केन्द्रीय भूमिजलबोर्ड

Central Ground Water Board

GROUND WATER YEAR BOOK, 2013–2014

UTTARAKHAND

Contributors

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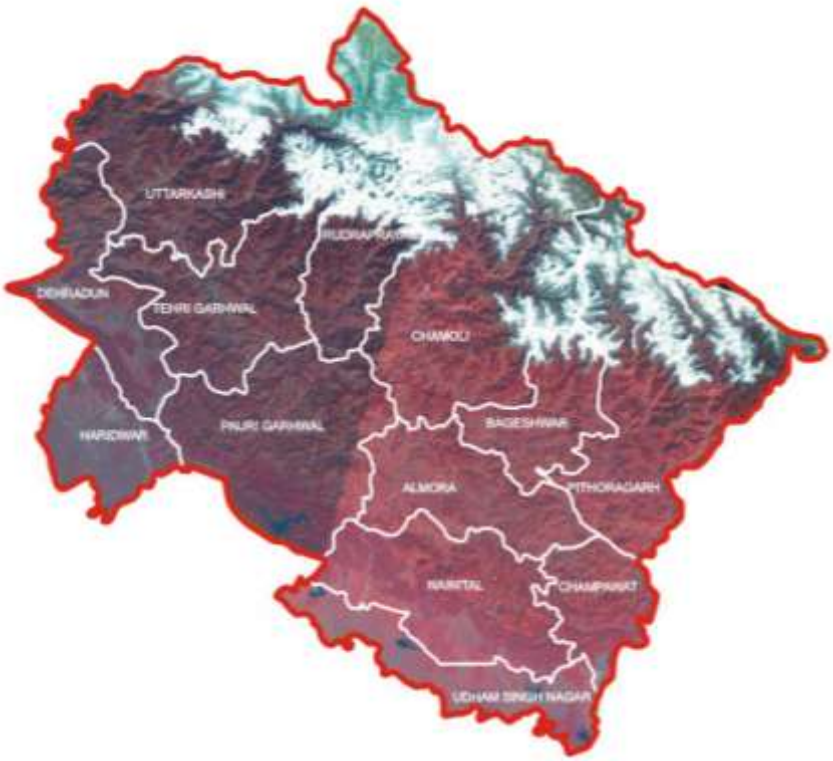

CENTRAL GROUND WATER BOARD

UTTARANCHAL REGION
DEHRA DUN
April 2015

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 2013 – 2014.*

Central Ground Water Board, Uttaranchal Region is monitoring the groundwater regime under various hydrogeological setting through 210 ground water monitoring wells in plain and hilly areas of Uttarakhand State, viz. Dehradun, Haridwar, Nainital, Udham Singh Nagar, Champawat and Uttarkashi districts four times in a year (January, May, August and November). In the hilly areas of the State twenty 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, 2013 – 2014 is the outcome of the efforts made by Ms. Amandeep Kaur, Scientist-'B' (Junior Hydrogeologist) and Dr. Somvir Singh, Scientist-'B' (Junior Geophysist). The maps of the year book were prepared both manually and in Surfer Software for the accuracy of the contours plotting in the maps. 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.

(Anurag Khanna)

Place: Dehradun *Head of the Office*

GROUND WATER YEAR BOOK, UTTARAKHAND (2013 – 2014)

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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 namely Almora, Bageshwar, Chamoli, Champawat, Dehradun, Haridwar, Nainital, Pauri Garhwal, Pithoragarh, Tehri Garhwal, Rudraprayag, Udham Singh Nagar and Uttarkashi and is located between latitude 28°43'20"N to 31°28'00"N and longitude 77°34'06"E to 81°01'31"E with a total geographical area of 53,483 km^2.

Uttarakhand State is broadly subdivided into two hydrogeomorphic units namely

1) Gangetic Alluvial Plain
2) Himalayan Mountain Belt.

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

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

During the period May 2013 to January 2014, 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 2013 and January 2014. To strengthen the existing monitoring network, a total of forty two ground water monitoring stations (including seven springs) were established to understand the groundwater regime.

The depth to water level maps and water level fluctuation maps viz. decadal, annual and seasonal water level fluctuations were generated both manually and using Surfer 9.2

software. These maps were prepared section wise viz. Dehradun Section, Haridwar section and Udham Singh Nagar-Nainital-Champawat section. Instead of categorizing the depth to water level into four categories, five categories were introduced for a better classification of depth to water level data.

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 2013 to January 2014 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 forms 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 2013, November 2013 (post monsoon) and January 2014 as compared to May 2013 (pre monsoon) are also given in separate tables.

A perusal of the depth to water level maps reveals the occurrence of deepest water levels in some areas in the northern part of Doon Valley and in the Bhabar Zone in Nainital district. 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 higher 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 2013 – 2014

State	**Range of depth to water level (m bgl)**	**Percentage of Wells Analyzed**			
		May 2013	August 2013	November 2013	January 2014
Uttarakhand	0–5	22.91	43.07	31.15	30.70
	5-10	21.30	25.55	27.05	30.70
	10-15	22.22	17.52	21.31	19.69
	>15	23.61	13.87	20.49	18.91

Fluctuation of Water Level during the Period 2013 – 2014 (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	33.96	49.06	31.67	36.67	47.37	26.32	59.32	22.04
	2–4	3.77	20.75	18.33	6.67	7.01	12.28	11.86	3.39
	>4	0	0	5	1.66	1.75	5.27	1.69	1.70

Annual Fluctuation of Water Level during the Period 2013 – 2014

State	Fluctuation (m)	Percentage of wells analyzed							
		May 2012 vs. 2013		August 2012 vs. 2013		November 2012 vs. 2013		January 2013 vs. 2014	
		Rise	Decline	Rise	Decline	Rise	Decline	Rise	Decline
Uttarakhand	0–2	52.77	35.16	48.95	17.73	42.16	34.32	63.46	18.27
	2–4	6.59	3.29	14.58	9.37	10.78	3.92	10.58	2.88
	>4	0	2.19	6.25	3.12	5.88	2.94	4.81	0

Seasonal Fluctuation of Water Level (Compared to May 2013)

State	Fluctuation (m)	Percentage of wells analyzed					
		August 2013		November 2013		January 2014	
		Rise	Decline	Rise	Decline	Rise	Decline
Uttarakhand	0–2	17.02	3.66	39.51	3.69	31.50	8.23
	2–4	39.02	1.22	28.40	0	36.98	2.74
	>4	39.02	0	28.40	0	20.55	0

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 six (106) 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 Western Region, Chandigarh. The water samples were analyzed for sixteen parameters viz. Electrical Conductivity (EC), pH, carbonate, bicarbonate, chloride, sulphate, nitrate, fluoride, calcium, magnesium, sodium, potassium, silica and Total Hardness (TH) as $CaCO_3$.

The analysis of physico chemical parameters like Electrical Conductivity, chloride, nitrate and fluoride was done on the basis of data for pre-monsoon 2012. The analysis result indicates that high Electrical Conductivity (>750–2250 µS/cm) was observed in 4.72% of samples whereas majority of samples (73.58% of total) recorded EC value in the range of >250-750 µS/cm. 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 >100-150 mg/L was observed in only one sample, which was a bare minimum of 0.94% of the total number of samples.

High nitrate viz. higher than the acceptable Limit (>45 mg/L, BIS, 2009) was recorded in only two samples out of 73 samples. The rest 33 samples have shown nil concentration of nitrate in ground water during pre-monsoon, 2012. The high nitrate concentrations were recorded as 128 mg/L in a dug well at Sarai in Haridwar district and as 101 mg/L in a hand pump at Kichha 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 was found that high nitrate was invariably associated with a shallow dug well in the Central Ganga Plains in Haridwar district and in a hand pump falling in the Tarai zone in Udham Singh Nagar district. 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 (92.45% of total) has recorded fluoride less than the acceptable limit of 1.0 mg/L (BIS, 2009). High fluoride in the range of 1.0-1.5 mg/L was found in four samples where fluoride higher than the permissible limit (>1.5 mg/L) was found in another four 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 was less in Dehradun-Haridwar section and relatively high in Udham Singh Nagar-Nainital section during pre-monsoon, 2012. To conclude, the available hydrochemical data in parts of District Dehradun, Haridwar, Udham Singh Nagar, Pauri Garhwal, Nainital, Champawat and Almora (pre-monsoon 2012) in Uttarakhand State reveals that ground water is fresh and potable and therefore, suitable for drinking and domestic purpose.

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 safe and sustainable development of ground water resource 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 both in time and in space, thus becomes essential. Indiscriminate withdrawal of ground water in rapidly developing urban and industrial areas pose a challenge to the scientific community. The challenge can be overcome by adopting sustainable ground water development and management practices.

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

During the period May 2013-January 2014, an effort was made to strengthen the existing monitoring network and also to abandon the stations which are not being utilized by the local community. For this purpose, a total of forty ground water monitoring stations (including Five springs) were established. Out of these, seven hand pumps were established in Dehradun District, six hand pumps and seven dug well were established in Haridwar District, fifteen hand pumps were established in Udham Singh Nagar District, two handpumps were established in Nainital District, five springs were established in Almora District and one hand pump in champawat district. Apart from these, some of the dug wells, which are not in use, were declared abandoned during the course of monitoring in Udham Singh Nagar and Dehradun District.

As on January 2014, a total of two hundred and ten ground water monitoring stations exist in Uttarakhand State, which are being monitored by the regional office four times in a time period of one 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 2013 – 14.
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) during the period May 2013 to January 2014 is given in ***Table 1.***

Table 1: District wise break up of active Ground Water Monitoring Stations (including Springs) in Uttarakhand State (as on January 2014)

Sl. No.	*District*	*Number of Ground Water Monitoring Stations*			
		May 2013	*Aug 2013*	*Nov 2013*	*Jan 2014*
1.	Dehradun	55	55	58	61
2.	Haridwar	44	44	46	46
3.	Udham Singh Nagar	34	34	49	50
4.	Nainital	19	19	20	20
5.	Champawat	3	3	4	4
6.	Pauri Garhwal	1	1	1	1
7.	Almora	14	14	18	18
8.	Uttarkashi	10	10	10	10
TOTAL		**180**	**180**	**206**	**210**

Apart from the dug wells, hand pumps and piezometers, a total of Thirty one springs in hilly areas of Uttarakhand were also monitored quarterly during the period May 2013-January 2014. The details of these springs are given in ***Table 2.***

Table 2 : District wise break up of Springs in Uttarakhand State (as on January 2014)

Sl. No.	*District*	*Number of Springs*			
		May 2013	*Aug 2013*	*Nov 2013*	*Jan 2014*
1.	Dehradun	3	3	3	3
2.	Nainital	6	6	6	6
3.	Almora	15	15	19	19
4.	Uttarkashi	3	3	3	3
TOTAL		**27**	**27**	**31**	**31**

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 2013)

River Basin/ Sub Basin	*Geology*	*Well No. & Location*
DEHRADUN DISTRICT		
Yamuna Basin, Tons Sub-basin	Doon Gravels (bouldery formation)	DDN-04 (Rampura), DDN-05 (Kuanwala), DDN-06 (Herbertpur), DDN-07 (Jhajra), DDN-08 (Lal Tappar), DDN-09 (Motichur), DDN-10 (Nanda ki Chowki), DDN-11 (Selaqui), 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-7 (TarlaNagal), DDN-HP-8 (Nanurkhera), DDN-HP-9 (Nanda Ki Chowki), DDN-HP-10 (Selaqui), DDN-HP-11 (Badripur), DDN-HP-12 (Baronwala), DDN-HP-13 (Kuanwala), DDN-HP-17 (Gularghati), DDN-HP-18 (Vikas Nagar), DDN-HP-19 (Khandgaon), DDN-HP-20 (Lal Tappar), DDN-HP-21 (Kotimaichak), DDN-HP-23 (KhadiriKhadakmap), DDN-HP-24 (Dudhli), DDN-HP-25 (Dakpatthar), DDN-HP-26 (Barothiwala), DDN-HP-27 (Dhakrani), DDN-HP-28 (Timli), DDN-HP-35 (Mathrowala), DDN-HP-33 (Telpura), DDN-HP-31 (Baronwala), DDN-32 (Baluwala), DDN-DW-30 (Haripur), DDN-HP-36 (Chandmari), DDN-DW-23 (Duggiawala), DDN-HP-37 (Chhorba), DDN-DW-13 (Dharmawal)
	Doon Gravels (bouldery formation) and Upper Siwaliks (conglomerate, pebbly sands, clay)	DDN-12 (Redapur), DDN-14A (Sabhawala), DDN-15 (Singhniwala), DDN-16 (Ramgarh), DDN-SP2 (Khandoli), DDN-HP16 (Maldeota), DDN-HP22 (Soda Sarauli), DDN-SP3 (Soda Sarauli), DDN-DW-16A(Ramgarh)
	Blaini – Krol, boulder beds	DDN-03 (Rishikesh), DDN-SP1 (Bhatta), DDN-HP-14 (Rishikesh), DDN-HP-15 (Purukulgaon)
HARIDWAR DISTRICT		
Ganga Basin, Upper Ganga Sub-basin	Tarai (gravel, sand and clay)	HRW-07 (Bahadrabad), HRW-08 (Missarpur), HRW-09 (Dhanpura), HRW-10 (Hussainpur), HRW-11 (Budhwa Shahid), HRW-12 (Shahidwala Grant), HRW-14 (Rathaura), HRW-15 (Sarai), HRW-16 (Librahedi), HRW-PZ1 (Roorkee), HRW-PZ2

		(Chudiala), HRW-HP-1 (Bhagwanpur), HRW-HP-2 (Bahabalpur), HRW-HP-3 (Jhabrera), HRW-HP-4 (Iqbalpur), HRW-HP-5 (Bugawala), HRW-HP-6 (ShahpurShitlakhera), HRW-HP-7 (Khanpur), HRW-HP-8 (Lakhnauta), HRW-HP-9 (Gurukul Narsen), HRW-HP-10 (Manglaur), HRW-HP-11 (Dallawala), HRW-HP-12 (Govardhanpur), HRW-HP-13 (Dhanpura), HRW-HP-14 (Bhikkampur), HRW-HP-15 (Bahadrabad), HRW-HP-16 (Chudiala), HRW-HP-17 (Shahidwala Grant), HRW-HP-18 (Imlikhera), HRW-HP-19 (Landhaura), HRW-HP-20 (Bhopatwala), HRW-HP-22 (Mudlana), HRW-HP-23 (Bhogpur), HRW-HP-24 (Sultanpur), HRW-HP-25(Kotamuradnagar), HRW-HP-26 (Laksar, HRW-HP-24 (Dudhadyalwala), HRW-HP-25 (Syampur), HRW-DW-16 (Teliwala), HRW-DW-17 (Sikhar), HRW-DW-18 (Kherajat), HRW-DW-19 (Nijampur), HRW-DW-20 (Ambkhera), HRW-DW-21 (Mohamadpur), HRW-DW-23 (Jasawawala), HRW-DW-24 (Kotamuradnagar)
	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-05 (Kichha), USN-06A (Sitarganj), USN-07 (Bara), USN-08 (Beria Daulat), USN-09 (Jaspur), USN-11 (Angadpur), USN-12 (Patrampur), USN-13 (Bharatpur), USN-15 (BarkharePande), USN-16 (Barhini), USN-17 (ThandaBanjara), USN-18 (Banna Khera), USN-19 (Shantipuri), USN-20 (Nanak Mata), USN-21 (Chakarpur), USN-HP-1 (KamariaPakki), USN-HP-2 (Gangapur), USN-HP-3 (Bhagwanpur), USN-HP-4 (Beria Daulat), USN-HP-5 (Mahabir Nagar), USN-HP-6 (Jogipura), USN-HP-7 (Jhagarpuri), USN-HP-9 (Majhola), USN-HP-10 (Dhanauri Patti), USN-HP-11 (Kalyanpur), USN-HP-12 (Patthar Chatta), USN-HP-13 (Sitarganj), USN-HP-14 (BarkharePande), USN-HP-15 (Angadpur), USN-HP-16 (Chakarpur), USN-HP-17 (Durgapur), USN-HP-18 (Kopa Signal), USN-HP-19 (Jharkhandi), USN-HP-20 (Tukri), USN-HP-21 (Sarasariya), USN-HP-22 (Rudrapur), USN-HP-28 (Missarwala), USN-HP-29 (Shankhera), USN-HP-30 (Kanaura), USN-HP-31 (Pritpur), USN-HP-32 (Badripur), USN-HP-33)Pattarpur), USN-HP-34 (Badakhera), USN-HP-35 (Lalpuri), USN-HP-36 (Kanakpur), USN-HP-37 (Rajpura), USN-HP-38 (Pipiliya), USN-HP-39 (Begur Mod), USN-HP-40 (Bidora), USN-HP-41 (Dhyanpur), USN-HP-42 (Barianjariya), USN-DW-16

		(Barhini)
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-9 (Sitapur), NTL-HP-10 (Khat Baas), NTL-HP-11 (Chilkiya), NTL-HP-12 (Chanda Devi Amratpur)
	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)
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 (Guruda-II), ALM-S-9 (Dhansari), ALM-S-10 (Someshwar), ALM-S-11 (Dharanaula Zoo), ALM-S-12 (Bachuradi), ALM-S-13 (Deepakot), ALM-S-14 (Ramgath), ALM-S-15 (Bhagtola),ALM-S-16 (Itola), ALM-S-17 (Potasarain), ALM-S-18 ChhaniBartola), ALM-S-19 (Lodh)
PAURI GARHWAL DISTRICT		
Ganga Basin, Upper Ganga Sub-basin	Bhabar (boulders, gravel, sand and clay)	PG-HP-1 (Kaudiya)
UTTARKASHI DISTRICT		
Ganga Basin, Upper Ganga Sub-basin	Lesser Himalaya	UK-HP-1 (Chinyalisaur), UK-HP-2 (Devidhar), UK-HP-3 (Uttarkashi), UK-HP-4 (Barkot), UK-HP-5 (Sherukhet), UK-HP-6 (Ganeshpur), UK-HP-7 (Maneri), UK-SP-1 (Dharasu), UK-SP-2 (Nagal), UK-SP-3 (Ratodisar)

Location of Ground Water Monitoring Stations in Uttarakhand (As on January 2014)

DEHRADUN DISTRICT

1. Rishikesh 2. Rampura 3. Kuanwala 4. Herbertpur 5. Motichur
6. Sabhawala 7. Singhniwala 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. Gularghat
30. Vikas Nagar 31. Khandgaon 32. Lal Tappar 33. Kotimaichak
34. Soda Sarauli 35. CGWB Office 36. Dandi 37. Khadakmaj
38. Dudhli 39. Bhatta Sp 40. Khandoli Sp 41. Soda Sarauli Sp
42. Dakpatthar 43. Barothiwala 44. Dhakrani 45. Badripur 46. Timli

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. Rathaura 60. Sarai 61. Shahpur Shitlakhera 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. Sultanpur Patti
93. Banna Khera 94. Shantipuri 95. Nanak Mata
96. Kamaria Pakki 97. Gangapur 98. Bhagwanpur
99. Mahabir Nagar 100. Jogipura 101. Jhagarpuri
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. Jyolikote

CHAMPAWAT DISTRICT

129. Banbasa 130. Tanakpur 131. Bastia 157. Bichayee

ALMORA DISTRICT

132. Patli Talla 133. Patli Malla 134. Katarmal 135. Dharanaula
136. Dharanaula Zoo 137. Palna 138. Chinoda 139. Guruda-I
140. Guruda-II 141. Bachuradi 142. Someshwar 143. Dhansari
144. Deepakot 145. Ramgath 146. Bhagtola

UTTARKASHI DISTRICT

147. Chinyalisaur 148. Devidhar 149. Uttarkashi 150. Dharasu 151. Barkot
152. Sherukhet 153. Ganeshpur 154. Maneri 155. Nagal 156. Ratodi Sar

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 of Uttarakhand State in mm (1901-1970)

District	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*July*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Annual*
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

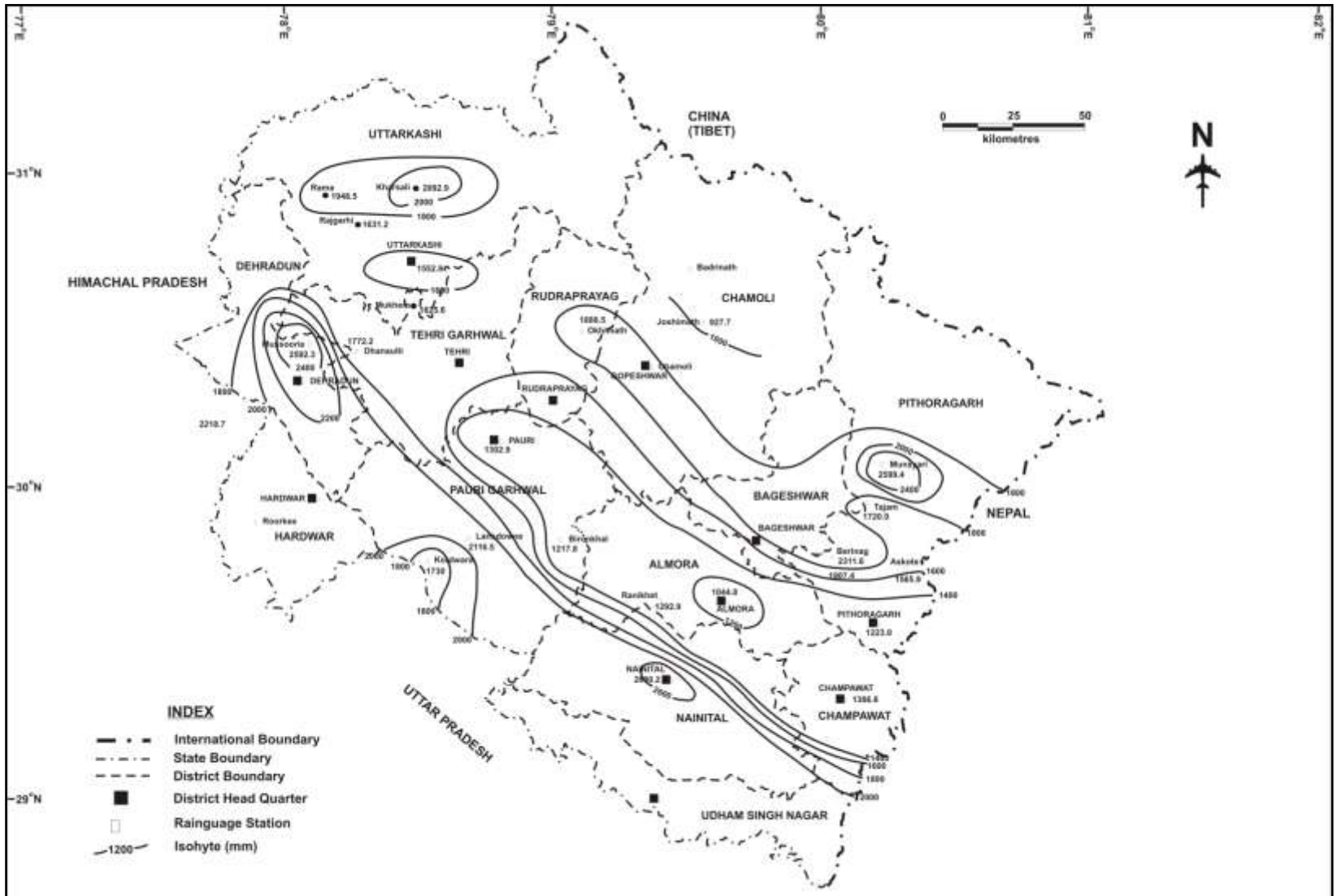

Fig. 2. Mean Annual Isohyetal Map, Uttarakhand State

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 emplaced by granites of variable ages along with weakly metamorphosed to unmetamorphosed sedimentary rocks (quartzites with interbedded volcanics, carbonates associated with slate, quartzite and shale) occur extensively in this zone. The granitoids are associated with volcano sedimentary sequence (Bhimtal Formation) and are emplaced along with the predominantly metamorphic and metasedimentary rocks of this zone, forming large-scale nappes like the Almora-Ramgarh nappe, Baijnath-Askot nappe and Garhwal nappe.

2.3. Central or Higher Himalaya

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

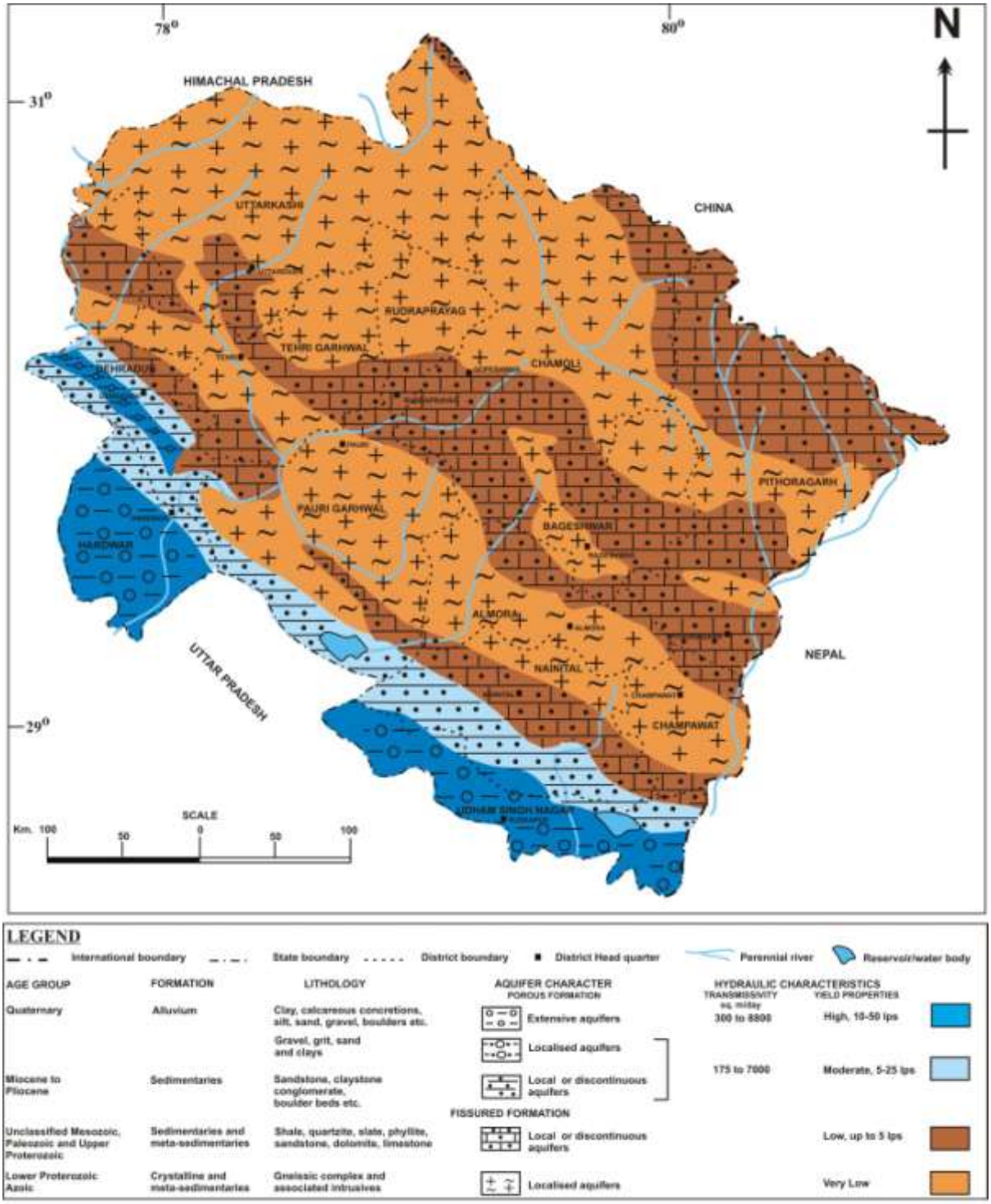

Fig. 3 HYDROGEOLOGICAL MAP OF UTTARAKHAND

frequently encountered in this zone.

2. Himalayan Mountain Belt

This is a part of the Alpine-Himalayan Mountain Chain and constitutes a major part of the total geographical area of Uttarakhand. This zone is also known as Extra-Peninsular Region. The belt trends northwest – southeast with roughly parallel mountain ranges spanning across the state. This region can be further subdivided into

five tectonic units from south to north. These units are Outer Himalaya, Lesser Himalaya, Central Himalaya, Tethyan Himalaya and Indus Suture Zone. However, the Indus Suture Zone does not fall within the geographical area of Uttarakhand State. A brief description of the remaining four units that falls in the state is as follows:

2.1. Outer Himalaya (Siwalik Mountain Range)

This unit is composed dominantly of sandstone, ferruginous shale and clay and is younger in age as compared to the other units of the belt. The general elevation of the zone is less than 1000 m above mean sea level. Due to the semi-consolidated nature of rocks, potential ground water bearing formations are present in areas, which have a good weathered mantle and highly fractured/jointed rocks. In the Siwaliks, a number of valleys have also been developed as a result of tectonic activities (e. g. Doon Valley), which are very important from the hydrogeological point of view. The Doon Valley was formed as an *Intermontane Valley* within the Siwalik Group of rocks in a foreland propagating thrust system. The Lower, Middle and Upper Siwaliks are exposed in the area, and the Doon Gravels, a post-Siwalik Formation, were deposited with the evolution of the valley. The Doon Gravels are thickly bedded coarse clastic fan deposit of late Pleistocene and Holocene age. The Central Ground Water Board has successfully constructed 11 deep 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 5^{th} order and 4^{th} 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

The water levels of Ground Water Monitoring Wells of Uttarakhand were measured four times during the period 2013-2014 (May, August, November 2013 and January 2014). The water levels observed are 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 2013 – January 2014 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:Water level data of Ground Water Monitoring Wells, Uttarakhand State

SL. No.	Location	May-13	Aug-13	Nov-13	Jan-14
DEHRADUN DISTRICT					
1	Rishikesh	19.17	9.87	10.57	12.74
2	Rampura	13.14	9.82	11.72	10.93
3	Kuanwala	13.89	NA	NA	8.56
4	Herbertpur	9.13	2.75	7.84	10.45
5	Jhajra	11.58	NA	1.86	8.69
6	Lal Tappar	17.54	11.7	NA	NA
7	Motichur	11.29	5.2	7.75	8.7
8	Nanda Ki Chowki	13.01	6.4	8.12	7.86
9	Selakui	10.4	5.24	7.44	8.37
10	Redapur	5.69	0.84	1.24	1.91
11	Sabhawala	9.04	3.93	3.68	7.56
12	Singhniwala	9.24	4.74	8.54	9.94
13	Kanwali	14.12	7	12.5	13.65
14	Chhorba	18.29	NA	NA	NA
15	Shankarpur	25.28	10.3	18.03	17.53
16	Judli DW	13.08	8.6	11.7	11.85
17	Dandi DW	6.65	5.36	1.86	5.22
18	Chhorba PZ1	71.24	NA	NA	NA
19	CGWB Office PZ2	56.56	50.16	NA	49.36
20	Jhajra HP	11.58	4.2	5.93	3.53
21	Redapur HP	7.43	2.05	3.15	3.84
22	Majra HP	25.84	19.65	19.57	20.3
23	Balliwala HP	50.76	49.95	54	52.15
24	Harbanswala HP	53.58	42.64	16.24	47.04

25	TarlaNagal PZ	74.16	57.1	65.17	69.2
26	Nanurkhera HP	75.14	72.38	55.58	61.08
27	Nanda Ki Chowki HP	15.89	6.1	7.72	7.64
28	Selakui HP	15.74	11.12	13.32	13.1
29	Badripur HP	8.34	4.68	8.13	7.49
30	Baronwala HP	23.94	21.7	20.3	21.15
31	Kuanwala HP	14.42	NA	4.57	9.52
32	Rishikesh HP	6.35	2.89	15.96	4.69
33	Purukulgaon HP	26.98	19.48	24.2	23.78
34	Maldeota HP	11.44	3.87	2.57	0.82
35	Gularghati HP	12.99	7.78	9.66	13.67
36	Vikas Nagar HP	NA	19.88	24.91	28.98
37	Khandgaon HP	10.88	5.1	11.1	9.16
38	Lal Tappar HP	17.3	12.24	12.54	13
39	Kotimaichak HP	21.05	10.32	17.32	18.72
40	Soda Sarauli HP	8.81	5.82	4.4	8.32
41	Khadiri (Khadakmap) HP	14.54	12.53	12.13	13.8
42	Dudhli HP	37.93	16.39	24.51	24.11
43	Dakpatthar HP	25.16	18.92	32.99	24.31
44	Barotiwala HP	27.24	27.7	12.3	25.04
45	Dhakrani HP	17.14	5.5	32.4	17.94
46	Timli HP	62.34	60.95	50.67	28.75
47	Bhaniawala HP	36.01	19.45	23.43	22.72
48	Mathrowala HP	2.4	NA	NA	8.13
49	Telpura HP	63.04	NA	NA	NA
50	Barawala HP	12.8	9.8	11.75	5.59
51	Baluwala HP	37.14	32.92	36.49	33.4
52	Haripur	5.74	4.05	4.92	15.22
53	Sehaspur HP*	NA	NA	6.75	8.91
54	Chandmari HP *	NA	NA	25.49	26.04
55	Duggiawala DW*	NA	NA	3.8	1.05
56	Chhorba HP	NA	NA	NA	27.53
57	Dharmawala DW	NA	NA	NA	5.17
58	Ramgarh DW	NA	NA	NA	5.6
59	TarlaNagal HP	NA	NA	NA	54.15
HARIDWAR DISTRICT					
1	Bahadrabad	5.44	10.15	4.41	NA
2	Hussainpur	4.15	1.48	2.2	2.13
3	Budhwa Shahid	4.52	2.97	2.92	2.27
4	Shahidwala Grant	12.63	9.2	8.93	9.2
5	Bandarjud	11.33	7.9	8.08	8.15
6	Rathaura	4.53	3.75	4.5	8.49
7	Sarai	12.59	10.26	11.76	11.71

8	Librahedi DW	6.99	5.55	4.77	5.9
9	Roorkee-Pz	7.98	4.58	5.49	4.98
10	Bhagwanpur HP	21.27	16.93	16.45	13.51
11	Bahabalpur HP	3.86	0.43	1.92	1.88
12	Jhabrera HP	11.16	4.84	8.88	7.39
13	Iqbalpur HP	18.11	10.7	13	10.9
14	Bugawala HP	5.36	3.18	4.21	3.96
15	ShahpurShitlakhera HP	5.17	NA	4.33	4.04
16	Khanpur HP	6.04	1.23	2.68	1.69
17	Lakhnauta HP	3.98	6.36	3.08	6.45
18	Bhoopatwala HP	9.86	6.61	9.96	NA
19	Chudiala HP	22.41	13.76	18.16	16.81
20	Imli Khera HP	16.58	13.84	15.24	12.94
21	Landhaura HP	16.26	17.6	17.83	17.78
22	Gurkul Narsan HP	5.95	4.58	5.16	5.7
23	Manglaur HP	6.3	2.98	5.51	5.08
24	Dallawala HP	2.44	NA	1.61	2.05
25	Govardhanpur HP	4.31	2	3.05	NA
26	Dhanpura HP	9.06	6.24	7.31	5.8
27	Bhikkampur HP	4.77	2.96	2.48	1.81
28	Bahadarabad HP	6.46	6.64	11.07	10.59
29	Shahidwala Grant HP	12.55	8.26	8.48	8.76
30	Laldhang HP	57.61	61	55.2	54.38
31	Mudlana HP*	18.77	NA	17.31	17.36
32	Bhogpur HP*	4.62	2.86	0.26	2.9
33	Sultanpur (Kunhari) HP *	5.98	3.8	4.84	4.22
34	Kota Muradnagar HP	11.05	9.15	6.87	8.6
35	Panjaheri HP*	7.85	5.54	6.17	6.64
36	DudhaDayalwala HP*	2.79	1.45	2.16	2.13
37	Shyampur HP*	10.46	8.65	10.23	4.99
38	Laksar HP*	3.52	2.72	2.32	2.2
39	Teliwala DW*	9	7.75	5.49	2.45
40	Sikhar DW*	28.05	25.3	15.98	14.1
41	Khera Jat DW*	6.5	4.95	5.17	4.87
42	Nizampur DW*	11	8.8	10.44	10.32
43	Ambkheri DW*	3.05	1.45	1.72	2.55
44	Mohammadpur DW*	1.9	0.6	0.6	1.25
45	Jawawala DW*	NA	NA	4.2	3.9
46	Kota Muradnagar DW*	NA	NA	6	7.38
PAURI GARHWAL DISTRICT					
1	Kotdwar HP	53.65	66.4	45.21	49.65
UDHAM SINGH NAGAR DISTRICT					
1	Kashipur	7.57	3.61	5.83	4.43

2	Khatima	2.91	0.07	1.7	1.90
3	Bazpur	2.94	0.68	0.47	1.12
4	Kichha	NA	5.33	5.93	6.89
5	Bara	2.46	0.45	1.83	1.69
6	Banna Khera	6.14	3.6	3.85	3.56
7	Shantipuri	2.46	1.15	1.79	1.02
8	Nanak Mata	4.81	1.89	3.29	3.49
9	KamariaPakki HP	7.5	4.35	3.62	4.62
10	Gangapur HP	3.7	1.83	1.87	2.10
11	Bhagwanpur HP	6.3	3.24	4.26	3.35
12	Beria Daulat HP	4.26	2.14	2.8	2.71
13	Mahabir Nagar HP	2.96	1.08	2.51	2.42
14	Jogipura HP	8.58	2.72	2.39	2.69
15	Jhagarpuri HP	2.73	1.66	**NA**	2.66
16	Majhola HP	4.95	2.75	4.00	4.40
17	Dhanauri Patti HP	4.46	2.31	2.50	2.26
18	Kalyanpur HP	3.14	2.26	1.87	2.06
19	Patthar Chatta HP	3.23	1.97	2.46	2.16
20	BarkharePande HP	9.96	5.17	1.79	5.67
21	Jaspur HP	17.58	12.58	8.84	8.48
22	Bharatpur HP	11.45	8.02	6.15	6.05
23	Patrampur HP	10.99	9.73	7.58	7.03
24	Sultanpur Patti HP	3.29	0.94	0.14	0.45
25	Sitarganj HP	3.52	0.84	1.44	0.98
26	Kichha HP	**NA**	6.8	**NA**	6.44
27	Durgapur HP	7.78	1.94	2.09	2.62
28	Kopa Signal HP	1.34	0.19	0.5	0.40
29	Chakarpur HP	7.1	4.3	6.4	6.47
30	Jharkhandi HP	2.28	2.06	1.49	1.24
31	Tukri HP	5.54	1.91	2.51	1.91
32	Sara Sariya HP	15.03	0.95	2.38	3.17
33	Angadpur HP	7.58	10.1	4.41	3.73
34	Rudrapur HP	3.46	0.71	2.31	1.00
35	Missarwala HP	NA	NA	6.10	4.10
36	Shankhera HP	NA	NA	5.65	4.80
37	Kanawra HP	NA	NA	3.81	3.83
38	Pritpur HP	NA	NA	2.65	2.83
39	Badaripur HP	NA	NA	3.95	3.37
40	Patharpur HP	NA	NA	3.73	2.91
41	Badakhera HP	NA	NA	2.36	3.50
42	Lalpuri HP	NA	NA	1.6	1.70
43	Kanakpur HP	NA	NA	3.41	3.49
44	Rajpur HP	NA	NA	2.21	1.72

45	Pipiliya HP	NA	NA	3.17	2.52
46	Begpur Mod HP	NA	NA	3.23	3.06
47	Bidora HP	NA	MA	2.52	2.46
48	Dhyanpur HP	NA	NA	1.47	1.10
49	Barianjariya HP	NA	NA	3.34	3.85
50	Barhini	NA	NA	NA	1.37
NAINITAL DISTRICT					
1	Lalkuan	11.23	9.52	6.59	8.31
2	Garjia	4.54	3.93	4.11	4.00
3	Maldhan Colony	5.48	2.18	2.53	2.98
4	Ramnagar HP	8.13	7.28	8.17	8.73
5	Belparao HP	58.66	59.96	55.55	60.16
6	Dhela HP	65	65.23	63.28	66.68
7	PeeruMadara HP	25.75	24.35	20.96	22.98
8	Dhoniya HP	71.28	63.63	58.28	64.58
9	Lamachaur HP	45.5	44.88	42.7	41.06
10	Kaladhungi HP	29.12	26.65	28.16	29.21
11	Kathgodam HP	19.56	14.86	18.22	18.28
12	Sitapur HP	59.86	57.6	57.39	55.09
13	Khaat Baas HP	37.02	10.2	32.81	33.96
14	Chilkiya HP	NA	NA	53.09	56.08
15	Chanda Devi Amaratpur HP	NA	NA	49.85	NA
CHAMPAWAT DISTRICT					
1	Tanakpur	11.7	6.5	10.3	10.90
2	Banbasa HP	5.84	2.63	5.21	4.65
3	Bastia HP	30.83	16.74	25.4	28.24
4	Bichayee HP	NA	NA	14.93	15.10
DISTRICT UTTARKASHI					
1	Chiniyalisaur HP	34.89	NA	NA	43.39
2	Devidhar HP	18.46	NA	NA	10.13
3	Uttarkashi HP	15.31	NA	NA	17.09
4	Barkot HP	12.48	NA	NA	15.89
5	Serukhet HP	12.56	NA	NA	41.46
6	Ganeshpur HP	12.26	NA	NA	17.51
7	Maneri HP	4.84	NA	NA	16.64

5.1 DEPTH TO WATER LEVEL

5.1.1May 2013

The depth to water level data was analyzed for 144 Ground Water Monitoring Wells in Uttarakhand during May 2013 and is given in ***Table 6.*** Analysis of depth to water level data given in the table indicates that the deepest water level was 71.28 m bgl at Dhoniya in Nainital district whereas the shallowest water level was 1.34 m bgl at Kopa Signal in Udham Singh Nagar, district. The depth to water level in the range of 0–5 m bgl was recorded in 33 ground water monitoring wells, which is 22.91% of the total number of wells. Water level in the range of 5–10 m bgl was shown by 35 monitoring wells (24.30% of total number), whereas deeper water level of 10–15 m bgl was recorded in 32 monitoring wells, which was 22.22% of the total number. The deepest water level of >15 m bgl was shown by 34 monitoring wells, which is 23.61% of the total monitoring wells in Uttarakhand during May 2013.

Table 6: District wise categorization of depth to water level data, May 2013

District	No. of stations analyzed	Depth to water level (m bgl)		Depth to water level (m bgl)							
				0-5		5-10		10-15		>15	
		Min	Max	No.	%	No.	%	No.	%	No.	%
Dehradun	50	2.4	71.24	1	2	9	18	21	42	19	38
Haridwar	38	2.44	57.61	12	31.57	13	34.21	10	26.31	3	7.89
U. S. Nagar	32	1.34	17.58	18	56.25	10	31.25	4	12.25	0	0
Nainital	13	4.54	71.28	1	7.69	2	15.38	1	7.69	9	69.23
Champawat	3	5.84	30.83	0	0	1	33.33	1	33.33	1	33.33
Pauri Garhwal	1	--	53.65	0	0	0	0	0	0	1	100
Uttarkashi	7	4.84	34.89	1	14.28	0	0	5	71.42	1	14.28
Total	**144**	**1.34**	**71.28**	**33**	**22.91**	**35**	**24.30**	**32**	**22.22**	**34**	**23.61**

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for ***May 2013*** 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 more than 15m. The water level in the range of 10-15 m occurs in a narrow zone in north central and central part of Doon valley and

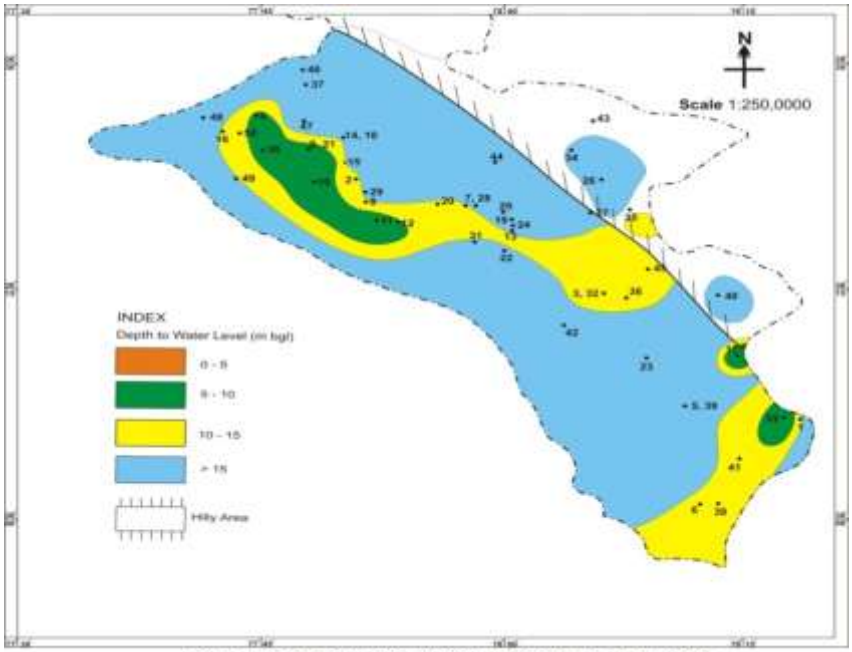

Fig. 4 Depth to Water Level, Dehradun, May, 2013

in Motichur – Redarpur – Khadrikhadakmap section in southeastern part of Doon valley. The water level in the range of 5-10 m occurs in more or less linear zone in north-central part of Doon gravels (Kuawala – Sabhawala - Ramgarh section); also occurs as small isolated patches in Dandhi&Rhishikesh section. Whereas no area showing shallow water level in the range of 0-5m.

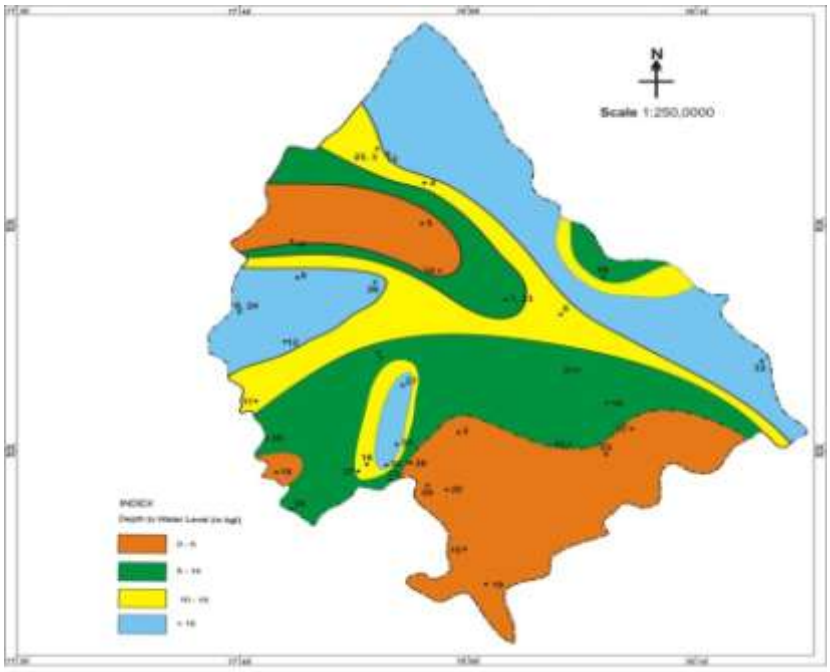

Fig. 5 Depth to Water Level, Haridwar, May, 2013

The visual interpretation of the **Fig. 5** indicates that the shallowest water level in the range of 0-5m occurs in North-western and southern part of Haridwar district; also as isolated patch at Lakhnauta. The water level in the range of 5-10m occurs as linear zone trending from south-west to south-east (Dhanpura – Bhupatwala section); also occurs as semi-circular narrow zone in north-western & central part of Haridwar district. The water level in the range of 10-15m zone occurs in the broad zone trending from northwest to southeast covering majority of central part of Haridwar district. It also occurs as isolated patch (elliptical shape) in southwestern i.e. Nizampur. The deepest water level in the range of more than 15m occur in the north, northeastern ans western part of the district; also as an isolated patch in southwestern part of Haridwar District.

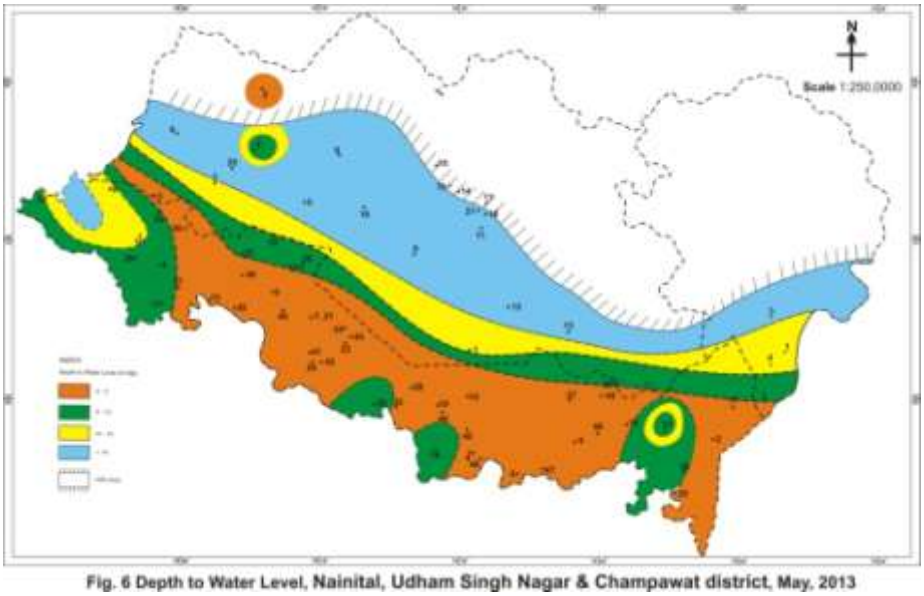

Fig. 6 Depth to Water Level, Nainital, Udham Singh Nagar & Champawat district, May, 2013

The visual interpretation of the **Fig. 6** indicates that the shallowest water leveli.e. 0-5m occurs in major part of the Tarai belt and as isolated patch at Garjia in Nanital district. The water level in the range of 5-10m occurs in the isolated patches around Bhagwanpur, KamariaPakki, Chakarpur, Angadpur; in more or less linear belt trending from northwest to southwest in the bhabhar zone. The water level in the range of 10-15m

occurs in northwestern part of Udham Singh Nagar in and around Patrampur, Bharatpur; as isolated patch in Sarasaria; Along the Udham singh Nagar and nanitaladministrarive boundary and at Tanakpur in Champawat district. The deepest water level of >20 m was seen in the north western part in and around Jaspur, in major parts of Bhabar zone (along Belparao-PeeruMadara-Dohniya-Lamachaur-Kaladhungi-Kathgodam-Sitapur-Khaat Baas area) in Nainital district and also in and around Bastia in Champawat district falling in the Bhabar zone. In general it is seen that the water level deepens from south to north.

5.1.2 August 2013

During the month of August 2013, a total of 137 ground water monitoring wells (including dug wells, hand pumps and piezometers) were monitoried 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 72.38 m bgl at Nanurkhera hand pump in District Dehradun district while the shallowest water level was 0.07 m bgl at Khatima dug well in Udham Singh Nagar district. The analysis of depth to water level data has also shown that shallowest water level of 0-5 m was recorded by 59 monitoring wells, which was 43.07% of the total number. Depth to water level in the range of 5-10 m was shown by 35 wells (25.55% of total number) during August 2013. Deeper water level of 10-15 m was shown by 24 wells (17.52% of total) whereas the deepest water level of >15 m was recorded by 19 monitoring wells, which was 19.27% of the total number of wells in Uttarakhand monitored during August 2013. The depth to water level maps (August 2013) 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.**

Table 7: District wise categorization of depth to water level data, August 2013

District	*No. of stations analyzed*	*Depth to water level (m bgl)*		**Depth to water level (m bgl)**							
				0- 5		***5-10***		***10-15***		***>15***	
		Min	***Max***	***No.***	***%***	***No.***	***%***	***No.***	***%***	***No.***	***%***
Dehradun	45	0.84	72.38	10	22.22	14	31.11	12	26.67	9	20.0
Haridwar	41	0.43	61.00	19	46.34	13	31.71	7	17.07	2	4.88
Udham Singh Nagar	34	0.07	12.58	27	79.41	5	14.71	2	5.88	0	0
Nainital	13	2.18	65.23	2	15.38	2	15.38	2	15.38	7	53.85
Champawat	3	2.63	16.74	1	33.33	1	33.33	1	33.33	0	0
Pauri Garhwal	1	--	66.40	0	0	0	0	0	0	1	100
Total	**137**	**0.07**	**72.38**	**59**	**43.07**	**35**	**25.55**	**24**	**17.52**	**19**	**13.87**

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for August 2012 is shown in ***Fig. 7****(Dehradun district),* ***Fig 8*** *(Haridwar district)* and ***Fig. 9*** *(Nainital, Udham Singh Nagar and Champawat districts).*

A perusal of **Fig.7** indicates that the minimum depth to water level of 0-5 m was seen in a linear zone in North central part of Doon Gravels(i.e Badripur-Sabhawala- Singhniwala-Herbertpur Area). This zone also occurs as isolated patches in and around Rishikesh and maldeota. Depth to water level of 5-10m was found as linear zone in North central, central part of Doon Gravels and in south eastern part of Doon Gravels (Motichur-Dandhi- Khandgaon Section). The water level in the range of 10-15m occurs in a narrow zone in North central and central part and in a wide zone in Southeastern part of valley (Laltappar-KhadiriKhadakmap section). Most of the areas shows the >15m water level.

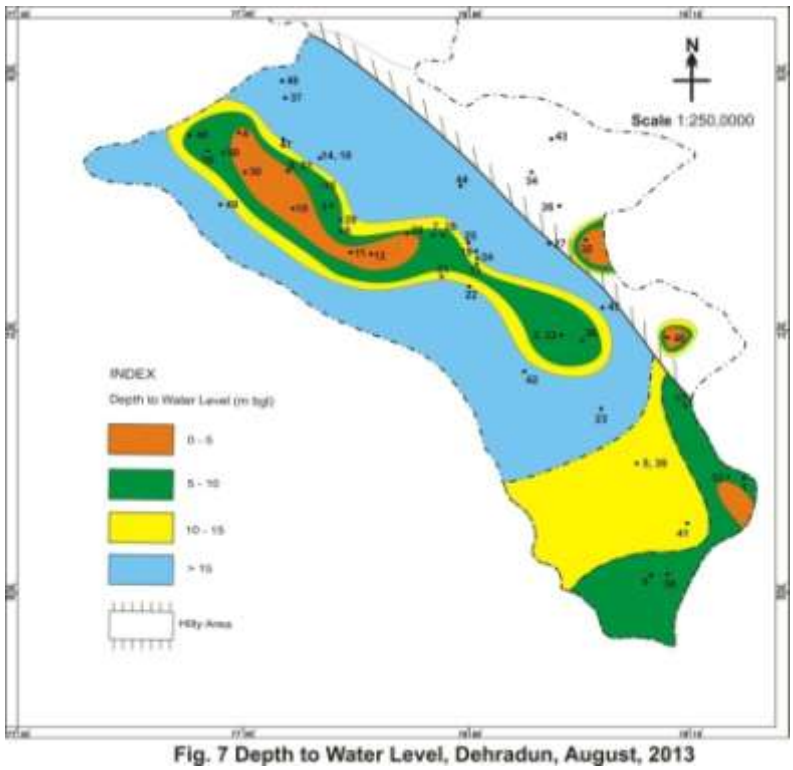

Fig. 7 Depth to Water Level, Dehradun, August, 2013

A perusal of **Fig. 8** indicates that the minimum depth to water level of 0-5 m was seen in southern and North western party of the Haridwar district; and also in and around Roorkee and Jhabrera. The water level in the range of 5-10 m occurs as a linear zone trending from Northwest to southeast and as a broad zone trending from southwest to southeast. Depth to water level of 10-15 m was found mainly in the western part of the district and also as elliptical patch in and around Nizampur. The water levels >15m was found as isolated patches in and around Bhagwanpur; also as eclipse around Nizampur, Shaidwala Grant and in and around Laldhang (which demarcates the Bhabar zone).

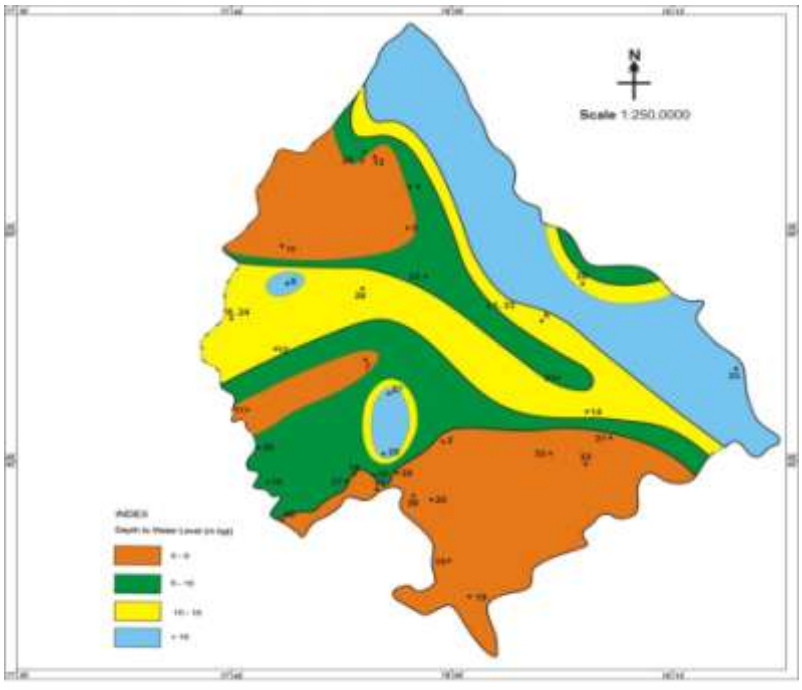

Fig. 8 Depth to Water Level, Haridwar, August, 2013

Interpretation of **Fig. 9** has again revealed that depth to water level generally increases from south to north in Udham Singh Nagar-Nainital section. The minimum depth to water level of 0-5 m covers more than 80% of the Tarai Belt and also as isolated patch at Garjia in Nanital district and around the Banbasa in Champawat district. Water level in the range of 5-10 m was seen just north of the zone of 0-5 m in Udham Singh Nagar district and also in Champawat district, this zone also occurs in and around Barkharepande, Patyrampur and Bharatpur. Water level in the range of 10-15 m was observed in and around Angadpur and also north of the zone of 5-10 m. The deepest water level of >15 m was seen in major portion of the Bhabar zone in Nainital district and also in a small area around Bastia in Champawat district.

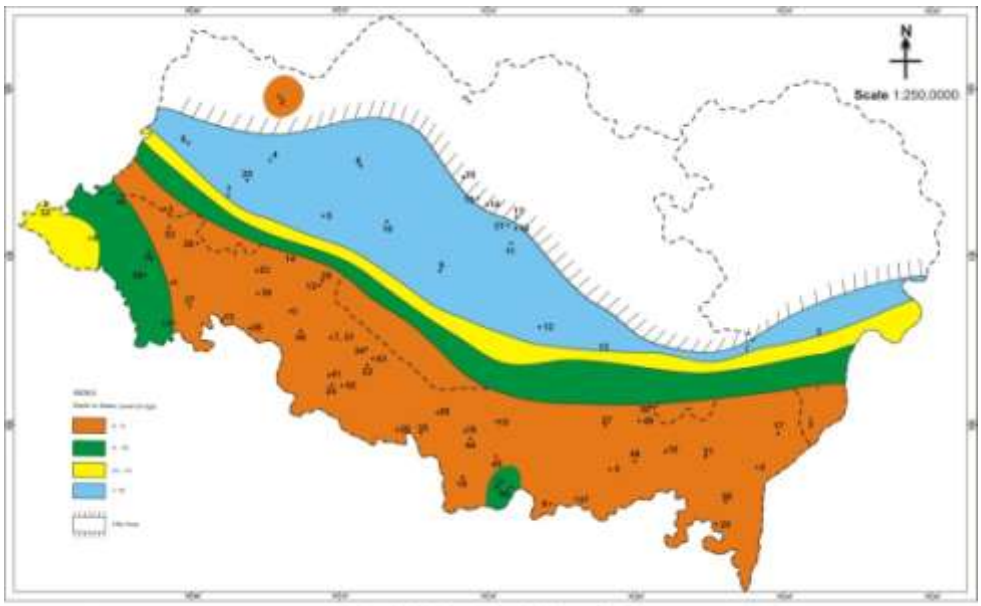

Fig. 9 Depth to Water Level, Nainital, Udham Singh Nagar & Champawat district, August, 2013

5.1.3. November 2013

The depth to water level data is available for 121 Ground Water Monitoring Wells of Uttarakhand during November 2013. The data has been analyzed and shown in ***Table 8***. During this period, the deepest water level of 64.95 m bgl was observed at TarlaNagal (Dehradun district) while the shallowest water level of 0.13 m bgl was observed at Kopa Signal in Udham Singh Nagar district. The analysis of depth to water level data shows that out of 122 wells, 38 wells (31.15% 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 33 monitoring wells (27.05% of the total number). Deeper water level of 10–15 m was observed in 26 wells, which was 21.31% of the total number whereas the deepest water level of >15 m bgl was recorded in 25 wells (20.49% of total wells) in Uttarakhand during November 2013.

Table 8: District wise categorization of depth to water level data, November 2013

District	No. of stations analyzed	Depth to water level (m bgl)		Depth to Water Level (m bgl)							
				0-5		5-10		10-15		>15	
		Min	Max	No.	%	No.	%	No.	%	No.	%
Dehradun	39	2.31	64.95	4	10.26	13	33.33	10	25.64	12	30.77

Haridwar	27	1.75	52.80	8	29.63	10	37.04	7	25.93	2	7.41
U. S. Nagar	32	0.13	14.53	24	75	6	18.75	2	6.25	0	0
Nainital	13	2.99	63.15	1	7.69	2	15.38	3	23.08	7	53.85
Champawat	3	3.26	24.03	1	33.33	1	33.33	0	0	1	33.33
Pauri Garhwal	1	--	50.49	0	0	0	0	0	0	1	100.0
Uttarkashi	7	5.50	37.70	0	0	1	14.29	4	57.14	2	28.57
Total	**122**	**0.13**	**64.95**	**38**	**31.15**	**33**	**27.05**	**26**	**21.31**	**25**	**20.49**

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for November 2013 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 level of 0-5 m was seen in more or less narrow linear zone in north central and central part of Doon valley; also in and around at Dandhi, Maldeota and Kuanawala. The water level in the range of 5-10m was observed surrounding the 0-5m water level zone in north central and central part of Doon valley; this zone also observed in and around at Gularghati, Motichur and Laltappar. The water level in the range of 10-15m was also observed as a narrow concentric zone surrouynding the 5-10m water level zone north central and central part of Doon valley, and in eastern part. It dominately occurs as a curvilinear zone in the southeastern part of Doon Valley covering areas KhadriKhadmap, Khandgaon and Kotimaichak. Most of the Doon Valley shows the water deeper than 15 m.

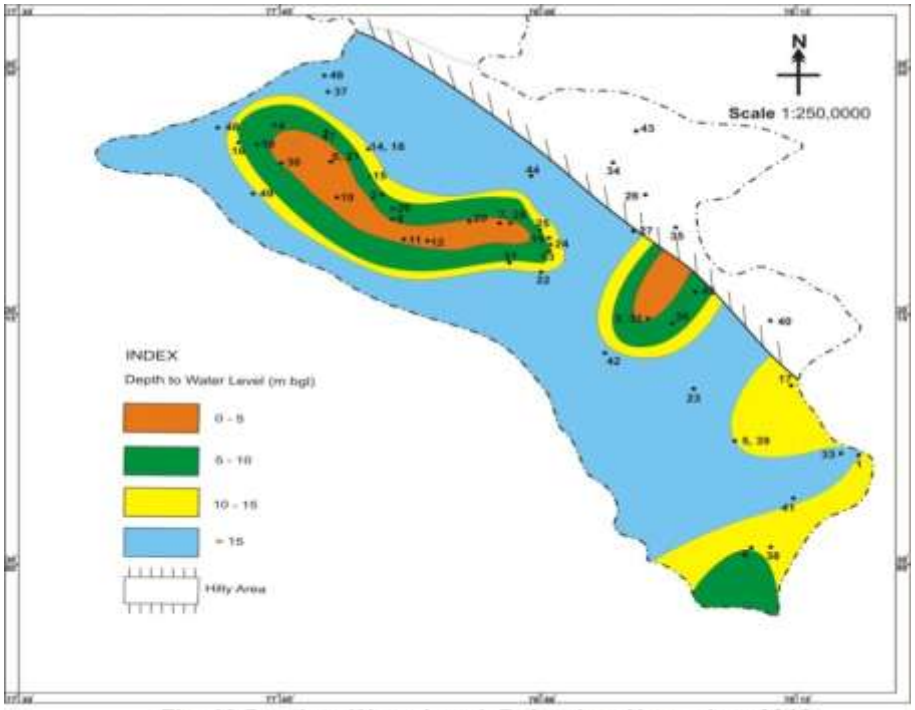

Fig. 10 Depth to Water Level, Dehradun, November, 2013

A perusal of **Fig. 11** (Haridwar Section) reveals that the shallowest water level of 0-5 m occurs mostly in the Southern and Northwestern part of Haridwar District; as isolated patches in and around Lakhnauta- Libhrahedi section. The water levels in the range of 5-10m was observed in Zone extending from northwestern, South western covering central part of the district and then tapers to the south eastern part of the Haridwar District covering area i.e. Jhabrera, Kherajat, Nizampur, Ambhikheri, GurkulNarsen, Roorkee, Dhanpura, Teliwala, Sahidwala Grant and Bandarjud. The water level in the range of 10-15m was observed around the Iqbalpur- Sarai Section; as elliptical patch in south western part of the district. The deeper water level more than 15m was observed as inlier in the 10-15m water level zone in southeastern part of the district; as long linear zone trending from north to southeastern part of the Haridwar district as per the available data.

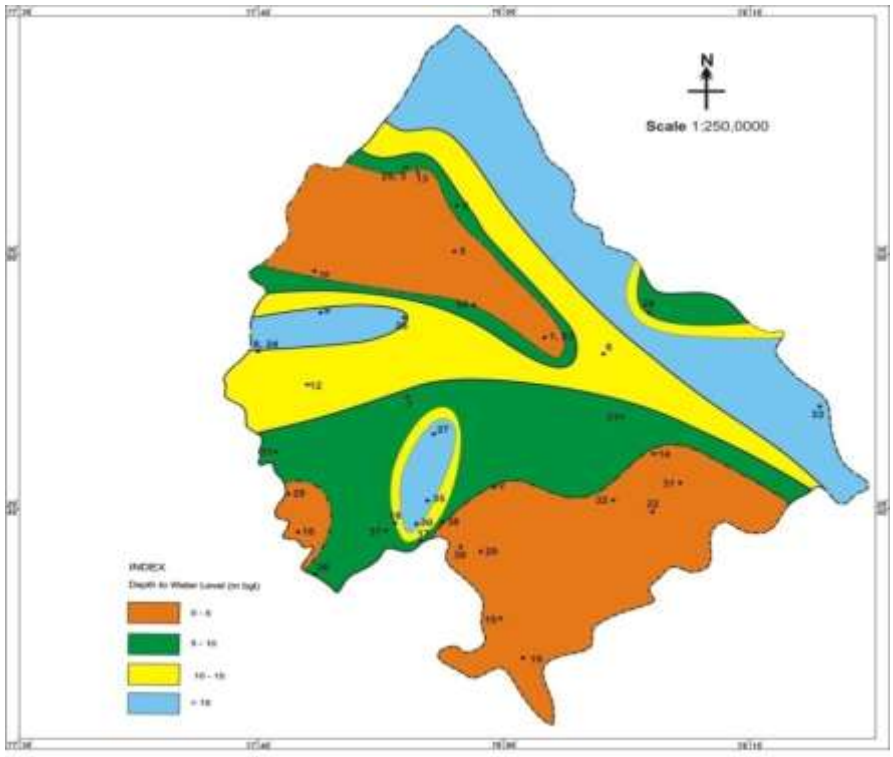

Fig. 11 Depth to Water Level, Haridwar, November, 2013

A perusal of **Fig. 12** reveals that the shallowest water level of 0-5 m was observed in more than 80% of the Tarai Belt; and as isolated patch at the Garjia in Nanital District. The water level zone 5-10m was observed just lying above the 0-5m zone along the Udham Singh Nagar and Nanital boundary; as lenticular shape patch in northern part of Udham Singh Nagar District and also as isolated patched at Kiccha in Udham singhnagar. The 10-15m Zone occurs runs parallel to 5-10m water level zone in the Bhabhar Zone; also occurs at Tanakpur in

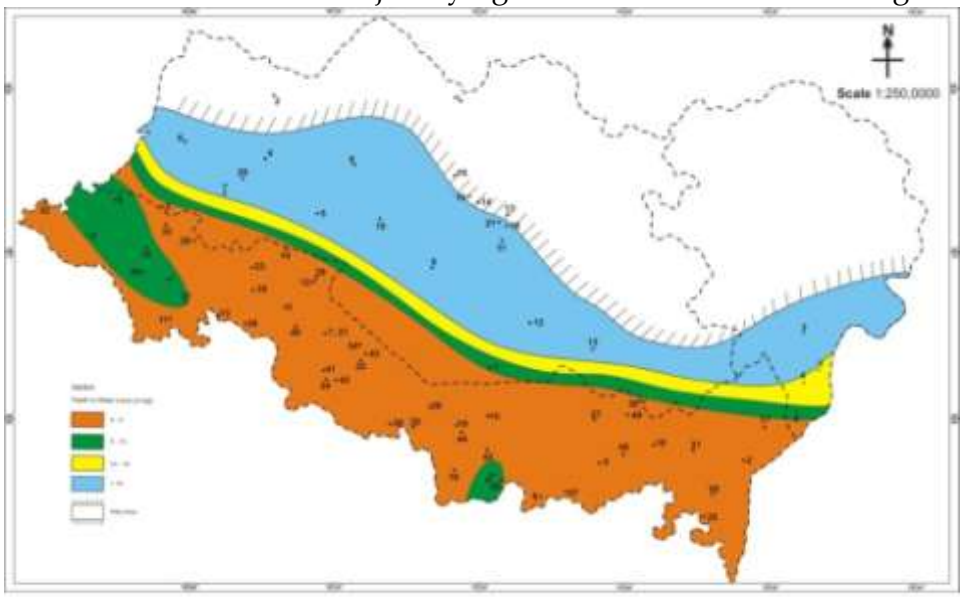

Fig. 12 Depth to Water Level, Nainital, Udham Singh Nagar & Champawat district, November, 2013

Champawat District. The deepest water level in the range of 15m was observed mostly in northern part of Bhabhar Belt.

5.1.4 January 2014

The depth to water level data was analysed for 127 Ground Water Monitoring Wells in Uttarakhand during January 2014 and is given in ***Table 9.*** Analysis of depth to water level data given in the table indicates that the deepest water level was 70.66 m bgl in a piezometer at TarlaNagal, Dehradun district whereas the shallowest water level was 0.29 m bgl at Sultanpur Patti in Udham Singh Nagar district. The shallowest depth to water level of 0–5 m bgl was recorded by 39 monitoring wells, which was 30.70 % of the total number of wells. Water level in the range of 5-10 m bgl was also shown by 39 wells (30.70% of total number of wells), whereas deeper water level of 10–15 m bgl was recorded by 25 monitoring wells, which was 19.69% of the total number of wells. The deepest water level of >15 m bgl was shown by 24 monitoring wells, which was 18.90% of the total number of wells in Uttarakhand monitored in January 2013.

Table 9: District wise categorization of depth to water level data, January 2014

District	*No. of stations analyzed*	*Depth to water level (m bgl)*		*Depth to water level (m bgl)*							
				0-5		*5-10*		*10-15*		*>15*	
		Min	*Max*	*No*	*%*	*No.*	*%*	*No*	*%*	*No*	*%*
Dehradun	43	2.52	70.66	3	6.77	12	27.91	14	32.57	14	32.57
Haridwar	32	1.45	18.09	9	28.12	15	46.88	6	18.75	2	6.25
U. S. Nagar	35	0.29	5.93	24	68.57	10	28.57	1	2.86	0	0
Nainital	9	1.38	60.53	2	22.22	2	22.22	2	22.22	3	33.33
Champawat	3	4.78	24.64	1	33.33	0	0	1	33.33	1	33.33
Pauri Garhwal	1	--	53.47	0	0	0	0	0	0	1	100.0
Uttarkashi	4	16.75	36.85	0	0	0	0	1	25.0	3	75.0
Total	**127**	**0.29**	**70.66**	**39**	**30.70**	**39**	**30.70**	**25**	**19.69**	**24**	**18.91**

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for ***January 2014*** 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 the shallowest water level of 0-5 m was seen in the isolated patches in and around north central (i.e. Redarpur), central and south eastern (i.e. Rhishikesh) part of Doon valley. Water level in the range of 5-10 m was restricted to narrow zones in more or less elliptical shapes in Central Part, Southern and in south eastern part of Doon Valley i.e. Dandhi-Motichur-Khandgaon-Rhishikesh Section.

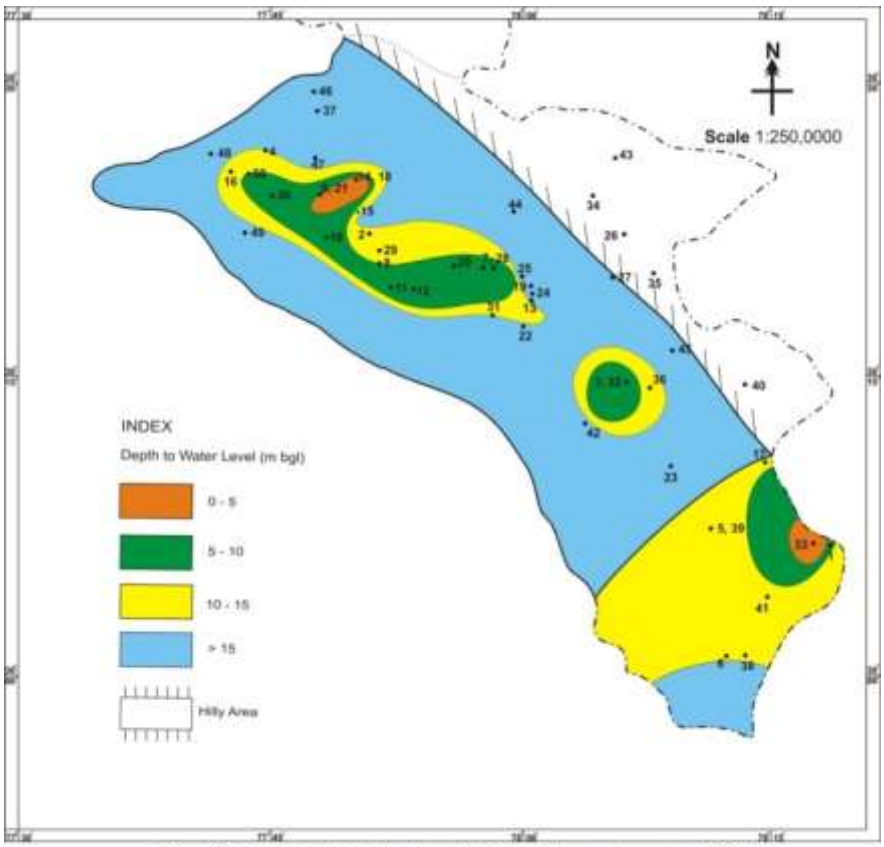

Fig. 13 Depth to Water Level, Dehradun, January, 2014

The water level in the range of 10-15m occurs around the 5-10 m water level zone in central part of Doon valley and is dominant in Southern part of Doon Gravels in and around Lal Tappar-Khadrikhadakmap Section. More than 50 % of the area shows water level deeper than 15m.

A study of ***Fig. 14*** that the water level in the range of 0-5m occurs dominantly covering the southern Part (ShapurShitalkera, Bhogpur, Ambhikhera, Mohamadpur, khanpur, Dallawala and Hussainpur) and North western part (Bhuggawala, Bhabhalpur, Teliwala) of Haridwar District. It also occurs as isolated patch at Kherajat. The water

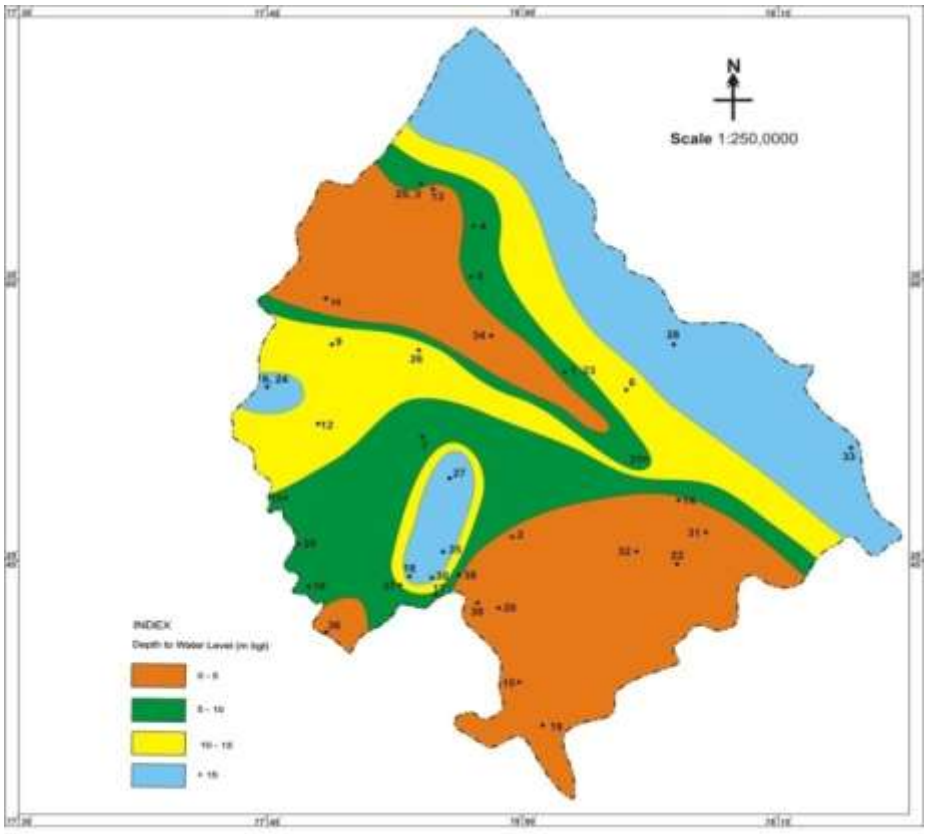

Fig. 14 Depth to Water Level, Haridwar, January, 2014

level in the range of 5-10m occurs in southwestern part of Haridwar district as broad zone which tapers as one move from south eastern to south western part of Haridwar district. It also occur in northwestern part surrounding the water level in the range of 0-5m. The water level in the range of 10-15m occurs as elliptical zone on southern part, and as broad zone in western part covering areas Bhagwanpur, Iqbalpur, Imlikhera, Sarai, Bahadrabad. The water level deeper than 15m occurs mostly in more or less linear zone trending from northern part of Haridwar district to south eastern part. This zone also occurs as inlier in the elliptical zone of 10-15m water level and as isolated patch at Chudiala.

A study of ***Fig. 15*** (Nainital-Udham Singh Nagar-Champawat section) reveals that the lowest depth to water level of 0-5 m was seen in more than 80 % of the Tarai Belt; including the Banbasa in Champawat District and also as isolated patch at Garjia in Nanital District. The water level in the Range of 5-10 m was found just north of the 0-5 m depth to water level zone in Nanital district, Udham Singh Nagar district, and as small isolated patches at BarkhrePande, Kichha, in and around Jaspur, Patrampur and Baratpur. The water level in the range of 10-15m was found resting above the 5-10m Zone. The Northern, Central; and Southern Part of Bhabhar Zone shows the deeper water level more than 15 m. In general it is observed that water level deepens when one goes from South to north.

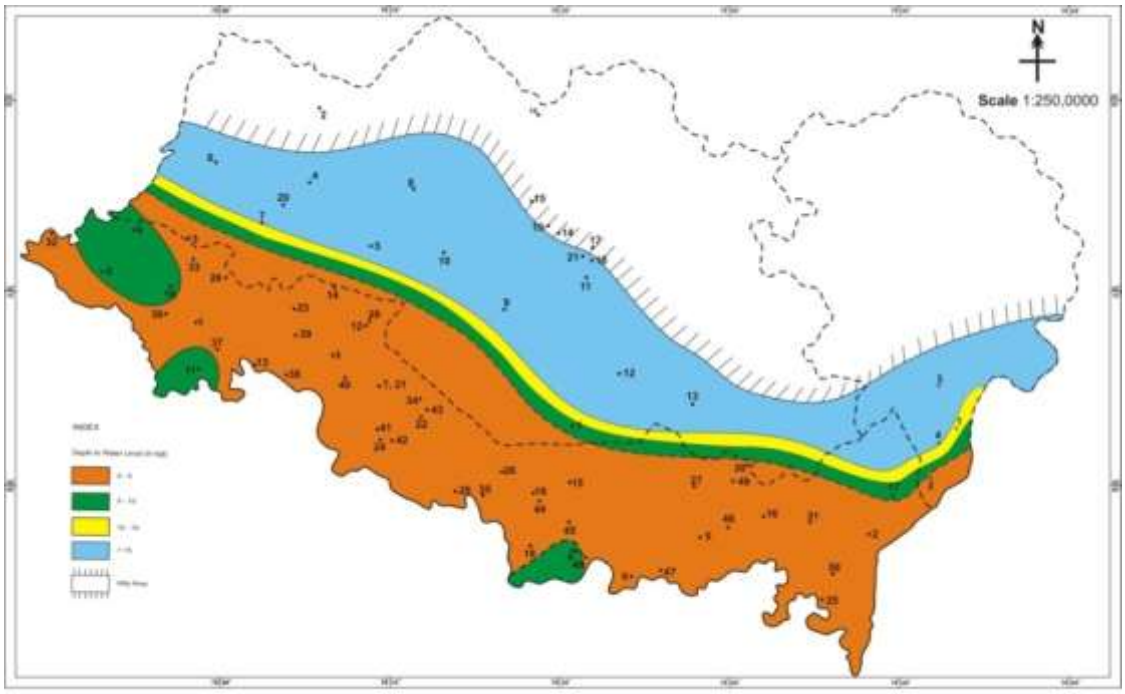

Fig.15 Depth to Water Level, Nainital, Udham Singh Nagar & Champawat district, January, 2014

5.2 DISCHARGE OF SPRINGS

The discharge data of thirty-four cold-water springs in Dehradun, Nainital, Uttarkashi and Almora districts for the months of May, August, November 2013 and January 2014 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 2013-January 2014 varies from a minimum measurable discharge of 0.41 LPM at Chinoda in Almora district during May 2013 to a maximum of 528.54 LPM at Sipahidhara in Nanital district during the Post-monsoon period (November 2013). Discharge of springs varies within wide limits during the intervening period.

In Dehradun district, spring discharge varies between 2 LPM at Bhatta in May 2012 and 31.15 LPM at Khandoli in January 2014. In Nainital district, spring discharge varies from a minimum of 2.51 LPM at Salari (May 2013) to a maximum of 267.58 LPM at Sipahidhara (January 2014). In Almora district, the spring discharge was found to be varying from a minimum of 0.41 LPM at Chinoda in May 2013 to a maximum of 150.0 LPM at Dhansari in January 2014. In Uttarkashi district, spring discharge was varying from 6.52 LPM at Nagal in January 2014 to a maximum of 40 LPM in Ratodisar in May 2013.

Table 10: Discharge of Springs in May, August, November 2013 and January 2014

SL. No.	Location	May-13	Aug-13	Nov-13	Jan-14
DEHRADUN DISTRICT					
1	Bhatta SP	2 lpm	11 lpm	10.00 lpm	7.5 lpm
2	Khandoli SP	8 lpm	NA	NA	31.15 lpm
3	Soda Sarauli SP	5 lpm	85 lpm	28.00 lpm	9.09 lpm
NAINITAL DISTRICT					
1	Dogaon SP	14.80 lpm	10 lpm	34.48 lpm	25.92 lpm
2	Sipahidhara SP I	60.61 lpm	450 lpm	150 lpm	**267.58**
3	Sipahidhara SP II	NA	NA	159.57 lpm	
4	Sipahidhara SP III	NA	NA	218.97 lpm	
5	Garampani SP	45.45 lpm	30 lpm	18.60 lpm	38.70 lpm
6	Salari SP I	2.51 lpm	33.33 lpm	13.3 lpm	26.98 lpm
7	Salari SP II	NA	NA	13.66 lpm	NA
8	Ranibagh SP	6.14 lpm	30 lpm	43.29 lpm	25 lpm
9	Jeolykot SP	23.46 lpm	100 lpm	35.62 lpm	88.23 lpm
ALMORA DISTRICT					
1	PataliTalla SP	1.15 lpm	20 lpm	5.69 lpm	16.17 lpm
2	PataliMalla SP	26.43 lpm	25 lpm	3.07 lpm	19.67 lpm
3	Katarmal SP	24.19 lpm	50 lpm	5.85 lpm	24.29 lpm
4	DharaNaula SP	6.45 lpm	10 lpm	44.38 lpm	9.74 lpm

5	Palna SP	1.58 lpm	2.3 lpm	17.03 lpm	2.90 lpm
6	Chinoda SP	0.41 lpm	6 lpm	62.0 lpm	2.04 lpm
7	Guruda - I SP	1.82 lpm	12 lpm	17.47 lpm	20.4 lpm
8	Guruda - II SP	10.71 lpm	30 lpm	4.09 lpm	
9	Dhansari SP	94.34 lpm	100 lpm	1.29 lpm	150.75 lpm
10	Someshwar SP	4.00 lpm	10 lpm	14.07 lpm	7.39 lpm
11	Dharanaulla Zoo SP	1.20 lpm	2.72 lpm	13.60 lpm	2.97 lpm
12	Bachuradi SP	32.86 lpm	5.45 lpm	4.10 lpm	53.57 lpm
13	Deepakot SP	6.00 lpm	4.41 lpm	7.58 lpm	8.35 lpm
14	Ramgath SP	15.79 lpm	42.85 lpm	2.55 lpm	18.18 lpm
15	Bhagtola SP	0.97 lpm	5.66 lpm	26.3 lpm	3.00 lpm
16	Itola SP	NA	NA	17.05 lpm	3.05 lpm
17	Potasarin SP	NA	NA	23.04 lpm	1.73 lpm
18	ChhaniBartola SP	NA	NA	18.53 lpm	8.68 lpm
19	Lodh SP	NA	NA	7.42 lpm	6.28 lpm
DISTRICT UTTARKASHI					
1	Dharasu Spring	36 lpm	NA	NA	7.66 lpm
2	Nagal Spring	13 lpm	NA	NA	6.52 lpm
3	RatodiSar Spring	40 lpm	NA	NA	15.01 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 2003 to 2012 and January for the period from 2004 to 2013). The average depth to water level data available for maximum 68 Ground Water Monitoring Wells is given in ***Table 11.***

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

Sr. No.	*Well No.*	*Location*	*Depth to Water Level (m bgl)*			
			Avg. May	*Avg. August*	*Avg. November*	*Avg. January*
			2003-2012			*2004-2013*
DEHRADUN DISTRICT						
1	DDN03	Rishikesh	16.7	11.07	11.91	13.07
2	DDN04	Rampura	14.55	6.74	10.97	12.74
3	DDN05	Kuanwala				9.42
4	DDN06	Herbertpur	10.35	5.56	8.08	9.4
5	DDN07	Jhajra				11.63
6	DDN08	Lal Tappar	18	15.12	13.82	14.44
7	DDN09	Motichur	10.81	4.38	8.79	9.8
8	DDN10	Nanda Ki Chowki	15.1	7.39	8.38	9.81
9	DDN11	Selakui	10.58	7.23	7.97	8.91
10	DDN12	Redapur	7.04	4.39	5.21	4.41
11	DDN14A	Sabhawala	9.31	6.02	7.67	8.24
12	DDN15	Singhniwala	9.71	6.8	8.65	9.38
13	DDN16	Ramgarh				5.97
14	DDN18	Kanwali	15.58	9	12.58	14.71
15	DDN19	Chhorba	18.35			
16		Judli		11.1	12.65	13.73
17		Shankarpur			17.99	18.64
HARIDWAR DISTRICT						
1	HRW07	Bahadrabad	5.08	3.68	3.89	
2	HRW08	Dhanpura	5.85	3.12	4.01	4.64
3	HRW10	Hussainpur	3.72	1.53	2.42	2.43
4	HRW12	Shahidwala Grant	13.34	11.59	11.5	12.08
5	HRW-PZ1	Roorkee Pz	7.21	5.49	5.81	5.98
6	HRW-PZ2	ChudialaPz		18.62		

7	HRW-HP1	Bhagwanpur	20.29	16.17	17.44	17.14
8	HRW-HP2	Bahabalpur	3.24	2.88	3.01	3.52
9	HRW-HP3	Jhabrera	10.26	7.91	8.82	8.36
10	HRW-HP4	Iqbalpur	17.17	12.59	14.5	15.53
11	HRW-HP5	Buggawala	8.12	5.1	5.54	6.27
UDHAM SINGH NAGAR DISTRICT						
1	USN 01A	Kashipur	5.2	2.77	3.25	3.7
2	USN 02	Khatima	3.52	0.88	1.6	2.51
3	USN 03	Bazpur	2.55	0.54	1.52	1.81
4	USN 05	Kichha		5.02	4.97	5.51
5	USN 06	Sitarganj	4.71	1.66	2.35	2.2
6	USN 07	Bara	2.73	0.98	1.95	2.27
7	USN11	Angadpur			3.81	3.83
8	USN12	Patrampur		7.1	6.32	6.49
9	USN13	BarkharePande		4.02		
10	USN16	Barhini			1.19	1.73
11	USN18	Banna Khera	4.8	3.32	3.53	3.8
12	USN19	Shantipuri	2.38	0.62	1.54	1.8
13	USN20	Nanak Mata	5.5	2.65	3.21	3.93
14	USN21	Chakarpur		4.74	4.29	4.55
15	USNHP1	KamariaPakki	6.72	3.32		4.8
16	USNHP2	Gangapur	3.4	2.73	2.34	2.97
17	USNHP3	Bhagwanpur	5.47	3.2	3.37	3.67
18	USNHP4	Beria Daulat	3.61	0.92	2.51	2.95
19	USNHP5	Mahabir Nagar	2.67	1.25	1.81	2.67
20	USN-HP6	Jogipura	7.22	4.63	4.91	5.41
21	USN-HP7	Jhagarpuri	2.73	1.11		
22	USN-HP9	Majhola	4.53	2.65	3.58	3.8
23	USN-HP10	Dhanauri Patti	4.49	2.48	2.63	3.36
24	USN-HP11	Kalyanpur	4.69	1.21		
25	USN-HP12	Patthar Chatta	2.72	1.74	2.66	2.48
NAINITAL DISTRICT						
1	NTL03	Lalkuan	9.15	8.2	7.2	6.68
2	NTL04	Garjiya	4.35	2.64	4.32	4.29
3	NTL05	Maldhan Colony	4.31	1.99	2.65	3.34
4	NTL-HP1	Ramnagar	7.3	6.27	6.33	7.41
5	NTL-HP2	Belparao	55.59		51.68	
6	NTL-HP3	Dhela	62.1	66.5	65.06	
7	NTLHP4	PeeruMadara	22.93	21.66	16.5	18.39
8	NTL-HP5	Dhoniya	70.4	67.35	56.18	
9	NTL-HP6	Lamachaur	46.36	45.39		44.47

10	NTL-HP7	Kaladhungi	25.74	25.76	24.74	27.16
11	NTL-HP8	Kathgodam	20.85	14.79	17.39	19.54
12	NTL-HP9	Sitapur	56.75	53.26	49.66	
13	NTL-HP10	Khaat Baas	36.52		26.75	30.28
CHAMPAWAT DISTRICT						
1	CPT1	Tanakpur	11.25	6.67	8.7	10.34
2	CPT-HP1	Banbasa	6.86	2.24	9.77	4.64
3	CPT-HP2	Bastia	34.53	21.95	26.42	28.05

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 was 0.54 m bgl at Bazpur hand pump in Udham Singh Nagar district in August whereas the maximum was 66.5 m bgl at Dhela hand pump in Nainital district in August. The table also shows that for Dehradun district, the minimum long-term water level was 4.38 m bgl at Motichur in August whereas the maximum was 18.64 m bgl at Shankarpur in January.

In Haridwar district, decadal water level was found to be varying from 1.53 m bgl at Hussainpur dug well in August to the maximum of 20.29 m bgl at Bhagwanpur hand pump in May. In Udham Singh Nagar district, the long-term depth to water level was variable from 0.54 m bgl at Bazpur in August to 6.72 m bgl at KamariaPakki hand pump in May viz. in the pre-monsoon period. The decadal water level in Nainital district was varying from 1.99 m bgl at Maldhan Colony dug well in August to a maximum of 70.40 m bgl at Dhoniya hand pump in May viz. in the pre-monsoon period. Long-term depth to water level in Champawat district was ranging from 2.24 m bgl at Banbasa Handpump in August to 34.53 m bgl at Bastia hand pump in May viz. during pre-monsoon period.

5.4 WATER LEVEL FLUCTUATION

The changes in ground water level in response to recharge and ground water withdrawal are important aspects for study of the overall hydrogeological scenario of an area. The water level fluctuation was 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 2003-2012 versus May 2013)

The analysis of decadal depth to water level data for 57 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 was observed in 18 monitoring wells (33.96 % of the total number) whereas higher rise in the range of 2-4 m was observed in 2 wells (3.77 % of total). The no well recorded the decadal rise in water level (>4 m). The lowest long-term decline in the range of 0-2 m was recorded in 26 wells, which was 49.06 % of the total number. Higher long-term decline in the range of 2-4 m was recorded in 11 wells, which was 20.75 % and the highest decline of >4 m was not observed in any monitoring wells. Analysis of the decadal data also shows that the lowest decadal rise was 0.01 m at Jhagarpuri in Udham Singh Nagar district while the highest rise was 2.76 m at Bugawala in Haridwar district. The lowest long-term decline in water level was 0.19 m at Garjia in Nanital district while the highest was 3.38 m at Kaladhungi in Nainital district.

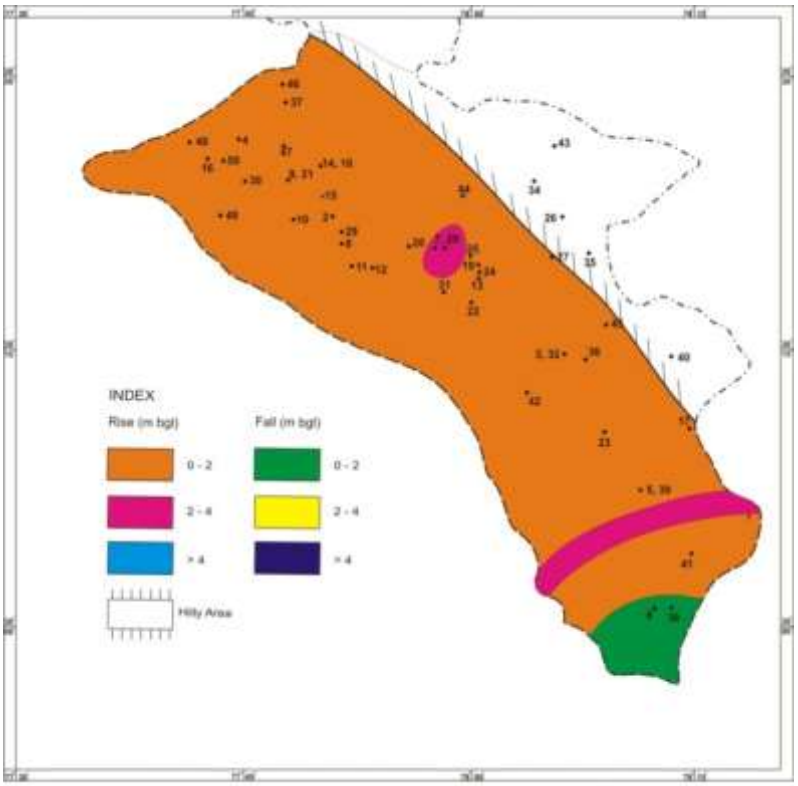

Fig. 16 Decadal Water Level Fluctuation Map, May (2003-2012 Vs 2013) Dehradun district

A study of **Fig. 16** reveals that the minimum rise of 0-2 m was observed in major parts of Doon

Valley in Dehradun district. Higher decadal rise of 2-4 m was found in the south eastern part of Doon Valley, Dehradun district. The highest decadal rise of >4 m was seen nowhere. Decadal decline in water level in the range of 0-2 m was seen in and around Chhorba-Nanda Ki Chowki & Motichur-Khandgaon area in the southeastern part of Doon Valley area in the northern part of Doon Valley. The decadal decline in the range og of 2-4 m and >4m was not observed in Dehradun district according to the available data.

A study of **Fig. 17** reveals that the minimum rise of 0-2 m was observed innorthern and northeastern part of the Haridwar District. Higher decadal rise of 2-4 m was found as isolated patch at Buggawala and the highest decadal rise of >4 m was not observed. Decadal decline in water level in the range of 0-2 m was seen in the central, western, eastern and southern part of the Haridwar district. Decline in the range of 2-4 m was seen as isolated patch at Dhanpura.

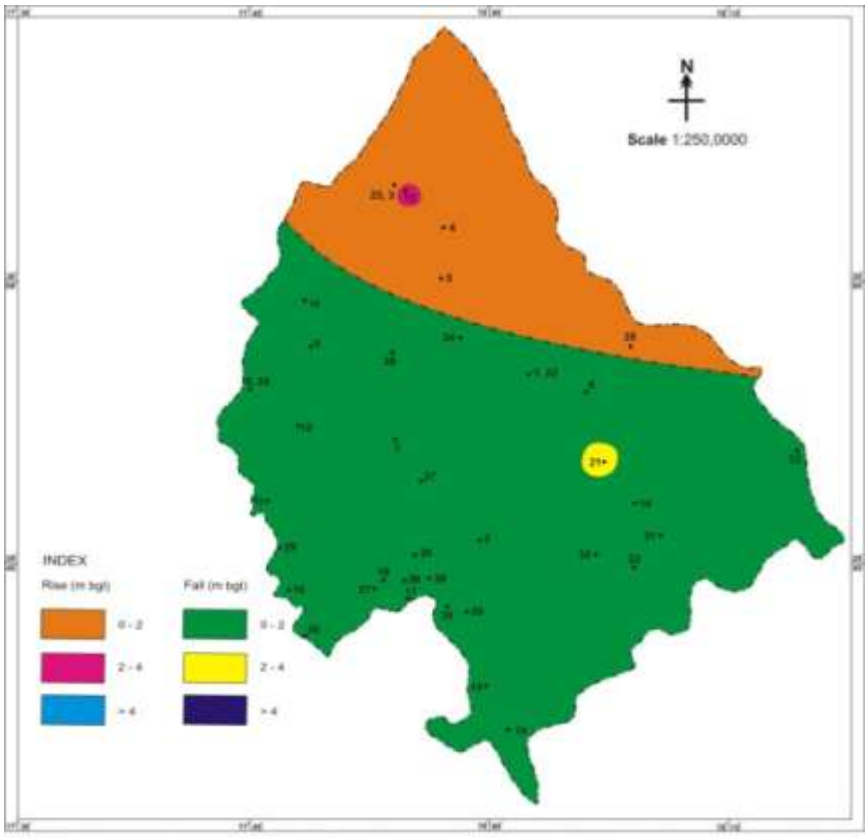

Fig. 17 Decadal Water Level Fluctuation Map, May (2003-2012 Vs 2013) Haridwar district

Interpretaton of **Fig. 18** has shown that decadal rise of 0-2 m was confined to Khatima-Nanak Mata-Bara area of Udham Singh Nagar district (in the Tarai zone), in Lamachaur- Kaladhungi area in Nainital district falling in the Bhabar zone and in and around Banbasa in Champawat district. Rise of 2-4 m was seen only around the Bastia in Champawat District. Highest decadal rise of >4 m was also observed nowhere in these areas (viz. in Udham Singh Nagar,Nainital and Champawat districts). It is also seen that decline in the range of 0-2 m was observed in major areas in Udham Singh Nagar-Nainital-Champawat section. It is more prominent in the western part of Nainital and Champawat districts, in the southern part of Nainital district and in central part of the Udham Singh Nagar District. Decadal fall of 2-4 m was seen in western part of Udham singhnagar District i.e. Angadpur-Kashipur-BarkharePande section), in and around Kaladhungi, Belparao,Dhela and PeeruMadara area in Nainital district. Highest decadal decline of >4 m was seen nowhere in these areas (viz. in Udham Singh Nagar, Nainital and Champawat districts).

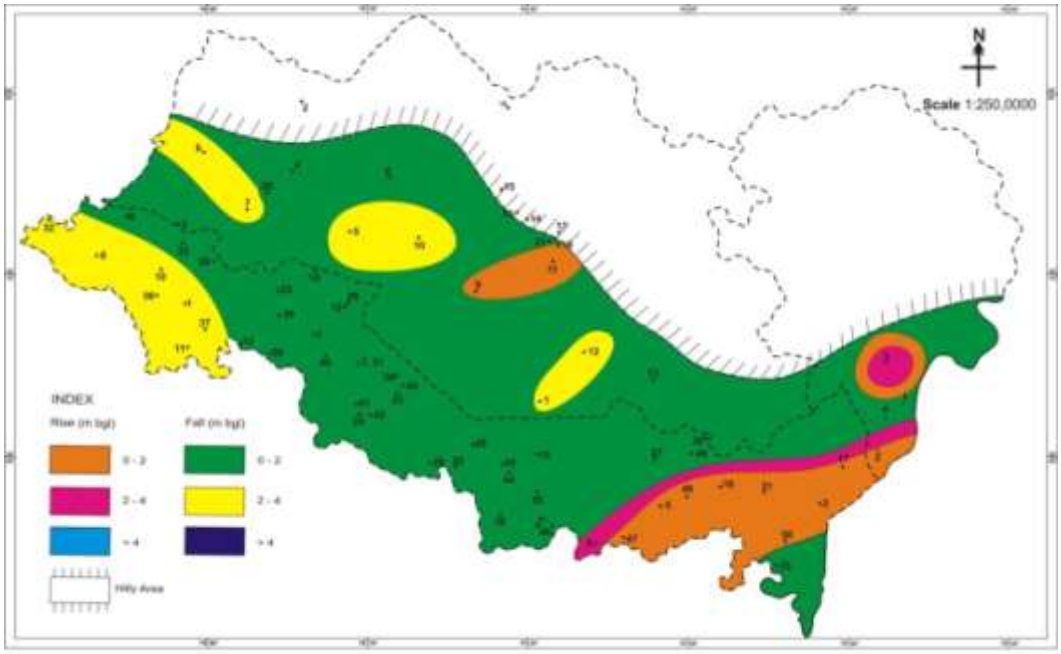

Fig. 18 Decadal Water Level Fluctuation Map, May (2003-2012 Vs 2013) Nainital, Udham Singh Nagar & Champawat district

Table 12. Decadal Water Level Fluctuation (May 2003 –May 2012 Versus May 2013)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	12	0.06	2.09	--	2.47	9	75.01	1	8.33	0	0	1	8.33	1	8.33	0	0
Haridwar	10	0.71	2.76	0.36	3.21	1	10	1	10	0	0	7	70	1	10	0	0
Udham Singh Nagar	19	0.01	0.69	0.08	2.89	6	31.58	0	0	0	0	11	57.89	2	10.53	0	0
Nainital	13	0.86	1.29	0.19	3.38	2	15.38	0	0	0	0	5	38.47	6	46.15	0	0
Champawat	3	--	--	0.45	3.70	0	0	0	0	0	0	2	75.00	1	25.00	0	0
Total	**57**	**0.01**	**2.76**	**0.19**	**3.38**	**18**	**33.96**	**2**	**3.77**	**0**	**0**	**26**	**49.06**	**11**	**20.75**	**0**	**0**

5.4.1.2 Water Level Fluctuation (August 2003-2012 versus August 2013)

Long-term water level data for 60 monitoring wells was analyzed and is shown in ***Table 13***. A perusal of the data shows that the minimum decadal rise was 0.05 m at Hussainpur in Haridwar district whereas the maximum decadal rise was 5.21 m at Bastia in Champawat district. The minimum long-term decline in water level was 0.04 m at Bhagwanpur in Udham Singh Nagar district whereas the maximum decadal decline of 4.34 m was recorded at Sitapur in Nainital district.

A perusal of **Table 13** indicates that the minimum long-term rise in the range of 0-2 m was observed in 19 monitoring wells (31.67 % of the total number), whereas higher rise in the range of 2-4 m was observed in 11 wells (18.33 % of total) and the highest rise of >4 m were observed in 3 monitoring wells each (5.00 % of total wells). The lowest long-term decline of water level in the range of 0-2 m was recorded in 22 monitoring wells, which was 36.67 % of the total number. Higher long-term decline in the range of 2-4 m was recorded by 4 wells (6.67 % of total) whereas the highest decline of >4 m was observed in 1 monitoring wells, which was 1.66% of the total number of wells.

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for ***May 2013*** 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 rise of 0-2 m was found in Lenticular shape zone in central part of Doon valley and also in southeastern part to a small area in the south central part i.e. in and around Rishikesh area. Higher rise of 2-4 m was seen in more than 70 % area of the Doon valley.

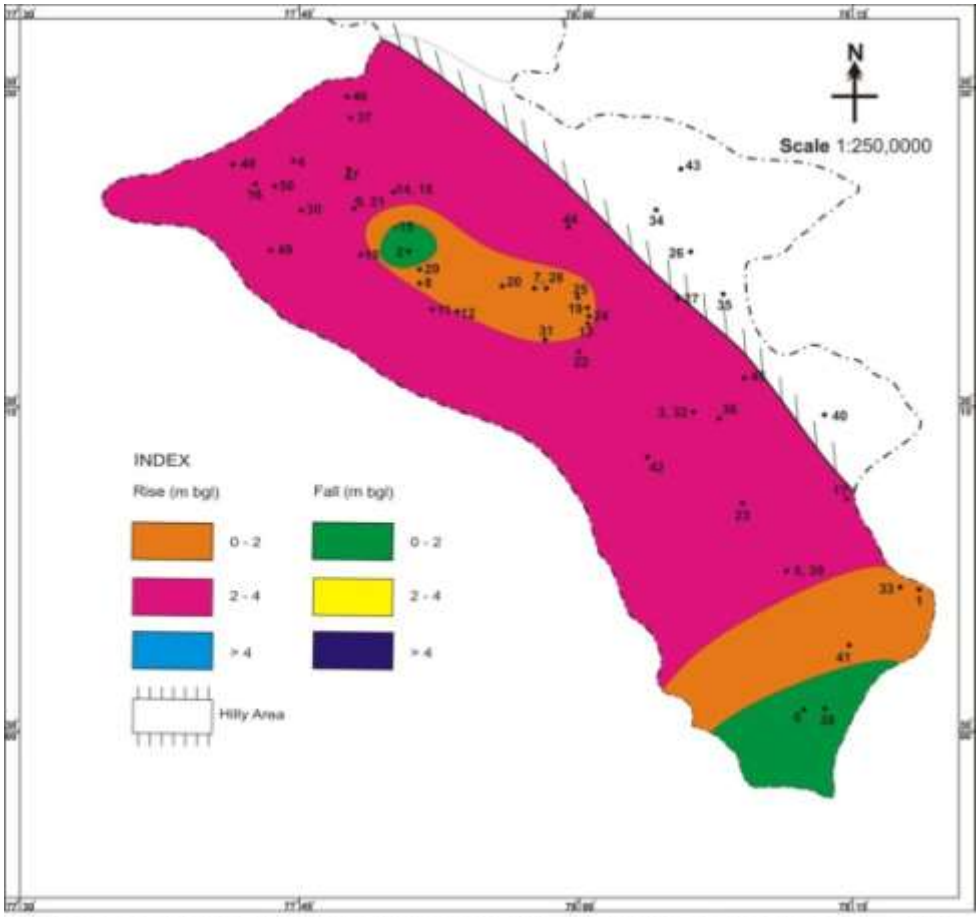

Fig. 19 Decadal Water Level Fluctuation Map, August (2003-2012 Vs 2013) Dehradun district

No area shows Decadal water level rise >4m in Doon valley. The minimum long-term decline of 0-2 m was seen in patches in and around Miotichur and Shankarpur in Dehradun district. Higher decline of 2-4 m was also seen in isolated patch at Rampura in Doon Valley. No area shows water level Deeper than 4m in Doon valley. From this figure it wasalso observed that during Monsoon Period i.e. August during the decade the water levels had been raised.

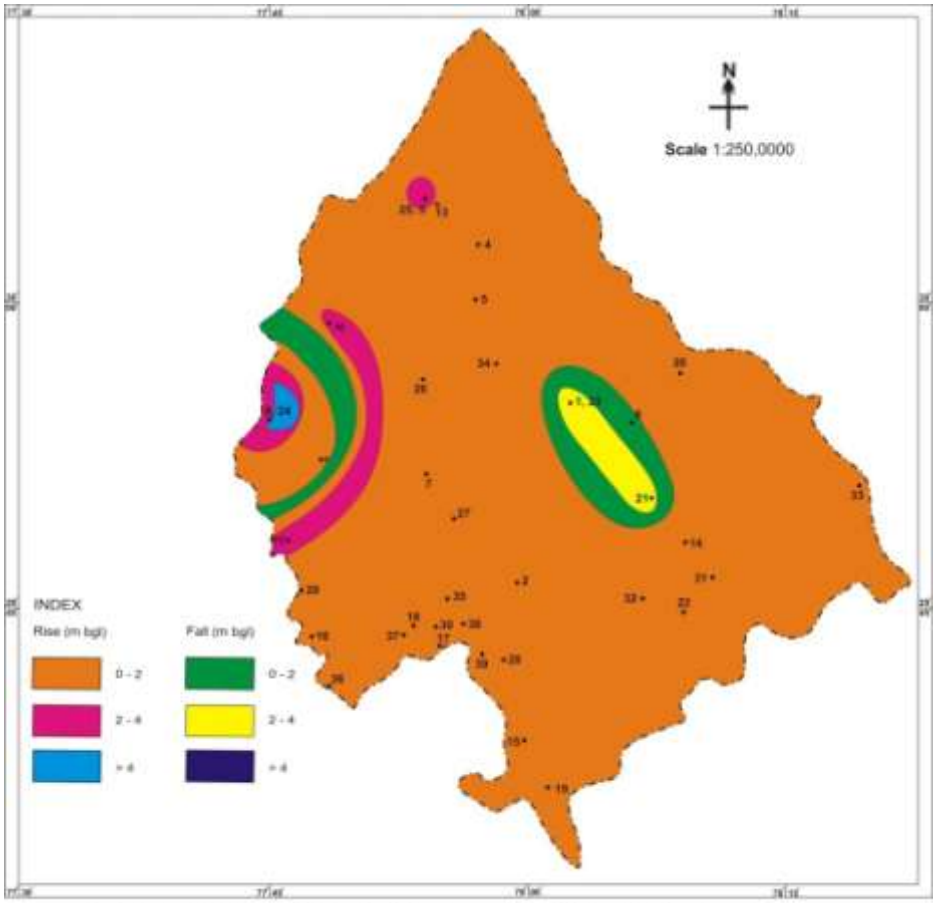

Fig. 20 Decadal Water Level Fluctuation Map, August (2003-2012 Vs 2013) Haridwar district

Visual interpretation of **Fig. 20** has shown that minimum decadal rise of 0-2 m was found in more than 80% of the areas in Haridwar District. Higher rise of 2-4 m was seen in isolated arc shaped patches in western part of the district i.e. at Sahidwala Grant and in Jhabrea-Lakhnauta section. The Decadal water level rise >4m was observed in and around Chudiala in Haridwar District. The minimum long-term decline of 0-2 m was seen in arc shaped patche at Shankarpur and elliptical patch at Sarai. Higher decline of 2-4 m was also seen in Bahadrabad and Dhanpur section. No area shows water level Deeper than 4m in Haridwar district. As new moves from western part to eastern part of District the water levels deepens.

Visual interpretation of **Fig. 21** reveals that minimum decadal rise of 0-2 m was seen dominantly in south eastern part of Udham Singh Nagar district , covering southern part of Champawat District. Besides this, it also occurs as isolated patches at Mahabir Nagar, Gangapur, Jogipura, Dhanuri Patti in Udham Singh Nagar district and at Dhela ,Lamachaur in Nainital district. Higher decadal rise of 2-4 m was seen only in the isolated patch at Garjia in Nanital District. The highest decadal rise of >4 m was found only in isolated patch at Bastia in Champawat District. The lowest decadal decline of 0-2 m was observed in major part of Tarai zone in Udham Singh Nagar district, occupying an area of ~70% of the entire district. The same situation was also seen in the central and in Bhabhar Zone. Higher decadal decline of 2-4 m was seen as isolated patch at Patrampur in Udham Singh Nagar district. The highest decadal decline of >4 m was seen in and around Jhagarpuri in Udham Singh Nagar district.

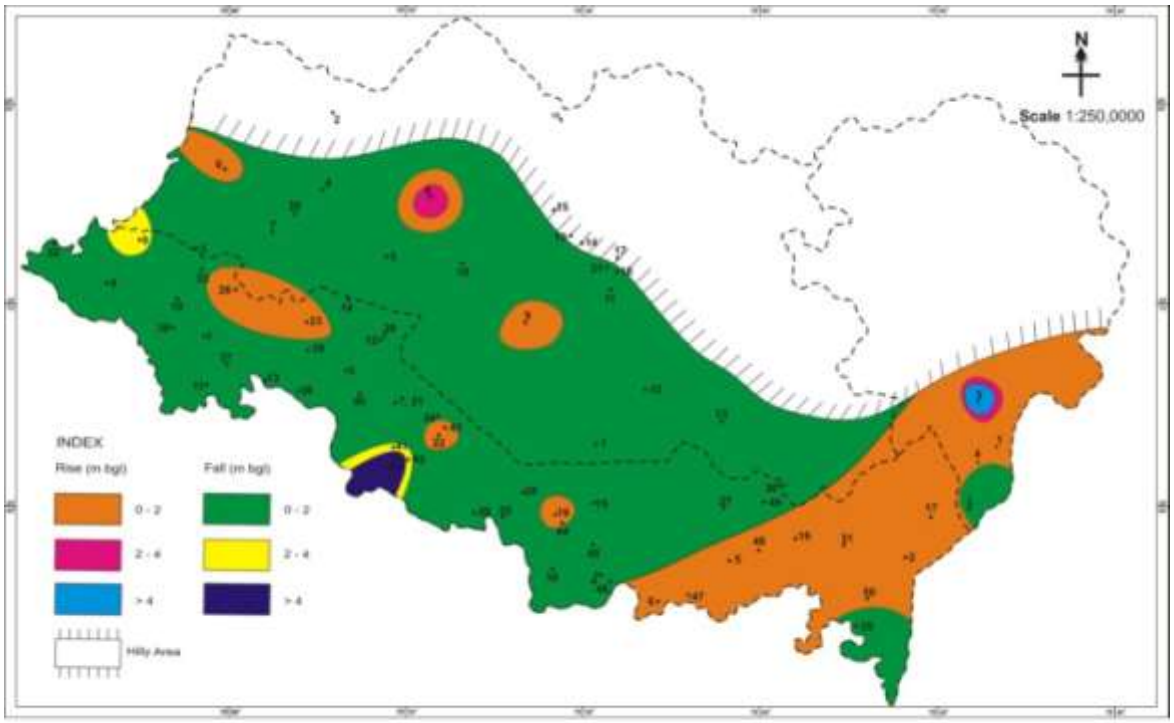

Fig. 21 Decadal Water Level Fluctuation Map, August (2003-2012 Vs 2013) Nainital, Udham Singh Nagar & Champawat district

Table 13. Decadal Water Level Fluctuation (August 2003 –August 2012 versus August 2013)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	12	0.99	4.75	--	1.20	3	25	7	58.34	1	8.33	1	8.33	0	0	0	0
Haridwar	11	0.05	4.86	0.76	3.12	4	36.35	3	27.27	1	9.10	1	9.10	2	18.18	0	0
Udham Singh Nagar	23	0.17	1.91	0.04	2.63	9	39.13	0	0	0	0	13	56.52	1	4.35	0	0
Nainital	11	0.51	3.72	0.07	4.34	2	18.18	1	9.09	0	0	6	54.55	1	9.09	1	9.09
Champawat	3	0.17	5.21	--	0.39	1	33.33	0	0	1	33.33	1	33.34	0	0	0	0
Total	**60**	**0.05**	**5.21**	**0.04**	**4.34**	**19**	**31.67**	**11**	**18.33**	**3**	**5**	**22**	**36.67**	**4**	**6.67**	**1**	**1.66**

5.4.1.3 Water Level Fluctuation (November 2003-2012 versus November 2013)

Long-term water level data for 57 monitoring wells was analyzed and is shown in ***Table 14***. A perusal of the data shows that the minimum decadal rise was 0.08 m at Kanwali dugwell in Dehradun district while the maximum decadal rise was 4.56 m at Banbasa in Champawat district. The minimum decadal decline in water level was 0.04 m at Kanwali in Dehradun district while the maximum decadal decline was 7.74 m at Sitapur in Nainital district. The table also indicates that 27 monitoring wells out of 57 (47.37 % of total) had shown decadal rise of 0-2 m, 4 monitoring wells (7.07 % of total) had shown rise of 2-4 m and another 1 monitoring wells (1.17 % of total) had shown the highest decadal rise of >4 m. As far as decadal decline in water level is concerned, 15 wells out of 57 (26.32 % of total) had recorded decadal decline in the range of 0-2 m, 7 monitoring wells (12.28 % of total) had shown higher decadal decline of 2-4 m and 3 monitoring wells (5.27 % 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 (January 2003-2012) versus January 2013 is shown in **Fig. 22(***Dehradun District),* **Fig 23** *(Haridwar District)* and ***Fig. 24*** *(Nainital-Udham Singh Nagar-Champawat section).*

A perusal of **Fig. 22** reveals that minimum decadal rise of 0-2 m was observed in >80% parts of Doon Valley. Higher decadal rise of 2-4 m was observed in the shape of dome in west central part of Doon valley covering areas of Redarpur-Sabhawala section. No area shows the highest decadal rise of >4 m, as per the available

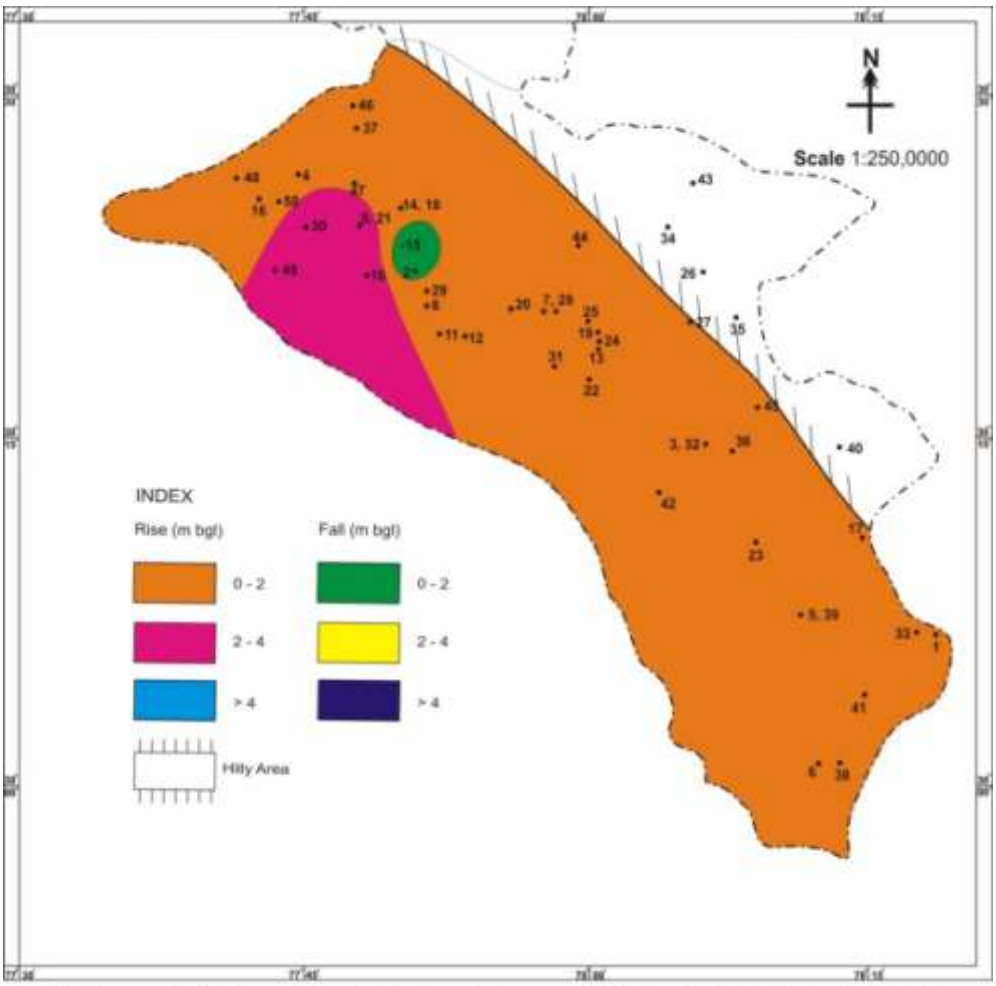

Fig. 22 Decadal Water Level Fluctuation Map, November (2003-2012 Vs 2013) Dehradun district

data. The figure also shows that minimum decadal decline of 0-2 m was seen only as isolated patch at Judli., The decadal decline in the range of 2-4m and >4 m was not recorded in Dehradun.

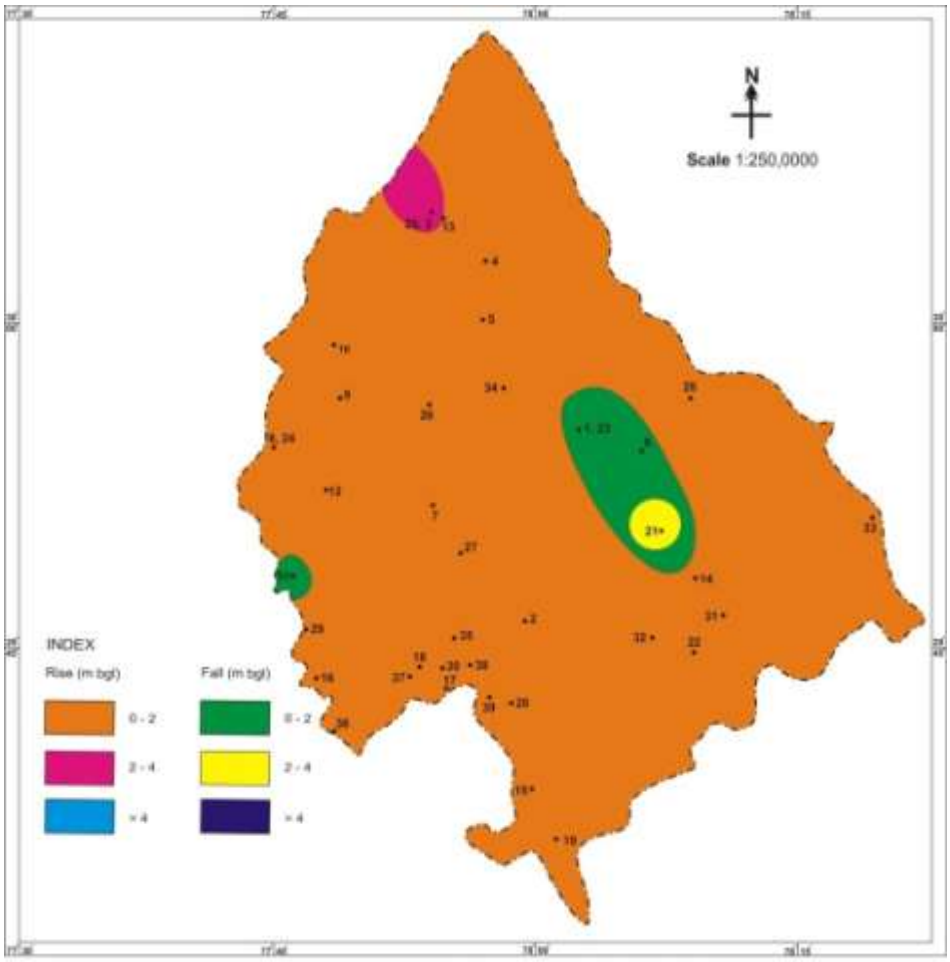

Fig. 23 Decadal Water Level Fluctuation Map, November (2003-2012 Vs 2013) Haridwar district

A perusal of **Fig. 23** reveals that minimum decadal rise of 0-2 m was observed in >80% parts of Haridwar District. Higher decadal rise of 2-4 m was observed as a as isolated patch at Sahidwala Grant. No area shows the highest decadal rise of >4 m, as per the available data. The figure also shows that minimum decadal decline of 0-2 m was observed as a linear zone trending NE-SW in the south eastern part of Haridwar district and as isolated patch at Jhabrera. Higher decadal decline of 2-4 m was observed in and around Goverdhanpur. The highest decadal decline of >4 m was not recorded in Haridwar District.

Visual interpretation of **Fig. 24** has shown that minimum decadal rise of 0-2 m was found in isolated areas in the north western, west central, southern and south eastern parts of Udham Singh Nagar district, in the western part of Nainital district and eastern part of Bhabar zone in Champawat district. Higher decadal rise of 2-4 m was seen as isolated patch in and around Jogipura in Udham Singh Nagar District whereas the highest decadal rise of >4 m was observed only at Banbasa in Champawat district in this section. The minimum decadal decline of 0-2 m was observed in ~70% area of Udham Singh Nagar district falling in the Tarai zone and in ~65% area in the Bhabar zone of Nainital district. Higher decadal decline of 2-4 m was observed in and around Kashipur- Patrampur section and as isolated patch at Chakarpur in Udham Singh Nagar District falling in the Tarai zone, in the north central and central part of the Bhabhar zone. The highest decadal decline of >4 m was inferred in the central part of Bhabhar Zone around Khaat Baas- Sitapur and as isolated patch at PeeruMadara in the Bhabar zone, Nainital district .

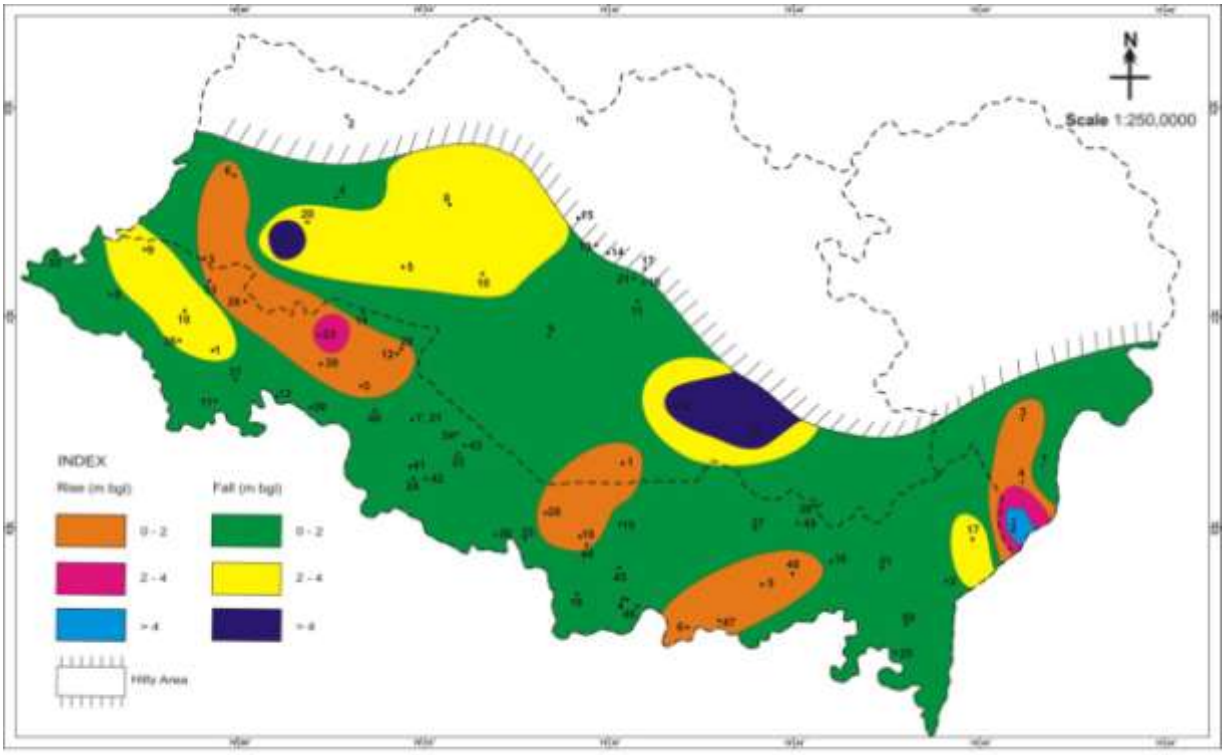

Fig. 24 Decadal Water Level Fluctuation Map, November (2003-2012 Vs 2013) Nainital, Udham Singh Nagar & Champawat district

Table 14. Decadal Water Level Fluctuation (November 2003-November 2012 Versus November 2013)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	13	0.08	3.99	0.04	0.75	9	69.24	2	15.38	0	0	2	15.38	0	0	0	0
Haridwar	10	0.22	2.57	0.06	3.30	6	60	1	10	0	0	2	20	1	10	0	0
Udham Singh Nagar	19	0.12	2052	0.08	3.41	7	36.84	1	5.26	0	0	8	42.11	3	15.79	0	0
Nainital	12	0.12	1.78	0.83	7.74	4	33.33	0	0	0	0	2	16.67	3	25	3	25
Champawat	3	1.02	4.56	--	1.60	1	33.33	0	0	1	33.33	1	33.34	0	0	0	0
Total	**57**	**0.08**	**4.56**	**0.04**	**7.74**	**27**	**47.37**	**4**	**7.01**	**1**	**1.75**	**15**	**26.32**	**7**	**12.28**	**3**	**5.27**

5.4.1.4 Water Level Fluctuation (January 2004-2013 Versus January 2014)

Decadal (long-term) water level data for 59 ground water monitoring wells was analyzed and is given in ***Table 15***. Analysis of the data reveals that the lowest decadal rise was 0.10 m at Angadpur in Udham Singh Nagar district whereas the highest decadal rise was 4.63 m at Iqbalpur in Haridwar district. As far as decadal decline in water level was concerned, the highest was 4.59 m at PeeruMadara in Nainital district while the lowest was 0.01 m at Banbasa in Champawat district.

A perusal of the table also indicates that out of 59 monitoring wells, 35 wells (59.32% of the total number) had shown the minimum decadal rise in the range 0-2 m, 7 wells (11.86% of total) had shown a higher rise in the range 2-4 m while only 1 well (1.69 % of total) had shown the highest decadal rise of >4 m. The minimum decadal decline in the range of 0-2 m was shown by 13 wells (22.04 % of total) while 2 wells (3.39%) had shown higher decadal rise of 2-4 m. only 1 monitoring well (1.70 %) has recorded the highest decadal decline (>4 m) in Uttarakhand State.

The decadal water level fluctuation map for average (January 2004-2013 versus January 2014) is shown in ***Fig. 25*** *(Dehradun section), Fig.26 (Haridwar section)* and ***Fig. 27*** *(Nainital-Udham Singh Nagar-Champawat section)*.

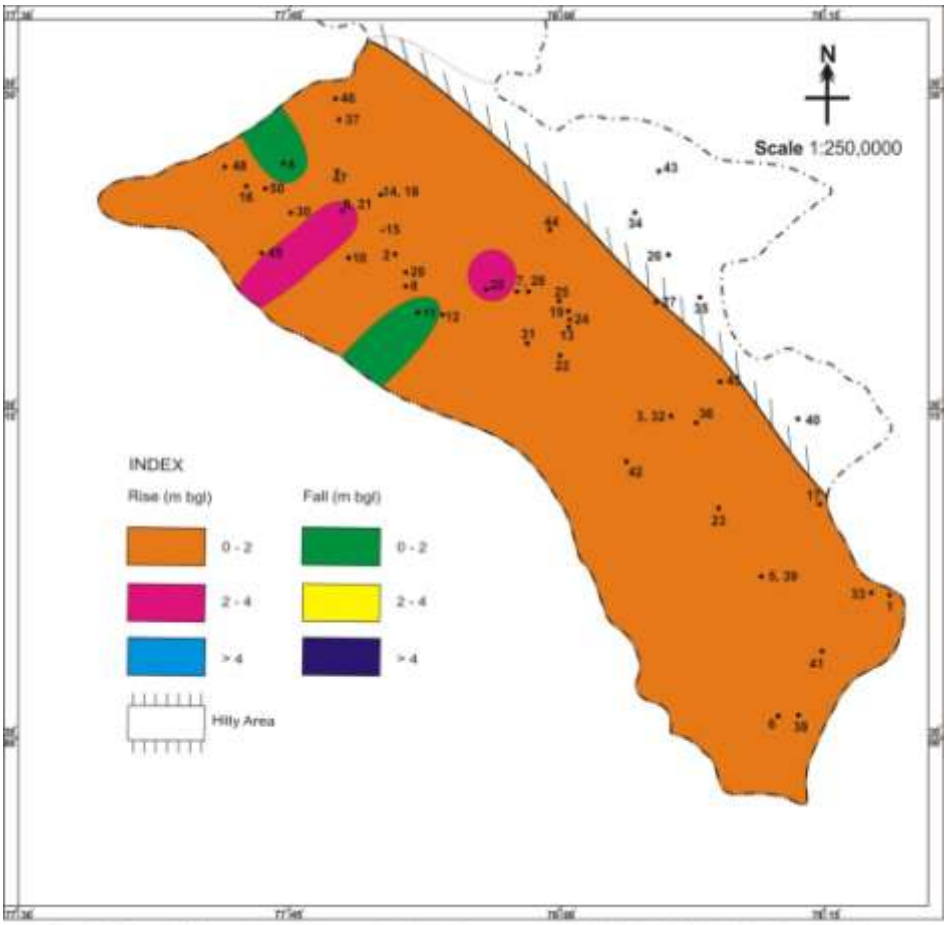

Fig. 25 Decadal Water Level Fluctuation Map, January (2004-2013 Vs 2014) Dehradun district

A perusal of **Fig. 25** (Dehradun District) reveals that minimum decadal rise of 0-2 m was seen in major parts of Doon Valley, Dehradun district. Higher decadal rise of 2-4 m was observed in isolated patches at Jhajra and Redarpur. The highest decadal rise of >4 m was not observed in Doon Valley. The minimum decadal decline of 0-2 m was observed in isolated patches at Singhniwala and Herbertpur. The decadal decline in the range of 2-4 m and >4m was not recorded in Doon valley.

A perusal of **Fig. 26** (Haridwar District) reveals that minimum decadal rise of 0-2 m was seen in major parts of Haridwar districts. Higher decadal rise of 2-4 m was observed in isolated patches at Bhagwanpur & Shahidwala Grant. The highest decadal rise of >4 m was observed only in small area at Iqbalpur. The decadal decline in the range of 2-4 m and >4m was not recorded in Haridwar district.

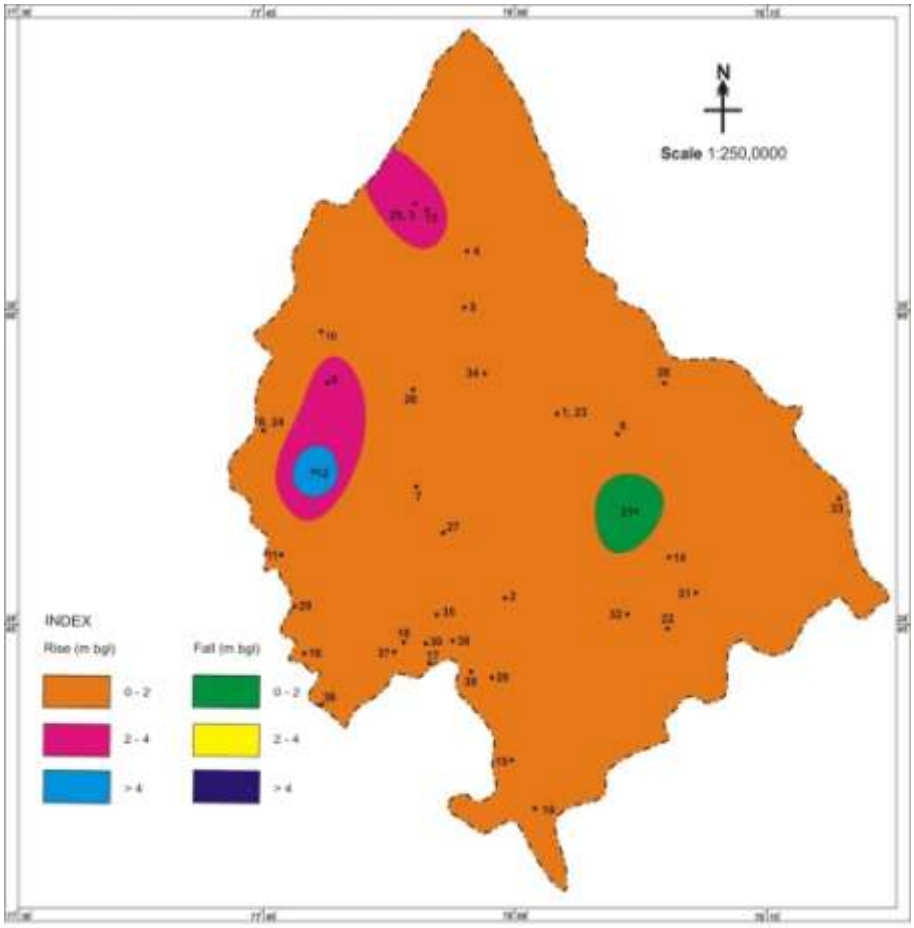

Fig. 26 Decadal Water Level Fluctuation Map, January (2004-2013 Vs 2014) Haridwar district

Visual interpretation of **Fig. 27***(Nainital-Udham Singh Nagar-Champawat section)* has shown that minimum decadal rise of 0-2 m was found in major parts of Tarai and

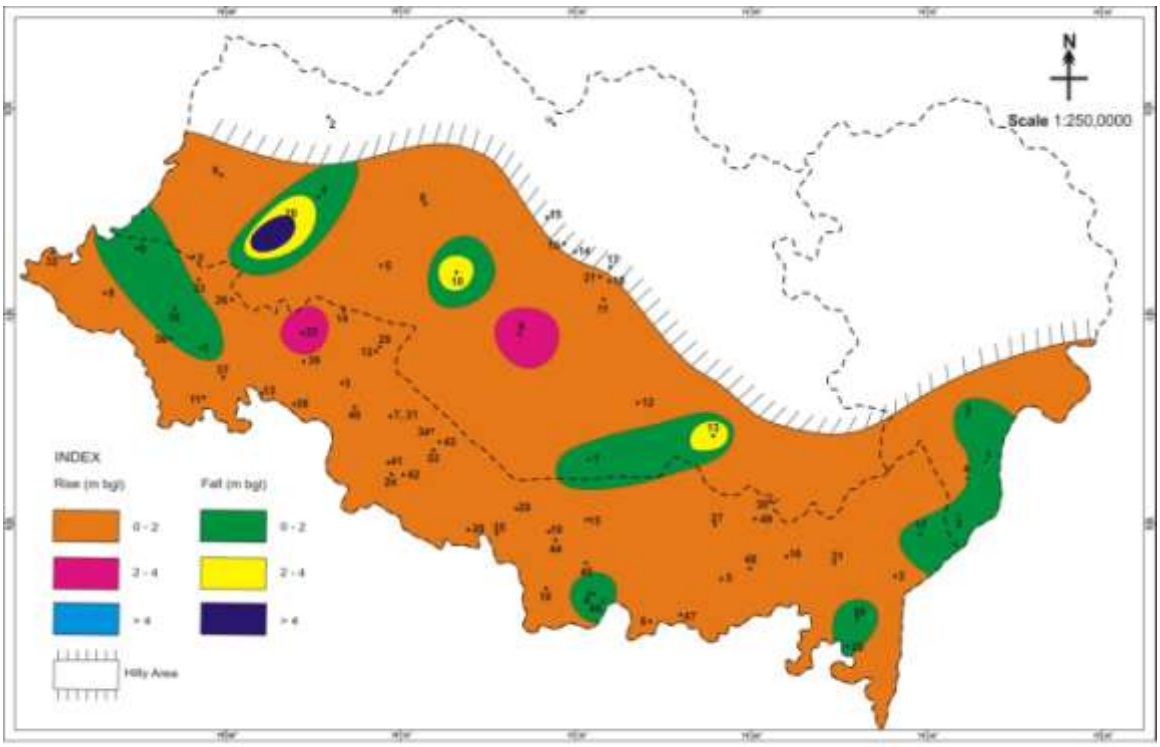

Fig. 27 Decadal Water Level Fluctuation Map, January (2004-2013 Vs 2014) Nainital, Udham Singh Nagar & Champawat district

Bhabhar Zone. Higher decadal rise of 2-4 m was observed in isolated patches at Jogipura in Trai belt (Udham Singh Nagar) &Lamachaur in Nanital District. The Highest decadal rise >4m was not recorded in this section. The minimum decadal decline of 0-2 m was observed in Northern Part of Tarai Zone, also in Northern and central part of Bhabhar zone. Higher decadal decline of 2-4 m was observed in and around Khatbass, Kathgodham and Chilkiya in Bhabhar Zone, Nanital District. Whereas the highest decadal decline of >4 m was observed in small isolated patch atPeeruMadara in Nanital District.

Table 15. Decadal Water Level Fluctuation (January 2004-January 2013 Versus January 2014)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	16	0.33	2.94	0.56	1.05	12	75	2	12.5	0	0	2	12.5	0	0	0	0
Haridwar	9	0.30	4.63	--	1.16	4	44.45	3	33.33	1	11.11	1	11.11	0	0	0	0
Udham Singh Nagar	22	0.10	2.72	0.54	1.92	16	72.73	1	4.55	0	0	5	22.72	0	0	0	0
Nainital	9	0.29	3.41	1.32	4.59	3	33.34	1	11.11	0	0	2	22.22	2	22.22	1	11.11
Champawat	3	--	--	0.01	0.56	0	0	0	0	0	0	3	100	0	0	0	0
Total	**59**	**0.10**	**4.63**	**0.01**	**4.59**	**35**	**59.32**	**7**	**11.86**	**1**	**1.69**	**13**	**22.04**	**2**	**3.39**	**1**	**1.70**

5.4.2 YEARLY WATER LEVEL FLUCTUATION

5.4.2.1 Water Level Fluctuation (May 2012 versus May 2013)

The analysis of data for 64 Ground Water Monitoring Wells for May 2012 versus May 2013 is given in ***Table 16.*** A perusal of the table shows that the minimum annual rise in water level was 0.02 m at Shantipuri in Udham Singh Nagar district while the maximum annual rise was 3.56 m at Purkulgaon, Dehradun district. The minimum annual decline in ground water level was 0.04 m at Bahadrabad, Haridwar district while the maximum annual decline was 5.85 m at Lamachaur in Nainital district.

The annual water level fluctuation data also reveals that 48 monitoring wells out of 91 (52.77% of total) had shown minimum rise in the range 0-2 m whereas higher rise of 2-4 m was shown by 6 monitoring wells (6.59% of the total) and the highest rise of >4 m was not recorded. A perusal of ***Table 16*** also shows that 32 out of 97 monitoring wells (35.15% of the total number) had recorded annual decline in the range of 0-2 m. Higher annual decline of 2-4 m was recorded by 3 monitoring wells (3.29% of total) whereas the highest decline of >4 m was recorded by only 2 monitoring wells, which was 2.19% of the total number of wells for calculating the annual fluctuation in ground water level for the pre-monsoon period.

The annual water level fluctuation map during the period May 2012 versus May 2013 has been shown in ***Fig. 28*** *(Dehradun District), Figure. 29(Haridwar section)* and ***Fig. 30*** *(Nainital-Udham Singh Nagar-Champawat section)*.

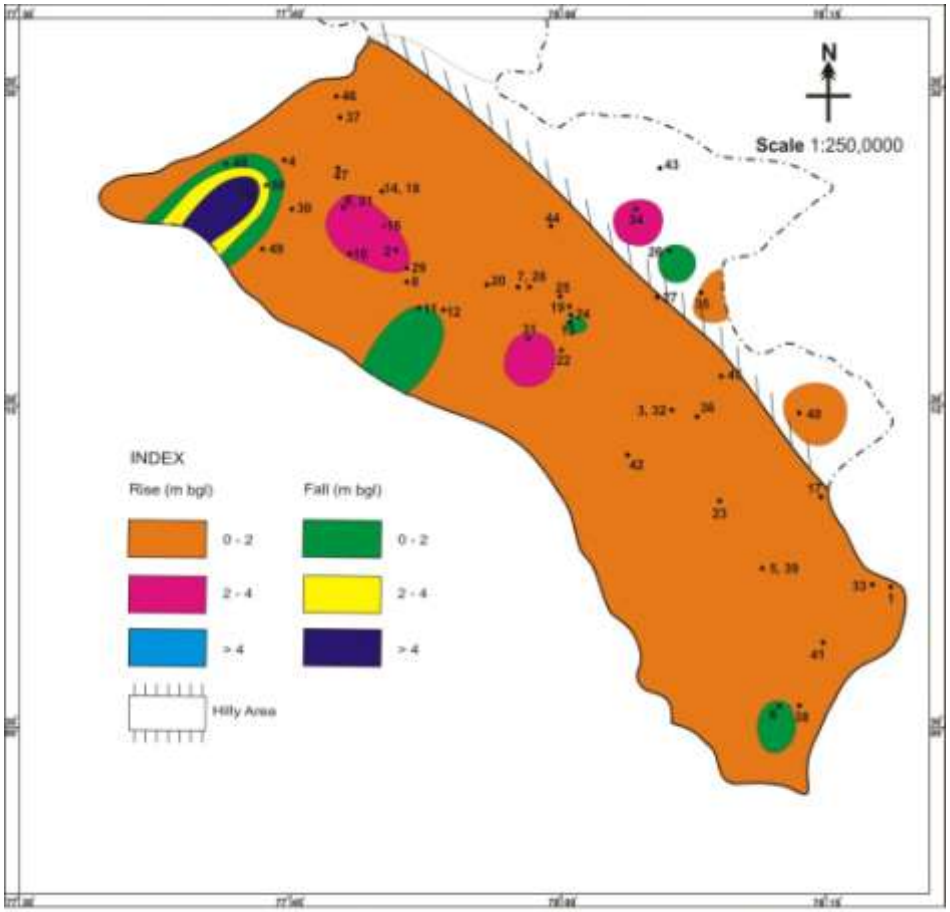

Fig. 28 Annual Water Level Fluctuation Map, May 2012 Vs May 2013, Dehradun district

A perusal of **Fig. 28** (Dehradun District) shows that the more than 70% area is recorded with the water level in the range of 0-2 m. Higher annual rise of 2-4 m was observed in and around Badripur, Purkulgaon, Rampura and Redarpur. The highest annual rise of >4 m was not observed

in Doon valley, Dehradun district. The minimum annual decline of 0-2 m was seen in the western and south western parts of Doon Valley, Dehradun district. It was also observed as isolated patches around Laltappar, Tarla Nagar and Balliwala. Higher annual decline of 2-4 m was seen as a semicircular shaped zone around Dhakrani - Judli section. The highest annual decline of >4 m was observed atJudli.

A perusal of **Fig. 29** (Haridwar District) shows that the more than 60% area is recorded with the water level in the range of 0-2 m. The annual rise of 2-4 m and >4m was not recorded anywhere in Haridwar district. The minimum annual decline of 0-2 m was seen in the central, northwestern, eastern and southeastern part of the district. This zone was also observed at isolated patches at Khanpur and GurkulNarsen. Higher annual decline of 2-4 m was seen as a semicircular shaped zone around Chudiala. The highest annual decline of >4 m was not observed in the district.

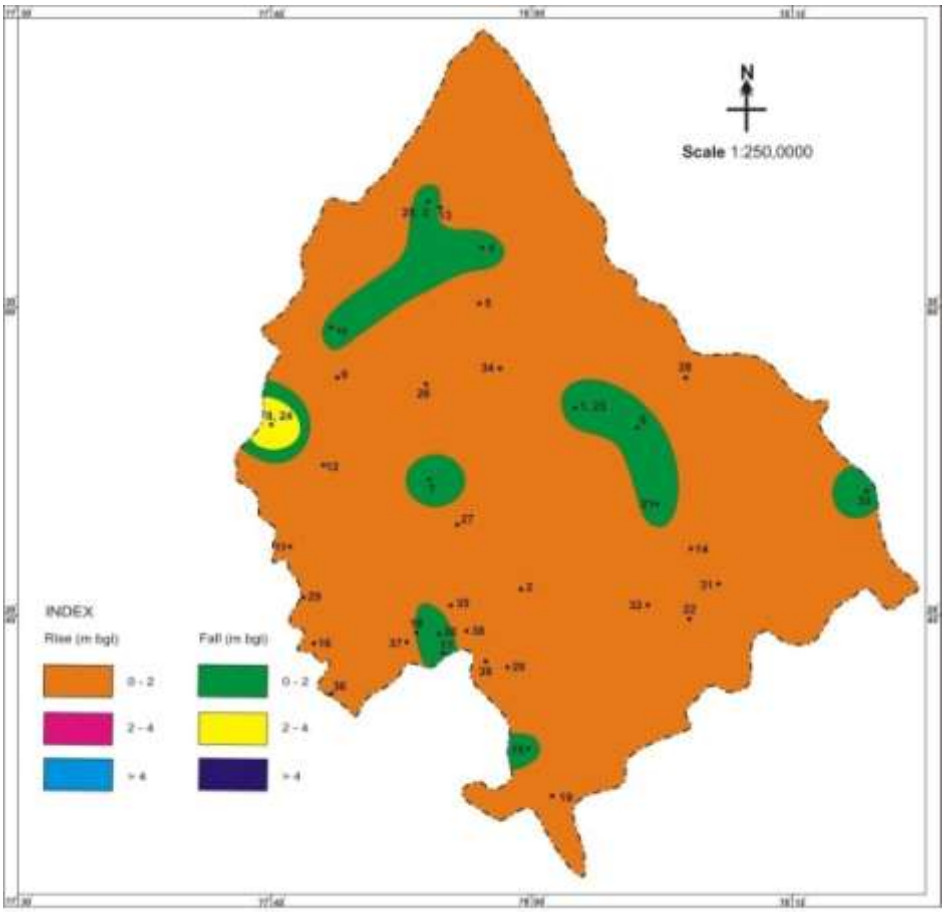

Fig. 29 Annual Water Level Fluctuation Map, May 2012 Vs May 2013, Haridwar district

A study of **Fig. 30** shows that during the pre monsoon period, the minimum annual rise of 0-2 m was seen in the northwestern, central and southern eastern parts of Udham Singh Nagar district. Higher annual rise of 2-4 m was seen at Banbasa in Chmpawat District. The highest annual rise of >4 m was not observed in the entire section. The lowest pre monsoon annual decline of 0-2 m was observed in major part Bhabhar Zone in Nanital District and in northwestern, central part of Tarai Zone of Udham Singh Nagar district. Higher annual decline of 2-4 m was seen in isolated patch at Dhela in Nanital District. Whereas, the highest annual decline of >4 m was seen in a small area around Lamachaur in Nanital district.

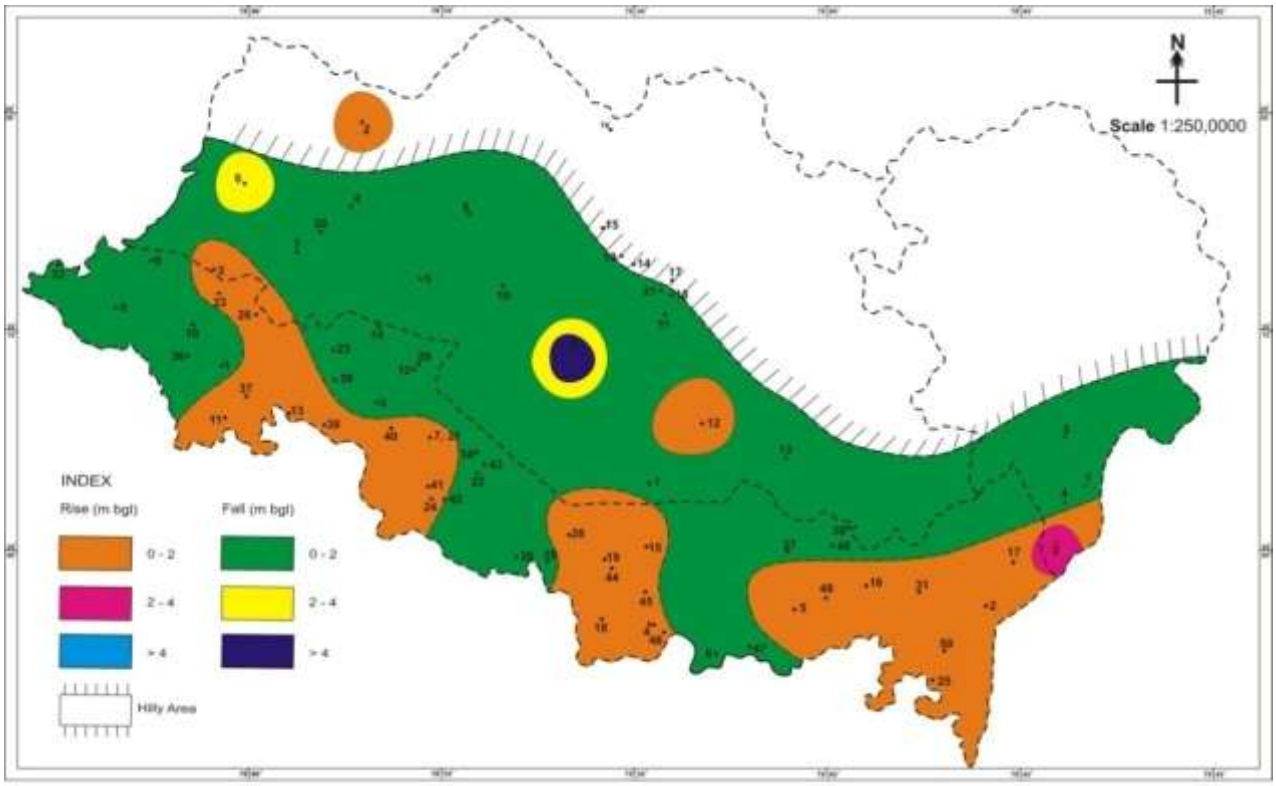

Fig. 30 Annual Water Level Fluctuation Map, May 2012 Vs May 2013, Nainital, Udham Singh Nagar & Champawat district

Table 16. Annual Water Level Fluctuation (May 2012 Versus May 2013)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	31	0.05	3.56	0.34	0.38	21	67.74	4	12.90	0	0	5	16.13	0	0	1	3.23
Haridwar	25	0.08	3.54	0.04	2.71	10	40	2	8	0	0	11	44	2	8	0	0
Udham Singh Nagar	22	0.02	1.24	0.04	1.54	13	9.09	0	0	0	0	9	40.91	0	0	0	0
Nainital	11	0.17	0.73	0.12	5.83	3	27.27	0	0	0	0	6	54.55	1	9.09	1	9.09
Champawat	2	--	2.19	--	0.40	1	50	0	0	0	01	50	0	0	0	0	0
Total	**91**	**0.02**	**3.56**	**0.04**	**5.83**	**48**	**52.77**	**6**	**6.59**	**0**	**0**	**32**	**35.16**	**3**	**3.29**	**2**	**2.19**

5.4.2.2 Water Level Fluctuation (August 2012 versus August 2013)

The analysis of annual water level fluctuation data for 96 Ground Water Monitoring Wells for the periods August 2012 and August 2013 is given in ***Table 17.*** Analysis of the fluctuation data indicates that the minimum annual rise of 0.03 m was observed at BanaKhera in Udham Singh Nagar district while the maximum annual rise was 7.92 m at Bahadrabad in Udham Singh Nagar district. The lowest annual decline was 0.05 m at Kopa Signal in Udham Singh Nagar district whereas the highest decline was 7.56 m at Bhaniawala in Dehradun district.

Analysis of the fluctuation data has indicated that out of 96 monitoring wells, 47 wells (48.95% of total) had shown an annual rise in the range 0-2 m while higher rise of 2-4 m was observed in 14 monitoring well (14.58% of total). The highest rise in the range >4 m was recorded by 6 monitoring wells, which was 6.25% of the total number of wells. It was also seen that majority of monitoring wells (17 out of 96, 17.73% of total) had recorded annual decline in the range of 0-2 m. Higher annual decline of 2-4 m was shown by 9 monitoring wells (9.37% of total) while the highest decline of >4 m was shown by 3 monitoring wells, which was 3.12% of the total number of wells.

The annual water level fluctuation map during the period August 2012 versus August 2013 is shown in ***Fig. 31*** *(Dehradun section),* ***Fig. 32*** *(Haridwar section)* and ***Fig. 33*** *(Nainital-Udham Singh Nagar-Champawat section).*

A perusal of **Fig. 31** indicates that minimum annual rise of 0-2 m was seen in northern, Northwestern, central, southeastern and southern parts in Doon valley. The higher annual rise of 2-4 m was seen in the central part, whereas the highest annual rise of >4 m was

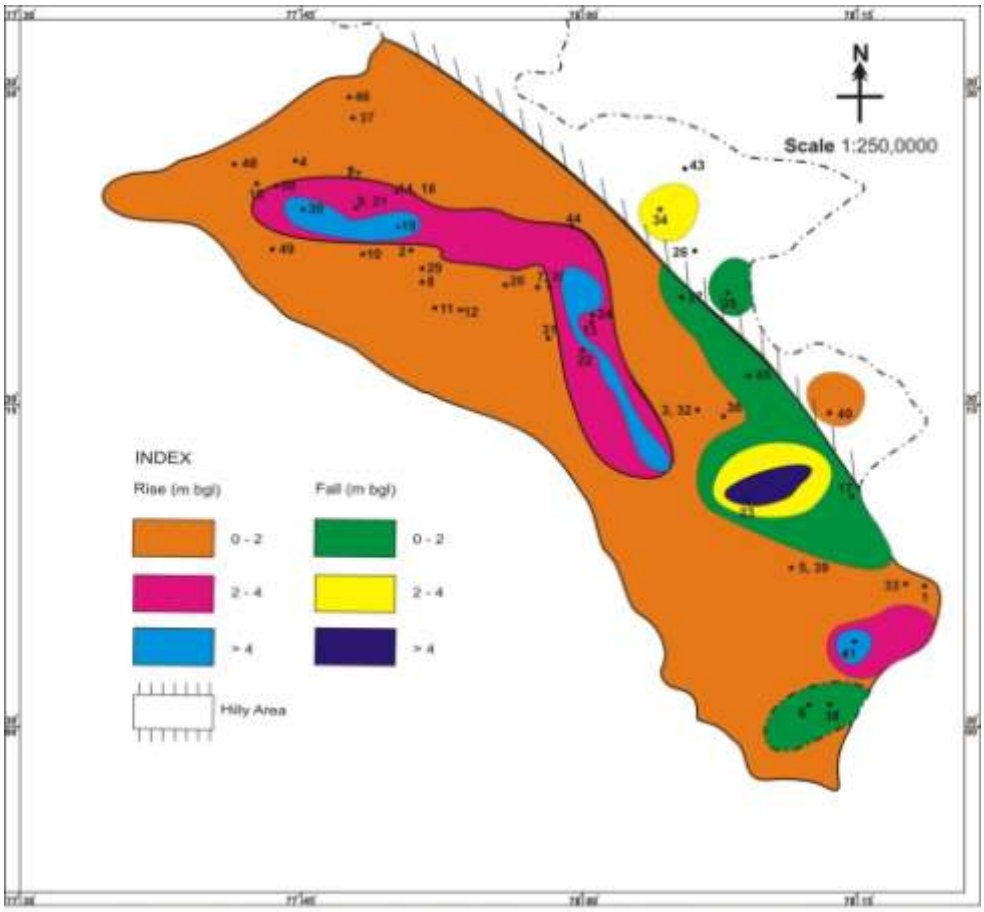

Fig. 31 Annual Water Level Fluctuation Map, August 2012 Vs August 2013, Dehradun district

found in and around KhadiriKhadakmap, Dudhli, Harbanswala, Shankarpur and Badripur. The minimum annual decline of 0-2 m was seen in central east and south eastern part of northern part around Motichur, Khandgaon, Dandhi, Sodasaroli, Maldeota whereas the Higher annual decline of 2-4 m was seen in Purkulgaon, Nanukhera. The highest annual decline of >4 m was inferred only at the Bhaniawala in Doon valley.

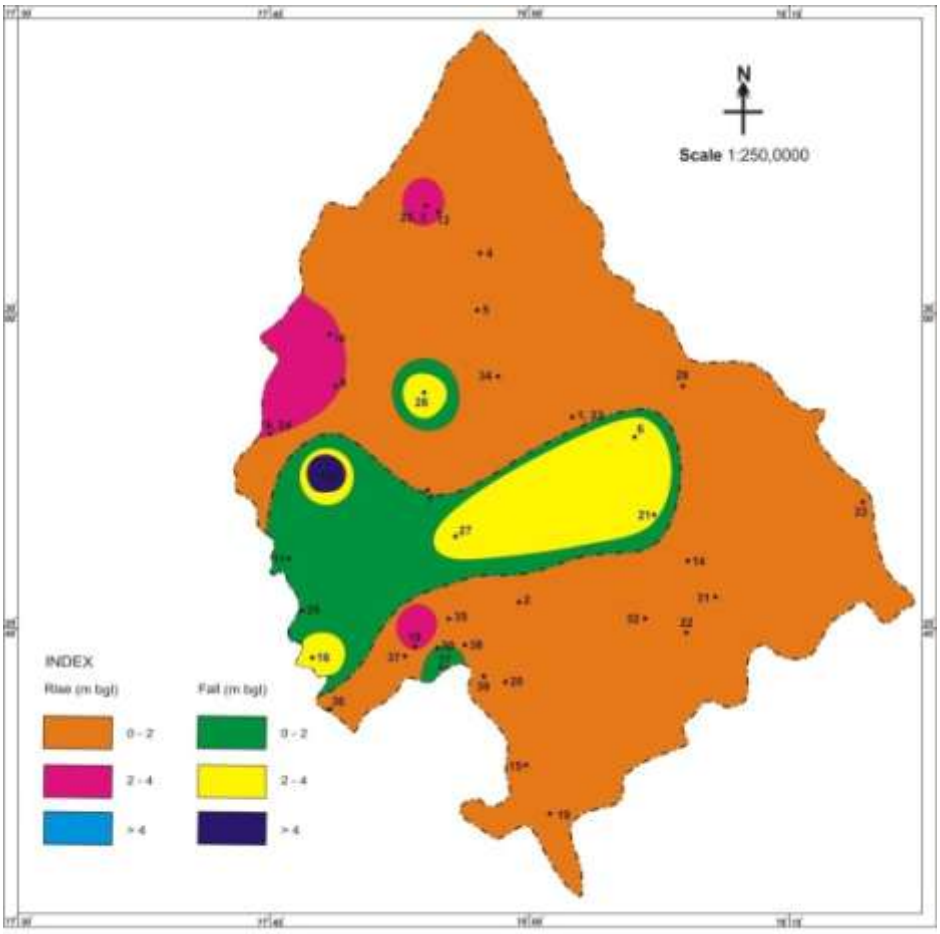

Fig. 32 Annual Water Level Fluctuation Map, August 2012 Vs August 2013, Haridwar district

A perusal of **Fig. 32** indicates that minimum annual rise of 0-2 m was seen in northern, southern and southeastern parts in Haridwar District. The higher annual rise of 2-4 m was seen in the western part; also at the Manglaur and Buggawala, Sahidwala grant as isolated patches. The highest annual rise of >4 m was not recorded in Haridwar district. The minimum annual decline of 0-2 m was seen in southern and central part of Haridwar district; also occurs as isolated patch at GurkulNasrsen. Higher annual decline of 2-4 m was seen in and around Landhaura, Dhanpura, Sarai, Imlikhera and Lakhnauta. The highest annual decline of >4 m was inferred only in and around Iqbalpur.

A perusal of **Fig. 33** indicates that minimum annual rise of 0-2 m was seen in major parts of Tarai belt; central and southern part of Bhabhar Zone and at Garjia in lesser Himalayas, Nanital district. The higher annual rise of 2-4 m was seen in the north western part of Tarai Zone in Udham Singh Nagar District and as isolated patch at Sitapur in Nanital district. The highest annual rise of >4 m was recorded only at Bastia in Champawat district in the entire section. The minimum annual decline of 0-2 m was seen in northern part of Bhabhar zone and in central part of Tarai Zone. Higher annual decline of 2-4 m was seen in Patrampur and Dhela in Udham Singh Nagar and Nanital District respectively. The highest annual decline of >4 m was inferred only in the Belparao in Nanital district.

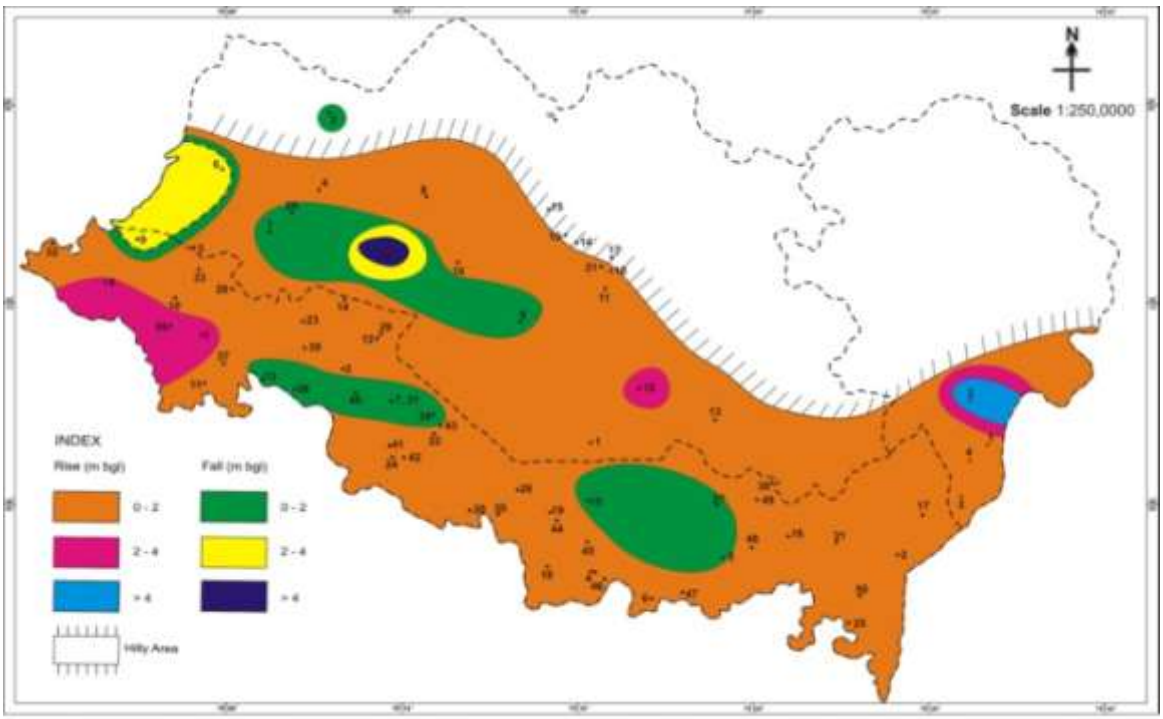

Fig. 33 Annual Water Level Fluctuation Map, August 2012 Vs August 2013, Nainital, Udham Singh Nagar & Champawat district

Table 17. Annual Water Level Fluctuation (August 2012 Versus August 2013)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	31	0.05	6.57	0.13	7.56	15	48.39	5	16.12	3	9.67	5	16.13	2	6.45	1	3.22
Haridwar	23	0.05	7.92	1.19	4.67	9	39.13	4	17.39	1	4.34	3	13.04	5	21.73	1	4.36
Udham Singh Nagar	28	0.03	3.94	0.05	2.94	17	60.71	4	14.28	0	0	6	21.44	1	3.57	0	0
Nainital	12	0.28	7.54	0.43	4.84	5	41.68	1	8.33	1	8.33	3	25	1	8.33	1	8.33
Champawat	2	1.97	11.04	--	--	1	50	0	0	1	50	0	0	0	0	0	0
Total	**96**	**0.03**	**3.94**	**0.05**	**7.56**	**47**	**48.95**	**14**	**14.58**	**6**	**6.25**	**17**	**17.73**	**9**	**9.37**	**3**	**3.12**

5.4.2.3 Water Level Fluctuation (November 2012 versus November 2013)

The analysis of annual water level fluctuation data for 102 Ground Water Monitoring Wells in Uttarakhand is available. Analysis of the data has shown that the lowest annual rise was 0.02m at Kashipur in Udham Singh Nagar district while the highest annual rise was 6.6 m at nanukhera in Dehradun district. The lowest annual decline during the post-monsoon period was 0.02 m at Selaqui in Dehradun district while the highest annual decline was 8.40m at Imlikhera in Haridwar district.

A study of the water level fluctuation data has revealed that 43 monitoring wells out of 102 wells (42.46% of the total number) has recorded a rise in the range of 0-2 m. 11 monitoring well (10.78 % of the total) had shown the higher rise of 2-4 m and 6 monitoring well (10.59 % of the total) had shown the highest rise of >4 m during this period. The 35 no of monitoring wells (34.34% of the total) had recorded an annual decline in the range of 0-2 m during the post monsoon period. 4 wells out of 102 (8.92% of total number) had shown higher decline of water level in the range of 2-4 m whereas only 3wells (2.94 % of total) had shown the highest annual decline of >4 m in water level.

The annual water level fluctuation map during the period November 2012 versus November 2013 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 rise in post monsoon period in the range of 0-2 m was recorded in western, central and southeastern part of Doon valley; also as isolated patch at Purkulgaon. Higher annual rise of 2-4 m was seen in and around Sabhawala, Dandhi and Harbanswala. The highest annual rise of >4 m was observed at Nanukhera and Maldeota in Dehradun district. The

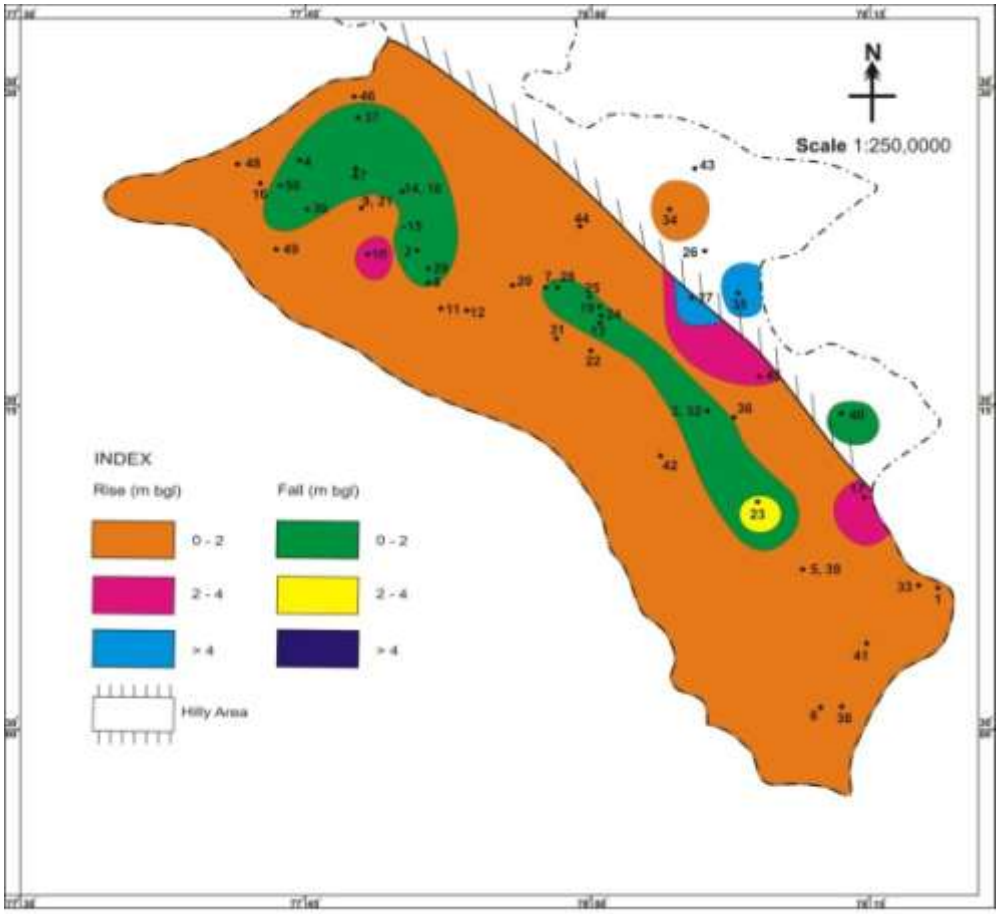

Fig. 34 Annual Water Level Fluctuation Map, November 2012 Vs November 2013, Dehradun district

minimum annual decline of 0-2 m was seen in Nanda kichownki – Balliwala section and as isolated patch at Kotimachak. Higher annual decline of 2-4 m was seen only in and around Bhaniawala. The highest annual decline of >4 m was not recorded in Doon valley during the post monsoon period.

A perusal of **Fig. 35** has shown that the minimum annual rise in post monsoon period in the range of 0-2 m was recorded in northern, central and southeastern parts; whereas the higher annual rise of 2-4 m was seen in and around Bhagwanpur and Chudiala. The highest annual rise of >4 m was not observed in the Haridwar district. The minimum annual decline of 0-2 m was seen in the eastern and southeastern part of the district; in and around Rathaura and Landhaura. Higher annual decline of 2-4 m was seen only at in and around Laldhang. The highest annual decline of >4 m was at Imlikhera in Haridwar district during the post monsoon period.

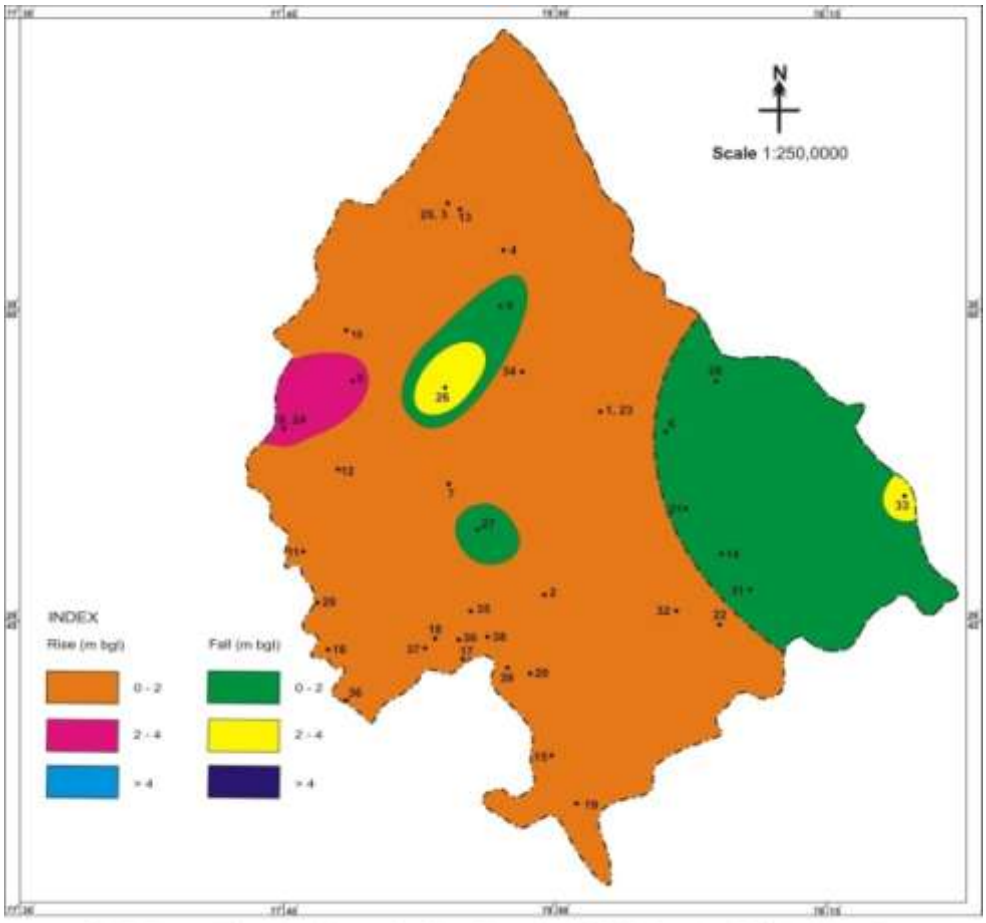

Fig. 35 Annual Water Level Fluctuation Map, November 2012 Vs November 2013, Haridwar district

Interpretation of **Fig. 36** has shown that for the post monsoon period, the minimum annual rise of 0-2 m was seen in the Khatima, Tukri as isolated patches; in and around Shantipuri- KamariaPakki area and Bazpur- Sultanpur Patti- Beria Daulat-Jhagarpuri area in Tarai belt in Udham Singh Nagar District. Higher annual rise of 2-4 m was seen only in the northwestern part of Udham Singh Nagar district and around PeeruMadara and Lalkuan in the Bhabar zone in Nainital district. The highest annual rise of >4 m was found in the BarkharePande, Jogipura, Garjia in isolated patches Nainital district. The minimum annual decline of 0-2 m was seen in a substantial part in the southern, eastern, west central parts of Tarai zone in Udham Singh Nagar district; also in central part of Bhabhar Zone in Nanital district and around Bastia in Champawat district. Higher annual decline of 2-4 m was seen in and around Lamachaur and Tanakpur in Nanital and Champawat districts respectively. The highest annual decline of >4 m was found in a very small zone in district.

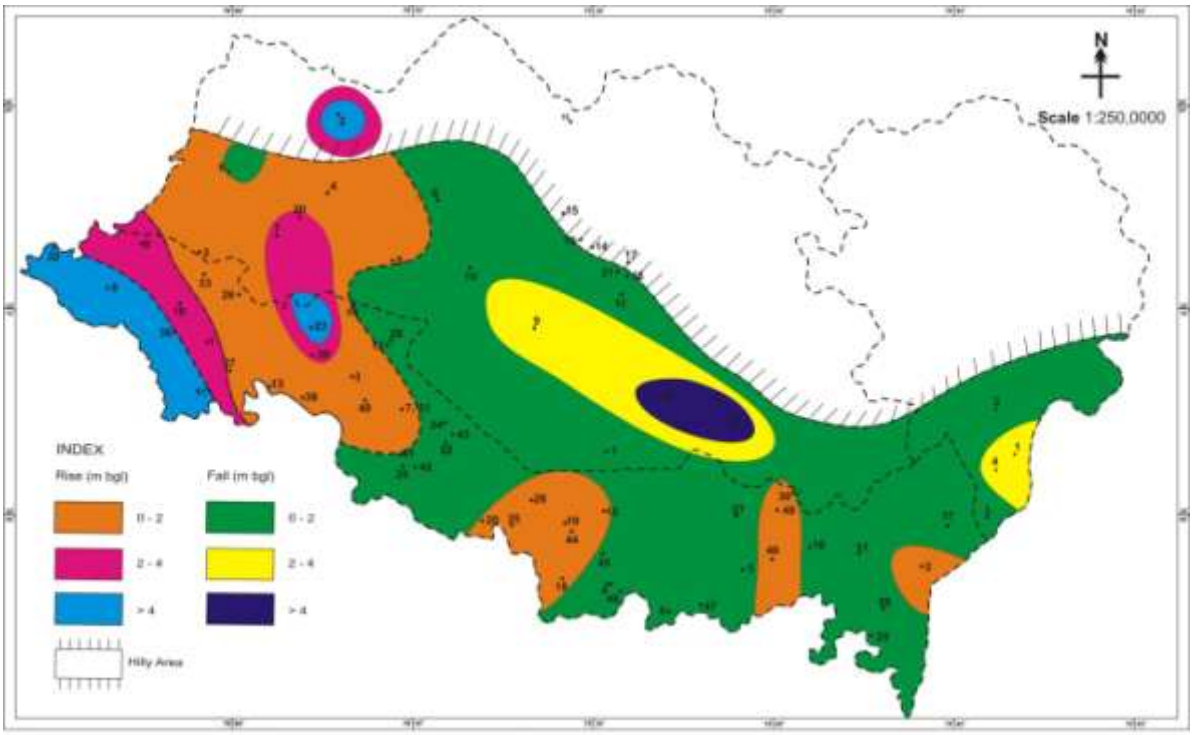

Fig. 36 Annual Water Level Fluctuation Map, November 2012 Vs November 2013, Nainital, Udham Singh Nagar & Champawat district

Table 18. Annual Water Level Fluctuation (November 2012 Versus November 2013)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	32	0.06	6.6	0.02	2.89	13	40.63	4	12.5	2	6.25	12	37.5	1	3.13	0	0
Haridwar	24	0.87	3.08	0.60	8.40	14	58.33	3	12.5	0	0	5	20.83	1	4.16	1	4.16
Udham Singh Nagar	31	0.02	5.69	0.04	1.32	13	41.94	2	6.45	3	9.68	13	41.93	0	0	0	0
Nainital	12	0.34	4.12	0.13	0.18	3	25	2	16.67	1	8.33	3	25	1	8.33	2	16.67
Champawat	3	--	--	1.37	2.12	0	0	0	0	0	0	2	66.66	1	33.34	0	0
Total	**102**	**0.02**	**6.6**	**0.02**	**8.40**	**43**	**42.16**	**11**	**10.78**	**6**	**5.88**	**35**	**34.32**	**4**	**3.92**	**3**	**2.94**

5.4.2.4 Water Level Fluctuation (January 2013 versus January 2014)

The analysis of water level data of 104 ground water monitoring wells for the period January 2013 versus January 2014 is given in ***Table 19.*** A perusal of the table indicates that the minimum annual rise was 0.01 m at Redarpur in Dehradun district whereas the maximum annual rise was 8.74 m at Bastia in Champawat district. The minimum annual decline was found to be 0.02 m at Durgapur in Udham Singh Nagar district whereas the maximum decline was 3.78 m at Peerumadara in Nanital district.
A perusal of the table also reveals that out of 104 monitoring wells, 66 wells (63.46%) have recorded the minimum annual rise in the range 0-2 m whereas 11 wells (10.58% of total) had shown higher rise in the range 2-4 m. 5(4.81% of the total) monitoring wells had recorded the highest annual rise of >4 m during the period January 2013 to January 2014. Lowest annual decline of 0-2 m was recorded by 19 monitoring wells (18.27% of total) while 3 wells (2.88%) had recorded higher decline in the range of 2-4 m. The highest decline of >4 m was not shown by any monitoring well.

The annual water level fluctuation map during the period January 2013 versus January 20134 is shown in ***Fig. 37*** *(Dehradun district), Fig. 38 (Haridwar district)* and ***Fig. 39*** *(Nainital-Udham Singh Nagar-Champawat section)*.

Visual interpretation of **Fig. 37** has shown that the more than 80% area of the Doon valley shows the minimum annual rise in the range of 0-2 m. Higher annual rise of 2-4 m was seen in and around Jhajra, Purkulgaon and CGWB office. The highest annual rise of >4 m was observed only at the Dandhi in Doon valley. The minimal annual decline of 0-2 m was seen as small isolated zones at the Khandgaon, Laltappar, Kuawala,

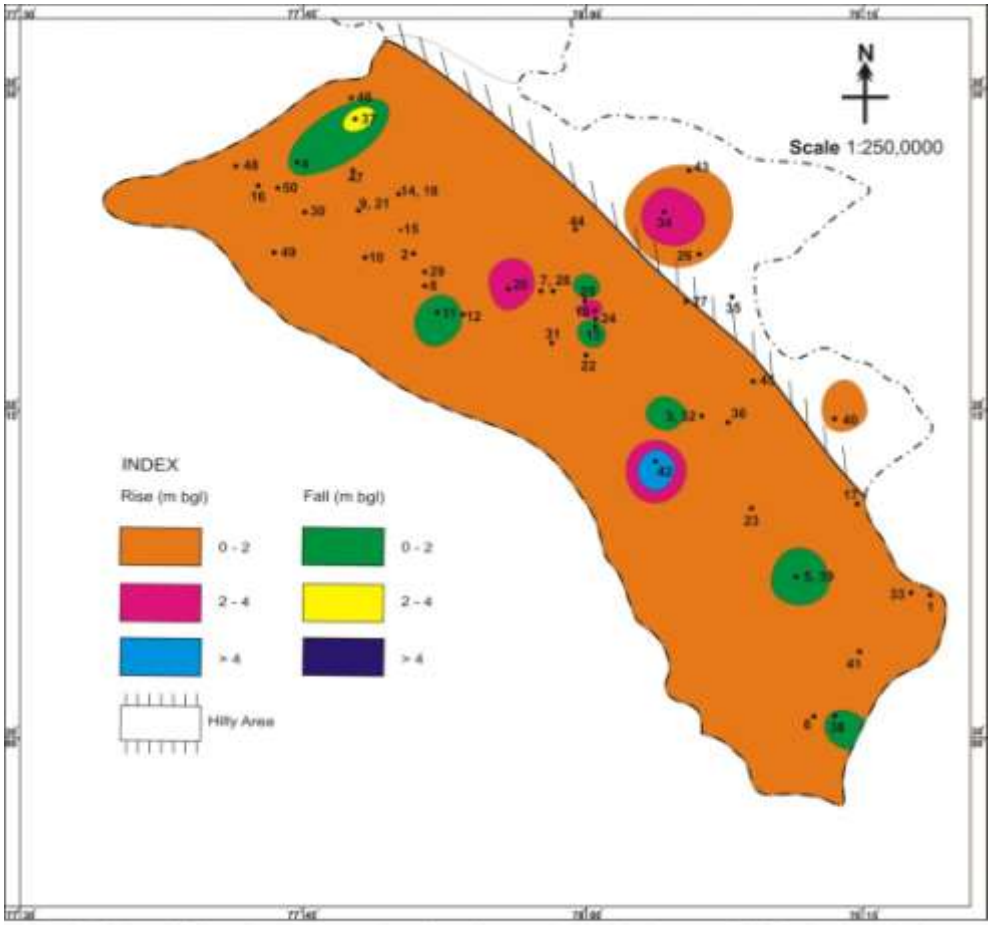

Fig. 37 Annual Water Level Fluctuation Map, January 2013 Vs January 2014, Dehradun district

Kanwali, Sighniwala, Herbertpur and Harbanswala. Higher annual decline of 2-4 m was seen at the Vikasnagar in Doon valley. The highest annual decline of >4 m was not recorded in Doon valley.

Visual interpretation of **Fig. 38** has shown that the except the western part rest majority of the Haridwar shows the minimum annual rise in the range of 0-2 m. Higher annual rise of 2-4 m was seen in western part. The highest annual rise of >4 m was not observed in Haridwar district. The minimal annual decline of 0-2 m was seen in Landhaura-Bahadrabad-Sahidwala Grant Section. Higher annual decline of 2-4 m was seen in and around Rathura. The highest annual decline of >4 m was not recorded in Haridwar district.

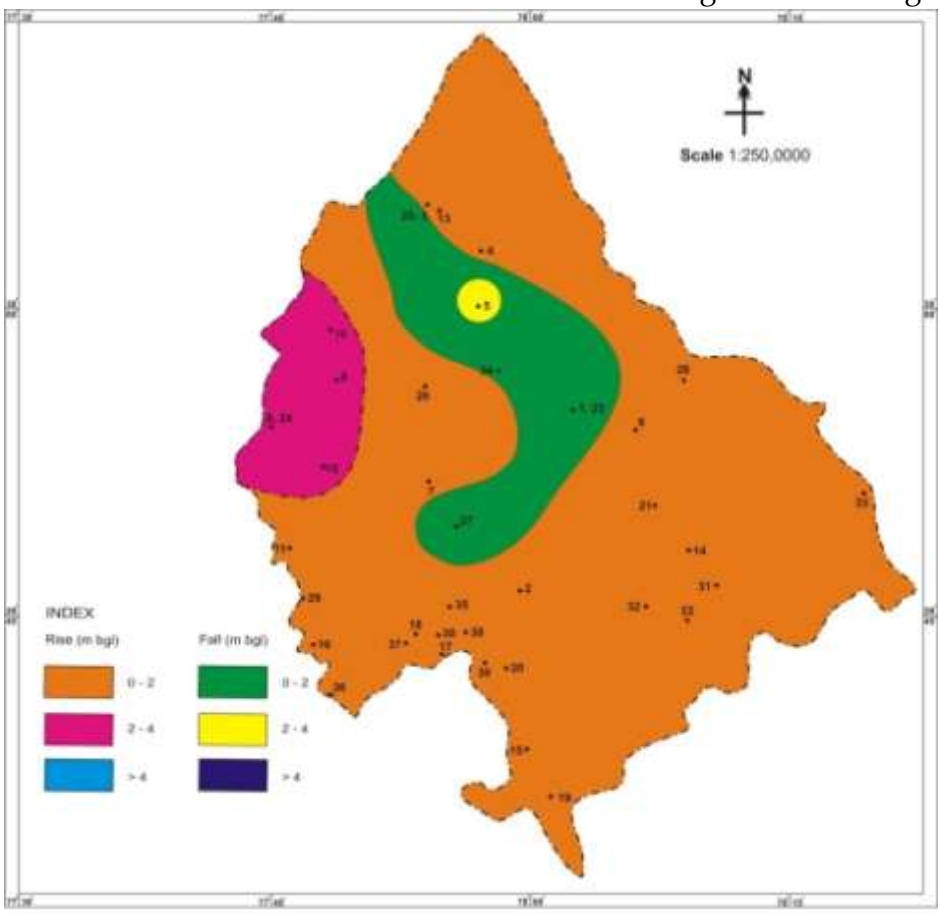

Fig. 38 Annual Water Level Fluctuation Map, January 2013 Vs January 2014, Haridwar district

A perusal of **Fig. 39** indicates that the minimum annual rise of 0-2 m was seen in majority of the Tarai zone of Udham Singh Nagar district and around Lalkuan, Kathgodham, Garjia in Nanital district. Higher annual rise of 2-4 m was seen in and around the Angadpur and khatbass in Udham Singh Nagar district and Nainital district respectively. The highest annual rise of >4 m was inferred around the Dhoniya in Udham singhnagar district and Lamachaur in Nainital district. The minimum annual decline of 0-2 m was seen in northern part of the Bhabhar zone in nanital district and around Kicchha and Jhagarpuri in Udham Singh Nagar district. Higher annual decline of 2-4 m was seen in and around Peerumadara in Nainital district. The highest annual decline of >4 m was not found anywhere in this entire section.

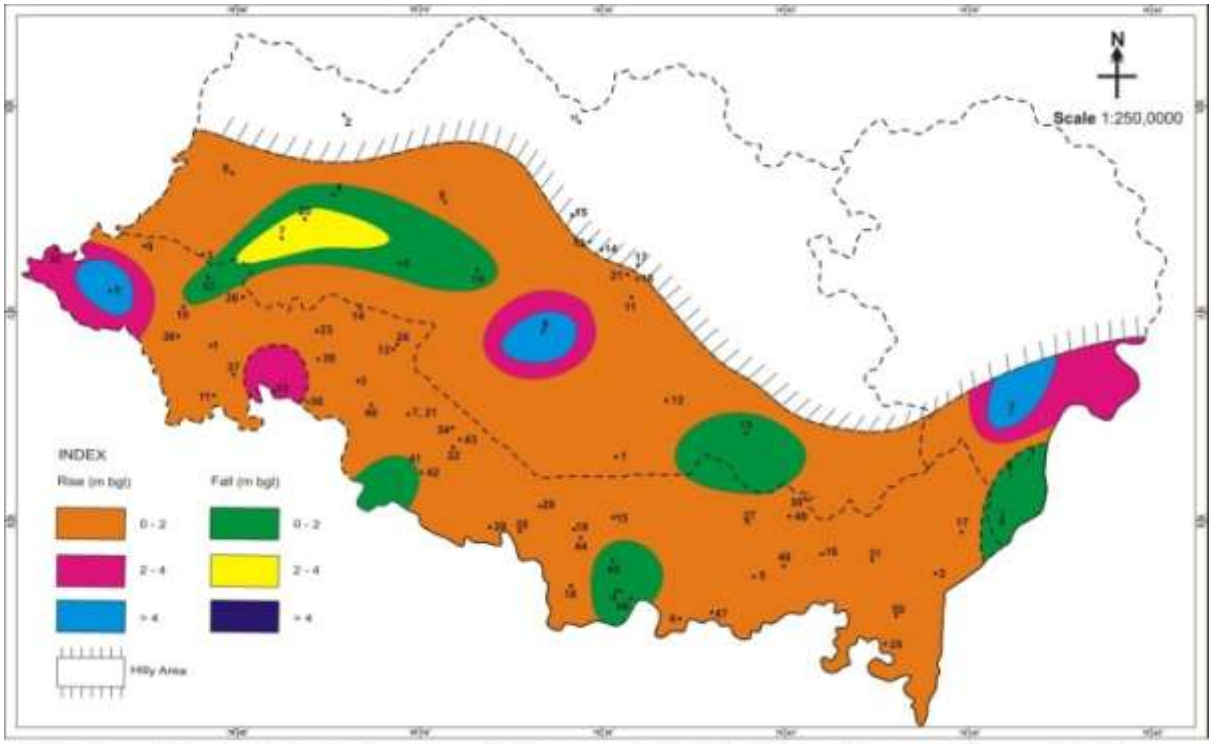

Fig. 39 Annual Water Level Fluctuation Map, January 2013 Vs January 2014, Nainital, Udham Singh Nagar & Champawat district

Table 19. Annual Water Level Fluctuation (Annual January 2013 Versus January 2014)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	35	0.01	7.1	0.06	2.32	22	62.86	3	8.57	2	5.71	7	20	1	2.86	0	0
Haridwar	25	0.16	3.47	0.2	3.15	15	60	6	24	0	0	3	12	1	4	0	0
Udham Singh Nagar	32	1.11	4.82	0.02	1.9	25	78.13	2	6.25	1	3.12	4	12.5	0	0	0	0
Nainital	9	0.26	5.40	0.77	3.78	4	44.45	0	0	1	1.11	3	33.33	1	11.11	0	0
Champawat	3	--	8.74	0.18	0.70	0	0	0	0	1	33.33	2	66.67	0	0	0	0
Total	**104**	**0.01**	**8.74**	**0.02**	**3.78**	**66**	**63.46**	**11**	**10.58**	**5**	**4.81**	**19**	**18.27**	**3**	**2.88**	**0**	**0**

5.4.3 SEASONAL WATER LEVEL FLUCTUATION

5.4.3.1 Water Level Fluctuation (May 2013 versus August 2013)

The seasonal fluctuation of water level during the period May 2013 versus August 2013 for 82 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 0.62m at Lamachaur in Nanital district whereas the maximum rise was 26.82 m at Khat Bass Nanital district. The minimum seasonal decline was 0.23 m at Dhela in Nanital district while the maximum decline was 2.38 m at Lakhnauta in Haridwar district. The classification of seasonal water level fluctuation indicates that rise in the range of 0-2 m was shown by 14 monitoring wells, which was 17.07% of the total number of wells. Higher rise in the range 2-4 m was shown by 32 wells (39.02% of total) while the highest rise of >4 m was shown by 32 wells (39.02% of total). The lowest seasonal decline of 0-2 m was recorded by 3 monitoring wells (3.66% of total). Higher seasonal decline of 2-4 m was shown by 1 monitoring wells, which was only 1.22% of the total number of wells during the period May versus August 2013. The highest seasonal decline of >4 m was not recorded by any monitoring well.

The seasonal water level fluctuation map during the period May 2013 versus August 2013 is shown in ***Fig. 40*** *(Dehradun District),* ***Fig. 41*** *(Haridwar section)* and ***Fig. 42*** *(Nainital-Udham Singh Nagar-Champawat section).*

Visual interpretation of **Fig. 40** has shown that the lowest seasonal fluctuation of 0-2 m was not recorded in Doon valley, whereas the Seasonal rise of 2-4 m was observed in a L shaped zone covering areas Badripur, Rampura, Sabhawala, Baronwala, Nanukhera and Kuanawala. The highest seasonal rise of water level (>4 m) was extensively found in Doon Valley covering ~80% of the area. The seasonal decline in the range of 0-2 m, 2-4m and >4m was not recorded

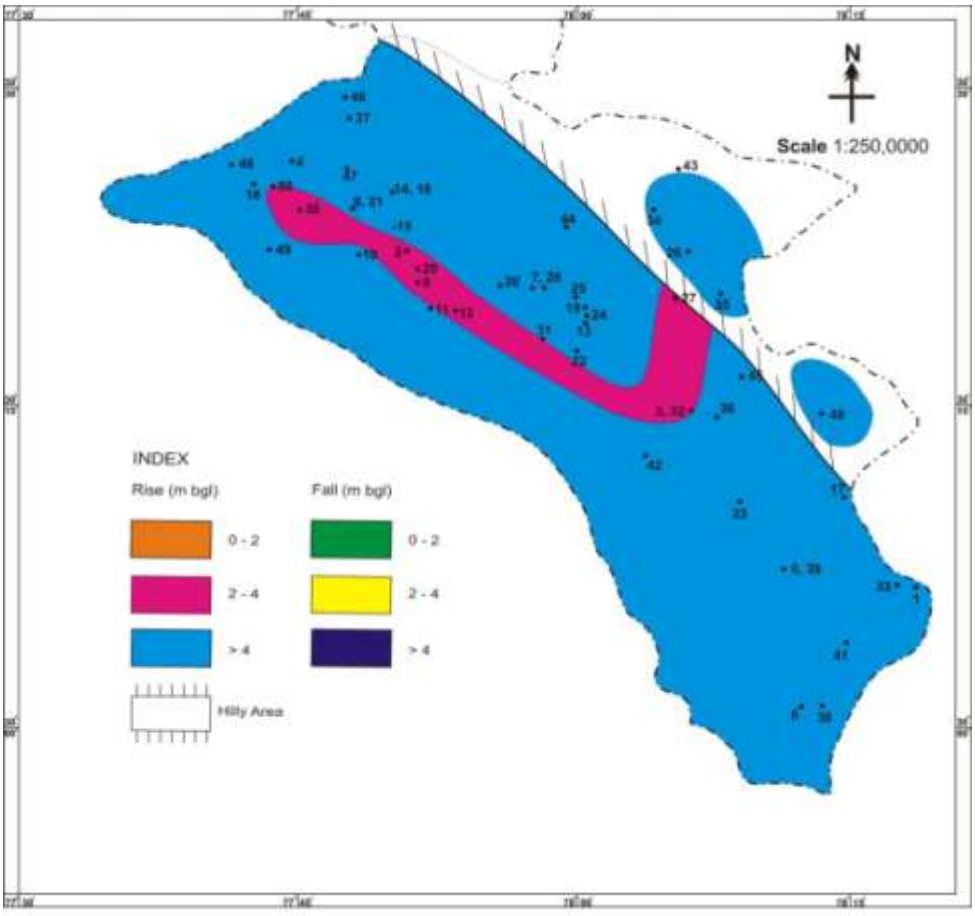

Fig. 40 Water Level Fluctuation Map, May 2013 Vs August 2013 Dehradun district

anyehere in the Doon valley.

Visual interpretation of **Fig. 41** has shown that the lowest seasonal fluctuation of 0-2 m was observed dominantly in the eastern, southeastern and southern part of the district. Beside this, it was also observed around Rathura. The Seasonal rise of 2-4 m was observed in a major part of Haridwar district in and around Hussainpur, Sarai, Buggawala, Imlikhera, Mudlana, Sahidwala grant and Govardhanpur. The highest seasonal rise of water level (>4 m) was observed in the western part (i.e. in and around Chudiala, Bhagwanpur, Iqbalpur and Jhabrera). The lowest seasonal decline of 0-2 m was seen as lenticular zone in south western part of Haridwar district. Higher seasonal decline of 2-4 m was seen as a small, isolated zone at Lakhnauta; whereas the highest decline (>4 m) was not recorded in Haridwar district.

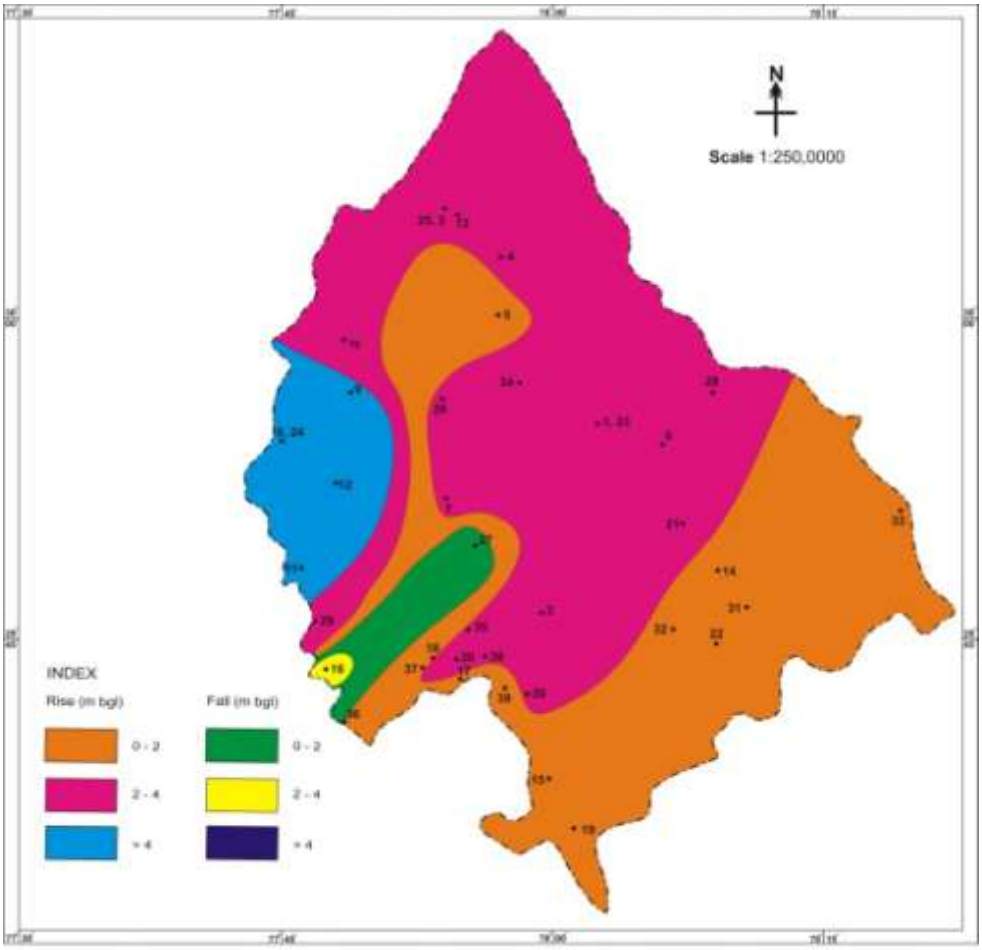

Fig. 41 Water Level Fluctuation Map, May 2013 Vs August 2013 Haridwar district

A perusal of **Fig. 42** indicates that the lowest positive seasonal fluctuation of 0-2 m was seen in the central part of Udham Singh Nagar district and in the north western parts of Nainital district; also as isolated patch at Garjia in Nanital district. Higher seasonal rise of 2-4 m was seen in isolated areas in the north central, southern and eastern parts of Udham Singh Nagar district, in the central part of Nainital district and in Banbasa, Champawat district. The highest seasonal rise of water level (>4 m) was seen in the western parts of Udham Singh Nagar district i.e. Angadpur, Jaspur, Missarwala,and Khatima; around Kathgodham, Dogaon, Dhoniya of Nainital district and in the eastern part of Champawat district. The lowest seasonal decline of 0-2 m was confined in the shape of a linear zone covering Dhela, Chilkiya and Belparao in Nainital district. Seasonal decline of 2-4m and >4m was not recorded in this section.

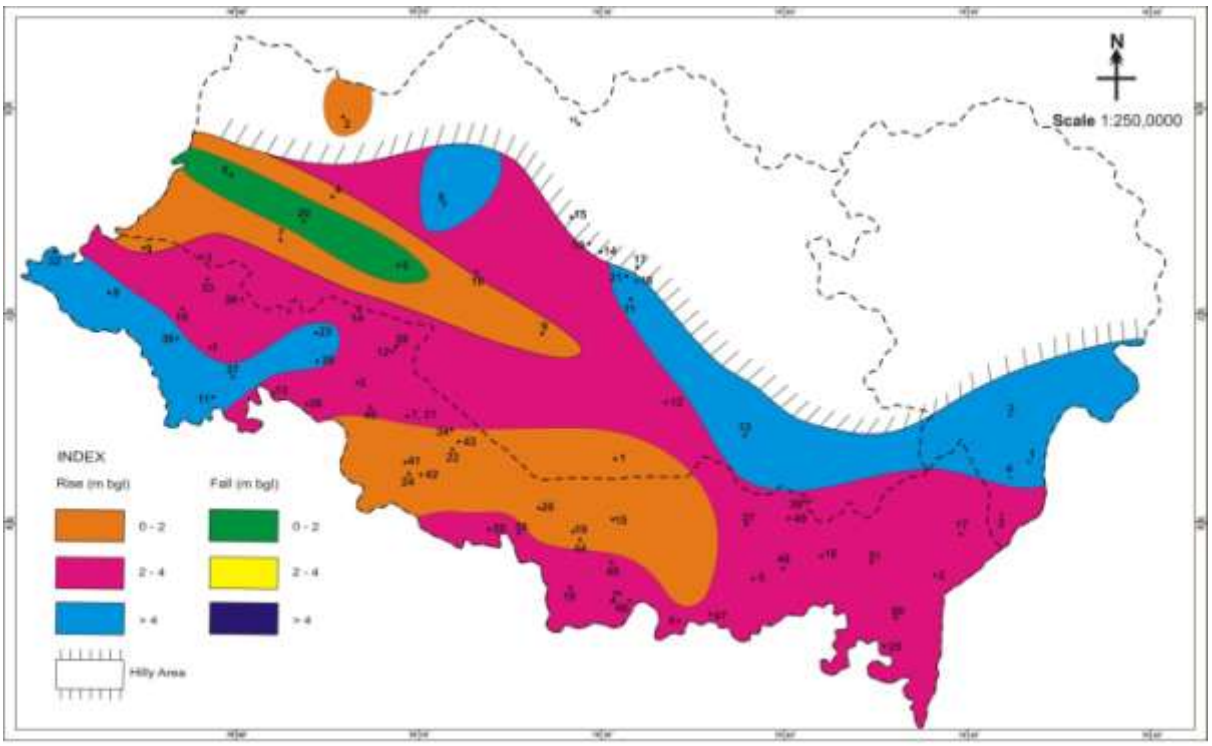

Fig. 42 Water Level Fluctuation Map, May 2013 Vs August 2013 Nainital, Udham Singh Nagar & Champawat district

Table 20. Seasonal Water Level Fluctuation (May 2013 Versus August 2013)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	24	2.24	17.06	--	--	0	0	4	16.67	20	83.33	0	0	0	0	0	0
Haridwar	20	0.78	8.65	1.34	2.38	3	15	10	50	5	25	1	5	1	5	0	0
Udham Singh Nagar	23	1.07	5.86	--	--	6	26.09	14	60.86	3	13.05	0	0	0	0	0	0
Nainital	13	0.62	26.82	0.23	1.30	5	38.47	3	23.07	3	23.07	2	15.39	0	0	0	0
Champawat	2	3.21	14.09	--	--	0	0	1	50	1	50	0	0	0	0	0	0
Total	**82**	**0.62**	**26.82**	**0.23**	**2.38**	**14**	**17.07**	**32**	**39.02**	**32**	**39.02**	**3**	**3.66**	**1**	**1.22**	**0**	**0**

5.4.3.2 Water Level Fluctuation (May 2013 versus November 2013)

The water level fluctuation data of May 2013 was compared with that of November 2013 for 81 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 0.03 m at Rathura in Haridwar district while the maximum was 19.56 m at Nanukhera in Dehradun district. The annual decline was 0.04 m at Ramnagar in Nanital district whereas the maximum decline was 1.57 m at Landhura in Haridwar district.

A perusal of the fluctuation data also shows that seasonal rise of 0-2 m was shown by 32 monitoring wells out of 81 (39.51%), that in the range of 2-4 m by 23 monitoring wells (28.40 % of total) and that in the range of >4 m by 23 wells (28.40% of total) in Uttarakhand State. Seasonal decline in the range 0-2 m was recorded by 3 wells (3.69% of total). Higher seasonal decline in the range of 2-4 m and the highest decline of >4 m was not recorded by any monitoring for which the data is available.

The seasonal water level fluctuation map during the period May 2013 versus November 2013 is shown in ***Fig. 43*** *(Dehradun district),* ***Fig.44*** *(Haridwar District)* and ***Fig. 45*** *(Nainital-Udham Singh Nagar-Champawat section).*

Visual interpretation of **Fig. 43** has revealed that the lowest seasonal rise of 0-2 m was seen dominantly in northern, western and southern parts of the Doon Gravels covering areas i.e. Herbertpur, Chhorba, Badripur and Singhniwala. Higher seasonal rise of 2-4 m was seen in the north western, eastern and south eastern parts in Doon Valley, Dehradun district. The highest seasonal rise of >4 m was

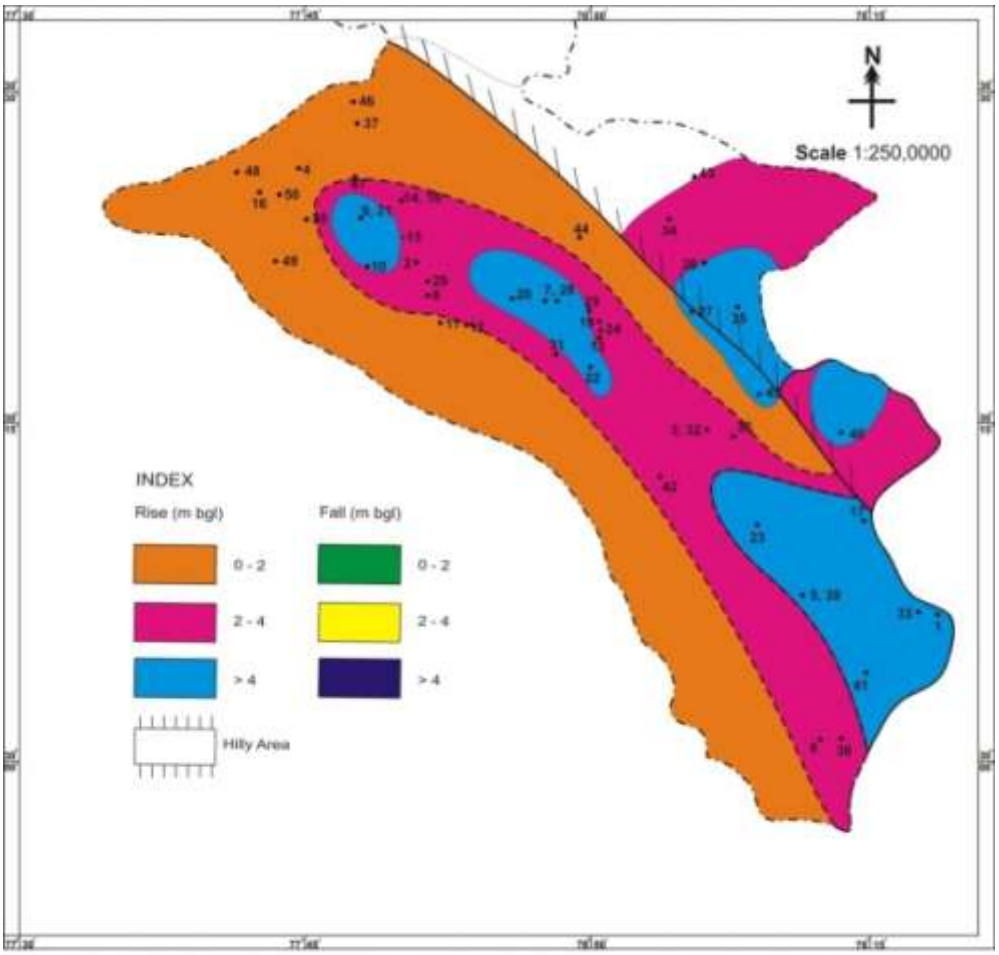

Fig. 43 Water Level Fluctuation Map, May 2013 Vs November 2013 Dehradun district

observed dominantly in southeastern part; also in and around Rishikesh, Bhaniawala, Baronwala, majra, Rampura Nanda Ki Chownki. Seasonal decline in the range of 0-2m, 2-4 m and >4 m was not recorded by any monitoring for which the data is available.

Visual interpretation of **Fig. 44** has revealed that the lowest seasonal rise of 0-2 m was seen dominantly in major part (~75% of the area) in north central, central and southern part. Higher seasonal rise of 2-4 m was seen in the south eastern part covering areas i.e. Laldhang, Bhikampur, Bhogpur. This zone also occurs as sinusoidal shape in western part of the district covering areas Jhabrera, Roorkee, Bandarjudh, Sahidwalagrant, Buggawala, Bahabalpur. The highest seasonal rise of >4 m was observed in and around Iqbalpur, Chudiala and Bhagwanpur. The lowest seasonal decline of 0-2 m was observed as elliptical patch around Landhura. The seasonal decline in the range of 2-4 m and >4 m was not recorded by any monitoring for which the data is available

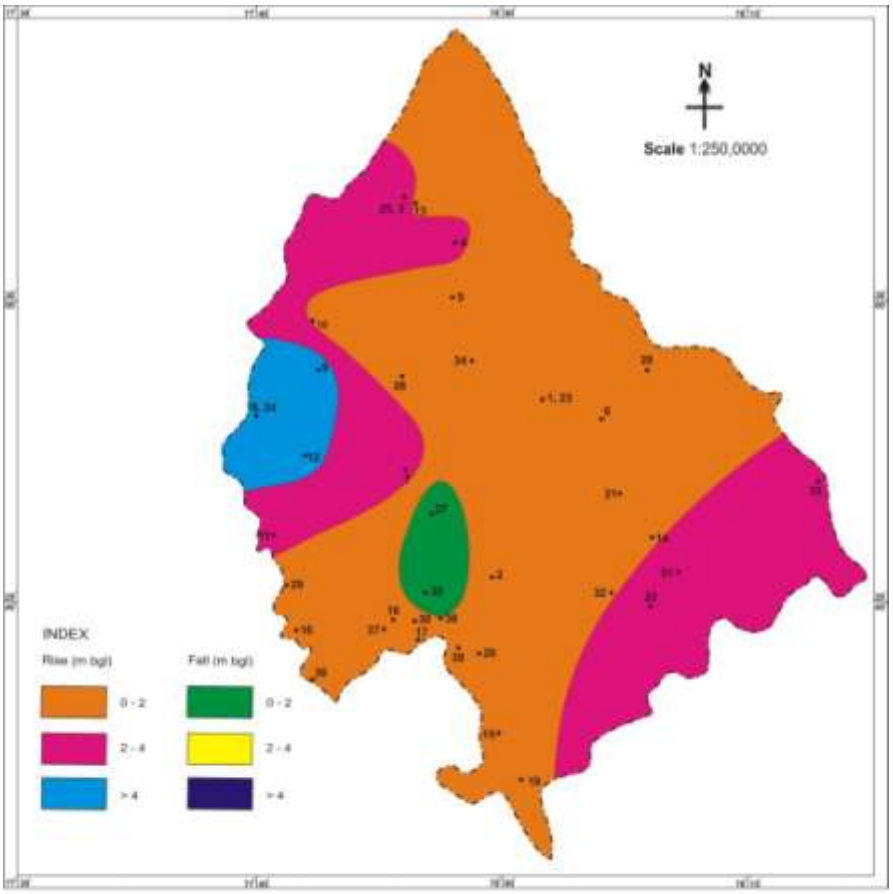

Fig. 44 Water Level Fluctuation Map, May 2013 Vs November 2013 Haridwar district

A perusal of **Fig. 45** has shown that the minimum decadal rise of 0-2 m was seen in isolated areas in the central, north western and south eastern parts of Udham Singh Nagar district and also as a isolated patches at Kathgodham, Garjia, Dhoniya in Nainital district. Higher decadal rise of 2-4 m was seen in and around Angadpur, patrampur, Dhanuri Patti, Sultanpur Patti, Banakhera, Bhagwanpur, Sitarganj and kamariaPakki(in Udham Singh Nagar district) and Maldhan Colony, Belparao, Lamachaur and Sitapur in Nanital District. The highest decadal rise of >4 m was observed in and around PeeruMadara, Lalkaun, and Khaat Baas in Nanital District and in the central and northern parts of Champawat district (in and around Bastia), both falling in the Bhabar formation. This zone was also observed as isolated patch at Jaspur and Jogipura in Udham Singh Nagar district. The minimum decline of 0-2 m was seen only at Ramnagar in Nanital District. The seasonal decline in the range of 2-4 m and >4 m was not recorded by any monitoring for which the data is available.

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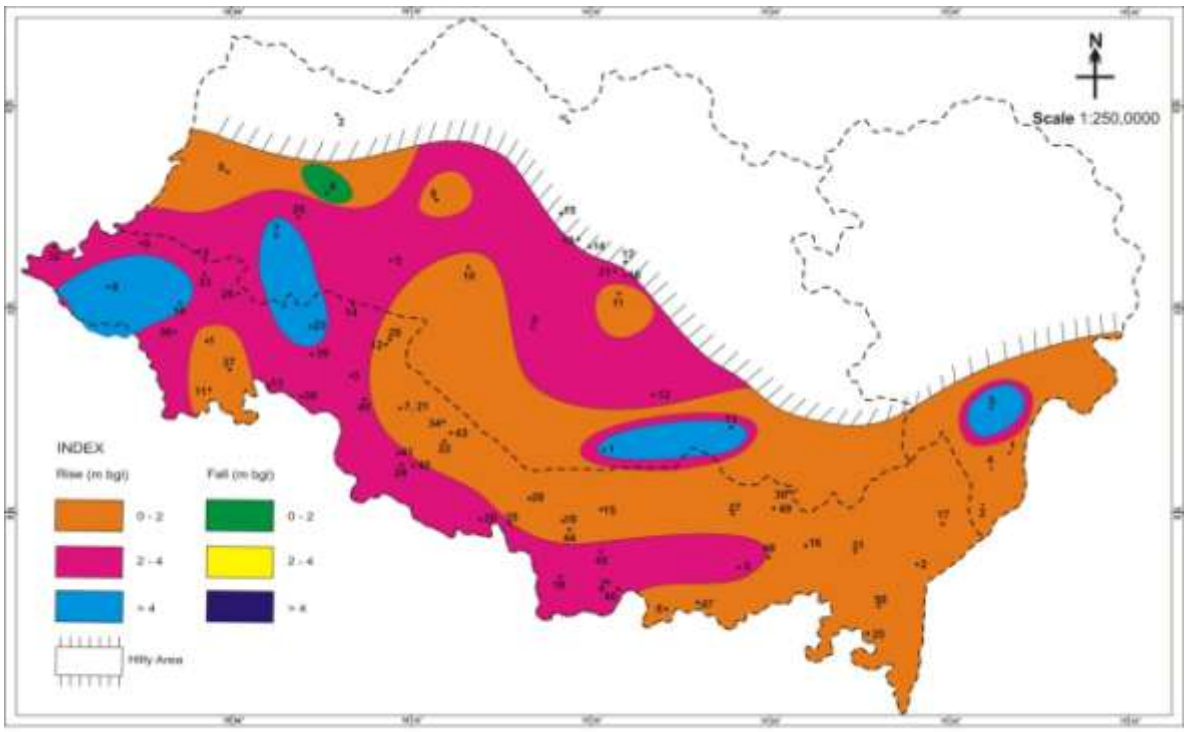

Fig. 45 Water Level Fluctuation Map, May 2013 Vs November 2013 Nainital, Udham Singh Nagar & Champawat district

Table 21. Seasonal Water Level Fluctuation (May 2013 Versus November 2013)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	25	0.21	19.56	--	0.22	6	24	6	24	12	48	1	4	0	0	0	0
Haridwar	20	0.03	5.11	--	1.57	10	50	6	30	3	15	1	5	0	0	0	0
Udham Singh Nagar	21	0.45	8.74	--	--	11	52.38	7	33.33	3	14.29	0	0	0	0	0	0
Nainital	13	0.43	13	--	0.04	4	30.77	4	30.77	4	30.77	1	7.69	0	0	0	0
Champawat	2	0.63	5.43	--	--	1	50	0	0	1	50	0	0	0	0	0	0
Total	**81**	**0.03**	**1.56**	**--**	**1.57**	**32**	**39.51**	**23**	**28.40**	**23**	**28.40**	**3**	**3.69**	**0**	**0**	**0**	**0**

5.4.3.3 Water Level Fluctuation (May 2013 Versus January 2014)

The seasonal water level fluctuation for the period May 2013 versus January 2014 is available for 73 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 0.25 m at GurkulNarsen in Haridwar District while the maximum fluctuation was 13.29 m at Bhaniawala in Dehradun district. The minimum seasonal decline in ground water level was 0.09 m at Kaladungi in Nainital District while the maximum decline was 3.96 m at Rathura in Haridwar District.

A perusal of **Table 22** also reveals that that the lowest seasonal rise of 0-2 m was shown by 23 monitoring wells (31.50% of total) whereas higher rise of 2-4 m was shown by 27 wells (36.98% of total). The highest seasonal rise of >4 m was shown by 15 wells, which was 20.55% of the total wells. Seasonal decline in the range of 0-2 m was shown by 6 monitoring wells (8.23% of total) while higher decline of 2-4 m was shown by 2 wells (2.74% of total). The highest decline of >4 m was not recorded by any monitoring for which the data is available in Uttarakhand State during the period May 2013 versus January 2014.

The seasonal water level fluctuation map during the period May 2013 versus January 2014 is shown in ***Fig. 46*** *(Dehradun district),* ***Fig 47(****Haridwar district)* and ***Fig. 48*** *(Nainital-Udham Singh Nagar-Champawat section)*.

Interpretation of **Fig. 46** indicates that the minimum decadal rise of 0-2 m was seen in isolated areas in the north western, central west and southern parts of Doon Valley covering areas Judli, Badripur, Sabhawala and Khandgaon. The seasonal rise of 2-4 m was observed just lying above the 0-2m water level zone covering areas Vikasnagar, Redapur, Selaqui, Baronwala, Dudhli, Motichur and

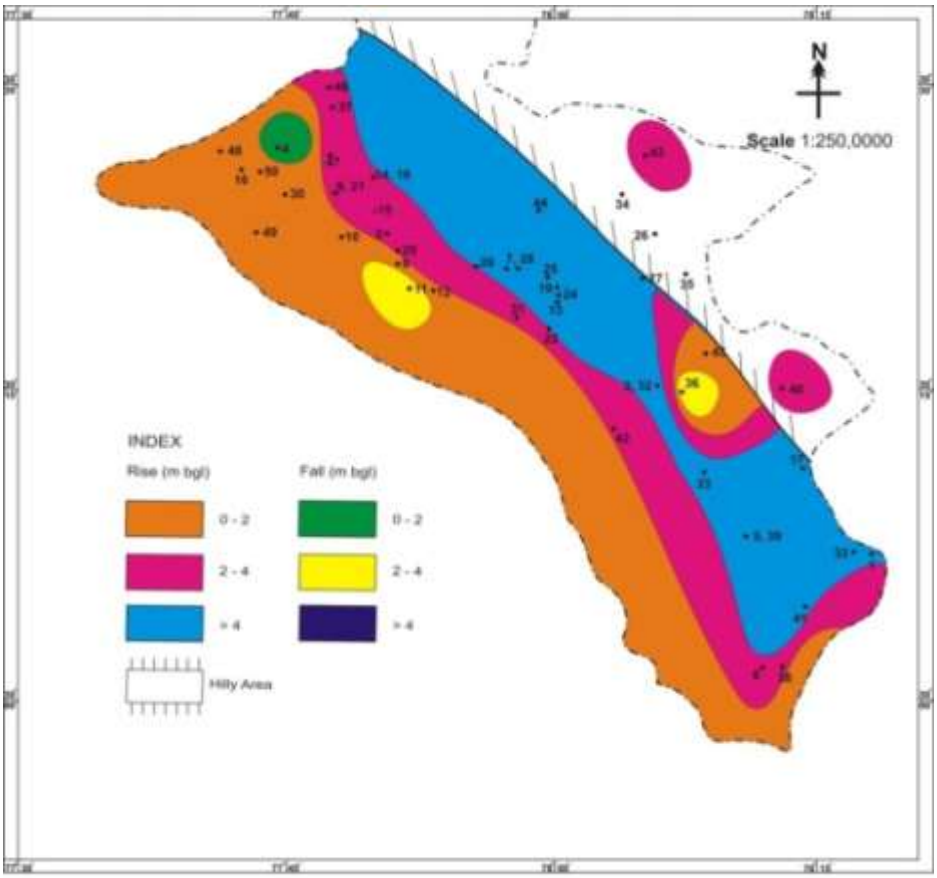

Fig. 46 Water Level Fluctuation Map, May 2013 Vs January 2014 Dehradun district

KhadriKhadakmap; also as isolated patches at Kotimachaik. The highest seasonal rise of >4 m was seen as a broad zone trending from Northwest to southeast , lying just above the 2-4m water level zone covering areas i.e. Rishikesh, Bhaniawala, Lal Tappar, Kuanwala, Jhajra, Nanda Ki Chowki, Harbanswala, Chhorba and Dhakpathar. The lowest seasonal decline of 0-2 m was found as isolated patches at Herbertpur, Singhniwala and Gularghati. The seasonal decline in the range of 2-4 m and >4 m was not recorded by any monitoring for which the data is available.

Interpretation of **Fig. 47** indicates that the minimum decadal rise of 0-2 m was seen in broad zone covering central and north western part of the district that is Buggawala, Bahabalpur, Bahadrabad, Sarai and Gurukul Narsan. The seasonal rise of 2-4 m was observed in Jhabrera, Roorkee, Imlekhera, Shahidwala Grant, Bhoopatwala, Laldhang and Bhikampur. The highest seasonal rise of >4 m was see in the western part (Chudiala, Bhagwanpur and Iqbalpur) and as a linear zone extending from south-east to south. It has been observed that water levels decreases towards the central of the district. The lowest seasonal decline of 0-2 m was observed as a linear zone extending from south-west to north central part of the district covering areas Teliwala, Landhura and Kherajat. The seasonal decline of 2-4 m was observed as an isolated patch around Rathoura and Lakhnauta. The seasonal decline in the range of >4 m was not recorded by any monitoring for which the data is available.

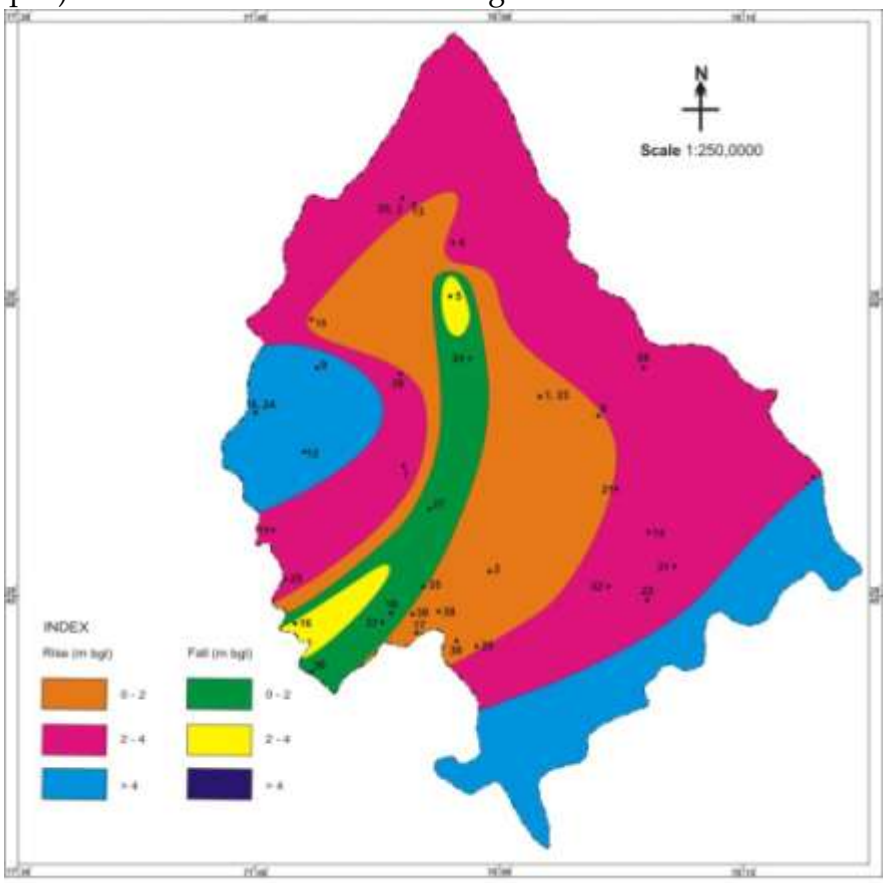

Fig. 47 Water Level Fluctuation Map, May 2013 Vs January 2014 Haridwar district

Visual interpretation of **Fig. 48** has shown that the minimum decadal rise of 0-2 m was seen in major part of Udham Singh Nagar district covering central and southern part. falling in the Tarai zone. This zone was also seen in the northern and central part of Nainital district falling in the Bhabar zone; also as isolated patch a Garjia. Higher seasonal rise of 2-4 m was seen in the south western part of Udham Singh Nagar covering areas Patrampur, Dhanauri Patti, Sultanpur Patti and Banakhera. This zone also occurs as isolated patches around Bhagwanpur, Sitarganj and Kashipur; as a linear zone trending from central to eastern part of Bhabar Zone. The highest seasonal rise of

>4 m was seen in an around Jaspur, Patrampur and Jogipura in Udham Singh Nagar district. The minimum seasonal decline of 0-2 m was seen in and around Dhela and Ramnagar in Nainital district. The seasonal decline in the range of 2-4 m and >4 m was not recorded by any monitoring for which the data is available.

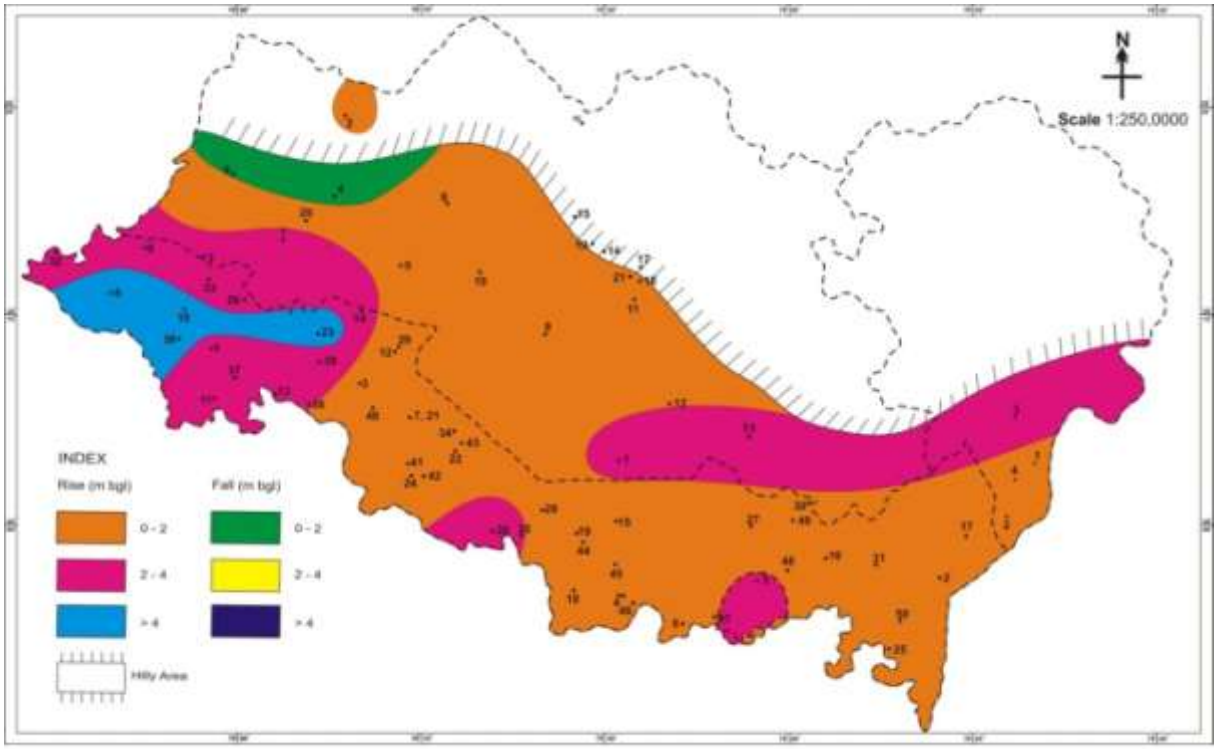

Fig. 48 Water Level Fluctuation Map, May 2013 Vs January 2014 Nainital, Udham Singh Nagar & Champawat district

Table 22. Seasonal Water Level Fluctuation (May 2013 Versus January 2014)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	24	0.85	13.29	0.68	1.32	6	25	7	29.17	8	33.33	3	12.50	0	0	0	0
Haridwar	20	0.25	7.76	1.52	3.90	5	25	8	40	4	20	1	5	2	10	0	0
Udham Singh Nagar	19	0.54	5.89	--	--	9	47.37	7	36.84	3	15.79	0	0	0	0	0	0
Nainital	8	0.54	3.06	0.09	0.60	2	25	4	50	0	0	2	25	0	0	0	0
Champawat	2	1.19	2.59	--	--	1	50	1	50	0	0	0	0	0	0	0	0
Total	**73**	**0.25**	**13.29**	**0.09**	**3.90**	**23**	**31.50**	**27**	**36.98**	**15**	**20.55**	**6**	**8.23**	**2**	**2.74**	**0**	**0**

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.

The chemical quality of groundwater in Uttarakhand State has been ascertained from complete chemical analysis of one hundred and six (106) water samples collected during pre-monsoon period (May 2012). The analysis was carried out in Chemical Laboratory, North Western Region, Chandigarh. The result of chemical analysis for four parameters viz. Electrical Conductivity (EC), chloride (Cl), nitrate (NO_3) and fluoride (F) has been used to prepare thematic maps in Surfer software. 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 and Champawat 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-HCO_3 and Ca-HCO_3 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 (NO_3) and fluoride (F) are given separately.

Table 23. Chemical Analysis of Water Samples Collected from Ground Water Monitoring Stations, Pre-monsoon (May 2012)

Sr. No.	Location	pH	EC (µS/cm at 25°C)	Concentration (mg/L)										
				CO_3	HCO_3	Cl	SO_4	NO_3	F	Ca	Mg	Na	K	SiO_2	TH as $CaCO_3$
District Dehradun															
1.	Gularghati HP	8.29	560	Nil	109	21	160	9.8	0.27	54	38	2.5	1.2	10	289
2.	Kuanwala HP	8.35	287	8.9	72	18	40	1.1	0.29	34	10	6.2	1.2	13	128
3.	Bhaniawala HP	8.35	413	5.9	84	18	115	4.9	0.15	36	31	3.4	1.0	9.4	220
4.	Lal Tappar HP	8.41	322	8.9	112	32	07	3.9	0.17	24	22	4.9	1.0	12	150
5.	Khandgaon HP	8.38	370	8.9	118	32	15	19	0.23	41	10	19	1.5	10	144
6.	Motichur HP	8.39	230	8.9	105	21	Nil	3.3	0.23	21	6.6	13	1.6	17	104
7.	Rishikesh	8.47	262	8.9	51	18	55	4.8	0.22	36	10	4.4	0.8	16	134
8.	Rishikesh HP	8.38	325	8.9	124	25	06	6.3	0.20	36	14	5.3	1.0	14	150
9.	Kotimachak HP	8.47	252	12	90	28	02	25	0.31	30	5.2	27	0.8	16	96
10.	Soda Sarauli HP	8.60	290	12	78	18	39	5.2	0.21	28	16	9.3	0.9	14	134
11.	Soda Sarouli SP	8.47	181	12	48	28	Nil	7.8	0.19	21	7.4	9.5	1.1	14	84
12.	TarlaNagal HP	8.56	272	12	114	21	Nil	8.5	0.08	11	29	2.1	1.6	12	148
13.	Purukulgaon HP	8.37	410	5.9	103	28	70	9.9	0.11	47	21	4.6	0.6	12	203
14.	Singhniwala	7.43	420	Nil	96	21	95	12	0.12	33	30	5.9	0.8	15	205
15.	Ramgarh HP	7.73	390	Nil	143	21	45	14	0.10	37	25	5.5	0.9	16	195
16.	Baronwala HP	8.04	310	Nil	143	21	14	11	0.13	21	25	7.8	0.8	14	154
17.	Dandi	8.07	250	Nil	120	14	04	05	0.11	33	7.5	5.6	1.2	11	113

18.	CGWB PZ	8.06	480	Nil	143	28	65	25	0.11	41	30	7.6	0.8	17	226
19.	Harbanswala HP	8.17	382	Nil	132	28	50	16	0.06	25	32	9.1	0.6	17	195
20.	Majra HP	8.18	470	Nil	108	28	95	16	0.06	33	32	11	0.8	20	215
21.	Bhatta SP	8.33	361	12	120	14	38	2.8	0.08	12	35	1.9	0.6	6.5	174
22.	Balliwala HP	7.99	431	Nil	120	28	50	28	0.04	21	32	12	0.7	20	185
23.	Nanda Ki Chowki HP	8.40	290	5.6	72	49	Nil	8.4	0.08	30	13	7.7	0.8	14	127
24.	Khandoli	8.29	50	Nil	24	11	Nil	0.1	0.05	6.4	2.7	4.3	0.3	18	27
25.	Jhajra HP	8.34	263	5.9	109	32	02	4.8	0.10	32	13	7.6	0.7	20	132
26.	Selaqui HP	8.15	188	Nil	66	25	05	19	0.09	21	1.3	23	0.7	17	59
27.	Rampura	8.25	172	Nil	66	25	Nil	11	0.09	18	4.6	15	0.6	13	64
28.	Shankarpur	8.18	223	Nil	79	32	02	24	0.12	20	4.7	27	0.8	18	70
29.	Redapur HP	8.29	125	Nil	44	21	01	4.3	0.11	10	3.0	15	0.6	17	38
30.	Chhorba	8.16	72	Nil	30	17	Nil	4.4	0.06	9.2	0.97	11	1.2	3.6	27
31.	Herbertpur	8.19	193	Nil	72	28	05	8.9	0.10	20	3.6	18	1.6	11	70
32.	Vikas Nagar HP	8.36	207	5.9	72	21	14	0.2	0.13	24	10	5.3	0.8	11	102
33.	Badripur HP	8.45	252	12	96	21	10	7.1	0.15	30	7.8	17	0.7	12	107
34.	Dharmawala HP	8.58	479	15	196	39	08	40	0.17	40	16	43	17	17	166
District Haridwar															
35.	Shahidwala Grant	7.97	310	Nil	120	28	02	33	0.05	25	20	6.2	1.2	17	146
36.	Bugawala HP	8.04	293	Nil	84	21	18	42	0.08	25	17	7.1	02	15	133
37.	Bandarjud	8.54	279	18	107	10	23	6.8	0.06	12	25	12	1.4	21	135
38.	Rathaura	8.87	368	35	119	10	55	Nil	0.11	12	30	32	2.5	21	156
39.	Imlikhera HP	8.94	427	35	131	10	80	Nil	0.30	12	15	79	1.6	17	94
40.	Bahabalpur HP	8.74	348	35	107	10	42	0.38	0.21	21	25	22	1.6	16	156
41.	Bhagwanpur HP	8.72	470	24	48	80	37	Nil	0.41	21	23	38	2.9	18	146

42.	Chudiala HP	8.84	281	14	96	10	27	Nil	0.71	8.3	23	21	2.5	19	115
43.	Manglaur HP	8.63	275	18	42	31	28	3.2	0.20	33	10	4.5	4.4	19	125
44.	Gurukul Narsen HP	8.47	503	18	42	56	65	57	0.05	29	30	26	4.2	30	198
45.	Lakhnauta HP	8.57	273	12	120	10	19	0.98	0.22	21	18	11	3.6	24	125
46.	Jhabrera HP	8.76	280	18	90	10	42	Nil	0.47	17	20	15	4.3	24	125
47.	Iqbalpur HP	8.71	382	18	95	35	37	0.15	0.27	17	25	22	2.6	22	146
48.	Roorkee PZ	8.74	320	18	78	21	50	Nil	0.09	33	7.7	25	4.3	25	114
49.	Landhaura HP	8.27	265	Nil	108	17	04	18	0.07	17	15	12	1.7	19	104
50.	Hussainpur	8.74	385	35	120	10	70	Nil	0.07	17	28	39	4.4	16	156
51.	Goverdhanpur HP	8.79	577	47	143	28	105	Nil	0.15	12	23	99	5.3	17	125
52.	Khanpur HP	8.73	430	47	119	10	70	Nil	0.29	17	15	72	6.5	15	104
53.	Bhikkampur HP	8.57	315	24	60	10	65	Nil	0.17	25	18	14	4.1	19	135
54.	ShahpurSitlakhera HP	8.54	465	24	60	28	70	41	0.17	21	28	13	35	18	166
55.	Dhanpura HP	8.52	755	35	60	69	120	75	0.15	21	40	36	73	19	218
56.	Missarpur	8.52	308	18	66	21	40	17	0.07	17	23	14	5.2	11	135
57.	Sarai	8.18	658	Nil	72	56	80	128	0.10	54	33	26	1.4	16	270
58.	Bahadrabad	8.35	230	18	54	10	31	3.3	0.29	37	5.1	4.1	0.4	15	114
59.	Bhoopatwala HP	8.43	470	18	101	38	60	23	0.17	25	28	30	4.2	18	177
60.	Laldhang HP	8.27	345	Nil	132	21	37	2.9	0.03	33	15	15	1.6	11	146
District Pauri Garhwal															
61.	Kaudiya HP	8.24	270	Nil	84	17	35	28	0.05	29	13	11	1.3	12	127
District Udham Singh Nagar															
62.	Angadpur	8.35	373	6.3	218	11	5	Nil	0.92	41	21	11	0.7	22	189
63.	Patrampur	8.65	363	25	183	12	Nil	Nil	1.61	12	27	28	0.9	18	143
64.	Jaspur	8.77	623	32	352	14	Nil	Nil	3.23	16	14	116	0.8	15	97

65.	Bharatpur	8.65	405	28	189	8.9	Nil	Nil	1.62	13	20	50	0.7	17	115
66.	BarkharePande	8.55	916	9.5	154	5.3	15	Nil	0.95	326	18	23	1.5	15	115
67.	Dhanauri Patti	8.45	273	9.5	122	11	10	Nil	0.5	15	16	17	1.2	16	105
68.	Banna Khera	8.40	401	16	125	18	50	Nil	0.96	21	33	11	3.2	9.7	189
69.	Shantipuri	8.28	247	--	109	8.9	20	4.5	0.52	26	12	5.7	2.1	20	112
70.	Patthar Chatta	8.20	276	--	157	7.1	5	3.7	0.53	24	17	7.2	2.3	24	128
71.	KamariaPakki	8.45	307	9.5	160	8.9	Nil	2.9	1.05	36	9.4	13	1.5	23	128
72.	Kichha	8.50	932	19	192	82	80	101	0.52	29	45	66	56	11	255
73.	Bara	8.55	418	15	167	16	35	Nil	1.36	25	22	35	0.8	14	150
74.	Sitarganj	8.58	251	6.3	143	5.3	Nil	Nil	1.35	16	14	16	1.4	17	102
75.	Nanak Mata	8.57	286	15	141	11	25	Nil	1.02	11	29	16	0.9	11	146
76.	Majhola	8.40	204	6.3	87	23	Nil	Nil	0.5	18	13	5.4	1.9	9.7	100
77.	Khatima	8.12	325	--	112	27	30	Nil	0.72	38	5.6	20	0.7	16	118
78.	Chakarpur	8.12	216	--	128	18	5	Nil	0.41	20	16	7.9	1.7	12	117
79.	Kalyanpur	8.30	197	--	115	7.1	Nil	3	0.52	17	0	414	5	8.4	0
80.	Bhagwanpur	8.60	252	6.3	128	11	Nil	Nil	0.62	16	15	10	1.9	23	105
81.	Mahabir Nagar	8.68	456	19	141	12	75	4.3	0.42	20	45	6	1.3	23	237
82.	Jhagarpuri	8.72	431	53	109	11	50	Nil	0.66	14	42	18	1.5	24	209
83.	Beria Daulat	8.68	470	25	163	30	40	Nil	0.59	9.2	50	14	1.6	22	227
84.	Bazpur	8.68	525	16	147	60	45	Nil	0.51	22	36	33	1.3	21	204
85.	Barhini	8.87	538	29	208	21	50	Nil	0.58	35	41	16	7.4	17	255
86.	Sultanpur Patti	8.47	290	6.3	128	15	11	1.5	0.45	17	20	7.7	0.9	14	128
District Nainital															
87.	PeeruMadara	8.36	836	25	70	145	145	Nil	0.34	20	71	52	2.5	11	342
88.	Dhela	8.40	238	19	80	14	Nil	16	0.29	25	7.5	18	1.3	4.1	92

89.	Garjia	8.30	261	--	77	41	Nil	6.4	0.6	28	9.2	7.3	2.3	5.2	107
90.	Ramnagar	8.52	326	22	154	7.1	Nil	3.4	0.41	8.2	30	13	2.5	14	143
91.	Belparao	8.52	354	19	131	5.3	40	3.9	0.55	8.2	38	7	1.3	15	179
92.	Dohniya	7.85	395	--	131	7.1	72	6.6	0.53	8.2	40	5.3	1	14	186
93.	Kaladhungi	8.30	385	--	176	11	40	6.6	0.5	15	39	4.8	1	11	197
94.	Lamachaur	8.45	220	9.5	109	7.1	Nil	Nil	0.32	11	18	6.3	0.8	14	102
95.	Khaat Baas	9.22	1801	139	756	28	Nil	Nil	10.32	0	0	414	5	8.4	0
96.	Sitapur	8.42	230	6.3	128	3.5	Nil	1	0.8	19	14	7.2	1	10	105
97.	Kathgodam	8.47	300	6.3	119	19	Nil	14	0.5	22	15	13	3.8	13	117
98.	Dogaon	8.45	195	9.4	90	19	Nil	Nil	0.47	15	10	17	1.2	9.7	77
99.	Sipahidhara	8.48	505	25	144	76	Nil	9.8	0.4	22	47	8.7	2.7	4.6	250
100.	Garampani	8.55	177	6.3	109	1.8	Nil	Nil	0.42	20	9.8	1.5	0.6	8.4	92
101.	Salari	8.42	327	3.1	99	28	38	17	0.37	35	20	5.2	0.6	14	169
District Champawat															
102.	Banbasa	8.12	339	--	148	35	Nil	18	0.45	31	17	12	7.7	18	145
103.	Bastia	8.16	211	--	125	3.5	Nil	9.7	0.38	35	3.2	6.1	0.7	16	100
District Almora															
104.	PataliMalla	8.40	352	13	140	21	Nil	19	0.46	55	6.2	8.3	0.8	16	163
105.	PataliTalla	8.34	210	6.3	81	18	Nil	4.6	0.48	28	4.3	7.8	1.4	16	87
106.	Katarmal	8.14	252	--	54	35	10	24	0.47	29	1.2	18	4.4	20	77

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, 2012 the EC value was observed to vary from a minimum of 50 µS/cm (at 25°C) at Khandoli spring in Dehradun district to a maximum of 1801 µS/cm at Khaat Baas – also in Nainital district. The frequency distribution of Electrical Conductivity in Uttarakhand is given in **Table 24.**

Table 24. Frequency distribution of Electrical Conductivity (May 2012)

Electrical Conductivity (µS/cm at 25°C)	0 – 250	>250 – 750	>750 – 2250	>2250
No. of Samples	23	78	5	0
% of Total No.	21.70	73.58	4.72	0

A study of the above table indicates that majority of the samples (78 out of 106 samples or 73.58%) have shown EC in the range of >250–750 µS/cm. Low EC value of 0–250 µS/cm was found in 23 ground water samples, which is 21.70% of the total number of samples. Only five samples out of 106 (4.72% of the total number) have shown higher EC value of >750–2250 µS/cm. The analysis results also indicate that during pre-monsoon 2012, no sample has shown EC higher than 2250 µS/cm in Uttarakhand State. A map showing the spatial distribution of EC in Dehradun-Haridwar section of Uttarakhand State is given in ***Fig. 49*** while another map showing the spatial variation in distribution of Electrical Conductivity in Udham Singh Nagar-Nainital section is shown in ***Fig. 50.***

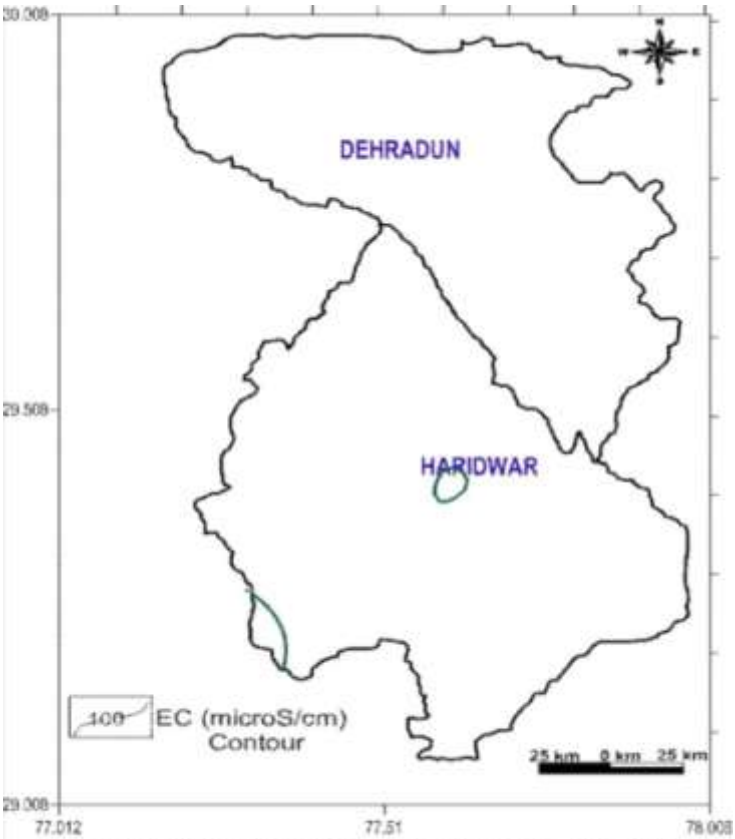

Fig. 49 Distribution of Electrical Conductivity(EC) in groundwater, Dehradun-Haridwar, May 2012

A study of these maps indicates that relatively high EC (>800 µS/cm) was observed only in a small zone in the east central part of Nainital district falling in the Bhabar zone. Rest of the area has shown low EC in groundwater samples collected during pre-monsoon, 2012.

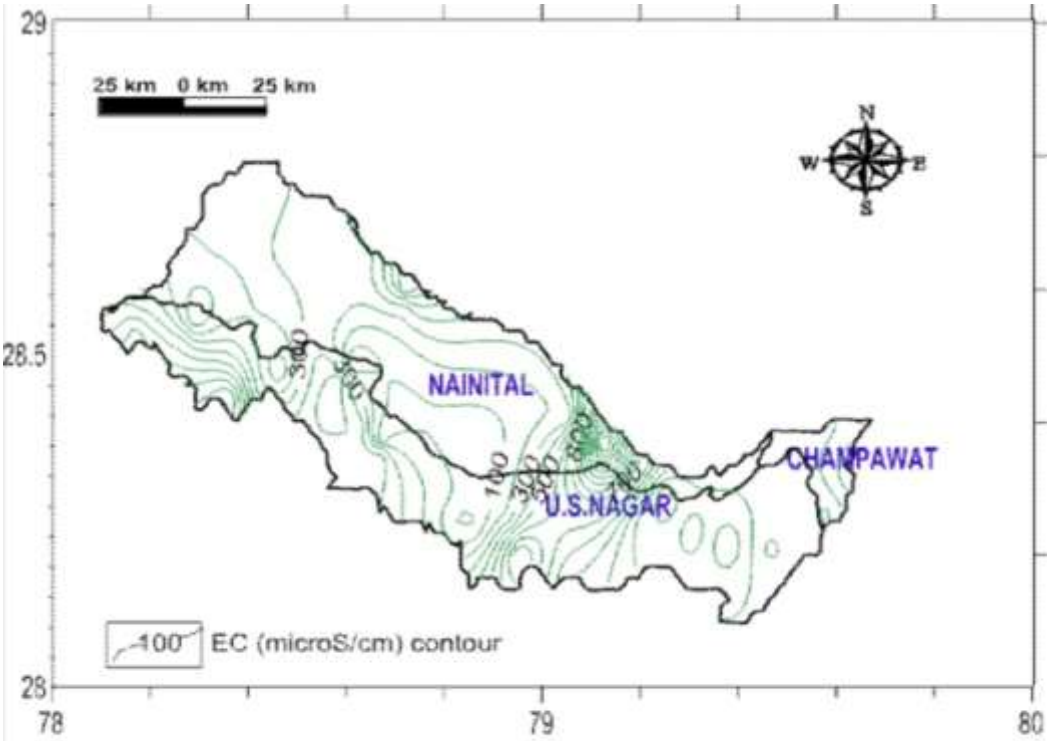

Fig. 50 Distribution of Electrical Conductivity (EC) in groundwater, U.S.Nagar-Nainital, May 2012

6.1.2 Chloride:

The analysis result of one hundred and six ground water samples collected in pre-monsoon 2012 indicates that the lowest concentration of chloride was 1.8 mg/L at Garampani spring and the highest chloride concentration was observed at PeeruMadara (145 mg/L), in Nainital district. The frequency distribution of chloride concentration in ground water of Uttarakhand State is given in ***Table 25.***

Table 25. Frequency distribution of Chloride concentration (May 2012)

Chloride (mg/L)	0-50	>50-100	>100-150	>150
No. of Samples	98	7	1	0
% of Total No.	92.45	6.60	0.94	0

A study of the above table indicates that majority of samples (98 out of 106 samples or 92.45%) have shown chloride concentration in the range of 0–50 mg/L whereas only seven samples (6.60% of total number) have shown chloride concentration in the range of >50–100 mg/L. It was also seen that only one sample (only 0.94% 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 2012. Hence, it can be stated that groundwater is predominantly fresh and potable during pre-monsoon 2012. ***Fig. 51*** depicts the spatial distribution of chloride concentration in groundwater in Dehradun-Haridwar section. The map depicting spatial variation of chloride concentration in ground water of Udham Singh Nagar-Nainital district is shown in ***Fig. 52.***

A perusal of the figures reveals that very low chloride concentration in groundwater was observed in Dehradun-Haridwar section. Low chloride in groundwater was also observed in District Udham Singh Nagar and parts of District Champawat. Relatively high chloride concentration (>50 mg/L) was recorded in a small area around Sipahidhara in Nainital district and also around Bazpur in the west central part of District Udham Singh Nagar falling in the Tarai zone. Visual interpretation of ***Fig. 52*** also shows a small zone of chloride >50 mg/L in the northern part of Bhabar zone in Nainital district.

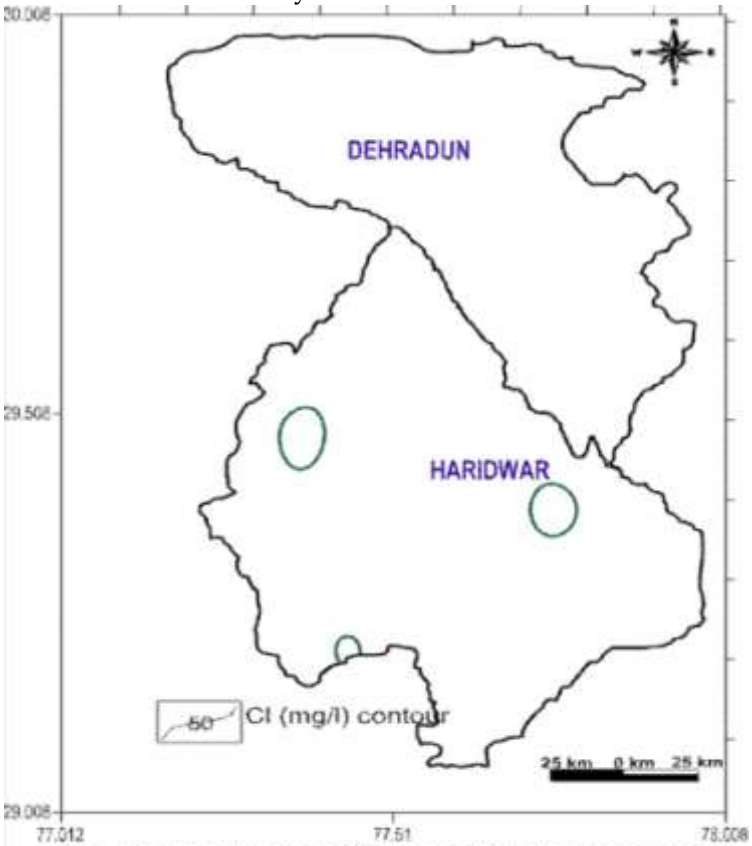

Fig. 51 Distribution of Chloride (Cl) in groundwater, Dehradun-Haridwar, May 2012

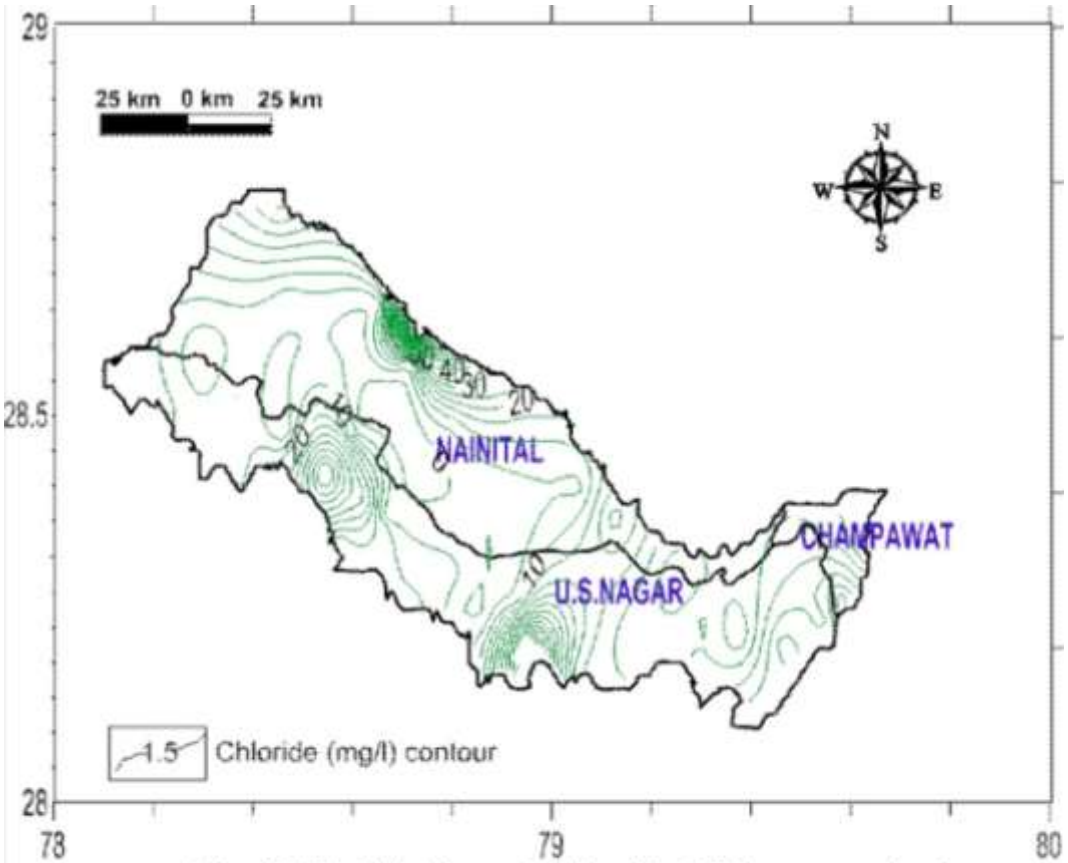

Fig. 52 Distribution of Chloride (Cl) in groundwater, U.S.Nagar-Nainital, May 2012

6.1.3 Nitrate

Concentration of nitrate in groundwater in Uttarakhand State during pre-monsoon 2012 was found to be highly variable. Out of one hundred and six samples, thirty three samples collected from ground water monitoring stations have shown Nil concentration of nitrate. This itself indicates that the problem of nitrate contamination in ground water of Uttarakhand State during pre-monsoon 2012 was minimal. Rest of the samples has shown variable nitrate concentration. The minimum nitrate concentration of 0.10 mg/L was observed in a spring at Khandoli in Dehradun district whereas the maximum concentration of 128 mg/L was recorded in a dug well at Sarai, Haridwar district. This was followed by very high nitrate concentration of 101 mg/L in a hand pump at Kichha, Udham Singh Nagar district. The frequency distribution of nitrate concentration in ground water in Uttarakhand State is given in ***Table 26.*** As thirty three groundwater samples have shown nitrate below the detection limit (viz. nil concentration), hence the sample size used for classification is seventy three samples.

Table 26. Frequency distribution of Nitrate concentration (May 2012)

Nitrate (mg/L)	<45	45–100	>100
No. of Samples	69	2	2
% of Total No.	94.52	2.74	2.74

A perusal of the above table indicates that majority of samples (69 out of 73 or 94.52% of total sample size) were suitable for drinking purpose as the nitrate concentration in these samples was below the Acceptable Limit of 45 mg/L (BIS, IS 10500, 2009). Higher nitrate concentration of 45–100 mg/L was found only in two samples (2.74% of total) viz. at Dhanpura and Gurukul Narsan in Haridwar district. Nitrate above 100 mg/L was recorded at two locations viz. at Sarai (128 mg/L) in Haridwar district and at Kichha (101 mg/L) in Udham Singh Nagar district. Overall, nitrate >100 mg/L was found only in two samples (2.74% of total) in Uttarakhand State during pre-monsoon, 2012.

The spatial variation in nitrate concentration in Dehradun-Haridwar section is shown in ***Fig. 53.*** The spatial variation in nitrate concentration in Udham Singh Nagar-Nainital section is shown in ***Fig. 54.***

Fig. 53 Distribution of Nitrate in groundwater, Dehradun-Haridwar, May 2012

Visual interpretation of ***Fig. 53*** has revealed that nitrate higher than the Acceptable Limit (>45 mg/L) was observed in two small zones in the west

central part and in the southern part of Haridwar district located in the Central Ganga Plains.

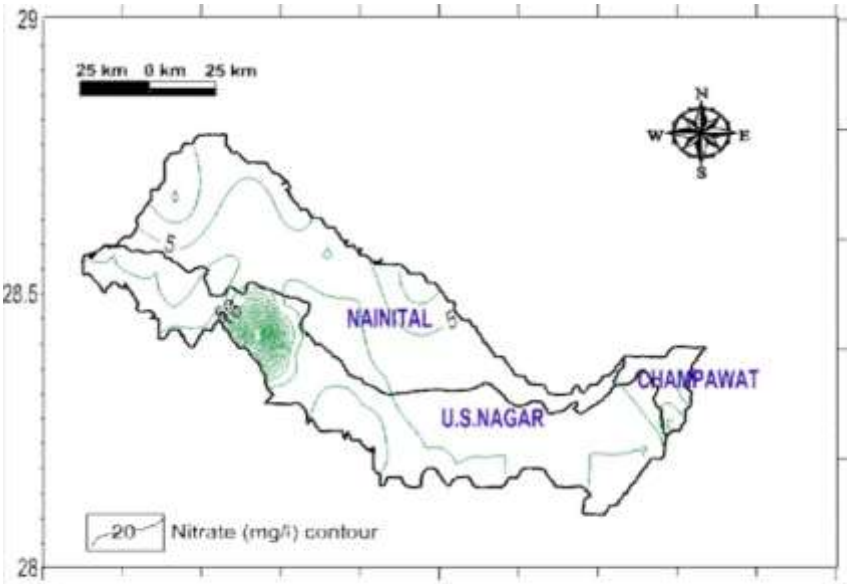

Fig. 54 Distribution of Nitrate in groundwater, U.S.Nagar-Nainital,May 2012

A perusal of ***Fig. 54*** has shown that nitrate higher than the permissible limit of 45 mg/L was found in a small area at Kichha located in the west central part of Udham Singh Nagar district.

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. The single sample in which high nitrate was collected from unconfined aquifer, which is limited in aerial extent. 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 106 ground water samples for which fluoride concentration is available (pre-monsoon, 2012) the highest concentration was 10.32 mg/L in a hand pump at Khaat Baas in Nainital district. However, such high value does not represent the true ground water quality as no other sample has shown fluoride higher than 3.5 mg/L. High fluoride of 3.23 mg/L was also found in a hand pump at Jaspur, Udham Singh Nagar district. The minimum concentration of fluoride in ground water during pre-monsoon 2012 was 0.03 mg/L in a hand pump at Laldhang, Haridwar district. It was also observed that very low fluoride concentration in groundwater was observed for samples collected from Dehradun-Haridwar section whereas relatively high fluoride concentration was recorded from samples collected from Udham Singh Nagar-Nainital section. The frequency distribution of fluoride concentration in groundwater in Uttarakhand State during pre-monsoon, 2012 is given in ***Table 27.***

Table 27. Frequency distribution of Fluoride concentration (May 2012)

Fluoride (mg/L)	<1.0	1.0-1.5	>1.5
No. of Samples	98	4	4
% of Total No.	92.45	3.77	3.77

A perusal of the table indicates that majority of samples (98 out of 106 samples or 92.45% of total) were 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 was found in four samples, which was 3.77% of the total samples. Fluoride higher than the Permissible Limit (>1.5 mg/L) was found in another four ground water samples during pre-monsoon, 2012.

Spatial variation in fluoride concentration in ground water of Dehradun-Haridwar section is depicted as ***Fig. 55*** whereas that for Udham Singh Nagar-Nainital section is shown in ***Fig. 56.***

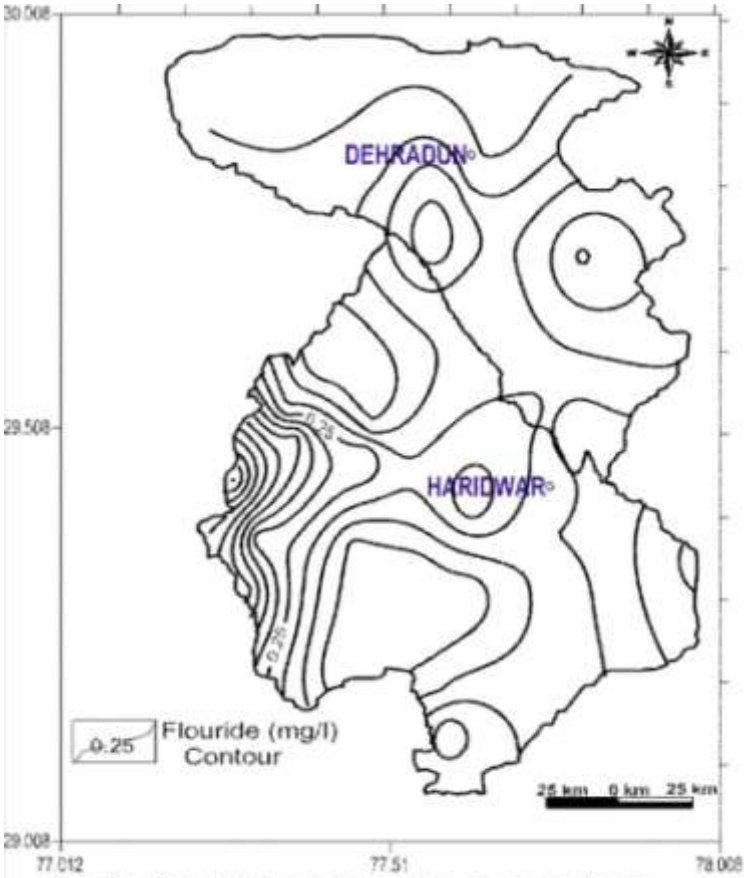

Fig. 55 Distribution of Flouride in groundwater, Dehradun-Haridwar, May 2012

Visual interpretation of ***Fig. 55*** has indicated that no area in Dehradun-Haridwar section has shown fluoride concentration higher than the Acceptable Limit of 1.0 mg/L. However, for the purpose of clarity, contours showing fluoride concentration of 0.25 mg/L were plotted on the map.

On the other hand, visual interpretation of ***Fig. 56*** indicates that high fluoride concentration (>1.0 mg/L) was found in and around Jaspur, Patrampur and Bharatpur in the western part and also in and around KamariaPakki, Bara, Sitarganj and Nanak Mata in the south central and central parts of Udham Singh Nagar district. Due to abnormally high fluoride (10.32 mg/L) at Khaat Baas, zones of high fluoride concentrations were also inferred in the west central

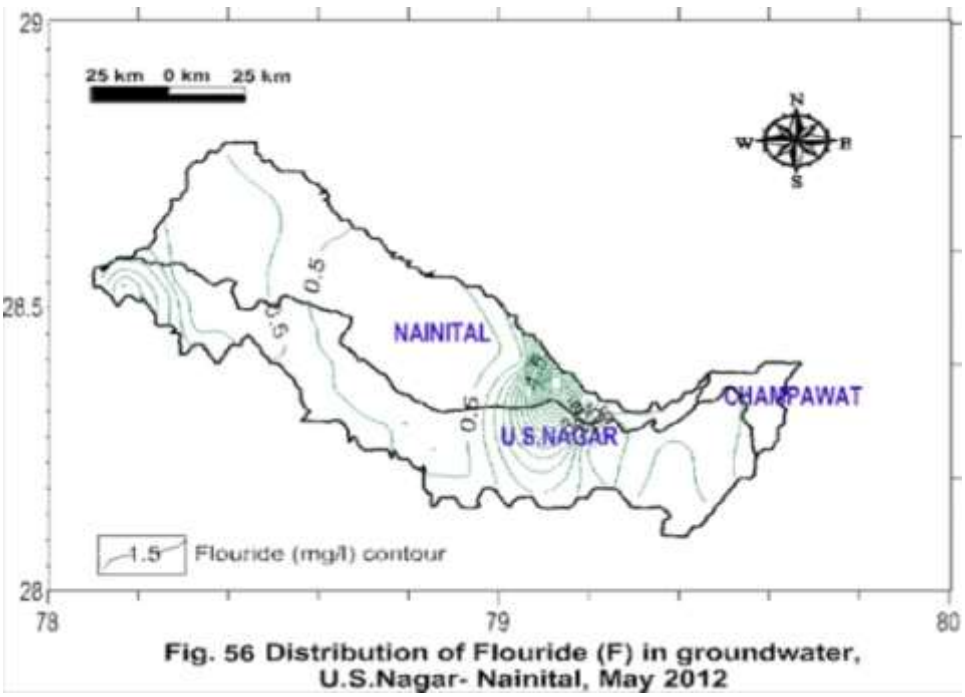

Fig. 56 Distribution of Flouride (F) in groundwater, U.S.Nagar- Nainital, May 2012

part of Nainital district falling in the Bhabar zone. However, this high value is possibly attributed to some local phenomenon and/or some anomalous rock-water interaction process as high fluoride was not recorded in this area of Nainital district for the last five years as per the historical hydrochemical data.