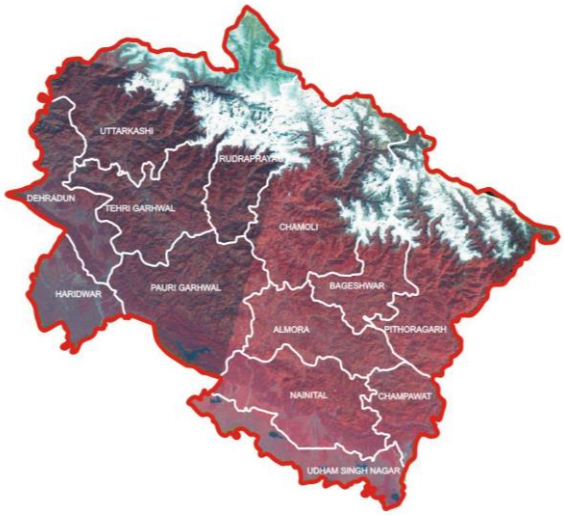
GROUND WATER YEAR BOOK

भू जल वार्षिक पुस्तिका

UTTARAKHAND

उत्तराखण्ड

2022-2023



GOVERNMENT OF INDIA

भारत सरकार

CENTRAL GROUND WATER BOARD

केंद्रीय भूमि जल बोर्ड

UTTARANCHAL REGION, DEHRADUN

उत्तरांचल क्षेत्र, देहरादून

DEPARTMENT OF WATER RESOURCES, RD & GR

जल संसाधन, नदी विकास और गंगा संरक्षण विभाग

MINISTRY OF JAL SHAKTI

जल शक्ति मंत्रालय

JULY-2023

जुलाई-२०२३

GROUND WATER YEAR BOOK
भू जल वार्षिक पुस्तिका
UTTARAKHAND
उत्तराखण्ड
(2022-2023)

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DEPARTMENT OF WATER RESOURCES, RIVER DEVELOMENT AND GANGA REJUVINATION
CENTRAL GROUND WATER BOARD, UTTARANCHAL REGION
GOVERNMENT OF INDIA
Dehradun
July-2023

प्रस्तावना

जल नीले ग्रह "पृथ्वी" पर जीवन को बनाए रखने के लिए आवश्यक प्राकृतिक संसाधनों में से एक है। जनसंख्या में तेजी से वृद्धि के कारण विश्व स्तर पर ताजे/उपयोग योग्य पानी की मांग में कई गुना वृद्धि हुई है, जिसके कारण कृषि पैटर्न में बदलाव और औद्योगिक गतिविधियों में वृद्धि हुई है। विभिन्न क्षेत्रों के ताजे पानी की मांग को पूरा करने के लिए भूजल संसाधनों पर भारी दबाव है क्योंकि सतही जल प्रदूषण दिन-प्रतिदिन बढ़ता जा रहा है। इसके परिणामस्वरूप देश के कई हिस्सों में जल स्तर में गिरावट आई है क्योंकि भूजल निकासी इसके भरण से आगे निकल गया है।

भूजल एक सीमित संसाधन होने के कारण इसके शासन पर कोई प्रतिकूल प्रभाव डाले बिना दीर्घकालिक आधार पर मांग को पूरा करने के लिए उचित प्रबंधन और इसके भंडारण के विवेकपूर्ण उपयोग की आवश्यकता है। इस उद्देश्य को पूरा करने के लिए, केंद्रीय भूमि जल बोर्ड देश भर में फैले भूजल निगरानी कुओं के नेटवर्क के माध्यम से भूजल शासन के व्यवहार की निगरानी करता है। प्रत्येक राज्य में ऐसे कुओं से एकत्र किए गए आंकड़ो को संकलित, संसाधित करने के पश्चात् मुख्य विशेषताओं को **"भूजल वार्षिक पुस्तिका"** के रूप में प्रकाशित किया जाता है। वर्तमान रिपोर्ट वर्ष 2022-**2023** के लिए उत्तराखंड राज्य से संबंधित है। केंद्रीय भूमि जल बोर्ड, उत्तरांचल क्षेत्र, उत्तराखंड राज्य के मैदानी और पहाड़ी क्षेत्रों में 229 भूजल निगरानी कुओं के माध्यम से विभिन्न हाइड्रोजियोलॉजिकल सेटिंग के तहत भूजल संशाधन की निगरानी देहरादून, हरिद्वार, नैनीताल, उधमसिंह नगर, चंपावत, अल्मोड़ा, पौड़ी गढ़वाल और उत्तरकाशी जिले में एक वर्ष में चार बार (जनवरी, मई, अगस्त और नवंबर) कर रहा है। राज्य के पहाड़ी क्षेत्रों में 41 झरनों की भी निगरानी की जा रही है।

माप की विशिष्ट अवधि के साथ-साथ दशक के लिए उतार-चढ़ाव को दर्शाते हुए विषयगत मानचित्रों के साथ जिलेवार भूजल स्तर का विवरण प्रस्तुत किया गया है। भूजल आंकड़ो को क्षेत्रीय कार्यालय, देहरादून के डेटा स्टोरेज सेंटर में उपयुक्त प्रारूप में संग्रहीत किया गया है।

वर्तमान भूजल वार्षिक पुस्तक, 2022-**2023** सुश्री अंजली कुशवाहा, वैज्ञानिक-'बी' (हाइड्रोजियोलॉजी) एवं सुश्री चंद्रेयी डे, वैज्ञानिक-'ग' (हाइड्रोजियोलॉजी) के द्वारा किए गए प्रयास का परिणाम है। भूजल स्तर के आंकड़ो को फील्ड अधिकारियों के परिश्रम से संकलित किया गया है। पानी के नमूनों का विश्लेषण करने वाले रासायनिक प्रयोगशाला, केंद्रीय भूमि जल बोर्ड, उत्तरी क्षेत्र, लखनऊ के अधिकारियों का प्रयास भी उल्लेखनीय हैं। मानचित्रों के माध्यम से उत्तराखण्ड राज्य के भूजल परिदृश्य को दर्शाने तथा इस रिपोर्ट को उचित रूप देने का प्रयास अत्यंत सराहनीय है।

इस रिपोर्ट में प्रस्तुत जानकारी और डेटा उपयोगकर्ता एजेंसियों, भूजल योजनाकारों और प्रबंधकों के लिए एक डेटाबेस के रूप में काम करेगा और उत्तराखंड राज्य में भूजल विकास के मात्रात्मक और गुणात्मक पहलुओं पर क्षेत्रीय तस्वीर को समझने के लिए अत्यधिक उपयोगी होगा।

स्थान : देहरादून
दिनांक :25.07.2023

(प्रशांत राय)
कार्यालय प्रमुख

FOREWORD

WATER is one of the essential natural resources for sustaining life on blue planet "**Earth**". The demand of fresh / usable water has increased manifold globally due to rapid growth in population, which in turn caused change in agricultural pattern and increase in industrial activities. To meet the demand of fresh water of various sectors, there is an enormous stress on ground water resources as the surface water pollution is increasing day by day. This has resulted in the water level decline in many parts of the country as the output has outstripped input of this resource.

Ground water being a limited resource requires proper management and judicious use of its storage for meeting out demand on long term basis without putting any adverse impact on its regime. To meet this objective, Central Ground Water Board monitors the behaviour of ground water regime through a network of Ground Water Monitoring Wells spread across the country. The data collected from such wells in each state are compiled, processed and the salient features brought out as a "**Ground Water Year Book**". The present report pertains to the State of Uttarakhand for the year 2022-2023.

Central Ground Water Board, Uttaranchal Region is monitoring the groundwater regime under various hydrogeological setting through **229 ground water monitoring wells** in plain and hilly areas of Uttarakhand State, viz. Dehradun, Haridwar, Nainital, Udham Singh Nagar, Champawat, Almora, Pauri Garhwal and Uttarkashi districts four times in a year (January, May, August and November). In the hilly areas of the State Forty-one springs are also being monitored.

The district wise details of ground water levels are presented along with thematic maps depicting the fluctuations for specific period of measurement as well as for the decade. The data has been stored in appropriate format in the data storage centre of the Regional Office, Dehradun.

The present Ground Water Year Book, 2022-2023 is the outcome of the effort made by Ms. Anjali Kushwaha, Scientist- 'B' (Hydrogeology) and Ms. Chandreyee De, Scientist- 'C'(Hydrogeology). The inputs data is generated by the untiring efforts of officers in the field. The efforts from officers of Chemical Laboratory, CGWB, NR, Lucknow who analysed the water samples is also noteworthy. The efforts in depicting the groundwater scenario of Uttarakhand State through maps and giving proper shape to this report, is highly appreciable.

The information and data presented in this report will serve as a database to the user agencies, ground water planners and managers and will be of immense use to understand the regional picture on the quantitative and qualitative aspects of ground water development in the State of Uttarakhand.

Place: Dehradun
Date :25.07.2023

(Prashant Rai)
Head of the Office

GROUND WATER YEAR BOOK
UTTARAKHAND
(2022-2023)

CONTENTS

TABLES

FIGURES

EXECUTIVE SUMMARY

The predominantly hilly Uttarakhand State was carved out of Uttar Pradesh in November 2000. The State comprises thirteen districts - Almora, Bageshwar, Chamoli, Champawat, Dehradun, Haridwar, Nainital, Pauri Garhwal, Pithoragarh, Tehri Garhwal, Rudraprayag, Udham Singh Nagar and Uttarkashi. The state is situated between latitude 28°43'20"N to 31°28'00"N and longitude 77°34'06"E to 81°01'31"E with a total geographical area of 53,483 km^2.

Uttarakhand State is broadly subdivided into two hydrogeomorphic units namely

1) Gangetic Alluvial Plain
2) Himalayan Mountain Belt.

Majority of area in the state falls under hilly terrain, except for Udham Singh Nagar, Haridwar and parts of Dehradun districts. Northern parts of the state remain under snow cover throughout the year. The drainage of the state is controlled by major rivers like Ganga (Gangotri) and Yamuna (Yamnotri), originating from the glaciers in high Himalayan Mountain Range and their tributaries like Ramganga, Kali, Saryu, Pindar etc. A variety of rock units ranging in age from Archean to Quaternary are exposed over the state. The rock units in the Himalayan Mountain regions have undergone repeated phases of deformation and metamorphism after their formation.

In the plain areas, ground water occurs in multi aquifer systems. Perched water bodies lying above the main water bearing formations are frequently encountered in Bhabar Zone and Doon Valley. Contrary to this, the occurrence of ground water in the hilly areas is limited to small, localized aquifers with limited ground water potential. Ground water in hilly terrains is found in the secondary porosity developed in crystalline igneous and metamorphic rocks in the form of fractures, joints and fissures. Low to moderate ground water potential exists in parts of the state where ground water is located in valley fill deposits of the alluvial plains and piedmont zones. The chemical quality of ground water is generally good and the water can be safely used for drinking, domestic and irrigation purpose.

During the period May 2022 to January 2023, ground water monitoring in the state was carried out in parts of Dehradun, Haridwar, Udham Singh Nagar, Nainital, Champawat, Pauri Garhwal, Almora and Uttarkashi districts. A number of dug wells, hand pumps and few piezometers, which are the part of Ground Water Monitoring Wells of Central Ground Water Board, were monitored in the plain areas of these districts during the months of January, May, August and November 2022.

The depth to water level maps and water level fluctuation maps viz. decadal, annual and seasonal water level fluctuations were generated by Arc GIS software. These maps were prepared district wise viz. Dehradun District, Haridwar District, Udham Singh Nagar District, Nainital District, and Champawat District.

To assess the behavior of ground water storage in space and time, the fluctuation in storage for each measurement has been evaluated with respect to decadal average value. A summary of depth to water level data in the State during the period January 2022 to November 2022 and the overall fluctuation pattern of ground water level (rise or decline) during the same period as compared to the long-term data (decadal average) are shown in tabular format below. Moreover, annual fluctuation of water level (for the corresponding periods of May, August, November and January) and the fluctuation pattern of ground water level during the periods August 2022, November 2022 (post monsoon) and January 2022 as compared to May 2022 (pre monsoon) are also given in separate tables.

Summary of Depth to Water Data in Uttarakhand during the Period 2022

State	Range of depth to water level (m bgl)	Percentage of Wells Analyzed			
		Jan 2023	May 2022	August 2022	Nov 2022
Uttarakhand	**0–5**	38.46	23.21	29.63	39.63
	5-10	20.11	23.81	29.63	23.78
	10-15	11.25	16.67	16.67	8.54
	>15	30.18	36.31	26.54	28.05

Fluctuation of Water Level during the Period 2022 (Compared to Decadal Average)

State	Fluctuation (m)	Percentage of Wells Analyzed							
		Avg. Jan		Avg. May		Avg. August		Avg. Nov	
		Rise	Decline	Rise	Decline	Rise	Decline	Rise	Decline
Uttarakhand	**0–2**	60.96	24.66	35.26	34.10	45.58	27.89	43.21	29.01
	2–4	6.16	4.79	5.78	11.56	7.48	9.52	9.26	5.56
	>4	2.05	1.37	6.94	6.36	6.12	3.40	8.64	4.94

Annual Fluctuation of Water Level during the Period 2022-23

State	Fluctuation (m)	Percentage of wells analyzed							
		May 2021 vs. 2022		August 2021 vs. 2022		November 2021 vs. 2022		January 2022 vs. 2023	
		Rise	Decline	Rise	Decline	Rise	Decline	Rise	Decline
Uttarakhand	**0–2**	42.86	39.61	21.29	66.45	44.97	48.32	71.71	17.11
	2–4	7.14	3.90	3.87	4.52	2.68	2.01	7.24	0.66
	>4	3.25	3.25	2.58	1.29	1.34	0.67	2.63	0.66

Seasonal Fluctuation of Water Level (Compared to May 2022)

State	Fluctuation (m)	Percentage of wells analyzed					
		August 2022		November 2022		January 2023	
		Rise	Decline	Rise	Decline	Rise	Decline
Uttarakhand	0–2	48.78	20.73	62.82	9.62	70.73	5.49
	2–4	12.80	3.05	16.03	0.64	9.76	1.22
	>4	13.41	1.22	10.90	0.00	5.49	0.00

A perusal of various maps viz. depth to water level maps and water level fluctuation maps reveals that in general, many areas of Doon Valley (Dehradun district), parts of Haridwar district and Tarai Zone in Udham Singh Nagar district have shown both rise and decline in water levels of various magnitudes in different temporal aspects. Fluctuation in water level is more conspicuous in the Bhabar Zone in Nainital and Champawat districts than in the relatively plain areas of Central Ganga Plains in Haridwar district and in the Tarai zone in Udham Singh Nagar district. This Bhabar zone shows high ground water level fluctuation due to steep hydraulic gradient.

Chemical analysis of Two hundred (200) ground water samples collected from ground water Monitoring Wells from parts of Dehradun, Haridwar, Pauri Garhwal, Udham Singh Nagar, Nainital, Champawat and Almora district were analysed at the Chemical Laboratory, Central Ground Water Board, North Region, Lucknow. The water samples were analyzed for fourteen parameters viz. Electrical Conductivity (EC), pH, carbonate, bicarbonate, chloride, sulphate, nitrate, fluoride, calcium, magnesium, sodium, potassium, silica and Total Hardness as $CaCO_3$.

The analysis of physico chemical parameters like Electrical Conductivity, chloride, nitrate and fluoride was done on the basis of data for pre-monsoon 2022. The available hydrochemical data in parts of District Dehradun, Haridwar, Udham Singh Nagar, Pauri Garhwal, Nainital, Champawat and Almora (premonsoon 2022) in Uttarakhand State reveals that ground water is fresh and potable and therefore, suitable for drinking and domestic purpose. As per the Piper Trilinear diagram, the ground water quality of Uttarakhand state is dominated by Ca-Mg cations and CO_3-HCO_3 anions. The U S Salinity diagram indicates that groundwater in major parts of the state is suitable for irrigation purposes in all types of soil. Groundwater of high salinity and low sodium content observed in few places of the state is indication of irrigation with semi-tolerant crops.

CHAPTER 1
INTRODUCTION

Ground water is a very important component of Earth's natural fresh water resource. Hence, ground water regime monitoring on periodic basis becomes essential for a safe and sustainable development and management of ground water resources of the hilly state of Uttarakhand. The directly measurable and often visible physical parameter of the otherwise invisible ground water system is the ground water level. Regular and systematic monitoring of ground water levels and evaluation of chemical parameters of ground water forms the base for scientific planning, development and management programs. Scientific information about the behaviour of water level in time and space becomes an essential exercise in this perspective. Indiscriminate withdrawal of ground water in rapidly developing urban and industrial areas poses a challenge to the scientific community. The challenge can be overcome by adopting sustainable ground water development and management practices.

Uttarakhand State lies between 28°43'20" – 31°28'00" N Latitude and 77°34'06" - 81°01'31" E Longitude and has a total geographical area of 53,483 km^2. The state has been divided into two Divisions and thirteen developmental blocks. Uttarakhand has a diverse hydrogeological set up. In order to assess the impact of continuously increasing stress on the ground water regime and to categorize various hydrogeological units in the State, systematic monitoring of ground water levels and spring discharge are being carried out four times in a year by the Central Ground Water Board, Uttaranchal Region, Dehradun through the Ground Water Monitoring Stations, which included periodic measurement of Springs discharge in the hilly terrain.

As on March 2022, a total of two hundred twenty-nine ground water monitoring stations exists in Uttarakhand State, which are being monitored by the regional office four times in a year. The map showing locations of Ground Water Monitoring Wells and Springs in Dehradun, Haridwar, Nainital, Udham Singh Nagar, Champawat, Almora and Pauri Garhwal districts is shown as ***Fig. 1.***

Chemical analysis of water samples, collected from selected locations within the state once in a year during the month of May (pre-monsoon monitoring), is being carried out to check whether any significant change is taking place in groundwater quality in time and space.

The main objectives of ground water regime monitoring in Uttarakhand may be summarized as follows:

1. To study the fluctuation of water level, both spatially and temporally, in response to ground water recharge and/or discharge.
2. To evaluate changes in ground water level with respect to the preceding year for the same period.
3. To evaluate changes in ground water level with respect to a long-term average water level such as the decadal mean.
4. To study the fluctuation of water level during different seasons of the period 2022.
5. To study the Hydrochemical behavior of shallow aquifers.

The district wise break up of Ground Water Monitoring Stations (including the springs in hilly terrain), which were monitored during the period from Jan 2022 to Nov 2022 is given in **Table 1.**

Table 1: District wise break up of active Ground Water Monitoring Stations (including Springs) monitored in Uttarakhand State

Sl. No.	District	Number of Ground Water Monitoring Stations			
		Jan 22	May 22	Aug 22	Nov 22
1.	Dehradun	53	53	53	50
2.	Haridwar	43	43	43	37
3.	Udham Singh Nagar	46	54	47	53
4.	Nainital	12	13	08	09
5.	Champawat	04	04	03	04
6.	Pauri Garhwal	02	02	02	02
7.	Almora	00	00	00	00
8.	Uttarkashi	09	09	09	09
TOTAL		169	178	165	164

Apart from the dug wells, hand pumps and piezometers, a total of thirty-four springs in hilly areas of Uttarakhand were also monitored (as on March 2023). The details of these springs during the period Jan 2022 to Nov 2022 are given in ***Table 2.***

Table 2: District wise break up of springs in Uttarakhand State

Sl. No.	District	Number of Springs			
		Jan 2023	May 2022	Aug 2022	Nov 2022
1.	Dehradun	3	3	3	3
2.	Nainital	7	7	7	7
3.	Almora	26	26	26	26
4.	Uttarkashi	4	4	4	4
TOTAL		40	40	40	40

District wise locations of the monitoring stations including springs of Uttarakhand State in given in the **figure 1**.

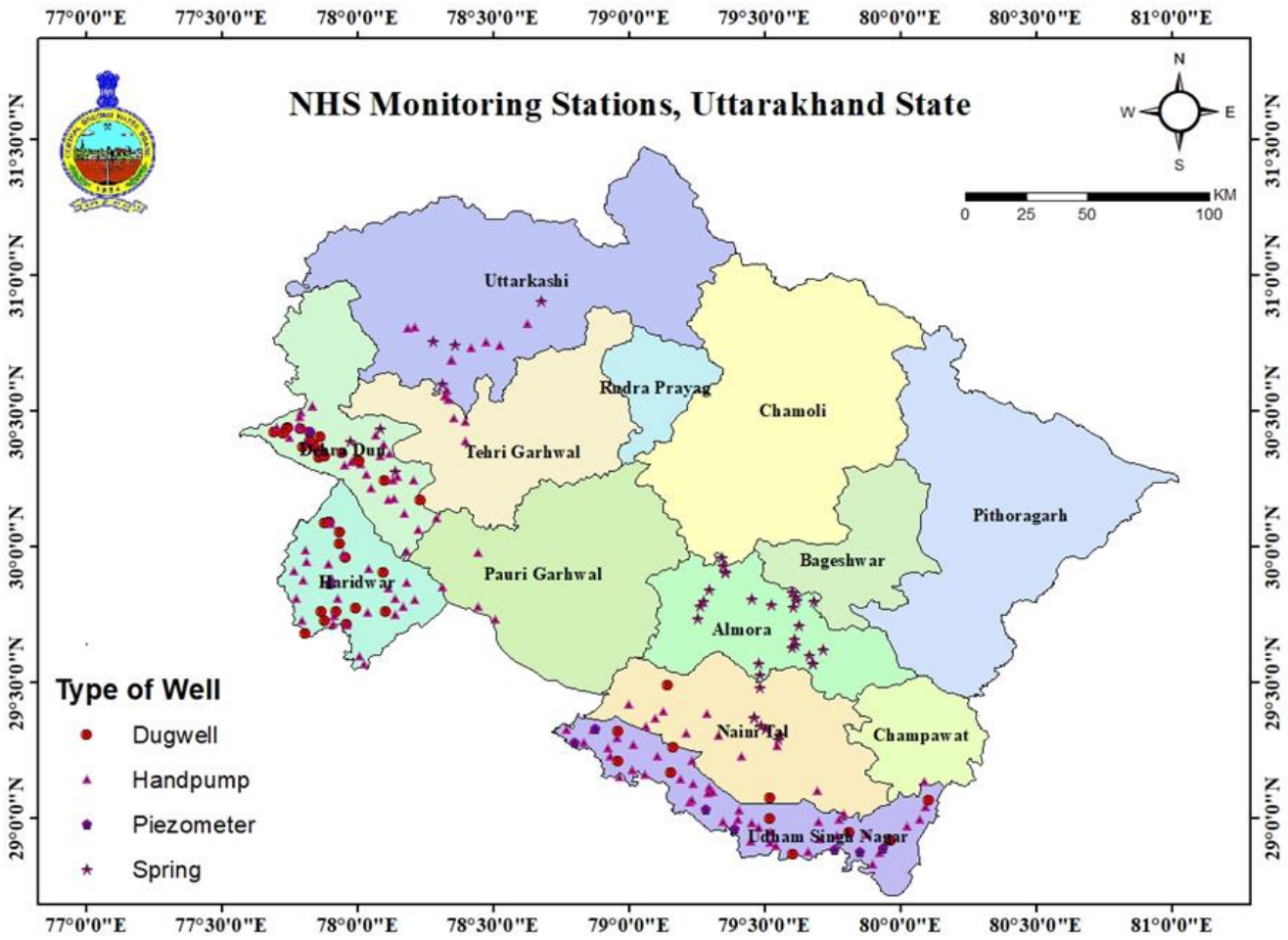


Figure 1: Location of Ground Water Monitoring Stations in Uttarakhand (As on March 2023)

CHAPTER 2
CLIMATE

The hilly parts of Uttarakhand experience cold climate and high rainfall. Significantly large part of the state remains under snow cover throughout the year. The intermontane valleys and the plain area in the southern part of the state experience a sub-tropical climate with three seasons – summer, monsoon and winter. The normal annual rainfall varies from 1182 mm in Haridwar district to 1927.30 mm in Pithoragarh district. The average annual rainfall varies from 1067.70 mm at Joshimath (Chamoli district) to 1927.30 mm at Munsyari (Pithoragarh district). Most of the rainfall occurs as monsoon rainfall during the months of July and August. The Isohyetal Map of Uttarakhand prepared using mean normal rainfall is given in **Fig. 2**. The map reveals that intensity of rainfall increases from SW to NW in a broadly linear pattern with high rainfall prevailing in both the eastern and the western parts of the state. The district wise normal monthly and annual rainfall data, available for fifty years (**1971 to 2020**) is given in **Table 3.**

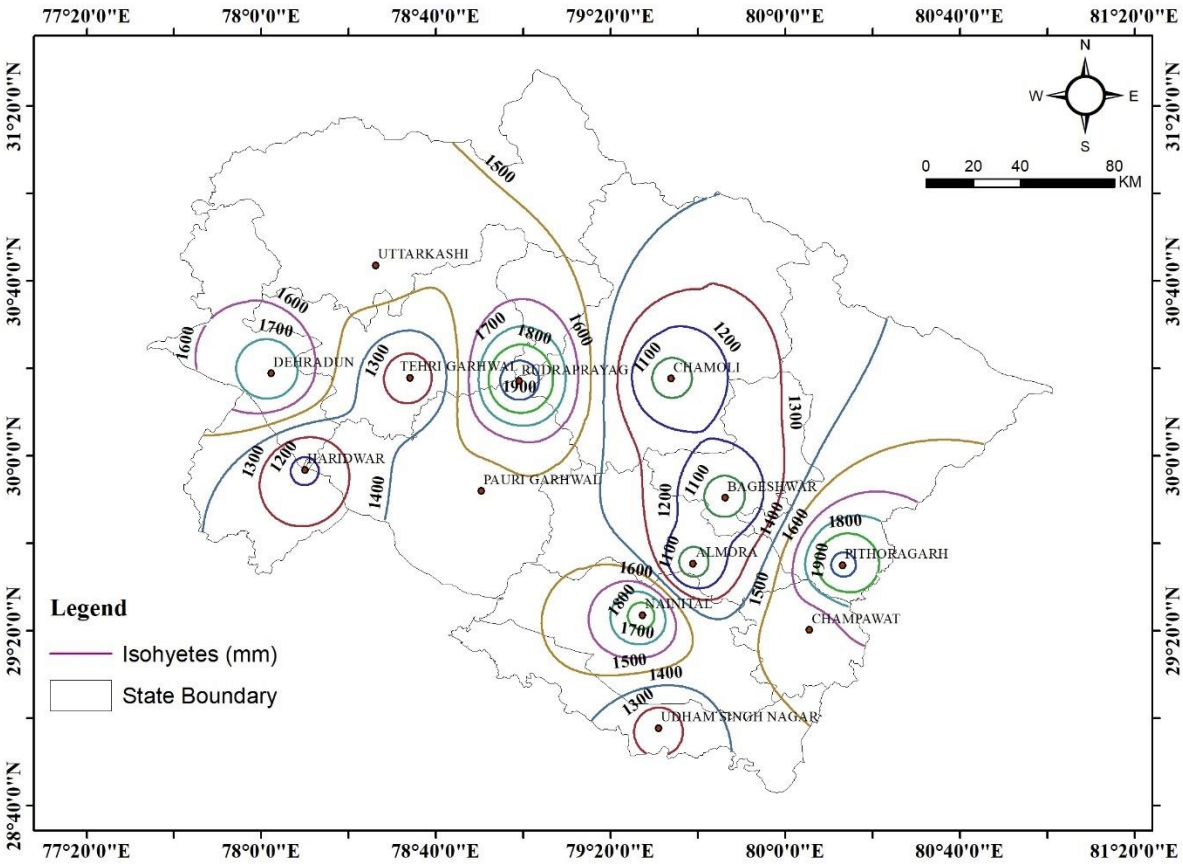
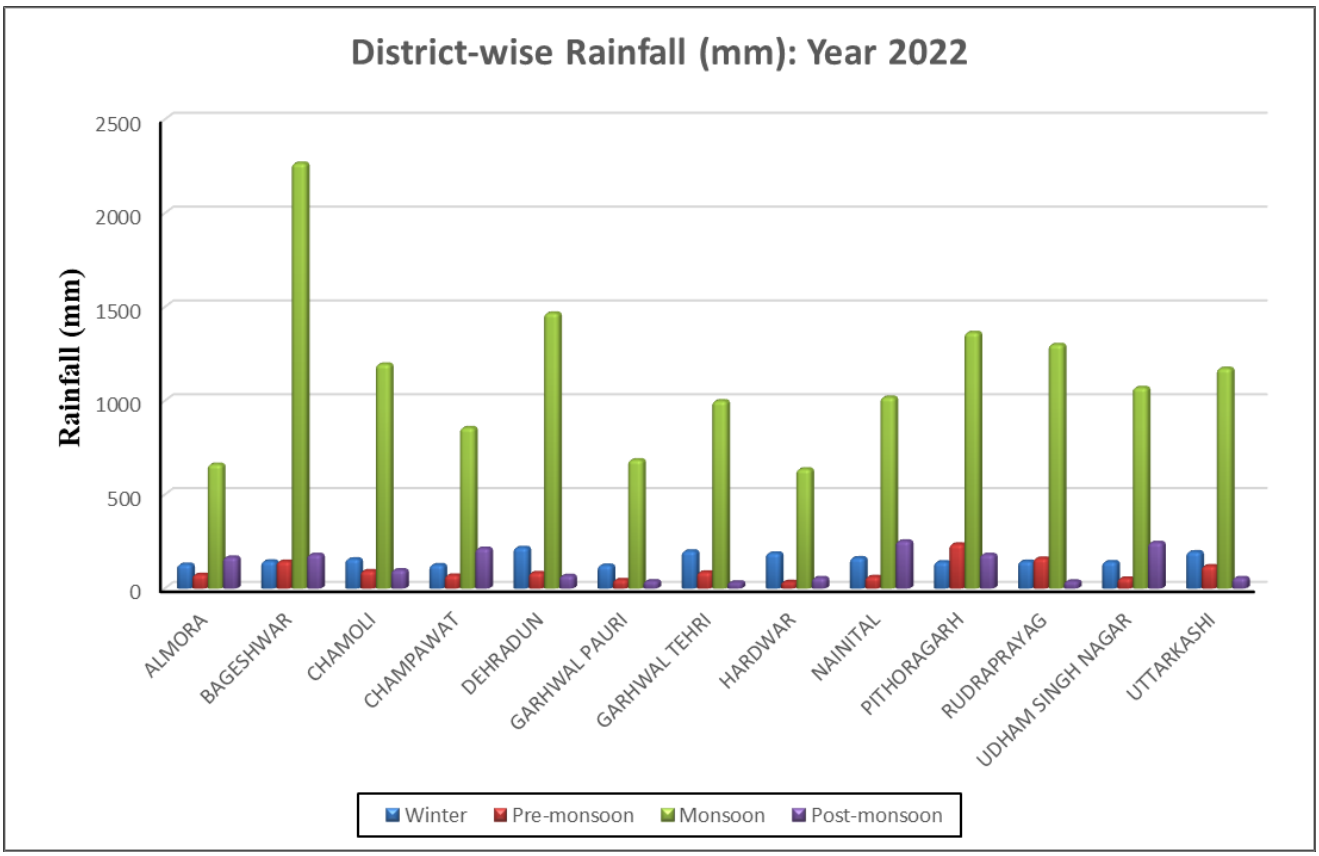


Fig. 2: Mean Isohyetal Map of Uttarakhand State



District-wise Actual Rainfall (mm) (Source: IMD)

Table 3: District wise normal monthly and annual rainfall (mm) in Uttarakhand State (Source:IMD) (1971-2020)

District	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Annual
ALMORA	35.1	53.3	45	31.1	50.3	146.3	274.2	241.8	130	20.4	5.1	18.3	1050.9
BAGESHWAR	35.1	53.3	45	31.1	50.3	146.3	274.2	241.8	130	20.4	5.1	18.3	1050.9
CHAMOLI	42.6	70.3	74	47	64	104.7	263.5	248.2	105	20.5	7.3	20.6	1067.7
CHAMPAWAT	37.4	46	28.6	25.2	51.2	211.9	473.8	397.6	230.5	43.9	4.6	15	1565.7
DEHRADUN	46.2	65.4	62.2	36.3	56.9	193.4	533.6	498.4	217.5	36.4	11.7	21.1	1779.1
PAURI GARHWAL	36.2	54.2	27.2	18.8	33.3	150.8	445.4	472.1	205	23.6	2.6	11.5	1480.7
TEHRI GARHWAL	47	58.5	54	34.6	50.1	129.5	332.6	333.1	152.8	22.8	5.1	18.2	1238.3
HARIDWAR	25.7	58.6	27.7	18.5	28.6	134.3	333.6	355.7	166.2	16	3.5	13.6	1182
NAINITAL	34.7	56	49.8	34.8	72.2	265.8	566.1	444.3	261.7	39	5.1	15.8	1845.3
PITHORAGARH	48.4	61.7	67	61.5	113.1	248.9	542.2	475.7	235.7	48.2	9.7	15.2	1927.3
RUDRAPRAYAG	58.7	66.7	72.6	67.1	105.7	220	552.7	568.8	207.6	20.4	8.4	21.2	1969.9
UDHAM SINGH NAGAR	20.4	17.6	13.8	11.2	37.1	174.5	390.2	375.5	185.3	35.3	0.9	7.9	1269.7
UTTARKASHI	54.7	71.4	71.2	49.2	70.4	176.6	425.4	380.9	168.3	38	8.3	23.7	1538.1

CHAPTER 3
GEOLOGY

The state of Uttarakhand has distinct geological attributes with a wide spectrum of rock types ranging in age from Achaean to Quaternary. Based on the diversity of geological processes in time and space, the state can be subdivided into two major physiographic-cum-tectonic units, viz.

1) Gangetic Alluvial Plain
2) Himalayan Mountain Belt.

A brief description of the geology of Uttarakhand is given below.

1) Gangetic Alluvial Plain

Gangetic Alluvial Plain, a part of the Indo-Gangetic Foreland Basin, occupies the southernmost part of the state. This zone consists of Quaternary fluvial sediments also known as Ganga Alluvium. Subsurface investigations in this belt have revealed a thick pile of alluvium resting unconformably over the Siwalik succession of Neogene to early Pleistocene Period. The thickness of alluvium increases towards north and attains its maximum adjacent to the *Foot Hill Fault* (FHF), which marks the northern limit of the youngest foreland basin in India i.e. the Ganga Fore deep Basin. The Ganga Fore deep sediments extend up to the south of depositional boundary of the Siwalik succession and rests over Precambrian cratonic rocks of Peninsular Indian Shield.

2)Himalayan Mountain Belt.

The Himalayan Mountain Belt is a part of the global mobile belt of Mesozoic to Cenozoic age that is believed to have evolved through the convergence of active Indian Plate and passive Eurasian Plate during the continent-continent lithospheric collision. It has a wide spectrum of rocks of sedimentary, metamorphic and igneous origin. Late Proterozoic (Neoproterozoic) to early Cenozoic crustal sequences form a small part of Himalaya, whereas the main mountain chain consisting predominantly of Proterozoic rocks represents a part of the Indian Shield. The Proterozoic crystalline rocks have been affected by various orogenic episodes of Mesozoic to Cenozoic Period and show signs of multiple phases of deformation and metamorphism.

Uttarakhand State is a part of Western Himalaya. Four distinct tectonic zones, each characterized by specific geological attributes and bounded by prominent dislocation zones can be recognized in Uttarakhand Himalaya from south to north. A brief description of the zones is given below:

2.1) Outer Himalaya or Sub Himalaya

This zone constitutes of a thick Cenozoic sedimentary pile ranging in age from Paleocene to Upper Pleistocene. Its northern and southern boundaries are delimited by the *Main Boundary Thrust* (MBT) and the *Foot Hill Fault* (FHF) also known as the *Main Frontal Thrust* (MFT), respectively. This zone consists predominantly of continental molasses sediments of Siwalik Group ranging in age from Middle Miocene to Upper Pleistocene. The Siwalik Group has been subdivided into the Lower Siwalik, Middle Siwalik and Upper Siwalik. The Lower Siwalik consists of fine to medium grained sandstone with clay, the Middle Siwalik is formed of medium grained sandstone with calcareous concretions and sandy clay and the Upper Siwalik consists predominantly of conglomerate with lenticular outcrops of sandstone and minor clay. The

elevation of this zone ranges from 250 to 800 m above mean sea level and width varies from 25 to 100 km. This zone is also characterized by a number of flat-floored structural valleys such as the *Doon Valley.*

2.2) Lesser Himalaya

The litho-units lying between the Main Boundary Thrust (MBT) in the south and the *Main Central Thrust* (MCT) in the north are included under the Lesser Himalayan Zone, which has the greatest exposed width of about 80 km in the Garhwal and Kumaun regions of Uttarakhand. The rocks of this zone are overlain by crystalline thrust sheets in the form of large klippe masses occupying mostly the higher topographical levels of the mountain ranges. Regionally metamorphosed Proterozoic rocks emplaced by granites of variable ages along with weakly metamorphosed to unmetamorphosed sedimentary rocks (quartzites with interbedded volcanics, carbonates associated with slate, quartzite and shale) occur extensively in this zone. The granitoids are associated with volcano sedimentary sequence (Bhimtal Formation) and are emplaced along with the predominantly metamorphic and metasedimentary rocks of this zone, forming large-scale nappes like the Almora- Ramgarh nappe, Baijnath-Askot nappe and Garhwal nappe.

2.3) Central or Higher Himalaya

This zone consists of thick slabs of Proterozoic crystalline rocks, which thrust southward along the *Main Central Thrust* (MCT), over-riding the Lesser Himalayan Zone. This zone is a 10-15 km wide sequence of metamorphic rocks and granites. This zone represents the Proterozoic basement that has been reactivated due to crustal shortening during the continent-continent collision of the Himalayan Orogeny. The metamorphic rocks exposed in this zone show progressive regional metamorphism ranging from green schist facies to upper amphibolite facies. Both foliated and non- foliated granitoids are emplaced in different structural and tectonic levels within the regionally metamorphosed crystalline.

2.4) Tethys Himalaya

This zone is occupied by the thick sedimentary sequence ranging in age from Late Precambrian (Neoproterozoic) to Lower Eocene. Sediments of marine facies, characteristic of continental shelf to continental slope environments of the Tethys Sea regime, are the predominant litho types of this zone. In Uttarakhand, this zone is well exposed in the Zanskar Mountains and mountain ranges of Kumaun region. This zone is separated from the Central Crystalline by Dar-Martoli Fault, with the Lower Martoli Formation representing the base of Phanerozoic, which is broadly folded and faulted with several local thrusts. The rock sequence comprises phyllite, mica schist and quartzite with lenticular outcrops of limestone.

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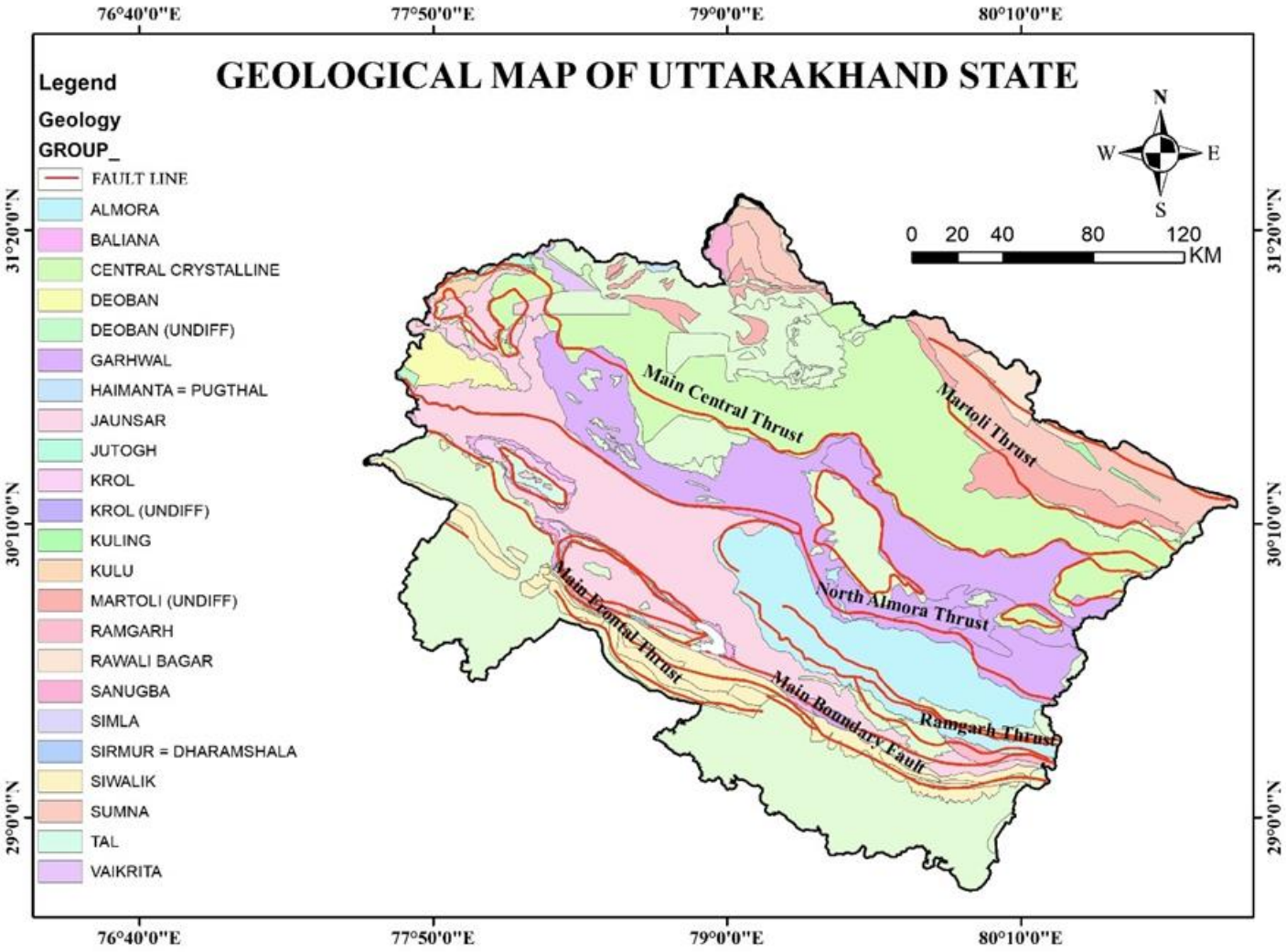


Fig.3: Geological Map of Uttarakhand State

CHAPTER 4
HYDROGEOLOGY

Uttarakhand State has a very diverse hydrogeological set-up. However, this hilly state can broadly be classified into two hydrogeological regimes namely Gangetic Alluvial Plain and Himalayan Mountain Belt. The description of these two types of hydrogeological-cum-physiographic units with further subdivisions is given below:

1. Gangetic Alluvial Plain

The Gangetic Alluvial Plain is a vast expanse of alluvium of Tertiary and Quaternary age. Alluvium is a generalized term for detrital unconsolidated sediments comprising predominantly of clay, silt, sand and gravels formed on river beds, flood plains, alluvial fans etc. This zone is very promising from the hydrogeological point of view having substantial water resource. This unit can be subdivided into three distinct hydrogeological regimes from south to north, viz. Axial Belt, Tarai and Bhabar.

1.1 Axial Belt

This unit, also called as the Alluvial Plains, is demarcated by the termination of alluvial fans that grade further down slope into vast alluvial plains. This zone is composed of a mixture of gravel, sand, silt and clay deposited in alternating layers. The aquifers present in this zone are of unconfined to confined nature. The area, in general, has good ground water resource potential but overexploitation of ground water reserve at places has resulted in the decline of water levels and needs implementation of artificial recharge methods. Drilling in this zone can be best accomplished by Rotary Drilling method having high drilling rate and hence, requiring less time for drilling.

1.2 Tarai

This is a generalized term for a sedimentary unit consisting of a mixture of gravel, sand and clay (sometimes also referred to as Tarai Formation). The boundary between Tarai and Bhabar is
demarcated by the presence of springs forming a linear pattern, thus delineating a "spring line". Due to the highly porous and permeable nature of the constituting material of sedimentary origin, many potential aquifers having groundwater of good chemical quality exist in this area. Two types of aquifers can be found in this zone –
a) Unconfined Aquifers down to depths of 30 meters below ground level (m bgl) and
b) Confined Aquifers that occur at depths greater than 30 m bgl under very high hydrostatic pressure.

The tubewell tapping these aquifers generally exhibit free flowing conditions with hydraulic head sometimes as high as 10 m agl and discharge of 5000 lpm.

1.3 Bhabhar

A mixture of clastic material having different size fractions (e.g., boulder, pebble, gravel, sand, silt and clay) constitutes this unit, which is also referred to as Bhabar Formation. Bhabar zone is also a promising hydrogeological entity though the occurrence of ground water at deeper levels (generally greater than 100 m bgl) poses a problem for ground water exploitation. Central Ground Water Board has constructed 28 deep tube wells (with discharge as high as 5540 lpm) by percussion drilling method in this zone of the state. Perched water bodies having smaller water resource potential are frequently encountered in this zone.

2. Himalayan Mountain Belt

This is a part of the Alpine-Himalayan Mountain Chain and constitutes a major part of the total geographical area of Uttarakhand. This zone is also known as Extra-Peninsular Region. The belt trends northwest – southeast with roughly parallel mountain ranges spanning across the state. This region can be further subdivided into five tectonic units from south to north. These units are Outer Himalaya, Lesser Himalaya, Central Himalaya, Tethyan Himalaya and Indus Suture Zone. However, the Indus Suture Zone does not fall within the geographical area of Uttarakhand State. A brief description of the remaining four units that falls in the state is as follows:

2.1 Outer Himalaya (Siwalik Mountain Range)

This unit is composed dominantly of sandstone, ferruginous shale and clay and is younger in age as compared to the other units of the belt. The general elevation of the zone is less than 1000 m above mean sea level. Due to the semi-consolidated nature of rocks, potential ground water bearing formations are present in areas, which have a good weathered mantle and highly fractured/jointed rocks. In the Siwaliks, a number of valleys have also been developed as a result of tectonic activities (e. g. Doon Valley), which are very important from the hydrogeological point of view. The Doon Valley was formed as an Intermontane Valley within the Siwalik Group of rocks in a foreland propagating thrust system. The Lower, Middle and Upper Siwaliks are exposed in the area, and the Doon Gravels, a post-Siwalik Formation, were deposited with the evolution of the valley. The Doon Gravels are thickly bedded coarse clastic fan deposit of late Pleistocene and Holocene age. The Central Ground Water Board has successfully constructed 11 deep tubewell, with discharge ranging from 252 to 3197 lpm in the Doon Valley of Dehradun district. The water levels in these aquifers range from 20 m bgl in the southern part of the valley to about 100 m bgl in the northern part.

2.2 Lesser Himalaya

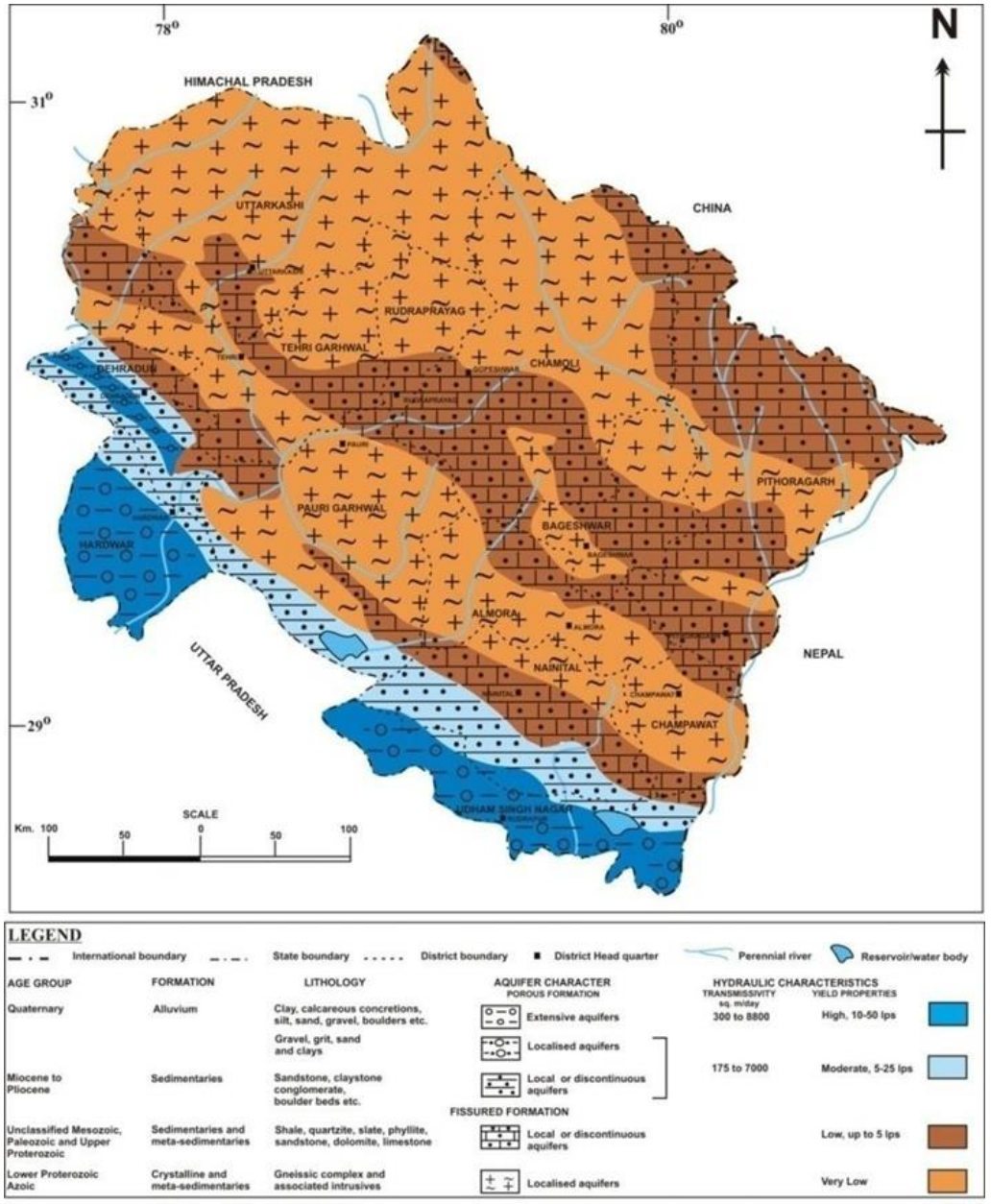
This zone is represented by mountains bounded by Main Boundary Thrust (MBT) in the south and Main Central Thrust (MCT) in the north having an elevation ranging between 1000 and 3000 m above mean sea level. This unit is dominantly composed of metasedimentary rocks and minor plutonic intrusive (granitoids). Springs form the most important source of ground water in this zone. In these formations, ground water occurrence is restricted to the weathered residuum and the highly fractured/jointed zones of the area. Several hand pumps have been installed successfully in this zone. At a few places, especially in the river valleys, tubewell having low to moderate discharges have also been successfully constructed.

2.3 Central Himalaya

The Central Himalayan zone lies to the north of Main Central Thrust (MCT) with an elevation ranging from 5000 to 8000 m above mean sea level. Both cold water and hot water (thermal) springs are present in this zone. So far, a total of 25 thermal springs have been investigated with temperatures ranging from 32°C to 70°C and discharge varying between 60 to 600 lpm, corresponding to 5th order and 4th order as per Meinzer's Classification of spring discharge. Due to highly inaccessible, snow-covered areas in this zone and a very steep hydraulic gradient, the possibility of ground water development is negligible.

2.4. Tethys Himalaya

Situated to the north of Central Himalayan zone, this zone is predominantly occupied by the highly fossiliferous sedimentary rocks ranging in age from Precambrian to Jurassic.



LEGEND

International boundary — State boundary — District boundary — District Head quarter — Perennial river — Reservoir/water body

AGE GROUP	FORMATION	LITHOLOGY	AQUIFER CHARACTER	HYDRAULIC CHARACTERISTICS TRANSMISSIVITY sq. m/day	YIELD PROPERTIES
Quaternary	Alluvium	Clay, calcareous concretions, silt, sand, gravel, boulders etc.	POROUS FORMATION: Extensive aquifers	300 to 8800	High, 10-50 lps
		Gravel, grit, sand and clays	Localised aquifers	175 to 7000	Moderate, 5-25 lps
Miocene to Pliocene	Sedimentaries	Sandstone, claystone conglomerate, boulder beds etc.	Local or discontinuous aquifers		
			FISSURED FORMATION		
Unclassified Mesozoic, Paleozoic and Upper Proterozoic	Sedimentaries and meta-sedimentaries	Shale, quartzite, slate, phyllite, sandstone, dolomite, limestone	Local or discontinuous aquifers		Low, up to 5 lps
Lower Proterozoic Azoic	Crystalline and meta-sedimentaries	Gneissic complex and associated intrusives	Localised aquifers		Very Low

Fig.4: Hydrogeological Map of Uttarakhand State

CHAPTER 5
BEHAVIOUR OF WATER LEVEL AND SPRING DISCHARGE

The water levels and spring discharge of Ground Water Monitoring Wells of Uttarakhand were measured four times during the year 2022-2023 (January 2023, May 2022, August 2022, and November 2022) as shown in Table 4. The ground water levels in different seasons were analyzed to evaluate the temporal behavior of water level. The behavior of water levels in each season during the period January 2022 – November 2022 has been compared with the water levels of previous year as well as with average water level for the last decade to ascertain the changes in ground water regime.

Apart from this, the fluctuation of water levels during the current year and previous year has also been evaluated in order to assess the adverse impact on hydrogeological regime, if any.

Table 4: Monitoring data of Ground Water Monitoring Wells, Uttarakhand

State Uttarakhand					
Sl No.	**Location Details**	**May-22**	**Aug-22**	**Nov-22**	**Jan-23**
DEHRADUN DISTRICT					
DOIWALA BLOCK					
1	**Khandgaon**	12.23	7.87	6.86	10.01
2	**Khadiri (Khadak Maf)**	14.23	12.23	16.04	16.79
3	**Rishikesh**	9.23	4.86	4.88	4.91
4	**Lal Tappar**	17.69	16.38	15.51	14.89
5	**Bhaniawala**	32.19	28.42	30.95	32.03
6	**Dudhli* new**	52.43	57.67	NA	44.21
7	**Kotimachak**	21.18	9.05	15.32	19.28
8	**Chandmari**	32.29	35.44	31.24	32.65
9	**Duggiawala**	9.93	3.34	5.37	6.39
10	**Mathrowala**	12.42	9.95	8.96	9.47
RAIPUR BLOCK					
11	**Kuanwala**	7.89	0.61	1.91	4.77
12	**Gularghagti**	13.64	8.58	9.93	11.6
13	**Maldeota**	14.13	4.34	6.73	12.5
14	**Nanurkhera**	67.41	62.83	55.53	60.09
15	**Tarla Nagal**	75.12	64.75	48.1	70.48
16	**Tarla Nagal**	58.38	45.61	61.47	53.66
17	**Purukulgaon**	26.55	13.3	22.18	25.37
18	**Niranjanpur**	35.3	36.86	31.69	31.98
19	**CGWB Office**	61.06	61.89	54.39	54.94
20	**Harbanswala**	48.26	51.83	45.67	46.18
21	**Kanwali**	13.27	8.88	10.85	12.68
22	Bhopalpani (Badawali)	10.86	0.24	2.21	7.03
23	**Ladpur Pz ***	86.62	85.48	79.1	84.3

SAHASPUR BLOCK					
24	**Singhniwala**	9.65	7.14	8.84	9.18
25	**Baronwala**	18.26	9.85	17.26	17.58
26	**Ramgarh**	9.05	6.05	6.15	6.39
27	**Jhajra**	13.61	7	5.48	9.63
28	**Jhajra**	15.1	5.24	6.19	11.02
29	**Nanda ki Chowki**	13.8	8.1	8.16	9.44
30	**Nanda ki Chowki**	18.55	11.75	12.03	13.4
31	**Selakui**	16.24	7.13	8.2	9.6
32	**Selakui**	17.4	9.59	NA	13.11
33	**Sabhawala**	8.97	6.38	7.62	8.57
34	**Rampura**	11.85	7.85	9.6	11.93
35	**Shankarpur**	24.54	16.61	19.1	20.84
36	**Redapur**	9.59	7.4	3.44	6.33
37	**Redapur**	5.07	6.5	6.12	3.56
38	**Sahaspur**	6.64	4.65	3.12	3.27
39	**Chhorba**	36.26	24.02	29.55	29.4
40	**Telpura**	37.25	38.52	35.62	34.25
VIKASNAGAR BLOCK					
41	**Badripur**	9.41	7.89	8.68	9.11
42	**Judli**	13.64	12.57	12.67	13.56
43	**Herbertpur**	10.73	6.78	9.11	10.42
44	**Vikas Nagar**	32.43	23.26	25.64	27.75
45	**Dharmawala**	5.6	4.92	3.55	3.59
46	**Dakpatthar**	27.73	22.35	25.07	26.47
47	**Barothiwala new Jan 2021**	4.6	2.66	NA	4.82
48	**Dhakrani**	18.01	12.15	14.44	18.97
49	**Timli**	71.5	67.36	68.1	67.91
50	**Baluwala**	40	27.67	32.41	35.24
51	**Luxmipur**	31.38	26.99	26.57	27.62
52	**Haripur**	10.48	7.83	9.73	10.17
53	**Jamuna Pull* new**	16.9	12.18	13.5	14.18
HARIDWAR DISTRICT					
BHAGWANPUR BLOCK					
1	**Shahidwala Grant**	13.67	13.88	12.59	13.02
2	**Sahidwala Grant**	14.18	13.02	12.16	13.06
3	**Budhwa Shahid**	5.61	4.38	3.86	4.58
4	**Bugawala**	9.57	8.28	7.93	9.6
5	**Bahabalpur**	3.75	3.3	2.72	2.99
6	**Bhagwanpur**	19.08	24.19	17.91	21.61
7	**Chudiala**	21.83	27.3	22.02	23.12

8	**Iqbalpur**	13.76	17.63	18.54	17.81
9	**Jaswawala**	3.66	3.94	2.95	3.32
10	**Kota Muradnagar**	10.21	8.24	7.85	9.92
11	**Mohammadpur**	1.35	1.4	1.12	N.A
BAHADRABAD BLOCK					
12	**Bandarjud**	10.77	13.18	11.22	13.32
13	**Rathora**	4.29	3.78	3.29	3.83
14	**Bahadrabad**	14.3	13.44	12.57	12.93
15	**Sarai**	14.43	13.69	12.82	14.17
16	**Dhanpura**	7.94	6.9	6.8	7.59
17	**Shahpur Shitlakhera**	5.29	4.88	3.54	3.93
18	**Laldhang**	59.93	61.87	52.18	58.5
19	**Bhogpur**	2.56	2.22	NA	4.27
20	**Dalupuri**	27.35	27.76	25.81	25.62
21	**Panjaheri**	7.55	6.32	6.71	8.31
22	**Dudhya Dayalwala**	3.54	3.21	NA	19.26
23	**Shyampur**	11.5	10.02	9.68	10.68
24	**Jassodharpur**	3.83	4.73	3.87	4.25
25	**Bhoopatwala**	10.69	8.99	NA	9.6
ROORKEE BLOCK					
26	**Imlikhera**	18.57	16.2	15.88	15.64
27	**Roorkee**	8.4	7.8	6.48	6.87
28	**Sikhar**	17.24	17.22	16.2	16.38
29	**Khera Jat**	6	6.11	4.65	4.78
30	**Nizampur**	10.99	11.03	NA	11.52
31	**Malakpur Mazra**	8.2	7.38	NA	6.33
NARSAN BLOCK					
32	**Jhabreda**	9.58	11.6	8.86	8.43
33	**Landhaura**	18.63	18.86	17.92	17.68
34	**Lakhnauta**	4.03	7.66	6.49	6.6
35	**Gurukul Narsen**	5.54	5.04	4.92	8.08
36	**Libhrahedi**	7.16	6.89	6.51	6.89
37	**Mudlana**	19.42	18.96	18.23	18.15
LAKSAR BLOCK					
38	**Hussainpur**	3.55	1.76	2.13	1.73
39	**Laksar**	5.19	4.31	NA	4.32
40	**Bhikkampur**	4.39	2.23	2.3	2.48
KHANPUR BLOCK					
41	**Govardhanpur**	4	3.81	2.17	2.18
42	**Dallawala**	1.29	0.96	1.33	1.27

43	**Khanpur**	5.04	4.79	2.78	3.62
NAINITAL DISTRICT					
HALDWANI BLOCK					
1	**Khaat Baans**	26.5	34.04	28.72	29.24
2	**Lalkuan**	16.14	17.55	13.9	8.13
3	**Lamachaur**	47.6	NA	41.74	42.36
4	**Kaladungi**	29.4	27.67	26.74	27.65
5	**Kathgodam**	18.57	14.53	16.11	17.35
RAMNAGAR BLOCK					
6	**Belparao**	56.29	57.07	55.2	55.39
7	**Peeru Madara**	26.21	26.76	23.41	23.47
8	**Maldhan Colony**	5.5	5.53	2.22	2.56
9	**Dhela**	69.82	NA	NA	N.A
10	**Ram Nagar**	6.12	5.39	5.47	5.66
11	**Garjiya**	NA	NA	NA	Dry
12	**Dohniya**	48.48	NA	NA	64.43
13	**Chilkiya**	55.46	NA	NA	56.38
UDHAM SINGH NAGAR DISTRICT					
KHATIMA BLOCK					
1	**Kanchanpur (Majhola)**	4.95	5.28	3.49	3.94
2	**Khatima**	2.55	0.88	1.44	2.08
3	**Charubeta**	6.41	6.1	4.1	5.53
4	**Mohamadpur Bhuriya**	6.49	4.91	4.47	3.95
5	**Sarasariya**	4.52	2.34	2.75	3.42
6	**Chakarpur**	NA	NA	6.11	4.07
7	**Barianjaniya**	NA	NA	3.62	3.57
SITARGANJ BLOCK					
8	**Sitarganj**	2.89	1.56	0.86	1.45
9	**Nanak Mata**	3.14	1.9	1.86	2.83
10	**Kalyanpur**	3.11	2	1.91	2.9
11	**Bijti**	NA	NA	0.74	2.86
12	**Tukri**	3.6	2.98	1.41	2.4
13	**Begur Mod**	3.81	3.72	2.78	3.32
14	**Bidora**	4.38	4.44	1.85	1.62
15	**Dhyanpur**	4.67	2.35	0.82	1.17
RUDRAPUR BLOCK					
16	**Bara**	2.15	1.89	3.84	1.92
17	**Kichha**	6.77	9.75	7.76	8.04

18	**Kamaria Pakki**	8.72	10.5	3.48	3.07
19	**Gangapur**	4.59	4.44	2.26	2.78
20	**Shantipuri**	2.13	1.09	1.42	1.72
21	**Patthar Chatta**	3.12	2.85	2.16	2.25
22	**Rudrapur**	6.68	7.58	3.6	2.13
23	**AN Jha School**	NA	NA	4	4.27
24	**Kanakpur**	3.59	NA	2.02	0.19
25	**Rajpura**	4.5	4.08	2.17	2.25
26	**Pipaliya**	6.87	8.26	2.4	3.38
GADARPUR BLOCK					
27	**Jhagarpuri**	2.28	5.18	5.38	5.32
28	**Mahabir Nagar**	2.18	1.6	2.52	0.08
29	**Kopa Signal**	0.53	0.31	2.64	0.1
30	**PipalyaNo.2**	NA	NA	0.47	N.A
31	**Beria Daulat**	3.8	2.83	0.2	2.73
32	**Bhagwanpur**	12.06	14	1.84	3.1
33	**Pattharpui**	3.49	3.18	2.93	3.03
34	**Lalpuri**	2.69	2.33	1.54	1.55
BAZPUR BLOCK					
35	**Bazpur**	2.12	1.83	0.68	1.45
36	**Jharkhandi**	2.14	2.24	0.66	1.03
37	**Jogipura**	5.98	6.59	7.86	4.35
38	**Banna Khera**	5.25	4.07	3.53	3.32
39	**Pritpur**	7.13	4.92	2.75	3.66
40	**Badaripur**	8.04	8.31	2.3	3.99
KASHIPUR BLOCK					
41	**Barkhare Pande**	15.55	12.37	6.07	2.33
42	**Sultanpur Patti**	7.78	6.9	4.24	4.48
43	**Kashipur**	7.75	6.81	3.93	4.36
44	**Bharatpur**	4.88	15.36	2.55	8.88
45	**Dhanauri Patti**	3.56	2.93	NA	0.09
46	**Shivlalpur, Amajhanda**	NA	NA	8.6	7.3
47	**Durgapur**	5.56	5.78	3.11	3.47
48	**Shand Khera**	11.26	10.77	4.2	5.58
JASPUR BLOCK					
49	**Jaspur**	17.29	Dry	15.96	13.8
50	**Patrampur**	10.13	15.63	8.4	7.96
51	**Mahuadabra**	NA	NA	13.6	14.59
52	**Patrampur**	NA	NA	11.41	7.96
53	**Angadpur**	15.82	9.24	6.17	7.06

54	**Missarwala**	17.75	15.34	8.54	9.47
CHAMPAWAT DISTRICT					
1	**Tanakpur**	11.58	7.92	6.9	9.83
2	**Banbasa**	NA	NA	2.81	3.99
3	**Bastia**	39.28	29.37	31.26	26.2
4	**Bichai**	10.22	7.84	6.98	8.64
PAURI GARHWAL DISTRICT					
DUGADDA BLOCK					
1	**Kaudia (Kotdwar)**	53.07	25.9	49.86	51.37
3	**Trilokpur* New**	76.17	93.9	66.76	70.78
UTTARKASHI DISTRICT					
1	**Chinyalisaur**	17.32	20.1	4.74	5.06
2	**Devidhar**	8.63	8.11	9.78	9.02
3	**Uttarkashi**	19.17	14.35	15.79	16.81
4	**Barkot**	16.58	13.47	16.54	16.45
5	**Sharukhet**	44.07	33.27	40.18	42.34
6	**Ganeshpur**	17.55	14.43	16.62	17.14
7	**Maneri**	29.18	13.73	27.61	28.76
8	**Charethi HP ***	24.16	22.03	23.31	23.64
9	**Dunda**	32.1	24	0.7	33.54

5.1 DEPTH TO WATER LEVEL

5.1.1 January 2023

The depth to water level data was analysed for 169 Ground Water Monitoring Wells in Uttarakhand during January 2023 and is given in ***Table 5.*** Analysis of depth to water level data givenin the table indicates that the deepest water level was 81.99 m bgl in Ladpur, Dehradun district whereas the shallowest water level was 0.05m bgl at Dallawala in Haridwar District. The shallowest depth to water level of 0–5 m bgl was recorded by 65 monitoring wells, which was 38.46 % of the totalnumber of wells. Water level in the range of 5-10 m bgl was also shown by 34 wells (20.11% of total number of wells), whereas deeper water level of 10–15 m bgl was recorded by 19 monitoring wells, which was 11.25% of the total number of wells. The deepest water level of >15 m bgl was shown by51 monitoring wells, which was 30.18% of the total number of wells in Uttarakhand monitored in January 2023.

Table 5: District wise categorization of depth to water level data, January 2023

District	No. of stations analyzed	Depth to water level		Depth to water level (m bgl)							
		(m bgl)		0-5		5 to 10		10 to 15		>15	
		Min	Max	No.	%	No.	%	No.	%	No.	%
Dehradun	53	3.32	81.99	6	11.32	14	26.41	10	18.86	23	43.41
Haridwar	43	0.05	56.41	16	37.21	11	25.58	8	18.60	8	18.60
U. S. Nagar	46	0.12	16.83	41	89.13	4	8.70	0	0.00	1	2.17
Nainital	12	2.58	66.48	1	8.33	1	8.33	1	8.33	9	75.00
Champawat	4	4.49	27.17	1	25.00	2	50.00	0	0.00	1	25.00
Uttarkashi	9	5.18	43.5	0	0.00	2	22.22	0	0.00	7	77.78
Pauri Garhwal	2	49.31	70.09	0	0.00	0	0.00	0	0.00	2	100.00
Total	**169**	**0.05**	**81.99**	**65**	38.46	**34**	20.11	**19**	11.25	**51**	30.18

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for ***January 2022*** is shown in ***Fig. 5*** *(Dehradun, Section),* ***Fig.6*** *(Haridwar section)* and ***Fig. 7****(Udham Singh Nagar District)* ***Fig. 8*** *(Nainital District) and* ***Fig. 9*** *(Champawat District).*

A perusal of **Fig. 5** reveals that the the major part of the Dehradun district shows water levels in the range of >15 m bgl. The water levels in the depth range of 10-15 mbgl are observed as elliptical patches in southern part of the valley i.e. in the Doiwala block and as concentric ring rimming the water level of 5-10 m bgl in the Sahaspur and Vikasnagar block of Dehradun district.

A perusal of **Fig. 6** indicates that major part of the Haridwar district shows water levels in the range of 10-15 m bgl covering major areas of Bhagwanpur, Bahadrabad, Roorkee,Narsan and Laksar blocks of the district. The minimum depth to water level i.e 0-5 m is observed mainly in the Khanpur

block of the district. The water level in the range of 15-30 occurs mostly in the western part of the district covering Roorkee, Narsan and Bhagwanpur block. Deepest water level in the range of >50 m bgl occur as eastern flank of bahadrabad block (Shiwalik Hills).

Interpretation of **Fig. 7** indicates that the major part of the section shows water level in the depth range of 0-5 m bgl covering major part of Khatima, Sitarganj, Rudrapur, Gadarpur, Bazpur and Kashipur Blocks of the Udham Singh Nagar District. The water levels in the range of 5-10 m bgl occur in majority locations of Jaspur and some areas of Kashipur Block of the district.

The visual interpretation of the **Fig. 8** indicates that the major part of the section shows water level in the depth range of greater than 15 m bgl. However shallow water level occurs as small concentric pathes in Ramnagar block and southern part of the Haldwani block of the section.

The visual interpretation of the **Fig.9** indicates that the depth to water level increases gradually from southern part (5-10 m bgl) to northern part (>15 m bgl) of the Champawat Section.

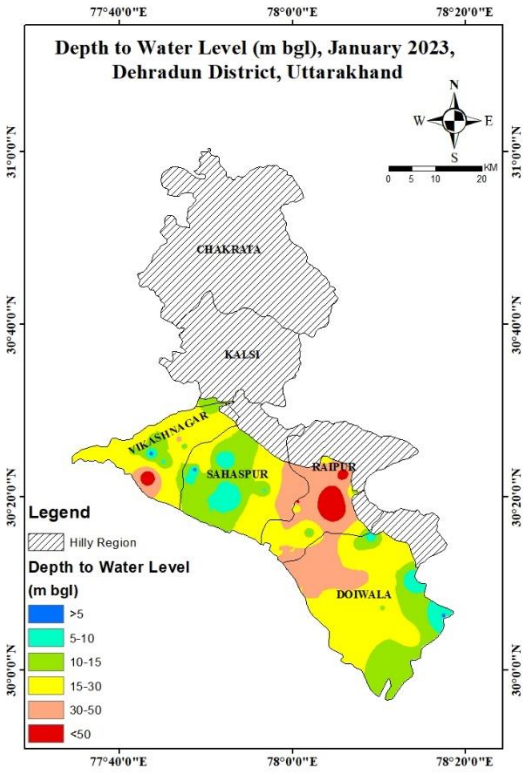


Fig. 5: Depth to water level map of Dehradun District (January 2023)

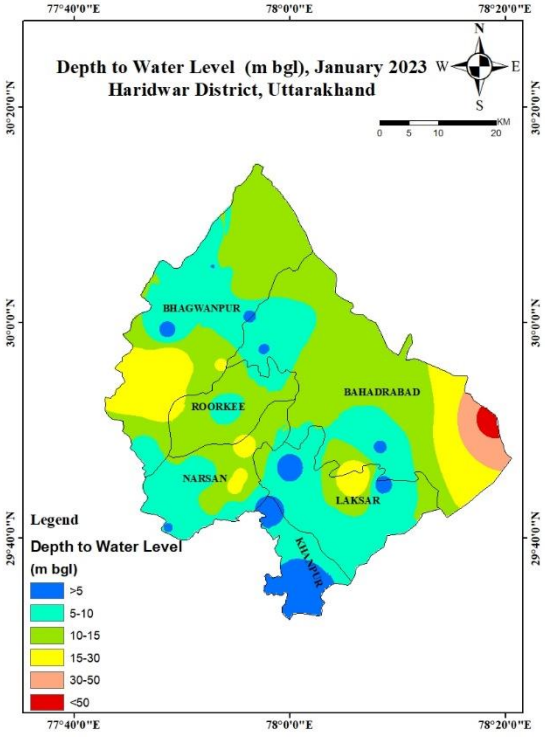


Fig. 6: Depth to water level map of Haridwar District (January 2023s)

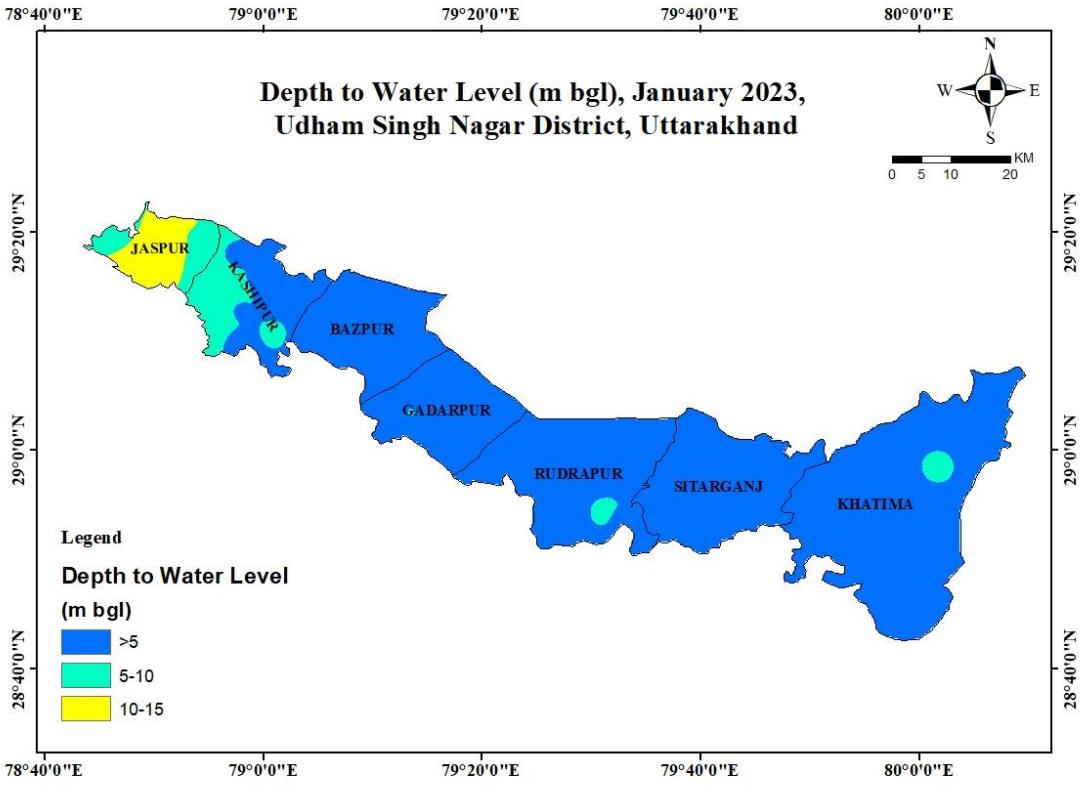


Fig. 7: Depth to water level map of Udham Singh Nagar District (January 2023)

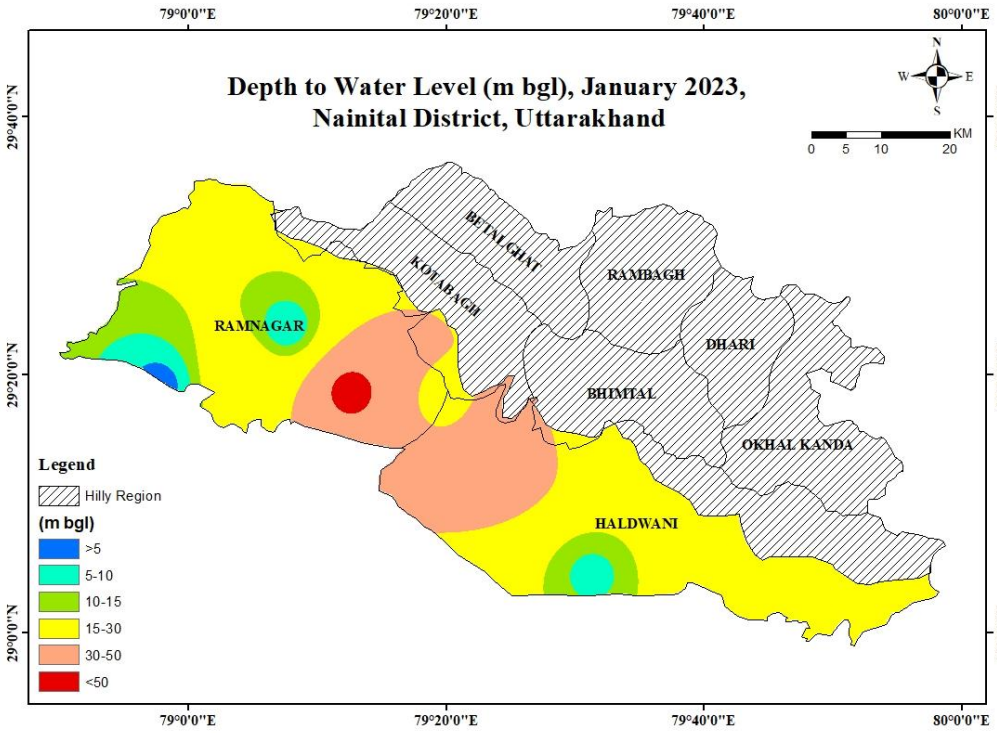


Fig. 8: Depth to water level map of Nainital District (January 2023)

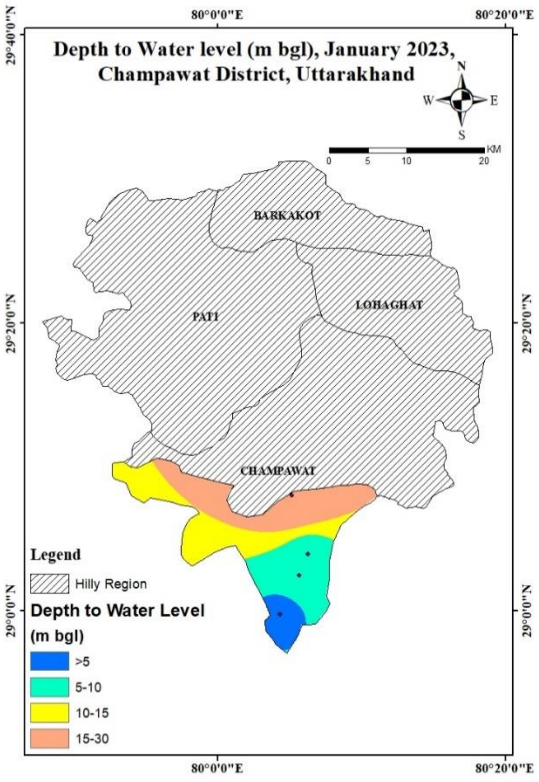


Fig. 9: Depth to water level map of Champawat District (January 2023)

5.1.2 May 2022

The depth to water level data was analysed for 168 Ground Water Monitoring Wells in Uttarakhand during May 2022 and is given in ***Table 6.*** Analysis of depth to water level data given in the table indicates that the deepest water level was 86.62 m bgl at Ladpur at Dehradun district whereas the shallowest water level was 0.53 m bgl at Kopa Singal in Udham Singh Nagar district. The depth to water level in the range of 0–5 m bgl was recorded in 39 ground water monitoring wells, which is 23.21% of the total number of wells. Water level in the range of 5–10 m bgl was shown by 40 monitoring wells (23.81% of total number), whereas deeper water level of 10–15 m bgl was recorded in 28 monitoring wells, which was 16.67% of the total number. The deepest water level of >15 m bgl was shown by 61 monitoring wells, which is 36.31% of the total monitoring wells in Uttarakhand during May 2022.

Table 6: District wise categorization of depth to water level data, May 2022

District	No. of stations analyzed	Depth to water level		Depth to water level (m bgl)							
		(m bgl)		0-5		5 to 10		10 to 15		>15	
		Min	Max	No.	%	No.	%	No.	%	No.	%
Dehradun	53	4.6	86.62	1	1.89	11	20.75	13	24.53	28	52.83
Haridwar	43	1.29	59.93	12	27.91	13	30.23	10	23.26	8	18.60
U. S. Nagar	44	0.53	17.75	26	59.09	13	29.55	3	6.82	4	9.09
Nainital	13	5.5	69.82	0	0.00	2	15.38	0	0.00	10	79.62
Champawat	4	10.22	39.28	0	0.00	0	0	2	50.00	1	25.00
Uttarkashi	9	8.63	44.07	0	0.00	1	11.11	0	0	8	88.89
Pauri Garhwal	2	53.07	76.17	0	0.00	0	0.00	0	0.00	2	100.00
Total	**168**	**0.53**	**86.62**	**39**	23.21	**40**	23.81	**28**	16.67	**61**	36.31

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for ***May 2022*** is shown in ***Fig. 10*** *(Dehradun, Section),* ***Fig.11*** *(Haridwar section)* and ***Fig. 12*** *(Udham Singh Nagar District)* ***Fig. 13*** *(Nainital District) and* ***Fig. 14*** *(Champawat District).*

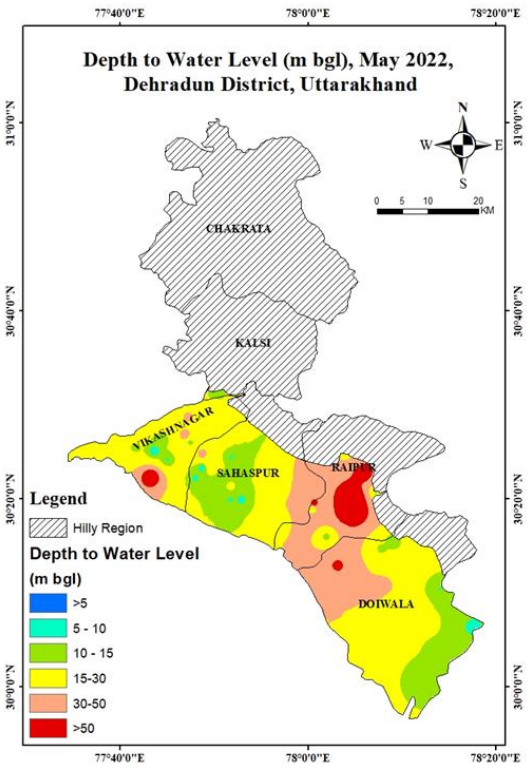


Fig. 10: Depth to water level map of Dehradun district (May 2022)

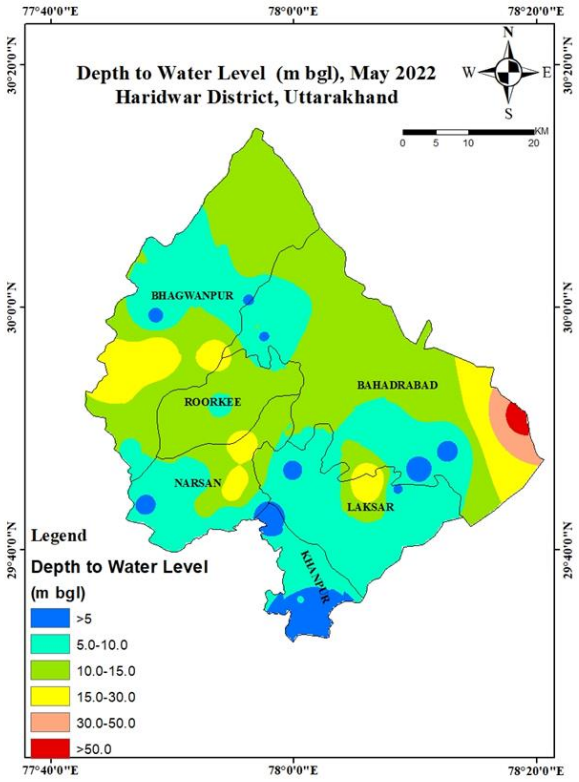


Fig. 11: Depth to water level map of Haridwar section (May 2022)

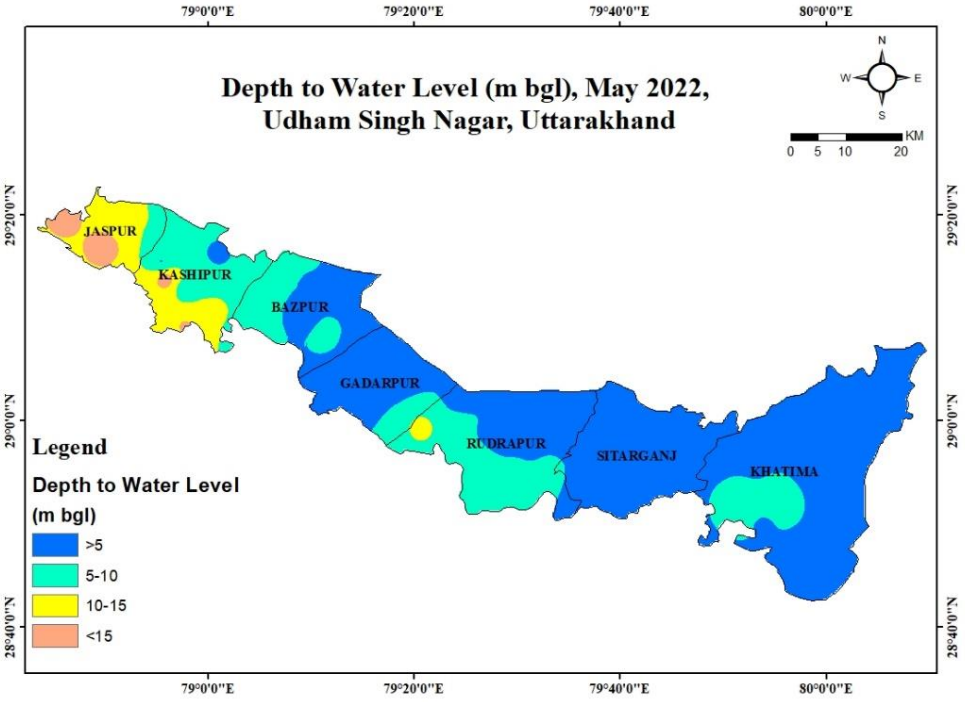


Fig. 12: Depth to water level map of Udham Singh Nagar District (May 2022)

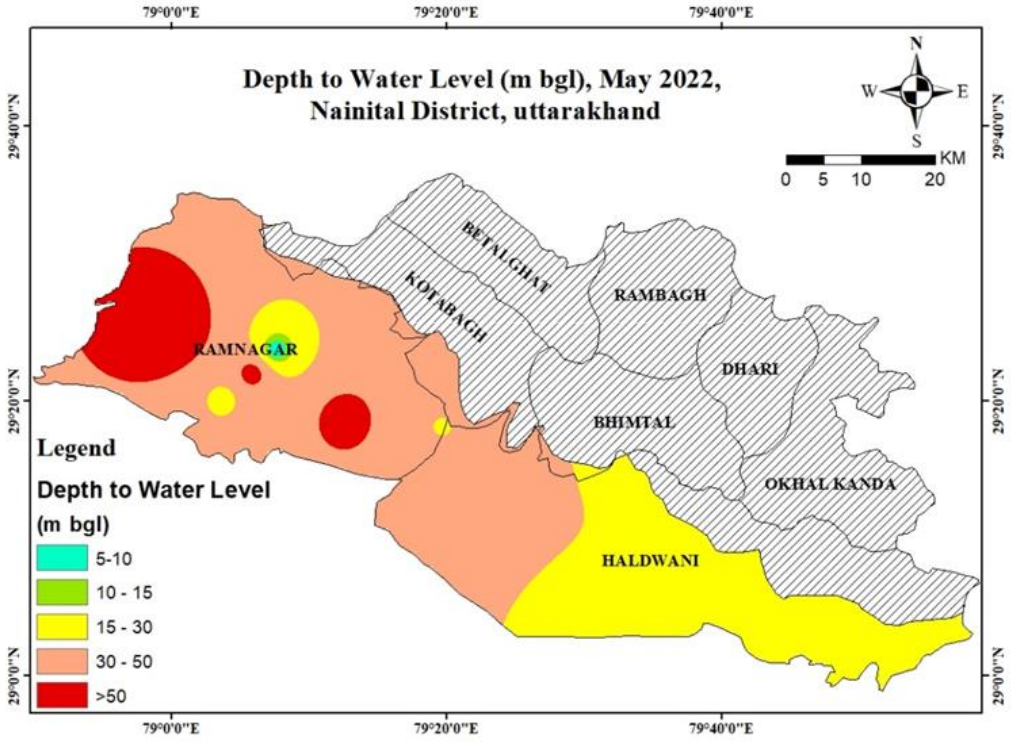


Fig. 13: Depth to water level map of Nainital Section (May 2022)

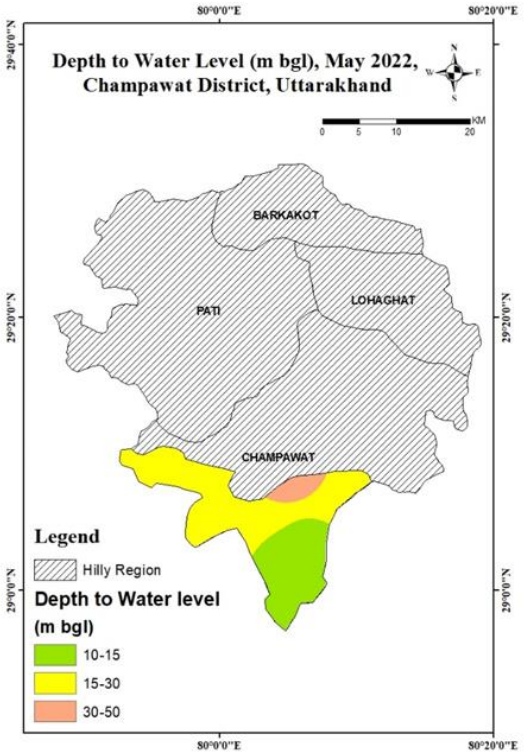


Fig. 14: Depth to water level map of Champawat Section (May 2022)

A study of **Fig. 10** indicates that the major part of the Dehradun district shows water levels deeper than 15 m bgl. The shallow water level in the range of 10-15 m bgl occurs in patches near extreme south eastern part (Rishikesh), in small patches near north western part in the Sahaspur Block and in limited patches in the Vikasnagar block of Doon Valley. The water level in the depth range of 30-50 m bgl occurs in almost the entire

area of Raipur Block and in the wastern part of the Doiwala Block. The deepest water level is encountered in the Ladpur area (>50 m bgl) of the Raipur Block.

The visual interpretation of the **Fig. 11** indicates that the major part of the Haridwar district shows water levels in the range of 5-10 and 10-15 mbgl. The water level in the range of 0-5mbgl zone occurs as patches in the southernpart (Dallwala-Khanpur areas) of Haridwar district. The water level in the range of 5-10 m bgl zone occurs in major part of Laksar, Khanpur, Narsan, central part of Bhagwanpur bock, southern part of Bahadrabad block of the district. The deepest water level in the range of more than 15m bgl occurs as small patches in the eastern flank of Bahadrabad and western flank of Bhagwanpur block of the district.

The visual interpretation of the **Fig. 12** indicates that the major part of the section shows water level in the depth range of 0-5 m bgl covering major part of Bazpur, Gadarpur, Rudrapur, Sitarganj and Khatima Blocks of the Udham Singh Nagar District. The water level in the range of 5-10 m bgl occur in north and central portion of Kashipur Block, southern portion of Rudrapur Block, western portion of Bazpur block and southern portion of Khatima block. The water level in the range of 10-15 m bgl occurs in major part of Jaspur block (with patches showing ground water level >15 m bgl) and southern part of Kashipur block of the district.

The visual interpretation of the **Fig. 13** indicates that the major part of the section shows water level in the depth range of greater than 15 m bgl i.e in the range of 15-30 m bgl and 30-50 m bgl. Deep water level (> 50 m bgl) occur in the western part of Ramnagar block of the Nainital section.

The visual interpretation of the **Fig. 14** indicates that the depth to water level increases gradually from southern part (10- 15 m bgl) to northern part (>15 m bgl and eventually 30-50 m bgl) of the Champawat Section.

5.1.3 August 2022

During the month of August 2022, total of 162 Groundwater monitoring wells (including dug wells, hand pumps and piezometers) were monitored in Uttarakhand State in District Dehradun, Haridwar, Udham Singh Nagar, Pauri Garhwal, Nainital and Champawat. The depth to water level data has been classified and is given in **Table 7.** A persual of the table indicates that deepest water level was 93.90 m bgl at Trilokpur in Pauri Garhwal district while the shallowest water level was 0.24 m bgl at Bhopalpani in Dehradun District. The analysis of depth to water level data has also shown that shallowest water level of 0-5 m was recorded by 48 monitoring wells, which was 29.63% of the total number. Depth to water level in the range of 5-10 m was shown by 48 wells (29.63% of total number), the deeper water levels of 10-15 m was shown by 27 wells (16.67% of total) and the deepest water levels (>15 m) was recorded by 43 monitoring wells, which was 26.54% of the total number of wells in Uttarakhand monitored during August 2022.

Table 7: District wise categorization of the depth to water level data, August 2022

District	No. of stations analyzed	Depth to water level		Depth to water level (m bgl)							
		(m bgl)		0-5		5 to 10		10 to 15		>15	
		Min	Max	No.	%	No.	%	No.	%	No.	%
Dehradun	53	0.24	85.48	8	15.09	20	37.74	6	11.32	19	35.85
Haridwar	43	0.96	61.87	15	34.88	11	25.58	12	27.91	9	20.93
U. S. Nagar	44	0.31	15.63	25	56.82	12	27.27	4	9.09	3	6.82
Nainital	8	5.39	57.07	0	0.00	2	25	1	12.5	5	62.5
Champawat	3	7.84	29.37	0	0.00	2	66.67	0	0.00	1	33.33
Uttarkashi	9	8.11	33.27	0	0.00	1	11.11	4	44.44	4	44.44
Pauri Garhwal	2	25.9	93.9	0	0.00	0	0.00	0	0.00	2	100.00
Total	**162**	**0.24**	**93.9**	**48**	29.63	**48**	29.63	**27**	16.67	**43**	26.54

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for **August *2022*** is shown in ***Fig. 15****(Dehradun, Section),* ***Fig.16*** *(Haridwar section)* and ***Fig. 17****(Udham Singh Nagar District)* ***Fig. 18*** *(Nainital District) anzd* ***Fig. 19*** *(Champawat District).*

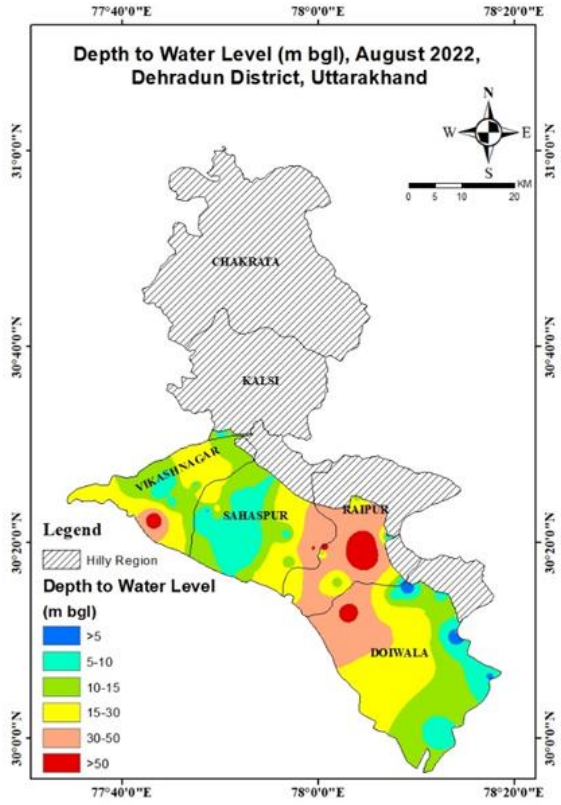


Fig. 15: Depth to water level map of Dehradun Section (August 2022)

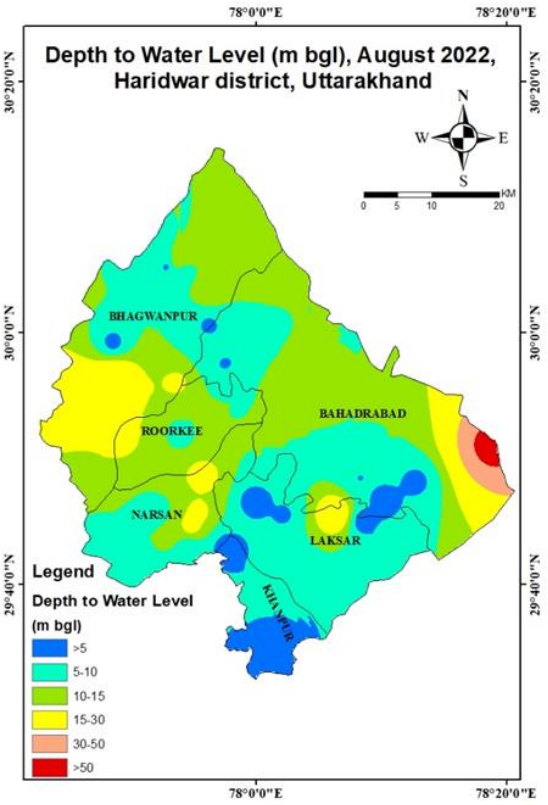


Fig. 16: Depth to water level map of Haridwar District (August 2022)

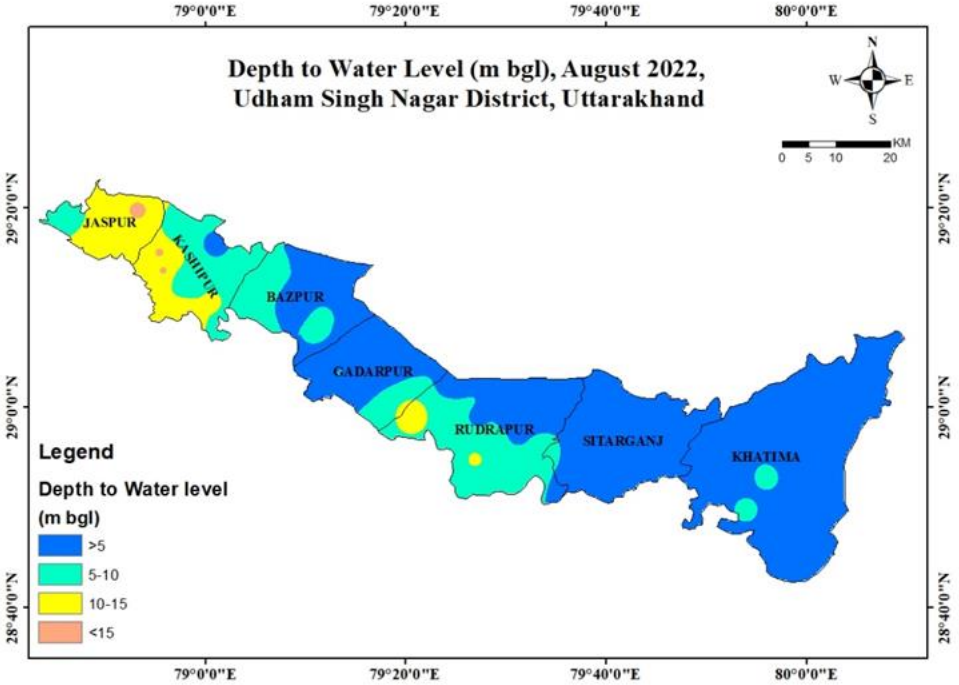


Fig. 17: Depth to water level map of Udham Singh Nagar District (August 2022)

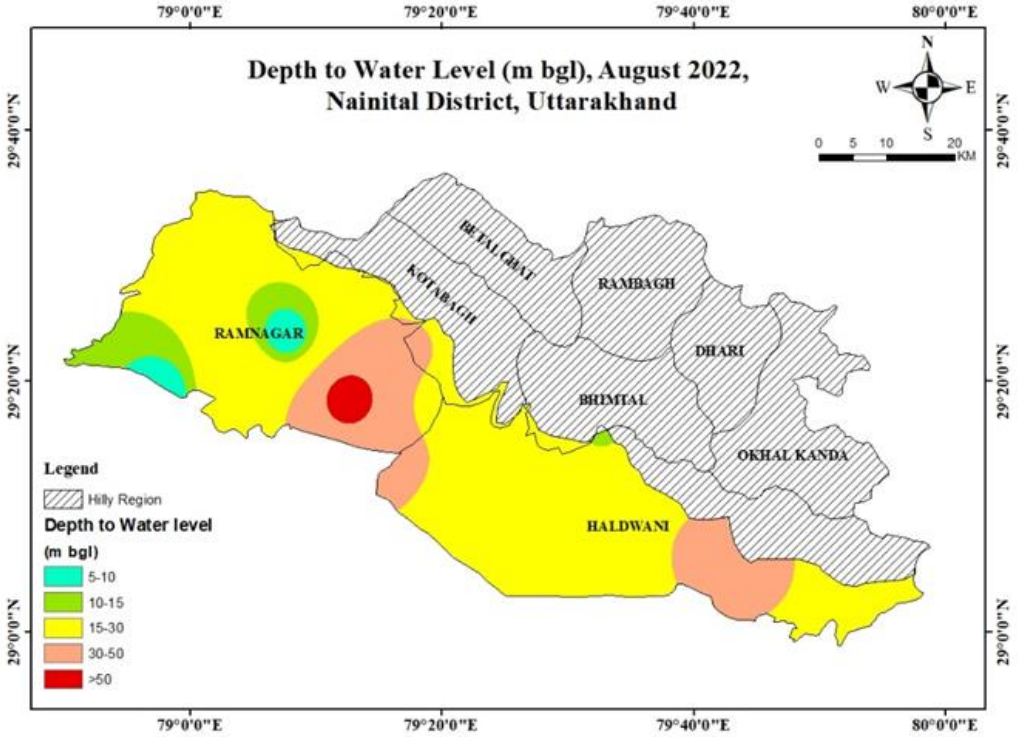


Fig. 18: Depth to water level map of Nainital District (August 2022)

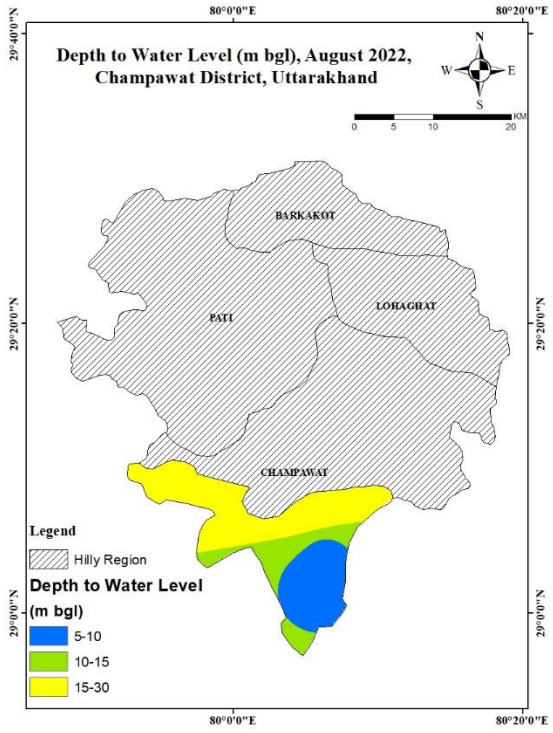


Fig. 19: Depth to water level map of Champawat District (August 2022)

A perusal of **Fig.15** indicates that the major part of the Dehradun district shows water levels in the range of >15 m bgl.The water levels in the depth range of 10-15 mbgl are observed as small patches in southern part of the valley i.e. in the Doiwala block and as concentric ring rimming the water level of 5-10 m bgl in the

Sahaspur and Vikasnagar block of Dehradun district. The water level in the range of 5-10 m bgl occurs in the southern eastern most part of the Doon valley.

A perusal of **Fig. 16** indicates that major part of the Haridwar district shows water levels in the range of 5-10 m bgl covering major areas of Bhagwanpur (northern and southern parts), Bahadrabad (southern parts), Laksar, Narsan (southern part), Khatima (northern part) blocks of the district. The minimum depth to water level i.e 0-5 m is observed mainly in the Khanpur block of the district and in small patches in Laksar and Bahadrabad district. The water level in the range of 10-15 occurs mostly in the north- western part and South eastern part of the district covering Bhagwanpur, Bahadrabad, Roorkee and Laksar block. Deepest water level in the range of >15 m bgl occur as elliptical patches near the eastern flank of Bahadrabad block.

Interpretation of **Fig. 17** indicates that the major part of the section shows water level in the depth range of 0-5 m bgl covering major part of Khatima, Sitarganj, Gadarpur, Bazpur and northern portion of Rudrapur Blocks of the Udham Singh Nagar District. The water level in the range of 5-10 m bgl occur in majority locations of Kashipur, southern portion of Rudrapur and small parts of Gadarpur and Bazpur blocks of the district. The water level in the range of 10-15 m bgl occurs in the southern part of the Kashipur and major portion of Jaspur blocks of the district.

The visual interpretation of the **Fig. 18** indicates that the major part of the section shows water level in the depth range of greater than 15 m bgl. However shallow water level occurs as small concentric patches in Ramnagar block of the Nainital section. Deeper water levels are encountered in the eastern part of Ramnagar block and in a small stretch in the Haldwani block.

The visual interpretation of the **Fig.19** indicates that the depth to water level increases gradually from southern part (5-10 m bgl) to northern part (>15 m bgl) of the Champawat Section.

5.1.4 November 2022

The depth to water level data is available for 164 Ground Water Monitoring Wells of Uttarakhand during November 2022. The data has been analyzed and shown in ***Table 8***. During this period, the deepest water level of 79.10 m bgl was observed at Ladpur Piezometer (Dehradun district) while the shallowest water level of 0.20 m bgl was observed at Beria Daulat in Udham Singh Nagar district. The analysis of depth to water level data shows that out of 164 wells, 65 wells (39.63% of total number) have recorded shallowest water level in the depth range of 0–5 m whereas water level in the range of 5-10 m was recorded in 39 monitoring wells (23.78% of the total number). Deeper water level of 10–15 m was observed in 14 wells, which was 8.54% of the total number whereas the deepest water level of >15 m bgl was recorded in 46 wells (28.05 % of total wells) in Uttarakhand during November 2022.

Table 8: District wise categorization of depth to water level data, November 2022

District	No. of stations analyzed	Depth to water level		Depth to water level (m bgl)							
		(m bgl)		0-5		5 to 10		10 to 15		>15	
		Min	Max	No.	%	No.	%	No.	%	No.	%
Dehradun	50	1.91	79.1	6	12	17	34	5	10	22	44
Haridwar	37	1.12	52.18	14	37.83	9	24.32	5	13.51	9	24.32
U. S. Nagar	53	0.2	15.96	41	77.35	9	16.98	2	3.77	1	1.89
Nainital	9	2.22	55.2	1	11.11	1	11.11	1	11.11	6	66.67
Champawat	4	2.81	31.26	1	25	2	50	0	0	1	25
Uttarkashi	9	0.7	40.18	2	22.22	1	11.11	1	11.11	5	55.56
Pauri Garhwal	2	49.86	66.76	0	0	0	0	0	0	2	100
Total	**164**	**0.2**	**79.1**	**65**	39.63	**39**	23.78	**14**	8.54	**46**	28.05

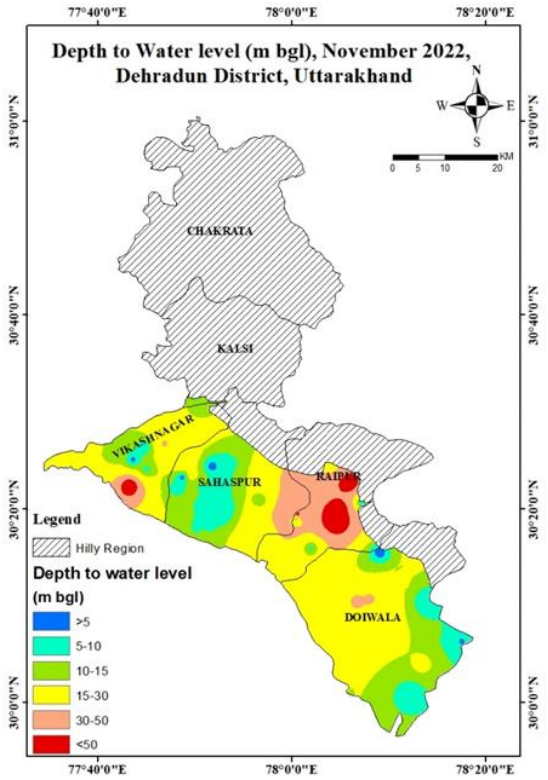


Fig. 20: Depth to water level map of Dehradun District (November 2022)

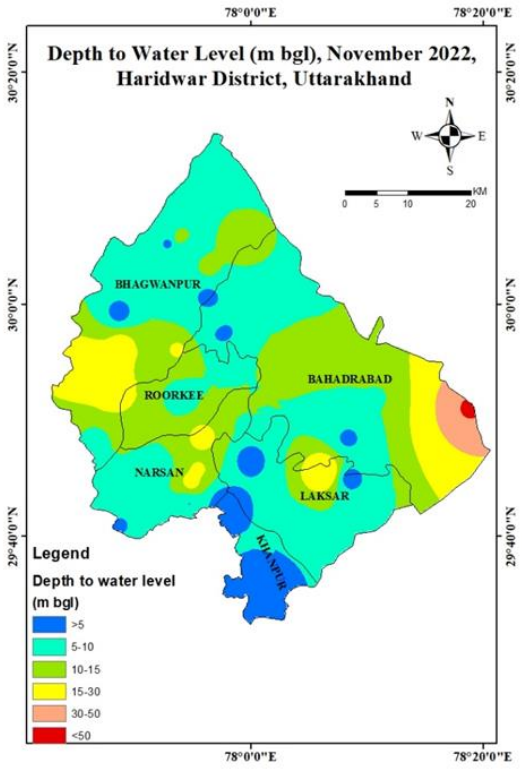


Fig. 21: Depth to water level map of Haridwar District (November 2022)

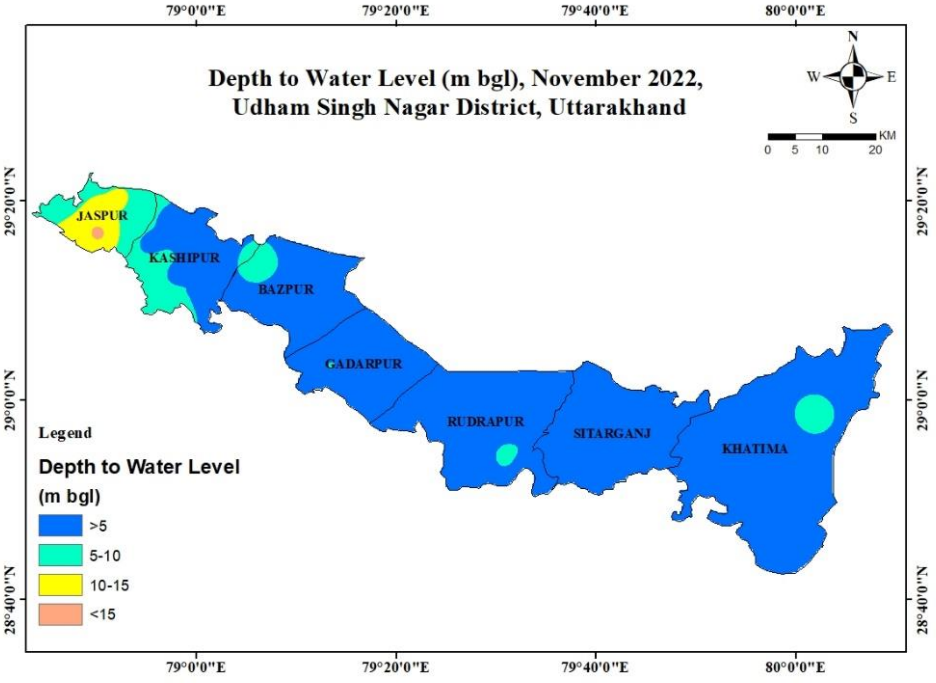


Fig. 22: Depth to water level map of Udham Singh Nagar District (November 2022)

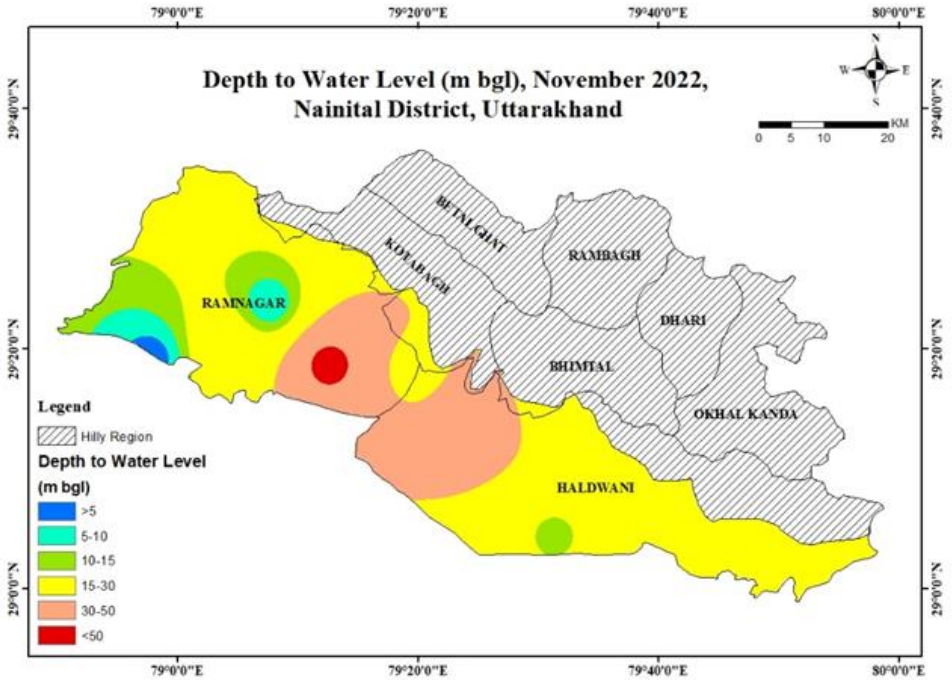


Fig. 23: Depth to water level map of Nainital District (November 2022)

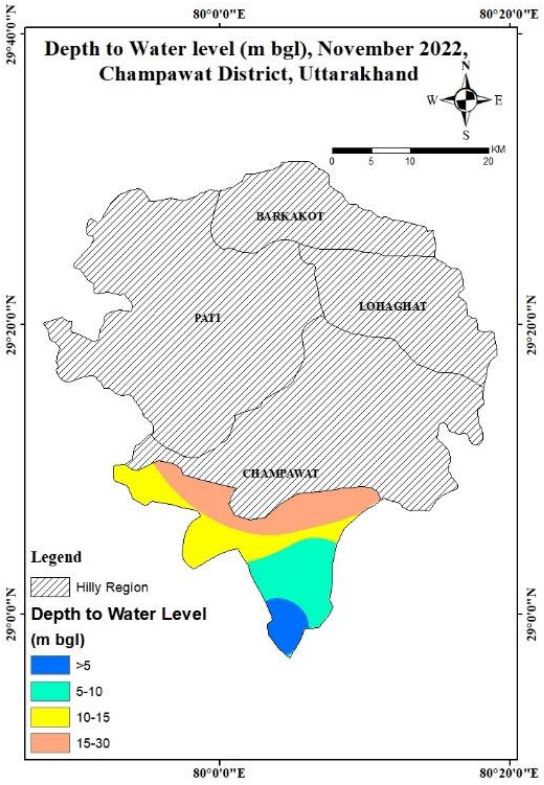


Fig. 24: Depth to water level map of Champawat District (November 2022)

A perusal of **Fig. 20** reveals that the major part of the Dehradun district shows water levels in the range of 15-30 m bgl.The water levels in the depth range of 10-15 mbgl are observed in southern part of the valley i.e. in the eastern part of Doiwala block and as concentric ring rimming the water level of 5-10 m bgl in the Sahaspur and Vikasnagar block of Dehradun district. The water level in the range of 5-10 m bgl mostly occurs

in patches in the Doiwala Block (eastern part), Sahaspur block (western part) and in isolated places in Vikasnagar block. The deep water levels are encountered in majority of Raipur block and in isolated patches in southern part of the Vikasnagar block.

A perusal of **Fig. 21** indicates that major part of the Haridwar district shows water levels in the range of 5-10 m bgl covering major areas of Bhagwanpur, Bahadrabad, Roorkee, Laksar blocks of the district. The minimum depth to water level i.e 0-5 m is observed mainly in the Khanpur block of the district. The water level in the range of 10-15 occurs mostly in the western and eastern part of the district covering Roorkee, Narsan, Bahadrabad and Bhagwanpur block. Deepest water level in the range of >15 m bgl occur as elliptical patches near the eastern flank of Bahadrabad block and the western part of Bhagwanpur block.

Interpretation of **Fig. 22** (Udham Singh Nagar) indicates that the major part of the section shows water level in the depth range of 0-5 m bgl covering major parts of Khatima, Sitarganj, Rudrapur, Gadarpur, Bazpur and Kashipur Blocks of the Udham Singh Nagar District. The water level in the range of 5-10 m bgl occurs in Kashipur Block (western part), and Jaspur blocks of the district. Deeper water levels are encountered in the Jaspur block.

The visual interpretation of the **Fig. 23** (Nainital District) indicates that the major part of the section shows water level in the depth range of 15-30 m bgl. However shallow water level occurs as small concentric patches in western and central part of Ramnagar block and southern part of the Haldwani block of the section. Deep water levels are encountered in the eastern part of Ramnagar block and western part of Haldwani block.

The visual interpretation of the **Fig.24** indicates that the depth to water level increases gradually from southern part (5-10 m bgl) to northern part (>15 m bgl) of the Champawat Section.

5.2DISCHARGE OF SPRINGS

The discharge data of forty-one springs in Dehradun, Nainital, Uttarkashi and Almora districts for the months of January, May, August, and November 2022 is given in Table 9. A study of the table shows that spring discharge is lowest in pre-monsoon (May) whereas during post-monsoon (August), the discharge increased significantly. This indicates that rainfall is the principal contributing factor for variation in spring discharge.

A perusal of ***Table 9*** indicates that discharge of the springs during the period January 2022-November 2022 varies from a minimum measurable discharge of 0.23 LPM at Golucheena (Almora) in May 2022 to a maximum of 215.91 LPM at Sipahi Dhara, Nainital district (November 2022). Discharge of springs varies within wide limits during the intervening period.

In Dehradun district, spring discharge varies between 3.33 LPM at Bhatta in May 2022, and 74.07 LPM at Khandoli in November 2022. In Nainital district, spring discharge varies from a minimum of 2.14 LPM at Kudaghat (May 2022) to a maximum of 215.91 LPM at Sipahidhara (November 2022). In Almora district, the spring discharge was found to be varying from a minimum of 0.23 LPM at Golucheena in May 2022 to a maximum of 83.14 LPM at Peepaldhar in November 2022. In Uttarkashi district, spring discharge was varying from 2.22 LPM at Dharasau in January 2022 to a maximum of 160 LPM in Ganganani in November 2022.

Table 9: Discharge of Springs in January May, August, and November 2022 (in LPM)

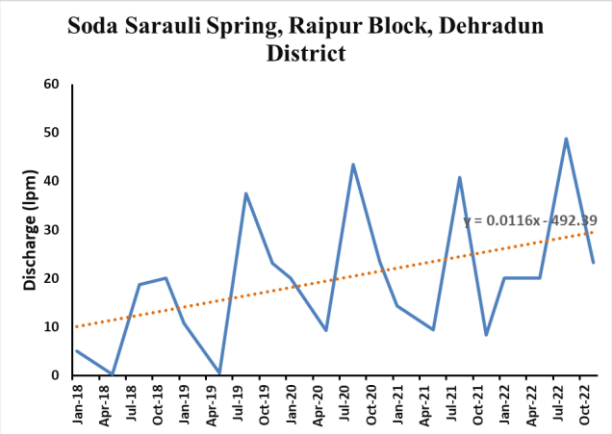
Sl No.	District	Block	Location Details	Jan-23	May-22	Aug-22	Nov-22
1	Dehradun	Raipur	Soda Saroli	11.86	20	48.78	23.26
2			Bhatta	6.25	3.33	15	7.28
3		Sahaspur	Khandoli	375	40	8.57	74.07
Sl No.	**District**	**Block**	**Location Details**	**Jan-23**	**May-22**	**Aug-22**	**Nov-22**
1	Nainital	Bhimtal	Amritpur (Ranibagh)	54.55	7.5	120.72	52.02
2			Salari	15.79	7.89	17.52	38.42
3			Dogaon	27.27	20	41.37	16.08
4			Sipahi Dhara	270	75	146.34	215.91
5			Garampani	60	33.33	28.84	68.31
6			Jyolikot	16.22	13.63	64.51	31.75
7			Kudaghat	9.38	2.14	13.25	8.27

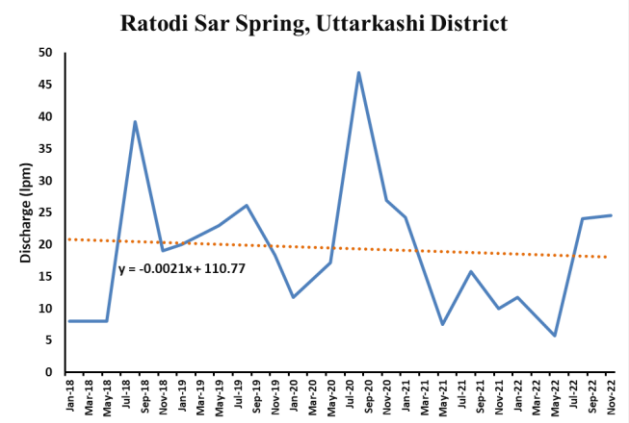
Sl No.	District	Block	Location Details	Jan-23	May-22	Aug-22	Nov-22
1	Almora	Tarikhet	Patali Talla	7.89	13.09	11.34	19.08
2			Patali Malla	6.38	8.57	2.23	6.37
3			Baniya Diggi	1.88	NA	5.47	4.3
4		Hawalbagh	Goluchheena	1.4	0.23	1.66	2.87
5			Katarmal	50	20	17.49	30.22
6			Dharanaula	7.89	7.5	7.86	8.65
7			Palna	3.53	2.38	1.78	4.61
8			Bhagtola	NA	0.97	3.05	NA
9			Jholi	17.65	10.71	10.32	11.5
10			Itola	2.4	1.66	3.45	3.74
11		Takula	Chanoda	1.88	1.36	2.06	1.41
12			Paitsaal	8.57	4.09	4.76	20.85
13			Guruda-I	3.52	1.58	6.45	3.87
14			Chhani Bartola	15	6.38	16.55	24.32
15		Chaukhutiya	Dhansari	30	4.41	9.27	22.63
16			Deepakot	13.33	8.57	10.64	11.97
17			Dhalnagaon	4.69	7.5	19.02	14.68
18			Simalkhet	10	2.61	33.13	8.11
19			Peepal Dhar	90	12.85	73.89	83.14
20			Khagsapani	1.71	0.94	11.56	6.8
21			Ramghat	15	7.5	NA	17.6
22			Naula	3.85	2.14	94.04	2.62
23		Someshwar	Mehragaon (Someshwar)	1.09	1.58	2.16	14.67
24			Lodh	8.57	4.17	8.95	1

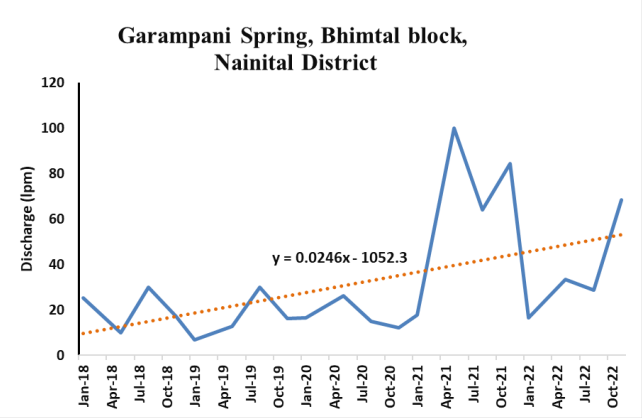
25			Bhoolgaon SP	17.65	21.43	68.1	66.05
26			Dudholi	18.75	4.41	19.92	15.99
27			Deghat	2.73	7.89	4.72	2.16
Sl No.	**District**	**Block**	**Location Details**	**Jan-23**	**May-22**	**Aug-22**	**Nov-22**
1	Uttarkas hi	Dunda	Dharasu	8.4	3.24	2.78	4.31
2		Bhatwari	Nagal	30.08	15	66	69.93
3			Ratodi Sar	52.6	5.71	24	24.57
4			Ganganani Spring	131	120	133.33	160

NA: Not Available

Long Term Spring Discharge:







The above graph shows that the springs of the Uttarkashi district is showing long term declining discharge (in LPM) whereas the springs of the Dehradun and Nainital district is showing long term rise in spring discharge.

5.3LONG TERM (DECADAL) DEPTH TO WATER LEVEL

The available long-term data of ground water levels in some of the Ground Water Monitoring Wells of the state was analysed to have an idea of the decadal (long-term) water level data and decadal versus current depth to water level fluctuations. The average value of depth to water level for selected Ground Water Monitoring Wells (based on availability of long-term water level data) was calculated for the past ten years (January, May, August and November for the period from 2012 to 2021). The average depth to water level data available for Ground Water Monitoring Wells is given in Table 10.

Table 10: Long-term (Decadal) Depth to Water Level Data, Uttarakhand State (in m bgl)

S. No.	Location Details	Avg January	Avg May	Avg August	Avg November
		2012-2021			
District Dehradun					
1	Khadiri (Khadak Maf)	13.64	15.69	12.45	14.68
2	Rishikesh	5.59	8.06	4.36	6.08
3	Lal Tappar	14.05	18.39	14.08	13.92
4	Dandi	NA	6.39	3.62	3.40
5	Bhaniawala	27.44	35.07	20.28	23.93
6	Kotimachak	19.79	21.31	11.53	16.66
7	Kuanwala	NA	14.65	1.00	3.22
8	Gularghagti	11.29	13.45	8.77	10.50
9	Balliwala	NA	55.66	55.56	NA
10	Maldeota	11.56	13.41	4.80	8.18
11	Nanurkhera	61.82	70.68	64.65	61.03
12	Tarla Nagal	73.28	75.38	50.11	68.71
13	Purukulgaon	25.92	27.57	18.26	23.35
14	Majra	32.73	22.53	20.46	20.95
15	CGWB Office	53.33	58.50	57.48	54.34
16	Harbanswala	49.38	53.66	51.15	45.99
17	Kanwali	13.81	15.18	8.89	11.85
18	Singhniwala	8.89	9.12	7.14	8.59
19	Ramgarh	5.98	6.94	4.85	6.02
20	Jhajra	9.59	13.02	6.78	7.99
21	Jhajra	12.36	12.58	7.67	7.40
22	Nanda ki Chowki	10.65	14.90	8.27	8.45
23	Nanda ki Chowki	11.82	16.78	11.39	10.65
24	Selakui	9.25	11.08	6.50	8.54
25	Selakui	13.74	16.13	12.06	13.11
26	Sabhawala	8.93	9.17	5.77	7.29
27	Rampura	11.10	11.44	7.56	10.08
28	Shankarpur	21.07	23.13	18.96	20.57
29	Redapur	6.17	9.00	6.39	5.75

30	Redapur	4.85	7.07	3.78	4.19
31	Badripur	8.87	9.38	7.21	8.63
32	Judli	13.07	12.87	11.10	12.76
33	Herbertpur	9.79	10.11	6.13	8.34
34	Vikas Nagar	26.55	26.13	21.96	24.63
35	Dharmawala	5.35	5.87	3.34	3.85
36	Dakpatthar	25.58	27.02	22.03	25.34
37	Dhakrani	17.37	16.01	10.30	15.55
District Haridwar					
1	Shahidwala Grant	9.85	11.00	10.47	9.96
2	Sahidwala Grant	10.38	11.79	9.94	9.88
3	Budhwa Shahid	3.28	4.83	2.97	2.97
4	Bugawala	6.11	7.37	6.02	5.90
5	Bahabalpur	2.79	3.27	2.07	2.59
6	Bhagwanpur	17.02	19.98	19.27	17.41
7	Chudiala	19.53	21.79	19.50	NA
8	Iqbalpur	13.84	16.52	12.98	14.95
9	Bandarjud	9.21	11.02	8.19	8.64
10	Rathora	5.12	5.16	4.26	4.22
11	Bahadrabad	11.84	9.69	12.84	12.29
12	Sarai	12.71	12.70	10.73	11.69
13	Dhanpura	6.48	8.63	5.25	8.86
14	Shahpur Shitlakhera	4.18	5.71	3.12	3.69
15	Laldhang	56.95	65.15	61.65	56.28
16	Bhogpur	3.43	4.26	1.80	2.74
17	Imlikhera	14.56	16.52	15.01	15.26
18	Roorkee	6.09	7.71	5.97	6.34
19	Sikhar	16.42	18.60	17.28	16.30
20	Khera Jat	5.88	6.75	11.31	5.70
21	Nizampur	10.40	10.92	15.53	10.35
22	Jhabreda	8.89	9.87	7.73	9.57
23	Landhaura	17.97	18.69	17.20	17.09
24	Lakhnauta	6.89	6.54	4.93	5.68
25	Gurukul Narsen	5.75	6.16	4.04	5.15
26	Libhrahedi	6.40	8.13	5.46	6.02
27	Mudlana	17.63	16.65	17.44	17.41
28	Hussainpur	1.89	3.75	1.32	2.10
29	Laksar	2.72	4.06	1.98	2.90
30	Bhikkampur	3.62	3.98	2.19	2.48
31	Govardhanpur	2.19	4.02	1.69	2.46
32	Dallawala	2.06	2.01	0.89	1.41
District Nainital					
1	Khaat Baans	29.21	30.35	27.25	30.11
2	Lalkuan	8.84	12.75	11.25	9.98
3	Lamachaur	44.90	47.09	NA	NA
4	Kaladungi	29.02	29.99	27.52	27.45
5	Kathgodam	19.13	20.16	15.28	17.01
6	Belparao	57.06	57.22	56.14	56.36
7	Peeru Madara	23.12	27.68	23.34	21.48

8	Maldhan Colony	3.23	5.13	3.26	4.25
9	Dhela	65.06	68.76	68.01	70.83
10	Garjiya	NA	4.46	3.30	4.63
District Udham Singh Nagar					
1	Kanchanpur	4.45	5.21	4.04	3.72
2	Khatima	2.31	3.13	1.38	1.82
3	Sarasariya	3.97	6.56	5.11	3.61
4	Chakarpur	6.17	6.50	4.58	4.36
5	Sitarganj	1.68	3.32	1.13	1.30
6	Nanak Mata	3.38	4.73	2.25	2.72
7	Kalyanpur	2.18	3.51	1.67	2.14
8	Tukri	2.92	4.45	3.15	2.74
9	Dhyanpur	1.83	4.07	2.27	1.26
10	Bara	2.11	2.20	1.06	1.80
11	Kichha	7.36	8.85	7.28	7.80
12	Kamaria Pakki	5.12	7.61	5.56	4.62
13	Gangapur	2.65	3.82	2.67	2.62
14	Shantipuri	1.69	2.03	1.02	1.78
15	Patthar Chatta	2.45	3.39	2.34	2.65
16	Rudrapur	2.76	3.33	2.29	2.75
17	Jhagarpuri	2.80	3.37	1.90	3.28
18	Mahabir Nagar	2.34	3.19	1.21	1.82
19	Beria Daulat	3.05	3.33	2.19	2.90
20	Bhagwanpur	3.95	9.72	7.46	3.57
21	Bazpur	1.80	2.73	0.77	1.37
22	Jharkhandi	1.68	2.33	1.59	1.35
23	Jogipura	3.52	5.95	4.17	3.59
24	Banna Khera	3.62	5.09	3.74	3.72
25	Badaripur	4.21	6.46	5.05	3.52
26	Barkhare Pande	6.64	10.72	6.98	4.04
27	Kashipur	4.92	7.16	5.13	5.41
28	Bharatpur	7.29	12.03	10.61	8.49
29	Dhanauri Patti	2.84	4.64	2.86	2.93
30	Durgapur	3.17	5.56	3.52	2.88
31	Jaspur	12.72	16.03	14.21	12.19
32	Patrampur	7.38	10.85	9.60	7.98
33	Angadpur	7.00	11.82	9.04	8.51
District Champawat					
1	Tanakpur	10.65	11.62	8.44	9.46
2	Banbasa	5.11	8.45	4.41	5.84
3	Bastia	33.96	34.82	24.99	24.49
4	Bichai	10.08	11.99	8.93	10.04

5.4 WATER LEVEL FLUCTUATION

The changes in ground water level in response to recharge and ground water withdrawal are important aspects for study of the overall hydrogeological scenario of an area. The water level fluctuation is calculated in each case under the following three categories.

- Changes in water level during each period of observation with respect to average water level for the last ten years for that period.
- Changes in water level during each season/period with respect to observed data of pre-monsoon water level during the same year.
- Changes in water level during each season/period with respect to water levels observed in previous year of the same period.

Tables and maps, which show the long-term (decadal), yearly and seasonal water level fluctuations, were prepared for the monitoring wells of Dehradun, Haridwar, Udham Singh Nagar, Nainital and Champawat district. The analysis of water level fluctuation data and conclusion drawn from it are discussed below.

5.4.1 DECADAL (LONG-TERM) WATER LEVEL FLUCTUATION

5.4.1.1 Water Level Fluctuation (January 2013-2022 versus January 2023)

Decadal (long-term) water level data for 146 ground water monitoring wells is analysed and is given in ***Table 11***. As per the analysis of Table 11, total 69% of the wells are showing decadal rise in water level in January.

A perusal of the table indicates that out of 146 monitoring wells, 89 wells (60.96% of the total number) had shown the minimum decadal rise in the range 0-2 m, 9 wells (6.16% of the totalnumber) of monitoring wells had shown a higher rise in the range 2-4 m while only 3 well (2.05% of total) had shown the highest decadal rise of >4 m. The minimum decadal decline in the rangeof 0-2 m is shown by 36 wells (24.66% of total) while 7 wells (4.79%) had shown higher decadal rise of 2-4 m. 2 monitoring well (1.37%) has recorded the highest decadal decline (>4 m) in Uttarakhand State.

The decadal water level fluctuation map for average (January 2013 -2022) versus January 2023 is shown in ***Fig.25****(Dehradun Section),* ***Fig.26*** *(Haridwar section)* and ***Fig. 27****(UdhamSingh Nagar)* ***Fig.28*** *(Nainital Section),* ***Fig. 29*** *(Champawat Section)*.

A perusal of **Fig. 25** (Dehradun District) reveals that minimum decadal rise of 0-2 m is observed in major part of the Doon Valley covering Raipur, Vikasnagar and Sahaspur blocks. Decadal decline of 0-2 m is observed in the major areas of Doiwala block, central part ofSahaspur block and western flank of Vikasnagar block of the district.

A perusal of **Fig. 26** (Haridwar District) reveals that minimum decadal rise of 0-2 m is observed in major portion of the district covering Khanpur, Laksar, Narsan, Roorkee, southern Bhagwanpur, and Bahadrabad block of the district. Minimum decadal decline of 0-2 m observedin northern part of the Bahadrabad and Bhagwanpur blocks of the district.

A perusal of **Fig. 27 (Udham Singh Nagar)** reveals that minimum decadal rise of 0-2 m is observed in 90% area of the district. Minimum decadal fall of 0-2 m occur in Jaspur, Kashipur and southern part of Gadarpur block of the district.

A perusal of **Fig. 28** reveals that Nainital district is showing decadal rising water level trend. Minimum decadal rise of 0.-2 m occurs in major parts of the Ramnagar block and western part of Haldwani Block. However, decadal decline in the range of 0-2 m is observed in the western portion of Ramnagar block and eastern portion of Haldwani block of the district.

A perusal of **Fig. 29** reveals that the Champawat district is representing mainly rising decadal water level trend from south to north of the district.

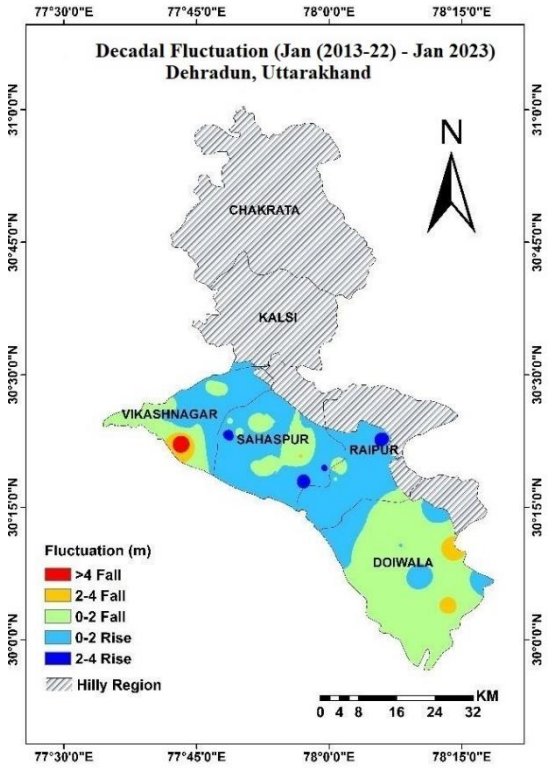


Fig. 25: Decadal Water Level Fluctuation of Dehradun District

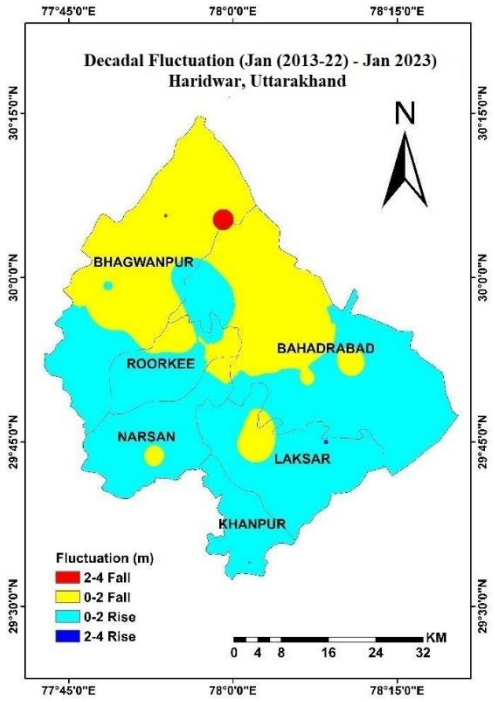


Fig. 26: Decadal Water Level Fluctuation of Haridwar District

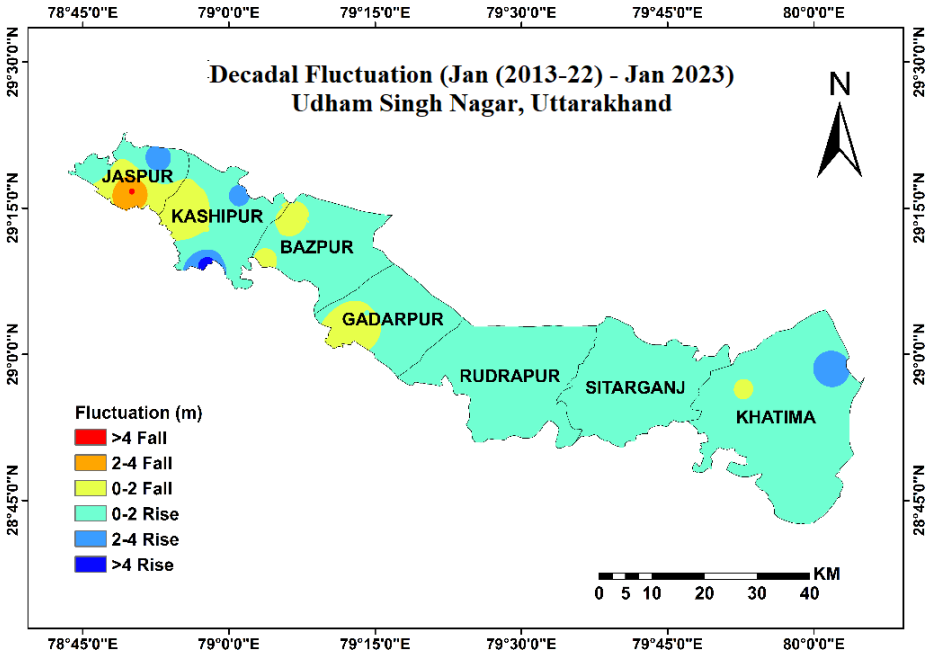


Fig. 27: Decadal Water Level Fluctuation of Udham Singh Nagar District

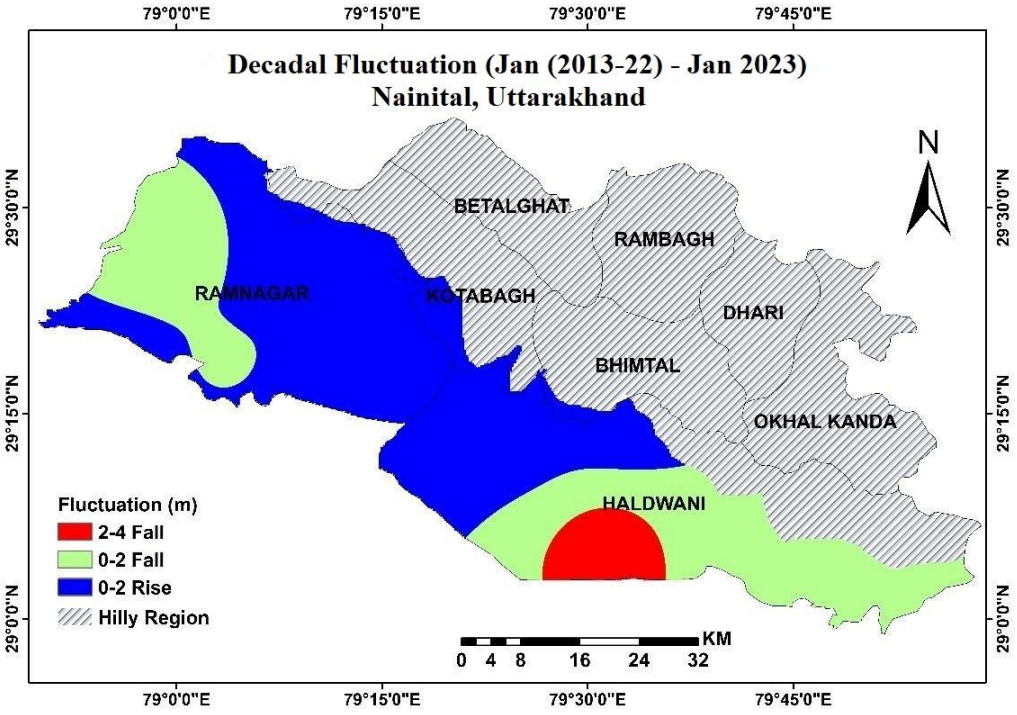


Fig. 28: Decadal Water Level Fluctuation of Nainital District

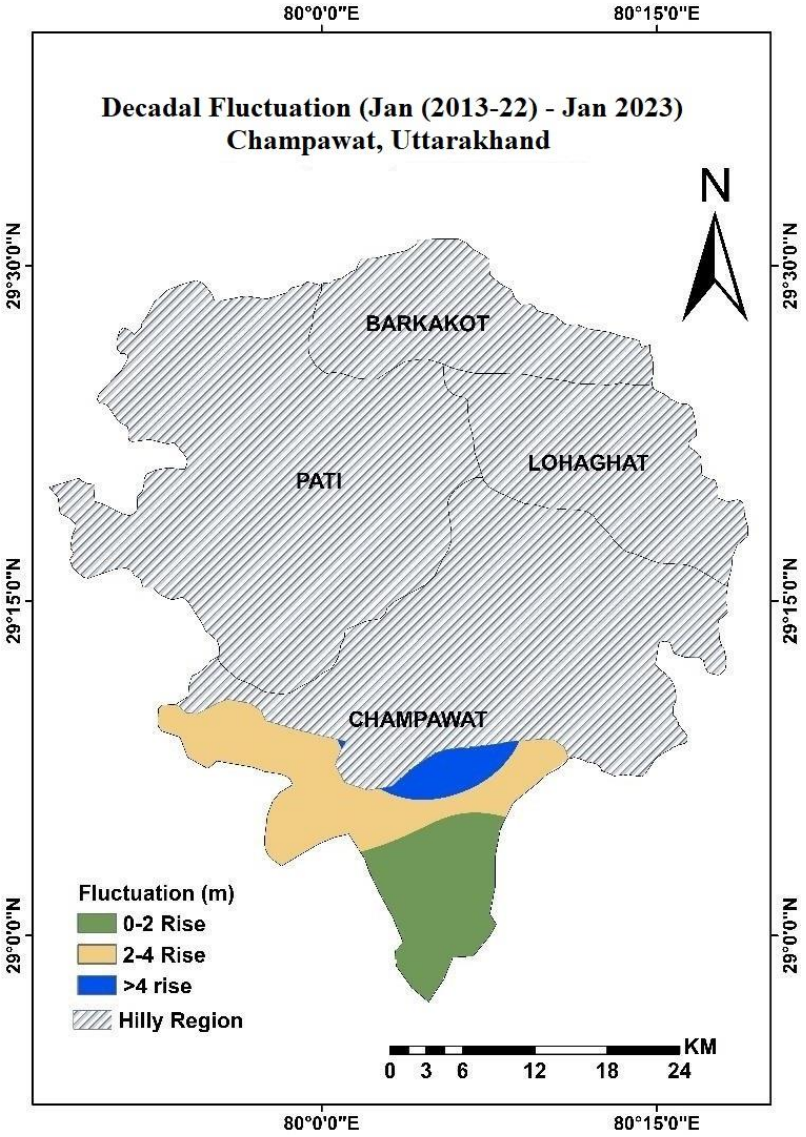


Fig. 29: Decadal Water Level Fluctuation of Champawat District

Table 11. Decadal Water Level Fluctuation (January 2013-January 2022 versus January 2023)

District	No. of stations analyzed	Fluctuation (m)				Rise (m)						Decline (m)					
		Rise		Decline		0-2		2 to 4		>4		0-2		2 to 4		>4	
		Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
Dehradun	46	0.04	4.07	0.02	6.82	21	45.65	4	8.69	1	2.17	15	32.6	4	8.69	1	2.17
Haridwar	39	0.01	2.03	0.09	2.34	24	61.53	2	5.12	0	0	11	28.2	2	5.12	0	0
Udham Singh Nagar	46	0.00	5.17	0.01	4.11	34	0.73	3	6.52	1	2.17	7	15.21	0	0	1	2.17
Nainital	11	0.27	1.716	0.39	3.84	7	63.63	0	0	0	0	3	27.27	1	9.09	0	0
Champawat	4	0.62	6.794	0.00	0.00	3	75	0	0	1	25	0	0	0	0	0	0
Total	**146**	**0.01**	**6.794**	**0.01**	**6.82**	**89**	**60.96**	**9**	**6.16**	**3**	**2.05**	**36**	**24.66**	**7**	**4.79**	**2**	**1.37**

5.4.1.2 Water Level Fluctuation (May 2012-2021 versus May 2022)

The analysis of decadal depth to water level data for **147** ground water monitoring wells is given in ***Table 12***. A perusal of the table indicates that the minimum long-term rise in the range of 0-2 m is observed in 67 monitoring wells (45.48 % of the total number) whereas higher rise in the range of 2-4 m is observed in 11 wells (7.48 % of total). The 9 nos. of well (6.12%) recorded the decadal rise in water level (>4 m). The lowest long-term decline in the range of 0-2 m is recorded in 41 wells, which is 27.89 % of the total number. Higher long-term decline in the range of 2-4 m is recorded in 14 wells, which is 9.52 % and the highest decline of >4 m is recorded in 5 wells, which is 3.40 % of the total number.

As per the analysis of Table 12, 48% of the NHS wells are showing decadal rise in water level in the pre-monsoon.

A study of **Fig. 30 (Dehradun district)** reveals that the minimum fall of 0-2 m is observed in major part of the Doon valley. Higher decline in the range of 2-4 m is observed as rimming the highest decline of >4m, mainly in the central part of Doiwala block of the Doon valley. Decadal rising water level is observed mainly in the central portion of Doiwala block and Eastern portion of Sahaspur Block.

A study of **Fig. 31 (Haridwar District)** reveals that the minimum fall of 0-2 m is observed in major part of the district covering Bahadrabad, Bhagwanpur, Khanpur and northern Roorkee block of the district. Higher decline of 2-4 m is observed as isolated patches in the Bahadrabad block. Minimum Rise of 0-2 m is observed in the eastern part of Bahadrabad and Laksar blocks of the district and in the western part of Bhagwanpur and Narsan blocks.

A study of **Fig. 32 (Udham Singh Nagar district)** reveals that the minimum fall of 0-2 m is observed in major part of the district covering western portion of Rudrapur, eastern portion of Gadarpur, Bazpur and parts of Kashipur and Jaspur blocks of the district. Higher decadal fall in the range of 2-4 m is observed mainly in the Jaspur and Kashipur blocks of the district as rimming the highest decadal decline in the range of >4 m. Minimum rise of 0-2 m occur mainly in the Khatima, Sitarganj and western portion of Gadarpur blocks of the district.

A study of **Fig. 27(Nainital district)** reveals that the decadal declining water level trend can be observed in the central portion of the Haldwani block of the district during pre-monsoon season whereas the Ramnagar block of the district is showing decadal rising water level in pre-monsoon.

A study of **Fig. 28(Chamapawat district)** reveals that he minimum fall of 0-2 m is observed in major part of the Champawat district. The southern part of the district shows a rise of 0-2.

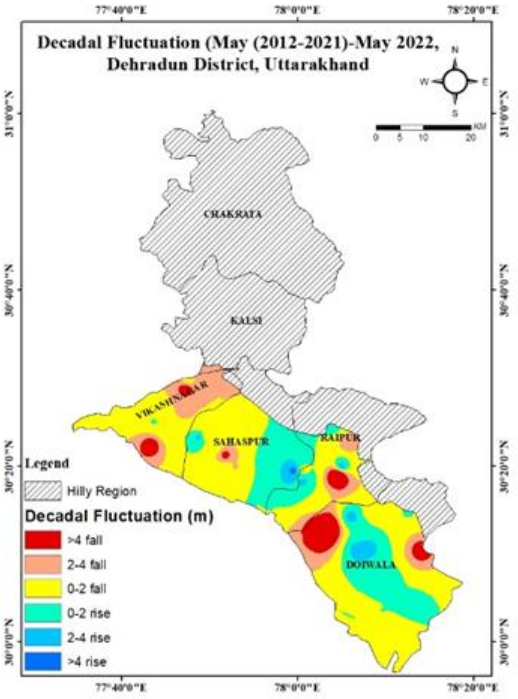


Fig. 30: Decadal Water Level Fluctuation of Dehradun District

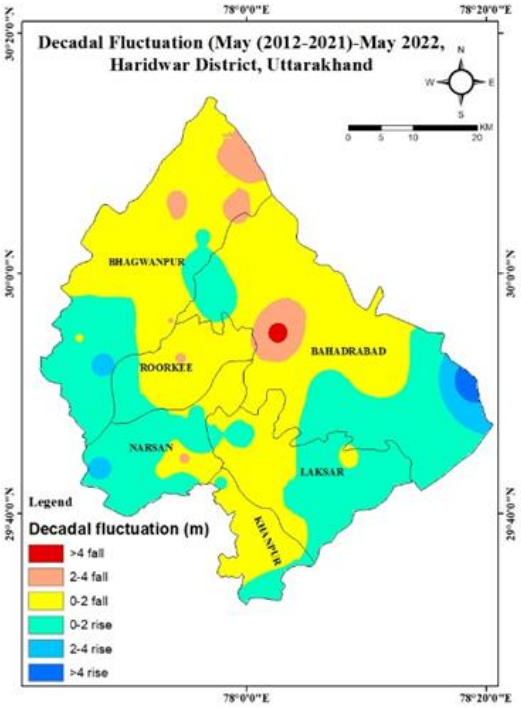


Fig. 31: Decadal Water Level Fluctuation of Haridwar District

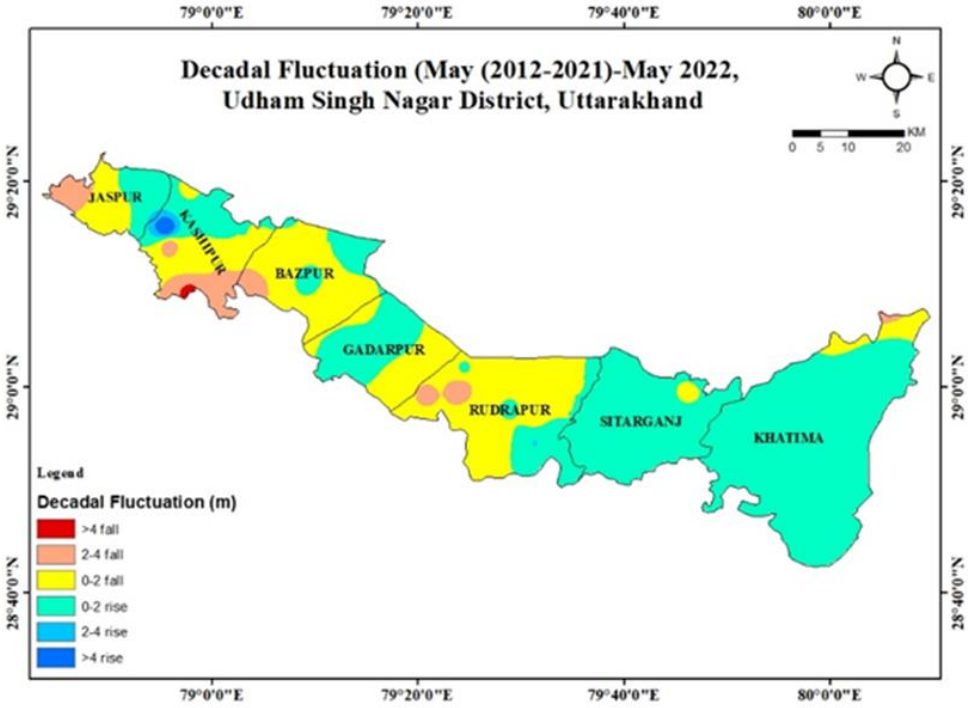


Fig. 32: Decadal Water Level Fluctuation of Udham Singh Nagar District

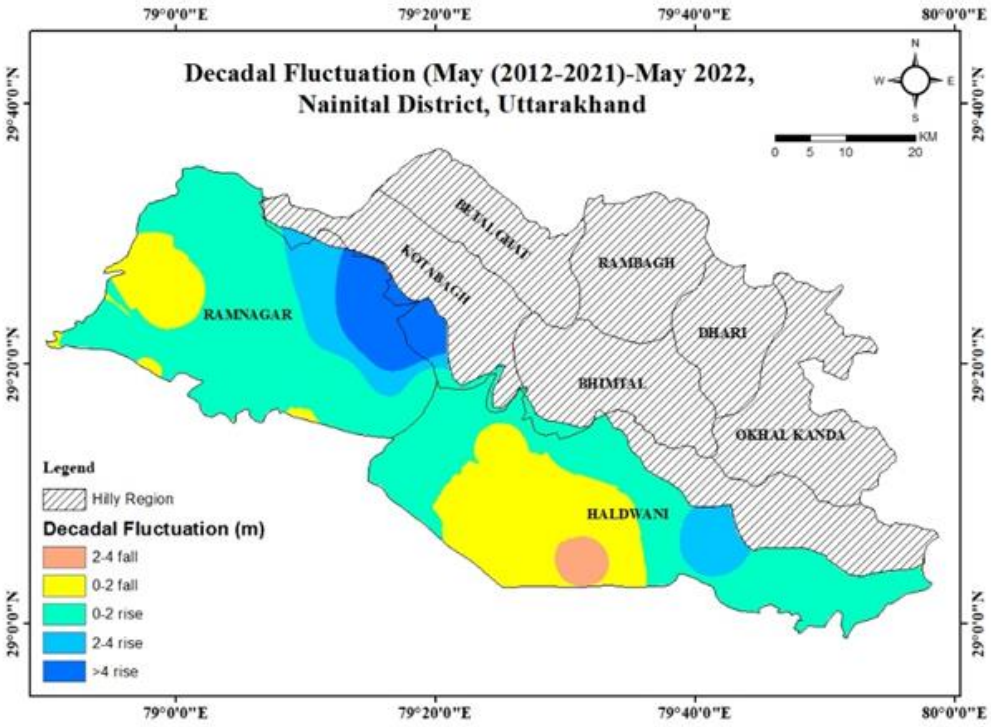


Fig. 33: Decadal Water Level Fluctuation of Nainital District

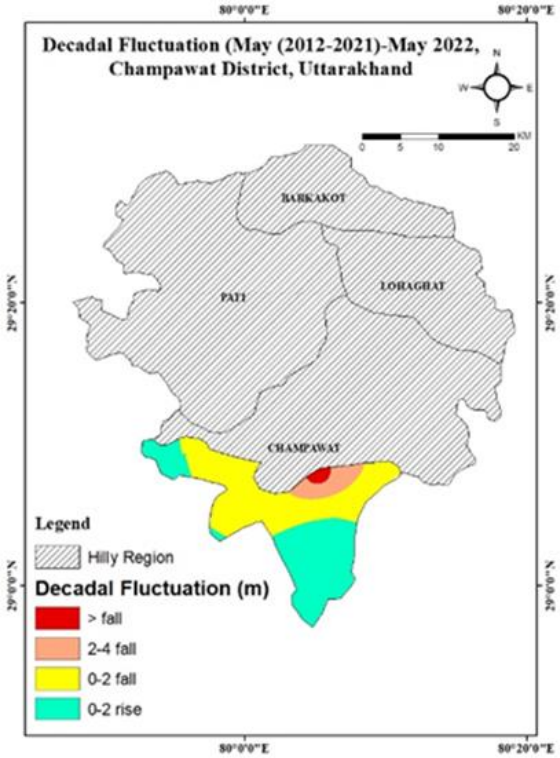


Fig. 34: Decadal Water Level Fluctuation of Champawat District

Table 12. Decadal Water Level Fluctuation (May 2012 –May 2021 versus May 2022)

District	No. of stations analyzed	Fluctuation (m)				Rise (m)						Decline (m)					
		Rise		Decline		0-2		2 to 4		>4		0-2		2 to 4		>4	
		Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
Dehradun	53	0.09	5.40	-0.03	-14.62	12.00	22.64	4.00	7.55	4.00	7.55	19.00	35.85	7.00	13.21	7.00	13.21
Haridwar	39	0.02	8.47	-0.01	-3.59	12.00	30.77	2.00	5.13	3.00	7.69	17.00	43.58	5.00	12.82	0.00	0.00
Udham Singh Nagar	57	0.01	16.25	0.00	-4.83	28.00	49.12	2.00	3.51	2.00	3.51	17.00	29.82	7.00	12.28	1.00	1.75
Nainital	12	0.59	16.25	-0.37	-3.39	6.00	50.00	1.00	8.33	1.00	8.33	3.00	25.00	1.00	8.33	0.00	0.00
Pauri Garhwal	2	4.80	14.93	0.00		0.00	0.00	1.00	50.00	1.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00
Champawat	3	0.04	1.77	-4.46		2.00	66.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	33.33
Uttarkashi	7	2.52	17.48	-0.37	-8.10	1.00	14.29	0.00	0.00	1.00	14.29	3.00	42.86	0.00	0.00	2.00	28.57
Total	**173**					**61**	35.26	**10**	5.78	**12**	6.94	**59**	34.10	**20**	11.56	**11**	6.36

5.4.1.3 Water Level Fluctuation (August 2012-2021 versus August 2022)

Long-term water level data for 147 monitoring wells is analysed and is shown in ***Table 13***.A perusal of **Table 13** indicates that the minimum long-term rise in the range of 0-2 m is observedin 67 monitoring wells 45.58 % of the total number), whereas higher rise in the range of 2-4 m is observed in 11 wells (7.48 % of total) and the highest rise of >4 m is observed in 9 monitoring wells(6.12% of total). The lowest long-term decline of water level in the range of 0-2 m is recorded in 41 monitoring wells, which is 27.89 % of the total number. Higher long-term decline in the range of 2-4 m is recorded by 14 wells (9.52 % of total) whereas the highest decline of >4 m is observed in 5 monitoring wells, which is 3.40% of the total number of wells.

As per the analysis of Table 13, 59% of the NHS wells are showing decadal rise in water level in the August month.

Visual interpretation of **Fig. 35 (Dehradun District)** has shown that minimum decadal decline of 0-2 m is found in Vikasnagar, Raipur and Doiwala block of the distirct. Whereas decadal rising water level is found in the major portion of Sahaspur, northern portion of Raipur and Vikasnagar of the district.

Visual interpretation of **Fig. 36(Haridwar District)** has shown that minimum decadal decline of 0-2 m is observed in major part of the district covering Bahadrabad, Bhagwanpur, Laksar, Khanpur, Narsan and parts of Roorkee block of the district. Higher decadal fall in the range of 2-4 m is observed in large portion of Bhagwanpur block of the district. Minimum decadal rise of 0-2 m is limited to the eastern portion of Bahadrabad and southern portion of Narsan block rimming areas with decadal rise of 2-4 m and > 4 m.

Visual interpretation of **Fig. 37(Udham Singh Nagar)** has shown that minimum decadal decline of 0-2 m is observed in major part of the district. Higher decadal decline of 2-4 m and > 4 m is observed in the western part of the district covering major parts of Jaspur, Kashipur, western part of Bazpur and Rudrapur blocks. Decadal rise of 0-2 m is observed in small patches of Khatima block.

Visual interpretation of **Fig. 38(Nainital district)** has shown that minimum decadal fall of 0-2 m is observed in major part of the district. Higher water level decline of 2-4 m and >4 m is observed in the central portion of Haldwani block and western portion of Ramnagar block. Decadal rise of 0-2 m is observed as very limited patches in Ramnagar district.

Visual interpretation of **Fig. 39(Champawat district)** has shown that generally decadal water level declines from north to south in district.

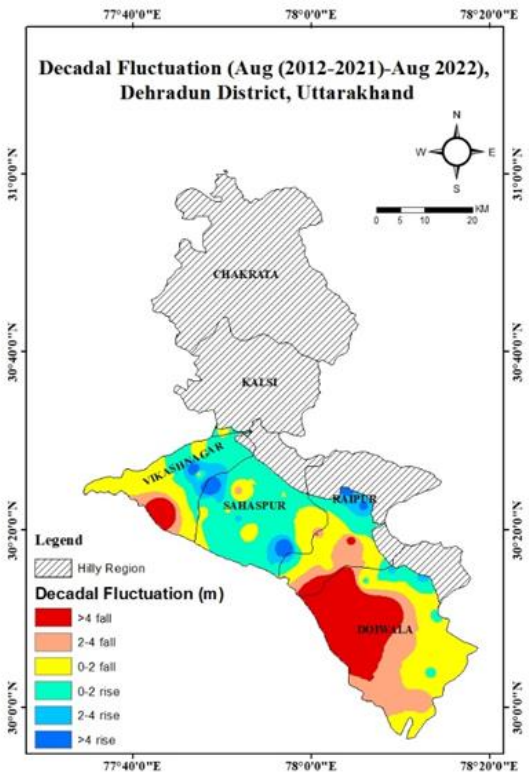


Fig. 35: Decadal Water Level Fluctuation of Dehradun District

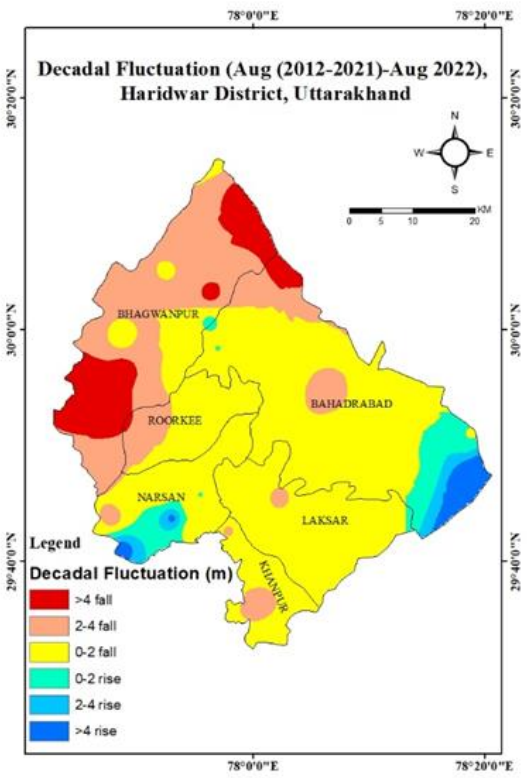


Fig. 36: Decadal Water Level Fluctuation of Haridwar District

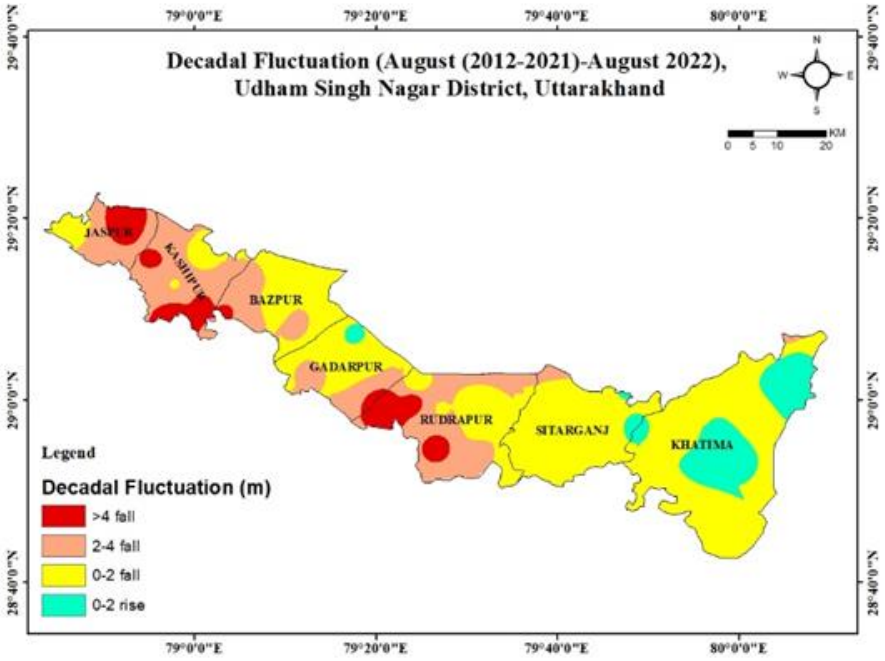


Fig. 37: Decadal Water Level Fluctuation of Udham Singh Nagar District

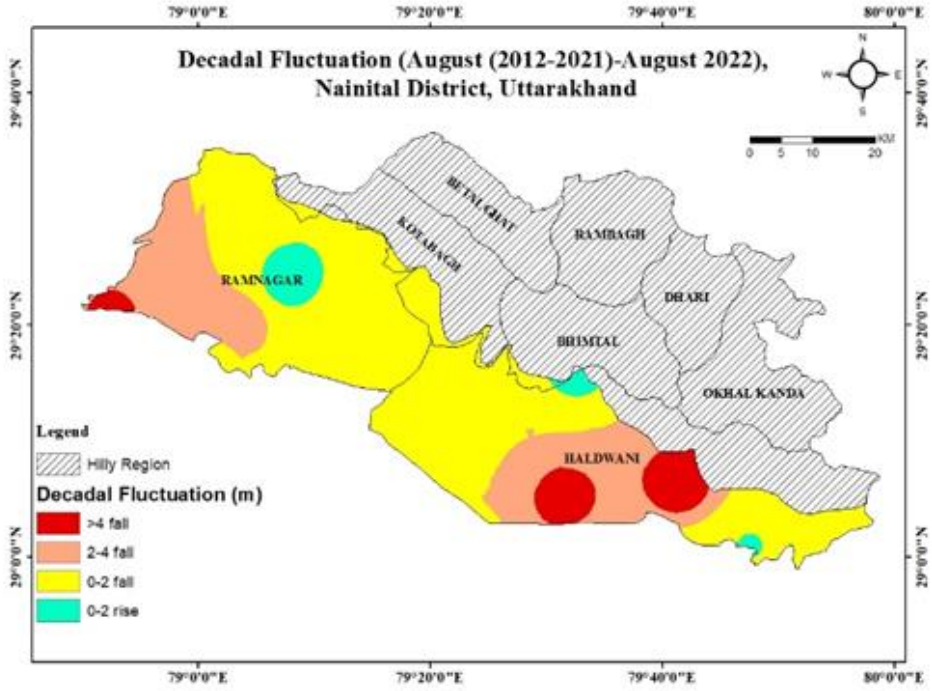


Fig. 38: Decadal Water Level Fluctuation of Nainital District

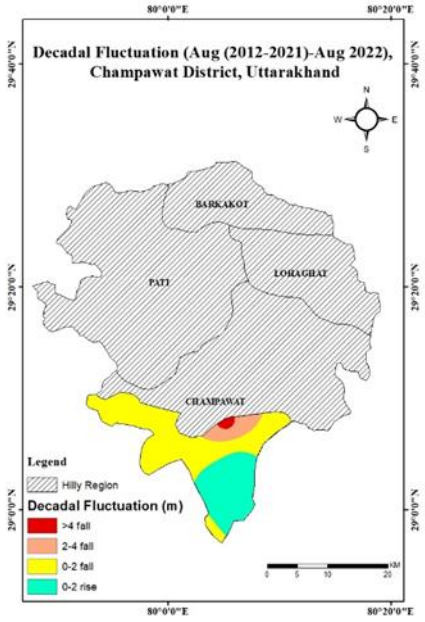


Fig. 39: Decadal Water Level Fluctuation of Champawat District

Table 13. Decadal Water Level Fluctuation (August 2012 –August 2021 versus August 2022)

District	No. of stations analyzed	Fluctuation (m)				Rise (m)						Decline (m)					
		Rise		Decline		0-2		2 to 4		>4		0-2		2 to 4		>4	
		Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
Dehradun	49.00	0.09	20.95	-0.05	-7.15	22.00	44.90	5.00	10.20	4.00	8.16	14.00	28.57	1.00	2.04	2.00	4.08
Haridwar	35.00	0.02	4.10	-0.01	-3.59	11.00	31.43	1.00	2.86	1.00	2.86	17.00	1.00	5.00	14.29	0.00	0.00
Udham Singh Nagar	45.00	0.04	5.94	-0.11	-4.27	28.00	62.22	2.00	4.44	1.00	2.22	7.00	15.56	6.00	13.33	1.00	2.22
Nainital	8.00	0.71	3.82	-1.93	-3.92	4.00	50.00	1.00	12.50	1.00	12.50	1.00	12.50	1.00	12.50	0.00	0.00
Pauri Garhwal	1.00	2.76		0.00		0.00	0.00	1.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Champawat	2.00	2.56		-6.77		0.00	0.00	1.00	50.00	1.00	50.00	0.00	0.00	0.00	0.00	1.00	50.00
Uttarkashi	7.00	0.40	15.43	-0.29	-4.91	2.00	28.57	0.00	0.00	1.00	14.29	2.00	28.57	1.00	14.29	1.00	14.29
Total	**147.00**					**67.00**	45.58	**11.00**	7.48	**9.00**	6.12	**41.00**	27.89	**14.00**	9.52	**5.00**	3.40

5.4.1.4 Water Level Fluctuation (November 2012-2021 versus November 2022)

Long-term water level data for 162 monitoring wells is analysed and is shown in ***Table14***. The table indicates that 70 monitoring wells out of 162 (43.21 % of total) had shown decadal rise of 0-2 m, 15 monitoring wells (9.26 % of total) had shown rise of 2-4 m and 14 wells (8.64 % of total) has shown the highest decadal rise of >4 m. As far as decadal decline in water level is concerned, 47 wells out of 162 (29.01 % of total) had recorded decadal decline in the range of 0- 2 m, 09 monitoring wells (5.56% of total) had shown higher decadal decline of 2-4 m, and total 8wells out of 162 (around 4.94%) of wells have shown decadal decline of >4 m in Uttarakhand in the post-monsoon period.

As per the analysis of Table 14, 61% of the NHS wells are showing decadal rise in water level in the post-monsoon.

A perusal of **Fig. 40(Dehradun district)** reveals that minimum decadal decline of 0-2 m is observed in southern portion of the Doon valley. Higher decadal decline of 2-4 m observed as scattered concentric patches in the central part of Doiwala block, Northern Raipur block and along wth isolated patch of Vikasnagar block of the district. Minimum decadal rise of 0-2 m is observed in the Vikasnagar, Sahaspur and Raipur blocks of the district. Rise of 2-4 m and >4 m is observed in the Raipur block.

A perusal of **Fig. 41(Haridwar district)** reveals that minimum decadal fall of 0-2 m is observed in >70% parts of Haridwar District. Minimum decadal rise in the range of 0.-2 m is observed mainly in the eastern part of the Bahadrabad and Laksar and in the Roorkee district.

A perusal of **Fig. 42(Udham Singh Nagar district)** reveals that minimum decadal rise of 0-2 m is observed in major parts of the Udham Singh Nagar District covering Khatima, Sitarganj, Rudrapur, Gadarpur and Bazpur block of the district. Minimum decadal decline of 0-2 m is observed in the major parts of Jaspur, Bazpur, Gadarpur and parts of the Sitarganj block of the district.

A perusal of **Fig. 43(Nainital district)** reveals that Nainital district is showing decadal rising water level trend. Ramnagar block and the northern portion of Haldwani block shows a decadal rise of 0-2 m. Decadal fall of 0-2 m is observed in the central and southern part of the Haldwani block which is rimmed by decadal decline of 2-4 m. Decadal decline of 0-2 m is also visibe in the southern part of the Ramnagar district.

A perusal of **Fig. 44(Champawat district)** reveals that the southern part of Champawat district is representing mainly rising decadal water level trend of 0-2 m. Higher decadal decline of 0-2 m, 2-4 m and > 4 m occur in the northern part of the district.

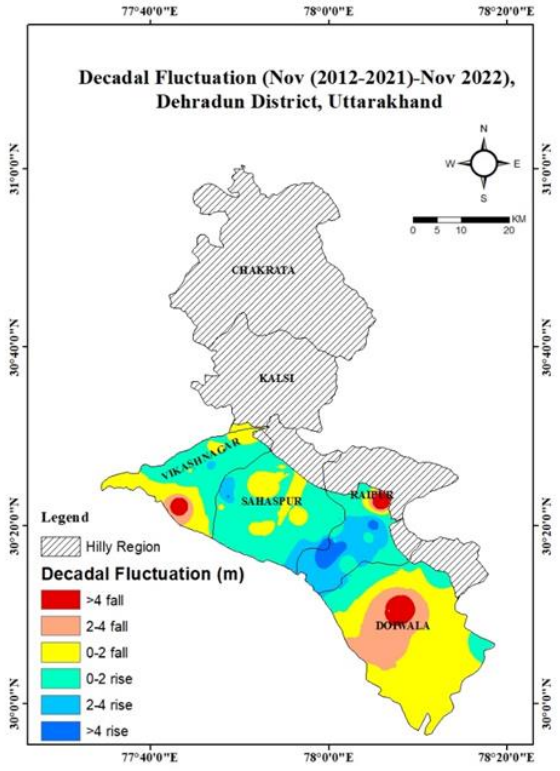


Fig. 40: Decadal Water Level Fluctuation of Dehradun District

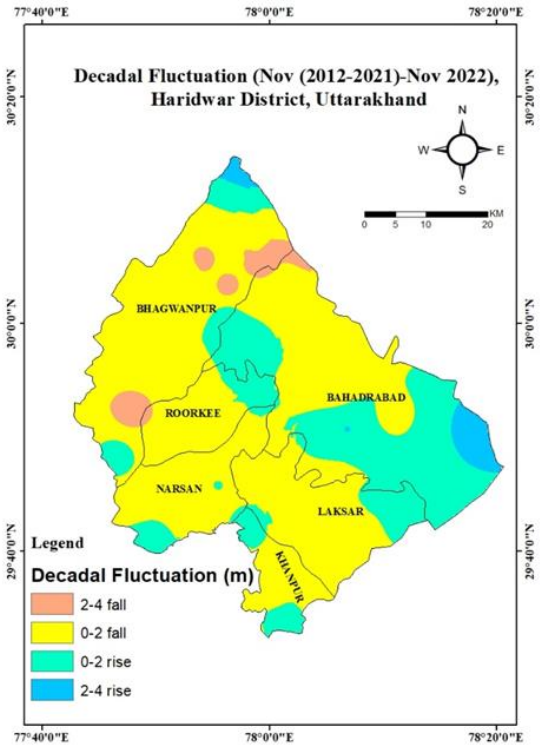


Fig. 41: Decadal Water Level Fluctuation of Haridwar District

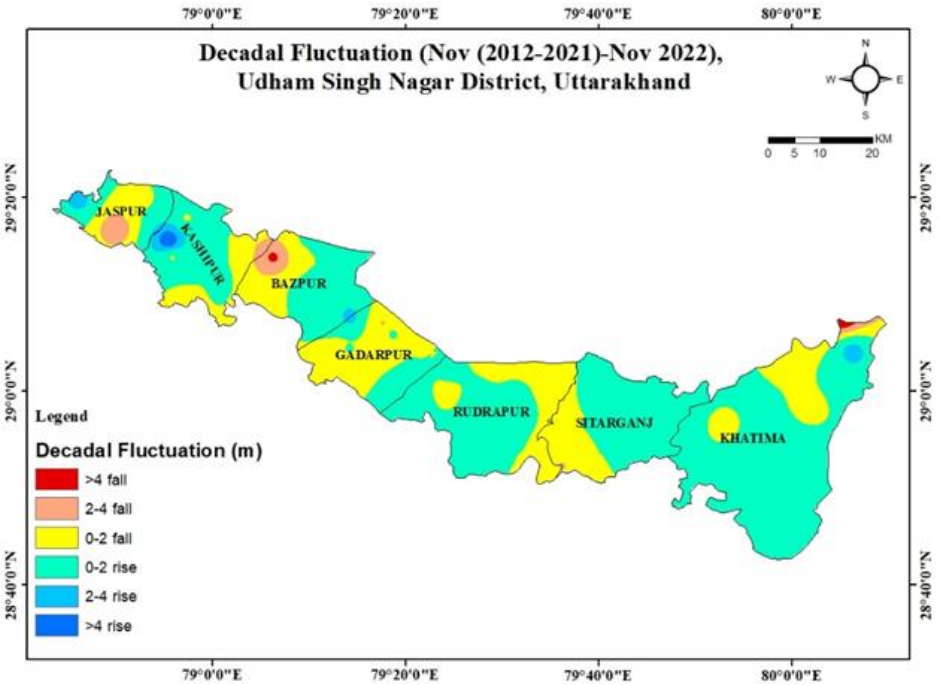


Fig. 42: Decadal Water Level Fluctuation of Udham Singh Nagar District

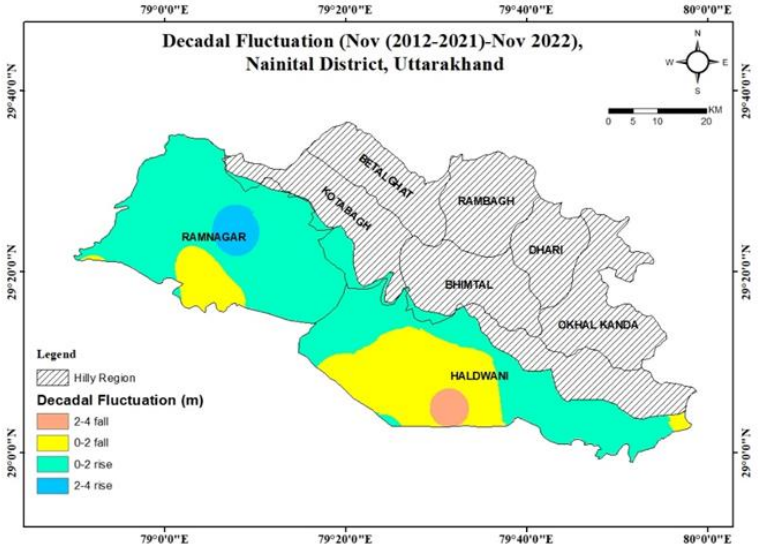


Fig. 43: Decadal Water Level Fluctuation of Nainital District

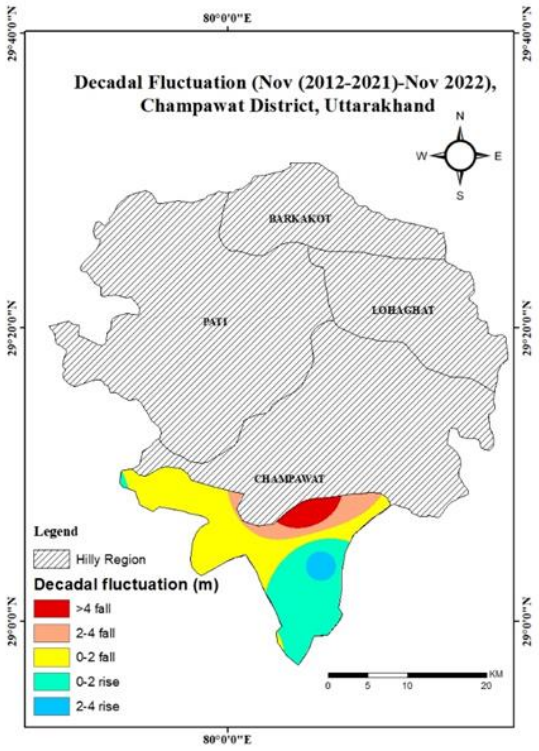


Fig. 44: Decadal Water Level Fluctuation of Champawat District

Table 14. Decadal Water Level Fluctuation (November 2012 - November 2021 versus November 2022)

District	No. of stations analyzed	Fluctuation (m)				Rise (m)						Decline (m)					
		Rise		Decline		0-2		2 to 4		>4		0-2		2 to 4		>4	
		Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
Dehradun	56.00	0.09	31.06	-0.05	-27.55	24.00	42.86	5.00	8.93	8.00	14.29	14.00	25.00	1.00	1.79	4.00	7.14
Haridwar	39.00	0.02	8.47	-0.01	-3.59	12.00	30.77	2.00	5.13	3.00	7.69	17.00	1.00	5.00	12.82	0.00	0.00
Udham Singh Nagar	45.00	0.04	5.94	-0.11	-4.27	28.00	62.22	2.00	4.44	1.00	2.22	12.00	26.67	1.00	2.22	1.00	2.22
Nainital	8.00	0.71	3.82	-1.93	-3.92	4.00	50.00	2.00	25.00	0.00	0.00	1.00	12.50	1.00	12.50	1.00	12.50
Pauri Garhwal	2.00	2.76	10.08	0.00		0.00	0.00	1.00	50.00	1.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00
Champawat	4.00	2.56	3.06	-6.77		0.00	0.00	3.00	75.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	25.00
Uttarkashi	8.00	0.40	15.43	-0.29	-4.14	2.00	25.00	0.00	0.00	1.00	12.50	3.00	37.50	1.00	12.50	1.00	12.50
Total	**162.00**					**70.00**	43.21	**15.00**	9.26	**14.00**	8.64	**47.00**	29.01	**9.00**	5.56	**8.00**	4.94

5.4.2 ANNUAL WATER LEVEL FLUCTUATION

5.4.2.1 Water Level Fluctuation (January 2022 versus January 2023)

The analysis of water level data of 152 ground water monitoring wells for the period January 2022versus January 2023 is given in ***Table 15.***

A perusal of the table also reveals that out of 152 monitoring wells, 109 wells (71.71%) have recorded the minimum annual rise in the range 0-2 m whereas 11 wells (7.24 % of total wells) had shown higher rise in the range 2-4 m. 4 nos. of monitoring well (2.63 % of the total)had recorded the highest annual water level rise of greater than 4 metres. Lowest annual decline of 0-2 m is recorded by 26 monitoring wells (17.11 % of total) while only 1 well (0.66%) had recorded higher decline in the range of 2-4 m.

As per the analysis of Table 15, 81% of the NHS wells are showing annual rise in water level in the month of January.

Visual interpretation of **Fig. 45(Dehradun district)** has shown that the minimum annual rise of 0-2 m is observed in more than 90% of the Doon Valley covering major parts of Doiwala, Sahaspur, Vikasnagar and Raipur blocks of the district. Minimum annual decline of 0-2 m is observed in patches throughout the district.

Visual interpretation of **Fig. 46(Haridwar district)** has shown that the annual minimum annual rise in the range of 0-2 m is observed in major prat of the district, however minimum annual rise of 0-2m is also observed in patches throughout the district specially in Bahadrabad block.

Visual interpretation of **Fig. 47(Udham Singh Nagar district)** has shown that the annual minimum annual rise in the range of 0-2 m is observed in major part of the district. Higher annual rise of 2-4 m can be observed as small concentric patches in Rudrapur, Kashipur, Bazpur and Jaspur blocks of the district, however, annual declining water level trend is also observed as concentric patches mainly in west part of Jaspur and northern part of Rudrapur block of the district.

Fig. 48 (Nainital District) reveals that most of the area is showing rising trend of water level in the range of 2-4 m mainly in Ramnagar block, however, declining trend is also found in southern portion of Haldwani block.

A perusal of **Fig. 49(Champawat district)** reveals that the Champawat district is representing mainly rising annual water level trend in the range of 0-2 m. Annual decline of 0-2m can be observed in the northern part of the district.

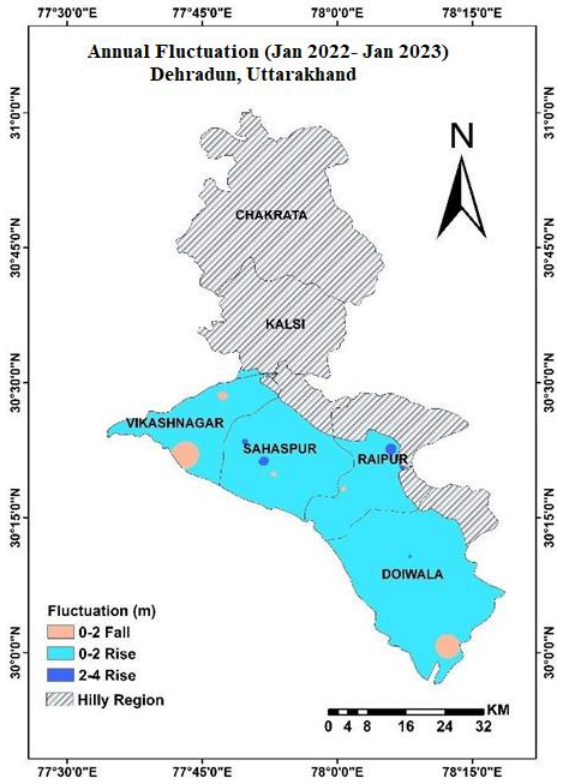


Fig. 45: Annual Water Level Fluctuation of Dehradun District (Jan 2022 Vs Jan 2023)

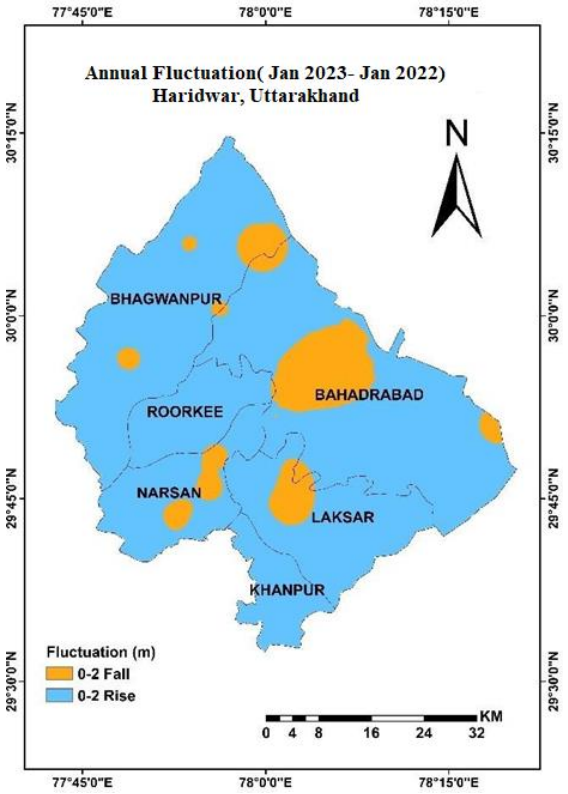


Fig. 46: Annual Water Level Fluctuation of Haridwar District (Jan 2022 Vs Jan 2023)

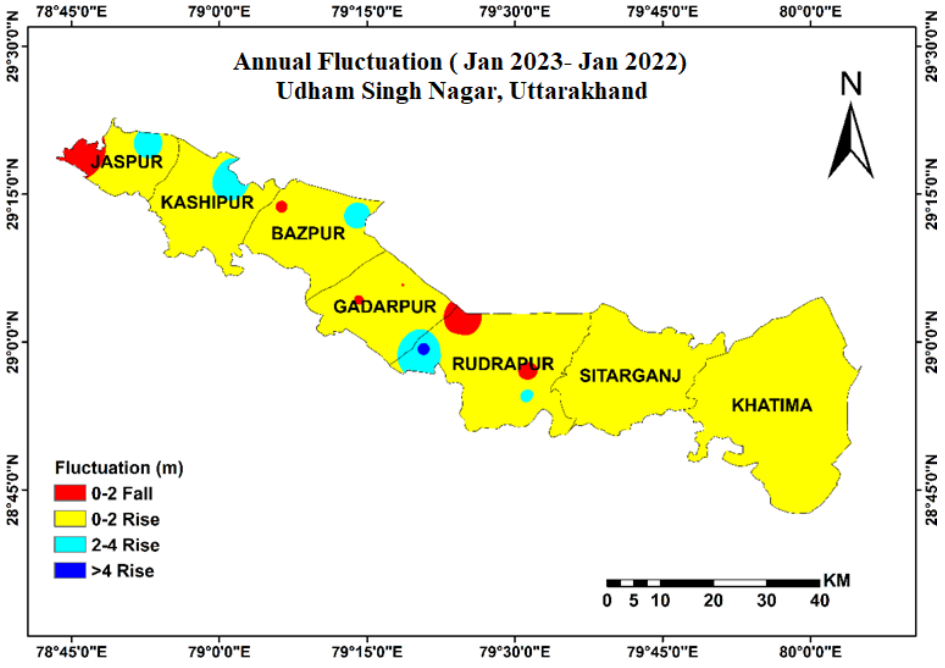


Fig. 47: Annual Water Level Fluctuation of Udham Singh Nagar District (Jan 2022 Vs Jan2023)

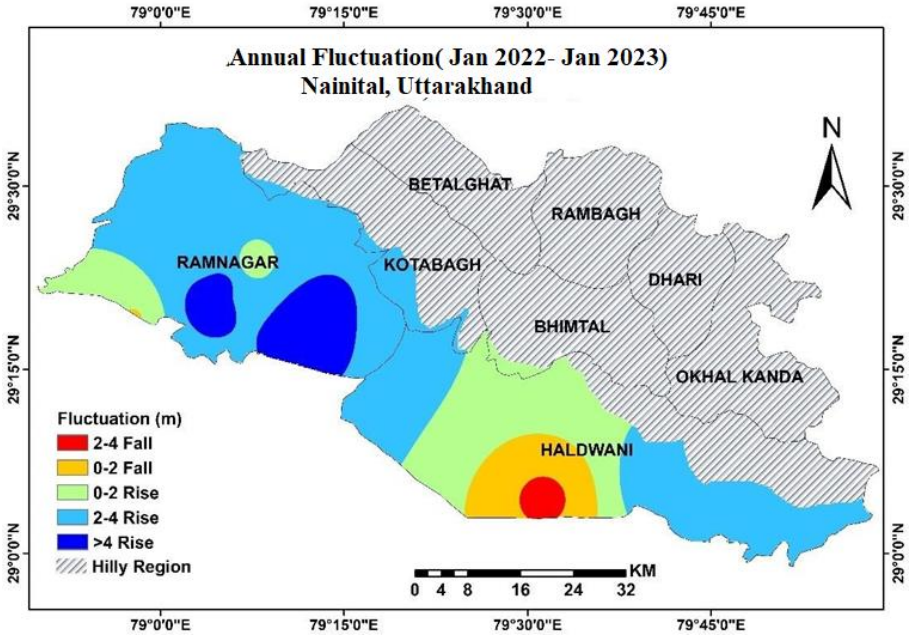


Fig. 48: Annual Water Level Fluctuation of Nainital District (Jan 2022 Vs Jan 2023)

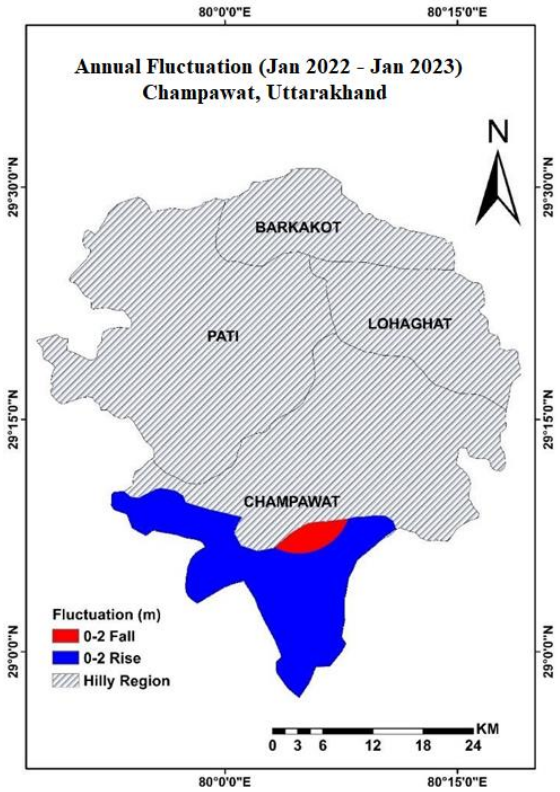


Fig. 49: Annual Water Level Fluctuation of Champawat District (Jan 2022 Vs Jan 2023)

Table 15: Annual Water Level Fluctuation (January 2022 versus January 2023)

District	No. of stations analyzed	Fluctuation (m)				Rise (m)						Decline (m)					
		Rise		Decline		0-2		2 to 4		>4		0-2		2 to 4		>4	
		Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
Dehradun	52	0.02	2.85	0.02	17.13	39	75	5	9.61	0	0	7	13.46	0	0	1	1.92
Haridwar	41	0.05	1.95	0.08	1.7	30	73.17	0	0	0	0	11	26.82	0	0	0	0
Udham Singh Nagar	46	0.07	4.4	0.03	1.77	35	76.08	4	8.69	1	2.17	6	13.04	0	0	0	0
Nainital	9	0.72	6.28	0.15	2.43	2	22.22	2	22.22	3	33.33	1	11.11	1	11.11	0	0
Champawat	4	0.24	0.86	0.43	0.43	3	75	0	0	0	0	1	25	0	0	0	0
Total	**152**	**0.02**	**6.28**	**0.02**	**17.13**	**109**	**71.711**	**11**	**7.24**	**4**	**2.63**	**26**	**17.11**	**1**	**0.66**	**1**	**0.66**

5.4.2.2 Water Level Fluctuation (May 2021 versus May 2022*)*

The analysis of data for 137 Ground Water Monitoring Wells for May 2021 versus May 2022 is given in ***Table 16.***

A perusal of ***Table 16*** reveals that out of 154 monitoring wells 66 (42.86% of total) has shown minimum rise in the range 0-2 m whereas higher rise of 2-4 m is shown by 11 monitoring wells (7.14% of the total) and the highest rise of >4 m is recorded by 5 monitoring wells (3.25%) for calculating the annual fluctuation in ground water level for the pre-monsoon period. The minimum decadal decline in the range of 0-2 m is shown by 61 out of 154 monitoring wells (39.61% of the total number) had recorded annual decline in the range of 0-2 m. Higher annual decline of 2-4 m is recorded by 6 monitoring wells (3.90% of total) whereas the highest declineof >4 m is recorded by 5 monitoring wells (3.25% of the total number).

As per the analysis of Table 16, 53% of the NHS wells are showing annual rise in water level in the pre-monsoon.

Fig. 50 (Dehradun District) reveals that minimum annual decline of 0-2 metres is observed in major parts of the district covering parts of Doiwala, Vikasnagar, Raipur and Sahaspur blocks of the district. Higher decline of 2-4 m occurs as small concentric patches rimming highest annual declining water level of >4 m observed mainly in the Doiwala block and Sahaspur block. Minimum annual rise of 0-2 m observed mostly in the Doiwala and Vikasnagar block of the district.

Fig. 51 (Haridwar District) reveals that minimum annual fall of 0-2 metres is observed in major parts of the district covering parts of Narsan, Khanpur, Laksar, Roorkee, and Bhagwanpur blocks of the district. Minimum annual rise of 0-2 m occurs mostly in the Bahadrabad, Bhagwanpur and southern part of Narsan block of the district.

Fig. 52 (Udham Singh Nagar District) reveals that minimum annual rise of 0-2 m is observed in the major part of the district whereas minimum annual decline of 0-2 m is observed in the eastern part of Khatima block, Kashipur, Bajpur and some part of Rudrapur Block of the district.

Fig. 53 (Nainital District) reveals that minimum annual rise of 0-2 meter is observed in most area of the district. Minimum annual decline of 0-2 m occurs as concentric patches western part of the Ramnagar block of the district.

A perusal of **Fig. 54** reveals that minimum annual decline of 0-2 m is observed in the major part of the district.

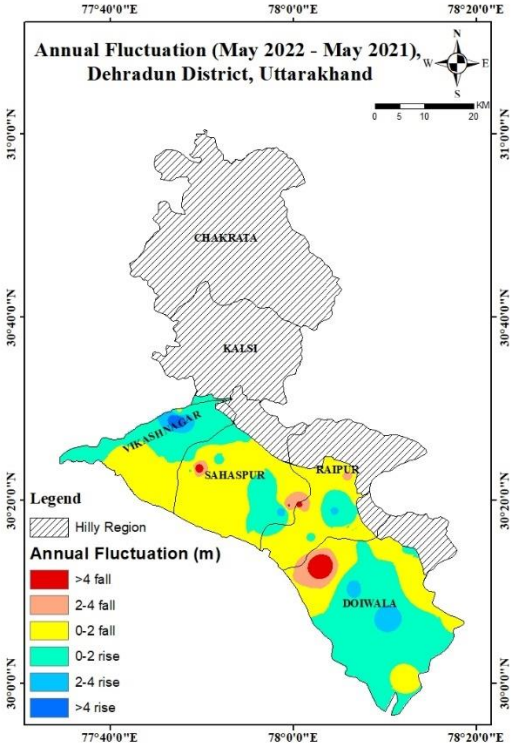


Fig. 50: Annual Water Level Fluctuation of Dehradun District (May 2021 Vs May 2022)

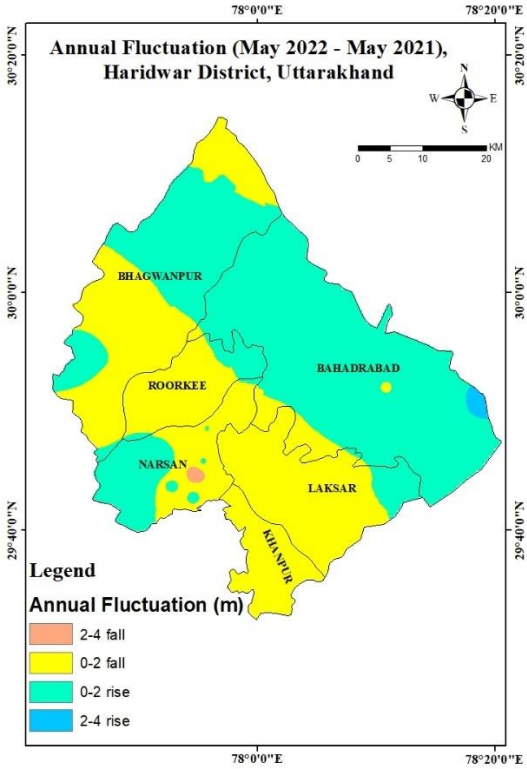


Fig. 51: Annual Water Level Fluctuation of Haridwar District (May 2021 Vs May 2022)

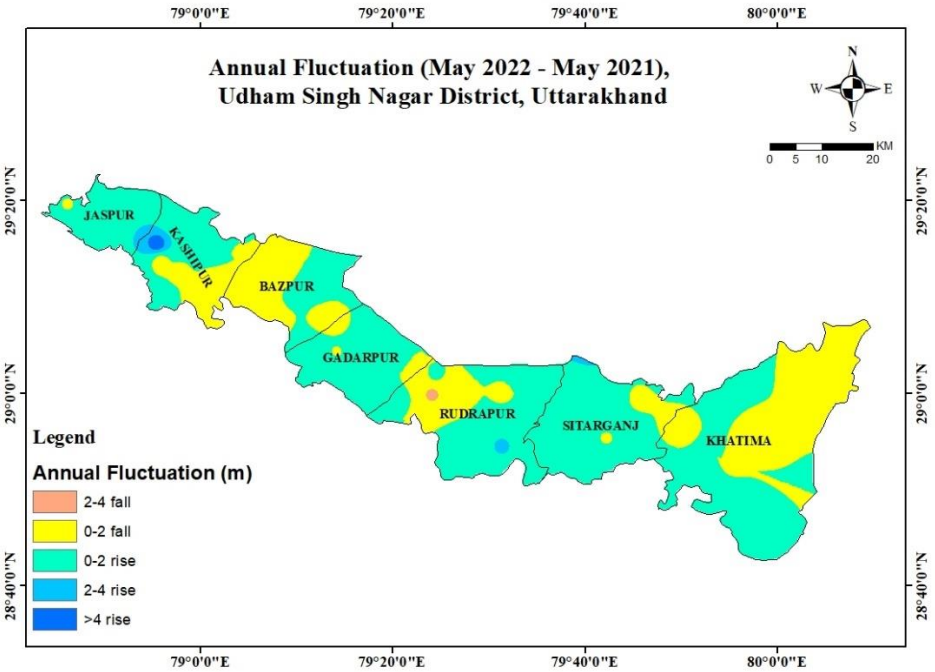


Fig. 52: Annual Water Level Fluctuation of Udham Singh Nagar District (May 2021 Vs May 2022)

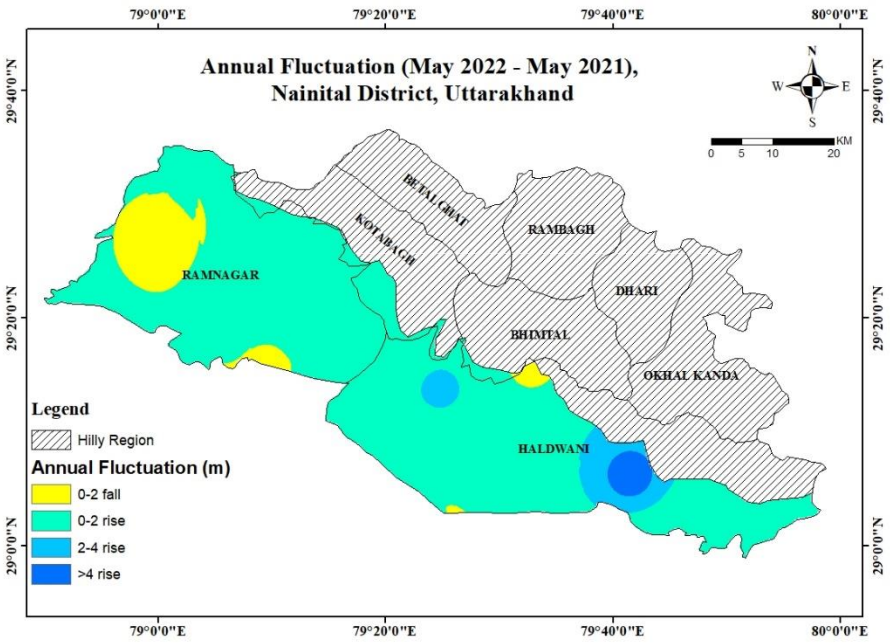


Fig. 53: Annual Water Level Fluctuation of Nainital District (May 2021 Vs May 2022)

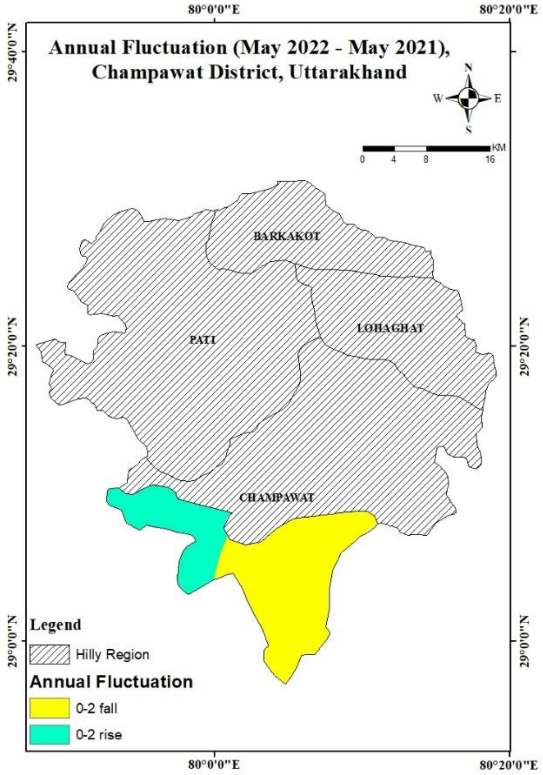


Fig. 54: Annual Water Level Fluctuation of Champawat District (May 2022 Vs May 2022)

Table 16. Annual Water Level Fluctuation (May 2021 versus May 2022)

District	No. of stations analyzed	Fluctuation (m)				Rise (m)						Decline (m)					
		Rise		Decline		0-2		2 to 4		>4		0-2		2 to 4		>4	
		Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
Dehradun	49	0.02	8.58	-0.07	-7.64	18	36.73	4	8.16	1	2.04	21	42.86	1	2.04	4	8.16
Haridwar	42	0.01	2.40	-0.005	-3.895	20	47.62	5	11.90	0	0	14	33.33	3	7.14	0	0.00
Udham Singh Nagar	39	0.02	5.92	-0.03	-2.54	18	46.15	1	2.56	1	2.56	18	46.15	1	2.56	0	0.00
Nainital	12	0.035	5.6	-0.39	-1.67	8	66.67	1	8.33	1	8.33	2	16.67	0	0.00	0	0.00
Champawat	2	0		-0.23	-0.44	0	0.00	0	0.00	0	0	2	100	0	0.00	0	0.00
Pauri Garhwal	2	8.64	10.37	0		0	0	0	0.00	2	100	0	0	0	0	0	0
Uttarkashi	8	0.5	0.805	-0.11	-7.365	2	25	0	0.00	0	0	4	50	1	12.5	1	12.5
Total	**154**					**66**	42.86	**11**	7.14	**5**	3.25	**61**	39.61	**6**	3.90	**5**	3.25

5.4.2.3 Water Level Fluctuation (August 2021 versus August 2022)

The analysis of annual water level fluctuation data for 155 Ground Water Monitoring Wells for the periods August 2021 and August 2022 is given in ***Table 17.***

Analysis of the fluctuation data has indicated that out of 155 monitoring wells, 33 wells (21.29% of total) had shown an annual rise in the range 0-2 m while higher rise of 2-4m is observed in 6 monitoring well (3.87 % of total). The highest rise in the range >4 m is recorded by 4 monitoring wells, which is 2.58% of the total number of wells. It is also seen that majority of monitoring wells (103 out of 155, 66.45% of total) had recorded annualdecline in the range of 0-2 m. Higher annual decline of 2-4 m is shown by 7 monitoring wells (4.52% of total) while the highest decline of >4 m is shown by 2 monitoring wells, which is 1.29% of the total number of wells.

As per the analysis of Table 17, only 28% of the NHS wells are showing annual rise in water level in the month of August.

A perusal of **Fig. 55 (Dehradun district)** indicates that minimum annual decline of 0-2 m is seen in major part of the Doon valley covering Raipur, Sahaspur and parts of Doiwala block of the district. Higher annual decline of 2-4 m concentric patches rimming highest water level of > 4m in the Doiwala block of the district.

A perusal of **Fig. 56 (Haridwar district)** indicates that minimum annual decline of 0-2 m is seen in the district covering all the blocks.

A perusal of **Fig. 57(Udham Singh Nagar district)** indicates that minimum annual decline of 0-2 m is seen in the major part of the district. Minimum annual rise of 0-2 m occurs in Gadarpur and some minor parts of Bazpur and Kashipur blocks of the district.

Fig. 58 (Nainital District) reveals that minimum annual decline of 0-2 metres is observed in major parts of the district covering major portion of Ramnagar block. Whereas minimum annual decline of 0-2 m is observed in the western part of Haldwani block and central part of Ramnagar block of the district.

A perusal of **Fig. 59** reveals that the Champawat district is representing declining annual water level trend. Annual decline of 0-2 m occurs in the most part of the district.

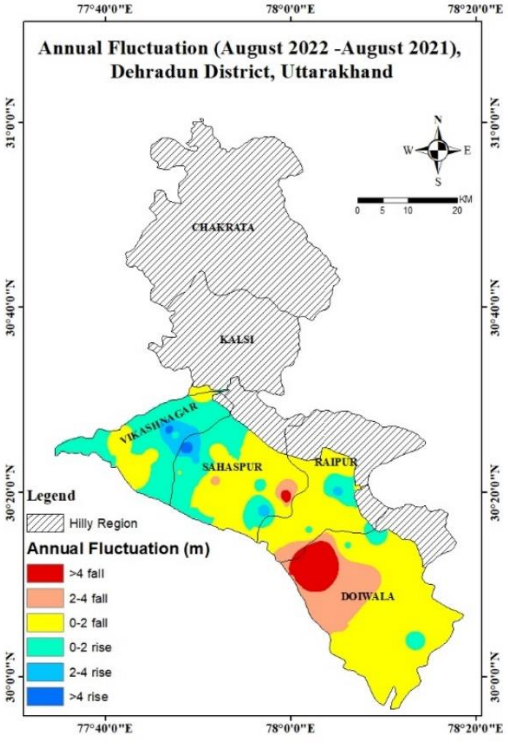


Fig. 55: Annual Water Level Fluctuation of Dehradun District (Aug 2021 Vs Aug 2022)

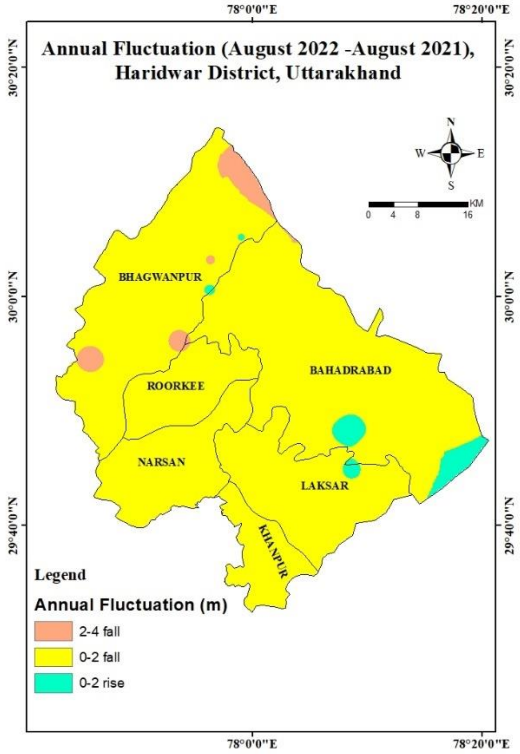


Fig. 56: Annual Water Level Fluctuation of Haridwar District (Aug 2021 Vs Aug 2022)

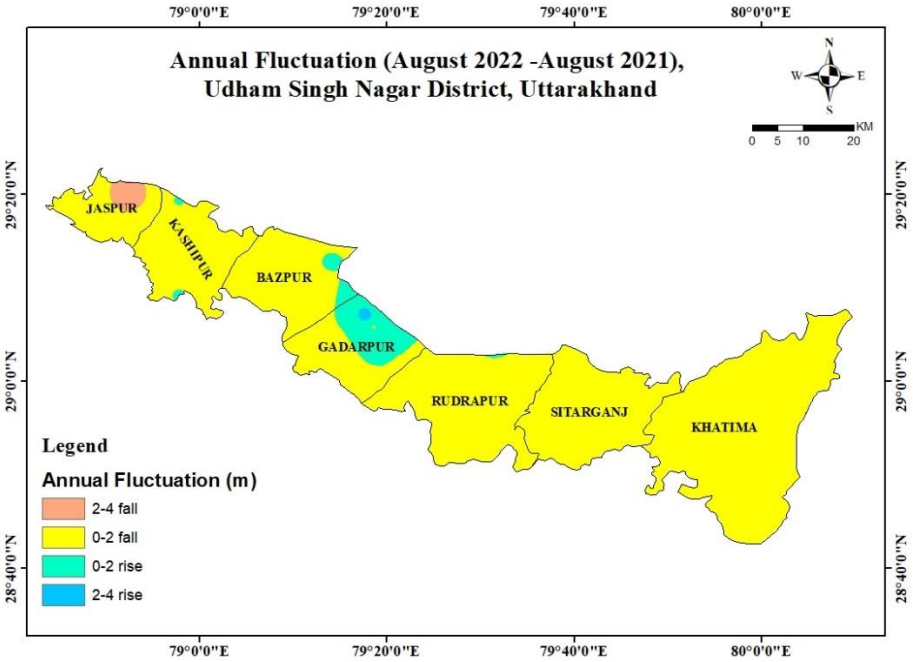


Fig. 57: Annual Water Level Fluctuation of Udham Singh Nagar District (Aug 2021 VsAug 2022)

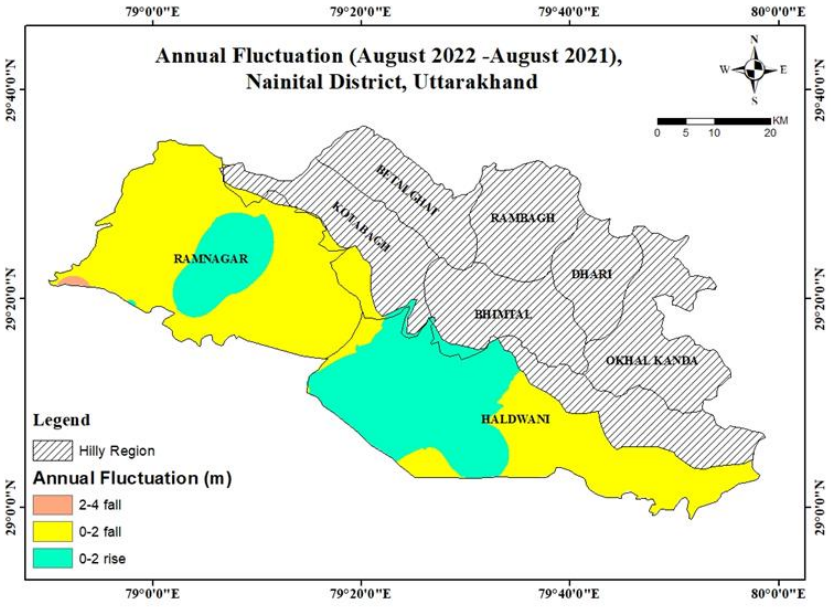


Fig. 58: Annual Water Level Fluctuation of Nainital District (Aug 2021 Vs Aug 2022)

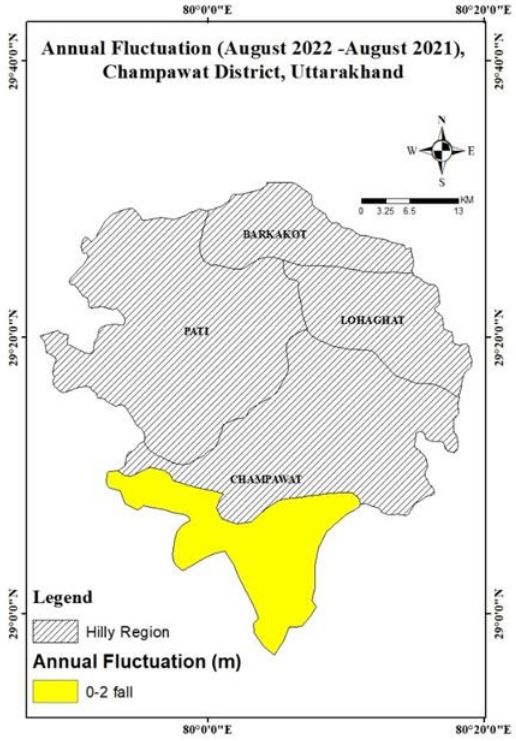


Fig. 59: Annual Water Level Fluctuation of Champawat District (Aug 2021 Vs Aug 2022)

Table 17. Annual Water Level Fluctuation (August 2021 versus August 2022)

District	No. of stations analyzed	Fluctuation (m)				Rise (m)						Decline (m)					
		Rise		Decline		0-2		2 to 4		>4		0-2		2 to 4		>4	
		Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
Dehradun	50	0.18	6.17	0.05	13.55	16	32.00	4	8	2	4.00	23	46.00	3	6.00	2	4.00
Haridwar	43	0.05	0.77	-0.11	-2.50	4	9.30	0	0.00	0	0.00	36	83.72	3	6.98	0	0.00
Udham Singh Nagar	41	0.06	2.95	-0.02	-0.87	3	7.32	1	2.44	0	0.00	37	90.24	0	0.00	0	0.00
Nainital	8	0.21	0.48	-0.05	-0.53	5	62.50	0	0.00	0	0.00	3	37.50	0	0.00	0	0.00
Champawat	3	0.00		-1.27	-0.85	0	0.00	0	0.00	0	0.00	3	100.0	0	0.00	0	0.00
Pauri Garhwal	2	2.04	17.45	0.00		0	0.00	1	50.00	1	50.00	0	0.00	0	0.00	0	0.00
Uttarkashi	8	0.45	4.54	-0.83	-2.79	5	62.50	0	0.00	1	12.50	1	12.50	1	12.50	0	0.00
Total	**155**					**33**	21.29	**6**	3.87	**4**	2.58	**103**	66.45	**7**	4.52	**2**	1.29

5.4.2.4 Water Level Fluctuation (November 2021 versus November 2022)

The analysis of annual water level fluctuation data for 149 Ground Water Monitoring Wells in Uttarakhand is available.

A study of the water level fluctuation data has revealed that 67 monitoring wells out of 149 wells (44.97% of the total number) has recorded a rise in the range of 0-2 m. 4 monitoring well (2.68% of the total) had shown the higher rise of 2-4 m during this period. Highest declineof >4 m was observed in 2 monitoring wells (1.34% of the total). The 72 nos. of monitoring well (48.32% of the total) had recorded an annual decline in the range of 0-2 m during the post monsoon period. 3 wells (2.01% of total number) had shown higher decline of water level in the range of 2-4 m, while highest decline of >4m was observed in only one well (0.67% of the total).

As per the analysis of Table 18, 49% of the NHS wells are showing annual rise in water level in the post-monsoon.

A perusal of **Fig. 60(Dehradun district)** has shown that the minimum annual rise in post monsoon period in the range of 0-2 m is observed in major part of Raipur, Sahaspur and Vikasnagar blocks of the district. Declining water level trend occur mostly in Doiwala block and western part of the Vikasnagar block of the district.

A perusal of **Fig. 61(Haridwar District)** has shown that the minimum annual deline in post monsoon period in the range of 0-2 m is observed in major part of the district. Whereas minimum annual rise of 0- 2 m can be observed mainly in eastern part of Bahadrabad block of the district.

A perusal of **Fig. 62(Udham Singh Nagar district)** has shown that the minimum annual rise in post monsoon period in the range of 0-2 m is observed mainly in the Kashipur block, Sitarganj, Rudrapur and parts of Gadarpur and Bazpur block of the district. However minimum annual fall in the range of 0-2 m can also be observed mainly in the Jaspur, Khatima, parts of gadarpur, rudrapur, Bazpur and Sitarganj blocks of the district.

Fig. 63 (Nainital District) reveals that minimum annual rise of 0-2 metres is observed in major part of the district, however, declining trend is also occurring southern part of the district.

A perusal of **Fig. 64** reveals that the Champawat district is representing majorily declining water level in the range of 0-2 m whereas annual rising water level trend in the range of 0-2 m is also being observed in the southern part of the district.

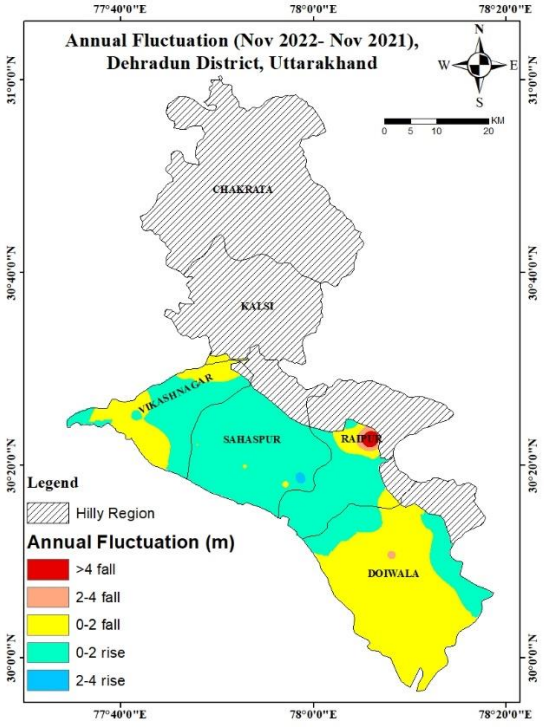


Fig. 60: Annual Water Level Fluctuation of Dehradun District (Nov 2021 Vs Nov 2022)

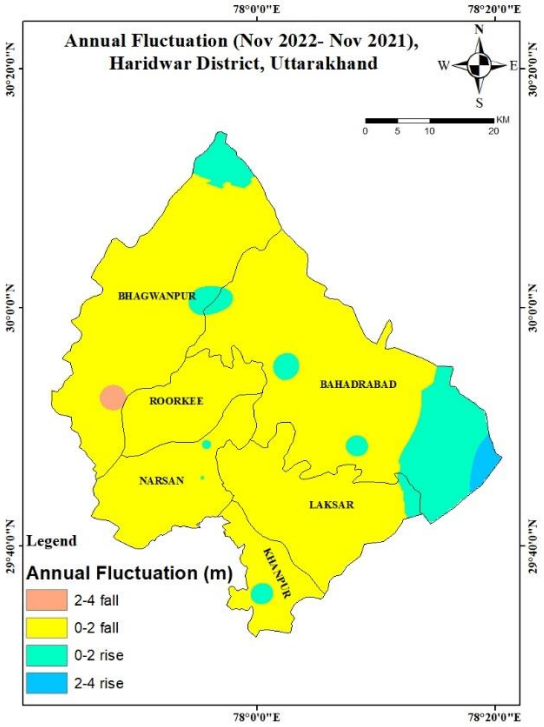


Fig. 61: Annual Water Level Fluctuation of Haridwar District (Nov 2021 Vs Nov 2022)

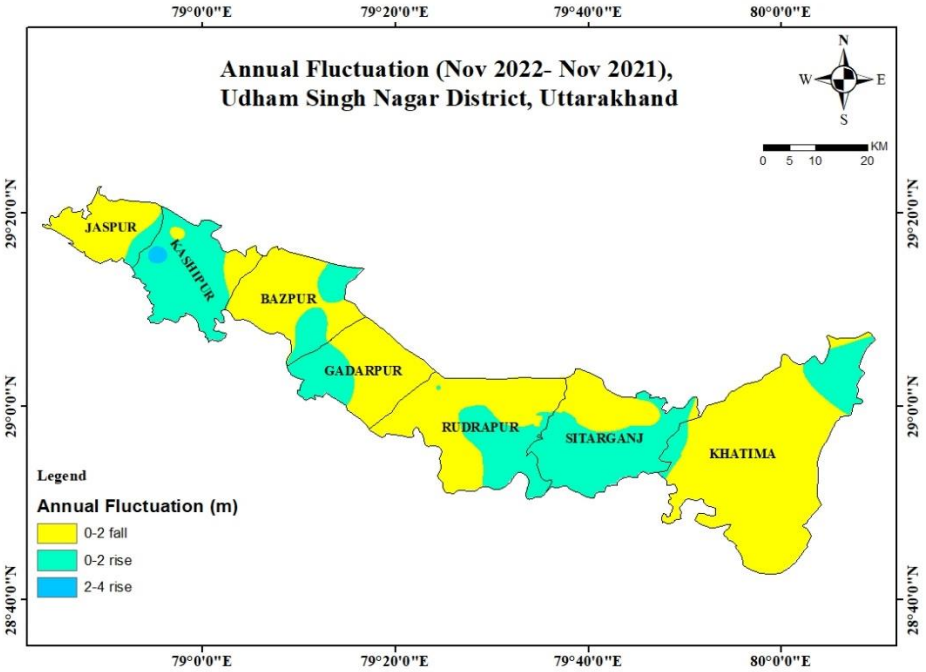


Fig. 62: Annual Water Level Fluctuation of Udham Singh Nagar District (Nov 2021 Vs Nov2022)

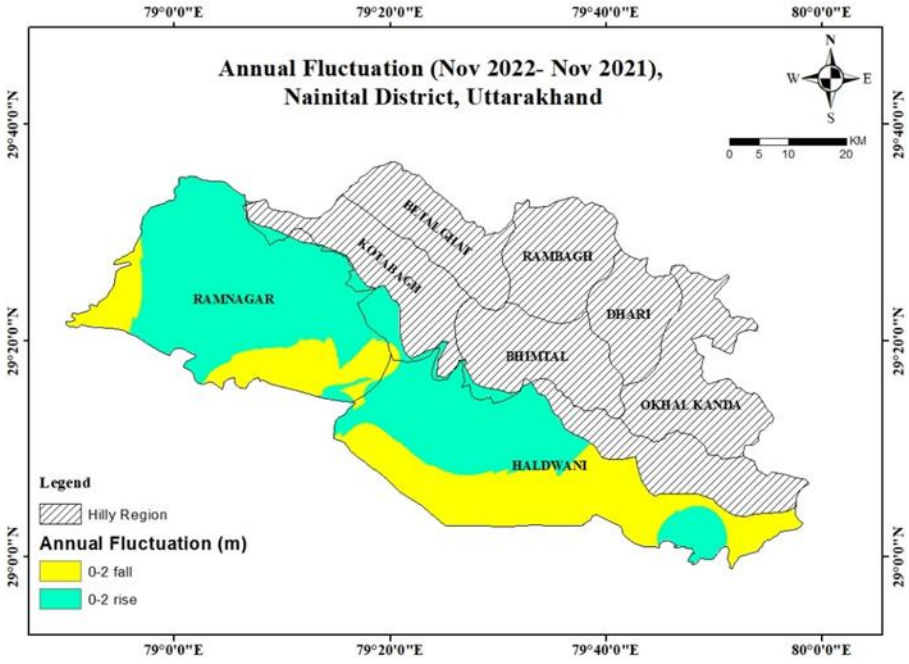


Fig. 63: Annual Water Level Fluctuation of Nainital District (Nov 2021 Vs Nov 2022)

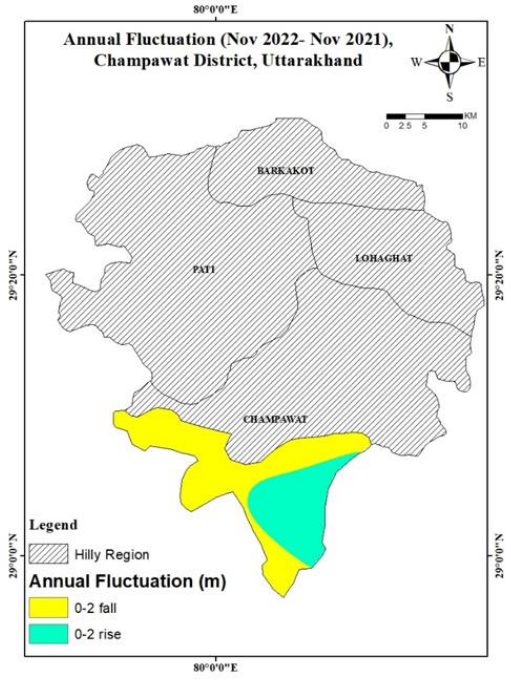


Fig. 64: Annual Water Level Fluctuation of Champawat District (Nov 2021 Vs Nov 2022)

Table 18. Annual Water Level Fluctuation (November 2021Versus November 2022)

District	No. of stations analyzed	Fluctuation (m)				Rise (m)						Decline (m)					
		Rise		Decline		0-2		2 to 4		>4		0-2		2 to 4		>4	
		Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
Dehradun	49	0.045	8.53	-0.01	-0.325	30	61.22	1	2.04	1	2.04	15	30.61	1	2.04	1	2.04
Haridwar	37	0.025	1.8	-0.09	-0.395	8	21.62	0	0.00	0	0.00	28	75.68	1	2.70	0	0.00
Udham Singh Nagar	42	0.01	3.28	-0.005	-0.035	20	47.62	1	2.38	0	0.00	21	50.00	0	26.00	0	0.00
Nainital	9	0.18	1.97	-0.02	-0.36	5	55.56	0	0.00	0	0.00	4	44.44	0	0.00	0	0.00
Champawat	2	0.635		-0.485		1	50.00	0	0.00	0	0.00	1	50.00	0	0.00	0	0.00
Pauri Garhwal	2	2.99	14.05	--		0	0.00	1	50.00	1	50.00	0	0.00	0	0.00	0	0.00
Uttarkashi	8	0.62	3.22	-0.1	-3.645	3	37.50	1	12.50	0	0.00	3	37.50	1	12.50	0	0.00
Total	**149**					**67**	44.97	**4**	2.68	**2**	1.34	**72**	48.32	**3**	2.01	**1**	0.67

5.4.3 SEASONAL WATER LEVEL FLUCTUATION

5.4.3.1 Water Level Fluctuation (May 2022 versus January 2023)

The seasonal water level fluctuation for the period May 2022 versus January 2023 is available for 164 monitoring wells in Uttarakhand State. The water level fluctuation data is given in ***Table 19.***

A perusal of **Table 19** also reveals that that the lowest seasonal rise of 0-2 m was shown by 116 monitoring wells (70.73% of total) whereas higher rise of 2-4 m was shown by 16 wells (9.76% of total). The highest seasonal rise of >4 m was shown by 9 wells, which was 5.49% of the total wells. Seasonal decline in the range of 0-2 m was shown by 9 monitoring wells (5.49 % of total) while higher decline of 2-4 m was recorded by only 2 monitoring well (1.22% of total) for which the data is available in Uttarakhand State during the period May 2022 versus January 2022.

As per the analysis of Table 19, 86% of the NHS wells are showing seasonal rise in water level in the month of January.

Visual interpretation of **Fig. 65(Dehradun district)** has shown that the lowest seasonal rise of 0-2 m and 2-4 m is observed in major parts of the Doon valley. Doon valley is representing mainly seasonal rising water level trend.

Visual interpretation of **Fig. 66(Haridwar district)** has shown that the lowest seasonal rise of 0-2 m is observed in major part of the district.

A perusal of **Fig. 67(Udham Singh Nagar district)** indicates that Udham Singh Nagar district is representing mainly seasonal rising water level trend. Minimum seasonal decline of 0-2m can be observed in Kashipur, Jaspur, Rudrapur and Sitarganj blocks of the district.

A perusal of **Fig. 68(Nainital district)** shows that the Nainital district were observed only rising trend of water level. Most of the area is showing seasonal rise of 2-4 m range however >4 m rise observed mainly in eastern part of the Haldwani block.

A perusal of **Fig. 69(Champawat district)** indicates that positive seasonal rise of 0-2 m is observed in major part of the district.

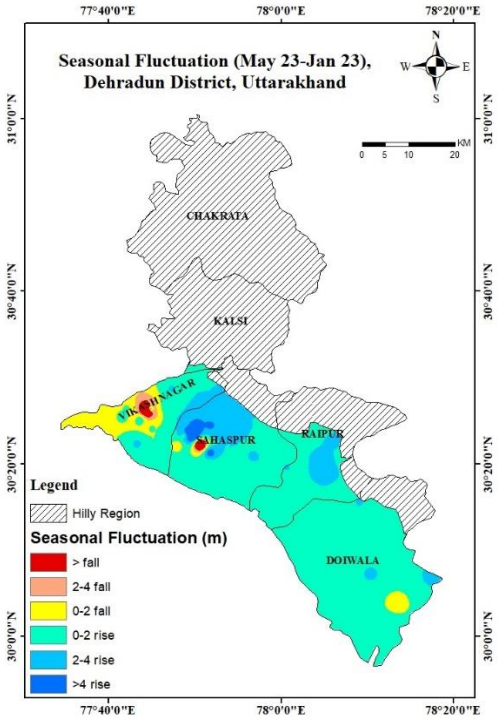


Fig. 65: Seasonal Water Level Fluctuation of Dehradun District (May22 Vs Jan23)

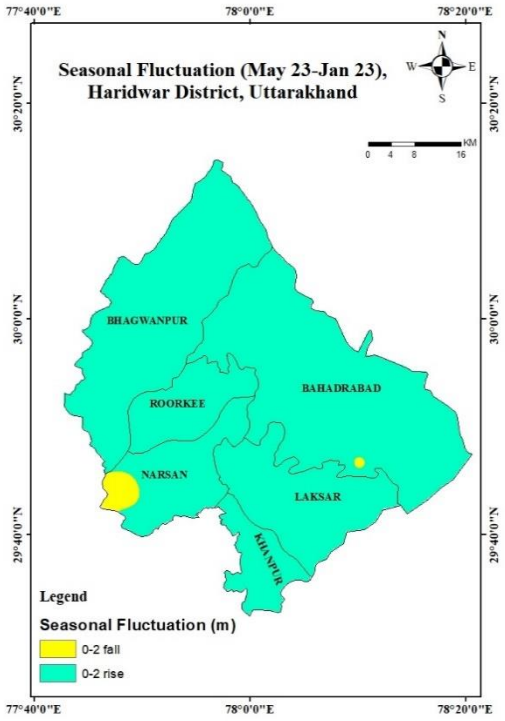


Fig. 66: Seasonal Water Level Fluctuation of Haridwar District (May 22 Vs Jan 23)

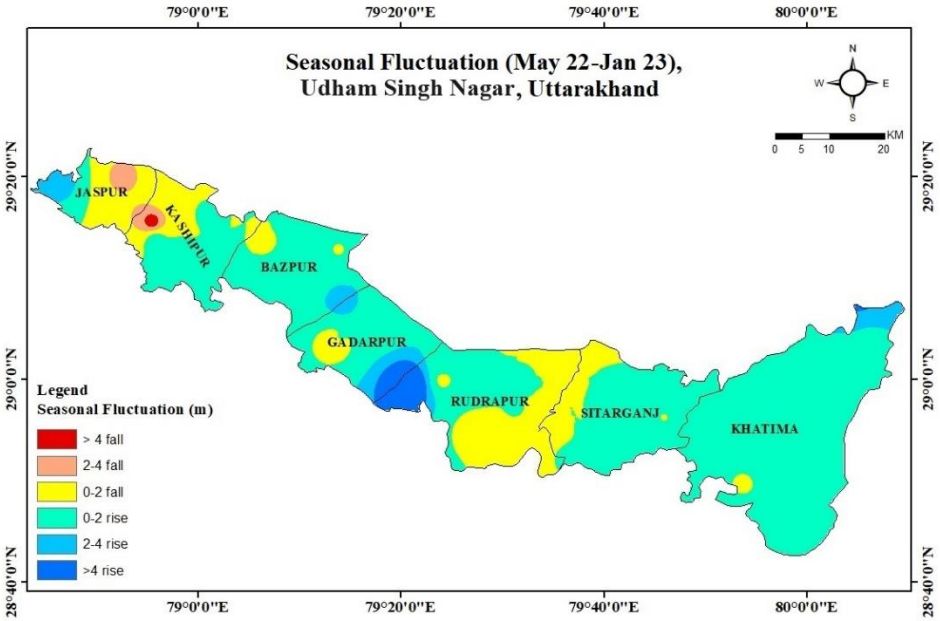


Fig. 67: Seasonal Water Level Fluctuation of Udham Singh Nagar District (May22 Vs Jan23)

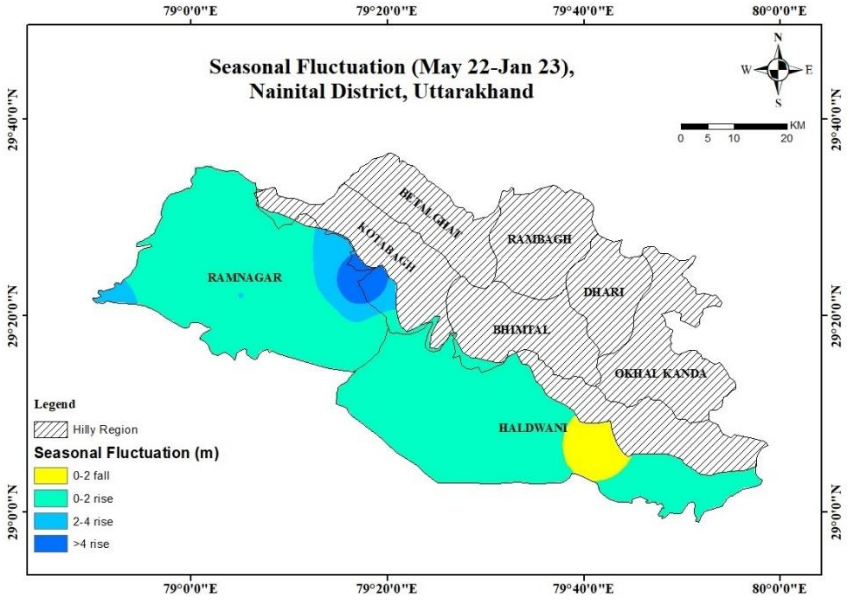


Fig. 68: Seasonal Water Level Fluctuation of Nainital District (May22 Vs Jan23)

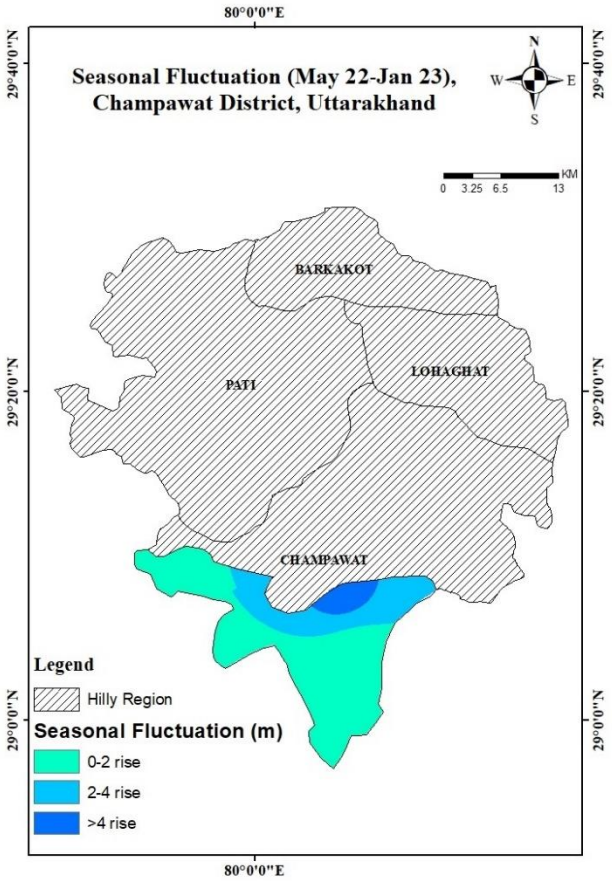


Fig. 69: Seasonal Water Level Fluctuation of Champawat District (May 22 Vs Jan 23)

Table 19. Seasonal Water Level Fluctuation (May 2022 Versus January 2023)

District	No. of stations analyzed	Fluctuation (m)				Rise (m)						Decline (m)					
		Rise		Decline		0-2		2 to 4		>4		0-2		2 to 4		>4	
		Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
Dehradun	51	0.08	16.49	-0.92	-17.1	31	60.78	13	25.49	3	5.88	2	3.92	2	3.92	0	0.00
Haridwar	43	0.11	1.76	-0.21	-0.94	41	95.35	0	0.00	0	0.00	2	1.00	0	0.00	0	0.00
Udham Singh Nagar	44	0.20	4.83	38	-2	26	59.09	1	2.27	3	6.82	2	4.55	0	0.00	0	0.00
Nainital	12	0.18	6.39	-1.55		9	75.00	1	8.33	1	8.33	1	8.33	0	0.00	0	0.00
Pauri Garhwal	2	1.88	3.04	0		1	50.00	1	50.00	0	0.00	0		0	0.00	0	0.00
Champawat	3	0.71	6.06	0		2	66.67	0	0.00	1	33.33	0	0.00	0	0.00	0	0.00
Uttarkashi	9	0.08	6.07	-0.23	-0.47	6	66.67	0	0.00	1	11.11	2	22.22	0	0.00	0	0.00
Total	**164**					**116**	70.73	**16**	9.76	**9**	5.49	**9**	5.49	**2**	1.22	**0**	0.00

5.4.3.2 Water Level Fluctuation (May 2022 versus August 2022)

The seasonal fluctuation of water level during the period May 2022 versus August 2022 for164 ground water monitoring wells in Uttarakhand State is given in ***Table 20.***

The perusal of Table 20 reveals that rise in the range of 0-2 m was shown by 8 0 monitoring wells, which was 48.78% of the total number of wells. Higher rise in the range 2-4 m was shown by 21 wells (12.80% of total) while the highest rise of >4 m was shown by 22 wells (13.41% of total). The lowest seasonal decline of 0-2 m was recorded by 34 monitoring wells (20.73% of total). Higher seasonal decline of 2-4 m was shown by 5 (3.05%) monitoring wells, while highest decline of >4 m was shown by 2 monitoring wells, which was only 1.22 % of the total number of wells during the period May versus August 2022.

As per the analysis of Table 20, 75% of the NHS wells are showing seasonal rise in water level in the month of August.

Visual interpretation of **Fig. 70(Dehradun district)** has shown that the higher seasonal rise of 2-4 m and >4 m is observed in major parts of the Dehradun district. Doon valley is representing mainly seasonal rising water level trend. Whereas, seasonal decline of 0-2 m is being observed as patches in the Doiwala block of the district.

Visual interpretation of **Fig. 71(Haridwar district)** has shown that the lowest seasonal rise of 0-2 m is observed in major part of the district. Minimum seasonal decline of 0-2m is observed mainly in eastern Bahadrabad block and western part of the district covering parts of Bhagwanpur, Roorkee and Narsan blocks of the district.

A perusal of **Fig. 72(Udham Singh Nagar district)** indicates that the lowest positive seasonal rise of 0-2 m is observed inthe major parts of the district. Highest seasonal rise of >4 m is observed as isolated patches in the Rudrapur and Gadarpur block of the district. Lowest seasonal fall in the range of 0-2 m is observed in the major parts of Jaspur, Kashipur and some parts of Rudrapur and Sitarganj blocks of the district.

A perusal of **Fig. 73(Nainital district)** indicates that the lowest positive seasonal rise of 0-2 m is observed inthe major parts of the district. Seasonal declining water level trend is observed as concentric patches in the western part of Ramnagar and eastern part of Haldwani blocks of the district.

A perusal of **Fig. 74(Champawat district)** indicates that the lowest positive seasonal rise of 0-2 m is observed in the major parts of the district.

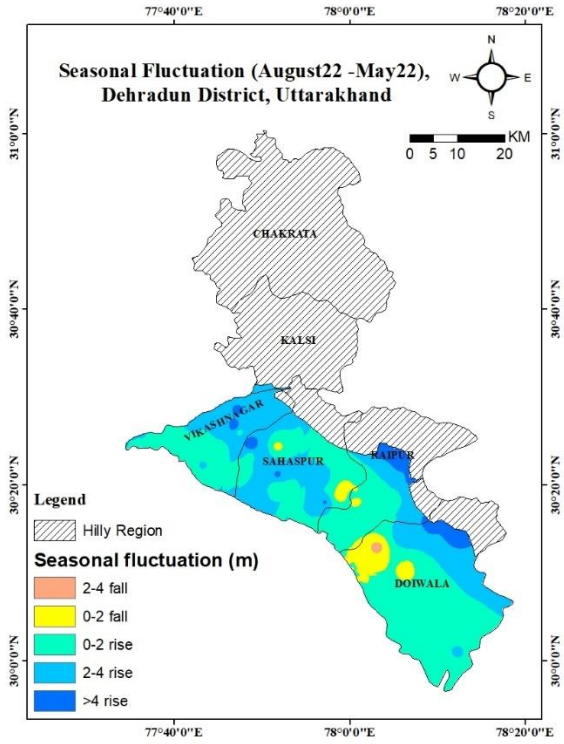


Fig. 70: Seasonal Water Level Fluctuation of Dehradun District (May 22 Vs Aug 22)

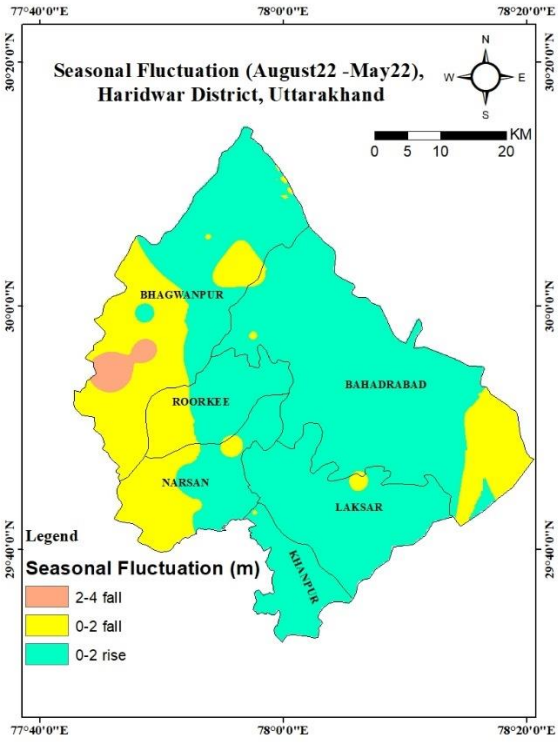


Fig. 71: Seasonal Water Level Fluctuation of Dehradun District (May 22 Vs Aug 22)

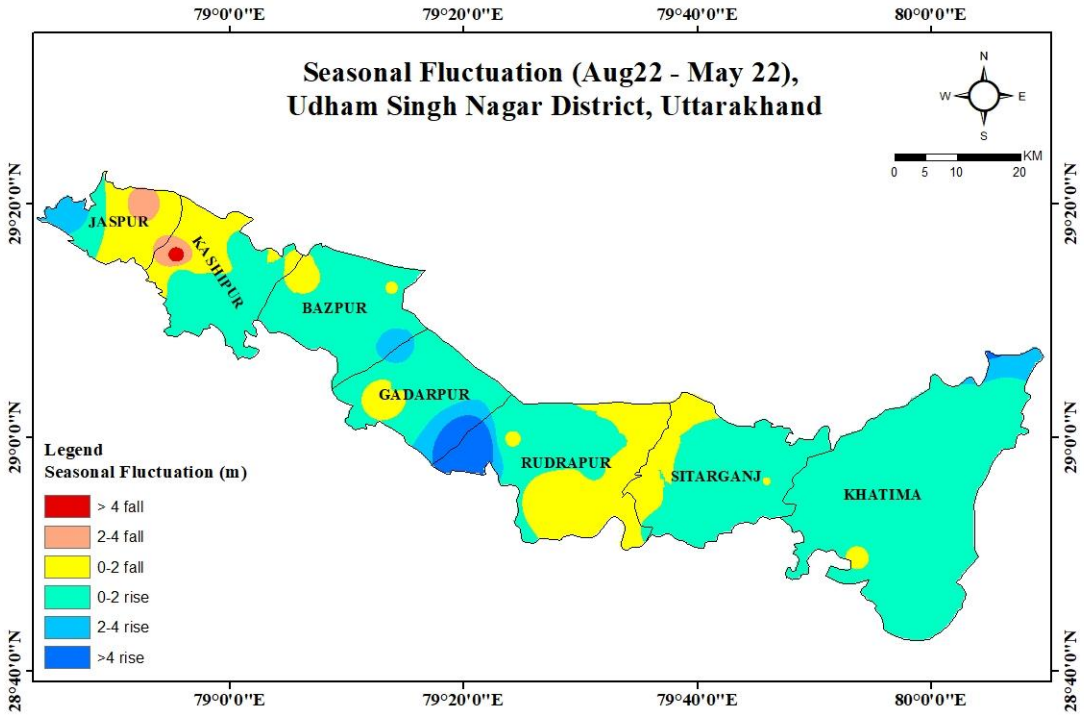


Fig. 72: Seasonal Water Level Fluctuation of Udham Singh Nagar District (May 22 VsAug 22)

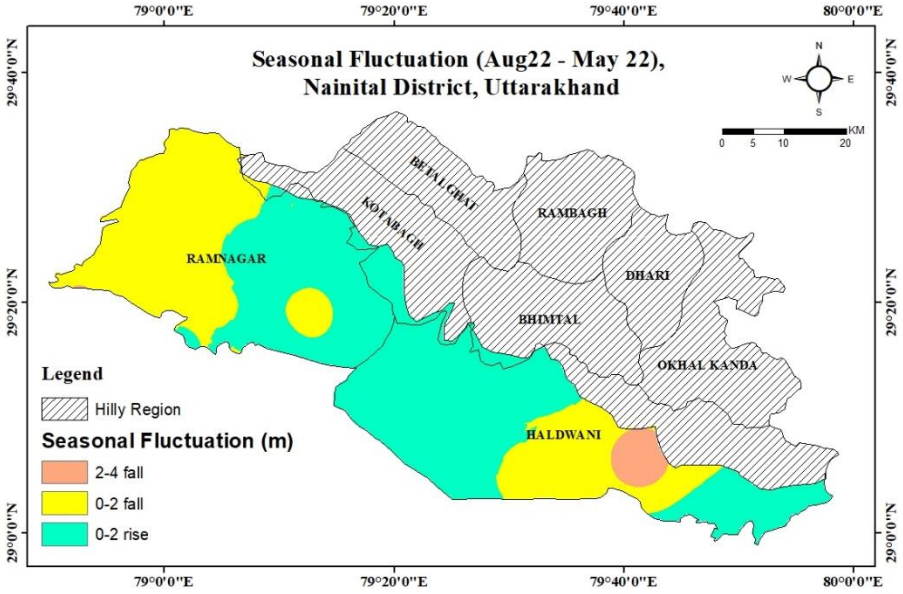


Fig. 73: Seasonal Water Level Fluctuation of Nainital District (May 22 Vs Aug 22)

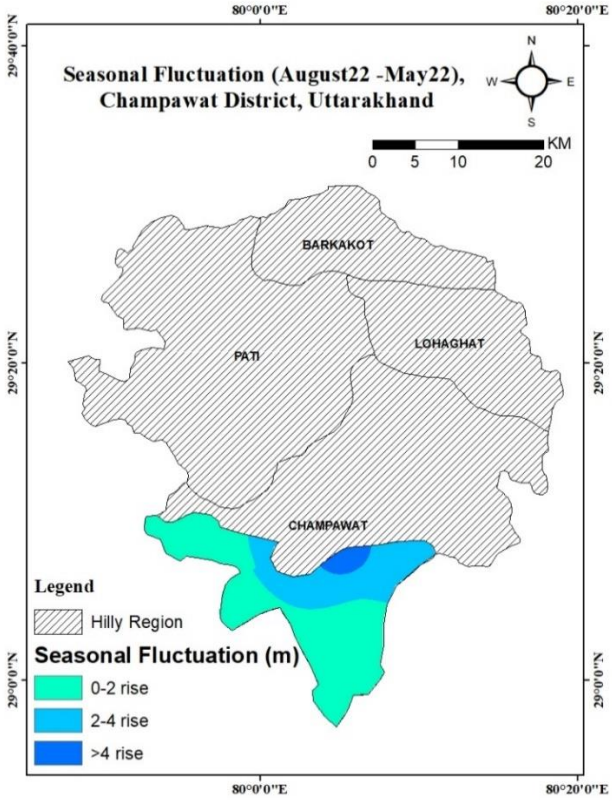


Fig. 74: Seasonal Water Level Fluctuation of Champawat District (May 22 Vs Aug 22)

Table 20. Seasonal Water Level Fluctuation (May 2022 Versus August 2022)

District	No. of stations analyzed	Fluctuation (m)				Rise (m)						Decline (m)					
		Rise		Decline		0-2		2 to 4		>4		0-2		2 to 4		>4	
		Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
Dehradun	53	0.34	6.625	-0.415	-2.62	17	32.08	17	32.08	12	22.64	6	11.32	1	1.89	0	0.00
Haridwar	43	0.01	1.185	-0.02	-2.735	28	65.12	0	0.00	0	0.00	13	1.00	2	4.65	0	0.00
Udham Singh Nagar	43	0.045	17.29	-0.03	-5.24	27	62.79	2	4.65	2	4.65	10	23.26	1	2.33	1	2.33
Nainital	11	0.365	69.82	-4.73	-3.77	2	18.18	1	9.09	3	27.27	4	36.36	1	9.09	0	0.00
Pauri Garhwal	2	13.585		-8.865		0	0.00	0	0.00	1	50.00	0	0.00	0	0.00	1	0.00
Champawat	3	1.19	4.955	0		2	66.67	0	0.00	1	33.33	0	0.00	0	0.00	0	0.00
Uttarkashi	9	0.26	7.725	-1.39		4	44.44	1	11.11	3	33.33	1	11.11	0	0.00	0	0.00
Total	**164**					**80**	48.78	**21**	12.80	**22**	13.41	**34**	20.73	**5**	3.05	**2**	1.22

5.4.3.3 Water Level Fluctuation (May 2022 versus November 2022)

The water level fluctuation data of May 2022 was compared with that of November 2022 for 156 ground water monitoring wells in Uttarakhand and the result is given in ***Table 21.***

A perusal of the fluctuation data shows that seasonal rise of 0-2 m was shown by 98 monitoring wells out of 156 (62.82%), that in the range of 2-4 m by 25 monitoring wells (16.03% of total) and that in the range of >4 m by 17 wells (10.90% of total) in Uttarakhand State. Seasonal decline in the range 0-2 m was recorded by 15 monitoring wells (9.62% of total). Higher seasonal decline in the range of 2-4 m had been recorded by 1 monitoring well only (0.64% of total).

As per the analysis of Table 19, 86% of the NHS wells are showing seasonal rise in water level in the month of January.

Visual interpretation of **Fig. 75(Dehradun district)** has shown that the higher seasonal rise of 2-4 m and >4 m is observed in major parts of the Doon valley covering major parts of Doiwala and Raipur block of the district. Doon valley is representing mainly seasonal rising water level trend.

Visual interpretation of **Fig. 76(Haridwar district)** has shown that the lowest seasonal rise of 0-2 m is observed in major part of the district. The Seasonal rise of 2-4 m is observed in northern and north-eastern of the district covering Bahadarabad and Bhagwanpur blocks. Minimum seasonal decline of 0-2m is observed as isolated patches at different locations especially southern part of Bhagwanpur, Narsan blocks.

A perusal of **Fig. 77(Udham Singh Nagar district)** indicates that the lowest positive seasonal rise of 0-2 m is observed in the major parts of the district covering majpr parts of Khatima, Sitarganj, Bazpur, Rudrapur and Gadarpur blocks. Higher seasonal rise of 2-4 m is observed as isolated patches rimming highest seasonal rise of greater than 4m in the southern part of Kashipur and Jaspur, gadarpur and Rudrapur blocks of thedistrict.

A perusal of **Fig. 78(Nainital district)** indicates that the positive seasonal rise of 0-2 m is observed in the major parts of the district covering major parts of the Haldwani and Ramnagar blocks. Seasonal declining water level trend is observed as isolated patch only in Haldwani block of the district.

A perusal of **Fig. 79(Champawat district)** indicates that the lowest positive seasonal rise of 0-2 m is observed throughout the area.

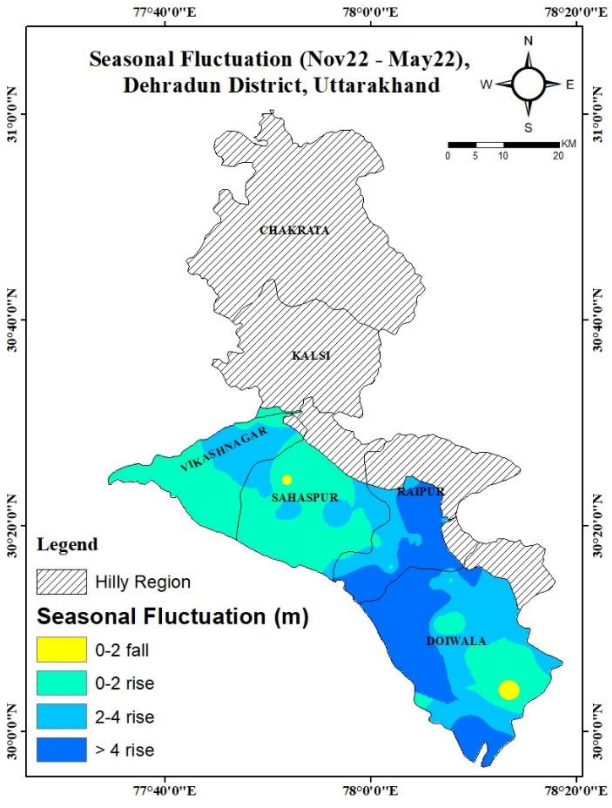


Fig. 75: Seasonal Water Level Fluctuation of Dehradun District (May 22 Vs Nov 22)

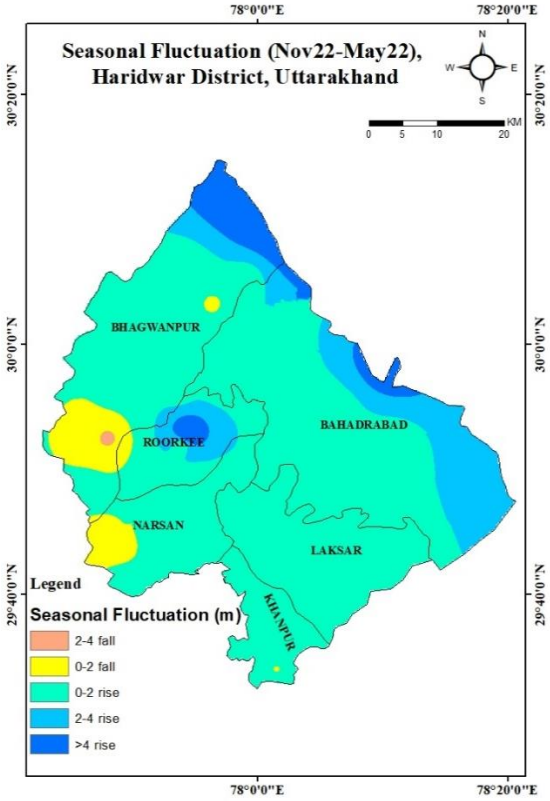


Fig. 76: Seasonal Water Level Fluctuation of Haridwar District (May 22 Vs Nov 22)

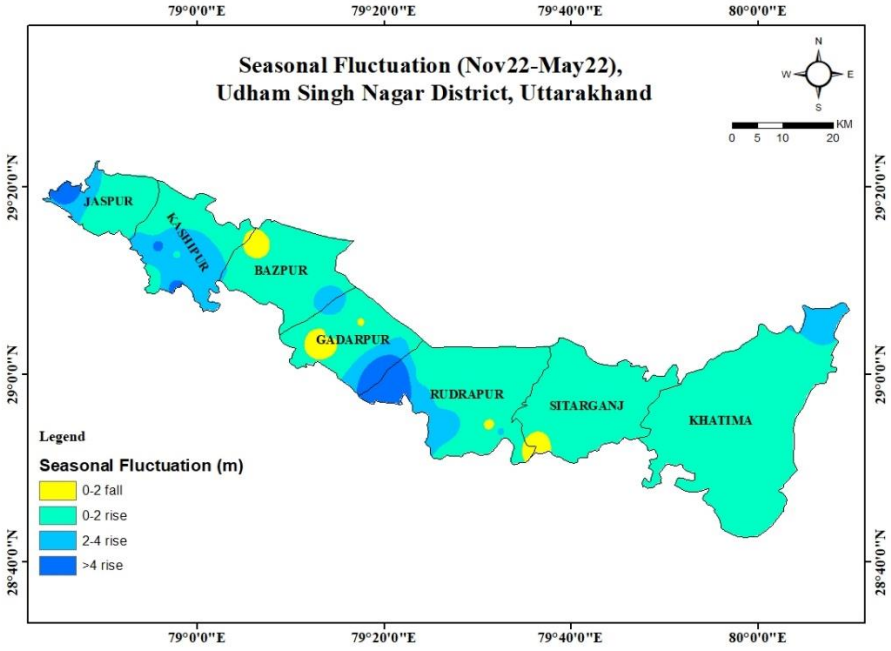


Fig. 77: Seasonal Water Level Fluctuation of Udham Singh Nagar District (May22 Vs Nov22)

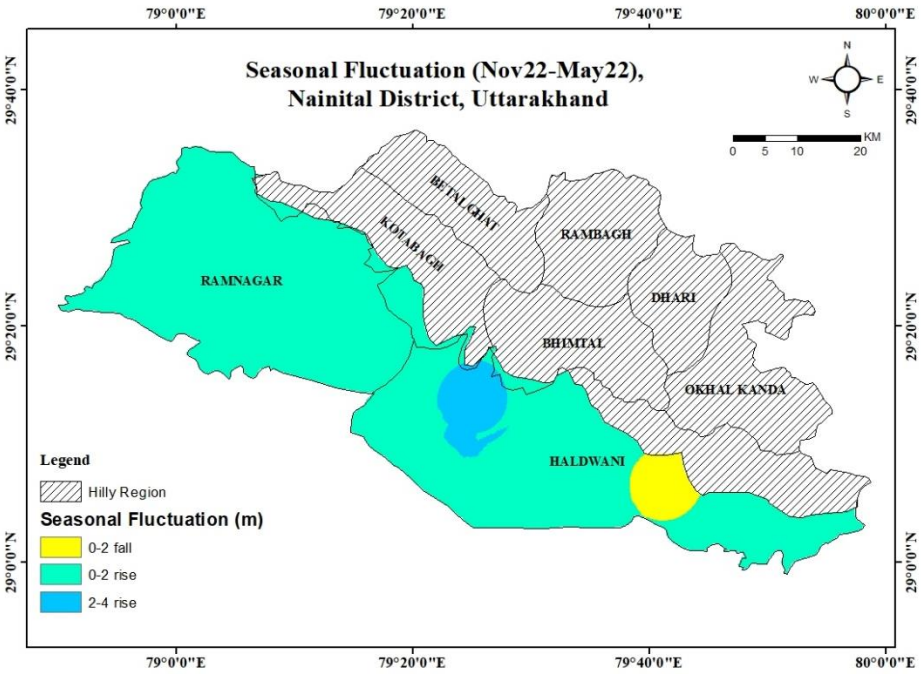


Fig. 78: Seasonal Water Level Fluctuation of Nainital District (May 22 Vs Nov 22)

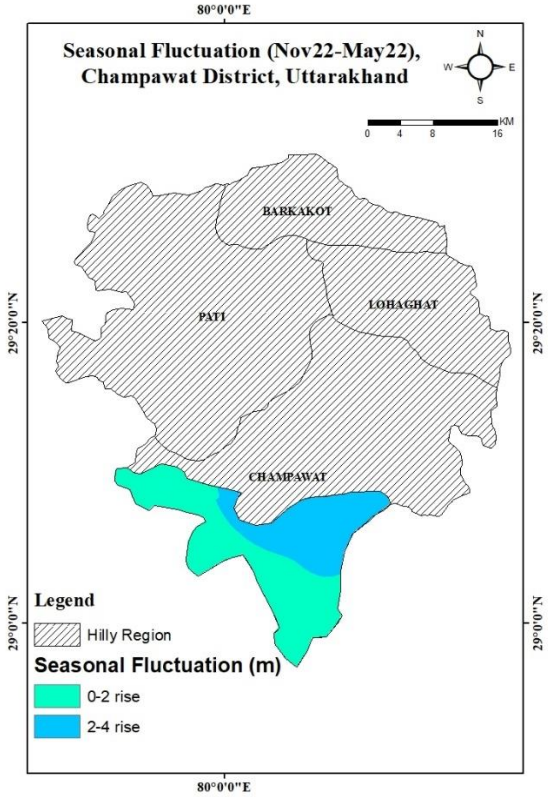
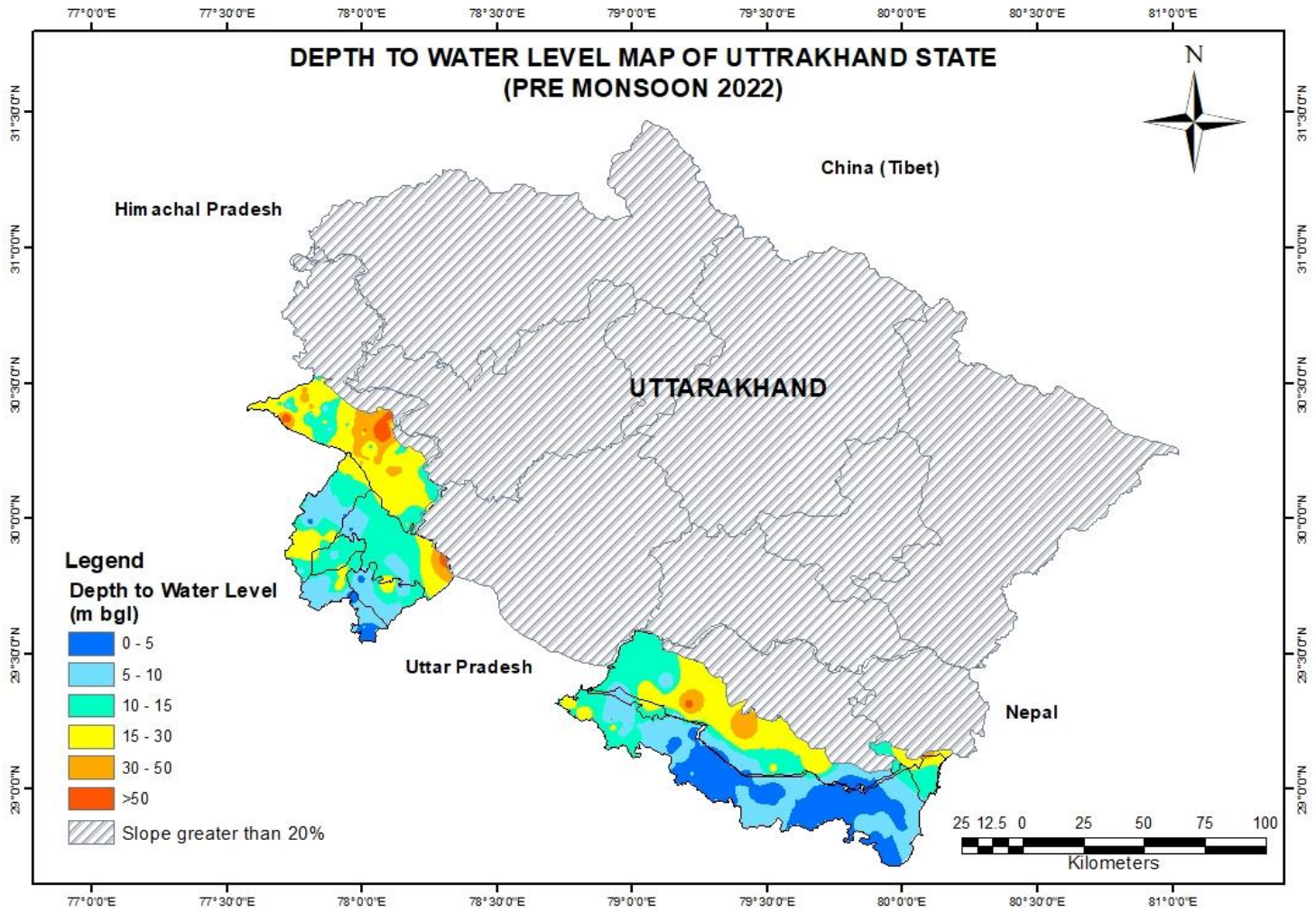


Fig. 79: Seasonal Water Level Fluctuation of Champawat District (May 22 Vs Nov 22)

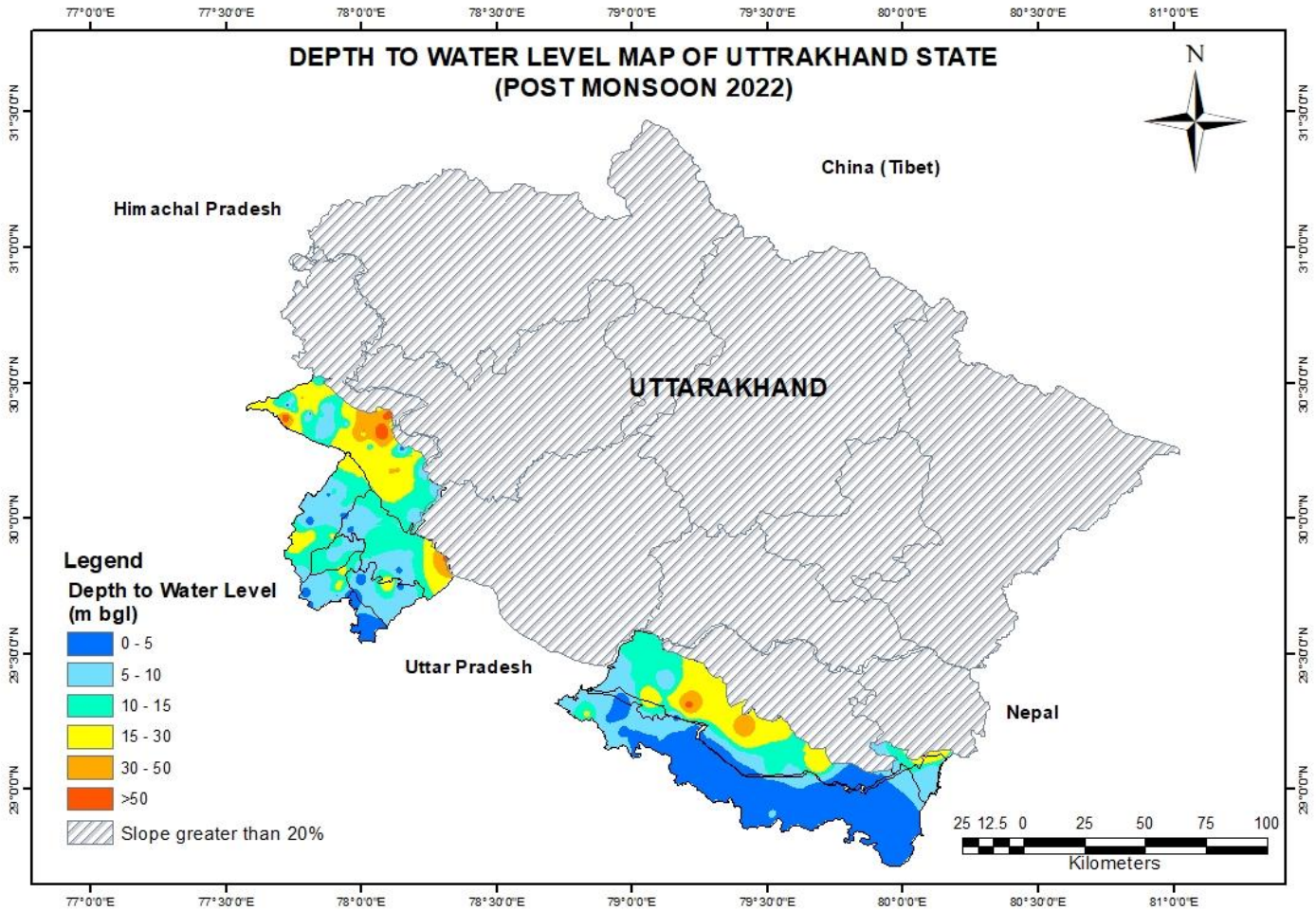
Table 21. Seasonal Water Level Fluctuation (May 2022 Versus November 2022)

District	No. of stations analyzed	Fluctuation (m)				Rise (m)						Decline (m)					
		Rise		Decline		0-2		2 to 4		>4		0-2		2 to 4		>4	
		Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
Dehradun	51	0.37	52.43	-0.52	-1.55	24	47.06	17	33.33	7	13.73	3	5.88	0	0.00	0	0.00
Haridwar	39	0.12	10.69	-0.02	-2.39	30	76.92	1	2.56	2	5.13	5	1.00	1	2.56	0	0.00
Udham Singh Nagar	43	0.28	12.06	-0.17	-1.55	29	67.44	5	11.63	4	9.30	5	11.63	0	0.00	0	0.00
Nainital	9	0.33	2.93	-1.11		7	77.78	1	11.11	0	0.00	1	11.11	0	0.00	0	0.00
Champawat	3	1.62	4.01	_		1	33.33	1	33.33	1	33.33	0	0.00	0	0.00	0	0.00
Pauri Garhwal	2	1.61	4.71	0		1	50.00	0	0.00	1	50.00	0	0.00	0	0.00	0	0.00
Uttarkashi	9	0.02	15.7	-0.57		6	66.67	0	0.00	2	22.22	1	11.11	0	0.00	0	0.00
Total	**156**					**98**	62.82	**25**	16.03	**17**	10.90	**15**	9.62	**1**	0.64	**0**	0.00

Annexure 1: Depth to Water Level Map (May 2022), Uttarakhand State



Annexure 2: Depth to Water Level Map (November 2022), Uttarakhand State



Annexure 3: Month-wise Actual Rainfall of Uttarakhand State for the year 2022

DISTRICT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
ALMORA	89.9	39.5	0.0	1.8	73.5	70.9	254.2	161	176.3	167.6	0.0	0.0
BAGESHWAR	79.2	67.4	5.7	13.4	126.2	339.7	900.1	523.7	503.8	176.6	5.2	0.0
CHAMOLI	98.2	59.5	5.2	15.7	74.4	167.9	493.1	342.3	193.1	96.6	3.2	0.0
CHAMPAWAT	88.7	38.3	2.2	2.3	67.2	120.9	190.8	202	343.9	214.1	0.3	0.3
DEHRADUN	161.7	57.0	0.0	2.4	82.7	76.3	444	561.4	386.6	67.6	1.8	0.5
GARHWAL PAURI	95.0	29.4	0.0	0.0	47.3	56.5	295.2	168.5	166.1	39.2	0.7	0.0
GARHWAL TEHRI	140.8	59.4	0.0	3.8	84.6	96.8	379.2	284.3	240.3	29.4	2.8	0.3
HARDWAR	129.4	59.6	0.0	0.0	35.4	40.7	214.7	142	239.8	57.8	0.0	0.0
NAINITAL	105.6	58.4	0.2	0.1	63.7	119.3	271	330.7	298.9	253.2	0.0	0.1
PITHORAGARH	85.7	56.7	5.2	15.7	216.3	200.1	480.3	360.6	324.1	180.4	1.5	0.0
RUDRAPRAYAG	86.3	59.0	1.9	10.3	149.6	170.8	543.2	342.4	244.5	34.4	4.0	0.0
UDHAM SINGH NAGAR	92.2	51.0	0.0	0.3	55.2	133	230.1	346.2	362.2	245.7	0.0	0.0
UTTARKASHI	137.9	57.9	2.6	13.0	105.9	71.7	447.7	418.6	235.8	54.2	4.0	0.0

Annexure 4: Summary of the ground water data analysis

Summary of Depth to Water Data in Uttarakhand during the Period 2022

State	Range of depth to water level (m bgl)	Percentage of Wells Analyzed			
		Jan 2022	May 2022	August 2022	Nov 2022
Uttarakhand	**0–5**	38.46	23.21	29.63	39.63
	5-10	20.11	23.81	29.63	23.78
	10-15	11.25	16.67	16.67	8.54
	>15	30.18	36.31	26.54	28.05

Fluctuation of Water Level during the Period 2022 (Compared to Decadal Average)

State	Fluctuation (m)	Percentage of Wells Analyzed							
		Avg. Jan		Avg. May		Avg. August		Avg. Nov	
		Rise	Decline	Rise	Decline	Rise	Decline	Rise	Decline
Uttarakhand	**0–2**	60.96	24.66	35.26	34.10	45.58	27.89	43.21	29.01
	2–4	6.16	4.79	5.78	11.56	7.48	9.52	9.26	5.56
	>4	2.05	1.37	6.94	6.36	6.12	3.40	8.64	4.94

Annual Fluctuation of Water Level during the Period 2022-23

State	Fluctuation (m)	Percentage of wells analyzed							
		May 2021 vs. 2022		August 2021 vs. 2022		November 2021 vs. 2022		January 2022 vs. 2023	
		Rise	Decline	Rise	Decline	Rise	Decline	Rise	Decline
Uttarakhand	**0–2**	42.86	39.61	21.29	66.45	44.97	48.32	71.71	17.11
	2–4	7.14	3.90	3.87	4.52	2.68	2.01	7.24	0.66
	>4	3.25	3.25	2.58	1.29	1.34	0.67	2.63	0.66

Seasonal Fluctuation of Water Level (Compared to May 2022)

State	Fluctuation (m)	Percentage of wells analyzed					
		August 2022		November 2022		January 2023	
		Rise	Decline	Rise	Decline	Rise	Decline
Uttarakhand	0–2	48.78	20.73	62.82	9.62	70.73	5.49
	2–4	12.80	3.05	16.03	0.64	9.76	1.22
	>4	13.41	1.22	10.90	0.00	5.49	0.00