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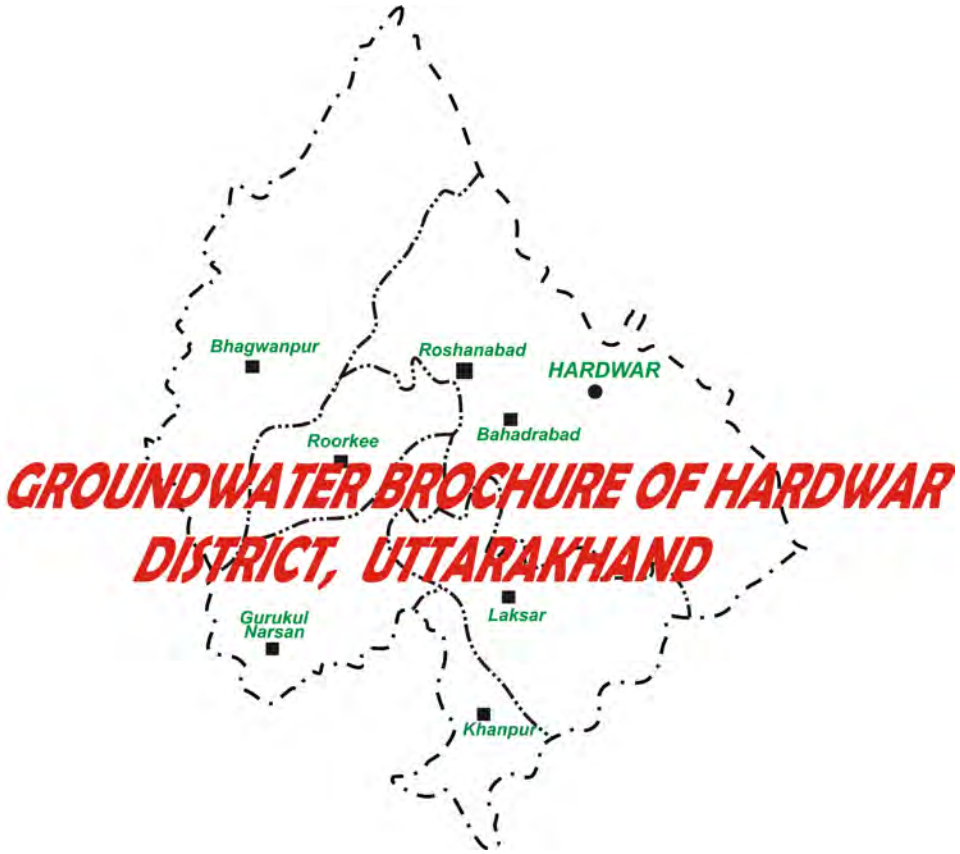
GOVERNMENT OF INDIA

MINISTRY OF WATER RESOURCES

CENTRAL GROUND WATER BOARD



GROUNDWATER BROCHURE OF HARDWAR DISTRICT, UTTARAKHAND

UTTARANCHAL REGION APRIL 2009 DEHRADUN

GROUNDWATER BROCHURE OF HARDWAR DISTRICT, UTTARAKHAND

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HARDWAR DISTRICT AT A GLANCE

Sl. No.	Items	Statistics
1	**GENERAL INFORMATION**	
	(i) Geographical area (sq.km.)	2360
	(ii) Administrative Divisions (As on 2001-02) Number of Panchayat /Villages	46/622
	(iii) Population (as on 2001 census)	14,47,187
	(iv) Average Annual Rainfall (mm)	1181.8mm
2	**GEOMORPHOLOGY**	
	Major physiographic units	Siwalik hills, piedmont plain, alluvium plain and flood plain
	Major drainage	Solani, Ratamau Roa, Banganga, and Ganga
3	**LAND USE (sq.km.)**	
	(a) Forest	724.31
	(b) Net Sown area	1220
	(c) Area Sown more than once	590
	(d) Cultivable area	
4	**MAJOR SOIL TYPES**	Ultisols, Entisols and Mollisols, Sandy loam, Silty Loam,
5	**AREA UNDER PRINCIPAL CROPS**	
6	**IRRIGATION BY DIFFERENT SOURCES (area and numbers of structures)**	
	Dug wells	nil
	Tube wells/bore wells	33,155 (84%)
	Tanks/Ponds	nil
	Canals	300km (15%)
	Other sources	Natural precipitation
	Net Irrigated area	1010
	Gross Irrigated area	1450
7	**NOS. OF GROUND WATER MONITORING WELLS OF CGWB (As on 31/03/2007)**	
	No. of Dug wells	12
	No. of piezometers	3
	No. of Handpumps	5
	No. of Observation wells	2
8	**PREDOMINANT GEOLOGICAL FORMATIONS**	Bhabar, Tarai and flood plains
9	**HYDROGEOLOGY**	
	Major water bearing formations	Tarai, Ganga alluvium and flood plains
	(pre-monsoon depth to water level Range	0.78 – 50.20 (mbgl)
	(post-monsoon depth to water	0.64 – 48.56

	level Range	
	Fluctuation range	Rise (0.02 to 5.63 -6.72) Decline (0.11 to 6.72)
	Long term water level trend in 10 yrs (1997-2006)	
10	**GROUND WATER E4XPLORATION BY CGWB (As on 31/03/2007)**	
	No. of wells drilled (EW,OW,PZ,SH, Total)	
	Depth Range (m)	
	Discharge (lpm)	
	Storativity (S)	
	Transmissivity (m^2/day)	
11	**GROUND WATER QUALITY**	
	Presence of Chemical constituents more than permissible limit	As per Partial Analysis data, the parameters are well with in permissible limit
12	**DYNAMIC GROUND WATER RESOURCES (2004) in mcm**	
	Annual replenishable Ground resources	92093.53
	Net annual ground water draft	84563.89
	Projected demand for domestic and industrial uses upto 2005	1083.11
	Stage of ground water development	91.82%
13	**AWARENESS AND TRAINING ACTIVITY**	
	Mass awareness programmes organized	1
	Date	24th February 2007
	Place	Bhagwanpur Block office
	No. of participants	200
14	**EFFORTS OF ARTIFICIAL RECHARGE & RAINWATER HARVESTING**	-
	Projects completed by cgwb (No. & ammount spent)	-
	Projects under technical guidance of CGWB (Numbers)	-
15	**GROUND WATER REGULATION AND CONTROL**	
	Number of OE/SC/C/S Blocks	2/3/0/1
16	**MAJOR GROUND WATER PROBLEMS AND ISSUES**	Declining of Water Levels, non-command area, less rainfall and excess withdrawal of ground water through tubewells

GROUNDWATER BROCHURE OF HARDWAR DISTRICT, UTTARAKHAND

1.0 INTRODUCTION

Hardwar district is located in south – western part of Uttarakhand State. It lies from 29^0 35' to 30^0 40' North latitude and 77^0 43 ' to 78^0 22' East longitude and falls in Survey of India Degree Sheet Nos. 53 J, F, G and K. Dehradun and Pauri bounds the district in northeast, Bijnor district of Uttar Pradesh in the south-east, southern boundary with Muzaffarnagar district of Uttar Pradesh while the western part is bounded by district Saharanpur. The geographical area of the district is 2360 km^2.

Hardwar district has been divided into three Tehsils viz. Roorkee, Bhagwanpur and Laksar and six Development Blocks namely Roorkee, Bhagwanpur, Laksar, Khanpur, Bahdarabad and Narsan and comprises 622 villages. The administrative map of Hardwar district is given at Fig 1.

Hardwar district has been very well connected with the network of metalled roads and railway lines. The length of metalled road in the district is 1871 km out of which 954 km are under the Public Works Department. The major towns of Hardwar district are connected by railways.

Tubewells form the chief means of irrigation. However, some parts are rainfed. Rainfall is the only source of water for ground water recharge. There are 225 State Goverment tubewells and 32930 private tubewells.

2.0 CLIMATE AND RAINFALL

District Hardwar experiences moderate subtropical to humid climate with three distinct seasons viz. summer followed by rainy and winter seasons. The hydrometereological observations for Roorkee observatory are given in Table 1.

Temperature begins to rise from March (29.1^0C) and reaches to its maximum in May (39.2^0C), with the commencement of monsoon season by mid-June, the temperature begins to fall. During the winter season in the month of November to February the temperature ranges between 10.5^0C and 6.1^0C.

The relative humidity is highest in monsoon season (85% in the morning and 79% in the evening). The lowest humidity is observed during the month of April and May i.e. 24% (in evening) and 40% in May (in morning).

The mean monthly wind speed is highest in the summer season when it goes up to 7.4 and 7.2 km/hour in the month of May and June and the minimum wind speed is observed during winter when it is 2.6 km/hour in the month of October. The potential evapotranspiration is maximum in the month of May 198.9 mm and minimum 38.5 mm in the month of December.

Table 1. Climatological data of Roorkee Observatory

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean/ Total
Temp^{0}C													
Maximum	20.4	23.5	29.1	35.7	39.2	38.1	33.5	32.4	22.7	31.4	27.1	22.3	38.5
Minimum	6.1	8.2	12.8	16.3	22.1	24.9	24.5	24.5	22.9	17.2	10.5	6.7	18.8
Humidity													
Morning	85	78	53	44	40	59	82	85	82	74	79	82	71
Evening	53	43	34	24	24	42	68	79	65	58	49	54	48
Rainfall (mm)	36.5	33.0	34.5	8.4	19.2	128.7	342.6	336.8	157.8	39.4	5.5	14.3	1156.4
No. of rainy days	3.2	1.8	2.3	0.9	1.9	5.8	12.3	13.1	6.0	1.7	0.5	1.0	50.5
WindSpeed (kmph)	3.9	4.9	5.6	6.4	7.4	7.2	5.8	4.7	4.1	3.1	2.6	3.0	4.9
PET (mm)	42.8	62.4	110.4	152.7	198.9	192.0	135.3	123.8	121.6	99.4	55.5	38.5	1333.8

The average normal annual rainfall in Hardwar district is 1174.3 mm, out of which 84% is received during monsoon season and only 16% occurs during non-monsoon period. The district receives heaviest rainfall in northern part. The rainfall gradually decreases towards south. To study the recent trend of rainfall distribution over the district, monthly rainfall during monsoon has been given in Table 2. The monthly distribution of rainfall during the monsoon season over the district shows that July and August are the wettest month in the district having a rainfall 329.3 and 393.8 mm, respectively. The rainfall during the month of July and August is more or less the same. The monsoons retreat in the first fortnight of October giving a meager rainfall of about 31 to 34 mm. Maximum rainfall occurs in the foothills of Himalayas and gradually decreases towards south.

Table 2. Monthly and Annual Normal Rainfall, District Hardwar (mm)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mon soon	Non Mon soon	Annual
Roorkee															
	43.3	**41.1**	**26.9**	**11.4**	**18.9**	**99.0**	**329.3**	**299.3**	**182.0**	**31.5**	**4.7**	**14.9**	**909.6**	**192.8**	**1102.4**
Hardwar															
	48.1	**45.8**	**24.5**	**9.8**	**19.9**	**108.9**	**360.1**	**393.8**	**192.2**	**34.3**	**5.4**	**15.4**	**1053.0**	**203.2**	**1256.2**

3.0 GEOMORPHOLOGY AND SOIL TYPES

The topography is undulating in the northern part and more or less plain towards south. The altitude ranges from 869 to 232 m. In the vicinity of Siwalik Hills, the gradient is steep. Geomorphologically Hardwar district can be divided into four geomorphic units. These are flood plain, lower piedmont plain, upper piedmont plain and structural hills. The geomorphological map of Hardwar district is shown in Fig 2.

The flood plain area is relatively flat, low lying and adjacent to Solani River. It comprises unconsolidated, coarse to fine sand with silt and clay. The area is repeatedly inundated during the floods. The lower piedmont plain is flat to undulating with gradient towards southwest having micro relief. The sediments vary from fine clastic to coarse clastic manifesting in variable runoff and infiltration.

The upper piedmont zone is narrow, southerly sloping upland adjoining the Siwalik Hills in varying lateral and areal extent formed at the foot hills by the coalescence of several alluvial fans comprising unsorted coarse clastic sediments (boulders, pebbles, gravels sand and clay). It has high gradient (about 10 m/km) in the northern part to about 0.4 m/km in the southern part close to Tarai. In this zone, most of the ephemeral rivers draining the area disappear. There is high moisture content in upper piedmont zone which support dense forest and lies to the south of Bhabar zone.

Structural hills show high relief and deep incised drainage with steep and sharp hill slopes and well defined crest line (northern boundary of the block). This unit shows rugged topography and homogenous lithology. The vegetation is dense indicating the presence of loose alluvial material.

Soils play an important role in ground water recharge and the agriculture production of the area. The land of Bhagwanpur block is highly fertile. The northern part, paleochannels and active floodplain of rivers have soils of sandy loam, where as remaining part of the block is covered by silty loam soils. Important soils are Ultisols, which are the brown hill soil, occurring all through the northern part of the block. These are the soils with a horizon of clay accumulation and low base supply. Entisols are the soils (also called the Bhabar soil) occurring all along the foothills of Siwaliks and extends up to Tarai. These soils are without pedogenic horizons. Though these soils consist of boulders, pebbles, sand, silt and clay, they are highly fertile. Mollisols, also called the Terai soil, occur in the southern part of the block. They consist mainly of fine-grained sand, silt and clay. These are the soils with a nearly black, organic-rich surface horizon and high base supply. These three types of soils are mineral soils with organic matter less than 25%. These are the most fertile soils of the block.

4.0 GEOLOGY

Geologically the area may de divided into three zones viz. Siwaliks, Bhabar and Gangetic Alluvial Plains from North to South.

Siwalik Range: This forms the outermost part of Himalaya and comprise Tertiary Group of rocks. In Bhagwanpur block only Upper and Middle Siwaliks are exposed. The Upper Siwaliks is constituted of boulders, pebbles, sand and clay. The boulders and pebbles are mostly of quartzites. Middle Siwaliks comprises mainly grey micaceous sandstone and siltstone.

Older Alluvium (Piedmont Plains or Bhabar): The Piedmont Plains are formed along the foothills of Siwaliks. It is formed by flooding hill torrents and nallahs (locally termed as 'Rao'). Alluvial fans in the piedmont zones are wider and longer when formed along mature streams. The Older Alluvium consist of polycyclic sequence of brown to grey silt, clay with boulders and pebbles.

Gangetic Alluvial Plains: The region south of the piedmont plains occupied by Gangetic Alluvial Plains, forms major part of the Bhagwanpur block. Lithologically, the alluvium is formed of unconsolidated to semi-consolidated deposits of sand, silt, clay and kankar.

5.0 GROUND WATER SCENARIO

Hardwar district comes under Ganga river system. The main tributaries of Ganges like Solani, Ratmau Rao and Banganga and their feeding nallahs drain the area. These tributaries are ephemeral in nature. As far as canal irrigation is concerned, western part of the district is well covered with 300 km length canal network. Bhagwanpur block comes under non-command area. Hence, there is an immense pressure on ground water due to which water levels are declining at faster pace. There are 225 State Government tubewells and 32930 private tubewells. The ground water abstraction for drinking, domestic and agriculture purposes is higher in Bhagwanpur block as compared to other blocks. Most of the tubewells are drilled in central and southern part of the block. The northern part of the block has less number of tubewells.

5.1 Hydrogeology

The ground water conditions in alluvial parts of Hardwar district are considerably influenced by the varying lithology of the subsurface formations. The fluvial deposits of Indogangetic Plains exhibit significant variations, both laterally and vertically. The main

source of water, which sustains groundwater in the district, is rainfall. The other sources of groundwater replenishment are infiltration from canals and irrigation return flow. The common ground water abstraction structures in Hardwar district are shallow and deep tubewells. Dug wells are also used for drinking and other domestic purposes up to a limited extent. Most of the dug wells have been abandoned. The location map of surveyed dug wells, hand pumps and GWMW of Hardwar district, Uttarakhand is shown in Fig 3.

Hrdrogeological surveys carried out in Hardwar district show that water levels range from 0.78 to 50.20 m bgl in pre-monsoon period and from 0.64 to 48.56 m bgl during post-monsoon period, respectively. The northern and northeastern parts of the district comprise boulders, pebbles, gravels, sand and clay, which form a good recharge zone. The water levels in this area range from 4.02 to 50.20 m bgl. The deepest water level was recorded at Laldang in Bahadrabad block. The water level in gangetic alluvium ranges from 0.64 to 24.13 m bgl. The deepest water level is recorded at Bhagwanpur town.

Alluvium is the main water bearing formation in the area, which consists of coarse sand, fine sand and silt. Ground water in Hardwar district occurs under unconfined, confined and semi-confined conditions. The aquifers are separated with thick clay with considerable thickness, which act as confining layers. The water level data suggests the presence of multilayer aquifer system. The first one is unconfined and the others are semi-confined to confined. The depth of first unconfined aquifer ranges from 4 to 8 m bgl and the others are 18 to 25 m bgl, 40 to 60 m bgl and 90 to 120 m bgl. Due to variable thickness of clay layers, the aquifers become double layered from west to east. Based on hydrogeological and geomorphological studies, the hydrogeological map of Hardwar district has been prepared and shown in Fig 4.

5.2 Ground Water Resources

Ground water resource of Hardwar district are estimated using Rainfall Infiltration Factor Method (RIF). Based on resource estimation, the total ground water availability in Hardwar district is arrived (as on March 2004) as 87719.6 ham and the gross ground water draft from all uses is estimated as 84563.89 ham. The stage of ground water development is 96.40% and the district is categorized as critical.

5.3 Ground Water Quality

The partial chemical analyses of samples of the district reveal that the chemical parameters of ground water are well within permissible limit and suitable for drinking and irrigation purposes.

5.4 Status of Ground Water Development

Ground water in Hardwar district has been extensively developed through tubewells. Central Ground Water Board has drilled three exploratory wells (one under construction), one piezometer and two observation wells with depth range 65.92 to 223.96 m bgl. The discharge of these wells ranges between 961 and 2300 lpm. State Government and private people have drilled maximum tubewells in the alluvial portions with depth ranging from 60 to 150 m bgl. The discharge of these tubewells ranges from 1200 to 2500 lpm.

6.0 GROUND WATER MANAGEMENT STRATEGY

Ground water in Hardwar district has been extensively developed through tubewells. Proper management is required to minimize the over withdrawl of ground water in Bhagwanpur block. Rainwater harvesting and artificial recharge are to be practiced on a larger scale. The Bhabar zone along the foothills of Siwalik consists of boulders, gravels, sand and clay, which exhibit high porosity and permeability enabling it to form a good recharge zone through direct infiltration of precipitation. The hydrogeolological investigations during pre-monsoon period reveal that the ground water flows in southwest direction. The high altitude areas of Siwalik and Bhabar may be used for the construction of check dams by tapping lower order streams, so that ground water is recharged in the plain areas. Soil Conservation and Watershed Management Department has constructed 48 check dams in Bhabar area. The surplus outflow of these check dams may be utilized for recharging the plain areas where ground water abstraction is more. The areas where maximum agricultural activities are going on may be selected for rainwater harvesting and groundwater recharge.

7.0 GROUND WATER RELATED ISSUES AND PROBLEMS

Hydrogeological investigations reveal that the water levels in Hardwar district are sustained except in Bhagwanpur block, where water levels are declining. Ground Water Resource Estimation of Hardwar district has been done in March 2004. The stage of ground water development is 96.40% and the district is categorized as critical. The declining water levels in Bhagwanpur block are due to excessive ground water abstraction.

8.0 AWARENESS AND TRAINING ACTIVITY

A Mass Awareness Programme on conservation of ground water, Rainwater Harvesting and Artificial Recharge to ground water was organized by CGWB, UR, Dehradun at Bhagwanpur block (in the premises of Block Headquarter). The Industrialist working in the area were advised and requested to save ground water from various sources of pollution and

adopt Rainwater Harvesting and Artificial Recharge to sustain ground water resources. The Gram Pradhans and Village Development Officers were especially invited so that they could increase the awareness among villagers on important issues like sustainable development of the fast depleting ground water resource by adopting methods on conservation of ground water. In order to create visual impact in the Mass Awareness Programme, an exhibition on different techniques of Rainwater Harvesting in rural and urban areas was also organized in the Block Office. During Mass Awareness Programme, Dr. R. P. Singh, Scientist 'D', delivered lecture on various techniques of Rainwater Harvesting in rural and urban areas and discussed about the significance of such activities, in context of Uttarakhand State and Bhagwanpur block in particular. Dr. S. K. Srivastava, Scientist 'B' (Chemist) elaborated on the quality of water for drinking and irrigational uses and discussed in detail about pollution hazards of ground water.

9.0 AREA NOTIFIED BY CGWA/SGWA

Nil

10.0 RECOMMENDATIONS

The recent hydrogeolological investigations reveal that the ground water flows in southwest direction. The higher areas of Siwalik and Bhabar are situated in the northern and northeastern part of the Hardwar district, which can be used for construction of check dams by tapping lower order streams, so that it can recharge the ground water in the plain areas, where ground water abstraction is more. The surplus water from these check dams can also be utilized for recharging the plain areas.

The Ganga Alluvium comparatively covers a large area in Hardwar district, where maximum agricultural activities are going on. In this area percolation ponds would be feasible for ground water recharge to unconfined aquifer. In Indogangetic Alluvial Plains, ground water can be recharged through recharge wells. The recharge wells may be constructed in the existing ponds. This practice has already been adopted in Khanpur village in Bhagwanpur block, where water levels are declining at faster rate. Existing ponds may be used for ground water recharge, after desilting. In the urban areas where industrial activities are increasing day-by-day, Roof Top Rainwater Harvesting and Artificial Recharge can be practised.

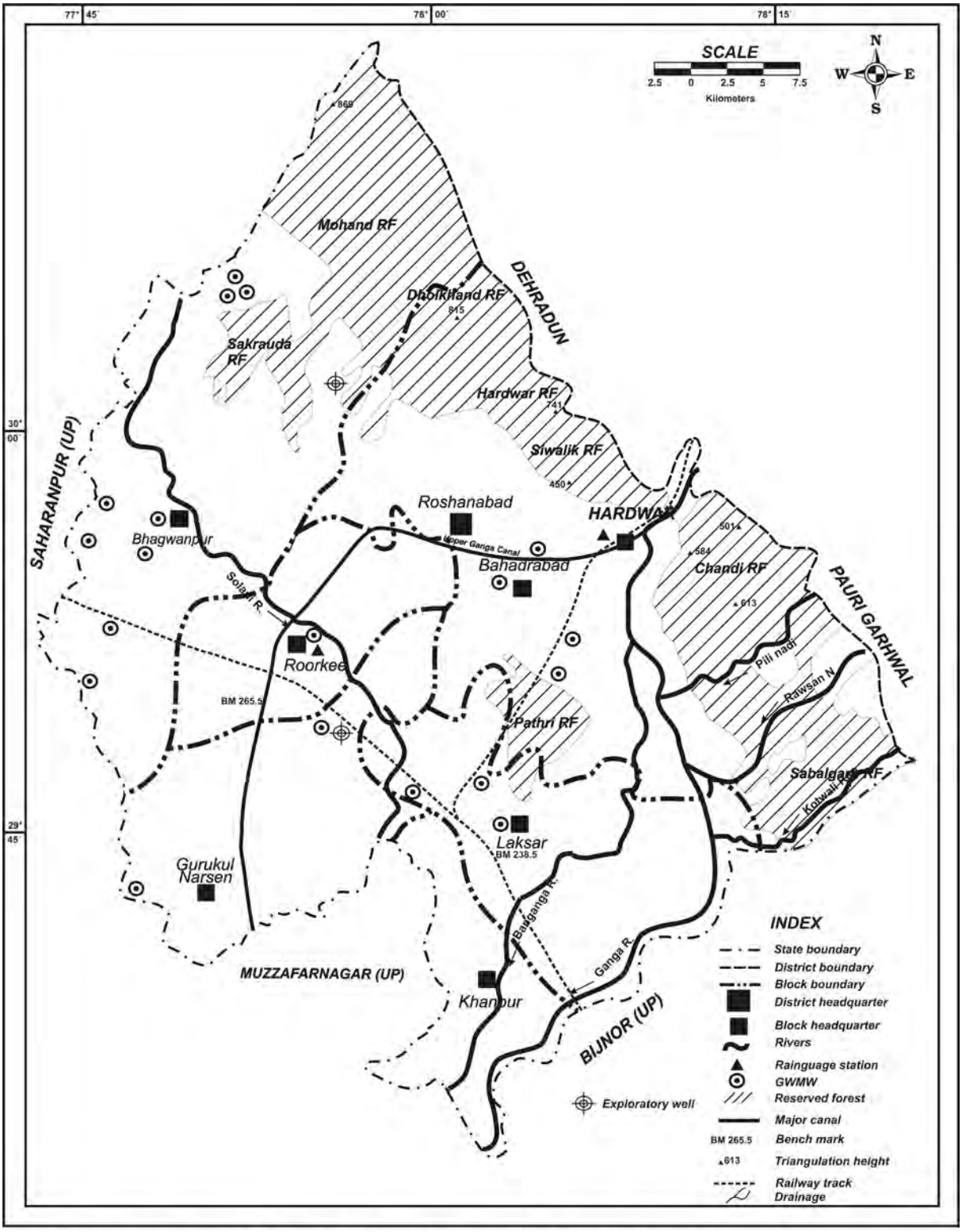


Fig. 1 ADMINISTRATIVE MAP OF HARDWAR DISTRICT, UTTARAKHAND

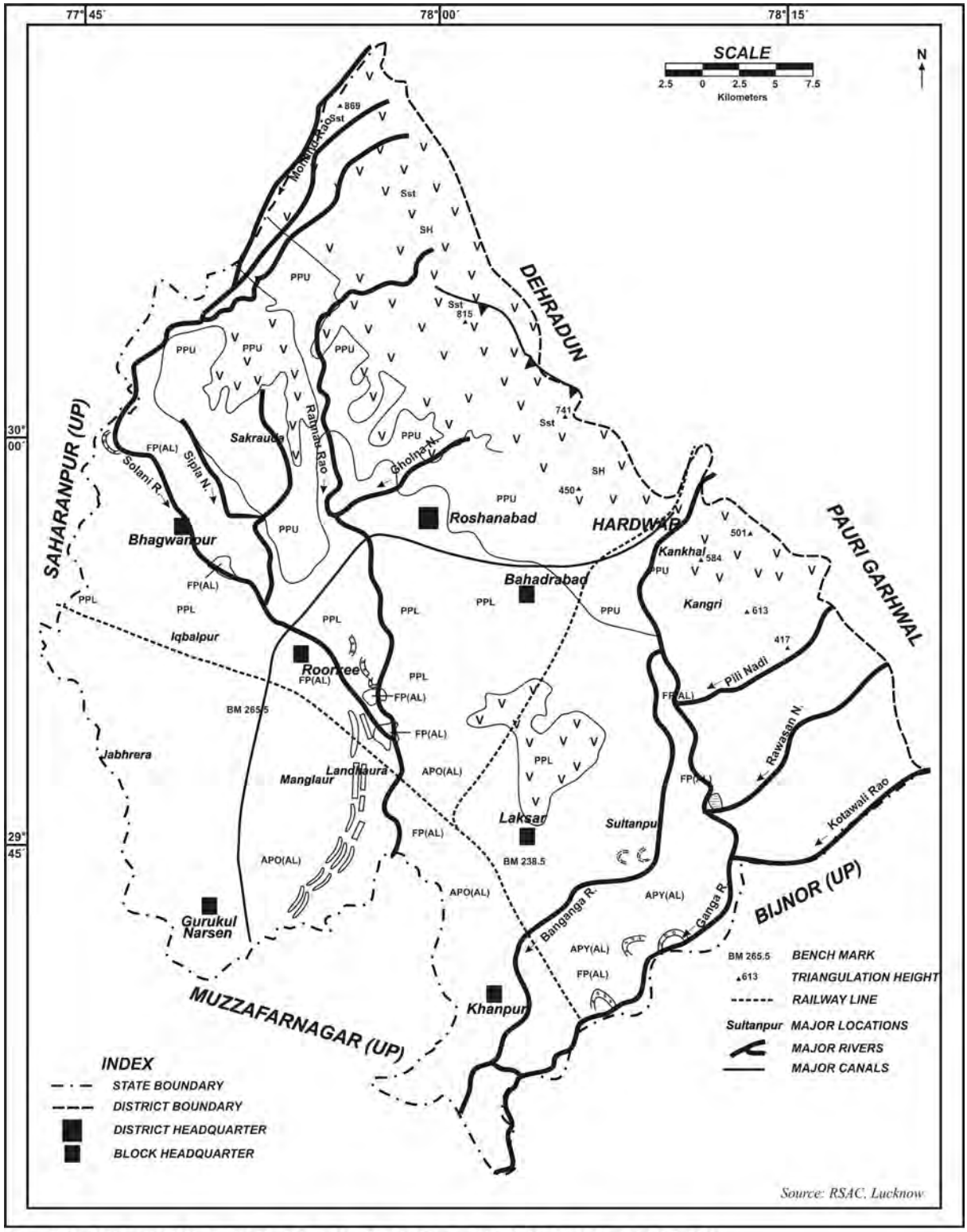
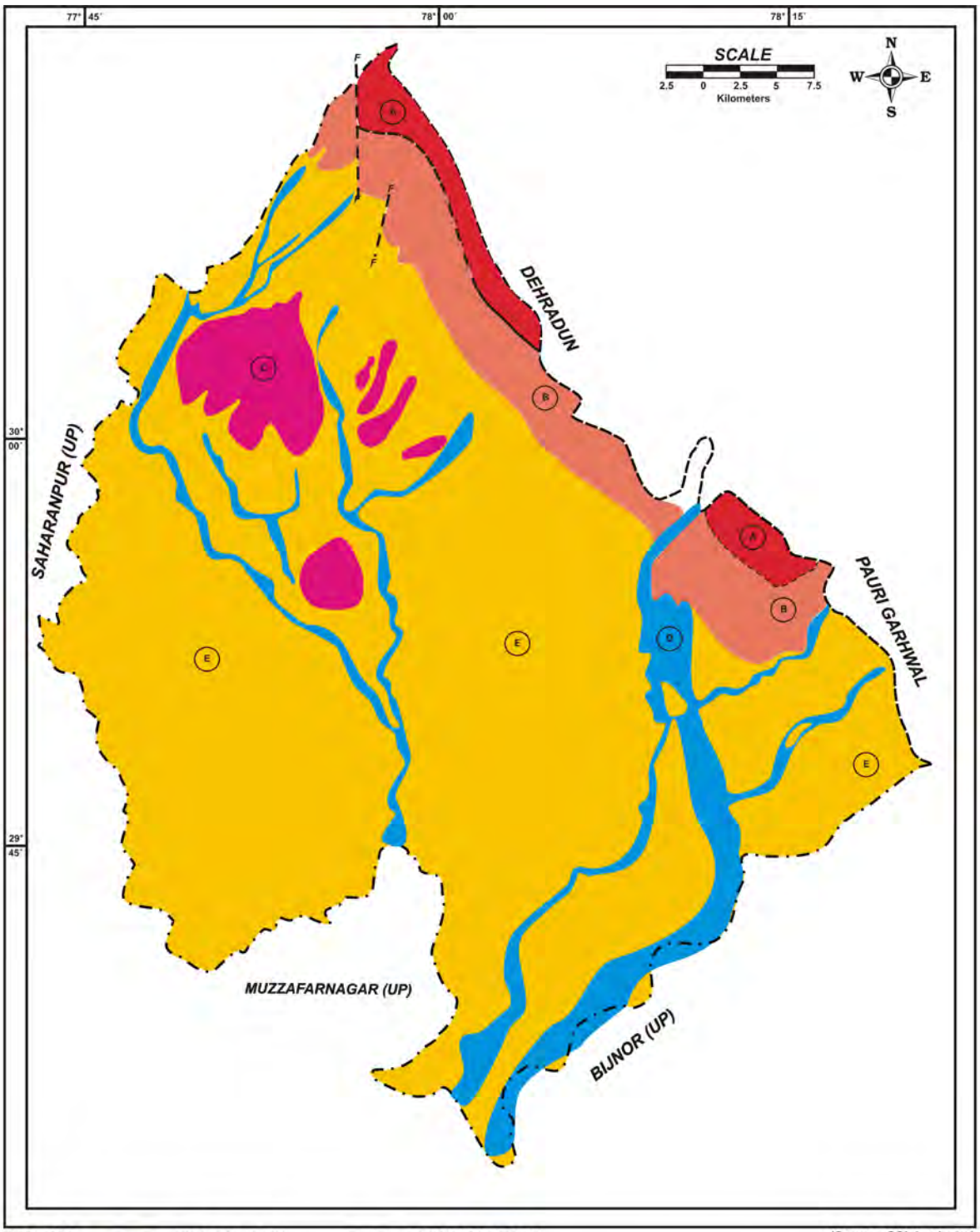


Fig. 2 GEOMORPHOLOGICAL MAP OF HARDWAR DISTRICT, UTTARAKHAND

LEGEND OF GEOMORPHOLOGICAL MAP

MAP SYMBOL	GEOMORPHIC UNIT	LITHOSTRATIGRAPHY	STRUCTURE	DESCRIPTION
	SAND BAR	RIVER SAND	—	Ganga, Yamuna and Solani rivers have produced extensive sand deposits of varying sizes along their margins through the fluvial action.
FP (AL)	FLOOD PLAIN (FP)	ALLUVIUM (AL)	—	Surface of relatively smooth, low lying, flat land adjacent to the Ganga, Yamuna and Solani rivers comprises unconsolidated, coarse to fine sand with silt and clay. The area is repeatedly inundated during the floods.
APY (AL)	YOUNGER ALLUVIUM PLAIN (APY)	ALLUVIUM (AL)	—	Flat to gentle sloping, slightly undulating terrain formed by the extensive deposition of sediments by the rivers Ganga and Yamuna. It comprises younger unconsolidated alluvium materials of varying lithology & consisting of fluvial landforms like palaeochannel, meander scar and point bar.
APO (AL)	OLDER ALLUVIUM PLAIN (APO)	ALLUVIUM (AL)	—	Similar to younger alluvial plains but formed at early stage by the rivers and consisting of older alluvium.
PPL	LOWER PIEDMONT PLAIN (PPL)	ALLUVIUM (AL)	—	Flat to undulating plain with gradient towards southwest having micro relief, sediment varies from fine clastic to coarse clastic with variable runoff and infiltration.
PPU	UPPER PIEDMONT PLAIN (PPU)	ROCK DEBRIS	—	It occurs all along the south of Siwalik hills in variable lateral and areal extent formed at the foot hills by the coalesence of several alluvial fans comprising boulders, gravel, sand and clay.
SH	STRUCTURAL HILLS	SAND STONE (Sst)	—	This unit shows high relief and deep incised drainage with steep and sharp hill slope and well defined crest line (northern boundary of the district). This unit shows rugged topography and homogenous lithology.
	LANDFORMS			
	VEGETATION ANOMALY		—	Dense vegetation indicates the presence of loose alluvial material.
	POINT BAR		—	Developed within the meanders having a trough which gets eventually filled up by the sediments of the fine to coarse material.
	OLD MEANDER		—	Gently sloping, crescent shaped features formed by drying up of abandoned meandering river channels developed along the rivers Ganga and Yamuna.
	MEANDER SCAR		—	An abandoned meander often filled with alluvium and covered with vegetation.
	PALAEOCHANNEL		—	Abandoned and buried river channels in alluvial plains.
	STRUCTURAL FEATURES			
F F	THRUST FAULT		Confirmed Thrust Confirmed Fault	Bhimgoda thrust and Ganga, Yamuna faults are delineated.



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(Source: GSI, Lucknow)

	AGE	FORMATION	GROUP	LITHOLOGY
E	Quaternary	Terrace/ Fan Alluvium	Newer Alluvium	Cyclic sequence of grey micaceous sand, silt & clay/ Brownish greyclay, sand & gravel with boulders
D		Channel Alluvium		Grey micaceous fine to coarse grained sand, silt & clay
C	Middle to Upper Pleistocene	Older Alluvium	Ramnagar/Varanashi/ Ambala older Alluvium	Polycyclic sequence of brown to grey silt, clay with kankar & reddish brown to grey fine to medium micaceous sand with pebbles
B	Pliocene to Early Pleistocene	Sedimentaries	Middle Siwalik Gp.	Grey micaceous sandstone, siltstone with conglomerates
A			Upper	Conglomerate, sandstone & claystone sequence

Fault (firm/inferred) (F ——— F/ ———)

Fig. 3. GEOLOGICAL MAP OF HARDWAR DISTRICT, UTTARAKHAND

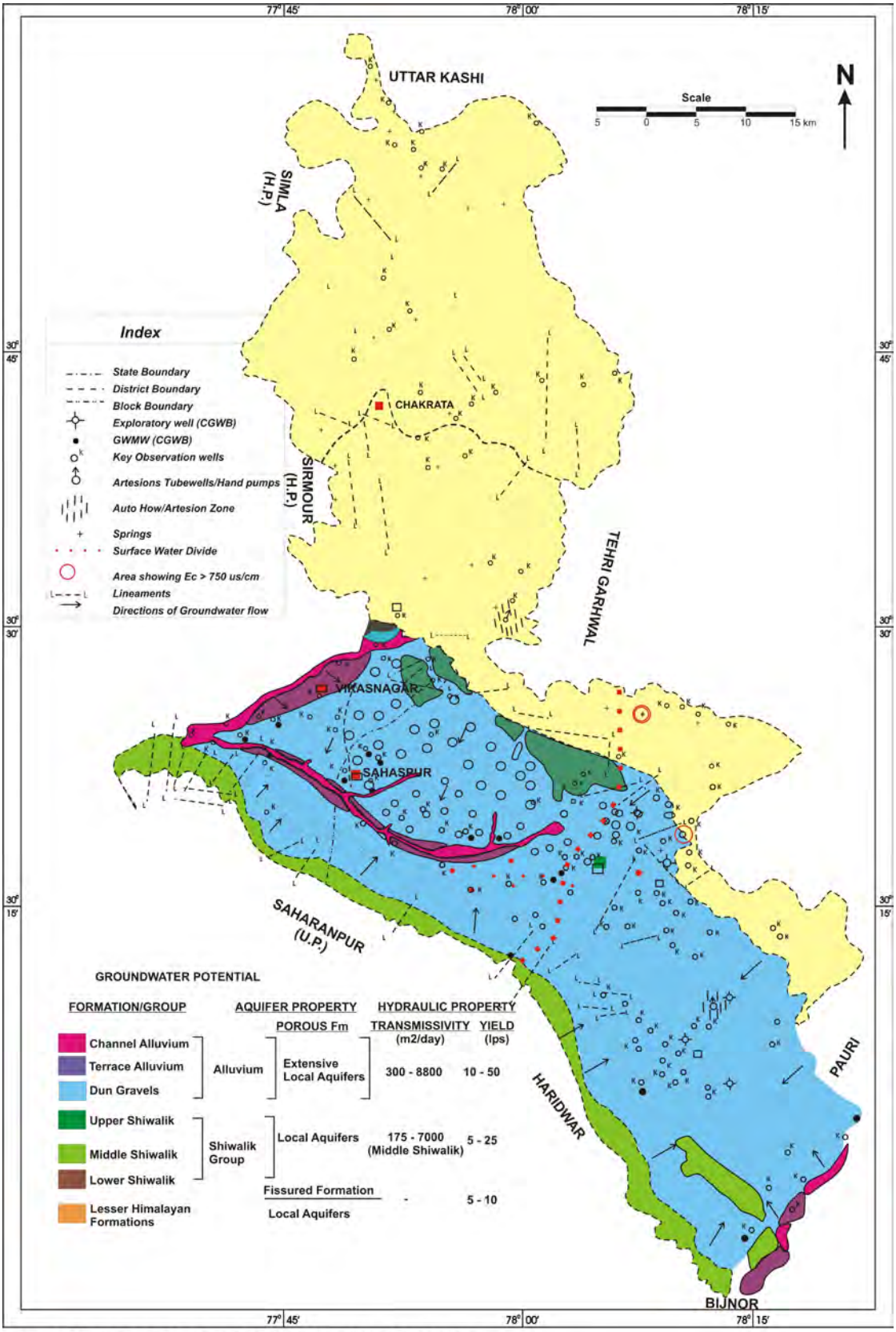

Plate 6.1 HYDROGEOLOGICAL MAP, DEHRADUN DISTRICT

Fig. 4. Hydrogeological Map of Hardwar district, Uttarakhand