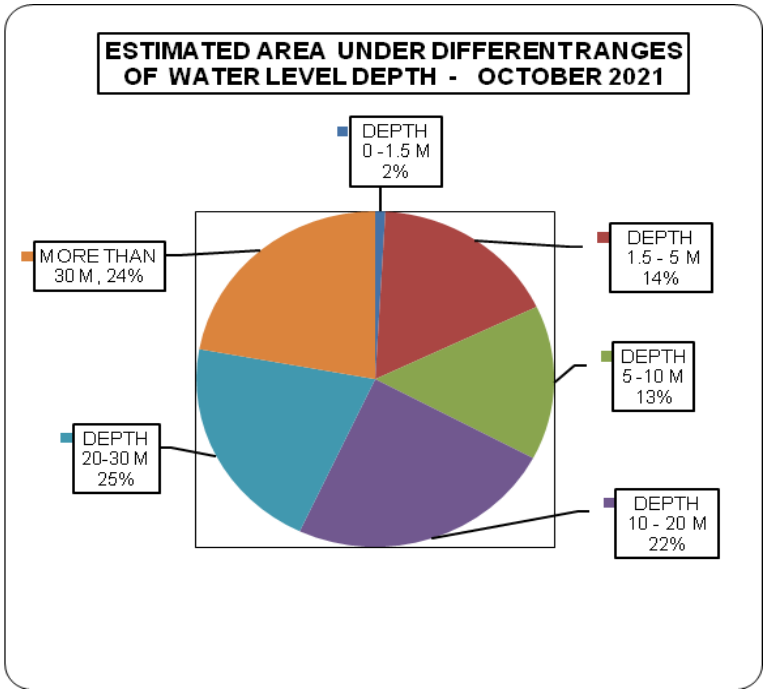
2.5.2 Depth to Ground Water Level – October 2021

The depth to ground water level during October 2011 varies from 0.47 m in Kot Bhai block of Sri Muktsar district to 52.42 m in Andana block of Sangrur district. Data for this period reveals that water level upto 1.50 mbgl has been observed in about 2% estimated area of the states, mainly in districts Sri Muktsar Sahib, Faridkot and Pathankot. and in some pockets of districts Fazilka , Ropar, Hoshiarpu and Patiala. Shallow water level in range from 1.50 to 5.00 mbgl has been encountered in about 14% estimated area mainly in districts Faridkot, Fazilka, Gurdaspur,

Pathankot, and Sri Muktsar Sahib and in some pockets of districts Ferozepur, Ropar , Hoshiarpur, Ludhiana and Patiala.

Ground Water Level Depth in the range of 5-10 mbgl has been encountered in about 13% estimated area, mainly in districts Bathinda, Hoshiarpur, Ludhiana, Fazilka, Kapurthala, Ferozepur, Gurdaspur, Mansa and Ropar. Ground Water Level Depth in the range of 10-20 mbgl has been encountered in about 22% estimated area, mainly in districts Amritsar, Bathinda, Ferozepur, Hoshiarpur, Kapurthala, Ludhiana, Mansa, S.B.S. Nagar (Nawan Shahr), Gurdaspur, Jalandhar and Tarn-Taran.

Deep water level of 20-30 mbgl been observed in about 25% estimated area of State mainly in parts of districts Barnala, Bathinda, Fatehgarh Sahib, Hoshiarpur, Jalandhar, Mansa, Ludhiana, Moga, Patiala and Tarn-Taran. Deeper water level of 30m or more has been estimated in about 24% estimated area of the state comprising parts of districts Barnala, Jalandhar, Moga, Bathinda, Hoshiarpur, Patiala and Sangrur.



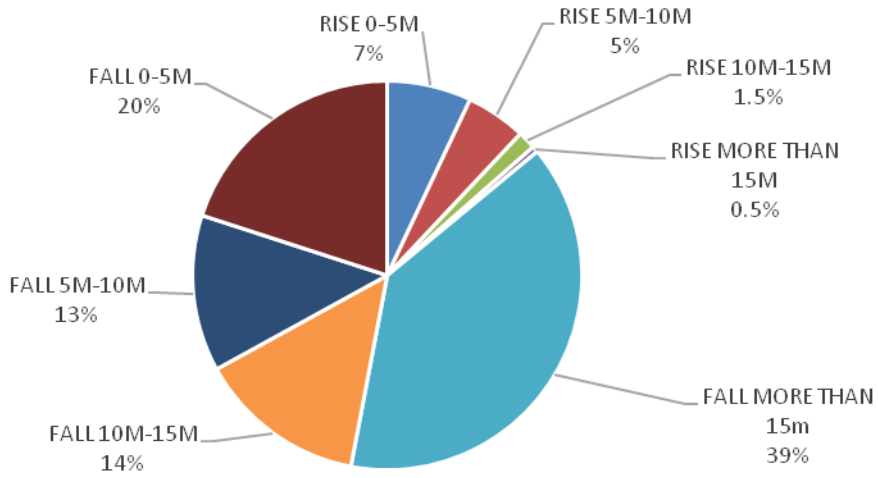
2.5.3 Ground Water Level Fluctuation In June 2021 w.r.t. June 1984

Minimum fall of 0.08 m has been noticed in block Mukatsar of district Sri Mukatsar Sahib and maximum fall of 41.04 m has been noticed in block Lehragaga of district Sangrur, whereas

minimun rise of 0.10 m has been noticed in block Pathankot of district Pathankot and maximum rise of 20.50 m has been noticed in block Hazipur of district Hoshiarpur.

It is observed that fall of water level of more than 15m occurs in about 39 % area, mainly in parts of districts Sangrur, Patiala, Ludhiana, Bathinda , Moga , Barnala, , Fatehgarh Sahib, Hoshiarpur, Jalandhar and Tarn-Taran. Fall of water level between 10m-15m is estimated in about 14% area mainly in parts of districts Amritsar, Ferozepur, Jalandhar, Hoshiarpur, Ludhiana, Ropar and Tarn-Taran. Fall of water level between 5m-10m is encountered in about 13 % area, mainly in parts of districts Amritsar, Ferozepur, Gurdaspur, Hoshiarpur, Mansa, Ludhiana and Tarn-Taran. In about 20% area of the state fall of water level upto 5 m is estimated, mainly in parts of districts Amritsar, Faridkot, Gurdaspur, Hoshiarpur, Kapurthala, Ludhiana, Mohali and Ropar. Rise of water level between 0-5m is estimated in about 7 % area, mainly in parts of districts Bathinda, Fazilka, Gurdaspur, Hoshiarpur, Patiala, 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, Pathankot, Hoshiarpur and Mohali. Rise of water level between 10m-15m is estimated in about 1.5% area, mainly in parts of districts Fazilka, Bathinda, Muktsar and Pathankot. Rise of water level of more than 15m is encountered in about 0.5% 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 2021 w.r.t. JUNE 1984)



2.5.4 Yearly Rate of Fall / Rise of Ground Water Level in June 2021 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, Bathinda , Fatehgarh Sahib , Hoshiarpur , Mansa, Moga and Jalandhar. Moderate districtwise yearly rate of fall of ground water level has been found in districts , Tarn-Taran, Kapurthala, Mansa, Ludhiana, Ferozepur and S.B.S. Nagar. In some of the districts , namely Ropar, Gurdaspur, Pathankot,, Hoshiarpur, 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 , Jalandhar-West, Lohian and Nakodar in district Jalandhar, Moga - I & Nihal Singh Wala in Moga district, Bhuner Heri, Patran, Ghanour, Nabha , Patiala 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, Khuyian Sarwar of district Fazilka, Dhariwal, Dera Baba Nanak, Dina Nagar ,Gurdaspur and Sri Hargobindpur of district Gurdaspur, Hazipur and Talwara of district Hoshiarpur, Jhunir of district Mansa, Pathankot and Gharota of district Pathankot, Ghanaur of district Patiala, Anandpur Sahib of district Ropar, 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 two 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 -

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

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

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

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:

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

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.

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

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

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

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

where,

R = Rainfall recharge during monsoon season

r = Monsoon season rainfall

a = a constant

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

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

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,

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

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:

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

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

Where

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

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

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

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 -

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

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

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

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:

$$\mathbf{R_C = WA * SF * Days} \qquad \mathbf{18}$$

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:

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

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:

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

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:

$$R_{WCS} = GS * RF \quad (22)$$

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.

$$GE_{DOM} = \text{Population} \times \text{Consumptive Requirement} \times Lg \quad (24)$$

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.

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

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,

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

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.

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

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.

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

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:

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

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.

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

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 2012-21 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 is used as is available with the Central Ground Water Board.

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. GEC-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 (& 3 urban blocks)
Years of Collection of Data (10 years)	2012-21
Year of Projection of Report	2022
No. of Over-Exploited Blocks	114
No. of Critical Blocks	04
No. of Semi-Critical Blocks	15
No. of Safe Blocks	17

Out of total 150 Blocks taken for study, 114 Blocks (76%) are "Over-Exploited", 4 Blocks (3%) are "Critical", 15 Blocks (10%) 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 2012-2021 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	17,07,272 Ham	13.83 MAF
Existing GW Draft for Irrigation	26,69,079 Ham	21.62 MAF
Existing GW Draft for Domestic and Industrial Use	1,32,756 Ham	1.08 MAF
Existing GW Draft for All Uses	28,01,834 Ham	22.70 MAF
Net GW Availability for Future Irrigation Development in Safe, Semi-critical, critical and Potential Resources in water logged areas	1,56,572 Ham	1.27 MAF
Average Stage of GW Extraction of State	164%	

- The Net Annual Ground Water Availability for the period 2012-21 works out to be 17,07,272 Ham (13.83 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 28,01,834 Ham (22.70 MAF). The existing gross ground water draft for all Uses has been observed to be maximum in Ludhiana district as 3,02,013 Ham and minimum in Pathankot district as 21,512 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 1,56,572 Ham (1.27 MAF) .
- The block-wise stage of ground water development varies from 17 % in Abohar Block of Fazilka district to maximum of 400 % in Jalandhar East block of Jalandhar 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 25% in Muktsar district to 313 % in Sangrur district.

- Shallow water level area having depth to water table less than 5 m bgl in the State is about 5645 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 → / **Category of Blocks ↓**	**1984**	**1986**	**1989**	**1992**	**1999**	**2004**	**2009**	**2011**	**2013**	**2017**	**2020**	**2022**
Over-exploited	53	55	62	63	73	103	110	110	105	109	117	114
Critical	7	9	7	7	11	5	3	4	4	2	6	4
Semi Critical	22	18	20	15	16	4	2	2	3	5	10	15
Safe	36	36	29	33	38	25	23	22	26	22	17	17
Total	**118**	**118**	**118**	**118**	**138**	**137**	**138**	**138**	**138**	**138**	**150**	**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
2020	0	0
2022	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 2020 study and for present 2022 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 2020 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 2012 and June 2021 has gone down in general thereby showing decline of water levels. The present Ground Water Estimation shows no improvement in ground water scenario in comparison to previous report as overall Stage of Ground Water Extraction remains same as 164%.

CHAPTER – 6

6.0 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 June 2021, 330 nos. ground water samples were collected from GWMS 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. Fig-1** depicts the Sampling location points of Punjab state.

6.2 Composition of Water

Chemical analysis shows that the ground water is slightly to moderately alkaline in nature. The district-wise concentration range of various chemical components in ground water is depicted in Table 1.

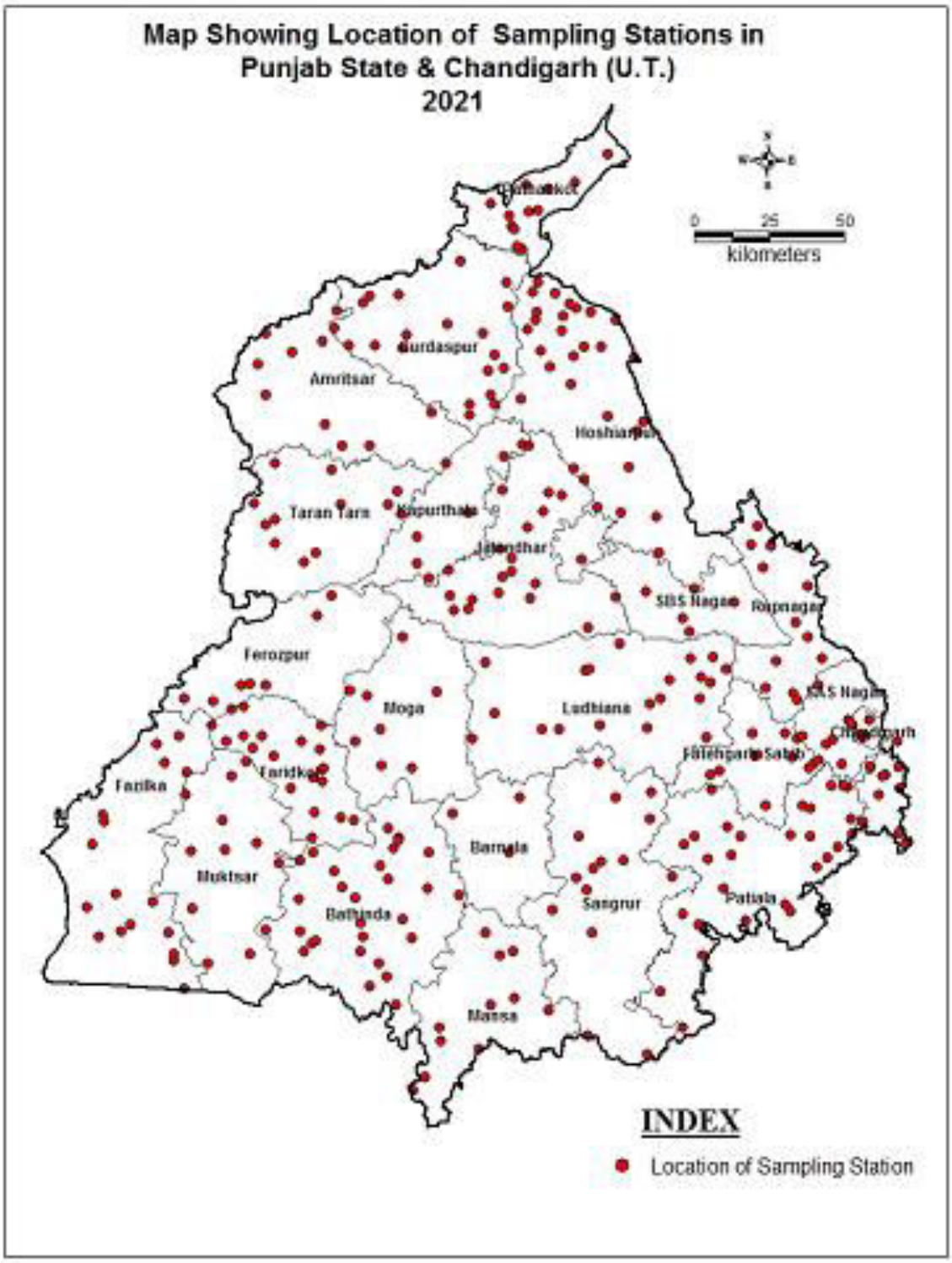

Map Showing Location of Sampling Stations in
Punjab State & Chandigarh (U.T.)
2021
0 25 50
kilometers
Gurdaspur
Amritsar
Hoshiarpur
Taran Taran
Kapurthala
Jalandhar
SBS Nagar
Rupnagar
Ferozpur
Moga
Ludhiana
Fatehgarh Sahib
Faridkot
Fazilka
Barnala
Muktsar
Sangrur
Patiala
Bathinda
Mansa
INDEX
Location of Sampling Station

Fig-1

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

Sr. No	DISTRICT	No. of Samples	Conc Range	pH	EC in µS/cm at 25^{0}C	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	Ca	Mg	Na	K	SiO_2	TH as $CaCO_3$	SAR	RSC
						(<---------- mg/l----------)														meq/l
1	AMRITSAR	11	Min	8.63	340	24	49	14	0	0	0.12	0	16	7.3	32	5.3	16	110	0.98	-0.60
			Max	9.07	1650	84	488	50	312	21	1.80	0	40	36	380	13	27	200	15.10	8.40
2	BARNALA	3	Min	8.90	1030	60	281	56	12	22	0.45	0	8	32	155	6	19	160	4.89	2.80
			Max	8.98	1180	84	427	90	50	34	0.60	0	12	44	205	11	23	200	7.05	6.60
3	BHATHINDA	29	Min	8.32	301	12	122	14	0	0	0.21	0	8	10	10	2.13	12	80	0.29	-6.79
			Max	9.08	5435	240	659	715	998	440	5.30	0.20	64	216	750	320	27	960	22.77	13.97
4	FARIDKOT	20	Min	7.46	307	0	49	35	50	2.17	0.30	0	8	22	14	3.42	4.98	170	0.46	-17.79
			Max	9.07	6172	108	818	945	1790	400	2.30	0	96	192	968	457	27	1030	19.91	12.42
5	FATEHGARH SAHIB	12	Min	8.50	482	24	98	14	0	0	0.20	0	4	17	49	3.8	18	100	1.55	-2.40
			Max	8.95	1385	84	549	146	132	120	1.20	0	28	46	284	80	22	240.2	9.77	7.80
6	FAZILKA	16	Min	8.30	273	12	72	35	0	2.79	0.29	0	16	7.3	24	2.3	12	70	0.85	-15.57
			Max	9.01	8500	168	549	1405	2032	210	14.00	0	140	240	1602	61	25	1010	21.92	9.19
7	FIROZEPUR	8	Min	8.52	490	10	98	28	0	0	0.31	0	12	17	44	2.2	15	120	1.21	-3.70
			Max	9.06	1635	192	281	111	298	135	4.90	0	28	66	310	43	27	330	9.57	6.01
8	GURDASPUR	20	Min	7.99	130	0	67	7	0	0	0.15	0	12	7.3	2.4	1.4	8	60	0.09	-2.20
			Max	9.07	900	72	244	92	106	100	0.61	1.38	80	39	75	130	35	320	2.02	3.00
9	HOSHIARPUR	29	Min	8.05	225	0	85	7	0	0	0.14	0	8	4.9	13	1.15	17	100	0.53	-3.00
			Max	8.90	648	48	268	63	65	113	0.52	0	40	46	57	64	22	250	2.16	2.00
10	JALANDHAR	20	Min	7.88	320	0	159	14	0	0	0.17	0	8	15	5.2	2.6	15	130	0.17	-5.40
			Max	8.76	1190	60	293	163	106	200	0.56	0	56	83	128	18	31	440	4.89	2.80
11	KAPURTHALA	8	Min	8.16	390	0	134	21	0	0	0.19	0	12	4.9	32	2.1	17	70	0.99	-3.00
			Max	8.91	926	72	293	149	106	62	0.49	0	52	46	190	9.5	28	300	9.88	4.60
12	LUDHIANA	21	Min	8.28	245	0	73	7	0	1	0.12	0	4	10	5.5	0.62	18	120	0.22	-1.80
			Max	8.92	1227	96	452	97	110	74	0.90	0.15	60	46	225	160	25	250	7.51	7.20

13	MANSA	11	Min	8.28	208	0	24	7	0	0	0.21	0	8	10	5.72	1.88	3.95	80	0.20	-14.22
			Max	9.01	5852	228	903	1022	1290	220	3.00	0	72	173	980	110	25	890	20.35	13.62
14	MOGA	8	Min	8.85	528	36	146	7	0	0	0.40	0	8	2.0	97	0.7	18	70	4.72	0.00
			Max	8.97	1445	84	586	139	242	70	4.50	0	28	46	275	7.5	25	210	12.74	8.80
15	MUKTSAR	11	Min	8.30	910	24	49	90	128	20	0.07	0	32	29	85	12	14	280	2.20	-19.39
			Max	8.76	7005	120	976	1230	2072	775	2.20	0	232	241	1450	600	27	1170	27.39	5.84
16	NAWANSHAHR	6	Min	8.05	442	0	159	7	0	1.1	0.11	0	8	19	48	2.6	18	100	1.37	-1.40
			Max	8.90	1032	72	330	90	72	115	0.52	0	40	58	110	115	21	340	4.78	3.80
17	PATHANKOT	13	Min	8.16	160	0	49	14	0	0	0.12	0.00	20	2.4	3.5	0.9	17	70	0.13	-1.80
			Max	8.88	663	36	317	99	34	31	0.79	0.00	72	34	32	14	42	290	1.01	0.80
18	PATIALA	28	Min	8.2	375	0	146	7	0	1.3	0.35	0.00	4.0	2	25	2	18	20	0.95	-0.40
			Max	8.95	1395	96	403	125	223	123	2.60	0.12	28	56	245	37	23	250	20.91	6.60
19	ROPAR	10	Min	8.45	335	12	61	14	0	0	0.12	0.00	8.0	5	12	0.5	18	110	0.43	-1.20
			Max	8.88	754	60	403	69	40	50	0.70	0.00	36	58	115	20	24	290	3.73	4.20
20	SANGRUR	15	Min	8.20	372	0	85	7	0	0	0.30	0.00	8.0	12	20	3	18	70	0.69	0.20
			Max	8.97	1630	132	793	125	102	75	7.00	0.00	36	85	385	80	25	370	17.65	15.20
21	SAS NAGAR	17	Min	8.02	413	0	85	7	0	0	0.10	0.00	4.0	7.3	52	0.8	17	70	1.73	-82.20
			Max	8.95	16910	96	513	4391	2785	298	3.00	0.00	517	703	2400	275	23	4183	16.15	8.60
22	TARANTARAN	14	Min	8.06	500	0	171	7	5.76	0	0.15	0.00	16	4.0	30	0.9	15	80	0.88	-3.00
			Max	9.15	2040	144	720	156	250	45	3.30	0.00	52	54	500	56	32	350	24.12	14.97
	TOTAL		Min	7.46	130	0	24	7	0	0	0.07	0.00	4	2	2.4	0.5	3.95	20	0	-82
			Max	9.15	16910	240	976	4391	2785	775	14.00	1.38	517	703	2400	600	42	4183	27	15

The pH values range from 7.46 at Mehmumna in Faridkot district to 9.15 at Gandiwind in Tarantaran 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 130 µS/cm at Nishya Majja Singh in district Gurdaspur to 16910µS/cm at Sirsini in SAS Nagar. Hardness reported in terms of $CaCO_3$ ranges from 20 to 4183 mg/l. The lowest hardness value is found at Behmana in district Patiala and highest at Sirsini in district SAS Nagar. The concentration of calcium ranges between 4.0 and 517 mg/l. Calcium below detection level has not been found in the State while the highest value is observed at Sirsini in district SAS Nagar. Magnesium concentration ranges between 2mg/l at Dagru district Moga and 703 mg/l at Sirsini in district SAS Nagar. 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 44.8% samples and less than the maximum permissible limit of 100 mg/l for drinking waters (BIS 1991) in 93.6% samples. In more than half of well waters examined, Ca + Mg are the dominant cations. Sodium is the dominant cation in majority of ground waters of districts Bhathinda, Faridkot, Ferozepur, Mansa, Moga, Muktsar, Patiala, Sangrur, SAS Nagar and Tarantaran. Sodium concentration varies widely from 2.4 mg/l at Nawapind district Pathankot to 2400 mg/l at Sirsini in SAS Nagar. 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 (59%). It ranges from 0.5 mg/l at Brahmpur district Ropar to 600 mg/l at Sherawali district Mukatsar. High concentration of potassium (>100mg/l) is found in 7.6% 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 240 mg/l at Koteguru in district Bhatinda. Bicarbonate is the dominant anions and it ranges from 24 mg/l at Ralla Mansa district to 976 mg/l at Sheranwali districtMuktsar. The Chloride concentration in ground water varies between 7.0 mg/l at several places and 4391 mg/l at Sirsini in district SAS Nagar. The Sulphate (SO_4) content in ground waters was found to be 0 at several places in the State. The highest value of 2785 mg/l of Sulphate has been observed at Sirsini in district SAS Nagar. In majority of ground water samples (78%), 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 mg/l a several places to 775 mg/l at Bhaliana,

Mukatsar district. The fluoride (F) content in ground water of the State is generally less than 1.0 mg/l (91%). It ranges from 0 at several places in the State to 14 mg/l at Swahwala in district Fazilka. Phosphate concentration varies from 0 mg/l to 1.38 mg/l at Pandordham in district Gurdaspur while Silica concentration, measured as SiO_2, ranged between 3.95 to 42 mg/l.

6.3 Distribution of EC

The EC value of ground waters in the State varies from 130 µS/cm to 16910µS/cm at 25°C. Grouping water samples based on EC values, it is found that 48.5 % of them have EC less than 750, 43.6% have between 750 and 3000 and the remaining 7.9% 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. Districts falling in different EC ranges are given in Table 2. The ground water occurring in the southern and southwestern parts comprising of mainly of Mukatsar and parts of Bhatinda, Faridkot, Fazilka, and Mansa districts is mostly saline and not suitable for drinking uses (Fig-2).

Table 2- District-wise distribution of Electrical Conductivity in Ground water of Punjab State.

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

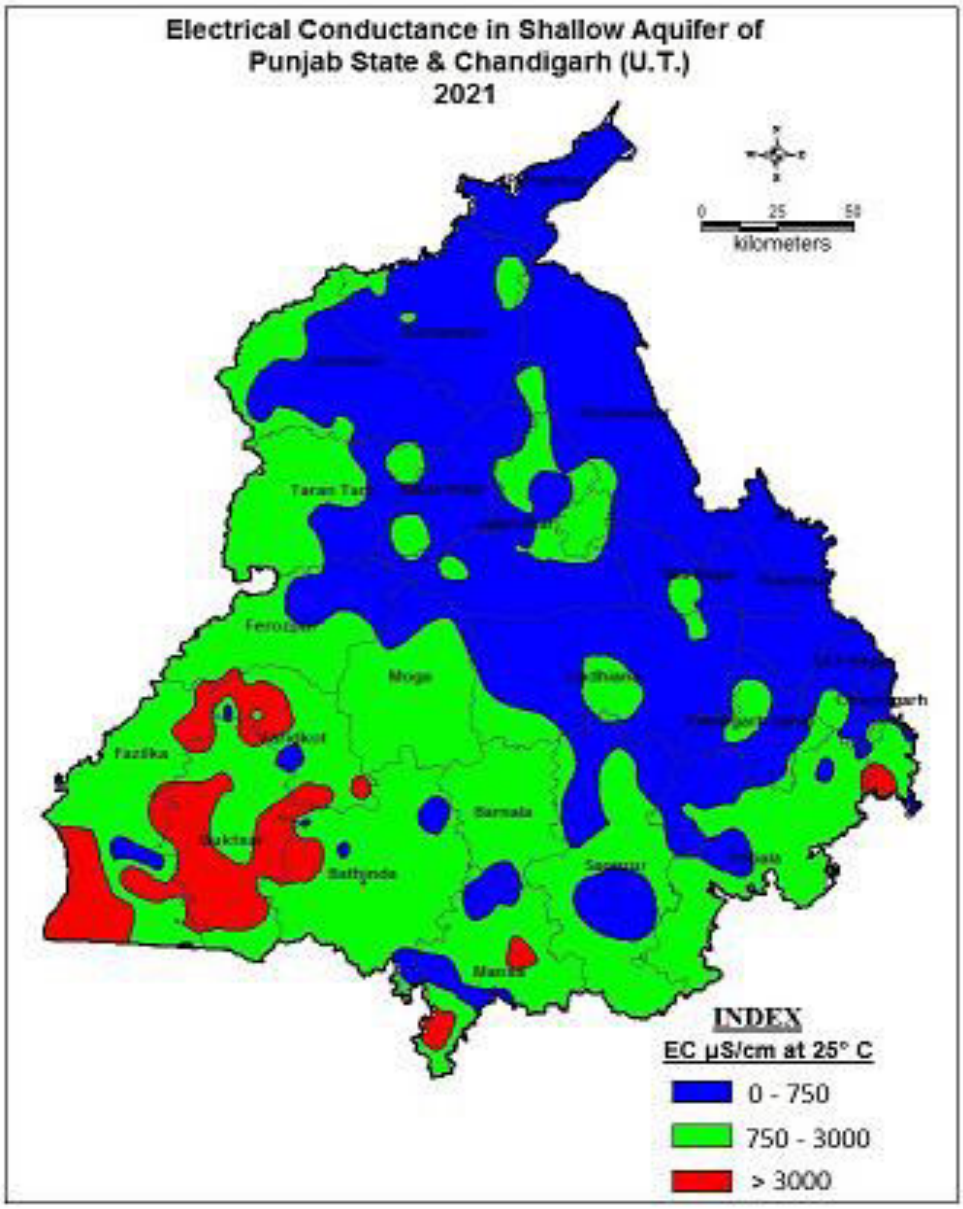


Fig-2

6.4 Distribution of Chloride (Cl)

Chloride content of ground water normally follows the distribution pattern of EC and it ranges from 7.0 mg/l to 4391 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 89.4 % of the samples, between 250 and 1000 mg/L in 8.8 % samples and only 1.8% of the samples are found to have Chloride above 1000 mg/L. Map showing spatial distribution of Cl contents in ground water (Fig 3) 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 Muktsar, Faridkot, Fazilka, Mansa and SAS Nagar district.

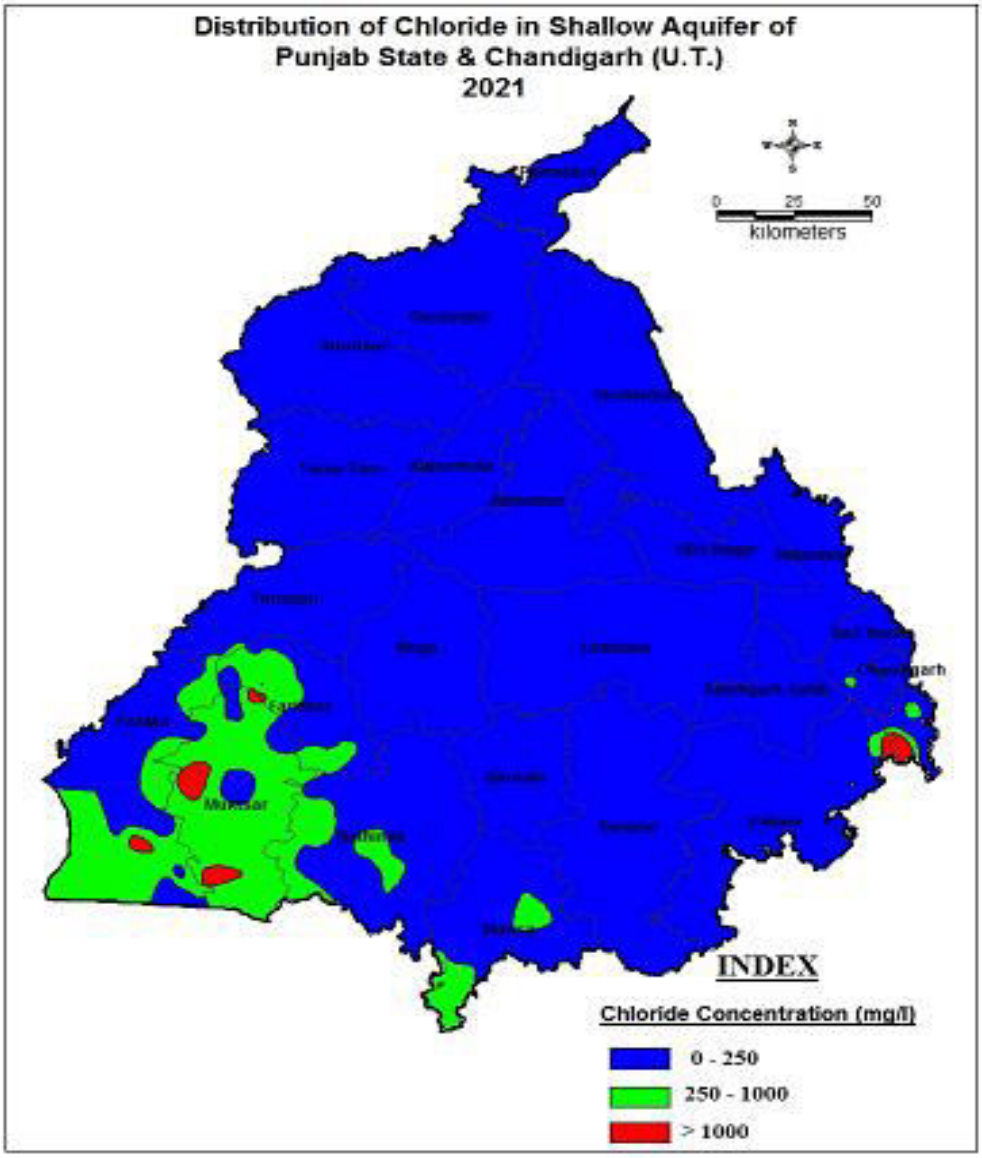


Fig-3

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 mg/l to 775 mg/l. BIS permits a maximum concentration of 45 mg/L nitrate in drinking

water. Considering this limit, it is found that 77.6 % of the samples, spread over the entire State, have nitrate below 45 and 22.4 % have more than 45 mg/L. District-wise wise distribution of Nitrate in Ground water of Punjab State is depicted in Table 3. 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, Bhatinda, Faridkot, Fazilka, Ferozepur, , Mansa, Muktsar, Patiala ,Sangrur and SAS Nagar districts have nitrate above 45 mg/L.

Table 3- District-wise distribution of Nitrate in Ground water of Punjab State.

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

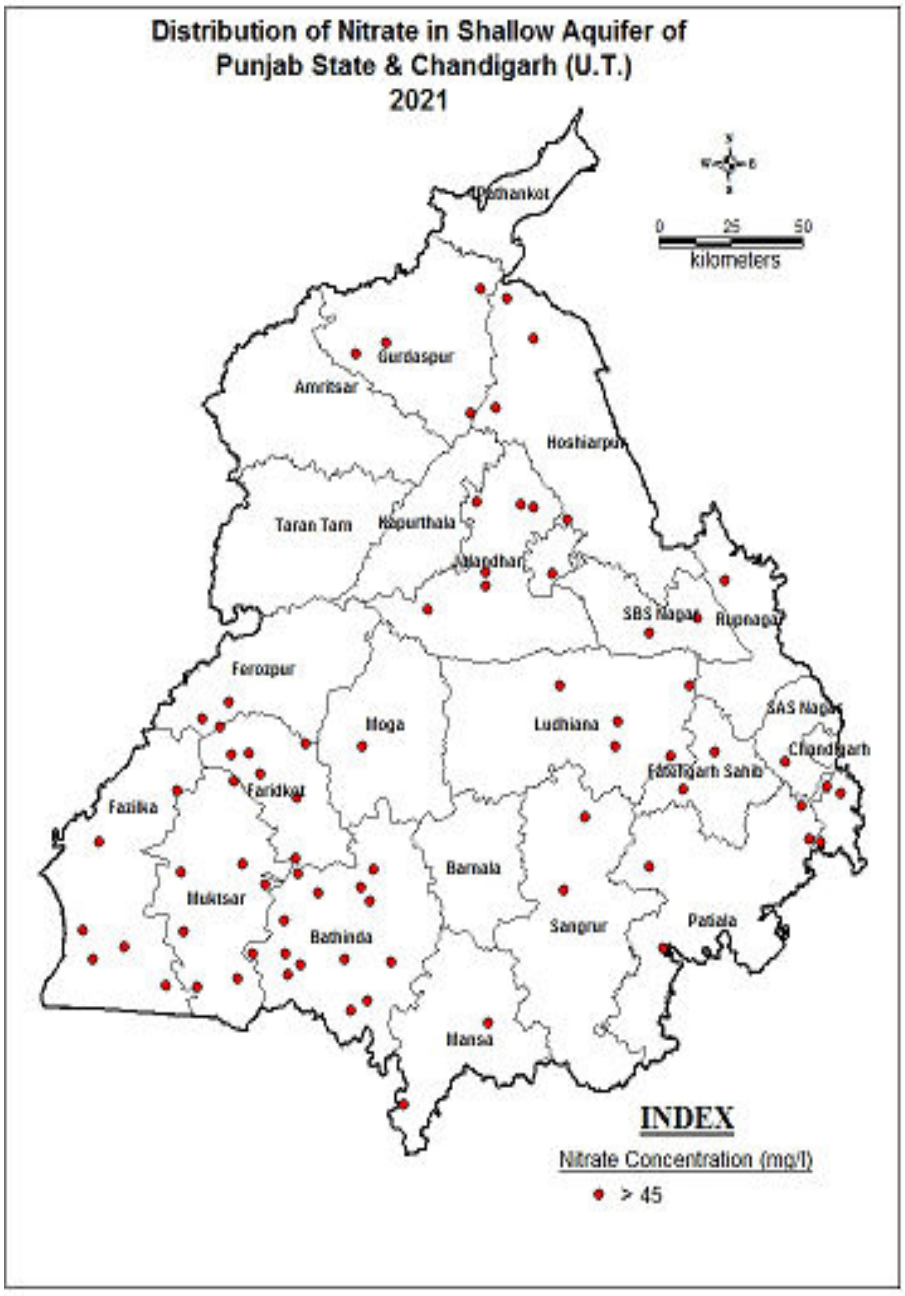


Fig-4

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 to 14 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. District wise distribution of Fluoride in Shallow Ground water of Punjab State is given in Table 4. Classification of samples based on this recommendation, it is found that 83.3 % samples have fluoride in desirable range, 7.9 % in the permissible and the

remaining 8.8% 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 and Mansa districts while isolated locations are also found in Firozepur, Sangrur, SAS Nagar and Tatantaran districts. 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.

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	Bhathinda	Amritsar
Barnala	Faridkot	Bhathinda
Bhathinda	Fatehgarh Sahib	Faridkot
Faridkot	Firozepur	Fazilka
Fatehgarh Sahib	Fazilka	Firozepur
Fazilka	Mansa	Mansa
Firozepur	Moga	Moga
Gurdaspur	Muktsar	Muktsar
Hoshiarpur	Nawanshahr	Patiala
Jalandhar	Patiala	Sangrur
Kapurthala	Tarantaran	SAS Nagar
Ludhiana		Tarantaran
Mansa		
Moga		
Muktsar		
Nawanshahr		
Pathankot		
Patiala		
Ropar		
Sangrur		
SAS Nagar		
Tarantaran		

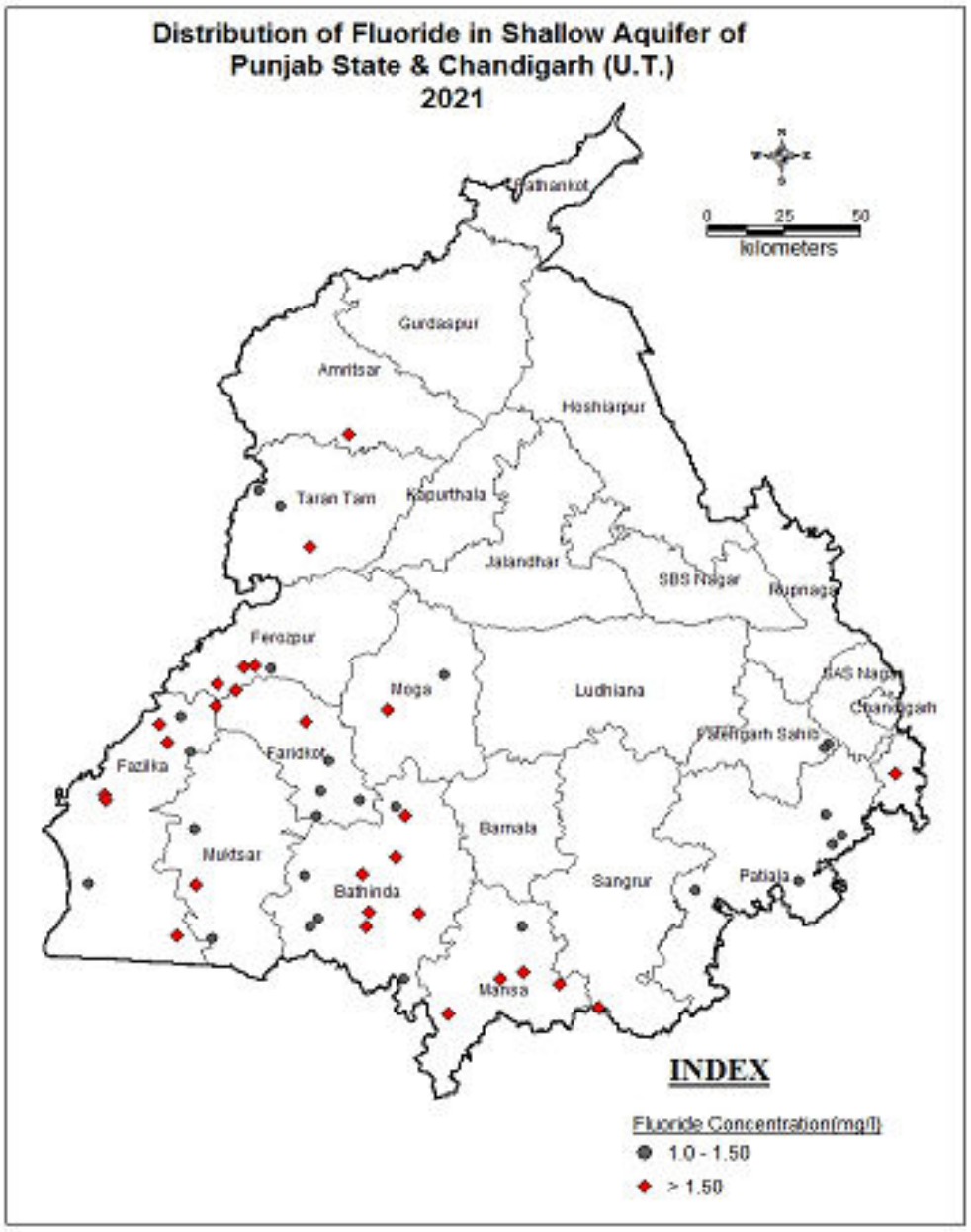


Fig-5

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 51 % ground waters of the State are fresh, have low salinity and predominance of calcium + magnesium cations and bicarbonate as anion. About 45 % ground waters having intermediate

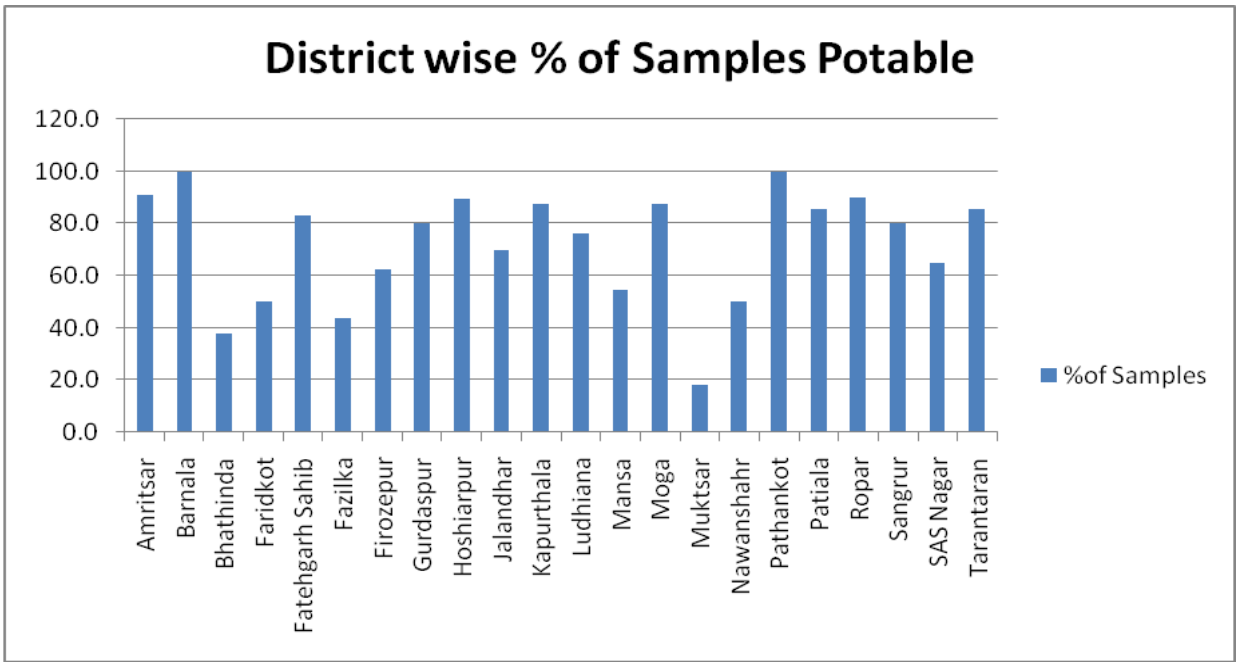
salinity and are of mixed type. In these waters, mostly HCO_3 as anion dominates but no individual cation predominates. At some places HCO_3-type of waters with sodium as dominant cation are also encountered in low to moderately saline ground waters. This can be attributed either to precipitation of $CaCO_3$ 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.

The bar diagram clearly shows that most of the groundwater occurring in the districts Amritsar, Barnala, Fatehgarh Sahib, Firozepur, Gurdaspur, Hoshiarpur, Kapurthala, Moga, Nawanshar, Pathankot, Patiala, Ropar and Sangrur 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, Faridkot, Fazilka , and Muktsar have bar length less than 50% indicating low potable rating. Fig-6.

Fig-6, District wise Distribution of Potable Waters in Punjab



Percentage wise classification of Potable Ground water in Punjab State is depicted in Table 5.Table-6 shows district-wise distribution of ground waters in different classes of suitability based upon EC, Cl, F and NO_3 contents.

Table 5-Percentage wise classification of Potable Ground water in Punjab State

Sr. No.	% wise classification	Name of the districts	Remarks
1.	>80	Amritsar, Barnala, Fatehgarh Sahib, Gurdaspur , Hoshiarpur , Kapurthala, Moga, Pathankot, Patiala Ropar & Tarantaran	Classification based on Salinity (EC), Cl,NO_3 & F
2.	50-80	Ferozepur, Jalandhar, Ludhiana, Sangrur, Nawanshahr, SAS Nagar	
3.	<50	Bathinda, Faridkot, Fazilka, Mansa, Muktsar, Nawanshahr	

Table-6: Distribution of Well Waters of Punjab State in Different Classes of Drinking Water Suitability

Sr. No	District	No. of	EC in 25^0C in µS/cm			Cl in mg/L			NO_3 in mg/L		F in mg/L		
		Samples	<750	750-3000	>3000	<250	250-1000	>1000	<45	>45	<1.00	1.00-1.50	>1.50
1	Amritsar	11	6	5	0	11	0	0	11	0	10	0	1
2	Barnala	3	0	3	0	3	0	0	3	0	3	0	0
3	Bathinda	29	4	23	2	24	5	0	15	14	19	4	6
4	Faridkot	20	2	11	7	13	7	0	13	7	13	4	3
5	Fatehgarh Sahib	12	8	4	0	12	0	0	10	2	10	2	0
6	Fazilka	16	3	8	5	10	5	1	11	5	9	2	5
7	Ferozepur	8	2	6	0	8	0	0	6	2	4	1	3
8	Gurdaspur	20	15	5	0	20	0	0	16	4	20	0	0
9	Hoshiarpur	29	28	1	0	29	0	0	26	3	29	0	0
10	Jalandhar	20	14	6	0	20	0	0	14	6	20	0	0
11	Kapurthala	8	5	3	0	8	0	0	7	1	8	0	0
12	Ludhiana	21	18	3	0	21	0	0	16	5	21	0	0
13	Mansa	11	3	6	2	8	2	1	9	2	6	1	4
14	Moga	8	1	7	0	8	0		7	1	6	1	1
15	Muktsar	11	0	3	8	2	6	3	3	8	8	2	1
16	Nawanshahr	6	4	2	0	6	0	0	3	3	6	0	0
17	Pathankot	13	13	0	0	13	0	0	13	0	13	0	0
18	Patiala	28	6	22	0	26	2	0	25	3	21	6	1
19	Ropar	10	9	1	0	10	0	0	9	1	10	0	0
20	Sangrur	15	9	6	0	15	0	0	13	2	14	0	1
21	SAS Nagar	17	7	8	2	14	2	1	12	5	16	0	1
22	Tarantaran	14	3	11	0	14	0	0	14	0	9	3	2
	TOTAL	**330**	**160**	**144**	**26**	**295**	**29**	**6**	**256**	**74**	**275**	**26**	**29**

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 130 µS/cm to 16910µS/cm at 25°C and 0.09 to 27 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 Bhatinda, Faridkot, Fazilka, Ferozepur, Mansa, Muktsar , 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 55.15% of the waters are safe, 11.82% marginal and the remaining 33.03 % are unfit for irrigational uses. RSC of ground waters are found to vary from below 0 to15 meq/l (Badrukhana, Sangrur 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-7, Irrigation Rating of Well Waters of Punjab

S.N.	District	IRRIGATION SUITABILITY				
		EATON's INDEX (RSC in meq/L)				USSL Classification
		Total No. of samples	Safe <1.25	Marginal 1.25-2.50	Unsafe >2.50	
1	Amritsar	11	7	0	4	C2S1, C3S1,C3S2,C3S3
2	Barnala	3	0	0	3	C3S1, C3S2
3	Bathinda	29	14	2	13	C2S1, C3S1,C3S2,C3S3,C3S4,C4S2,C4S3,C4S4
4	Faridkot	20	11	1	8	C2S1,C3S1,C3S2,C3S3,C4S3,C4S4
5	Fatehgarh Sahib	12	3	2	7	C2S1,C3S1,C3S2
6	Fazilka	16	12	0	4	C2S1,C3S1,C3S2,C3S3,C4S2,C4S3,C4S4
7	Ferozepur	8	3	2	3	C2S1,C3S1,C3S2
8	Gurdaspur	20	15	2	3	C1S1,C2S1,C3S1
9	Hoshiarpur	29	24	4	1	C1S1,C2S1,C3S1
10	Jalandhar	20	15	4	1	C2S1,C3S1
11	Kapurthala	8	4	2	2	C2S1,C3S1,C3S2
12	Ludhiana	21	13	3	5	C1S1,C2S1,C3S1,C3S2
13	Mansa	11	6	0	5	C1S1, C2S1, C3S1, C3S2, C3S4, C4S4
14	Moga	8	1	0	7	C2S1, C3S2, C3S3
15	Muktsar	11	8	0	3	C3S1, C4S2, C4S3, C4S4
16	Nawanshahr	6	3	2	1	C2S1, C3S1

17	Pathankot	13	13	0	0	C1S1,C2S1
18	Patiala	28	11	4	13	C2S1,C3S1,C3S2,C3S4
19	Roper	10	6	3	1	C2S1,C3S1
20	Sangrur	15	5	3	7	C2S1,C3S1,C3S2,C3S3,C3S4
21	SAS Nagar	17	2	5	10	C2S1,C3S1,C3S2,C4S3
22	Taran Taran	14	6	0	8	C2S1,C3S1,C3S2,C3S3,C3S4
	Grand Total	**330**	**182**	**39**	**109**	

Most of ground waters from Amritsar, Fatehgarh Sahib, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Ropar and Patiala are suitable for irrigation for semi-salt tolerant crops on adequately drained soils. The waters from districts of Bathinda, 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-2012 standards during 2021 are compared with percent well waters in same classes during 2017, 2018, 2019, 2020 & 2021. 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 2017 to 2021.

On perusal of the Table-8, it is evident that there is improvement in the quality of ground water from 2017 to 2021. It is observed that there is decrease in salinity and % of samples falling with EC below 750 µS/cm at 25^0C has increased by 11.8 %. Whereas there is decrease by 8.3 % samples falling in 750-3000 µS/cm at 25^0C. There is decrease of 3.4 % samples showing EC more than 3000 µS/cm at 25^0C. It is inferred that there is a improvement in groundwater quality in the respect of salinity. Not much variation is chloride concentration observed in 2021 when compared with 2017 while there is improvement in water quality in respect of Nitrate as samples having its concentration >45mg/l has increased by 2.6%.

There is improvement in groundwater quality from 2017 to 2021in respect of Salinity.

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

Parameter	Class	% of Samples					Periodic Variation 2017-2021
		2017 (n=281)	2018 (n=278)	2019 (n=302)	2020 (n=323)	2021 (n=330)	
Salinity as EC	<750 µS/cm	36.7	48.9	47.7	51.4	48.5	+11.8
	750-3000	51.9	42.4	44.4	39.6	43.6	-8.3
	>3000	11.3	8.6	7.95	9.0	7.9	-3.4
Chloride as Cl	<250 mg/l	88.9	88.8	88.7	88.9	89.4	+0.5
	250 - 1000	9.6	9.0	10.9	10.2	8.8	-0.8
	>1000 mg/l	1.8	2.2	0.3	0.9	1.8	0
Nitrate as NO_3	< 45 mg/l	75	82.0	76.8	69.0	77.6	+2.6
	> 45 mg/l	24.9	18.0	23.2	31.0	22.4	-0.5
Fluoride as F	<1.0 mg/l	81.8	88.1	84.4	84.2	83.3	+1.5
	1.0 - 1.50	7.5	4.7	5.3	7.4	7.9	+0.4
	>1.50 mg/l	10.7	7.2	10.3	8.4	8.8	-1.9

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 2021. 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.

****

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. 2012-21.
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 76% area of the state is over-exploited. Out of 150 blocks, 114 blocks are “over-exploited” 05 blocks are “critical” 15 blocks are “semi-critical” and 15 blocks are in “safe” category.
3. In this report, there is no improvement in the Ground Water scenario of the State in comparison to previous report. The Overall Stage of Ground water extraction has remained 164%.

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. The following shall be the Terms of Reference:-	Member Secretary

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 of Technical Sub-Committee on Water balance of Punjab State -2022 held under the Chairmanship of Superintending Engineer, Ground Water Management Circle, Water Resources Management Circle- cum - Chairman, Technical Sub Committee on Water balance of Punjab State, S.A.S. Nagar on Tuesday 25th January, 2022 at 11:30 AM.

The first meeting of the Technical Sub-Committee on Water Balance, to discuss the modalities for the preparation of Dynamic Ground Water Estimation Study of Punjab State, 2022 was held under the Chairmanship of Superintending Engineer, Ground Water Management Circle, Water Resources Management Circle-cum-Chairman, Technical Sub Committee on Water balance of Punjab State, S.A.S. Nagar on 25th January, 2022 at 11:30AM in the Committee Room of Water Resource Bhawan, Sector 68, SAS Nagar.

2.0 The list of participants is attached as **Annexure-'1'.**

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, 2022 is to commence immediately. He further informed that the aim of the meeting is to work out the modalities for the preparation of Dynamic Ground Water Estimation study of Punjab State, 2022. The Chairman asked the Scientist from CGWB to brief the House regarding the guidelines for preparation of Dynamic Ground Water Estimation study of Punjab State, 2022.

4.0 Scientists from CGWB apprised the house that the Dynamic Ground Water Estimation study of Punjab State, 2022 needs to cater to all the 150 administrative blocks of the State. In addition, canal water supply details, surface water irrigation details, water conservation structure details, tanks/ponds details, cropping pattern, ground water draft/withdrawal for irrigation, domestic and industrial uses etc have to be collected from different State Government Departments ie. water resources, agriculture, irrigation, rural water supply, industry, soil & water conservation & statistics etc. Like-wise, cropping pattern & ground water draft 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.

5.0 After detailed deliberations, it was unanimously decided that:

a) The monthly rainfall data (Year 2012-2021) of Punjab State available with Indian Meteorological Department, Punjab, Chandigarh & other various agencies would be collected and analysed by Ground Water Management Circle (GWMC), Punjab.

(Action: IMD, Punjab & GWMC, Pb)

b) The pre & post monsoon groundwater level data of GWMC, Punjab, Department of Agriculture & Farmers' Welfare (DoA&FW), Punjab and CGWB for the years 2012-2021 would be incorporated in the report. The data of GWMC, Punjab and DoA&FW, Punjab is under analysis therefore initially CGWB data would be incorporated in the provisional draft report to be prepared. The ground water level data of two departments would be incorporated in the final report to be prepared.

(Action: CGWB, NWR, GWMC, Pb & DoA&FW,Pb)

c) The area of Paddy under Direct Seeded Rice (DSR) and thereby water saving in HAM would be supplied by DoA&FW, Punjab in collaboration with Punjab Agriculture University (PAU), Ludhiana.

(Action: DoA&FW,Pb & PAU, Ludhiana)

d) Like in the preparation of previous GW balance 2020, DoA&FW, Punjab will supply the block wise draft figures based on cropping pattern for Ground water as well as for Surface Water. For this, GWMC, 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.

(Action: DoA&FW,Pb & GWMC, Pb)

e) Since the work of re-assessment is to be carried out on INGRES software, as such CGWB will provide the formats for collection of data as per the INGRES software.

(Action: CGWB,NWR,Chd.)

f) Representative of following departments may be invited as special invitee in the next meeting:

   i Department of Soil & Water Engineering, PAU, Ludhiana to explore the possibility of using their data of specific yield, evapo transpiration (ET) demand, rainfall infiltration and return flows etc. of different soil types.

   ii Department of Industries, Punjab to discuss the availability of data of industries and water used by them.

iii Chief Engineer (Canals), Department of Irrigation, Punjab for Canal data required for the estimation study. In the previous study, the data supplied by them gave erroneous results therefore block wise reassessed canal data may be furnished on the prescribed format given by CGWB. For this, CGWB would supply them a prescribed format for collection of block wise Canal data.

iv Punjab Water Regulatory Development Authority (PWRDA) to have an insight of industrial water usage figures.

v Punjab Pollution Control Board (PPCB), Patiala for Industrial Water requirement figures.

vi Rural Development & Panchayats, Punjab to discuss the availability of block wise GPS coordinate based information of water conservation structure details & tanks and village ponds etc...

(Action: DoA&FW,Pb)

While concluding, the Chairman assured the Scientists from CGWB, NWR, Chandigarh that all departments involved in the preparation of Dynamic Ground Water Estimation study of Punjab State, 2022 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, 2022. To discuss the timelines for supply of data and to work out roadmap for preparation of Dynamic Ground Water Estimation study of Punjab State, 2022, *the Second meeting of the Sub-Committee would be held on Monday i.e. 07th February, 2022.*

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

****

APPENDIX -2.2

Minutes of 2nd Meeting of Technical Sub-Committee on Water balance of Punjab State -2022 held under the Chairmanship of Superintending Engineer, Ground Water Management Circle, S.A.S. Nagar on Monday 07th February, 2022 at 11:30 AM.

The 2nd meeting of the Technical Sub-Committee on Water Balance to discuss the modalities and availability of data for the preparation of Dynamic Ground Water Estimation Study of Punjab State, 2022 was held on 07th February, 2022 under the Chairmanship of Superintending Engineer, Ground Water Management Circle (GWMC), in the Committee Room of Water Resource Bhawan, Sector 68, SAS Nagar.

2.0 The list of participants is attached as **Annexure-'1'.**

3.0 At the outset, the Chairman while welcoming the Committee Members apprised that the agenda of the meeting is to discuss the data availability, guidelines and time lines for the preparation of Dynamic Ground Water Estimation study of Punjab State, 2022. He further informed that in the 1st meeting of the Technical Sub-Committee to work out the modalities for the preparation of Dynamic Ground Water Estimation study of Punjab State, 2022 held on 25-01-2022, it was decided that all concerned departments involved in supplying data be invited to discuss the data availability format.

The Chairman desired that absentees {Representative of Chairman, Punjab Water Regulatory Development Authority (PWRDA), Representative of Chairman, Punjab Pollution Control Board (PPCB), Patiala & Geologist/Hydrologist, Ground Water Cell, Division no 2, DoA & FW, Punjab} should be present in the next meeting. The Chairman then asked the Scientist from Central Ground Water Board (CGWB) to brief the House especially, the special invitees regarding the guidelines for preparation of Dynamic Ground Water Estimation study of Punjab State, 2022.

4.0 Scientists from CGWB appraised the house that the Dynamic Ground Water Estimation study of Punjab State, 2022 would be carried for 150 administrative blocks of the State. Further, canal water supply details, surface water irrigation details, water conservation structure details, tanks/ponds details, cropping pattern, ground water draft/withdrawal for irrigation, domestic and

industrial uses cropping pattern & ground water draft etc. have to be collected from different State Government Departments. Also in present meeting soil type wise/ blocks wise availability of specific yield, rain infiltration and return flows etc. were discussed with representatives of Punjab Agricultural University, Ludhiana. In addition, Dynamic Ground Water Estimation study of Punjab State, 2020 needs to be officially released by either Worthy Chief Secretary, Government of Punjab or of the level of Principal Secretary.

5.0 After detailed deliberations, it was unanimously decided that:

a) CGWB would send the data sheet for collection of required data for preparation of Dynamic Ground Water Estimation study of Punjab State, 2022 to all the concerned departments/members.

(Action: CGWB, NWR)

b) The GWMC and DoA & FW would pursue the matter of official release of Dynamic Ground Water Estimation study of Punjab State, 2020 with office of Worthy Chief Secretary, Punjab and Principal Secretary, Irrigation, Punjab.

(Action: GWMC, Pb. & DoA & FW, Pb.)

c) Indian Meteorological Department, Punjab, Chandigarh would furnish the monthly rainfall data (Year 2012-2021) of Punjab State available with them by 31st March, 2022 and thereafter analysed will be done by Ground Water Management Circle (GWMC), Punjab.

(Action: IMD, Punjab & GWMC, Pb)

d) The area of Paddy under Direct Seeded Rice (DSR) and thereby water saving in HAM would be supplied by DoA & FW, Punjab in collaboration with Punjab Agriculture University (PAU), Ludhiana. For this, Department of Agronomy, PAU, Ludhiana may be invited as special invitee in the next meeting.

(Action: DoA & FW,Pb & PAU, Ludhiana)

e) Head, Department of Soil & Water Engineering, PAU, Ludhiana informed the Chair that the data of specific yield, evapo- transpiration (ET) demand, rainfall infiltration and return flows etc. is already well documented. The soil type wise data is not available and Specific yield @15% and rate of infiltration @22% is highly suited for Punjab's Hydro-geological conditions which is mostly Sandy Loam Soil. The house agreed that the specific yield @15% and rate of infiltration @ 22% be kept as fixed parameters in the report to be prepared.

(Action: CGWB, NWR, Chd. & GWMC, Pb)

f) Chief Engineer (Canals), Department of Irrigation, Punjab would supply the Canal data required for the estimation study in the prescribed format given by CGWB. Thereafter, to analyse the results, the representatives of CE (Canals), Punjab would assist GWMC, Punjab to arrive at some conclusion.

(Action: CE (Canals), Punjab & GWMC, Pb)

g) Chairman, Punjab Water Regulatory Development Authority (PWRDA) would be communicated by Chairman about the absence of representative of Authority in the meeting and would be called for next meeting to have an insight of industrial water usage figures.

(Action: GWMC, Pb)

h) Representative from Department of Industries stated that they did not have any data of water consumed by industries and the number of wells installed by them. Chairman observed that the figure of 0.7% of the total water consumed by the industries shown in the previous studies seemed to be erroneous and it needs to be re-looked. Department of Industries, Punjab would supply block wise industrial units registered and if they are not in position to supply block wise industrial units then district wise coordinates of the industrial units would be supplied. He also assured that all the available data would be supplied by 31st March, 2022 positively.

(Action: Department of Industries, Pb)

i) Representative from Department of Industries informed that the NOC for new industrial units and renewal of old units were being earlier given by Punjab Pollution Control Board. As such, PPCB may be asked to provide the data of water consumed by the industrial units. Now, PWRDA is giving NOC for the new industrial units. As such PWRDA may also be asked to supply the data of water consumed by these units.

(Action: PPCB, Patiala & PWRDA)

j) Department of Rural Development & Panchayats, Punjab would supply the block wise/ GPS coordinate based information of water conservation structure details & tanks and village ponds etc.

(Action: Department of Rural Development & Panchayats, Punjab)

k) SE (Policy & Evaluation), Department of Irrigation, Punjab be invited as special invitee to discuss parameters of ground water incorporated in Mekerot Reports.

(Action: DoA & FW, Pb)

The Chairman while concluding the meeting desired that all State Government departments involved in the preparation of Dynamic Ground Water Estimation study of Punjab State, 2022 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, 2022. To discuss the progress of work as per availability of data in prescribed format of CGWB and to work out roadmap for preparation of Dynamic Ground Water Estimation study of Punjab State, 2022, the third meeting of the Sub-Committee would be held on Monday i.e. 07th March, 2022.

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

****

ANNEXURE-'I'

S.N.	Name	Designation	Department
1	Sh. Rakesh Rana	Scientist 'D'	Central Ground Water Board (NWR) Chandigarh.
2	Dr. J.P. Singh	Professor & Head	Soil & Water Engineering, PAU, Ludhiana.
3	Sh. Devinder Kumar Hans	SE, Panchayati Raj	Department of Rural Development & Panchayat, Punjab.
4	Sh. Surinder Singh	Assistant Director	Department of Industries & Commerce, Punjab.
5	Sh. A.K. Singh	Scientist	Indian Meteorological Centre Chandigarh.
6	Sh. Jaspal Singh	Geologist/Hydrologist, Ground Water Cell, Division no 1 - Member Secretary	Department of Agriculture & Farmers Welfare, Punjab.
7	Sh. Atul Kumar Sood	Sr. Geophysicist	Ground Water Management Circle, Sector-68, SAS Nagar.
8	Sh. G.S. Dhillon	DSCO(QC)	Department of Soil and Water Conservation, Punjab.
9	Dr. Sandeep Singh Walia	Assistant Geologist	Department of Agriculture & Farmers Welfare, Punjab.
10	Sh. Akashdeep Singh	Executive Engineer	XEN Regulation, Water Resources Department, Punjab.
11	Sh. Balveer Singh	XEN, Canal-II	Canals-2 Administration, Water Resources Department, Punjab.
12	Sh Ankit Dhir	XEN, Canal-1	Water Resources Department, Punjab.
13	Sh. Sonpreet Singh	ADE/ Canal	Canals-2 Administration, Water Resources Department, Punjab.
14	Sh. Bhupinder Singh	S.D.O	Ground Water Management Circle, Sector 68, SAS Nagar.
15	Shr. Aikjot Kaur Narula	Technical Assistant	Ground Water Management Circle, Sector 68, SAS Nagar.

APPENDIX -2.3

Minutes of 3rd Meeting of Technical Sub-Committee on Water Balance of Punjab State-2022 held under the Chairmanship of Superintending Engineer, Ground Water Management Circle, Water Resources Management Circle- cum - Chairman, Technical Sub Committee on Water balance of Punjab State, S.A.S. Nagar (Mohali) on 20th April, 2022 at 11:00 AM.

The third meeting to discuss the progress of data furnishing by member departments for the preparation of Dynamic Ground Water Estimation study of Punjab State, 2022 was held under the Chairmanship of Superintending Engineer, Ground Water Management Circle, Water Resources Management Circle- cum - Chairman, Technical Sub Committee on Water balance of Punjab State, S.A.S. Nagar (Mohali) on 20th April, 2022 at 11:00 AM in the Committee Room of Water Resource Bhawan, Sector 68, SAS Nagar (Mohali).

2.0 The list of participants is attached as **Annexure-'1'.**

3.0 At the outset, the Chairman while welcoming the Committee Members apprised all present that the meeting is to review the progress of data furnishing in the prescribed format given by Central Ground Water Board (CGWB) to be incorporated in INGRES software for preparation of Dynamic Ground Water Estimation study of Punjab State, 2022. The Chairman then asked the Scientist from CGWB to brief the House regarding the receipt of data from different member department for preparation of Dynamic Ground Water Estimation study of Punjab State, 2022

4.0 Scientists from CGWB apprised the house that the Dynamic Ground Water Estimation study of Punjab State, 2022 needs to cater to all the 23 districts (including newly carved District Malerkotla). In addition, as discussed in previous meetings, canal water supply details, surface water irrigation details, water conservation structure details, tanks/ponds details, cropping pattern, cropping pattern & ground water usages for irrigation, domestic and industrial uses etc have to be collected from different State Government Departments i.e. Water Resources, Agriculture, Irrigation, Public Health Department, Rural Water Supply, Industry, Soil & Conservation, Statistics, Punjab Pollution Control Board etc.

Till date, only Department of Rural Development & Panchayats, Punjab has supplied the tank/pond data, which is also incomplete. The data regarding Average Water Spread area of Single Tank is missing. Department representatives have assured to supply the same before the next

meeting Further, Department of Agriculture & Farmers' Welfare, Punjab has communicated that the cropping pattern and water usage data would be supplied in about three weeks time.

The House also discussed that Punjab Water Regulation & Management Development Authority (PWRMDA) is giving the permission of ground water abstraction in the State of Punjab. As such their representation in the meeting is of utmost importance. However, a message was received from PWRDA that due to busy schedule they could not attend the meeting but would send the data of all the permissions given by them to the industries at the earliest so that the same can be finalized in all respects by 31st May 2022.

5.0 After detailed deliberations, it was unanimously decided that:

i. All the Member Departments would furnish the data completed in all aspects in the prescribed Performa at the earliest. It was also decided that the next meeting of the Sub-committee shall be held on 24/5/2022 in which the data received from all the departments would be validated The data is to be sent to dwrhp2@yahoo.com with cc to rdnwr-cgwb@nic.in so that in case of any shortcoming in the data supplied by the departments the same would be communicated through e-mail to the concerned department by the Member Secretary.

ii. It was decided that for the convenience of department of Industries and Punjab Pollution Control Board, they would be shared the data supplied by the Industry Department in the year 2009 to Ground Water Management Circle, so that they can compile the data further and submit back the complete data for the estimation report 2022 **as per 2009 format** (Industrial Water requirement figures) to GWMC and CGWB. However, no data has been provided by the Industry Department after 2009 which is a cause of great concern.

iii. In the light of letter received from the Member (South) Central Ground Water Board & Member Secretary, Central Level Expert Group (CLEG) whereby it has been categorically stated that Industrial Extraction data may be collected/ compiled from concerned State Industrial Department/SGWA/CGWA etc. Zero/Null values of Industrial Extraction data from States/UTs won't be accepted for National Compilation of Dynamic Ground Water Resources -2022. As such, the Chairman asked the representatives of Department of Industries and Punjab Pollution Control Board that the block wise data pertaining to number

of industries and industrial draft is of utmost important and asked them to provide the same positively without failing.

iv. Chairman, **Technical Sub Committee** would communicate to Chairman, Punjab Water Regulation & Management Development Authority (PWRMDA) regarding continuous absence of their representative from Technical Sub-Committee on Ground Water Balance meetings.

v. Punjab Agriculture University (PAU), Ludhiana would also be communicated about the absence of their representative for supplying the area of Paddy under Direct Seeded Rice (DSR) and thereby water saving in HAM. Further, PAU, Ludhiana must ensure participation by representative in future meetings of the Technical Sub-Committee.

vi. Department of Rural Development & Panchayats, Punjab would supply block wise GPS coordinate based information of water conservation structure details & tanks and village ponds etc...

While concluding, the Chairman desired that all departments involved in the preparation of Dynamic Ground Water Estimation study of Punjab State, 2022 would extend full cooperation & furnish the data at the earliest positively so as to accomplish the task of preparation of Dynamic Ground Water Estimation study of Punjab State, 2022 (Study period 2012-2021) within stipulated time period.

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

****

ANNEXURE-'1'

Attendance Sheet of 3rd Meeting of Technical Sub-Committee on water balance of Punjab State held the Chairmanship of Director, Water Resources & Environment Directorate, Punjab-cum-Chairman, Technical Sub-Committee on water balance of Punjab State, S.A.S. Nagar on 20-04-2022 at 11:00 AM.

S. N.	Name	Department & Designation
1.	Sh. Manmohan Singh	Director, Indian Meteorological Centre, Chandigarh
2.	Sh. Rakesh Rana	Scientist-D CGWB,
3.	Sh. Ankit Dhir	Executive Engineer, Canals I, WRD,PB
4.	Sh. Balvir Singh	XEN/ Canals II, WRD,PB
5.	Sh. Satyajet Attri	E.E. (C.E.E.) Office
6.	Sh. Devinder Kumar	S.E. Rural Dev. & Panchayat ,PB
7.	Sh. R.S. Gupta	Sr. Hydrogeologist, PWRMDC, Mohali
8.	Sh. Jaspal Singh	Geologist/ Hydrologist , G.W.C. Div. No.I
9.	Dr. Arun Kumar	Geologist/ Hydrologist, G.W.C. Div. No.II
10.	Sh. Avtar Singh	A.S.O, P.P.C.B, Patiala
11.	Sh. Suresh Narang	Project Officer, GWMC, Sec. 68
12.	Sh. Atul Kumar Sood	Sr. Geophysicist , GWMC, Sec. 68
13.	Sh. Sandeep Kumar	XEN,GWR, Div 1
14.	Ms. Naima Akhtar	Scientist-B CGWB,
15.	Sh. Manish Shrivastav	AHG CGWB,
16.	Sh. Jasvir Singh	Superintendent Grade-I
17.	Dr. Sandeep Singh Walia	Assistant Geologist, Do A & FW, Pb
18.	Dr. Manpreet Singh	Assistant Geologist, DO A& FW, PB
19.	Sh. Bhupinder Singh	SDO, GWMC, WRD, PB
20.	Sh. Sahil Thakur	SDO, GWMC, WRD, PB
21.	Ms. Aikjot Kaur Narula	TA, GWMC, WRD, PB

APPENDIX -2.4

Minutes of 4th meeting of Technical Sub-committee on Water Balance of Punjab State-2022 held under the Chairmanship of Superintending Engineer, Ground Water Management Circle-cum-Chairman Technical Sub-Committee on Water Balance of Punjab State- held on 27th July, 2022 at 11:00 AM.

The 4th meeting to discuss the progress of data furnishing by member departments & the preparation of Dynamic Ground Water Estimation Study of Punjab State, 2022 on INGRES software was held under the Chairmanship of Superintending Engineer, Ground Water Management Circle, Water Resource Circle-cum-Chairman Technical Sub-Committee on Water Balance of Punjab State was held on 27th July, 2022 at 11:00 AM through Video Conferencing mode.

2.0 The list of officers who attended the meeting is as under:

- Mr. Rakesh Rana, Scientist-D, CGWB.
- Mr. Jaspal Singh, Geologist/Hydrologist, Ground Water Cell, Div. No.1, Pb-cum member Secretary, Technical Sub-Committee on Water Balance of Punjab State.
- Mr. Atul Kumar Sood, Sr Geophysicist, GWMC, Sector 68, Mohali.
- Mr. Suresh Narang, Project Officer, GWMC, Sector 68-Mohali
- Mr. Sandeep Singh Walia, Assistant Geologist, DoA&FW, Punjab
- Mr. Manpreet Singh, Assistant Geologist, DoA&FW, Punjab
- Mr. Sahil Thakur, SDO, GWMC,WRD, Punjab
- Mr. Manish Shrivastava, AHG, CGWB.
- Representative of Industries Deptt, Punjab.

3.0 At the outset, the Chairman while welcoming the Committee Members apprised them that the last date for finalising the Dynamic Ground Water Estimation Study of Punjab State, 2022 on INGRES software is 31st July, 2022. Further Industries Department, Punjab & Punjab Pollution Control Board (PPCB) have not submitted the data in the prescribed format given by CGWB. The Chairman then asked Member Secretary to put forward the agenda of the meeting.

4.0 Member Secretary apprised the Chair that the data of Industries Department, Punjab & Punjab Pollution Control Board (PPCB) has not been received as per information received from CGWB & GWMC, Department of Irrigation, Punjab. The Committee needs to deliberate on non-supply of data by these departments & inadequate data supplied by XEN, Irrigation (Canals), Department of Soil & Water Conservation (DSWC), Punjab, Secondly, the cropping

pattern data supplied by Department of Agriculture & Farmers' Welfare (DoA&FW), Punjab for year 2021 is of 138 blocks. The GW Balance, 2022 to be prepared needs the data of 150 blocks. Therefore, it is put before Committee that cropping pattern data of 2019 be taken in the present report.

5.0 After detailed deliberations, the following decisions were taken:

(i) The Chairman took serious note of absentees of DSWC, PPCB & Punjab Water Regulation Development Authority.

(ii) DSWC, Punjab & Industries Department, PPCB to supply the data within 7 days.

(iii) Due to paucity of time, cropping pattern data of year 2019 be incorporated in the Dynamic Ground Water Estimation Study of Punjab State, 2022. For Dynamic Ground Water Estimation Study of Punjab State, 2023, DoA & FW, Punjab would ensure to supply the cropping pattern data of all 150 blocks.

(iv) As there is no change in data of Canal outlets, the data of year 2019 be incorporated in the Dynamic Ground Water Estimation Study of Punjab State, 2022.

(v) DSWC, Punjab to provide the block wise storage data of water conservation structures.

(vi) CGWB would incorporate the data in the INGRES software and any change in the data received from Member departments who have not supplied the data would be made within 7 days.

(vii) The data received within 7 days would be incorporated & uploaded in INGRES software by CGWB. The department who fail to submit the data would be solely responsible for non-supply of data and a comment would be made in the report that data has not been received by concerned department.

The Chairman while concluding desired that all departments should submit the data within one week in prescribed format so that the task of preparation of Dynamic Ground Water Estimation Study of Punjab State, 2022 could be accomplished timely.

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

******

APPENDIX -2.5

Minutes of 5th meeting of Technical Sub-committee on Water Balance of Punjab State-2022 held under the Chairmanship of Superintending Engineer, Ground Water Management Circle-cum-Chairman Technical Sub-Committee on Water Balance of Punjab State- held on 22nd August, 2022 at 11:00AM.

The 5th meeting to discuss the progress of data furnishing by member departments for the preparation of Dynamic Ground Water Estimation Study of Punjab State, 2022 was held under the Chairmanship of Superintending Engineer, Ground Water Management Circle -cum-Chairman Technical Sub-Committee on Water Balance of Punjab State was held on 22nd August, 2022 at 11:00AM.

2.0 The list of officers who attended the meeting is attached as Annexure-A

3.0 At the outset, the Chairman while welcoming the Committee Members apprised them that the last date for submission of the Dynamic Ground Water Estimation Study of Punjab State, 2022 on INGRES software is 31st August, 2022. The Chairman then asked Member Secretary to put forward the agenda of the meeting.

4.0 Member Secretary apprised the House that the data of Industries Department, MC Ludhiana, Jalandhar & Sri Amritsar Sahib & Punjab Pollution Control Board (PPCB) has not been received as per information received from CGWB & GWMC, Department of Irrigation, Punjab. Further, the meeting is to review the progress of preparation of Dynamic Ground Water Estimation Study of Punjab State, 2022.

5.0 After detailed deliberations, the following decisions were taken:

(i) The Chairman took serious note of absentees of MC-Jalandhar, MC-Amritsar, PWRMDC & PWRDA.

(ii) The block wise storage data of Water Conservation structures of DSWC, Punjab is of Silt Detection Structures (DSS). Therefore the same would not be considered in the report.

(iii) MC-Ludhiana would furnish the water requirement of total MC tubewells of Ludhiana in the prescribed performa by 24th August, 2022. The representative from MC Ludhiana has been asked to get the similar data from MC Jalandhar and MC Amritsar also.

(iv) The representative from the Industries Department, Punjab has been asked to provide block wise water requirement/ number of structures by 25th August, 2022 positively.

(v) The representative of Canal Department has been asked to provide the updated canal outlet data by 24th August, 2022.

(vi) Poor quality area of district Sri Mukatsar Sahib & Fazilka would be considered in the present study.

(vii) CGWB would look into the data supplied by PWRDA and upgrade the same in the INGRES.

(ix) CGWB would incorporate the data as received from the member departments in the INGRES software for the final assessment. The report would be submitted in the next meeting of the Sub-Committee for approval.

(x) For finalisation of report by Member Departments of the Technical Sub-Committee, the **next meeting would be held on Monday ie. 29th August, 2022 at 3:00 PM in the Committee Room of Water Resources Bhawan, Sector 68, S.A.S. Nagar.**

The Chairman while concluding instructed that for next Water Balance of Punjab State, Industries Department/PPCB/PWRDA would provide block level data of water requirement/number of structures available. For this, they should customise their data accordingly. He further desired that all departments should submit the data by 26th August, 2022 in prescribed format so that the task of preparation of Dynamic Ground Water Estimation Study of Punjab State, 2022 could be accomplished timely i.e by 31st August, 2022. The data received within stipulated time would be incorporated & uploaded by CGWB in INGRES software. The department who fail to submit the data would be sole responsible for non supply of data and a comment would be made in the report that data has not been received from that department.

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

***

ANNEXURE-'A'

1. Mr. Rakesh Rana, Scientist-D, CGWB.
2. Ms. Naima Akhtar, Scientist-B, CGWB.
3. Mr. Jaspal Singh, Geologist/Hydrologist, Ground Water Cell, Div no 1, Pb cum Member Secretary, Technical Sub-Committee on Water Balance of Punjab State.
4. Mr. Surinder Singh, Assistant Director, Deptt of Industries & Commerce, Pb.
5. Mr. Rajinder Singh, Meteorologist, IMD, Chandigarh
6. Mr. Atul Kumar Sood, Sr Geophysicist, GWMC, Sector 68, Mohali.
7. Dr. Arun Kumar, Geologist/Hydrologist, Ground Water Cell, Div no2, Pb
8. Mr. GS Dhillon, DSCO, Deptt of Soil & water Conservation, Pb.
9. Sh. Suresh Narang, Project Officer, GWMC, Sector 68-Mohali
10. Dr. Sandeep Singh Walia, Assistant Geologist, DoA&FW, Punjab
11. Dr. Manpreet Singh, Assistant Geologist, DoA&FW, Punjab
12. Mr. Balvir Singh, XEN, Canals-II
13. Mr. Tushar Goyal, ADE, Canals
14. Mr. Pradeep Balu, Environmental Engineer, PPCB, Ludhiana
15. Mr. Purshottam Singh, Executive Engineer, MC, Ludhiana
16. Mr. Sahil Thakur, SDO (Jr Geologist), GWMC,WRD, Punjab
17. Mr. Bhupinder Singh, SDO Environment Division, GWMC, Sector 68, Mohali
18. Mr. Tarun Kumar, SDO Hydrogeological Division, Sector 68, SAS Nagar
19. Mr. Rajinder Singh Chohan, SDO Hydrogeological Division, Sector 68, SAS Nagar
20. Mr. Anuj Tomar, JE, Surface Hydrology-2
21. Mr. Manmeet Singh, JE, Surface Hydrology-2

APPENDIX -2.6

Minutes of 6th meeting of Technical Sub-committee on Water Balance of Punjab State-2022 held under the Chairmanship of Superintending Engineer, Ground Water Management Circle-cum-Chairman, Technical Sub-Committee on Water Balance of Punjab State- held on 31st August, 2022 at 12:30 PM through Video Conferencing mode.

The 6th meeting to finalize the report of preparation of Dynamic Ground Water Estimation Study of Punjab State, 2022 by Technical Sub Committee under the Chairmanship of Superintending Engineer, Ground water Management Circle-cum-Chairman, Technical Sub-Committee on Water Balance of Punjab State was held on 31st August, 2022 at 12:30 PM through VC mode.

2.0 The following officers attended the meeting:

1. Mr. Rakesh Rana, Scientist-D, CGWB.
2. Mr. Jaspal Singh, Geologist/Hydrologist, Ground Water Cell, Div. No. 1, Punjab -cum Member Secretary, Technical Sub-Committee on Water Balance of Punjab State.
3. Mr. R.S. Gupta, Sr. Hydrogeologist, PWRMDC, Mohali.
4. Mr. Atul Kumar Sood, Sr. Geophysicist, GWMC, WRD, Punjab Sector 68-Mohali
5. Sh. Suresh Narang, Project Officer, GWMC, WRD, Punjab Sector 68-Mohali
6. Mr. Sahil Thakur, SDO (Jr. Geologist), GWMC, WRD, Punjab Sector 68-Mohali

3.0 At the outset, the Chairman while welcoming the Committee Members apprised them that the Agenda of the meeting is to finalize the draft report of the Dynamic Ground Water Estimation Study of Punjab State, 2022 prepared on INGRES software.

4.0 Mr. Rakesh Rana, Scientist –D, CGWB presented before the house a summarized presentation on the Dynamic Ground Water Estimation Study of Punjab State, 2022. He briefed the salient features, methodology adopted for preparing the draft report as well as findings of the report.

5.0 After detailed deliberations, the following decisions were taken:

i. Draft Dynamic Ground Water Estimation Study of Punjab State, 2022 as prepared by CGWB in coordination with Do A & FW & GWMC, WRD, Punjab Sector 68-Mohali was approved.

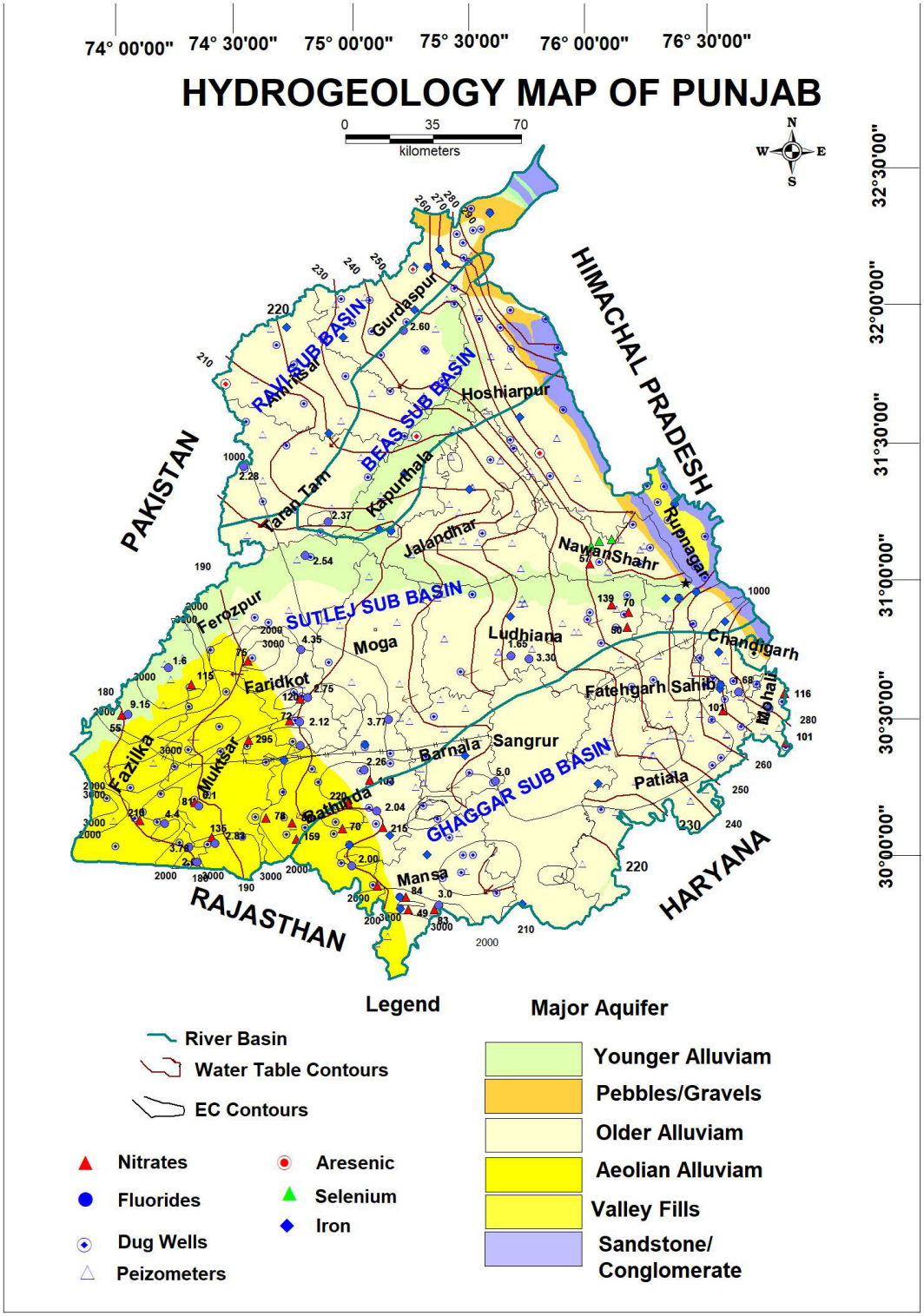
ii. CGWB should seek time from higher authorities for State Level Committee on Water Balance of Punjab State for final approval.

The Chairman while concluding appreciated the efforts puts in by Scientist from CGWB and all other officers of Do A & FW, Punjab and GWMC, WRD, Punjab, Sector 68-Mohali for adhering to time schedule for preparation of Dynamic Ground Water Estimation Study of Punjab State, 2022 report on INGRES software..

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

***

PLATE 1



Source: CGWB, NWR, Chandigarh

PLATE-2

ADMINISTRATIVE BASE MAP

PLATE- 3

CATEGORIZATION OF GROUND WATER ASSESSMENT UNITS IN PUNJAB STATE (2022)

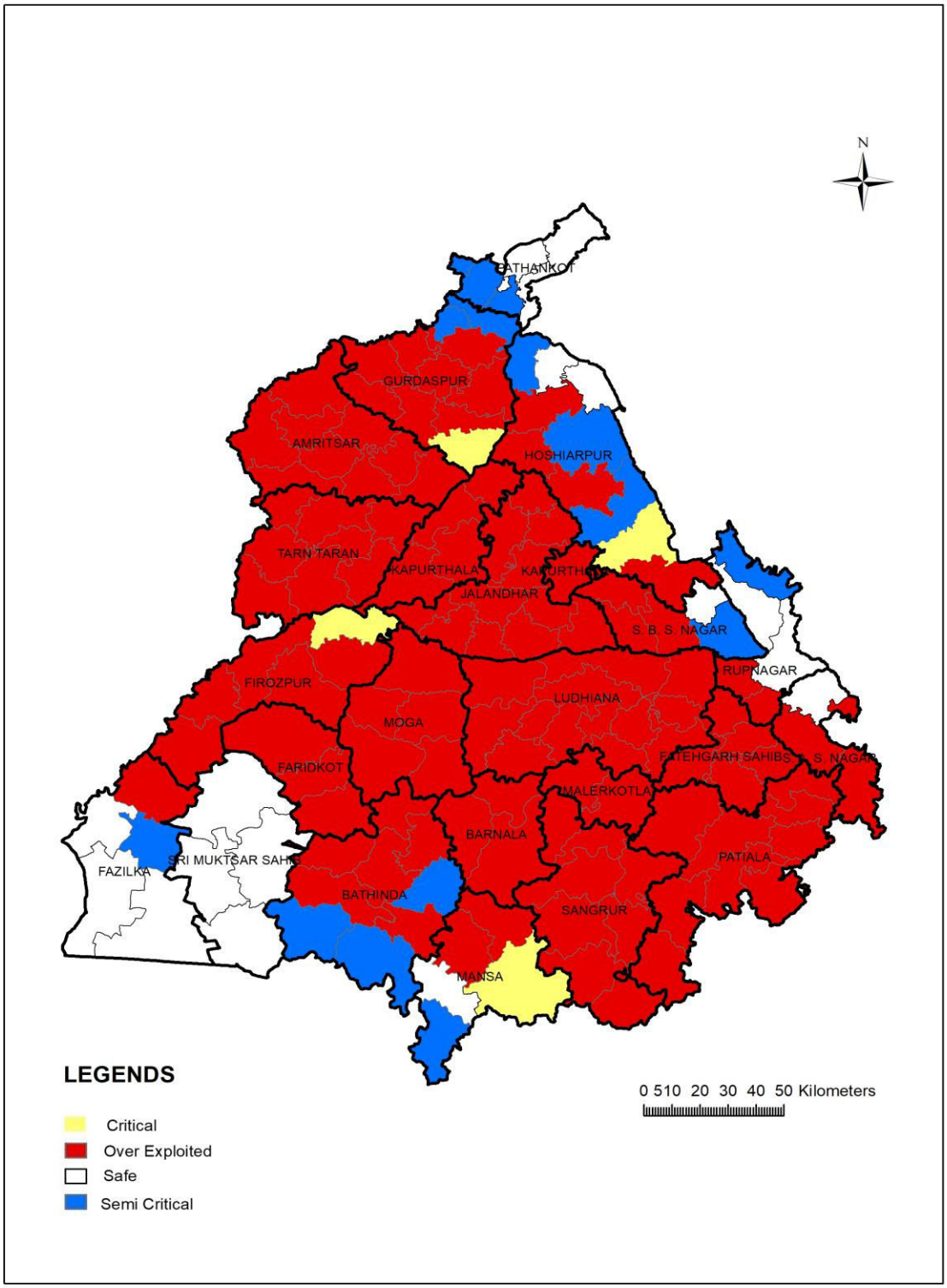


FIGURE-1 ISOHYETS FOR THE YEAR, 2021

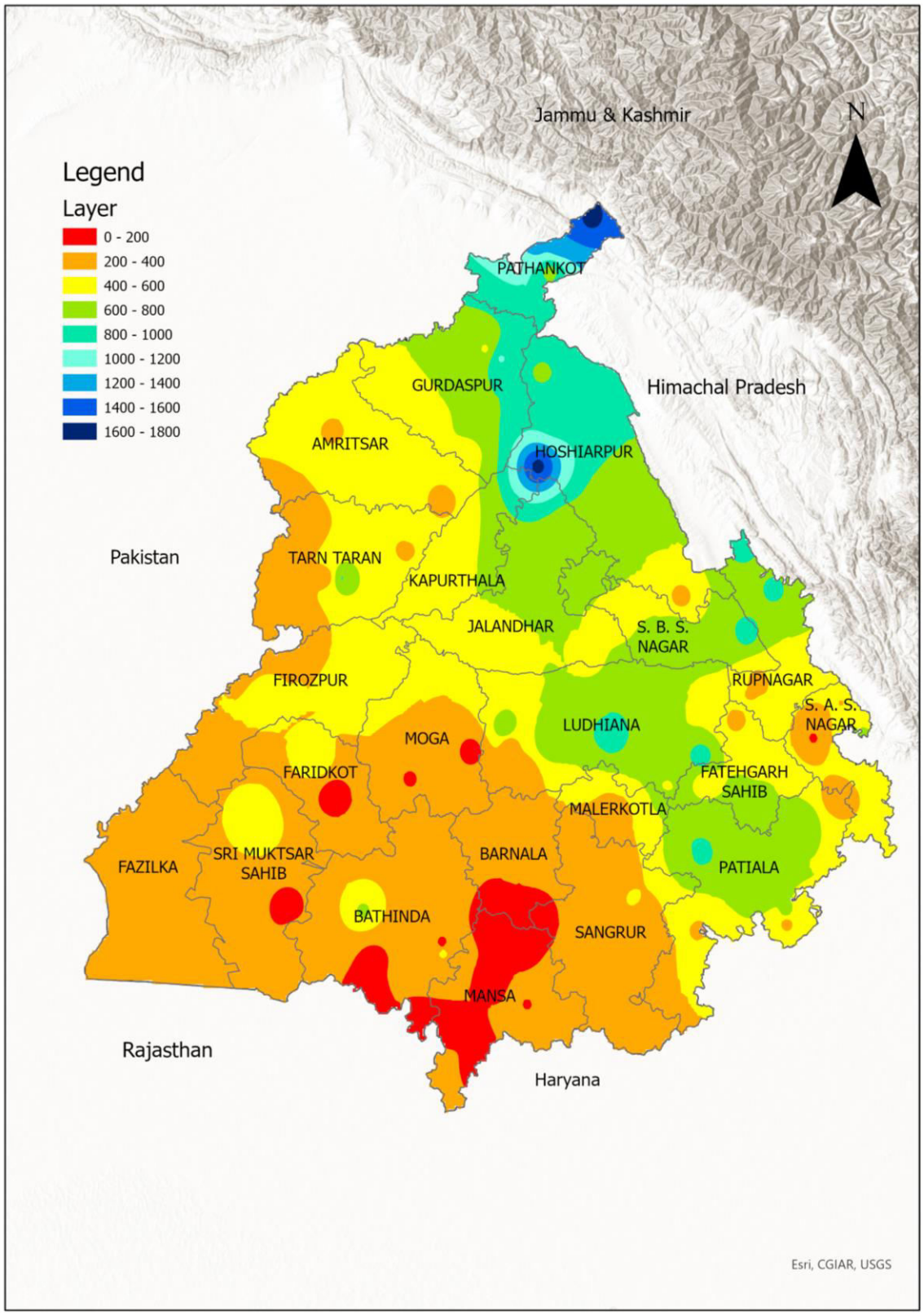


FIGURE-2 DEPTH TO WATER LEVEL, JUNE-2021

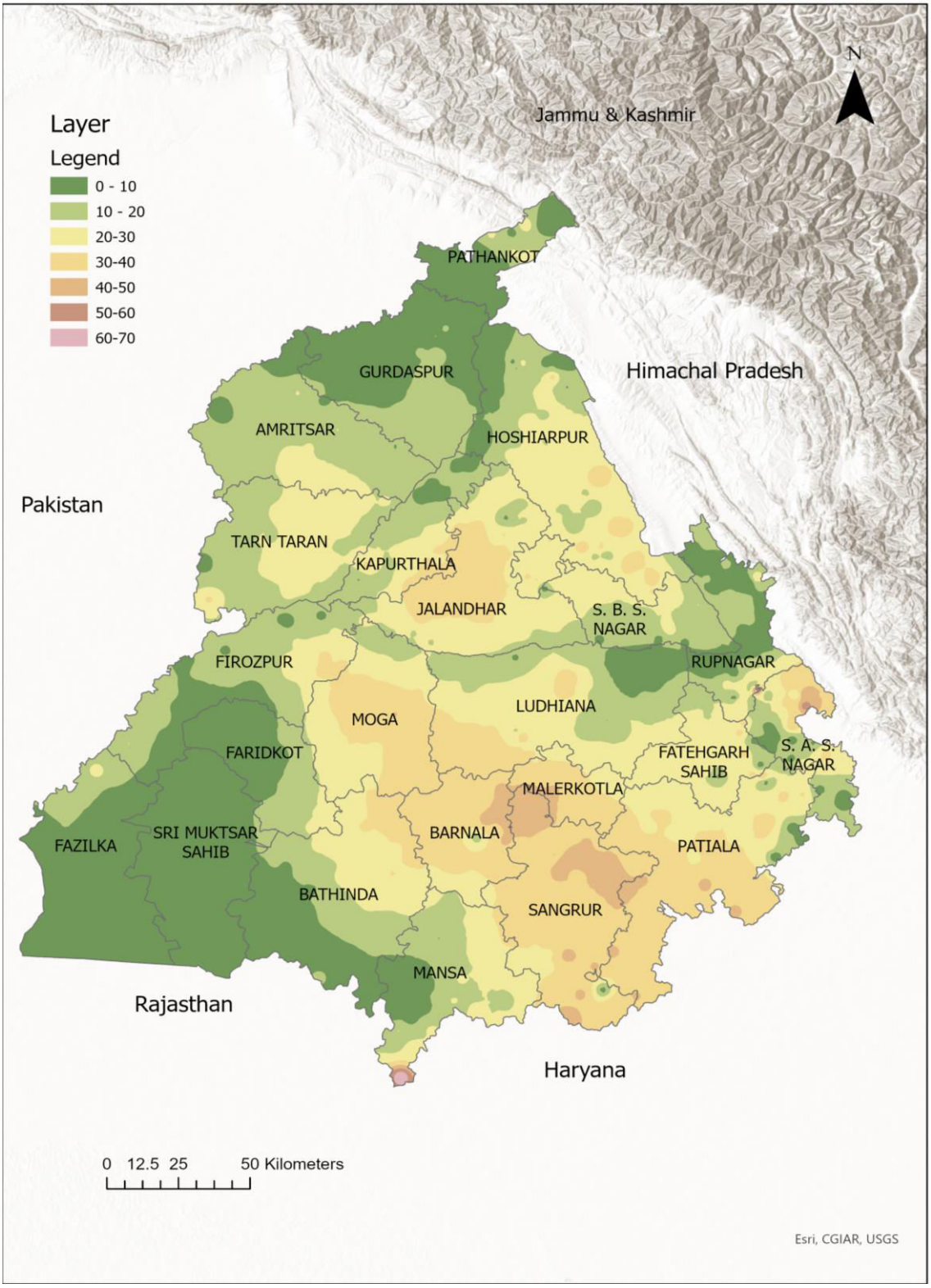


FIGURE-3 WATER TABLE CONTOURS, JUNE-2021

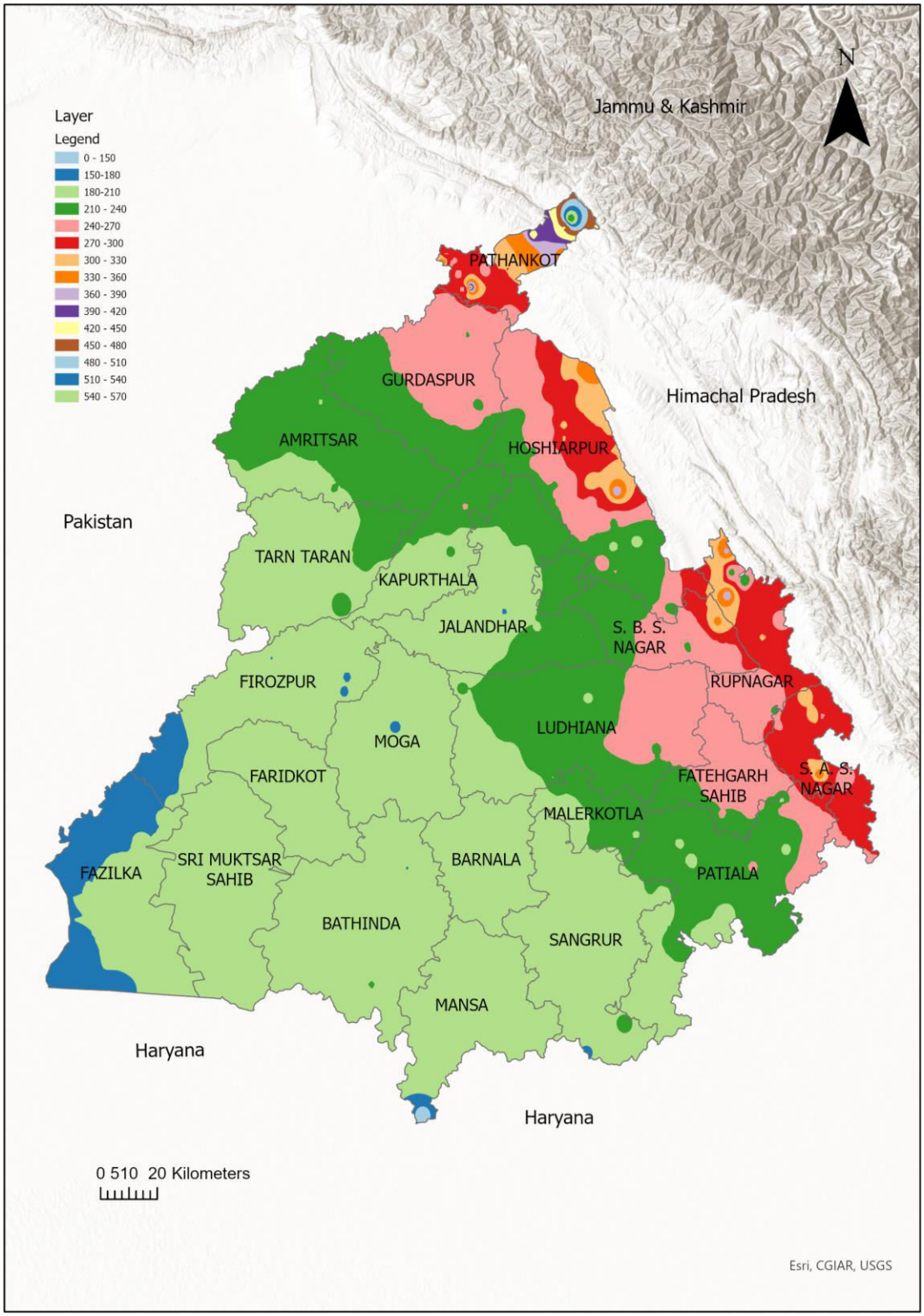


FIGURE-4 DEPTH TO WATER LEVEL, OCTOBER – 2021

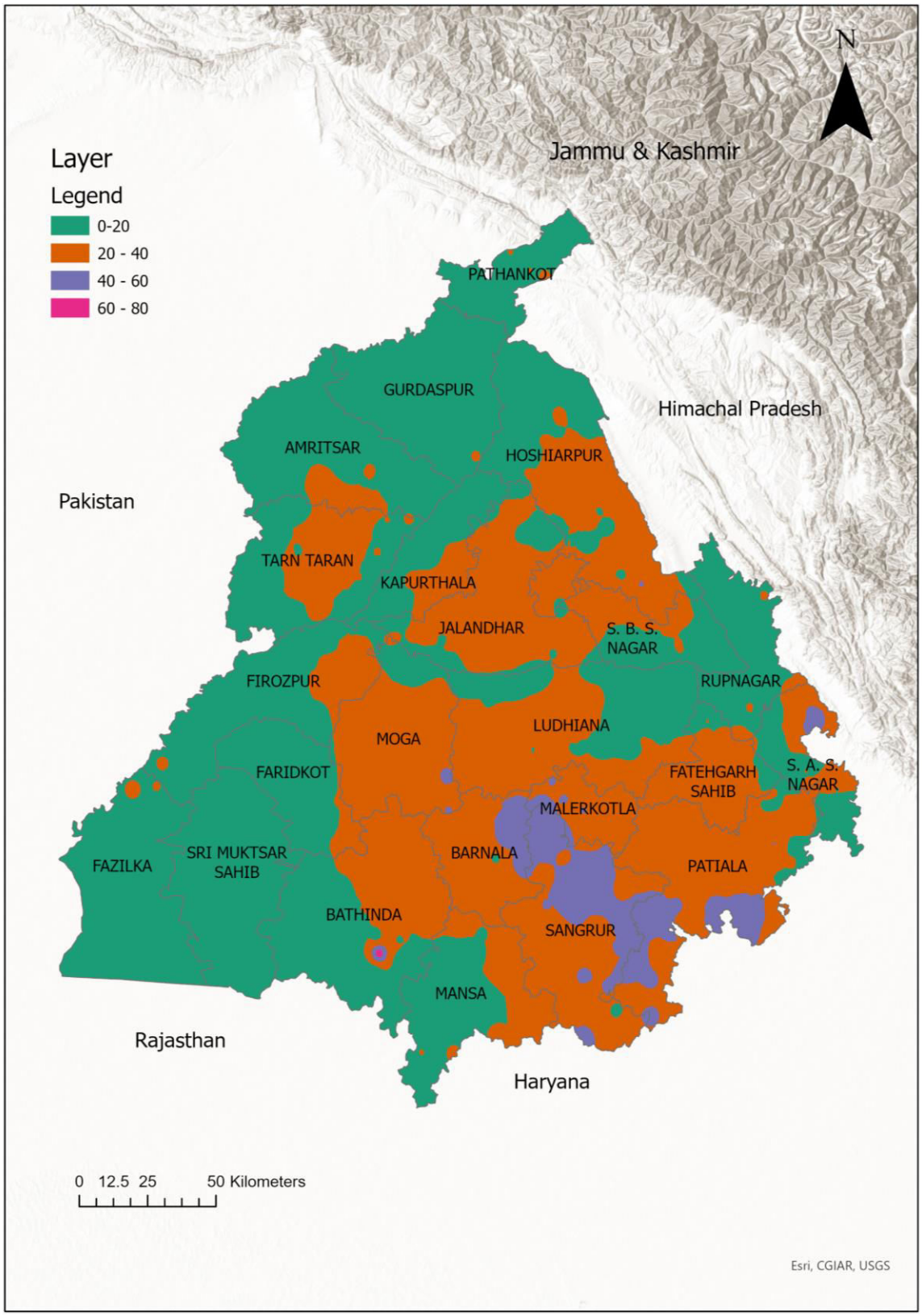


FIGURE-5 WATER TABLE CONTOURS, OCTOBER -2021

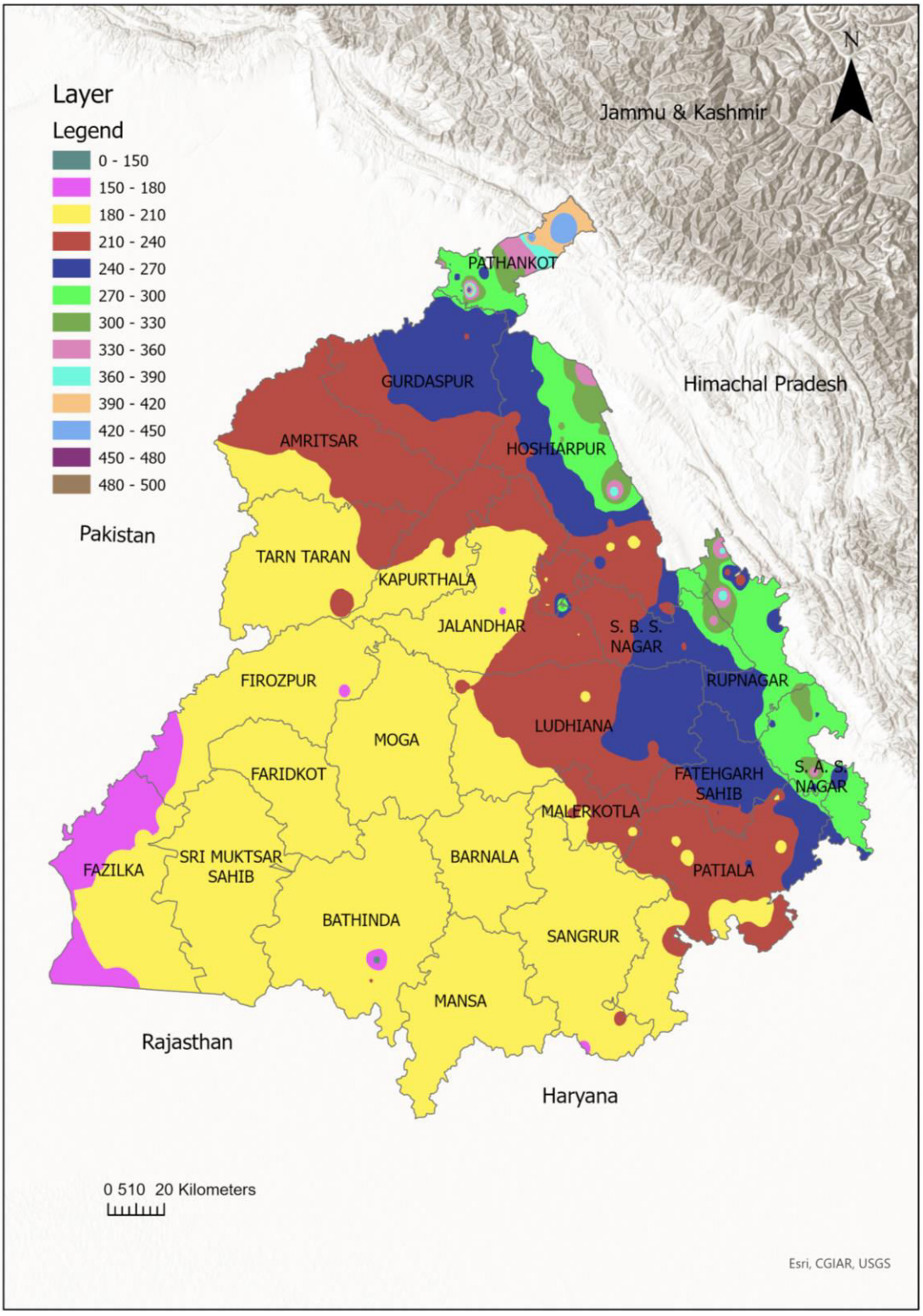


FIGURE-6 RISES and FALL OF WATER LEVEL, JUNE 1984- JUNE 2021

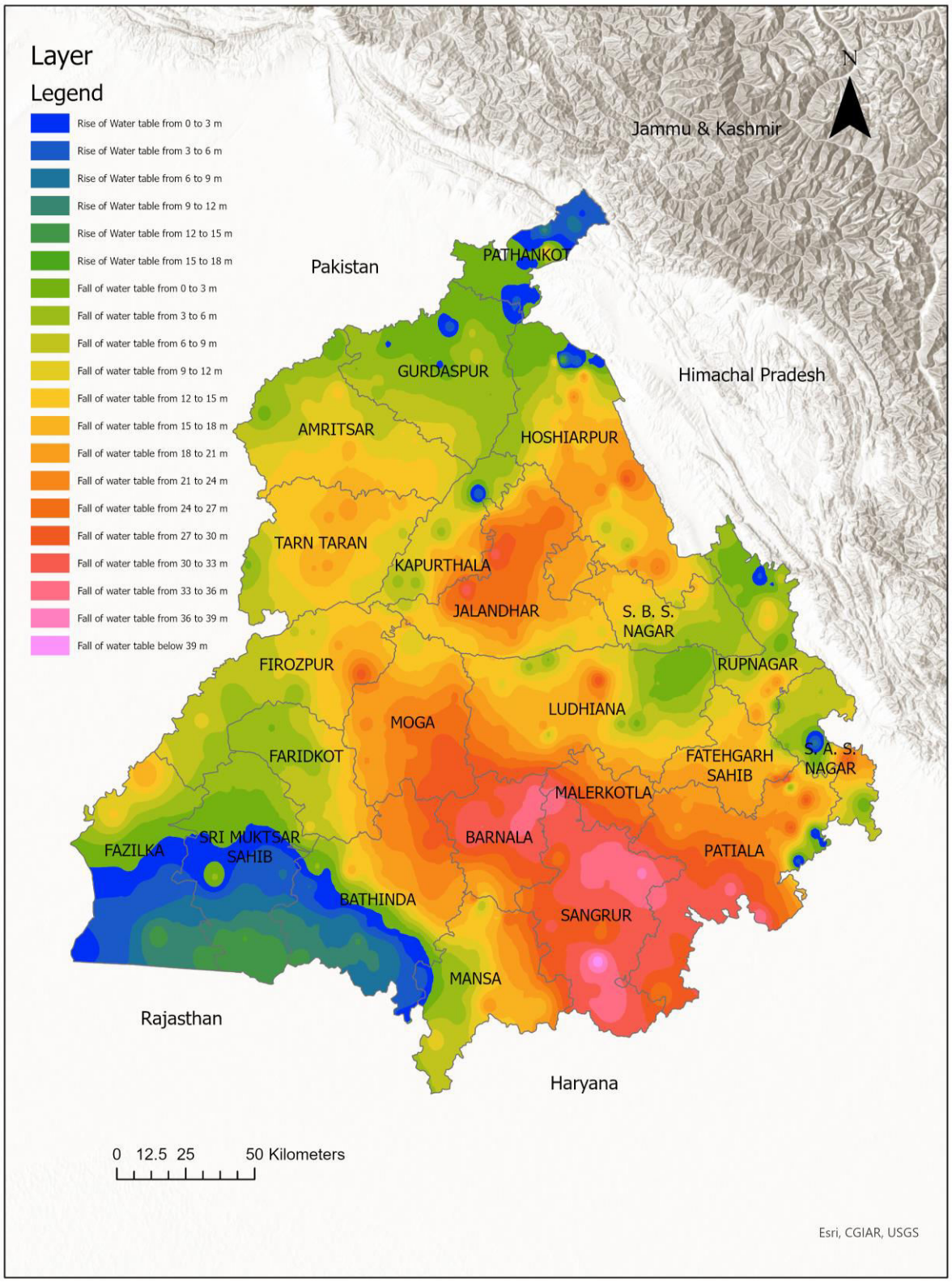


FIG. 7 PERCENTAGE OF BLOCKS UNDER DIFFERENT CATEGORIES

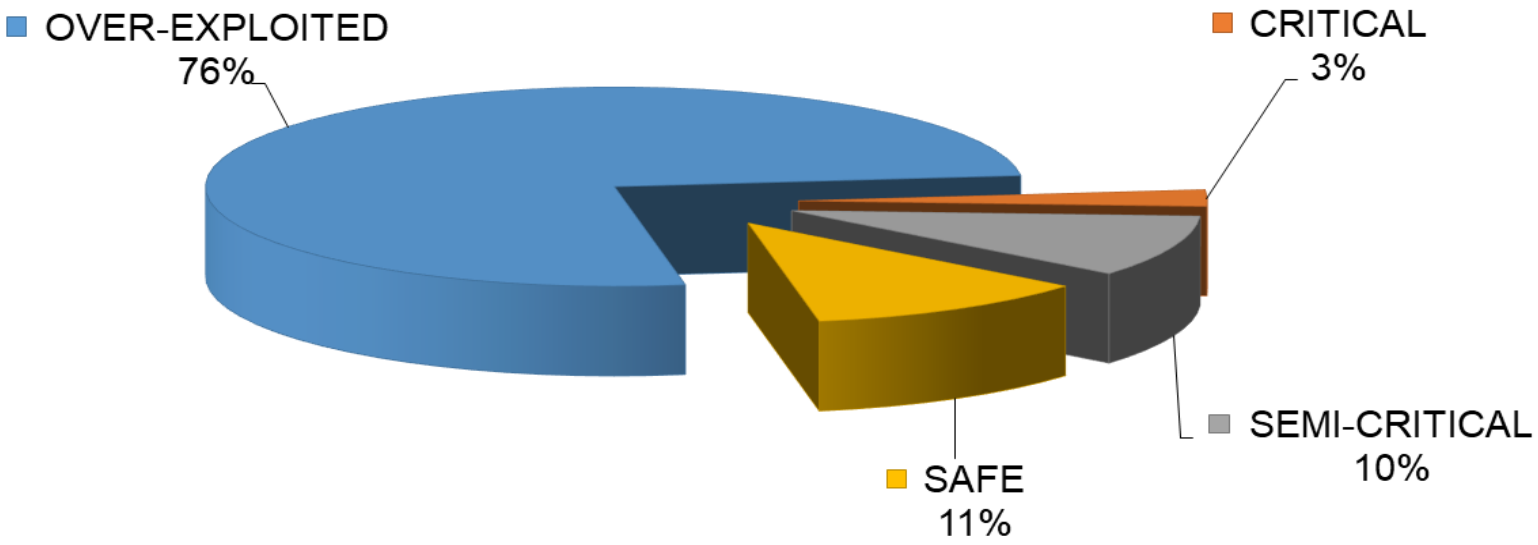


FIG. 8 DISTRICT- WISE RECHARGE FROM RAINFALL AND OTHER SOURCES , PUNJAB

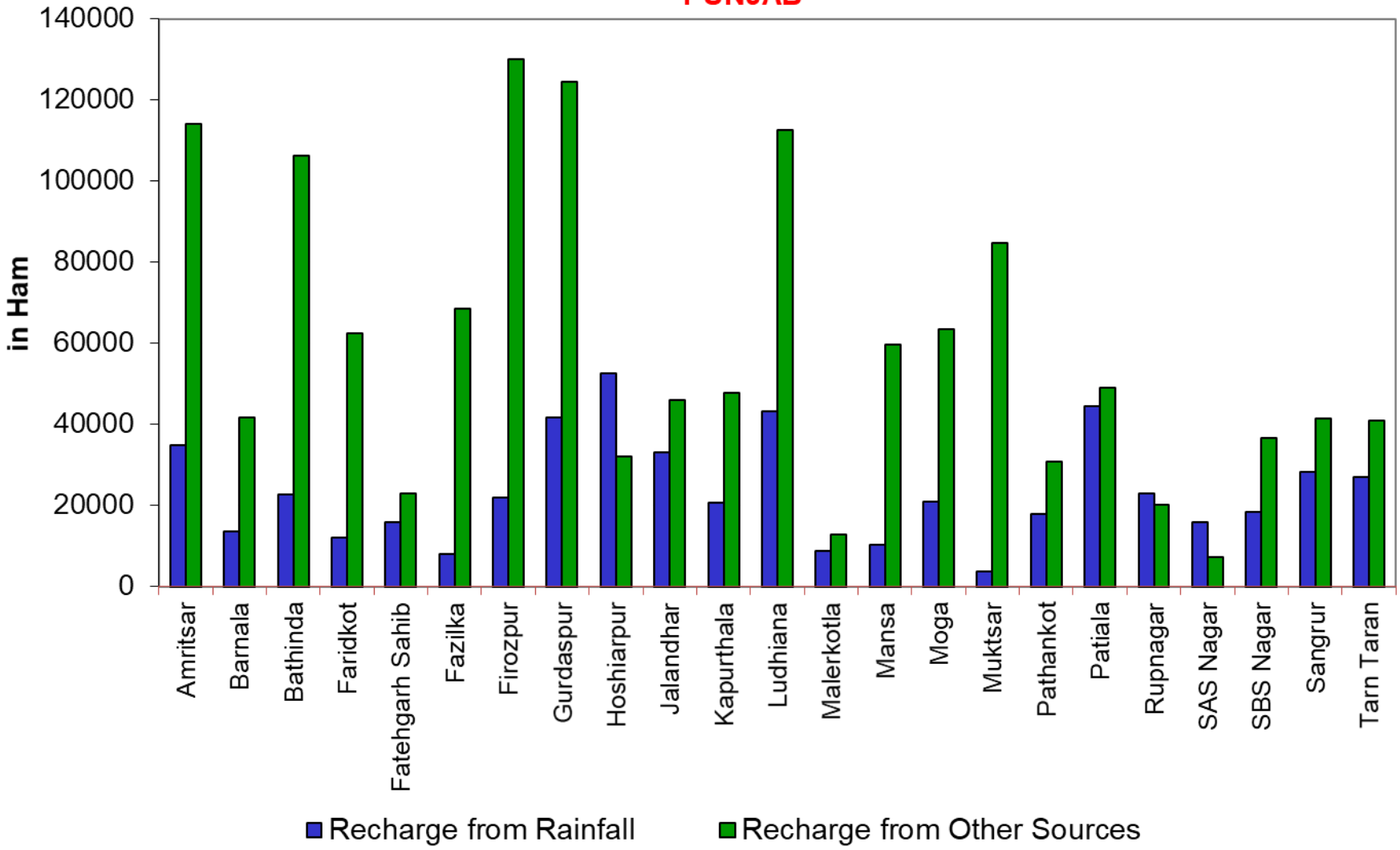


FIG. 9 DISTRICT-WISE GROUND WATER DRAFT, PUNJAB

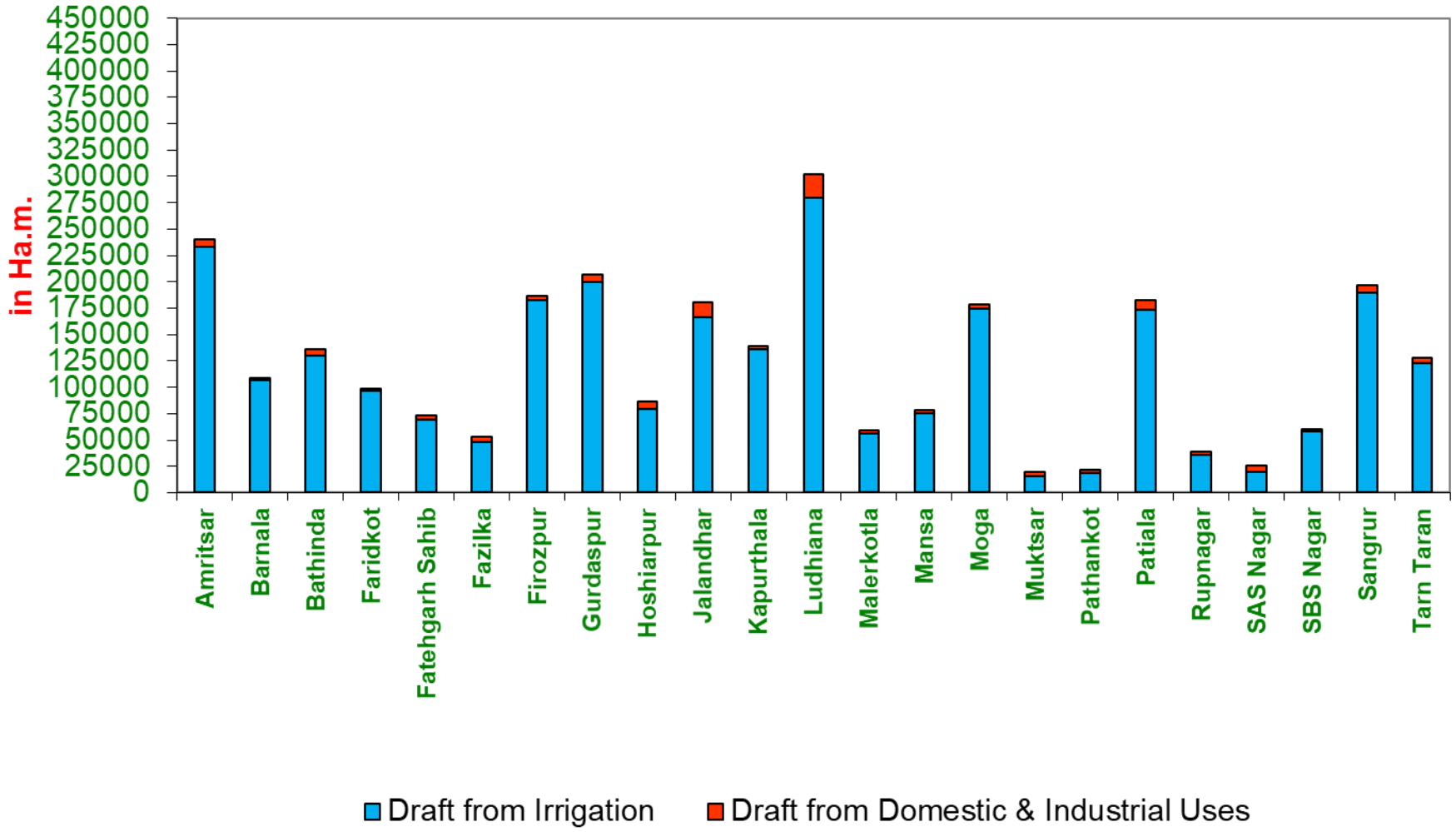


FIG.10 DISTRICT-WISE GROUND WATER AVAILABILITY, GROUND WATER DRAFT, NET GROUND WATER AVAILABILITY FOR FUTURE IRRIGATION PUNJAB

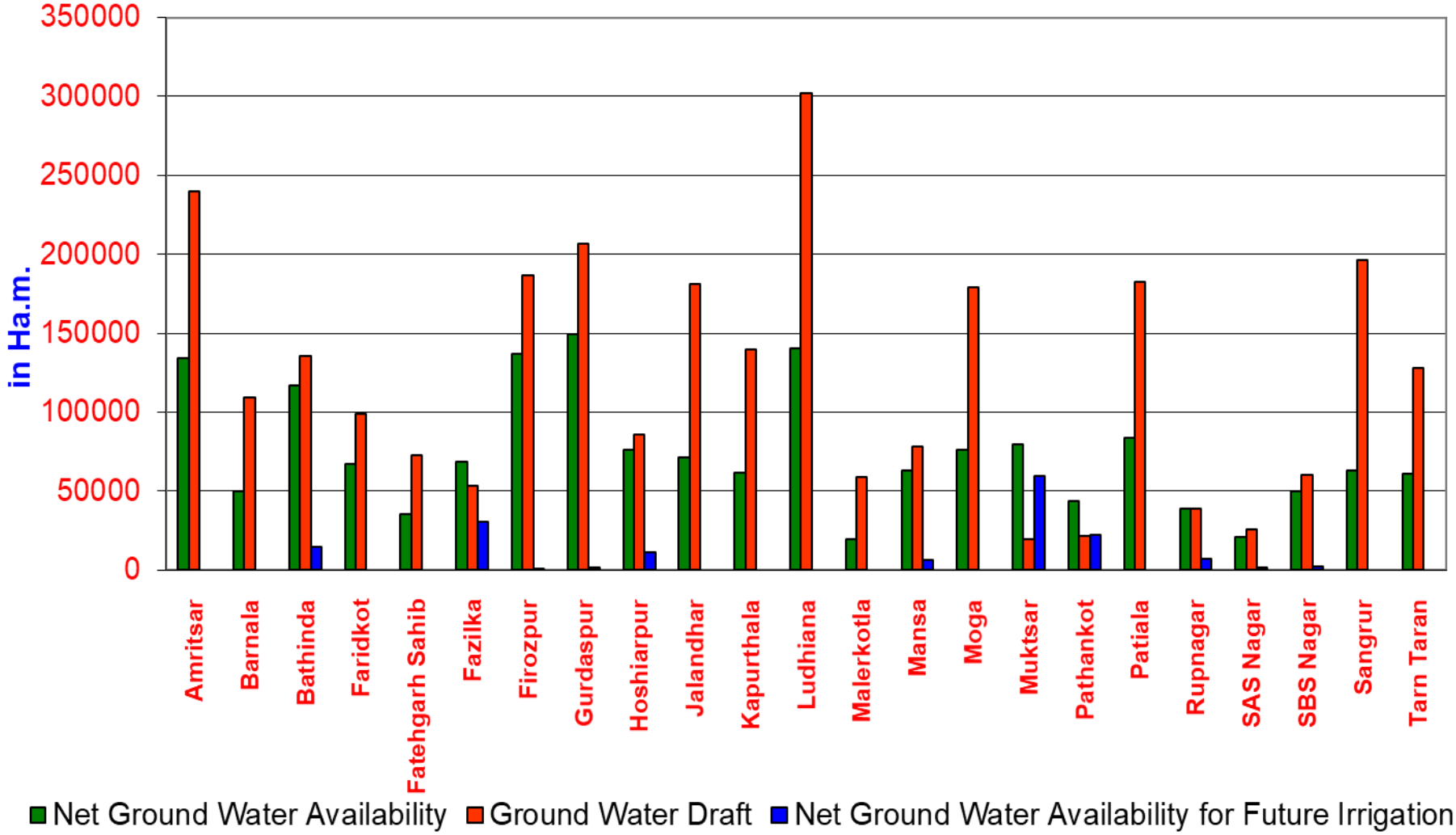
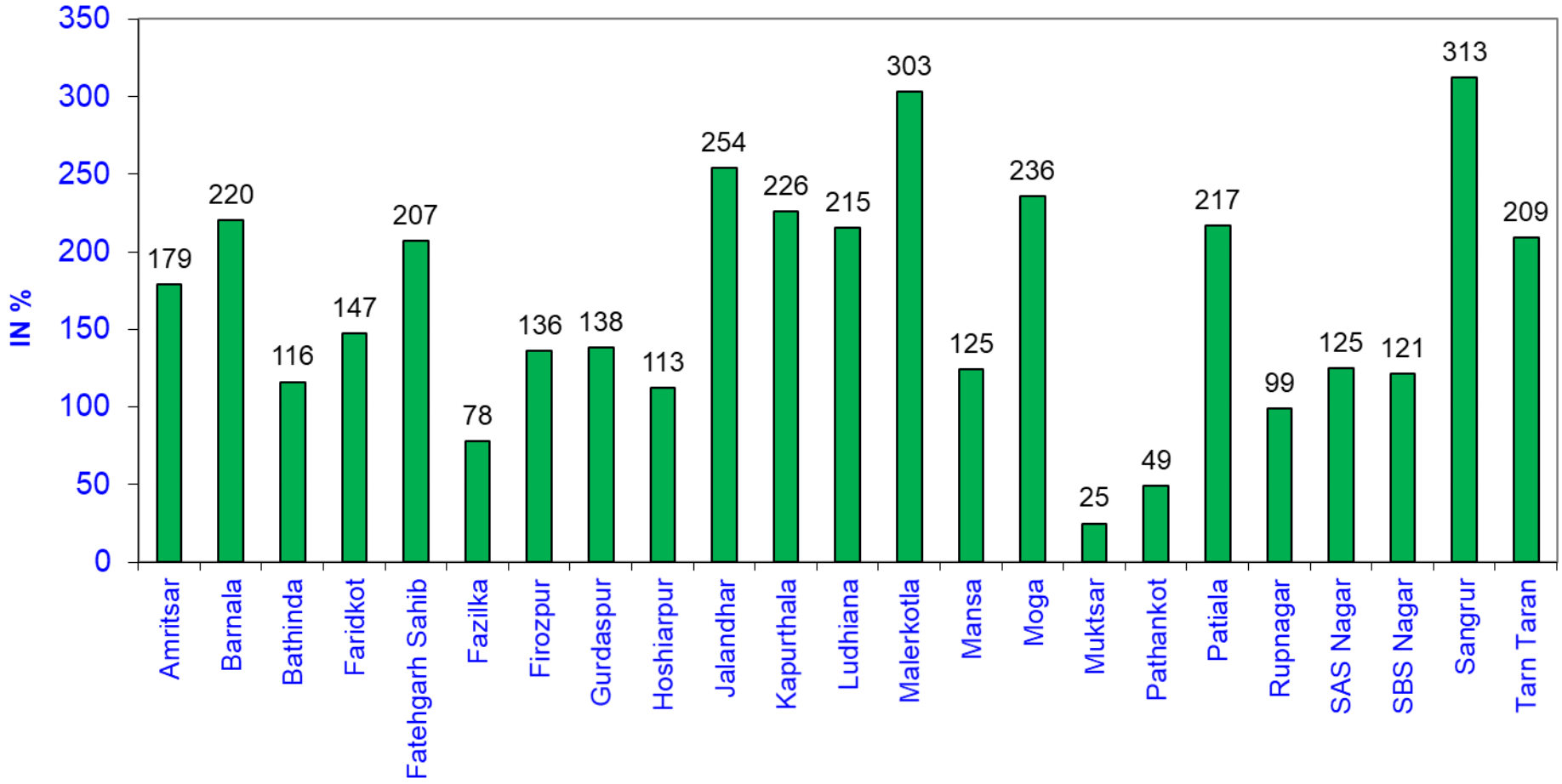


FIG.11 DISTRICT-WISE STAGE OF GROUND WATER DEVELOPMENT, PUNJAB



LIST OF CONTRIBUTORS

Central Ground Water Board, NWR, Chandigarh

1. Sh. Rakesh Rana, Scientist 'D'
2. Ms. Naima Akhtar, Scientist-'B'
3. Sh. Manish Shrivastav, Assistant Hydrogeologist

Water Resources and Environment Directorate, Punjab, Chandigarh

1. Sh. Atul Kumar Sood, Senior Geophysicist.
2. Sh. Suresh Narang, Senior Hydrologist (Executive Engineer)
3. Sh. Bhupinder Singh, Junior Hydrologist (SDO)
4. Sh. Sahil Thakur, Junior Geologist (SDO)
5. Sh. Jaspreet Singh, SDO.
6. Sh. Rajinder Singh Chohan, Junior Hydrologist.

Agriculture Department

1. Sh. Jaspal Singh, Geologist/Hydrologist, GWC, Division No 1.
2. Dr. Arun Kumar, Geologist/Hydrologist, GWC, Division No 2.
3. Sh. Sandeep Singh Walia, Assistant Geologist.

PWRMDC

1. Sh. R.S. Gupta, Senior Hydrogeologist.
2. Sh. D.K. Arora, Junior Hydrogeologist.

Under the Supervision of:

1. Sh. Hardeep Singh Mehndiratta, Superintending Engineer, Ground Water management Circle, Punjab, Chandigarh.
2. Sh. Anoop Nagar, Regional Director, Central Ground Water Board, MoWR and GR, NWR, Chandigarh.

ANNEXURE I

DYNAMIC GROUND WATER RESOURCES OF PUNJAB STATE 2022 (BLOCK WISE)

PUNJAB

S.No	DISTRICT	BLOCK	Total Geographical Area (ha)			TOTAL ANNUAL RECHARGE (ham)						Annual Ground water Recharge (ham)	Environmental Flows (ham)	Annual Extractable Ground water Resource (ham)	GROUNDWATER EXTRACTION FOR ALL USES (ham)								Stage of Ground Water Extraction (%)	Categorization of Assessment Unit
			Recharge Worthy Area (ha)			Rainfall Recharge	Canals	Surface Water Irrigation	Ground Water Irrigation	Tanks and Ponds	Water Conservation Structure				Domestic	Industrial	Irrigation			Command	Poor Quality	Total		
			Command	Poor Quality	Total												Command	Poor Quality	Total					
1	2	3	4	6	7	8	9	10	11	12	13	15	16	17	18	19	20	22	23	24	26	27	28	29
1	**Amritsar**	Ajnala	45610	0	45610	5570	7067	1405	12503	33	0	26577	2658	23919	944	5	36642	0	36642	37591	0	37591	157	Over-Exploited
2		**Amritsar City (Urban)**	8664	0	8664	607	0	0	0	0	0	607	61	546	0	181	1590	0	1590	1771	0	1771	324	Over-Exploited
3		Attari	25434	0	25434	3276	2077	651	3905	34	0	9942	994	8948	606	26	15923	0	15923	16555	0	16555	185	Over-Exploited
4		Chogawan	42030	0	42030	5189	4736	5463	11153	33	0	26574	2657	23916	896	0	33847	0	33847	34743	0	34743	145	Over-Exploited
5		Harsha Chhina	23162	0	23162	2845	2941	659	6589	22	0	13055	1306	11749	438	20	21340	0	21340	21798	0	21798	186	Over-Exploited
6		Jandiala Guru	23186	0	23186	2958	2954	596	5278	19	0	11805	1181	10624	512	48	24747	0	24747	25307	0	25307	238	Over-Exploited
7		Majitha	26159	0	26159	3630	8334	1080	7727	30	0	20801	2080	18721	631	25	28719	0	28719	29375	0	29375	157	Over-Exploited
8		Rayya	32251	0	32251	4949	3877	877	7180	55	0	16940	1694	15246	1132	5	27362	0	27362	28499	0	28499	187	Over-Exploited
9		Tarsikka	23578	0	23578	3426	3405	506	6255	42	0	13633	1363	12270	635	0	24205	0	24205	24840	0	24840	202	Over-Exploited
10		Verka	17566	0	17566	2412	2681	413	3472	17	0	8995	900	8096	566	88	18921	0	18921	19575	0	19575	242	Over-Exploited
11	**Barnala**	Barnala	68971	0	68971	6531	3228	2616	6732	48	0	19155	1915	17239	1421	44	53629	0	53629	55094	0	55094	320	Over-Exploited
12		Mahal Kalan	30275	0	30275	2989	10226	1325	2120	34	0	16694	1669	15025	586	0	16959	0	16959	17546	0	17546	117	Over-Exploited
13		Sehna	42055	0	42055	3966	9535	1211	4509	45	0	19265	1927	17339	495	0	36102	0	36102	36598	0	36598	211	Over-Exploited
14	**Bathinda**	Bathinda	44559	0	44559	3096	1104	7098	7263	34	0	18594	930	17664	1407	148	20781	0	20781	22336	0	22336	126	Over-Exploited
15		Bhagta Bhai Ka	26696	0	26696	1856	400	432	1657	17	0	4362	436	3926	203	0	13331	0	13331	13535	0	13535	345	Over-Exploited
16		Goniana Mandi	31977	0	31977	2558	24	113	3099	28	0	5823	582	5241	938	0	10537	0	10537	11474	0	11474	219	Over-Exploited
17		Maur	29581	0	29581	2056	633	2055	4376	30	0	9151	915	8236	351	4	14384	0	14384	14738	0	14738	179	Over-Exploited
18		Nathana	37558	0	37558	2466	3909	4382	2213	19	0	12989	1299	11690	622	17	13098	0	13098	13737	0	13737	118	Over-Exploited
19		Phul	28221	0	28221	1709	5669	4236	2031	14	0	13659	1366	12293	249	0	16295	0	16295	16543	0	16543	135	Over-Exploited
20		Rampura	33258	0	33258	1141	10621	6195	1645	35	0	19638	1964	17674	612	14	13211	0	13211	13838	0	13838	78	Semi-Critical
21		Sangat	48201	0	48201	3588	270	13896	5005	47	0	22806	2281	20525	529	7	14314	0	14314	14850	0	14850	72	Semi-Critical
22		Talwandi Sabo	57373	0	57373	4292	4469	8230	4841	42	0	21874	2187	19687	918	27	13855	0	13855	14800	0	14800	75	Semi-Critical
23	**Faridkot**	Faridkot	72753	0	72753	6050	8721	9245	18737	36	0	42788	4279	38509	1919	20	53590	0	53590	55529	0	55529	144	Over-Exploited
24		Jaiton	42490	0	42490	3485	981	2762	6064	40	0	13334	1333	12000	351	0	22150	0	22150	22501	0	22501	188	Over-Exploited
25		Kot Kapura	32355	0	32355	2657	3726	4926	7107	20	0	18436	1844	16593	324	38	20448	0	20448	20811	0	20811	125	Over-Exploited
26	**Fatehgarh Sahib**	Amloh	25765	0	25765	3180	1437	542	1755	43	0	6957	696	6261	854	1247	13399	0	13399	15500	0	15500	248	Over-Exploited
27		Bassi Pathanan	18098	0	18098	2639	552	224	1246	24	0	4685	469	4217	332	19	10094	0	10094	10445	0	10445	248	Over-Exploited
28		Khamanon	19670	0	19670	2888	2207	678	2436	52	0	8260	826	7434	384	11	12265	0	12265	12660	0	12660	170	Over-Exploited
29		Khera	20212	0	20212	2635	394	271	2124	39	0	5463	273	5190	302	16	9938	0	9938	10256	0	10256	198	Over-Exploited
30		Sirhind	30501	0	30501	4415	3978	714	4282	31	0	13421	1342	12079	646	207	23146	0	23146	23999	0	23999	199	Over-Exploited
31	**Fazilka**	Abohar	26719	60000	86719	1787	9335	9816	550	159	0	21647	2165	19482	1769	10	1589	9557	11147	3369	9557	12927	17	Safe
32		Arniwala SheikhSubanpur	12837	20000	32837	845	0	3536	1195	23	0	5599	560	5039	628	0	3435	13742	17176	4063	13742	17804	81	Semi-Critical
33		Fazilka	15610	22000	37610	953	7126	4229	1185	24	0	13517	1352	12165	767	18	3395	13742	17137	4180	13742	17922	34	Safe
34		Jalalabad	33807	14000	47807	2607	3495	3117	11288	16	0	20523	2052	18470	1244	12	32367	2264	34631	33624	2264	35887	182	Over-Exploited
35		Khuian Sarwar	28981	40000	68981	1852	3130	7559	2668	33	0	15242	1524	13718	635	3	7680	2656	10336	8319	2656	10975	61	Safe
36	**Firozpur**	Firozpur	45410	0	45410	4011	15758	1938	11362	17	0	33086	3309	29778	1329	6	32220	0	32220	33555	0	33555	113	Over-Exploited
37		Ghall Khurd	51840	0	51840	4561	7999	11029	17731	42	0	41361	4136	37225	507	9	51056	0	51056	51573	0	51573	139	Over-Exploited
38		Guruhar Sahai	47053	0	47053	3821	11525	3529	8940	21	0	27835	2784	25052	386	5	25482	0	25482	25872	0	25872	103	Over-Exploited
39		Makhu	33406	0	33406	2840	13938	433	6314	16	0	23541	2354	21187	234	6	20714	0	20714	20954	0	20954	99	Critical
40		Mamdot	33040	0	33040	2756	1461	1511	7259	13	0	12999	1300	11699	341	0	22441	0	22441	22783	0	22783	195	Over-Exploited
41		Zira	41204	0	41204	3827	4428	894	3911	29	0	13089	1309	11780	667	12	31175	0	31175	31854	0	31854	270	Over-Exploited
42	**Gurdaspur**	Batala	25611	0	25611	3934	4116	1081	8996	27	0	18155	1815	16339	1500	8	25789	0	25789	27297	0	27297	167	Over-Exploited
43		Dera Baba Nanak	28954	0	28954	4406	1433	924	8652	25	0	15441	1544	13897	549	0	24811	0	24811	25361	0	25361	182	Over-Exploited
44		Dhariwal	23414	0	23414	3943	3081	809	8153	32	0	16017	1602	14415	548	0	23583	0	23583	24131	0	24131	167	Over-Exploited
45		Dina Nagar	19734	0	19734	2773	4018	443	2522	18	0	9774	977	8797	455	7	7122	0	7122	7584	0	7584	86	Semi-Critical
46		Dorangala	10920	0	10920	1436	528	74	723	10	0	2772	139	2633	217	0	2076	0	2076	2293	0	2293	87	Semi-Critical
47		Fatehgarh Churian	23070	0	23070	3274	3976	872	8686	32	0	16839	1684	15155	459	3	24861	0	24861	25322	0	25322	167	Over-Exploited
48		Gurdaspur	28902	0	28902	5050	5537	999	5288	24	0	16898	1690	15208	1507	8	15131	0	15131	16647	0	16647	109	Over-Exploited
49		Kahnuwan	33691	0	33691	6243	6231	844	8328	29	0	21675	2167	19507	556	22	25598	0	25598	26176	0	26176	134	Over-Exploited
50		Kalanaur	19269	0	19269	3372	855	437	6164	14	0	10843	1084	9759	335	0	17627	0	17627	17962	0	17962	184	Over-Exploited
51		Qadian	20372	0	20372	3451	7460	1059	5117	27	0	17113	1711	15402	413	11	15366	0	15366	15790	0	15790	103	Over-Exploited
52		Sri Hargobindpur	27488	0	27488	3822	10155	1298	5349	39	0	20663	2066	18597	496	0	17721	0	17721	18217	0	18217	98	Critical

53	**Hoshiarpur**	Bhunga	54759	0	54759	7271	0	688	879	20	657	9514	951	8562	571	0	5929	0	5929	6500	0	6500	76	Semi-Critical
54		Dasuya	32398	0	32398	6342	0	1044	4016	20	0	11422	1142	10280	722	7	14018	0	14018	14747	0	14747	143	Over-Exploited
55		Garh Shankar	38858	0	38858	5081	636	522	2942	21	0	9202	920	8282	779	8	13977	0	13977	14764	0	14764	178	Over-Exploited
56		Hajipur	17944	0	17944	3724	451	2442	1489	1984	0	10089	1009	9080	349	0	5494	0	5494	5843	0	5843	64	Safe
57		Hoshiarpur-1	35411	0	35411	5531	90	441	695	147	0	6905	690	6214	1453	50	8839	0	8839	10342	0	10342	166	Over-Exploited
58		Hoshiarpur-2	43591	0	43591	6090	0	261	830	29	349	7559	378	7181	631	16	5194	0	5194	5841	0	5841	81	Semi-Critical
59		Mahilpur	40804	0	40804	5013	111	351	415	18	0	5908	591	5317	592	1	4200	0	4200	4793	0	4793	90	Critical
60		Mukerian	23162	0	23162	4028	215	1568	1923	54	0	7787	779	7008	747	3	5536	0	5536	6286	0	6286	90	Semi-Critical
61		Talwara	22573	0	22573	4551	26	358	447	11	0	5392	539	4853	334	4	1304	0	1304	1642	0	1642	34	Safe
62		Tanda	27371	0	27371	4891	0	1128	4700	19	0	10738	1074	9664	465	2	14775	0	14775	15242	0	15242	158	Over-Exploited
63	**Jalandhar**	Adampur	21823	0	21823	3064	395	290	3708	16	0	7473	747	6726	409	13	13921	0	13921	14343	0	14343	213	Over-Exploited
64		Bhogpur	18255	0	18255	2822	3671	548	3038	23	0	10102	1010	9092	293	10	18176	0	18176	18478	0	18478	203	Over-Exploited
65		**Jalandhar City (Urban)**	10295	0	10295	617	0	0	0	0	0	617	62	556	0	0	1696	0	1696	1696	0	1696	305	Over-Exploited
66		Jalandhar East	20202	0	20202	2775	61	74	1079	21	0	4011	401	3610	5414	352	8674	0	8674	14440	0	14440	400	Over-Exploited
67		Jalandhar West	30329	0	30329	4353	600	714	1861	33	0	7561	756	6805	1798	416	14352	0	14352	16567	0	16567	243	Over-Exploited
68		Lohian	19004	0	19004	2132	2041	701	1993	18	0	6886	689	6197	245	0	15080	0	15080	15325	0	15325	247	Over-Exploited
69		Mehatpur	17754	0	17754	2109	0	692	1857	17	0	4676	468	4208	469	0	11007	0	11007	11476	0	11476	273	Over-Exploited
70		Nakodar	28349	0	28349	3470	1126	425	2529	37	0	7586	759	6827	871	27	20444	0	20444	21343	0	21343	313	Over-Exploited
71		Nur Mahal	26121	0	26121	3252	3774	386	2065	23	0	9501	950	8551	345	0	16690	0	16690	17035	0	17035	199	Over-Exploited
72		Phillaur	29146	0	29146	3701	689	603	3511	58	0	8563	856	7706	2210	42	17736	0	17736	19989	0	19989	259	Over-Exploited
73		Rurka Kalan	19307	0	19307	2193	2619	1056	2099	18	0	7984	798	7186	361	11	16928	0	16928	17301	0	17301	241	Over-Exploited
74		Shahkot	22414	0	22414	2560	37	75	1506	12	0	4190	419	3771	1029	0	11941	0	11941	12970	0	12970	344	Over-Exploited
75	**Kapurthala**	Dhilwan	27232	0	27232	3791	0	1731	9951	2655	0	18128	1813	16315	466	6	28412	0	28412	28884	0	28884	177	Over-Exploited
76		Kapurthala	37167	0	37167	4766	254	75	4294	25	0	9414	941	8473	1060	28	23163	0	23163	24251	0	24251	286	Over-Exploited
77		Nadala	24377	0	24377	3683	0	1594	7448	11	0	12735	1274	11462	369	0	21328	0	21328	21697	0	21697	189	Over-Exploited
78		Phagwara	29635	0	29635	3252	3585	167	2675	17	0	9696	970	8726	1022	62	22029	0	22029	23112	0	23112	265	Over-Exploited
79		Sultanpur Lodhi	44464	0	44464	5296	32	2314	10889	26	0	18557	1856	16702	515	3	41052	0	41052	41570	0	41570	249	Over-Exploited
80	**Ludhiana**	Dehlon	14040	0	14040	1754	1674	448	2561	21	0	6458	646	5812	573	167	13039	0	13039	13779	0	13779	237	Over-Exploited
81		Doraha	20269	0	20269	2673	9627	56	6933	29	0	19318	1932	17386	546	192	23939	0	23939	24677	0	24677	142	Over-Exploited
82		Jagraon	37126	0	37126	3989	12024	897	3285	33	0	20227	2023	18204	974	74	27449	0	27449	28496	0	28496	157	Over-Exploited
83		Khanna	27469	0	27469	3536	858	348	3474	24	0	8240	824	7416	987	874	20186	0	20186	22046	0	22046	297	Over-Exploited
84		**Ludhiana City (Urban)**	16553	0	16553	1115	0	0	0	0	0	1115	112	1004	0	2964	1310	0	1310	4274	0	4274	426	Over-Exploited
85		Ludhiana-1	23364	0	23364	3086	1834	258	2268	21	0	7467	747	6720	7754	1300	14684	0	14684	23738	0	23738	353	Over-Exploited
86		Ludhiana-2	47566	0	47566	6703	3	305	12201	35	0	19246	1925	17322	1238	1189	34969	0	34969	37397	0	37397	216	Over-Exploited
87		Machhiwara	33303	0	33303	2060	7399	276	8844	39	0	18618	1862	16756	342	71	25283	0	25283	25695	0	25695	153	Over-Exploited
88		Maloud	20188	0	20188	2442	4850	233	2804	15	0	10344	1034	9310	297	0	18248	0	18248	18545	0	18545	199	Over-Exploited
89		Pakhowal	24087	0	24087	3018	1941	337	2390	34	0	7719	772	6947	360	28	18603	0	18603	18992	0	18992	273	Over-Exploited
90		Raikot	30304	0	30304	3568	1843	800	2750	37	0	8997	900	8097	541	43	22282	0	22282	22866	0	22866	282	Over-Exploited
91		Samrala	18016	0	18016	2511	1194	306	4521	29	0	8561	856	7705	509	105	17439	0	17439	18054	0	18054	234	Over-Exploited
92		Sidhwan Bet	44370	0	44370	5063	580	617	7517	15	0	13793	1379	12414	291	80	30770	0	30770	31142	0	31142	251	Over-Exploited
93		Sudhar	14060	0	14060	1743	1932	610	1440	39	0	5764	576	5187	525	17	11769	0	11769	12311	0	12311	237	Over-Exploited
94	**Malerkotla**	Malerkotla-1	42287	0	42287	4906	2296	622	3853	16	0	11693	1169	10524	1362	76	30930	0	30930	32367	0	32367	308	Over-Exploited
95		Malerkotla-2	32242	0	32242	3859	1966	886	3174	28	0	9913	991	8922	626	466	25481	0	25481	26574	0	26574	298	Over-Exploited
96	**Mansa**	Bhikhi	36834	0	36834	2859	1457	1873	4734	29	0	10952	1095	9857	415	0	20770	0	20770	21184	0	21184	215	Over-Exploited
97		Budhlada	29590	43000	72590	2526	1345	15753	4925	79	0	24627	2463	22165	1056	13	21077	21855	42932	22146	21855	44001	100	Critical
98		Jhunir	16601	16000	32601	1160	5201	3941	1441	40	0	11782	1178	10604	389	0	4660	13643	18302	5049	13643	18691	48	Safe
99		Mansa	39177	0	39177	2969	2048	3917	7415	46	0	16395	1639	14755	900	16	24218	0	24218	25134	0	25134	170	Over-Exploited
100		Sardulgarh	10660	25000	35660	884	1794	2663	820	34	0	6195	619	5575	468	4	4411	14945	19356	4883	14945	19828	88	Semi-Critical
101	**Moga**	Bagha Purana	55866	0	55866	4788	10538	2723	6263	51	0	24363	2436	21927	936	26	44762	0	44762	45724	0	45724	209	Over-Exploited
102		Kot Ise Khan (Dharamkot)	56234	0	56234	5669	11248	4056	9108	35	0	30116	3012	27104	755	4	42458	0	42458	43216	0	43216	159	Over-Exploited
103		Moga-1	40872	0	40872	3840	2389	920	4140	37	0	11326	1133	10193	1411	18	32498	0	32498	33927	0	33927	333	Over-Exploited
104		Moga-2	30930	0	30930	2854	1067	976	3112	28	0	8038	804	7234	454	18	24420	0	24420	24892	0	24892	344	Over-Exploited
105		Nihal Singh Wala	39194	0	39194	3767	1064	1661	3897	40	0	10429	1043	9386	581	7	30482	0	30482	31070	0	31070	331	Over-Exploited
106	**Muktsar**	Kot Bhai (Gidderbaha)	12681	53000	65681	888	9807	2828	1498	64	0	15087	1509	13578	914	4	4293	7350	11642	5211	7350	12561	38	Safe
107		Lambi	11733	47000	58733	832	14348	9655	1419	45	0	26299	2630	23669	628	2	4131	4276	8407	4761	4277	9037	20	Safe
108		Malout	11233	45000	56233	769	6691	4561	1070	57	0	13147	1315	11832	926	6	3119	6168	9286	4051	6168	10219	34	Safe
109		Muktsar	16781	66000	82781	1149	12403	18183	1899	66	0	33699	3370	30329	1320	0	4430	12855	17285	5751	12855	18605	19	Safe

110	**Pathankot**	Bamial	4641	0	4641	852	0	259	348	0	0	1460	73	1387	183	0	959	0	959	1141	0	1141	82	Semi-Critical
111		Dhar Kalan	28999	0	28999	5129	520	1137	496	0	0	7282	728	6554	444	0	1329	0	1329	1774	0	1774	27	Safe
112		Gharota	11638	0	11638	2306	121	871	757	3	0	4058	406	3652	468	0	2119	0	2119	2586	0	2586	71	Semi-Critical
113		Narot Jaimal Singh	19651	0	19651	3168	453	1822	1531	5	0	6979	698	6281	473	0	4356	0	4356	4829	0	4829	77	Semi-Critical
114		Pathankot	14428	0	14428	2938	4510	1726	1737	3	0	10914	1091	9823	641	28	4869	0	4869	5538	0	5538	56	Safe
115		Sujanpur	15720	0	15720	3445	11429	1234	1802	3	0	17912	1791	16121	623	14	5006	0	5006	5643	0	5643	35	Safe
116	**Patiala**	Bhunarheri	36316	0	36316	4647	766	209	2560	46	0	8228	823	7405	512	0	20339	0	20339	20851	0	20851	282	Over-Exploited
117		Ghanaur	24174	0	24174	3229	1191	1057	1522	50	0	7048	705	6343	307	137	5908	0	5908	6352	0	6352	100	Over-Exploited
118		Nabha	61803	0	61803	8099	6949	1052	4972	75	0	21147	2115	19033	1192	101	39390	0	39390	40682	0	40682	214	Over-Exploited
119		Patiala	41740	0	41740	6149	5963	156	3080	33	0	15381	1538	13843	2550	77	24451	0	24451	27078	0	27078	196	Over-Exploited
120		Patran	41841	0	41841	4592	2293	161	3207	28	0	10282	1028	9253	738	54	25659	0	25659	26450	0	26450	286	Over-Exploited
121		Rajpura	26352	0	26352	4239	555	33	1251	37	0	6115	611	5503	712	165	10176	0	10176	11053	0	11053	201	Over-Exploited
122		Samana	39231	0	39231	4413	3466	18	1989	25	0	9912	991	8921	751	115	16029	0	16029	16894	0	16894	189	Over-Exploited
123		Sanaur	37045	0	37045	5349	639	1145	2529	39	0	9701	970	8731	554	29	20090	0	20090	20673	0	20673	237	Over-Exploited
124		Shambu Kalan	23345	0	23345	3768	166	175	1481	29	0	5619	562	5057	628	0	11779	0	11779	12407	0	12407	245	Over-Exploited
125	**Rupnagar**	Anandpur Sahib	32031	0	32031	5887	525	553	1503	14	0	8482	848	7634	722	18	5046	0	5046	5786	0	5786	76	Semi-Critical
126		Chamkaur Sahib	19223	0	19223	3103	3453	1371	5012	15	0	12955	1296	11659	497	38	14582	0	14582	15116	0	15116	130	Over-Exploited
127		Morinda	13971	0	13971	2180	692	263	2234	30	0	5397	540	4858	274	35	7405	0	7405	7714	0	7714	159	Over-Exploited
128		Nurpur Bedi	33372	0	33372	5209	0	739	1284	23	0	7255	363	6893	419	9	4337	0	4337	4765	0	4765	69	Safe
129		Rupnagar	39056	0	39056	6660	353	548	1427	32	0	9019	902	8118	957	12	4317	0	4317	5286	0	5286	65	Safe
130	**Sangrur**	Andana	32794	0	32794	2834	2348	838	2283	25	0	8328	833	7496	539	16	18287	0	18287	18842	0	18842	251	Over-Exploited
131		Bhawanigarh	33158	0	33158	3775	602	1169	3481	29	0	9056	906	8150	488	115	27788	0	27788	28391	0	28391	348	Over-Exploited
132		Dhuri	23337	0	23337	2193	296	2030	2685	23	0	7227	723	6504	629	256	21457	0	21457	22342	0	22342	344	Over-Exploited
133		Dirba	30716	0	30716	3212	641	94	2374	29	0	6350	635	5715	416	109	19029	0	19029	19554	0	19554	342	Over-Exploited
134		Lehra Gaga	40808	0	40808	4026	733	1401	2639	55	0	8854	885	7969	648	16	21378	0	21378	22042	0	22042	277	Over-Exploited
135		Sangrur	47418	0	47418	3981	3166	1274	4198	32	0	12650	1265	11385	1138	549	33641	0	33641	35328	0	35328	310	Over-Exploited
136		Sher Pur	28584	0	28584	3803	227	511	2071	27	0	6638	664	5974	473	47	16565	0	16565	17085	0	17085	286	Over-Exploited
137		Sunam	48981	0	48981	4525	448	1734	3970	39	0	10716	1072	9644	625	433	31810	0	31810	32867	0	32867	341	Over-Exploited
138	**SAS Nagar**	Derabassi	39044	0	39044	6230	101	851	2815	26	0	10024	1002	9021	1806	1675	11187	0	11187	14667	0	14667	163	Over-Exploited
139		Kharar	42275	0	42275	5379	0	981	1726	19	253	8359	836	7523	1944	374	6299	0	6299	8616	0	8616	115	Over-Exploited
140		Majri	28064	0	28064	4230	0	288	224	27	0	4769	477	4292	390	50	2346	0	2346	2786	0	2786	65	Safe
141	**SBS Nagar**	Aur	23037	0	23037	2980	96	11779	8743	36	0	23635	2363	21271	382	0	24023	0	24023	24406	0	24406	115	Over-Exploited
142		Balachaur	32464	0	32464	5338	3892	322	2140	27	0	11719	586	11133	527	34	9409	0	9409	9970	0	9970	90	Semi-Critical
143		Banga	26066	0	26066	2835	120	1028	1652	33	0	5669	567	5102	560	0	9807	0	9807	10367	0	10367	203	Over-Exploited
144		Nawan Shahr	27592	0	27592	4775	965	1213	3912	27	0	10892	1089	9803	845	27	13329	0	13329	14201	0	14201	145	Over-Exploited
145		Saroya	16802	0	16802	2386	0	372	157	13	0	2928	293	2635	265	0	1289	0	1289	1554	0	1554	59	Safe
146	**Tarn Taran**	Bhikhiwind	32937	0	32937	3665	622	158	4461	39	0	8944	894	8049	512	6	17086	0	17086	17604	0	17604	219	Over-Exploited
147		Chohla Sahib	28817	0	28817	3313	375	562	2521	17	0	6788	679	6109	499	0	14589	0	14589	15088	0	15088	247	Over-Exploited
148		Gandiwind Tatla	20990	0	20990	2520	3176	739	2796	23	0	9254	925	8329	311	0	10025	0	10025	10337	0	10337	124	Over-Exploited
149		Khadur Sahib	28654	0	28654	3795	1261	585	4638	29	0	10308	1031	9277	566	17	20120	0	20120	20703	0	20703	223	Over-Exploited
150		Naushera Pannuan	17247	0	17247	1921	205	515	2216	32	0	4890	489	4401	393	0	10927	0	10927	11319	0	11319	257	Over-Exploited
151		Patti	39482	0	39482	4196	365	717	3157	46	0	8481	848	7633	911	6	17104	0	17104	18021	0	18021	236	Over-Exploited
152		Tarn Taran	36094	0	36094	3847	2290	702	2269	44	0	9152	915	8236	1091	40	18688	0	18688	19818	0	19818	241	Over-Exploited
153		Valtoha	37614	0	37614	3792	331	1261	4693	36	0	10112	1011	9101	418	0	14688	0	14688	15106	0	15106	166	Over-Exploited
TOTAL			**4583468**	**451000**	**5034468**	**538871**	**453878**	**285842**	**604818**	**9254**	**1259**	**1893923**	**186651**	**1707272**	**116967**	**15789**	**2669078**	**123053**	**2792131**	**2801835**	**123053**	**2924887**	**164**	

ANNEXURE II

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2022

PUNJAB

S.NO	State/Union Territories	Ground Water Recharge (ham)					Total Natural Discharges (ham)	Annual Extractable Ground Water Resource (ham)	Current Annual Ground Water Extraction (ham)				Annual GW Allocation for Domestic use as on 2025 (ham)	Net Ground Water Availability for future use (ham)	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	29516	81946	5345	32122	148928	14893	134035	233297	398	6360	240055	6453	0	179
2	Barnala	12217	25792	1269	15836	55114	5511	49603	106691	44	2503	109238	2540	0	220
3	Bathinda	19385	68072	3376	38062	128896	11960	116936	129805	217	5830	135852	5915	14368	116
4	Faridkot	10968	42939	1224	19427	74558	7456	67102	96187	59	2594	98840	2632	0	147
5	Fatehgarh Sahib	14087	14780	1671	8249	38787	3606	35181	68841	1501	2518	72860	2555	0	207
6	Fazilka	7126	45265	918	23218	76528	7653	68875	48466	44	5044	53554	5118	30418	78
7	Firozpur	19238	87217	2577	42879	151911	15191	136720	183089	39	3463	186591	3514	229	136
8	Gurdaspur	35358	88948	6344	35539	166190	16480	149709	199685	59	7035	206780	7138	1915	138
9	Hoshiarpur	44796	21336	7725	10659	84516	8074	76442	79265	92	6644	86000	6741	11050	113
10	Jalandhar	28762	30618	4286	15483	79149	7915	71234	166646	871	13445	180962	13642	0	254
11	Kapurthala	18016	33864	2772	13878	68531	6853	61678	135983	99	3432	139514	3482	0	226
12	Ludhiana	37582	75106	5680	37499	155867	15587	140280	279970	7104	14939	302013	15158	0	215
13	Malerkotla	7710	8277	1054	4564	21606	2161	19445	56411	542	1988	58941	2017	0	303
14	Mansa	9225	38123	1172	21431	69951	6995	62956	75136	33	3227	78396	3274	6238	125
15	Moga	18490	45099	2427	18255	84272	8427	75844	174620	73	4137	178830	4197	0	236
16	Muktsar	3088	50594	550	33999	88232	8823	79409	15972	13	3789	19774	3845	59580	25
17	Pathankot	14265	19906	3573	10861	48605	4787	43817	18638	42	2832	21512	2873	22264	49
18	Patiala	39261	30227	5224	18721	93433	9343	84089	173819	678	7943	182440	8059	0	217
19	Rupnagar	19952	12185	3087	7886	43109	3948	39161	35688	112	2868	38668	2910	6776	99
20	SAS Nagar	13809	4580	2031	2732	23152	2315	20837	19831	2098	4139	26069	4200	1500	125
21	SBS Nagar	16098	27236	2216	9292	54842	4898	49944	57858	61	2579	60498	2617	2232	121
22	Sangrur	25257	28676	3091	12795	69819	6982	62837	189954	1542	4956	196452	5028	0	313
23	Tarn Taran	23148	28113	3901	12766	67928	6793	61136	123226	68	4702	127996	4770	0	209
	Total (Ham)	**467356**	**908897**	**71516**	**446155**	**1893923**	**186651**	**1707272**	**2669079**	**15789**	**116967**	**2801834**	**118680**	**156572**	**164**
	Total (BCM)	**4.67**	**9.09**	**0.72**	**4.46**	**18.94**	**1.87**	**17.07**	**26.69**	**0.16**	**1.17**	**28.01**	**1.19**	**1.57**	**164.11**

ANNEXURE III

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2022										
PUNJAB										
S.No	**Name of District**	**Total No. of Assessed Units**	**Safe**		**Semi-Critical**		**Critical**		**Over-Exploited**	
			No	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
1	Amritsar	10	-	-	-	-	-	-	10	100.0
2	Barnala	3	-	-	-	-	-	-	3	100.0
3	Bathinda	9	-	-	3	33.33	-	-	6	66.67
4	Faridkot	3	-	-	-	-	-	-	3	100.0
5	Sahib	5	-	-	-	-	-	-	5	100.0
6	Fazilka	5	3	60.0	1	20.0	-	-	1	20.0
7	Firozpur	6	-	-	-	-	1	16.67	5	83.33
8	Gurdaspur	11	-	-	2	18.18	1	9.09	8	72.73
9	Hoshiarpur	10	2	20.0	3	30.0	1	10.0	4	40.0
10	Jalandhar	12	-	-	-	-	-	-	12	100.0
11	Kapurthala	5	-	-	-	-	-	-	5	100.0
12	Ludhiana	14	-	-	-	-	-	-	14	100.0
13	Malerkotla	2	-	-	-	-	-	-	2	100.0
14	Mansa	5	1	20.0	1	20.0	1	20.0	2	40.0
15	Moga	5	-	-	-	-	-	-	5	100.0
16	Muktsar	4	4	100.0	-	-	-	-	-	-
17	Pathankot	6	3	50.0	3	50.0	-	-	-	-
18	Patiala	9	-	-	-	-	-	-	9	100.0
19	Rupnagar	5	2	40.0	1	20.0	-	-	2	40.0
20	Sangrur	8	-	-	-	-	-	-	8	100.0
21	SAS Nagar	3	1	33.33	-	-	-	-	2	66.67
22	SBS Nagar	5	1	20.0	1	20.0	-	-	3	60.0
23	Tarn Taran	8	-	-	-	-	-	-	8	100.0
	Total	153	17	11.11	15	9.8	4	2.61	117	76.47

ANNEXURE IV

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2022										
PUNJAB										
S.No	**Name of District**	**Total Annual Extractable Resource of Assessed Units (in mcm)**	**Safe**		**Semi-Critical**		**Critical**		**Over-Exploited**	
			Total Annual Extractable Resource (in mcm)	**%**	**Total Annual Extractable Resource (in mcm)**	**%**	**Total Annual Extractable Resource (in mcm)**	**%**	**Total Annual Extractable Resource (in mcm)**	**%**
1	Amritsar	1,340	0	0	0	0	0	0	1,340	100
2	Barnala	496	0	0	0	0	0	0	496	100
3	Bathinda	1,169	0	0	579	50	0	0	590	50
4	Faridkot	671	0	0	0	0	0	0	671	100
5	Fatehgarh Sahib	352	0	0	0	0	0	0	352	100
6	Fazilka	689	454	66	50	7	0	0	185	27
7	Firozpur	1,367	0	0	0	0	212	15	1,155	85
8	Gurdaspur	1,497	0	0	114	8	186	12	1,197	80
9	Hoshiarpur	764	139	18	228	30	53	7	344	45
10	Jalandhar	712	0	0	0	0	0	0	712	100
11	Kapurthala	617	0	0	0	0	0	0	617	100
12	Ludhiana	1,403	0	0	0	0	0	0	1,403	100
13	Malerkotla	194	0	0	0	0	0	0	194	100
14	Mansa	630	106	17	56	9	222	35	246	39
15	Moga	758	0	0	0	0	0	0	758	100
16	Muktsar	794	794	100	0	0	0	0	0	0
17	Pathankot	438	325	74	113	26	0	0	0	0
18	Patiala	841	0	0	0	0	0	0	841	100
19	Rupnagar	392	150	38	76	19	0	0	165	42
20	Sangrur	628	0	0	0	0	0	0	628	100
21	SAS Nagar	208	43	21	0	0	0	0	165	79
22	SBS Nagar	499	26	5	111	22	0	0	362	72
23	Tarn Taran	611	0	0	0	0	0	0	611	100
	Total States	**17,073**	**2,037**	**12**	**1,328**	**8**	**673**	**4**	**13,035**	**76**

ANNEXURE V

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2022										
PUNJAB										
S.No	**Name of District**	**Total Recharge Worthy Area of Assessed Units (in sq.km)**	**Safe**		**Semi-Critical**		**Critical**		**Over-Exploited**	
			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	Fazilka	2739	1933	70.56	328	11.99	-	-	478	17.45
2	Pathankot	950	591	62.21	359	37.79	-	-	-	-
3	SAS Nagar	1093	280	25.66	-	-	-	-	813	74.34
4	Muktsar	2634	2634	100.0	-	-	-	-	-	-
5	Kapurthala	1628	-	-	-	-	-	-	1628	100.0
6	Hoshiarpur	3368	405	12.03	1215	36.07	408	12.11	1340	39.79
7	Amritsar	2676	-	-	-	-	-	-	2676	100.0
8	Barnala	1413	-	-	-	-	-	-	1413	100.0
9	Sangrur	2857	-	-	-	-	-	-	2857	100.0
10	Malerkotla	745	-	-	-	-	-	-	745	100.0
11	Jalandhar	2629	-	-	-	-	-	-	2629	100.0
12	Mansa	2168	326	15.03	356	16.44	725	33.47	760	35.05
13	Bathinda	3374	-	-	1388	41.14	-	-	1985	58.86
14	Fatehgarh Sahib	1142	-	-	-	-	-	-	1142	100.0
15	Faridkot	1475	-	-	-	-	-	-	1475	100.0
16	Rupnagar	1376	724	52.62	320	23.27	-	-	331	24.11
17	Moga	2230	-	-	-	-	-	-	2230	100.0
18	Tarn Taran	2418	-	-	-	-	-	-	2418	100.0
19	Patiala	3318	-	-	-	-	-	-	3318	100.0
20	SBS Nagar	1259	168	13.34	324	25.77	-	-	766	60.89
21	Ludhiana	3707	-	-	-	-	-	-	3707	100.0
22	Firozpur	2519	-	-	-	-	334	13.26	2185	86.74
23	Gurdaspur	2614	-	-	306	11.73	274	10.51	2032	77.76
	Total	**50344**	**7062**	**14.03**	**4599**	**9.14**	**1742**	**3.46**	**36939**	**73.37**

TABLE-1

DYNAMIC GROUND WATER RESOURCES OF PUNJAB, AS ON 31.03.2022

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	29516	81946	5345	32122	148928	14893	134035
2	Barnala	12217	25792	1269	15836	55114	5511	49603
3	Bathinda	19385	68072	3376	38062	128896	11960	116936
4	Faridkot	10968	42939	1224	19427	74558	7456	67102
5	Fatehgarh Sahib	14087	14780	1671	8249	38787	3606	35181
6	Fazilka	7126	45265	918	23218	76528	7653	68875
7	Firozpur	19238	87217	2577	42879	151911	15191	136720
8	Gurdaspur	35358	88948	6344	35539	166190	16480	149709
9	Hoshiarpur	44796	21336	7725	10659	84516	8074	76442
10	Jalandhar	28762	30618	4286	15483	79149	7915	71234
11	Kapurthala	18016	33864	2772	13878	68531	6853	61678
12	Ludhiana	37582	75106	5680	37499	155867	15587	140280
13	Malerkotla	7710	8277	1054	4564	21606	2161	19445
14	Mansa	9225	38123	1172	21431	69951	6995	62956
15	Moga	18490	45099	2427	18255	84272	8427	75844
16	Muktsar	3088	50594	550	33999	88232	8823	79409
17	Pathankot	14265	19906	3573	10861	48605	4787	43817
18	Patiala	39261	30227	5224	18721	93433	9343	84089
19	Rupnagar	19952	12185	3087	7886	43109	3948	39161
20	SAS Nagar	13809	4580	2031	2732	23152	2315	20837
21	SBS Nagar	16098	27236	2216	9292	54842	4898	49944
22	Sangrur	25257	28676	3091	12795	69819	6982	62837
23	Tarn Taran	23148	28113	3901	12766	67928	6793	61136
	Total (Ham)	**467356**	**908897**	**71516**	**446155**	**1893923**	**186651**	**1707272**

TABLE-2

DYNAMIC GROUND WATER RESOURCES OF PUNJAB, AS ON 31.03.2022

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	134035	233297	398	6360	240055	6453	0	179
2	Barnala	49603	106691	44	2503	109238	2540	0	220
3	Bathinda	116936	129805	217	5830	135852	5915	14368	116
4	Faridkot	67102	96187	59	2594	98840	2632	0	147
5	Fatehgarh Sahib	35181	68841	1501	2518	72860	2555	0	207
6	Fazilka	68875	48466	44	5044	53554	5118	30418	78
7	Firozpur	136720	183089	39	3463	186591	3514	229	136
8	Gurdaspur	149709	199685	59	7035	206780	7138	1915	138
9	Hoshiarpur	76442	79265	92	6644	86000	6741	11050	113
10	Jalandhar	71234	166646	871	13445	180962	13642	0	254
11	Kapurthala	61678	135983	99	3432	139514	3482	0	226
12	Ludhiana	140280	279970	7104	14939	302013	15158	0	215
13	Malerkotla	19445	56411	542	1988	58941	2017	0	303
14	Mansa	62956	75136	33	3227	78396	3274	6238	125
15	Moga	75844	174620	73	4137	178830	4197	0	236
16	Muktsar	79409	15972	13	3789	19774	3845	59580	25
17	Pathankot	43817	18638	42	2832	21512	2873	22264	49
18	Patiala	84089	173819	678	7943	182440	8059	0	217
19	Rupnagar	39161	35688	112	2868	38668	2910	6776	99
20	SAS Nagar	20837	19831	2098	4139	26069	4200	1500	125
21	SBS Nagar	49944	57858	61	2579	60498	2617	2232	121
22	Sangrur	62837	189954	1542	4956	196452	5028	0	313
23	Tarn Taran	61136	123226	68	4702	127996	4770	0	209
	Total (Ham)	**1707272**	**2669079**	**15789**	**116967**	**2801834**	**118680**	**156572**	**164**
	FIG. IN MAF	**13.83**	**21.62**	**0.13**	**0.95**	**22.70**	**0.96**	**1.27**	
	FIG IN BCM	**17.07**	**26.69**	**0.16**	**1.17**	**28.02**	**1.19**	**1.57**	

TABLE-3

DYNAMIC GROUND WATER RESOURCES OF PUNJAB, AS ON 31.03.2022

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

Sr. No		Assessment Unit (Block)/ District	2020		2022	
			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	**Amritsar**	Ajnala	154	OVER-EXPLOITED	157	OVER-EXPLOITED
2		Attari	164	OVER-EXPLOITED	185	OVER-EXPLOITED
3		Chogawan	137	OVER-EXPLOITED	145	OVER-EXPLOITED
4		Harsha Chhina	172	OVER-EXPLOITED	186	OVER-EXPLOITED
5		Jandiala Guru	221	OVER-EXPLOITED	238	OVER-EXPLOITED
6		Majitha	155	OVER-EXPLOITED	157	OVER-EXPLOITED
7		Rayya	174	OVER-EXPLOITED	187	OVER-EXPLOITED
8		Tarsikka	191	OVER-EXPLOITED	202	OVER-EXPLOITED
9		Verka	194	OVER-EXPLOITED	242	OVER-EXPLOITED
10	**Barnala**	Barnala	296	OVER-EXPLOITED	320	OVER-EXPLOITED
11		Mahal Kalan	118	OVER-EXPLOITED	117	OVER-EXPLOITED
12		Sehna	206	OVER-EXPLOITED	211	OVER-EXPLOITED
13	**Bathinda**	Bathinda	107	OVER-EXPLOITED	126	OVER-EXPLOITED
14		Bhagta Bhai Ka	261	OVER-EXPLOITED	345	OVER-EXPLOITED
15		Goniana Mandi	198	OVER-EXPLOITED	219	OVER-EXPLOITED
16		Maur	143	OVER-EXPLOITED	179	OVER-EXPLOITED
17		Nathana	109	OVER-EXPLOITED	118	OVER-EXPLOITED
18		Phul	135	OVER-EXPLOITED	135	OVER-EXPLOITED
19		Rampura	81	SEMI-CRITICAL	78	SEMI-CRITICAL
20		Sangat	40	SAFE	72	SEMI-CRITICAL
21		Talwandi Sabo	94	CRITICAL	75	SEMI-CRITICAL
22	**Faridkot**	Faridkot	139	OVER-EXPLOITED	144	OVER-EXPLOITED
23		Jaiton	165	OVER-EXPLOITED	188	OVER-EXPLOITED
24		Kot Kapura	117	OVER-EXPLOITED	125	OVER-EXPLOITED
25	**Fatehgarh Sahib**	Amloh	235	OVER-EXPLOITED	248	OVER-EXPLOITED
26		Bassi Pathanan	219	OVER-EXPLOITED	248	OVER-EXPLOITED
27		Khamanon	168	OVER-EXPLOITED	170	OVER-EXPLOITED
28		Khera	188	OVER-EXPLOITED	198	OVER-EXPLOITED
29		Sirhind	206	OVER-EXPLOITED	199	OVER-EXPLOITED
30	**Fazilka**	Abohar	32	SAFE	17	SAFE
31		Arniwala SheikhSubanpur	124	OVER-EXPLOITED	81	SEMI-CRITICAL
32		Fazilka	96	CRITICAL	34	SAFE
33		Jalalabad	137	OVER-EXPLOITED	182	OVER-EXPLOITED
34		Khuian Sarwar	35	SAFE	61	SAFE
35	**Ferozepur**	Ferozepur	102	OVER-EXPLOITED	113	OVER-EXPLOITED
36		Ghall Khurd	122	OVER-EXPLOITED	139	OVER-EXPLOITED
37		Guruhar Sahai	106	OVER-EXPLOITED	103	OVER-EXPLOITED
38		Makhu	132	OVER-EXPLOITED	99	CRITICAL
39		Mamdot	170	OVER-EXPLOITED	195	OVER-EXPLOITED
40		Zira	251	OVER-EXPLOITED	270	OVER-EXPLOITED

Sr. No		Assessment Unit (Block)/ District	2020		2022	
			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)
41	**Gurdaspur**	Batala	152	OVER-EXPLOITED	167	OVER-EXPLOITED
42		Dera Baba Nanak	160	OVER-EXPLOITED	182	OVER-EXPLOITED
43		Dhariwal	151	OVER-EXPLOITED	167	OVER-EXPLOITED
44		Dina Nagar	74	SEMI-CRITICAL	86	SEMI-CRITICAL
45		Dorangala	67	SAFE	87	SEMI-CRITICAL
46		Fatehgarh Churian	153	OVER-EXPLOITED	167	OVER-EXPLOITED
47		Gurdaspur	99	CRITICAL	109	OVER-EXPLOITED
48		Kahnuwan	127	OVER-EXPLOITED	134	OVER-EXPLOITED
49		Kalanaur	155	OVER-EXPLOITED	184	OVER-EXPLOITED
50		Qadian	99	CRITICAL	103	OVER-EXPLOITED
51		Sri Hargobindpur	91	CRITICAL	98	CRITICAL
52	**Hoshiarpur**	Bhunga	58	SAFE	76	SEMI-CRITICAL
53		Dasuya	116	OVER-EXPLOITED	143	OVER-EXPLOITED
54		Garh Shankar	164	OVER-EXPLOITED	178	OVER-EXPLOITED
55		Hajipur	65	SAFE	64	SAFE
56		Hoshiarpur-1	141	OVER-EXPLOITED	166	OVER-EXPLOITED
57		Hoshiarpur-2	78	SEMI-CRITICAL	81	SEMI-CRITICAL
58		Mahilpur	81	SEMI-CRITICAL	90	CRITICAL
59		Mukerian	83	SEMI-CRITICAL	90	SEMI-CRITICAL
60		Talwara	53	SAFE	34	SAFE
61		Tanda	137	OVER-EXPLOITED	158	OVER-EXPLOITED
62	**Jalandhar**	Adampur	203	OVER-EXPLOITED	213	OVER-EXPLOITED
63		Bhogpur	235	OVER-EXPLOITED	203	OVER-EXPLOITED
64		Jalandhar East	329	OVER-EXPLOITED	400	OVER-EXPLOITED
65		Jalandhar West	243	OVER-EXPLOITED	243	OVER-EXPLOITED
66		Lohian	260	OVER-EXPLOITED	247	OVER-EXPLOITED
67		Mehatpur	245	OVER-EXPLOITED	273	OVER-EXPLOITED
68		Nakodar	296	OVER-EXPLOITED	313	OVER-EXPLOITED
69		Nur Mahal	221	OVER-EXPLOITED	199	OVER-EXPLOITED
70		Phillaur	269	OVER-EXPLOITED	259	OVER-EXPLOITED
71		Rurka Kalan	261	OVER-EXPLOITED	241	OVER-EXPLOITED
72		Shahkot	307	OVER-EXPLOITED	344	OVER-EXPLOITED
73	**Kapurthala**	Dhilwan	189	OVER-EXPLOITED	177	OVER-EXPLOITED
74		Kapurthala	261	OVER-EXPLOITED	286	OVER-EXPLOITED
75		Nadala	167	OVER-EXPLOITED	189	OVER-EXPLOITED
76		Phagwara	280	OVER-EXPLOITED	265	OVER-EXPLOITED
77		Sultanpur Lodhi	229	OVER-EXPLOITED	249	OVER-EXPLOITED

Sr. No		Assessment Unit (Block)/ District	2020		2022	
			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)
78	**Ludhiana**	Dehlon	233	OVER-EXPLOITED	237	OVER-EXPLOITED
79		Doraha	156	OVER-EXPLOITED	142	OVER-EXPLOITED
80		Jagraon	156	OVER-EXPLOITED	157	OVER-EXPLOITED
81		Khanna	310	OVER-EXPLOITED	297	OVER-EXPLOITED
82		Ludhiana-1	295	OVER-EXPLOITED	353	OVER-EXPLOITED
83		Ludhiana-2	182	OVER-EXPLOITED	216	OVER-EXPLOITED
84		Machhiwara	148	OVER-EXPLOITED	153	OVER-EXPLOITED
85		Maloud	218	OVER-EXPLOITED	199	OVER-EXPLOITED
86		Pakhowal	262	OVER-EXPLOITED	273	OVER-EXPLOITED
87		Raikot	274	OVER-EXPLOITED	282	OVER-EXPLOITED
88		Samrala	214	OVER-EXPLOITED	234	OVER-EXPLOITED
89		Sidhwan Bet	230	OVER-EXPLOITED	251	OVER-EXPLOITED
90		Sudhar	215	OVER-EXPLOITED	237	OVER-EXPLOITED
91	**Malerkotla**	Malerkotla-1	297	OVER-EXPLOITED	308	OVER-EXPLOITED
92		Malerkotla-2	273	OVER-EXPLOITED	298	OVER-EXPLOITED
93	**Mansa**	Bhikhi	192	OVER-EXPLOITED	215	OVER-EXPLOITED
94		Budhlada	144	OVER-EXPLOITED	100	CRITICAL
95		Jhunir	120	OVER-EXPLOITED	48	SAFE
96		Mansa	163	OVER-EXPLOITED	170	OVER-EXPLOITED
97		Sardulgarh	170	OVER-EXPLOITED	88	SEMI-CRITICAL
98	**Moga**	Bagha Purana	221	OVER-EXPLOITED	209	OVER-EXPLOITED
99		Kot Ise Khan (Dharamkot)	181	OVER-EXPLOITED	159	OVER-EXPLOITED
100		Moga-1	339	OVER-EXPLOITED	333	OVER-EXPLOITED
101		Moga-2	336	OVER-EXPLOITED	344	OVER-EXPLOITED
102		Nihal Singh Wala	301	OVER-EXPLOITED	331	OVER-EXPLOITED
103	**Muktsar**	Kot Bhai (Gidderbaha)	63	SAFE	38	SAFE
104		Lambi	27	SAFE	20	SAFE
105		Malout	48	SAFE	34	SAFE
106		Muktsar	43	SAFE	19	SAFE
107	**Pathankot**	Bamial	83	SEMI-CRITICAL	82	SEMI-CRITICAL
108		Dhar Kalan	42	SAFE	27	SAFE
109		Gharota	70	SEMI-CRITICAL	71	SEMI-CRITICAL
110		Narot Jaimal Singh	85	SEMI-CRITICAL	77	SEMI-CRITICAL
111		Pathankot	54	SAFE	56	SAFE
112		Sujanpur	32	SAFE	35	SAFE

Sr. No		Assessment Unit (Block)/ District	2020		2022	
			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)
113	**Patiala**	Bhunarheri	276	OVER-EXPLOITED	282	OVER-EXPLOITED
114		Ghanaur	106	OVER-EXPLOITED	100	OVER-EXPLOITED
115		Nabha	234	OVER-EXPLOITED	214	OVER-EXPLOITED
116		Patiala	216	OVER-EXPLOITED	196	OVER-EXPLOITED
117		Patran	317	OVER-EXPLOITED	286	OVER-EXPLOITED
118		Rajpura	176	OVER-EXPLOITED	201	OVER-EXPLOITED
119		Samana	204	OVER-EXPLOITED	189	OVER-EXPLOITED
120		Sanaur	254	OVER-EXPLOITED	237	OVER-EXPLOITED
121		Shambu Kalan	207	OVER-EXPLOITED	245	OVER-EXPLOITED
122	**Rupnagar**	Anandpur Sahib	79	SEMI-CRITICAL	76	SEMI-CRITICAL
123		Chamkaur Sahib	126	OVER-EXPLOITED	130	OVER-EXPLOITED
124		Morinda	147	OVER-EXPLOITED	159	OVER-EXPLOITED
125		Nurpur Bedi	92	CRITICAL	69	SAFE
126		Rupnagar	55	SAFE	65	SAFE
127	**Sangrur**	Andana	244	OVER-EXPLOITED	251	OVER-EXPLOITED
128		Bhawanigarh	303	OVER-EXPLOITED	348	OVER-EXPLOITED
129		Dhuri	332	OVER-EXPLOITED	344	OVER-EXPLOITED
130		Dirba	342	OVER-EXPLOITED	342	OVER-EXPLOITED
131		Lehra Gaga	287	OVER-EXPLOITED	277	OVER-EXPLOITED
132		Sangrur	324	OVER-EXPLOITED	310	OVER-EXPLOITED
133		Sher Pur	270	OVER-EXPLOITED	286	OVER-EXPLOITED
134		Sunam	338	OVER-EXPLOITED	341	OVER-EXPLOITED
135	**SAS Nagar**	Derabassi	133	OVER-EXPLOITED	163	OVER-EXPLOITED
136		Kharar	101	OVER-EXPLOITED	115	OVER-EXPLOITED
137		Majri	54	SAFE	65	SAFE
138	**SBS Nagar**	Aur	101	OVER-EXPLOITED	115	OVER-EXPLOITED
139		Balachaur	88	SEMI-CRITICAL	90	SEMI-CRITICAL
140		Banga	166	OVER-EXPLOITED	203	OVER-EXPLOITED
141		Nawan Shahr	158	OVER-EXPLOITED	145	OVER-EXPLOITED
142		Saroya	44	SAFE	59	SAFE
143	**Tarn Taran**	Bhikhiwind	194	OVER-EXPLOITED	219	OVER-EXPLOITED
144		Chohla Sahib	218	OVER-EXPLOITED	247	OVER-EXPLOITED
145		Gandiwind Tatla	118	OVER-EXPLOITED	124	OVER-EXPLOITED
146		Khadur Sahib	212	OVER-EXPLOITED	223	OVER-EXPLOITED
147		Naushera Pannuan	215	OVER-EXPLOITED	257	OVER-EXPLOITED
148		Patti	225	OVER-EXPLOITED	236	OVER-EXPLOITED
149		Tarn Taran	225	OVER-EXPLOITED	241	OVER-EXPLOITED
150		Valtoha	159	OVER-EXPLOITED	166	OVER-EXPLOITED