GROUND WATER RESOURCES
OF
JAMMU & KASHMIR
(As on 31-03-2023)

Prepared Jointly
By

CENTRAL GROUND WATER BOARD
NORTH WESTERN HIMALAYAN REGION
JAMMU

JAL SHAKTI DEPARTMENT
UNION TERRITORY OF
JAMMU & KASHMIR

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PREFACE

For an efficient management and development of ground water resources, it is imperative to have a reliable estimation of Ground Water Resources. Estimation of Ground Water Resources for all watersheds or administrative units was recommended in Ground Water Estimation Committee (GEC-2015) is also applicable for the Union Territory of Jammu and Kashmir. Union Territory being hilly terrain, whole of the area has not been assessed. The ground water resources have been estimated as on 31st of March 2023, for assessment units (districts) of Union Territory having surface slope of less than 20%.

As per the estimation, 19 out of 20 assessment units (districts) of Union Territory fall under the safe category except one assessment unit, Srinagar urban area, fall under semi-critical category and overall stage of ground water development in the Union Territory is 24.20%. In Jammu administrative division, the stage of ground water development ranges from 12.41% in Rajouri to 47.37% in Doda, whereas in Kashmir administrative division it ranges from 13.86% in Baramulla District to 78.21% in Srinagar urban District.

The efforts made by the Ground Water Assessment Cell comprising of officers from Central Ground Water Board, North Western Himalayan Region, Jammu and Department of Jal Shakti, Union Territory of Jammu and Kashmir, in bringing out this report are highly appreciated. Working on India –Groundwater Resource Estimation System (IN-GRES) platform, Sh. Rayees Ahmad Pir, Scientist-B, and Naresh Singh Barti, Assistant Hydrogeologist completed the assignment well in time, under the efficient guidance of supervisor and their efforts are worth mentioning.

The present report consists of information on annually replenishable ground water resources and Static/ In-storage ground water resources. The details of natural losses, available ground water resources, ground water draft, allocation for domestic and industrial uses, available ground water resources for future irrigation and the stage of ground water development have also been provided.

This report is repository of very useful data for planners and user agencies engaged in development and management of groundwater resources in the Union Territory of Jammu and Kashmir. We hope that Report would be utilized fully for real-time management of groundwater resources in the Union territory of Jammu and Kashmir.

(Mohinder Lal Angurala)
Head of Office

GROUND WATER RESOURCES, JAMMU & KASHMIR 2023

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CHAPTER-1

INTRODUCTION

1.0 BACKGROUND

Ground water is an important source to meet the water requirements of various sectors like irrigation, domestic, and industries. Groundwater usage, if left unregulated, may lead to serious inter-sectoral conflicts. Hence the growth in agriculture and industry is impingent on how India can manage its groundwater resources, particularly the aquifers in different parts of the country. The sustainable development of ground water resources requires a precise quantitative assessment based on reasonably valid scientific principles. The fundamental basis for good ground water management is a clear understanding of aquifers and the status of ground water accumulation and movement in these aquifers.

An estimate of ground water resources was made in 1973 to assess the irrigation potential from the groundwater by the Ministry of Agriculture in consultation with Union Territory ground water and minor irrigation organization. Subsequently, in the early eighties, the ground water resource was re-estimated based on the Methodology proposed by the Ground Water Over Exploitation Committee-1977. In 1982, the Government of India constituted a Ground Water Estimation Committee to improve the quantitative assessment of ground water and 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 Jammu and Kashmir Union Territory.

However, some limitations were encountered in the estimation and this necessitated revision of the methodology for more accurate assessment. Therefore, 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 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 the relevant information to the Planning Commission and to review the GEC-97 and to suggest suitable modifications, if any. However, the R&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 the 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 the refinement of data.

The Ground Water Estimation Committee- 1997 has been the basis of ground water assessment in the country for the last two decades. The groundwater development program implemented in the country was also guided by ground water resource availability worked out using this methodology. However, experience gained in the last more than one decade of employing this methodology supplemented by several research and pilot project studies has shifted the need to update this groundwater resource assessment methodology. The National Water Policy also enunciates periodic assessment of ground water potential on a scientific basis.

In 2010, the Ministry of Water Resources constituted a Central Level Expert Group (CLEG) to supervise the reassessment of ground water resources in the entire country. The group finalized its report, and the draft report was circulated to all the Committee members 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, necessary modifications were made, and the 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 significant changes proposed in the workshop were (i) to change the criteria for categorization of assessment units and (ii) to remove the potentiality tag.

The revised methodology, as recommended, has incorporated several changes compared to the recommendations of the Groundwater Estimation Committee - 1997. The revised methodology GEC 2015 recommends aquifer-wise ground water resource assessment to which demarcation of lateral and vertical extent and disposition of different aquifers is a pre-requisite. However, it is recommended that ground water resources be assessed to a depth of 100m in hard rock areas and 300m in soft rock areas till the aquifer geometry is completely established throughout the country through aquifer mapping.

It also recommends the estimation of Replenishable and in-storage ground water resources for both unconfined and confined aquifers. Keeping in view the rapid change in ground water extraction, GEC-2015 recommends resource estimation once every three years. This methodology suggests that a quality flag may be added to the assessment unit for parameters salinity, fluoride, and arsenic after the assessment. In inhabited hilly areas, where surface and sub-surface runoff are high, and generally, water level data is missing, it is challenging to compute the various components of the water balance equation. Hence, it is recommended that wherever spring discharge data is available, the same may be assessed as a proxy for 'ground water resources' in hilly areas.

The Ministry of Jal Shakti Department of Water Resources RD&GR requested all the State/UT Governments to constitute a State/UT Level Committee. As per the guideline of the Government of J&K vide Order No. 1053-JK (GAD) of 2023 Dated: 30-08-2023 **(Appendix–1),** has notified a Union Territory Level Ground Water Estimation Committee (***UTLEC)*** as on March 2023 for ground water resource estimation.

Accordingly, steps were taken to carry out the groundwater resource assessment with data for the period 2022-2023 for the present study. The recommendations of GEC-2015 have been suitably incorporated into the present report. The Dynamic Study of Ground Water Estimation in the Jammu and Kashmir Union Territory in 2004, 2009, 2011, and 2013 has been carried out based on the GEC-97 Methodology**.**

1.1 ASSESSMENT AREA

The Union Territory of Jammu & Kashmir is the northernmost Union territory of India and the 22nd largest state in geographical area. It lies between the latitudes 32º17' to 35º08' N and longitudes 73º23' to 76º47' E. The UT has a total geographical area of 42,241 sq. Km. The Union Territory has an international border with Pakistan in the west. The States of Punjab and Himachal Pradesh form their southern border, and the UT of Ladakh forms the northern and northeastern border. Major parts of the J&K UT represent high and rugged mountainous terrain.

The Jammu & Kashmir is divided into two administrative divisions' viz. Kashmir Division and Jammu division. In the Jammu region, NHS monitoring is being done for the valley and Alluvium plains of six districts Jammu, Samba, Kathua, Rajouri, Reasi, and Udhampur. The remaining four areas are hilly and do not have a represented water level monitoring network. Therefore, the groundwater estimation is computed by the rainfall infiltration method only.

The UT has great diversity in its temperature and precipitation. Except in the plain, south of the Siwaliks of the Jammu Division, the climate over the greater parts of the UT resembles the mountainous and continental parts of the temperate latitudes.

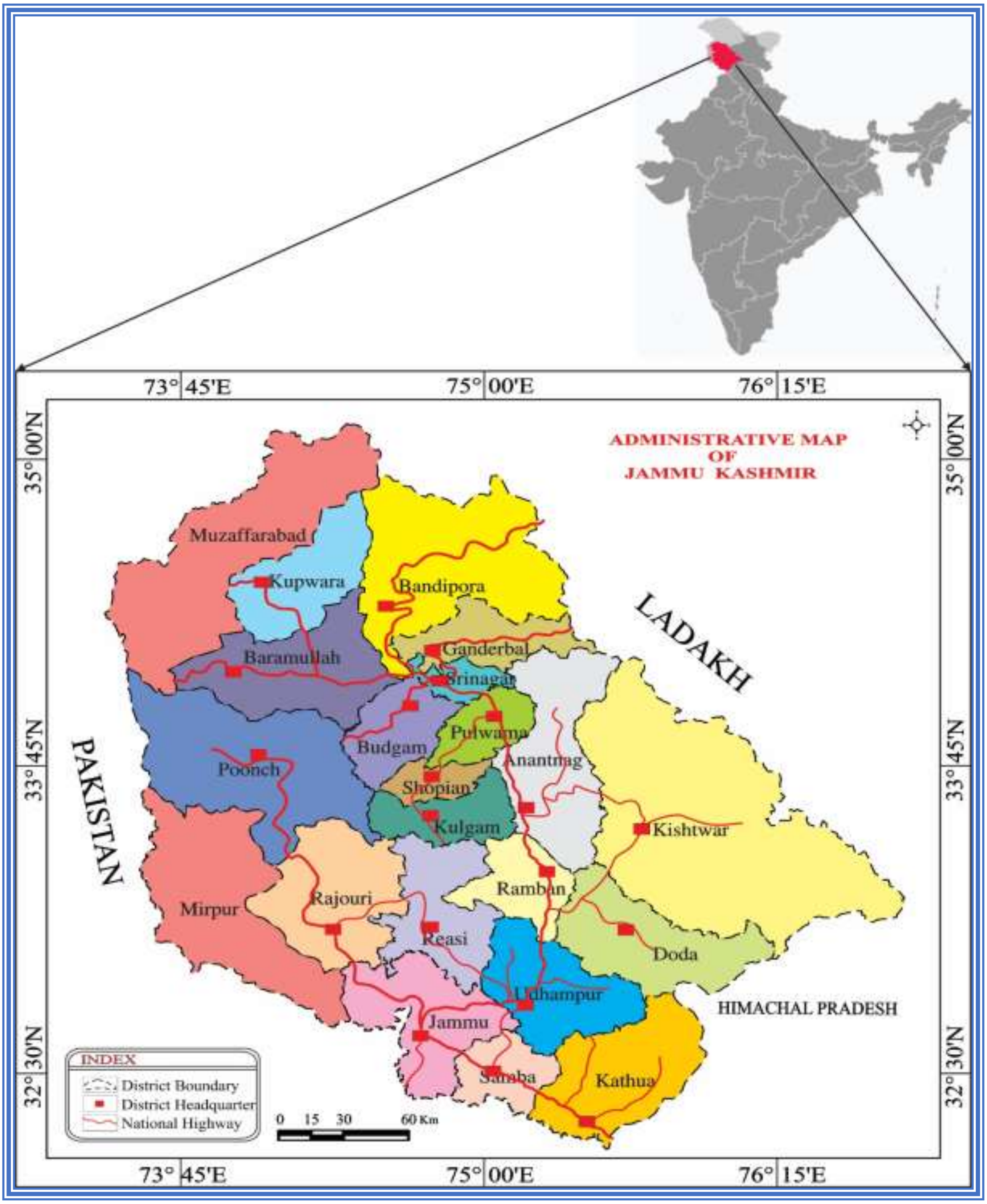


Figure 1 Administrative Map of UT of Jammu & Kashmir.

In Jammu and Kashmir, surface water resources are committed through IWT, and the Indian share is being fully utilized through a well-organized canal irrigation system. However, the available surface water resources of the UT being unable to meet the demand of agriculture; are increasing pressure on groundwater resources. In groundwater resources, the UT is facing the dual phenomenon of the rising water level in small valleys in Jammu divisions and some parts of Kashmir and the falling water table Kandi belt in certain parts of Jammu Province, where groundwater is generally fresh and fit for drinking and irrigation purpose

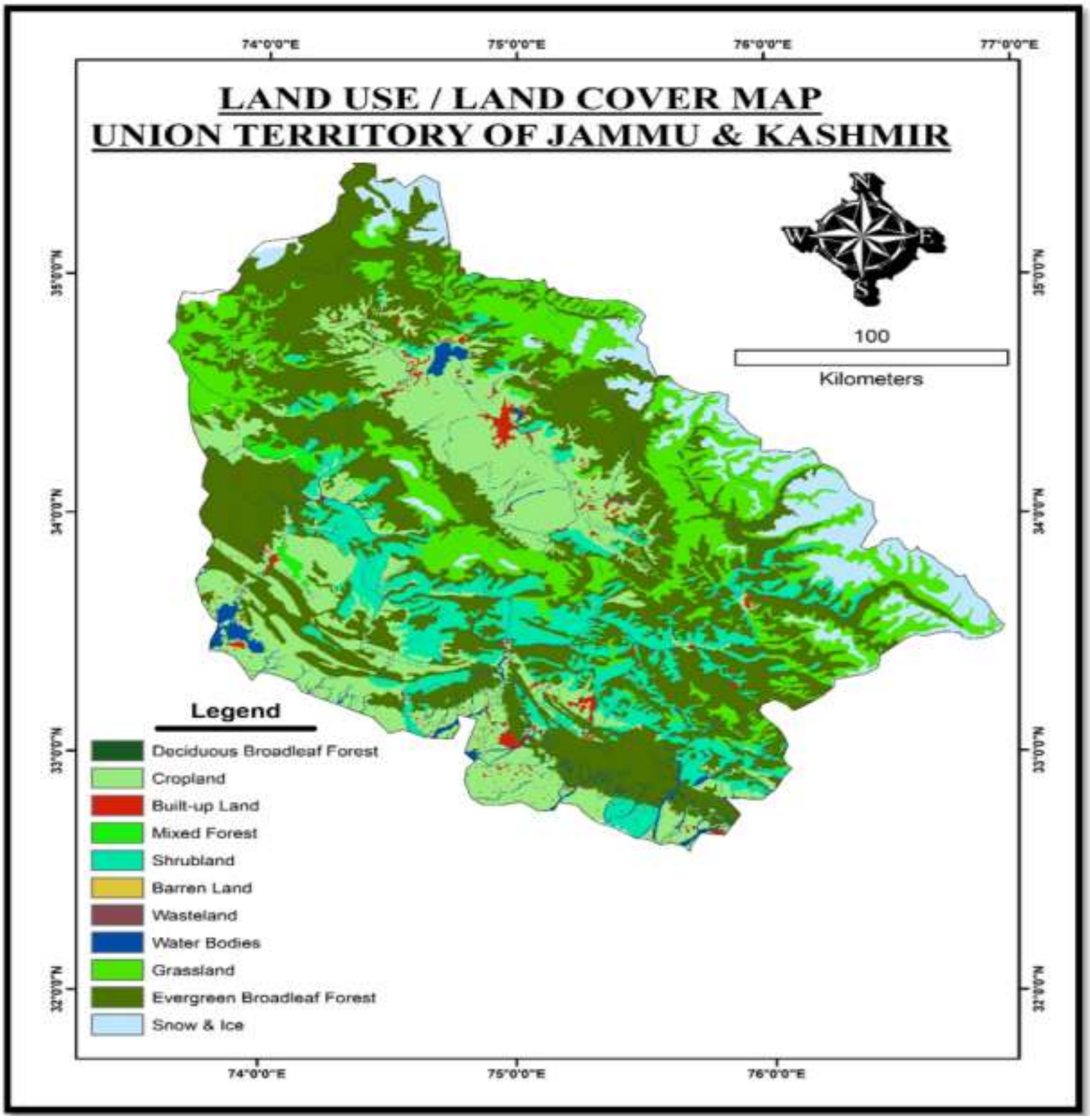


Figure 2 Land Use/land Cover Map of UT of J&K

Unlike other States, the estimation of groundwater resources is not done block-wise since the entire Union Territory is hilly and mountainous. As such, groundwater resources are computed only for alluvial plains and taking the district as an assessment unit of the Jammu Region and Kashmir division. Therefore, instead of a block unit for the evaluation of the groundwater resources is taken as valleys and plain areas of all districts. Hence, Ground Water resources of all 20 districts have been estimations for areas found as Ground Water recharge worthy.

1.2. GEOLOGY

Geological formations ranging in age from Pre-Cambrian to Recent were exposed in Kashmir Valley, and the brief geological succession is given below:-

Table 1 Geology of Jammu & Kashmir

Stratigraphic Unit	LITHOLOGY	AGE
Alluvium	Heterogeneous Clastic sediments comprising Sand, Silt, Clay	Sub-Recent to Recent
Karewa formation	Fine greenish sands alternating with	Pleistocene
Siwalik Group	Clay, Sand, Sandstone, Silt stones	Middle Miocene to lower Pleistocene
Murre Group	Purple colored Clay, Shale, Silt stones, green sandstones	Middle Eocene to Oligocene
Subathu Group	Shales, sand Stones	Late Paleocene to Middle Eocene
----------Un Conformity--------		
Triassic Lime Stones and Shales	Limestones, Shales	Triassic
Zewan Formation	Lime Stones and Shales	Middle and Upper Permian
Panjal Volcanics	Andesitic and Basaltic flows	Permo – Carboniferous
Agglomeratic slate series	Slates, Quartzites	Late Carboniferous to Early Permian
Muth formation	Quartzites, Shales, Silt stones, dolomitic limestones	Upper Silurian – Devonian
----------Un Conformity--------		
Dogra Slates, Salkhala Series	Carbonaceous Shales, Schists, graphitic phyllites, carbonaceous limestones, dolomites, marbles, quartzites	Precambrian

The Salkhala outcrops have been traced in the form of a hairpin bend around the northwestern end of the Kashmir Valley. The salkhala group comprises a succession of Carbonaceous Shales, Schists, graphitic phyllites, carbonaceous limestones, dolomites, marbles, and quartzites. The Salkhala group is stratigraphically overlain by Dogra Slates, which conformably grades into the lower paleozoic succession. In the southern part of Kashmir, the Dogra Slates are conformably overlain by a succession of phyllites, sandstones, massive quartzites, grits, and conglomerates known as Tanawals and suggested that the succession bridges the gap between Dogra Slates and upper Paleozoic rocks in the south and southwestern Kashmir. The Palaeozoic formations of Kashmir exposed along with the pirpanjal range and great Himalayan ranges rest either over Dogra slates or pre-Cambrian crystalline rocks of the Salkhal group. A succession of white quartzites, shales, siltstones, and dolomitic limestones exposed around Kashmir synclinorium has been referred to as Muth formation. In the Northern part of Kashmir, the Muth Quartzites are conformably overlain by Syringothris limestone, a succession of Grey and dark blue limestone with a few interbedded shales, quartzites, and traps. The formation is exposed along the southern slopes of Pirpanjal near Banihal.

Agglomerates slate series is well exposed in the Pir Panjal range Baramulla district, Liddar valley, Anantnag District, and Kistwar in the Doda district. The polymictites consist of rock fragments derived from glacial erosion as well as from volcanic outbursts. It is a succession of slates, sandstone, quartzite, and a few bands of conglomerates.

The Agglomeratic slate series is overlain and often intermixed with a thick succession of Andesitic and basaltic traps known as Panjal volcanic. The volcanic occupy the steep slopes and high peaks of the pir panjal ranges and higher reaches of liddar valley. The volcanic activity seems to have persisted in Kashmir from the late Carboniferous to late Triassic epochs.

Permian rocks of Kashmir are conformably overlain by a thick succession of limestones and shales known as zeewan formation.

The outcrops of Jurassic rock have restricted distribution in Kashmir. A significant part of the rock is buried beneath the quarternary sediments and reported in the northern slopes of the Pir Panjal range Baltal and Joji-la areas. The Cretaceous rocks have not been found from the Kashmir Himalayas.

The Murres extensively exposed on the Jammu-Srinagar highway around Batote consists of a basal conglomerate bed overlain by intercalations of bright red-purple clay and green sandstones and is overlain by Siwalik group rock formations.

Most of the Kashmir valley is occupied by this gravel-sand and mud succession known in Indian Stratigraphy as 'Karewa formation.' There are different opinions about the deposition of Karewa formations. Based on detailed geological mapping, Bhatt (1978, 1982) proposed that sedimentation of Karewa deposits took place in a lake basin but suggested that during the deposition of Lower Karewa lake occupied the whole Kashmir valley floor, but during Upper Karewa time, the lake was localized only in the north-eastern flank of the basin.

Karawas covers an area of about 5600 sq.Km in Kashmir Valley. Karewa group is defned to include the more or less unconsolidated layered sedimentary succession deposited in fluvio-lacustrine environments in the Kashmir valley, overlying the Precambrian-Mesozoic basement and overlain by Holocene alluvium of modern rivers, etc.'. The Karewa group is divided into two formations viz., Lower Karewa and Upper Karewa. The Lower Karewa formation is characterized by plastic grey to bluish-grey clay, light grey sandy clay, lignite, lignitic clay, coarse to medium-grained sand, and conglomerates. It is about 1200-mt thick formations.

The Upper Karewa formation is characterized by brown, grey sandy clay, medium to coarse-grained sand, cream-colored marl, conglomerate, and loam (loess) sediments. In this upper Karewas lignitic shale and grey bluish shale are absent. The thickness of this formation is about 50 to 200 mt. The loamy sediments are present throughout the valley, making the top of the Karewa Plateau. The Upper Karewa formation sediments are exposed extensively on the Pir Panjal flank due to the uplift of the Pir Panjal range and its Karewa sediments.

A fine-grained predominantly silty succession caps the top of Karewa terraces without any bedding structures. These are mainly loam or loess formations. The formation is, in some places, extremely muddy, silty, or somewhat sandy. In some cases, sand layers are intercalated.

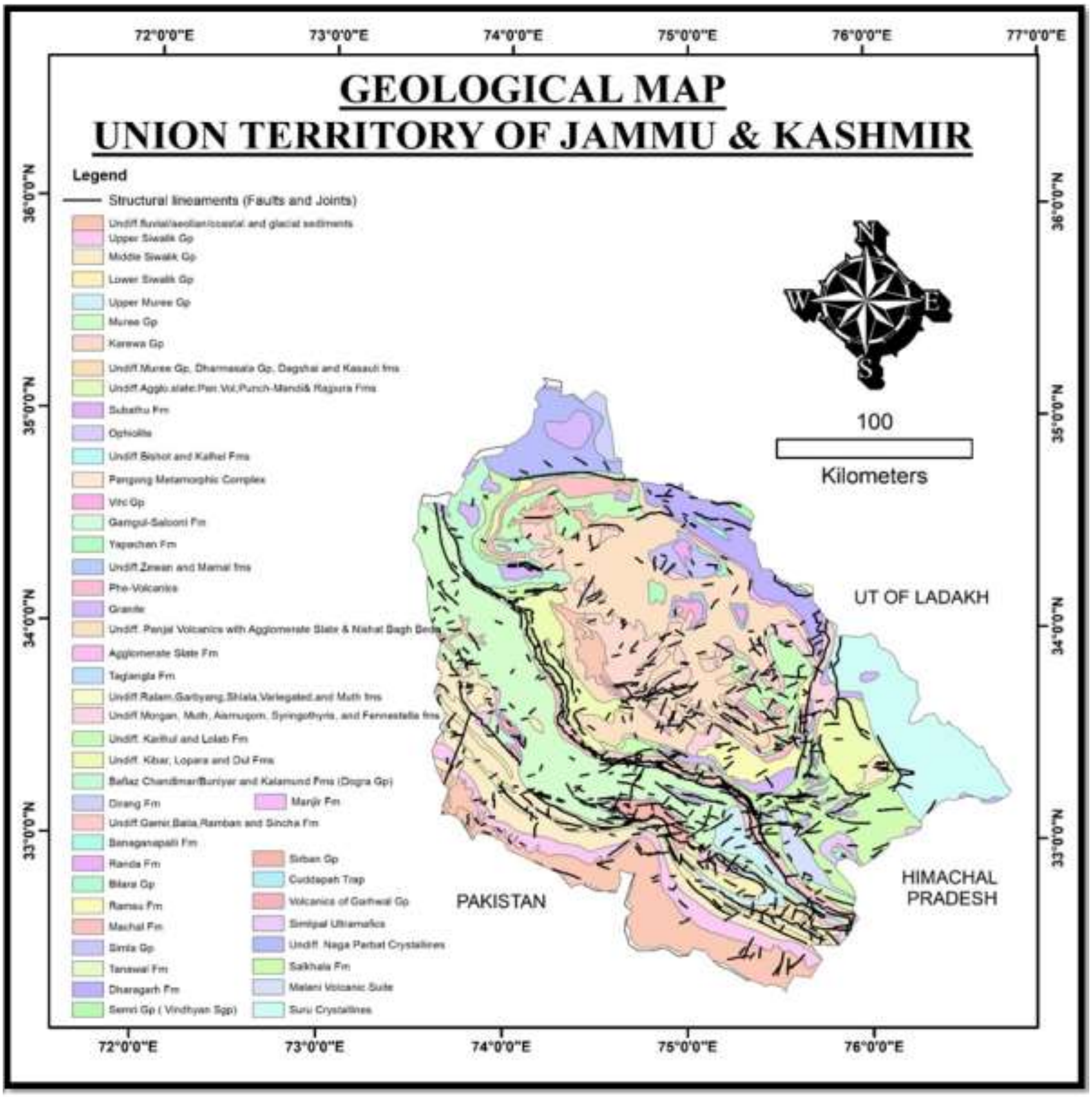


Figure 3 Geological Map of Union Territory of Jammu & Kashmir

1.3. HYDROMETEOROLOGY

The climate of Jammu & Kashmir

The UT of Jammu and Kashmir is situated in the subtropical latitudes and has micro-level variation in the altitudes. Hence, it has a great diversity in its temperature and precipitation. Excepting the plain, south of the Siwaliks of the Jammu Division, the climate over the greater part of the UT resembles the mountainous and continental parts of the temperate latitudes. In Koppen's scheme of climatic types, the hilly parts of the Jammu Kashmir Divisions as Dfb (humid continental with severe and moist winters and short summers) while the plain areas of the Jammu Division/Region, adjacent to the plain of Punjab have been described as Ca (less most winter, long hot summers, followed by moderately heavy rains in July, August, and September.

The normal lapse rate of temperature entails an average decrease of about 60C per thousand meters increase of elevation. There are important exceptions to this are actual lapse rates, but on the whole, higher altitudes are associated with significantly lower temperatures and a smaller annual range of temperature. This is because air Pressure always decreases with altitude. In addition, the atmosphere at a higher elevation is ordinarily free from dust, smoke, and other non-gaseous material. The air is accordingly more transparent to the passage of both incoming and outgoing radiation during a cloudless period.

Jammu district has a subtropical climate with a hot and dry climate in summer and a cold climate in winter. It lies in the northern hemisphere above the tropic of Cancer. The sub-tropical climate zone of the world occurs between tropical and tempered zones (25^0 to 40^0 North and South latitudes). The district's minimum and Maximum temperatures vary between -8.8˚C to 47˚C, and the monsoon starts from the beginning of July to the first week of September. The average rainfall in the district is about 1151 mm. The climate of this region is characterized by a rhythm of seasons which is caused by the reversal of winds in the form of the south-west and north-east monsoon. The reversal of pressure takes place regularly twice a year.

Rainfall

It is found that the average annual rainfall of the Jammu district is 1151mm. It is evident from the plot of average rainfall and no. of rainy-day versus month. The rainfall occurs in two phases. One of the rainfall periods takes place from June to September and the other period from December to March. In Jammu District, Rainfall occurs between June to September due to the southwest monsoon. SW monsoon reaches the district in the last week of June or in the first week of July and lasts till the 20th of September. In the monsoon period, the average rainfall of the last fifty years for July, August, and September is 347,323 and 119 mm respectively. The monsoon is called the Southwest monsoon because it approaches from the southwest direction. In this, the southern hemisphere's moist air first travels in the SE direction and after crossing the equator travels in the SW direction and hits the Indian coast from the southwest side. By the end of September, the low-pressure system over north and northwest India gradually weakens, leading to the retreat of the monsoon winds.

In the district, rainfall also occurs from December to March. In this period, rains occur mainly due to the western disturbance. The extratropical storm brings sudden winter rain and snow to the north-western parts of the Indian subcontinent. The moisture in these storms usually originates over the Mediterranean Sea and the Atlantic Ocean. During the last fifty years, the average rainfall during the winter seasons is about 188 mm, and the maximum rainfall of 295.4mm was observed in March.

Temperature

The monthly mean temperature in the Jammu district is about 20^0C, and the annual range of temperature is about 17^0C. The outstanding feature of the annual march of temperature is the maximum before the commencement of the summer monsoon. In April, the day and night temperatures become 32^0C and 18^0C, increasing to 38^0C to 25^0C in May. On Vidal day, the month of May or June, the maximum temperature goes up to 47^0C (June 1953). The relative humidity in May falls to below 20 percent. At the outbreak of the summer monsoon, the temperature decreases. The cloudy weather and high relative humidity help in the reduction of the day and night temperatures in July, August, and September.

CHAPTER-2
HYDROGEOLOGY

2.0. HYDROGEOLOGY OF JAMMU & KASHMIR

The hydrogeological set up in the Union Territory is very complicated owing to varied geological settings and groundwater conditions. Both the regions of Jammu & Kashmir UT viz. Kashmir and Jammu represent entirely different groundwater regimes. Based on geology and aquifer characteristics, the area of the UT can be divided into two broad hydrogeological units. These units are

A Porous formation

B Fissured formation

Porous Formation

Porous formations are best suitable for exploration and development. Potential zones are encountered in these formations. These formations are:

Jammu Region

In the Outer Plains of the Jammu region extending between River Ravi in the east to Munnawar Tawi in the west, the groundwater occurs in Piedmont deposits belonging to the upper Pleistocene to the Recent age. The deposits comprise unconsolidated sediments in terraces and coalescent alluvial fans developed by streams debauching out of Siwalik Hills. The sediments consist of coarse clastics ranging in size from boulders to gravel in the loose clay matrix and occasionally alternating bands of clay of varying thickness. Kankar is also intercalated with these sediments at different intervals and variable quantities.

These deposits are graded into finer sediments from north to south in that order. Down south, it comprises alternate bands of sands of all grades and clay with subordinate packs of gravel and pebbles.

Kandi Formation

The typical Kandi formation comprises coarse material with little clay, but the typical Kandi formation is not seen in the Outer Plain of Jammu & Kashmir UT. Instead, they comprise boulder gravel, pebble, and coarse sand with substantial clay, sometimes hard and sticky of varying thickness. The clay proportion increases towards the southwest. The occurrence of perched water bodies is a common phenomenon in the Kandi belt of Jammu &

Kashmir UT. The groundwater generally occurs under unconfined conditions in the Kandi formation.

Sirowal Formation

The Kandi formation coalesces into Sirowal formations in the south, which are finer outwash of Siwalik debris brought by streams. Groundwater occurs under both the confined as well as unconfined conditions in Sirowal formation. A spring line demarcates the contact between Kandi and Sirowal formations because the water table oozes out along this line causing marshy conditions. The spring line has undergone deformation due to a decline in water level resulting from groundwater development in the Sirowal area. However, the base flow could be seen in streams south of this line and in the Sirowal formation, which shows auto-flow conditions in the deeper aquifer system.

The Dun Belt separates the Siwalik hills in the middle Himalayas and runs as a series of river terraces between Basoli (32°30', 76°49'30") in the east to Reasi (33°05', 74°50') and beyond in the west. The sediments are in the form of isolated sub-recent to recent valley-fill deposits ranging in thickness between a few meters to a few tens of meters. These deposits are often dissected as a result of the present-day drainage pattern. The deposits comprise coarse clastics such as boulders, cobbles, pebbles, etc., interbedded with lenticular clays.

Isolated Valley Fills in the Middle Himalayas

There are many isolated valleys in the middle Himalayas where groundwater occurs in valley-fill deposits comprising lacustrine to fluvioglacial sediments. A few meter-thick layers of loess overlies these deposits, which is windblown. Groundwater in such valleys generally occurs under confined conditions. One of the prominent, isolated valleys in the middle Himalayas is Kistwar valley (33°18' 30", 75°46’) in the Doda district of the Jammu region.

Kashmir Region

Kashmir valley covers an area of 5600 km and is occupied by Karewas, which consists of a huge pile of alternating bands of sand, silt, and clay interspersed by glacial boulder beds. The sands are mostly fine to very fine-grained, and it is infrequent that they are medium to coarse-grained. There is considerable lateral facies variation in the nature of the sediments. The aggregate thickness of these sediments is of the order of 2500-3000 m.

Groundwater in the Karewas of Kashmir valley occurs under both confined as well as unconfined conditions.

Fissured Formation

About 15000 Sq. Km. The area in the Jammu region is occupied by hilly terrain. It comprises rocks ranging in age from the Pre-Cambrian (Salkhala series) to the Miocene or even Pliocene (Murees and upper-middle Siwaliks). The rock types range from soft or friable sandstones, Clays, Shales, and Conglomerates to hard rocks such as traps and metamorphic rocks such as quartzite and crystalline limestone. The Siwalik terrain where groundwater is tapped comes mainly from the weathered mantle or the joints or cracks in these rocks. Friable Siwalik sandstone does possess primary porosity but is not a very potential aquifer.

2.1. BEHAVIOUR OF WATER LEVELS

2.1.1. DEPTH TO WATER LEVEL

The water levels in Groundwater Monitoring Wells of Jammu and Kashmir State were measured four times during the period 2022–2023 (May 2022, August 2022, November 2022, and January 2023). The groundwater levels in different seasons were analyzed to evaluate the temporal behavior of water levels. The behavior of water levels during the period May 2022 to January 2023 has been compared with the previous water levels as well as with the average water level for the last decade (decadal behavior) to ascertain the changes in the groundwater regime. All the data has been put in the GIS format and the data has been analyzed. After analysis, the contours of water levels below the ground surface have been created by joining the areas with the same water levels and the areas have been demarcated with uniform contour intervals. The contouring has been done by the IDW Interpolation method.

Depth to Water Level -May 2022

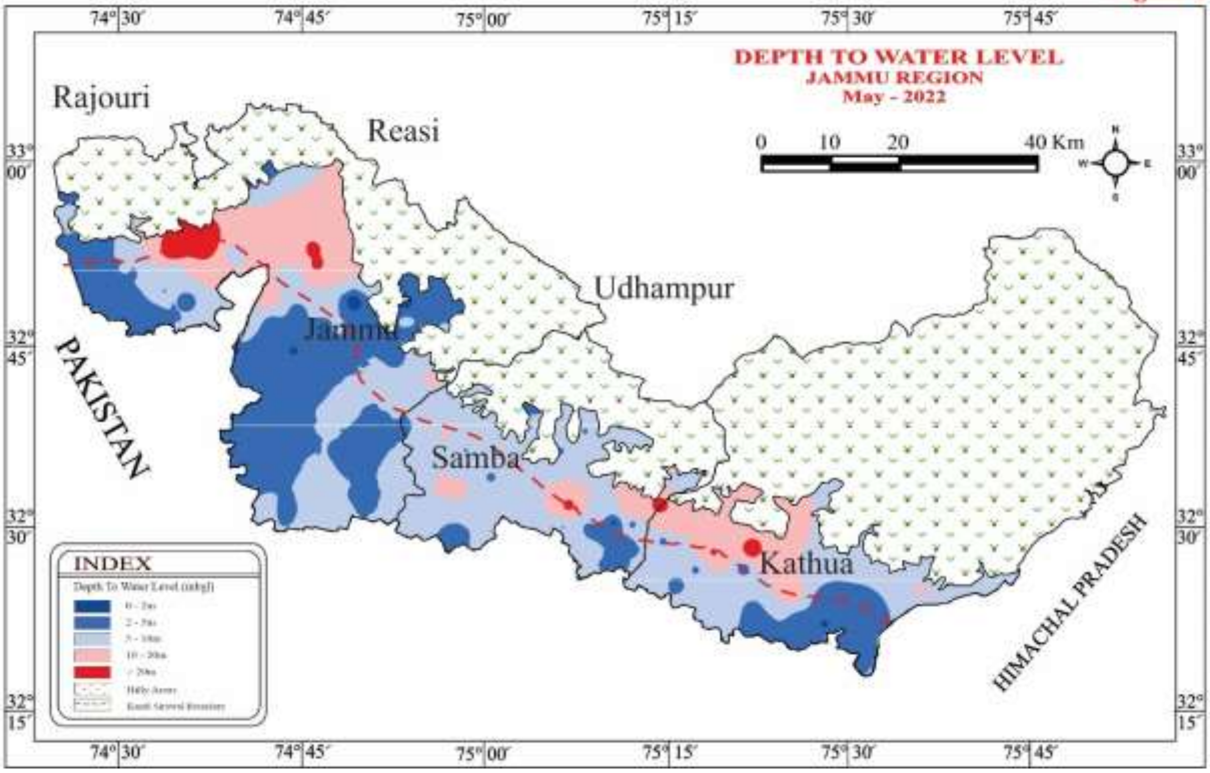
Jammu Region: The water level data in respect of 207 wells for May 2022 were analyzed. The depth to water level varied from 0.10 m bgl (Sanoora in Samba District) to 36.57 m bgl (Taryai in Jammu district). The categorization of depth to the water level in May 2022 is given in table 2.

11 wells (5.3%) have recorded a water level of less than 2.0 m bgl. About 11 (53.6%) of the total wells analyzed have shown depth to water level in the range of 2-5 m bgl. Whereas 62 wells (30%) have shown water levels in the range of 5-10 m bgl. 15 (7.2%) wells have registered deeper water levels, in the range of 10-20 m bgl. Another 8 wells (3.9%) of the total wells analyzed have shown water levels in the range of >20 m bgl.

Valley areas of Jammu, Samba, and Kathua districts below the contact of Kandi Sirowal show water levels between 2-5 m bgl except few patches that show water levels between 0-2m bgl. In the Sirowal area of Outer Plains, most of the water levels have been recorded between 2 - 10 m bgl except a few small patches that show water levels from 0 to 2 m & above 10 m bgl. In the Kandi

Belt, the water levels are deeper ranging between 5-20 m bgl, and a few patches of northern and north western Jammu, central, parts of Samba & north-western parts of Kathua respectively) having water levels of more than 20 m bgl (Figure 4).

Figure 4



Kashmir Region: The water level data in respect of 51 wells for May 2022 were analyzed. The depth to water level varied from 0.10 m bgl to 15.40 m bgl. 24 wells (47.1%) have recorded a water level of less than 2.0 m bgl. About 25% of the total wells (51 wells) analyzed have shown depth to water level in the range of 2-5 m bgl. Whereas 2 wells (13.9%) have shown water levels in the range of 5-10 m bgl. 1 (2.0%) wells have registered deeper water levels, in the range of 10-20 m bgl. Another 0 wells (0%) of the total wells analyzed have shown water levels in the range of >20 m bgl. The categorization of depth to the water level in May 2022 is given in table 2.

Valley areas of the Kashmir Region have shown water levels in all ranges. A major portion has shown within 2m bgl in Kupwara and Baramulla districts. Water levels above 2 but under 5 m have been shown in the northern parts of Baramulla few patches in the Kupwara Srinagar and Pulwama districts. The water level is deeper towards the northern and north-eastern parts of Pulwama & Anantnag district (Figure 5).

Figure 5

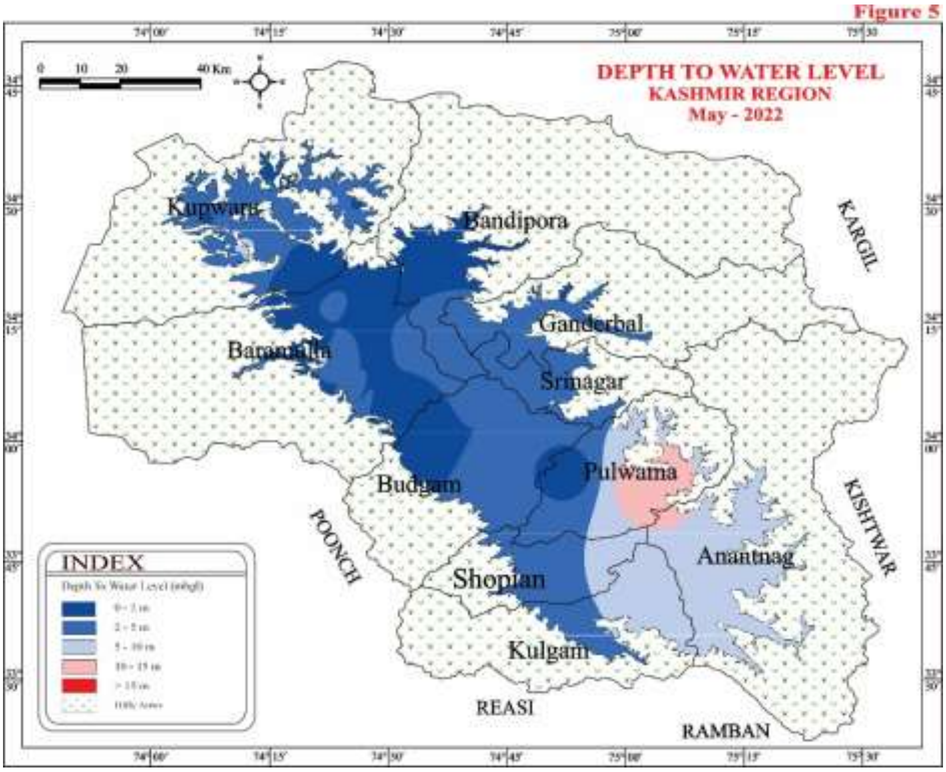


Table 2 CATEGORIZATION OF DEPTH TO WATER LEVEL- MAY 2022														
REGION	**District**	**No. Of wells Analyzed**	**Depth to Water Level (mbgl)**		**Number of Wells Showing Depth to Water Level (mbgl) in the Range of**					**Percentage of Wells Showing Depth to Water Level (mbgl) in the Range of**				
			Min	**Max**	**0–2**	**2–5**	**5–10**	**10–20**	**> 20**	**0–2**	**2–5**	**5–10**	**10–20**	**> 20**
Kashmir Region	Baramulla	17	0.76	4.30	11	6	0	0	0	64.7	35.3	0.0	0.0	0.0
	Kupwara	31	0.10	7.20	11	18	2	0	0	35.5	58.1	6.5	0.0	0.0
	Pulwama	2	0.35	15.40	1	0	0	1	0	50.0	0.0	0.0	50.0	0.0
	Srinagar	1			1	0	0	0		100.0	0.0	0.0	0.0	0.0
	Total	**51**	**0.10**	**15.40**	**24**	**24**	**2**	**1**	**0**	**47.1**	**47.1**	**3.9**	**2.0**	**0.0**
Jammu Region	Jammu	79	0.10	36.57	3	42	23	7	4	3.8	53.2	29.1	8.9	5.1
	Kathua	32	1.40	25.12	2	11	13	4	2	6.3	34.4	40.6	12.5	6.3
	Rajauri	33	1.77	16.40	1	27	5	0	0	3.0	81.8	15.2	0.0	0.0
	Reasi	6	2.27	7.14	0	4	2	0	0	0.0	66.7	33.3	0.0	0.0
	Samba	33	1.40	26.68	1	14	12	4	2	3.0	42.4	36.4	12.1	6.1
	Udhampur	24	1.05	9.60	4	13	7	0	0	16.7	54.2	29.2	0.0	0.0
	Total	**207**	**0.10**	**36.57**	**11**	**111**	**62**	**15**	**8**	**5.3**	**53.6**	**30.0**	**7.2**	**3.9**
	TOTAL J&K	**258**			**35**	**135**	**64**	**16**	**8**	**13.6**	**52.3**	**24.8**	**6.2**	**3.1**

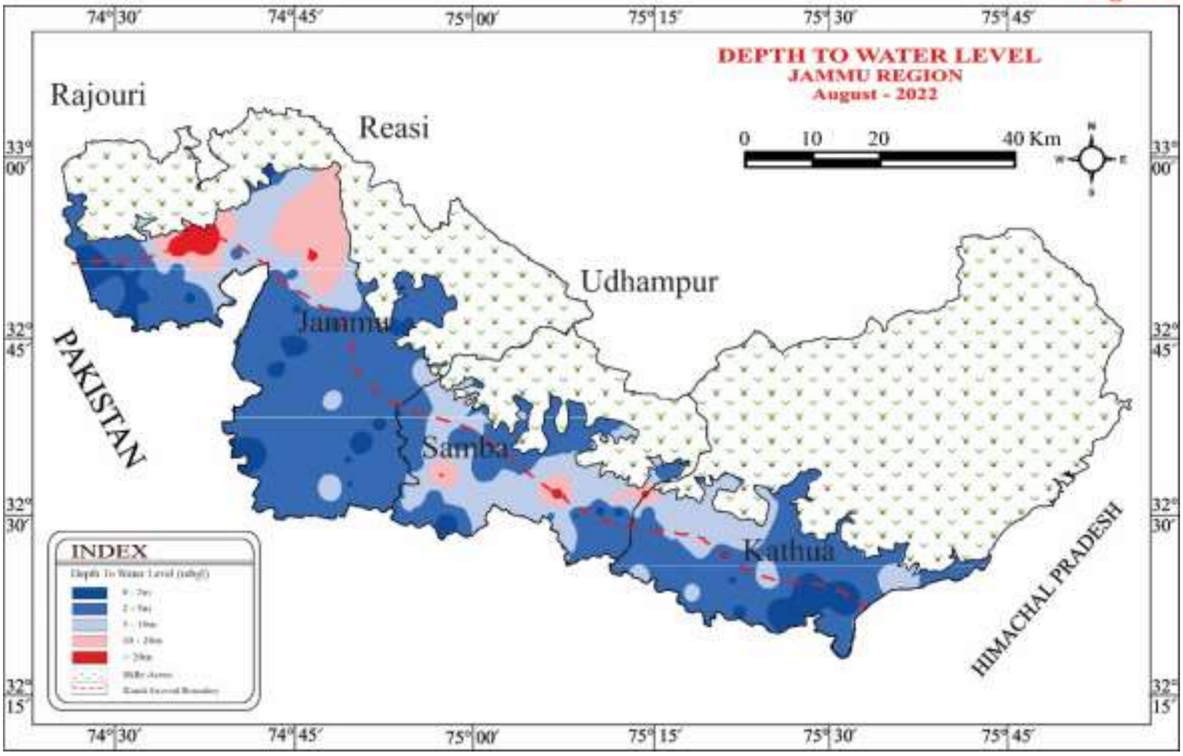
Depth to Water Level -August 2022

Jammu Region: The water level data in respect of 221 wells for August 2022 were analyzed. The depth to water levels varied from 0.31 m bgl to a maximum of 34.06 m bgl (Taryai in Jammu district). The categorization of DTWL is given in table 3.

The water level less than 2 meters below ground level was recorded in 90 wells. 91 wells have shown water levels in the range of 2 to 5 m bgl, whereas 24 wells have shown water levels in the range of 5 to 10 m bgl. 8 wells have shown deeper water levels i.e. in the range of 10 to 20 m bgl. 8 wells have shown a very deep-water level of >20 m bgl.

In Sirowal formation, water levels varied between 0 to 5 in the major portion and 5-10 m bgl at a few places. The transition part of the Sirowal belt and Kandi belt of both Jammu and Kathua Districts shows varied water levels. Water levels deeper than 20m bgl was observed in the extreme north-western portion of the Jammu district in the Kandi belt and middle and N-Eastern areas in the Samba district (Figure 6).

Figure 6



Kashmir Region: The water level data in respect of 50 wells for August 2022 were analyzed. The depth to water level varied from 0.50 m bgl to 15.56 m bgl. 21 wells have recorded a water level of less than 2.0 m bgl. About 25 wells have shown depth to the water level in the range of 2-5 m bgl. Whereas 3 wells have shown water levels in the range of 5-10 m bgl. 01 well wells have registered deeper water levels, in the range of 10-20 m bgl. 0 wells of the total wells analyzed have shown water levels in the range of >20 m bgl. The categorization of DTWL is given in table 3.

Valley areas of the Kashmir Region have shown water levels in all ranges. The major portion has shown within 2m bgl. In Kupwara and Baramulla districts water levels above 2 but under 5 m have been shown in the northern parts of Baramulla few patches in Kupwara and Srinagar and Pulwama districts. The water level is deeper towards the northern and north-eastern parts of Anantnag & Pulwama district (figure 7).

Figure 7

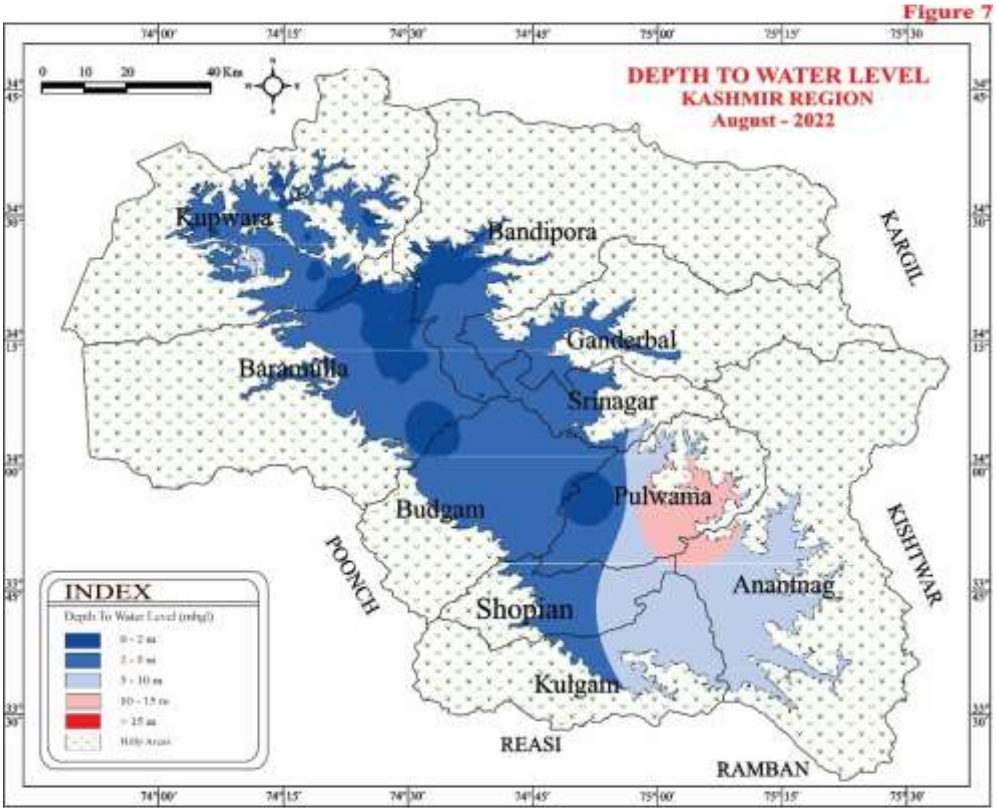


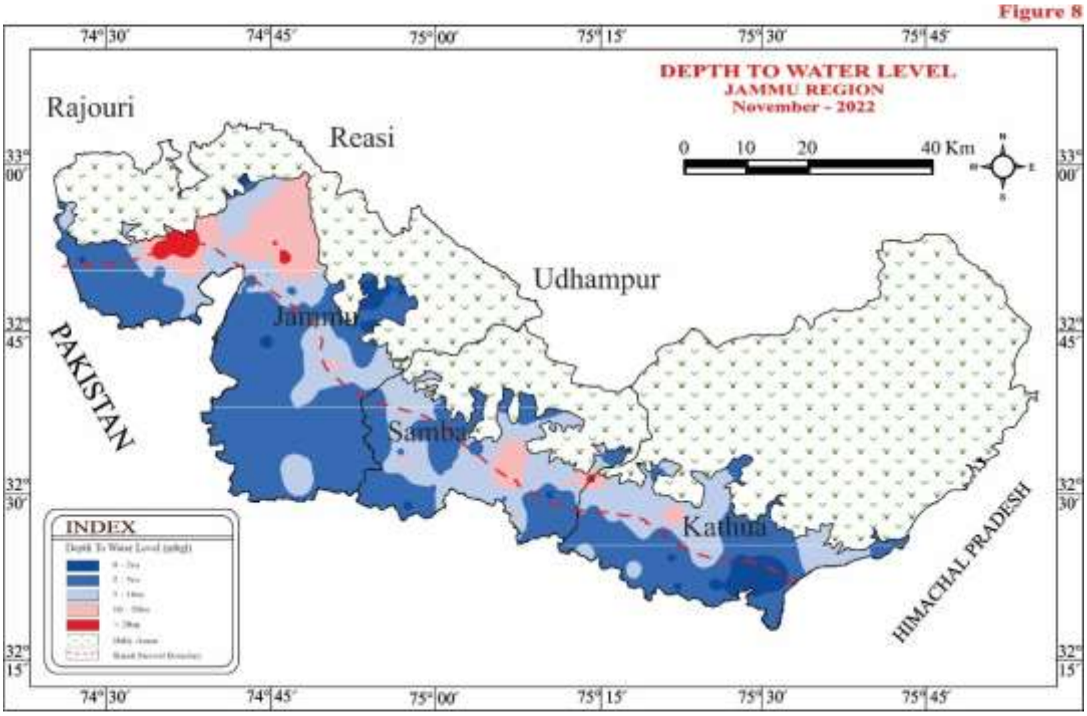
Table 3 CATEGORIZATION OF DEPTH TO WATER LEVEL- AUGUST 2022														
REGION	**District**	**No. Of wells Analyzed**	**Depth to Water Level (mbgl)**		**Number of Wells Showing Depth to Water Level (mbgl) in the Range of**					**Percentage of Wells Showing Depth to Water Level (mbgl) in the Range of**				
			Min	**Max**	**0–2**	**2–5**	**5–10**	**10–20**	**> 20**	**0–2**	**2–5**	**5–10**	**10–20**	**> 20**
Kashmir Region	Baramulla	17	1.20	4.60	9	8	0	0	0	52.9	47.1	0.0	0.0	0.0
	Kupwara	31	0.7	8.45	11	17	3	0	0	35.5	54.8	9.7	0.0	0.0
	Pulwama	2	0.50	15.56	1	0	0	1	0	50.0	0.0	0.0	50.0	0.0
	Srinagar													
	Total	**50**	**0.50**	**15.56**	**21**	**25**	**3**	**1**	**0**	**42.0**	**50.0**	**6.0**	**2.0**	**0.0**
Jammu Region	Jammu	82	0.35	34.06	26	39	8	5	4	31.7	47.6	9.8	6.1	4.9
	Kathua	37	0.40	10.00	13	15	8	1	0	35.1	40.5	21.6	2.7	0.0
	Rajauri	38	0.35	4.92	26	12	0	0	0	68.4	31.6	0.0	0.0	0.0
	Reasi	8	0.66	24.90	2	5	0	0	1	25.0	62.5	0.0	0.0	12.5
	Samba	34	0.31	23.59	7	16	6	2	3	20.6	47.1	17.6	5.9	8.8
	Udhampur	22	0.35	5.35	16	4	2	0	0	72.7	18.2	9.1	0.0	0.0
	Total	**221**	**0.31**	**34.06**	**90**	**91**	**24**	**8**	**8**	**40.7**	**41.2**	**10.9**	**3.6**	**3.6**
	TOTAL J&K	**271**			**111**	**116**	**27**	**9**	**8**	**41.0**	**42.8**	**10.0**	**3.3**	**3.0**

Depth to Water Level -November 2022

Jammu Region: The water level data in respect of 235 wells for November 2022 were analyzed. The depth to water level ranges from 0.30 m bgl (Kotka Swal Jammu district) to 32.86 m bgl (Taryai in Jammu district). The categorization of DTWL Nov. 2022 is given in table 4. A total of 62 numbers of wells have recorded a water level of less than 2.0 m bgl. The majority of the wells (119 wells, of the total wells) analyzed have shown depth to water level in the range of 2-5 m bgl. Whereas 34 wells have shown water levels in the range of 5-10 m bgl. 13 wells have registered deeper water levels, in the range of 10-20 m bgl. Another 7 wells of the total wells analyzed have shown water levels in the range of >20 m bgl.

In the Sirowal formation of Jammu, Samba, and Kathua, water levels varied between 0 to 5 in major parts and 0-2 m bgl in a few parts. A major part of the Sirowal belt in all three districts shows water levels between 2 and 5 m bgl and water levels in the range of 2-5 m & 5 – 10 m bgl have been observed at a few patches. In the Kandi belt, the water levels generally found are within the range of 5 - 15 mbgl. Water levels deeper than 20m bgl were observed in the extreme north & north-western portion of the Jammu district in the Kandi belt and central & eastern parts of the Samba district (Figure 8).

Figure 8



Kashmir Region: The water level data in respect of 50 wells for November 2022 were analyzed. The depth to water level varied from 0.0.35 m bgl to 15.24 m bgl. 21 wells have recorded a water level of less than 2.0 m bgl. About 25 wells have shown depth to the water level in the range of 2-5 m bgl. Whereas 4 wells have shown water levels in the range of 5-10 m bgl. 01 well wells have registered deeper water levels, in the range of 10-20 m bgl. 0 wells of the total wells analyzed have shown water levels in the range of >20 m bgl. The categorization of DTWL Nov. 2022 is given in table 4.

Valley areas of the Kashmir Region have shown water levels in all ranges. The major portion has shown within 2m to 5 m bgl. In Kupwara and Baramulla districts water levels above 2 but under 5 m have been shown in the northern parts of Baramulla few patches in Kupwara and Srinagar and Pulwama districts. The water level is deeper towards the northern and north-eastern parts of Anantnag & Pulwama district (figure 9).

Figure 9

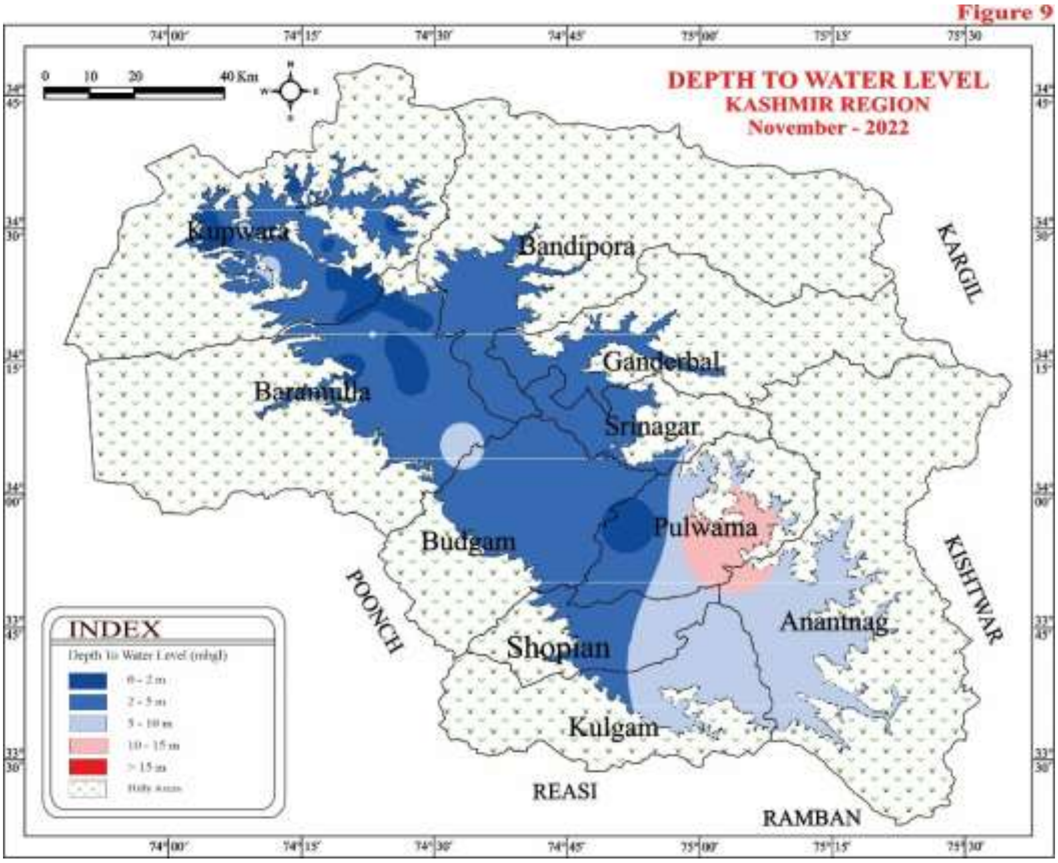


Table 4 CATEGORIZATION OF DEPTH TO WATER LEVEL- NOVEMBER 2022														
REGION	District	No. Of wells Analyzed	Depth to Water Level (mbgl)		Number of Wells Showing Depth to Water Level (mbgl) in the Range of					Percentage of Wells Showing Depth to Water Level (mbgl) in the Range of				
			Min	Max	0–2	2–5	5–10	10–20	> 20	0–2	2–5	5–10	10–20	> 20
Kashmir Region	Anantnag													
	Baramulla	17	0.80	6.80	7	8	2	0	0	41.2	47.1	11.8	0.0	0.0
	Kupwara	31	0.5	9.2	12	17	2	0	0	38.7	54.8	6.5	0.0	0.0
	Pulwama	2	0.35	15.24	1	0	0	1	0	50.0	0.0	0.0	50.0	0.0
	Srinagar	1			1	0	0	0	0	100.0	0.0	0.0	0.0	0.0
	Total	**51**	**0.35**	**15.24**	**21**	**25**	**4**	**1**	**0**	**41.2**	**49.0**	**7.8**	**2.0**	**0.0**
Jammu Region	Jammu	87	0.30	32.86	11	52	13	6	5	12.6	59.8	14.9	6.9	5.7
	Kathua	40	0.45	14.92	13	15	10	2	0	32.5	37.5	25.0	5.0	0.0
	Rajauri	37	0.60	5.42	13	23	1	0	0	35.1	62.2	2.7	0.0	0.0
	Reasi	9	1.25	24.93	4	2	2	0	1	44.4	22.2	22.2	0.0	11.1
	Samba	38	0.90	23.51	7	17	8	5	1	18.4	44.7	21.1	13.2	2.6
	Udhampur	24	0.47	5.68	14	10	0	0	0	58.3	41.7	0.0	0.0	0.0
	Total	**235**	**0.30**	**32.86**	**62**	**119**	**34**	**13**	**7**	**26.4**	**50.6**	**14.5**	**5.5**	**3.0**
	TOTAL J&K	**286**			**83**	**144**	**38**	**14**	**7**	**29.0**	**50.3**	**13.3**	**4.9**	**2.4**

Depth to Water Level – January 2023

Jammu Region: The water level data in respect of 228 wells for January 2023 were analyzed. The depth to water levels varied from 0.11 at Dalsar Udhampur District to 35.50 m bgl in Taryai Jammu District. The categorization of depth to water level in January 2022 is given in table 5.

A total of 38 of the wells analyzed have recorded a water level of less than 2.0 m bgl. 120 wells have shown depth to the water level in the range of 2-5 m bgl, whereas 47 wells have shown water levels in the range of 5-10 m bgl, 13 wells have shown deeper water levels i.e. 10-20 m bgl and 10 wells have shown water level > 15 m bgl.

In the entire Sirowal area, the water levels varied between 2 to 5 m bgl with a few small patches of 0-2 and 5-10 m. Besides, small portions of all three districts recorded water levels in the range of 5 to 10 mbgl. The Kandi belt shows deeper water levels between 5 to 15 m bgl. In all three districts, the deeper water levels deeper i.e. more than 20 m bgl was also observed in the northern & northwestern parts of Jammu, northeastern parts of Samba, and north-western parts of Kathua districts (Figure 10).

Figure 10

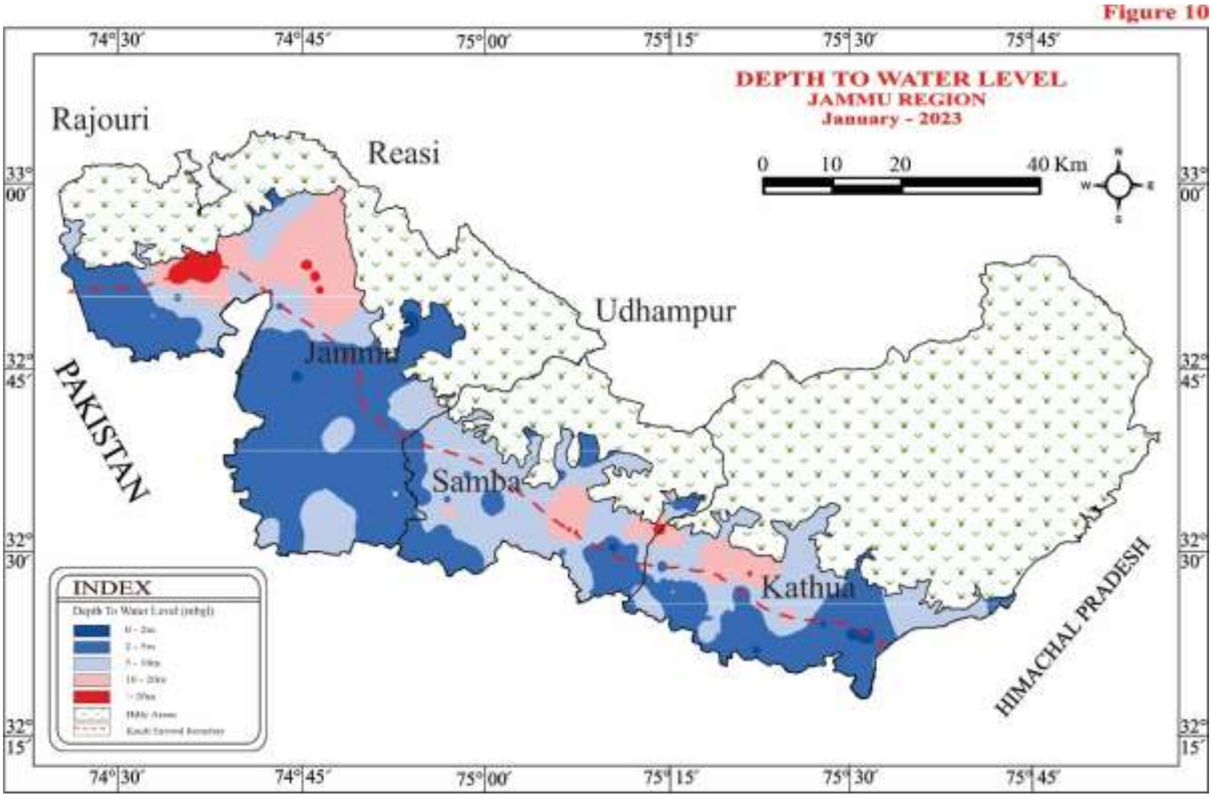


Table 5 CATEGORIZATION OF DEPTH TO WATER LEVEL- JANUARY 2023

REGION	District	No. Of wells Analyzed	Depth to Water Level (mbgl)		Number of Wells Showing Depth to Water Level (mbgl) in the Range of					Percentage of Wells Showing Depth to Water Level (mbgl) in the Range of				
			Min	Max	0–2	2–5	5–10	10–20	> 20	0–2	2–5	5–10	10–20	> 20
Jammu Region	Jammu	82	0.19	35.50	6	47	17	6	6	7.3	57.3	20.7	7.3	7.3
	Kathua	38	0.69	18.62	7	15	12	3	1	18.4	39.5	31.6	7.9	2.6
	Rajauri	38	0.19	5.50	9	25	4	0	0	23.7	65.8	10.5	0.0	0.0
	Reasi	9	1.63	24.88	3	3	2	0	1	33.3	33.3	22.2	0.0	11.1
	Samba	38	0.18	24.33	4	20	8	4	2	10.5	52.6	21.1	10.5	5.3
	Udhampur	23	0.11	8.06	9	10	4	0	0	39.1	43.5	17.4	0.0	0.0
	Total	**228**	**0.11**	**35.50**	**38**	**120**	**47**	**13**	**10**	**16.7**	**52.6**	**20.6**	**5.7**	**4.4**

2.1.2 SEASONAL FLUCTUATION OF WATER LEVEL

November 2022 v/s May 2022

Jammu Region: The seasonal water level fluctuation between November 2022 & May 2022 in respect of 206 National Hydrograph Stations is analyzed. It is observed that 199 stations have shown a rise in water level as only 7 stations have shown a fall in water levels. The minimum rise is 0.02 m and the maximum rise of 12.25 m, whereas a minimum decline of 0.09 m and a maximum of 1.85 m is recorded. The categorization of fluctuations in water levels is given in Table 6. Out of 199 stations showing a rise in water levels, 130 wells have shown a rise of less than 2 m. 48 wells and 21 wells have shown a rise in the range of 2-4 m and >4 m respectively. 7 wells have shown a decline between 0-2 m. 0 wells have shown a fall between 2-4 and 0 wells have shown a decline of>4 m.

The effect of rainfall is directly reflected in all parts of the area monitored during November 2022. Almost all the valley areas are showing a rise in the water levels except for small patches in all districts. A few locations of each district have registered fall within 0-5 m bgl (Figure 11).

Figure 11

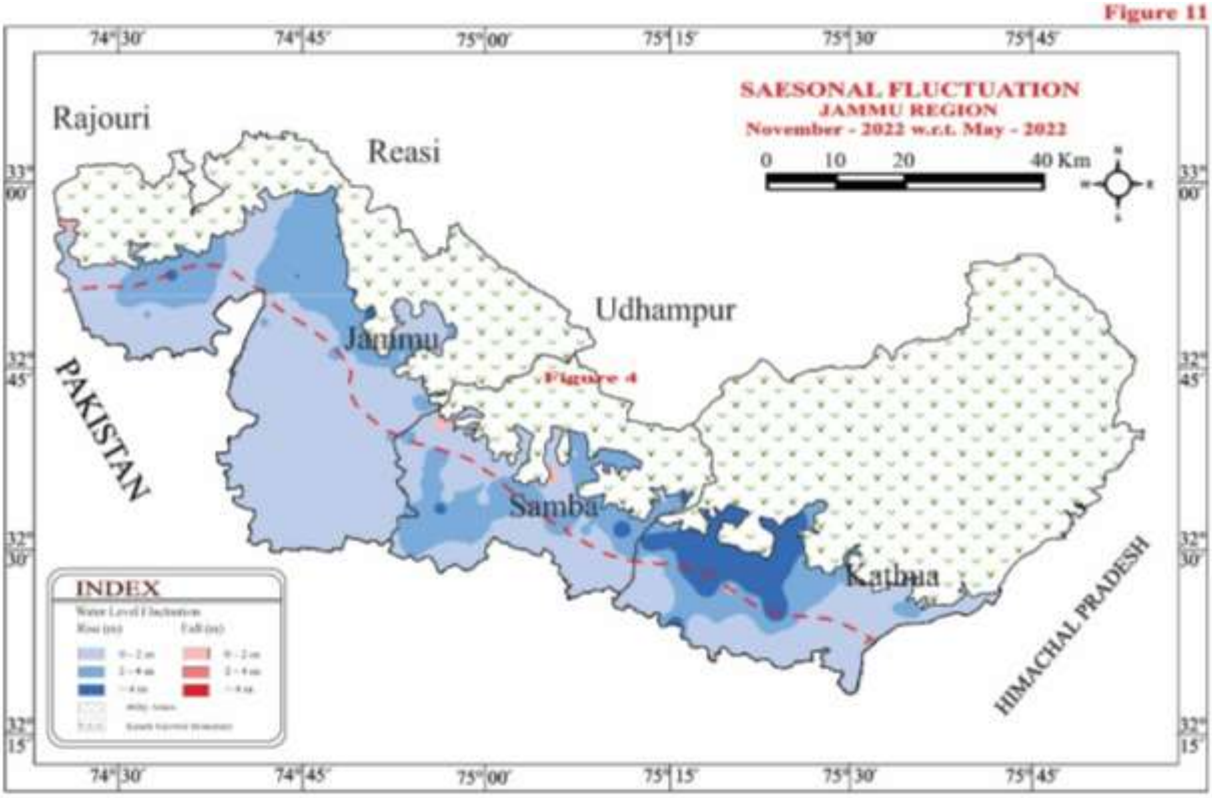


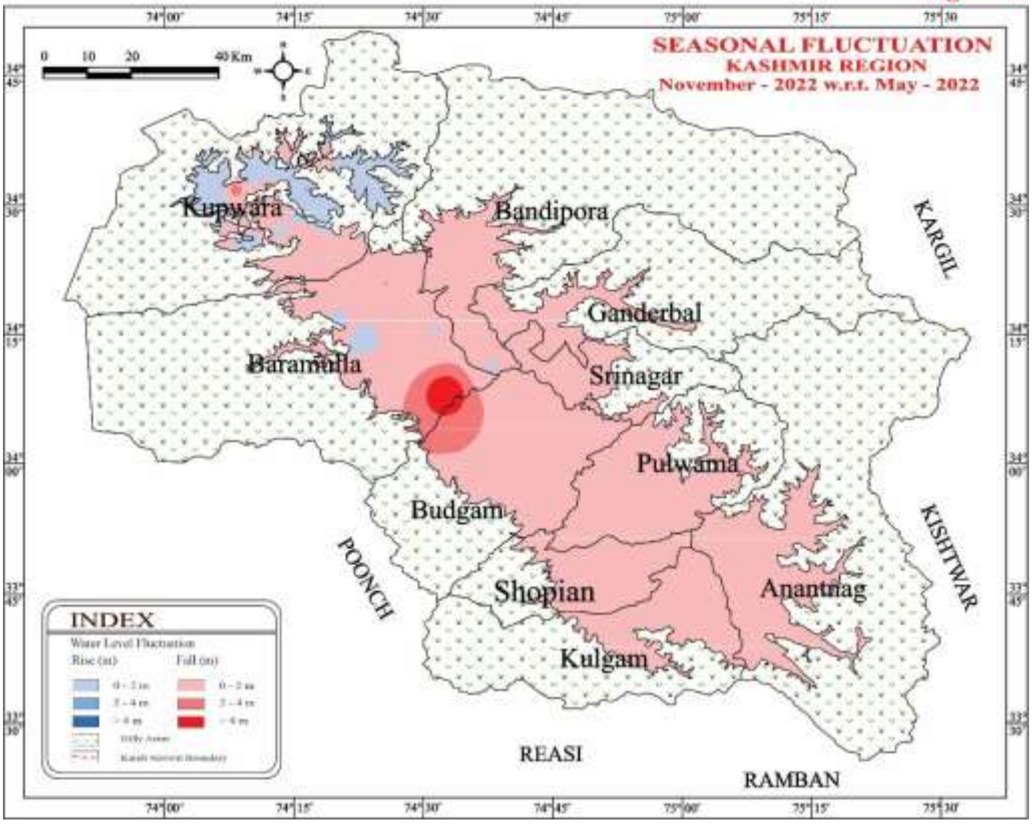
Table 6 CATEGORIZATION OF CHANGES IN WATER LEVEL BETWEEN MAY 2022-NOVEMBER 22 - JAMMU DIVISION

District	No. Of wells Analyzed	Range of Fluctuation (m)				No. of Wells Showing Fluctuation (m)						Percentage of wells Showing Fluctuation						Total No. Of Wells	
		Rise		Fall		Rise			Fall			Rise			Fall				
		Min	Max	Min	Max	0 – 2	2 – 4	> 4	0 – 2	2 – 4	> 4	0 – 2	2 – 4	> 4	0 – 2	2 – 4	> 4	Rise	Fall
Jammu	78	0.02	6.76	0.09	1.85	53	16	6	3	0	0	67.9	20.5	7.7	3.8	0.0	0.0	75	3
Kathua	32	0.25	12.25			19	5	8	0	0	0	59.4	15.6	25.0	0.0	0.0	0.0	32	0
Rajauri	33	0.10	4.10		1.02	23	8	1	1	0	0	69.7	24.2	3.0	3.0	0.0	0.0	32	1
Reasi	6	0.43	3.50		0.40	3	2	0	1	0	0	50.0	33.3	0.0	16.7	0.0	0.0	5	1
Samba	33	0.12	5.85	0.95	1.19	17	11	3	2	0	0	51.5	33.3	9.1	6.1	0.0	0.0	31	2
Udhampur	24	0.46	0.05	4.28		15	6	3	0	0	0	62.5	25.0	12.5	0.0	0.0	0.0	24	0
TOTAL	**206**	**0.02**	**12.25**	**0.09**	**1.85**	**130**	**48**	**21**	**7**	**0**	**0**	**63.1**	**23.3**	**10.2**	**3.4**	**0.0**	**0.0**	**199**	**7**

Kashmir Region: The seasonal water level fluctuation between November 2022 & May 2022 in respect of 50 National Hydrograph Stations are analyzed. It is observed that 25 stations have shown a rise in water level whereas 25 other stations have shown a fall in water levels in the range of 0-2 m, 2-4 m, and >4 m. The minimum rise is 0.10 m and the maximum rise of 2.27 m. Whereas a minimum decline of 0.04 m is recorded and a maximum of 5.96 m is shown.

Out of 50 stations showing a rise in water levels, 24 wells have shown a rise of less than 2 m. 1 well and 0 wells have shown a rise in the range of 2-4 m and >4 m respectively. 20 wells have shown a decline between 0-2 m 4 wells have shown a fall between 2-4 and 1 well has shown a decline of>4 m. (Figure 12).

Figure 12



2.1.3. Conclusion

The data of water level depths in J&K has been statistically analyzed and the water level contours are created by IDW Interpolation method. In the Jammu region effect of rainfall is directly reflected in all parts of the area monitored during Post-monsoon 2022. Almost all the valley areas are showing a rise in the water levels due to monsoon recharge. However, in Kashmir Valley, the water levels in May 2022 are very shallow as compared to the water levels of the August & November seasons. The decline of water levels in the August and November seasons is due to the decline in snow melt and rainfall together with the withdrawal of ground water in the summer season.

2.2. QUALITY TAG

GEC, 2015 recommends that each assessment unit, in addition to the quantity-based categorization should bear a quality hazard identifier. If any of the quality hazards in terms of Arsenic, Fluoride, and Salinity are encountered in the assessment sub-unit in mappable units, the assessment unit may be tagged with the particular hazard. The results of the analysis of 273 locations of the water samples of May 2023 are described below:

2.2.1. Electrical Conductance (E.C)

The analysis of the results of 273 samples shows that EC is less than 750 µS/cm at 25ºC in 161 wells, 109 wells show 750-2000 µS/cm, and 3 wells show>2000 µS/cm. The minimum value was recorded i.e. 150 µS/cm at Mir Mohalla (Katyan Wali) Kupwara and a maximum of 2400 µS/cm at Chakara, Kathua. The majority of the wells 227 have shown values below 1000 µS/cm.

2.2.2. Fluoride

The analysis of the results of 273 samples shows that 271 wells have less than 1.50 mg/l and 2 wells shows > 1.50 mg/l. The minimum value was recorded i.e. 0.00 mg/l at Lower Barnai, Jammu district and maximum of 1.71 mg/l at Londi, Kathua.

2.2.3. Total Hardness – TH (as $CaCO_3$)

The analysis of the results of 273 samples shows that 45 wells have less than 200 mg/l and 228 wells shows > 200 mg/l. The minimum value was recorded i.e. 64.97 mg/l at Jhangar Rajouri district and maximum of 998.51 mg/l at Mothian Kalan, Samba. Majority of the wells 247 have shown the values below 500 mg/l.

2.2.4. Conclusions

The Ground Water quality is mostly suitable for drinking and agriculture purposes.

CHAPTER 3
GROUNDWATER RESOURCES ESTIMATION METHODOLOGY

3.0 METHODOLOGY

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

3.1 PERIODICITY OF ASSESSMENT

Because of the rapid change in Groundwater Extraction, the committee recommends more frequent estimation of Groundwater Resources. The committee observes that the comprehensive assessment of Groundwater Resources is a time-intensive exercise. Hence as a tradeoff, it recommends that the resources should be assessed once every three years. There is a considerable time lag between the assessment and publication of the results as per the present practice. Hence the committee recommends making all-out efforts to reduce the time lag, and the results may be reported within the successive water year.

3.2 GROUNDWATER ASSESSMENT UNIT

This methodology recommends aquifer-wise groundwater resource assessment. An essential requirement for this is to demarcate the lateral and vertical extent and disposition of different aquifers. A watershed with well-defined hydrological boundaries is an appropriate unit for groundwater resource estimation if the principal aquifer is other than alluvium. Groundwater resources worked out on the watershed as a unit may be apportioned and presented on administrative units (block/ taluka/ mandal/ firka). This would facilitate local administration in the planning of groundwater management programs. 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 an appropriate scale, the existing practice of using watersheds in hard rock areas and District/ mandals/ firkas in soft rock areas may be continued.

3.3 GROUNDWATER ASSESSMENT SUB-UNITS

It is recommended that groundwater recharge may be estimated for the entire assessment unit. Out of the total geographical area of the unit, hilly areas wherever the slope is greater than 20%, are to be identified and subtracted as these areas have more runoff than infiltration. The hilly areas wherever the slope is more than 20% may be demarcated using DEM data and geomorphological maps. This would allow the valleys, terraces, and plateaus occurring within >20% slope zone to be considered for recharge computations. It is quite likely that with hilly areas, the densely forested area may also be excluded; this may affect to some extent groundwater losses caused due to transpiration by deep-rooted trees in the area of assessment. Apart from this, it is also important that the areas where the quality of groundwater is beyond the usable limits (for drinking water in particular) in terms of salinity are identified and handled separately. This methodology recommends that after the assessment is done, a quality flag may be added to the assessment unit for parameters salinity, fluoride, and arsenic. In inhabited hilly areas, where surface and sub-surface runoff is high and generally water level data is missing, it is difficult to compute the various components of the water balance equation. Hence, it is recommended that wherever spring discharge data is available, the same may be assessed as a proxy for 'groundwater resources' in hilly areas. The assessment of spring discharge would constitute the 'replenishable potential groundwater resource' but it will not be accounted for in the categorization of groundwater assessment, at least not in the near future.

The groundwater resource beyond the permissible quality limits in terms of the salinity has to be computed separately. The remaining area after excluding the area with poor groundwater quality is to be delineated as follows:

(a) Non-command areas which do not come under major/medium surface water irrigation schemes. (Command area <100 Ha in the assessment unit should be ignored)

(b) Command areas that come under major/medium surface water irrigation schemes which are supplying water (>100 Ha of command area in the assessment unit.)

It is proposed to have all these areas of an assessment unit in integer hectares to make it a national database with uniform precision.

SRINAGAR URBAN AREA

A total of 20 assessment area units have been taken while calculating the current resource estimation. These include the Srinagar urban area which has also been incorporated during the assessment. A separate assessment area (Srinagar Urban Area) has been taken into consideration subject to a condition of having a population > 10 Lakhs. The Boundary file of the area has been collected from the Srinagar Development Authority, Srinagar.

3.4 GROUNDWATER RESOURCES OF AN ASSESSMENT UNIT

The groundwater resources of any assessment unit are the sum of the total groundwater availability in the principal aquifer (mostly unconfined aquifer) and the total groundwater availability of semi-confined and confined aquifers existing in that assessment unit. The total groundwater availability of any aquifer is the sum of dynamic groundwater resources and the in-storage or static resources of the aquifer.

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

The groundwater 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 the canal, return flow from irrigation, recharge from tanks and ponds, and recharge from water conservation structures and discharge through groundwater draft.

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

3.5 GROUNDWATER ASSESSMENT OF UNCONFINED AQUIFER

As mentioned earlier, the assessment of groundwater includes the assessment of dynamic and in-storage groundwater resources. The development planning should mainly depend on dynamic resources only as it gets replenished every year. Changes in static or in-storage resources reflect the impacts of groundwater 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.

3.5.1 Assessment Of Annually Replenishable Or Dynamic Groundwater Resources

The methodology for groundwater 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 -

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

Where,
ΔS – Change in storage
RRF – Rainfall recharge
RSTR- Recharge from stream channels
Rc – Recharge from canals
RSWI – Recharge from surface water irrigation
RGWI- Recharge from groundwater irrigation
RTP- Recharge from Tanks and Ponds
R_{WCS} – Recharge from water conservation structures
VF – Vertical flow across the aquifer system
LF- Lateral flow along with the aquifer system (through flow)
GE-Groundwater Extraction
T- Transpiration
E- Evaporation
B-Base flow

It is preferred that all the components of the water balance equation should be estimated in an assessment unit. The present status of the database available with Government and non-government agencies is not adequate to carry out detailed groundwater 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 a lumped parameter estimation approach keeping in mind that data from many more sources if available may be used for refining the assessment.

3.5.1.1 Rainfall recharge:

It is recommended that groundwater recharge should be estimated on groundwater level fluctuation and specific yield approach since this method takes into account the response of groundwater levels to groundwater input and output components. This, however, requires adequately spaced representative water level measurements 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 10 years), along with corresponding rainfall data. Regarding the frequency of water level data, three water level readings during pre and post-monsoon seasons and in 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 groundwater levels. In units or subareas where adequate data on groundwater level fluctuations are not available as specified above, groundwater recharge may be estimated using the rainfall infiltration factor method only. The rainfall recharge during the non-monsoon season may be estimated using the rainfall infiltration factor method only.

3.5.1.2 Groundwater level fluctuation method

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

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

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 groundwater 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 with the aquifer system (through flow)
GE-Groundwater Extraction
T- Transpiration
E- Evaporation
B-Base flow

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

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

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 groundwater extraction, the depth from which groundwater is being extracted should be considered, and certain limits should be fixed. First, by estimating recharge by Water Level Fluctuation method, a 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:

$$\Delta S = \Delta h * A * S_Y \quad \ldots (5)$$

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, equations 3 and 4 become,

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

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

The recharge calculated from equation 6 in the case of non-command subunits and equation 7 in the case of command subunits and poor groundwater quality subunits gives the rainfall recharge for the particular monsoon season. However, it may be noted that in case of base flow/ recharge from the 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 normalized 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 the 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 subunit for which the normalization is being done.

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

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

Where,

Ri = Rainfall recharge estimated in the monsoon season for the i^{th} particular year
h = Rise in groundwater level in the monsoon season for the i^{th} particular year
Sy =Specific yield
A = Area for computation of recharge
GE = Groundwater extraction in monsoon season for the i^{th} particular year
B = Base flow of 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 normalization procedure is to be carried out for obtaining the rainfall recharge corresponding to the normal monsoon season rainfall. Let r(normal) be the normal monsoon season rainfall obtained based on recent 30 to 50 years of monsoon season rainfall data. Two methods are possible for the normalization procedure.

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

R = ar ……………………………………………………………………………(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:

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

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 - Rainfall 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,

R = ar+b ………………………………………………………………………………(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 linear regression analysis. The computational procedure to be followed in the second method is as given below:

$$a = \frac{NS_4 - S_1 S_2}{NS_3 - S_1^2} \qquad \text{………………......……(13)}$$

$$b = \frac{S_2 - aS_1}{N} \qquad \text{……………..…………(14)}$$

Where

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

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

R_{rf} (normal) = a x r(normal) + b ……………………………………..………(15)

3.5.1.3 Rainfall Infiltration Factor method

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

Recharge from rainfall is estimated by using the following relationship –

R_{rf} = RFIF * A* (R – a)/1000 …………………………………………….……(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 groundwater recharge in mm

The relationship between rainfall and groundwater 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 the computation of the 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 to sharpen the estimates of precipitation. Average rainfall data from nearby rain gauge stations may be considered for the Groundwater 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 events that can induce recharge to the aquifer is to be considered while estimating groundwater recharge using the 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 is 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 the Minimum Rainfall Threshold and 3000 mm as the 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 the 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.

3.5.1.4 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

$$PD = \frac{Rrf\,(normal, wtfm) - Rrf\,(normal, rifm)}{Rrf\,(normal, wtfm)} \times 100 \qquad \text{.........................(17)}$$

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.

3.5.1.5 Recharge from other Sources

Recharge from other sources constitutes recharges from canals, surface water irrigation, groundwater irrigation, tanks and ponds, and water conservation structures in command areas whereas in non-command areas the recharge due to surface water irrigation, groundwater irrigation, tanks and ponds, and water conservation structures are possible.

3.5.1.6 Recharge from Canals:

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

R_C=WA * SF * Days …………………………………………………………………(18)

Where:

R_C= Recharge from Canals WA=Wetted Area
SF= Seepage Factor
Days = Number of Canal Running Days.

3.5.1.7 Recharge from Surface Water Irrigation:

Recharge due to applied surface water irrigation, either through canal outlets or by lift irrigation schemes is to be estimated based on the following formula:

R_{SWI} =AD*Days*RFF ………………………………………………………….…. (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

3.5.1.8 Recharge from Groundwater Irrigation:

Recharge due to applied groundwater irrigation is to be estimated based on the following formula:

R_{GWI} =GE_{IRR}*RFF …………………………………………….…………..(20)

Where:

R_{GWI} = Recharge due to applied groundwater irrigation GE_{IRR}=
Groundwater Extraction for Irrigation
RFF= Return Flow Factor

3.5.1.9 Recharge due to Tanks & Ponds:

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

R_{TP} =AWSA*RF ……………………………………………………………..(21)

Where:
R_{TP} = Recharge due to Tanks and Ponds AWSA=
Average Water Spread Area RF= Recharge Factor

3.5.1.10 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 ……………………………………………….………..…(22)

Where:
R_{WCS} = Recharge due to Water Conservation Structures
GS = Gross Storage = Storage Capacity multiplied by the number of fillings.
RF= Recharge Factor

3.5.1.11 Lateral flow along with the aquifer system (Throughflow)

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 an 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 modeling with well-defined flow boundaries. Once the modeling is complete, the lateral through flows (LF) across boundaries for any assessment unit can be obtained from the model. In case of Lateral Flow is calculated using a computer model, the same should be included in the water balance equation.

3.5.1.12 Baseflow and Stream Recharge

If stream gauge stations are located in the assessment unit, the base flow and recharge from streams can be computed using the 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 centers, educational institutes, or NGOs may also be used to improve the estimates on base flows.

Baseflow 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 groundwater modeling techniques. Digital filters are available for separating the base flow component of the stream hydrograph.

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

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

3.5.1.13 Vertical Inter-Aquifer Flow

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

3.5.1.14 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 the 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 the 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 the estimation of actual evapotranspiration. Assessing offices may apply available lysimeter data or other techniques for the estimation of evapotranspiration. In cases where such data is not available, evapotranspiration losses can be empirically estimated from PET data provided by IMD.

3.5.1.15 Recharge/ Accumulations during Monsoon Season

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

3.5.1.16 Recharge/ Accumulations during Non-Monsoon Season

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

3.5.1.17 Total Annual Ground-Water Recharge

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

3.5.2 Annual Extractable Groundwater Resource (EGR)

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

In case base flow contribution to the ecological flow of rivers is not determined then the following assumption is to be followed. In the water level fluctuation method, a significant portion of the 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 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 the water level fluctuation method this will be 5% of the annual recharge and if it is assessed using the rainfall infiltration factor method, it will be 10% of the annual recharge. The balance will account for Annual Extractable Groundwater Resources (EGR).

3.5.2.1 *Estimation of Groundwater Extraction*

Groundwater draft or extraction is to be assessed as follows.

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

Where,

GE_{ALL}=Groundwater extraction for all uses

GE_{IRR}=Groundwater extraction for irrigation

GE_{DOM} =Groundwater extraction for domestic uses

GE_{IND} = Groundwater extraction for industrial uses

3.5.2.2 *Groundwater Extraction for Irrigation (GE_{IRR}):*

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

Unit Draft Method:

In this method, a season-wise unit draft of each type of well in an assessment unit is estimated. The unit draft of different types (e.g., Dug well, dug cum bore well, shallow tube well, deep tube, bore, etc.) is multiplied by the number of wells of that particular type to obtain season-wise groundwater extraction by that particular structure. This method is being widely practiced in the country. Several sources maintain records on the well census. These include the 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 the good census should be maintained for resource computation at all India levels. 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 groundwater abstraction structures. The database on crop area is obtained from Revenue records in the Tehsil office, Agriculture Census, and also by using Remote Sensing techniques.

Power Consumption Method:

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

3.5.2.3 Groundwater 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, the unit draft of each type of well is multiplied by the number of wells used for domestic purposes to obtain the domestic groundwater draft.

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

GE_{DOM}= Population X Consumptive Requirement X Lg ……………………….……(24)
Where,
Lg = Fractional Load on Groundwater for Domestic Water Supply

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

3.5.2.4 *Groundwater 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, the unit draft of each type of well is multiplied by the number of wells used for the industrial purpose to obtain the industrial groundwater extraction.

Consumptive Use Pattern Method: **–** In this method, the water consumption of different industrial units is determined. The number of Industrial units that are dependent on groundwater is multiplied by unit water consumption to obtain groundwater draft for industrial use.

GE_{IND}= Number of industrial units X Unit Water Consumption X Lg ………. (25)

Where,

Lg = Fractional load on groundwater for industrial water supply

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

Groundwater extraction obtained from different methods need to be compared and based on field checks, the seemingly best value may be adopted. At times, groundwater 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 groundwater extraction during that particular period.

3.5.3 *Stage of Groundwater Extraction*

The stage of groundwater extraction is defined by,

$$\textit{Stage of Groundwater Extraction}\ (\%) = \frac{\text{Existing gross groundwater extraction for all uses}}{\text{Annual Extractable Groundwater Resources}} * 100 \quad \ldots\ldots\ldots\textbf{(26)}$$

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

3.5.3.1 Validation of Stage of Groundwater Extraction

The assessment based on the stage of groundwater extraction has inherent uncertainties. The estimation of groundwater 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 groundwater. The denominator in equation 26, namely Annual Extractable Groundwater Resources also has uncertainties due to limitations in the assessment methodology, as well as uncertainties in the data. Because of this, it is desirable to validate the „Stage of Groundwater Extraction" with a long-term trend of groundwater levels.

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

In interpreting the long-term trend of groundwater 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 groundwater development. Such a trend indicates that there is a balance between recharge, extraction, and natural discharge in the unit. However, further groundwater development may be possible, which may result in a new stable trend at a lower groundwater level with associated reduced natural discharge.

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

Table 7 Stage of Groundwater Extraction based on Ground water Level Trend

SOGWE	Groundwater 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, an assessment should be attempted. If the mismatch persists even after reassessment, the subunit may be categorized based on the Stage of Groundwater Extraction of the reassessment. However, the subunit should be flagged for strengthening of observation well network and parameter estimation.

3.5.3.2 Categorization of Assessment Units

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

3.5.3.3 Categorization of Assessment Units Based on Quantity:

The categorization based on the status of groundwater quantity is defined by the Stage of Groundwater extraction as given below:

Table 8 Stage of Ground water Extraction based on Quantity

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

In addition to this Category, every assessment subunit should be tagged with a potentiality tag indicating its groundwater potentiality viz. Poor Potential (Unit Recharge <0.025m), moderate potential (Unit Recharge in between 0.025 and 0.15m), and high potential (Unit Recharge > 0.15m)

3.5.3.4 Categorization of Assessment Units Based on Quality

GEC 1997 proposed the categorization of assessment units based on groundwater extraction only.

To adequately inform management decisions, the quality of groundwater is also an essential criterion. The Committee deliberated upon the possible ways of categorizing the assessment units based on groundwater quality in the assessment units. It was realized that based on the available water quality monitoring mechanism and available database on groundwater quality it may not be possible to categorize the assessment units in terms of the extent of the 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 groundwater monitoring data of State Groundwater Departments and/or Central Groundwater Board. If any of the three quality hazards in terms of Arsenic, Fluoride, and Salinity are encountered in the assessment subunit in mappable units, the assessment subunit may be tagged with the particular Quality hazard.

3.5.4 *Allocation of Groundwater Resources for Utilization*

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

Alloc = 22 X N X L_g mm per year ………………………………………..…(27)

Where

Alloc= Allocation for domestic water requirement

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

L_g = fractional load on groundwater 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 the 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.

3.5.4.1 *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 Groundwater Recharge. The resulting groundwater potential is termed as the net annual groundwater availability for future use. The Net annual groundwater 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 groundwater 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 groundwater available for future uses will be zero.

3.5.4.2 *Additional Potential Resources under Specific Conditions*

Potential Resource Due to Spring Discharge:

Spring discharge constitutes an additional source of groundwater in hilly areas which emerges at the places where groundwater level cuts the surface topography. The spring discharge is equal to the groundwater recharge minus the outflow through evaporation and evapotranspiration and vertical and lateral sub-surface flow. Thus Spring Discharge is a form of „Annual Extractable Groundwater Recharge‟. It is a renewable resource, though not to be used for Categorization. Spring discharge measurement is to be carried out by volumetric measurement of the 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 for spring discharges, the discharge measurement should be made at least 4 times a year in parity with the existing water level monitoring schedule.

Potential groundwater resource due to springs = Q x No of days ……….….(28)
Where
Q = Spring Discharge
No of days = No of days spring yields.

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". However, the resource calculated by the water level fluctuation approach is likely to lead to the underestimation of recharge in areas with the 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 groundwater reservoir should be drawn to the optimum limit before the onset of monsoon, to provide adequate scope for its recharge during the following monsoon period.

In the area where the groundwater 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, groundwater resources may be estimated up to 5m bgl only assuming that where the 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 evidence that this 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/ Firka.

The computation of potential resources to groundwater reservoir can be done by adopting the following equation:

Potential groundwater resource in shallow water table areas = (5-D) x A x S_Y ……..(29)

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

A = Area of shallow water table zone.

S_Y = Specific Yield

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

This potential recharge to groundwater is available only after the 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 groundwater potential in the overall area.

Potential Resource in Flood-Prone Areas:

Groundwater recharge from a floodplain is mainly the function of the following parameters-

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

Since the collection of data on all these factors is time-consuming and difficult, in the meantime, the potential recharge from floodplains 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 groundwater resource in Flood Prone Areas = 1.4 x N x A/1000 ……..(30)

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

Apportioning of Groundwater Assessment from Watershed to Development Unit:

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

A block may comprise one or more watersheds, in part or full. First, the groundwater assessment in the subareas, command, non-command, and poor groundwater quality areas of the watershed may be converted into depth units (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 groundwater resource of the block.

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

Assessment of In-Storage Groundwater Resources or Static Groundwater Resources

The quantum of groundwater 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 groundwater development, it is necessary to restrict it to dynamic resources. Static or in-storage groundwater resources could be considered for development during exigencies that are also for drinking water purposes. It is also recommended that no irrigation development schemes based on static or in-storage groundwater resources be taken up at this stage.

Assessment of In-storage groundwater 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 Groundwater Resources in northwest India. Such estimation presents a larger-scale scenario. A more precise estimation of groundwater depletion in the over-exploited area based on actual field data can be obtained by estimating the Change in In-storage during successive assessments. Thus In-storage computation is necessary not only for estimation of emergency storage available for utilization in case of natural extremities (like drought) but also for an assessment of storage depletion in over-exploited areas for sensitizing stakeholders about the damage done to the environment.

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

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

Where,

SGWR = Static or in-storage Groundwater 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

Assessment of Total Groundwater Availability in Unconfined Aquifer The sum of Annual Exploitable Groundwater Recharge and the In-storage groundwater resources of an unconfined aquifer is the Total Groundwater Availability of that aquifer.

3.6 GROUNDWATER ASSESSMENT OF CONFINED AQUIFER SYSTEM

Assessment of groundwater resources of confined aquifers assumes crucial importance, since over-exploitation of these aquifers may lead to far more detrimental consequences than 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 its specific yield. Because of the small amounts of water released from storage in the confined aquifers, large-scale pumpage from confined aquifers may cause a decline in piezometric levels amounting to over a hundred meters and subsidence of land surface posing serious geotechnical problems.

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

$\Delta V = S \Delta h$ ……………..(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

$Q = A \Delta V = SA \Delta h$ ……………..(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 a confined aquifer is associated with the compressibility of the aquifer matrix and the 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 groundwater 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 groundwater potential. The quantity of water released in a confined aquifer due to a change in pressure can be computed between the piezometric head (h_t) at any given time 't' and the bottom of the top confining layer (h_o) by using the following equation.

$Q_p = SA\Delta h = SA (h_t - h_0)$ …………….(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 groundwater resources of the confined aquifer, there is a need to have a sufficient number of observation wells tapping exclusively that particular aquifer and proper monitoring of the piezometric heads is also needed.

Dynamic Groundwater Resources of Confined Aquifer

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

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

Where
Q_D = Dynamic Groundwater 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)

In storage Groundwater Resources of Confined Aquifer

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

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

Where
Q_I =In storage Groundwater 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 the 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.

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

Where

Q_p = In storage Groundwater 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 a post-monsoon period (m amsl) h_0 = Bottom of the Top Confining Layer (m amsl)

The calculated resource includes a small amount of dynamic resource of the confined aquifer, 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.

Assessment of Total Groundwater Availability of Confined Aquifer

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

Groundwater assessment of semi-confined aquifer system

The Assessment of Groundwater 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 overlying 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 underestimate rather than 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 a methodology similar to that used in assessing the resources of Confined aquifers.

Total groundwater availability of an area

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

Groundwater assessment in urban areas

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

Even though the data on existing groundwater abstraction structures are available, accuracy is somewhat doubtful and individuals cannot even enumerate the good census in urban areas. Hence it is recommended to use the difference of the actual demand and the supply by surface water sources as the withdrawal from the groundwater resources.

The urban areas are sometimes concrete jungles and rainfall infiltration is not equal to that of rural areas unless and until special measures are taken in the construction of roads and pavements. Hence, it is proposed to use 30% of the rainfall infiltration factor proposed for urban areas as an Adhoc arrangement till field studies in these areas are done and documented field studies are available.

Because of the water supply schemes, there are many pipelines available in the urban areas and the seepages from these channels or pipes are huge in some areas. Hence this component is also to be included in the other resources and the recharge may be estimated. The percent losses may be collected from the individual water supply agencies, 50% of which can be taken as recharge to the groundwater system.

In the urban areas in India, normally, there are no separate channels either open or sub-surface for drainage and flash floods. These channels also recharge to some extent the groundwater reservoir. As of today, there is no documented field study to assess the recharge. The seepages from the sewerages, which normally contaminate the groundwater resources with nitrate also contribute to the number of resources and hence the same percent as in the case of water supply pipes may be taken as a norm for the recharge on the quantity of sewerage when there is subsurface drainage system. If estimated flash flood data is available, the same percentage can be used on the quantum of flash floods to estimate the recharge from the flash floods. Even when the drainage system is open channels, till further documented field studies are done same procedure may be followed.

It is proposed to have a separate groundwater assessment for urban areas with a population of more than 10 lakhs.

Groundwater assessment in coastal areas

The Assessment of Groundwater Resources in coastal areas is similar to that of other areas. Because of the nature of hydraulic equilibrium of groundwater with seawater care should be taken in assessing the groundwater resources of this area. While assessing the resources in these areas, the following few points are to be considered.

The groundwater resources assessment in coastal areas includes the areas where the influence of seawater has an effect on the existence of fresh water in the area. It can be demarcated from the Coastal Regulatory zone or the Geomorphological maps or from the maps where seawater influences are demarcated.

Wherever the pre-monsoon and post-monsoon water levels are above mean sea level the dynamic component of the estimation will be the same as other areas.

If both these water levels are below sea level, the dynamic component should be taken as zero.

Wherever the post-monsoon water table is above sea level and the pre-monsoon water table is below sea level the pre-monsoon water table should be taken as at sea level and fluctuation is to be computed.

The static or in-storage resources are to be restricted to a minimum of 40 times the pre-monsoon water table or the bottom of the aquifer.

Groundwater assessment in water level depletion zones

There may be areas where the groundwater level shows a decline even in the monsoon season. The reasons for this may be any one of the following: (a) There is a genuine depletion in the groundwater regime, with groundwater extraction and natural groundwater discharge in the monsoon season (outflow from the region and baseflow) exceeding the recharge. (b) There may be an error in water level data due to the inadequacy of observation wells.

If it is concluded that the water level data is erroneous, a recharge assessment may be made based on the rainfall infiltration factor method. If, on the other hand, water level data is assessed as reliable, the groundwater level fluctuation method may be applied for recharge estimation. As ΔS in Equations 3& 4 is negative, the estimated recharge will be less than the gross groundwater extraction in the monsoon season. It must be noted that this recharge is the gross recharge minus the natural discharges in the monsoon season. The immediate conclusion from such an assessment in water depletion zones will be that the area falls under the over-exploited category which requires micro-level study.

Micro-level study for notified areas

In all areas that are 'Notified' for groundwater regulation by the Central and/ or State Groundwater Authorities, it is necessary to increase the density of observation wells for carrying out micro-level studies to reassess the groundwater recharge and draft. The following approach may be adopted:

1. The area may be subdivided into different hydrogeological sub-areas and recharge areas, discharge areas, and transition zones, and also on quality terms.

2. The number of observation wells should be increased to represent each such sub-area with at least one observation well with continuous monitoring of water levels.

3. Hydrological and hydrogeological parameters particularly the specific yield should be collected for different formations in each sub-area.

4. Details regarding other parameters like seepage factor from canals and other surface water projects should be collected after field studies, instead of adopting recommended norms. Baseflow should be estimated based on stream gauge measurement.

5. The data of several existing structures and unit drafts should be reassessed after fresh surveys and should match the actual irrigation pattern in the sub-area.

6. All data available with the Central Groundwater Board, State Groundwater Departments, and other agencies including research institutions and universities, etc. should be collected for the watershed/sub-areas and utilized for reassessment.

7. Groundwater assessment for each sub-area may be computed adopting the recommended methodology and freshly collected values of different parameters. The assessment may be made separately for monsoon and non-monsoon periods as well as for command, non-command, and poor groundwater quality areas.

8. The groundwater potential so worked out may be cross-checked with the behavior of groundwater levels in the observation wells and both should match. If it does not, the factor

that causes such an anomaly should be identified and the revised assessment should be re-examined.

9. Based on the micro-level studies, the sub-areas within the unit and the unit as a whole may be classified adopting norms for categorization as recommended elsewhere in the methodology.

Norms to be used in the assessment

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

Specific Yield

Recently under the Aquifer Mapping Project, the Central Groundwater Board has classified all the aquifers into 16 Principal Aquifers which in turn were divided into 42 Major Aquifers. Hence, it is required to assign Specific Yield values to all these aquifer units. The Major aquifer map can be obtained from the regional offices of the Central Groundwater Board.

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

Rainfall Infiltration Factor

It is recommended to assign Rainfall Infiltration Factor values to all the aquifer units recently classified by the Central Groundwater Board. The recommended Rainfall Infiltration Factor values are to be used for assessment unless sufficient data based on field studies are available to justify the minimum, maximum, or other intermediate values. An additional 2% of rainfall recharge factor may be used in such areas or parts of the areas where watershed development with associated soil conservation measures are implemented. This additional factor is subjective and is separate from the contribution due to the water conservation structures such as check dams, nalla bunds, percolation tanks, etc. The norms for the estimation of recharge due to these structures are provided separately. This additional factor of 2% is at this stage, only provisional, and will need revision based on pilot studies.

The Norms suggested below are the redistribution of norms suggested by GEC-1997 methodology and hence people are encouraged to conduct field studies and strengthen the Norms database.

Norms for Canal Recharge

Unlike other norms, the Recharge factor for calculating Recharge due to canals is given in two units viz. ham/million m^2 of wetted area/day and cusecs per million m2 of wetted area. As all other norms are in ham, the committee recommends the norm in ham/million m2 of wetted area for computing the recharge due to canals. There is a wide variation in the values of the recharge norms proposed by GEC 1997. The Canal seepage norm is approximately 150 times the other recharge norms. In the absence of any field studies to refine the norms, it is decided by the committee to continue with the same norms. The committee strongly recommends that each state agency must conduct one field study at least once in each district before completing the first assessment using this methodology. The committee also suggests a recommended value and minimum and maximum values as in the case of other norms. Where specific results are available from case studies in some states, the Adhoc norms are to be replaced by norms evolved from these results.

The Norms suggested in Table 9 below are the rationalization and redistribution of norms suggested by GEC-1997 methodology and hence people are encouraged to conduct field studies and strengthen the Norms database.

Norms for Recharge Due to Irrigation

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

10m. Similarly, the norm recommended for 25m may be used for water levels more than 25m as well. The Recommended Norms are presented in Table 10.

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

Norms for Recharge due to Tanks & Ponds

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

Norms for Recharge due to Water Conservation Structures

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

The norm for Per Capita Requirement

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

Norm for Natural Discharges

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

Unit Draft

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

$$Unit\ Draft = Discharge\ in\ m^3/hr \times No.\ of\ \ Pumping\ hrs\ in\ a\ day \times No.\ of\ \ days \qquad \textbf{38}$$

One basic drawback in the methodology of computing unit draft is that there is no normalization procedure for the same. As per GEC-1997 guidelines, the recharge from rainfall is normalized for normal rainfall. It means that even though the resources are estimated in a surplus rainfall year or a deficit rainfall year, the assessment is normalized for a normal rainfall which is required for planning. For recharge from other sources, average figures/ values are taken. If the average figures are not available for any reason,60% of the design figures are taken. This procedure is essential as the planning should be for average resources rather than for the recharge due to excess rainfall or deficit rainfall. However, the procedure that is being followed for the computing unit draft does not have any normalization procedure. Normally, if the year in which one collects the draft data in the field is an excess rainfall year, the abstraction from groundwater will be less. Similarly, if the year of the computation of the unit draft is a drought year the unit draft will be high. Hence, there is a requirement to devise a methodology that can be used for the normalization of unit draft figures. The following are the two simple techniques, which can be followed. If the unit draft values for one rainfall cycle are available for at least 10 years second method shown in equation 40 is to be followed or else the first method shown in equation 39 may be used.

$$Normalized\ Unit\ Draft = \frac{Unit\ Draft \times Rainfall\ \ for\ the\ Year}{Normal\ \ Rainfall} \qquad \textbf{39}$$

$$Normalized\ Unit\ Draft = \frac{\sum_{i=1}^{n} Unit\ Draft_i}{Number\ of\ Years} \qquad \textbf{40}$$

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

CHAPTER – 4

PROCEDURE FOLLOWED IN THE PRESENT ASSESSMENT INCLUDING ASSUMPTIONS

4.0. DYNAMIC GROUND WATER RESOURCES ESTIMATION

The Dynamic Ground Water Resource of Jammu and Kashmir UT has been assessed as per the GEC-2015 Methodology by taking the District as a Unit of Assessment. At present, there are a total of 20 Districts in the UT of Jammu and Kashmir, which represent the entire geographical area of the UT. The block boundaries and other technical details in respect of Blocks are not available. The Minor Irrigation Census for tube wells for the year 2019-20 has been carried out by the Agriculture Department for 20 Districts. As such, 20 Districts have been considered (Refer to **Fig–1** for Administrative Base Map) for this study, assessing Dynamic Ground Water Resources for which the multidisciplinary data have been provided by the following Agencies:

Central Ground Water Board, North Western Himalayan Region, Jammu.

Irrigation & Flood Control Department, Jammu and Kashmir.

Public Health Engineering Department, Jammu and Kashmir.

Agriculture Department Jammu and Kashmir.

Indian Meteorological Department, Pune, and Jammu and Kashmir.

Industries Department Jammu & Kashmir.

The water level data for the year 2017-22 has been used for calculation of average monsoon recharge which has been normalized as per GEC-2015 guidelines. The unit draft figures for the year 2020-21 on a pro-rata basis have been made available by Agriculture and Irrigation & Flood Control Department and part from the Digest of Statistics of UT of J& K year 2020-21. The block-wise figures of population provided by the Census Department GOI have been used as per the 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 District-wise water use requirement figures for Industry as supplied by the Department of Industries, Jammu and Kashmir for the year 2020 have been used by projecting the data on a 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 UT of Jammu and Kashmir, the canal data has been obtained from the various Canal Divisional Offices, and I & FC Department, Jammu and Kashmir have been updated and taken into the calculations.

The value of Specific Yield for calculating the Dynamic Ground Water Resource of the State has been taken as 02 to 20% which is within the norms provided in the guidelines of GEC-2015 issued by the Ministry of Water Resources, River Development and Ganga Rejuvenation, 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: -

The various dependency factors for the calculation of domestic ground water consumption have been taken from the GEC-2015 Methodology of CGWB.

The various modifications have been incorporated based on the various inputs made available from CGWB, Agriculture, Irrigation, the University's Department of Jammu and Kashmir, and other agencies associated with this estimation.

The present estimation is as follows: -

The geographical area of Districts is taken from the digest of statistics year 2020-21, wherein certain discrepancies in boundary areas, however, information given in the form of digitized boundary of each district was utilized to arrive total geographical area of districts. Out of which, part of the valley and hilly areas were demarcated using toposheets and updated Digital Elevation Model (DEM) data taken from various resources. In the hilly region, the geographical area calculated by using DEM data and Toposheets after demarcation of the hilly area having a slope less than 20% has been considered for ground water worthy area in the Ground Water Estimation.

A uniform value of Specific Yield has been adopted instead of a soil-related value. The value of Sp. Yield, as adopted has been taken in between 02-20% for the Jammu and Kashmir.

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

For this Report, the Agriculture Department and Digest of Statistics have supplied district-wise areas under Paddy/Non-Paddy crops on a pro-rata basis. Data for the Number of Tube wells was supplied by the Agriculture Department, Irrigation & Flood Control Department, and Digest of Statistics.

For this Report, the Agriculture Department and Digest of Statistics have supplied district-wise areas under Paddy/Non-Paddy crops on a pro-rata basis. Data for the Number of Tube wells was supplied by the Agriculture Department, Irrigation & Flood Control Department, and Digest of Statistics (2020-2021).

The District-wise industrial draft figures supplied by the Department of Industry and the digest of statistics have been used in this report as new data not supplied by the Department of Industry. It was decided that the Ground Water Extraction by industries may be calculated as per the growth rate of 1.5% per annum on a pro-rata basis of population growth rate i.e. 1.5% per annum.

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

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

Districts where more than 96.5% of its geographical area has groundwater level less than 5 m (below ground level) have been considered "Safe".

CHAPTER – 5

COMPUTATION OF GROUND WATER RESOURCES ESTIMATION IN UT of JAMMU AND KASHMIR

5.0. SALIENT FEATURES OF DYNAMIC GROUND WATER RESOURCES

The ground water resource assessment of J&K UT has been computed as per GEC-15 Methodology and the computations and its various details are given in **Annexure 1 to Annexure 3**. The abstract of Dynamic Ground Water Assessment is as follows: -

Table 9. Dynamic Ground Water Resources Assessment	
Net annual ground water availability	446326.49 ham
Existing GW draft for irrigation	31549.52 ham
Existing GW draft for industrial use	5414.82 ham
Existing GW draft for domestic use	71059.55 ham
Existing GW draft for all uses	108023.94 ham
Average stage of GW extraction of UT	24.20 %

The Net Annual Ground Water Availability for the period 2023 works out to be 446326.49 ham. The gross ground water draft for all uses has been worked out to be 108023.94 ham. The existing gross ground water draft for all uses has been observed to be maximum in Jammu district as 32440.72 Ham and minimum in Kishtwar district as 230.81 Ham. The Average Annual Recharge figures for all the districts from rainfall and other sources have been calculated and indicated in **Annexure- 5.** The district-wise ground water draft for irrigation and other uses (domestic and industrial use) is given in **Annexure- 4.** Domestic and Industrial water use demand for the next 25 years has been taken in this estimation. The district-wise ground water availability of Jammu and Kashmir UT vis-a-vis the ground water draft and net ground water availability for future irrigation Development have been depicted in **Annexure-6**. The district-wise stage of ground water development varies from 12.41 % in Rajouri district to a maximum of 78.21 % in Srinagar Urban Area **(Annexure 6) (Figure 13).**

Out of a total of 20 assessment units taken for study, “Over-Exploited and critical districts are Nil, whereas the Srinagar Urban area was assessed to be “Semi-Critical” and 19 Districts (80%) are in “Safe” category. **(Table 10) (Figure 14)**.

Table 10. Type of Assessment Units

Type of Assessment Units	District
No. of Assessment Units taken for Study	20
Years of Collection of Data (5 years)	2018-23
Year of Projection of Report	2023
No. of Over-Exploited District	0
No. of Critical District	0
No. of Semi-Critical District	1
No. of Safe District	19

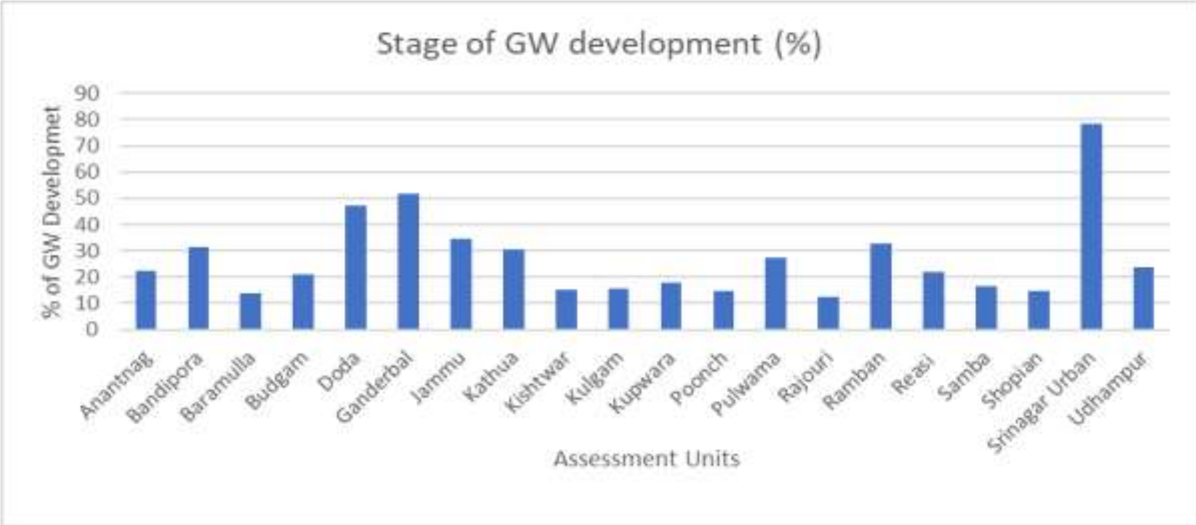


Figure 13. Stage of groundwater Development in %.

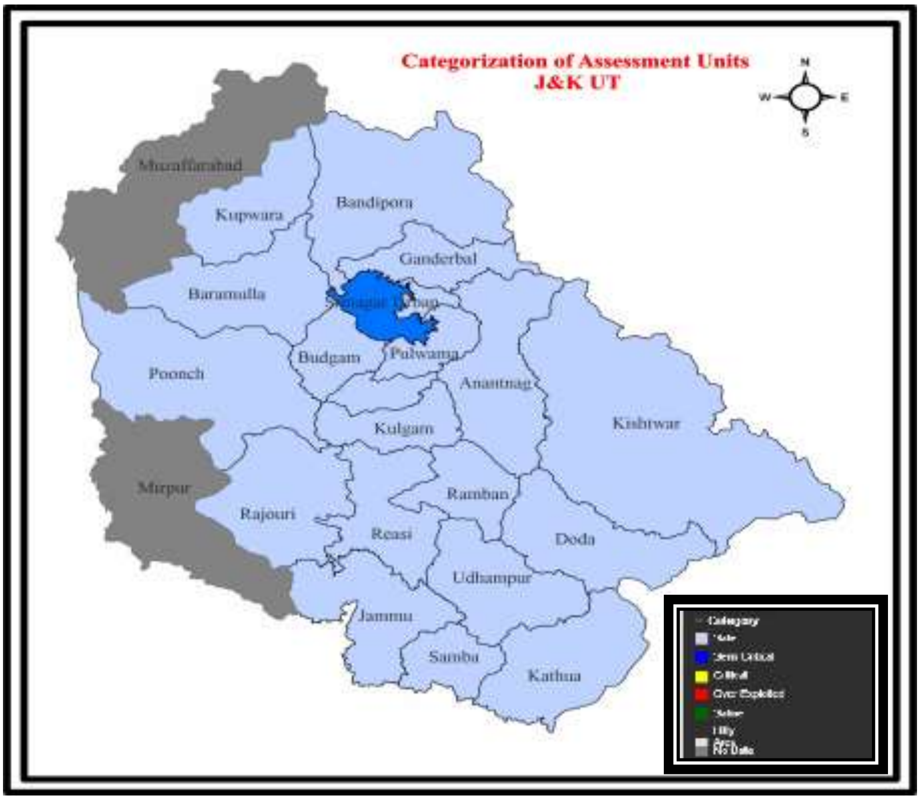


Figure 14. Categorization Of Assessment Unit UT Of J&K.

5.1. METHOD ADOPTED FOR COMPUTING RAINFALL RECHARGE DURING MONSOON SEASON

The Administrative District has been taken as an assessment unit for computing the district rainfall recharge during monsoon season. The rainfall Infiltration Factor (RIF) Method has been mostly applied as the difference of computing this with the Water Level Fluctuations (WLF) Method. WLF Method was not considered due to random and erratic data and found to be not much decline tread for study. The district-wise details of the method applied for rainfall recharge during the monsoon season are shown in **Annexure 5**.

5.2. GROUND WATER ASSESSMENT COMPARISON OF PREVIOUS STUDIES

The number of district categories of overexploited/critical/semi-critical/safe time as per various Ground Water Estimation Studies carried out from time to time, as shown below in **Table: 11.**

Table 11 Ground Water Assessment Comparison

Study Year	2004	2009	2011	2013	2017	2020	2022	2023
Category of District								
Dark / Over- exploited	-	-	-	-	-	-	-	-
Dark /Critical	-	-	-	-	-	-	-	-
Grey / Semi Critical	-	-	-	-	-	-	1	1
White/ Safe	12	12	20	20	20	20	19	19
Total	12	12	20	20	20	20	20	20

5.3. SPATIAL VARIATION OF GROUND WATER RECHARGE AND DEVELOPMENT SCENARIO

The annual ground water recharge and the method adopted for computing monsoon recharge for the previous 2022 study and the present 2023 study have been compared in **Annexure-5.** Similarly, Categorization for Future Ground Water Development and the Stage of Ground Water development for each assessment unit of this study as a whole has also been compared with previous studies as shown in **Annexure-7.**

5.4. CONCLUSION

The Dynamic Ground Water Estimation has been done as per the GEC-2015 Methodology adopted by CGWB and based on data observed in the field for the last five years i.e. 2018-22. The Administrative District has been taken as an assessment unit for computing the district rainfall recharge during monsoon season. The rainfall Infiltration Factor (RIF) Method has been mostly applied as the Water Level fluctuation (WLF) Method was not considered due to random and erratic data.

There is no overexploitation of Ground Water for the agriculture requirement of the UT, as surface water is limited to certain parts of the UT and there is a good scope for development of ground water in agriculture, drinking, and Industrial uses. The overall stage of ground water extraction of the UT is 24.20 % as estimated in this report. As per this report, all 19 assessment units are in the “safe” category. While 1 assessment unit i.e. Srinagar Urban Area is under Semi-critical category. There is no change in the category of assessment units in comparison to the previous year.

ANNEXURE 1: GENERAL DESCRIPTION OF THE ADMINISTRATIVE UNIT OF THE JAMMU & KASHMIR UT, AS ON 31.3.2023									
S. No.	**Name of Assessment Unit (Part of the district)**	**Type of rock formation**	**Areal Extent (in Hectares)**						
			Total Geographical Area	**Hilly Area**	**Ground Water Recharge**		**Shallow Water Table Area**	**Flood Prone Area**	**Bottom of the unconfined aquifer in soft rock areas and depth of weathered zone and/or maximum depth of fractures under unconfined zone(m)**
					Command Area/Non-Command Area	**Poor Ground Water Quality Area**			
1	**2**	**3**	**4**	**5**	**6**	**8**	**9**	**10**	**11**
1	**Anantnag**	Alluvial Soil	357400	291689	65711	NIL	NIL	NIL	25
2	**Kulgam**	Alluvial Soil	41000	26600	14400	NIL	NIL	NIL	25
3	**Pulwama**	Alluvial Soil	108600	51100	57500	NIL	NIL	NIL	10
4	**Shopian**	Alluvial Soil	31200	7800	23400	NIL	NIL	NIL	10
5	**Srinagar Urban**	Alluvial Soil	197900	110400	87500	NIL	NIL	NIL	15
6	**Ganderbal**	Alluvial Soil	25900	23500	2400	NIL	NIL	NIL	15
7	**Budgam**	Alluvial Soil	136100	78100	58000	NIL	NIL	NIL	14
8	**Baramulla**	Alluvial Soil	424300	311800	112500	NIL	NIL	NIL	9
9	**Bandipora**	Alluvial Soil	34500	31172	3328	NIL	NIL	NIL	9
10	**Kupwara**	Alluvial Soil	237900	177900	60000	NIL	NIL	NIL	12
11	**Jammu**	Alluvial Soil	234200	68989	165211	NIL	8219	NIL	120
12	**Samba**	Alluvial Soil	90400	45611	44789	NIL	1092	NIL	120
13	**Udhampur**	Alluvial Soil	263700	241853	21847	NIL	NIL	NIL	9
14	**Reasi**	Alluvial Soil	171900	164900	7000	NIL	NIL	NIL	9
15	**Kathua**	Alluvial Soil	250200	172700	77500	NIL	4458	NIL	120
16	**Doda**	Alluvial Soil	891200	888955	2245	NIL	NIL	NIL	7
17	**Kishtwar**	Alluvial Soil	164400	162400	2000	NIL	NIL	NIL	7
18	**Ramban**	Alluvial Soil	132900	131069	1831	NIL	NIL	NIL	10
19	**Rajouri**	Alluvial Soil	263000	228000	35000	NIL	NIL	NIL	10
20	**Poonch**	Alluvial Soil	167400	143137	24263	NIL	NIL	NIL	5
			4224100	**3357675**	**866425**				

ANNEXURE 2: DATA VARIABLES USED IN DYNAMIC GROUND WATER RESOURCES OF THE JAMMU & KASHMIR UT, AS ON 31.3.2023						
Sr. No	**Assessment Unit**	**Poor GW Quality**	**Rainfall (mm)**	**Average Pre-Monsoon Water Level (mbgl)**	**Average Post-Monsoon Water Level (mbgl)**	**Average Fluctuation (m)**
1	**2**	**3**	**4**	**5**	**6**	**7**
1	**Anantnag**	0	1235.1	NA	NA	NA
2	**Kulgam**	0	1235.1	NA	NA	NA
3	**Pulwama**	0	721.8	NA	NA	NA
4	**Shopian**	0	1235.1	NA	NA	NA
5	**Srinagar Urban**	0	721.8	NA	NA	NA
6	**Ganderbal**	0	721.8	NA	NA	NA
7	**Budgam**	0	721.8	NA	NA	NA
8	**Baramulla**	0	1535.1	NA	NA	NA
9	**Bandipora**	0	1069.1	NA	NA	NA
10	**Kupwara**	0	993.9	NA	NA	NA
11	**Jammu**	0	1338.7	NA	NA	NA
12	**Samba**	0	1338.7	NA	NA	NA
13	**Udhampur**	0	2198.3	NA	NA	NA
14	**Reasi**	0	2198.3	NA	NA	NA
15	**Kathua**	0	1338.7	NA	NA	NA
16	**Doda**	0	1262.8	NA	NA	NA
17	**Kishtwar**	0	1262.8	NA	NA	NA
18	**Ramban**	0	1350.2	NA	NA	NA
19	**Rajouri**	0	2198.3	NA	NA	NA
20	**Poonch**	0	1458.1	NA	NA	NA

ANNEXURE 3: DATA VARIABLES USED IN DYNAMIC GROUND WATER RESOURCES OF THE JAMMU & KASHMIR UT, as on 31.3.2023						
S. N.	**Assessment Unit**	**Assessment Sub-Unit**	**Type of Structures**	**Irrigation**	**Domestic**	**Industrial**
1	**Anantnag**	Non-Commanad	STW (ELECTRIC & DIESEL)	80	485	35
2	**Kulgam**	Non-Commanad	STW (ELECTRIC & DIESEL)	28	225	27
3	**Pulwama**	Non-Commanad	STW (ELECTRIC & DIESEL)	171	463	16
4	**Shopian**	Non-Commanad	STW (ELECTRIC & DIESEL)	45	431	25
5	**Srinagar Urban**	Non-Commanad	STW (ELECTRIC & DIESEL)	8	695	63
6	**Ganderbal**	Non-Commanad	STW (ELECTRIC & DIESEL)	40	12	2
7	**Budgam**	Non-Commanad	STW (ELECTRIC & DIESEL)	19	541	13
8	**Baramulla**	Non-Commanad	STW (ELECTRIC & DIESEL)	68	694	7
9	**Bandipora**	Non-Commanad	STW (ELECTRIC & DIESEL)	2	87	1
10	**Kupwara**	Non-Commanad	STW (ELECTRIC & DIESEL)	3	565	10
11	**Jammu**	Non-Commanad	STW (ELECTRIC & DIESEL)	1790	1040	271
12	**Samba**	Non-Commanad	STW (ELECTRIC & DIESEL)	61	212	12
13	**Udhampur**	Non-Commanad	STW (ELECTRIC & DIESEL)	83	187	23
14	**Reasi**	Non-Commanad	STW (ELECTRIC & DIESEL)	17	84	7
15	**Kathua**	Non-Commanad	STW (ELECTRIC & DIESEL)	381	604	0
16	**Doda**	Non-Commanad	STW (ELECTRIC & DIESEL)	15	25	123
17	**Kishtwar**	Non-Commanad	STW (ELECTRIC & DIESEL)	9	23	4
18	**Ramban**	Non-Commanad	STW (ELECTRIC & DIESEL)	17	114	5
19	**Rajouri**	Non-Commanad	STW (ELECTRIC & DIESEL)	191	291	5
20	**Poonch**	Non-Commanad	STW (ELECTRIC & DIESEL)	205	233	5

ANNEXURE 4: Parameters Used In The Assessment Of Dynamic Ground Water Resources Of The Jammu & Kashmir UT, as on 31.3.2023										
S. No.	Assessment unit	Sub-unit (Command/non-Command/poor quality)	Specific Yield (in %)	Rainfall Infiltration Factor (in %)	Ground Water Draft (in ham)					
			Formation Value	Formation Value	Irrigation		Domestic		Industrial	
					Monsoon	Non-Monsoon	Monsoon	Non-Monsoon	Monsoon	Non-Monsoon
1	Anantnag	Nil	16	22	189.36	231.44	1682.4	3415.9	12.474	25.326
2	Kulgam	Nil	16	22	66.276	81.004	780.52	1584.7	9.6228	19.537
3	Pulwama	Nil	16	22	808.9	988.65	1606.1	3260.9	5.7024	11.578
4	Shopian	Nil	16	22	58.32	71.28	748.13	1518.9	8.91	18.09
5	Srinagar Urban	Nil	16	22	27.76	56.32	2411.7	4892.8	218.61	443.52
6	Ganderbal	Nil	16	22	189.22	231.26	41.628	84.516	3.4406	6.9854
7	Budgam	Nil	16	22	89.878	109.85	1876.7	3810.3	19.89	9.4068
8	Baramulla	Nil	16	22	321.67	393.15	2407.5	4887.9	8.085	16.415
9	Bandipora	Nil	16	22	9.4608	11.563	100.49	204.02	1.155	2.345
10	Kupwara	Nil	16	22	14.191	17.345	1960	3979.3	11.55	23.45
11	Jammu	Nil	16	22	10382	10901	3608.8	7321.6	940.37	1907.8
12	Samba	Nil	16	22	587.17	440.42	735.42	1493.1	41.62	84.5
13	Udhampur	Nil	16	22	392.62	479.87	648.7	1317	39.703	80.61
14	Reasi	Nil	16	22	80.417	98.287	291.39	591.62	24.283	49.301
15	Kathua	Nil	16	22	3291.8	2468.9	2095.3	4254	426.68	866.29
16	Doda	Nil	16	22	70.95	86.7	86.75	176	5.8	11.8
17	Kishtwar	Nil	16	22	14.175	17.325	79.786	161.99	4.62	9.38
18	Ramban	Nil	16	22	26.775	32.725	131.67	267.33	5.775	11.725
19	Rajouri	Nil	16	22	300.83	367.68	1009.5	2049.5	5.775	11.725
20	Poonch	Nil	16	22	322.88	394.63	808.27	1641	5.775	11.725

ANNEXURE 5: Assessment Of Dynamic Ground Water Resources Of The Jammu & Kashmir UT as on 31.3.2023 (continued)..								
		Ground Water Recharge						
		Monsoon Season		Non-Monsoon Season				
S. No	Assessment Unit/District	Recharge from rainfall	Recharge from Other Sources	Recharge from Rainfall	Recharge from Other Sources	Total Annual Ground Water Recharge	Total Natural Discharges	Annual Extractable Ground Water Resource
1	2	3	4	5	6	7	8	9
1	**Anantnag**	4892.06	7761.42	12963.08	2013.1	27629.66	2762.96	24866.7
2	**Bandipora**	184.65	516.14	598.1	9.3	1308.19	130.82	1177.37
3	**Baramulla**	9157.5	19690.9	28836.22	6688.11	64372.73	6437.27	57935.46
4	**Budgam**	2604.32	18610.8	6605.85	3618.81	31439.78	3143.98	28295.8
5	**Doda**	96.31	661.15	187.19	161.07	1105.72	110.58	995.14
6	**Ganderbal**	107.76	528.9	273.35	287.82	1197.83	119.79	1078.04
7	**Jammu**	40664.23	41281.3	12172.41	7990.22	102108.16	8409.27	93698.89
8	**Kathua**	18699.68	13411.33	5710.04	10059.18	47880.23	4788.04	43092.19
9	**Kishtwar**	188.76	745	366.87	390	1690.63	169.07	1521.56
10	**Kulgam**	1072.05	7787.4	2840.75	2121.38	13821.58	1382.16	12439.42
11	**Kupwara**	3329.04	17403.2	10783.08	5467.41	36982.73	3698.27	33284.46
12	**Poonch**	1591.22	10246.4	5615.96	2659.02	20112.6	2011.26	18101.34
13	**Pulwama**	2581.86	15025.21	6548.9	3376.43	27532.4	2753.24	24779.16
14	**Rajouri**	10492.44	14807.3	4278.95	7557.19	37135.88	3713.59	33422.29
15	**Ramban**	120.08	665.55	423.81	349.63	1559.07	155.9	1403.17
16	**Reasi**	2404.71	2596.28	980.67	1117.29	7098.95	709.9	6389.05
17	**Samba**	8363.41	8264.01	3299.96	3476.67	23404.05	2340.4	21063.65
18	**Shopian**	1742.08	8140.4	4616.21	3575.33	18074.02	1807.4	16266.62
19	**Srinagar Urban**	2966.34	472.42	7524.12	631.48	11594.36	1159.44	10434.92
20	**Udhampur**	6104.51	5708.02	3060.67	2850.41	17723.61	1642.35	16081.26
	Total (Ham)	**117363.01**	**194323.13**	**117686.19**	**64399.85**	**493772.18**	**47445.69**	**446326.49**
	Total (Bcm)	**1.17**	**1.94**	**1.18**	**0.64**	**4.94**	**0.47**	**4.46**

ANNEXURE 6: ASSESSMENT OF DYNAMIC GROUND WATER RESOURCES OF THE JAMMU & KASHMIR UT, as on 31.3.2023.								
S. No	Assessment Unit/District	Current Annual Ground Water Extraction				Annual GW Allocation for Domestic Use as on 2025	Net Ground Water Availability for future use	Stage of Ground Water Extraction(%)
		Irrigation	Industrial	Domestic	Total			
1	2	10	11	12	13	14	15	16
1	Anantnag	420.8	34.83	5098.32	5553.95	5098.32	19312.75	22.33
2	Bandipora	21.02	3.5	345.28	369.81	428.61	724.23	31.41
3	Baramulla	714.82	20.9	7295.33	8031.05	7295.33	49904.41	13.86
4	Budgam	188.96	29.3	5686.99	5905.25	5686.99	22390.55	20.87
5	Doda	157.65	17.6	296.11	471.36	364.66	455.23	47.37
6	Ganderbal	420.48	10.43	126.14	557.06	553.82	93.3	51.67
7	Jammu	19123.4	2848.21	10469.11	32440.72	10911.64	60815.64	34.62
8	Kathua	4576.46	1292.98	7283.68	13153.11	7350.27	29872.49	30.52
9	Kishtwar	31.5	14	185.31	230.81	185.31	1290.75	15.17
10	Kulgam	147.28	29.16	1776.81	1953.25	1776.81	10486.17	15.7
11	Kupwara	31.54	35	5939.28	6005.81	5939.28	27278.65	18.04
12	Poonch	717.5	17.5	1939.25	2674.26	1939.25	15427.08	14.77
13	Pulwama	1854.45	17.28	4867.06	6738.79	4867.06	18040.37	27.2
14	Rajouri	668.5	17.5	3462.84	4148.85	3516.65	29219.64	12.41
15	Ramban	59.5	17.5	381.08	458.08	409.66	916.51	32.65
16	Reasi	178.7	73.58	1147.31	1399.6	1195.27	4941.49	21.91
17	Samba	1147.57	126.12	2221.36	3495.05	2241.26	17548.69	16.59
18	Shopian	129.6	27	2267.06	2423.66	2267.06	13842.96	14.9
19	Srinagar Urban	87.28	662.13	7412.15	8161.56	8049.81	1635.7	78.21
20	Udhampur	872.5	120.31	2859.1	3851.91	2923.74	12164.71	23.95
	Total (Ham)	**31549.52**	**5414.82**	**71059.55**	**108023.94**	**73000.8**	**336361.32**	**24.2**
	Total (Bcm)	**0.32**	**0.05**	**0.71**	**1.08**	**0.73**	**3.36**	**24.2**

ANNEXURE 7: COMPARISON OF STAGE OF GROUND WATER EXTRACTION & CATEGORIZATION OF PREVIOUS AND PRESENT STUDY, OF THE JAMMU & KASHMIR UT.										
Sr. No	**Assessment Unit (Block)/ District**	**Stage of Ground Water Development (%)**								**Categorization for future ground water development (Safe/semi-critical /critical/over-exploited**
		2004	**2009**	**2011**	**2013**	**2017**	**2020**	**2022**	**2023**	
1	**Anantnag**	4.83	10.64	11.07	15.48	18.66	20.85	22.33	22.33	SAFE
2	**Bandipora**	NA	NA	NA	44.17	50.29	12.22	31.06	31.41	SAFE
3	**Baramulla**	9.18	9.85	9.6	10.21	29.61	11.71	13.48	13.86	SAFE
4	**Budgam**	14.29	29.91	26.81	26.82	29.28	23.28	20.87	20.87	SAFE
5	**Doda**	NA	18.9	19.51	21.48	31.13	44.61	47.02	47.37	SAFE
6	**Ganderbal**	NA	NA	NA	28.15	24.53	32.81	55.18	51.67	SAFE
7	**Jammu**	17.62	22.83	18.36	25.66	31.53	25.71	35.72	34.62	SAFE
8	**Kathua**	12.42	18.93	17.8	20.35	31.45	27.29	29.39	30.52	SAFE
9	**Kishtwar**	NA	NA	NA	5.87	10.48	12.18	15.1	15.17	SAFE
10	**Kulgam**	NA	NA	NA	30.24	33.64	21.64	20.43	15.7	SAFE
11	**Kupwara**	16.93	23.57	25.76	18.39	22.47	10.52	18.04	18.04	SAFE
12	**Poonch**	NA	32.94	40.11	33.64	31.24	12.05	14.28	14.77	SAFE
13	**Pulwama**	8.38	27.42	28.82	24.71	26.59	38.01	26.69	27.2	SAFE
14	**Rajouri**	NA	34.18	31.39	33.88	41.56	7.11	10.56	12.41	SAFE
15	**Ramban**	NA	NA	NA	48.92	11.31	29.78	32.35	32.65	SAFE
16	**Reasi**	NA	NA	NA	43.79	62.03	20	21.96	21.91	SAFE
17	**Samba**	NA	NA	NA	28.83	29.96	14.4	16.58	16.59	SAFE
18	**Shopian**	NA	NA	NA	24.51	29.14	10.84	14.9	14.9	SAFE
19	**Srinagar Urban**	45.71	62.28	65.73	66.25	32.02	58.51	73.85	78.21	SEMI – CRITICAL
20	**Udhampur**	NA	37.61	48	27.66	38.81	16.65	23.83	23.95	SAFE
	Total:	**13.74**	**21.97**	**21.08**	**26.32**	**29.46**	**21.00**	**24.18**	**24.20**	**SAFE**

APPENDIX 1

GOVERNMENT OF JAMMU AND KASHMIR,
GENERAL ADMINISTRATION DEPARTMENT.
CIVIL SECRETARIAT, J&K.

Subject:- Constitution of a standing Union territory Level Committee for assessment of Ground Water Resources in the Union territory of Jammu and Kashmir.

Ref: **U.O No. JSD-PS04/13/2021-PLG received from Jal Shakti Department.**

Government Order No:1053-JK(GAD) of 2023
Dated:30-08-2023

Sanction is hereby accorded to constitution of a standing Union territory Level Committee, comprising the following, for assessment of Ground Water Resources in the Union territory of Jammu and Kashmir:-

1	Administrative Secretary, Jal Shakti Department	**Chairman**
2	Administrative Secretary, Planning, Development & Monitoring Department	**Member**
3	Director Rural Sanitation, J&K	Member
4	Director Agriculture, Jammu/Kashmir	Member(s)
5	Director Industries, Jammu/Kashmir	Member(s)
6	Chief Engineer, Jal Shakti (PHE), Jammu/Kashmir	Member(s)
7	Chief Engineer, Jal Shakti (I&FC), Jammu/Kashmir	Member(s)
8	Regional Director, Central Ground Water Board, Jammu	Member Secretary
9	General Manager, NABARD, Jammu	Member
10	Representative of Central Water Commission	Member
11	Representative from Rural Development Department & SKUAST Jammu/Kashmir	Member(s)
12	Representative of Geology & Mining Department (not below the rank of Additional Secretary).	Member
13	Representative of Forest, Ecology & Environment Department (not below the rank of Additional Secretary).	Member
14	Any other Officer to be co-opted by the Chairman of the Committee, if required.	Special Invitee

Terms of Reference:-

i) To ensure the assessment of annual ground water recharge of the Union territory.

ii) To work on ground water assessments for water year (June to May) in accordance with the approved latest methodology.

iii) To adopt improved procedures and practices wherever possible for the sake of achieving greater accuracy of assessment.

iv) To supervise the estimation of status of utilization of the annual ex-tractable ground water resource as in specified water year.

The Committee shall be serviced by the Jal Shakti Department.

By order of Government of Jammu and Kashmir.

Sd/-
(Sanjeev Verma) IAS
Commissioner/Secretary to the Government
Dated: 30.08.2023

No. GAD-ADM0IV/23/2022-09-GAD

Copy to the:-

1. All Financial Commissioners (Additional Chief Secretaries).
2. Director General of Police, J&K.
3. All Principal Secretaries to the Government.
4. Principal Secretary to the Hon'ble Lieutenant Governor, J&K.
5. Joint Secretary (J&K) Ministry of Home Affairs, Government of India, New Delhi.
6. All Commissioner/Secretaries to the Government.
7. Chief Electoral Officer, J&K.
8. Divisional Commissioner, Kashmir/Jammu.
9. Director Information, J&K.
10. All Deputy Commissioners.
11. All Heads of Department/Managing Directors/Secretary, Advisory Boards.
12. Registrar General, J&K High Court.
13. Secretary, J&K Public Service Commission/SSB/BoPEE.
14. Director, Archives, Archaeology and Museums, J&K.
15. Director Rural Sanitation, J&K.
16. Director Agriculture, Jammu/Kashmir.
17. Director Industries, Jammu/Kashmir.
18. Chief Engineer, Jal Shakti (PHE), Jammu/Kashmir.
19. Chief Engineer, Jal Shakti (I&FC), Jammu/Kashmir.
20. Regional Director, Central Ground Water Board, Jammu.
21. General Manager, NABARD, Jammu.
22. Private Secretary to the Chief Secretary, J&K.
23. Private Secretary to Advisor (B) to the Lieutenant Governor.
24. Private Secretary to Commissioner/Secretary to the Government, GAD.
25. Government Order/Stock file/Website, GAD. Hindi and Urdu version shall follow.

30.08.23

(Malik Suhail) JKAS
Deputy Secretary to the Government

CONTRIBUTORS

1. DEPARTMENT OF JAL SHAKTI, GOVT OF J&K UT

Chairman of UT Level GWAC

Chief Engineer, Irrigation & Flood Control Department Jammu, J&K UT.

Contributors

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2. CENTRAL GROUND WATER BOARD, NWHR, JAMMU

Overall Guidance

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