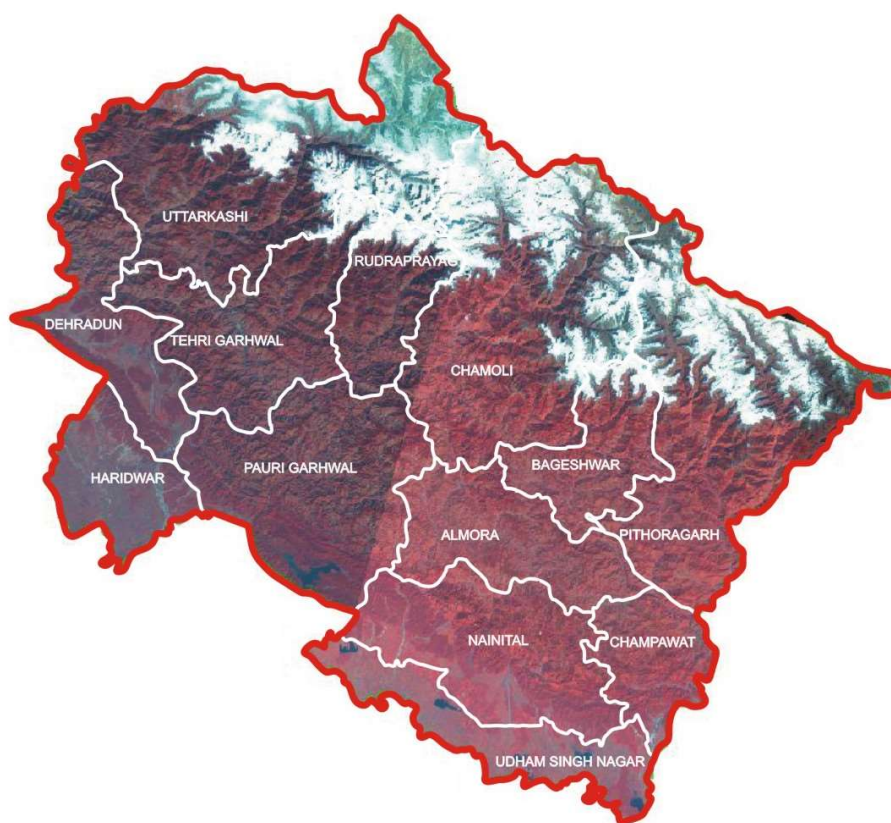




**GROUND WATER YEAR BOOK
UTTARAKHAND
(2019 -2020)**



**Ministry of Jal Shakti
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT
AND GANGA REJUVINATION
CENTRAL GROUND WATER BOARD, UTTARANCHAL REGION
GOVERNMENT OF INDIA**

**Dehradun
March - 2021**

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Contributor

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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 2019-20.

Central Ground Water Board, Uttaranchal Region is monitoring the groundwater regime under various hydrogeological setting through **200 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 Thirty-seven 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 center of the Regional Office, Dehradun.

The present Ground Water Year Book, 2019-2020 is the outcome of the effort made by Sh. Debojyoti Mondal (Junior Hydrogeologist) and Ms. Anjali Kushwaha, Scientist- ‘B’ (Junior Hydrogeologist). 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 :01.03.2020

(**Prashant Rai**)
Head of the Office

**GROUND WATER YEAR BOOK
UTTARAKHAND
(2019-2020)**

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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 km².

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 2019 to January 2020, 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 May, August and November 2019 and January 2020.

The depth to water level maps and water level fluctuation maps viz. decadal, annual and seasonal water level fluctuations were generated manually and then digitised by using coral draw software. These maps were prepared section wise viz. Dehradun Section, Haridwar section and Udham Singh Nagar-Nainital-Champawat section.

To assess the behaviour 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 May 2019 to January 2020 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 2019, November 2019 (post monsoon) and January 2020 as compared to May 2019 (pre monsoon) are also given in separate tables.

The status of water level fluctuation during each season/period with respect to observed data of pre-monsoon water level (May) during the same year indicated that decline in water level in the categories 0-2 m, 2-4 m and >4 m were significantly lower than the corresponding rise in the range of water level. The same situation was also observed for the annual water level fluctuation data also.

Summary of Depth to Water Data in Uttarakhand during the Period 2019-20

State	Range of depth to water level (m bgl)	Percentage of Wells Analyzed			
		May 2019	August 2019	November 2019	January 2020
Uttarakhand	0-5	21.19	32.03	34.42	35.29
	5-10	26.49	24.18	27.27	20.26
	10-15	19.21	13.07	8.44	13.07
	>15	33.11	30.72	29.87	31.37

Fluctuation of Water Level during the Period 2019-20 (Compared to Decadal Average)

State	Fluctuation (m)	Percentage of Wells Analyzed							
		Avg. May		Avg. August		Avg. November		Avg. January	
		Rise	Decline	Rise	Decline	Rise	Decline	Rise	Decline
Uttarakhand	0-2	27.19	36.84	18.10	40.00	35.16	41.41	47.83	28.99
	2-4	7.89	12.28	1.90	22.86	3.13	7.03	3.62	3.62
	>4	7.02	8.77	4.76	12.38	3.13	10.06	4.35	11.59

Annual Fluctuation of Water Level during the Period 2019-20

State	Fluctuation (m)	Percentage of wells analyzed							
		May 2018 vs. 2019		August 2018 vs. 2019		November 2018 vs. 2019		January 2019 vs. 2020	
		Rise	Decline	Rise	Decline	Rise	Decline	Rise	Decline
Uttarakhand	0-2	68.46	10.00	56.58	28.95	62.18	26.28	33.96	33.33
	2-4	15.38	1.54	6.58	2.63	5.13	1.92	10.06	6.29
	>4	4.62	0.00	3.29	1.97	1.92	1.28	6.92	9.43

Seasonal Fluctuation of Water Level (Compared to May 2019)

State	Fluctuation (m)	Percentage of wells analyzed					
		August 2019		November 2019		January 2020	
		Rise	Decline	Rise	Decline	Rise	Decline
Uttarakhand	0-2	68.46	10.00	59.68	12.10	70.9	8.21
	2-4	15.38	1.54	20.16	0.81	11.94	2.99
	>4	4.62	0.00	7.26	0.00	5.22	0.75

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 One hundred and eighty six (186) 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 CaCO₃.

The analysis of physico chemical parameters like Electrical Conductivity, chloride, nitrate and fluoride was done on the basis of data for pre-monsoon 2019. The analysis result indicates that high Electrical Conductivity (>750–2250 $\mu\text{S}/\text{cm}$) is observed in 7.53% of total samples whereas majority of samples (73.65% of total) recorded EC value in the range of >250-750 $\mu\text{S}/\text{cm}$. Low EC value of 0-250 $\mu\text{S}/\text{cm}$ was found. The high EC may be either due to higher mineralization of ground water (geogenic) or due to industrial activity (anthropogenic). Data on chloride concentration in ground water samples indicates that relatively high chloride in the range of >100 mg/L is observed in only two samples, which was a bare minimum of 1% of the total number of samples. High nitrate viz. higher than the acceptable Limit (>45 mg/L, BIS, 2012) is recorded in seven samples out of 186 samples. The highest nitrate concentration recorded is 76 mg/L at Khatima in Udham Singh Nagar district. High nitrate in ground water is attributed to anthropogenic source like unhygienic practices near the monitoring wells by the local populace. It is suggested the dug wells and hand pump in which high nitrate was observed should be avoided for drinking purpose and treated pipe line water should be used instead. Chemical data on fluoride concentration in groundwater sample indicates that majority of samples (98.39 % of total) has recorded fluoride less than the acceptable limit of 1.0 mg/L (BIS, 2012). Fluoride higher than the permissible limit (>1.5 mg/L) is observed in 2 samples. High fluoride in ground water is attributed to geogenic source like leaching of fluoride from rocks and/or minerals into the groundwater system during rock-water interaction. It was found that fluoride concentration in groundwater is less in Dehradun Haridwar Nainital Udham Singh Nagar section and relatively high in Uttarkashi section during premonsoon, 2019. To conclude, the available hydrochemical data in parts of District Dehradun, Haridwar, Udham Singh Nagar, Pauri Garhwal, Nainital, Champawat and Almora (premonsoon 2019) 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 CO₃-HCO₃ 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 programmes. Scientific information about the behaviour of water level in time and in 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 km². 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 2019, a total of two hundred ground water monitoring stations exist 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 summarised 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 2019 – 2020.
5. To study the hydrochemical behaviour 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 May 2019 to January 2020 is given in **Table 1**.

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

<i>Sl. No.</i>	<i>District</i>	<i>Number of Ground Water Monitoring Stations</i>			
		<i>May 2019</i>	<i>Aug 2019</i>	<i>Nov 2019</i>	<i>Jan 2020</i>
1.	Dehradun	44	44	46	46
2.	Haridwar	37	38	38	36
3.	Udham Singh Nagar	46	46	44	45
4.	Nainital	12	12	13	13
5.	Champawat	3	4	4	4
6.	Pauri Garhwal	1	1	1	1
7.	Almora	20	20	20	20
8.	Uttarkashi	8	8	8	8
TOTAL		171	173	174	173

Apart from the dug wells, hand pumps and piezometers, a total of thirty-three springs in hilly areas of Uttarakhand were also monitored (as on January 2020). The details of these springs during the period May 2019 to January 2020 are given in **Table 2**.

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

<i>Sl. No.</i>	<i>District</i>	<i>Number of Springs</i>			
		<i>May 2019</i>	<i>Aug 2019</i>	<i>Nov 2019</i>	<i>Jan 2020</i>
1.	Dehradun	3	3	3	3
2.	Nainital	7	7	7	6

3.	Almora	20	20	20	20
4.	Uttarkashi	4	4	4	4
TOTAL		34	34	34	33

The Ground Water Monitoring Stations (including Springs) have been further categorized on the basis of geological set up and catchments of the river basins in Uttarakhand. The relevant information in this regard is given in *Table 3*.

Table 3: Geology and Basin wise breakup of the existing Ground Water Monitoring Stations in Uttarakhand State (as on January 2020)

<i>River Basin/ Sub Basin</i>	<i>Geology</i>	<i>Well No. & Location</i>
DEHRADUN DISTRICT		
Yamuna Basin, Tons Sub-basin	Doon Gravels (bouldery formation)	DDN-04 (Rampura), DDN-06 (Herbertpur), DDN-07 (Jhajra), DDN-10 (Nanda ki Chowki), DDN-11 (Selaqui), UK-DDN-PZ-12 (Ladpur) DDN-18 (Kanwali), DDN-19 (Chhorba), DDN-20 (Shankarpur), DDN-21 (Judli), DDN-22 (Dandi), DDN-PZ1 (Chhorba), DDN-PZ2 (CGWB Office), DDN-HP-1 (Jhajra), DDN-HP-2 (Redapur), DDN-HP-3 (Majra), DDN-HP-4 (Bhaniawala), DDN-HP-5 (Balliwala), DDN-HP-6 (Harbanswala), DDN-HP-6 (TarlaNagal), DDN-Pz-7 (TarlaNagal), DDN-HP-8 (Nanurkhera), DDN-HP-9 (Nanda Ki Chowki), DDN-HP-10 (Selaqui), DDN-HP-11 (Badripur), DDN-HP-13 (Kuanwala), DDN HP14(Vikas Nagar), DDN-HP-16 (Gularghati), DDN-HP-19 (Khandgaon), DDN-HP-20 (Lal Tappar), DDN-HP-21 (Kotimaichak), DDN-HP-23 (Khadakmaf), DDN-HP-25 (Dakpatthar), DDN-HP-26 (Barothiawala), DDN-HP-27 (Dhakrani), DDN-HP-28 (Timli), DDN-HP-35 (Mathrowala), DDN-HP-33 (Telpura), DDN-HP-35 (Dudhli), DDN-HP-36 (Baronwala), DDN-32 (Baluwala), DDN-DW-30 (Haripur), DDN-HP-36 (Chandmari), DDN-DW-23 (Duggiawala), DDN-HP-37 (Chhorba), DDN-DW-13 (Dharmawala), UK-DDN-HP 54 (Barotiawala), UK-DDN-58 (Luxmipur)
	Doon Gravels (bouldery formation) and Upper Siwaliks (conglomerate, pebbly sands, clay)	DDN--33 (Redapur), UK-DDN-47 (Sabhawala), UK-DDN-48 (Singhniwala), UK-DDN-DW-49 (Ramgarh), DDN-SP2 (Khandoli), DDN HP16 (Maldevta), DDN-SP3 (Soda Sarauli)
	Blaini – Krol, boulder beds	DDN-SP1 (Bhatta), UK-DDN-15 (Rishikesh), UK-DDN-42 (Purukulgaon) ,
HARIDWAR DISTRICT		
Ganga Basin, Upper Ganga Sub-basin	Tarai (gravel, sand and clay)	HRW-10 (Hussainpur), HRW-11 (Budhwa Shahid), HRW-12 (Shahidwala Grant), HRW-14 (Rathaura), HRW-15 (Sarai), HRW-16 (Librahedi), HRW-PZ1 (Roorkee),

		HRW-HP-1 (Bhagwanpur), HRW-HP-2 (Bahabalpur), HRW-HP-3 (Jhabrera), HRW-HP-4 (Iqbalpur), HRW-HP-5 (Bugawala), HRW-HP-6 (Shahpur Shitlakhera), HRW-HP-7 (Khanpur), HRW-HP-8 (Lakhnauta), HRW-HP-9 (Gurukul Narsen), HRW-HP-11 (Dallawala), HRW-HP-12 (Govardhanpur), HRW-HP-13 (Dhanpura), HRW-HP-14 (Bhikkampur), HRW-HP-15 (Bahadradabad), HRW-HP-16 (Chudiala), HRW-HP-17 (Shahidwala Grant), HRW-HP-18 (Imlikhera), HRW-HP-19 (Landhaura), HRW-HP-22 (Mudlana), HRW-HP-23 (Bhogpur), HRW-HP-25 (Kotamuradnagar), HRW-HP-26 (Laksar), HRW-HP-24 (Dudhadyalwala), HRW-HP-25 (Syampur), HRW-DW-17 (Sikhar), HRW-DW-18 (Kherajat), HRW-DW-19 (Nijampur), HRW-DW-23 (Jaswawala), HRW-DW-25 (Mohammadpur), HRW-HP-29 (Jasodharpur), UK-HRW-68 (Dalupuri), UK-HRW-64 (Panjanheri), UK-HRW-82 (Dandi Ibrahimpur)
	Siwaliks (sandstone, siltstone, conglomerate)	HRW-13 (Bandarjud), HRW-HP-21 (Laldhang)

UDHAM SINGH NAGAR DISTRICT

Ganga basin, Ramganga Sub- basin	Tarai (gravel, sand and clay)	USN-01A (Kashipur), USN-02 (Khatima), USN-03 (Bazpur), USN-07 (Bara), USN-09 (Jaspur), USN-HP-11 (Angadpur), USN-18 (BannaKhera), USN-19 (Shantipuri), USN-20 (Nanak Mata), USN-HP-1 (KamariaPakki), USN-HP-2 (Gangapur), USN-HP-3 (Bhagwanpur), USN-HP-4 (Beria Daulat), USN-HP-6 (Jogipura), USN-HP-9 (Majhola), USN-HP-10 (Dhanauri Patti), USN-HP-11 (Kalyanpur), USN-HP-12 (PattharChatta), USN-HP-13 (BarkharePande), USN-HP-14 (Sultanpur Patti), USN-HP-15 (Bharatpur), USN-HP-16 (Patrampur), USN-HP-18 (Sitarganj), USN-HP-20A (Durgapur), USN-HP-22 (Chakarpur), USN-HP-23 (Jharkhandi), USN-HP-24 (Mahabir Nagar), USN-HP-25 (Sarasariya), USN-HP-26 (Rudrapur), USN-HP-28 (Missarwala), USN-HP-29 (Shankhera), USN-HP-31 (Pritpur), USN-HP-32 (Badripur), USN-HP-33 (Pattharpui), USN-HP-35 (Lalpuri), USN-HP-36 (Kanakpur), USN-HP-37 (Rajpura), USN-HP-39 (Begur Mod), USN-HP-40 (Bidora), USN-HP-41 (Dhyanpur), USN-HP-42 (Barianjaniya), USN-HP-126 (Kichha), USN-HP-19 (Tukri), USN-HP-7A (Jhagarpuri), USN-HP-38 (Pipiliya)
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NAINITAL DISTRICT

Ganga basin, Ramganga Sub- basin	Bhabar (boulders, gravel, sand and clay)	NTL-03 (Lalkuan), NTL-05 (Maldhan Colony), NTL-HP-1 (Ramnagar), NTL-HP-2 (Belparao), NTL-HP-3 (Dhela), NTL-HP-4 (PeeruMadara), NTL-HP-5 (Dhoniya), NTL-HP-6 (Lamachaur), NTL-HP-7 (Kaladhungi), NTL-HP-8 (Kathgodham), NTL-HP-10 (Khat Baas), NTL-HP-11 (Chilkiya),
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	Middle Siwaliks (sandstone with minor clay)	NTL04 (Garjiya), NTL-S1 (Dogaon), NTL-S3 (Garampani), NTL-S4 (Salari), NTL-S5 (Ranibagh), NTL-S6 (Jyolikote)
	Blaini-Krol, boulder beds	NTL-S2 (Sipahidhara), NTL-S7 (Kuda Ghat)
CHAMPAWAT DISTRICT		
Ganga basin, Ramganga Sub-basin	Bhabar (boulders, gravel, sand and clay)	CPT-01 (Tanakpur), CPT-HP-1 (Banbasa)
	Middle Siwaliks	CPT-HP-2 (Bastia), CPT-HP-3 (Bichayee)
ALMORA DISTRICT		
Ganga basin, Ramganga Sub-basin	Almora – Ramgarh Formation	ALM-S-1 (PataliTalla), ALM-S-2 (PataliMalla), ALM-S-3 (Katarmal), ALM-S-4 (Dharanaula), ALM-S-5 (Palna), ALM-S-6 (Chinoda), ALM-S-7 (Guruda-I), ALM-S-8 (Dhansari), ALM-S-20 (Someshwar), ALM-S-11 (Bhoolgaon), ALM-S-12 (Deepakot), ALM-S-13 (Ramgath), ALM-S-14 (Bhagtola), ALM-S-15 (Itola), ALM-S-17 ChhaniBartola), ALM-S-18 (Lodh), ALM-S-21 (Dhahnagaon), ALM-S-22 (Semalkhet), ALM-S-23 (Naula), ALM-S-24 (Bania Diggi), ALM-S-19 (Peepal Dhar), ALM-S-25 (Jholi),
PAURI GARHWAL DISTRICT		
Ganga Basin, Upper Ganga Sub-basin	Bhabar (boulders, gravel, sand and clay)	PG-HP-1 (Kaudiya), PG-HP-2 (Ramdayalpur), PG-HP-3 (Trilokpur)
UTTARKASHI DISTRICT		
Ganga Basin, Upper Ganga Sub-basin	Lesser Himalaya	UK-HP-1 (Chinyalisaur), UK-HP-2 (Devidhar), UK-HP-2A (Dunda), UK-HP-3 (Uttarkashi), UK-HP-4 (Barkot), UK-HP-5 (Sharukhet), UK-HP-6 (Ganeshpur), UK-HP-7 (Maneri), UK-SP-1 (Dharasu), UK-SP-2 (Nagal), UK-SP-3 (Ratodisar), UK-HP8 (Charethi), UK-SP-4 (Gangnani),



- DEHRADUN DISTRICT**
1. Rishikesh
 2. Rampura
 3. Kuanwala
 4. Herbertpur
 5. Motichur
 6. Sabhawala
 7. Singhiwala
 8. Ramgarh
 9. Kanwali
 10. Chhorba
 11. Shankarpur
 12. Judli
 13. Jhajra
 14. Redapur
 15. Majra
 16. Bhaniawala
 17. Balliwala
 18. Harbanswala
 19. Tarla Nagal
 20. Nanurkhera
 21. Chhorba Pz
 22. Nanda Ki Chowki
 23. Selaqui
 24. Baronwala
 25. Kuanwala
 26. Rishikesh
 27. Purukulgaon
 28. Maldeota
 29. Gularghati
 30. Vikas Nagar
 31. Khandgaon
 32. Lal Tappar
 33. Kotimaichak
 34. Soda Sarauli
 35. CGWB Office
 36. Dandi
 37. Khadakmap
 38. Dudhli
 39. Bhatta Sp
 40. Khandoli Sp
 41. Soda Sarauli Sp
 42. Dakpatthar
 43. Barothiwala
 44. Dhakrani
 45. Badripur
 46. Timil
- HARIDWAR DISTRICT**
47. Bahadrabad
 48. Dhanpura
 49. Hussainpur
 50. Roorkee
 51. Bhagwanpur
 52. Chudiala
 53. Bahabalpur
 54. Jhabrera
 55. Iqbalpur
 56. Bugawala
 57. Shahidwala Grant
 58. Bandarjud
 59. Rathaure
 60. Sarai
 61. Shahpur Shitakhera
 62. Khanpur
 63. Lakhnauta
 64. Chudiala
 65. Gurukul Narsan
 66. Manglaur
 67. Dallawala
 68. Govardhanpur
 69. Bhikkampur
 70. Imlikhera
 71. Landhaura
 72. Bhopatwala
 73. Laldhang
- PAURI GARHWAL DISTRICT**
74. Kaudiya
- UDHAM SINGH NAGAR DISTRICT**
- | | | |
|--------------------|-----------------|---------------------|
| 75. Kashipur | 76. Khatima | 77. Bazpur |
| 78. Kichha | 79. Sitarganj | 80. Bara |
| 81. Beria Daulat | 82. Jaspur | 83. Chakarpur |
| 84. Dhanauri Patti | 85. Kalyanpur | 86. Patthar Chatta |
| 87. Angadpur | 88. Patrampur | 89. Bharatpur |
| 90. Barkhare Pande | 91. Barhini | 92. Suitanpur Patti |
| 93. Banna Khera | 94. Shantipuri | 95. Nanak Mata |
| 96. Kamaria Pakki | 97. Gangapur | 98. Bhagwanpur |
| 99. Mahabir Nagar | 100. Jogipura | 101. Jhagarपुरi |
| 102. Majhola | 103. Jharkhandi | 104. Tukri |
| 105. Sarasariya | 106. Durgapur | 107. Kopa Signal |
| 108. Rudrapur | | |
- NAINITAL DISTRICT**
110. Lalkuan
 111. Garjia
 112. Maldhan Colony
 113. Ramnagar
 114. Belparao
 115. Dhela
 116. Peeru Madara
 117. Dohniya
 118. Lamachaur
 119. Kaladhungi
 120. Kathgodham
 121. Sitapur
 122. Khat Baas
 123. Dogaon
 124. Sipahidhara
 125. Garampani
 126. Salari
 127. Ranibagh
 128. Jyolkote
- CHAMPAWAT DISTRICT**
129. Banbasa
 130. Tanakpur
 131. Bastia
- ALMORA DISTRICT**
132. Patti Talla
 133. Patti Malla
 134. Katarmal
 135. Dharanaula
 136. Dharanaula Zoo
 137. Paina
 138. Chinoda
 139. Guruda-I
 140. Guruda-II
 141. Bachuradi
 142. Someswar
 143. Dhansari
 144. Deepakot
 145. Ramgath
 146. Bhagtolia
- UTTARKASHI DISTRICT**
147. Chinyalisaur
 148. Devidhar
 149. Uttarkashi
 150. Dharasu
 151. Barkot
 152. Sherukhet
 153. Ganeshpur
 154. Maneri
 155. Nagal
 156. Ratodi Sar

Figure 1: Location of Ground Water Monitoring Stations in Uttarakhand (As on March 2020)

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 1256 mm in Haridwar district to 2426 mm in Pithoragarh district. The average annual rainfall varies from 927.7 mm at Joshimath (Chamoli district) to 2599.4 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 seventy years (1901 to 1970) is given in **Table 4**.

Table 4: District wise normal monthly and annual rainfall (mm) in Uttarakhand State (1901-1970)

<i>District</i>	<i>Jan</i>	<i>Feb</i>	<i>Mar</i>	<i>Apr</i>	<i>May</i>	<i>Jun</i>	<i>July</i>	<i>Aug</i>	<i>Sep</i>	<i>Oct</i>	<i>Nov</i>	<i>Dec</i>	<i>Annual</i>
Dehradun	57.4	55.8	37.6	17.1	34.0	178.9	686.9	751.5	314.5	47.1	7.8	37.4	2212.0
Chamoli	103.0	107.8	114.5	57.2	47.9	117.1	314.4	322.0	169.0	51.4	23.5	47.0	1474.8
Nainital	37.7	33.4	18.7	8.6	27.2	173.6	466.2	454.7	239.7	52.2	3.9	11.9	1527.8
Pithoragarh	257.8	193.4	190.9	78.2	70.9	239.4	496.7	441.8	290.9	57.2	32.4	76.3	2425.9
Haridwar	48.1	45.8	24.5	9.8	19.9	108.9	360.1	393.8	190.2	34.3	5.4	15.4	1256.2
Tehri Garhwal	64.1	50.5	57.5	25.9	47.0	120.7	374.3	339.8	207.2	62.5	10.6	34.5	1394.6
Uttarkashi	102.4	59.2	90.4	46.6	72.7	128.8	400.3	426.5	301.4	46.9	20.4	36.5	1732.1
Almora	54.8	56.5	49.8	32.4	56.8	162.4	345.5	321.5	165.5	56.0	7.5	21.6	1330.3
Pauri Garhwal	58.9	59.8	41.9	23.5	45.0	151.4	412.9	402.5	188.9	43.7	6.8	23.0	1458.4

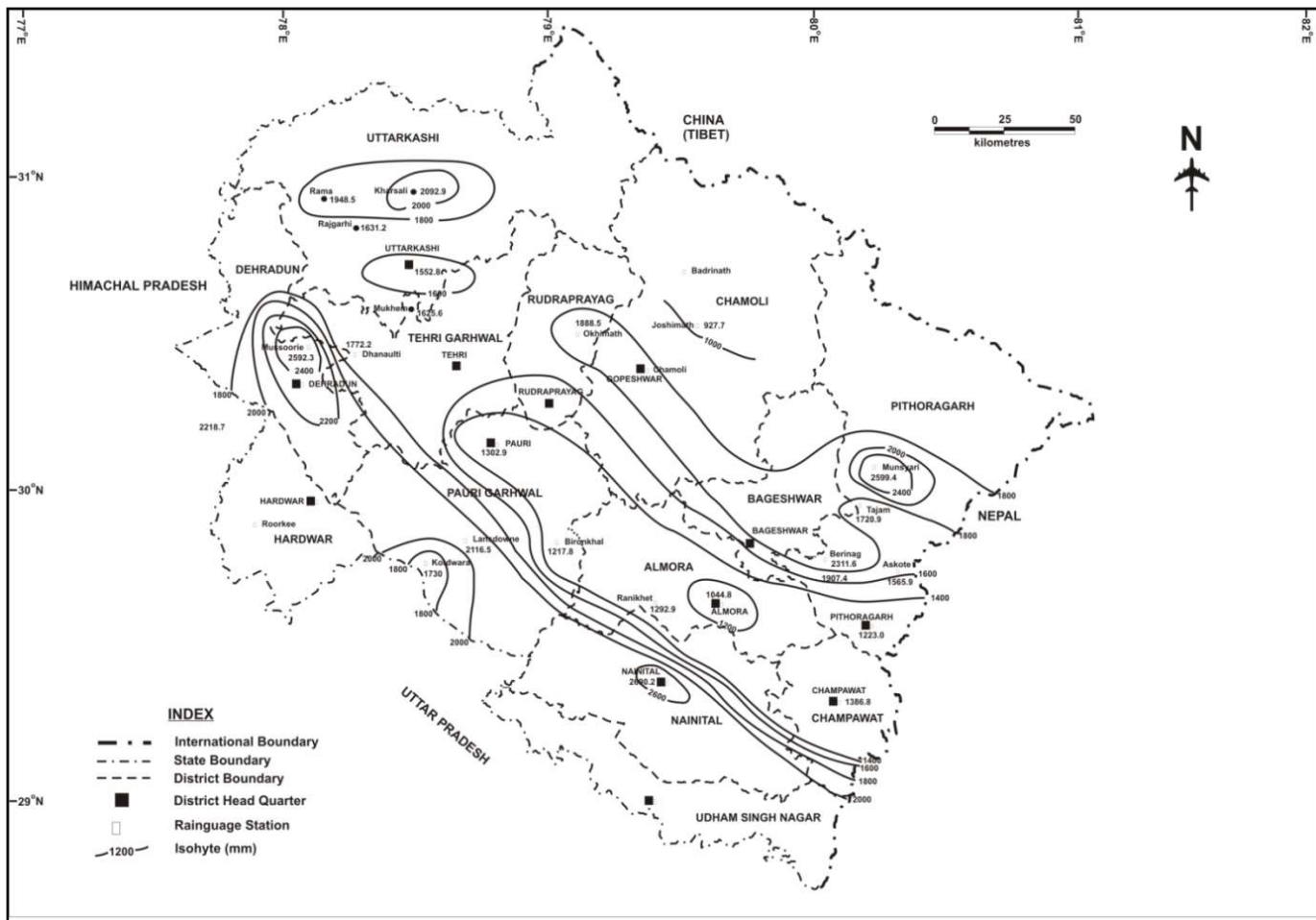


Figure 2 Mean Annual Isohyetal Map, Uttarakhand State

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 conformably 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 (Extra Peninsular 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. 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. The Extra-Peninsular region has a wide spectrum of rocks of sedimentary, metamorphic and igneous origin.

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 klippen masses occupying mostly the higher topographical levels of the mountain ranges. Regionally metamorphosed Proterozoic rocks replaced 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 crystallines.

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 Zaskar Mountains and mountain ranges of Kumaun region. This zone is separated from the Central Crystallines 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.

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 generalised 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. Bhabar

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.

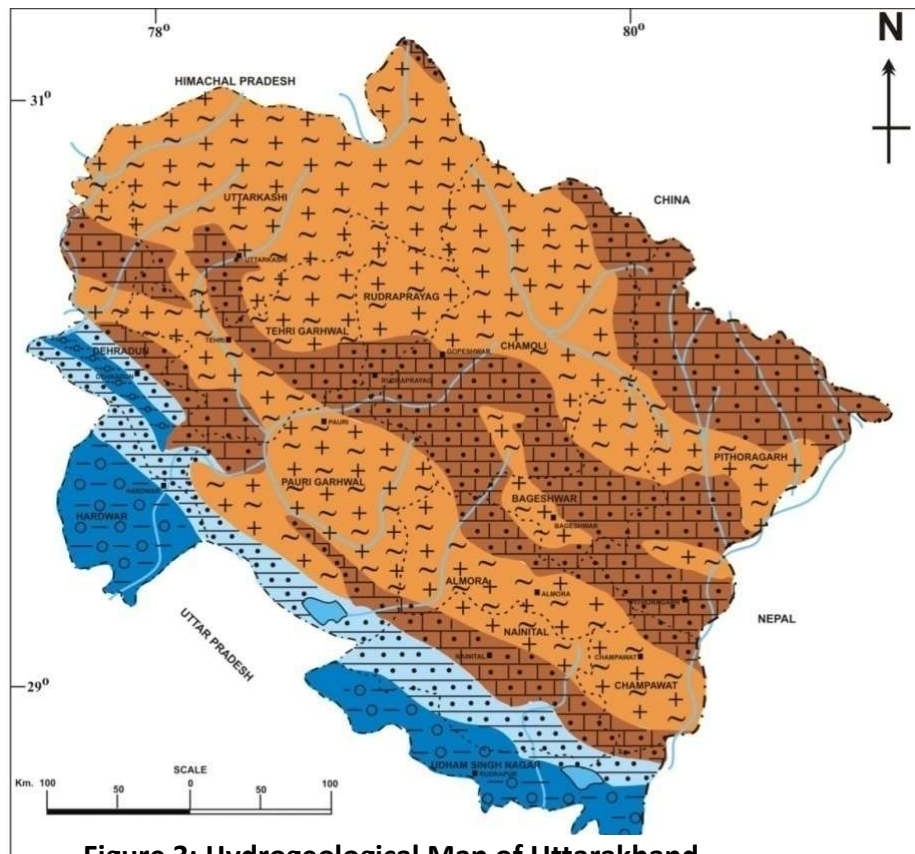


Figure 3: Hydrogeological Map of Uttarakhand

AGE GROUP	FORMATION	LITHOLOGY	AQUIFER CHARACTER	HYDRAULIC CHARACTERISTICS
Quaternary	Alluvium	Clay, calcareous concretions, silt, sand, gravel, boulders etc.	<ul style="list-style-type: none"> Extensive aquifers Localised aquifers 	<ul style="list-style-type: none"> 300 to 8800 High, 10-50 lps
Miocene to Pliocene	Sedimentaries	Sandstone, claystone, conglomerate, boulder beds etc.	Local or discontinuous aquifers	<ul style="list-style-type: none"> 175 to 7000 Moderate, 5-25 lps
Unclassified Mesozoic, Paleozoic and Upper Proterozoic	Sedimentaries and meta-sedimentaries	Shale, quartzite, slate, phyllite, sandstone, dolomite, limestone	Local or discontinuous aquifers	<ul style="list-style-type: none"> Low, up to 5 lps
Lower Proterozoic, Azoic	Crystalline and meta-sedimentaries	Gneissic complex and associated intrusives	Localised aquifers	<ul style="list-style-type: none"> Very Low

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 tubewells, 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 intrusives (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, tubewells 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 almost 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. Due to the porous and permeable nature of the litho units, this zone is generally suitable for ground water development.

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 period 2019-2020 (May 2019, August 2019, November 2019 and January 2020) as shown in Table 5. The ground water levels in different seasons were analyzed to evaluate the temporal behaviour of water level. The behaviour of water levels in each season during the period May 2019 – January 2020 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 5: Monitoring data of Ground Water Monitoring Wells, Uttarakhand State

Sl. No.	Location	May-19	Aug-19	Nov-19	Jan-20
DEHRADUN DISTRICT					
<i>Raipur Block</i>					
1	Kanwali	13.14	12.9	11.48	12.8
2	CGWB Office	59.96	59.16	56.12	56.33
3	TarlaNagal	75.4	NA	70.26	72.08
4	Majra	16.59	24	24.2	24.67
5	Balliwala	NA	NA	NA	NA
6	Harbanswala	56.5	54.8	46.57	48.17
7	TarlaNagal	53.75	52.95	49.68	52.32
8	Nanurkhera	67.34	68.1	61.54	63.01
9	Kuanwala	14.76	9.4	5.15	9.61
10	Purukulgaon	29.78	25.68	23.07	25.43
11	Maldeota	14.27	5.17	8.35	12.11
12	Gularghati	14.08	11	9.86	11.95
13	Ladpur PZ*	89.75	72.3	82.3	83.75
<i>Doiwala Block</i>					
14	Rishikesh HP	8.79	5.86	5.32	6.36
15	Lal Tappar	17.48	16.08	16.95	17.03
16	Khandgaon	11.41	5.41	6.39	8.43
17	Kotimachak	22.92	15.82	16.5	19.13
18	KhadakMaaf	14.7	14.08	16.15	16.9
19	Bhaniawala	NA	22.72	0.58	32.09
20	Duggiawala DW	5.1	4.5	6.25	6.46
21	Mothrowala HP	12.52	9.22	9.46	9.99
22	Chandmari HP	36.34	22.24	29.56	30.99
<i>Sahaspur Block</i>					
23	Rampura	9.8	7.9	9.34	14.68
24	Jhajra DW	14.62	12.34	7.13	8.08
25	Jhajra HP	13.4	10.5	7.91	11.78

26	Selakui DW	Dry	5.74	8.28	9.38
27	Selakui HP	16.62	12.92	14.19	15.18
28	Nanda ki Chowki DW	17.3	12.6	8.81	9.53
29	Nanda ki Chowki HP	18.2	11.2	13.68	14.52
30	Redapur DW	6.74	12.9	4.28	6.55
31	Redapur HP	11.51	6.2	6.43	4.26
32	Shankarpur	25.44	17.9	19.92	20.87
33	Chhorba HP	34.56	30.4	30.14	27.62
34	Telpura HP	40.34	36.42	32.99	34.45
Vikas Nagar Block					
35	Herbertpur	10.85	7.85	7.73	10.07
36	Dharmawala	8.85	NA	1.91	5.4
37	Sabhawala	9.18	6.08	6.65	7.97
38	Singhniwala	9.37	7.84	7.53	9.14
39	Ramgarh	7.8	4.2	6.02	6.18
40	Judli	13.7	10.2	11.51	13.1
41	Badripur	9.53	7.33	8.37	8.69
42	Dak Patthar	29.17	22.97	23.41	25.91
43	Barotiwala	22.7	20	17.91	20.2
44	Dhakrani	12.3	10.7	11.84	17.19
45	Timli	67	62.9	63.01	63.59
46	Baluwala HP	38.85	38.95	31.76	35.16
47	Luxmipur HP	30.74	24.64	25.89	27.57
HARIDWAR DISTRICT					
Bahadrabad Block					
1	Bahadrabad	11.34	14.68	11.93	12.08
2	Dhanpura	7.44	5.32	6.92	6.94
3	Bandarjud	12.5	7.95	9.86	8.85
4	Rathura	5.45	4.81	3.52	3.79
5	Sarai	13.76	10.77	12.43	13.34
6	Shahpur shitlakhera	5.75	2.97	3.44	3.47
7	Laldhang	67.7	64.01	54.79	50.96
8	Panjanheri	7.34	3.82	6.68	NA
9	DudhyaDayalwala	3.19	1.15	0.31	2.59
10	Shyampur	9.15	7.95	9.54	10.15
11	Jaswawala	4.28	3.45	3.45	3.64
12	Dalupuri DW	27.25	26.95	26.1	
Bhagwanpur Block					
13	Budhwa shahid	5.53	2.73	3.02	2.59
14	Shahidwala Grant DW	10.83	10.7	10.73	10.44
15	Shahidwala Grant HP	10.76	11	10.14	10.8
16	Bhagwanpur	20.73	20.56	22.72	21.09
17	Bahabalpur	3.38	1.1	3.21	3.21

18	Iqbalpur	19.6	17.78	15.72	13.01
19	Bugawala	9.95	5.79	7.19	6.89
20	Chudiala HP	22.4	20.98	20.39	19.02
Roorkee Block					
21	Roorkee	7.7	6.1	6.54	6.15
22	Imlikhera	18.4	17.89	19.49	16.58
23	Nijampur	10.9	10.87	10.52	10.9
24	Landhaura	19.4	17.22	18.06	17.82
Laksar Block					
25	Hussainpur	3.53	0.42	2.15	1.56
26	Bhikkampur	4.1	3.02	2.22	1.93
27	Laksar	4.07	1.04	2.93	2.32
Narsan Block					
28	Jhabrera	10.55	8.66	8.67	9.19
29	Lakhnauta	7.86	5.24	7.18	6.9
30	Gurukul Narsen	6.28	5.89	5.79	6.04
31	Libberhedi	6.8	4.28	7.04	7.16
32	Mundlana	19.85	16.28	18.27	17.8
33	Bhogpur	4.84	1.33	3.33	3.44
34	Sikhar	17.15	15.17	16.75	16.73
35	KheraJat	6.75	5.38	6.11	6.15
Kanpur Block					
36	Khanpur	4.62	1.76	3.09	2.58
37	Dallawala	NA	2.32	1.45	1.28
38	Govardhanpur	3.45	0.75	2.43	1.88
PAURI GARHWAL DISTRICT					
1	Kaudiya(Kotdwar)	60.8	68	50.53	50.92
UDHAM SINGH NAGAR DISTRICT					
Jaspur Block					
1	Jaspur	12.63	11.33	10.91	14.21
2	Patrampur	12.63	11.33	7.55	5.49
3	Angadpur	18.21	10.72	12.08	12.59
4	Durgapur	5.82	4.64	1.95	1.94
5	Missarwala	16.8	15.15	8.88	6.61
Kashipur Block					
6	BarkharePande	13.07	1.57	1.5	11.06
7	Sultanpur Patti	5.28	5.54	5.28	2.96
8	Kashipur	7.53	7.34	6.58	4.46
9	Bharatpur	11.85	13.93	9.64	7.28
10	Dhanauri Patti	4.06	3.03	2.92	2.6
11	Shand Khera	9.56	8.03	4.93	3.02
Bazpur Block					
12	Bazpur	3.88	1.48	1.66	1.48
13	Jharkhandi	1.94	1.94	1.78	1.67
14	Jogipura	6.22	5.42	3.97	3.84
15	BannaKhera	4.9	3.87	3.91	3.77

16	Pritpur	8.35	5.49	3.53	3.25
17	Badaripur	6.4	5.84	3.75	3.43
Gadarpur Block					
18	Jhagarpuri	2.98	3.98	5.5	2.21
19	Mahabir Nagar	4.58	1.2	1.5	0.61
20	Beria Daulat	1.98	2.18	2.94	2.71
21	Bhagwanpur	14.3	8.52	2.91	2.12
22	Pattharpui	4.43	2.5	3.38	3.08
23	Badakhera	4.9	2.17	NA	NA
24	Lalpuri	2.5	1.92	2.09	1.58
Rudrapur Block					
25	Bara	2.85	1.32	2.22	1.91
26	Kichha HP	11.42	9.34	8.56	8.04
27	KamariaPakki	5.82	8.89	8.07	5.15
28	Gangapur	4.3	3.2	2.74	2.07
29	Shantipuri	2.7	0.56	1.78	0.95
30	PattharChatta	4.26	2.22	2.71	2.34
31	Rudrapur	2.71	0.9	2.52	1.97
32	Kanakpur	5.19	6.92	2.46	1.9
33	Rajpura	5.08	3.3	3.3	1.9
34	Pipiliya	9.02	5.74	4.47	2.32
Sitarganj Block					
35	Sitarganj	3.44	1.02	1.38	0.99
36	Nanak Mata	3.79	2.13	2.6	2.57
37	Kalyanpur	3.66	1.44	1.61	2.18
38	Tukri	5.64	2.49	2.77	1.71
39	Begur Mod	3.96	2.22	3.6	3.02
40	Bidora	2.46	4.1	NA	2.46
41	Dhyampur	4.4	1.55	1.22	0.95
Khatima Block					
42	Kanchanpur (Majhola)	5.9	5.23	4.38	4.21
43	Khatima	3.7	0.96	1.75	1.65
44	Sara Sariya	6.95	7.5	4.83	4.62
45	Chakarpur	6.97	3.88	3.68	3.9
46	Barianjaniya	6.75	2.59	3.42	3.46
NAINITAL DISTRICT					
Haldwani Block					
1	KhaatBaans	39.6	32.6	34.06	32.82
2	Lalkuan	11.51	NA	11.79	11.11
3	Lamachaur	NA	54.94	52.39	53.77
4	Kaladungi	29.57	28.53	27.89	28.4
5	Kathgodam	19.06	16.21	16.77	16.23

Ramnagar Block					
6	Belparao	58.06	59.31	61.81	61.08
7	PeeruMadara	19.9	18.3	19.33	24
8	Maldhan Colony	5.58	4.02	2.83	2.23
9	Dhela	73.58	66.42	72.63	71.47
10	Ram Nagar	6.83	4.77	7.76	5.82
11	Garjiya	3.34	3.2	4.1	4.03
12	Dohniya	71.9	62.16	60.01	60
13	Chilkiya	48.2	38.23	49.65	53.79
CHAMPAWAT DISTRICT					
1	Tanakpur	NA	9.4	9.62	10.56
2	Banbasa HP	9.73	4.25	3.74	4.03
3	Bastia HP	45.04	33.47	23.54	29.56
4	Bichayee HP	10.08	8.77	8.52	9.37
UTTARKASHI DISTRICT					
1	Chinyalisaur HP	22.85	23.78	5.4	29.6
2	Devidhar HP	10.75	9.85	8.63	8.65
3	Uttarkashi HP	18.3	16.15	16.46	16.72
4	Barkot HP	16.07	15.57	16.94	16.41
5	Sharukhet HP	45.5	40.99	43.95	43.92
6	Ganeshpur HP	19.63	17.39	16.99	17.18
7	Maneri HP	31.75	25.98	28.98	29.27
8	Charethi HP*	24.63	22.46	23.79	18.49

NA: Not Available

DEPTH TO WATER LEVEL

5.1.1 May 2019

The depth to water level data was analyzed for 151 Ground Water Monitoring Wells in Uttarakhand during May 2019 and is given in **Table 6**. Analysis of depth to water level data given in the table indicates that the deepest water level was 89.75 m bgl at Ladpur in Dehradun district whereas the shallowest water level was 1.94 m bgl at Jharkhandi in Udham Singh Nagar, district. The depth to water level in the range of 0–5 m bgl was recorded in 32 ground water monitoring wells, which is 21.19% of the total number of wells. Water level in the range of 5–10 m bgl was shown by 40 monitoring wells (26.49% of total number), whereas deeper water level of 10–15 m bgl was recorded in 29 monitoring wells, which was 19.21% of the total number. The deepest water level of >15 m bgl was shown by 50 monitoring wells, which is 33.11% of the total monitoring wells in Uttarakhand during May 2019.

Table 6: District wise categorization of depth to water level data, May 2019

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	44	5.1	89.75	0	0.00	9	20.45	13	29.55	22	50.00
Haridwar	37	3.19	67.7	9	24.32	12	32.43	7	18.92	9	24.32
U. S. Nagar	46	1.94	18.21	22	47.83	16	34.78	6	13.04	2	4.35
Nainital	12	3.34	73.58	1	8.33	2	16.67	1	8.33	8	66.67
Champawat	3	9.73	45.04	0	0.00	1	33.33	1	33.33	1	33.33
Uttarkashi	8	10.75	45.5	0	0.00	0	0.00	1	12.50	7	87.50
Pauri Garhwal	1	60.8		0	0.00	0	0.00	0	0.00	1	100.00
Total	151	2.22	90.75	32	21.19	40	26.49	29	19.21	50	33.11

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for *May 2019* is shown in **Fig. 4** (Dehradun, Section), **Fig.5** (Haridwar section) and **Fig. 6** (Nainital-Udham Singh Nagar-Champawat Section).

A study of Fig. 4 indicates that the major part of the Dehradun district shows water levels in deeper than 15 m bgl. The shallow water level in the range of 5-10 m bgl occurs in patches near extreme south eastern part (Rishikesh) and in small patches near north western part (Singhniwala- Ramgarh- Rampura- Sabhawala- badripur –Dharmawala areas) of Doon valley. The water level in the depth range of 10-15 m bgl occurs in the North-western part (Jhajhra-

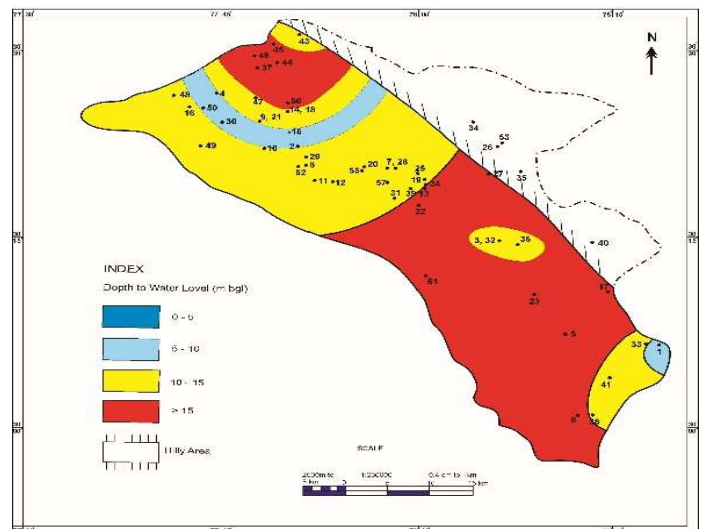


Figure 4: Depth To water Level Map (May 2019), Dehradun District

baronwala- Redapur-Haripur areas), central part (Gularghati-Kuanwala areas) of Doon valley.

The visual interpretation of the **Fig. 5** indicates that the shallowest water level in the range of 10-15m occurs mostly in the northern part of the Haridwar district. The major part of the Haridwar district shows shallow water levels in the range of 10-15mbgl. The water level in the range of 0-5mbgl zone occurs as patches in the southern part (Bhogpur-Husainpur-Khanpur-Bhikampur areas) of Haridwar district. The water level in the range of 5-10 m bgl zone occurs as curvilinear band in the southern part (Panjanheri-Dandi ibrahimpur- Roorkee- Libberhedi areas) and as concentric ring around the water level zone of 10-15 m bgl in the northern part (Rathaura-Buggwala-BudhwaSahid areas) of Haridwar district. The deepest water level in the range of more than 15m occurs as patches in western part (Landhaura-Shikhar-Imlikhera – Iqbalpur- Imlikhera- Bhagwanpur areas) of the district.

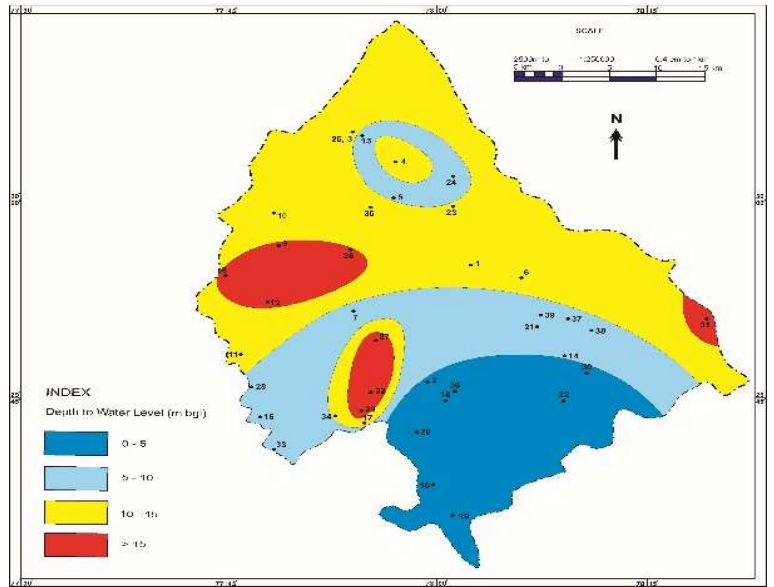


Figure 5: Depth To water Level Map (May 2019), Haridwar District

The visual interpretation of the **Fig. 6** indicates that the major part of the section shows water level in the depth range of more than 15 m bgl along with linear bands of water level in the depth range of 5-10 m and 10-15 m the section. The deepest water level in the range of more than 15 m bgl occurs in Nainital and Champawat districts. The water levels in the depth range of 0-5 m bgl in the southern portion (Khatima-Nanakmatta-Bara-lalpuri-Jharkhandi-Sultanpur patti-Dhanauri Patti areas) of the section. Thenarrow linear band of water

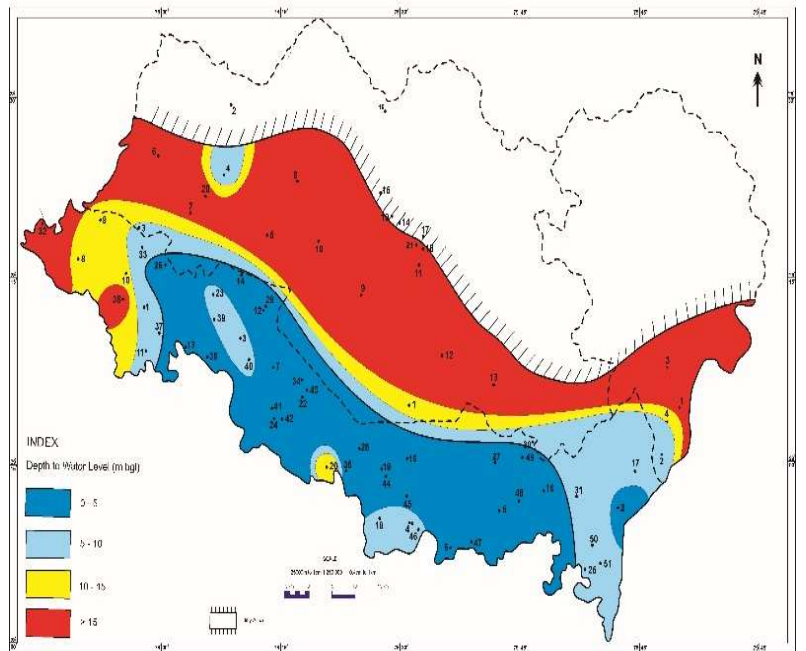


Figure 6: Depth To Water Level Map (May 2019), US Nagar – Nainital - Champawat Section

level in the depth range of 5-10 m bgl stretches form north eastern part of the section to the south south western portion of the section covering major portion(Kashipur-Sankhera- Rudrapur-Tukri-Kanchanpuri- Chakarpur areas) of Udham Singhnagar district and southern portion(Banbasa-Bichayee) of Champawat district.

5.1.2 August 2019

During the month of August 2019, total of 153 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 perusal of the table indicates that deepest water level was 72.3 m bgl at Ladpur in District Dehradun district while the shallowest water level was 0.42 m bgl at Husainpur in Haridwar district. The analysis of depth to water level data has also shown that shallowest water level of 0-5 m was recorded by 49 monitoring wells, which was 32.03% of the total number. Depth to water level in the range of 5-10 m was shown by 37 wells (24.18% of total number), the deeper water levels of 10-15 m was shown by 20 wells (13.07% of total) and the deepest water levels (>15 m) was recorded by 47 monitoring wells, which was 30.72% of the total number of wells in Uttarakhand monitored during August 2019.

Table 7: District wise categorization of depth to water level data, August 2019

District	No. of stations analyzed	Depth to water level (m bgl)		Depth to water level (m bgl)							
				0-5		5 to 10		10 to 15		>15	
		Min	Max	No.	%	No.	%	No.	%	No.	%
Dehradun	44	4.2	72.3	2	4.55	12	27.27	11	25.00	19	43.18
Haridwar	38	0.42	64.01	15	39.47	9	23.68	5	13.16	9	23.68
U. S. Nagar	46	0.56	15.15	28	60.87	13	28.26	4	8.70	1	2.17
Nainital	12	3.2	66.42	3	25.00	0	0.00	0	0.00	9	75.00
Champawat	4	4.25	33.47	1	25.00	2	50.00	0	0.00	1	25.00
Uttarkashi	8	9.85	40.99	0	0.00	1	12.50	0	0.00	7	87.50
Pauri Garhwal	1		68	0	0.00	0	0.00	0	0.00	1	100.00
Total	153	0.42	72.3	49	32.03	37	24.18	20	13.07	47	30.72

The depth to water level maps (August 2019) for Dehradun section in fig 7, Haridwar section is given in Fig. 8 and for Udham Singh Nagar-Nainital-Champawat section is given in Fig. 9.

A perusal of **Fig.7** 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 elliptical patches rimming the water level of depth in the range of 5-10 m bgl in the northern part of Doon valley (Nanda ki Chowki-Judli- Dhakrani areas) and also as narrow band in the central part of the district (Gularghati). The water level in the range of 5-10 m bgl occur as elliptical patches in the northwestern part (Herbertpur- Badripur- Singhniwala-Sabhawala-Rampura- Haripur areas) and also as narrow band in the south eastern part of the district (in and around Rishikesh-Khand gaon areas).

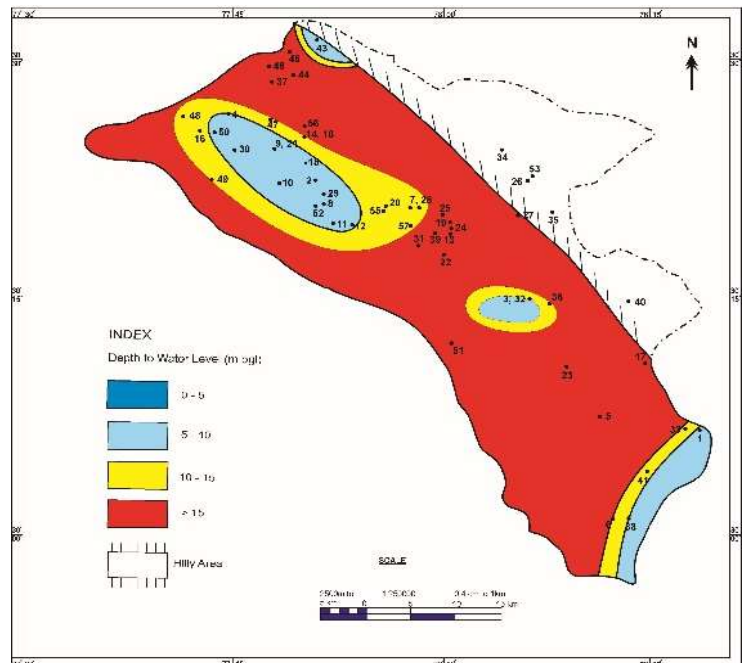


Figure 7:Depth To water Level Map (August 2019), Dehradun District

A perusal of Fig. 8 indicates that major part of the Haridwar district shows deeper water levels (in the range of >15 m bgl). The minimum depth to water level i.e 0-5 m is observed in southern part of the Haridwar district (in and around Shahpur Shitalikhera- Husainpur-Goverdhanpur-Bhikhampur- Dallawala-Laksar-Khanpur areas) and as patches around the north eastern part (Jaswawala-Budhwa Shahid-Rathaura areas) of the district. The water level in the depth range of 5-10 m bgl occurs as linear band in the southern portion (Gurukul Narsan- KheraJatt- Lakhnauta-Jhabrera areas) and North-eastern portion. The water levels in the range of 10-15

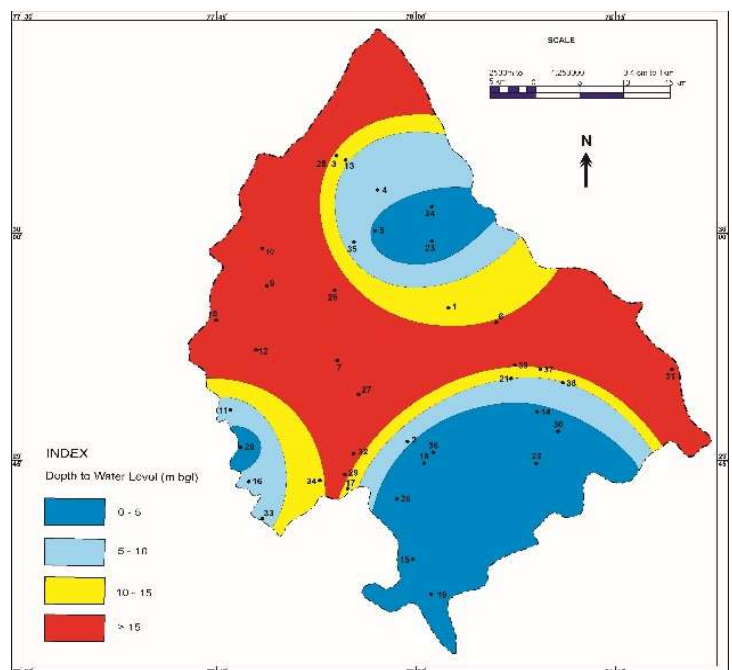


Figure 8 Depth To water Level Map (August 2019), Haridwar District

mbgl occur as a concentric patches in north eastern part (in and around Bahadrabad-Shahidwala grant-Sarai areas) and also in south western part (around Nizampur area) rimming the deepest water level of >15 m bgl. The deepest water level (>15 m bgl) mostly occur in central part of Haridwar district in and around Chudiala-Bhagwanpur-Jhabrera- Imlikhera-Landhaura-Dandi Imbrahimpur areas.

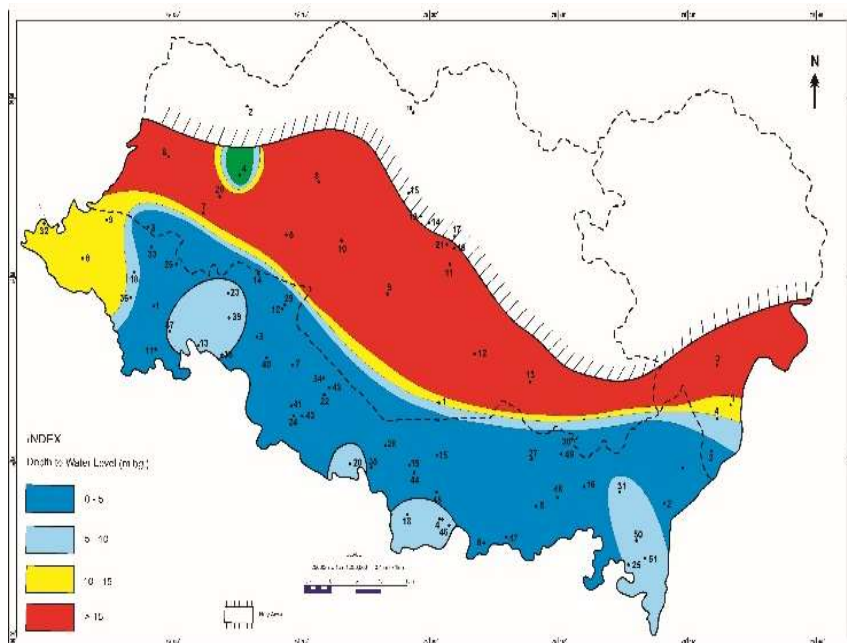


Figure 9: Depth To water Level Map (August 2019), US Nagar – Nainital - Champawat Section

Interpretation of **Fig. 9** has again revealed that depth to water level generally increases from south to north in Udham Singh Nagar- Nainital- Champawat section. The shallowest water level (0-5 m) is observed as a continuous band stretching from the western to the eastern part of the Udham Singh Nagar district and covering the southern part of the Champawat district along with isolated patches in and around Ramnagar- Maldhan Colony- Garjiya in the Nainital district. The water level in the range

of 5-10m is observed as narrow band in the Udham Singh Nagar district (in and around Sandkhera-Jogipura-Bhagwanpur-KamariaPakki-Sarasariya-Kanchanpuri) rimming the water level zone of 10-15 m (in and around Patrampur-Jaspur-Angadpur). The deepest water level (>15 m) is running parallel to the 10-15 m water level zone stretching from the north western part of the Nainital section to eastern part of the Champawat section.

5.1.3. November 2019

The depth to water level data is available for 154 Ground Water Monitoring Wells of Uttarakhand during November 2019. The data has been analyzed and shown in **Table 8**. During this period, the deepest water level of 82.30 m bgl was observed at Ladpur Piezometer (Dehradun district) while the shallowest water level of 0.31 m bgl was observed at DudhyaDayalwala in Haridwar district. The analysis of depth to water level data shows that out of 154 wells, 53 wells (34.42 % 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 42 monitoring wells (27.27 % of the total number). Deeper water level of 10–15

m was observed in 13 wells, which was 8.44 % of the total number whereas the deepest water level of >15 m bgl was recorded in 46 wells (29.87 % of total wells) in Uttarakhand during November 2019.

Table 8: District wise categorization of depth to water level data, November 2019

District	No. of stations analyzed	Depth to water level (m bgl)		Depth to water level (m bgl)								
				0-5		5 to 10		10 to 15		>15		
		Min	Max	No	%	No	%	No	%	No	%	
Dehradun	46	0.58	82.3	3	6.52	18	39.1	3	5	10.8	20	43.4
Haridwar	38	0.31	54.79	13	34.2	11	28.9	5	5	13.1	9	23.6
U. S. Nagar	44	1.22	12.08	34	77.2	8	18.1	8	2	4.55	0	0.00
Nainital	13	2.83	72.63	2	15.3	1	7.69	1	1	7.69	9	69.2
Champawat	4	3.74	23.54	1	25.0	2	50.0	0	0	0.00	1	25.0
Uttarkashi	8	5.4	43.95	0	0.00	2	25.0	0	0	0.00	6	75.0
Pauri Garhwal	1	50.53		0	0.00	0	0.00	0	0	0.00	1	100.00
Total	154	0.43	76.47	53	34.4	42	27.2	7	13	8.44	46	29.8

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for November 2018 is shown in **Fig. 10** (Dehradun Section), and **Fig. 11** Haridwar Section) and **Fig. 12** (Nainital, Udham Singh Nagar and Champawat Section).

A perusal of **Fig. 10** reveals that the shallowest water levels (0-5m) are observed as isolated patches in and around Dharmawala. The major part of the Dehradun district shows deeper water levels in the range of >15 m bgl occurring in and around Majra-Harbanswala-TarlaNagal-CGWB office-Ladpur-Telpura-Purukulgaon-Maldeota areas. The water levels in the range of 10-15m bgl observed as concentric patches around the water level of 5-10 m bgl in the northern part (in and around Dhakrani-Judli-Nanda ki chowki areas) and also as narrow bands in the south eastern part (around KhadiriKhadakmaf-Motichur areas) of the Doon valley

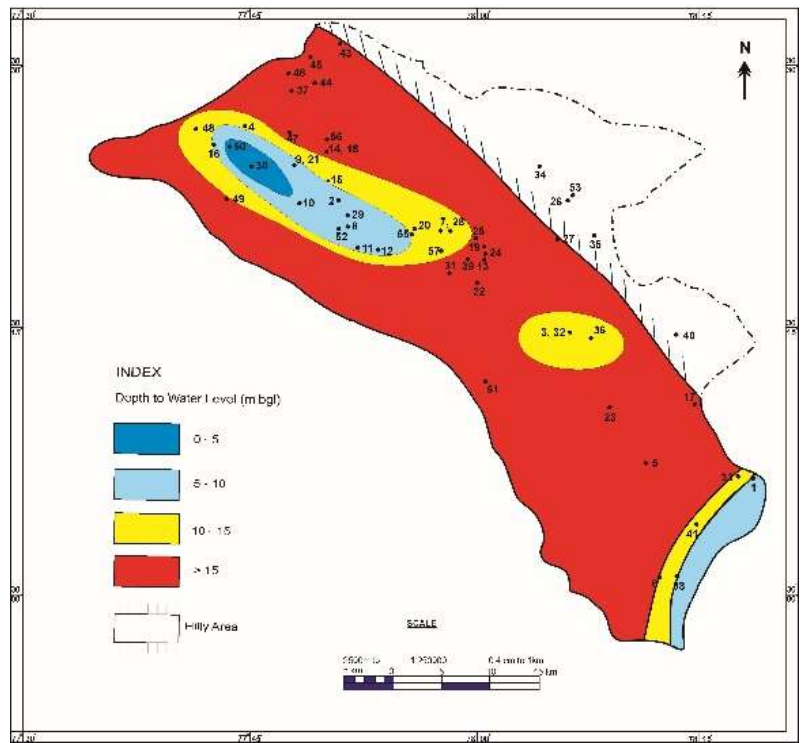


Figure 10: Depth To water Level Map (November 2019), Dehradun District

A perusal of **Fig. 11** indicates that major part of the Haridwar district shows shallow water levels in the range of 5-10 m bgl covering shyampur-Dhanpura-Roorkee-Libberhedi-Kherajatt-Bandarjud-Buggawal areas. The minimum depth to water level i.e 0-5 m is observed in southern part of the Haridwar district in and around Bhikkampur- Bhogpur-Hussainpur-GoverdhanpurLaksar- Khanpur-Dallawala and also as isolated patches around the northern part (Rathaura-BudhwaSahid-Bahabalpur-Jaswawala)of the

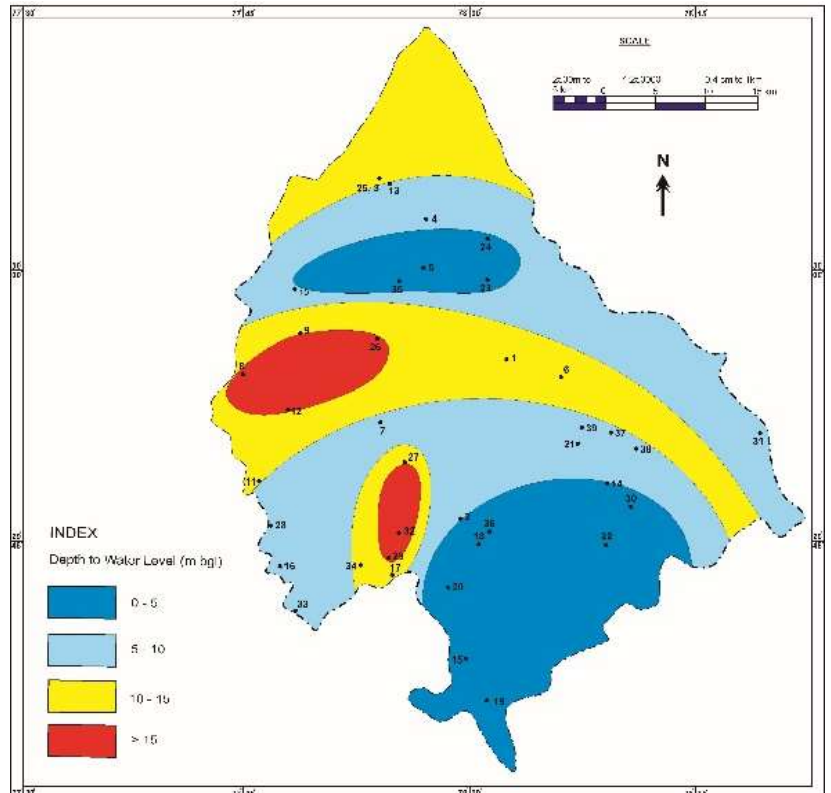


Figure 11: Depth To water Level Map (November 2019), Haridwar District

district. The water levels in the range of 10-15 m are observed as band (in and around Bahadarabad- Sarai areas) extending from the western to eastern part of the district and rimming the water level of depth greater than 15 m (in and around Imlikhera- Bhagwanpur- Chudiala-Iqbalpur).

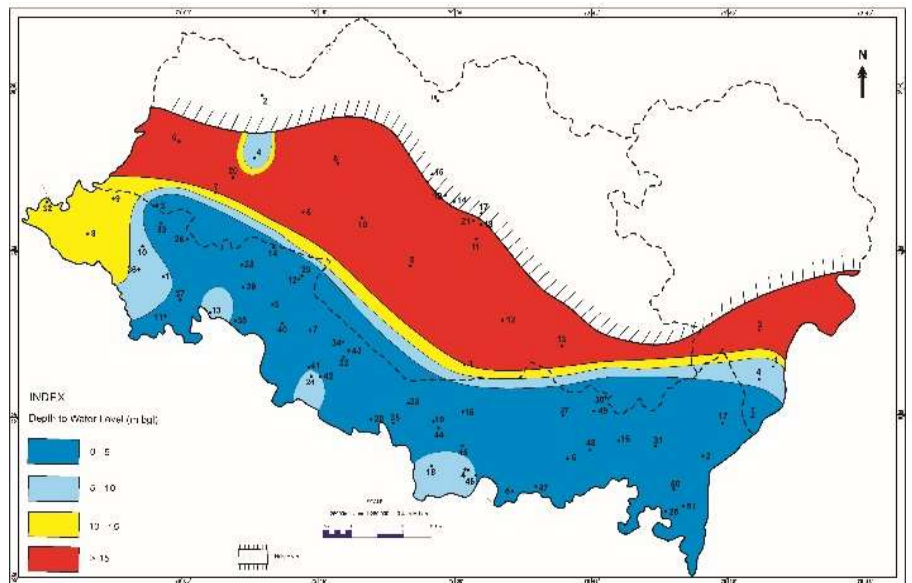


Figure 12: Depth To water Level Map (November 2019), US Nagar – Nainital - Champawat Section

Interpretation of **Fig. 12** has again revealed that depth to water level generally increases from south to north in Udham Singh Nagar- Nainital- Champawat section. The shallowest water level (0-5 m) is observed as a broad continuous band stretching from the western to the eastern part of the Udham Singh Nagar district and covering the southern part of the Champawat district. The water level in the range of 5-10m is observed as narrow band in the USN district (in and around Kashipur-Sandkhera- Bharatpur- Misserwala) rimming the water level zone of 10-15 m (in and around Jaspur- Angadpur). The water level depth of greater than 15 m is observed as band running from North Western part of the Nainital district covering central part of district and extending till eastern part of the Champawat district.

5.1.4 January 2020

The depth to water level data was analysed for 153 Ground Water Monitoring Wells in Uttarakhand during January 2020 and is given in **Table 9**. Analysis of depth to water level data given in the table indicates that the deepest water level was 83.75 m bgl in Ladpur, Dehradun district whereas the shallowest water level was 0.61 m bgl at Mahabir Nagar in Udham Singh Nagar District. The shallowest depth to water level of 0–5 m bgl was recorded by 54 monitoring wells, which was 35.29 % of the total number of wells. Water level in the range of 5-10 m bgl was also shown by 31 wells (20.26 % of total number of wells), whereas deeper water level of 10–15 m bgl was recorded by 20 monitoring wells, which was 13.07% of the total number of wells. The deepest water level of >15 m bgl was shown by 48 monitoring wells, which was 31.37% of the total number of wells in Uttarakhand monitored in January 2020.

Table 9: District wise categorization of depth to water level data, January 2020

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	46	4.26	83.75	1	2.17	14	30.43	8	17.39	23	50.00
Haridwar	36	1.28	50.96	13	36.11	9	25.00	7	19.44	7	19.44
U. S. Nagar	45	0.61	14.21	37	82.22	5	11.11	3	6.67	0	0.00
Nainital	13	2.23	71.47	2	15.38	1	7.69	1	7.69	9	69.23
Champawat	4	4.03	29.56	1	25.00	1	25.00	1	25.00	1	25.00
Uttarkashi	8	8.65	43.92	0	0.00	1	12.50	0	0.00	7	87.50
Pauri Garhwal	1		50.92	0	0.00	0	0.00	0	0.00	1	100.00
Total	153	0.61	83.75	54	35.29	31	20.26	20	13.07	48	31.37

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for *January 2020* is shown in *Fig. 13 (Dehradun Section)*, *Fig. 14 (Haridwar Section)* and *Fig. 15 (Nainital, Udham Singh Nagar and Champawat Section)*.

A perusal of **Fig. 13** reveals that major part of Dehradun district shows water level in the depth range of greater than 15 m bgl. The water level in the depth range of 5- 10 m bgloccurs as narrow band in the south eastern part (Rishikesh-Khandgaon areas) and as concentric

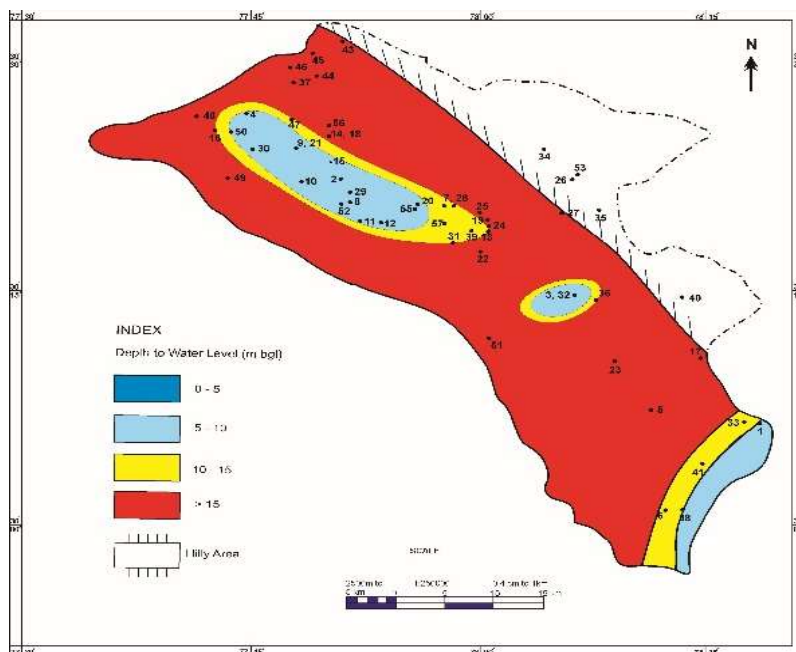


Figure 13: Depth To water Level Map (January 2020), Dehradun District

ring rimming water level zone of 10-15 m bgl in the northern portion (Dharmawala-badripur-Sabhawala- Ramgarh-Jhajhra areas). The water level in the depth range of 10-15 m bgl occurs as narrow band in the south eastern part (KhadiriKhadakmaaf) and as concentric ring in the northern portion (Judli-Kanwali-Nanda Ki Chowki areas).

A perusal of Fig. 14 indicates that shallow water levels (in the range of 0-5 m bgl) occurs as band in the southern part (Bhogpur-Shahpur shitlakhera- Laksar- Goverdhanpur-Khanpur areas) and as isolated patch in the northern portion(jaswawala-budhwaSahid-Bahabalpur-Rathaura) of the district.TheThe water levels in the range of 5-10mbgl are observed as parallel bands in the northern portion (Buggawala- Bnadarjud)and southern portion (Dhanpura-Roorkee-Jhabrera-Libberhedi-Lakhnauta-KheraJatt areas) of the district. The water levels in the range of 10-15 m bgl are observed as band in the central part (shyampur-Sarai-Bahadrabad-iqbalpur areas) and as concentric ring (Nizampur) of the district.The water level in the depth range of greater than 15 m bgl occurs as scattered patches around Laldhang- landhaura-Mundlana- Imlikhera-Bhagwanpur areas of the district.

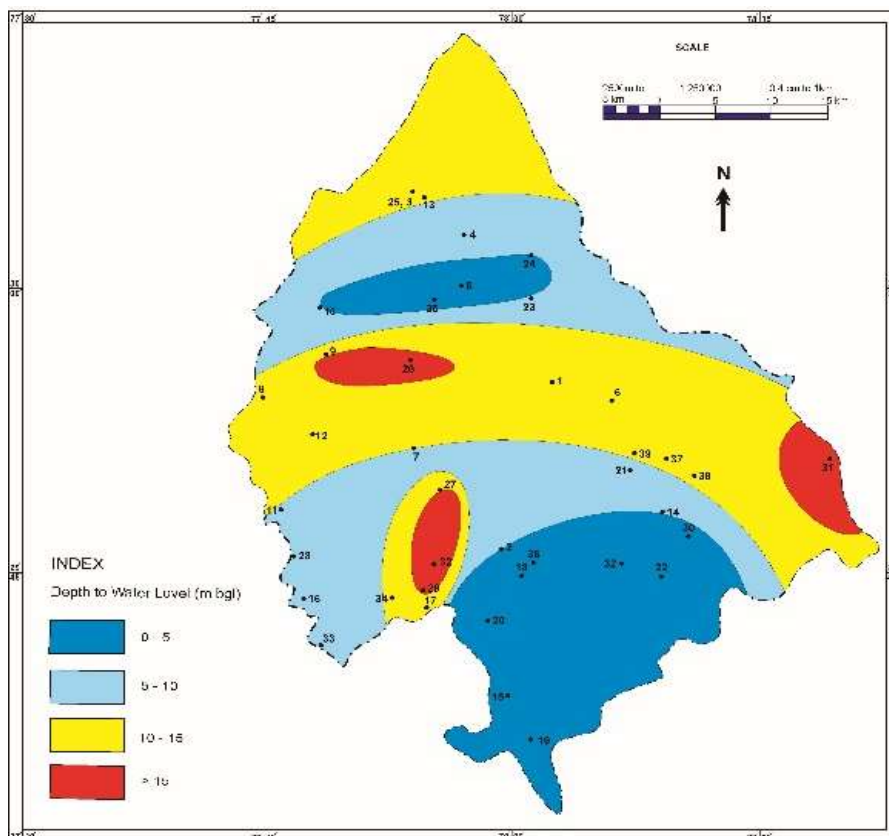


Figure 14: Depth To water Level Map (January 2020), Haridwar District

Interpretation of **Fig. 15** has again revealed that depth to water level generally increases from south to north in Udham Singh Nagar- Nainital- Champawat section. The shallowest water level (0-5 m) is observed as a broad continuous band stretching from the western to the eastern part of the Udham Singh Nagar district and covering the southern part of the Champawat district. The water level in the range of 5-10m is observed as narrow band in the USN district (in and around Kashipur- Sandkhera- Bharatpur- Misserwala) rimming the water level zone of 10-15 m (in and around Jaspur- Angadpur) .The water level depth of greater than 15 m bgl observed as band running from North Western part of the Nanital district covering central part of district and extending till eastern part of the Champawat district.

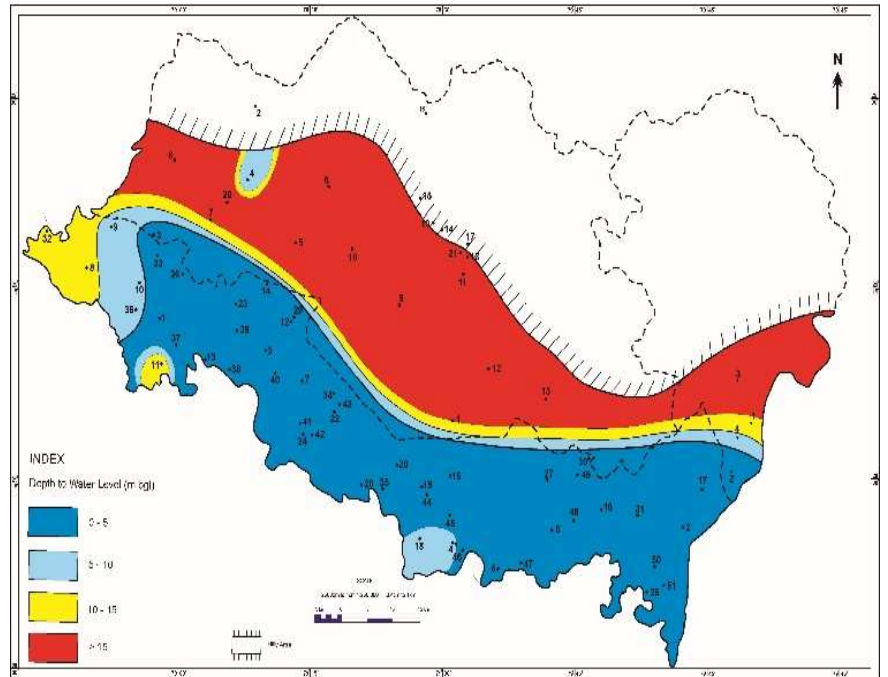


Figure 15: Depth To water Level Map (January 2020), US Nagar – Nainital – Champawat Section

5.2 DISCHARGE OF SPRINGS

The discharge data of thirty-fix cold-water springs in Dehradun, Nainital, Uttarkashi and Almora districts for the months of May, August, November 2019 and January 2020 is given in **Table 10**. 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 10** indicates that discharge of the cold-water springs during the period May 2019-January 2020 varies from a minimum measurable discharge of 0.36 LPM at Someshwar in January 2020 to a maximum of 180 LPM at Sipahidhara (August 2019). Discharge of springs varies within wide limits during the intervening period.

In Dehradun district, spring discharge varies between 0.56 LPM at Soda Sarauli in May, 2019 and 37.50 LPM at Soda Sarauli in August 2019. In Nainital district, spring discharge varies from a minimum of 0.62 LPM at Kudaghat (May 2019) to a maximum of 180 LPM at Sipahidhara (August 2019). In Almora district, the spring discharge was found to be varying from a minimum of 0.52 LPM at Chanoda in May 2019 to a maximum of 85.71LPM at Bhoongaon in January 2020. In Uttarkashi district, spring discharge was varying from 2.22 LPM at Dharasau in January 2020 to a maximum of 120.55 LPM in Ganganani in January 2020.

Table 10: Discharge of Springs in May, August, November 2019 and January 2020

<i>Sl No.</i>	<i>District</i>	<i>Block</i>	<i>Location Details</i>	<i>Type of Well</i>	<i>May-19</i>	<i>Aug-19</i>	<i>Nov-19</i>	<i>Jan-20</i>
1	Dehradun	<i>Raipur</i>	Soda Saroli	Spring	0.56 lpm	37.5 lpm	23.07 lpm	20.0 lpm
2			Bhatta	Spring	4.38 lpm	12.76 lpm	5.28 lpm	7.31 lpm
3		<i>Sahaspur</i>	Khandoli	Spring	21.28 lpm	15 lpm	18 lpm	31.08 lpm
<i>Sl No.</i>	<i>District</i>	<i>Block</i>	<i>Location Details</i>	<i>Type of Well</i>	<i>May-19</i>	<i>Aug-19</i>	<i>Nov-19</i>	<i>Jan-20</i>
1	Nainital	<i>Bhimtal</i>	Amritpur (Ranibagh)	Spring	2.52 lpm	85.71 lpm	46.15 lpm	5 lpm
2			Salari	Spring	5.74 lpm	42.86 lpm	21.43 lpm	30 lpm
3			Dogaon	Spring	14.03 lpm	8.57 lpm	18.75 lpm	6.82 lpm

4			SipahiDhara	Spring	100.84 lpm	180 lpm	105.8 8 lpm	100 lpm	
5			Garampani	Spring	12.82 lpm	30 lpm	16.22 lpm	16.67 lpm	
6			Jyolikot	Spring	14.83 lpm	100 lpm	26.09 lpm	6.8 lpm	
7			Kudaghat (KudaPahar)	Spring	0.62 lpm	50 lpm	22.22 lpm	NA	
Sl No.	District	Block	Location Details	Type of Well	May- 19	Aug- 19	Nov- 19	Jan- 20	
1	Almora	<i>Tarikheth</i>	PataliTalla	Spring	5.34 lpm	10.71 lpm	11.54 lpm	8.11 lpm	
2			PataliMalla	Spring	2.26 lpm	1.62 lpm	6 lpm	12.5 lpm	
3			Baniya Diggi	Spring	3.73 lpm	7.5 lpm	6 lpm	4.29 lpm	
4		<i>Hawalbagh</i>		Katarmal	Spring	16.79 lpm	13.33 lpm	15 lpm	15.0 lpm
5				Dharanaula	Spring	10.21	8.33 lpm	6.82 lpm	8.10 lpm
6				Palna	Spring	1.48 lpm	2.4 lpm	1.43 lpm	1.71 lpm
7				Jholi	Spring	7.88 lpm	8.57 lpm	5 lpm	2.4 lpm
8				Itola	Spring	1.43 lpm	6 lpm	2.31 lpm	6.0 lpm
9		<i>Takula</i>		Chanoda	Spring	0.52 lpm	3.33 lpm	2 lpm	2.73 lpm
10				Guruda-I	Spring	1.24 lpm	7.5 lpm	1.5 lpm	1.88 lpm
11				ChhaniBartola	Spring	5.89 lpm	20 lpm	6 lpm	5.45 lpm
12		<i>Chaukhutiya</i>		Dhansari	Spring	7.82 lpm	27.27 lpm	4 lpm	13.04 lpm
13				Deepakot	Spring	7.15 lpm	12 lpm	7.5 lpm	10.0 lpm
14				Dhálnagaon	Spring	6.95 lpm	26.09 lpm	10 lpm	9.38 lpm
15				Simalkhet	Spring	1.81 lpm	40 lpm	0.6 lpm	5.77 lpm
16				Peepal Dhar	Spring	18.91 lpm	35.29 lpm	20 lpm	20.0 lpm
17				Naula	Spring	5.15 lpm	4 lpm	4 lpm	5.45 lpm

18		Someshwar	Mehragaon (Someshwar)	Spring	0.49 lpm	1.82 lpm	2.4 lpm	0.36 lpm
19			Lodh	Spring	0.94 lpm	8.57 lpm	2.5 lpm	0.30 lpm
20			Bhoolgaon SP	Spring	30.25 lpm	85.71 lpm	50 lpm	42.86 lpm
Sl No.	District	Block	Location Details	Type of Well	May-19	Aug-19	Nov-19	Jan-20
1	Uttarkashi	Dunda	Dharasu	Spring	3.06 lpm	6.191 pm	2.88 lpm	2.22 lpm
2		Bhatwari	Nagal	Spring	15.77 lpm	17.01 lpm	53.57 lpm	27.49 lpm
3		Bhatwari	Ratodi Sar	Spring	23 lpm	26.11 lpm	18.37 lpm	11.78 lpm
4			Ganganani Spring *	Spring *	68.67 lpm	87.88 lpm	116.27 lpm	120.55 lpm

NA: Not Available

5.3 LONG 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 analyzed 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 (May, August and November for the period from 2009 to 2018 and January for the period from 2010 to 2019). The average depth to water level data available for Ground Water Monitoring Wells is given in *Table 11*.

Table 11: Long-term (Decadal) Depth to Water Level Data, Uttarakhand State

S.No	Location	Depth to Water Level (m bgl)			
		Avg May	Avg August	Avg November	Avg January
		2009-18			2010-2019
District Dehradun					
1	Khadi (KhadakMaf)	15.5966667	12.6575	14.01625	12.777143
2	Rishikesh	7.52125	3.8433333	5.81	6.1344444
3	Lal Tappar	18.40125	13.451111	12.658889	12.41
4	Dandi	6.4625	NA	4.46875	NA
5	Bhaniawala	33.272	18.688	21.555	26.351
6	Kotimachak	20.9625	11.063333	16.7225	19.858889
7	Chandmari	NA	NA	25.995	28.915
8	Duggiawala	NA	NA	3.33	1.915

9	Kuanwala	14.665714 3	9.3342857	5.225	9.81125
10	Gularghagti	13.295	8.3833333	10.625556	11.0475
11	Balliwala	55.798888 9	NA	NA	NA
12	Maldeota	13.33375	4.5677778	7.9822222	11.018889
13	Nanurkhera	70.607	65.23	60.913333	61.916667
14	TarlaNagal	76.113333 3	51.584	68.666	72.932
15	Purukulgaon	27.49	16.826667	23.532222	25.927778
16	Majra	22.954444 4	21.161111	19.954444	17.761111
17	CGWB Office	58.59625	55.813333	51.665	51.998889
18	Harbanswala	54.322222 2	52.331	44.999	49.127
19	Kanwali	15.836	9.012	12.108	14.242222
20	Singhniwala	9.224	6.794	8.482	8.985
21	Ramgarh	7.1975	4.26625	5.8766667	6.0511111
22	Jhajra	12.761111 1	6.174	7.2811111	9.728
23	Jhajra	11.733333 3	6.6025	6.9042857	11.84875
24	Nanda ki Chowki	14.34125	7.451	8.192	10.674
25	Nanda ki Chowki	15.375714 3	9.96375	8.8677778	10.68
26	Selakui	11.262857 1	7.12	8.224	9.173
27	Selakui	15.477142 9	10.748889	13.091111	13.321111
28	Sabhawala	9.161	5.352	7.174	8.625
29	Rampura	12.517	6.954	10.437	11.164
30	Shankarpur	23.807	16.527	19.521	20.331
31	Redapur	8.9366666 7	6.155	5.0966667	6.218
32	Redapur	6.86	3.3628571	3.0575	4.5688889
33	Badripur	9.2125	7.3188889	8.4933333	8.7866667
34	Judli	12.909	11.003	12.793	13.341
35	Herbertpur	9.9688888 9	5.471	8.091	9.651
36	Vikas Nagar	26.056666 7	NA	24.231111	NA
37	Dharmawala	5.3325	NA	4.1485714	5.3214286
38	Dakpatthar	26.528333 3	21.748333	26.223333	25.434286
39	Dhakrani	16.68	9.8816667	16.475	17.252857
District Haridwar					
40	Shahidwala Grant	11.348	10.594	9.916	10.572
41	Sahidwala Grant	11.56375	8.9442857	9.085	9.48875

42	Budhwa Shahid	4.4928571 4	2.77	2.71	3.09
43	Bugawala	7.80625	5.64	5.03	5.78625
44	Bahabalpur	3.014	2.055	2.4555556	2.735
45	Bhagwanpur	19.518	16.972	16.686	14.955
46	Chudiala	21.38625	18.7325	18.87625	19.50625
47	Iqbalpur	17.062	12.877	14.422	14.104
48	Jaswawala	NA	NA	3.8333333	4.06
49	Bandarjud	10.635555 6	7.915	7.924	8.645
50	Rathora	5.2211111 1	4.349	4.065	5.21
51	Bahadrabad	8.895	13.14375	12.38875	11.7575
52	Sarai	11.933333 3	9.757	10.93	12.189
53	Dhanpura	8.8575	4.81875	8.88125	6.3014286
54	Shahpur Shitlakhera	5.34625	2.6328571	3.4822222	4.055
55	Laldhang	64.76875	62.274286	56.09375	57.895714
56	Bhogpur	4.4516666 7	1.82	2.7166667	3.3785714
57	Imlikhera	15.7425	14.12125	12.223333	13.93
58	Roorkee	7.657	5.504	5.975	5.943
59	Sikhar	19.261666 7	17.923333	16.35	16.473333
60	KheraJat	6.8283333 3	13.881429	5.86	5.85
61	Nizampur	10.762	17.575714	10.338333	10.335
62	Jhabreda	9.754	7.149	9.176	8.643
63	Landhaura	18.47125	16.84375	16.622857	18.025
64	Lakhnauta	6.2677777 8	5.052	5.245	6.689
65	Gurukul Narsen	6.0725	3.67625	5.1142857	5.715
66	Librahedi	8.4716666 7	5.5216667	5.9033333	6.2571429
67	Mudlana	17.833333 3		17.438333	17.634286
68	Hussainpur	4.06	1.38	2.239	1.933
69	Laksar	4.1716666 7	2.025	2.6566667	2.8116667
70	Bhikkampur	4.06	2.08125	2.7357143	4.00375
71	Govardhanpur	4.35	1.935	2.8457143	2.14
72	Dallawala	2.0585714 3	NA	1.585	2.2425
District Udham Singh Nagar					
73	Kanchanpur (Majhola) HP	4.968	3.512	3.555	4.4744444
74	Khatima	3.316	1.346	1.801	2.511

75	Sarasariya	6.4183333 3	4.66	3.29	3.7885714
76	Chakarpur	5.9975	4.705	4.429	
77	Sitarganj	3.257	1.074	1.518	1.711
78	Nanak Mata	5.33	2.3977778	2.826	3.464
79	Kalyanpur	NA	1.5444444	2.0333333	2.219
80	Tukri	4.1566666 7	3.75	2.9128571	3.1128571
81	Bara	2.266	0.887	1.715	2.077
82	Kichha	7.9555555 6	6.775	6.7942857	7.098
83	KamariaPakki	7.406	4.3833333	3.817	5.1777778
84	Gangapur	3.702	2.915	2.449	2.731
85	Shantipuri	2.25	0.958	1.604	1.756
86	PattharChatta	3.192	2.105	2.7433333	2.706
87	Rudrapur	3.77	1.73	2.9316667	2.9114286
88	Jhagarpuri	3.244	1.373	2.0166667	2.4388889
89	Mahabir Nagar	2.776	1.147	2.18	2.805
90	Beria Daulat	3.615	2.083	2.89	3.074
91	Bhagwanpur	7.458	5.112	3.2866667	3.825
92	Bazpur	2.781	0.681	1.425	1.823
93	Jharkhandi	2.2183333 3	1.3183333	1.1628571	1.3066667
94	Jogipura	6.65	4.12	3.765	4.052
95	BannaKhera	5.176	3.639	3.624	3.679
96	BarkharePande	9.093	6.176	4.1866667	6.5077778
97	Kashipur	6.824	3.9144444	4.766	4.707
98	Bharatpur	10.588	9.072	7.359	6.796
99	Dhanauri Patti	4.816	2.698	2.601	2.925
100	Durgapur	5.6516666 7	3.385	2.9842857	3.2928571
101	Jaspur	11.928	13.365	10.46	12.611
102	Patrampur	10.992	8.727	7.157	7.521
103	Angadpur	8.22	7.8955556	7.2122222	5.9688889
District Nainital					
104	KhaatBaans	28.9333333 3	24.773	28.577	27.591
105	Kaladungi	28.774	26.973	27.133	28.71
106	Kathgodam	20.615	15.376	17.367	19.849
107	PeeruMadara	27.159	22.789	19.862222	21.68
108	Dhela	66.732	NA	67.151	62.25
109	Garjiya	4.54	NA	4.28	4.678
110	Lamachaur	NA	50.554444	40.313333	41.905
111	Belparao	NA	55.094	53.987	54.545
112	Maldhan Colony	NA	2.523	4.266	3.447
District Champawat					
113	Banbasa	7.927	7.2022222	5.5944444	NA

114	Bastia	30.984	9.4855556	24.207778	33.668
115	Tanakpur	NA	7.8466667	9.283	10.524

NA:NotAvailable

A perusal of the long-term (decadal) depth to water level data given in **Table11** indicates that the depth to water level varies widely. The minimum long-term water level is 0.681 m at Bazpur in Udham Singh Nagar District in August whereas the maximum was 76.11 m bgl at TarlaNagal in Dehradun district in May.

The table also shows that for Dehradun district, the minimum long-term water level is 3.05 m bgl at Redapur in November whereas the maximum is 76.11 m bgl at TarlaNagal in May. In Haridwar district, decadal water level is varying from 1.38 m bgl at Hussainpur in August to the maximum of 64.76 m bgl at Laldhang in May. In Udham Singh Nagar district, the long-term depth to water level is varying from 0.681 m bgl at Bazpur in August to 13.36 m bgl at Jaspur hand pump in August viz. in the pre-monsoon period. The decadal water level in Nainital district was varying from 2.52 m bgl at Maldhan Colony in August to a maximum of 67.15 m bgl at Dhela hand pump in November. Long-term depth to water level in Champawat district was ranging from 5.59 m bgl at Banbasa in August to 33.66 m bgl at Bastia Handpump in January.

5.3 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 (May 2009-2018 versus May 2019)

The analysis of decadal depth to water level data for 102 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 23 monitoring wells (22.55 % of the total number) whereas higher rise in the range of 2-4 m is observed in 5 wells (4.90 % of total). The 3 nos. of well (2.94%) recorded the decadal rise in water level (>4 m). The lowest long-term decline in the range of 0-2 m is recorded in 50 wells, which is 49.02 % of the total number. Higher long-term decline in the range of 2-4 m is recorded in 14 wells, which is 13.73 % and the highest decline of >4 m is recorded in 7 wells, which is 6.86 % of the total number. Analysis of the decadal data also shows that the lowest decadal rise is 0.078 m at Kherajat in Haridwar district while the highest rise is 6.36 m at Majra in Dehradun district. The lowest long-term decline in water level is 0.02 m at Sabhawala in Dehradun district while the highest is 14.05 m at Bastia in Champawat district.

The decadal water level fluctuation map for average (May 2008-2018) versus May 2019 is shown in **Fig.16 (Dehradun Section)**, **Fig.17 (Haridwar section)** and **Fig. 18 (Nainital-Udham Singh Nagar-Champawat section)**.

A study of Fig. 16 reveals that the minimum rise of 0-2 m is observed as concentric patches in the northern part (in and around Vikasnagar) and southern part (Latappar-KhadirikhadakMaaf) of the Doon valley. Higher decadal rise of 2-4 m is observed as concentric patches in the northern part (Rampura-Readpur areas) and central part (kanwali-Nanurkhera-Redapur-Rampura). Decadal rise in the range of more than 4 m bgl is observed as elliptical patch in and around Majara areas only. Decadal decline in water level in the range of 0-2 m is observed in major part of the Doon valley (Kotimaichak-Jhajhra-shankarpur-CGWB office-Rishikesh-Maldeota-herbertpur areas). The decadal decline in the range of 2-4 m is observed as parallel bands in the northern part Dakpathar, Dharmawala areas) and central part (Nanda Ki chowki-Harbanswala-Telpura areas) of Doon valley.

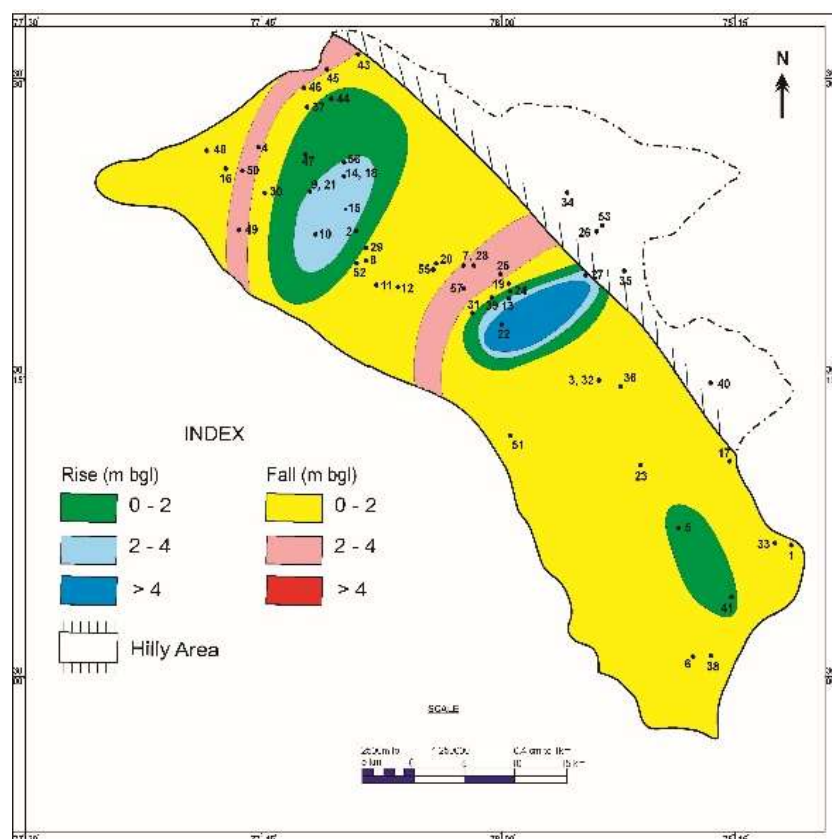


Figure 16: Decadal Water Level Fluctuation Map (May 2009-2018 vs 2019), Dehradun District

A study of **Fig. 17** reveals that the minimum fall of 0-2 m is observed in major part of the district (Chudiala-Bhagwanpur-Budhwasahid- Jhabrera –Mundlana –Bahabalpur-Gurukul narsen-Roorkee areas). Higher decadal decline of 2-4 m is observed as band in and around the Laldhang-Bahadrabad-Imlikhera-Iqbalpur areas. Decadal rise in water level in the range of 0-2 m is observed as concentric patches in and around Khera Jatt-Laksar-Hussainpur-Sahidwala grant-Goverdhanpur-Libberhedi areas of the Haridwar District. Rise in the range of 2-4 m is observed in and around Sikhar areas only.

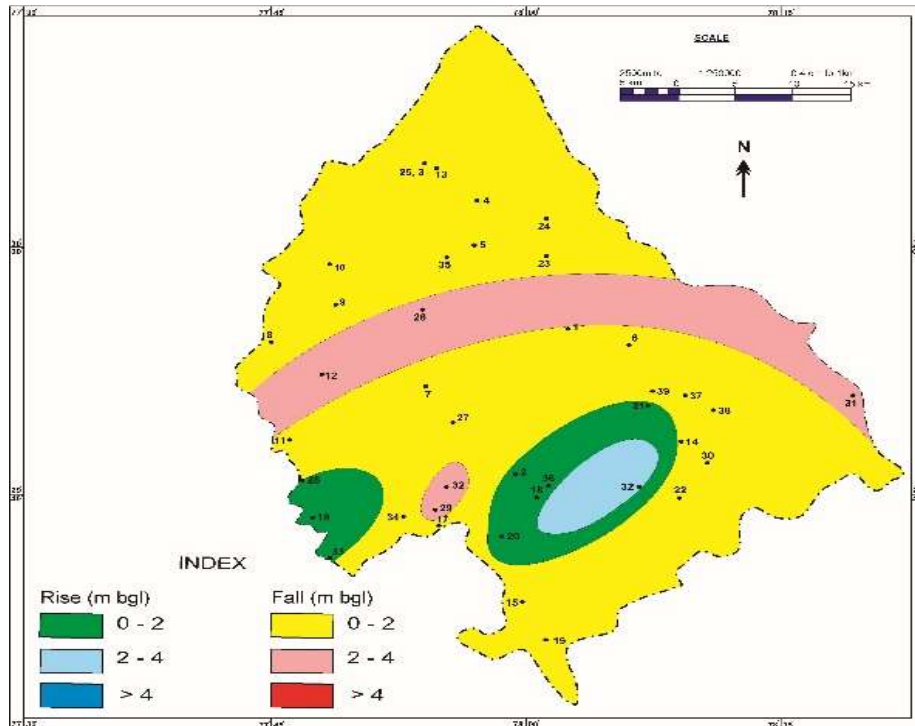


Figure 17: Decadal Water Level Fluctuation Map (May 2009-2018 vs 2019), Haridwar District

Interpretation of **Fig. 18** has shown that decadal fall of 0-2 m is observed in major part of the section. Decadal decline of 2-4 m is observed as isolated patches in and around barkharePande-Missarawala- Kichccha(Udham Singh Nagar district) and Tanakpur-Biuchayee (Champawat district). Decadal decline in water level in the range of >4 m bgl is observed in Jaspur-Angadpur(Udham Singh Nagar district), Dhela-Khatbans(Nainital district) , Bastia(Champawat district) areas only. Decadal rise in the range of 0-2 m bgl m is observed around Rudrapur-KamariaPakki-Jogipura-Bannakhera-Jharkhandi-Dhnauri Patti–Nankmatta areas in udham Singh Nagar District and Kathgodam areas in Nainital district.

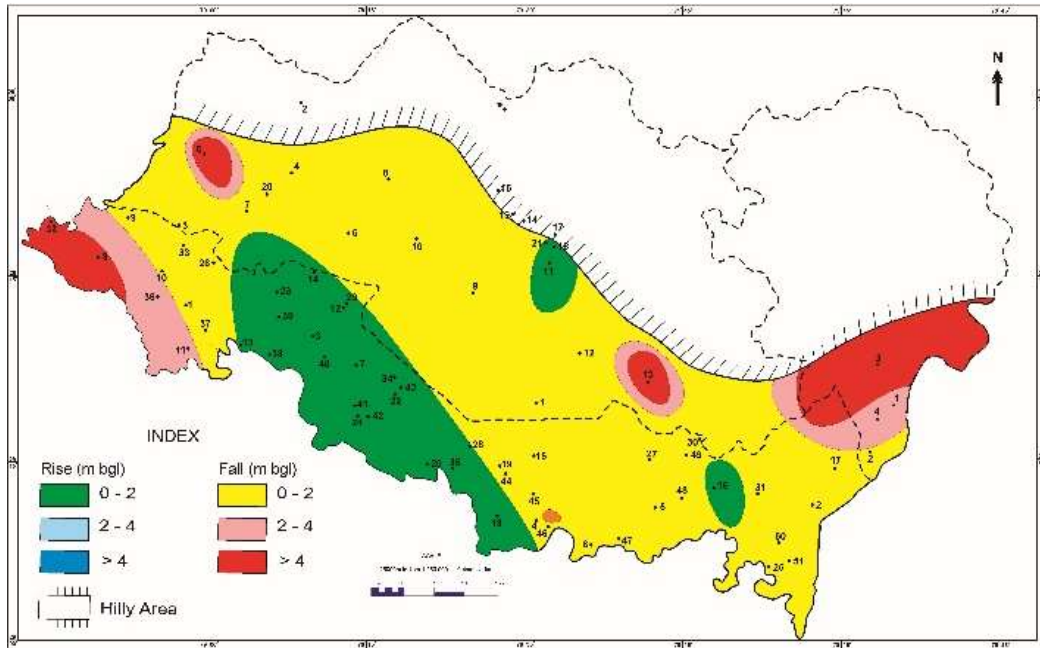


Figure 18: Decadal Water Level Fluctuation Map (May 2009-2018 vs 2019), US Nagar – Nainital - Champawat Section

Table 12. Decadal Water Level Fluctuation (May 2009 –May 2018versus May 2019)

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	33	0.71	6.36	0.02	4.65	4	12.12	4	12.12	2	6.06	16	48.48	6	18.18	1	3.03
Haridwar	31	0.0783	2.11166	0.04	2.93	8	25.81	1	3.23	0	0.00	16	51.61	6	19.35	0	0.00
Udham Singh Nagar	30	0.264	1.635	0.168	9.99	9	30.00	0	0.00	0	0.00	16	53.33	2	6.67	3	10.00
Nainital	6	1.2	7.25	0.79	10.66	2	33.33	0	0.00	1	16.67	1	16.67	0	0.00	2	33.33
Champawat	2	0	0	1.8	14.056	0	0.00	0	0.00	0	0.00	1	50.00	0	0.00	1	50.00
Total	102	2.25	17.36	2.82	42.29	23	22.55	5	4.90	3	2.94	50	49.02	14	13.73	7	6.86

5.4.1.2 Water Level Fluctuation (August 2009-2018 versus August 2019)

Long-term water level data for 106 monitoring wells is analyzed and is shown in **Table 13**. A perusal of the data shows that the minimum decadal rise is 0.04 m at Budhwa Shahid in Haridwar district whereas the maximum decadal rise is 8.50 m at Kherajat in Haridwar district. The minimum long-term decline in water level is 0.01 m at Badripur in Dehradun district; whereas the maximum decadal decline of 23.98 m is recorded at Batia in Champawat district.

A perusal of **Table 13** indicates that the minimum long-term rise in the range of 0-2 m is observed in 19 monitoring wells (17.92% of the total number), whereas higher rise in the range of 2-4 m is observed in 2 wells (1.89% of total) and the highest rise of >4 m is observed in 5 monitoring wells (4.72% of total). The lowest long-term decline of water level in the range of 0-2 m is recorded in 42 monitoring wells, which is 39.62 % of the total number. Higher long-term decline in the range of 2-4 m is recorded by 24wells (22.64 % of total) whereas the highest decline of >4 m is observed in 13 monitoring wells, which is 12.26% of the total number of wells.

The decadal water level fluctuation map for average (August 2008-2017) versus August 2018 is shown in **Fig.19** (Dehradun, Section), **Fig.20** (Haridwar section) and **Fig. 21** (Nainital -Udham Singh Nagar-Champawat section).

Visual interpretation of **Fig. 19** has shown that minimum decadal fall of 0-2 m is found in major part of the district. Decadal fall of 2-4 m is observed as concentric patches in and around Hebertpur-badripur-nanurkhera-harabanswala-kanwali-Latappar-Rishikesh areas of doon valley. The long-term decline of more than 4 m bgl is observed in and around Bhaniawala areas of Doon Valley. The water level

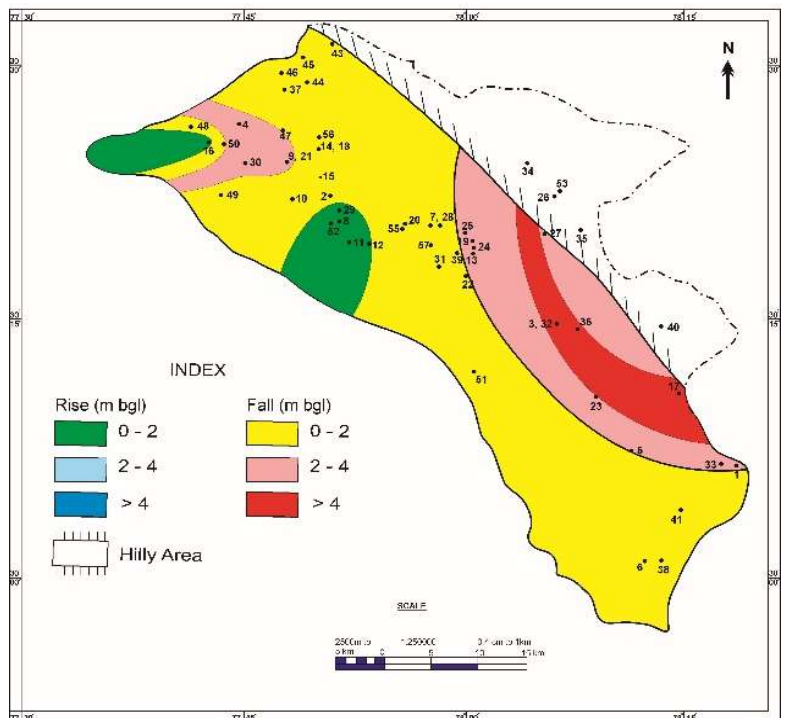


Figure 19: Decadal Water Level Fluctuation Map (August 2009-2018 vs 2019), Dehradun District

depths in the range of 0-2 m bgl is observed in and around Judli-Selaqui-Singhniwala areas only.

Visual interpretation of **Fig. 20** has shown that minimum decadal fall of 0-2 m is observed in major part of the district. Higher decadal fall in the range of 2-4m bgl is observed in and around Chudiala-Bhgawnpur-Imlikhera-Gurukul narsen areas only. The minimum long-term rise of 0-2 m is observed in and around Libberhedi-BudhwaSahid-Bahabalpur-Hussainpur-Laksar-Goverdhanpur areas of Haridwar District. Higher water level decline of 2-4 m is observed in and around Chudiala area of Haridwar district.

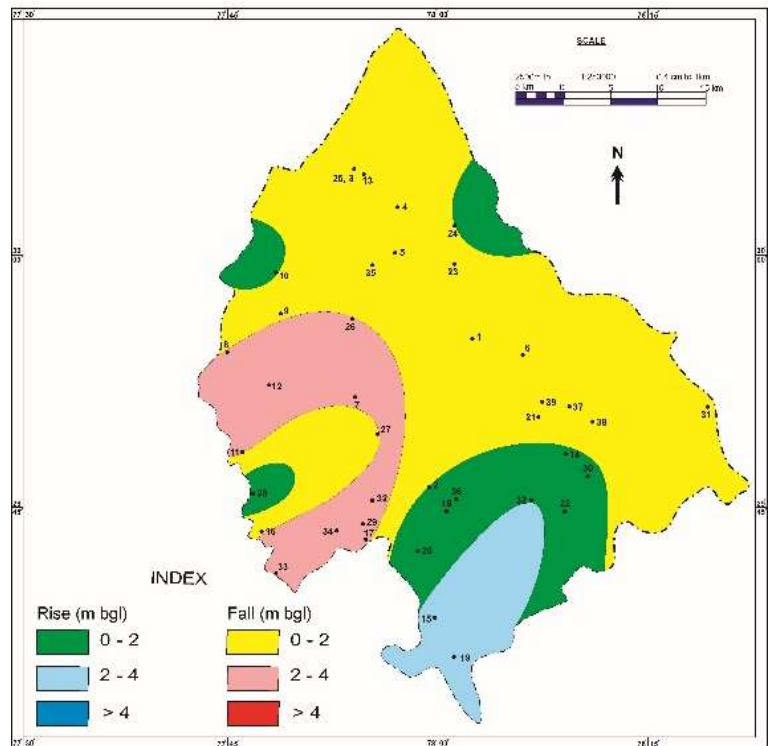


Figure 20: Decadal Water Level Fluctuation Map (August 2009-2018 vs 2019), Haridwar District

Visual interpretation of **Fig. 21** reveals that minimum decadal fall of 0-2 m is seen dominantly in major part of the section. The higher decadal decline of 2-4mbgl is observed as patches in and around Jaspur-Jhagarpuri-Barakhera-Pattharpur-Kiccha-Sarasaraiya of the section. The highest decadal decline of >4 m is observed around Bharatpur, Missarwala, Khant Bans area of the above section. The decadal rise of 0-2 m is observed in and around Sandkhera, Kalyanpur, Shantipuri, Khatima, Chakarpur, Rudrapur, Tukri areas of the section.

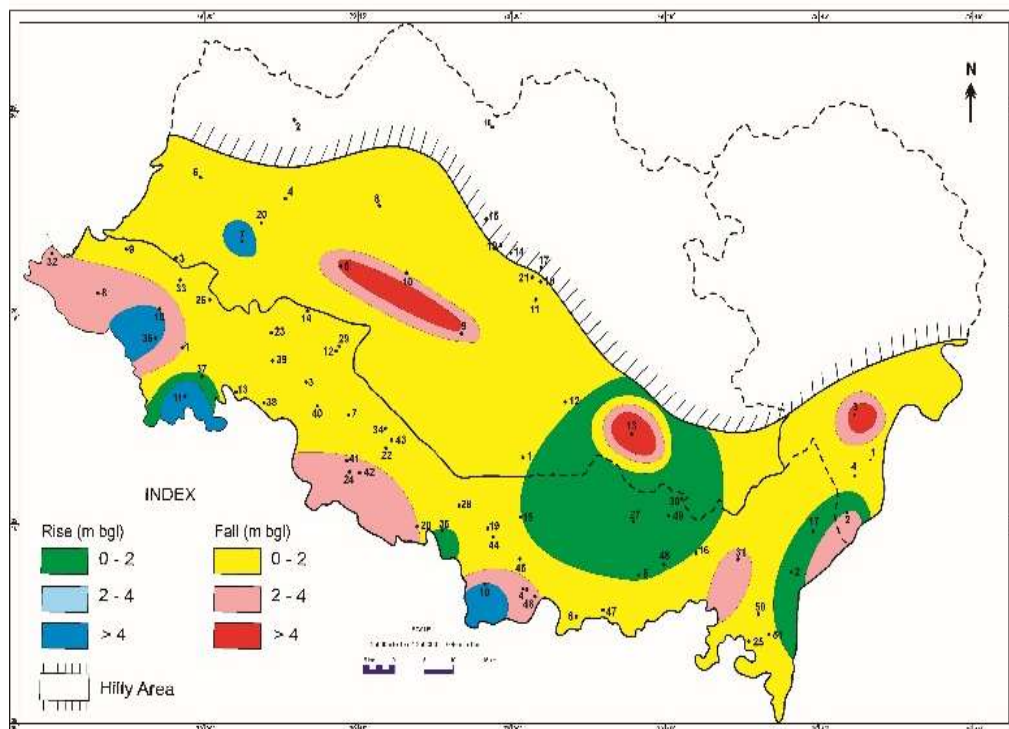


Figure 21: Decadal Water Level Fluctuation Map (August 2009-2018 vs 2019), US Nagar – Nainital - Champawat Section

Table 13. Decadal Water Level Fluctuation (August 2009 –August 2018 versus August 2019)

<i>District</i>	<i>No. of stations analyzed</i>	<i>Fluctuation (m)</i>				<i>Rise (m)</i>						<i>Decline (m)</i>					
		<i>Rise</i>		<i>Decline</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>	
		<i>Min</i>	<i>Max</i>	<i>Min</i>	<i>Max</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>
Dehradun	33	0.06	1.38	0.01	8.85	3	9.09	0	0	0	0.00	12	36.36	12	36.36	6	18.18
Haridwar	30	0.04	8.5	0.03	4.903	7	23.33	1	3.33	2	6.67	14	46.67	5	16.67	1	3.33
Udham Singh Nagar	31	0.054	5.335	0.053	4.858	8	25.81	0	0.00	2	6.45	12	38.71	7	22.58	2	6.45
Nainital	9	0.056	4.489	0.834	7.827	1	11.11	0	0.00	1	11.11	3	33.33	0	0.00	3	33.33
Champawat	3	2.9522		1.553333	23.98444	0	0.00	1	33.33	0	0.00	1	33.33	0	0.00	1	33.33
Total	106	3.1622	19.704	2.48	50.42	19	17.92	2	1.89	5	4.72	42	39.62	24	22.64	13	12.26

5.4.1.3 Water Level Fluctuation (November 2009-2018 versus November 2019)

Long-term water level data for 130 monitoring wells is analyzed and is shown in *Table 14*. A perusal of the data shows that the minimum decadal rise is 0.33 m at Pattarchatta in Udham Singh Nagar District while the maximum decadal rise is 8.23 m at Bhaniyawala in Dehradun District. The minimum decadal decline in water level is 0.007 m at Barianjaniya at Udham Singh Nagar district while the maximum decadal decline is 12.08 m at LamachurinNainital district. The table also indicates that 45 monitoring wells out of 130 (34.62 % of total) had shown decadal rise of 0-2 m, 4 monitoring wells (3.08 % of total) had shown rise of 2-4 m and 4 monitoring wells(3.08 % of total) had shown the highest decadal rise of >4 m. As far as decadal decline in water level is concerned, 53 wells out of 130 (40.77 % of total) had recorded decadal decline in the range of 0-2 m, 9 monitoring wells (6.92% of total) had shown higher decadal decline of 2-4 m and 13 monitoring wells (10.0% of total) had shown the highest decadal decline of >4 m in Uttarakhand in the post-monsoon period.

The decadal water level fluctuation map for average (November 2009 -2018) versus November 2019 is shown in **Fig. 22 (Dehradun District)**, **Fig 23 (Haridwar District)** and **Fig. 24 (Nainital-Udham Singh Nagar-Champawat section)**.

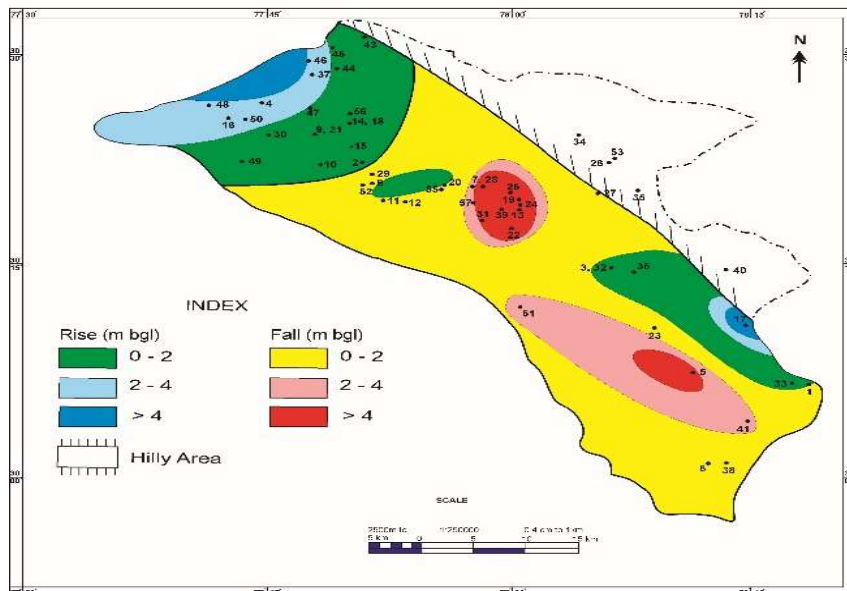


Figure 22: Decadal Water Level Fluctuation Map (November 2009-2018 vs 2019), Dehradun District

A perusal of **Fig. 22** reveals that minimum decadal decline of 0-2 m is observed in major portion of the Doon valley. Decadal Rise of 0-2 m is observed around Kuanwala, badripur, Jhajhra, kotimaichak, Herbertpur, Singhniwala, rampura, judli areas of the section. Higher decadal rise of 2-4 m is observed around Dakpathar, Dharmawala areas and highest Rise of >4m are observed around Vikasnagar, Dhakrani and Dandi areas. The decadal decline in the range of 2-4m is observed in Chandmari, redapur, KhadiriKhadakmaf. The highest decadal decline of >4 m is observed around CGWB Office, Nanda ki chowki, Lal tappar and Majraarea.

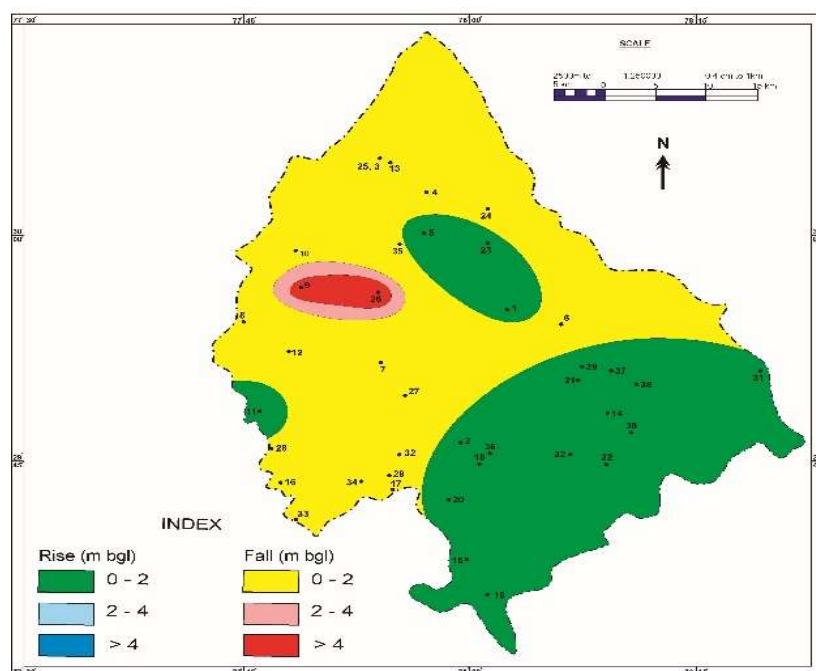


Figure 23: Decadal Water Level Fluctuation Map (November 2009-2018 vs 2019), Haridwar District

A perusal of **Fig. 23** reveals that minimum decadal decline of 0-2 m is observed in >70% parts of Haridwar District. The minimum decadal rise of 0-2 m is observed as in and around Shahpur Shitalikhera, Husainpur, Dallawala, Jaswawala, Goverdhanpur, Bahadrabad, Jhabrera, bhikhampur, Rathaura, Laldhand, Dhanpuraareas of the section. Higher decadal decline of 2-4 m in and around Bhagwanpur and highest decadal decline of >4 m observed in and around Imlikheraareas of the section.

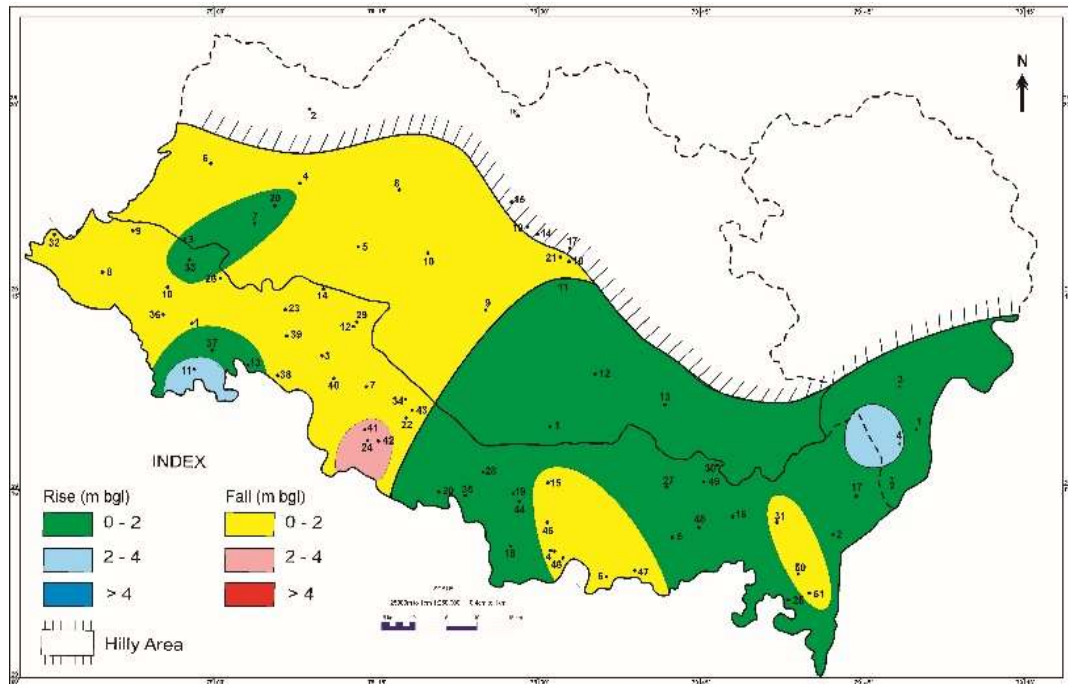


Figure 24: Decadal Water Level Fluctuation Map (November 2009-2018 vs 2019),US Nagar – Nainital - Champawat District

Visual interpretation of **Fig. 24** has shown that minimum decadal falloff of 0-2 m is observed in and around jaspur-patrapur-kaladhungi-Shantipuri-Begur mod-Peeplichauraha-Sara sariya-Barianjariya areas of the section. Higher decadal fall of 2-4 m is seen as isolated patch in and around Jhagarपुरi-lalkuan areas only. The minimum decadal rise of 0-2 m is observed as isolated patch in and around tNankmatta-Chakarpur-kalyanpur-Sitarganj-patharchatta-Bhagwanpur-rudrapur-Bazpur –Jaspur –Maldhan Colony-Banbasa-Bastia areas only. Higher decadal rise of 2-4 m is observed around Bichayee-Barkharepande areas only.

Table 14. Decadal Water Level Fluctuation (November 2009-November 2018 versus November 2019)

<i>District</i>	<i>No. of stations analyzed</i>	<i>Fluctuation (m)</i>				<i>Rise (m)</i>						<i>Decline (m)</i>					
		<i>Rise</i>		<i>Decline</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>	
		<i>Min</i>	<i>Max</i>	<i>Min</i>	<i>Max</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>
Dehradun	39	0.07	8.23	0.06	4.812	14	35.90	2	5.13	4	10.26	10	25.64	4	10.26	4	10.26
Haridwar	33	0.04	1.96	0.18	7.27	11	33.33	0	0.00	0	0.00	19	57.58	1	3.03	2	6.06
Udham Singh Nagar	42	0.03	2.69	0.01	4.87	14	33.33	1	2.38	0	0.00	22	52.38	2	4.76	3	7.14
Nainital	12	0.53	1.44	0.76	12.08	4	33.33	0	0.00	0	0.00	1	8.33	2	16.67	4	33.33
Champawat	4	0.67	2.1	0.337		2	50.00	1	25.00	0	0.00	1	25.00	0	0.00	0	0.00
Total	130	1.35	16.42			45	34.62	4	3.08	4	3.08	53	40.77	9	6.92	13	10.00

5.4.1.4 Water Level Fluctuation (January 2010-2019 versus January 2020)

Decadal (long-term) water level data for 138 ground water monitoring wells is analyzed and is given in **Table 15**. Analysis of the data reveals that the lowest decadal rise is 0.003 m at Dohniya in Nainital District whereas the highest decadal rise is 14.92 m at Chandmari in Dehradun District. As far as decadal decline in water level is concerned, the highest is 11.87 m at Lamachaur in Nainital district while the lowest is 0.036 m at Tanakpur in Champawat district.

A perusal of the table also indicates that out of 138 monitoring wells, 66 wells (47.83% of the total number) had shown the minimum decadal rise in the range 0-2 m, 5 wells (3.62% of the total number) of monitoring wells had shown a higher rise in the range 2-4 m while only 6 well (4.35 % of total) had shown the highest decadal rise of >4 m. The minimum decadal decline in the range of 0-2 m is shown by 40 wells (28.99% of total) while 5 wells (3.62%) had shown higher decadal rise of 2-4 m. 16 monitoring well (11.59%) has recorded the highest decadal decline (>4 m) in Uttarakhand State.

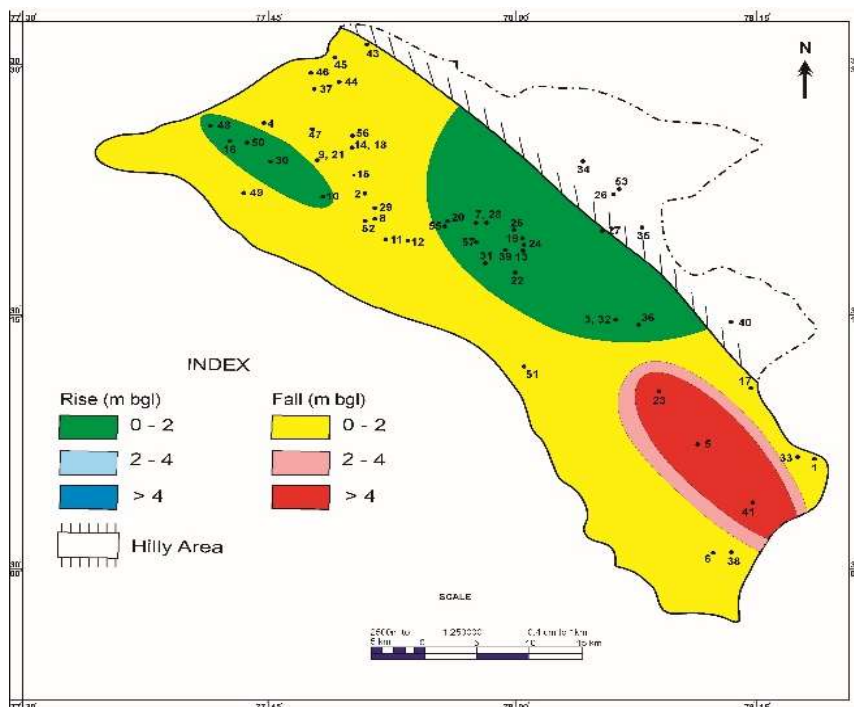


Figure 25: Decadal Water Level Fluctuation Map (January 2010-2019 vs 2020), Dehradun District

A perusal of **Fig. 25** (Dehradun District) reveals that minimum decadal fall of 0-2 m is observed in major part of the Doon Valley. Higher decadal fall of 2-4m is observed as elliptical rim around water level depths in the range of greater than 4m bgl. The highest decadal decline of greater than 4 m bgl is observed as isolated elliptical patch in the southern portion (Bhaniawala-Herbertpur – Khadirikhadakmaaf areas). The decadal rise in the range of 0-2 m is observed in and around Kuanwala-Kanwali-Harbanswala-Nanda ki Chowki-Jhajhra-Badripur-Timli areas of Doon valley.

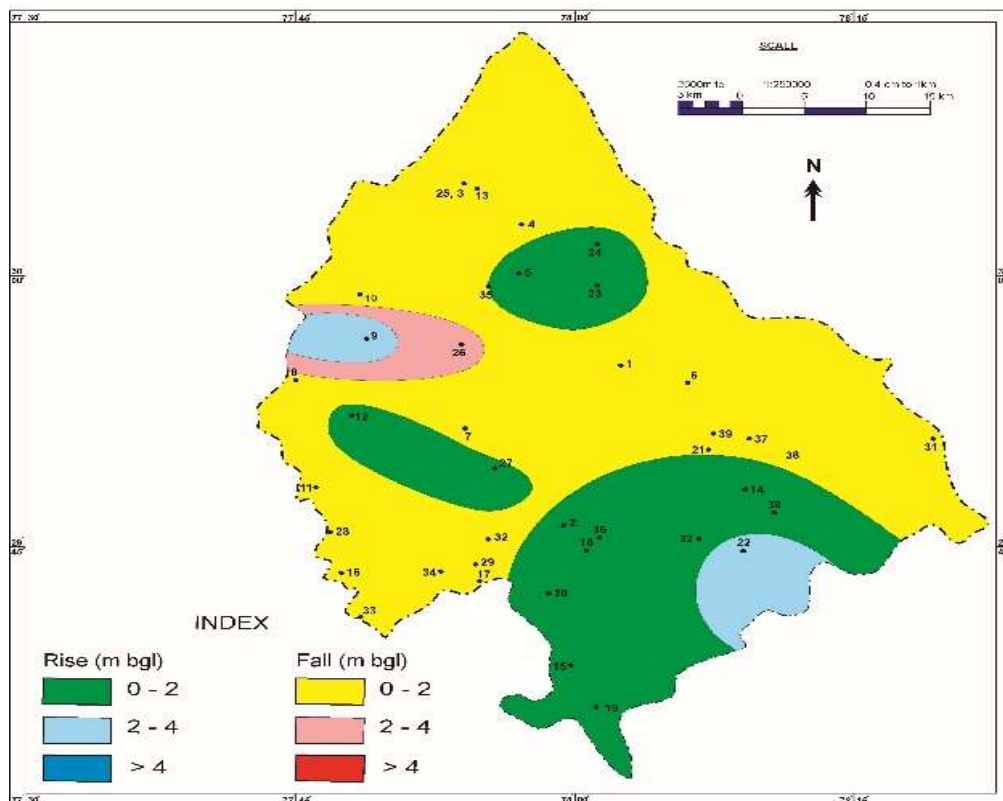


Figure 26: Decadal Water Level Fluctuation Map (January 2010-2019 vs 2020), Haridwar District

A perusal of **Fig. 26** (Haridwar District) reveals that minimum decadal fall of 0-2 m is observed in major portion of the district. The decadal fall of 2-4 m is observed in and around Imlikhera areas only. The decadal decline in the range of greater than 4 m bgl is observed in and around Bhagwnapur area only. The decadal rise in the range of 0-2 m bgl is observed as patches

in and around Iqbalpur-Dallawala-Rathaura-jaswawala-Budhwasahid –Laksar-Goverdhanpur areas. The decadal decline in the range of 2-4mbgl is observed in and around Bhikampur areas only.

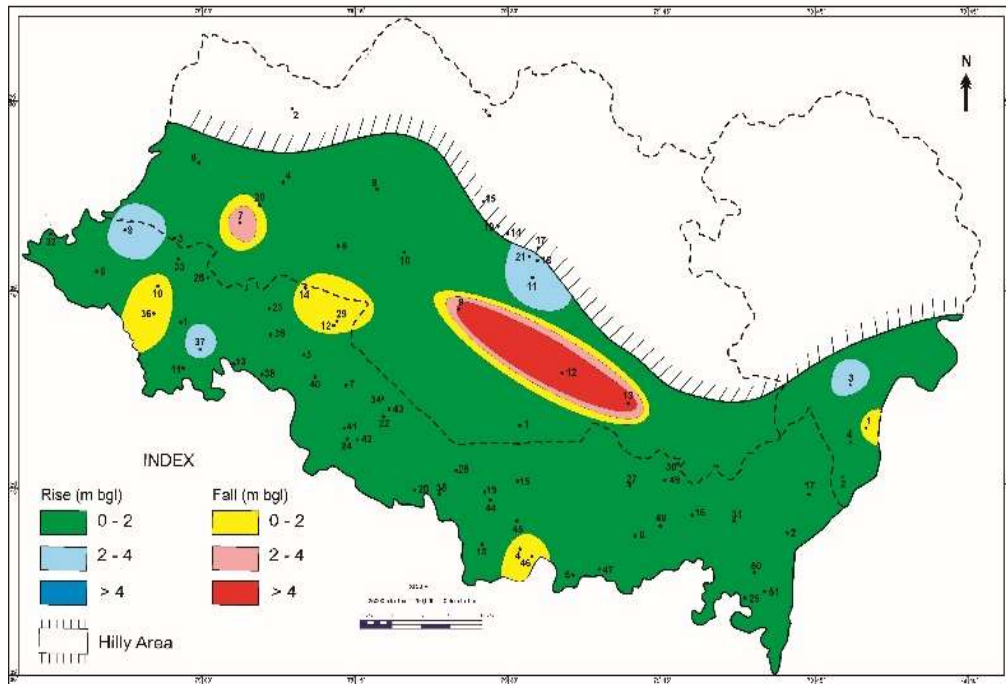


Figure 27: Decadal Water Level Fluctuation Map (January 2010-2019 vs 2020), US Nagar – Nainital - Champawat Section

Visual interpretation of **Fig. 27** (Nainital-Udham Singh Nagar-Champawat section) has shown that minimum decadal rise of 0-2 m is observed in major part of the section. Higher decadal rise of 2-4 m is observed as isolated patches in and around Patrampur-Shenkhera-Kathgodam-Bastia areas of the section. The decadal decline of water level in the range of 0-2 m bgl is observed as patches in and around bannakhera-Jharkhandi-missarwala-Bharatpur-Tanakpur-Kichcha-Peepli chauraha areas only. The decadal decline of water level in the range of 2-4 m bgl is observed as elliptical rim around water level contour of greater than 4 m bgl (Lamachaur-khatbans areas only).

Table 15. Decadal Water Level Fluctuation (January 2010-January 2019 versus January 2020)

<i>District</i>	<i>No. of stations analyzed</i>	<i>Fluctuation (m)</i>				<i>Rise (m)</i>						<i>Decline (m)</i>					
		<i>Rise</i>		<i>Decline</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>	
		<i>Min</i>	<i>Max</i>	<i>Min</i>	<i>Max</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>
Dehradun	39	0.012	14.92	0.079	6.91	15	38.46	0	0	2	5.13	13	33.33	2	5.13	7	17.95
Haridwar	34	0.132	6.94	0.061	6.14	12	35.29	1	2.94	1	2.94	18	52.94	1	2.94	1	2.94
Udham Singh Nagar	43	0.029	2.62	0.091	6.62	30	69.77	3	6.98	0	0.00	8	18.60	0	0.00	2	4.65
Nainital	12	0.003	3.62	2.32	11.87	5	41.67	1	8.33	0	0.00	0	0.00	2	16.67	4	33.33
Champawat	3	0.94	4.1	0.036		1	33.33	0	0.00	1	33.33	1	33.33	0	0.00	0	0.00
Uttarkashi	7	0.151	7.95	6.48	8.81	3	42.86	0	0.00	2	28.57	0	0.00	0	0.00	2	28.57
Total	138	0.003	24.41	0.002	30.75	66	47.83	5	3.62	6	4.35	40	28.99	5	3.62	16	11.59

5.4.2 ANNUAL WATER LEVEL FLUCTUATION

5.4.2.1 Water Level Fluctuation (May 2018 versus May 2019)

The analysis of data for 147 Ground Water Monitoring Wells for May 2018 versus May 2019 is given in **Table 16**. A perusal of the table shows that the minimum annual rise in water level is 0.005 m at Sultanpur Patti in Udham Singh Nagar district while the maximum annual rise is 8.02 m at Kanwali, Dehradun district. The minimum annual decline in ground water level is 0.01 m at Sitarganj in Udham Singh Nagar district while the maximum annual decline is 8.49 m at Baluwala in Dehradun district.

A perusal of **Table 16** reveals that out of 147 monitoring wells 61 (41.05% of total) has shown minimum rise in the range 0-2 m whereas higher rise of 2-4 m is shown by 5 monitoring wells (3.40% of the total) and the highest rise of >4 m is recorded by 4 monitoring wells (2.72%) 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 70 out of 147 monitoring wells (47.62% 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 2 monitoring wells (1.36% of total) whereas the highest decline of >4 m is recorded by 5 monitoring wells (3.46% of the total number).

The annual water level fluctuation map during the period May 2018 versus May 2019 has been shown in **Fig. 28 (Dehradun District)**, **Figure. 29 (Haridwar section)** and **Fig. 30 (Nainital-Udham Singh Nagar-Champawat section)**.

Fig. 28 (Dehradun District) reveals that minimum Annual rise of 0-2 metres is observed Northern and Central part of Doon valley covering major part of the area such as Kuanwala, Gularghati, Chandmari, Bhaniyawala, Lal Tappar, Rishikesh. Higher annual rise of 2-4 m is observed as elliptical patches in the central portion of the Doon valley in and around Balliwala area. The highest annual rise of >4 metres is observed in and around Majra, Nanurkhera, Kanwalai areas. The minimum annual decline of 0-2 m is observed in northern part of the valley in and around Motichur, Khandgaon, Khadiri Khadakmaf, Redapur, Sabhawala, Sankarpur, Chhorba, Dhakrani area of Dehradun district.

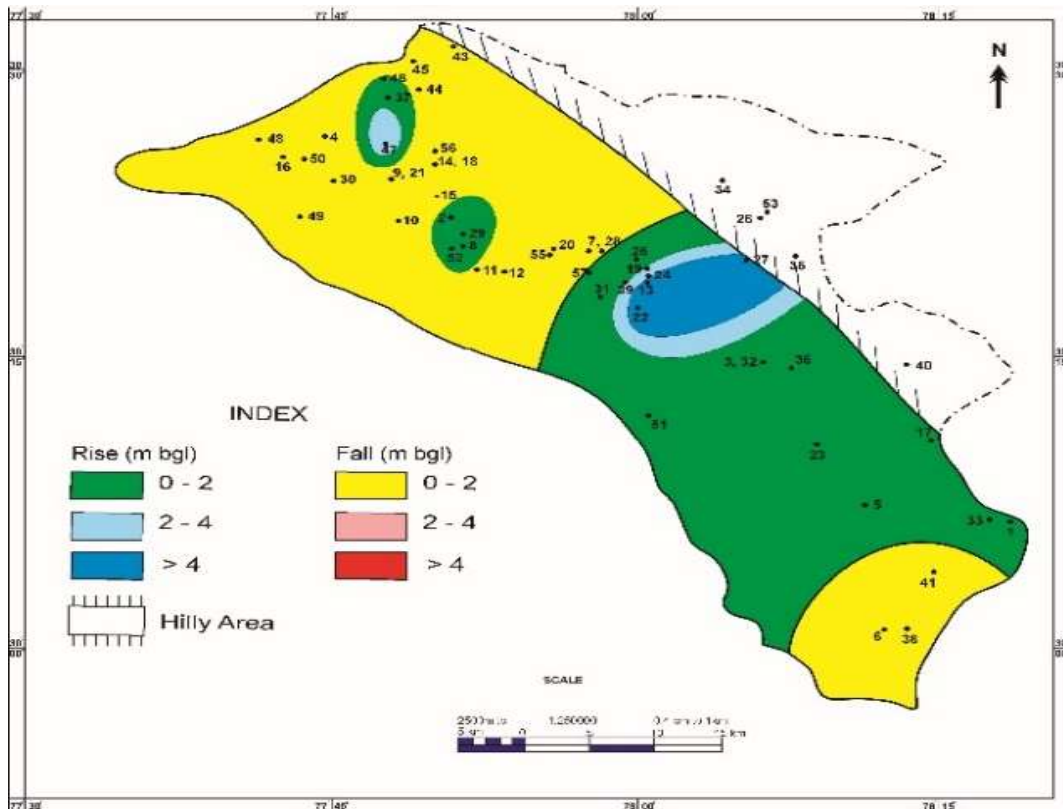


Figure 28: Annual Water Level Fluctuation Map (May 2018 vs 2019), Dehradun District

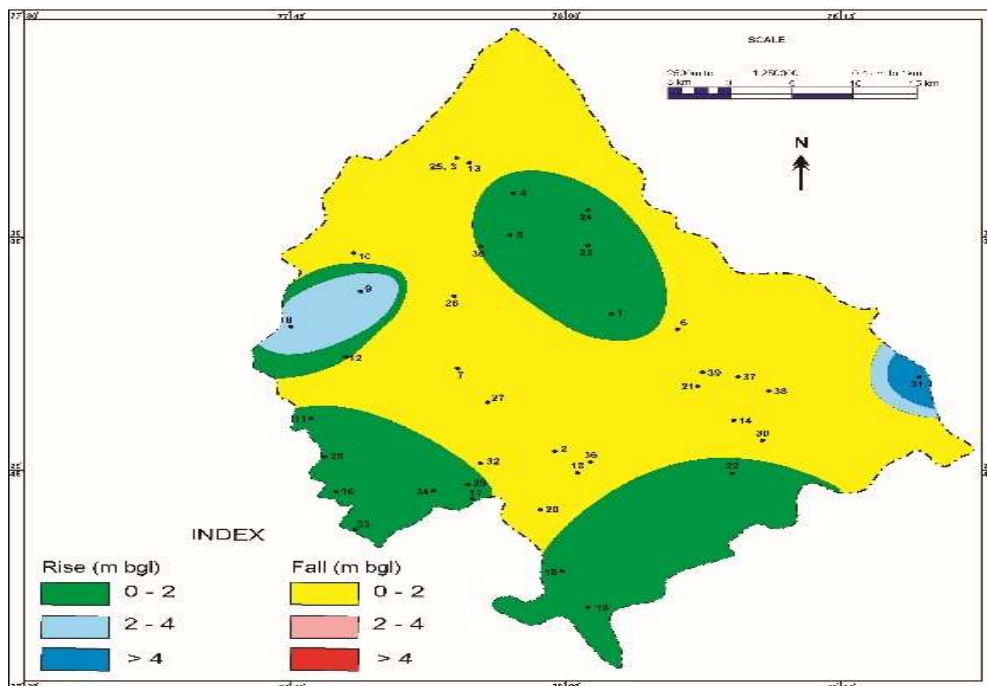


Figure 29: Annual Water Level Fluctuation Map (May 2018 vs 2019), Haridwar District

A perusal of **Fig. 29** (Haridwar District) shows that major part of district having annual declining water level in the range of 0-2 metres. The annual rise of 0.2 m is observed as isolated patches in southern and northeastern part of the district in and around Bandarjud, Budhwa Shahid, Kota Muradnagar, Bahadrabad, Laknauta, Nizampur, Jhabrera, Gurukul Narsan, Khanpur, Bhikkampur, Iqbalpur areas. The annual rise of 2-4 m is observed as isolated patches in eastern and western part of the district. The annual rise of >4 m is observed in and around Laldhang area of the district.

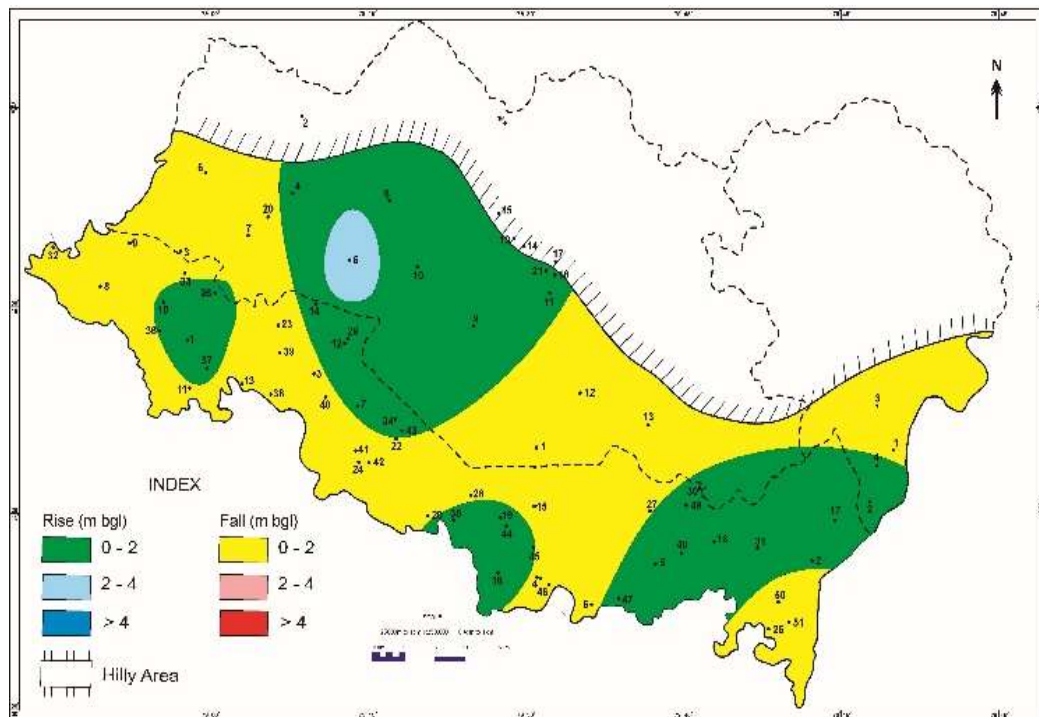


Figure 30: Annual Water Level Fluctuation Map (May 2018 vs 2019), US Nagar -Nainital - Champawat Section

A study of **Fig. 30** shows that during the pre-monsoon period, the minimum annual rise of 0-2 m is observed as isolated patches in and around Dhoniya, Kathgodam, Ramnagar, Bannakhera, Jharkhandi, Bharatpur, Sandkhera, Kashipur, Banbasa area of the section. The annual rise of 2-4 and greater than 4 metres is not observed in any part of the section. The lowest pre monsoon annual decline of 0-2 m is observed in major part of the section. Higher annual decline of 2-4 m and greater than 4 m decline is not observed in the section.

Table 16. Annual Water Level Fluctuation (May 2018 versus May 2019)

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	44	0.04	8.02	0.04	8.49	12	27.27	1	2.27	3	6.82	23	52.27	2	4.55	3	6.82
Haridwar	36	0.05	4.3	0.025	7.3	19	52.78	2	5.56	1	2.78	13	36.11	0	0.00	1	2.78
Udham Singh Nagar	43	0.005	0.56	0.01	1.115	21	48.84	0	0.00	0	0.00	22	51.16	0	0.00	0	0.00
Nainital	12	0.03	2.8	0.075	11.05	5	41.67	2	16.67	0	0.00	4	33.33	0	0.00	1	8.33
Champawat	3	0.065		0.71	0.815	1	33.33	0	0.00	0	0.00	2	66.67	0	0.00	0	0.00
Pauri Garhwal	1	0.2		0		1	100.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Uttarkashi	8	0.075	1.85	0.05	1.91	2	25.00	0	0.00	0	0.00	6	75.00	0	0.00	0	0.00
Total	147	0.005	8.81	0.04	10.98	61	41.50	5	3.40	4	2.72	70	47.62	2	1.36	5	3.40

5.4.2.2 Water Level Fluctuation (August 2018 versus August 2019)

The analysis of annual water level fluctuation data for 152 Ground Water Monitoring Wells for the periods August 2018 and August 2019 is given in **Table 17**. Analysis of the fluctuation data indicates that the minimum annual rise of 0.015 metres is observed at Rudrapur, Udham Singh Nagar district. The maximum annual rise of 24.67 metres is observed at Timli in Dehradun district. The lowest annual decline is 0.015 metres at Govardhanpur, Haridwar district, whereas the highest decline is 10.29m at Harbanswala in Dehradun district.

Analysis of the fluctuation data has indicated that out of 152 monitoring wells, 86wells (56.58% of total) had shown an annual rise in the range 0-2 m while higher rise of 2-4 m is observed in 10 monitoring well (6.58% of total). The highest rise in the range >4 m is recorded by 5 monitoring wells, which is 3.29% of the total number of wells. It is also seen that majority of monitoring wells (44 out of 152, 28.95% of total) had recorded annual decline in the range of 0-2 m. Higher annual decline of 2-4 m is shown by 4 monitoring wells (2.63% of total) while the highest decline of >4 m is shown by 3 monitoring wells, which is 1.97% of the total number of wells.

The annual water level fluctuation map during the period August 2018 versus August 2019 is shown in **Fig. 31 (Dehradun section)**, **Fig. 32 (Haridwar section)** and **Fig. 33 (Nainital-Udham Singh Nagar-Champawat section)**.

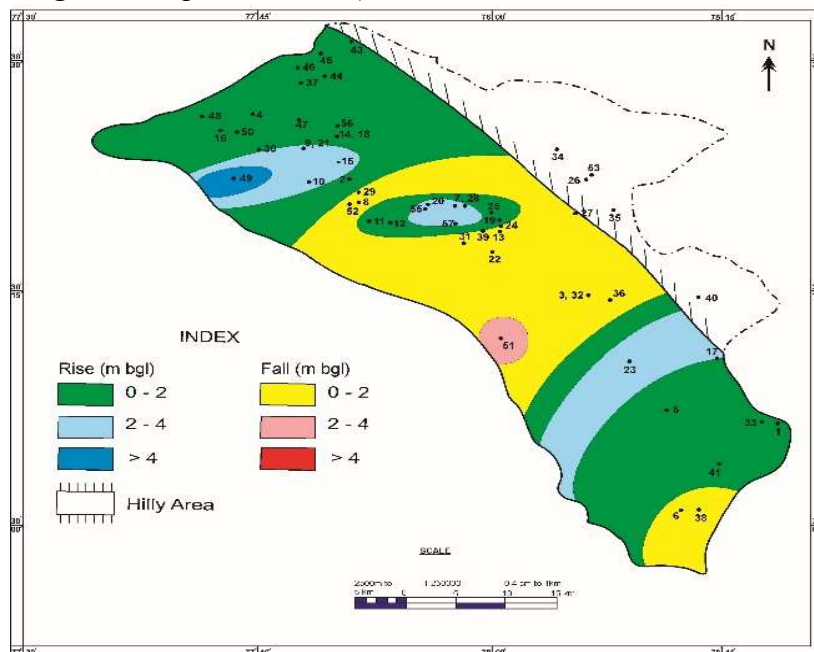


Figure 31: Annual Water Level Fluctuation Map (August 2018 vs 2019), Dehradun District

A perusal of Fig. 31 indicates that minimum annual rise of 0-2 m is seen in major part of the Doon valley. The higher annual rise of 2-4 m is observed in and around Shankarpur, Sabawala, Bhaniwala, Telpura, Nandki Chowki, Jhajhra areas of the district. The highest water level rise in the range of greater than 4 metres is observed as isolated patches around Timli area of the district. The minimum annual decline of 0-2 m is observed in and around KhandGaon, Motichur, Kuanwala, Gularghati, Majra, Badowala, Kanwali, Selaqui areas of the Doon Valley. The higher annual decline of 2-4 m is observed in and around Chandmari area of the district. The highest annual decline of greater than 4 metres is not observed in any part of the section.

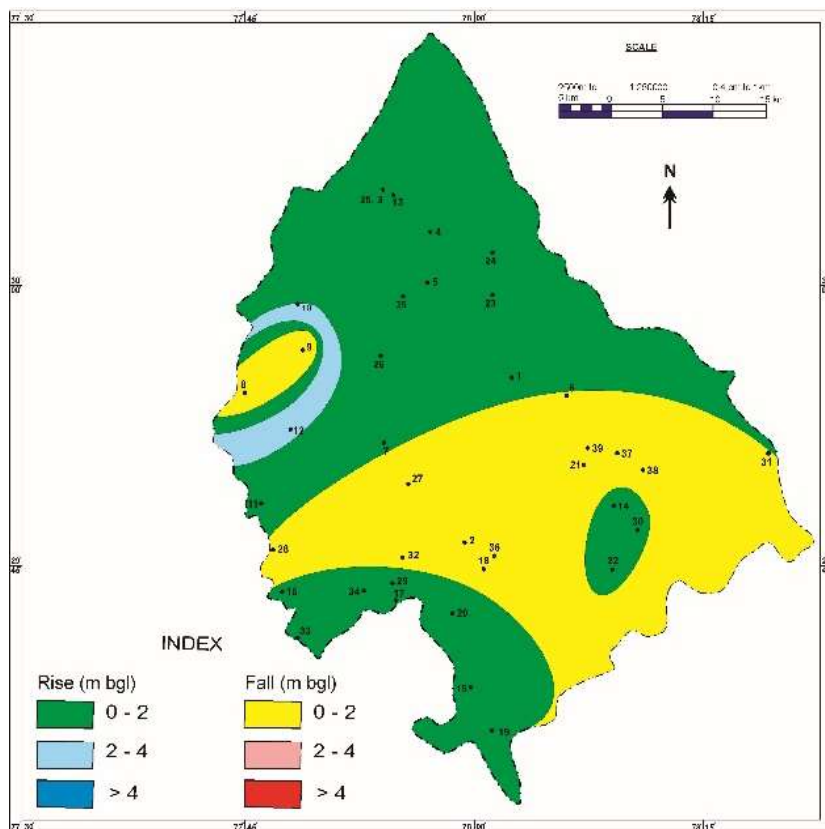


Figure 32: Annual Water Level Fluctuation Map (August 2018 vs 2019), Haridwar District

A perusal of **Fig. 32** indicates that minimum annual rise of 0-2 m is observed in major parts of the district. The 2-4m water level zone is observed as isolated patch around Iqbalpur and Bahabalpur area of the district. The highest annual rise of >4 m is not observed in any part of the section. The minimum annual decline of 0-2 m is observed in and around Liberheri, Landhaura, Shikhar

Husainpur, Laksar, Dhanpura, Dandi, Ibrahimpur, Shyampur, Bhagwanpur areas of the district. Higher annual decline of 2-4 m and highest decline of >4m is not observed in any part of the section.

A perusal of **Fig. 33** indicates that minimum annual rise of 0-2 m is observed in major part of the section. Higher annual water level rise in the range of 2-4 m is observed as isolated patches around Khant Bans and KamariaPakki areas of the section. Highest annual water level rise in the range of greater than 4 is not observed in the section. Minimum annual water level decline in the range of 0-2 m is observed in and around Belparao, Dhoniya, Ramnagar, Patrampur, Angadpur, BarkharePande, Tukri, Kanchanpuri, Khatima, Chakarpur areas of the section. Higher water level decline in the range of 2-4 m is observed in and around Peru Madan, Dhela areas of the Nainital district. Highest water level decline in the range of >4 m is observed in and around Chilkiya and Jaspur areas of the section.

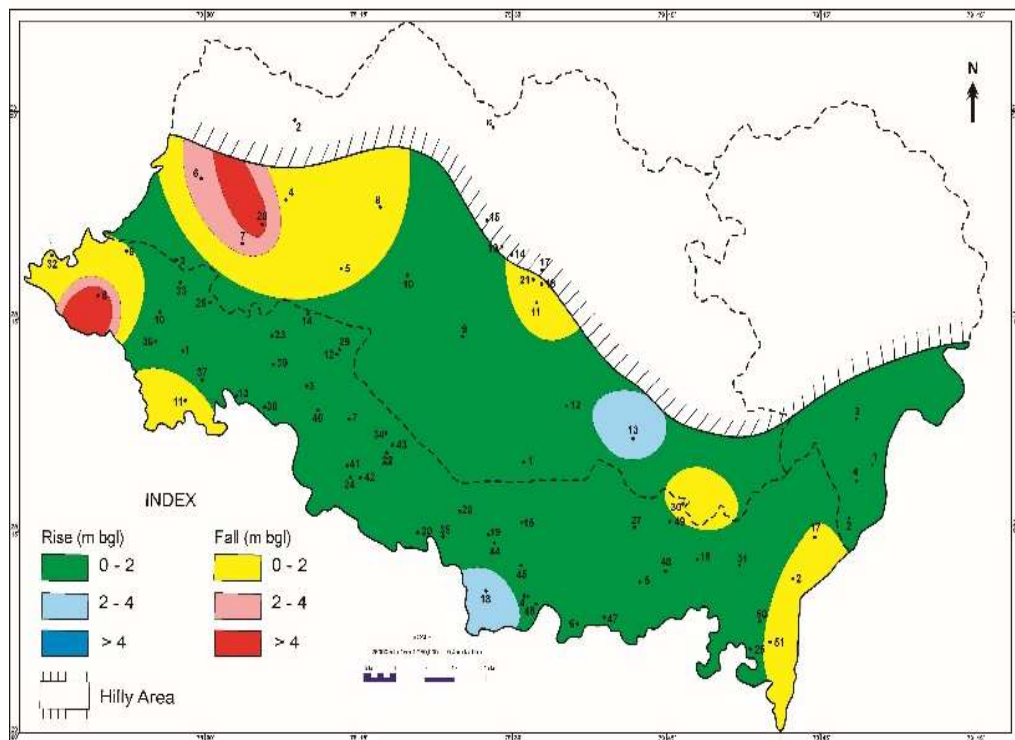


Figure 33: Annual Water Level Fluctuation Map (August 2018 vs 2019), US Nagar – Nainital - Champawat Section

Table 17. Annual Water Level Fluctuation (August 2018 versus August 2019)

<i>District</i>	<i>No. of stations analyzed</i>	<i>Fluctuation (m)</i>				<i>Rise (m)</i>						<i>Decline (m)</i>					
		<i>Rise</i>		<i>Decline</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>	
		<i>Min</i>	<i>Max</i>	<i>Min</i>	<i>Max</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>
Dehradun	43	0.1	24.67	0.26	10.29	22	51.16	7	16.27906977	4	9.30	8	18.60	1	2.33	1	2.33
Haridwar	40	0.03	3.67	0.015	2.04	18	45.00	1	2.50	0	0.00	20	50.00	1	2.50	0	0.00
Udham Singh Nagar	44	0.015	2.865	0.035	5.795	34	77.27	1	2.27	0	0.00	8	18.18	0	0.00	1	2.27
Nainital	12	0.1	2.245	0.025	4.73	4	33.33	1	8.33	0	0.00	4	33.33	2	16.67	1	8.33
Champawat	4	0.265	1.43	0		4	100.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Pauri Garhwal	1	0		0.8		0	0.00	0	0.00	0	0.00	1	100.00	0	0.00	0	0.00
Uttarkashi	8	0.115	6.38	0.095	1.615	4	50.00	0	0.00	1	12.50	3	37.50	0	0.00	0	0.00
Total	152	0.005	21.88	0.02	21.25	86	56.58	10	6.58	5	3.29	44	28.95	4	2.63	3	1.97

5.4.2.3 Water Level Fluctuation (November 2018 versus November 2019)

The analysis of annual water level fluctuation data for 154 Ground Water Monitoring Wells in Uttarakhand is available. Analysis of the data has shown that the lowest annual rise is 0.015 metres at Rampura in Dehradun district while the highest annual rise is 8.155 m at Maneriin Uttarkashi district. During the post-monsoon period the lowest annual decline is 0.005 m at Patharpuriin Udham Singh Nagar district while the highest annual decline is 8.35 m at Dudhliin Dehradun district.

A study of the water level fluctuation data has revealed that 93 monitoring wells out of 146 wells (63.70 % of the total number) has recorded a rise in the range of 0-2 m. 7 monitoring well (4.79% of the total) had shown the higher rise of 2-4 m and 2 monitoring well (1.37 % of the total) had shown the highest rise of >4 m during this period. The 39 nos. of monitoring well (26.71% of the total) had recorded an annual decline in the range of 0-2 m during the post monsoon period. 3 wells (2.05% of total number) had shown higher decline of water level in the range of 2-4 m whereas only 2 wells (1.37 % of total) had shown the highest annual decline of >4 m in water level.

The annual water level fluctuation map during the period November 2018 versus November 2019 is shown in **Fig. 34** (*Dehradun district*), **Fig.35** (*Haridwar section*) and **Fig. 36** (*Nainital-Udham Singh Nagar-Champawat section*).

A perusal of Fig. 34 has shown that the minimum annual decline in post monsoon period in the range of 0-2 m is observed in major part of the valley. Higher annual decline of 2-4 m is observed as isolated patches around Chandmari, Lal Tappar, Badowala and Ladpur areas of the Doon valley. The minimum annual rise of 0-2 m is observed as isolated patches in and around Judli, Dharmawala, Herbertpur, Badripur, Dandi, Singhniwala and Rampura areas of the section. Higher annual rise of 2-4 m and greater than 4 m is not observed in the Doon valley.

A perusal of **Fig. 35** has shown that the minimum annual decline in post monsoon period in the range of 0-2 m is major parts of the district; whereas the annual water level rise of 2-4 m is observed in and around Shikhar, Dhanpura, Dandi Ibrahimpur, Jhabrera areas of the district

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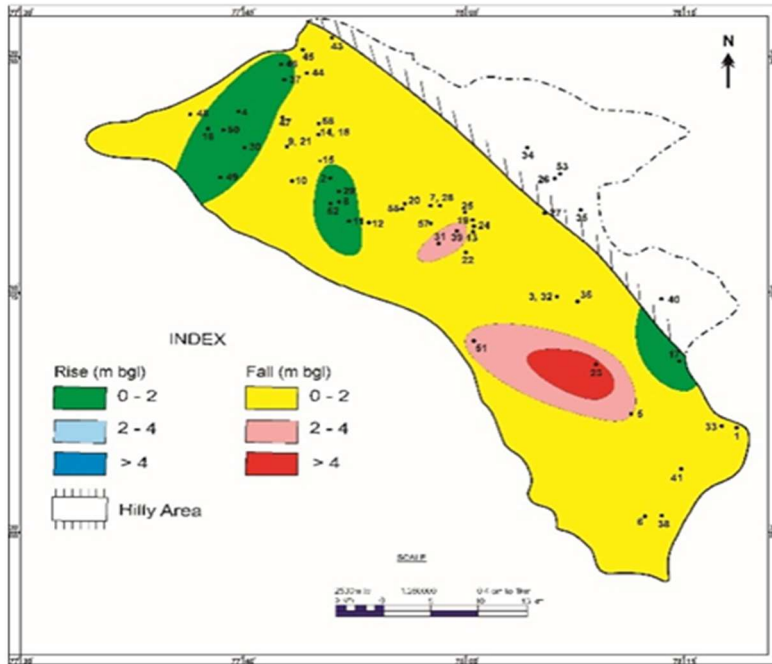


Figure 34: Annual Water Level Fluctuation Map (November 2018 vs 2019), Dehradun District

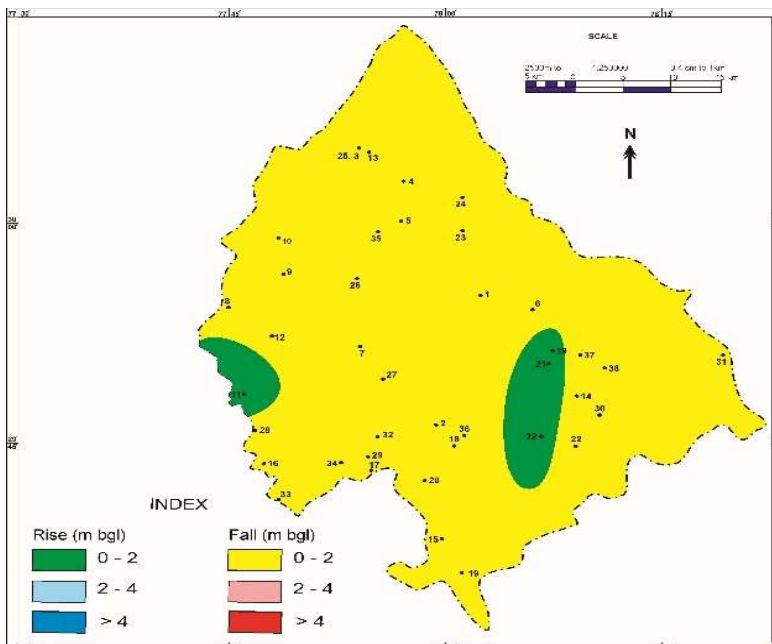


Figure 35: Annual Water Level Fluctuation Map (November 2018 vs 2019), Haridwar District

Interpretation of **Fig. 36** has shown that for the post monsoon period, the minimum annual decline of 0-2 m is observed in major part of the section. Higher annual water level decline in the range of 2-4 m is observed in and around KamariaPakki, Jhagarpuri, Missarwala, Patrampur, Chilkiya, Lamachaur, Jaspur areas of the section. Highest annual decline of >4 m is observed in and around Belparao, Angadpur areas of the section. Minimum annual rise of 0-2 m is observed in and around Dhanauri Patti, Jogipura, Bannakhera, Jharkhadi, Rudrapur, Shantipuri areas of the section. Higher (2-4 m) and highest (> 4m) is not observed in the section as per the available data.

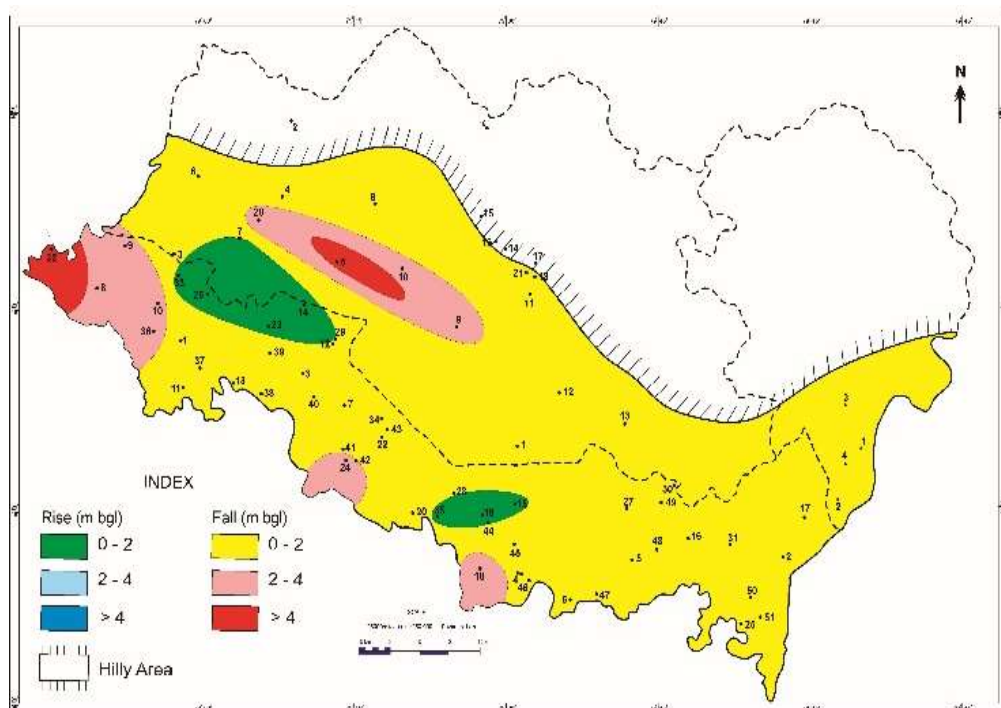


Figure 36: Annual Water Level Fluctuation Map (November 2018 vs 2019), US Nagar – Nainital - Champawat Section

Table 18: Annual Water Level Fluctuation (November 2018 versus November 2019)

<i>District</i>	<i>No. of stations analyzed</i>	<i>Fluctuation (m)</i>				<i>Rise (m)</i>						<i>Decline (m)</i>					
		<i>Rise</i>		<i>Decline</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>	
		<i>Min</i>	<i>Max</i>	<i>Min</i>	<i>Max</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>
Dehradun	45	0.015	2.69	0.07	8.35	29	60.42	5	10.4166667	2	4.17	5	10.42	2	4.17	2	4.17
Haridwar	39	0.02	1.295	0.05	1.305	26	66.67	0	0.00	0	0.00	13	33.33	0	0.00	0	0.00
Udham Singh Nagar	45	0.02	1.625	0.005	1.415	28	63.64	0	0.00	0	0.00	17	38.64	0	26.00	0	0.00
Nainital	13	0.1	3.25	0.09	3.625	7	53.85	2	15.38	0	0.00	3	23.08	1	7.69	0	0.00
Champawat	4	0.205	0.745	0.445		3	75.00	0	0.00	0	0.00	1	25.00	0	0.00	0	0.00
Pauri Garhwal	1	0.955		--		1	100.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Uttarkashi	7	0.19	8.155	0.07	1.62	3	42.86	1	14.29	1	14.29	2	28.57	0	0.00	0	0.00
Total	154	0.02	8.155	0.005	8.97	97	62.18	8	5.13	3	1.92	41	26.28	3	1.92	2	1.28

5.4.2.4 Water Level Fluctuation (January 2019 versus January 2020)

The analysis of water level data of 159 ground water monitoring wells for the period January 2019 versus January 2020 is given in **Table 19**. A perusal of the table indicates that the minimum annual rise is 0.06 m at Selaqui in Dehradun district and at Nanak Matta in US Nagar district whereas the maximum annual rise is 33.15 m at TarlaNagal in Dehradun district. The minimum annual decline is found to be 0.01 m at Khanpur in Haridwar District and Jhagarpuri in Udham Singh Nagar district whereas the maximum decline is 14.74 m at Majra in Dehradun district.

A perusal of the table also reveals that out of 159 monitoring wells, 54 wells (35.53%) have recorded the minimum annual rise in the range 0-2 m whereas 16 wells (10.53% of total wells) had shown higher rise in the range 2-4 m. 11nos. of monitoring well (7.24 % 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 53 monitoring wells (34.87% of total) while 10wells (6.58%) had recorded higher decline in the range of 2-4 m. The highest decline of greater than 4 metres is shown by 15 no of monitoring well (9.87% of total).

Visual interpretation of **Fig. 37** has shown that the minimum annual decline in the range of 0-2 m is observed in major part of the section. The higher annual water level fall in the range of 2 to 4 metres is observed as elliptical rim around water level depths in the range of greater than 4m bgl in and around Telpura-Ladpur areas and as isolated patch in and around vikasnagar-Laxmipur areas only. Highest decline of greater than 4m bgl is observed in and around Baronwala-Majra-Lal Tappar-Bhaniawala areas only. The minimal annual rise of 0-2 m bgl is observed as isolated patches in and around Judli-Badripur areas, whereas higher annual rise of 2-4

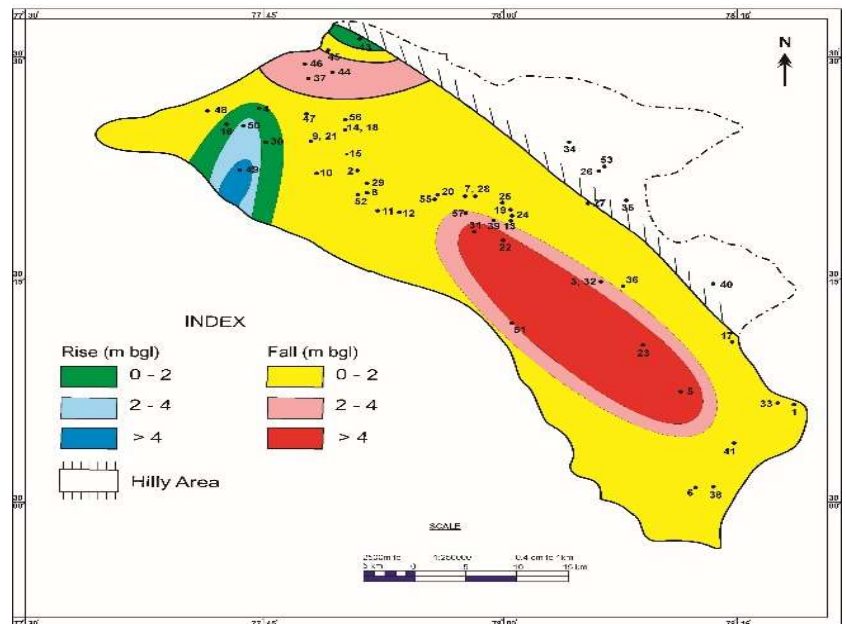


Figure 37: Annual Water Level Fluctuation Map (January 2019 vs 2020), Dehradun District

whereas higher annual rise of 2-4

m is observed as patch in and around Dharmawala areas only. The annual water level zone having rise in the range of greater than 4 metres in and around Timli. Visual interpretation of **Fig. 38** has shown that the annual minimum annual decline in the range of 0-2 m is observed in major part of the district. The minimal annual rise of 0-2 m is observed as elliptical rim around water level depth contours of 2-4 m bgl and greater than 4 m bgl as isolated patches in and around Govardhanpur-Dhanpura-Bhogpur-Bhagwanpur-Jhabrera –Laksar- Shampur

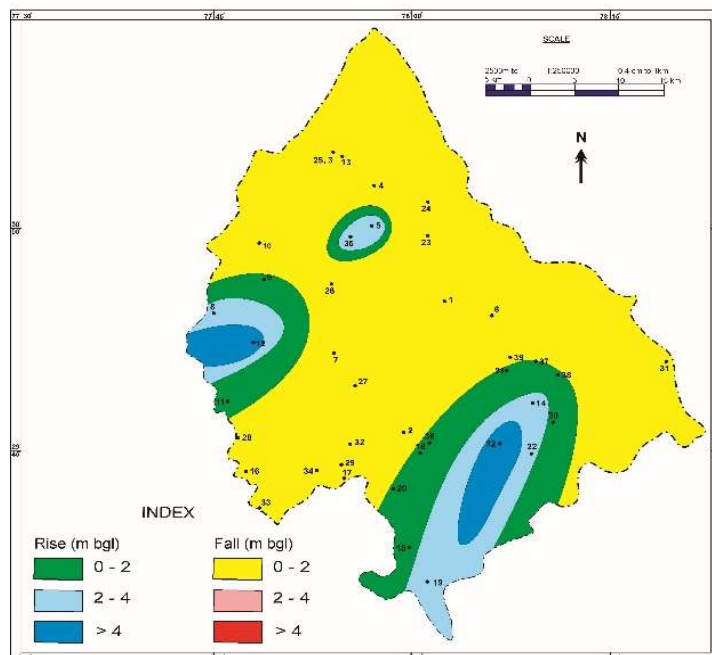


Figure 38: Annual Water Level Fluctuation Map (January 2019 vs 2020), Haridwar District

areas only. The annual water level rise in the depth range of 2-4 m bgl is observed in and around Dallwala-Bhikampur-Shahpur shitalkhera-Chudiala-Rathaura-Kota Muradnagar areas only. The annual water level rise in the range of greater than 4 m bgl is observed in and around Iqbalpur-Laldhang areas only.

A perusal of **Fig. 39** indicates that the minimum annual rise of 0-2 m is observed in major part of the section. Higher annual rise of 2-4 m is observed as isolated patches in and around Missarwala-Shenkhera-Tukri (Udham Singh Nagar district) and Ramnagar-Peeru Madara-Kaladhungi-

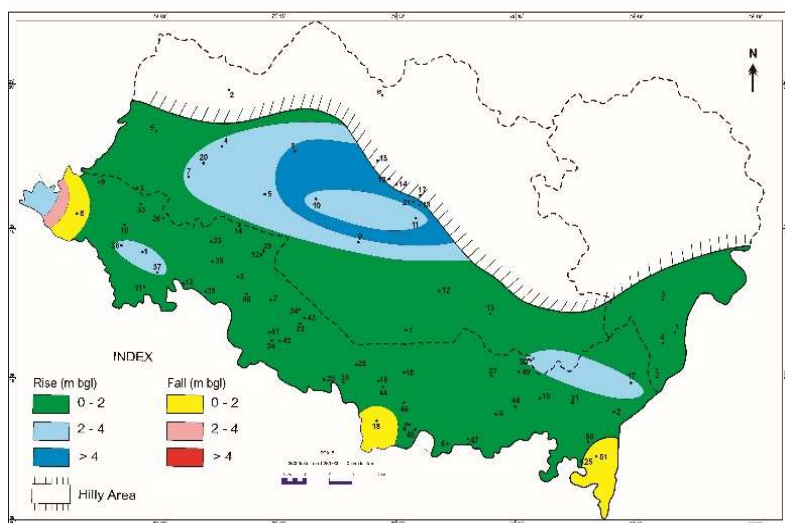


Figure 39: Annual Water Level Fluctuation Map (January 2019 vs 2020), US Nagar – Nainital - Champawat Section

Kathgodam (Nainital district) The highest annual rise of >4 mbgl is observed in and Dhoniya-Lamachaur areas of the section. The minimum annual decline of 0-2 mbgl is mostly observed as patches in and around kanchanpuri-Kamaria Pakki-Jaspurof Udham Singh Nagar district. Annual water level zone showing decline in the range of 2 to 4 metres is observed as rim around water level decline of greater than 4 m bgl in the extreme eastern portion of the district.

Table 19 :Annual Water Level Fluctuation (January 2019 versus January 2020)

<i>District</i>	<i>No. of stations analyzed</i>	<i>Fluctuation (m)</i>				<i>Rise (m)</i>						<i>Decline (m)</i>						
		<i>Rise</i>		<i>Decline</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>		
		<i>Min</i>	<i>Max</i>	<i>Min</i>	<i>Max</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	
Dehradun	47	0.06	33.15	0.13	14.74	7	16.28	2	4.65	1163	3	6.98	22	51.16	4	9.30	9	20.93
Haridwar	40	0.12	8.94	0.01	2.54	9	22.50	6	15.00		2	5.00	21	52.50	2	5.00	0	0.00
Udham Singh Nagar	46	0.06	5.39	0.01	5.54	30	68.18	5	11.36		1	2.27	8	18.18	0	0.00	2	4.55
Nainital	13	0.08	11.17	0.28	8.06	1	8.33	3	25.00		2	16.67	1	8.33	4	33.33	2	16.67
Champawat	4	0.11	7.18	0.21		2	50.00	0	0.00		1	25.00	1	25.00	0	0.00	0	0.00
Pauri Garhwal	1	9.33		0		0	0.00	0	0.00		1	100.00	0	0.00	0	0.00	0	0.00
Uttarkashi	8	0.44	21.49	10.1	13.15	5	62.50	0	0.00		1	12.50	0	0.00	0	0.00	2	25.00
Total	159					54	35.53	16	10.53		11	7.24	53	34.87	10	6.58	15	9.87

5.4.3 SEASONAL WATER LEVEL FLUCTUATION

5.4.3.1 Water Level Fluctuation (May 2019 versus August 2019)

The seasonal fluctuation of water level during the period May 2019 versus August 2019 for 130 ground water monitoring wells in Uttarakhand State is given in **Table 20**. A perusal of the fluctuation data has shown that the minimum seasonal rise in ground water level was 0.015 m at Nizampur in Haridwar district whereas the maximum rise was 7.05 m at Chandmari in Dehradun district. The minimum seasonal decline was 0.01 m at Sand Khera in Udham Singh Nagar district while the maximum decline was 3.71 m atMajrainDehradun district.

The perusal of Table 20 also reveals that rise in the range of 0-2 m was shown by 89 monitoring wells, which was 68.46% of the total number of wells. Higher rise in the range 2-4 m was shown by 20 wells (15.38% of total) while the highest rise of >4 m was shown by 6 wells (4.62% of total). The lowest seasonal decline of 0-2 m was recorded by 13 monitoring wells (10.0% of total). Higher seasonal decline of 2-4 m was shown by 2 monitoring wells, which was only 1.54% of the total number of wells during the period May versus August 2019.

Visual interpretation of **Fig. 40** has shown that the lowest seasonal rise of 0-2 m is observed in major parts of the Doon valley. The seasonal rise of 2-4 m is observed as isolated patches in and around Khandgaon-Kuanwala-Nanda Ki Chowki-Shankarpur-Dakpathar Areas only. The highest seasonal rise in the range of > 4 m bgl is observed in and around Chandmari areas only. The minimum seasonal water level decline in the range of 0-2 m bgl is observed in and around Nanurkhera areas only.

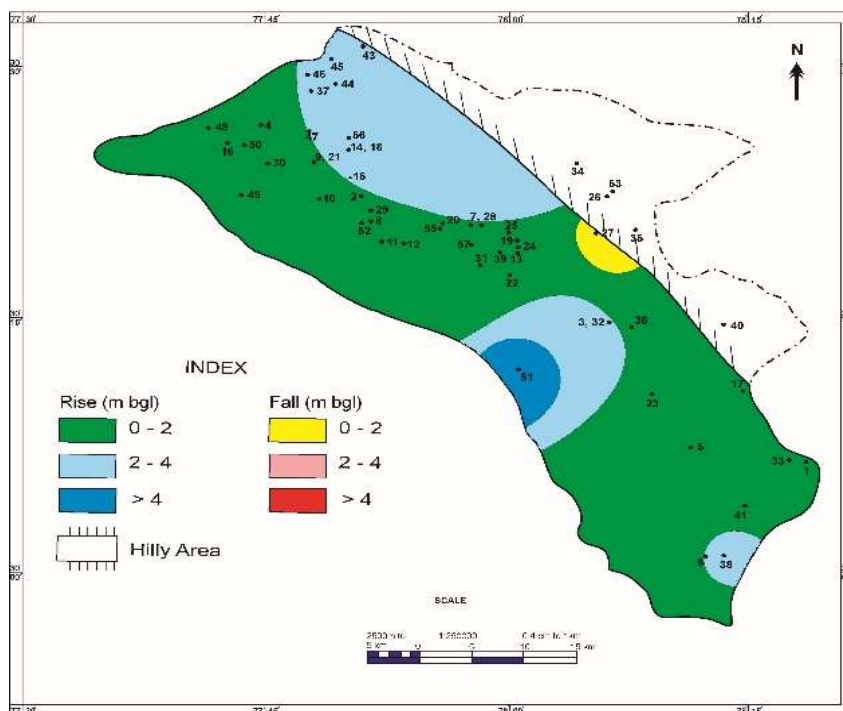


Figure 40: Water Level Fluctuation Map (May 2019 vs August 2019), Dehradun District

Visual interpretation of Fig. 41 has shown that the lowest seasonal rise of 0-2 m is observed in majorpart of the district. The Seasonal rise of 2-4 m is observed as isolated patch in and aroundBandarjud-Buggawala areas of the district .The lowest seasonal decline of 0-2 m is observed as Bahadrabad areas of the district.

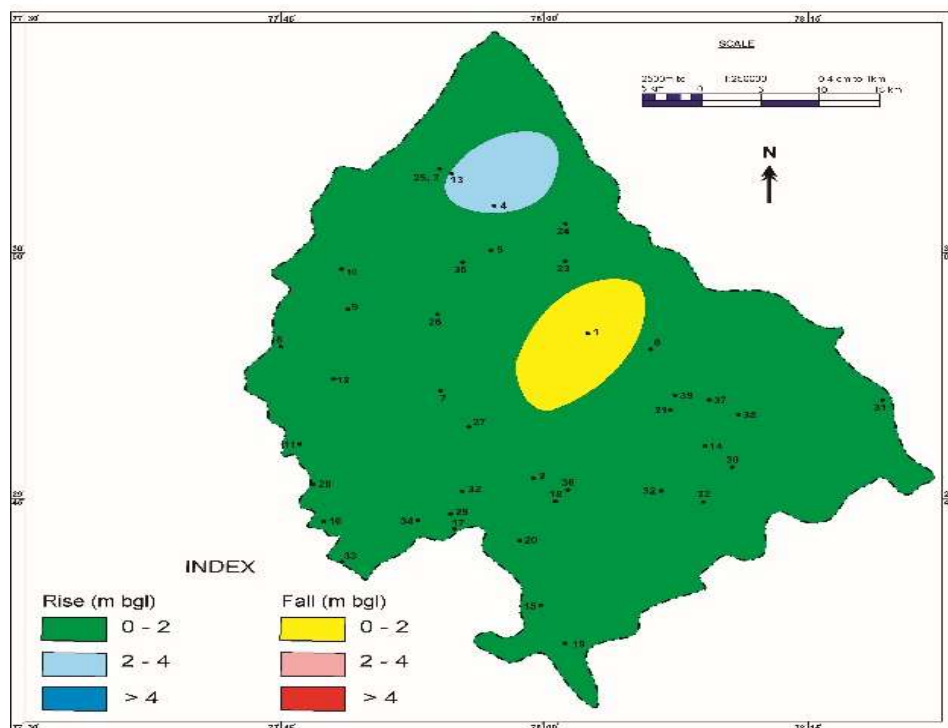


Figure 41: Water Level Fluctuation Map (May 2019 vs August 2019), Haridwar District

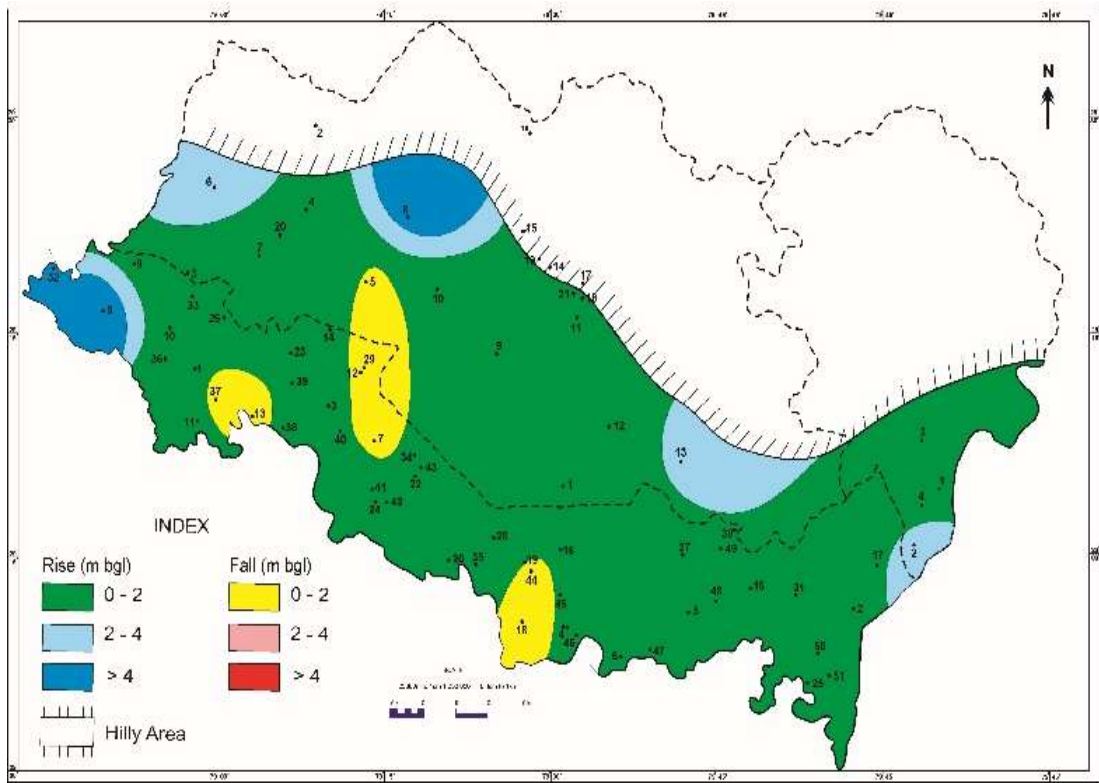


Figure 42: Water Level Fluctuation Map (May 2019 vs August 2019), US Nagar – Nainital - ChampawatSection

A perusal of **Fig. 42** indicates that the lowest positive seasonal rise of 0-2 m is observed in the major parts of the section. Higher seasonal rise of 2-4 m is observed as isolated patches in and around Khatbans–Dhela-Banbasa of the section. The highest seasonal rise of > 4m bgl is observed as isolated patches in Jaspur–dhoniya areas of the section.

Table 20. Seasonal Water Level Fluctuation (May 2019 Versus August 2019)

<i>District</i>	<i>No. of stations analyzed</i>	<i>Fluctuation (m)</i>				<i>Rise (m)</i>						<i>Decline (m)</i>					
		<i>Rise</i>		<i>Decline</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>	
		<i>Min</i>	<i>Max</i>	<i>Min</i>	<i>Max</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>
Dehradun	35	0.12	7.05	0.38	3.71	20	57.14	10	28.57	2	5.71	1	2.86	2	5.71	0	0.00
Haridwar	33	0.015	2.275	0.12	1.67	29	87.88	2	6.06	0	0.00	2	1.00	0	0.00	0	0.00
Udham Singh Nagar	42	0.095	5.75	0.01	1.535	29	69.05	3	7.14	2	4.76	8	19.05	0	0.00	0	0.00
Nainital	10	0.07	4.87	0.625		6	60.00	2	20.00	1	10.00	1	10.00	0	0.00	0	0.00
Champawat	3	0.655	5.785	0		1	33.33	1	33.33	1	33.33	0	0.00	0	0.00	0	0.00
Uttarkashi	7	0.25	2.885	0.465		4	57.14	2	28.57	0	0.00	1	14.29	0	0.00	0	0.00
Total	130					89	68.46	20	15.38	6	4.62	13	10.00	2	1.54	0	0.00

5.4.3.2 Water Level Fluctuation (May 2019 versus November 2019)

The water level fluctuation data of May 2019 was compared with that of November 2019 for 134 ground water monitoring wells in Uttarakhand and the result is given in **Table 21**. Analysis of the fluctuation data for the period May-November (pre-monsoon versus post-monsoon) indicates that the minimum seasonal rise was 0.05 m at Shahidwala Grant in Haridwar district while the maximum was 10.75 m at Bastia in Champawat district. The annual decline was 0.12 m at Libhrahedi in Haridwar district whereas the maximum decline was 3.81 m at Majrain Dehradun district.

A perusal of the fluctuation data also shows that seasonal rise of 0-2 m was shown by 74 monitoring wells out of 134 (55.22%), that in the range of 2-4 m by 25 monitoring wells (18.66% of total) and that in the range of >4 m by 09 wells (6.72% of total) in Uttarakhand State. Seasonal decline in the range 0-2 m was recorded by 15 monitoring wells (11.19% of total). Higher seasonal decline in the range of 2-4 m had been recorded by one monitoring well only (0.75% of total).

Visual interpretation of **Fig. 43** has revealed that the lowest seasonal rise of 2-4 mbgl is observed in major parts of the Doon valley. The minimum seasonal rise of 0-2 mbgl is observed as band in Kanwali-Singhniwala-Selaqui-Rampura-Redapur-Dhakrani-Herbertpur-Timli-Sabhawala areas and also as isolated patches in southern portion (Rishikesh-Lal Tappar) of Doon valley. The highest seasonal rise of greater than 4 metres is observed in Shankarpur, Redapur areas of the district. The highest seasonal rise of >4 m is observed in and around Harbanswala areas only. The minimum seasonal decline in the range of 0-2m is observed as isolated patch in and around Khadiri Khadakmaaf areas only.

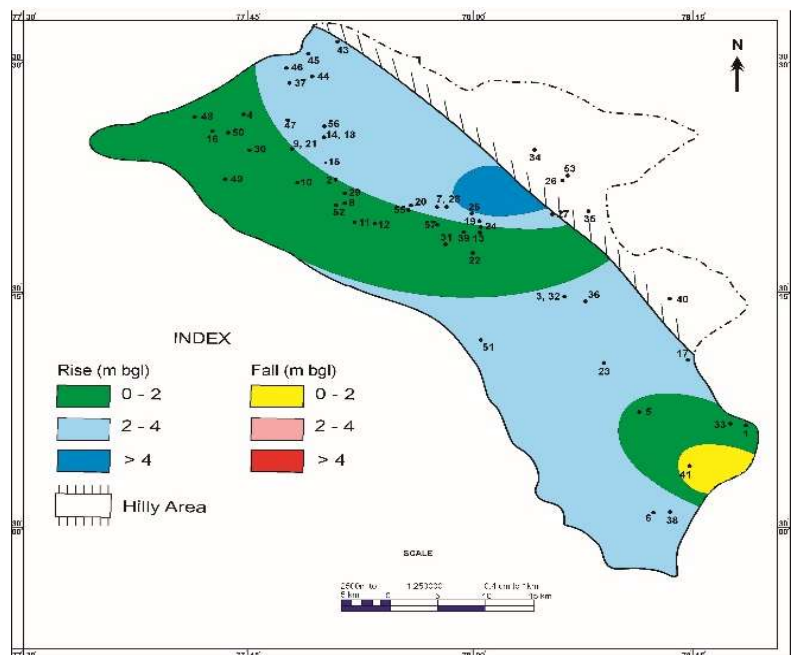


Figure 43: Water Level Fluctuation Map (May 2019 vs November 2019), Dehradun District

Visual interpretation of **Fig. 44** has revealed that the lowest seasonal rise of 0-2 m is observed in major part of the district. Higher seasonal rise of 2-4 m is observed as rim around the water level depths in the range of greater than 4 m bgl in the extreme Eastern part of the district. The highest seasonal rise of greater than 4 metres is observed in and around Laldhang areas only. seasonal fall of 0 to 2 m bgl is observed as elliptical patches in the central portion (Bahadrabad-Imlikhera-Bhagwanpur-Libberhedias) of the district.

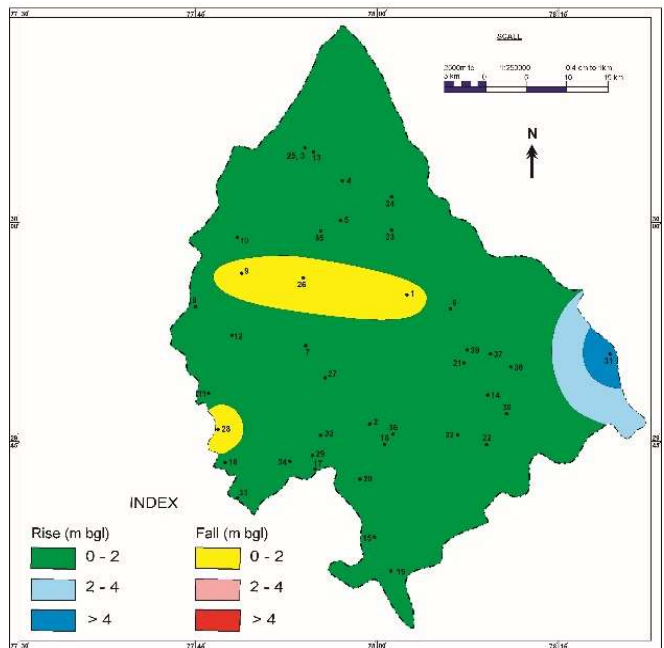


Figure 44: Water Level Fluctuation Map (May 2019 vs November 2019), Haridwar District

A perusal of **Fig. 45** has shown that the lowest positive seasonal fluctuation of 0-2 m is observed in major part of the section. Higher seasonal rise of 2-4 m is observed as isolated patches in and around Peeplichauraha-Shenkhera-Pritampur-Jaspur-patrapur-Angadpur(Udhamsingh Nagar district) , Bnabasa (Champawat district) and Khatbans (Nainital district). The highest seasonal rise of water level (>4 m) is observed as patches in and around BarkharePande and Dhobiys areas of the section. The lowest seasonal decline of 0-2 m is observed as patches in and aroundramnagar-Belparao (Nainital district) and Kamariapakki (Udham Singh Nagar district).

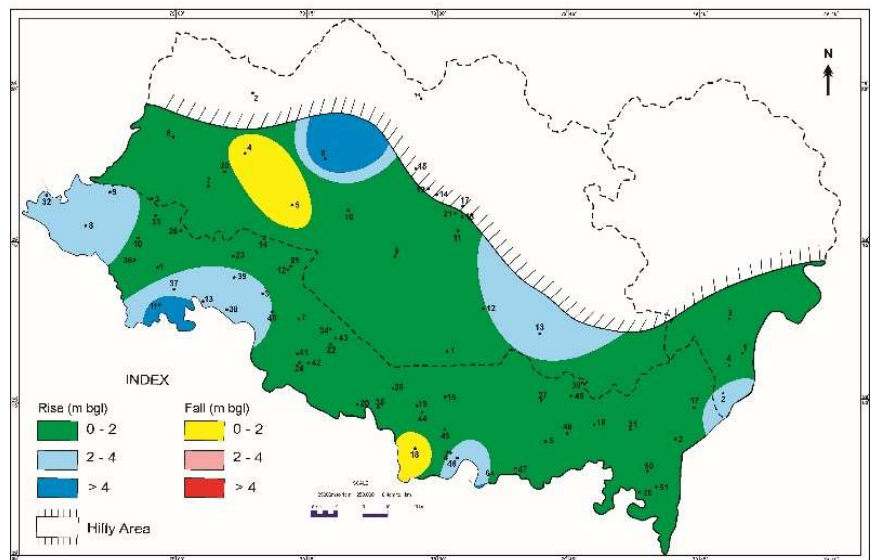


Figure 45: Water Level Fluctuation Map (May 2019 vs November 2019), US Nagar – Nainital - Champawat Section

Table 21. Seasonal Water Level Fluctuation (May 2019 versus November 2019)

<i>District</i>	<i>No. of stations analyzed</i>	<i>Fluctuation (m)</i>				<i>Rise (m)</i>						<i>Decline (m)</i>					
		<i>Rise</i>		<i>Decline</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>		<i>0-2</i>		<i>2 to 4</i>		<i>>4</i>	
		<i>Min</i>	<i>Max</i>	<i>Min</i>	<i>Max</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>	<i>No</i>	<i>%</i>
Dehradun	37	0.23	4.965	0.58	3.81	15	40.54	16	43.24	3	8.11	2	5.41	1	2.70	0	0.00
Haridwar	33	0.05	6.455	0.12	0.995	18	54.55	0	0.00	1	3.03	4	1.00	0	0.00	0	0.00
Udham Singh Nagar	43	0.08	5.785	0.48	1.27	30	69.77	7	16.28	2	4.65	4	9.30	0	0.00	0	0.00
Nainital	11	0.285	5.945	0.14	1.875	5	45.45	1	9.09	1	9.09	4	36.36	0	0.00	0	0.00
Champawat	3	0.78	10.75	-	-	1	33.33	1	33.33	1	33.33	0	0.00	0	0.00	0	0.00
Uttarkashi	7	0.775	8.725	0.435		5	71.43	0	0.00	1	14.29	1	14.29	0	0.00	0	0.00
Total	134					74	55.22	25	18.66	9	6.72	15	11.19	1	0.75	0	0.00

5.4.3.3 Water Level Fluctuation (May 2019 versus January 2020)

The seasonal water level fluctuation for the period May 2018 versus January 2019 is available for 124 monitoring wells in Uttarakhand State. The water level fluctuation data is given in **Table 22**. A perusal of the table indicates that the minimum rise was 0.085metres atBahabalpur in Haridwardistrictwhile the maximum rise was 11.175metres atChandmari in Dehradun district. The minimum seasonal decline in ground water level was 0.02 m at Shahidwala Grant in Haridwar District while the maximum decline was 4.04 m at Majra in Dehradun District.

A perusal of **Table 22** also reveals that that the lowest seasonal rise of 0-2 m was shown by 95 monitoring wells (70.90% of total) whereas higher rise of 2-4 m was shown by 16 wells (11.94% of total). The highest seasonal rise of >4 m was shown by 7 wells, which was 5.22% of the total wells. Seasonal decline in the range of 0-2 m was shown by 11 monitoring wells (8.21% of total) while higher decline of 2-4 m was shown by 4 wells (2.99% of total). The highest decline of >4 m was recorded by only 1 monitoring well (0.75% of total) for which the data is available in Uttarakhand State during the period May 2019 versus January 2020.

Interpretation of **Fig. 46** indicates that the minimum decadal rise of 0-2 m is observed in major part of the Doon valley. The seasonal rise of 2-4 m is observed as isolated patches in and around Kunawala-Shankarpur-Redapur areas only. The zone of seasonal rise of water level showing fluctuation in the range of greater than 4 metres is observed in and around Chandmari areas of the section. The lowest seasonal decline of 0-2 m is observed as isolated patches in and around Judli-KhadairiKhadakmaaf areas only. The seasonal decline in the range of 2 to 4metresbglis observed as isolated patch around Dhakrani areas only.

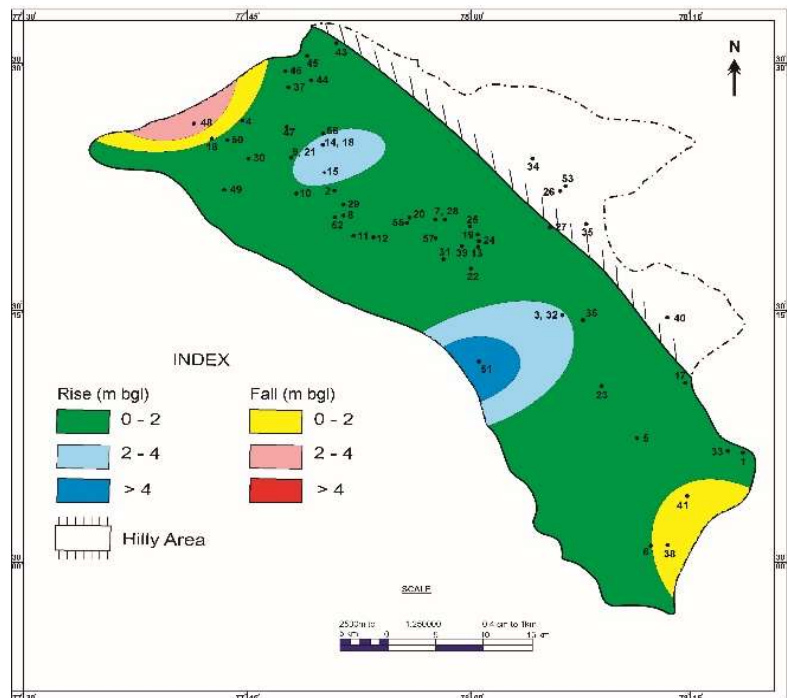


Figure 46: Water Level Fluctuation Map (May 2019 vs January 2020), Dehradun District

Visual interpretation of **Fig. 47** has revealed that the lowest seasonal rise of 0-2 m is observed in major parts of the district. Higher seasonal rise of 2-4 m is observed as isolated patches around Iqbalpur and also in the extreme eastern part of the district. The highest seasonal rise of >4 m is observed around Laldhang. The lowest seasonal decline of 0-2 m is observed around Bahadrad-Bhagwanpur areas of the district.

Visual interpretation of **Fig. 48** has shown that the minimum seasonal rise of 0-2 m is observed in major part of the district. Higher seasonal rise of 2-4 m is observed as isolated patches around peeplicghauraha-Shenkhera- Bharatpur- Patrampur (Udhm Singh Ngar district) Khatbans (Nainital district) and Banbasa (Champawat district). The seasonal decline of >4 m bgl m is observed as isolated patches around Bhagwnapur-

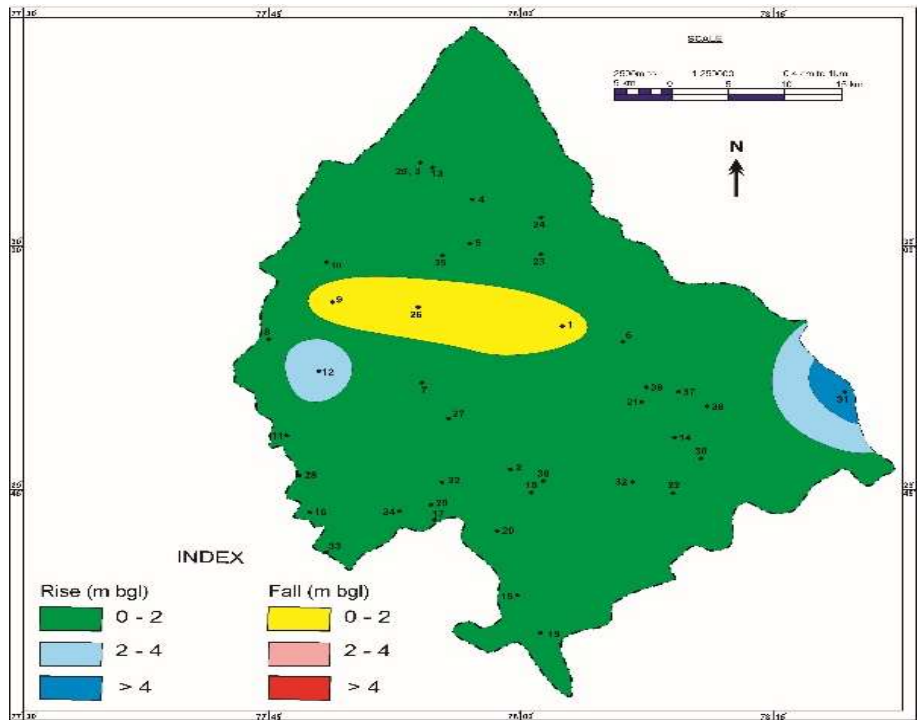


Figure 47: Water Level Fluctuation Map (May 2019 vs January 2020), Haridwar District

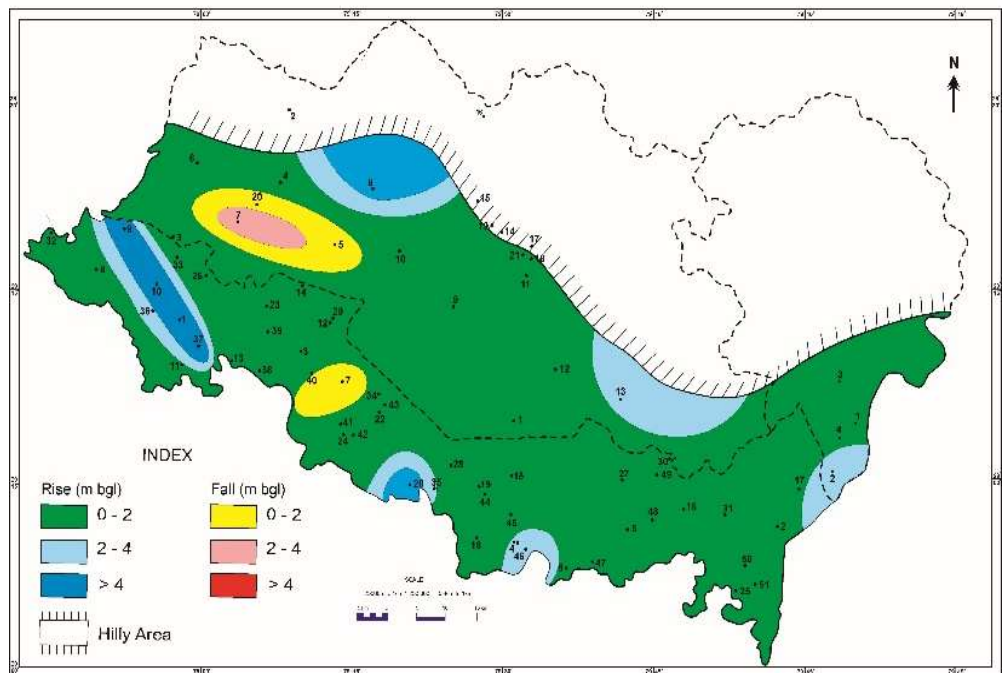


Figure 48: Water Level Fluctuation Map (May 2019 vs January 2020), US Nagar – Nainital - Champawat Section

Missarawala (Udham Singh Nagar district) and Dhoniya (Nainital district).The seasonal decline in the range of 0-2 m bgl is observed as isolated patches in and around Beria Daulat- Belaparao areas of the section.the seasonal decline in the range of 2-4 m bgl is observed as ptches in and around Peer Madara areas only.

Table 22. Seasonal Water Level Fluctuation (May 2019 versus January 2020)

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	37	0.095	11.175	0.68	4.04	23	62.16	7	18.91891892	2	5.41	2	5.41	2	5.41	1	2.70
Haridwar	33	0.085	8.37	0.02	0.37	26	78.79	1	3.03	1	3.03	5	1.00	0	0.00	0	0.00
Udham Singh Nagar	43	0.12	6.09	0.365		34	79.07	6	13.95	2	4.65	1	2.33	0	0.00	0	0.00
Nainital	11	0.2	5.95	0.345	2.05	6	54.55	1	9.09	1	9.09	2	18.18	1	9.09	0	0.00
Champawat	3	0.355	7.74	0		1	33.33	1	33.33	1	33.33	0	0.00	0	0.00	0	0.00
Uttarkashi	7	0.79	1.24	0.17	3.375	5	71.43	0	0.00	0	0.00	1	14.29	1	14.29	0	0.00
Total	134					95	70.90	16	11.94	7	5.22	11	8.21	4	2.99	1	0.75

CHAPTER 6

HYDROCHEMISTRY

Monitoring of groundwater quality is very important as this determines the suitability of groundwater for various purposes like domestic, agricultural and industrial use and also for deciphering the water quality trends in space and time. Analysis of hydrochemical data also helps in evaluating the nature and extent of groundwater pollution and to ascertain the effectiveness of pollution control measures already in existence.

One hundred and eighty six (186) water samples collected during pre-monsoon period (May 2019) for Normal, Heavy and Arsenic analysis were deposited at Chemical Laboratory, North Region, Lucknow. The water samples were collected from ground water monitoring stations like dug wells, hand pumps and springs in Dehradun, Haridwar, Pauri Garhwal, Udham Singh Nagar, Nainital, Almora, Champawat and Uttarkashi districts. The result of chemical analysis is given in *Table 23*

6.1 Analytical Results and Discussions

The chemical quality of groundwater of shallow and deep aquifers in Uttarakhand State varies widely depending on physiography, soil texture and geology of the area. The aquifers are mostly dominated by Ca-Mg-HCO₃ and Ca-HCO₃ types of groundwater. The general chemical quality reveals that most of the wells contain low dissolved mineral contents and hence, groundwater in Uttarakhand state is fresh and potable. The chemical quality of groundwater with respect to Electrical Conductivity (EC), chloride (Cl), nitrate (NO₃) and fluoride (F) are given separately.

Table 23: Ground Water Chemical Quality Data of Uttarakhand State for Pre-monsoon 2019

Sl.No	Sample Location	Conductivity $\mu\text{mho/cm}$ at 25°C	CO ₃	HCO ₃	Cl	F	NO ₃	SO ₄	Hardness as CaCO ₃	Ca Hardness	Mg Hardness	Na	K	SiO ₂
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
District Dehradun														
1	Khandgaon	757	0	322	50	0.28	0	43	28	9	1	160	1.6	7.1
2	Khadiri (KhadakMaf)	353	0	137	21	0.06	1	33	155	28	20	10	1.0	4.8
3	Rishikesh	320	0	111	14	0.06	5	43	145	40	11	7	1.1	7.8
4	Lal Tappar	452	0	154	14	0.05	10	69	212	48	22	6	1.1	8.3
5	Kotimachak	180	0	73	7	0.2	11	11	70	16	7	9	1.0	9.9
6	Chandmari	550	0	165	7	0.06	0	127	265	52	32	5	1.5	4.3
7	Duggiawala	139	0	54	7	0.03	0	15	34	10	2	16	1.0	3.0
8	Mathrowala	636	0	204	21	0.06	1	116	291	72	27	12	1.9	4.4
9	Kuanwala	294	0	93	14	0.07	8	43	130	28	14	7	1.8	10.6
10	Gularghagti	649	0	133	7	0.11	6	193	316	62	39	3	1.4	5.2
11	Soda Saroli	213	0	77	7	0.14	9	25	80	22	6	12	1.7	10.0
12	Maldeota	2091	29	150	113	0.51	1	684	83	18	9	440	10.0	0.7
13	Nanurkhera	544	0	262	21	0.07	11	20	260	43	36	6	0.9	4.7
14	TarlaNagal	529	0	254	14	0.18	11	27	255	72	18	4	0.9	6.7
15	Purukulgaon	392	0	142	7	0.08	7	62	182	48	15	6	0.8	6.2
16	Bhatta	540	0	214	14	0.02	6	70	255	35	40	6	1.4	3.4
17	Majra	724	0	232	14	0.03	17	133	335	51	50	12	1.0	9.7
18	Harbanswala	667	0	262	28	0.03	18	62	312	67	35	9	0.9	9.7
19	Dudhli	311	0	146	21	0	1	5	131	23	18	11	1.4	2.3
20	Badawali	344	0	159	7	0.05	3	28	136	48	4	16	1.1	12.3
21	Kanwali	788	0	336	7	0	38	77	345	94	27	22	1.3	8.5

22	Singhniwala	588	0	256	14	0	20	47	273	48	37	9	1.4	9.7
23	Baronwala/Badowala	658	0	244	21	0.08	22	78	311	43	49	8	1.0	7.7
24	Ramgarh	659	0	238	21	0.12	18	86	310	86	23	9	1.2	10.5
25	Jhajra	325	0	146	21	0.08	7	6	143	43	9	9	1.2	9.3
26	Nanda ki Chowki	315	0	143	21	0.01	3	8	94	10	17	26	6.0	5.4
27	Khandoli	65	0	31	4	0.09	0	3	22	2	4	5	0.0	13.0
28	Selakui	188	0	57	14	0	11	18	66	20	4	12	1.0	12.2
29	Sabhawala	360	0	122	21	0.09	34	23	133	24	17	16	10.1	7.9
30	Rampura	190	0	73	7	0	2	22	73	19	6	10	1.0	10.1
31	Shankarpur	143	0	63	7	0.07	2	9	50	10	6	10	0.8	12.4
32	Redapur	107	0	44	7	0.08	5	3	29	10	1	11	0.7	17.3
33	Chhorba	106	0	46	7	0	1	5	28	10	1	11	0.7	8.1
34	Telpura	589	0	231	14	0	18	68	275	52	35	9	1.0	7.7
35	Badripur	300	0	142	14	0.07	2	12	130	43	6	9	1.0	12.5
36	Judli	380	0	216	7	0.04	0	3	150	48	7	18	1.0	10.4
37	Herbertpur	196	0	70	7	0.07	11	21	78	28	2	9	1.1	11.7
38	Vikas Nagar	209	0	72	7	0.14	9	27	90	28	5	6	1.0	9.5
39	Dharmawala	270	0	133	7	0.07	12	6	105	40	1	13	2.6	12.6
40	Dakpatthar	369	0	165	7	0.09	7	33	144	43	9	18	1.7	6.6
41	Barothiwal	125	0	61	7	0.01	0	4	42	11	3	9	0.7	7.7
42	Dhakrani	126	0	50	7	0.13	0	12	50	14	3	5	0.9	3.7
43	Timli	196	0	76	7	0.01	0	26	78	25	4	8	2.3	6.4
44	Baluwala	122	0	57	7	0.04	0	4	40	12	2	9	0.7	4.1
45	Luxmipur	111	0	24	4	0.05	3	29	35	14	0	9	0.6	9.8
46	Haripur	318	0	142	7	0.15	9	24	125	41	5	14	2.1	7.4
District Haridwar														
47	Sahidwala Grant	404	0	201	7	0.16	26	7	189	68	5	6	1.0	8.2
48	Budhwa Shahid	531	0	271	14	0.06	21	6	245	86	7	9	1.5	8.0
49	Bugawala	396	0	204	14	0	0	10	169	48	12	12	2.5	6.6
50	Bahabalpur	481	0	264	14	0.07	2	5	168	56	7	33	1.7	8.6

51	Bhagwanpur	495	0	268	14	0.56	0	6	63	20	3	85	0.6	9.2
52	Chudiala	379	37	122	14	0.44	0	6	143	43	9	20	2.4	10.1
53	Iqbalpur	621	0	305	21	0.42	11	21	172	52	10	60	7.4	10.8
54	Jaswawala	598	0	337	14	0.31	0	2	200	38	25	44	2.1	9.3
55	Kota Muradnagar	1659	0	397	220	0.09	60	140	345	77	37	220	7.0	10.1
56	Bandarjud	554	0	294	14	0.04	16	3	226	58	20	23	1.6	10.3
57	Rathora	559	0	315	14	0.02	0	2	215	58	17	29	1.7	10.7
58	Bahadrabad	291	0	138	7	0.28	0	21	135	42	7	5	0.6	4.8
59	Sarai	665	0	244	28	0	63	43	284	96	11	23	1.4	11.0
60	Dhanpura	714	0	259	35	0.08	57	48	285	76	23	30	5.4	9.3
61	Shahpur Shitlakhera	751	0	281	35	0.11	58	47	275	72	23	25	36.0	8.3
62	Laldhang	619	0	249	21	0	30	50	256	86	10	23	2.0	7.4
63	Bhogpur	958	0	366	57	0.04	24	77	290	91	15	46	70.0	10.0
64	Dalupuri	525	0	248	14	0	8	32	235	81	8	12	2.2	6.3
65	Panjaheri	390	0	171	14	0	6	29	153	38	14	17	4.5	4.9
66	DudhyaDayalwala	455	0	216	14	0.01	0	30	175	67	2	23	2.1	10.1
67	Shyampur	535	0	246	14	0	13	34	240	76	12	11	3.1	7.7
68	Imlikhera	505	0	276	14	0.14	1	5	82	20	8	77	2.0	8.4
69	Sikhar	382	0	187	7	0.04	20	12	147	38	12	18	4.2	14.4
70	KheraJat	1231	0	481	78	0.13	42	74	302	91	18	85	100.0	13.8
71	Nizampur	567	0	275	14	0.02	12	31	262	76	17	8	3.9	13.3
72	Jhabreda	516	0	275	14	0.51	4	8	190	48	17	28	5.4	11.3
73	Landhaura	547	0	275	14	0.12	22	12	212	57	17	27	3.1	13.0
74	Lakhnauta	562	0	264	14	0.04	20	28	257	72	19	9	3.6	12.3
75	Gurukul Narsen	307	0	124	7	0.17	0	40	140	38	11	4	3.0	10.6
76	Libhrahedi	238	0	104	7	0.24	0	24	105	33	5	4	3.7	7.4
77	Mudlana	704	0	329	21	0.19	31	26	284	100	8	30	4.3	13.2
78	Hussainpur	513	0	287	14	0.03	0	3	183	60	8	32	4.6	11.2
79	Laksar	830	0	397	35	0.01	2	37	267	72	21	66	6.7	9.5

80	Bhikkampur	730	0	327	43	0.14	15	24	213	72	8	57	22.0	6.5
81	Govardhanpur	661	0	376	14	0.08	0	3	135	48	4	87	5.0	10.1
82	Dallawala	528	19	188	43	0.17	1	16	60	14	6	88	10.0	8.9
83	Khanpur	507	0	274	14	0.37	0	8	58	16	4	87	5.5	8.7
84	Dandi Ibrahimpur *	605	0	232	14	0.07	35	62	212	84	1	38	6.4	8.7
District Pauri Garhwal														
85	Kaudia (Kotdwar)	600	0	244	28	0	41	26	262	93	7	17	1.5	6.9
86	Ramdayanpur	360	0	193	14	0	0	2	155	52	6	11	1.8	5.2
District Uttarkashi														
87	Chinyalisaur	412	0	142	28	0.17	32	23	70	18	6	61	3.5	7.0
88	Devidhar	277	0	133	14	0.14	0	9	110	28	9	13	0.8	6.5
89	Uttarkashi	311	0	107	28	0	14	16	106	28	8	19	6.6	8.5
90	Dharasu	329	0	165	14	0	0	9	130	48	3	11	8.9	8.4
91	Barkot	307	0	159	14	0.1	0	3	123	43	4	14	0.3	7.9
92	Sharukhet	227	0	123	7	0	0	3	27	8	2	40	0.0	2.3
93	Ganeshpur	89	0	38	4	0	0	8	40	10	4	0	3.3	2.8
94	Maneri	226	0	82	7	0.35	0	35	23	6	2	40	3.0	3.7
95	Nagal	152	0	73	7	0	0	7	55	20	1	9	0.0	5.7
96	Ratodi Sar	166	0	73	7	0	5	10	60	24	0	10	1.0	8.0
97	Charethi HP *	201	0	72	7	1.44	0	29	50	14	4	20	7.0	5.4
98	GangananiSpring outlet 1	1100	0	488	71	4.42	2	36	71	19	6	210	20.0	37.1
99	Ganganani Spring outlet 2	901	0	384	64	3.49	6	32	75	24	4	165	15.0	28.7
District Nainital														
100	KhaatBaans	515	0	268	14	0.08	11	10	183	42	19	34	1.4	6.9
101	Lalkuan	443	0	220	14	0.14	5	17	155	42	12	29	2.7	12.5
102	Kaladungi	578	0	250	7	0.05	7	68	156	62	0	61	1.2	7.9
103	Kathgodam	528	0	244	21	0.09	16	21	215	62	14	20	4.1	6.6
104	Belparao	343	0	98	14	0.08	0	69	50	16	2	56	1.3	1.5

105	PeeruMadara	412	0	195	14	0	13	16	138	52	2	30	2.1	7.6
106	Maldhan Colony	443	0	237	14	0.21	0	7	171	51	11	23	0.8	10.4
107	Dhela	364	0	172	14	0.03	3	18	127	51	0	24	2.6	5.5
108	Ram Nagar	516	0	277	14	0	8	5	186	48	16	31	3.2	8.7
109	Garjiya	363	0	172	14	0.09	1	19	109	38	3	32	2.3	5.5
110	Dohniya	368	0	116	14	0.08	0	66	63	18	4	56	1.1	1.6
111	Chilkiya	363	0	171	14	0.14	3	18	125	48	1	25	2.6	5.5
112	Amritpur (Ranibagh)	315	0	169	7	0.05	0	9	102	38	2	25	1.4	12.8
113	Salari	213	0	105	7	0.02	3	7	73	25	2	15	1.0	6.0
114	Dogaon	398	0	224	7	0	0	5	170	57	6	13	1.4	6.0
115	SipahiDhara	630	0	195	21	0.05	8	118	288	48	41	12	2.7	3.3
116	Garampani	281	19	93	14	0.19	0	12	109	20	14	14	1.1	12.9
117	Jyolikot	439	0	188	14	0.01	6	39	214	33	31	2	0.8	2.6
118	Kudaghat (KudaPahar)	642	0	195	21	0.01	10	118	291	52	39	12	3.0	3.2
District Almora														
119	PataliTalla	403	0	159	28	0	19	16	179	62	6	10	1.1	8.4
120	PataliMalla	292	0	136	14	0	4	11	89	24	7	25	1.7	7.8
121	Baniya Diggi	239	0	110	14	0.09	5	5	88	24	7	14	1.4	9
122	Katarmal	255	0	75	21	0.14	21	18	89	28	4	15	4.6	15
123	Dharanaula	569	0	116	64	0.09	70	37	120	46	1	66	11.0	13
124	Palna	164	0	63	14	0.16	7	4	60	24	0	9	1.7	16
125	Jholi	140	0	56	7	0.05	5	10	49	16	2	9	1.9	11
126	Itola	144	0	71	7	0.07	4	1	54	19	2	8	1.0	11
127	Chanoda	165	0	88	7	0.1	0	0	75	19	7	3	0.5	7
128	Guruda-I	98	0	47	7	0.19	0	0	47	19	0	1	0.1	4
129	ChhaniBartola	85	0	46	4	0.06	0	0	37	14	0	2	1.0	4
130	Dhansari	498	0	198	28	0.17	21	29	135	50	2	48	7.6	11
131	Deepakot	234	0	87	21	0.22	15	4	70	24	3	21	1.6	17
132	Dhalnagaon	548	0	129	85	0.22	21	30	161	62	1	47	7.8	11

133	Simalkhet	534	0	220	28	0.26	21	29	155	52	6	48	7.5	10
134	Peepal Dhar	350	0	113	35	0.09	25	12	125	41	6	21	1.7	13
135	Naula	484	0	183	32	0.18	21	30	130	41	6	47	7.7	11
136	Mehragaon (Someshwar)	152	0	61	14	0.04	8	0	73	24	3	1	0.2	4
137	Lodh	139	0	73	7	0.09	2	0	55	19	2	6	1.0	9
138	Bhoolgaon SP	560	0	259	21	0.2	32	12	240	62	20	10	15.0	5
District Udham Singh Nagar														
139	Kanchanpur (Majhola) HP	461	0	257	14	0.16	0	0	137	43	7	41	2.7	12
140	Khatima	780	0	285	43	0.44	76	33	235	76	11	63	16.0	11
141	Sarasariya	494	0	281	7	0.25	1	5	155	52	6	41	1.7	8
142	Chakarpur	536	0	273	21	0.07	7	8	241	67	18	12	1.0	7
143	Barianjaniya	439	0	238	11	0.36	0	8	204	72	6	6	1.4	8
144	Sitarganj	393	0	232	7	0.12	2	6	177	58	8	8	1.2	9
145	Nanak Mata	530	0	277	7	0.63	7	23	197	62	10	28	6.8	10
146	Kalyanpur	391	0	206	14	0.11	2	6	177	54	10	9	1.3	9
147	Tukri	411	0	216	14	0.24	1	7	174	56	8	14	1.0	10
148	Begur Mod	358	0	187	14	0.18	0	6	150	48	7	12	1.2	11
149	Bidora	531	0	256	7	0.09	21	29	155	57	3	47	6.9	11
150	Dhyanpur	391	0	207	14	0.17	0	6	170	53	9	12	1.2	9
151	Bara	439	0	220	14	0.41	0	18	155	43	11	30	0.8	10
152	Kichha	423	0	183	21	0.36	0	33	179	43	17	14	1.8	10
153	KamariaPakki	191	0	81	21	0.08	0	1	90	29	4	3	0.7	5
154	Gangapur	483	0	244	14	0.11	1	21	227	48	26	6	1.8	8
155	Shantipuri	477	0	224	14	0.32	0	33	207	62	12	13	1.9	10
156	PattharChatta	440	0	193	28	0.14	4	18	200	62	11	8	2.5	13
157	Rudrapur	356	0	157	21	0.12	5	15	157	48	9	9	1.9	12
158	Kanakpur	448	0	221	21	0.23	0	12	195	67	6	13	1.0	13
159	Rajpura	535	0	246	21	0.28	0	33	237	72	14	14	1.8	11

160	Pipaliya	408	0	193	14	0.29	1	24	179	48	14	11	1.4	12
161	Jhagarपुर	570	0	282	7	0.21	0	42	243	43	33	18	1.9	12
162	Mahabir Nagar	560	0	264	14	0.21	0	42	243	33	38	16	1.7	10
163	Beria Daulat	503	0	228	14	0.2	2	41	229	29	38	10	1.6	9
164	Bhagwanपुर	375	0	179	14	0.3	5	15	165	33	20	9	2.1	12
165	Pattharpui	513	0	253	7	0.21	0	37	220	32	34	16	1.8	11
166	Lalpuri	553	0	256	14	0.15	1	44	256	38	38	9	1.6	10
167	Bazpur	886	0	407	21	0.47	50	36	373	48	61	29	6.1	11
168	Jharkhandi	666	0	343	7	0.12	6	36	313	33	55	9	1.2	9
169	Jogipura	612	0	317	7	0.22	5	31	281	38	45	11	1.5	11
170	BannaKhera	675	0	342	14	0.18	5	32	311	38	52	11	1.5	11
171	Pritpur	644	0	322	14	0.25	5	32	296	35	50	11	1.5	11
172	Badaripur	772	0	378	21	0.21	0	44	336	43	55	22	2.8	8
173	BarkharePande	471	0	251	14	0.41	0	8	155	43	12	36	1.7	10
174	Sultanपुर Patti	461	0	201	21	0.16	3	32	210	53	19	9	1.1	11
175	Kashipur	458	0	183	25	0.2	2	42	209	52	19	9	1.1	11
176	Bharatपुर	836	0	415	43	0.55	0	15	300	27	56	54	2.0	7
177	Dhanauri Patti	523	0	293	7	0.18	1	10	128	41	6	61	0.9	12
178	Durgapur	485	0	281	7	0.31	0	3	190	24	31	23	1.5	8
179	Shand Khera	480	0	262	7	0.12	3	12	230	41	30	5	1.7	10
180	Jaspur	584	29	268	14	1.4	0	1	53	17	2	110	0.9	7
181	Patrampur	500	0	278	14	0.44	0	1	174	43	16	35	0.8	9
182	Angadपुर	510	0	272	21	0.54	0	1	145	38	12	50	1.0	10
183	Missarwala	363	0	203	7	0.2	0	5	128	33	11	24	1.6	11
184	Banbasa	517	0	250	28	0.07	7	8	230	43	30	12	1.0	8
185	Bastia	463	0	229	21	0.06	7	8	205	43	24	12	1.0	8
186	Bichai	481	0	277	7	0.05	0	4	225	52	23	6	2.1	10

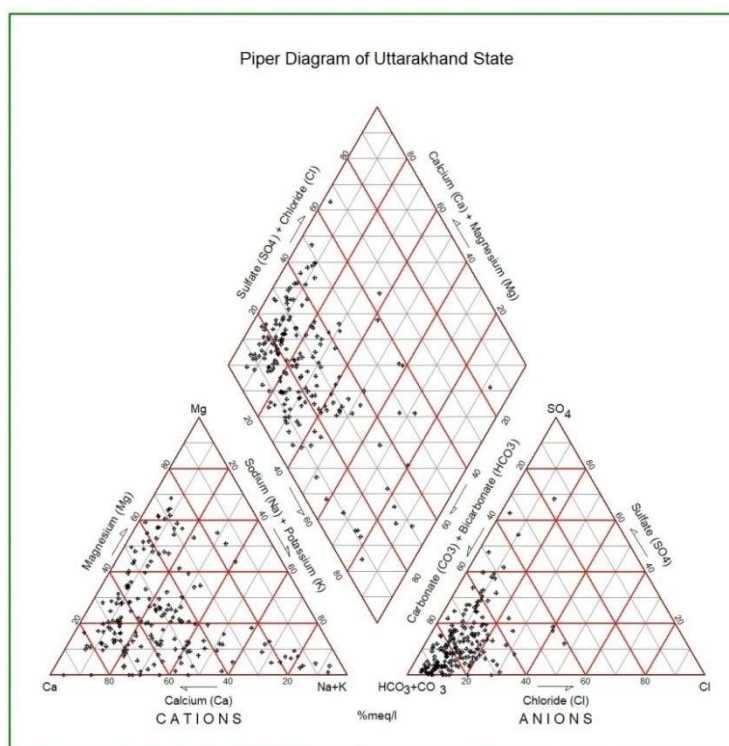


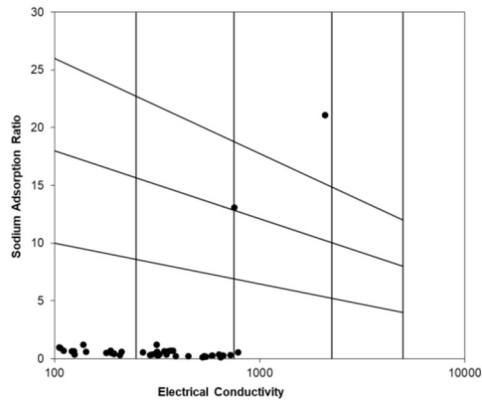
Fig. 49: Piper Diagram showing general chemical quality of Uttarakhand State

Chemical data of representative samples from the NHS samples of Uttarakhand State presented by plotting them on a Piper-tri-linear diagram for pre-monsoon. These diagrams reveal the analogies, dissimilarities and different types of waters in the state, which are identified and listed in Table No. 24.

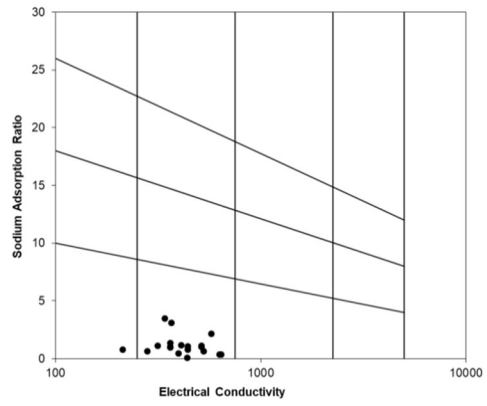
Table 24: Characterization of groundwater of Uttarakhand State on the basis of Piper-Trilinear diagram

Subdivision of the diamond	Characteristics of corresponding subdivisions of diamond-shaped fields	Percentage of samples in this category
1	Alkaline earth (Ca+Mg) exceeds Alkalies (Na+K)	88.70
2	Alkalies exceeds alkaline earths	11.30
3	Weak acids (CO ₃ +HCO ₃) exceeds strong acids (SO ₄ +Cl)	95.70
4	Strong acids exceeds weak acids	4.30
5	Magnesium bicarbonate type	86.55
6	Calcium chloride type	0.54
7	Sodium chloride type	2.15
8	Sodium bicarbonate type	4.84
9	Mixed type (No cation-anion exceed 50%)	5.92

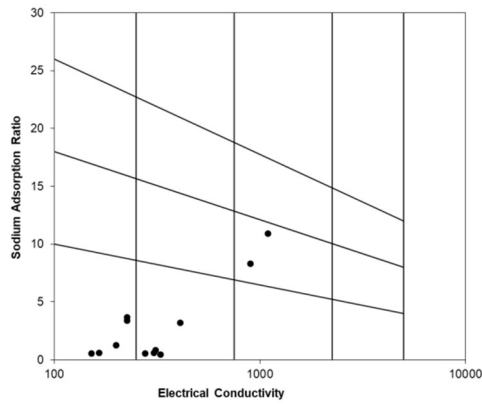
From the above table, it can be easily inferred that the groundwater of Uttarakhand state is dominated by Ca-Mg cations and CO₃-HCO₃ anions.



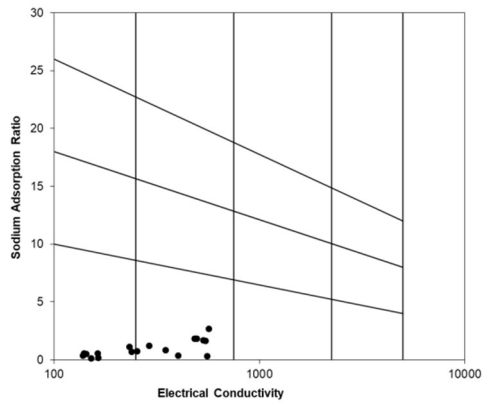
Dehradun district



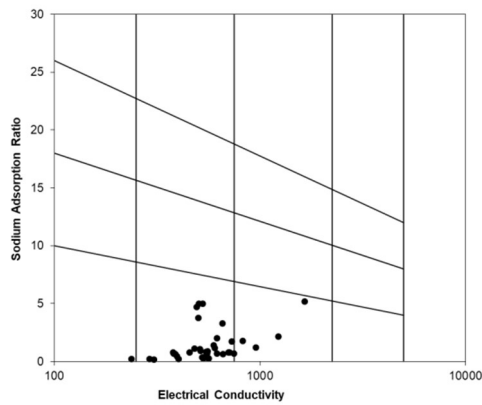
Nainital district



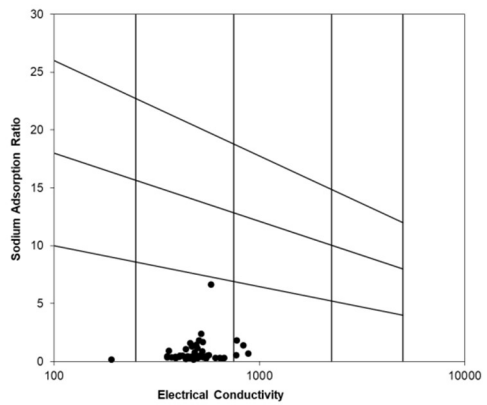
Uttarkashi district



Almora district



Haridwar district



Udham Singh Nagar district

Fig. 50 : U S Salinity Diagram for the NHS pre monsoon samples of Uttarakhand state

Table 25: Characterization of groundwater of Uttarakhand State on the basis of U S Salinity diagram

Sl. No.	Subdivision of the diagram	Percentage of samples in this category	Districts	Interpretation
1	C1S1	16	Almora (40%), Uttarkashi (38%), Dehradun (35%)	Low salinity and Low Sodium hazard
2	C2S1	69	Dehradun (58%), Uttarkashi (46%), Almora (60%), Udaham Singh Nagar (89%), Nainital (94%), Haridwar (87%)	Medium Salinity and Low Sodium hazard
3	C3S1	5	Haridwar (11%), Dehradun (2%), Udham Singh Nagar (8%)	High Salinity and Low Sodium Hazard
4	C3S2	1	Uttarkashi (15%)	High Salinity and Medium Sodium hazard

As per the U S salinity diagram, major ground water samples of Uttarakhand state i.e. Dehradun, Uttarkashi, Almora, Udham Singh Nagar districts is falling in the C2S1 region which indicates its suitability for irrigation purposes on all types of soils. Groundwater in some parts of Almora, Uttarkashi and Dehradun districts fall in C1S1 types i.e. medium salinity and low sodium hazard. Groundwaters that fall within the C1-S1 and C2-S1 region can be used for irrigation on all types of soil with little danger of the development of harmful levels of exchangeable sodium. However, C3-S1 watertypes of high salinity and low sodium content occurred in few parts of Haridwar, Dehradun and Udham Singh Nagar districts and this water could only be used to irrigate certain semi-tolerant crops.

6.1.1 Electrical Conductivity (EC)

The Electrical Conductivity (EC) of groundwater is a measure of the degree of mineralization in it. During Pre-monsoon 2019, EC value observed to vary from a minimum of 65 $\mu\text{S}/\text{cm}$ (at 25⁰C) at Khandoli spring in Dehradun district to a maximum of 2091 $\mu\text{S}/\text{cm}$ (at 25⁰C) at Maldeota also in Dehradun district. The frequency distribution of Electrical Conductivity in Uttarakhand is given in Table 26.

Table 26: Frequency distribution of Electrical Conductivity in Uttarakhand (May 2019)

Electrical Conductivity ($\mu\text{S}/\text{cm}$ at 25°C)	0-250	>250-750	>750-2250	>2250
No. of Samples	35	137	14	0
% of Total No.	18.82	73.65	7.53	0

A study of the above table indicates that majority of the samples (137 out of 186 samples or around 74%) have shown EC in the range of >52-750 $\mu\text{S}/\text{cm}$ at 25°C . Low EC value of 0-250 $\mu\text{S}/\text{cm}$ was found in 35 ground water samples, which is around 19% of the total number of samples. Only 14 samples out of 186 (around 8% of the total number) have shown higher EC value of >750-2250 $\mu\text{S}/\text{cm}$.

A map showing the spatial distribution of EC concentration in Dehradun and Haridwar section of Uttarakhand State is given in Fig. 51 and Fig. 52 respectively while another map showing the spatial variation in the distribution of EC values in Udham Singh Nagar-Nainital section is shown in Fig. 53.

A perusal of these maps indicates that the EC value between 750-2250 $\mu\text{S}/\text{cm}$ is observed as small isolated patches around Kanwali, Maldeota and Khand Gaon in Dehradun district; around Shahpur shitalikhera, Laksar, Bhogpur, Kherajat and Kota Muradnagar in Haridwar district; Badripur and Khatima of Udham Singh Nagar district. Rest of the areas in all the three sections had shown the low EC values in Groundwater samples collected during pre-monsoon, 2019.

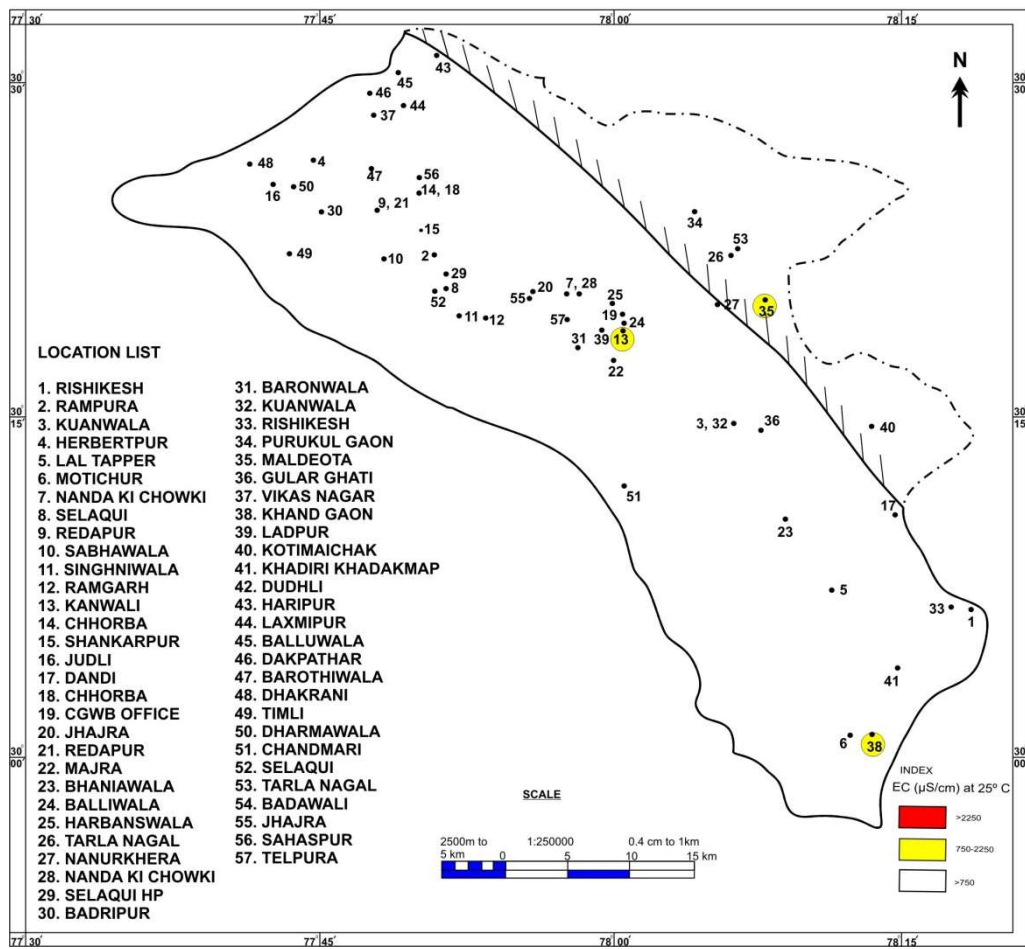


Fig. 51: EC Map of Dehradun District

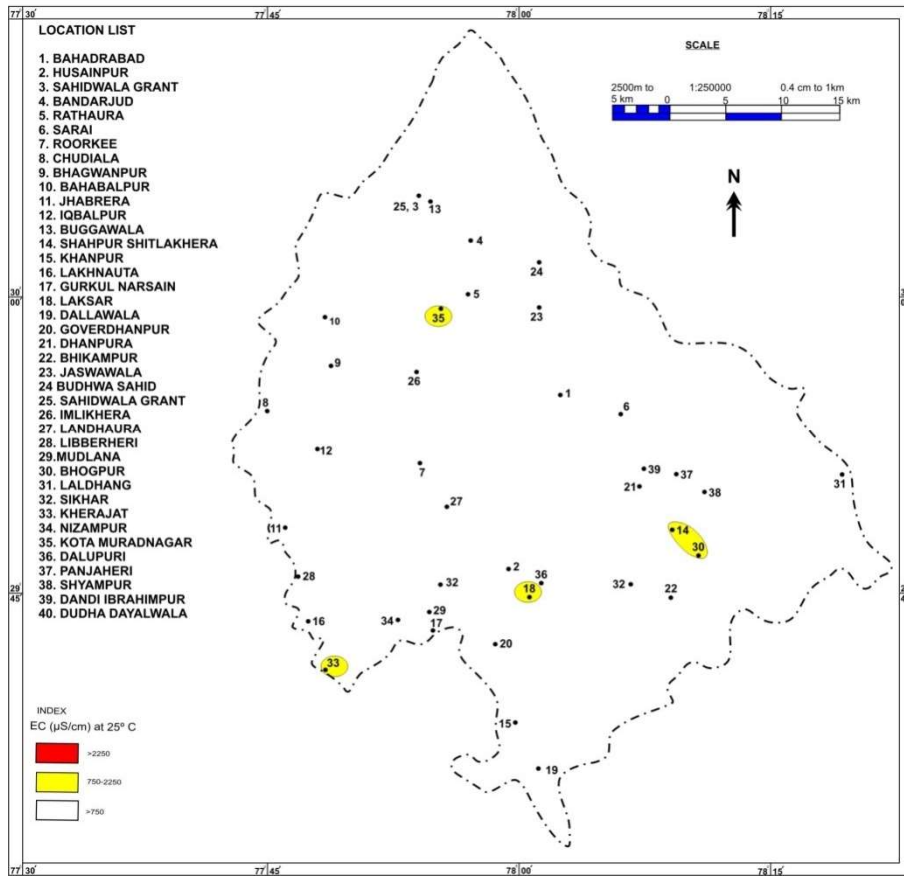


Fig. 52: EC Map of Haridwar District

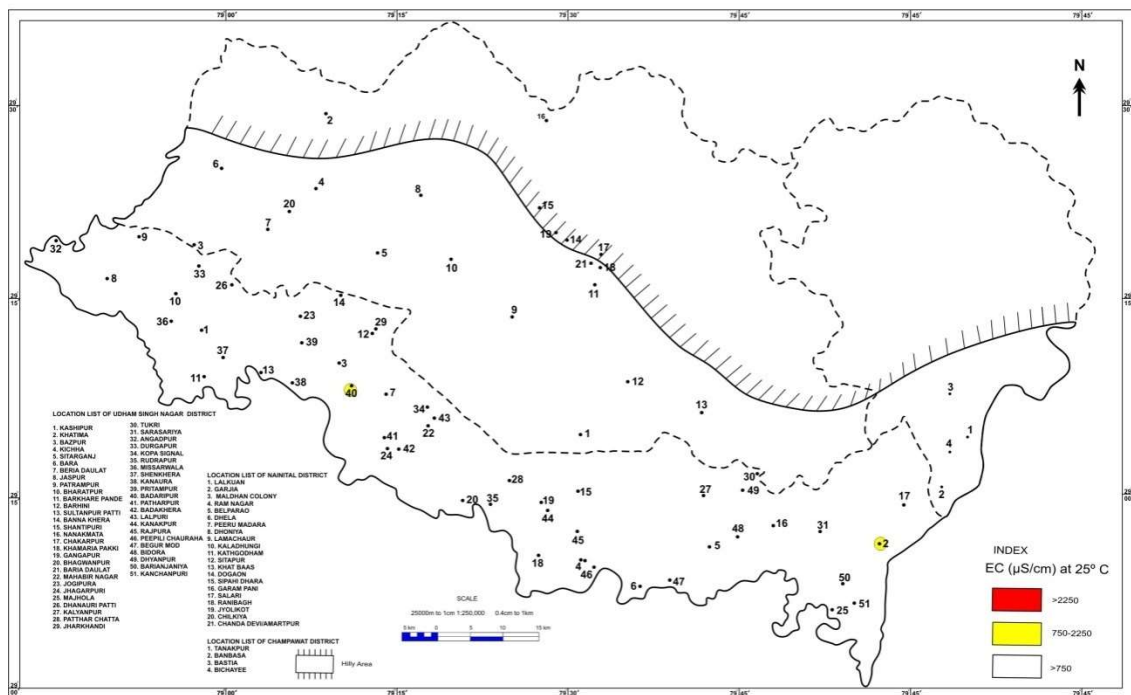


Fig. 53: EC Map of Udham Singh Nagar, Nainital and Champawat Section

6.1.2 Chloride:

The analysis result of one hundred and eighty six (186) ground water samples collected in pre-monsoon 2019 indicates that the highest chloride concentration is observed at Kota Muradnagar (220 mg/L), in Haridwar district. The frequency distribution of chloride concentration in ground water of Uttarakhand State is given in Table 27.

Table 27: Frequency distribution of chloride concentration in ground water

Chloride (mg/L)	0-50	>50-100	>100-150	>150
No. of Samples	178	6	2	0
% of Total No.	95.70	3.22	1.08	0

A study of the above table indicates that majority of samples (178 out of 186 samples or around 69%) have shown chloride concentration in the range of 0–50 mg/L; whereas only six samples (3% of total number) have shown chloride concentration in the range of >50–100 mg/L. It is also observed that only two sample (1% of total) has shown relatively high chloride concentration in the range >100–150 mg/L whereas no sample has shown the highest chloride concentration of >150 mg/L in Uttarakhand State during pre-monsoon 2019. Hence, it can be stated that groundwater is predominantly fresh and potable during pre-monsoon 2019.

A map showing the spatial distribution of chloride concentration in Dehradun and Haridwar section of Uttarakhand State is given in Fig. 54 and Fig 55 respectively while another map showing the spatial variation in distribution of chloride concentration in Udham Singh Nagar-Nainital section is shown in Fig. 56.

A perusal of the figures reveals that very low chloride concentration (0-50 mg/l) in groundwater is observed dominantly in all the three sections i.e Dehradun, Haridwar and Udham Singh Nagar-Nainital section. Relatively high chloride concentration (>50 mg/L) is observed as isolated patches around Khandgaon in Dehradun section; around Kherajat and Bhogpur in Haridwar district. The Highest chloride concentration (100-150 mg/l) is observed only around Maldeota in Dehradun district; Kota Muradnagar in Haridwar district. None of the areas in all the 3 sections has shown chloride value >150 mg /l.

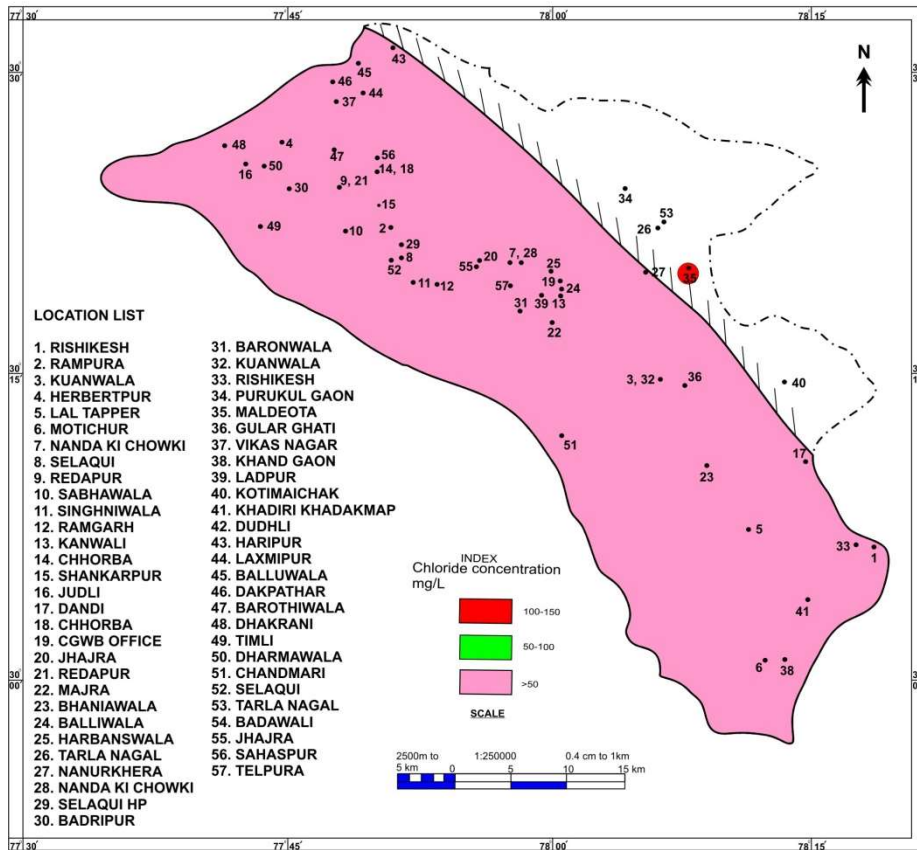


Fig. 54: Chloride Concentration Map of Dehradun District

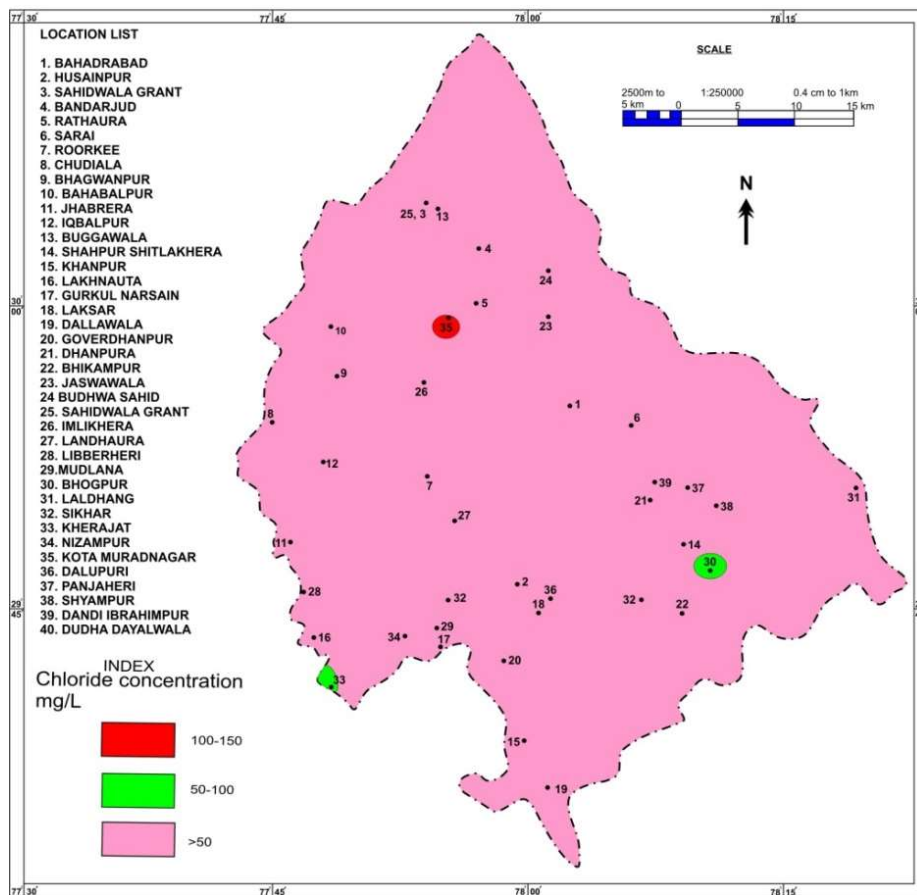


Fig. 55: Chloride Concentration Map of Haridwar District

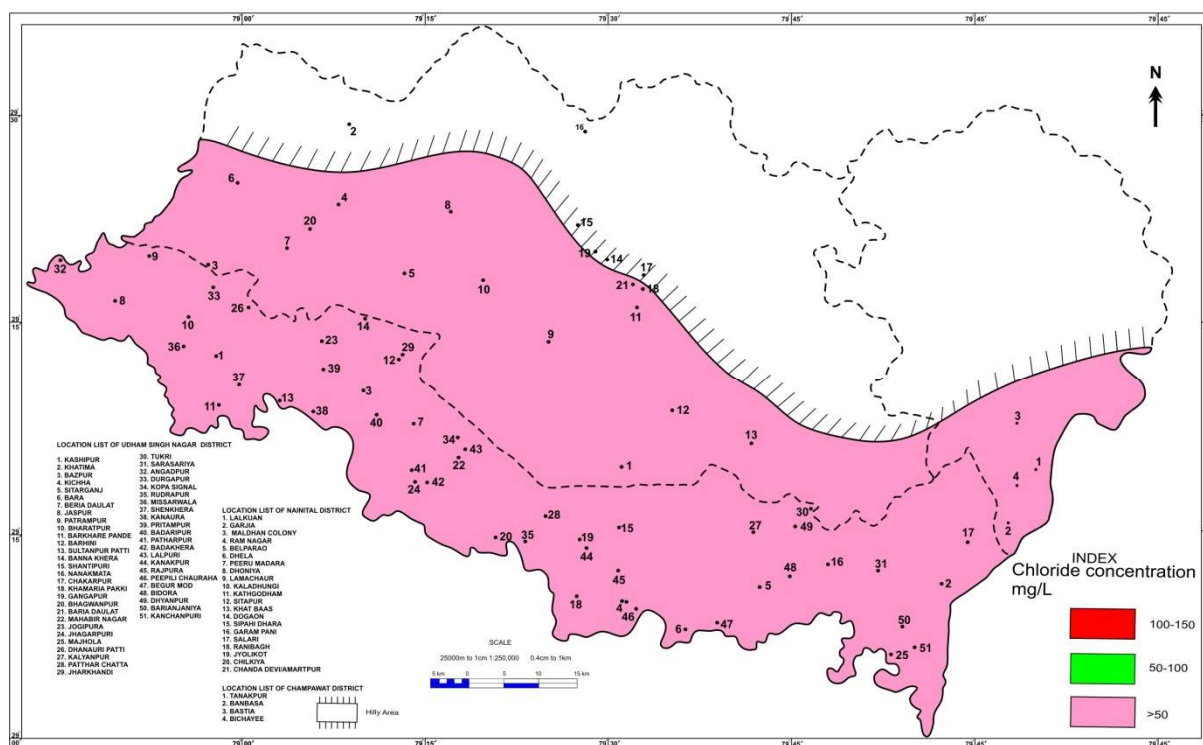


Fig. 56: Chloride Concentration Map of Udham Singh Nagar-Nainital-Champawat Section

6.1.3 Nitrate

Concentration of nitrate in groundwater in Uttarakhand State during premonsoon 2019 is found to be highly variable. The maximum concentration of 70 mg/L is recorded in Khatima, Udham Singh Nagar district. The frequency distribution of nitrate concentration in ground water in Uttarakhand State is given in Table 28.

Table 28: Frequency distribution of nitrate concentration in ground water

Nitrate (mg/L)	<45	45-100
No. of Samples	179	7
% of Total No.	96.24	3.76

A perusal of the above table indicates that majority of samples (179 out of 186 or 96% of total samples) are suitable for drinking purpose as the nitrate concentration in these samples is below the Acceptable Limit of 45 mg/L (BIS, IS 10500, 2009). Higher nitrate concentration of 45–100 mg/L is found only in 7 samples (4% of total) viz. at Kota Muradnagar, Sarai, Dhanpura, Shahpur Shitalikhera in Haridwar district, Dharanaula spring in Almora district and Khatima, Bazpur at Udham Singh Nagar district.

A map showing the spatial distribution of chloride concentration in Dehradun and Haridwar section of Uttarakhand State is given in Fig. 57 and Fig 58 respectively while another map showing the spatial variation in distribution of chloride concentration in Udham Singh Nagar-Nainital section is shown in Fig. 59.

Visual interpretation of Fig. 58 indicated that no area in Dehradun has shown Nitrate concentration higher than the Acceptable Limit of 45 mg/L. On the other hand, visual interpretation of Fig. 59 and 60 indicates that high Nitrate concentration (>45 mg/L) is found in and around Kota Muradnagar, Sarai and southeastren part of haridwar in and around Dhanpura; Khatima and Bazpur area of Udham Singh Nagar also showing high Nitrate concentration (>45 mg/L).

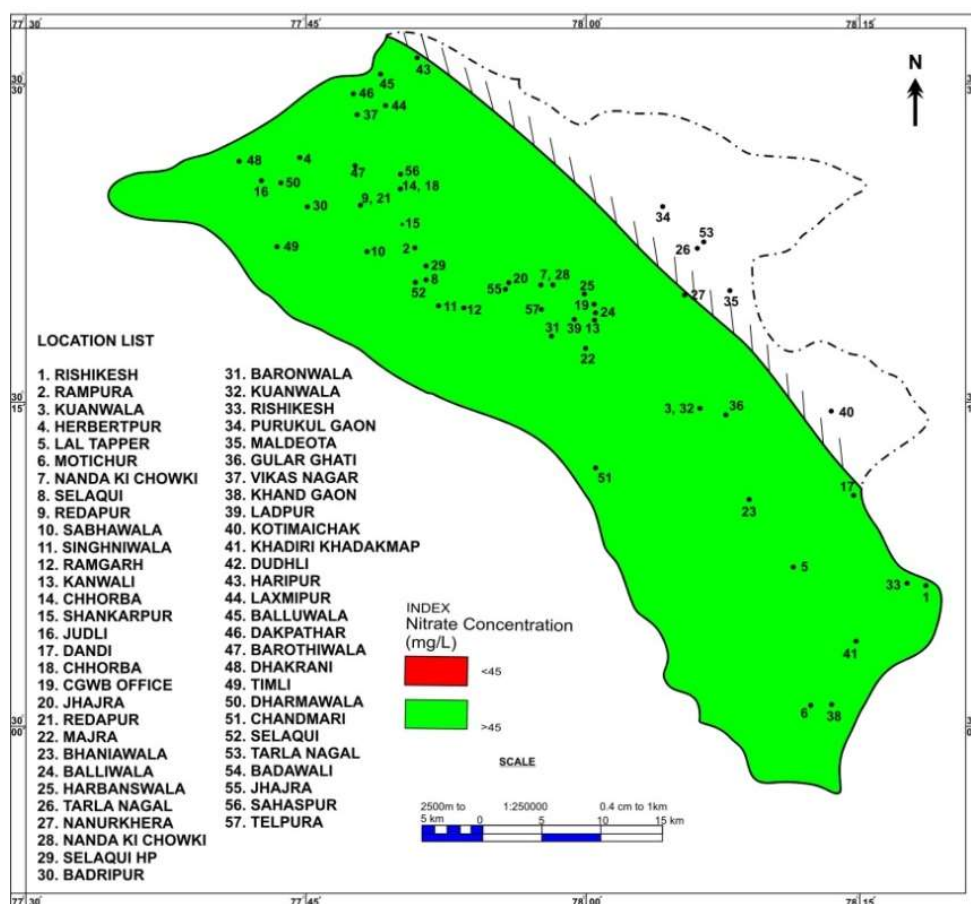


Fig. 57: Nitrate Concentration Map of Dehradun District

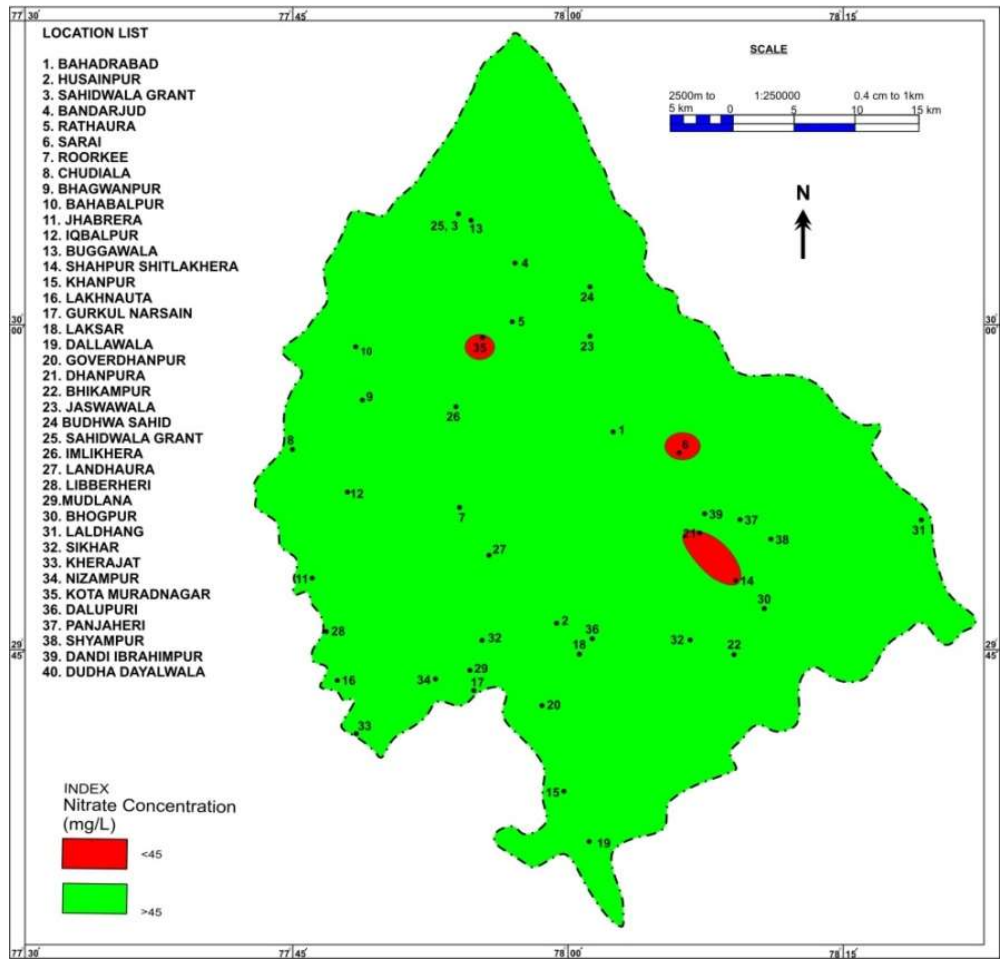


Fig. 58: Nitrate Concentration Map of Haridwar District

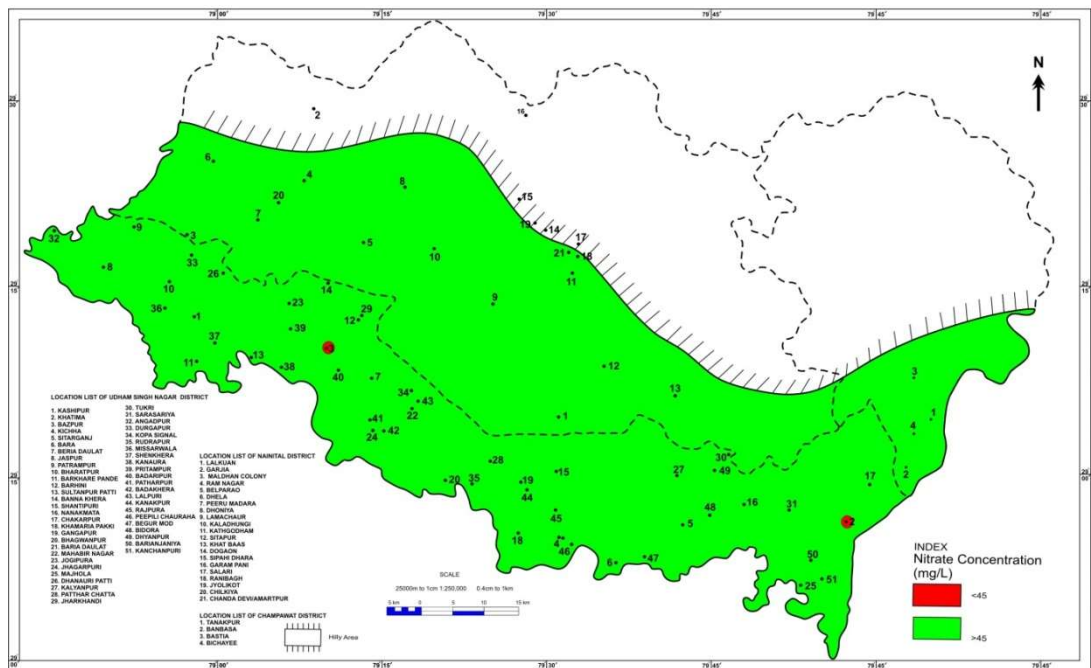


Fig. 59: Nitrate Concentration Map of Udham Singh Nagar-Nainital-Champawat Section

The high nitrate concentration in groundwater is anthropogenic and probably caused by disposal of solid/liquid waste and effect of sewerage in and around the source. Overall, the nitrate concentration in the groundwater monitoring stations in Uttarakhand indicates that groundwater is suitable for drinking purpose.

6.1.4 Fluoride

Out of 186 ground water samples for which fluoride concentration is available (pre-monsoon, 2019) the highest concentration was 4.42 mg/L at Ganganani Spring outlet in Uttarkashi district. The frequency distribution of fluoride concentration in groundwater in Uttarakhand State during premonsoon, 2019 is given in Table 29.

Table 29: frequency distribution of fluoride concentration in groundwater

Fluoride (mg/L)	<1.0	1.0-1.5	>1.5
No. of Samples	183	1	2
% of Total No.	98.39	0.54	1.07

A perusal of the table indicates that majority of samples (183 out of 186 samples or 98% of total) are suitable for drinking purpose as fluoride concentration in them was below the Acceptable Limit of 1.0 mg/L (BIS, IS 10500, 2009). Higher fluoride concentration (higher than the Acceptable Limit but lower than the Permissible Limit) in the range of 1.0-1.5 mg/L is found only in one sample, which was 1% of the total samples. Fluoride higher than the Permissible Limit (>1.5 mg/L) is also found in only one ground water samples during pre-monsoon, 2019. However, this high value is possibly attributed to some local phenomenon and/or some anomalous rock-water interaction process.

A map showing the spatial distribution of chloride concentration in Dehradun-Haridwar section of Uttarakhand State is given in Fig. 60 and Fig 61 respectively while another map showing the spatial variation in distribution of chloride concentration in Udham Singh Nagar-Nainital section is shown in Fig. 62.

Visual interpretation of Fig. 60& 61 indicated that no area in Dehradun-Haridwar section has shown fluoride concentration higher than the Acceptable Limit of 1.0 mg/L. On the other hand, visual interpretation of Fig. 62 indicates that high fluoride concentration (>1.0 mg/L) is found in and around Jaspur in the western part of Udham Singh Nagar district.

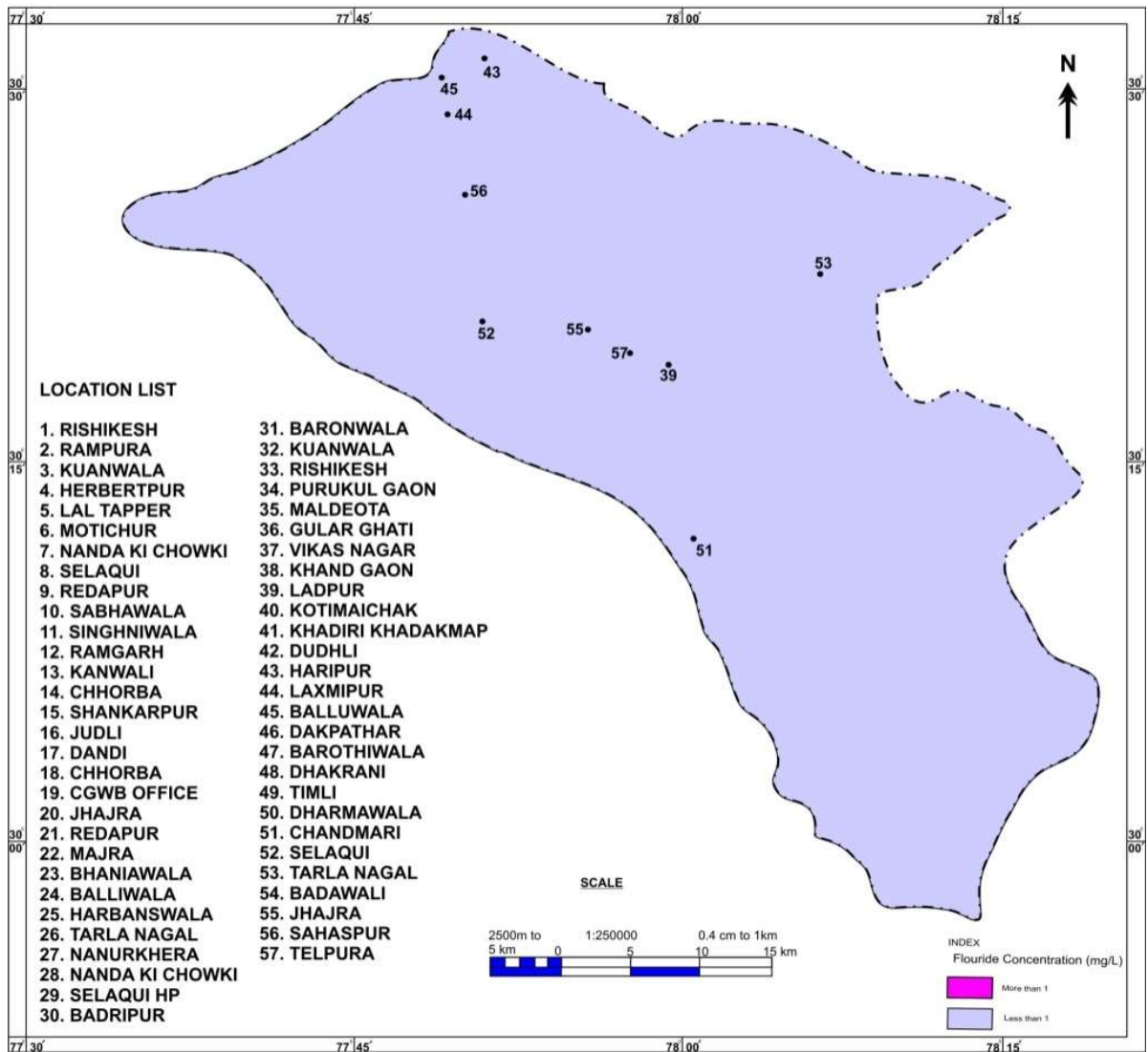


Fig. 60: Fluoride Concentration Map of Dehardun District

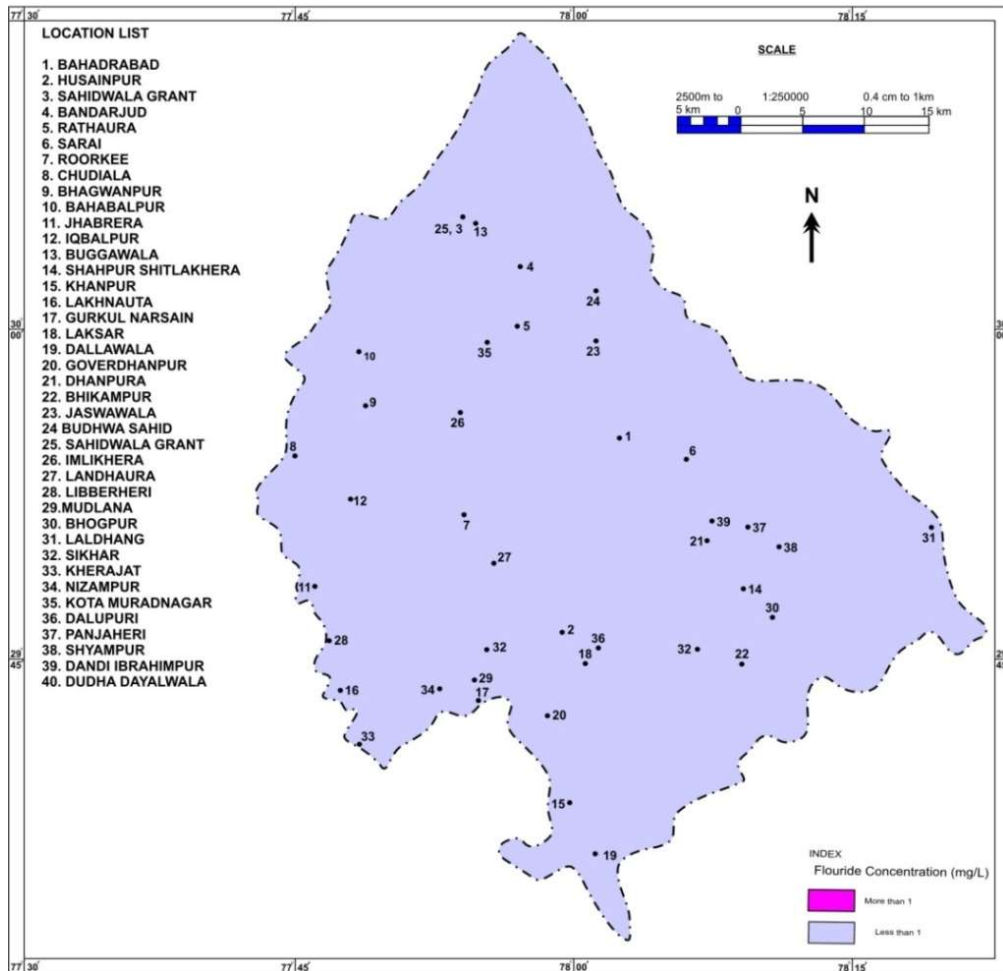


Fig. 61: Fluoride Concentration Map of Haridwar District

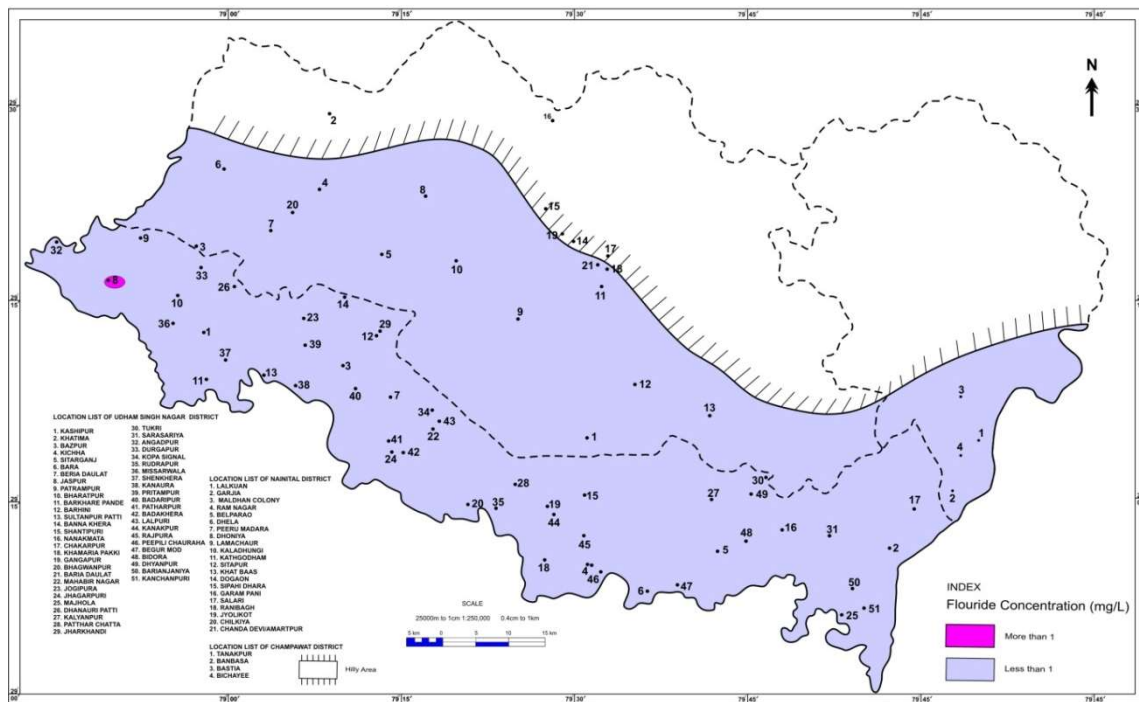


Fig. 62: Fluoride Concentration Map of Udham Singh Nagar-Nainital-Champawat Section

