केन्द्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

DEHRADUN DISTRICT
UTTARAKHAND

उत्तरांचल क्षेत्र, देहरादून

Uttaranchal Region, Dehradun

केंद्रीयभूमिजलबोर्ड
जलशक्तिमंत्रालय
जलसंसाधन, नदीविकासऔरगंगासंरक्षणविभाग

Central Ground Water Board
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AAP 2021-22

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REPORT ON

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

Dehradun District, Uttarakhand

CONTRIBUTORS:

MS. CHANDREYEE DE, SCIENTIST- B

&

MS. ANJALI KUSHWAHA, SCIENTIST- B

UNDER SUPERVISION OF

SH. PRASHANT RAI, SCIENTIST- E

HEAD OF OFFICE

CENTRAL GROUND WATER BOARD
UTTARANCHAL REGION, DEHRADUN
AAP 2021-22

Executive Summary

- The study area (Dehradun District) is situated in NW corner of Uttarakhand State and extends from Latitude 29^0 58' N to 31^0 02' 30" N and Longitude 77^0 34' 45" E to 78^0 18' 30" E. The study area has been taken up for aquifer mapping study in AAP 2020-21.
- The total area of Dehradun district is 3088 km^2 with an average altitude of 640 m above MSL. The present study area comprises of parts of Dehradun district covering an area of 2138.00 sq. km. NAQUIM studies have been carried out in the Doiwala block (1000 sq.km), Raipur Block (393.13 sq. km), Vikasnagar block (224.26 sq. km) and Sahaspur block (520.61 sq.km). The remaining blocks have slope greater than 20% and hence have not been included in the scope of NAQUIM studies.
- The study area receives an average annual rainfall of 2051.4 mm. Most of the rainfall is received during the period from June to September; July and August being the wettest months of the year.
- The study area may be divided into four geomorphological units namely alluvium, piedmont fan deposits, structural and denudational hills and residual hills.
- Dehradun is one of the largest intermontane valleys between the Mussoorie Ranges of the Lesser Himalaya to the north and the Siwalik Ranges to the south. The study area is bounded by major faults from all sides; the Main Boundary Thrust (MBT) to its north, the Himalayan Frontal Thrust (HFT) to its south, the Yamuna Tear Fault (YTF) to the west, and the Ganga Tear Fault (GTF) to the east, making it a structurally isolated block.
- Alluvial fans, hillocks, river terraces, and floodplains are the major geomorphic units in this region, and the valley fills have been described as 'Dun gravels'.
- Geologically whole Doon valley can be divided into three regions of Lesser Himalaya, the Siwalik group and the Doon Gravels.
- Canals and tube wells are main means for the irrigation in the study area. The area, irrigated by Canal is 13181 ha which contributes to 54 % of the total irrigated area. Ground water contributes to 10 % of total irrigated area.
- The two rivers Ganga and the Yamuna form the major drainage of the NAQUIM area and are effluent in nature.
- The general flow direction of groundwater is NW- SE in the eastern part of the study area and NE- SW in the western part of the study area.

- The Central Ground Water Board, Dehradun constructed four gabion structures on MedawalaKhala in Thano Forest Range. It is observed that the Doon Gravels are highly receptive to the artificially recharged water.
- There are 44 Number of NHS monitoring stations in the study area, which are being regularly monitored for ground water level and quality.
- To attempt the hydrogeological interpretation of aquifer disposition and its nature within the study area, the data from 12 Nos. of CGWB Exploratory Wells have been analyzed in detail.
- Doon Gravels are highly porous and they have a significant permeability and act as good groundwater reservoirs. Groundwater occurs under unconfined and semi-confined conditions. The saturated granular zones occur in a depth range between 35.50 and 138.68 m bgl. The shallow aquifers occur under unconfined conditions, while deeper aquifers occur under semi-confined to confined state of disposition. The confining layers are impermeable clay beds.
- To know the water level and its behavior with respect to time and space, 44 NHS monitoring wells comprising of Piezometers, dug wells and Handpumps were analyzed. 97% wells show rise in depth to water level during post-monsoon. The seasonal fluctuation (rise) in the district varies from 0.035 to 6.93 metres. Long term water level trends from the existing 29 nos. of hydrograph stations were statistically analyzed (2010-19). It is observed that the long-term water level trends during pre and post-monsoon seasons are rising.
- Rising trend of water level suggests that surface water irrigation not only compensates the withdrawal but puts additional recharge through return flow in the system and through direct seepage from running canal.
- For estimation of the quality of ground water, ground water samples from the 44 locations of NHS monitoring stations have been collected during pre-monsoon 2020. The ground water samples were analysed for major chemical constituents at Chemical Laboratory, CGWB, NR, Lucknow.
- The general chemical quality reveals that most of the wells contain low dissolved mineral contents and hence, groundwater in Dehradun district is fresh and potable.
- All the blocks of Dehradun District fall under the Safe Category with an average of 21.77% Stage of GW Extraction for the entire district.
- Based upon the climatic conditions, topography, hydro-geology of the area, suitable structure for rain water harvesting and artificial recharge to ground water need to be planned and implemented.
- Farm ponds, chalkhal, efficient irrigation practices like drip irrigation and sprinklers can help in water conservation.

- Dehradun district is growing day by day as an Industrial City having clusters of Industries. Each industry is having very large roof area. Therefore, industries may be directed to harvest the roof top rain water by constructing recharge structures in their premises as the area receives plenty of rainfall.

कार्यकारी सारांश

- जलभृत मानचित्रण के अंतर्गत चयनित अध्ययन क्षेत्र 'देहरादून', उत्तराखंड राज्य के उत्तर पश्चिमी भाग में 29°58' अक्षांश से 31°2'30" अक्षांश तक तथा 77°34'45" देशांतर से 78°18'30" देशांतर तक विस्तारित है।
- देहरादून जिला औसत समुद्र ताल से मीटर की ऊंचाई पर अहइ तथा इसका कुल 640 मी का क्षेत्र जलभृत मानचित्रण के.वर्ग कि 2138 है जिसमे से .मी.वर्ग कि 3088 शेत्रफत अध्ययन के लिए चुना गया है, क्योंकि बाकी बचे हे क्षेत्रफल में ढलान 20% से अधिक है।
- अध्यनन क्षेत्र में औसत वार्षिक वर्षा 2051. मि मी होती है अधिकांश वर्षा जून से 4 सितम्बर माह कि अवधि के दौरान होती है तथा जुलाई एवं अगस्त में सबसे नममाह होते है
- अध्यनन क्षेत्र को चार भूआकृति विज्ञान इकाईयों में विभाजित किया जा सकता है ।
- अध्ययन क्षेत्र को चार भू आकृति विज्ञान इकाइयों में विभाजित किया जा सकता है अर्थात्- जलोढ़, पीडमोंट प्रशंसक जमा , संरचनात्मक और अनाच्छादितपहाड़ियाँ और अवशिष्ट पहाड़ियाँ।
- नहरें और ट्यूबवेल अध्ययन क्षेत्र में सिंचाई के लिए मुख्य साधन हैं नहर द्वारा सिंचित . क्षेत्र13181 हेक्टेयर है जो कुल सिंचित क्षेत्र का 54% है सिंचित क्षेत्र .में भूजल का योगदान 10%है।
- दो नदियाँ गंगा और यमुना जलभृत मानचित्रणक्षेत्र की प्रमुख जल निकासी बनाती हैं और प्रकृति में प्रवाह के रूप में कार्य करती हैं।
- भूजल का सामान्य प्रवाह दिशा अध्ययन क्षेत्र के पूर्वी भाग में NW- SE और अध्ययन क्षेत्र के पश्चिमी भाग में NE- SW है।
- सेंट्रल ग्राउंड वाटर बोर्ड , देहरादून ने थानो वन रेंज में मेदावला खाला पर चार गैबियन संरचनाओं का निर्माण किया। यह देखा गया है कि दून बजरीकृत्रिम रूप से पुनर्भरण किए गए पानी के लिए अत्यधिक ग्रहणशील हैं।
- अध्ययन क्षेत्र में एनएचएस निगरानी स्टेशनों की संख्या 44 है, जिनसे नियमित रूप से भूजल स्तर और गुणवत्ता के लिए निगरानी की जा रही है।
- देहरादून उत्तर में लघु हिमालय के मुसोरी पर्वतमाला और दक्षिण में शिवालिक पर्वतमाला के बीच सबसे बड़ी अंतर पर्वतीय घाटियों में से एक है अध्ययन क्षेत्र चारो ओर से प्रमुख भ्रंशों से घिरा हैइसके उत्तर में मेन बाउंड्री थ्रस्ट)MBT),इसके दक्षिण में हिमालयन फ्रंटल थ्रस्ट)HFT), पश्चिम में यमुना टियर भ्रंश)YTF) एवं पूर्व में गंगा टियर भ्रंश)GTF)है ।
- जलोढ़ प्रशंसक, पहाड़ी, नदी की छतें, और बाढ़ के मैदान इस क्षेत्र की प्रमुख भू आकृतिक-इकाइयाँ हैं, और घाटी की भराव को के रूप में वर्णित किया गया है। ' डन बजरी '
- भूवैज्ञानिक रूप से पूरी दून घाटी को तीनों क्षेत्रों , लघु हिमालय, शिवालिक हिमालय समूह और दून बजरी में विभाजित किया जा सकता है।

- अध्ययन क्षेत्र के भीतर जलभृत का स्वभाव और इसकी प्रकृति की हाइड्रोजोलोजिकल व्याख्या का प्रयास करने के लिए , CGWB के द्वारा खोजपूर्ण कुओं का अध्यनन 12किया गया।
- दून ग्रेवेल्स अत्यधिक छिद्रपूर्ण एवं परागमय हैं और अच्छे यह अच्छे भूजल भंडार के के रूप में कार्य करते हैं।संतृप्त ग्रैनुलर क्षेत्र 35.50 और 138.68 मीटर बीजीएल के बीच एक गहराई सीमा में होते हैं उथले जलभृतअपुष्ट परिस्थितियों में होते हैं ., जबकि गहरे जलभृत अर्ध सीमित स्थिति में सीमित स्थिति में होते हैं।-
- समय और स्थान के संबंध में जल स्तर और उसके व्यवहार को जानने के लिए , जिसमें पीजोमीटर, कुएं एवं हैंडपंप शामिल है,44 NHS निगरानी कुओं का विश्लेषण किया गया। 97% कुओं में मानसून के बाद के जल स्तर को दिखाते हैं (वृद्धि) चढ़ाव-जिले में मौसमी उतार . 0.035 से 6.93 मीटर के बीच होता है मौजूदा .29 के द्वारा दीर्घकालिक जल स्तर का सांख्यिकीय विश्लेषण किया गया था)2010-19) यह देखा गया है कि पूर्व और बाद के मौसम के दौरान दीर्घकालिक जल स्तर के रुझान बढ़ रहे हैं।
- जल स्तर की बढ़ती प्रवृत्ति बताती है कि सतह के पानी की सिंचाई न केवल निकासी की भरपाई करती है , बल्कि सिस्टम में वापसी प्रवाह के माध्यम से और नहरों से रिस करअतिरिक्त पुनर्भरणभीकरती है।
- भूजल की गुणवत्ता के आकलन के लिए , एनएचएस निगरानी स्टेशनों के 44 स्थानों से भूजल के नमूने पूर्व मानसून-2020 के दौरान एकत्र किए गए। रासायनिक प्रयोगशाला , CGWB, NR, लखनऊ में प्रमुख रासायनिक घटकों के लिए भूजल नमूनों का विश्लेषण किया गया।
- सामान्य रासायनिक गुणवत्ता से पता चलता है किदेहरादून जिले में भूजल ताजा और पीने योग्य है।
- देहरादून जिले के सभी ब्लॉक एवं पूरे ज़िले में औसतन 21.77% भूजल निष्कर्षण का चरण है।
- जलवायु परिस्थितियों, स्थलाकृति, क्षेत्र के जल भूविज्ञान के आधार पर-, वर्षा जल संचयन के लिए उपयुक्त संरचना और भूजल के लिए कृत्रिम पुनर्भरण की योजना और कार्यान्वयन की आवश्यकता है।
- तालाब, चलखाल-, ड्रिप सिंचाई एवं स्प्रिंकलर जैसी कुशल सिंचाई पद्धतियां जल संरक्षण में मददगार साबित होती है।
- देहरादून जिला उद्योगों के समूह वाले एक औद्योगिक शहर के रूप में दिन प्रतिदिन- विकास कि ओर अग्रसर है।प्रत्येक उद्योगमें बहुत बड़ा छत क्षेत्र है इसलिए ., उद्योगों को अपने परिसर में रिचार्ज संरचनाओं का निर्माण करके छत के शीर्ष वर्षा जल का संरक्षण करने के लिए निर्देशित किया जा सकता है क्योंकि इस क्षेत्र में बहुत अधिक मात्रा में वर्षा होती है।

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES, DEHRADUN DISTRICT, UTTARAKHAND

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CHAPTER 1

INTRODUCTION

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES, DEHRADUN DISTRICT, UTTARAKHAND

1 INTRODUCTION

In XII FiveYear Plan, National Aquifer Mapping (NAQUIM) had been taken up by CGWB to carry out a detailed hydrogeological investigation on toposheet scale of 1:50,000. The NAQUIM has been prioritized to study Over-exploited, Critical and Semi-Critical Blocks as well as the quality problematic area. Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers.

The vagaries of rainfall, inherent heterogeneity & unsustainable nature of aquifers, over exploitation of once copious alluvial aquifers and lack of regulation mechanism has a detrimental effect on the ground water scenario of the Country in last decade or so. Thus, prompting the paradigm shift from the "**traditionalgroundwater developmentconcept**" to the "**moderngroundwater management concept**".

Varied and diverse hydrogeological settings demand precise and comprehensive mapping of aquifers down to the optimum possible depth at appropriate scale to arrive at the robust and implementable ground water management plans. The proposed management plans will provide the **"Road Map"** for ensuring sustainable management and equitable distribution of ground water resources, thereby primarily improving drinking water security and irrigation coverage. Thus, the crux of NAQUIM is not merely mapping, but reaching the goal-that of ground water management through community participation. The aquifer maps and management plans has been shared with the Administration of Dehradun district, Uttarakhandfor its effective implementation.

1.1 Objective and Scope

Aquifer mapping itself is an improved form of groundwater management – recharge, conservation, harvesting and protocols of managing groundwater. These protocols will be the real derivatives of the aquifer mapping exercise and will find a place in the output i.e., the aquifer map and management plan. The activities under NAQUIM are aimed at:

- identifying the aquifer geometry,
- aquifer characteristics and their yield potential
- quality of water occurring at various depths,
- aquifer wise assessment of ground water resources

- preparation of aquifer maps and
- Formulate ground water management plan.

This clear demarcation of aquifers and their potential will help the agencies involved in water supply in ascertaining, how much volume of water is under their control. The robust and implementable ground water management plan will provide a **"Road Map"** to systematically manage the ground water resources for equitable distribution across the spectrum.

1.2 Approach and Methodology

The ongoing activities of NAQUIM include toposheet wise micro-level hydrogeological data acquisition supported by geophysical and hydro-chemical investigations supplemented with ground water exploration down to the depths of 300 meters.

Considering the objectives of the NAQUIM, the data on various components was segregated, collected and brought on GIS platform by geo-referencing the available information for its utilisation for preparation of various thematic maps. The approach and methodology followed for Aquifer mapping is as given below:

Compilation of existing data (Central & State

↓

Generation of different thematic layers

↓

Identification of Primary Aquifer

↓

Identification of data gaps

↓

Data generation (water level, exploration,
geophysical, hydrochemical, hydrogeological

↓

Robust Aquifer Maps with 3D

↓

Preparation of Aquifer Management

1.3 Study area

District Dehradun is situated in NW corner of Uttarakhand state and extends from N Latitude 29^0 58' to 31^0 02' 30" and E Longitude 77^0 34' 45" to 78^0 18' 30".**(Fig: 1.1)** It falls in Survey of India Degree sheet Nos. 53E, F, G, J and K. The district is bounded by Uttarkashi district on the north, Tehri Garhwal and Pauri Garhwal districts on the east and Saharanpur district (UP) on the south. Its western boundary adjoins Sirmour district of Himachal Pradesh separated by Rivers Tons and Yamuna.

The total area of Dehradun district is 3088 km^2 with an average altitude of 640 m above MSL. The district comprises of six tehsils, namely Dehradun, Chakrata, Vikasnagar, Kalsi, Tiuni and Rishikesh. Further, it is divided into six developmental blocks, viz: Chakrata, Kalsi, Vikasnagar, Sahaspur, Raipur and Doiwala. There are seventeen towns and 764 villages in this district. The administrative map of the district is shown in **Fig. 1.2.**

The present study area comprises of parts of Dehradun district covering an area of 2138.00 sq. km. NAQUIM studies have been carried out in the Doiwala block (1000 sq.km), Raipur Block (393.13 sq. km), Vikasnagar block (224.26 sq. km) and Sahaspur block (520.61 sq.km). The remaining blocks have slope greater than 20% and hence have not been included in the scope of NAQUIM studies.

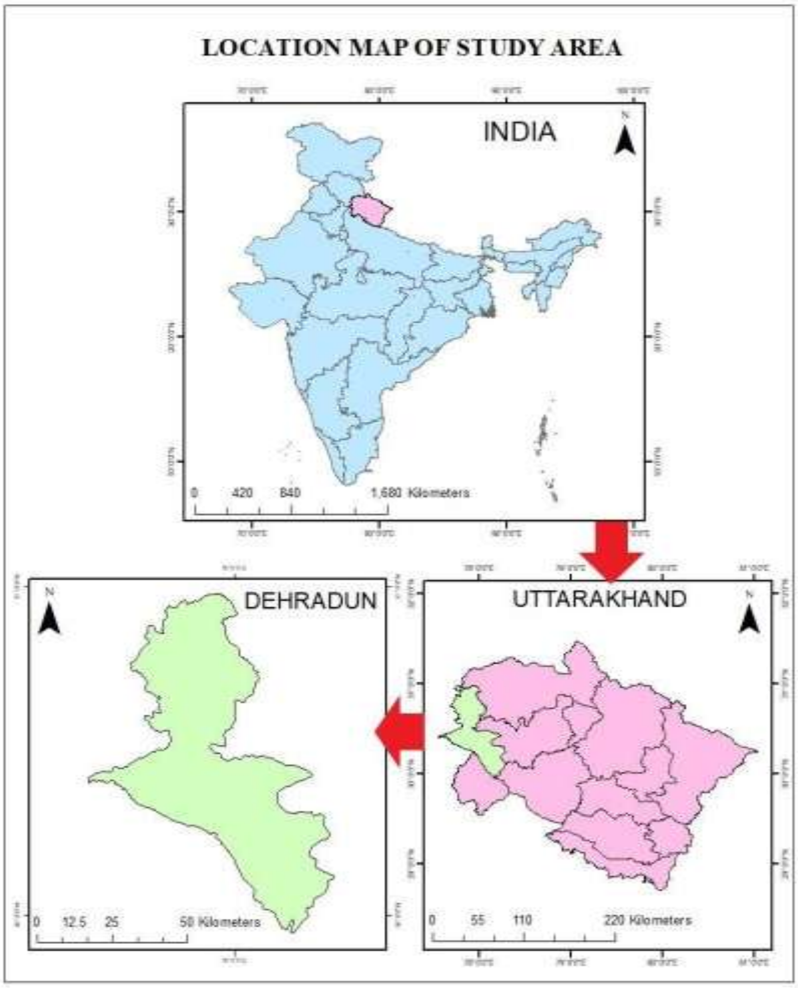


Fig 1.1: Location Map of Dehradun District, Uttarakhand

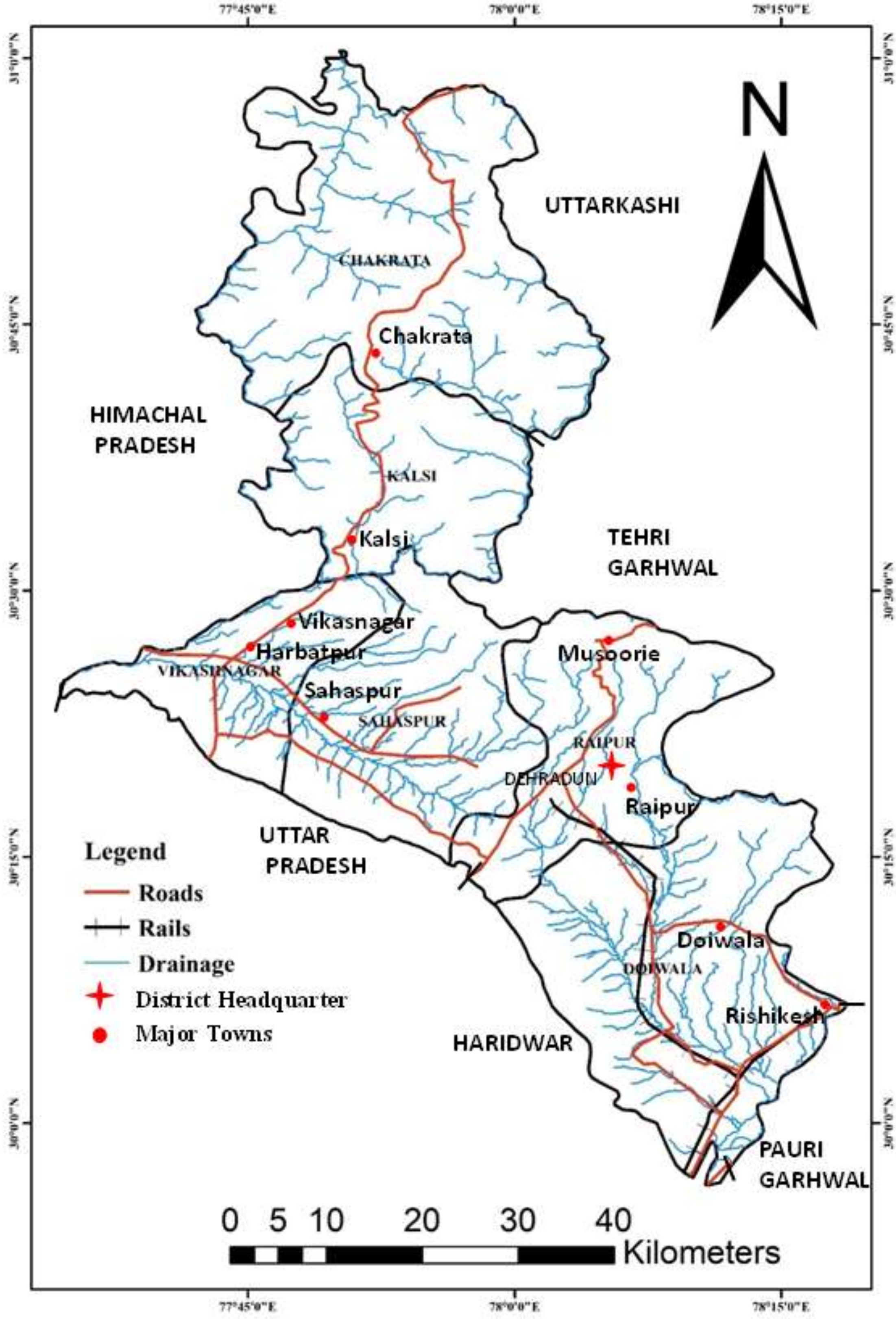


Figure 1.2 Administrative Map of Dehradun District, Uttarakhand

1.4 Rainfall and Climate

The district has within its limits lofty peaks of the Outer Himalayas as well as the Dun Valley with climatic conditions nearly similar to those in the plains. The temperature depends on the elevation. The climate of the district, in general, is temperate. In the hilly regions, the summer is pleasant but, in the Doon Valley, the heat is often intense. The temperature drops below freezing point not only at high altitudes but also even at places like Dehradun during the winters, when the higher peaks are under snow.

The summer starts by March and lasts up to mid of June when the monsoon sets in. Generally, the month of May and early part of June is hottest with mean temperatures shooting upto 36.2^0c at Dehradun and 24.8^0C at Mussoorie. The maximum temperature rises to over 42^0C at Dehradun while at Mussoorie it doesn't exceed 32^0C. Winter starts from November and continue upto February. The highest maximum temperature recorded at Dehradun was 43.9^0C on June 4, 1902 and that at Mussoorie was 34.4^0C, on May 24^{th} 1949. The mean daily maximum temperature during winter is 19.1^0C at Dehradun and 10.2^0C at Mussoorie. The mean daily minimum temperature in January is 6.1^0C at Dehradun and 2.5^0C at Mussoorie. In Mussoorie the temperature drops to about -6^0C to -7^0C when snow fall occurs. The lowest minimum temperature at Dehradun during winter was - 1.1^0C, on February 1^{st}, 1905 and January 1945 while at Mussoorie it was -6.7^0C, on February 10^{th}, 1950. Monsoon starts by the mid of June and lasts upto September.

The study area receives an average annual rainfall of 2051.4 mm. Most of the rainfall is received during the period from June to September, July and August being the wettest months. The region around Raipur gets the maximum rainfall, while the southern part receives the least rainfall in the study area. About 87% of the annual rainfall is received during the period June to September. The climatic data of Doon Valley is summarized in **Table 1.1.**

Table 1.1Climate data of the study area

Month	Normal Rainfall(mm)	Relative Humidity %	Temperature (^{0}C)		
			Maximum	Minimum	Average
January	46.9	91	19.3	3.6	10.9
February	54.9	83	22.4	5.6	13.3
March	52.4	69	26.2	91.	17.5
April	21.2	53	32	13.3	22.7
May	54.2	49	35.3	16.8	25.4
June	230.2	65	34.4	29.4	27.1
July	630.7	86	30.5	22.6	25.1
August	627.4	89	29.7	22.3	25.3
September	261.4	83	29.8	19.7	24.2
October	32.0	74	28.5	13.3	20.5
November	10.9	82	24.8	7.6	15.7
December	2.8	89	21.9	4.0	12.0
Annual	**2051.4**	**76**	**27.8**	**13.3**	**20.0**
	Normal	**Average**			

1.5 Physiography and Geomorphology

1.5.1 Geomorphic Divisions

The study area may be divided into four geomorphological units namely alluvium, piedmont fan deposits, structural and denudational hills and residual hills. [Source:http://cgwb.gov.in/District_Profile/Uttarakhand/Dehradun.pdf].

- **Alluvium:** This unit is represented by unconsolidated and loose admixture of sand, gravel, pebbles, silt and clay of varied grades deposited in the form of terraces along Asan, Song, Tons, Yamuna, Ganges etc. and in the intermontane valley as well. These are represented by unconsolidated material like sand, gravel, silt and clay. The terraces are formed by river cuttings followed by deposition of eroded and transported material in step like features along the river.
- **Piedmont Fan Deposits:** The area comprising of Dun gravels formed of numerous coalesced fans constitute this unit. The older Dun gravels belong to the upper realm of principal Doon fans whereas the younger and youngest duns belong to lower realm of principal Doon fans and dip controlled pedimont fans respectively.

- **Denudational and Structural Hills:** The denudational and structural hills comprise Siwalik and Lesser Himalayan Ranges. The Siwaliks are exposed as a narrow band all along the southern boundary of Doon Valley and also in isolated patches. These hills have undergone severe denudation, weathering and erosion, making steep to moderate slopes.
- **Residual Hills:** The residual hills are mostly formed by erosion and are the remnants of post Upper Siwalik deposits. These are called Older Doon Gravels or Langha Boulder Beds. Boulder beds, shales and red clay represent this unit. The residual hills are present in Doiwala and Vikas Nagar blocks.

1.6 Soil

Soil Types

The nature and soil type play an important role in agriculture and have direct relation with groundwater recharge. Physiography, climate, drainage and geology of the study area are the factors responsible for the nature and type of soil and soil cover. The soil type also depends upon the slope and rate of erosion. The soil types of the study areaare given in Table 1.2.

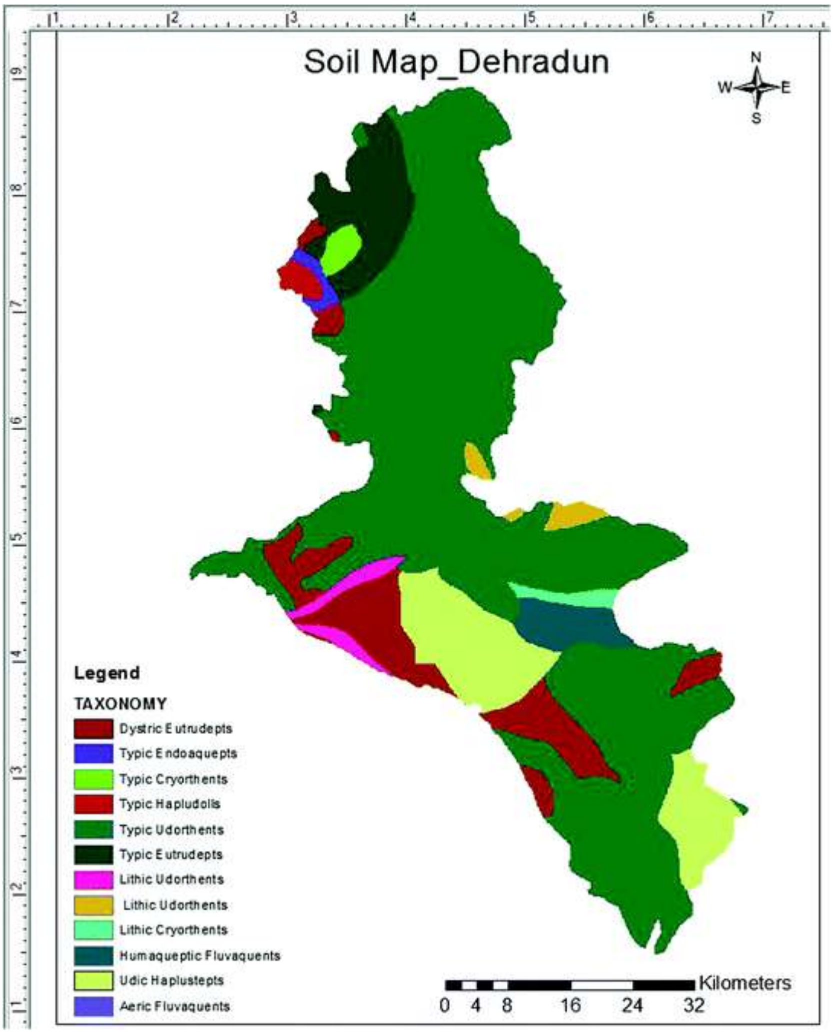


Fig 1.3: Soil Types present in the Study Area

Table 1.2Soil Types ofStudy Area

Physiography	Characteristics	Taxonomic Classification
Mountains	Moderately deep, well-drained, thermic coarse loamy soils on steep slopes, strong, stoniness, associated with shallow excessively drained, loamy skeletal soil.	Loamy skeletal, Dystric Eutrochrepts, Fine loamy lithic and typic Hapludolls- Loamy skeletal typic Udrothants
Soils on Upper piedmont plains	Deep, well-drained, coarse loamy cover, fragmental soils on heavy gentle slope with loamy surface and slight erosion.	Udifluventic Ustochrepts
	Associated with excessively drained soils with loamy surface and slight to moderate erosion	Typic Ustipsamments
	Deep, well- drained, fine to coarse loamy surface and slight to moderate erosion	Udic Ustorchrepts
Soil on Lower piedmont plains	Deep, well- drained, coarse loamy cover over fragmental soils on nearly level plains with loamy surface.	Udifluventic Ustochrepts
	Associated with deep, well drained, fine loamy soil with loamy surface.	Udic Ustochrepts
	Deep, well drained, fine silty soil on very gentle slopes with loamy surface and slight erosion	Udic Haplustolls
	Deep, well drained, fine to coarse loamy surface and slight to moderate erosion, silty soil with loamy surface	Udic Ustochrepts

1.7 Land Use, Agriculture, Cropping Pattern and Irrigation

Table – 1.3 Land Use Pattern(Area in Ha), Dehradun District

Year	Total Reorted Area	Barren Cult Waste	Present Fallow Land	Other Fallow Land	Barren &Uncult Land	Land put to non Agricultural Use	Pastures	Area under bush, forest & garden	Net area sown
2018-19	209694	3895	4774	11440	3659	19332	1871	4189	26321

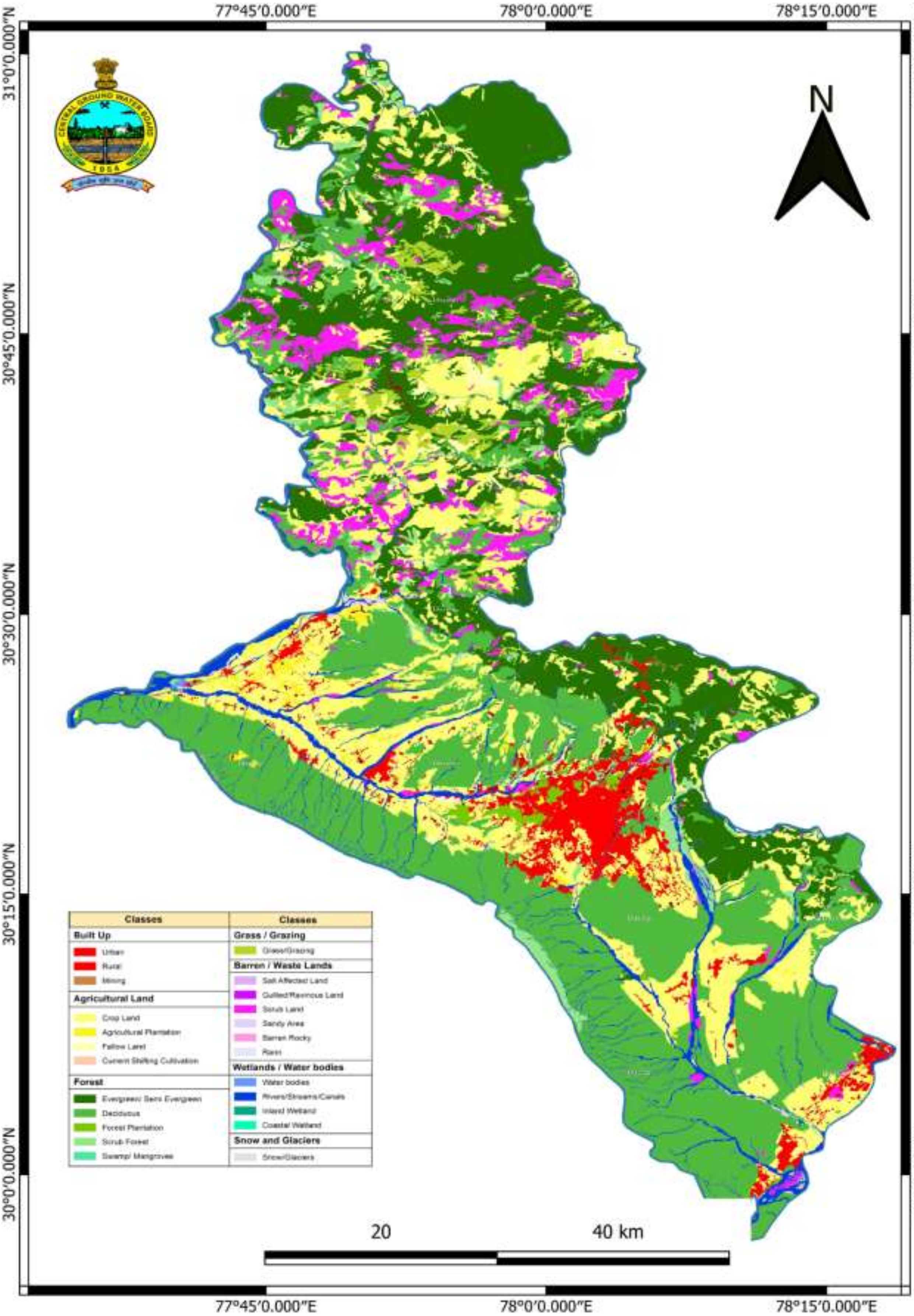


Fig. 1.4 Landuse and Land Cover Map of the Study Area

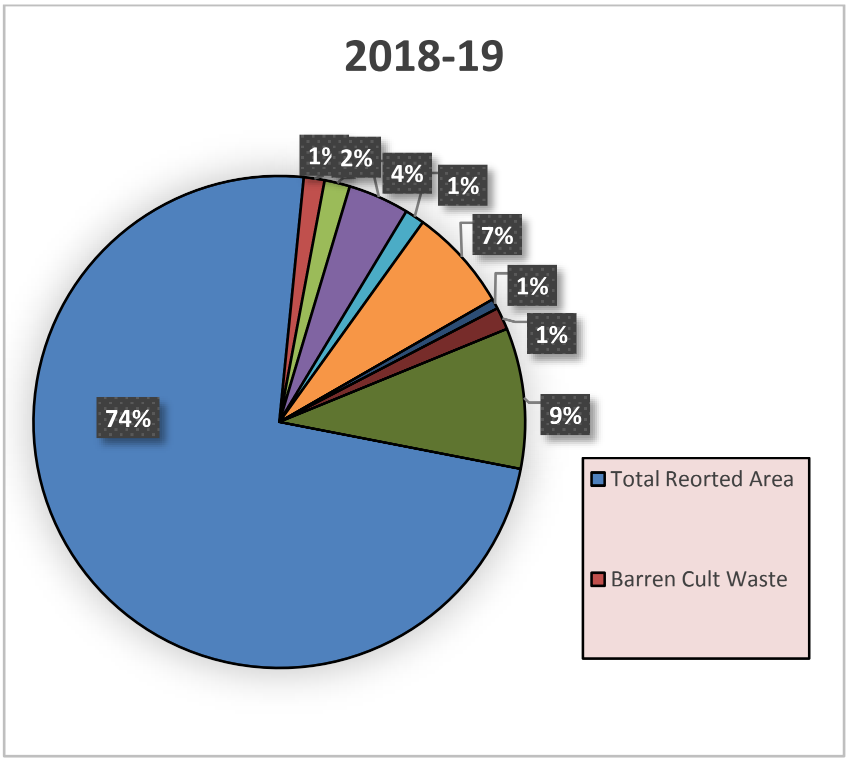


Figure 1.5- Land Use Pattern of the Study Area

Both surface and subsurface sources are being developed for irrigation purpose. The perennial rivers/ springs/ gadheras are being developed by constructing canals and guls. Canals in the study area run for a length of 786 km. There are four main canal systems namely Bijapur, Rajpur, Kalanga and Jakhan. These canal systems were developed during the British period and now being maintained by the state irrigation department. The Rajpur canal system, Jakhan canal system, Kalanga canal system, and Bijapur canal system have 7,5,7 and 10 number of canals, respectively.

Sub surface water is developed through tubewells. There are 118 functional Irrigation tubewells in the study area. Most of these tubewells are located in the Intermentane Doon Valley tapping the Doon Gravels. Besides the canals and tubewells, there are other irrigation practices like pump sets, hydrum, hauz, tanks etc. The area irrigated through different practices is given in **Table 1.4.**

Table1.4 Area irrigated through different sources/practices, District Dehradun (hectares)

Block	Reported Area	Canals	Tubewells		Dug wells	Pond	Other sources	Total
			Govt.	Private				
Vikas Nagar	44606	4897	671	-	-	1	53	5622

Sahaspur	61693	2471	733	-	-	-	106	3310
Raipur	53396	1812	609	-	-	-	78	18869
Doiwala	59648	4001	320	-	-	-	439	4760
Total	219343	13181	2333	0	0	1	676	32561

1.7.1 Agriculture and Cropping Pattern

Cropping activities are going on throughout the year in the area. Cropping season starts since the onset of monsoon, crops grow from July to October are known as Kharif, from October to March is Rabi and Jayad crops grow between March to June. Majority of crops are grown during Kharif and Rabi crops.Rice, Bajra,Jwar are main kharif crop. Rabi is main crop season here and Wheat (7898 ha) is the most dominant crop.Whole wheat cultivation is based on irrigation. Rice is second dominant crop in the area. Bajra contributes third among cereals crop. In sugarcane growing area,mono cropping is in practice. The cropping pattern of the study area is given in the Table-1.5 and Fig: 1.6.

Masoor,Arhar, Gram, pea , moong and urad are main pulse crops,while mustard is major crop among. Vegetables are grown in 640 ha of land. Potato and onion are major vegetable crops.

Table 1.5 Cropping Pattern of Study Area

YEAR	Net area sown	Area sown more than once	Gross Area Sown	Rabi	Kharif	Jayad
2018-19	26321	11887	38444	16187	19993	2279

Table 1.5- Cont.

Year		Rice	Wheat	Barley	Jwar	Bajra	Maize	Pulses	Oil-seeds	Sugar cane
2016-17	Gross Irrigated	6958	11866	128	0	0	4776	2471	372	3810

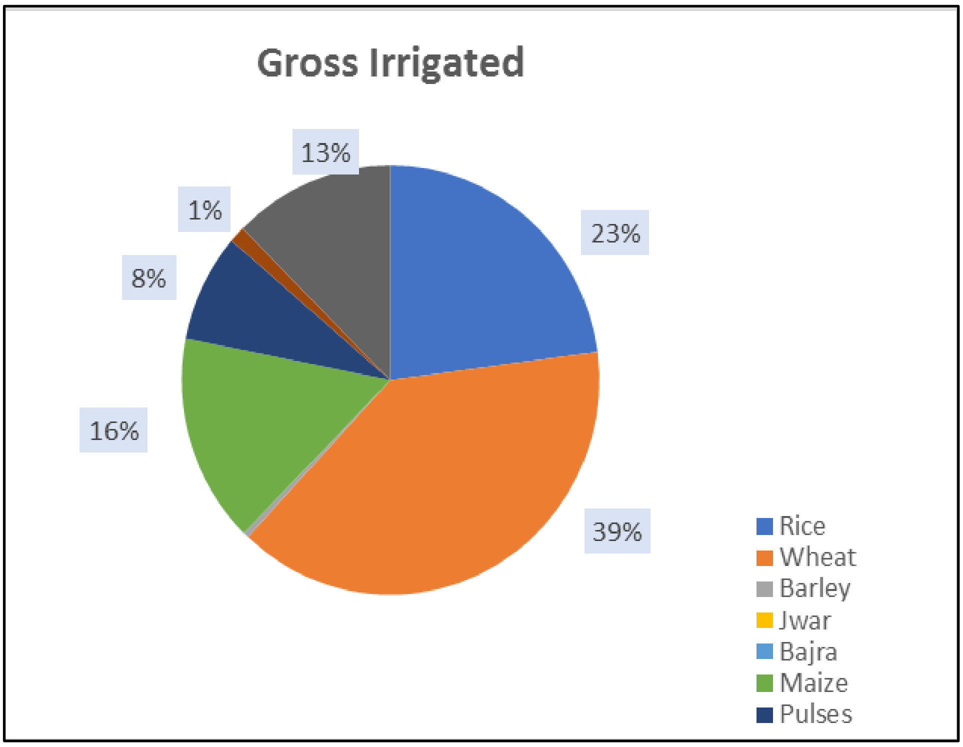


Figure 1.6Pie Chart Showing Cropping Pattern,Dehradun District

1.7.2Irrigation

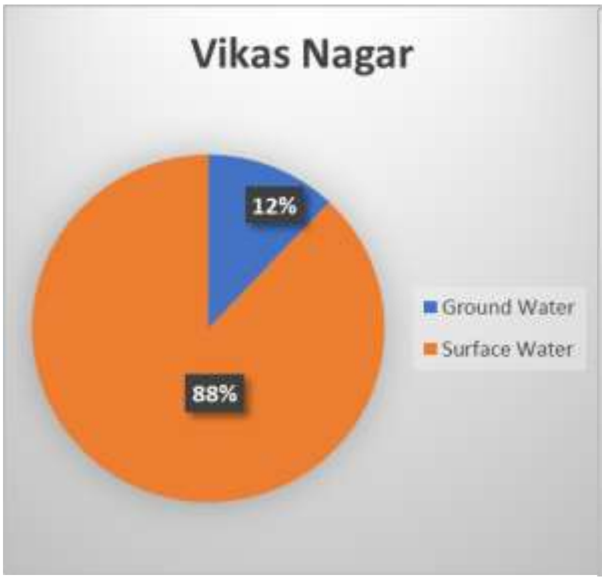
Water is essential for sustainable growth of agriculture. Irrigation facilities have been gradually developed through different Five-Year Plans, irrigation intensity becomes 64.34. Till 2016-17, 59.67% of the net sown area has been irrigated. Canals and tubewell are main means for the irrigation in the study area. Area irrigated through conventional methods like pondis decreasing with time. The area, irrigated by Canal is 13181 ha which 54% of the total irrigated area. Ground water contributing 10 % of total irrigated area. Free boring scheme sponsored by Central / State Government State encouraged exploitation of ground water for irrigation. Permanent Well, shallow, Medium and Deep Tubewell are means of irrigation through ground water. Table – 1.6 a, b show irrigated area through different sources.

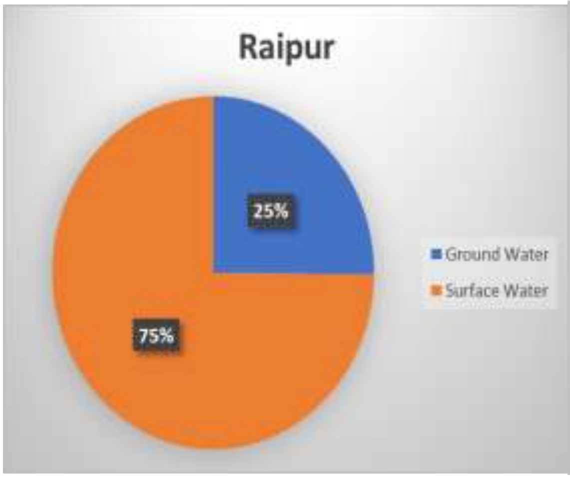
Table 1.6 a - Source Wise Irrigated Area (Ha) in Study Area

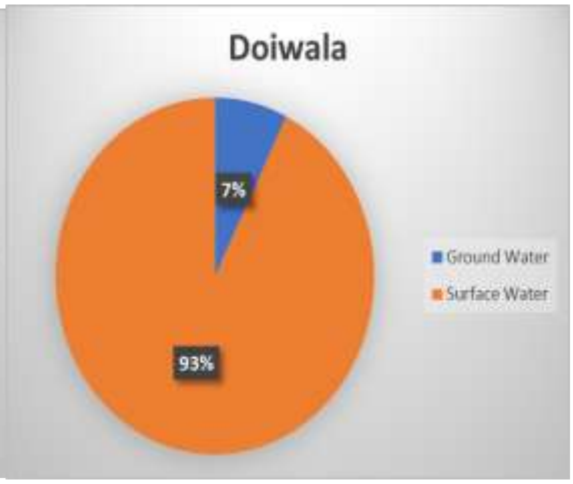
Net Area Sown	Net Irrig. Area	Percentage of Irrig. Area	Gross Irrig. Area	Irrig. Intensity (%)	Canal	Gov. TW	Priv. TW	Dug Well	Pond	Other	Total
26321	15710	59.67	24417	64.34	13181	2333	0	0	1	676	9850

Table 1.6 a - Source Wise Irrigated Area (Ha) in Study Area

Block	Reported Area	Ground Water	Surface Water	Other Sources	Total
Vikas Nagar	44606	671	4898	53	5622
Sahaspur	61693	733	2471	106	3310
Raipur	53396	609	1812	78	18869
Doiwala	59648	320	4001	439	4760
Total	219343	2333	13182	676	32561







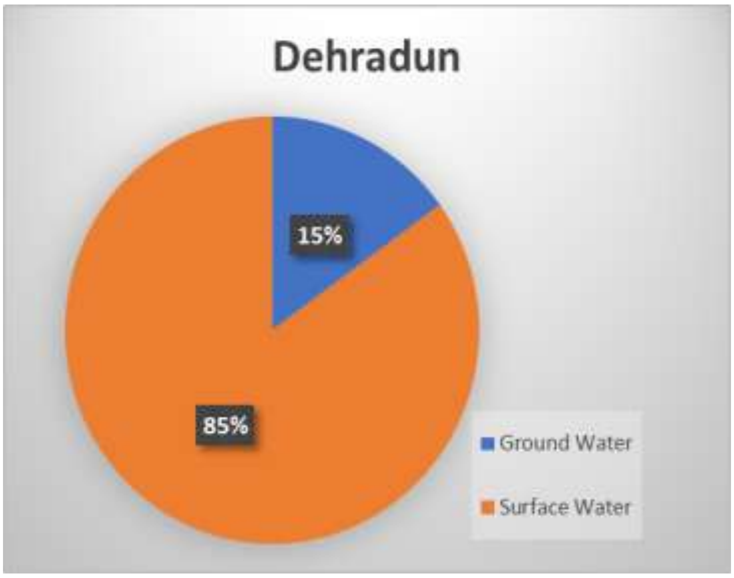


Figure 1.7 Pie Chart Showing percentage of source wise irrigated area through groundwater and surface water

Table 1.6 b -Means of Irrigationin Study Area

Canal (Km)	Govt TW	Permanent Well	Pump set
549.281	203	2	203

1.8 Prevailing Water Conservation and Recharge Practices

The groundwater development is going on at a faster rate and management practices are required for the sustainability of this resource. The Central Ground Water Board, Dehradun constructed four gabion structures on MedawalaKhala in Thano Forest Range. It is observed that the Doon Gravels are highly receptive to the artificially recharged water.

The structures suitable in high reaches and foot hill zones are gabion, check dam, gully plug and brushwood check dam. In the valley portion rain water may be harvested for the use other than drinking. Roof top rainwater harvesting and recharge well are suitable in the plain areas of the valley. Technical guidance has been provided to the state government departments for designing artificial recharge structures.

CHAPTER 2

DATA COLLECTION AND GENERATION

2DATA COLLECTION AND GENERATION

The primary data such as water levels, quality, and lithological inputs were available with CGWB, UR, Dehradun and utilised as baseline data. However, the ancillary data such as numbers of ground water abstraction structures, irrigation facilities, rainfall etc., have been collected from the various State govt. departments and compiled.

2.1 Data Collection and Compilation

The data collection and compilation for various components was carried out as given below.

i. Hydrogeological Data – Current and historical water levels along with water level trend data from 44 monitoring wells in Dehradun district
ii. Hydrochemical Data – Ground water quality data from the 44 NHS monitoring stations of Pre-monsoon 2020 has been collected and compiled
iii. Exploratory Drilling – Ground water exploration data of twelve existing exploratory wells was complied.
iv. Geophysical Data – 77 nos. of Vertical Electrical Soundings (VES) were conducted earlier in this area.
v. Hydrology Data – Data on various irrigation projects, their utilisation status, number of ground water abstraction structures and area irrigated from Irrigation department were compiled.
vi. Hydrometeorological Data - Long term rainfall data from IMD were complied.
vii. Cropping Pattern Data – Data on prevailing cropping pattern from Agriculture Dept. were complied.

2.2Data availability and data gap analysis

After taking into consideration, the data available with CGWB on Ground Water Exploration, Geophysical survey, Ground Water Monitoring Wells (GWMW) and Ground Water Quality, the data adequacy were compiled. The requirement, availability and gap of major data inputs i.e., exploratory wells, geophysical data, GWMW and ground water quality data are detailed in the **Table 2.1.**Based on Data Gap Analysis, all the necessary data was generated as discussed below.

Table 2.1 Data Gap Analysis in establishing Exploratory Wells & piezometerin the Study Area

Exploratory data available	Requirement of additional exploratory data	Monitoring data available	Requirement of additional monitoring data
12	6	44	25 PZs for deeper aquifer analysis

2.2.1 Ground Water Exploration

As seen from **Table-2.1**, exploratory data is required at 6 locations. However, lithology of 12 locations of the district is available with the CGWB, UR, Dehradun that has been used for the compilation of the report. (Annexure 1)

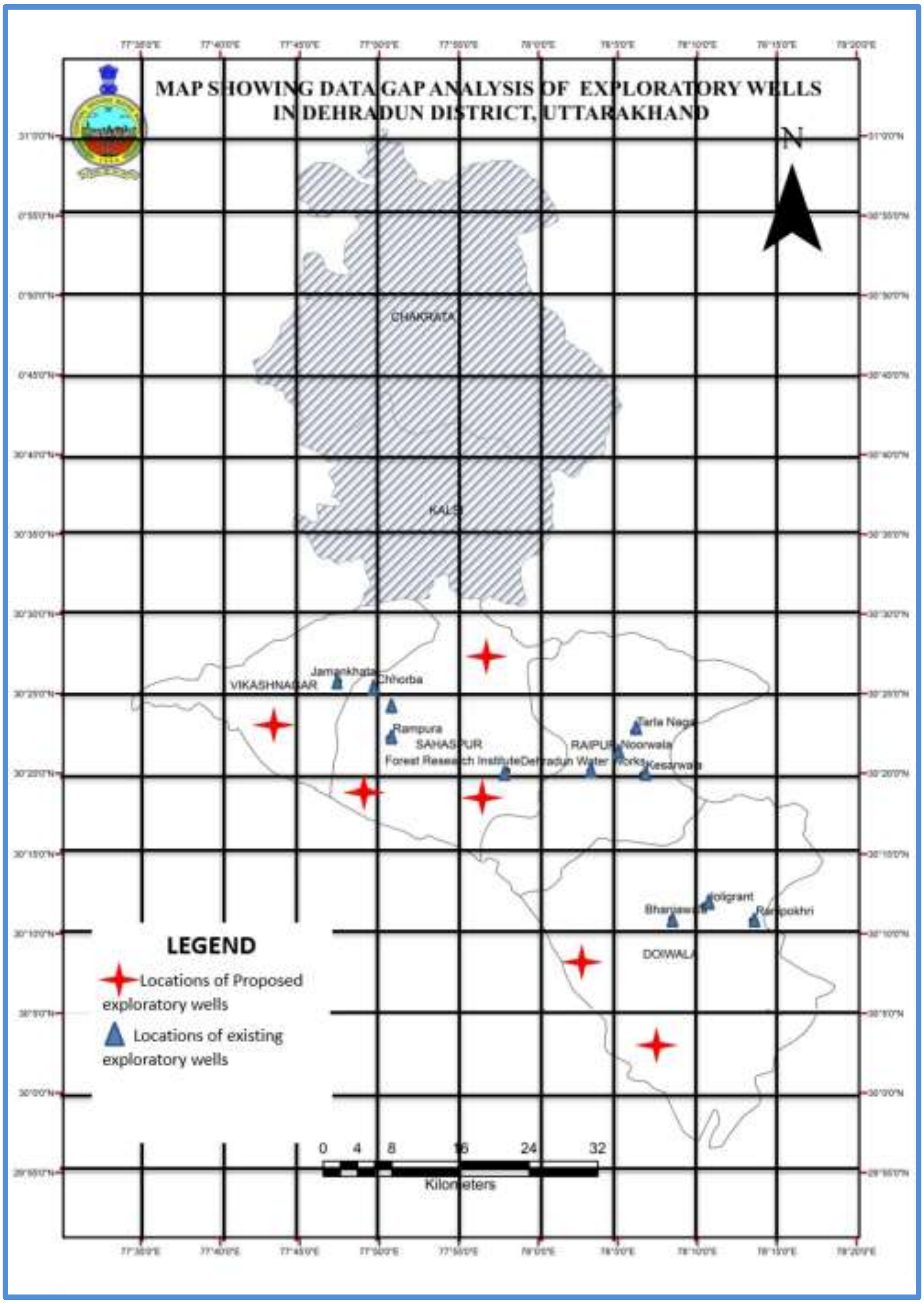


Figure2.1 : Location of Proposed and existing exploratory wells in Dehradun

2.2.2 Ground Water Monitoring Wells

As observed from **Table-2.1**, Piezometers were required at 25 locations of the study area for the analysis of deeper aquifers and the proposed sites have been illustrated in **Fig: 2.2.**

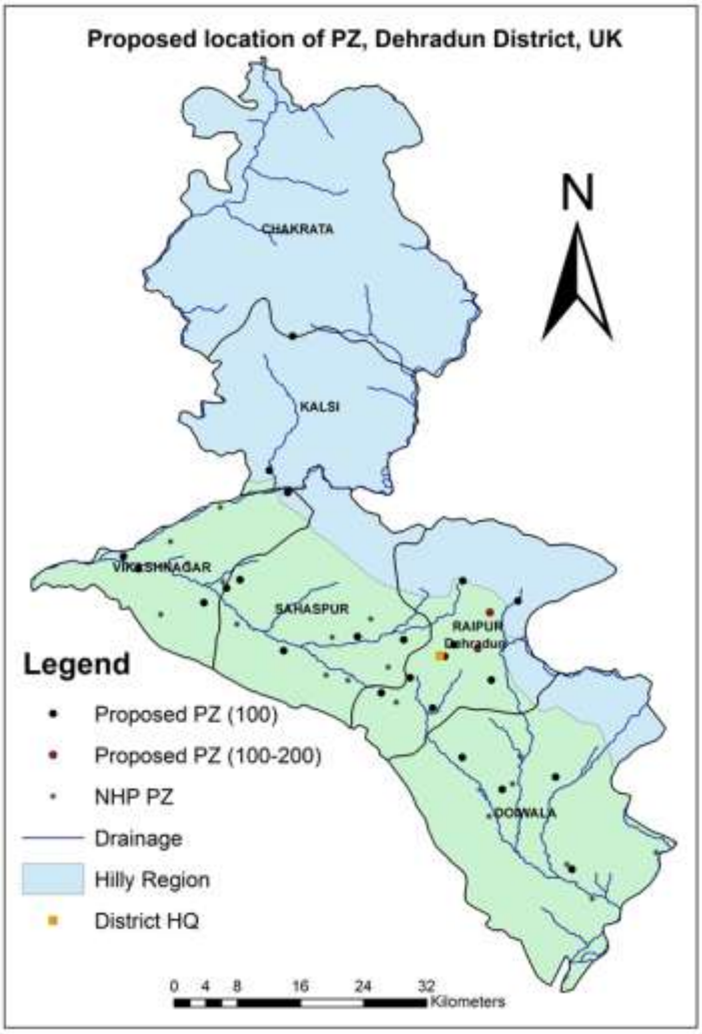


Figure2.2 : Location of Proposed PZ in Dehradun

2.2.3 Ground Water Quality

Ground Water Samples were collected from 44 NHS locations of the study area and the samples were analysed for the basic as well as heavy metals at the Chemical Laboratory of CGWB, NR, Lucknow.

CHAPTER 3

DATA INTERPRETATION, INTEGRATION & AQUIFER MAPPING

3 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

The data collected and generated on various parameters viz., water levels, water quality, exploration, aquifer parameters, geophysical, hydrology, hydrometeorology, irrigation was interpreted and integrated. Based on this the various aquifer characteristic maps on hydrogeology, current and long term water level scenario, ground water quality, 2-D and 3-D sub surface disposition of aquifers by drawing fence and lithological sections, , resource estimation, aquifer maps were generated and as discussed in details.

3.1 Geology

Dehradun is one of the largest intermontane valleys between the Mussoorie Ranges of the Lesser Himalaya to the north and the Siwalik Ranges to the south (Sinha et al., 2016). The Siwalik Ranges are mainly a group of rocks and categorized as lower (mudstone), middle

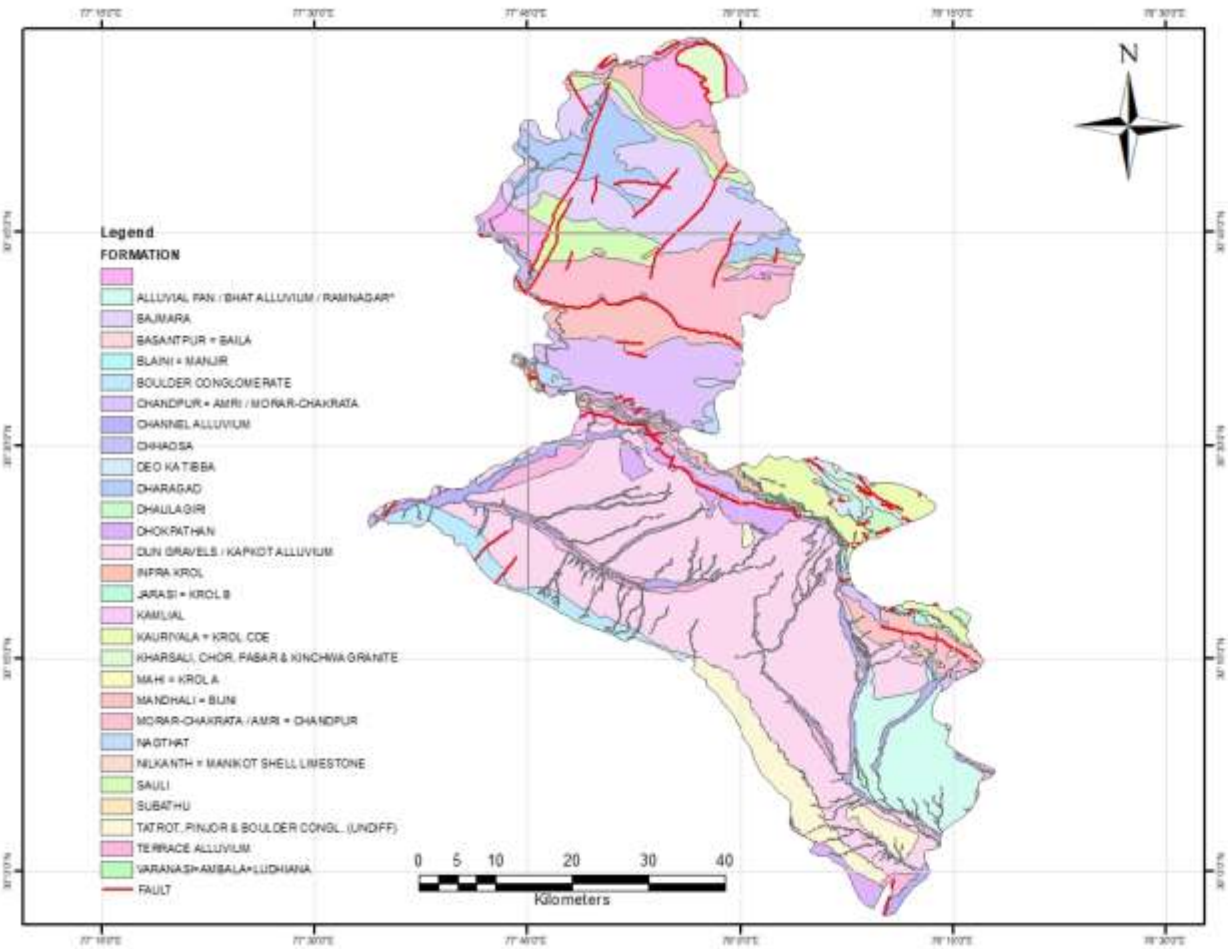


Fig 3.1 : Geological Map of the Study Area, Dehradun District (Source: Bhukosh, GSI)

(sandstone), and upper (conglomerate) units. The Dehradun is bounded by major faults from all sides; the Main Boundary Thrust (MBT) to its north, the Himalayan Frontal Thrust (HFT) to its south, the Yamuna Tear Fault (YTF) to the west, and the Ganga Tear Fault (GTF) to the east, making it a structurally isolated block. The Ganga and Yamuna rivers break through the Siwalik Ranges along the transverse faults, the GTF, and the YTF, respectively (Karunakaran and Rao, 1979; Raiverman et al., 1994) **(Fig: 3.1).** The NW-SE trending intermontane valley is ~80 km long and ~25 km wide. It is an asymmetrical valley with a gentler (0–5°) SW slope and a steeper (0–10°) NE slope. Alluvial fans, hillocks, river terraces, and floodplains are the major geomorphic units in this region, and the valley fills have been described as 'Dun gravels' (Nossin, 1971; Nakata, 1972; Singh et al., 2001; Thakur and Pandey, 2004; Thakur et al., 2007).

3.1.1 Evolution of the Doon Valley

Dehradun valley was formed as an intermontane valley between lesser Himalaya in the north and the Siwaliks in the south. The present Doon valley is developed in two phases **(Fig:3.2).** In the first phase, around 18 million years ago there was an upliftment in the Himalaya around the Main Boundary Thrust (MBT) that raised the Mussorie Range and the Lower Himalaya. It resulted in the formation of a synclinal depression known as Doon Syncline, in which the eroded sediments of the uplifted part were deposited and this continued for the long period. In the second phase, around 0.5 million years ago another tectonic event uplifted the Siwalik Range strata along the Himalayan Frontal Thrust (HFT) and the Doon valley came into existence (Thakur, 1995).

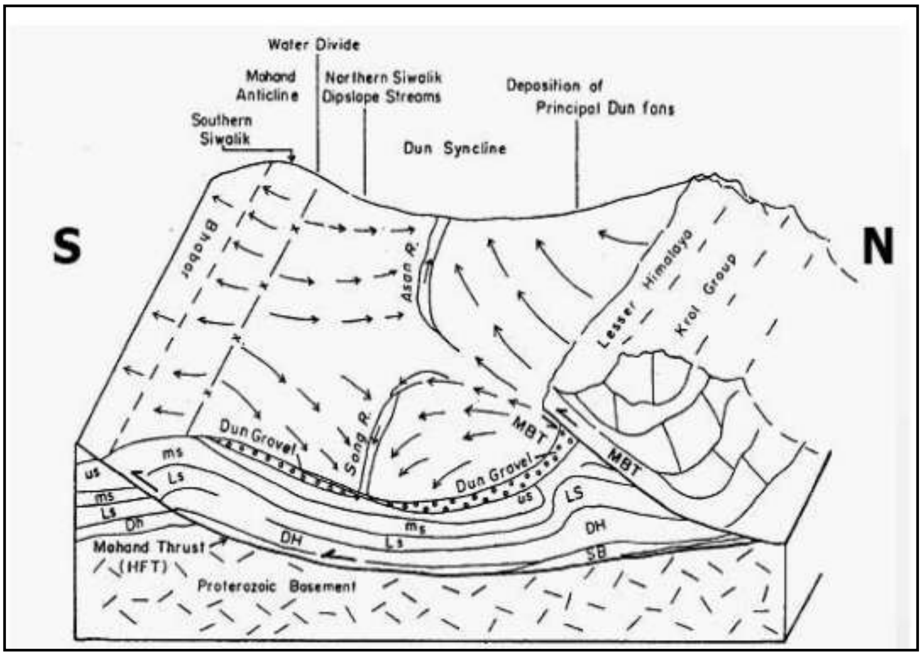


Fig 3.2: Evolution of Doon valley showing Himalayan Frontal Thrust (HFT), Main Boundary Thrust (MBT), tectonically controlled drainage (Song river, Asan river) Subathu Formation (SB),Dharamsala

Formation (DH), Lower Siwalik (LS), Middle Siwalik (MS) and Upper Siwalik (US) (After Thakur, 1995)

3.1.2 Lithostratigraphy

Doon valley is an intermontane valley located in the lap of the Siwalik Hills. The large part of the valley is occupied by a broad synclinal depression. Geologically whole Doon valley can be divided into three regions of Lesser Himalaya, the Siwalik group and the Doon Gravels and the lithostratigraphy is given in **Table: 3.1**.

Table3.1: Litho-stratigraphy of Doon valley (After Thakur,1995; and Patel and Kumar, 2003.)

Age	**Geological units/ Formations**	**Lithology**
Recent	River Alluvium	Loose unconsolidated materials of sand, silt and clay derived from Upper Siwalik and Lesser Himalaya
Sub Recent to Late Pleistocene	Young Doon Gravel	Sub rounded boulders and gravels of sandstone and quartzite derived from Siwalik and Lesser Himalaya
	Old Doon Gravel	Big angular and sub-rounded boulders of quartzite and sandstones embedded in clay
Unconformity		
Late Pliocene To Middle Miocene	Upper Siwalik	Coarse boulders, conglomerates and clay
	Middle Siwalik	Hard and soft sand stone and clay intercalation in pockets
	Lower Siwalik	Hard sandstone, interbeded with mudstone

Main Boundary Thrust		
Palaeocene to Early Eocene	Subathu Formation	Red shale and lenticular bands of sandstone
Krol Thrust		
Pre-Tertiary	Tal	Quartzites
	Krol	Dolomitic limestone, cherty red shale, sandstone, black shale.
	Blaini / Infra Krol	Boulder beds, slate, dark shale, pink dolomite, violate quartzite and shale
	Nagthat	Quartzite and slate
	Chandpur	Phyllite, slate and limestone
	Damta	Grey slate, quartzite and turbidites

3.2 Hydrogeology

The hydrogeology of the study area is mainly controlled by the geology and geomorphology. A wide variation in the geology and land forms, in the study area, gives rise to different hydrogeological conditions. Broadly Dehradun district is divided into three hydrogeological units, viz. (1) Himalayan Mountain Belt (2) Siwalik zone and (3) Doon Gravels

3.2.1 Himalayan Mountain Belt

Groundwater, in this unit, occurs as disconnected local bodies both under confined and unconfined conditions. Quartzite, schist, shale, slate, phyllite, compact sandstone, limestone and dolomite of Jaunsar, Baliana, Krol and Tal Groups are the main rock types. The rock formations are characterized by fissures, fractures, veins and joints which provide the secondary porosity. The secondary porosity and permeability help forming the local bodies of groundwater. The weathered veneers found on hill tops, ridges, spurs etc. give rise to groundwater repositories, under perched conditions. The alluvial deposits of fluvial and colluvial origin in the lower reaches of streams/ rivers in the form of fans and terraces are highly porous and permeable. The springs and seepages are the main source for hilly areas. The springs show wide variation in discharge ranging from 1400 to 1507000 liters/ day (Bartarya, 1995)

3.2.2 Siwalik Zone

Groundwater occurs under confined and unconfined conditions in this unit. The water levels are comparatively deep. In spite of the boulder- conglomerate bed of Upper Siwalik Formation being highly porous and permeable most of the water goes as run off due to steep slopes and the sediments forming piedmont fans dipping into the Intermontane valley. About 70 gravitational type springs have been reported which have a varying discharge from less than a liter per second to 113 liters/second (0.002 m^3/min). The fresh water bearing zones are present in the Upper Siwaliks due to the presence of pebble–gravel–conglomerate–boulder beds and there is a less chances of Groundwater occurrance. There is a very less or negligible chances of Ground Water occurrances in the Middle and Upper Siwaliks due to their compaction.

3.2.3 Doon Gravels

The intermontane valley portion, of district Dehradun, is underlain by alluvial fan deposits. The sediments descend from the Lesser Himalayan front as well as well as the North facing Siwalik hill slopes. These fan deposits are called as ‘Doon Gravels’ and characterized by boulders and pebbles embedded in sandy and silty matrix. The clasts are mainly composed of quartzite, sandstone and phyllite, which are mainly derived from the Krol belt of the Himalayas Pebbles from Siwalik conglomerates are also present in the Doon Gravels.

Doon Gravels are highly porous and they have a significant permeability. Groundwater occurs under unconfined and semi confined conditions. The saturated granular zones occur in a depth range between 35.50 and 138.68 m bgl. The piezometric head ranges from 20.0 to 125.0 mbgl. Transmissivity varies from 1648.0to 3500.0 m^2/day while the field permeability ranges from 5.86 to 104.0 m/day. The discharge from the tubewell varies from 600 to 3000 lpm for a tapped thickness of 30 to 50 m with a drawdown of 2 to 7 m. The hydraulic conductivity, in the district, varies from 13 to 583 m/day. The hydrogeological map of the district is given in **Fig: 3.3 .**

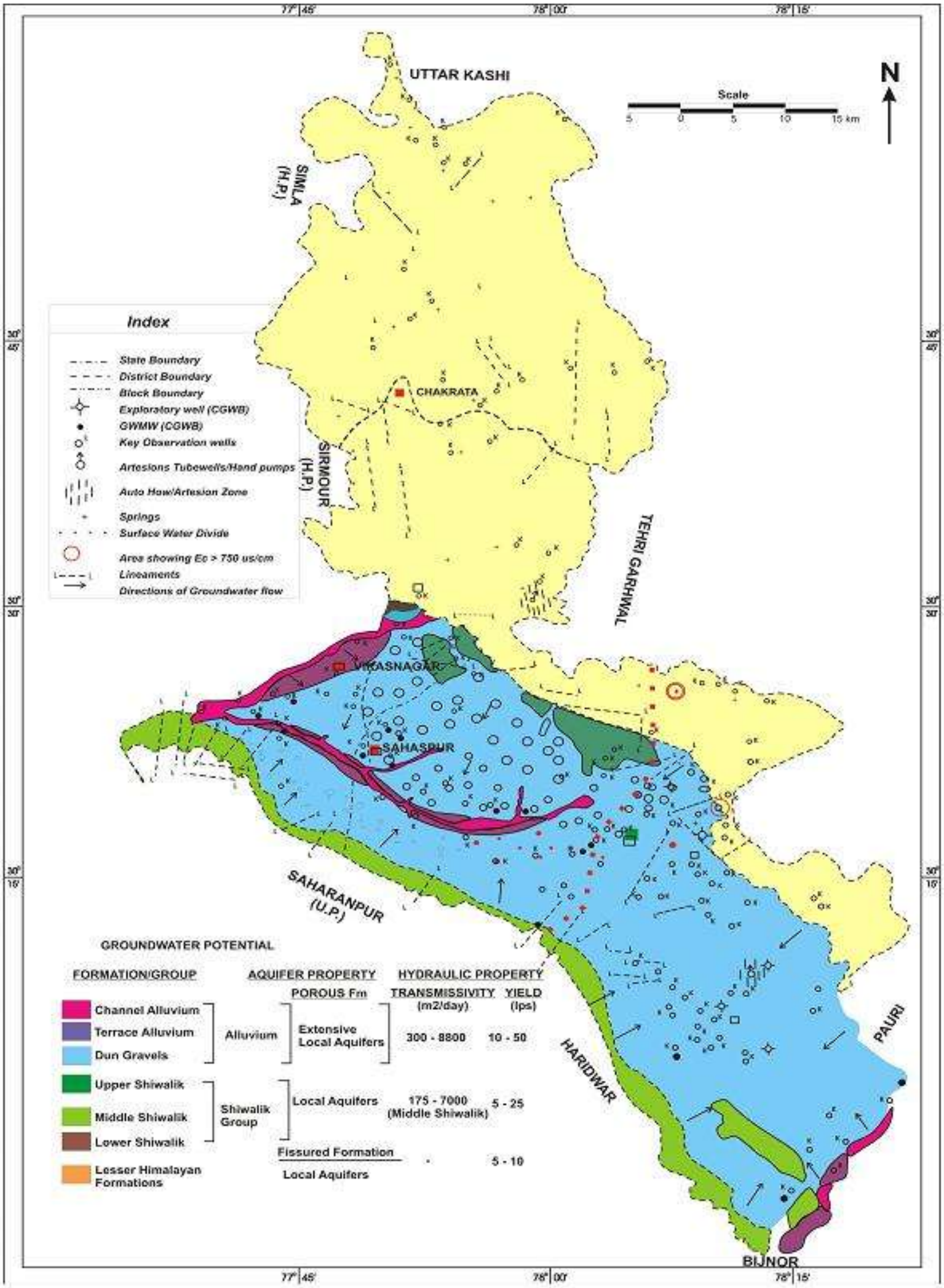


Fig 3.3: Hydrogeological Map of Dehradun District, Uttarakhand

3.3 Hydrogeological Interpretation

To attempt the hydrogeological interpretation of aquifer disposition and its nature within the study area, the data from 12 Nos. of CGWB Exploratory Wells have been analysed in detail and the litholog data has been enclosed in Annexure 1.

In order to study the subsurface disposition of the aquifer system, 2 nos. of fence diagrams (**Fig: 3.4, 3.5**), 1 no. of three dimensional Model (**Fig: 3.6, 3.7**) and four geological cross sections (**Fig: 3.8a, b; 3.9a,b; 3.10a,b and 3.11a,b**) have been constructed from the data of CGWB Exploratory Wells keeping in mind the detailed lithological variations and overall Stratigraphy encountered in the study area.. Locations of these wells are shown in the Index Map (**Plate-1**).

Fig:

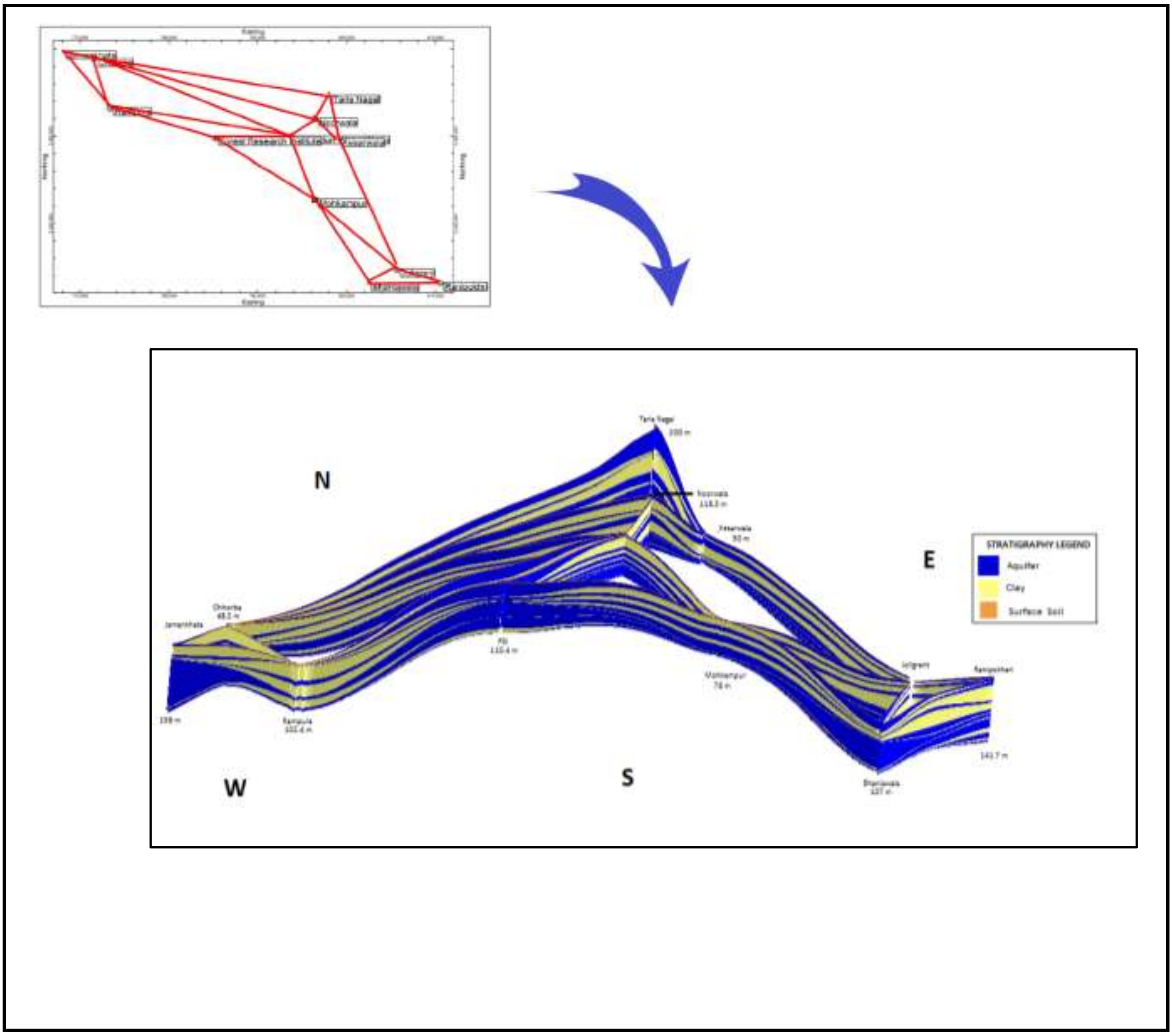


Fig 3.4 : Fence diagram Depicting Sub-surface Aquifer disposition of the Study area

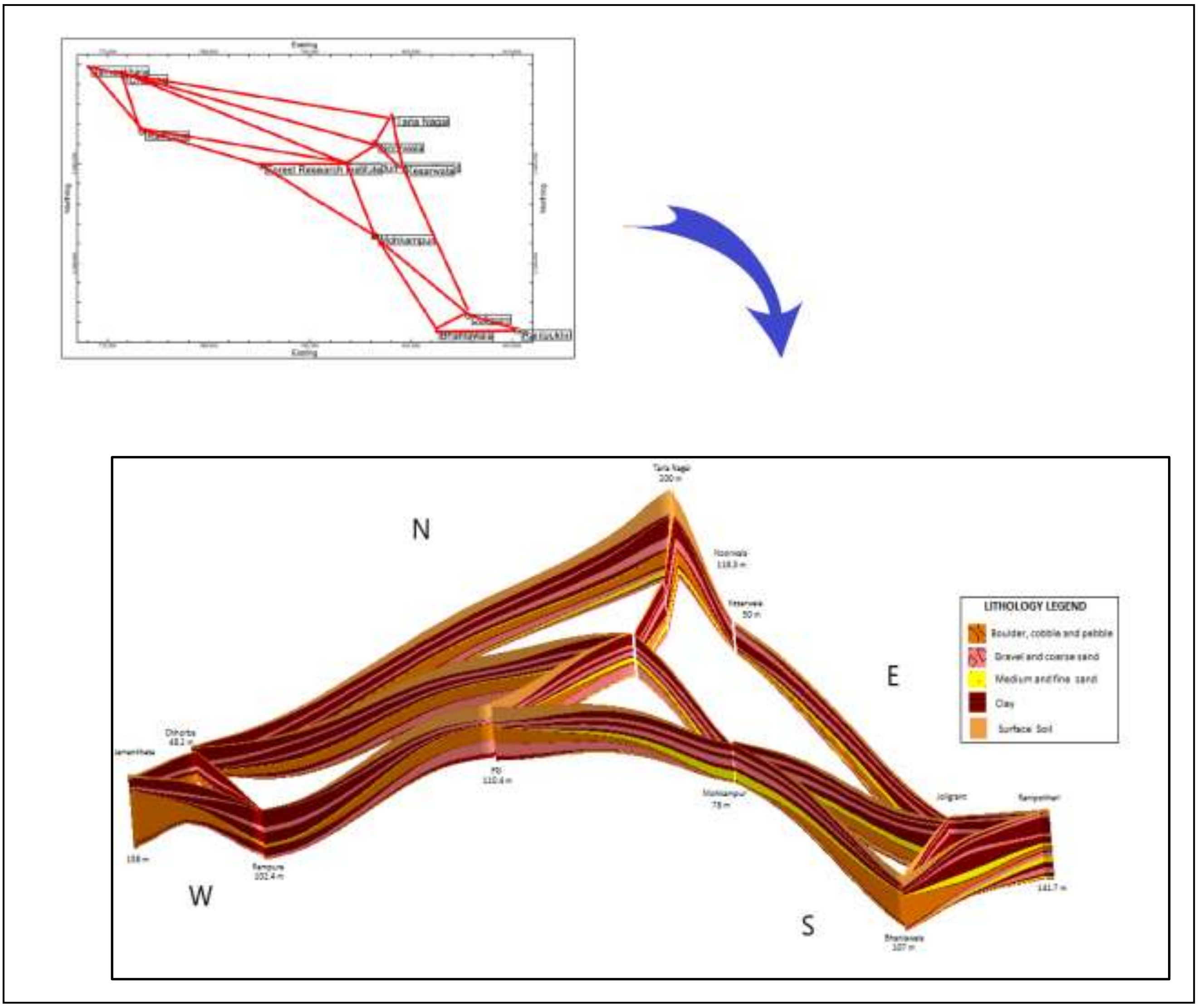


Fig 3.5: Fence diagram Depicting Sub-surface Regionalized Lithological Variation of the Study area

3.3.1 Fence Diagram:

To study the disposition of aquifers, 12 nos. of CGWB exploratory well data were considered. The entire lithological succession encountered in all the wells have been grouped into five major lithological types i.e. **Surface Soil** (SS), **Boulders mixed with pebble, cobble and minor proportions of gravel** (B**), Gravel combined with coarse sand** (G), **Medium to Fine Sand** (S) and **Clay** (C). Review of the fence diagram (Fig 3.4) reveals that the lithological units are occurring in cyclic repetitions with varying proportions of clay and absence of Boulders in certain locations. A detailed perusal of the Fence diagram indicated that the proportion of clay content is high in the Western part with the maximum clay content occurring at Rampura which gradually diminishes as one moves from West to East. The clay content again starts increasing as one moves towards the South Eastern part of the District (Doiwala Block) with prominent thick clay layers encountered at Bhaniawala, Ranipokhri and Joligrant. The beds of gravel and coarse sand, medium to fine sand and boulders form the major aquifer systems of the study area and are considered to be the potential zones which are separated by clay layers of varying thickness as shown in Fig: 3.5.

Perusal of Fig: 3.5 reveal that the nature of the aquifer system of Dehradun district varies from Unconfined aquifer to multi- tiered confined aquifer. The unconfined nature of aquifer is visible in the southern portion of the Sahaspurblock (in and around Forest Research Institute) where 65 m of boulders is underlain by 25 m of gravel and coarse sand.

In the SE part of the District (Doiwala Block) the aquifer system is mostly confined to semi confined in nature with first thick Clay layer occurring at 14 m -50 m depth which gradually pinches into layers of diminishing thickness as one moves westward. The second and third clay layers are present at depths of 55 m and 110m and their thickness are non uniform. Variations of thickness of granular zones and clay layers have been interpreted through various lithological and stratigraphical sections.

The stratigraphy model (Fig: 3.6 and Fig: 3.7) reveals the overall aquifer disposition of the district and its lithological variations.

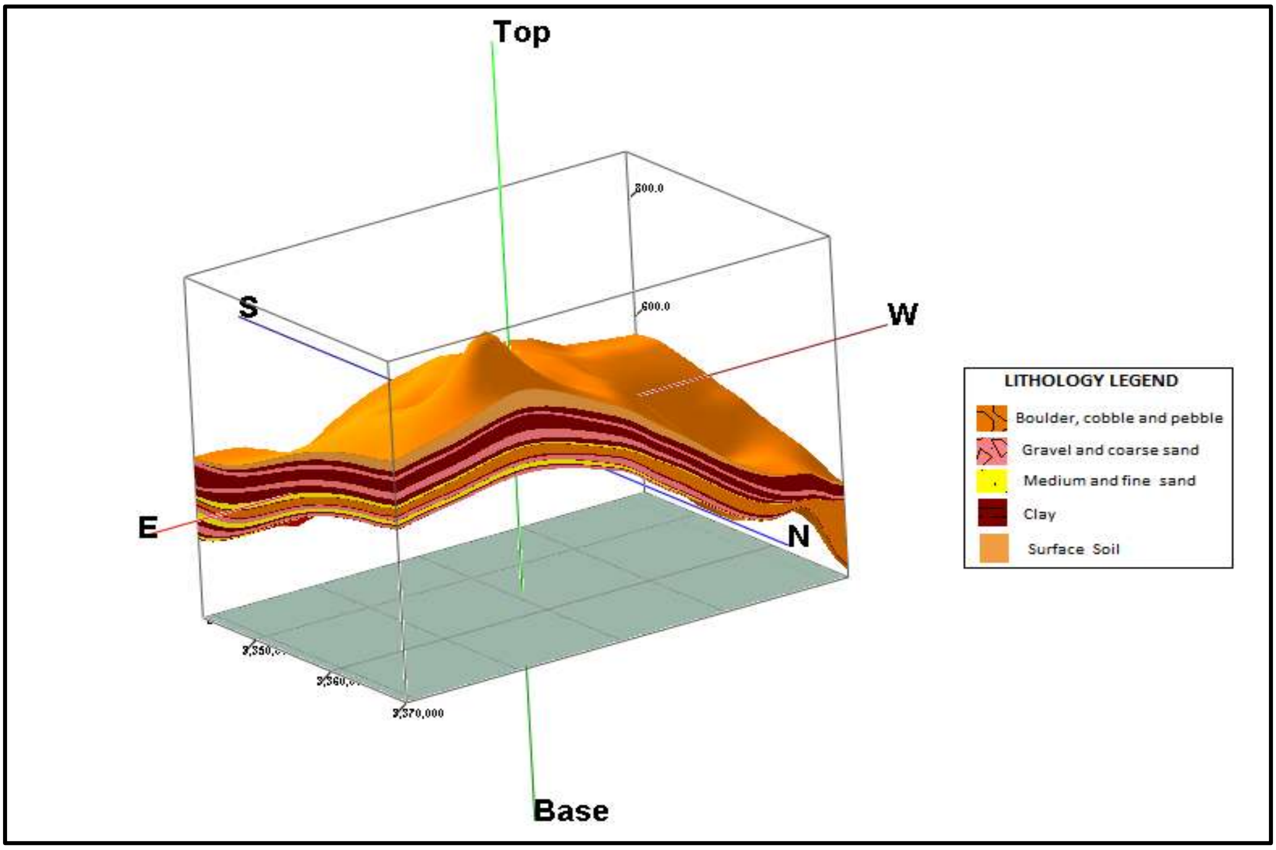


Fig 3.6: 3D Model of the Study area showing lithological variations

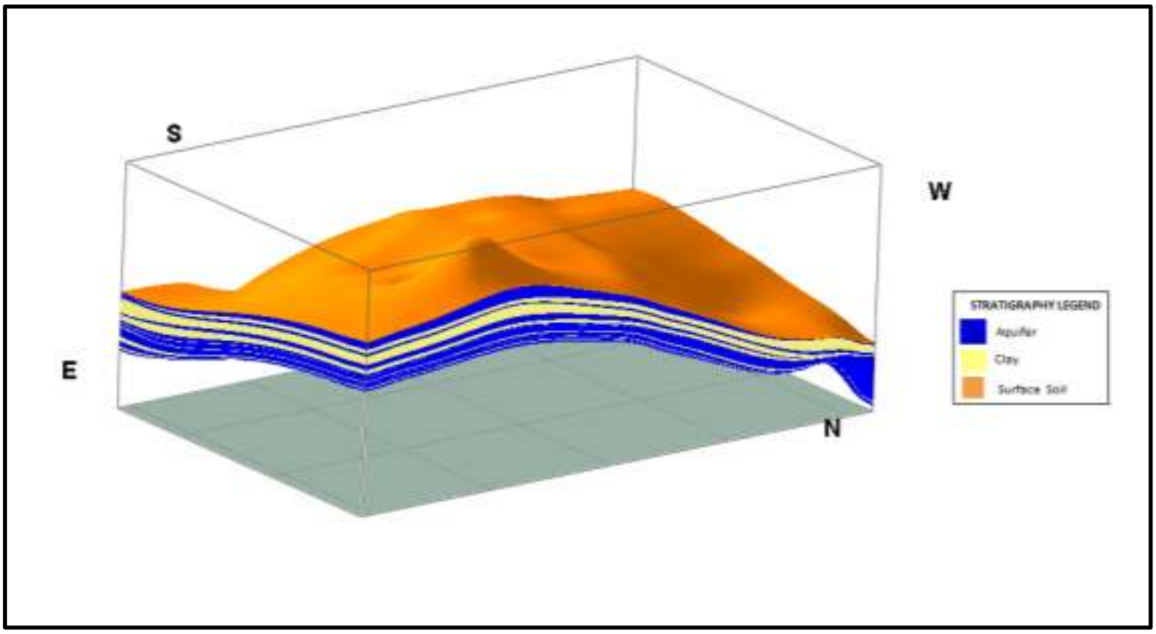


Fig3.7: Aquifer Disposition of the Study arearepresented by 3D Model

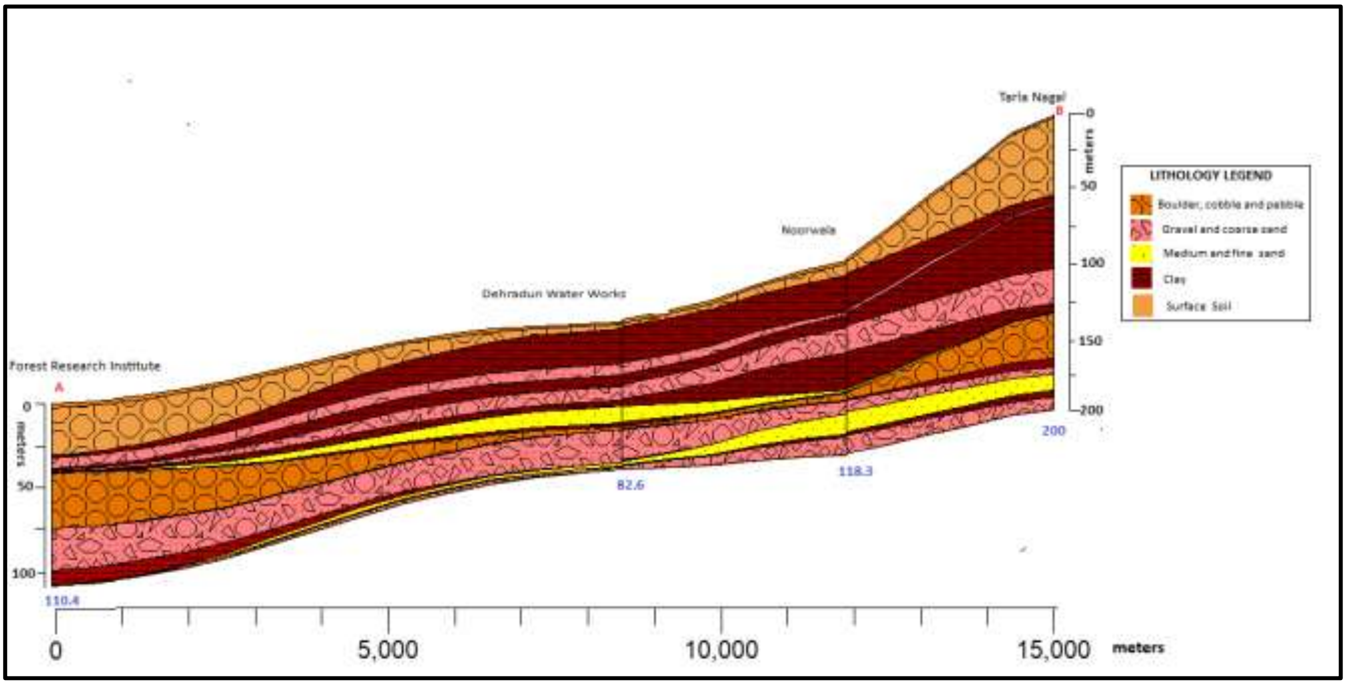
3.3.2 Geological Cross Sections

Section-1 (Forest Research Institute- Dehradun Water Works- Noorwala- TarlaNagal)

This section stretching approximately 15 kms runs in west to east direction of the study area (Sahaspur and Raipur blocks of Dehradun District) covering Forest Research Institute- Dehradun Water Works- Noorwala- TarlaNagal**. Fig: 3.8a,b** clearly shows that the clay proportion gradually decreases as one moves from the East to West. The potential zones encountered in the form of boulders also show non uniform thickness with thickness of 30 m in the western part (Forest Research Institute) which pinches out in the middle of the section and gradually increases to thickness of 60 m at TarlaNagal. The yield prospects are good and maximum discharge of 2526 lpm has been encountered at Forest Research Institute with a drawdown of 7.62 m. At Noorwala, discharge of 815 lpm has been encountered. The zones tapped are listed in **Table3.2.** .The groundwater quality is good and fit for drinking, domestic and irrigation purposes.

Table 3.2: Details of Zone tapped in the Exploratory Wells of Section 1

Location	Type of well	1st Zone tapped	2nd Zone tapped	3rd Zone tapped	4th Zone tapped	5th Zone tapped
Forest Research Institute	EW	29.5- 35.6 m	83.8- 102 m			
Noorwala	EW	91-101 m	103-118 m			
TarlaNagal	EW	109-127 m	133-137 m	146-152 m	155-159 m	184-190 m



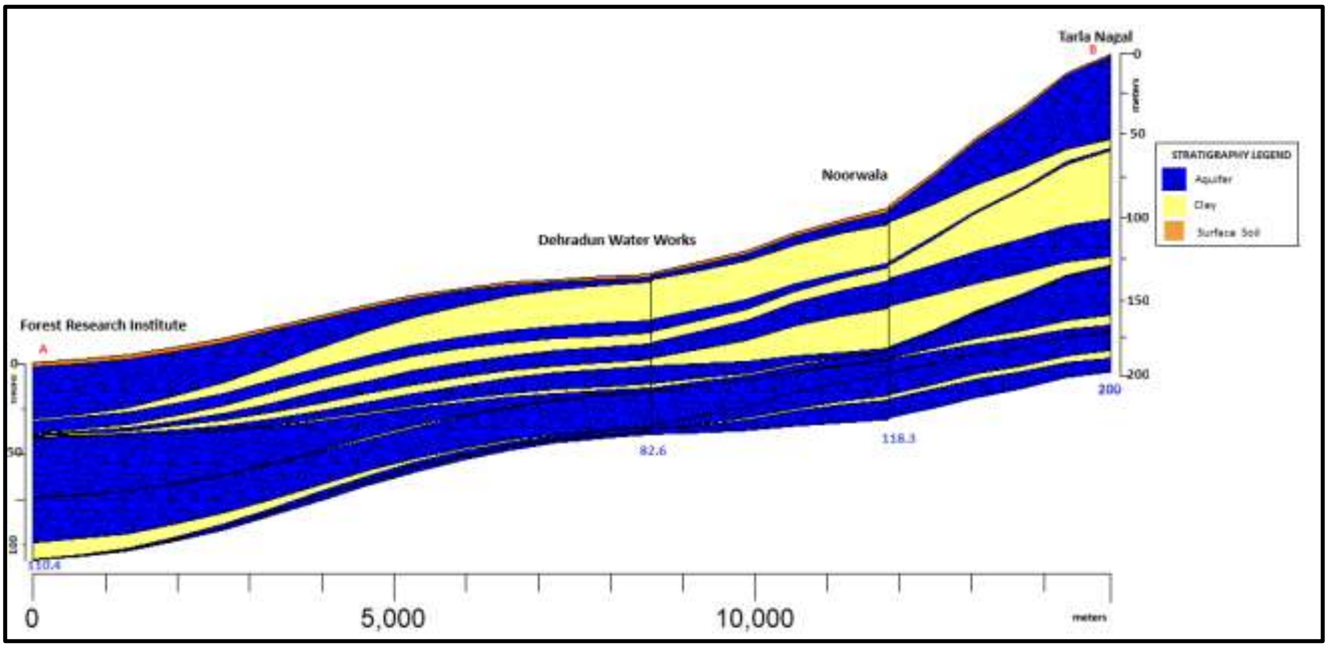


Fig 3.8(a): Section Depicting Sub-surface Lithological Variation from Forest Research Institute to TarlaNagal

3.8(b): Section depicting Sub-surface aquifer disposition from Research Institute to TarlaNagal

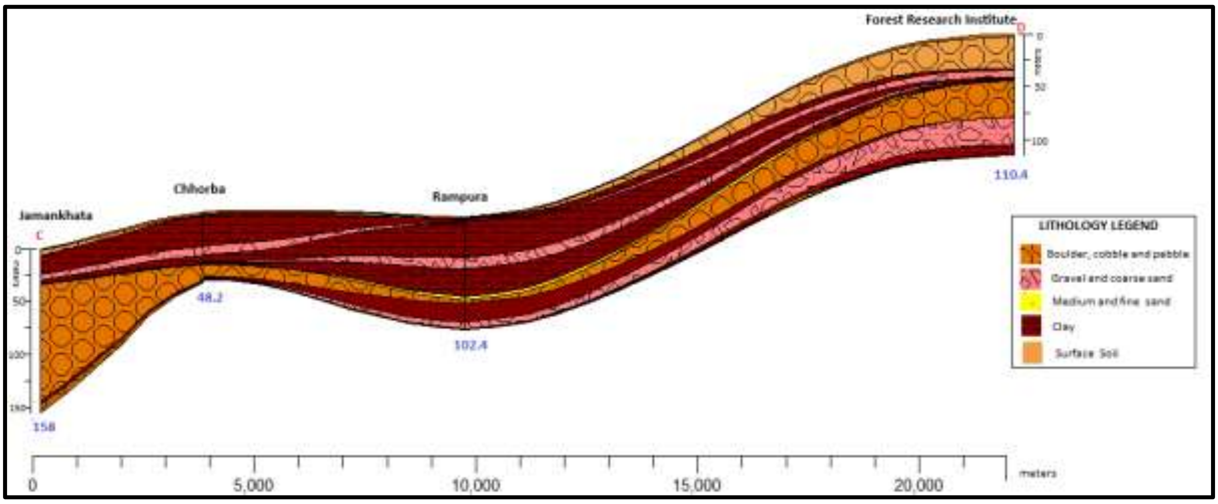
Section-2 (Jamankhata- Chhorba- Rampura- Forest Research Institute)

This section stretching approximately 22 kms runs in North-west to South-east direction of the study area (Vikasnagar and Sahaspur blocks of Dehradun District) covering Jamankhata- Chhorba- Rampura- Forest Research Institute. **Fig: 3.9 a, b** shows that the clay proportion is highest at a stretch of 6 kms starting from Chhorba to rampura and gradually pinches out in the

South east towards Forest Research Institute. The thickness of the first clay layer varies from 16 m (Jamankhata) to 30m (Chhorba) and pinches out in the SE direction. The second clay layer has non uniform thickness throughout the section with the highest thickness of 35 m encountered at Rampura. The potential zones are in the form of boulders and gravel with the highest thickness of the boulders encountered at Jamankhata and Forest Research Institute. Confined- semi confined multi-tiered aquifer conditions exist in the NW part of the section which changes to unconfined condition at the SE part. The yield prospects are good and discharge of 1629 lpm has been encountered at Chhorba with a reasonable drawdown. The zones tapped are listed in **Table3.3.** .The groundwater quality is good and fit for drinking, domestic and irrigation purposes.

Table 3.3: Details of Zone tapped in the Exploratory Wells of Section 2

Location	Type of well	1st Zone tapped	2nd Zone tapped	3rd Zone tapped	4th Zone tapped	5th Zone tapped
Jamankhata	EW	60-64 m	72-84 m	87-99 m	105-109 m	
Chhorba	EW	45-48 m	60-70 m	84-92 m	94-107 m	
Rampura	EW	35-45 m	54-57 m	74-77 m	105-112 m	114-117 m



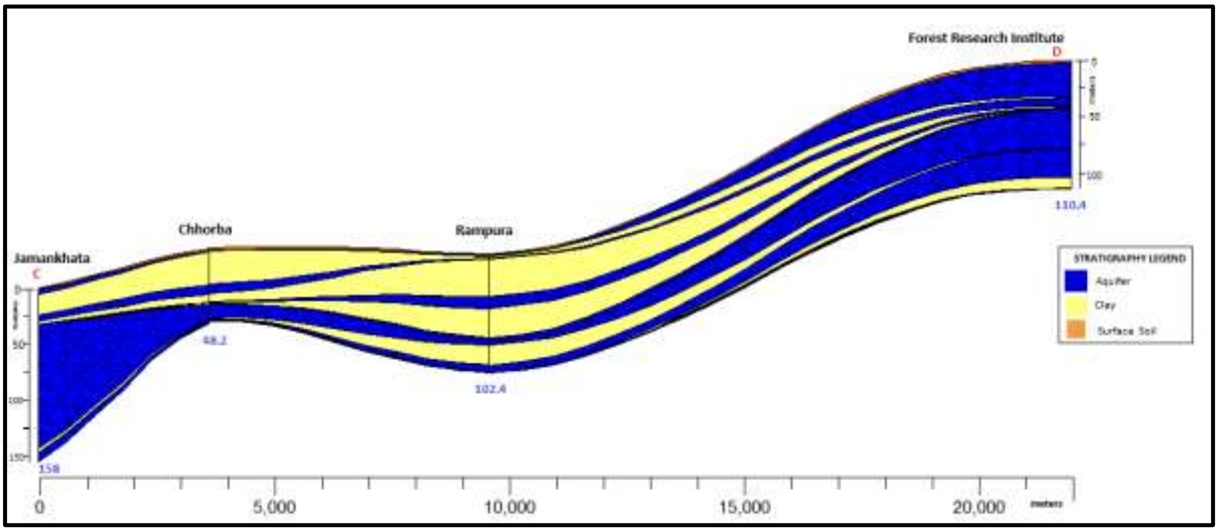
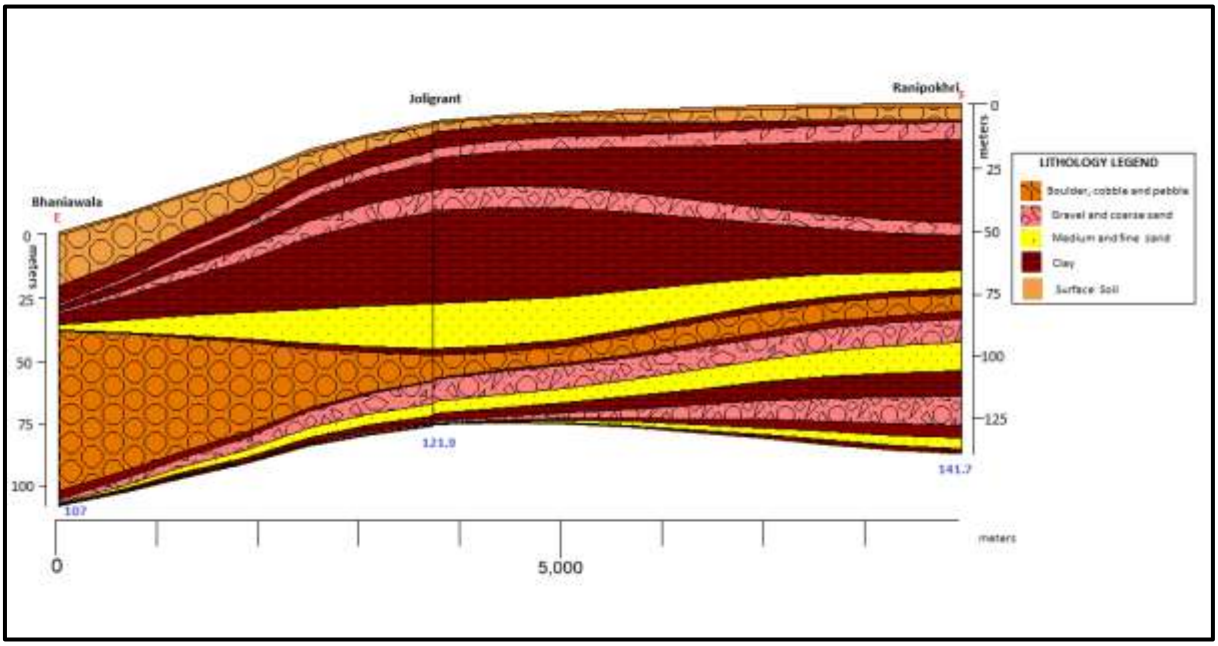


Fig 3.9 (a): Section Depicting Sub-surface Lithological Variation from Jamankhata to Forest Research Institute

3.9(b) Section depicting Sub-surface aquifer disposition from Jamankhata to Forest Research Institute

Section-3 (Bhaniawala- Joligrant- Ranipokhri)

This section stretching approximately 9 kms runs in West to East direction of the study area (Doiwala block of Dehradun District) covering Bhaniawala- Joligrant- Ranipokhri.**Fig: 3.10 a, b** shows that the clay proportion decreases as one moves from west to east with the maximum thickness of clay layer encountered at Joligrant. The overall section displays a multi-tiered Confined to Semi confined aquifer system with two distinct clay layers of varying thickness which occurs all throughout the section. The potential zones are in the form of boulders with the highest thickness of the boulders encountered at Bhaniawala and five potential zones tapped (41-47m, 49-55m, 62-68m, 71-77m, 80-88m). The gravel and fine to medium sand form potential zones for rest of the section with zones tapped at 82-85m, 88-97m and 103-118m at Joligrant and at 83-86m, 88-96m, 100-105m, 115-128m and 135-138m at Ranipokhri. The yield prospects are good with discharge ranging between 2000-3000 lpm and drawdown ranging from 2-7m. The groundwater quality is good and fit for drinking, domestic and irrigation purposes.



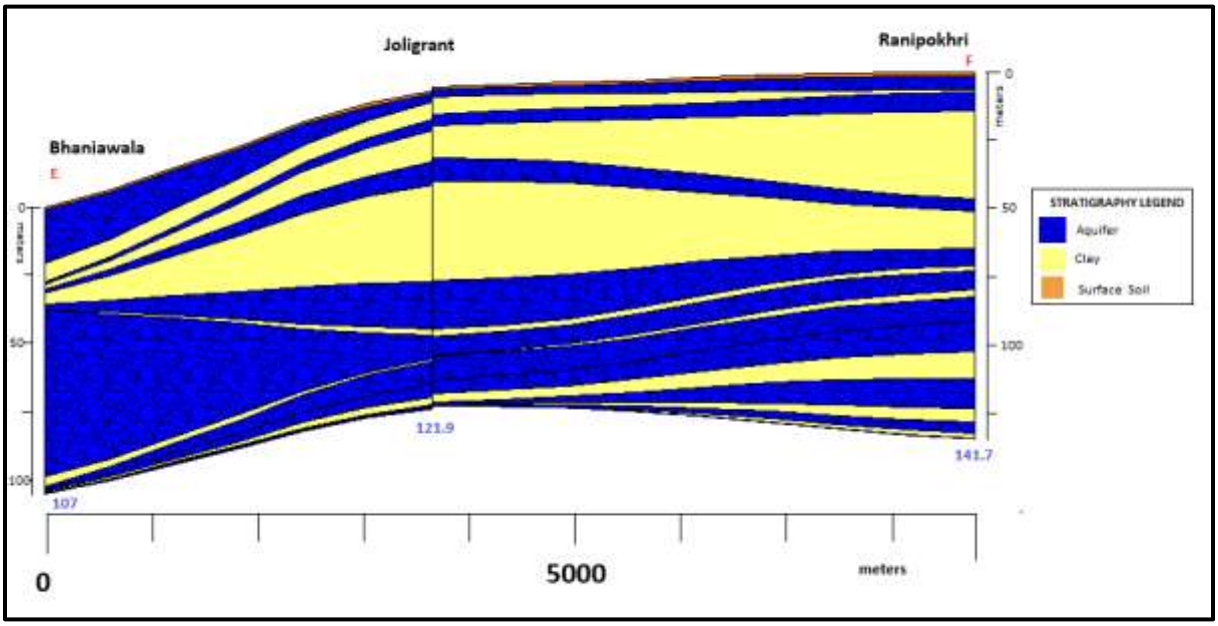
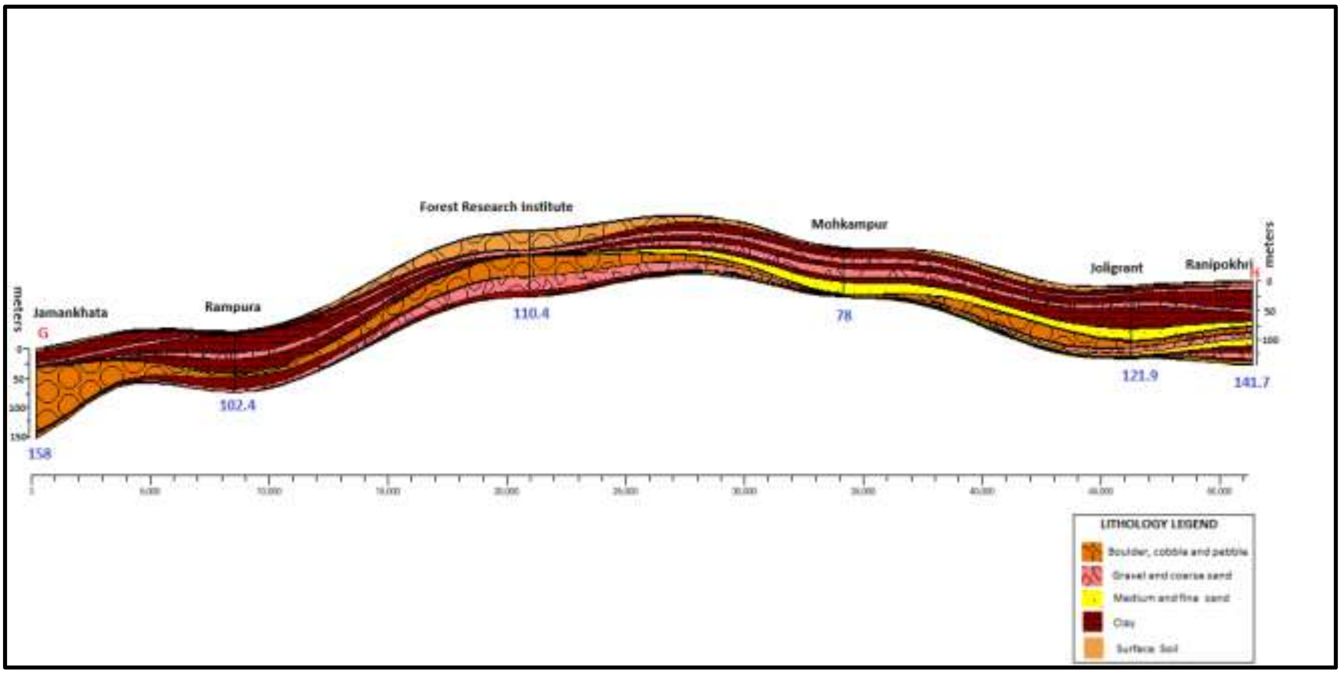


Fig: 3.10 (a): Section Depicting Sub-surface Lithological Variation from Bhaniawala to Ranipokhri
3.10 (b): Section depicting Sub-surface aquifer disposition from Bhaniawala to Ranipokhri

Section-4 (Jamankhata- Rampura- Forest Research Institute- Mohkampur- Joligrant- Ranipokhri)

This section stretching approximately 51 kms runs in North-West to South-East direction of the study area (Vikashnagar, Sahaspur, Raipur and Doiwala blocks of Dehradun district) covering Jamankhata- Rampura- Forest Research Institute- Mohkampur- Joligrant- Ranipokhri**. Fig: 3.11 a, b** shows that the clay proportion increases as one moves from North-west to South-east. The overall section displays a multi tiered Confined to Semi confined aquifer system with two distinct clay layers of varying thickness except at Forest Research Institute, where unconfined aquifer system prevails. The potential zones are in the form of boulders, gravel and sand of varying thickness. The yield prospects are good with discharge ranging between 1500-3000 lpm with reasonable discharge. The groundwater quality is good and fit fordrinking, domestic and irrigation purposes.



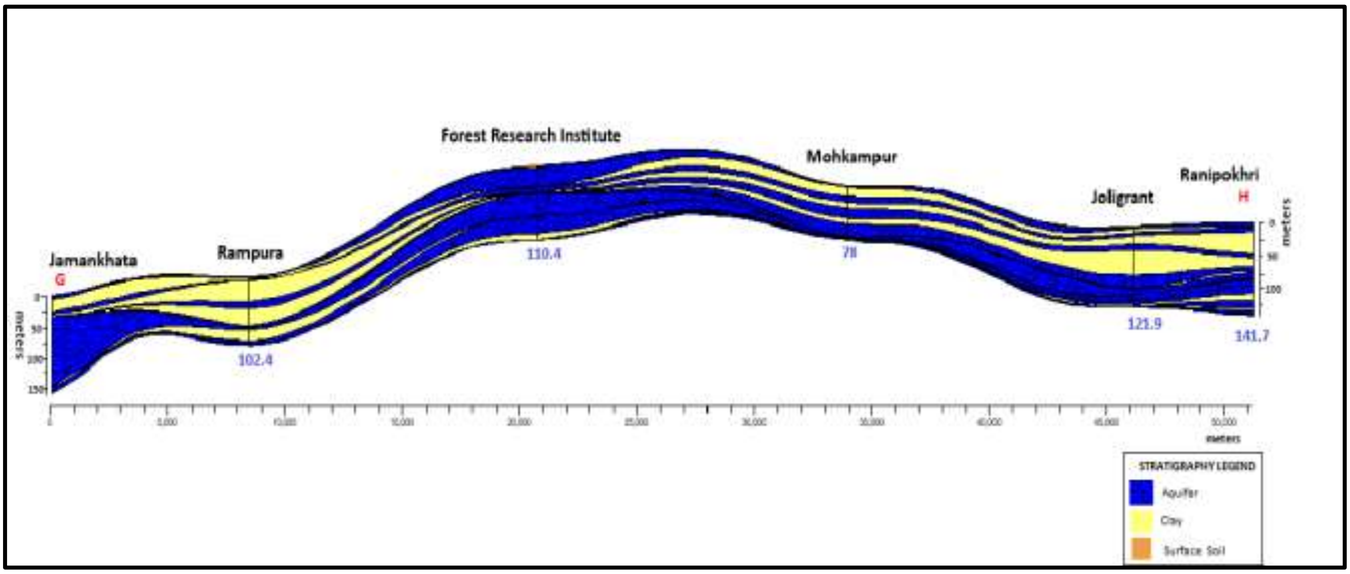


Fig 3.11(a): Section Depicting Sub-surface Lithological Variation from Jamankhata to Ranipokhri
3.11(b): Section depicting Sub-surface aquifer disposition from Bhaniawala to Jamankhata to Ranipokhri

3.3.3 Occurrence of Ground Water and Movement of Groundwater

Doon Gravels are highly porous and they have a significant permeabilityand act as good groundwater reservoirs. Groundwater occurs under unconfined and semi-confined conditions. The saturated granular zones occur in a depth range between 35.50 and 138.68 m bgl. The shallow aquifers occur under unconfined conditions, while deeper aquifers occur under semi-confined to confined state of disposition. The confining layers are impermeable clay beds.

In a groundwater regime, equipotential lines, the line joining points of equal head on the potentiometric surface, were drawn based on the area of variation of the head of an aquifer. Water table contour map of the study has been prepared **(Fig: 3.12)** on the basis of NHS monitoring wells already established. Based on the Water table elevation, ground water flow directions are demarcated shown in arrow. The altitude of water table in the area varies from 320 to 860 metres above mean sea level for the multi-tiered aquifer system of the area. Groundwater flows towards the South Eastern part of the district wherein the groundwater eventually contributes to the Ganga River. In the Western part of the district, the groundwater flows towards the west and ends up contributing water to the Yamuna River. The two rivers Ganga and the Yamuna form the major drainage of the NAQUIM area and act as effluent in nature.

The general flow direction of groundwater is NW- SE in the eastern part of the study area and NE-SW in the western part of the study area. The water divide (shown in black dotted line) divides the entire study area into two drainage basins- the Ganga Basin and the Yamuna basin.

Doiwala and part of Raipur blocks fall under the Ganga basin whereas Sahaspur and Vikasnagar fall under the Yamuna Basin.

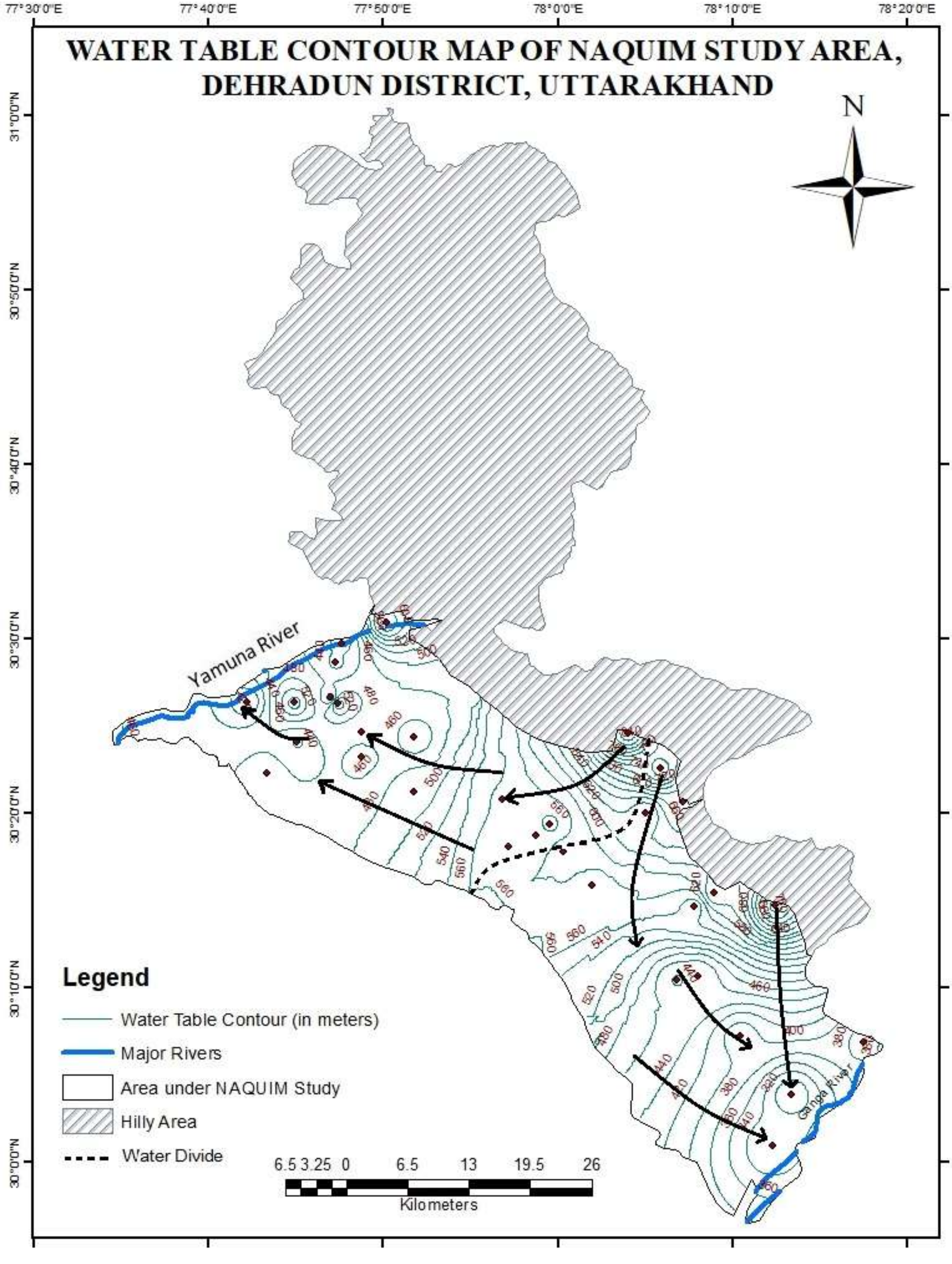


Fig 3.12: Water table Contour map of the Study area showing movement of groundwater

3.3.4 Depth to Water Level

In the Study area, around 49 NHS well are monitored for water level and water quality analysis purpose. .The depths to water level maps have been prepared for pre-monsoon and post monsoon period of year 2021 (**Figure 3.13a, b**). A study of pre-monsoon water level data reveals that the around 41% NHS wells of the study area is having water level more than 20 m bgl and around 10% NHS wells are having water level in the range of 15-20 m bgl, 24% NHS wells are having water level in the range of 10-15 m bgl and the rest below 10 m bgl.During Pre-monsoon 2020, deepest water level of 91.55 m bgl has been observed in LadpurPz of Raipur block of the district whereas shallowest water level of 3.05 m bgl has been observed in Dharmawala DW of Sahaspur block of the district.

A study of Fig. **3.13a** indicates that the major part of the the study area shows water levels deeper than 15 m bgl. The shallow water level in the range of 5-10 m bgl occurs in patches near extreme south eastern part (Rishikesh) and in small patches near north western part in the Sahaspur block of the Study area. The water level in the depth range of 10-15 m bgl occurs in the north-western part (Jhajhra-Baronwala- Redapur-Haripur areas), southern part (Khandgaon areas) of Doon valley.

A study of post-monsoon water level data reveals that the around 44% NHS wells of Dehradun district is having water level more than 15 m bgl, around 14% NHS wells are having water level in the range of 10-15 m bgl and around 40% NHS wells of Dehradun district are having water level in the range of 5-10 m bgl. During Post-monsoon 2020, deepest water levcl of 79.18 m bgl has been observed in LadpurPz of Raipur block of the district whereas shallowest water level of 3.68 m bgl has been observed in Dharmawala DW of Vikasnagar block of the district.

A perusal of Fig. **3.13b** indicates that the major part of the Dehradun district shows water levels in the range of >15 m bgl. The water levels in the depth range of 10-15 m bgl are observed in southern part of the valley i.e. in the Doiwala block and covering majority of the Sahaspurblock and at central part of Vikasnagar block of Dehradun district. The water level in the range of 5-10 m bgl occurs in the southern-most part of the Doon valley and at isolated locations in the Sahaspur block.

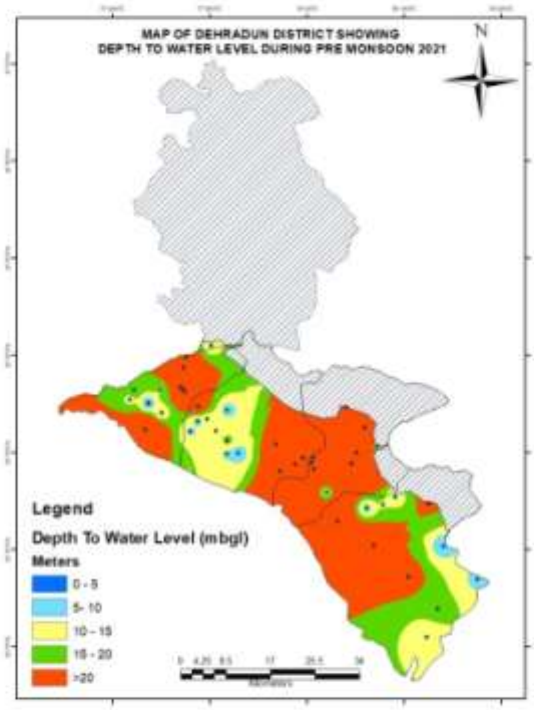


Figure 3.13(a)- Depth to Water Level Map (Pre Monsoon), Dehradun District

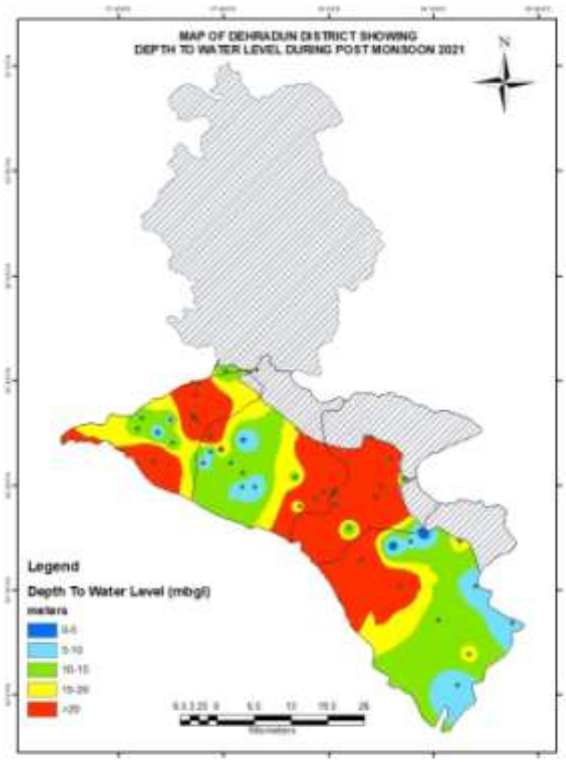


Figure 3.13(b)– Depth to Water Level Map (Post Monsoon), Dehradun District

3.3.5 Water Level Fluctuation:

Water Level fluctuates corresponding to recharge to phreatic aquifer or withdrawal from it. The quantum of fluctuation is a direct function of aforesaid components. Mainly recharge takes place during rainy season (June to September) and withdrawal during the rest of the period. The shallowest representative water table depth below ground is expected some time at the end of monsoon season and it will be deepest just before the inception of rainy season. A part of rainfall infiltrating into soil is effective to rejuvenate the soil moisture deficiency (covered by ET losses and other localized factors) in the beginning of rainy season.

To study the seasonal fluctuation in the district, water level data of NHS wells were considered and a fluctuation map (**Fig: 3.14)** has been prepared by using the pre-monsoon and post monsoon data. The 97% wells show rise in depth to water level during post-monsoon.The seasonal fluctuation (rise) in the district varies from 0.035 to 6.93 metres. Fig 3.7 represent that the higher seasonal rise of 2-4 m is observed in major parts of the Doon valley covering major parts of Doiwala and Raipur blocks of the district. Doon valley is representing mainly seasonal rising water level trend.

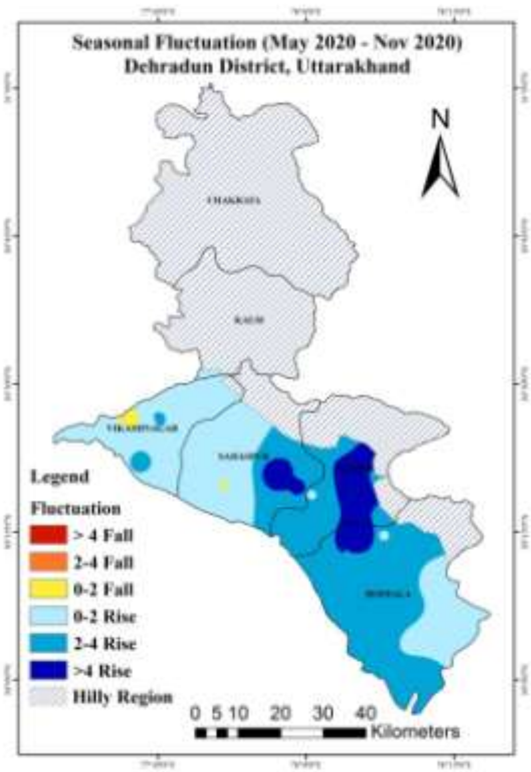


Figure3.14- Water Level Fluctuation Map, Dehradun District

3.2.6Long Term Water Level Trends:

Long term water level trends from the existing 29 nos. of hydrograph stations were statistically analysed (2010-19) and are enclosed in the Annexure. To study the pattern of water table fluctuation in space and time, the hydrographs of existing stations have been generated. It is observed that the long-term water level trends during pre and post-monsoon seasons are rising **(Fig: 3.15).**

Rising trend of water level suggests that surface water irrigation not only compensates the withdrawal but puts additional recharge through return flow in the system and through direct seepage from running canal.

The variation in short term and long-term water level trends may be due to variation in natural recharge due to rainfall and withdrawal of groundwater for various agricultural activity, domestic requirement and industrial needs. The analysis of hydrographs show that the annual rising limbs in hydrographs indicate the natural recharge of groundwater regime due to monsoon rainfall, as the monsoon rainfall is the only source of water (hydrographs). However, the groundwater draft continuously increases as indicated by the recessionary limb.

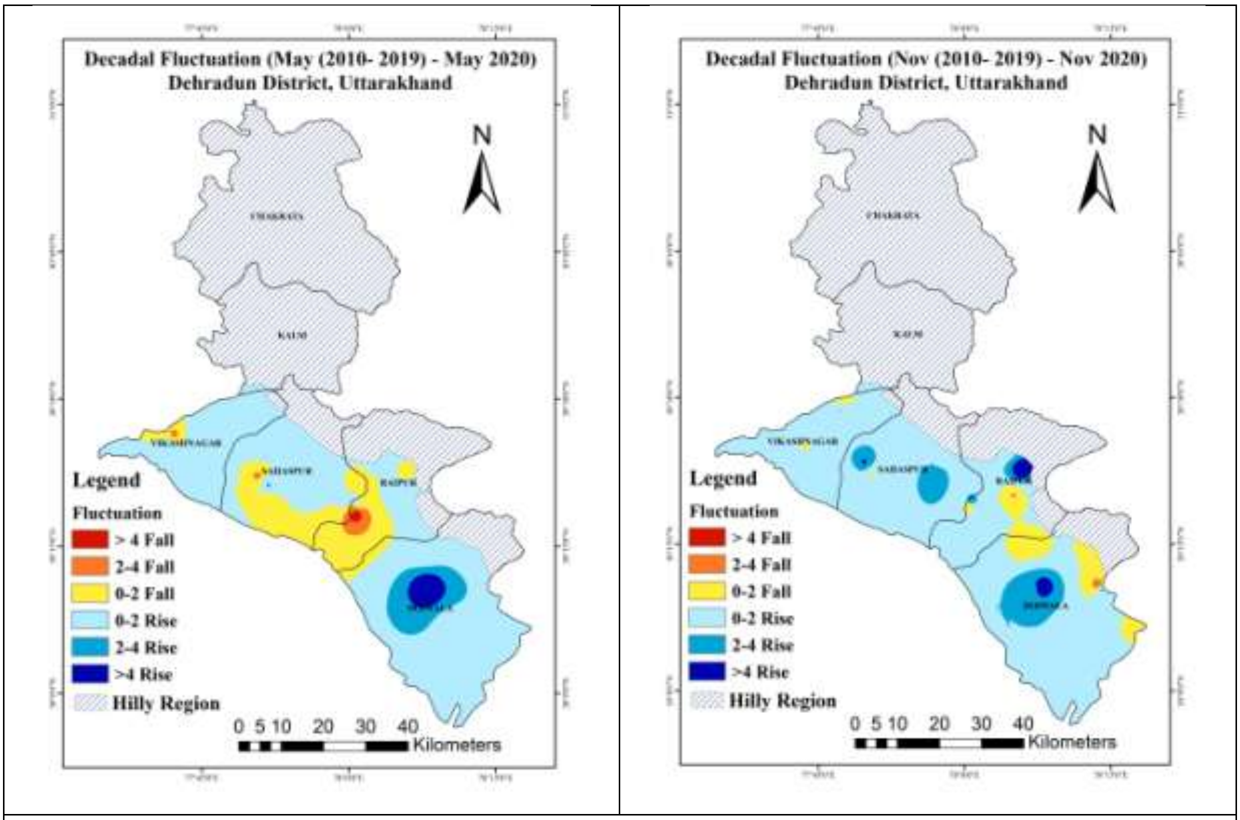
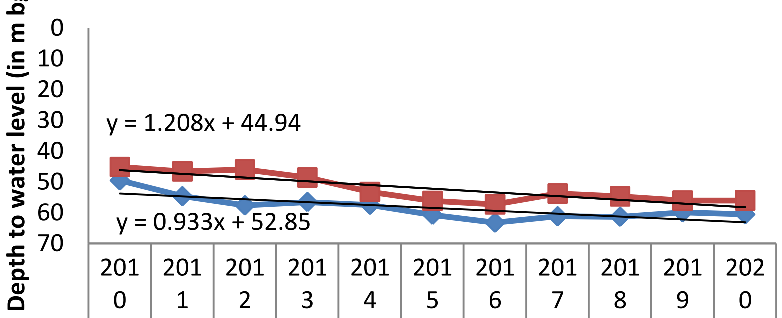


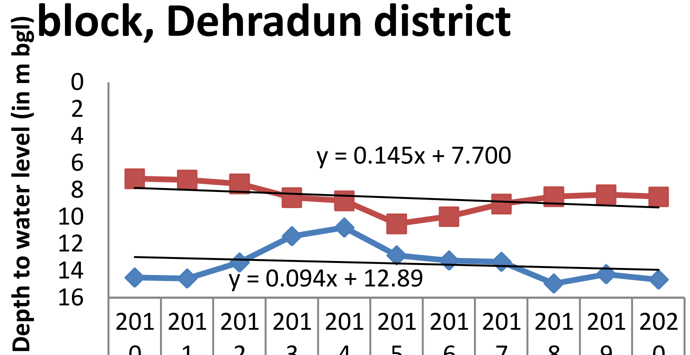
Figure 3.15- Decadal water level Fluctuation map of Dehradun district

CGWB Office PZ, Raipur block, Dehradun district



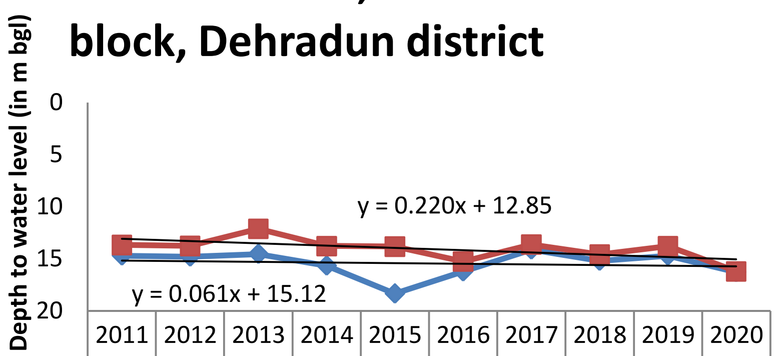
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
pre-monsoon	49.5	54.6	57.6	56.5	57.5	60.7	63.2	61.2	61.3	59.9	60.5
post-monsoon	45.1	46.6	46.0	48.6	53.3	56.1	57.3	53.8	54.7	56.1	56.0

Maldeota HP, Raipur block, Dehradun district



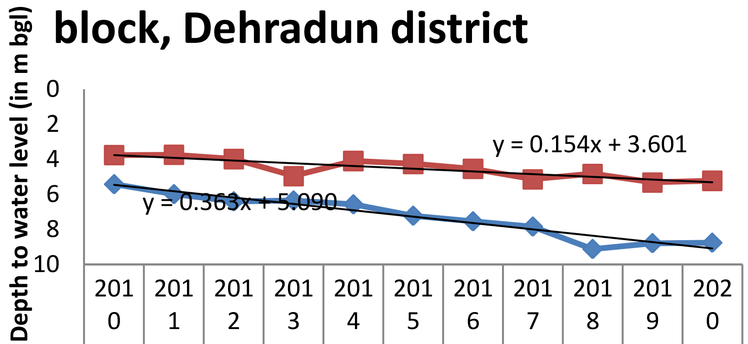
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pre-monsson	14.	14.	13.	11.	10.	12.	13.	13.	15	14.	14.
Post-monsoon	7.1	7.2	7.5	8.5	8.8	10.	9.9	9.0	8.5	8.3	8.5

Khadakmaf HP, Doiwala block, Dehradun district

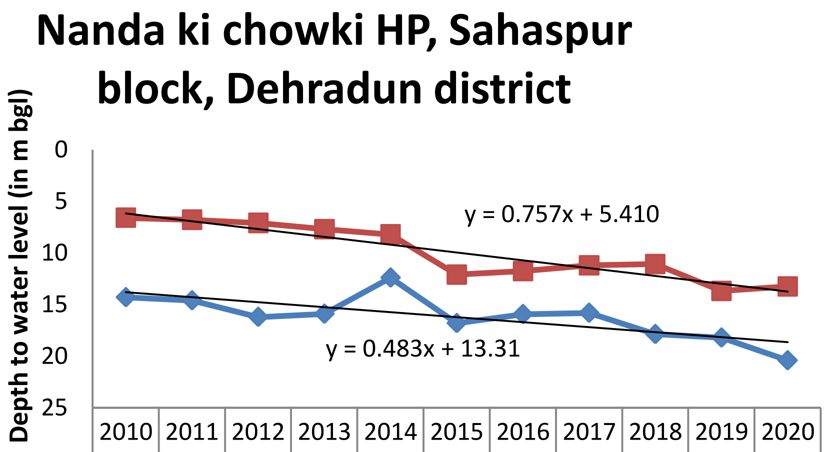


	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pre-monsoon	14.7	14.8	14.54	15.66	18.34	16.22	14.12	15.2	14.7	16.28
Post-monsoon	13.68	13.77	12.13	13.78	13.83	15.27	13.64	14.6	13.8	16.21

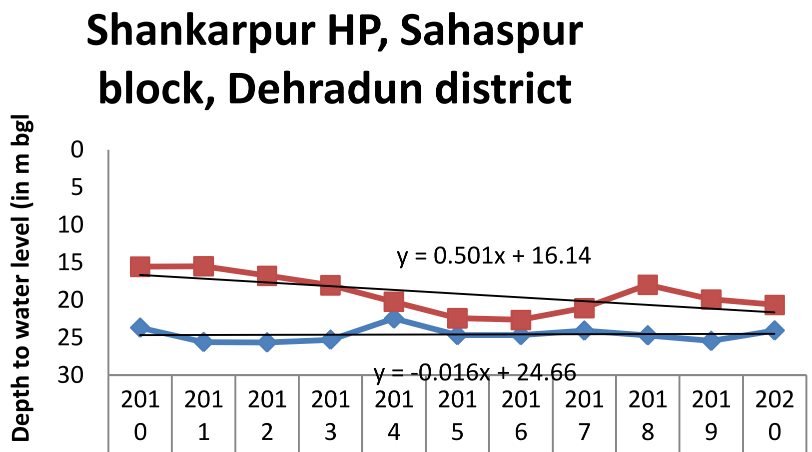
Rishikesh HP, Doiwala block, Dehradun district



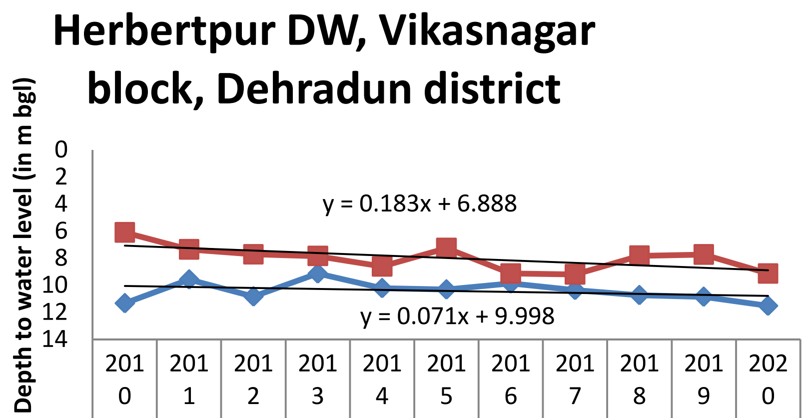
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pre-monsoon	5.42	5.99	6.4	6.35	6.57	7.22	7.54	7.84	9.12	8.79	8.76
Post-monsoon	3.75	3.74	3.98	4.96	4.09	4.26	4.54	5.14	4.83	5.32	5.22



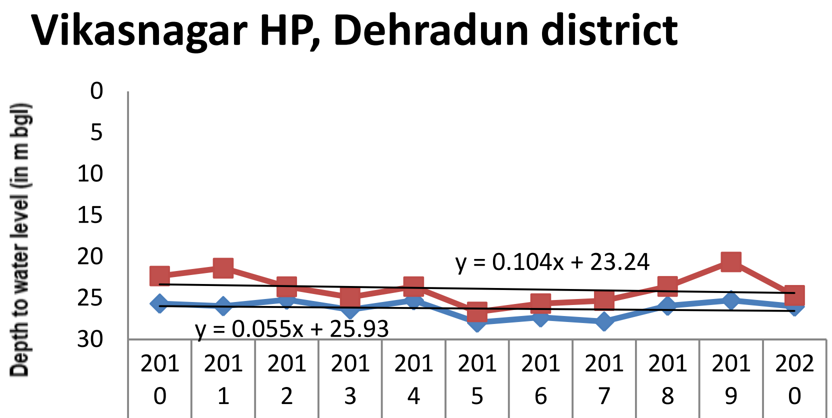
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pre-monsoon	14.3	14.6	16.2	15.9	12.4	16.8	15.9	15.8	17.8	18.2	20.4
Post-monsoon	6.6	6.8	7.1	7.7	8.2	12.1	11.7	11.2	11.0	13.6	13.2



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pre-monsoon	23.6	25.5	25.6	25.2	22.4	24.6	24.6	24.0	24.7	25.4	24.0
Post-monsoon	15.5	15.5	16.7	18.0	20.2	22.4	22.6	21.0	17.9	19.9	20.6



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pre-monsoon	11.3	9.57	10.8	9.13	10.2	10.3	9.87	10.3	10.7	10.8	11.5
Post-monsoon	6.1	7.35	7.72	7.84	8.62	7.25	9.13	9.2	7.82	7.73	9.13



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pre-monsoon	25.6	25.9	25.2	26.4	25.2	27.9	27.3	27.8	25.9	25.2	26.0
Post-monsoon	22.3	21.4	23.6	24.9	23.6	26.6	25.6	25.3	23.6	20.6	24.6

3.4 Ground Water Quality

The suitability of ground water for drinking/irrigation/industrial purposes is determined keeping in view the effects of various chemical constituents present in water on the growth of human being, animals, and various plants and also on industrial requirement. Though many ions are very essential for the growth of plants and human body but when present in excess, have an adverse effect on health and growth. For estimation of the quality of ground water, ground water samples from the 44 locations of NHS monitoring stations have been collected during pre-monsoon 2020. The ground water samples were analysed for major chemical constituents at Chemical Laboratory, CGWB, NR, Lucknow.

Table 3.4: Chemical constituents in Ground Water samples of the Study Area

Constituents	Min	Max	Average	Std. Deviation
pH	7.16	9.2	7.79	0.32
EC	68	893	378.77	217.49
TDS	44	2444	296.19	360.22
TH	30	440	175.23	111.69
Calcium	8	104	39.64	25.99
Magnesium	2.4	45.6	18.27	13.10
Potassium	1	9.8	1.79	1.94
Sodium	2.2	8.5	24.92	127.30
Carbonate	NIL			
Chloride	7	43	17	8.95
Nitrate	5	37	14.46	9.74
Fluoride	BDL	0.66		

The average pH value of Dehradun district is 7.79 indicating that the groundwater of the study area is neutral to alkaline in nature. Based on the permissible limit of pH in drinking water 6.5 to 9.2 (WHO, 2011; BIS, 2012), Value of pH observed from all water samples of shallow and deep aquifer are within the permissible range.

The EC is defined as the measurement of the dissolved ions in groundwater, which is based on the conductivity of the aqueous solution. EC of the groundwater samples measured during this study ranges from 68 to 893μS/cm. The Electrical Conductivity measured from the ground water samples of Dehradun district indicate that the ground water is generally fresh and potable.

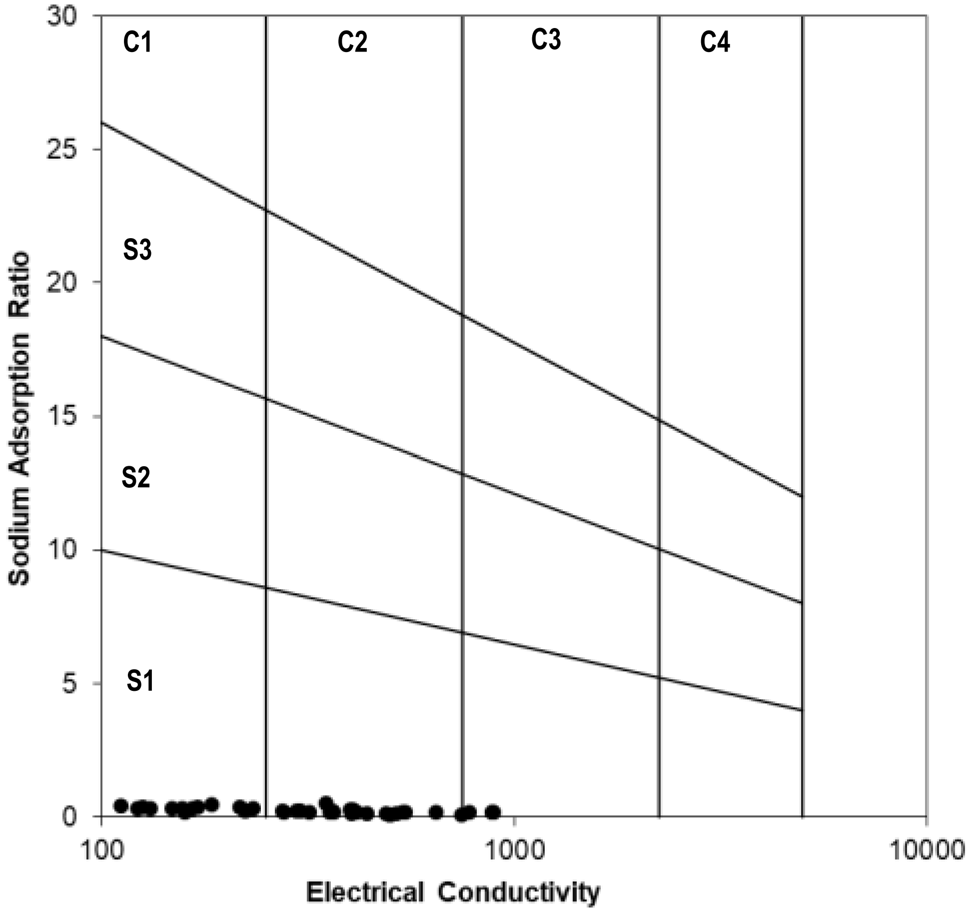


Figure 3.16 -Suitability of Water for Irrigation Uses :(a) USSL diagram Sodium adsorption ratio (SAR)

The alkali hazard is caused by high levels of sodium in soil. A high concentration of Na^+ in groundwater use for irrigation may create a tremendous concentration of sodium in soil and then lead to the destruction of soil structure. As per the U S salinity diagram**(Fig: 3.16)**, major ground water samples of Dehradun district is falling in the C2S1 region, which indicates its suitability for irrigation purposes on all types of soils. Groundwater in some parts of the district fall in C1S1 types i.e. medium salinity and low sodium hazard. Ground waters that fall within the C1-S1 and C2-S1 region can be used for irrigation on all types of soil with little danger of the development of harmful levels of exchangeable sodium. However, C3- S1 water types of high salinity and low sodium content occurred in few parts of the district (around 6% of the total samples) and this water could only be used to irrigate certain semi-tolerant crops.

The piper diagram is used to display the relative abundance of ions in groundwater samples and then to identify the hydrochemical facies. As interpreted from the Piper-Trilinear diagram and Modified Piper diagram**(Fig: 3.17)**, the aquifers are mostly dominated by Calcium sulphate and calcium bicarbonate types of groundwater. The general chemical quality reveals that most of the wells contain low dissolved mineral contents and hence, groundwater in Dehradun district is fresh and potable.

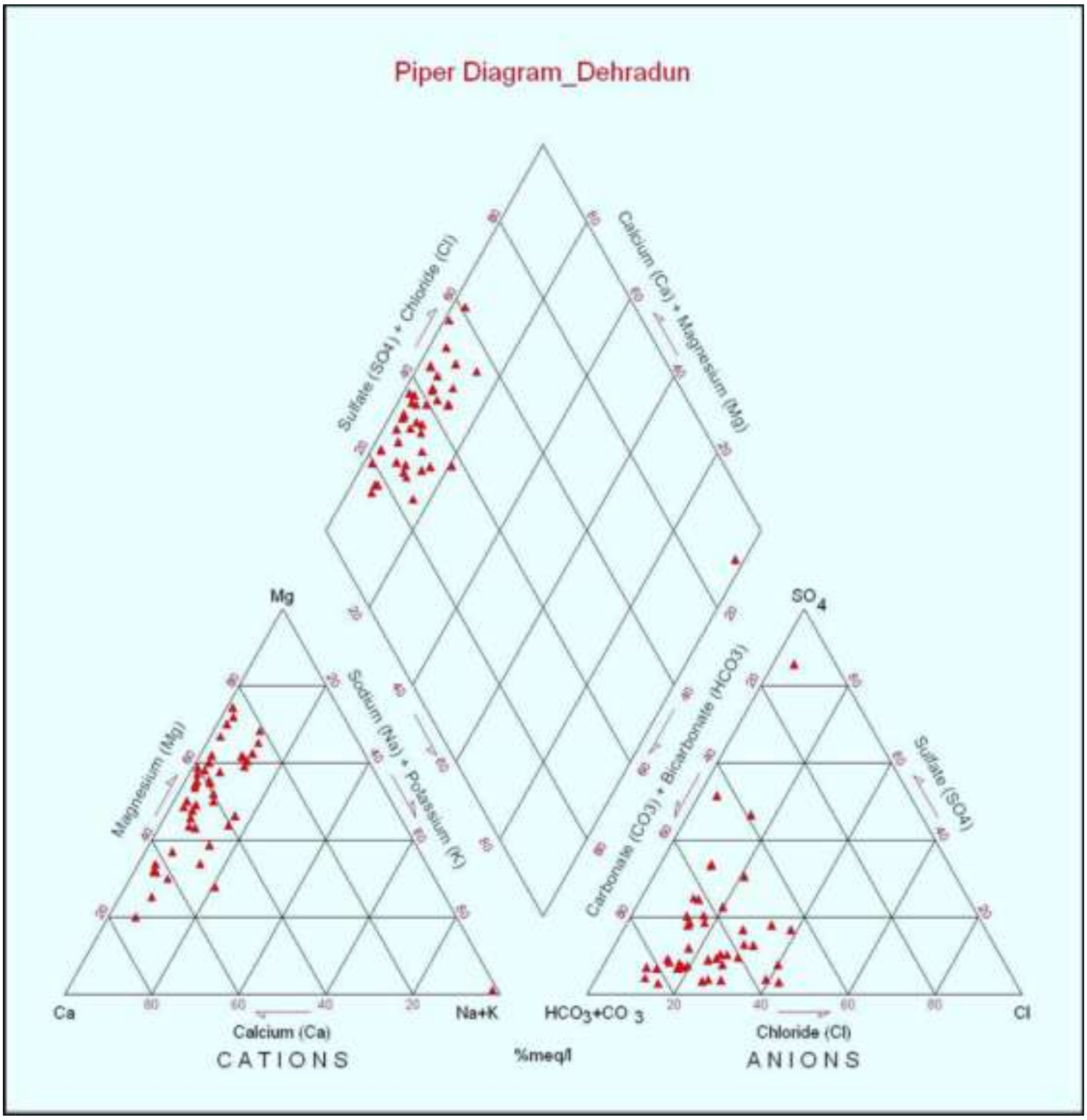
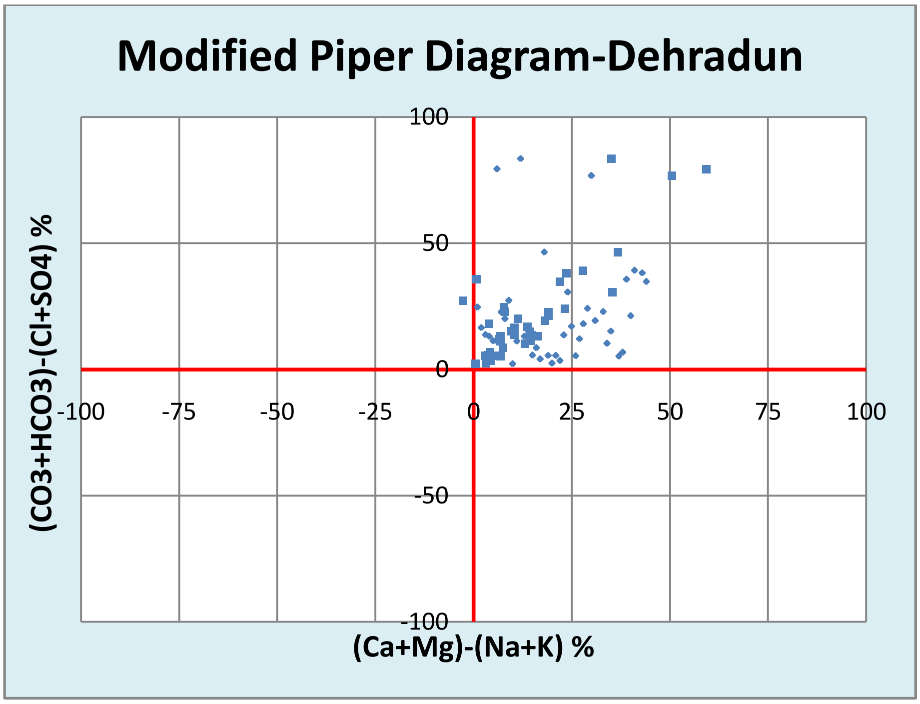


Figure 3.17-- Piper Diagram constructed after analysis of groundwater samples collected from the study area

Table 3.5: Percentage of samples falling in different zones of Piper Diagram

Subdivision of the diamond	Characteristics of corresponding subdivisions of diamond-shaped fields	Percentage of samples in this category
1	Alkaline earth (Ca+Mg) exceeds Alkalies (Na+K)	97.73
2	Alkalies exceeds alkaline earths	2.27
3	Weak acids (CO_3+HCO_3) exceeds strong acids (SO_4+Cl)	86.36
4	Strong acids exceeds weak acids	13.64
5	Magnesium bicarbonate type	84.09
6	Calcium chloride type	4.55
7	Sodium chloride type	2.27
8	Sodium bicarbonate type	0.0
9	Mixed type (No cation-anion exceed 50%)	9.09



The water hardness is a major aspect of drinking water quality. The Hardness of the water caused by calcium and magnesium is usually indicated by precipitation of soap scum and the need for excess use of soap to achieve cleaning (WHO, 2011). High hardness of water could also affect its taste. Total hardness of the aquifer in the study area varies between 30 to 440 mg $CaCO_3$/l well within the permissible limit of 600 CaCO3mg/l (BIS 2012).The total hardness has been classified according to (Sawyer and McCarty 1978) (**Table 3.6**).11.36 % of the samples fall under very hard water category.

Table- 3.6Total Hardness of Aquifer

Category (Sawyer and McCarty 1978)	Hardness (mg/l of CaCO3	No of groundwater samples (%)
Soft	75	27.27
Moderataly Hard	75-150	22.73
Hard	150-300	38.64
Very Hard	>300	11.36

Fluoride is within permissible limits (1.5 mg/L) throughout the study area. **Nitrate** is also within permissible limits in all the samples collected as shown in **Fig: 3.18a, b, c, d.**

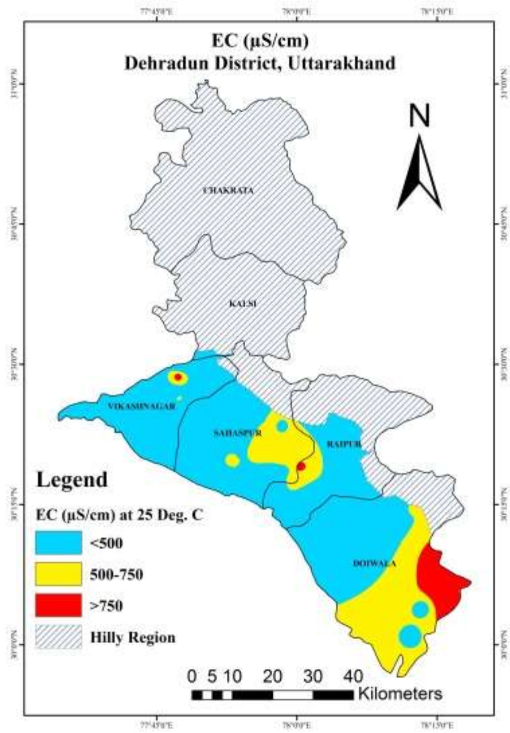


Fig3.18(a): EC Map of the Study area

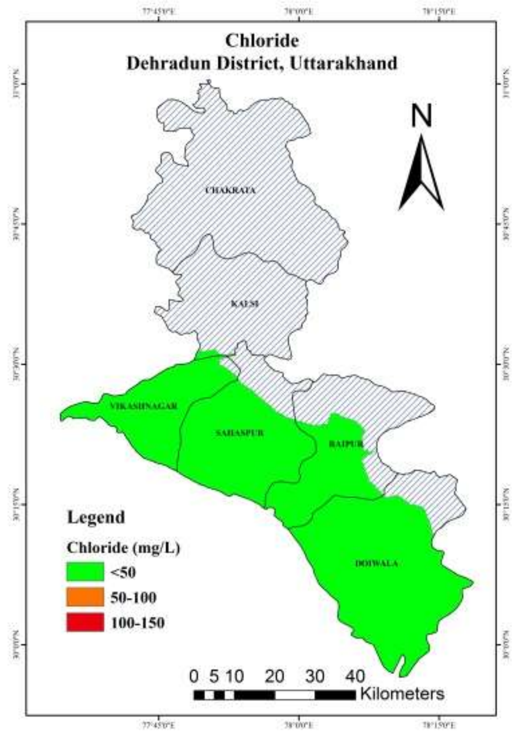


Fig3.18(b): Chloride Map of the Study area

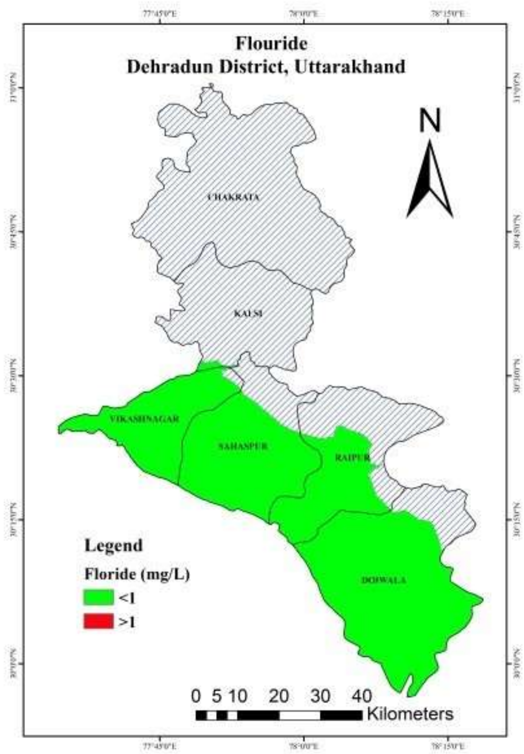


Fig 3.18(c): Fluoride Map of the Study area

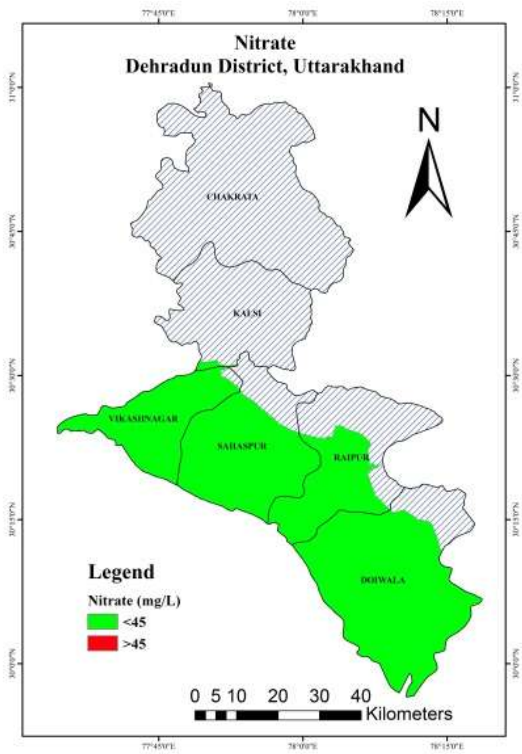


Fig 3.18(d): Nitrate Map of the Study area

CHAPTER 4

GROUND WATER RESOURCES

4.0 INTRODUCTION

Dynamic Ground Water Resource Estimation for the year 2020 has been carried out for the three administrative blocks (Sahaspur, Vikashnagar and Doiwala) as ground water assessment units by CGWB. The precise estimation of ground water reserves and irrigation potential is prerequisite for proper planning and execution for socio-economic development in the area. The ground water recharge has been estimated on the basis of water level fluctuation method and Rainfall Infiltration Method. The dynamic ground water resource estimation is summarized as follows in **Table: 4.1.**

Table: 4.1 Summary of Assessment of Dynamic Ground Water Resources of Dehradun District (2020)

1.	Total Annual ground water recharge by all sources	**59,709.89 ham**
2.	Annual Extractable Ground Water Resource in the district	**54,883.83 ham**
3.	Existing gross ground water draft for all uses	**11946.81 ham**
4.	Annual GW Allocation for Domestic Use as on 2025	**5460.81 ham**
5.	Net ground water available for future use	**42,937.02 ham**
6.	Stage of ground water development average of district	**21.77%**
7.	Number of Safe Blocks (Out of Total blocks assessed)	**3 (3)**
8.	Number of OCS blocks (Out of Total blocks assessed)	**0 (3)**

4.1 Rechargefrom Rainfall

Precipitation is the principal source of recharge to ground water in the district. The quantity of recharge depends upon the intensity and duration of rainfall, nature and texture of soil, vegetation cover and land use pattern of the area. Recharge from rainfall has been computed separately for monsoon and non-monsoon periods. Recharge from rainfall is mainly a function of geographical area of the district, normal monsoon rainfall and lithology of the area. The recharge from rainfall during monsoon season has been computed using mainly Water Level Fluctuation Method &Rainfall Infiltration Factor Method, whereas recharge from rainfall during non-monsoon period has been computed using Rainfall Infiltration Factor Method. Block-wise recharge from rainfall is given in **Table: 4.2.**

Table: 4.2 Details of Recharge and Natural discharge (ham), Study Area, Dehradun District (Uttarakhand)

Sl. No	District	Assessment Unit Name	Total Area of Assessment Unit (Ha)	Recharge from Rainfall-Monsoon Season	Recharge from Other Sources-Monsoon Season	Recharge from Rainfall-Non Monsoon Season	Recharge from Other Sources-Non Monsoon Season	Total Annual Ground Water (Ham) Recharge	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)
1	**Dehradun**	**Doiwala**	51057	20,107.32	767.1	1194.47	1,940.66	22,898.46	1,144.92	21,753.54
2	**Dehradun**	**Sahaspur**	52,061	22,547.75	526.81	1217.96	1,835.09	24,960.13	2,496.01	22,464.12
3	**Dehradun**	**Vikashnagar**	22426	9,712.76	825.38	524.65	1,238.67	11,851.30	1,185.13	10,666.17

4.2 Recharge from Other Sources

Total Recharge to ground water has several components, rainfall being the major one. The other component include seepage from canals, return flow from surface water irrigation, return flow from ground water irrigation, seepage from Tanks and Ponds etc. for command area. Block wise recharge from other sources is also given in **Table: 4.2.** The recharge from other sources during monsoon and non-monsoon period in Dehradun district is 2119.29 ham and 5014.42 ham respectively.

4.3 Recharge from All Sources

Total replenishable ground water resources including rainfall recharge and recharge from other sources have been computed block- wise which is presented Table: 4.2. Total annual ground water recharge from all sources in Dehradun is of the order 59709.89 ham with Sahaspur block having the highest recharge of 24960.13 ham whereas Vikashnagar block has the minimum recharge of the order of 11851.30 ham.

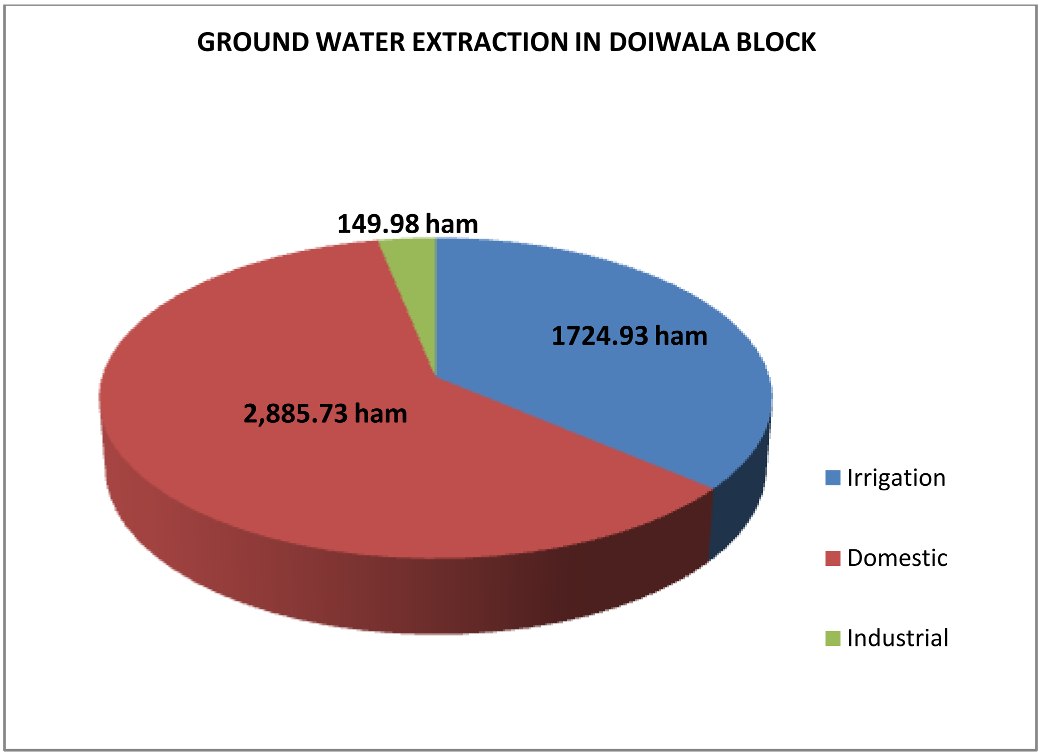
4.4 Unaccounted Natural Discharge and Annual Extractable Groundwater Resource

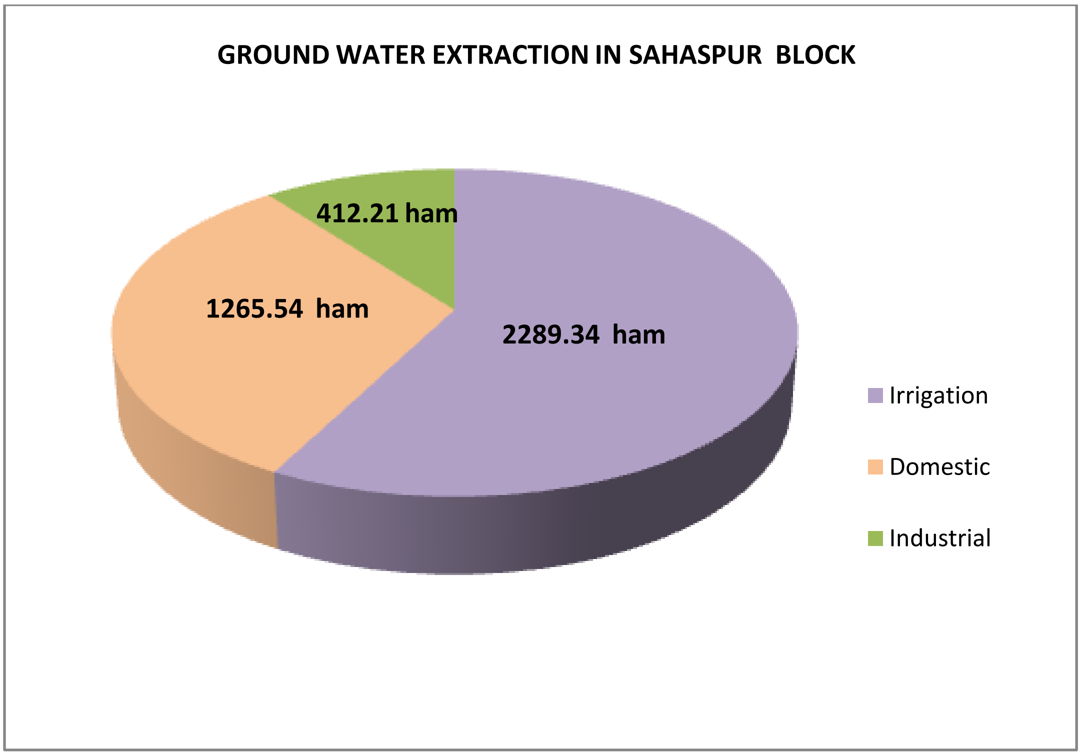
The total annual ground water recharge of the area is the sum of monsoon and non-monsoon recharge. An allowance of 5-10 % of total annual ground water recharge has been kept for natural discharge in the non-monsoon season because WLF/RIF method respectively is employed to compute rainfall recharge during monsoon season. The balance of ground water available accounts for existing net ground water availability for various uses and potential for future development. Block wise unaccounted natural discharge and net ground water availability is given in **Table: 4.2**. Total unaccounted natural discharge in all the blocks is of the order of 4826.06 ham, with Sahaspur block having the highest discharge of 2496.01 ham and Doiwala block with lowest of 1144.92 ham. Annual extractable groundwater resource in the district is 54883.83 ham with Sahspur block having the highest Annual extractable groundwater resource of 22464.12 ham followed by Vikashnagar and Doiwala.

4.5 Ground Water Draft

The ground water draft is the quantity of water withdrawn from ground water reservoirs. The principal ground water development structures for utilization of ground water in the district are dug wells, private tubewells/ government tubewells/ government tubewells constructed under minor irrigation works and by other state government departments.

On the basis of statistical data available on the number of various ground water structures, the block wise annual gross draft has been computed by multiplying the average discharge of the wells and their annual operational hours. The total draft (extraction) for all the blocks of Dehradun district is 11946.81 ham. From the **Table: 4.3**, it is seen that maximum ground water draft (extraction) for all uses is ham in Doiwala block is 4760.64 ham and minimum draft of ground water for all uses is 3219.08 ham in Vikashnagar block. The blockwise groundwater draft due to various sources have been illustrated in **Fig: 4.1 .**


GROUND WATER EXTRACTION IN DOIWALA BLOCK
149.98 ham
1724.93 ham
2,885.73 ham
Irrigation
Domestic
Industrial


GROUND WATER EXTRACTION IN SAHASPUR BLOCK
412.21 ham
1265.54 ham
2289.34 ham
Irrigation
Domestic
Industrial

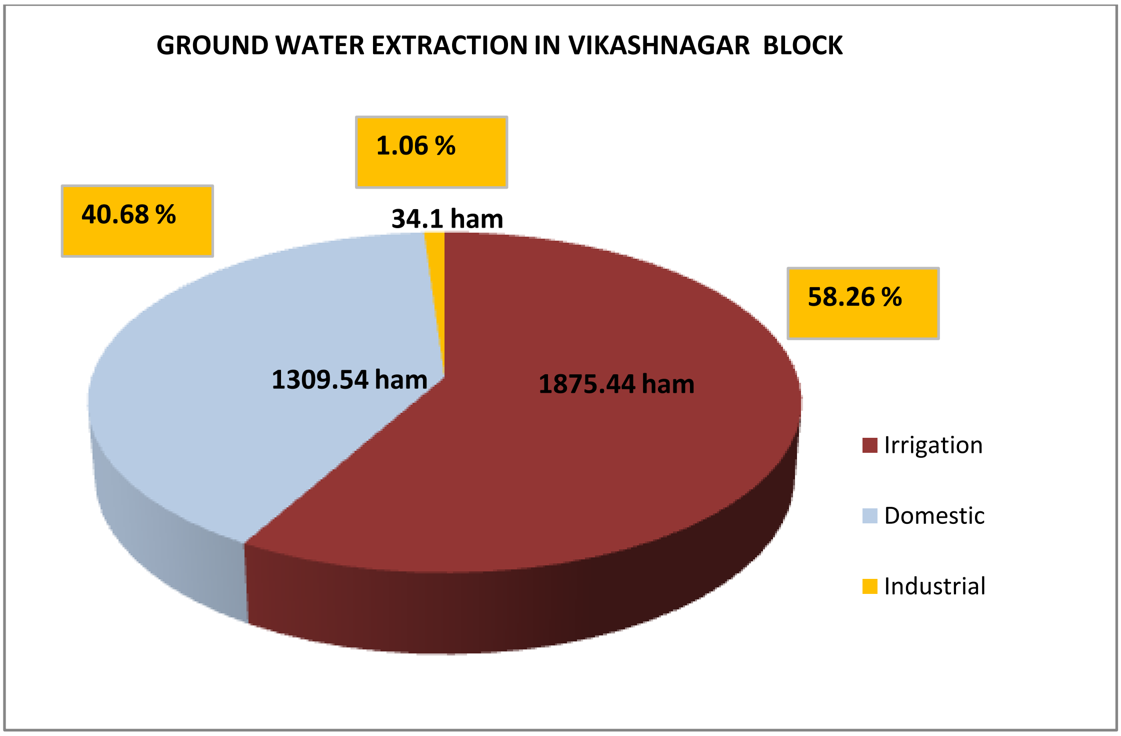


Figure 4.1: Pie charts representing groundwater draft due to different purposes in the Doiwala block, Sahaspur block and Vikasnagr block of the study area

4.6 Stage of Ground Water Extraction and Categorization of Blocks

The Stage of Ground Water Extraction in Dehradun has been worked out for each blocks as the ratio of existing gross ground water extraction for all uses to Annual Extractable Ground Water Resource.

The distributions of various categorized blocks in Dehradun district are shown in the **Table: 4.3.** All the blocks of Dehradun District fall under the Safe Category with an average of 21.77% Stage of GW Extraction for the entire district.

Table: 4.3 Details of Draft for Different Purposes, Study Area, Dehradun District (Uttarakhand)

Sl. No	District	Assessment Unit Name	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization (Over-Exploited /Critical/ Semicritical/ Safe/Saline)
1	**Dehradun**	**Doiwala**	1724.93	149.98	2,885.73	4760.64	2885.73	16,992.90	21.88	**Safe**
2	**Dehradun**	**Sahaspur**	2289.34	412.21	1265.54	3967.09	1265.54	18,497.03	17.66	**Safe**
3	**Dehradun**	**Vikashnagar**	1875.44	34.1	1309.54	3219.08	1309.54	7,447.09	30.18	**Safe**

CHAPTER 5

GROUND WATER MANAGEMENT PLANS

5. GROUND WATER MANAGEMENT PLANS

Ground water issues can be addressed by focusing on measures to increase recharge and reducing the draft.It can be managed by a mix of measures such as:

Supply Side Management

• Water conservation and Artificial Recharge to ground water

• On Farm Activities and

Demand Side Management

• Adoption of techniques to enhance water Use Efficiency

• Adoption of new irrigation practices in sugarcane cultivation area to save 35-40 % irrigation water.

5.1Status of Ground Water Development

Groundwater is developed mainly through tubewells and India mark-II hand pumps. Jal Sansthan, Jal Nigam and Irrigation departments have constructed a number of tubewells in Doiwala, Sahaspur and Vikas Nagar blocks to meet the domestic and irrigational requirements. In hilly areas, springs and gadheras form the main sources of drinking water. The springs are developed for irrigation purpose also. India mark-II hand pump is common in hilly areas also. The depth of the tubewells, constructed in Doon Valley, range in depth from 50 to 150 m bgl whereas the discharge ranges from 500 to 1500 lpm.

5.1.1 Urban Water Supply Schemes

The existing water supply system in Dehradun city, which is more than 30 years old, consists of three sub systems viz. North zone, South zone and Pithuwala zone. The North zone is supplied mostly with surface water sources, and south and Pithuwala zones (peri urban areas) are supplied with ground water from tube wells located at various places in the city. All water supply scheme of the city is implemented by Uttarakhand Pey Jal Nigam (UPJN) and maintained by Uttarakhand Jal Sansthan (UJS).

In-spite of the adequate water sources availability as per sub project appraisal report of Uttarakhand Urban Sector Development Investment Program (ground water within the city and surface water near by the city) and water production of about 178 MLD, the actual supply at the consumer end is only 71.2 MLD, due to the huge losses in the system. The per capita supply at the consumer end averages to 114 lpcd in place of 135 lpcd creating a demand and supply Gap which needs to be minimised by implementing interventions like rainwater harvesting and other artificial recharge measures.

As per the data of Uttarakhand Urban Sector Development Investment Program, the present water production of 178 MLD, is sufficient to meet water demand of Dehradun till the year 2026, and the present inadequacy in the water supply system, is due to poor water management, old and leaking distribution system and inadequate water treatment facility. These issues need to be addressed immediately to provide water supply to the citizens of Dehradun as per the National standards. The **Table:5.1** shows the major demand and supply gap of different parameters.

Table 5.1: Demand- Supply Gap in Urban Water Supply Schemes in Dehradun district.

Parameters	**Present Status**	**Requirement/ demand**			**Gap**
		2011	**2026**	**2041**	
Population covered with city water supply system	6,25,206	6,25,206	10,12,189	14,88,274	2011: NIL 2026: 3,86,983 2041: 8,63,068
Population receiving water as per GOI standard	NIL	6,25,206	10,12,189	14,88,274	2011: 6,25,206 2026: 10,12,189 2041: 14,88,274
Service delivery standard at the consumer end (1)Average per capita supply (2) Duration (3) Quality	114 Ipcd 8 hr. contaminated (7%) and hard water (6%)	135 Ipcd 24 hr Potable water (100%)			21 Ipcd 16 hr
Production of Potable water	178 MLD	118 MLD	189 MLD	279 MLD	2011:NIL 2026: 11 MLD 2041: 101 MLD
Physical losses	107 MLD	23 MLD (20%)	38 MLD (20%)	56 MLD (20%)	Reduction by 71 LMD (40%)
Consumer end supply	71 MLD	95 MLD	151 MLD	223 MLD	2011: 24 MLD 2026: 80 MLD 2041: 152 MLD

Considering that 80% of the water supply is being done through ground water, the gap in the Supply clearly indicates that a huge stress will be created on the groundwater resources with the increasing population in the Dehradun district due to migration of people from the hilly areas of Uttarakhand State.

5.2 Increasing Storage Capacity and Conservation of Rainfall

Supply Side Management

Recharge / Water Conservation

• Water conservation structures such as check dams, farm ponds, nalabunds etc result in ground water recharge to the tune of about 50% of the storage capacity considering 3 annual fillings. Further construction of recharge trenches in the upstream side of the check dams is also proposed to enhance rate of infiltration by about 30 to 40%.

• The existing ponds and tanks lose their storage capacity as well as the natural ground water recharge due to siltation and encroachment by farmers for agriculture purposes. Through desilting, coupled with providing proper waste weir, the village tanks can be converted into recharge structure.

5.3 On Farm Practices

Supply Side Management

• Leveling of crop field is essential for uniform distribution of water. Laser leveling has been found very effective ensuring saving of 10 to 30% of applied irrigation. The in situ farm activities such as contour bounding, land leveling, bench terracing, water harvesting structures, a forestation and diversification of cropping pattern are other measures to increase recharge in the block.

5.4 Enhancing Water Use Efficiency

Demand Side Management

Efficient irrigation

• In flood/furrow irrigation method more than 50% of applied water is wasted through seepage to deeper level, localized inundation causes loss through evaporation and it leaches out the nutrients from the plant.

• Adoption of new irrigation practices in sugarcane cultivation area to save 35-40 % irrigation water

• While through drip & sprinkler irrigation wastage of irrigational water could be minimized. The conveyance losses (mainly seepage & evaporation) can be saved upto 25 to 40% through utilization of HDPE pipes.

• Agriculture department should promote to conserve the soil moisture by reducing ET losses through cultivation of 'Green Manure'

Diversification of cropping pattern

• Horticulture department should promote Baghwani in the area. This will bring in money without high use of water. These will also help conserve soil moisture.

• Alternate cropping system having lower requirement of water are better option.

• Summer paddy and maize need to be avoided which are grown over substantial area in the Doiwala block.

• Large scale adoption of rice-wheat rotation system is the main reason of over exploitation of groundwater. Late sown wheat/peas are replaced by spring maize which consumes more water. Suggested cropping pattern are as under.

• Kharif- Maize, cotton, sorghum, pulses, groundnut

• Rabi- Mustard, gram, pulses, vegetable

• By adopting suggested croppingpattern 20 to 30% of irrigation water saving is possible.

Effective Use of Waste Water

- The greywater generated from the industrial offices and buildings can be further treated in series of greywater treatment ponds which will in turn provide substantial benefits for water supply system by reducing the demand for fresh clean water and for wastewater system by reducing the amount of wastewater required to be conveyed and treated.

Water Management Training Programs and IEC Activities

Four training programmes were conducted by CGWB in District Dehradun on topics like per drop more crop, Groundwater management and Rainwater harvesting and Artificial Recharge. The target groups included MES Engineers, Uttarakhand Jal Sansthan, Jalagam, Uttarakhand Pey Jal Nigam, Degree college professors and students, NGOs, Irrigation, Mirror irrigation, Block Development Officers etc.

Public Interaction programs have also been conducted in Raipur and Doiwala blocks of the Dehradun district in order to make the public aware of the local groundwater system and ways of managing groundwater for sustainable use. Awareness campaigns on Rainwater harvesting and Artificial recharge have been conducted in various schools in the district., State Government officers and officials have been provided training in Tier II and Tier III training programs regarding local groundwater scenario, effective groundwater management and conservation techniques.

5.5 Conclusion and Recommendation

As it has been established that there is sufficient, exploitable, ground water resource available both in quantity and quality, it is recommended that:

- Artificial recharge is recommended only for those locations where water levels are deep and the aquifer has the potential to recharge.
- Tubewells should be constructed scientifically viz. suitable sites, distance between them, identifying aquifer parameters, recommended discharge and drawdown, recuperation time etc. should be strictly adhered to.
- Geophysical logging is recommended for deciphering the exact potential zones.
- Tubewell assemblies should be shrouded with a thick gravel pack, so as to avoid pumping of sand and silt and screen size and gravel pack size should be determined after carrying out proper grain size analysis of the aquifer to be tapped.
- Conjuctive use of surface and groundwater should be parctised in order to reduce the load on aquifers. Overpumping/Overdrawal from aquifer should not be allowed in any case.
- To arrest the decline in ground water levels and depletion of ground water resources, there is urgent need to implement both Supply side and Demand side measures which includes artificial recharge and water conservation, On-farm activities and adoption of water use efficiency measures.
- There is considerable scope for implementing Roof Top Rain Water Harvesting in the urban areas of the district. Check dams, nala bunds, renovation of ponds are ideal structures for rain water harvesting in rural areas. Water conservation structures such as check dams, farm ponds, nala bunds etc. result in ground water recharge to the tune of about 40% of the storage capacity considering 3 annual fillings.
- It is also proposed to adopt On Farm practices such as laser leveling, bench terracing, construction of farm ponds, afforestation, diversification of crops etc.
- Alternate cropping system having lower requirement of water should be encouraged in accordance to the irrigation water availability.
- Furrow irrigation with raised bed planting in wide row crops should be practised. 10. Drip irrigation (fertigation) in sugarcane and other wide row crops should be practised with mulch in the area. 11. Multi use of water through integrated farming system.
- Modern irrigation practices like drips and sprinklers, skip furrow method of irrigation, ring and pit method of sugarcane planting etc. should be adopted as these methods can effectively save 30-40% of irrigation water.

- A water budget should be formulated for the overall district in a blockwise or village wise manner and farmers should be encouraged to grow crops accordingly for that particular season/year.
- The nned of the hour is to conduct participatory ground water management in the area which will further help in bringing more awareness among the common farmers and local people.
- All efforts should be taken to ensure treatment of waste disposal both solid and liquid from industries and urban areas to prevent pollution of ground water and surface water.

BLOCKWISE GROUND WATER MANAGEMENT PLANS

BLOCKWISE GROUND WATER MANAGEMENT PLAN

(DOIWALA BLOCK, DEHRADUN DISTRICT, UTTARAKHAND)

General Information:

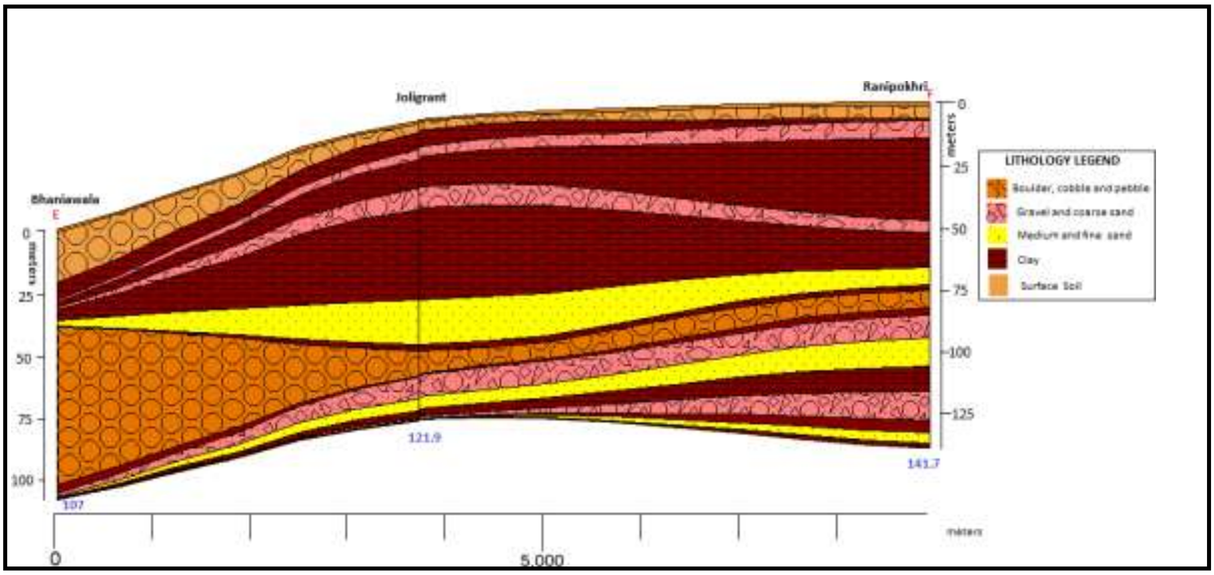
GEOGRAPHICAL AREA	1000 sq km
BASIN/SUB-BASIN	Ganga
PRINCIPAL AQUIFER SYSTEM	Dun Gravel
MAJOR AQUIFER SYSTEM	Boulders Gravels and Sand of Dun Gravel
NORMAL ANNUAL RAINFALL	1550mm

Latitude	78°16'12.62" E and 30°18'00.55" N 78°10'50.21" E and 29°56'19.68" N
Longitude	78°18'35.19" E and 30°06'28.18" N 77°59'00.71" E and 30°11'53.39" N

Aquifer Disposition

Aquifer Disposition	The potential zones are in the form of boulders with the highest thickness of the boulders encountered at Bhaniawala and five potential zones tapped (41-47m, 49-55m, 62-68m, 71-77m, 80-88m). The gravel and fine to medium sand form potential zones for rest of the section with zones tapped at 82-85m, 88- 97m and 103-118m at Joligrant and at 83-86m, 88-96m, 100-105m, 115-128m and 135-138m at Ranipokhri.
Status of GW Exploration	Exploratory wells under NAQUIM: 03 nos (Ranipokhari, Jolly grant and Bhaniyawala)
Aquifer Characteristics	Confined- semi confined multi-tiered aquifer and in places unconfined aquifer exists
GW Quality	The groundwater quality is good and fit for drinking,domestic and irrigation purposes.
Aquifer Potential	The yield prospects are good with discharge ranging between 2000-3000 lpm and drawdown ranging from 2-7m.

CGWB Monitoring Status	NHS Monitoring wells: 10 nos



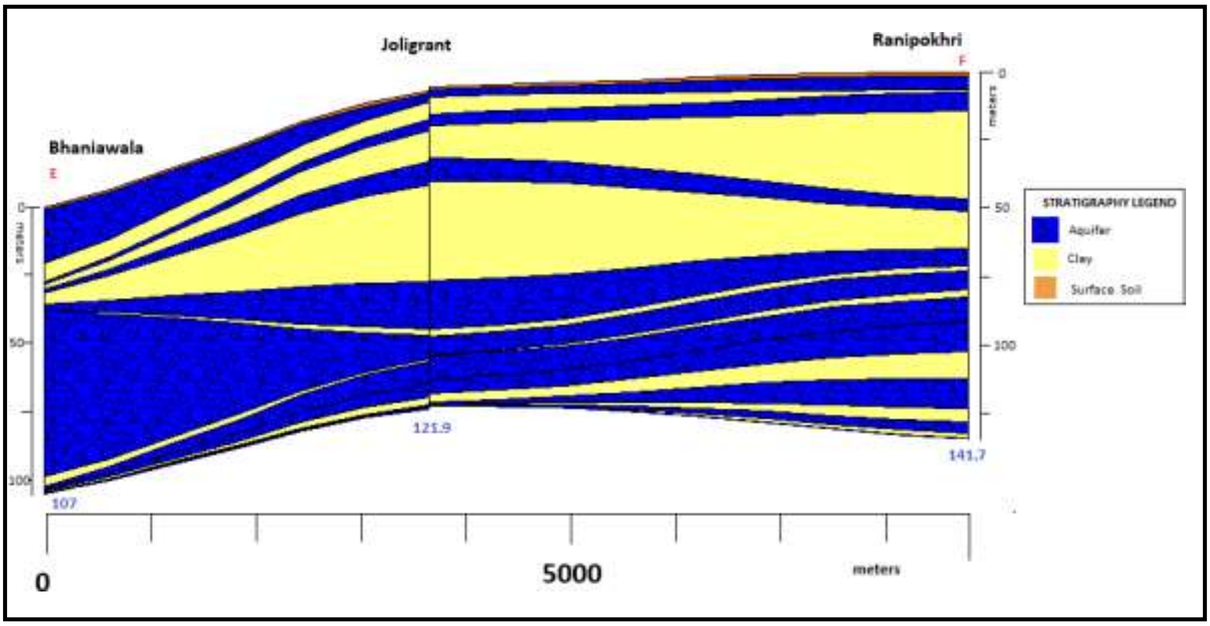


Fig: 6.1 (a) Section Depicting Sub-surface Lithological Variation from Bhaniawala to Ranipokhri
(b): Section depicting Sub-surface aquifer disposition from Bhaniawala to Ranipokhri

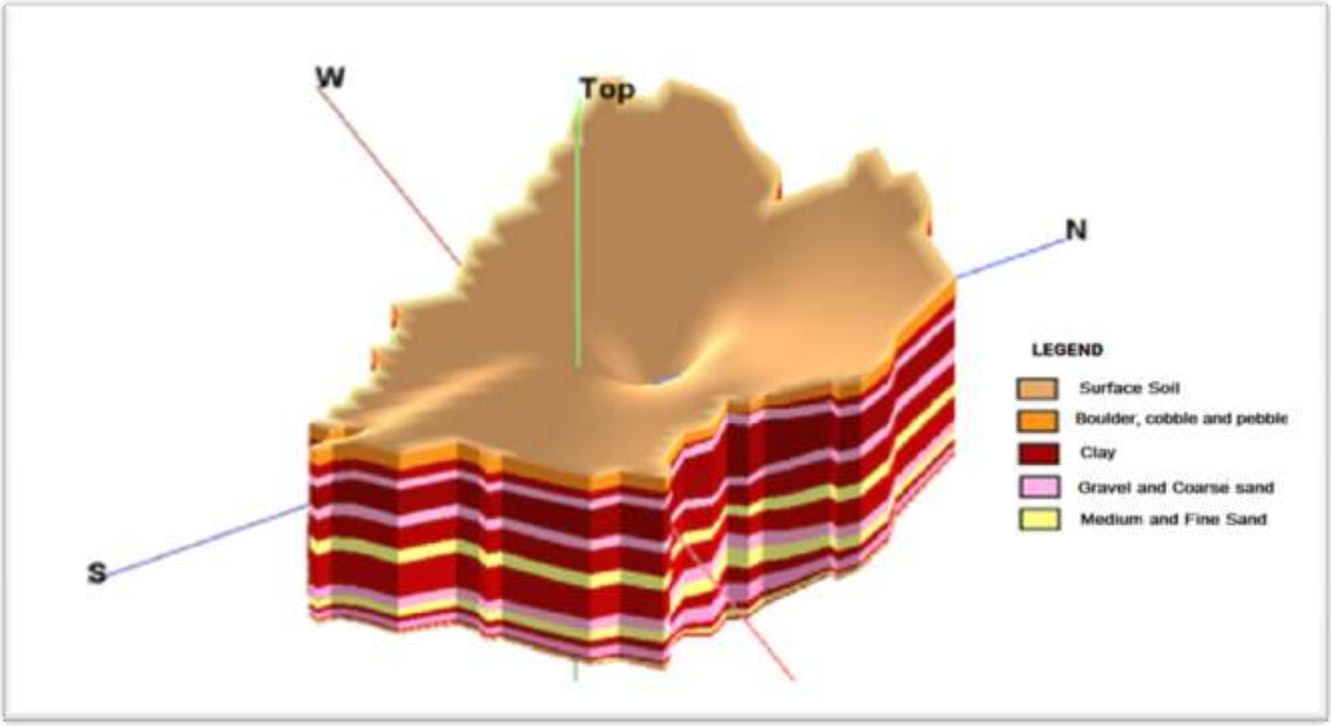
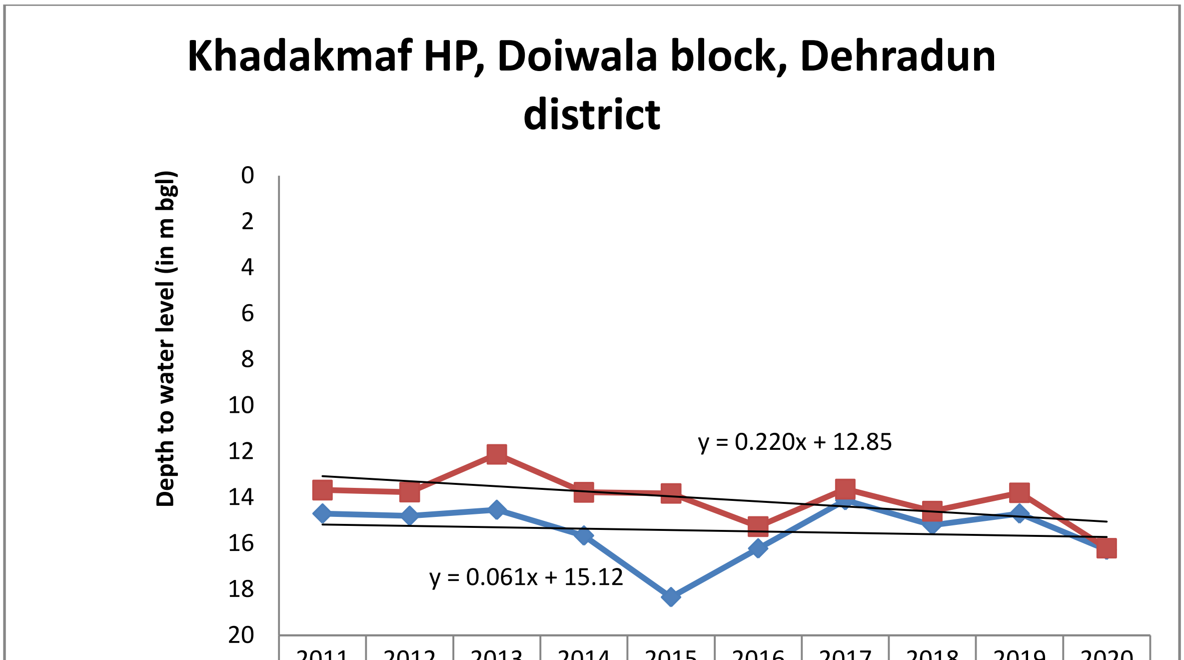
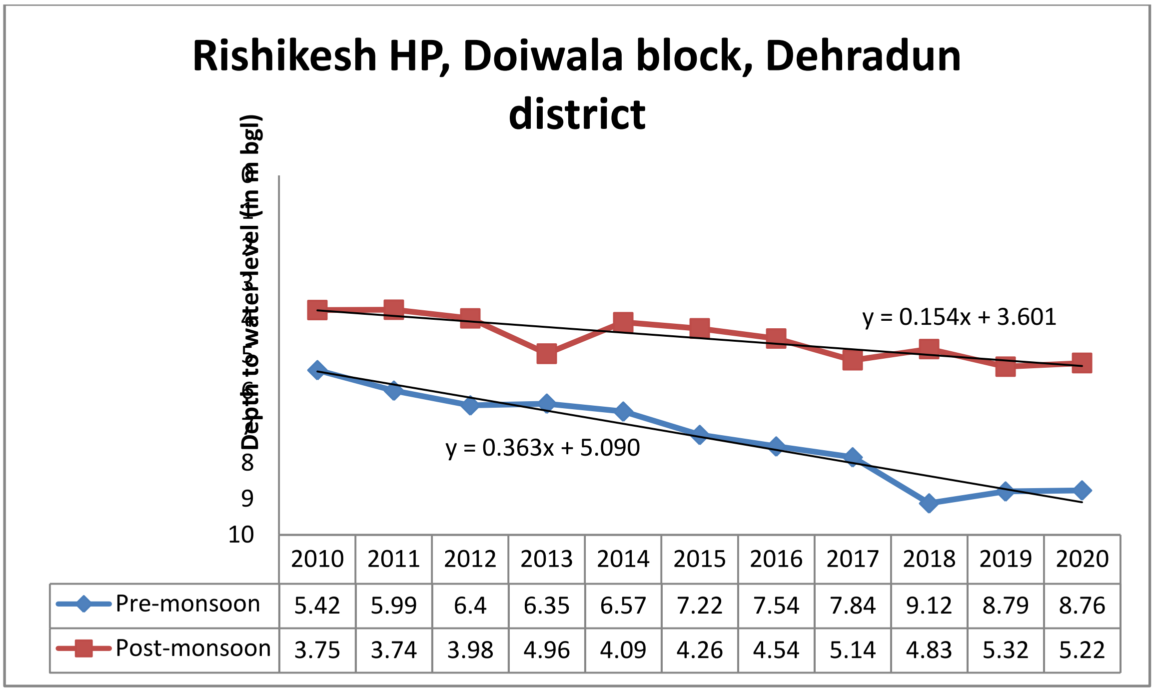


Fig6.2 3D Model of Doiwala block depicting Sub-surface Lithological Variation



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pre-monsoon	14.7	14.8	14.54	15.66	18.34	16.22	14.12	15.2	14.7	16.28
Post-monsoon	13.68	13.77	12.13	13.78	13.83	15.27	13.64	14.6	13.8	16.21



AQUIFER MANAGEMENT PLAN

GW Management Issues	DeclineinwaterleveltrendintheBlock
GW Resource	AnnualExtractableGWRecharge:217.54 MCM,GWDraft: 47.60 MCM, StageofGWDevelopment:21.88%Totalin-storageresourceoftheDistrict(fresh)is169.92 MCMCategorization-Safe
GW Stage of Development (%)	21.88
Existing and Future Water Demand	PresentdemandforAllUsage 47.60 MCM FutureDemandforDomesticUse:28.85 MCM

WATER MANAGEMENT PLAN OF DOIWALA BLOCK

Supply Side Management

Water conservation and Artificial Recharge to ground water

• Water conservation structures such as check dams, farm ponds, nalabunds etc result in ground water recharge to the tune of about 50% of the storage capacity considering 3 annual fillings.

Further construction of recharge trenches in the upstream side of the check dams is also proposed to enhance rate of infiltration by about 30 to 40%.

• The existing ponds and tanks lose their storage capacity as well as the natural ground water recharge due to siltation and encroachment by farmers for agriculture purposes. Through desilting, coupled with providing proper waste weir, the village tanks can be converted into recharge structure.

Water Management through Rooftop Rain Water Harvesting and Artificial Recharge

Due to the increasing population and increasing trend of expansion of the city limits, there has been construction of buildings for residential as well as non-residential purposes resulting in the concretization of the open areas. This has led to a drastic decrease in the infiltration of rainwater within the sub-surface soil leading to a decrease in natural recharge and lowering of groundwater levels.

Surface water sources are limited and in order to sustain the increasing population load in terms of drinking water, water for domestic use and irrigational practices, we have to depend on groundwater. Hence there is a dire need of storing the rainwater and recharging the groundwater through artificial means. Rainwater harvesting is the collection and storage of rainwater that runs off from rooftops, parks, roads, and open ground commonly termed as runoff. This runoff can be either stored or recharged into the groundwater through artificial recharge techniques.

Doiwala block, Dehradun district covering an area of 1000 sq. km (NAQUIM Area) falls in the South Eastern part of Dehradun district. The block receives an annual rainfall of 2151.2 mm. Using the real-time data through Google Earth, the residential areas were demarcated which comprised clusters of residential buildings, schools, colleges, offices and other commercial buildings as viewed in Satellite data. 39.6 sq. km of area is available at present with good potential of implementing rooftop rainwater harvesting. Industrial pocket of 0.24 sq. km was also demarcated where there is potential for Rainwater Harvesting and Artificial recharge.

However, keeping in mind the infrastructural development that is yet to happen like the building of new roads, parking areas, footpaths, etc., 50% of the potential area has been considered which can be utilized for rooftop rainwater harvesting.

Area suitable for Rooftop rainwater harvesting (at present)= 19920000 sq.m

Annual Rainfall (as per IMD data of 2019-20)= 2151.2 mm or 2.15 m

Runoff Generated= Suitable Area * Normal Rainfall * Runoff Coefficient

The Runoff Coefficient of tiled roofs can be considered 0.8- 0.9 while roofs made up of corrugated metal sheets have a runoff coefficient of 0.7- 0.9 (Source: Rainwater Harvesting and Conservation Manual, Govt. of India). An average runoff coefficient of 0.7 has been considered to estimate the runoff generated.

Estimated Annual Quantum of Runoff Generated = 19920000 m^2 * 2.15 m * 0.7

= 29979600 m^3 or 2997.96 ham

As per the Ground Water Resource Estimation, 2020 the current groundwater extraction due to domestic and industrial use in respect of Doiwala block is 2885.73 ham and 149.98 ham respectively. Using proposed rooftop rainwater harvesting, 2997.96 ham of water can be harvested annually which can be used for various domestic purposes and can bring down the current extraction requirements. Since the study area has good potential for recharge, the stored runoff can also be artificially recharged through the construction of recharge shafts or recharge pits in areas having post-monsoon water levels greater than 7-8 m bgl. The map shows the areas which have been identified as clusters having the potential of implementing rooftop rainwater harvesting presently (fig: 6.3).

The other areas, marked in yellow (Fig: 6.3) are mostly agricultural fields and are demarcated as suitable areas for water conservation through on- farm activities. Farm ponds, chalkhal, efficient irrigation practices like drip irrigation and sprinklers can help in water conservation. The river Ganga flows through the southern part of the block around Rishikesh area where the river water can be diverted to feeder channels or canals and the surface water can be used for irrigating the nearby agricultural lands.

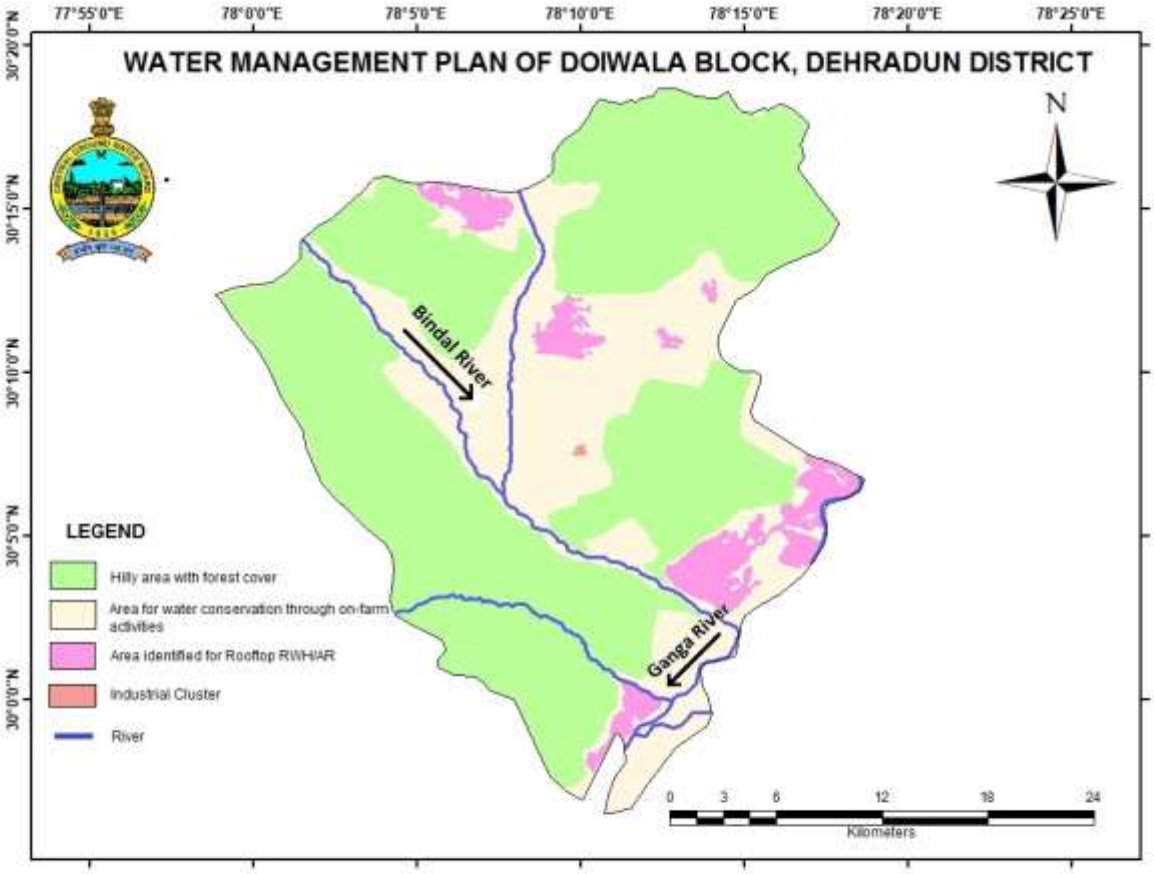


Fig: 6.3Map showing Water Management Plan of Doiwala Block, Dehradun

The Bindal River along with its small tributaries mostly remain dry during lean period, however during monsoon attains flow. Small Gabion structures can be constructed across such small streams to conserve stream flows with practically no submergence beyond stream course. The boulders can be stored in a steel wire and such structures can easily be made using locally available boulders and are cost- effective. The height of such structures is around 0.5 m and is normally used in the streams with width of about 10 to 15 m. The excess water overflows this structure storing some water to serve as source of recharge. The silt content of stream water in due course is deposited in the interstices of the boulders to make it more impermeable.

The hilly areas are also demarcated in Fig: 6.3 which are covered with forests and have steep slopes. Such areas are very appropriate for Springshed Development and Management. Pilot projects can be taken up in such areas to identify the lost springs and rejuvenate them since springs are the lifeline in hills.

On Farm Practices

• Levelling of crop field is essential for uniform distribution of water. Laser levelling has been found very effective ensuring saving of 10 to 30% of applied irrigation. The in situ farm activities such as contour bounding, land levelling, bench terracing, water harvesting structures, afforestation and diversification of cropping pattern are other measures to increase recharge in the block.

Fig6.4 Field Pics showing agricultural activities taking place in Doiwala Block

Demand Side Management

Efficient irrigation

• In flood/furrow irrigation method more than 50% of applied water is wasted through seepage to deeper level, localized inundation causes loss through evaporation and it leaches out the nutrients from the plant.

• Adoption of new irrigation practices in sugarcane cultivation area to save 35-40 % irrigation water

• While through drip & sprinkler irrigation wastage of irrigational water could be minimized. The conveyance losses (mainly seepage & evaporation) can be saved upto 25 to 40% through utilization of HDPE pipes.

• Agriculture department should promote to conserve the soil moisture by reducing ET losses through cultivation of 'Green Manure'

Effective Use of Waste Water

- The grey-water generated from the industrial offices and buildings can be further treated in series of grey-water treatment ponds which will in turn provide substantial benefits for water supply system by reducing the demand for fresh clean water and for wastewater system by reducing the amount of wastewater required to be conveyed and treated.

(VIKASNAGAR BLOCK, DEHRADUN DISTRICT, UTTARAKHAND)

General Information:

GEOGRAPHICAL AREA	224.26 sq km
BASIN/SUB-BASIN	Ganga
PRINCIPAL AQUIFER SYSTEM	Dun Gravel
MAJOR AQUIFER SYSTEM	Boulders Gravels and Sand of Dun Gravel
NORMAL ANNUAL RAINFALL	1550mm

Latitude	77°52'07.61" E and 30°30'54.04" N 77°46'51.03" E and 30°18'39.42" N
Longitude	77°53'43.95" E and 30°30'54.04" N 77°34'30.13" E and 30°24'04.50" N

Aquifer Disposition

Aquifer Disposition	The potential zones are in the form of boulders and gravel with the highest thickness of the boulders encountered at Jamankhata. Confined-semi confined multi-tiered aquifer conditions exist in the Chhorba-Rampura part of the section which changes to unconfined condition at the Jamankhata part. The yield prospects are good and discharge of 1629 lpm has been encountered at Chhorba with a reasonable drawdown.
Status of GW Exploration	Exploratory wells under NAQUIM: 01 no (Jamankhata)
Aquifer Characteristics	Confined- semi confined multi-tiered aquifer and in places unconfined aquifer exists
GW Quality	The groundwater quality is good and fit for drinking,domestic and irrigation purposes.
Aquifer Potential	The yield prospects are good with discharge ranging between 2000-3000 lpm and drawdown ranging from 2-7m.

Location	Typeofwell	1st Zonetapped	2nd Zonetapped	3rd Zonetapped	4th Zonetapped
Jamankhata	EW	60-64m	72-84m	87-99m	105-109m
CGWB Monitoring Status	NHS Monitoring wells: 11 nos				

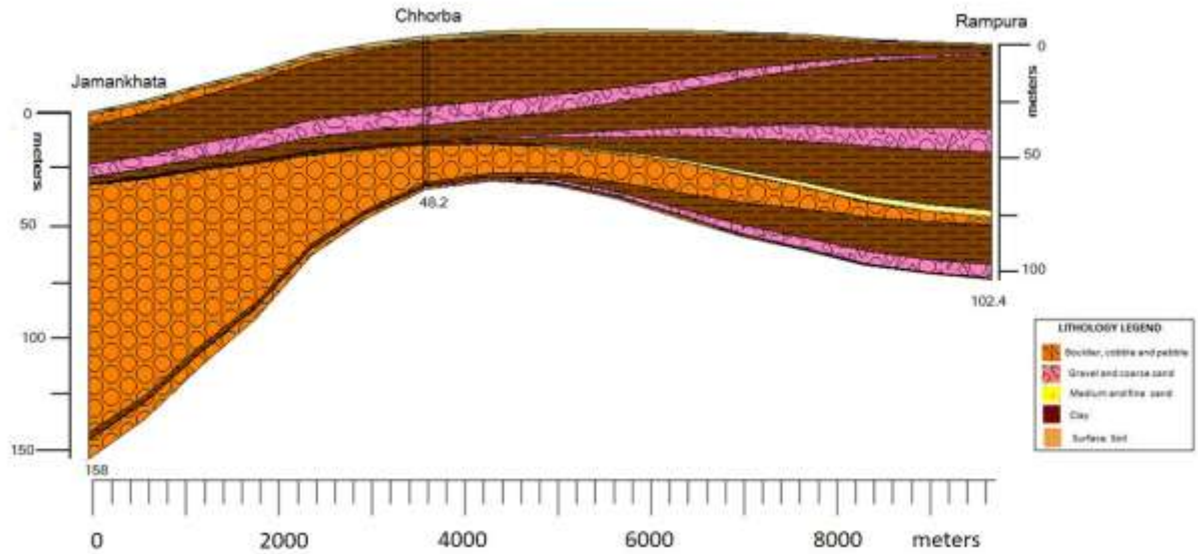


Fig6.5 (a) Section Depicting Sub-surface Lithological Variation from Jamankhata to Rampura

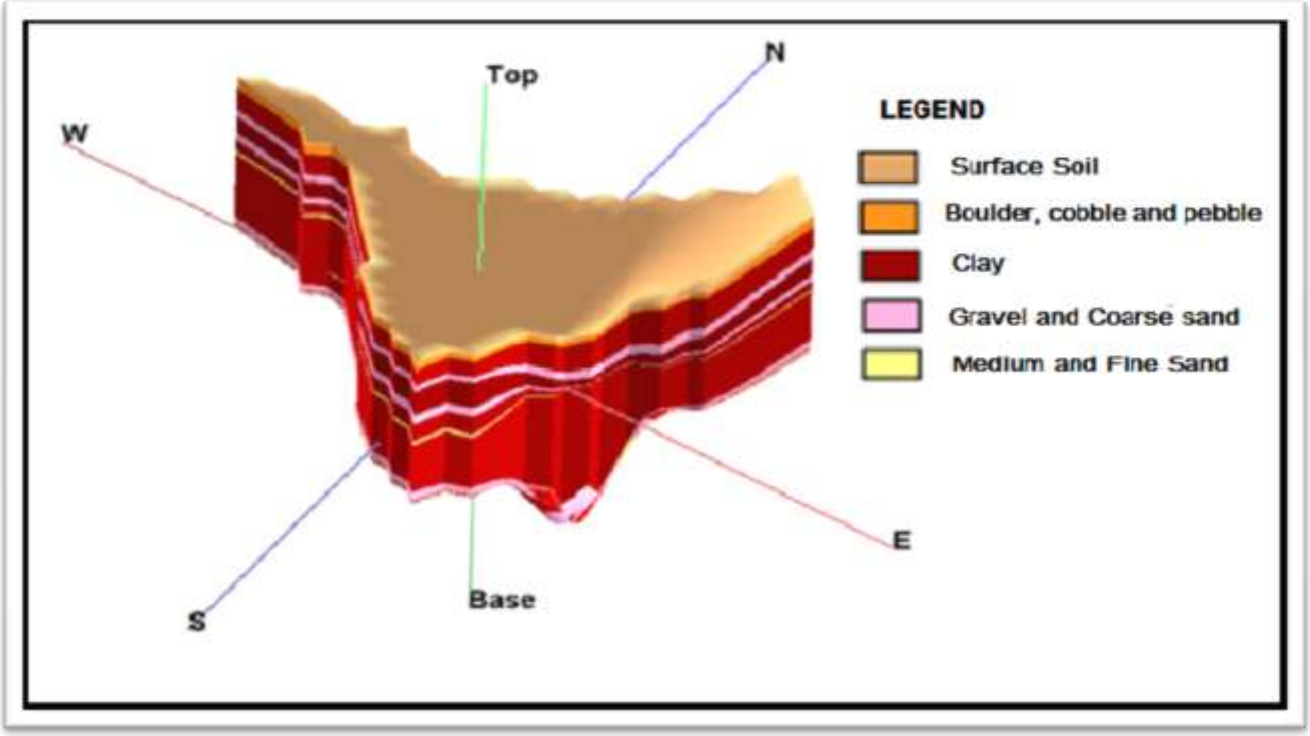
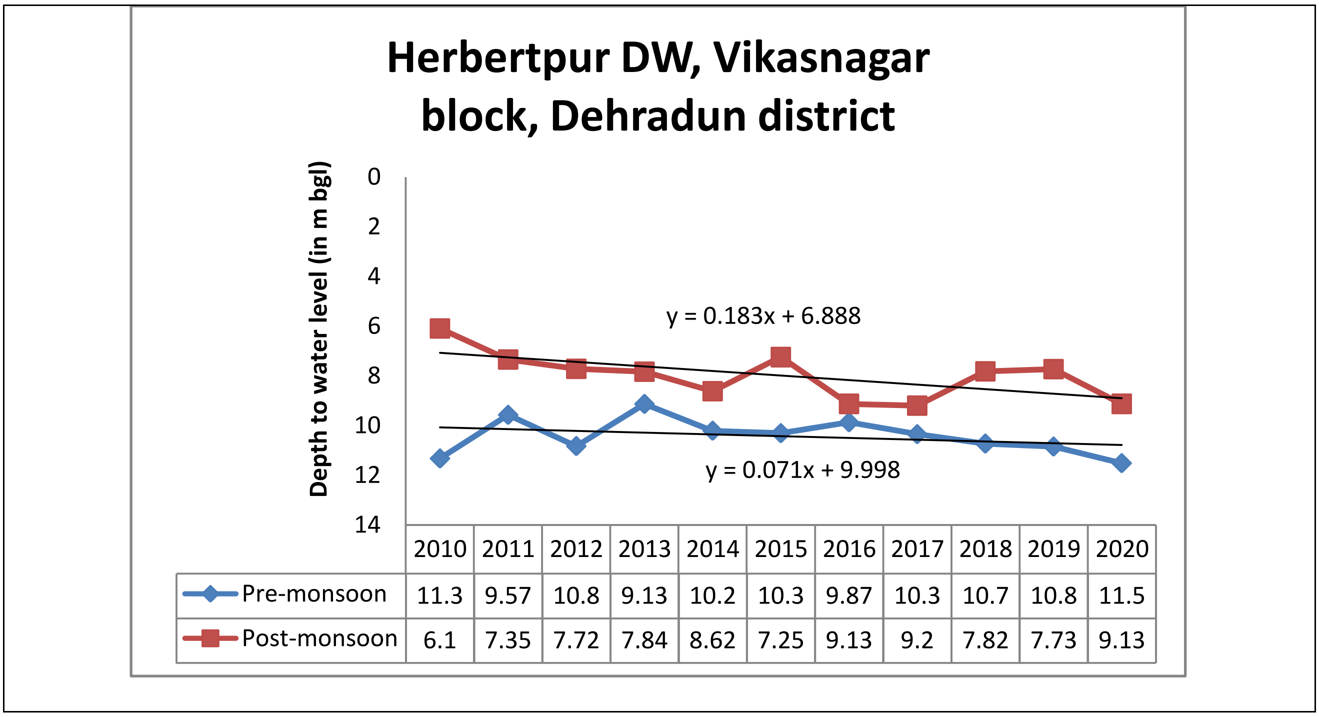
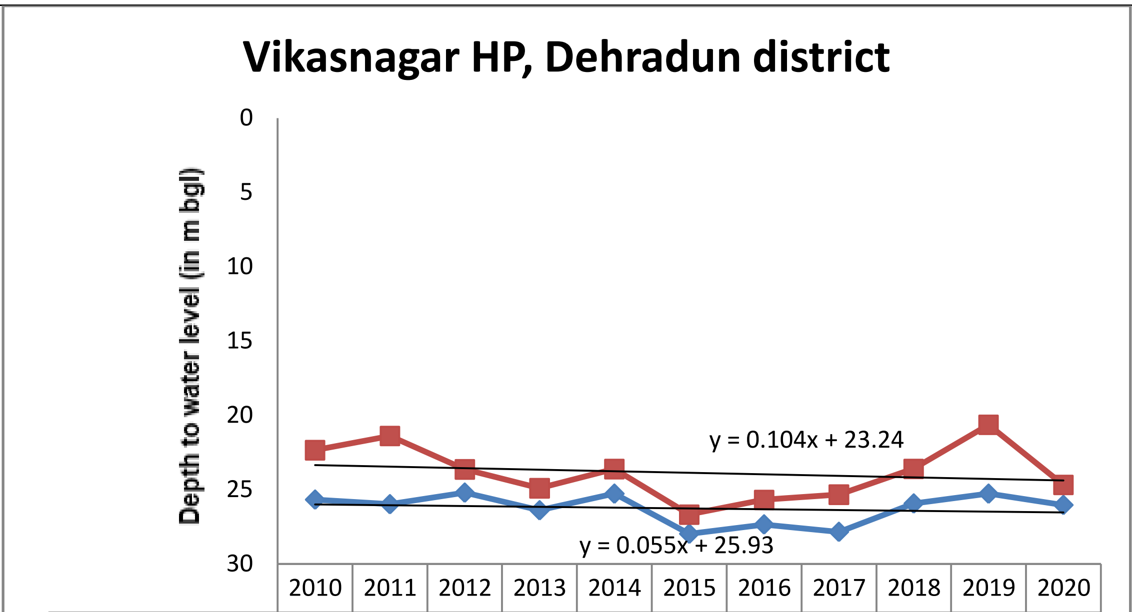


Fig: 6.6 3D Model of Vikasnagar block depicting Sub-surface Lithological Variation



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pre-monsoon	11.3	9.57	10.8	9.13	10.2	10.3	9.87	10.3	10.7	10.8	11.5
Post-monsoon	6.1	7.35	7.72	7.84	8.62	7.25	9.13	9.2	7.82	7.73	9.13



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pre-monsoon	25.68	25.99	25.21	26.4	25.28	27.98	27.35	27.85	25.94	25.28	26.04
Post-monsoon	22.35	21.4	23.64	24.91	23.62	26.68	25.69	25.34	23.61	20.65	24.69

AQUIFER MANAGEMENT PLAN

GW Management Issues	DeclineinwaterleveltrendintheBlock
GW Resource	AnnualExtractableGWRecharge:106.66 MCM,GWDraft: 32.19 MCM, Stageof GWDevelopment:30.18%Totalin-storageresourceof the District(fresh)is74.47MCMCategorisation-Safe
GW Stage of Development(%)	30.18
Existing and Future Water Demand	PresentdemandforAllUsage: 32.19 MCM FutureDemandforDomesticUse:13.09 MCM

WATER MANAGEMENT PLAN OF VIKASNAGAR BLOCK

Supply Side Management

Water conservation and Artificial Recharge to ground water

• Water conservation structures such as check dams, farm ponds, nalabunds etc result in ground water recharge to the tune of about 50% of the storage capacity considering 3 annual fillings. Further construction of recharge trenches in the upstream side of the check dams is also proposed to enhance rate of infiltration by about 30 to 40%.

• The existing ponds and tanks lose their storage capacity as well as the natural ground water recharge due to siltation and encroachment by farmers for agriculture purposes. Through desilting, coupled with providing proper waste weir, the village tanks can be converted into recharge structure.

Water Management through Rooftop Rain Water Harvestingand Artificial Recharge

Due to the increasing population and increasing trend of expansion of the city limits, there has been construction of buildings for residential as well as non-residential purposes resulting in the concretization of the open areas. This has led to a drastic decrease in the infiltration of rainwater within the sub-surface soil leading to a decrease in natural recharge and lowering of groundwater levels.

Surface water sources are limited and in order to sustain the increasing population load in terms of drinking water, water for domestic use and irrigational practices, we have to depend on groundwater. Hence there is a dire need of storing the rainwater and recharging the groundwater through artificial means. Rainwater harvesting is the collection and storage of rainwater that runs off from rooftops, parks, roads, and open ground commonly termed as runoff. This runoff can be either stored or recharged into the groundwater through artificial recharge techniques.

Vikasnagar block, Dehradun district covering an area of 224.26 sq. km (NAQUIM Area) lies in the Western part of Dehradun district sharing boundaries with Himachal Pradesh and Uttar Pradesh. The block receives an annual rainfall of 2151.2 mm. Using the real-time data through Google Earth, the residential areas were demarcated which comprised clusters of residential buildings, schools, colleges, offices and other commercial buildings as viewed in Satellite data. 6.53 sq. km of area is available at present with good potential of implementing rooftop rainwater harvesting.

However, keeping in mind the infrastructural development that is yet to happen like the building of new roads, parking areas, footpaths, etc., 50% of the potential area has been considered which can be utilized for rooftop rainwater harvesting.

Area suitable for Rooftop rainwater harvesting (at present)= 3265000 sq.m

Annual Rainfall (as per IMD data of 2019-20)= 2151.2 mm or 2.15 m

Runoff Generated= Suitable Area * Normal Rainfall * Runoff Coefficient

The Runoff Coefficient of tiled roofs can be considered 0.8- 0.9 while roofs made up of corrugated metal sheets have a runoff coefficient of 0.7- 0.9 (Source: Rainwater Harvesting and

ConservationManual, Govt. of India). An average runoff coefficient of 0.7 has been considered to estimate the runoff generated.

Estimated Annual Quantum of Runoff Generated = 3265000 m^2 * 2.15 m * 0.7

= 4913825 m^3 or 491.38 ham

As per the Ground Water Resource Estimation, 2020 the current groundwater extraction due to domestic use in respect of Vikasnagar block is 1309.54 ham. Using proposed rooftop rainwater harvesting, 491.38 ham of water can be harvested annually which can be used for various domestic purposes and can bring down the current extraction requirements. Since the study area has good potential for recharge, the stored runoff can also be artificially recharged through the construction of recharge shafts or recharge pits in areas having post-monsoon water levels greater than 7-8 m bgl. The map shows the areas which have been identified as clusters having the potential of implementing rooftop rainwater harvesting presently (fig: 6.7).

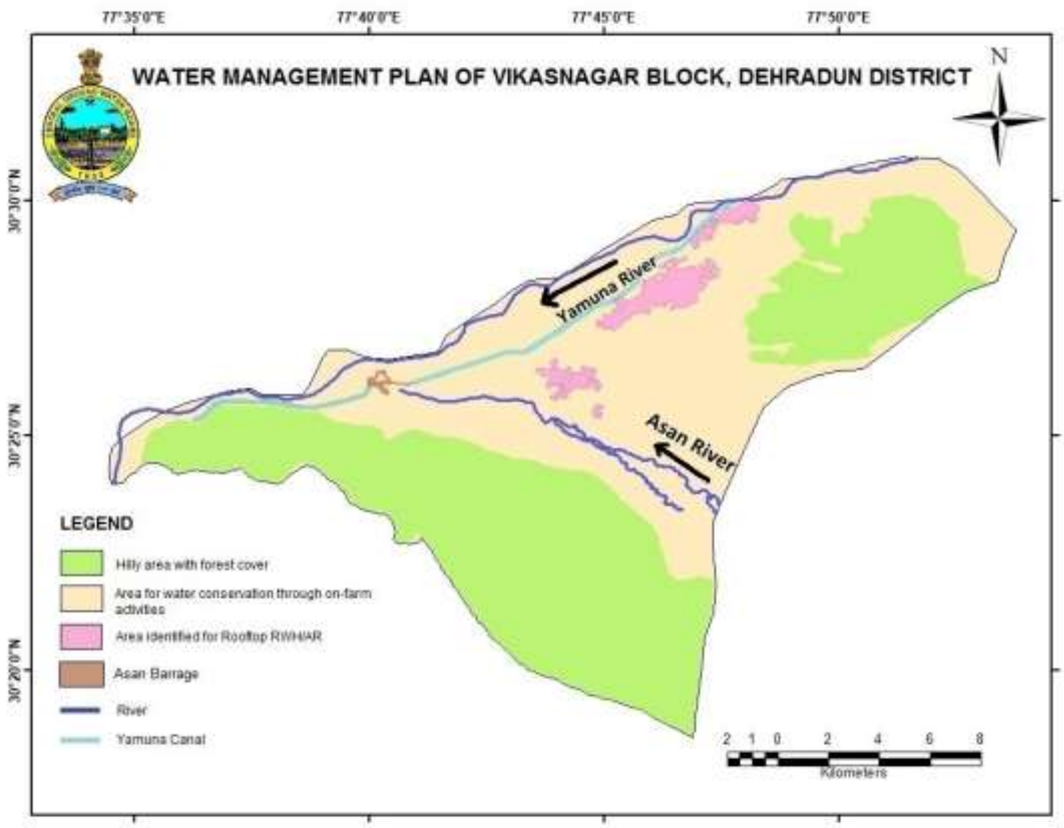


Fig: 6.7 Map showing Water Management Plan of Vikasnagar Block, Dehradun

The other areas, marked in yellow (Fig: 6.7) are mostly agricultural fields and are demarcated as suitable areas for water conservation through on- farm activities. Farm ponds, chalkhal, efficient irrigation practices like drip irrigation and sprinklers can help in water conservation. The river Yamuna flows through the northern part of the block. The river water is diverted through the Dakpathar Barrage to the Yamuna Canal whichserves as the main surface water source for irrigation.

The hilly areas are also demarcated in Fig: 6.7 which are covered with forests and have steep slopes. Such areas are very appropriate for Springshed Development and Management. Pilot projects can be taken up in such areas to identify the lost springs and rejuvenate them since springs are the lifeline in hills.

On Farm Practices

• Levelling of crop field is essential for uniform distribution of water. Laser levelling has been found very effective ensuring saving of 10 to 30% of applied irrigation. The in situ farm activities such as contour bounding, land levelling, bench terracing, water harvesting structures, a forestation and diversification of cropping pattern are other measures to increase recharge in the block.

Demand Side Management

Efficient irrigation

• In flood/furrow irrigation method more than 50% of applied water is wasted through seepage to deeper level, localized inundation causes loss through evaporation and it leaches out the nutrients from the plant.

• Adoption of new irrigation practices in sugarcane cultivation area to save 35-40 % irrigation water

• While through drip & sprinkler irrigation wastage of irrigational water could be minimized. The conveyance losses (mainly seepage & evaporation) can be saved up to 25 to 40% through utilization of HDPE pipes.

• Agriculture department should promote to conserve the soil moisture by reducing ET losses through cultivation of 'Green Manure'

Effective Use of Waste Water

- The grey-water generated from the industrial offices and buildings can be further treated in series of grey-water treatment ponds which will in turn provide substantial benefits for water supply system by reducing the demand for fresh clean water and for wastewater system by reducing the amount of wastewater required to be conveyed and treated.

(SAHASPUR BLOCK, DEHRADUN DISTRICT, UTTARAKHAND)

General Information:

GEOGRAPHICAL AREA	520.61 sq km
BASIN/SUB-BASIN	Ganga
PRINCIPAL AQUIFER SYSTEM	Dun Gravel
MAJOR AQUIFER SYSTEM	Boulders Gravels and Sand of Dun Gravel
NORMAL ANNUAL RAINFALL	1550mm

Latitude	78°00'58.76" E and 30°28'25.73" N 77°56'17.70" E and 30°14'34.15" N
Longitude	78°01'48.36" E and 30°20'32.15" N 77°46'57.55" E and 30°18'31.11" N

Aquifer Disposition

Aquifer Disposition	The clay proportion is highest at a stretch of 6 kms starting from Chhorba to Rampura and gradually pinches out in the South east towards Forest Research Institute. The thickness of the first clay layer varies from 16 m (Jamankhata) to 30m (Chhorba) and pinches out in the SE direction. The second clay layer has non uniform thickness throughout the section with the highest thickness of 35 m encountered at Rampura. The potential zones are in the form of boulders and gravel with the highest thickness of the boulders encountered at Jamankhata and Forest Research Institute. Confined- semi confined multi-tiered aquifer conditions exist in the NW part of the section which changes to unconfined condition at the SE part. The yield prospects are good and discharge of 1629 lpm has been encountered at Chhorba with a reasonable drawdown.
Status of GW Exploration	Exploratory wells under NAQUIM: 03 no (Chhorba, Rampura, Forest Research Institute)
Aquifer Characteristics	Confined- semi confined multi-tiered aquifer conditions exist in the NW part of the section which changes to unconfined condition at the SE part. The yield prospects are good and discharge of 1629 lpm has

	been encountered at Chhorba with a reasonable drawdown.
GW Quality	The groundwater quality is good and fit for drinking,domestic and irrigation purposes.
Aquifer Potential	The yield prospects are good with discharge ranging between 2000-3000 lpm and drawdown ranging from 2-7m.
CGWB Monitoring Status	NHS Monitoring wells: 11 nos

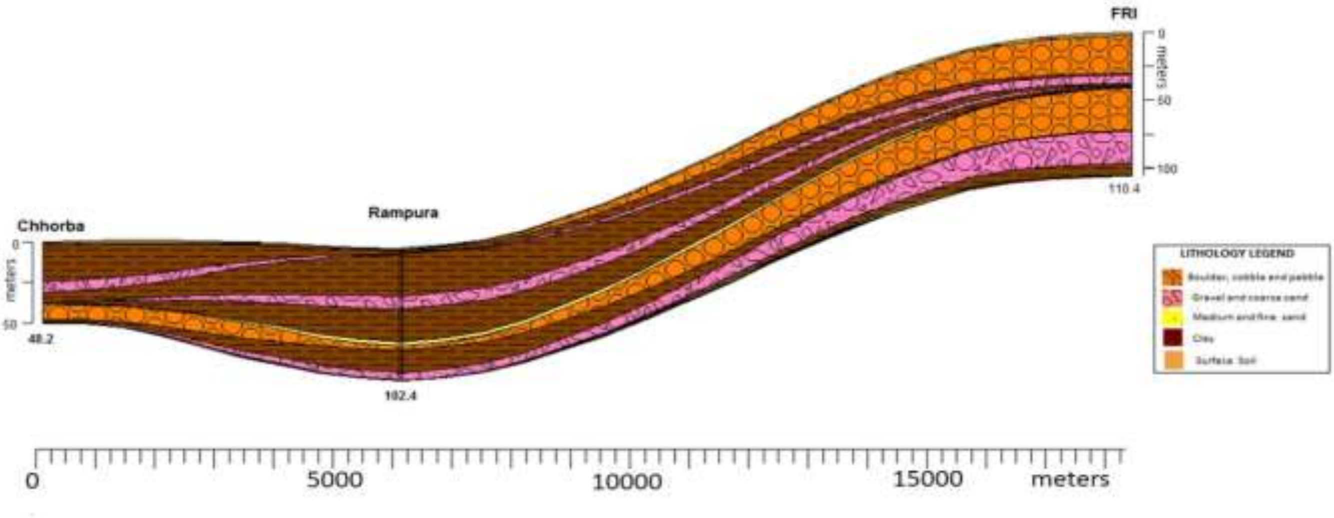


Fig6.8 Section Depicting Sub-surface Lithological Variation from Chhorba to Forest research Institute (FRI)

Location	Type of well	1st Zone tapped	2nd Zone tapped	3rd Zone tapped	4th Zone tapped	5th Zone tapped
Chhorba	EW	45-48 m	60-70 m	84-92 m	94-107 m	
Rampura	EW	35-45 m	54-57 m	74-77 m	105-112 m	114-117 m
Forest Research Institute	EW	29.5- 35.6 m	83.8- 102 m			

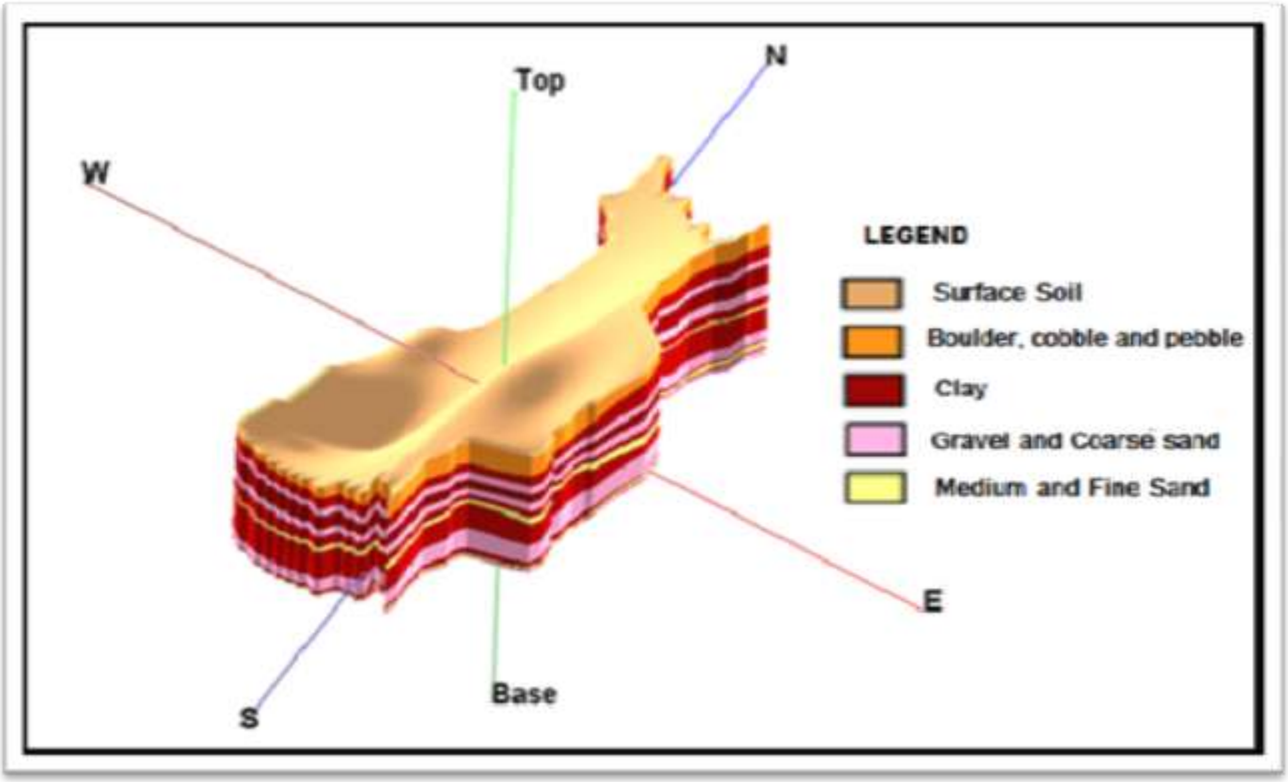
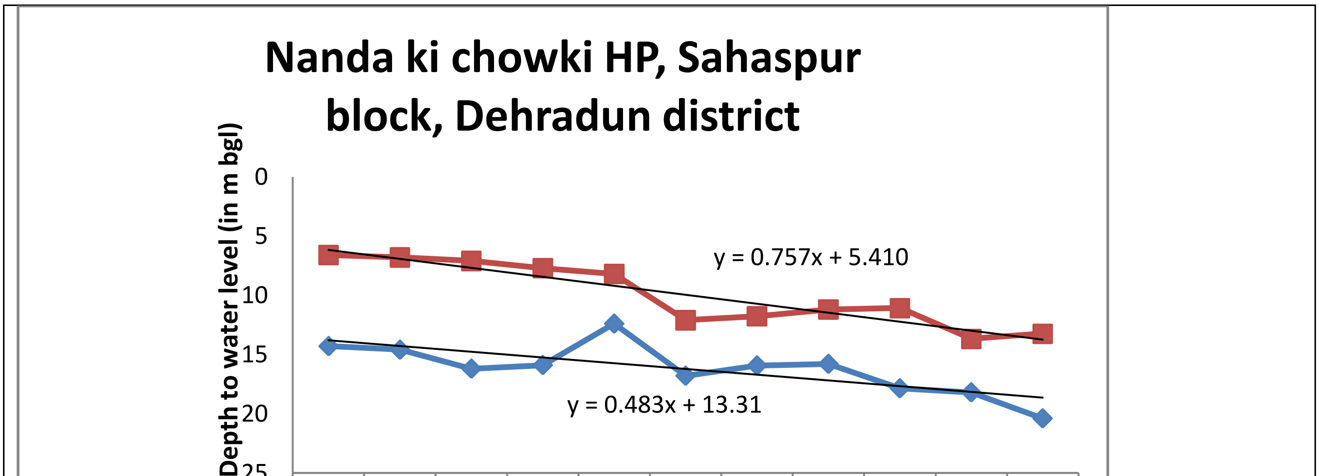
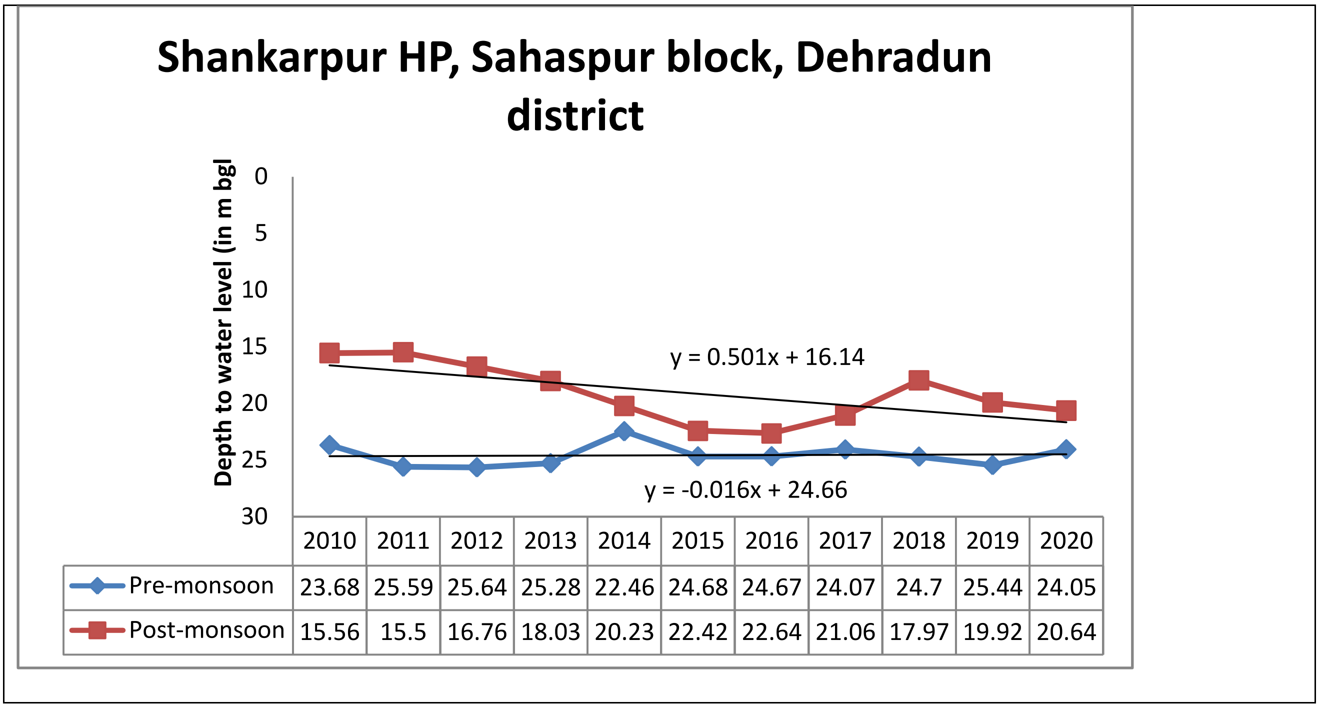


Fig: 6.9 3D Model of Sahaspur block depicting Sub-surface Lithological Variation



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pre-monsoon	14.3	14.6	16.2	15.9	12.4	16.8	15.93	15.8	17.86	18.2	20.4
Post-monsoon	6.6	6.8	7.1	7.7	8.2	12.1	11.77	11.2	11.08	13.68	13.25



AQUIFER MANAGEMENT PLAN

GW Management Issues	Decline in water level trend in the Block
GW Resource	AnnualExtractableGWRecharge:249.60 MCM,GWDraft: 39.67 MCM, StageofGWDevelopment:17.66%Totalin-storageresourceoftheDistrict(fresh)is184.97 MCMCategorisation-Safe
GW Stage of Development(%)	17.66
Existing andFuture Water Demand	PresentdemandforAllUsage39.67 MCM FutureDemandforDomesticUse:12.65 MCM

WATER MANAGEMENT PLAN OF SAHASPUR BLOCK

<u>Supply Side Management</u>

Water conservation and Artificial Recharge to ground water

• Water conservation structures such as check dams, farm ponds, nalabunds etc result in ground water recharge to the tune of about 50% of the storage capacity considering 3 annual fillings. Further construction of recharge trenches in the upstream side of the check dams is also proposed to enhance rate of infiltration by about 30 to 40%.

• The existing ponds and tanks lose their storage capacity as well as the natural ground water recharge due to siltation and encroachment by farmers for agriculture purposes. Through desilting, coupled with providing proper waste weir, the village tanks can be converted into recharge structure.

Water Management through Rooftop Rain Water Harvestingand Artificial Recharge

Due to the increasing population and increasing trend of expansion of the city limits, there has been construction of buildings for residential as well as non-residential purposes resulting in the concretization of the open areas. This has led to a drastic decrease in the infiltration of rainwater within the sub-surface soil leading to a decrease in natural recharge and lowering of groundwater levels.

Surface water sources are limited and in order to sustain the increasing population load in terms of drinking water, water for domestic use and irrigational practices, we have to depend on groundwater. Hence there is a dire need of storing the rainwater and recharging the groundwater through artificial means. Rainwater harvesting is the collection and storage of rainwater that runs off from rooftops, parks, roads, and open ground commonly termed as runoff. This runoff can be either stored or recharged into the groundwater through artificial recharge techniques.

Sahaspur block, Dehradun district covering an area of 520.61 sq. km (NAQUIM Area) falls in the central part of Dehradun district. The block receives an annual rainfall of 2151.2 mm. Using the real-time data through Google Earth, the residential areas were demarcated which comprised clusters of residential buildings, schools, colleges, offices and other commercial buildings as viewed in Satellite data. 17.05 sq. km of area is available at present with good potential of implementing rooftop rainwater harvesting. Industrial pockets of 4.51 sq. km were also demarcated where there is potential for Rainwater Harvesting and Artificial recharge.

However, keeping in mind the infrastructural development that is yet to happen like the building of new roads, parking areas, footpaths, etc., 50% of the potential area has been considered which can be utilized for rooftop rainwater harvesting.

Area suitable for Rooftop rainwater harvesting (at present)= 10780000 sq.m

Annual Rainfall (as per IMD data of 2019-20)= 2151.2 mm or 2.15 m

Runoff Generated= Suitable Area * Normal Rainfall * Runoff Coefficient

The Runoff Coefficient of tiled roofs can be considered 0.8- 0.9 while roofs made up of corrugated metal sheets have a runoff coefficient of 0.7- 0.9 (Source: Rainwater Harvesting and Conservation

Manual, Govt. of India). An average runoff coefficient of 0.7 has been considered to estimate the runoff generated.

Estimated Annual Quantum of Runoff Generated = 10780000 m^2 * 2.15 m * 0.7

= 16223900 m^3 or 1622.39 ham

As per the Ground Water Resource Estimation, 2020 the current groundwater extraction due to domestic and industrial use in respect of Sahaspur block is 1265.54 ham and 412.21 ham respectively. Using proposed rooftop rainwater harvesting, 1622.39 ham of water can be harvested annually which can be used for various domestic purposes and can bring down the current extraction requirements. Since the study area has good potential for recharge, the stored runoff can also be artificially recharged through the construction of recharge shafts or recharge pits in areas having post-monsoon water levels greater than 7-8 m bgl. The map shows the areas which have been identified as clusters having the potential of implementing rooftop rainwater harvesting presently (fig: 6.10).

The other areas, marked in yellow (Fig: 6.10) are mostly agricultural fields and are demarcated as suitable areas for water conservation through on- farm activities. Farm ponds, chalkhal, efficient irrigation practices like drip irrigation and sprinklers can help in water conservation. The Asan River flows through the southern portion of the block for quite a long stretch. The river water can be diverted to feeder channels or canals and the surface water can be used for irrigating the nearby agricultural lands.

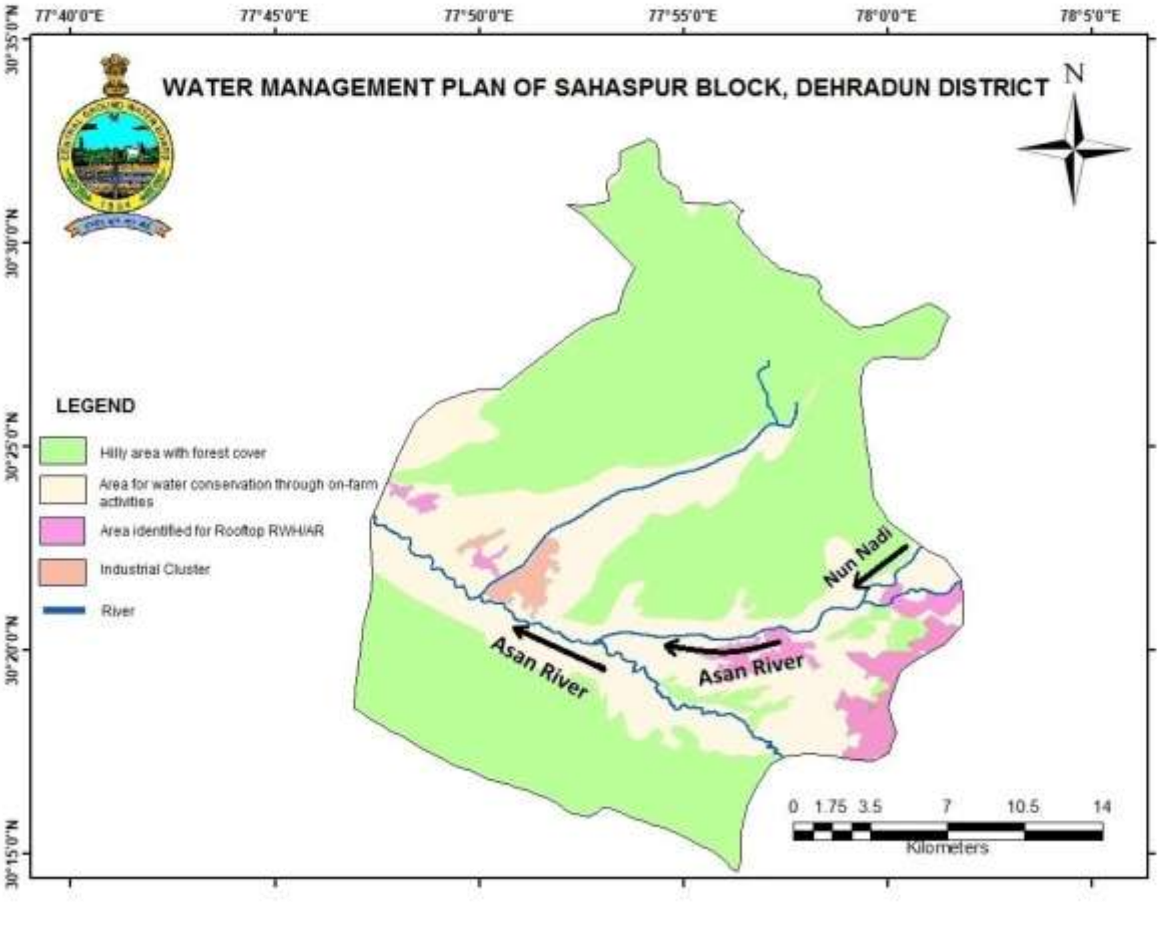


Fig: 6.10 Map showing Water Management Plan of Sahaspur Block, Dehradun

The Nun River along with other small tributaries join the Asan River along their course. Small Gabion structures can be constructed across such small streams to conserve stream flows with practically no submergence beyond stream course. The boulders can be stored in a steel wire and such structures can easily be made using locally available boulders and are cost- effective. The height of such structures is around 0.5 m and is normally used in the streams with width of about 10 to 15 m. The excess water overflows this structure storing some water to serve as source of recharge. The silt content of stream water in due course is deposited in the interstices of the boulders to make it more impermeable.

Industrialization in this block is taking place along the tributaries of the Asan River which may lead to pollution of the surface water body and deteriorate the quality of river water and also influence the groundwater quality. Urbanization, industrialization and encroachment all along the path of the river and its tributaries will lead to increase in runoff potential and change in hydrological scenario which may in turn result to urban flooding.

The hilly areas are also demarcated in Fig: 6.10 which are covered with forests and have steep slopes. Such areas are very appropriate for Springshed Development and Management. Pilot projects can be taken up in such areas to identify the lost springs and rejuvenate them since springs are the lifeline in hills.

On Farm Practices

• Levelling of crop field is essential for uniform distribution of water. Laser levelling has been found very effective ensuring saving of 10 to 30% of applied irrigation. The in situ farm activities such as contour bounding, land levelling, bench terracing, water harvesting structures, a forestation and diversification of cropping pattern are other measures to increase recharge in the block.

<u>Demand Side Management</u>

Efficient irrigation

• In flood/furrow irrigation method more than 50% of applied water is wasted through seepage to deeper level, localized inundation causes loss through evaporation and it leaches out the nutrients from the plant.

• Adoption of new irrigation practices in sugarcane cultivation area to save 35-40 % irrigation water

• While through drip & sprinkler irrigation wastage of irrigational water could be minimized. The conveyance losses (mainly seepage & evaporation) can be saved up to 25 to 40% through utilization of HDPE pipes.

• Agriculture department should promote to conserve the soil moisture by reducing ET losses through cultivation of 'Green Manure'

Effective Use of Waste Water

- The grey-water generated from the industrial offices and buildings can be further treated in series of grey-water treatment ponds which will in turn provide substantial benefits for water supply system by reducing the demand for fresh clean water and for wastewater system by reducing the amount of wastewater required to be conveyed and treated.

(RAIPUR BLOCK, DEHRADUN DISTRICT, UTTARAKHAND)

General Information:

GEOGRAPHICAL AREA	393.13 sq km
BASIN/SUB-BASIN	Ganga
PRINCIPAL AQUIFER SYSTEM	Dun Gravel
MAJOR AQUIFER SYSTEM	Boulders Gravels and Sand of Dun Gravel
NORMAL ANNUAL RAINFALL	1550mm

Latitude	78°06'05.84" E and 30°28'48.01" N 77°58'51.00" E and 30°12'20.62" N
Longitude	78°14'26.40" E and 30°25'18.60" N 77°56'23.98" E and 30°14'32.80" N

Aquifer Disposition

Aquifer Disposition	The potential zones are in the form of boulders and gravel . Confined-semi confined multi-tiered aquifer conditions exist. The yield prospects are good and maximum discharge of 2526 lpm has been encountered at Forest Research Institute with a drawdown of 7.62 m. At Noorwala, discharge of 815 lpm has been encountered.
Status of GW Exploration	Exploratory wells under NAQUIM: 04 no (Dehradun Water Works, Noorwala, TarlaNagal, Kesarwala)
Aquifer Characteristics	Confined- semi confined multi-tiered aquifer and in places unconfined aquifer exists
GW Quality	The groundwater quality is good and fit for drinking,domestic and irrigation purposes.
Aquifer Potential	The yield prospects are good and maximum discharge of 2526 lpm has been encountered at Forest Research Institute with a drawdown of 7.62 m. At Noorwala, discharge of 815 lpm has been encountered.
CGWB Monitoring Status	NHS Monitoring wells: 11 nos

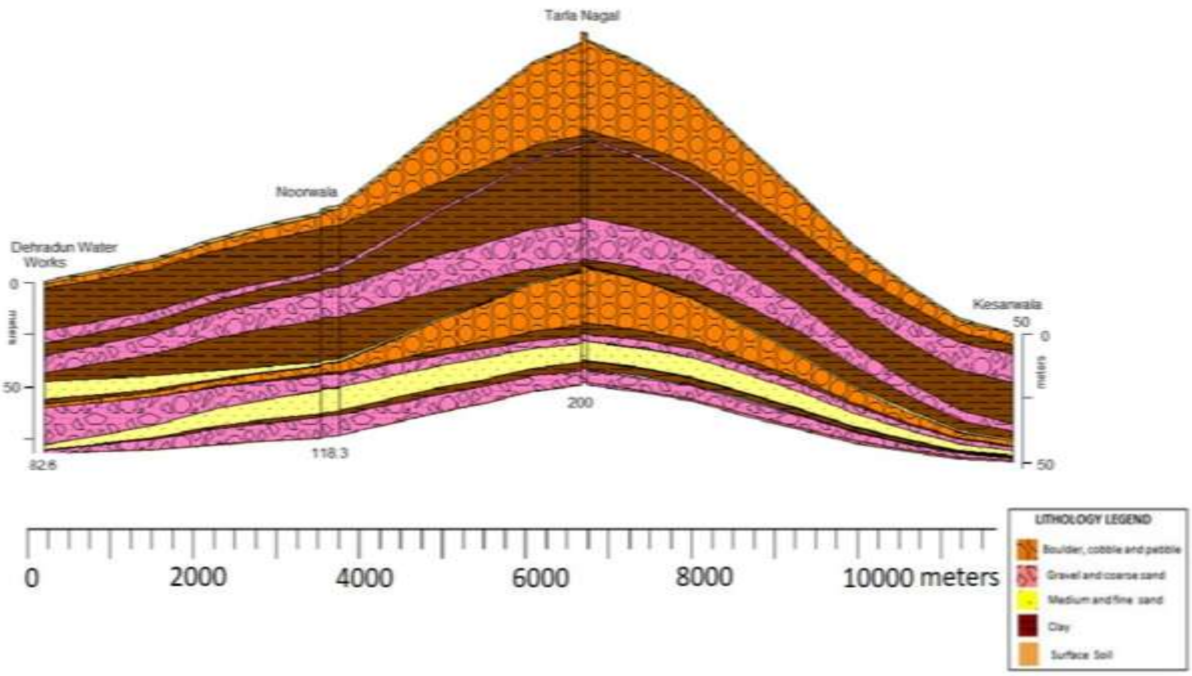


Fig6.11 Section Depicting Sub-surface Lithological Variation from Dehradun Water Works to Kesarwala

Location	Type of well	1st Zone tapped	2nd Zone tapped	3rd Zone tapped	4th Zone tapped
Noorwala	EW	91-101 m	103-118 m		
TarlaNagal	EW	109-127 m	133-137 m	146-152 m	155-159 m

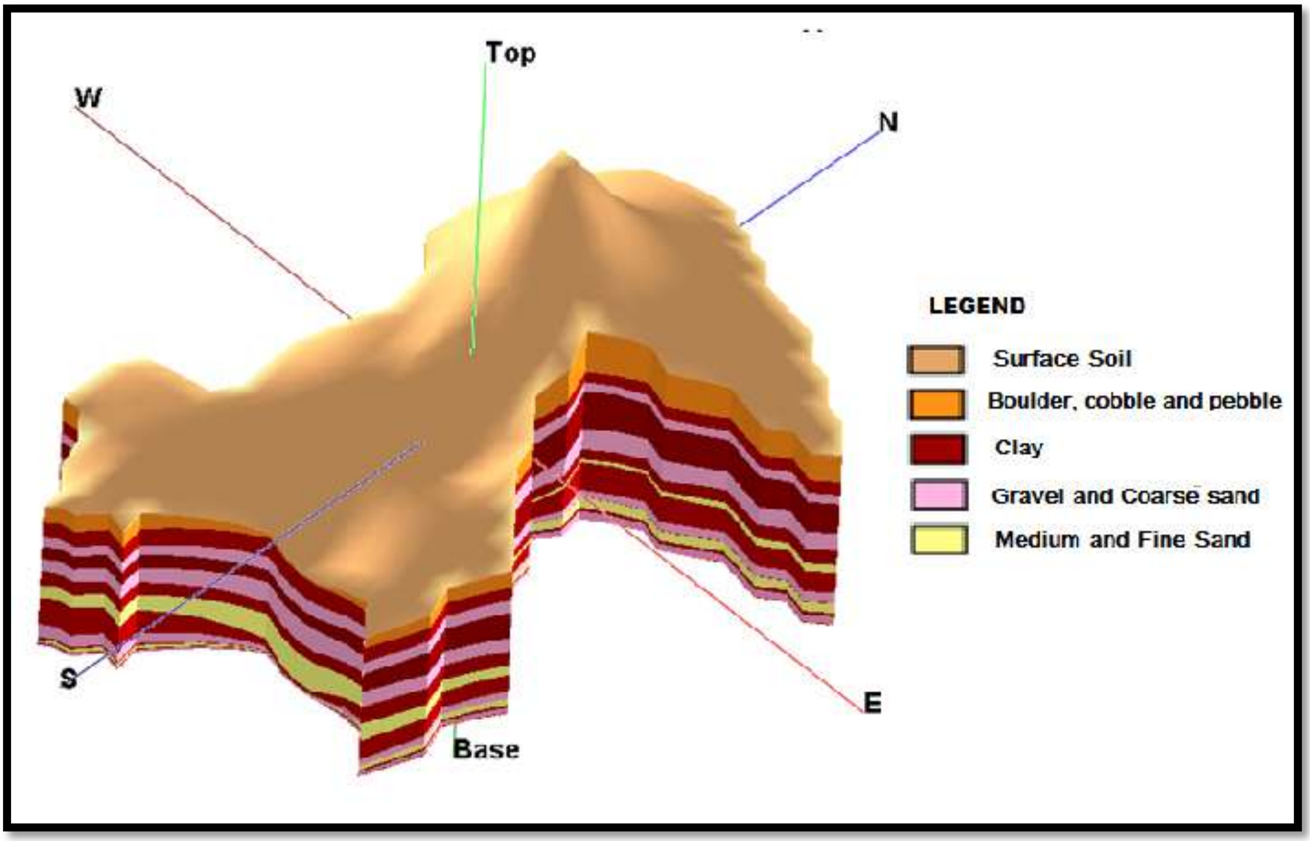
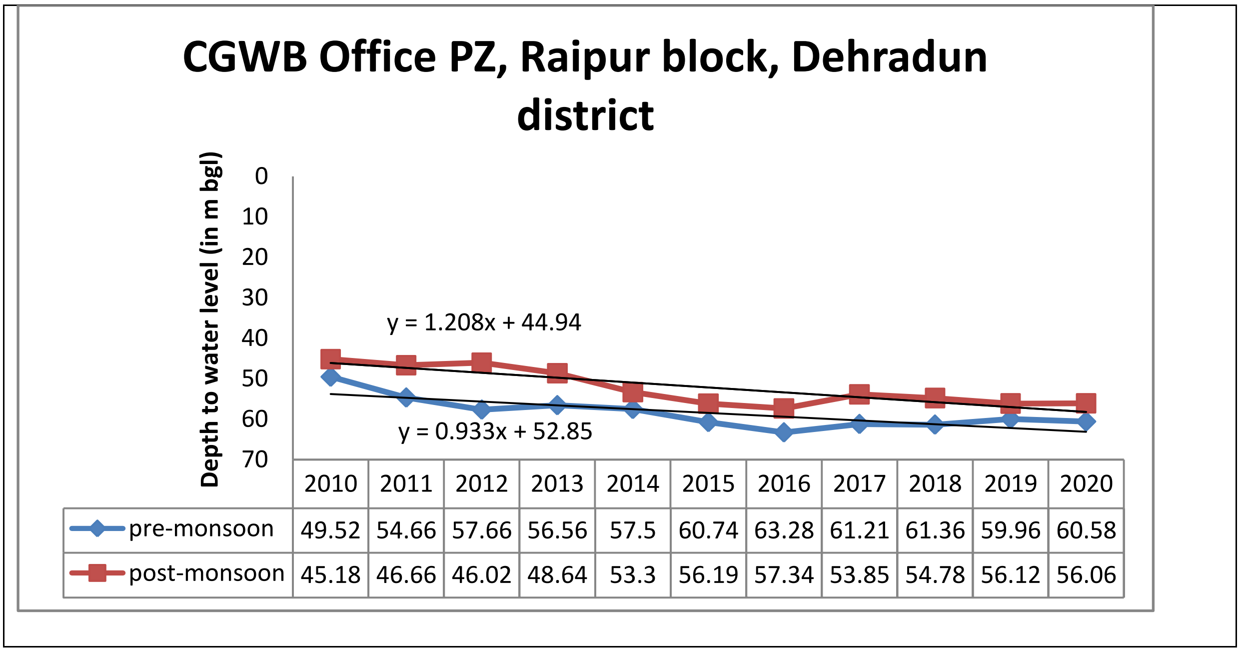
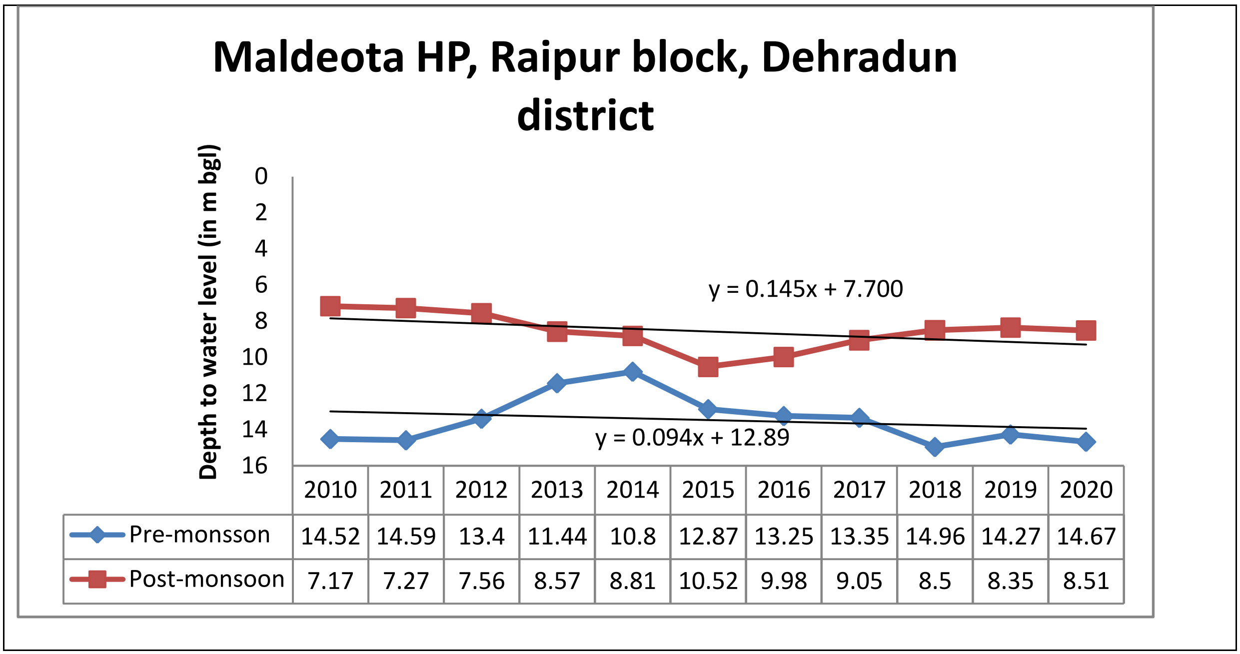


Fig6.12 3D Model of Raipur block depicting Sub-surface Lithological Variation



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
pre-monsoon	49.52	54.66	57.66	56.56	57.5	60.74	63.28	61.21	61.36	59.96	60.58
post-monsoon	45.18	46.66	46.02	48.64	53.3	56.19	57.34	53.85	54.78	56.12	56.06



AQUIFER MANAGEMENT PLAN

GW Management Issues	DeclineinwaterleveltrendintheBlock
GW Resource	Ground Water Resource Estimation has not been done in the Raipur Block due to high slope
GW Stage of Development(%)	
Existing andFuture Water Demand	

WATER MANAGEMENT PLAN OF RAIPUR BLOCK

Supply Side Management

Water conservation and Artificial Recharge to ground water

• Water conservation structures such as check dams, farm ponds, nalabunds etc result in ground water recharge to the tune of about 50% of the storage capacity considering 3 annual fillings. Further construction of recharge trenches in the upstream side of the check dams is also proposed to enhance rate of infiltration by about 30 to 40%.

• The existing ponds and tanks lose their storage capacity as well as the natural ground water recharge due to siltation and encroachment by farmers for agriculture purposes. Through desilting, coupled with providing proper waste weir, the village tanks can be converted into recharge structure.

Water Management through Rooftop Rain Water Harvestingand Artificial Recharge

Due to the increasing population and increasing trend of expansion of the city limits, there has been construction of buildings for residential as well as non-residential purposes resulting in the concretization of the open areas. This has led to a drastic decrease in the infiltration of rainwater within the sub-surface soil leading to a decrease in natural recharge and lowering of groundwater levels.

Surface water sources are limited and in order to sustain the increasing population load in terms of drinking water, water for domestic use and irrigational practices, we have to depend on groundwater. Hence there is a dire need of storing the rainwater and recharging the groundwater through artificial means. Rainwater harvesting is the collection and storage of rainwater that runs off from rooftops, parks, roads, and open ground commonly termed as runoff. This runoff can be either stored or recharged into the groundwater through artificial recharge techniques.

Raipur block covering an area of 393.13 sq. km (NAQUIM Area) falls in the central part of Dehradun district. The block receives an annual rainfall of 2151.2 mm. Using the real-time data through Google Earth, the residential areas were demarcated which comprised clusters of residential buildings, schools, colleges, offices and other commercial buildings as viewed in Satellite data. 51.9 sq. km of area is available at present with good potential of implementing rooftop rainwater harvesting.

However, keeping in mind the infrastructural development that is yet to happen like the building of new roads, parking areas, footpaths, etc., 50% of the potential area has been considered which can be utilized for rooftop rainwater harvesting.

Area suitable for Rooftop rainwater harvesting (at present)= 25950000 sq.m

Annual Rainfall (as per IMD data of 2019-20)= 2151.2 mm or 2.15 m

Runoff Generated= Suitable Area * Normal Rainfall * Runoff Coefficient

The Runoff Coefficient of tiled roofs can be considered 0.8- 0.9 while roofs made up of corrugated metal sheets have a runoff coefficient of 0.7- 0.9 (Source: Rainwater Harvesting and Conservation Manual, Govt. of India). An average runoff coefficient of 0.7 has been considered to estimate the runoff generated.

Estimated Annual Quantum of Runoff Generated = 25950000 m^2 * 2.15 m * 0.7

= 39054750 m^3 or 3905.475 ham

Using proposed rooftop rainwater harvesting, 3905.475 ham of water can be harvested annually which can be used for various domestic purposes and can bring down the current extraction requirements. Since the study area has good potential for recharge, the stored runoff can also be artificially recharged through the construction of recharge shafts or recharge pits in areas having post-monsoon water levels greater than 7-8 m bgl. The map shows the areas which have been identified as clusters having the potential of implementing rooftop rainwater harvesting presently (fig: 6.13).

The other areas, marked in yellow (Fig: 6.13) are mostly agricultural fields and are demarcated as suitable areas for water conservation through on- farm activities. Farm ponds, chalkhal, efficient irrigation practices like drip irrigation and sprinklers can help in water conservation. The Song River flows through the eastern portion of the block for quite a long stretch. The river water can be diverted to feeder channels or canals and the surface water can be used for irrigating the nearby agricultural lands.

The Asan River, Rispana River and Bindal River along with their tributaries form the major drainage in this area. Small Gabion structures can be constructed across small streams to conserve stream flows with practically no submergence beyond stream course. The boulders can be stored in a steel wire and such structures can easily be made using locally available boulders and are cost-effective. The height of such structures is around 0.5 m and is normally used in the streams with width of about 10 to 15 m. The excess water overflows this structure storing some water to serve as source of recharge. The silt content of stream water in due course is deposited in the interstices of the boulders to make it more impermeable.

Check dams can be constructed across small streams having gentle slope; however the site selected for check dam should have sufficient thickness of permeable bed to facilitate recharge of stored water within short span of time. The water stored in these structures is mostly confined to stream course and the height is normally less than 2 m. These are designed based on stream width and excess water is allowed to flow over the wall. In order to avoid scouring from excess run off, water cushions are provided at down streamside. To harness the maximum run off in the stream, series of such check dams can be constructed to have recharge on regional scale.

Since Raipur block has a lot of habitable villages along with urban and peri-urban areas, there are chances of finding lots of abandoned dug wells which have run out dry. These dug wells can be used as structures to recharge. The ground water reservoir, storm water, tank water, canal water etc. can be diverted into these structures to directly recharge the dried aquifer. The quality of source water including the silt content should be such that the quality of ground water reservoir is not deteriorated.

Urbanisation in this block is taking place along the tributaries of the Rispana River and Bindal River which may lead to pollution of the surface water body and deteriorate the quality of river water and also influence the groundwater quality of the area. Urbanization and encroachment all along the path of the river and its tributaries will lead to increase in runoff potential and change in hydrological scenario which may in turn result to urban flooding.

The hilly areas are also demarcated in Fig: 6.13 which are covered with forests and have steep slopes. Such areas are very appropriate for Springshed Development and Management. Pilot projects can be taken up in such areas to identify the lost springs and rejuvenate them since springs are the lifeline in hills.

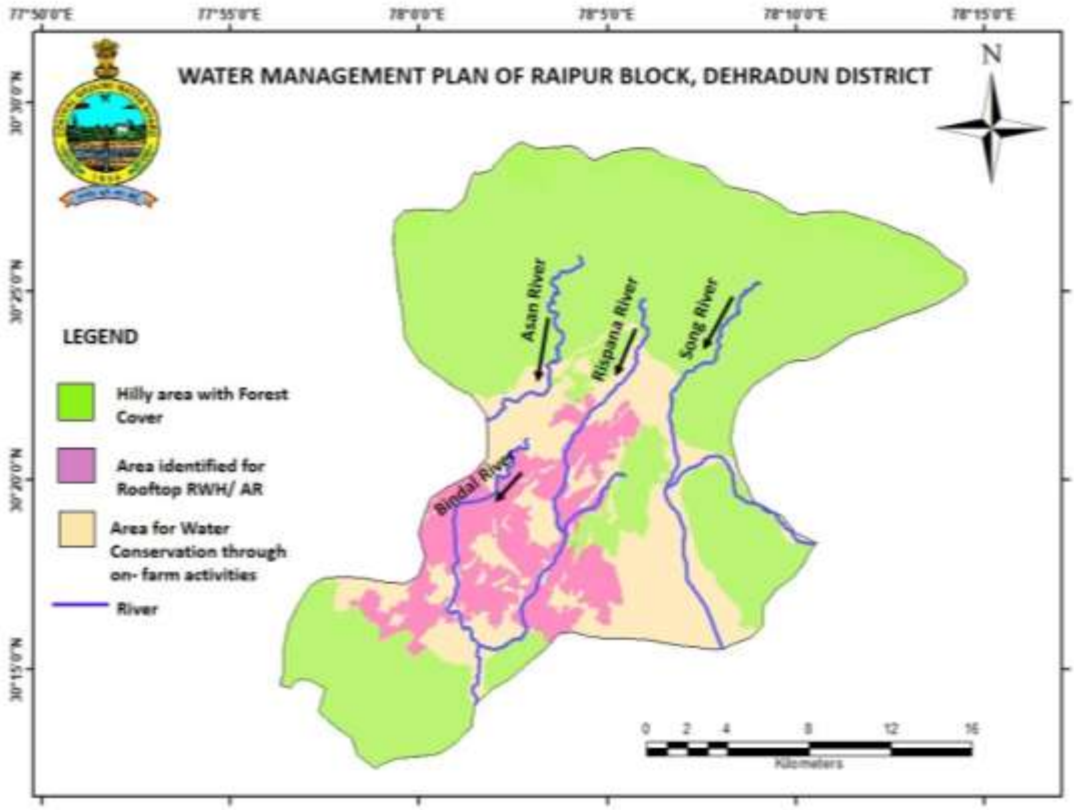


Fig: 6.13 Map showing Water Management Plan of Raipur Block, Dehradun

On Farm Practices

• Levelling of crop field is essential for uniform distribution of water. Laser levelling has been found very effective ensuring saving of 10 to 30% of applied irrigation. The in situ farm activities such as contour bounding, land levelling, bench terracing, water harvesting structures, a forestation and diversification of cropping pattern are other measures to increase recharge in the block.

Demand Side Management

Efficient irrigation

• In flood/furrow irrigation method more than 50% of applied water is wasted through seepage to deeper level, localized inundation causes loss through evaporation and it leaches out the nutrients from the plant.

• Adoption of new irrigation practices in sugarcane cultivation area to save 35-40 % irrigation water

• While through drip & sprinkler irrigation wastage of irrigational water could be minimized. The conveyance losses (mainly seepage & evaporation) can be saved up to 25 to 40% through utilization of HDPE pipes.

• Agriculture department should promote to conserve the soil moisture by reducing ET losses through cultivation of 'Green Manure'

Effective Use of Waste Water

- The grey-water generated from the industrial offices and buildings can be further treated in series of grey-water treatment ponds which will in turn provide substantial benefits for water supply system by reducing the demand for fresh clean water and for wastewater system by reducing the amount of wastewater required to be conveyed and treated.

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Plate I : Location Map of Monitoring Wells (NHS) in the Study Area

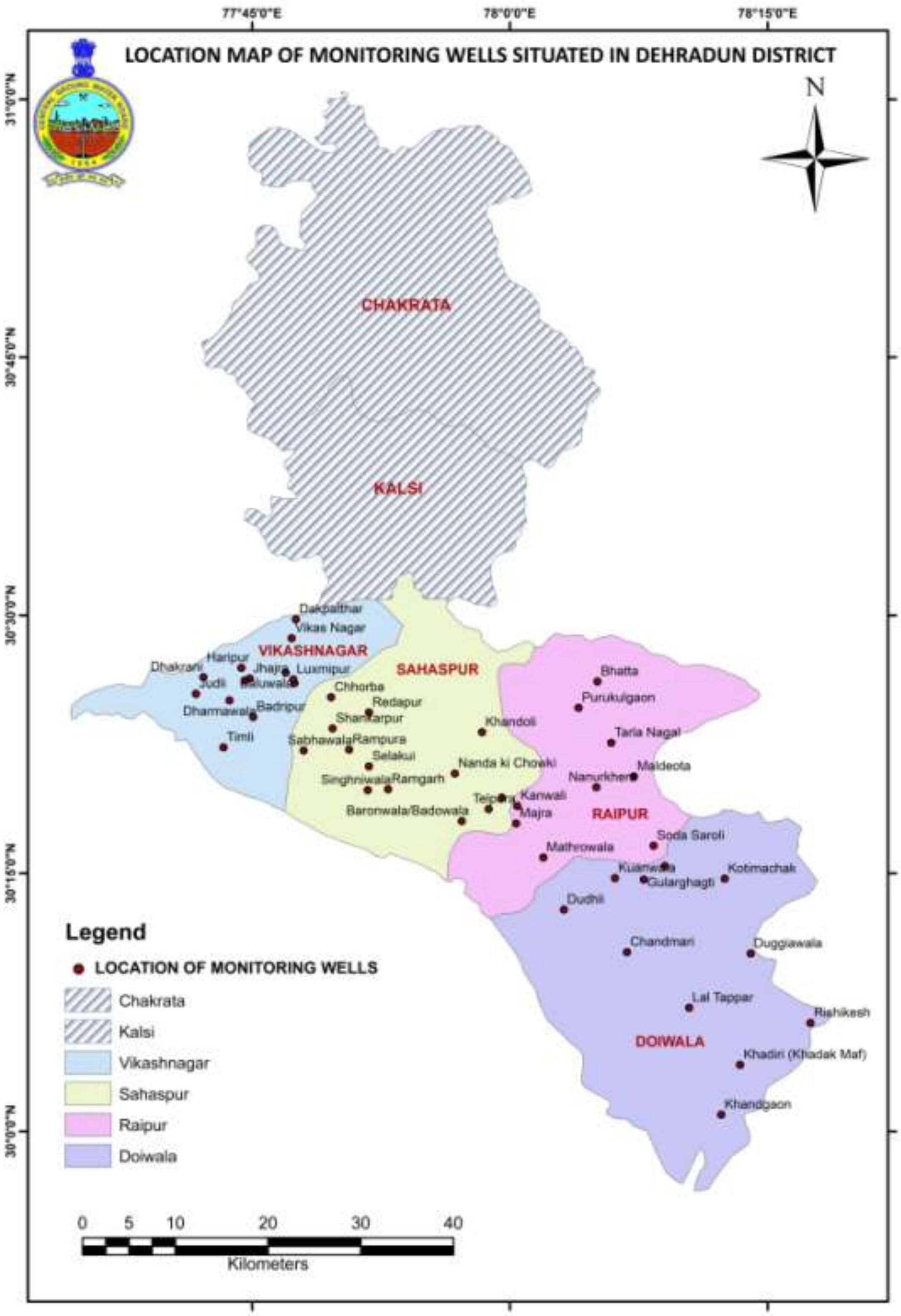
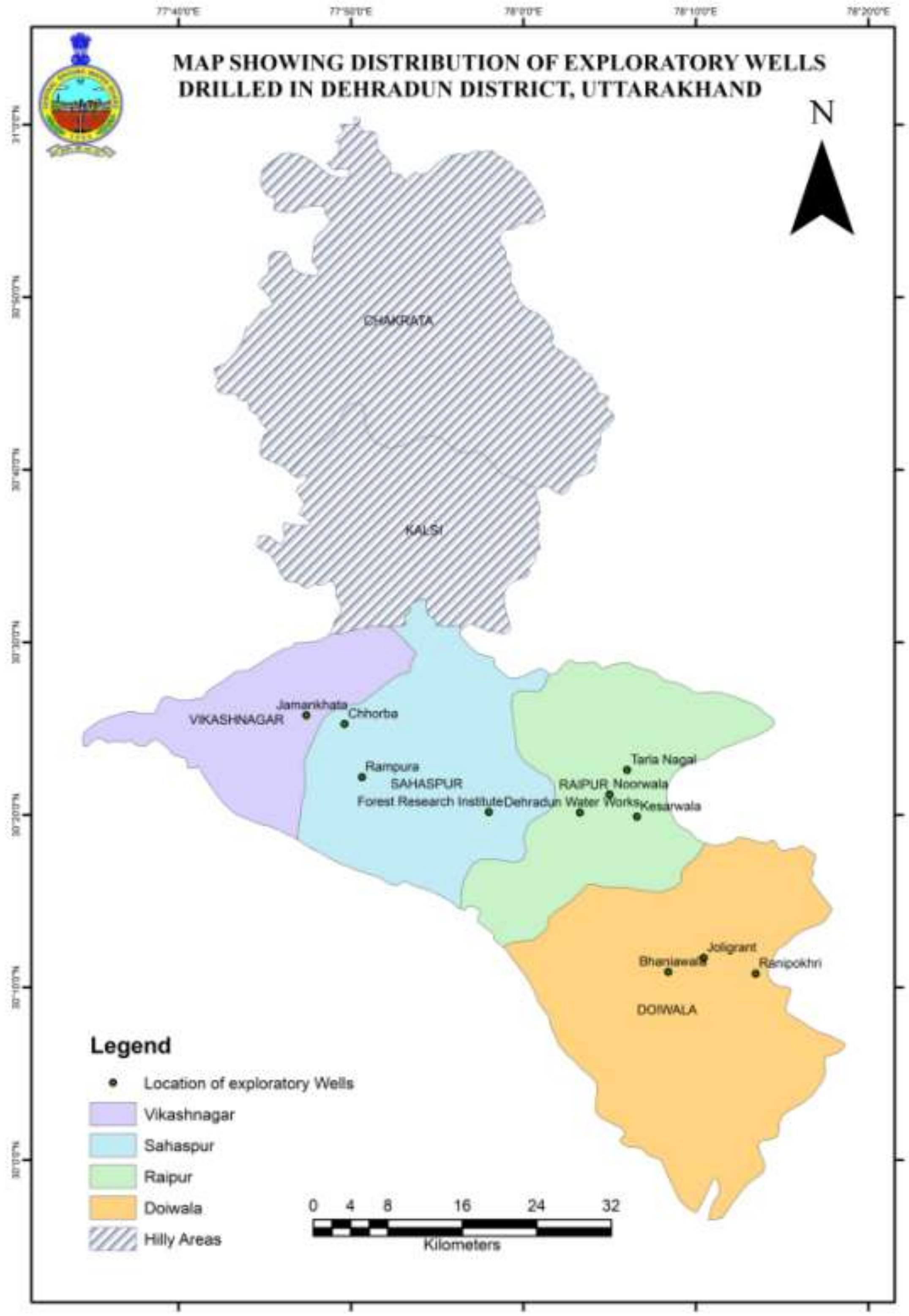


Plate II : Location Map of Exploratory Wells of CGWB drilled in the Study Area



Annexure:I Lithology of Exploratory wells in the Study Area

CHHORBA-2				
Depth Range (m bgl)		**Thickness**	**Lithology**	
From	**To**			
0.0	6.7	6.7	Clay with gravel	Surface clay, earthy in colour with gravel, pebbles, cobbles and boulders of quartzite.
6.7	17.4	10.7	Clay	Dark brown, plastic and sticky
17.4	19.8	2.4	Gravel with clay	Gravel angular to sub-angular essentially of quartzite with clay, yellow in colour and little coarse sand.
19.8	21.4	1.6	Clay	Light brown, sticky and slightly plastic with gravel sub- angular to sub- rounded in texture and constituted of quartzite with little coarse sand.
21.4	22.0	0.6	Gravel with clay	Sub-angular to sub-rounded, constituted of quartzite and basic rocks with little clay and sand.
22.0	24.4	2.4	Clay	Light brown, sticky, slightly plastic with gravel essentially constituted of quartzite, and with little medium sand.
24.4	28.3	3.9	Gravel with clay	Gravel, constituted of quartzite, basic rocks and shale, angular to sub- rounded in texture with clay of earthy colour and with pebbles and boulders and quartzite.
28.3	29.3	1.0	Clay	Brown, plastic and sticky without any gravel.
29.3	32.9	3.6	Clay	With medium to coarse sand and gravel, clay, light brown in colour, gravel, angular to sub-rounded and constituted of quartzite and shale.
32.9	36.6	3.7	Gravel	With fine to coarse sand and clay, gravel, angular to sub- rounded and constituted of quartz, quartzite and shale with few pebbles.
36.6	39.0	2.4	Clay	Reddish brown, sticky, plastic with a few embedded gravel pieces.
39.0	41.8	2.8	Sand	Coarse to very coarse with gravel, pebbles, cobbles and boulders of quartzite.
41.8	43.9	2.1	Clay	Mottled, mainly light brown with patches of yellow, violet, with embedded coarse sand and gravel, and with boulders of quartzite.
43.9	48.2	4.3	Clay	Sticky, plastic, brown, with little embedded coarse sand and gravel and with pebbles and cobbles of quartzite.

JOLIGRANT		
Depth	**Thicknes**	**Lithology**

Range (m bgl)		s			
From	To				
0.0	1.5	1.5	Clay sticky	Brown with a little coarse sand and gravel with pebbles and boulders of quartzite.	
1.5	7.6	6.1	Clay	Grey, silty with some gravel and medium to coarse sand and boulders of quartzite (gravel essentially constituted of angular to sub-rounded pieces of quartzite, basic rock and limestone)	
7.6	12.2	4.6	Sand and Gravel	Coarse to medium sand, pebbles and boulders of quartzite and basic rock, (gravel and coarse sand are essentially constituted of angular to sub-rounded pieces of quartzite, basic rock and limestone)	
12.2	24.4	12.2	Clay	Grey, silty with medium to coarse sand, gravel, pebbles and boulders of quartzite, gravel same as above.	
24.4	30.2	5.8	Gravel	With coarse sand pebbles and boulders of quartzite, gravel essentially constituted of angular to sub-rounded pieces of quartzite and limestone (limestone pieces more than that in the gravel in the depth zone 7.6-12.2 metres)	
30.2	34.4	4.2	Sand	Medium to coarse with gravel (same type as described), pebbles and boulders of quartzite (152 mm – 203 mm or 6-8	
34.4	36.0	1.6	Clay	Light brown, sticky with cobbles, pebbles and boulders of quartzite	
36.0	41.8	5.8	Gravel with clay	Clay, grey, slightly sticky with gravel (angular) and occasional boulders.	
41.8	45.7	3.9	Clay	Grey to white, calcareous with (pulverized) pebbles cobbles of quartzite and shale with occasional boulders.	
45.7	48.8	3.1	Clay	White to light grey, slightly variegated gritty (due to the presence of angular gravel) associated with pebbles cobbles and boulders of quartzite, shale and slates (most of the pebbles are flattened and angular)	
48.8	54.9	6.1	Clay	Mottled, yellowish grey in colour with patches of violet, white and greenish grey colours with pieces of embedded gravel.	
54.9	56.7	1.8	Coarse sand gravel	With pebbles cobbles and boulders of quartzite, and shale.	
56.7	61.9	5.2	Clay	Grey to light brown in colour with gravel pebbles and cobbles of shale.	
61.9	66.8	4.9	Clay	Mottled, deep brown to grey in colour with yellowish grey coloured sandy clay and with coarse sand, gravel, pebbles and boulders of shale, quartzite and sandstone	
66.8	69.5	2.7	Sand	Medium to coarse with some gravel, pebbles and boulders of quartzite and shale.	
69.5	75.6	6.1	Clay	Sticky, deep reddish brown in colour with pieces of embedded gravel and with boulders of quartzite.	
75.	78.	3.3	Clay	Grey, gritty with boulders and cobbles essentially of quartzite	

6	9			(pebbles and cobbles not well rounded).	
78.9	86.0	7.1	Sand	Medium to coarse (grey colour) with a few pebbles quartzite and slate.	
86.0	87.8	1.8	Clay	Grey, sticky and gritty with angular pieces of quartzite, limestone and slate embedded in the clay.	
87.8	90.2	2.4	Sand	Fine to medium (grey in colour) with a little gravel and silt.	
90.2	91.4	1.2	Sand	Medium to very coarse (grey in colour) with a little silt.	
91.4	93.6	2.2	Sand	Medium to coarse with some silt and gravel	
93.6	95.1	1.5	Gravel	Angular to sub-rounded with medium to very coarse sand	
95.1	97.5	2.4	Gravel	With coarse sand, a little clay, pebbles of sandstone and cobbles and boulders of quartzite	
97.5	99.1	1.6	Clay with Gravel	With pebbles and cobbles (of quartzite and sandstone) and boulders of quartzite, the clay is mottled	
99.1	100.6	1.5	Gravel	With pebbles, coarse sand and a little clay gravel is constituted of quartzite	
100.6	103.6	3.0	Clay	Yellowish Brown, sticky with gravel pebbles of quartzite and limestone and cobbles of quartzite	
103.6	105.5	1.9	Gravel	Angular and mostly constituted of quartzite, with coarse and sand, a little clay and pebbles.	
105.5	105.8	0.3	Clay and Gravel	Earthy, yellow, silty with pebbles composed of quartzite and limestone, cobbles and boulders of quartzite.	
105.8	106.7	0.9	Sand	Coarse with gravel, pebbles and in a little clay.	
106.7	108.8	2.1	Gravel and Sand	With pebbles of quartzite and a little clay; sand grey and coarse grained.	
108.8	109.1	0.3	Clay	Yellow earthy in colour, silty with gravel, pebbles, cobblesandbouldersofquartzite;clayformshardround masses with thegravel.	
109.1	110.0	0.9	Sand	Light grey, coarse with gravel and pebbles of quartzite	
110.0	111.6	1.6	Sand	Medium to coarse with a little gravel.	
111.6	113.7	2.1	Gravel	Withmediumtocoarsesandwithbouldersofquartzite.	
113.7	114.9	1.2	Sand	Coarse to fine with gravel.	
114.9	115.5	0.6	Sand	Yellowish, sticky brown in colour with boulders of quartzite.	
115.5	118.9	3.4	Sand	Fine with pebbles, cobbles and boulders of quartzite.	
118.9	121.9	3.0	Clay	Coarse with clay, yellowish brown in colour and with gravel, pebbles, cobbles, and boulders, essentially of quartzite.	

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Depth Range (m bgl)		Thickness	Lithology		
From	To				
0.0	1.5	1.5	Clay	Brown to light grey and sticky.	
1.5	3.7	2.2	Pebbles, Cobles and Gravel	Withalittlebrownclaypebblesandcobblesaremostlyof quartzite andlimestone.	
3.7	6.7	3.0	Boulders, Pebbles and Cobles	With coarse sand and little grey clay boulders, cobbles and pebbles are constituted of limestone and quartzite (various shades) and are not well rounded.	
6.7	11.0	4.3	Gravel	Very angular constituted of limestone and quartzite with boulders and cobbles of quartzite.	
11.0	14.0	3.0	Sand	Mediumto coarsewithpebbles,cobbles andbouldersof quartzite (various shades of pink, grey etc.) and slate (mostofthepebblesareelongated andnotwellrounded).	
14.0	17.1	3.1	Clay	With yellowish brown clay and pebbles, cobbles and boulders of variegated quartzite.	
17.1	20.1	3.0	Clay	Silty, yellowish brown and gritty (due to the presence of gravel) with pebbles, cobbles and boulders of quartzite.	
20.1	33.2	13.1	Clay	Silty,yellowishbrown,associatedwithsomecoarsesand andgravelandwithpebblesandcobblesofquartziteand sandstone.	
33.2	35.4	2.2	Clay	Brown, plastic with pebbles, cobbles and boulders of quartzite.	
35.4	38.4	3.0	Clay	Silty,yellowishbrownassociatedwithsomecoarsesandandgravelandwithpebblesandcobblesofquartzite.	
38.4	43.3	4.9	Clay	Yellowish brown silty with gravel and pebbles (of quartzite, shale and slate) cobbles and boulders of quartzite.	
43.3	46.3	3.0	Clay	Chocolate yellow, sticky with gravel and pebbles of quartzite.	
46.3	49.1	2.8	Clay	With gravel and pebbles of quartzite and shale.	
49.1	50.3	1.2	Clay	Light brown, sticky, plastic with pebbles and gravel of quartzite of different shades.	
50.3	51.8	1.5	Gravel	With boulders, cobbles and pebbles of quartzite and a little sandy clay; gravel angular to sub-rounded constituted of quartzite, slate and shale pieces.	
51.8	52.4	0.6	Sand	Coarse, light grey with gravel and pebbles.	
52.4	54.6	2.2	Gravel	With pebbles and cobbles of quartzite, shale and slate with a little coarse sand; gravel essentially made up of quartzite and slate.	
54.6	56.7	2.1	Clay	With gravel and pebbles, cobbles and boulders of quartzite and slates.	
56.7	57.3	0.6	Gravel	With coarse sand, few pebbles of quartzite and slate; gravel is highly angular and constituted of quartziteand slate pieces.	
57.3	57.9	0.6	Clay	Yellowish brown, slightly mottled, sticky with a little gravel and embedded pieces of quartzite.	
57.9	59.1	1.2	Sand	coarse with some gravel and pieces of quartzite, pebbles and	

				cobbles.	
59.1	60.0	0.9	Clay	Light brown, sandy, slightly mottled (white, yellow and violet) with pieces of quartzite.	
60.0	61.2	1.2	Clay	Light brown, slightly silty with gravel of quartzite.	
61.2	64.3	3.1	Gravel	Gravel,mostlyangular,withsomecoarsesand,associated withpebblesandcobbles (fairlyroundedtosub-angular) ofquartzite.	
64.3	66.4	2.1	Clay	Brown, sticky with a little embedded gravel and pebbles and cobbles of quartzite.	
66.4	67.7	1.3	Gravel	With coarse sand, a little yellowish-brown clay, pebbles, cobbles and boulders of quartzite.	
67.7	68.3	0.6	Sand	Coarse with boulders of quartzite.	
68.3	69.2	0.9	Clay	Yellowish brown silty with cobbles and boulders of quartzite.	
69.2	70.4	1.2	Sand	Coarse with gravel and a very little clay.	
70.4	71.9	1.5	Gravel	With clay; clay, yellowish brown in colour, sticky and plastic.	
71.9	74.1	2.2	Clay	Yellowish, brown, sticky plastic with a little gravel and pebbles of quartzite.	
74.1	77.1	3.0	Gravel and Boulders	Gravel(angular)essentiallyconstitutedofquartzitewitha littlecoarsesand, pebbles,andbouldersofquartzite.	
77.1	79.9	2.8	Gravel	With coarse sand pebbles, cobbles and boulders of quartzite and slate.	
79.9	80.8	0.9	Clay	With gravel, pebbles and cobbles of quartzite; clay is of earthyyellowincolourandformsroundedmasseswith gravel.	
80.8	83.2	2.4	Clay	With less gravel, pebbles and cobbles; clay is of earthy colour and sticky.	
83.2	86.3	3.1	Gravel	Angular to sub-angular with pebbles of quartzite of all shades with a little coarse sand.	
86.3	87.2	0.9	Gravel and Sand	Sand medium to coarse grained of light grey colour with pebbles of quartzite.	
87.2	88.1	0.9	Clay	of brown colour, hard and sticky.	
88.1	89.9	1.8	Gravel	With coarse to medium sand and a few pebbles and boulders of quartzite.	
89.9	92.7	2.8	Gravel with Clay	Gravelwithpebbles,cobblesandbouldersofquartziteof different shades and clay, mottled, sticky with a little mediumsand.	
92.7	94.2	1.5	Sand	Medium to coarse grained, light grey in colour with gravel constituted essentially of quartzite.	
94.2	96.6	2.4	Sand	Coarse grained with gravel and clay; gravel made up of quartzite.	
96.6	97.2	0.6	Clay	of earthy colour, sticky with little medium grained sand and gravels and boulders, clay forms hard masses with sand and gravels.	
97.2	99.7	2.5	Sand	Coarse to fine grained light grey in colour with boulders of quartzite.	
99.7	100.6	0.9	Clay	Chocolate yellow in colour with gravel, pebbles and boulders of quartzite; clay plastic in nature.	
100.6	104.9	4.3	Grave	With coarse sand and pebbles, cobbles and boulders of	

			l	quartzite of different shades; sand, light grey in colour; gravel angular to sub-angular essentially constituted of quartzite, shale and quartz.	
104.9	107.6	2.7	Clay	Earthy yellow in colour with sand; gravel, pebbles and boulders of quartzite.	
107.6	113.7	6.1	Clay	Sticky, mottled with embedded pieces of gravel and boulders, cobbles and pebbles of quartzite.	
113.7	114.6	0.9	Clay	Withgravelpebblesandbouldersofquartziteofdifferent shades;clayofearthycolourandstickywithalittlesand.	
114.6	116.1	1.5	Sandy Clay	of earthy colour without gravel, pebbles etc.	
116.1	118.9	2.8	Grave l	Small size gravel, essentially constituted of quartzite, quartz, shale and basic rock with coarse sand and with pebbles and cobbles of quartzite.	
118.9	121.9	3.0	Sand	Finetocoarsegrainedwithsomegravelandwithpebbles, cobblesandbouldersofquartzite,phylliteandshale.	
121.9	125.0	3.1	Sand	Medium to coarse grained with little gravel; gravel constituted of the material as described above.	
125.0	126.5	1.5	Grave l	With sand coarse grained and with a few pebbles of quartzite; gravel angular and same as above in constitution.	
126.5	126.8	0.3	Clay	Light brown in colour, sticky with embedded gravel, pebbles and boulders.	
126.8	129.2	2.4	Grave l	Angular to sub-angular essentially constituted of quartzite withsomecoarseSandandfewpebblesofquartziteand shale.	
129.2	132.3	3.1	Clay	Light brown in colour, sticky, slightly mottled, with gravelandpebblesessentiallyofquartzite,fewpebblesof sandstone purple incolour.	
132.3	132.9	0.6	Grave l	With pebbles and cobbles essentially of quartzite and shale with little coarse sand and silt.	
132.9	134.7	1.8	Clay	Light brown, sticky, mottled and slightly plastic with essentially of quartzite.	
134.7	136.2	1.5	Sand	Light to earthy in colour with a little gravel and coarse sand.	
136.2	139.6	3.4	Sand	Coarse, light grey in colour with pebbles, cobbles and boulders essentially of quartzite and shale.	
139.6	141.7	2.1	Clay	Brown, sticky.	

RAMPURA				
Depth Range (m bgl)		**Thickness (m)**	**Lithology**	
From	**To**			
0	0.9	0.9	Clay	Sandy with few pebbles and (surface) cobbles of quartz and quartzite.
0.9	4	3.1	Clay	Light grey with gravel (angular) mostly constituted of limestone, shale and quartzite with cobbles and pebbles of quartzite (different shades).
4	10.4	6.4	Clay	Grey,gritty(withgravelsameasabove)withafewpebblesof quartzite andshale.
10.4	22.6	12.2	Clay	Light brown plastic with a few angular pebbles of shale.
22.6	23.8	1.2	Clay	Silty with a few pebbles of shale.
23.8	27.4	3.9	Clay	Plastic, slightly gritty (due to angular pieces of shale

				and quartzite) with a few cobbles of quartzite (with quartz veins).
27.4	30.5	3.1	Slit	Light brown without any pebbles.
30.5	33.5	3	Clay	Deep reddish brown, sticky without any pebbles.
33.5	35.7	2.2	Clay	Sticky, deep red with gravel.
35.7	36.6	0.9	Sand	Coarse with gravel, pebbles and boulders (pebbles and boulders constituted of quartzite and laminated Talc withfolded laminae).
36.6	42.7	6.1	Sand	Coarse with some medium sand with cobbles boulders ofquartzite and shale.
42.7	46.6	3.9	Gravel	With coarse sand, pebbles (of shale and quartzite) and cobbles(of shale and quartzite).
46.6	50.6	4	Clay	Yellowish brown with gravel, pebbles (of shale and quartzite)cobbles (of shale and quartzite) and boulders ofquartzite.
50.6	52.1	1.5	Clay	Dirty brown, sticky with a few boulders of quartzite.
52.1	55.8	3.7	Silty Clay	Light dirty brown with a little gravel, pebbles (of shale andquartzite cobbles (of shale and quartzite) and boulders ofquartzite.
55.8	58.5	2.7	Sand	Fine to coarse with gravel, pebbles and cobbles of shale andquartzite and boulders of quartzite (a few pieces are laminated-Talc?).
58.5	60	1.5	Clay	patches ofyellow clay with coarse and boulders ofquartzite
60	66.8	6.8	Clay	Light brown in colour, sticky and plastic with pebbles andboulders ofquartzite.
66.8	68.6	1.8	Sand	Coarse, with some gravel (constituted mainly of quartzite, quartz and basic rocks), pebbles, cobbles and boulders ofquartzite and some clay.
68.6	70.4	1.8	Clay	Brown, sticky, mottled (yellow, violet, white and brown) withembedded pebbles, and boulders.
70.4	73.5	3.1	Clay	Silty, with boulders of quartzite.
73.5	74.1	0.6	Clay	Silty and muffled, with coarse sand, pebbles and boulders of quartzite.
74.1	76.2	2.1	Sand	Coarse with gravel and a little clay, pebbles and cobbles andboulders of quartzite (a few laminated)'
76.2	77.4	1.2	Sand	Coarse and without pebbles and boulders.
77.4	82.3	4.9	Clay	Light brown, muffled (violet and yellow) with coarse sand,pebbles and boulders of quartzite.
82.3	86.9	4.6	Clay	Deep reddish brown, sticky and plastic with embedded pieces ofgravel, pebbles and boulders (quartzite).
86.9	87.5	0.6	Sand	Coarse with some gravel and clay associated with pebbles andboulders ofquartzite.
87.5	89.6	2.1	Clay	Light brown, sticky, gritty with embedded gravel, pebbles andboulders ofquartzite.
89.6	91.7	2.1	Clay	Light brown, sticky without gravel and pebbles.
91.7	96.3	4.6	Clay	Deep brown, sticky without boulders.
96.3	97.2	0.9	Gravel	With mottled clay and with pebbles and cobbles of quartziteand shale (pebbles sub-angular to sub-rounded).

97.2	98.1	0.9	Gravel	With pebbles and cobbles of quartzite (sub-angular to sub-rounded)with some clay.
98.1	99.4	1.3	Sand	Fine with a few pebbles of quartzite and with some gravel.
99.4	102.4	3	Gravel	Gravel and coarse sand with some clay and with pebbles andcobbles ofquartzite (ofdifferent shades) and slates.

BHANIAWALA (DOIWALA)				
Depth Range (m bgl)		**Thickness**	**Lithology**	
From	**To**			
0.00	4.00	4.0	Boulders	Boulders, sub rounded to rounded, greyish in colour and admixedwith medium grained sand
4.00	21.00	17.0	Boulders	Boulders with medium to coarse grained sand, greyish in colour
21.00	24.00	3.0	Boulders	Boulders mixed with little clay, yellowish in colour
24.00	29.00	5.0	Clay	Clay, sticky and plastic in nature, brownish in colour and admixedwith little kankar
29.00	31.00	2.0	Clay	Clay, light reddish brown in colour admixed with kankar
31.00	32.00	1.0	Boulders	Boulders admixed with brown coloured clay
32.00	35.00	3.0	Boulders	Boulders with medium to coarse grained sand, greyish in colour,admixed with little clay
35.00	36.00	1.0	Boulders	Boulders with greyish coloured clay
36.00	47.00	11.0	Boulders	Boulders with coarse grained sand, greyish in colour
47.00	54.00	7.0	Boulders	Boulders with minor clay, greyish in colour
54.00	58.00	4.0	Boulders	Boulders admixed with clay, light reddish brown in colour
58.00	60.00	2.0	Clay	Clay, reddish brown in colour, sticky and plastic in nature
60.00	68.00	8.0	Boulders	Boulders mixed with medium to coarse grained sand, greyish incolour
68.00	69.00	1.0	Boulders	Boulders with yellowish clay
69.00	77.00	8.0	Boulders	Boulders mixed with medium to coarse grained sand, greyish incolour
77.00	80.00	3.0	Boulders	Boulders with minor clay, greyish in colour
80.00	81.00	1.0	Boulders	Boulders mixed with medium to coarse grained sand
81.00	84.00	3.0	Boulders	Boulders mixed with yellowish clay
84.00	103.00	19.0	Boulders	Boulders mixed with medium to coarse grained sand
103.00	107	4.0	Clay	Clay, sticky and plastic in nature, deep

				red in color.

KESARWALA(RAIPUR)				
Depth Range (m bgl)		**Thickness**	**Lithology**	
From	**To**			
0.00	4.00	4.0	Gravel, Pebbles and Boulders	Sand, coarse grained mixed with gravel, pebble and boulders, rounded to sub rounded, greyish black in colour.
4.00	5.00	1.0	Clay	Clay, sticky and plastic in nature, yellow in colour
5.00	7.00	2.0	Boulders	Boulders, whitish to greyish in colour
7.00	24.00	17.0	Sand with Gravel and Boulders	Sand coarse grained, mixed with gravel and boulders, white to greyish black in colour
24.00	25.00	1.0	Boulders	Boulders, grey to black in colour
25.00	26.00	1.0	Boulders	Boulders admixed with coarse (big chips) of shale
26.00	34.00	8.0	Shale	Shale, greyish black colour, fractured in nature.
34.00	37.00	3.0	Shale	Shale, greyish black colour and massive in nature.
37.00	39.00	2.0	Shale	Shale, greyish black in colour, fractured in natured.
39.00	40.00	1.0	Shale	Shale, massive in nature.
40.00	43.00	3.0	Shale	Shale,hardandcompact,fracturedinnature,andgreyishblackin colour.
43.00	50.00	7.0	Shale	Shale, hardandcompact,inmassiveinnatureand greyishblackin colour

JAMANKHATA				
Depth Range (m bgl)		**Thickness**	**Lithology**	
From	**To**			
0.00	6.00	6.0	Soil with Boulders	Soil, admixed with boulder, greyish in colour.
6.00	15.00	9.0	Clay	Sticky and plastic in nature, yellowish in colour
15.00	17.00	2.0	Boulder with Gravel	Boulder, whitish to greyish in colour; mixed with gravel.
17.00	18.00	1.0	Clay	Mixed with gravel 2%, greyish in colour.
18.00	20.00	2.0	Clay	Sticky and plastic in nature, yellowish in colour'
20.00	22.00	2.0	Clay	Clay; admixed with a little kankar and gravel.
22.00	26.00	4.0	Boulder	Yellowish and greyish in colour;

				admixed with gravel,and coarse-grained sand.
26.00	27.00	1.0	Sand	fine to medium grained, yellowish to greyish in colouradmixed with micaceous fragments, greyishblack in colour'
27.00	28.00	1.0	Clay	Sticky and plastic in nature, yellowish in colour.
28.00	29.00	1.0	Clay with Boulders	admixed with boulders.
29.00	50.00	21.0	Boulder	Whitish to yellowish in colour, admixed with fine tomedium grained sand.
50.00	55.00	5.0	Boulder	Coarse chips, yellowish to greyish in colour.
55.00	65.00	10.0	Boulder with sand	Boulder whitish, yellowish and greyish in colour, admixed with fine to medium grained sand.
65.00	67.00	2.0	Boulder with sand	fine to medium grained, admixed with boulder.
67.00	105.00	38.0	Boulder	Boulder, whitish to greyish in colour, admixed with a little sand, fine to medium grained.
105.00	106.00	1.0	Boulder	fine to medium grained, admixed with boulder.
106.00	146.00	40.0	Boulder	Whitish, yellowish and light greyish in colour, adrnixedwith a little sand; fine to medium grained
146.00	149.00	3.0	Clay	Reddish in colour, sticky and plastic in nature.
149.00	158.00	9	Boulder	Yellowish in colour, sticky in colour, admixed with a little sand, fine to medium grained.

FOREST RESEARCH INSTITUTE				
Depth Range (m bgl)		**Thickness**	**Lithology**	
From	**To**			
0.0	2.4	2.4	Top soil	Clay
2.4	6.1	3.7	Gravel	and shingle
6.1	9.1	3.0	Sand	Coarse
9.1	10.6	1.5	Boulders	and gravel mixed.
10.6	11.6	1.0	Boulders	Hard
11.6	18.9	7.3	Boulders	With intercalated clay and pebbles
18.9	21.4	2.5	Cobbles	Pebbles and boulders of limestone, shale and quartzite.
21.4	32.9	11.5	Boulders	Of quartzite, conglomerates
32.9	39.6	6.7	Sand	Medium to coarse with gravel and pebbles.
39.6	50.3	10.7	Boulders	Of quartzite, and limestone with fine sand
50.3	51.8	1.5	Clay	Brown with gravel and boulders.

51.8	74.7	22.9	Pebbles	Of conglomerates, shale and limestone
74.7	92.7	18.0	Gravel	Of quartzite and limestone.
92.7	100.6	7.9	Sand	Fine to medium with pebbles of conglomerates.
100.6	110.4	9.8	Clay	Yellow, soft with gravel and boulders

DEHRADUN WATER WORKS				
Depth Range (m bgl)		**Thickness (m)**	**Lithology**	
From	**To**			
0.0	3.0	3.0	Clay	Chocolate, brown in colour, sticky with coarse sand and some gravel, pebbles and cobbles of quartzite.
3.0	6.1	3.1	Clay	Brown, sticky, plastic, slightly mottled with a littleembedded gravel and with boulders of quartzite.
6.1	15.5	9.4	Clay	Dark brown to reddish brown, sticky and plastic
15.5	16.8	1.3	Clay with gravel	With some coarse sand, clay, brown in colour, gravelangular to sub-angular, constituted of quartzite and basicrock.
16.8	18.3	1.5	Clay with gravel	Clay, yellowish brown in colour, sticky with gravel ofquartzite and basic rock and some coarse sand.
18.3	20.7	2.4	Clay	Dark brown in colour, slightly mottled, sticky and forms rounded masses with gravel and coarse to medium sand,gravels are essentially of quartzite
20.7	22.9	2.2	Clay	Chocolate brown, hard, sticky, slightly plastic, with little coarse sand and cobbles ofshale.
22.9	23.8	0.9	Clay	Sand, pebbles; clay is brown, sticky with a little coarse sand and pebbles, sub-rounded consisting ofquartzite andshale.
23.8	25.0	1.2	Clay	Brown, mottled, plastic, sticky with a little coarse tomedium sand and gravels consisting essentially ofquartzite.
25.0	29.9	4.9	Gravel with clay	Clay brown in colour, sticky, gravels angular to subrounded, consisting of quartzite and basic rocks withcoarse sand and few pebbles.
29.9	31.1	1.2	Sand with clay	Sand medium to coarse grained

				with clay of light browncolour and gravels, pebbles of quartzite and other basicrocks.
31.1	32.3	1.2	Sand With Gravel	Sand very coarse grained, with gravels, sub-roundedessentially of quartzite with clay of light brown colour.
32.3	35.1	2.8	Clay	Light brown in colour, mottled, slightly plastic, stickywith a little sand, medium to coarse grained with fewgravel, pebbles and cobbles essentially ofquartzite
35.1	37.2	2.1	Clay	Brown, sticky and plastic with gravel sub-rounded to sub-angular,essentially ofquartzite and few pebbles.
37.2	39.6	2.4	Sand with Gravel	Very coarse to coarse sand with gravel sub-rounded tosub-angular of different shades of quartzite and basicrocks and pebbles essentially of quartzite with clay lightbrown in colour.
39.6	42.7	3.1	sand	Light grey in colour, very coarse to coarse grained withfew gravels essentially of quartzite
42.7	44.5	1.8	Gravel with very coarse sand	Constituted mainly of quartzite and a few lime stonepieces, angular to sub-rounded with pebbles, cobbles andboulders of quartzite (and some of talc).
44.5	51.2	6.7	Sand	Coarse to very coarse with some gravel and medium sandwith boulders of quartzite.
51.2	54.9	3.7	Sand	Medium to coarse with a little gravel and with pebblesand boulders of quartzite (some laminated).
54.9	56.4	1.5	Gravel	Constituted of quartzite and basic rocks, angular to sub-angular with little coarse to medium sand.
56.4	59.4	3.0	Clay	Brown, sticky and slightly plastic with few gravelessentially constituted of quartzite, sub-angular to sub-rounded.
59.4	62.5	3.1	Sand	Fine grained, light grey in color with little gravel of quartzite.
62.5	67.1	4.6	Gravel	Angular to sub-rounded and constituted of quartzite and basic rocks with pebbles, cobbles and boulders, crushedmainly of

				quartzite.
67.1	70.1	3.0	Clay	Gritty and silty, light brown in colour, moderately plastic with embedded gravel and coarse sand and with fewboulders.
70.1	70.7	0.6	Sand	Fine to coarse with little gravel
70.7	71.3	0.6	Sand	Medium to very coarse with gravel and few pebbles'
71.3	73.2	1.9	Gravel	With medium to very coarse sand constituted of angularto sub-rounded pieces of quartzite and basic rocks withfew pebbles and boulders ofquartzite.
73.2	75.6	2.4	Clay	Gritty and silty, moderately sticky, light brown in colour; clay embedded with gravel and medium to coarse sand with few pebbles.
75.6	76.5	0.9	Sand	Fine to coarse with some gravel.
76.5	77.7	1.2	Gravel	Gravel mixed with clay and some coarse sand, clay greyin colour, gravel essentially constituted ofquartzite, basicrocks and shale pieces
77.7	81.4	3.7	Sand	Coarse with some gravel, pebbles and cobbles ofquartzite, basic rock and limestone.
81.4	82.0	0.6	Clay	With gravel, clay, light brown, with gravel and littlecoarse sand, sub-angular to sub-angular to sub-roundedand constituted of quartzite basic rock and limestone;with pebbles, cobbles and boulders of quartzite and limestone.
82.0	82.6	0.6	Gravel with sand	Gravel, sub-rounded to sub-angular and constituted of quartzite and bas

MOHKAMPUR - 2 (DEPOSITE WELL)				
Depth Range (m bgl)		**Thickness (m)**	**Lithology**	
From	**To**			
0	0.9	0.9	Clay	Sticky
0.9	3.7	2.8	Clay	Sticky, brown with flat pebbles of quartzite
3.7	7.6	3.9	Clay	Sticky brown, gritty with angular gravel constituted ofquartzite, phyllite etc.
7.6	10.7	3.1	Clay	Sandy, brown
10.7	11.6	0.9	Clay	Sticky, brown
11.6	12.2	0.6	Clay	Sticky, brown with gravel

12.2	12.5	0.3	Sand	Fine to medium with little gravel
12.5	14.6	2.1	Clay	Sandy, with gravel, pebbles and cobbles ofquartzite (fewof them laminated)
14.6	19.8	5.2	Sandstone	Clayey, gritty with gravel (pulverized)
19.8	21.9	2.1	Clay	Sticky, light brown, with gravel
21.9	22.2	0.3	Sand	Very coarse to small size gravel
22.2	24.1	1.9	Gravel	Angular with pebbles and some clay
24.1	27.1	3	Clay	Brown, sticky, with pebbles and cobbles of quartzite
27.1	29.6	2.5	Clay	Light brown, slightly mottled and gritty with angularquartzite pieces
29.6	31.7	2.1	Clay	Brown, sticky
31.7	32.3	0.6	Gravel	With clay (not constituted of any limestone pieces)
32.3	33.8	1.5	Sand	Fine to coarse with gravel, pebbles and cobbles ofquartzite (shades of grey and white)
33.8	35.1	1.3	Gravel	With some clay
35.1	35.7	0.6	Clay	Sandy and silty
35.7	37.8	2.1	Gravel	With sandy clay
37.8	39.3	1.5	Sandstone	Clayey, kaolinitic and mottled, pebbles and cobbles ofquartzite
39.3	40.8	1.5	Sandstone	Clayey, brown, not mottled and without pebbles andcobbles of quartzite
40.8	41.4	0.6	Clay	Gritty with pebbles of quartzite
41.4	42.7	1.3	Sandstone	Clayey, mottled (violet, yellow and white), occasionallykaolinitic with pebbles of shale and quartzite
42.7	45.1	2.4	Sandstone	Clayey and gritty with gravel (2mm – 5mm)
45.1	46	0.9	Gravel	With pebbles 1.6 - 3.2 mm and cobbles, angular to sub-angular, essentially constituted of quartz, quartzite andshale pieces (Limestone conspicuously absent) and withsome clay.
46	46.9	0.9	Clay	Silty, brown
46.9	47.5	0.6	Gravel	Angular to sub angular (2mm - 5 mm) size with littleclay.
47.5	52.4	4.9	Clay	Sticky, brown and gritty with angular pieces of gravel
52.4	54.3	1.9	Clay	Sticky, brown
54.3	55.2	0.9	Clay	Sticky, brown to deep brown, slightly gritty in depthzones 54.9 - 55.2 m
55.2	55.5	0.3	Clay	Sticky, mottled (yellow, violet,

				white); gritty with some gravel, few sandstone pieces embedded in clay.
55.5	57.6	2.1	Gravel	With coarse sand of 2mm - 5 mm size, highly angularand flaky, constituted of quartz, quartzite etc (limestoneconspicuously absent) and with boulders 102 - 127 mm size made up of quartzite
57.6	58.8	1.2	Sand	Fine to coarse with some gravel and boulders of quartzite
58.8	61.3	2.5	Gravel	With coarse sand and pebbles of quartzite
61.3	62.5	1.2	Sand	Fine to medium with some coarse sand and boulders ofquartzite
62.5	63.7	1.2	Gravel	With boulders and cobbles of quartzite and granite gneissand with sand
63.7	64.3	0.6	Clay	Gritty, mottled (pink, light green and white) with graveland pebbles
64.3	70.1	5.8	Gravel	Angular with fine to coarse sand and with boulders ofquartzite
70.1	71.3	1.2	Gravel	With boulders, gravel essentially angular, boulders andcobbles constituted of quartzite
71.3	71.9	0.6	Clay	Reddish brown associated with few patches of mottled clay, gritty with boulders of quartzite
71.9	73.1	1.2	Gravel	Angular to surrounded with some sand and clay
73.1	73.7	0.6	Sand	Coarse with gravel and cobbles of quartzite
73.7	74	0.3	Sandstone	Clayey, mottled (violet, grey, yellow and white), with cobbles and boulders, essentially quartzite, cobbles sub-rounded
74	76.8	2.8	Gravel	Angular to sub rounded with some sand
76.8	78	1.2	Clay	Brownish, hard and gritty (due to the presence of graveland coarse sand) with pebbles and cobbles of quartzite.

NOORWALA				
Depth Range (m bgl)		**Thickness**	**Lithology**	
From	**To**			
0.0	0.9	0.9	Clay	Light gravel with a little gravel.
0.9	6.1	5.2	Clay	Deep brown with Kankar and gravel.
6.1	9.1	3.0	Clay	Light brown slightly sticky.

9.1	12.2	3.1	Clay	Grey with a few pieces of calc nodules and limestone and boulders of phyllite and quartzite
12.2	18.3	6.1	Clay	Light brown with gravel.
18.3	21.2	3.0	Clay	Light brown with sub-rounded gravel and boulders ofquartzite and limestone.
21.2	24.4	3.1	Clay	Silty, brown, with a little gravel and cobbles.
24.4	29.3	4.9	Clay	Dark brown, sticky with boulders of quartzite.
29.3	29.9	0.6	Clay	Light brown with sand and gravel.
29.9	43.0	13.1	Gravel & Clay	Gravel and boulders with grey clay.
43.0	44.2	1.2	Sand	Coarse, with gravel and boulders.
44.2	45.7	1.5	Clay	Brown, sandy, with boulders.
45.7	46.9	1.2	Gravel	With sand and boulders of quartzite.
46.9	61.0	14.1	Clay	Light brown, sticky, hard with boulders and cobbles ofphyllite, quartzite and limestone with occasional pellets ofyellow ochre (in the depth zone 51.8-56.1 m)smallboulders contain pyrite specks.
61.0	63.7	2.7	Clay	Grey, hard, with boulders of quartzite.
63.7	64.6	0.9	Sand	With gravel and boulders.
64.6	65.8	1.2	Clay	Grey with gravel and pebbles.
65.8	68.9	3.1	Clay	Reddish brown with cobbles and boulders of limestone and quartzite.
68.9	79.2	10.3	Clay	Grey with pebbles and gravel of quartzite limestone.
79.2	82.3	3.1	Gravel	of 3mm-6mm size, mostly flat, constituted essentially of quartzite and limestone with a little clay and pebbles and boulders of limestone and quartzite.
82.3	85.3	3.0	Gravel	Without clay, of 3mms-5mms size with boulders andcobbles of garnet ferrous quartzite and limestone.
85.3	91.4	6.1	Sand	Coarse to very coarse with gravel and boulders of Laminated(Talc) and brown quartzite.
91.4	101.5	10.1	Sand	Coarse to very coarse with gravel and boulders ofquartzite.

101.5	103.6	2.1	Clay	Sticky hard with angular fragments of embedded limestoneand quartzite.
103.6	107.3	3.7	Gravel and Sand	Coarse sand with pebbles and cobbles of quartzite (some femrginous) and limestone.
107.3	108.5	1.2	Clayey Sand	Clayey sand, fine grained (quick sands).
108.5	109.7	1.2	Sand	Medium to very coarse and gravel with pebbles andcobbles of quartzite gneissose rock (?) a few pieces oflimestone.
109.7	116.1	6.4	Sand	Medium to coarse with a little gravel and very fewpebbles.
116.1	118.3	2.2	Sand	Fine to medium with a little gravel.

Annexure II: Depth to Water level data of Dehradun District

Sl. No.	Location	May-21	Aug-21	Nov-21	Jan-22
Doiwala Block					
1	**Khandgaon**	12.35	7.07	10.26	12.8
2	**Khadiri (KhadakMaf)**	60.58	58.84	56.06	55.76
3	**Rishikesh**	75.35	67.2	67.42	72.89
4	**Lal Tappar**	17.01	4.43	**NA**	**NA**
5	**Bhaniawala**	56.7	49.89	46.01	47.23
6	**Dudhli* new**	60.65	44.93	49.93	52.91
7	**Kotimachak**	71.98	66.98	58.12	61.61
8	**Chandmari**	28.48	17.18	23.5	25.92
9	**Duggiawala**	14.67	4.15	8.51	13.39
10	**Mathrowala**	13.38	8.1	10.17	12.12
Raipur Block					
11	**Kuanwala DW**	7.4	1	2.75	3.94
12	**Gularghagti * replace**	14.63	8.08	9.63	12.1
13	**Soda Saroli**	9.45 lpm	40.8 lpm	8.33 lpm	692 lpm
14	**Balliwala**	53	50.1	NA	NA
15	**Maldeota**	13.07	4.07	7.57	11.31
16	**Nanurkhera**	69.08	68.88	58.98	61.29
17	**TarlaNagal**	76.25	66.95	65.15	70.61
18	**TarlaNagal**	53.75	45.05	48.95	52.41
19	**Purukulgaon**	25.93	12.48	23.32	25.47
20	**Bhatta**	5.64 lpm	480 lpm	9.375 lpm	7.15 lpm
21	**Niranjanpur**	37.89	36.39	32.6	32.83
22	**CGWB Office**	50.3	58.62	55.36	55.78
23	**Harbanswala**	39.8	34.8	45.65	46.44
24	**Kanwali**	12.87	8.2	11.5	12.57
25	Bhopalpani (Badawali)	9.26	2.57	1.86	6.64
26	**LadpurPz ***	91.55	82.51	80.77	81.99
SahaspurBlock					
27	**Singhniwala**	9.35	7.04	8.94	9.12
28	**Baronwala**	19.74	16.8	16.97	17.42
29	**Ramgarh**	6.4	5	6.1	6.58
30	**Jhajra**	14.3	7.7	7.74	9.92
31	**Jhajra**	15.99	5.94	7.32	11.17
32	**Nanda ki Chowki**	DRY	8.75	8.77	9.3
33	**Nanda ki Chowki**	22.25	16.3	13.05	13.92
34	**Khandoli**	23.17 lpm	180 lpm	13.63 lpm	429 lpm
35	**Selakui**	DRY	1	9.06	9.42
36	**Selakui**	16.72	13.42	11.77	12.89
37	**Sabhawala**	8.78	6.21	7.58	7.82
38	**Rampura**	11.5	8.2	9.85	9.86
39	**Shankarpur**	11.8	21.7	21.76	21.96
40	**Redapur**	10.15	8.45	7.05	6.76
41	**Redapur**	7.54	4.84	4.19	3.9
42	**Sahaspur**	6.93	5.45	4.15	3.77
43	**Chhorba**	37.51	36.36	31.88	30.92

44	**Telpura**	44.8	37.58	42.32	34.13
Vikas Nagar Block					
45	**Badripur**	9.03	6.68	8.93	8.95
46	**Judli**	13.5	11.9	12.8	12.92
47	**Herbertpur**	NA	NA	NA	9.81
48	**Vikas Nagar**	27.88	24.78	25.98	27.75
49	**Dharmawala**	3.05	2.55	3.65	3.32
50	**Dakpatthar**	26.87	23.17	22.5	24.54
51	**Barothiwala**	3.85	20.2	NA	NA
52	**Barothiwala new Jan 2021**	3.85	NA	26.6	3.75
53	**Dhakrani**	18.3	11.7	13.23	17.6
54	**Timli**	67.94	65.08	65.75	66.67
55	**Baluwala**	41.67	39.05	35.81	36.11
56	**Luxmipur**	34.58	29.14	27.72	28.18
57	**Haripur**	10.8	8.8	10.1	10.33
58	**Jamuna Pull* new**	13.3	9.63	10.5	13.6

Annexure III- Ground water quality data of the Study Area

Sl.No.	Sample Location	pH	Conductivity µmho /cm at 25°C	TDS	CO_3	HCO_3	Cl	F	NO_3	SO_4	Hardness as CaCO3	Ca Hardness	Mg Hardness	Na	K	SiO_2	PO_4
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	Ramgarh	7.81	545	354.25	nil	195	14	BDL	19.5	75	270	52	33.6	5.01	1.1	24	nd
2	Sabhawala	7.62	411	267.15	nil	171	28	BDL	37	17	200	40	24	6.68	9.8	19	0.53
3	Badripur	7.64	408	265.2	nil	159	21	BDL	29	16	170	44	14.4	6.64	9.8	20	0.6
4	Timli	7.71	304	197.6	nil	171	7	BDL	BDL	9	150	32	16.8	5.43	1	31	nd
5	Baadowala	7.4	278	180.7	nil	159	7	BDL	BDL	5	130	32	12	4.25	2	18	nd
6	Telpura	7.61	403	261.95	nil	232	14	BDL	BDL	5	190	48	16.8	7.5	1	28	nd
7	Majra	7.74	540	351	nil	256	21	BDL	BDL	27	250	52	28.8	5	1	19	nd
8	Khandoli	7.89	491	319.15	nil	195	14	BDL	BDL	48	220	32	33.6	4.3	1	16	nd
9	Nanda Ki Chowki	7.95	650	422.5	nil	171	21	BDL	19.5	126	300	60	36	6.2	1	22	nd
10	Nanda Ki Chowki	7.77	68	44.2	nil	24	7	BDL	BDL	5.7	30	8	2.4	3.1	BDL	30	nd
11	Jhajra	7.92	276	179.4	nil	122	28	BDL	BDL	5.1	130	28	14.4	5.4	1	15	nd
12	Jhajra	7.98	298	193.7	nil	146	21	BDL	BDL	5	140	40	9.6	5.4	1	11	nd
13	Selakui	7.9	301	195.65	nil	134	35	BDL	BDL	5	150	36	14.4	5.5	1	10	nd
14	Rampura	7.78	366	237.9	nil	183	21	BDL	5	5.4	170	52	9.6	5.2	1	24	nd
15	Shankarpur	7.69	172	111.8	nil	73	14	BDL	5	10.5	75	12	10.8	7	1	35	nd
16	Sahaspur	7.74	233	151.45	nil	110	14	BDL	BDL	9.8	105	24	10.8	7.1	BDL	18	nd
17	Chhorba	7.71	123	79.95	nil	61	7	BDL	BDL	5.1	55	8	8.4	5.47	BDL	22	nd
18	Barothiwala	7.29	132	85.8	nil	55	14	BDL	BDL	5	60	8	9.6	5.4	BDL	23	nd
19	Baluwala	7.34	149	96.85	nil	79	7	BDL	BDL	5	70	12	9.6	5.45	BDL	22	nd
20	Haripur	7.53	112	72.8	nil	49	7	BDL	BDL	5	40	12	2.4	5.95	1	23	nd
21	Dakptthar	7.16	158	102.7	nil	85	7	BDL	BDL	5	70	12	9.6	5.4	1	20	nd

22	Bhopalpani (Badawali)	7.43	126	81.9	nil	61	7	BDL	BDL	5	50	12	4.8	5.8	1	10	nd
23	Dhakrani	7.67	363	235.95	nil	183	14	BDL	BDL	12	160	52	7.2	6.6	2.5	14	nd
24	Herberpur	7.25	224	145.6	nil	61	14	BDL	25	14	90	20	9.6	4.9	1.5	28	nd
25	Purukulgaon	7.66	407	264.55	nil	201	28	BDL	5	15	200	52	16.8	8.7	2	16	nd
26	TarlaNagal	7.63	160	104	nil	61	7	BDL	BDL	15	65	20	3.6	3.3	1.3	7.8	nd
27	Nanurkhera	7.69	320	208	nil	122	21	BDL	11	17	140	48	4.8	4.4	2.8	20	nd
28	Maldeota	7.91	417	271.05	nil	146	21	BDL	5	57	200	60	12	4.7	1	20	nd
29	Bhaniawala	7.71	502	326.3	nil	268	14	BDL	13	14	260	56	28.8	3.1	1	13	nd
30	Lal Tappar	8.01	501	325.65	nil	220	14	BDL	5	54	260	36	40.8	2.5	1	10	nd
31	KhadakMaaf	7.94	406	263.9	nil	220	14	BDL	BDL	15	210	36	28.8	3.1	1.3	6.8	nd
32	Rishikesh	9.2	376	244.4	48	256	43	0.66	5	1410	30	8	2.4	850	1.3	4.1	nd
33	Kotimaichak	7.92	520	338	nil	195	14	BDL	BDL	74	250	56	26.4	4.1	1.7	9.4	nd
34	Kuanwala	8.18	351	228.15	nil	171	21	BDL	BDL	5.9	140	40	9.6	14	1.1	8.6	nd
35	Gularghati	7.92	359	233.35	nil	159	14	BDL	5	32	170	52	9.6	4.3	1.4	18.4	nd
36	Mothrowala	8.05	186	120.9	nil	92	7	BDL	BDL	5	70	16	7.2	8.5	1.2	8	nd
37	Chandmari	7.65	167	108.55	nil	85	7	BDL	BDL	5.1	70	12	9.6	6.2	1.2	18	nd
38	Soda Sarauli	8.11	217	141.05	nil	85	14	BDL	8.6	16	90	16	12	7.8	2	22	nd
39	Harbanswala	7.76	750	487.5	nil	232	7	BDL	5	167	380	80	43.2	2.2	1.7	13	nd
40	Khandgaon	7.91	441	286.65	nil	232	14	BDL	13	17	230	36	33.6	3.3	1	13	nd
41	Bhatta	8.04	890	578.5	nil	403	28	BDL	20	66	430	104	40.8	8.2	2	21	nd
42	Kanwali	8.07	893	580.45	nil	390	28	BDL	21	67	440	100	45.6	8.5	2	22	nd
43	Vikash Nagar	8.15	889	577.85	nil	378	35	BDL	21	69	420	104	38.4	8.1	2	21	nd
44	Luxmipur	7.91	783	508.95	nil	329	21	BDL	26	62	380	84	40.8	6.7	1.3	22	nd