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Ministry of Jal Shakti, Government of India

जलभृत मानचित्रण और प्रबंधन योजना
कुल्लू घाटी, जिला कुल्लू
हिमाचल प्रदेश

AQUIFER MAPPING AND MANAGEMENT PLAN OF KULLU VALLEY, DISTRICT KULLU HIMACHAL PRADESH

उत्तरी हिमालयन क्षेत्र, धर्मशाला

Northern Himalayan Region, Dharamshala

GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RD & GR
CENTRAL GROUND WATER BOARD,

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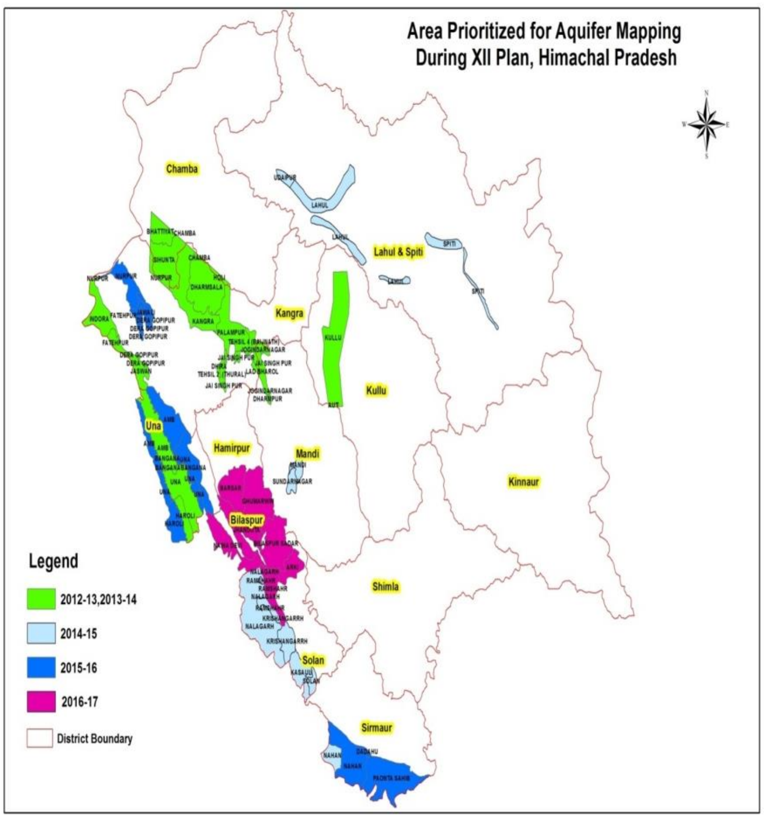

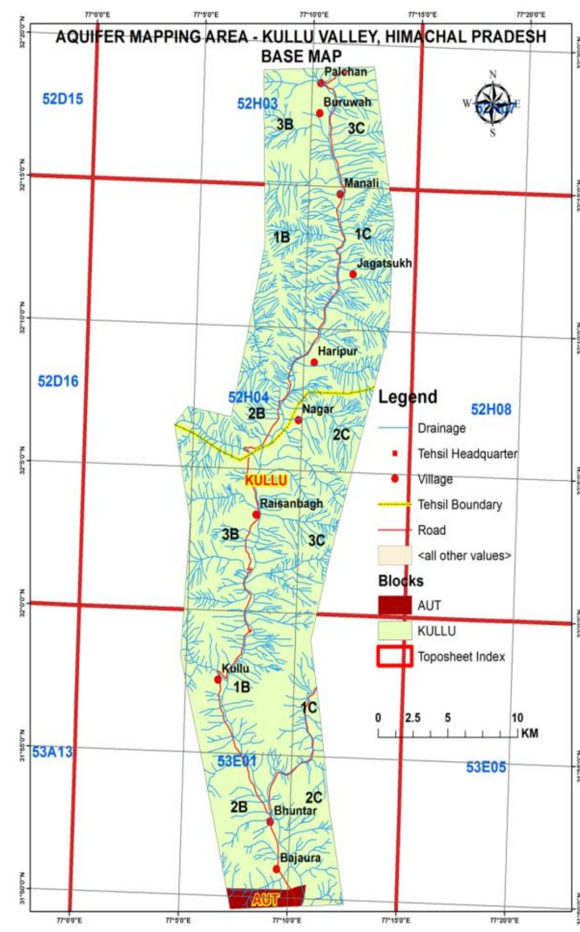

Northern Himalayan Region, Dharamshala

2012-2013

AQUIFER MAPPING AND MANAGEMENT PLAN OF KULLU VALLEY, DISTRICT KULLU, HIMACHAL PRADESH

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AQUIFER MAPPING AND MANAGEMENT PLAN OF KULLU VALLEY, DISTRICT KULLU, HIMACHAL PRADESH

1. INTRODUCTION

Aquifer mapping is a process where in a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers. There has been a paradigm shift from “groundwater development” to “groundwater management”. An accurate and comprehensive micro-level picture of groundwater in India through aquifer mapping in different hydrogeological settings will enable robust groundwater management plans at the appropriate scale to be devised and implemented for this common-pool resource. This will help achieving drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural India, and many parts of urban India as well. The aquifer mapping program is important for planning suitable adaptation strategies to meet climate change also. Thus the crux of NAQUIM is not merely mapping, but reaching the goal – that of ground water management through community participation.

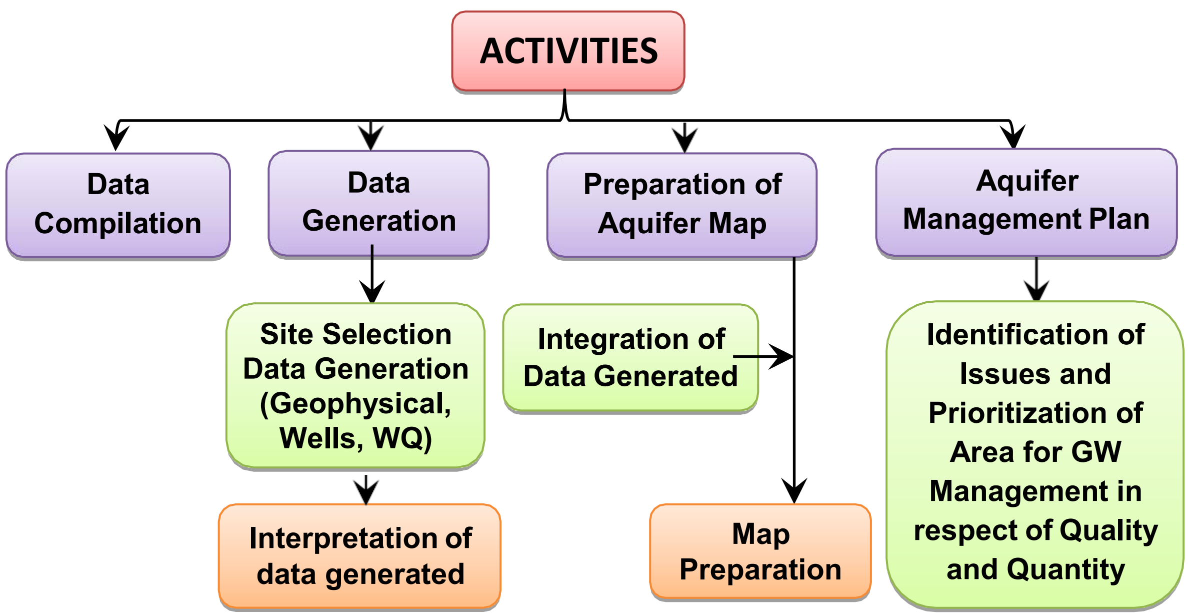
1.1 Objectives

The primary objective of the Aquifer Mapping Exercise can be summed up as “Know your Aquifer, Manage your Aquifer”. Demystification of Science and thereby involvement of stake holders is the essence of the entire project. The involvement and participation of the community will infuse asense of ownership amongst the stakeholders. This is an activity where the Government and the Community work in tandem. Greater the harmony between the two, greater will be the chances of successful implementation and achievement of the goals of the Project. As per the Report of the Working Group on Sustainable Ground Water Management, “It is imperative to design an aquifer mapping programme with a clear-cut groundwater management purpose. This will ensure that aquifer mapping does not remain an academic exercise and that it will seamlessly flow into a participatory groundwater management programme. The aquifer mapping approach can help integrate ground water availability with ground water accessibility and quality aspects.

With these aims, Aquifer Mapping Study is carried out in Kullu valley of Kullu District of Himachal Pradesh under the Annual Action Programme 2012-13. These surveys are carried out to integrate the information on the scenario of groundwater occurrence, availability and utilization in terms of quality and quantity along with exploratory drilling, monitoring of water levels with quality, spring monitoring (discharge and quality), pumping tests, infiltration tests, geophysical surveys etc. Development of aquifer mapping at the appropriate scale and formulation of sustainable management plan will help in achieving drinking water security, improving the sustainability of water resources development through springs. It will also result in better management of vulnerable areas. During this study,3 key observation wells (Dugwells: 3 Nos.) were established. Subsequently, all the available data on ground water from the earlier studies are compiled and integrated with these studies to bring out the ground water scenario, lateral and vertical characteristics of the aquifers and better management plan of ground water in a scientific manner.

1.2 Methodology

Various activities of NAQUIM are as follows:



1.3 Location, Extent and Accessibility

Kullu district is situated in the central part of Himachal Pradesh and lies between 31^{0}20’25” and 32^0 25’00” North Latitude and 76^{0}56’30” and 77^{0}52’20” East Longitude. It is bounded on the north and east by Lahul and Spiti district, on the south-east by Kinnaur district, on the south by Shimla district, on the south- west and west by Mandi district and on the north-west by Kangra district. The aquifer mapping area has total area about 516 sq. km and covers central part of the Kullu district. The area falls in Survey of India Toposheets No. 52 H/03, 52 H/04 and53 E/01, within the N Latitudes 31°50’ & 32°20’ and E Longitudes 77°05’ &77°15’.The study area is well connected by road and airways (Bhuntar airport). Almost all villages of aquifer mapping area is connected by village road. National Highway no.21 passes through the area.

1.4 Administrative divisions

The study area falls in Kullu district and Mandi Districts of Himachal Pradesh, 2 tehsil and 1 tehsil fall in the study area Kullu ,Manali and Aut.(fig.1).

Table 1: Demographical details of the area

Sr. No	District	Tehsil	Area (Hect.)	NAQUIM Area (Hect.)	Percentage%	Total Population	Male	Female	SC	ST	Density
1	Kullu	Manali	76995	20950	27	51661	7481	6466	2223	1481	0.670966
		Kullu	287300	30120	10	114310	5840	5591	2615	642	0.397877
2	Mandi	Aut	14350	530	4	30893	625	610	414	9	2.152822
Total			**378645**	**51600**		**196864**	**13946**	**12667**	**5252**	**2132**	**3.221665**

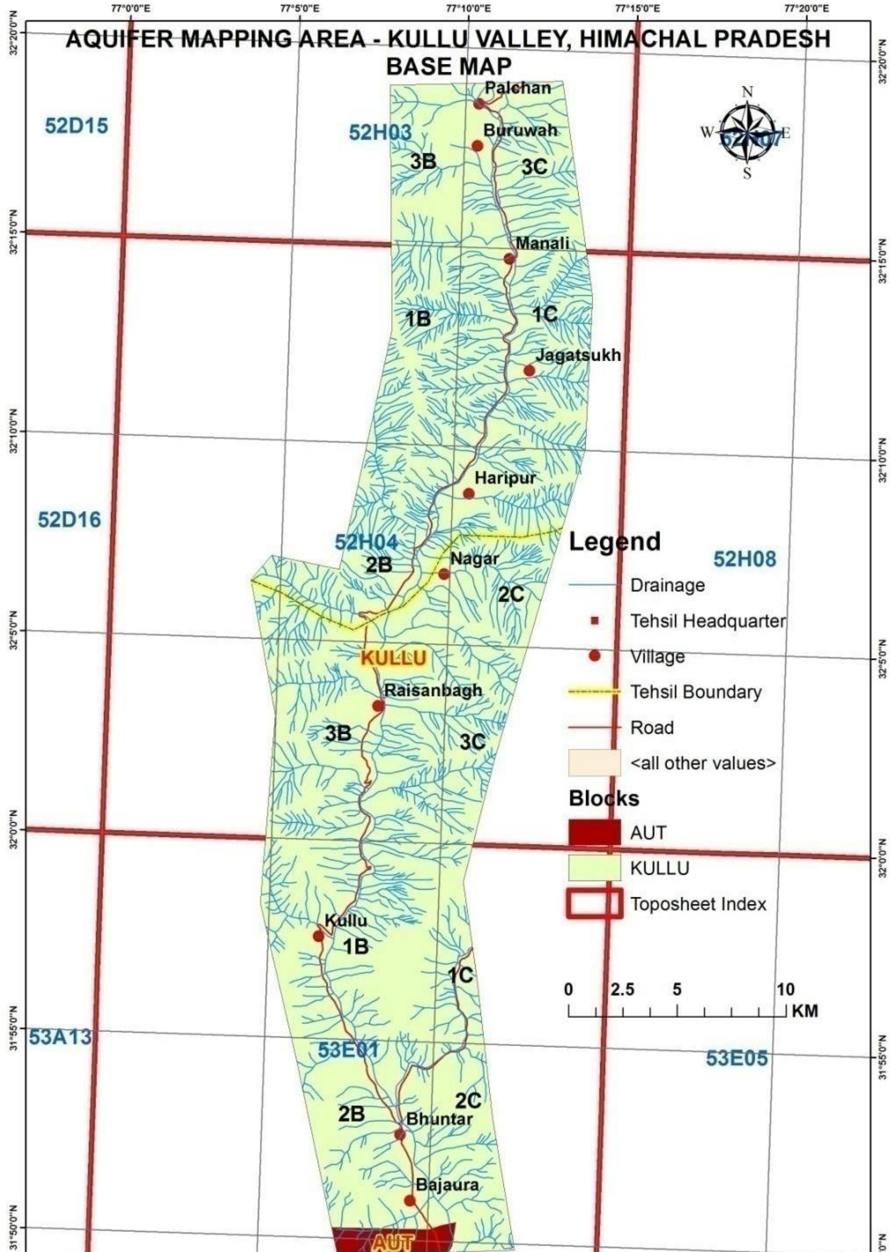


Fig 1: The Administrative Division of the Study Area

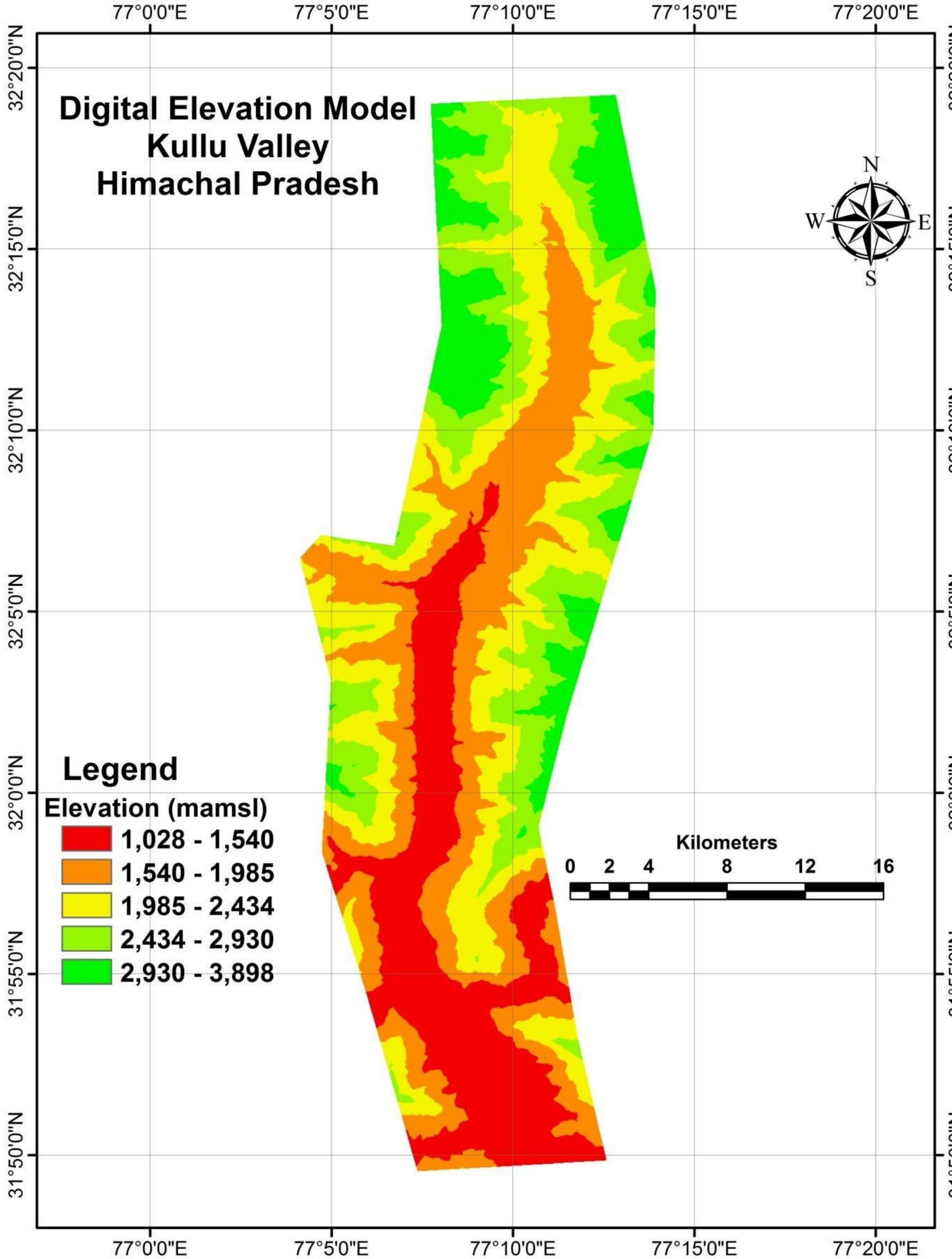


Fig 2: Digital Elevation Map of the study area

1.5 Data Gap Analysis

The Data gap analysis was done on the basis of NAQUIM & EFC guidelines in Aquifer Mapping Study area of 516 sq.kms in Kullu Valley, District Kullu of Himachal Pradesh. The study area falls in Survey of India Toposheets No.52 H/3, 52H/4 and 53E/01 covering full or partial area of4 quadrants (Figure -3 Toposheet Index Map). The Data Gap analysis of all the attributes are given in Table 2.

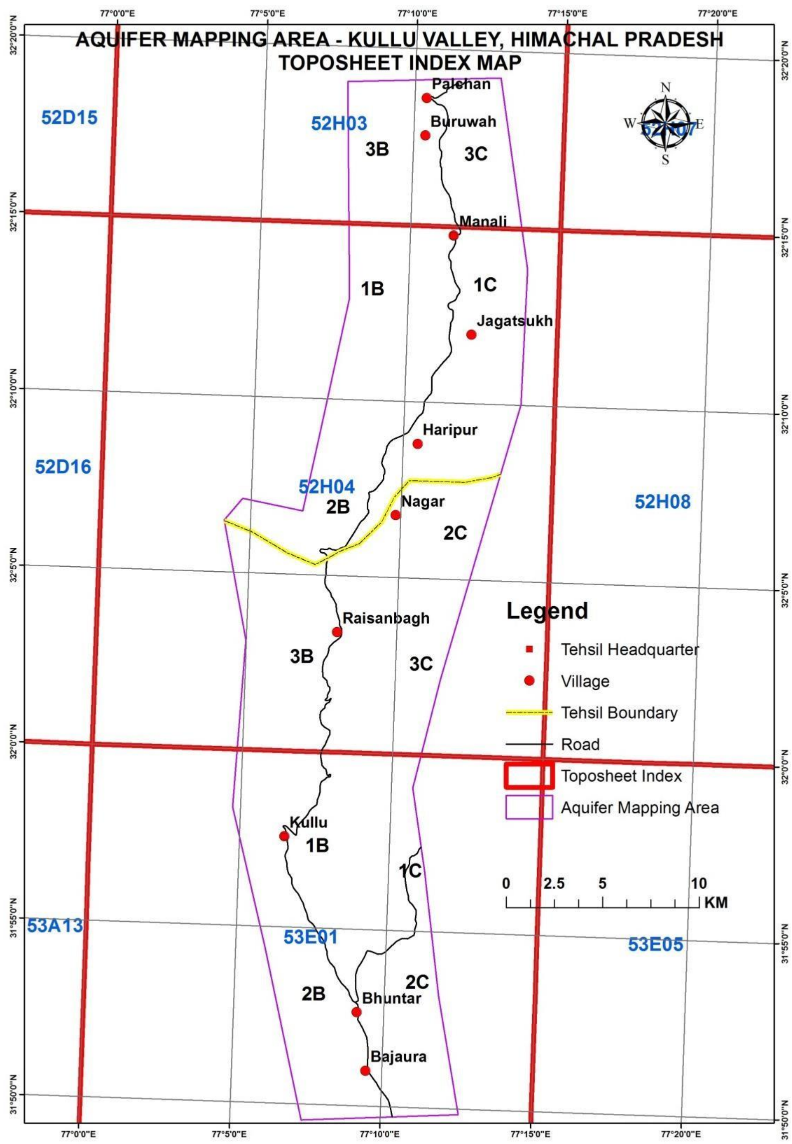


Fig. 3: Toposheet Index Map - Kullu Valley, Kullu District

1.5.1 Exploratory Data

The Data gap Analysis indicates the required Ground Water Exploration sites, sets of exploratory and observation wells to ascertain the aquifer parameters, in the area as per the EFC and the existing number of sites in the area and the Gap is indicated where ever the required number of sites is higher than the existing number of sites. If the number of existing exploratory wells is higher than the required exploration sites, the gap is considered as zero and the existing structures were taken as fulfilling the norms. On the basis of data gap analysis, quadrant-wise existing and recommended sites is presented and shown as square diagram in the figure.4 and Table No.2.

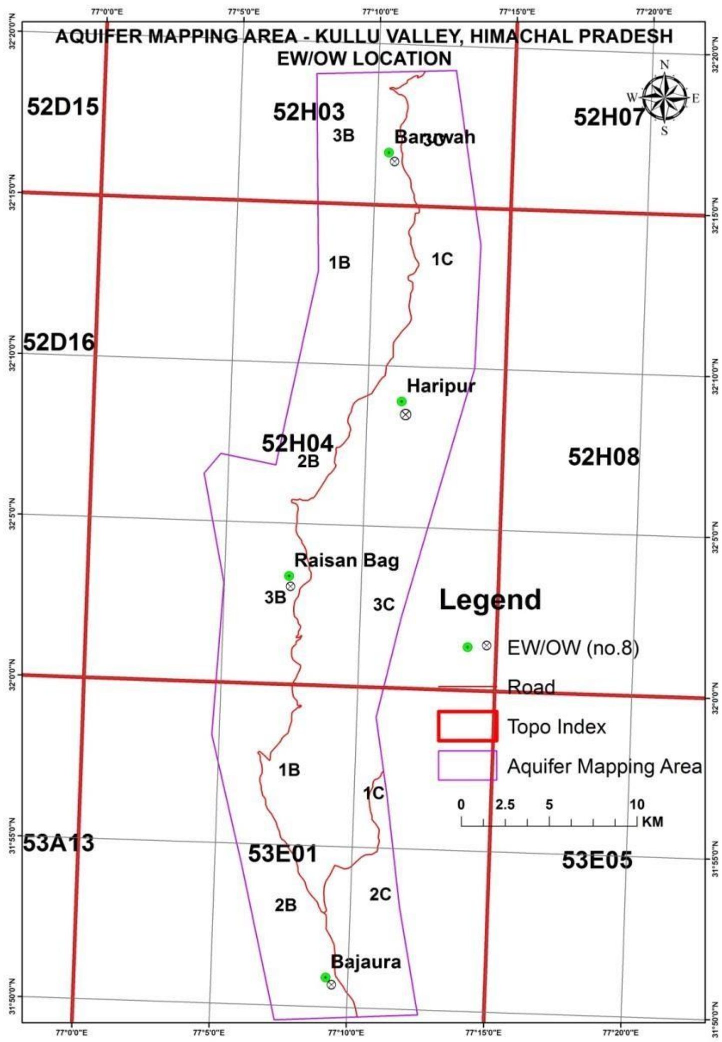


Fig.4 Exploratory Data Required Kullu Valley, Kullu District

1.5.2 Geophysical Data

The Vertical Electrical Soundings (VES) is required for lithological interpretation to a depth of 300 m but due to hilly terrain the adequate spread may not be available, therefore, TEM is also recommended for lithological interpretation to a depth of about 100 m. But for the study area, no VES data is available with CGWB and state agencies. On the basis of data gap analysis, the required no. of VES are 18 Nos. The quadrant-wise existing and recommended VES sites is presented and shown as diagram in the figure.5.

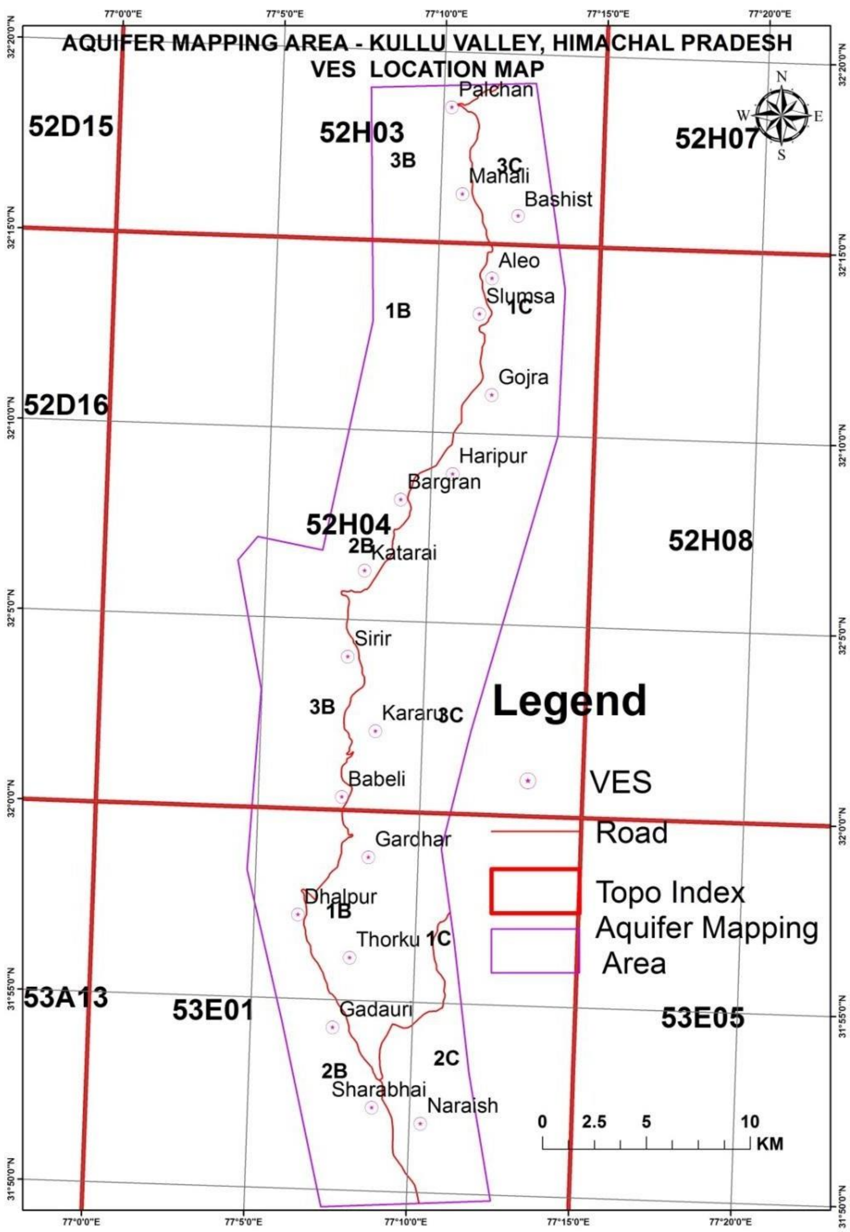


Fig.5 Data Gap Analysis of Surface Geophysical Surveys Kullu Valley, Kullu District

1.5.3 Ground Water Monitoring Stations (GWMS)

The ground water monitoring NHS and Key well observation stations in the area tap the unconfined aquifer. Wells constructed by CGWB and hand pumps by State agencies which tap the deeper and shallow aquifers are utilised for drinking water supply instead of monitoring the piezometric head in the deeper and shallow aquifers. On the basis of data gap analysis, quadrant-wise and aquifer-wise existing and recommended ground water monitoring stations is presented as Annexure-III and shown as square diagram in the figure.6. The additional 3 nos. Pzs are required for ground water monitoring of 1st aquifer.

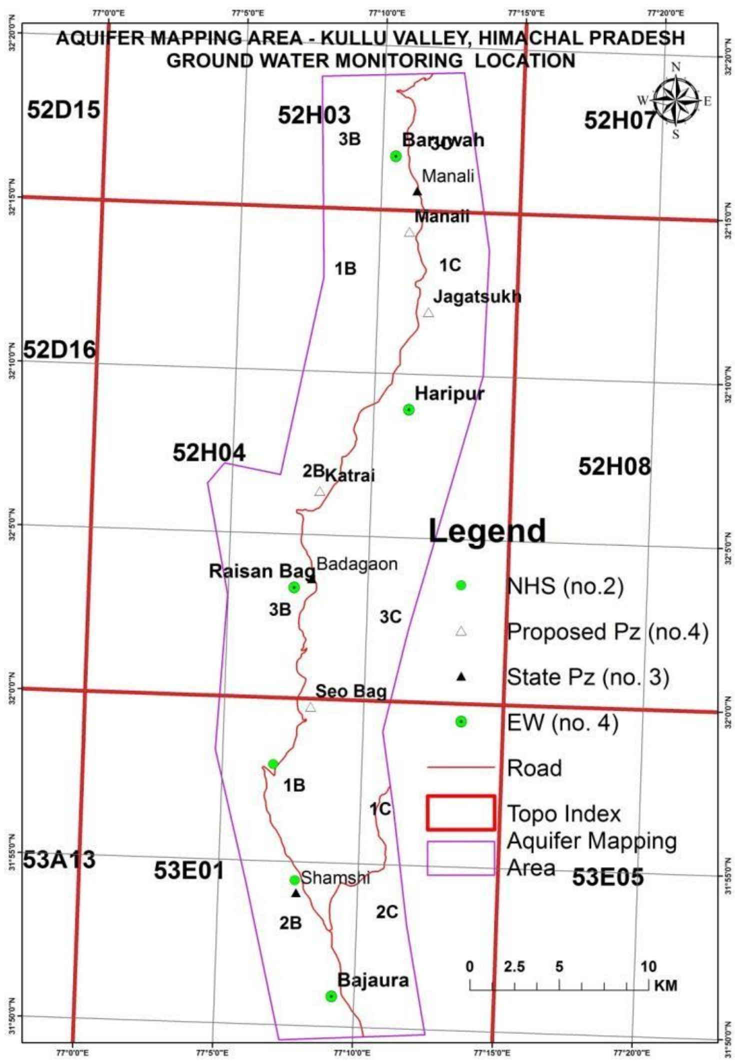


Fig.6 Data Gap Analysis for Ground Water Monitoring - Kullu Valley, Kullu District

Table 2: DATA GAP ANALYSIS, KULLU VALLEY (2012-13)

Toposheet No: - 53H/3, 53H/4, 53E/1

Quadrant no.	No. of additional EW's Required	No. of additional OW's Required	No. of additional VES/TEM Required	No. of additional water level monitoring Stations Required	No. of Soil Infiltration test Required	Monthly discharge of Existing Springs
	100 m depth	100 m depth	100 m depth	100 m depth		
52H03/3B			1		2	
52H03/3C	1	1	2		2	2
52H04/1B				1	2	
52H04/1C			3	1	2	6
52H04/2B			2	1	3	
52H04/2C	1	1	1	1	1	1
52H04/3B	1	1	2		2	6
52H04/3C			1	1	2	
53E01/1B			3		4	
53E01/1C						
53E01/2B	1	1	2		3	
53E01/2C			1	1	1	
Total	4	4	18	6	24	15

1.6 CLIMATE & RAINFALL

Climate of the district is cool and dry and the year unfolds three broad seasons viz. cold season from October to February, hot season from March to June and rainy season from July to September. Snowfall generally occurs in December and January at high elevations and most of the regions are cut off from the district headquarters since the mountain passes are closed. The district receives moderate rainfall and bulk of it received during the months of July, August, December and January. August is the wettest month throughout the district. Based on the analysis of rainfall data for record at the Regional Research Station, Bajoura, the Average annual rainfall is maximum of 1305.8 mm and minimum 976.80 mm respectively.

1.7 Physiography, Geomorphological features and landforms

Geomorphology of the area plays an important role in deciphering the sub-surface and surface hydrogeological conditions. On the basis of hydro geomorphologic and geological set up, the study area can be divided into following geomorphic units.

I) Mountainous area- Dhauladhar and Pir-Panjal ranges trends NW-SE and with peak ranging in height between 4200-5000 meters above mean sea level,snowcap and snow line exists in this area.

II) Snow covered area- Northern and northeastern parts of Kullu district are covered with snow and snow line exists in this area.

III) Denuded hills- The presence of residual ridges along the intermountain valleys suggest that these ridges are the remnant of high relief mountains and formed by active erosion.

IV) Valley area -Fluvial processes and structural disturbances in the area form intermountain valleys. Kullu valley is elongated and broadly v-shaped in cross-section and the sides with denuded areas.

V) Terrace area- Numbers of terraces are formed along the river valleys in Kullu. Terraces are generally noticed on the western bank of the Beas River. Two levels of terraces are demarcated near Bhunter, which are covered with thick vegetation.

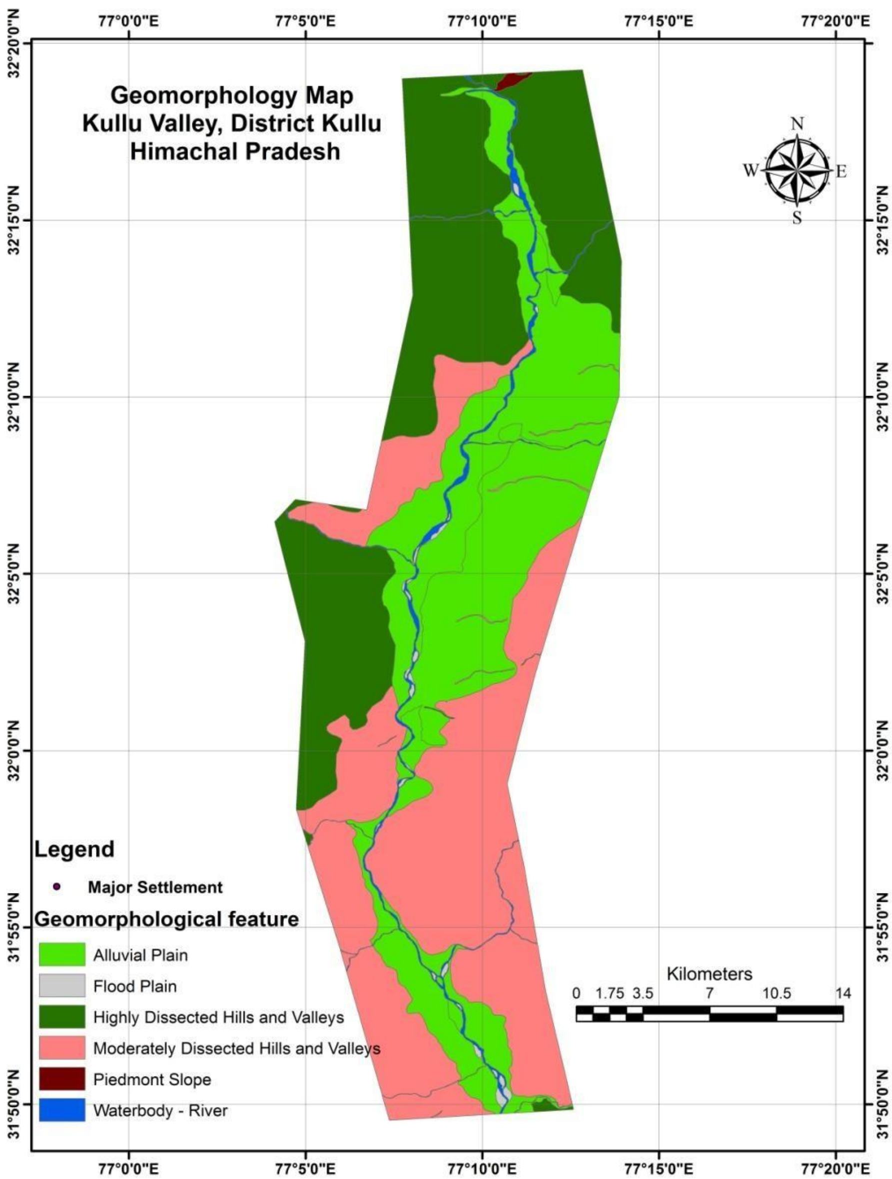


Fig.7: Geomorphology Map of the study Area

1.8 Drainage

The elevation of Kullu district ranges from 914 meters to 4084 meters above mean sea level with varied agro-climatic conditions.

The river Beas and its tributaries drain more than 80% of the area. The Beas river originates in the Pir-Panjal range near Rohatang, at an elevation of about 4000 meters. The river is joined by a number of tributaries viz. Parbati, Hurla, Sainj etc. All the tributaries are perennial.

Beas river flows in south- southwest direction up to Largi and thereafter it flows more or less southerly.Another river i.e. Satlus also passes near border on the southern fringes of Aniblock. Both the rivers are in their youth stages as indicated by 'V' shaped river profile and deeper river channels. Drainage map of the study area is given in figure 8.

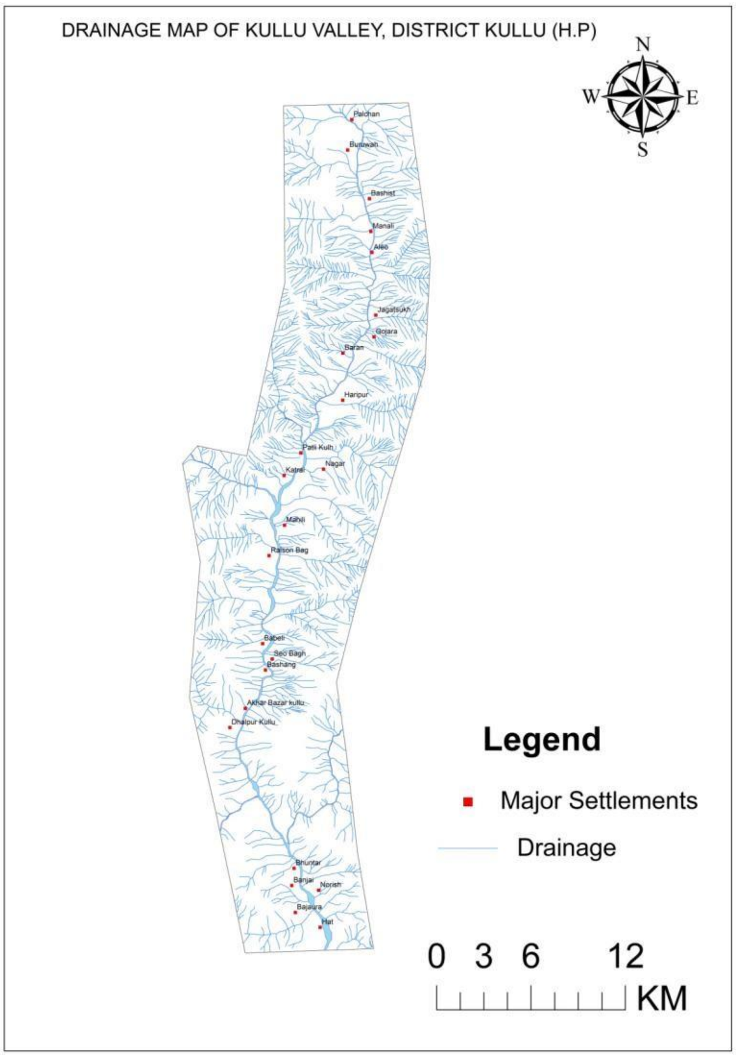


Fig.8: The Drainage Map ,Kullu Valley, Kullu District

1.9 General Geology

The geology of the district has been studied in detail by the geological Survey of India (1996). Broadly, the following geological sequence, which includes rocks of Precambrian to Quaternary age, is noticed in the district (Fig. 8& Table - 3)

Table. 3: Geological succession of Kullu district

ERA	PERIOD	GROUP / FORMATION
CAINOZOIC	Quaternary	Alluvium
PROTEROZOIC	Neoproterozoic to Terminal Proterozoic	Batal formation
	Neoproterozoic	Chamba formation
	Neoproterozoic	Kullu Group
	Mesoproterozoic	Largi Formation
Precambrian		Vaikrita Group
Precambrian		Granites & Gneisses

Granites & Gneisses

The Precambrian granites and gneisses are the oldest rock formations in the district and are exposed in south-central part of the district. The general trend of the rock formations is NW-SE.

Vaikrita Group

They are represented by slates, phyllites, quartzites, sandstones, granites, gneisses and schists and are exposed in the northern and north-eastern part of the district.

Largi Formation

Thick succession of phyllites, slates, quartzites with dolomites and conglomerates represent the Largi formation in the district. These rocks are exposed in western part of the district as a very small patch.

Kullu Group

The term Kullu Group has been divided for the sequence of metasediments carved out of the Salkhala on its sub-thrust side. The Kullu Group fully frames the Larji-Rampur window zone. The group comprises following sequence of formation.

Chamba Formation

The formation is exposed in the western part of the district and comprises of meta siltstone, grey wackes, slates and phyllites

Khokan Formation	Quatrzites, Quartz chlorite and Quatrz-biotite schists, slates, phyllites and schists, garnetiferous schists
Garh-Manjrot Formation	Streaky mylonitic gneisses, banded and augen gneisses.
Khamarada Formation	Carbonaceous to graphitic schists and phyllites locally garnetiferous, lenticular grayish blue and cream colored platy limestone and calc-schists.

Batal Formation

The Manjir Formation is succeeded by the Batal formation without any perceptible break. The formation comprises dark grey carbonaceous slates and phyllites with interbands of quartzite. At places lenticular bands of dolomite are seen in the basal part of the Batal formation closer to its contact with the Manjir formation. These dolomite bands are also associated with magnesite.

Alluvium

The Quaternary deposits occur as alluvium, terrace deposits and other fluvial deposits in the intermountain valleys. The valley fill includes the terrace deposits along the fringes of the hill slopes and the river alluvium in the low plains. The terraces, which occupy large portions of the valley, have been deeply dissected forming steep scarp faces along the major streams.

The terrace deposits chiefly comprise of clays in association with the large quantities of sub-angular to sub rounded boulders, cobbles pebbles etc., derived from the rock formations exposed in the surrounding hills. Lenses of granular deposits often occur within the clays. The granular fractions of the deposits generally show gradual gradation from coarse-grained material nearer the hills to fine-grained aggregates towards central parts of the valley.

In the low plains there is granular deposits predominance. The deposits comprise a heterogeneous mixture of boulders, cobbles pebbles, sand and silt composed mainly of gneisses, phyllites, slates, granites, limestones, shales etc. which are extensively exposed in the adjacent hills.

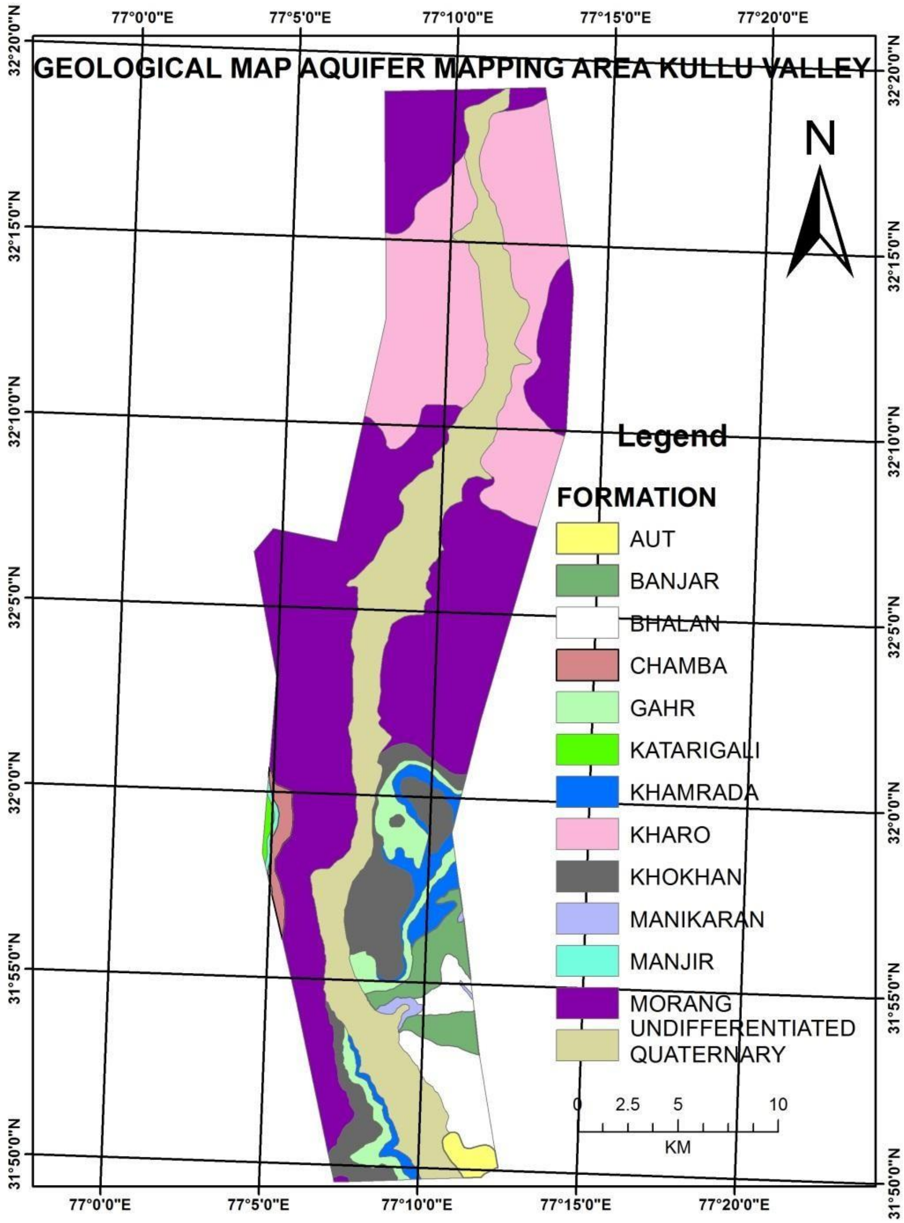


Fig.9: Geology Map of the study area

Formation sand Lithology

Aut:- Grey dolomite, grey-purple limestone.

Banjar:- Schist, Phyllite, Quartzite.

Bhalan: - Phyllite, Quartzite with basic flow.

Chamba:- Carbonaceous slate, Phyllite, Quartite.

Gahr:- Streaky and Banded gneiss.

Katarigali:- Slate, Phyllite, Quartzarenite, Limestone.

Khamrada:- Carbonaceous slate, Phyllite, Limestone, Quartzite.

Kharo:- Schist, Gneiss, Migmatite, Quartzite, Marble

Khokhan:- Schist and Quartzite.

Manikaran:- White –Greenquartzite, Phyllite, Basic flow.

Manjir:-Diamictite, Shale, Slate, Sandstone, Limstone

Morang:-Sillimanite-Kyanite-bearing Schist,Quartzite

Unidentified Quarternary:- Valley filled deposits.

1.10 Hydrogeology

Hydrogeologically the Kullu valley can be divided into porous and fissured formations.

Porous formation includes the unconsolidated sediments. These sediments include fluvial channel kullu districts & deposits, valley fill deposits, terrace deposits and alluvial fans. These sediments form the potential aquifers.

Unconsolidated sediments underlie Kullu valley, Garsa valley, Manikaran valley, Lag valley and longitudinal valley all along the major rivers and khads. Fissured formation includes the semi-consolidated to consolidated sediments exposed in the district and are of sedimentary, metamorphic and igneous in origin. These form low to high hill ranges throughout the district. In Kullu valley, ground water generally occurs under confined to semiconfined conditions. Phreatic aquifers are tapped mainly by open wells and form major source of domestic and irrigation water supply in the valley area.

The aquifer zone mainly comprises of sand and silt in association with pebbles and boulders in low plains and predominantly boulders, cobbles, pebbles mixed with little clay in terraces. Static water level varies from 1.62m to 31.45m below ground level. Central Ground Water Board has drilled 9 wells including observation wells in the district to know the aquifer parameters and sub-surface geology. The discharge of these wells varies from 299 lpm to 1079 lpm. The source of major water supply schemes are based on springs in the district. The discharge of the springs varies from 0.5 lps to 25 lps. Majority of the springs are gravity springs. In gravity springs, the most common are the contact springs, which are formed by permeable water bearing formations overlying less permeable formations the contact of these formations intersects the ground surface. There are lots of hot springs in Kullu and Parbati valleys. Along Beas river valley hot springs vary in temperature from 29 0C to 590C and in Parbati river valley the thermal springs vary in temperature from 350C to 960C. In Beas river valley, all the rocks belong to Pre-Cambrian age and are represented by gneisses, phylites, quartzite and limestones. A major fault extending in north- south direction from Bashist to Katrain for a distance of 25 kms, appears to control the emergence of thermal activity.

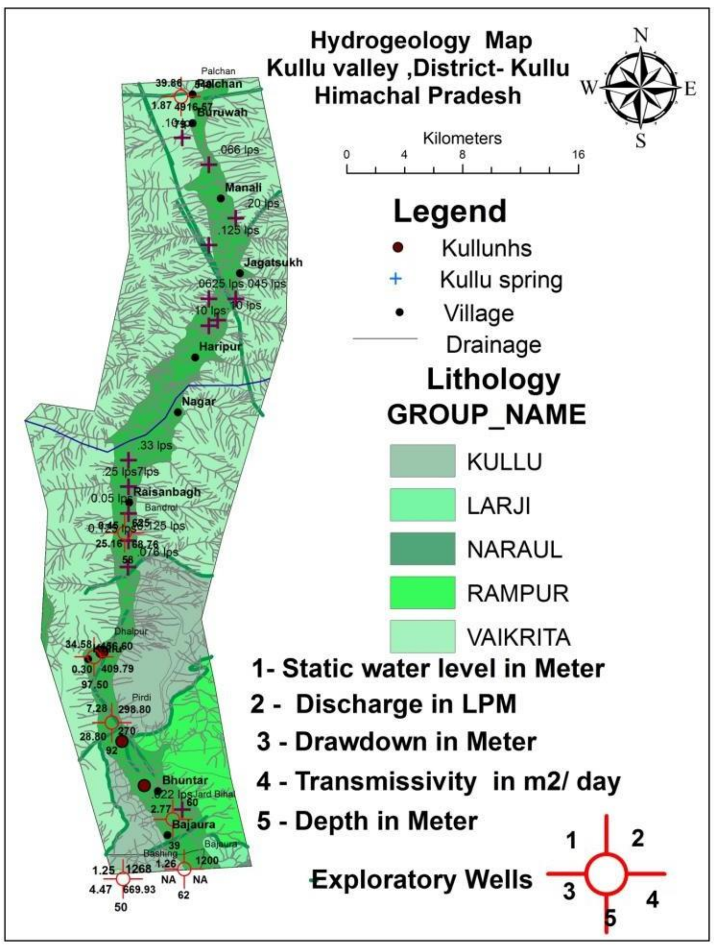


Fig.10: Hydrogeology Map, Kullu Valley ,District Kullu

1.11 Land use Map

The landuse / land cover map was prepared using Survey of India topographic sheets and IRS P6 LISS – III satellite imagery. The Landuse and land cover features in the study area Open Forest, Land with scrub, Plantation and River (fig.10). Similarly Forest Area map was prepared with the help of processed satellite imagery.

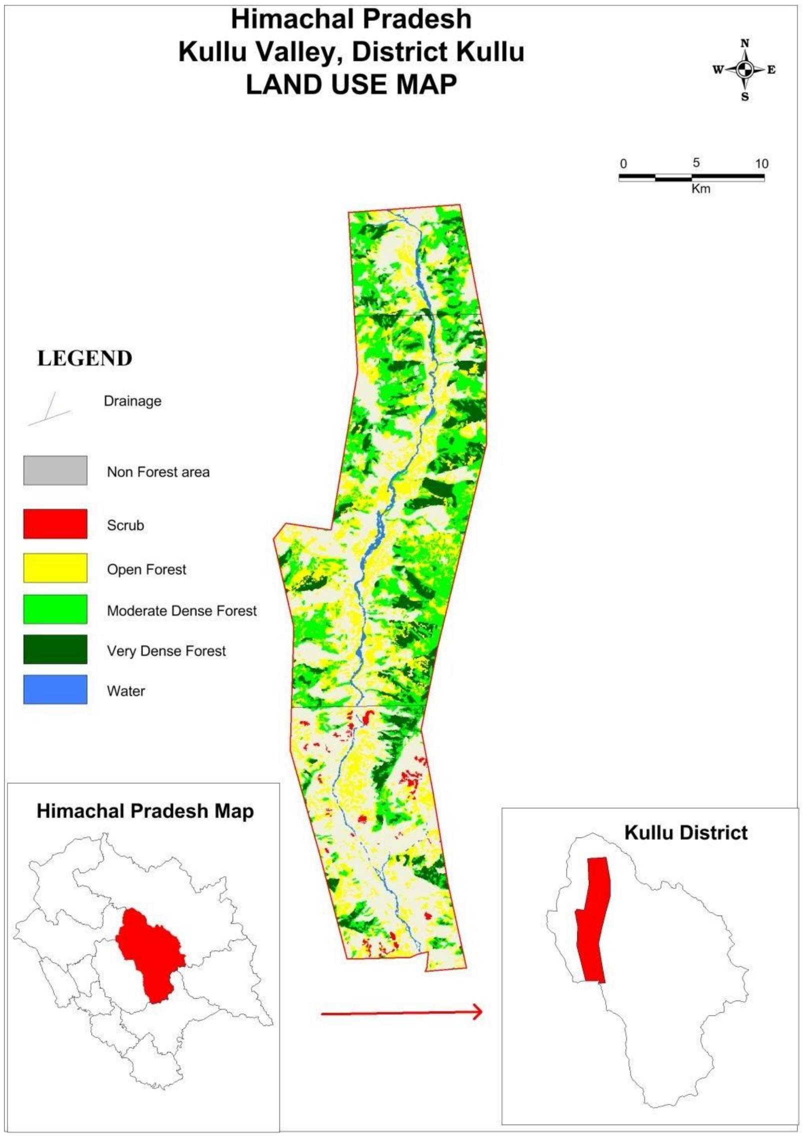


Fig. 11: Land Use Map, Kullu Valley District Kullu

Table .4: Category wise Land use/Land Cover in the study area (contd..)							
Sr. No.	**District**	**Tehsil**	**Forest**	**Land Put to Non-Agri Use**	**Barren Land**	**Permanent Pastures**	**Misc. Tree & Grooves**
1.	Kullu	Manali	475	343	184	216	226
		Kullu	76	368	173	311	296
2.	Mandi	Aut	385	29		89	0.2
Source: District Revenue Officer of respective districts & District Statistical Abstracts of respective districts for the Year-2017-18. (Figures in Hectares)							

Table 5: Category wise Land use/Land Cover in the study area										
Sr. No.	**District**	**Tehsil**	**Cultivable Wasteland**	**Other Fallow**	**Current Fallow**	**Net Sown Area**	**Area sown more than once**	**Gross Sown**	**Net Sown/ Total Sown**
1.	Kullu	Manali	124	28	109	560	112	671	83.5
		Kullu	26	13	47	1699	1000	2699	62.9
2.	Mandi	Aut	2.2	3		111	63	174	63.8
Source: District Revenue Officer of respective districts & District Statistical Abstracts of respective districts for the Year-2017-18. (Figures in Hectares)									

1.12 :Cropping patterns: The principal crops of area are Wheat , Maize and Apple. In Khariff season in addition to Maize, Paddy, Fruits, Vegetables are also cultivated over small area. During Rabi season Wheat is principal crop along with fruits and fodders etc.

Table 6: Tehsil-wise breakup of area cropped under each crop type in study area									
				Rabi		**Khariff**		**others**	
Sr. No	**District**	**Tehsil**	**NAQUIM Area**	**Wheat**	**Vegetables**	**Maize**	**Paddy**	**Fruits**	**Fodder**
1	Kullu	Manali	20950	44	32	101	52	305	
2		Kullu	30120	900	107	692	51	503	8
3	Mandi	Aut	530	48	15	53		33	0.68
		Total		**992**	**154**	**745**	**103**	**841**	**8.68**
Source: District Revenue Officer of respective districts & District Statistical Abstracts of respective districts for the Year: 2017-18. (Figures in Hectares)									

1.12 Irrigation

The area is blessed with sufficient Monsoon Rainfall and Non Monsoon rainfall. The irrigation sources in area are Mainly *Kuhl/* Channels, Tube wells, Dug well and lift Irrigation Schemes and one Medium irrigation Scheme. The source wise breakup of irrigation in area is given below:

Table. 7: Irrigation pattern in study area								
Sr. No	**District**	**Tehsli**	**Kuhl/ Canal**	**Pond**	**Wells/TW**	**other**	**Total Irrigated**	**% of Net wn**
1	Kullu	Manali	214	0	0	0	58	10.4
2		Kullu	108	0	0	11	12	0.7
3	Mandi	Aut	0.8	0	2	70	3	2.7
		Total	**322.8**	**0**	**2**	**81**	**73**	3.1
Source: District Revenue Officer of respective districts & District Statistical Abstracts of respective districts for the Year: 2017-18. (Figures in Hectares)								

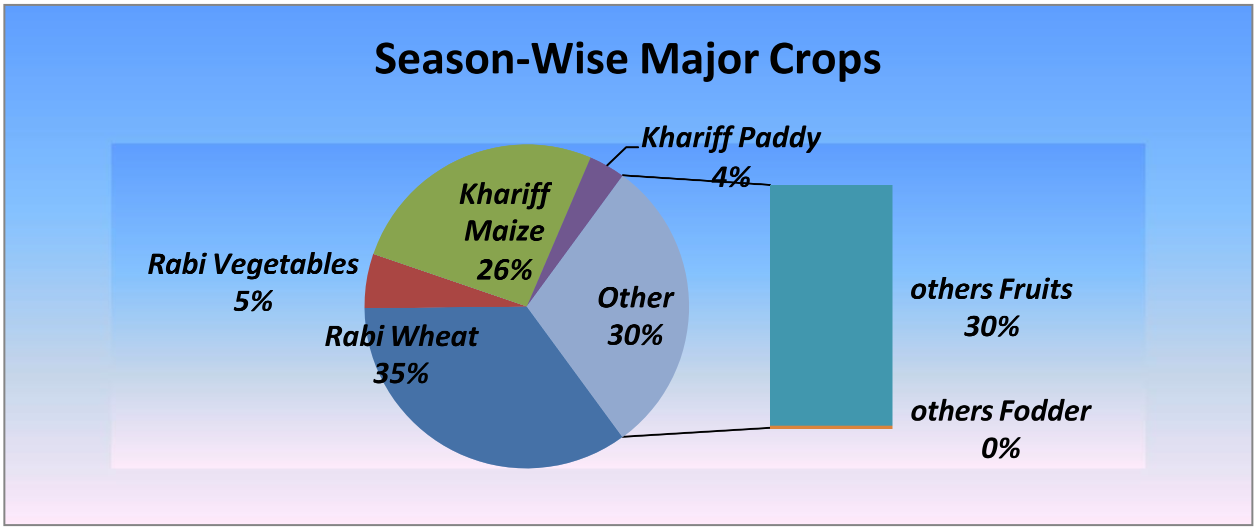


Fig.12: Season wise major crops in study area.

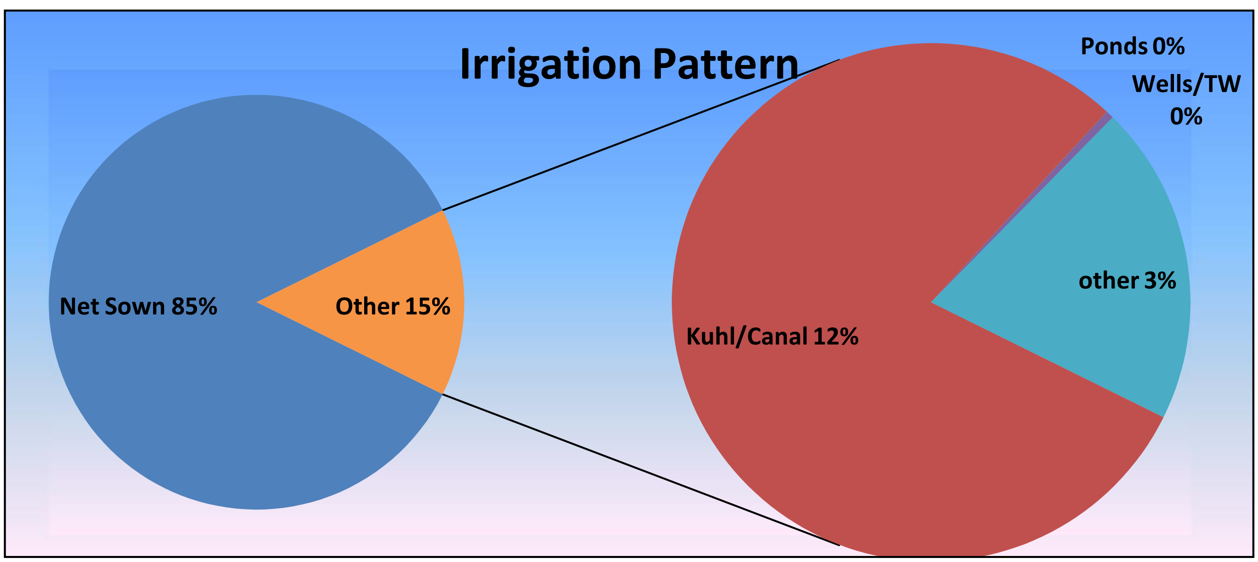


Fig. 13 : Source wise irrigation pattern in study area.

1.13 Soil Types

For the preparation of the soil map, the soil atlas of the Himachal Pradesh, prepared by C.G.W.B. Northern Himalayan Region is used as the primary source and then updated with satellite imagery **(fig 13)**

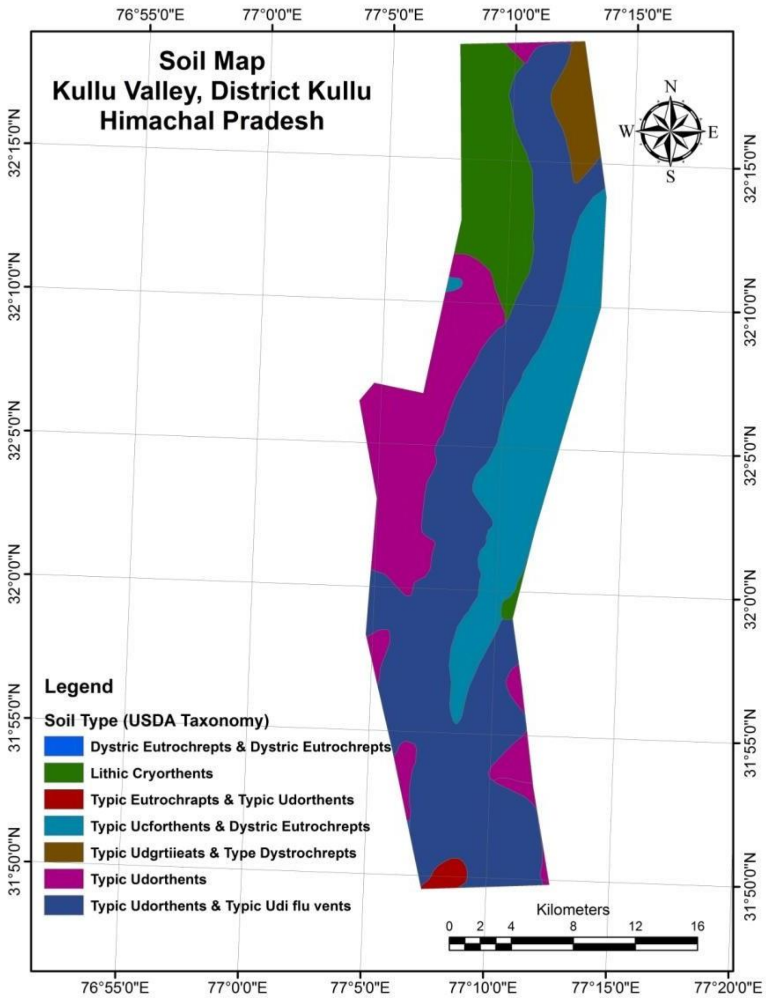


Fig. 14 : Soil map of the study area

1.14 Previous Work and Present Status of Data

Central Ground Water Board, NHR, Dharamshala has brought out district reports, ground water management studies reports, ground water exploration reports periodically on all districts of Himachal Pradesh. The systematic surveys and reappraisal hydrogeological surveys were carried out by CGWB in Kullu district during various field seasons.

CGWB NHR, Dharamshala is monitoring ground water levels from National Hydrograph Network observations wells since 1977 in all valleys of Himachal Pradesh four times a year in the months of, May, August, November and January. The ground water quality is being studied by CGWB once in a year from the samples collected in observation wells during the month of May.

Also, the Irrigation and Public Health Department of Himachal Pradesh also measures ground water quality on monthly basis in some of water supply abstraction structures.

Table.8: National Hydrograph Network observations and aquifer mapping wells of Kullu Valley, Kullu District, Himachal Pradesh

Sl.No	Name of Village/site	Latitude	Longitude	Estt. Date	RL (mamsl)	Type (DW/)	Measuring Point (magl)	Depth of Dug Well
1	GADAURI	31.657278	77.121667	5/28/2013	1120.31	DW	0.55	10.00
2	KULLU	31.965167	77.105	5/29/2013	1185.24	DW	0.20	6.00
3	HATHITHAN	31.895361	77.149194	5/29/2013	1110.20	DW	0.20	8.47

Chapter-II

2.0 DATA COLLECTION AND GENERATION

2.1 Hydrogeological Data

Water Level Behavior: To know the water level and its behavior with respect to time and space, 3 dug wells have been inventoried for Ground Water Management Studies all over the area. The dug wells are located in and around Kullu valley. The water levels were taken during the month of May and November, 2013 & 2014 and on the basis of these data, pre-monsoon, post monsoon and seasonal fluctuation map have been prepared for the Kullu valley area. The hydrogeological data of the inventoried dug wells are given in Table 9.

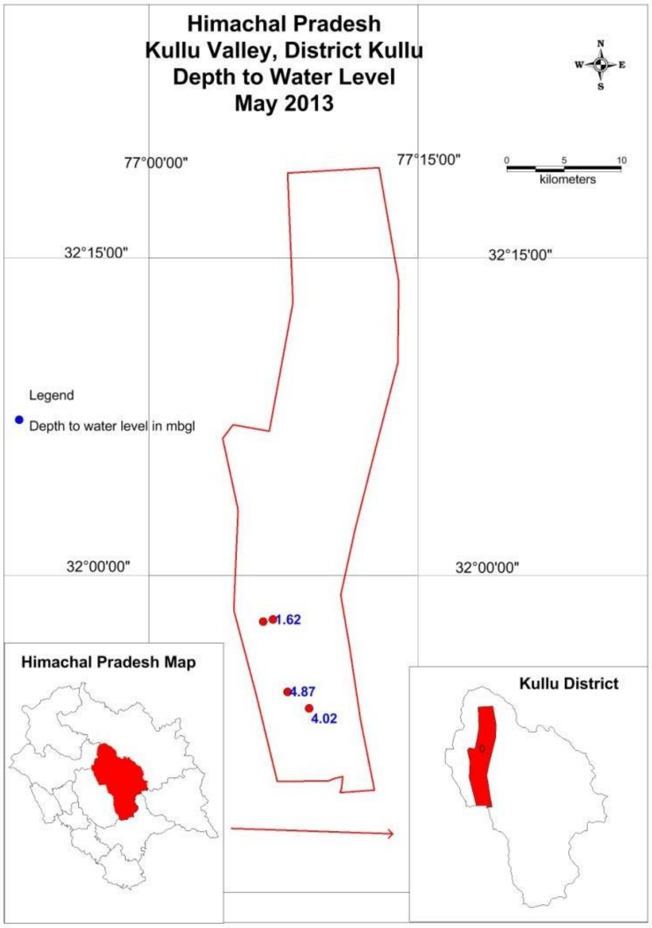
In Kullu valley depth to water level shows wide variation. During pre-monsoon period (May 2013) it ranges from 1.62 to 4.87 bgl (Fig. 13) and post monsoon period (Nov.2013) ranges from 4.3 to 5.13 m bgl.(Fig. 14).In major parts of Kullu valley, Seasonal Water Level Fluctuation ranges between less than (-2.68) to (-0.26)m bgl (Fig.15).Whereas in pre-monsoon period of (May 2014)it ranges from 0.20 to 5.02 m bgl (Fig.16) and post monsoon period (Nov.2014) ranges from 1.68 to 5.19 m bgl and Seasonal Water Level Fluctuation ranges between (-0.17) to (-1.48) m bgl .

Table. 9: Water level data (May & Nov.2013 and May& Nov.2014) GWMS and Aquifer Mapping Wells of Kullu Valley, Kullu District, Himachal Pradesh

Location	Latitude	Longitude	Water Level, 2013		2013 Fluctuation	Water Level, 2014		2014 Fluctuation
			May 2013	Nov. 2013		May 2014	Nov. 2014	
GADAURI	31.657278	77.121667	4.87	5.13	-0.26	5.02	5.19	-0.17
KULLU	31.965167	77.105	1.62	NA	1.62	0.20	1.68	-1.48
HATHITHAN	31.895361	77.138333	4.02	4.3	-0.28	Dry	Dry	Dry

Table. 10: Spring Discharge (July,2012 and July & Nov.2014) of Kullu Valley, Kullu District, Himachal Pradesh

S.No	Name of village/site	Latitude in degrees decimal	Longitude in degrees decimal	July,2012 Discharge(LPM)	July,2014 Discharge(LPM)	Nov,2014 Discharge(LPM)
1	Babeli	32.01666	77.133	4.56	3	3.25
2	Raison (Catch factory)	32.05	77.1333	120	19.8	37.5
3	Raison(Spring cum Tubewell)	32.066	77.1333	420	33.33	30
4	Kalath(Hot spring)	32.18333	77.1833	19.8	30	10.84
5	Rawari Manali (old manali)	32.25	77.1833	0.6	10	13
6	Vashist Chowk	32.2666	77.1833	39.6	4.76	5.1
7	Baruah	32.2833	77.1666	6	19.8	120
8	Aloe (Manali)	32.2333	77.2	12	12	6
9	Gojara	32.1833	77.2	27	30	44.11
10	Mahili	32.066	77.1333	15	18	1.48
11	Karasu	32.0333	77.1333	7.5	8.7	30



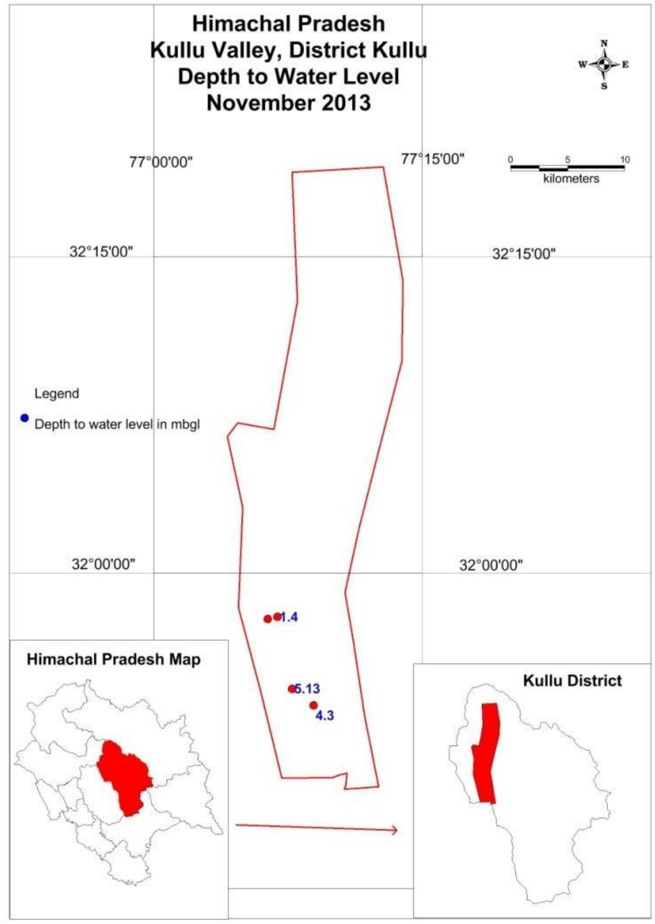
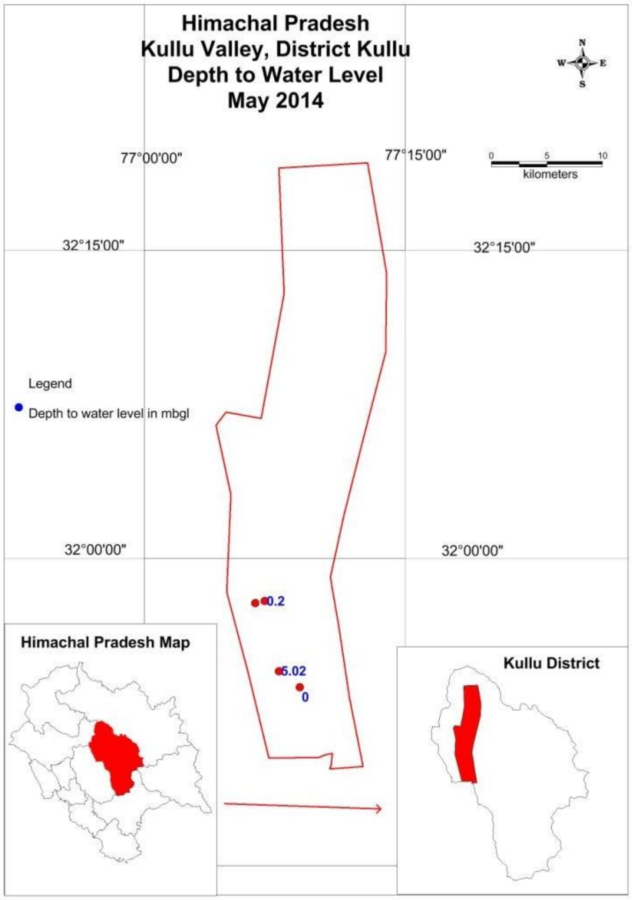


Fig.15: DTWL, May 2013

Kullu Valley, Kullu District

Fig.16: DTWL, November 2013

Kullu Valley, Kullu District



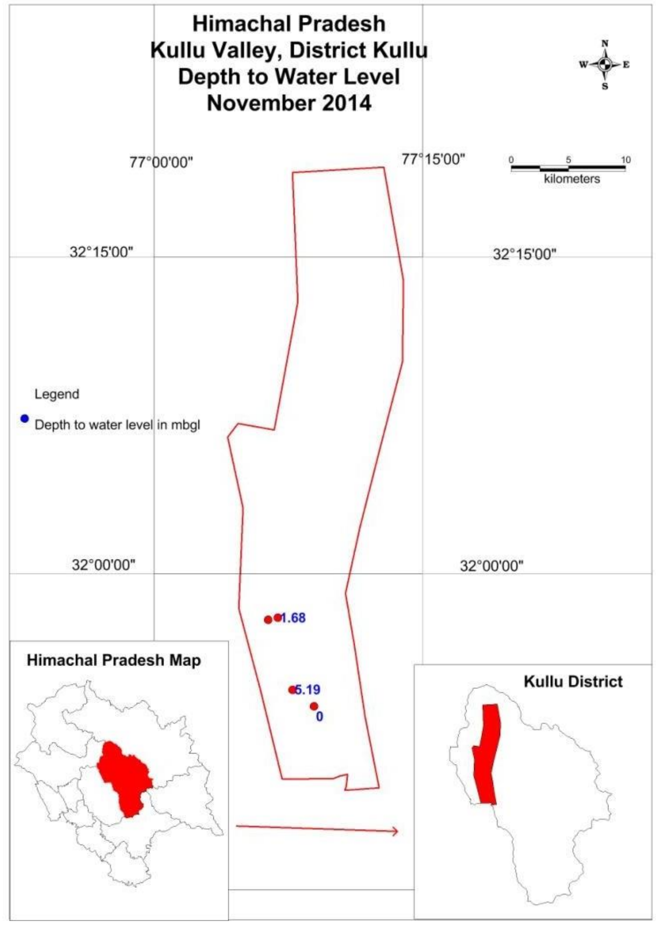
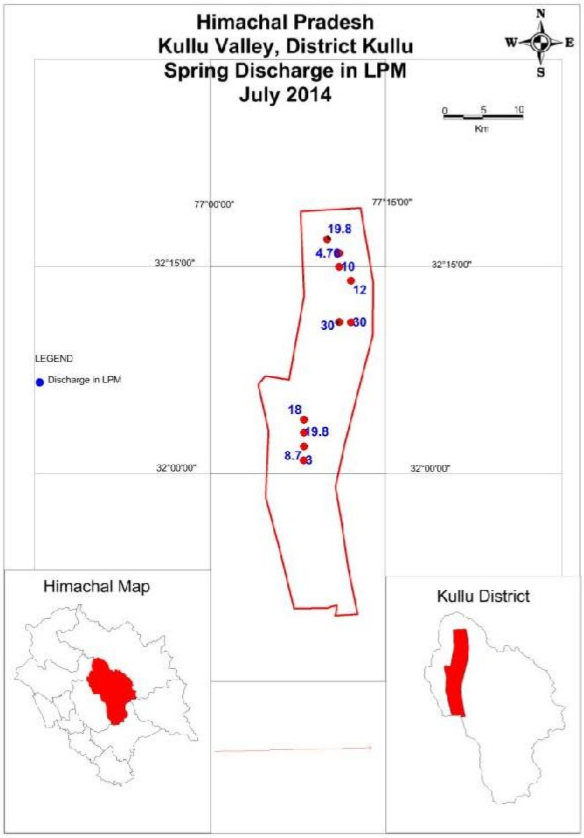


Fig.17: DTWL, May 2014

Kullu Valley,Kullu District

Fig.18: DTWL, November 2014

Kullu Valley, Kullu District



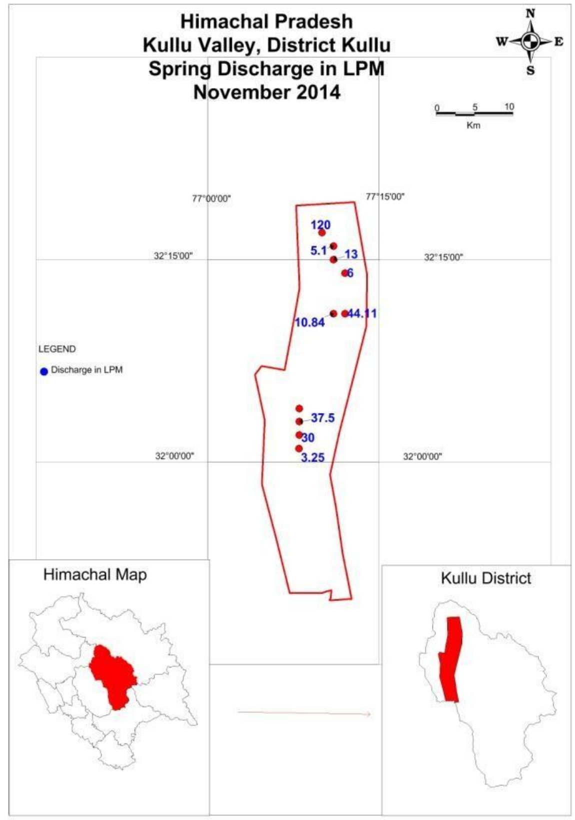


Fig.19: Spring Discharge, July 2014 Kullu Valley, Kullu District

Fig.20: Spring Discharge, November 2014 Kullu Valley, Kullu District

2.2. Exploratory Drilling– CGWB & I& PH Wells

The Lithologs 8 Nos. of Exploratory Well productive wells of CGWB, have been used to validation for preparation of aquifer maps. Deeper well data of CGWB is available. The details are shown in Table-2.6. The compromised logs derived from lithologs and geophysical well loggings have been taken as reliable data base.

Table.11: Data availability of Exploration wells in Kullu Valley, Kullu District.

Table of Wells, Kullu Valley			
Agency	Well Depth (meters)		
	<100	100-150	>150
CGWB	7	0	0
Total	**8**	**0**	**0**

2.3 Ground Water Quality

The water quality standards are laid down to evaluate suitability of water for intended uses and to safeguard water from degradation. These recommended limits form the basis of treatment needed for improvement in quality of water before use. In the formulation of water quality standards, the selection of parameters is considered depending upon its end use. Two types of standards are referred in India decipher the quality of water suitable for drinking purposes, namely Bureau of Indian Standards (BIS) and World Health Organisation (WHO) Standards.

2.4 Drinking Water

The BIS has laid down the standard specification for drinking water during 1983, which have been revised and updated from time to time. In order to enable the users to exercise their discretion, the maximum permissible limit has been prescribed especially where no alternative sources are available. It is medically established fact that water with concentration beyond permissible limits cause short term or permanent adverse health effects.

2.4.1 Standards for Chemical Parameters

The water quality standards as laid down in BIS standard (IS-10500, 1991), First Revision, 2003-2009 and WHO (2008) standards are summarized in Table 2.7 and Table 2.8respectively. In addition separate standards for the use of Surface water i.e. lakes and rivers for drinking purposes have been laid down by BIS and have been given in table 2.9.

Table.12: Drinking water Standards - BIS (IS-10500, 1991)

S. No.	Parameters	Desirable limits (mg/l)	Permissible limits (mg/l)
Essential Characteristics			
1	Colour Hazen unit	5	25
2	Odour	Unobjectionable	-
3	Taste	Agreeable	-
4	Turbidity (NTU)	5	10
5	pH	6.5 - 8.5	No relaxation
6	Total Hardness, $CaCO_3$	300	600
7	Iron (Fe)	0.3	1
8	Chloride (Cl)	250	1000
9	Residual Free Chlorine	0.2	-
10	Fluoride (F)	1	1.5
Desirable Characteristics			

11	Dissolved Solids	500	2000
12	Calcium (Ca)	75	200
13	Magnesium (Mg)	30	100
14	Copper (Cu)	0.05	1.5
15	Manganese (Mn)	0.1	0.3
16	Sulphate (SO_4)	200	400
17	Nitrate (NO_3)	45	100
18	Phenolic Compounds	0.001	0.002
19	Mercury (Hg)	0.001	No relaxation
20	Cadmium (Cd)	0.01	No relaxation
21	Selenium (Se)	0.01	No relaxation
22	Arsenic (As)	0.01	No relaxation
23	Cyanide (CN)	0.05	No relaxation
24	Lead (Pb)	0.05	No relaxation
25	Zinc (Zn)	5	15
26	Anionic Detergents (as MBAS)	0.2	1
27	Hexavelant Chromium	0.05	no relaxation
28	Poly Nuclear Hydrocarbons (as PAH)	-	-
29	Alkalinity	200	600
30	Aluminium (Al)	0.03	0.2
31	Boron (B)	1	5
32	Pesticides	Absent	0.001
33	Mineral Oil	0.01	0.03
34	Radioactive Material		
	Alpha Emmiters, Bq/l	-	.0.1
	Beta Emmiters, pci/l	-	1

NTU = Nephelometric Turbidity Unit

Table 12. Drinking Water Standards, WHO (2008)

S. No.	Parameters	Guideline value (mg/l)	Remarks
1	Aluminium	0.2	
2	Ammonia	-	NAD
3	Antimony	0.005	
4	Arsenic	0.01	For excess skin cancer risk of 6 x 10^{-4}
5	Asbestos	-	NAD
6	Barium	0.3	
7	Beryllium	-	NAD
8	Boron	0.3	
9	Cadmium	0.003	
10	Chloride	250	
11	Chromium	0.05	
12	Color	-	Not Mentioned
13	Copper	2	ATO
14	Cyanide	0.07	
15	Dissolved Oxygen		NAD

16	Fluoride	1.5	Climatic conditions, volume of water consumed, and intake from other sources should be considered when setting national standards.
17	Hardness		NAD
18	Hydrogen Sulfide		NAD
19	Iron		NAD
20	Lead	0.01	It is recognized that not all water will meet the guideline value immediately; meanwhile, all other recommended measures to reduce the total exposure to lead should be implemented.
21	Manganese	0.5 (P)	ATO
22	Mercury (total)	0.001	-
23	Molybdenum	0.07	-
24	Nickel	0.02	-
25	Nitrate (as NO_3) Nitrite (as NO_2)	50	The sum of the ratio of the concentration of each to its respective guideline value should not exceed 1.
26	Turbidity		Not Mentioned
27	pH		NAD
28	Selenium	0.01	-
29	Silver		NAD
30	Sodium	200	
31	Sulfate	500	
32	Inorganic Tin		NAD
33	TDS		NAD
34	Uranium	1.4	
35	Zinc	3	

NAD - No adequate data to permit recommendation
ATO - Appearance, taste or odour of the water

Table.12: Surface Water Quality Standards -BIS

Characteristic	**Tolerance Limit**				
	Class A	**Class B**	**Class C**	**Class D**	**Class E**
pH value	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
Dissolved Oxygen (mg/l), min.	6	5	4	4	--
BOD (5-days at 20° C, mg/l, min.	2	3	3	--	--
Total Coliform Organism, MPN/100ml, max	50	500	5000	--	--
Colour, Hazen units, max.	10	300	300	--	--
Odour	10	300	300	--	--
Taste	Tasteless	--	--	--	--
Total dissolved solids, mg/l, max.	500	--	1500	--	2100
Total hardness(as $CaCo_3$), mg/l, max.	300	--	--	--	--
Calcium hardness (as $CaCO_3$), mg/l, max.	200	--	--	--	--
Magnesium hardness (as $CaCO_3$), mg/l, max.	100	--	--	--	--
Copper (as Cu), mg/l, max.	1.5	--	1.5	--	--
Iron (as Fe), Mg/l, max.	0.3	--	0.5	--	--
Manganese (as Mn), mg/l, max.	0.5	--	--	--	--
Chlorides (as Cl), mg/l, max.	250	--	600	--	600

Sulphates (as SO_4), mg/l, max.	400	--	400	--	1000
Nitrates (as NO_3), mg/l, max.	20	--	50	--	--
Fluorides (as F), mg/l, max.	1.5	1.5	1.5	--	--
Phenolic compounds (as C_6H_5 OH), mg/l, max.	0.002	0.005	0.005	--	--
Mercury (as Hg), mg/l, max.	0.001	--	--	--	--
Cadmium (as Cd), mg/l, max.	0.01	--	0.01	--	--
Salenium (as Se), mg/l, max.	0.01	--	0.05	--	--
Arsenic (as As), mg/l, max.	0.05	0.2	0.2	--	--
Cyanide (as CN), mg/l, max.	0.05	0.05	0.05	--	--
Lead (as Pb), mg/l, max.	0.1	--	0.1	--	--
Zinc (as Zn), mg/l, max.	15	--	15	--	--
Chromium (as Cr^{6+}), mg/l, max.	0.05	--	0.05	--	--
Anionic detergents (as MBAS) mg/l, max.	0.2	1	1	--	--
Polynucleararomatic hydrocarbons, (as PAH)	0.2	--	--	--	--
Mineral oil, mg/l, max.	0.01	--	0.1	0.1	--
Barium (as Ba), mg/l, max.	1	--	--	--	--
Silver (as Ag), mg/l, max.	0.05	--	--	--	--
Pesticides	Absent	--	Absent	--	--
Alpha emitters, uC/ml, max.	10^{-9}	10^{-9}	10^{-9}		
Beta emitters, uC/ml, max.	10^{-8}	10^{-8}	10^{-8}	10^{-8}	10^{-8}
Free ammonia (as N), mg/l, max.	--	--	--	1.2	--
Electrical conductance at 25° C, mhos, max.	--	--	--	1000×10^{-6}	2250×10^{-6}
Free carbon dioxide (as CO), mg/l, max.	--	--	--	61	--
Sodium absorption ratio	--	--	--	--	26
Boron (as B), mg/l, max.	--	--	--	--	--
Percent sodium, max.	--	--	--	--	--

*Explanation for Symbols:

A: Drinking water sources without conventional treatment but after disinfection.

B: Organized outdoor Bathing.

C: Drinking water sources with conventional treatment followed by disinfection.

D: Propogation of wild life and Fisheries.

E: Irrigation, industrial cooling and controlled water disposal.

2.4.2 Standards for Bacteriological Parameters

Faecal contamination is widespread in most of the Rural Areas. The major bacteriological contamination and their limits are given below:

E. Coli is the more precise indicator of faecal pollution. The count of thermo-tolerant, coliform bacteria is an acceptable method however, if necessary, proper confirmatory tests of the sample should be carried out. As per Indian standard for drinking water - specification (First Revision) IS-10500:1991 BIS, ideally, all samples taken from the distribution system including consumers' premises should be free from coliform organisms. In practice, this is not always attainable. The following standard of water collected in the distribution system is therefore recommended when tested in accordance with IS 1622:1981.

a) 95 percent of samples should not contain any coliform organisms in 100 ml;

b) No sample should contain E. coli in 100 ml;

c) No sample should contain more than 10 coliform organism per 100 ml; and

d) Coliform organism should not be detectable in 100 ml of any two consecutive samples.

WHO has also suggested guidelines for bacteriological parameters are as follows (Table 2.10)

Table.13: Bacteriological quality of drinking water (WHO, 2008)

Organisms	Guideline Value
All water intended for drinking	
E. Coli or thermo-tolerant coliform bacteria	Must not be detectable in any 100/ml sample.
Treated water entering the distribution system	
E. Coli or thermo-tolerant coliform bacteria	Must not be detectable in any 100/ml sample.
Total coliform bacteria	Must not be detectable in any 100/ml sample.
Treated water in the distribution system	
E. Coli or thermo-tolerant coliform bacteria	Must not be detectable in any 100/ml sample.
Total coliform bacteria	Must not be detectable in any 100/ml sample. In the case of large supplies, where sufficient samples are examined must not be present in 95% of sample taken throughout any 12 month period.

The detrimental effect of various pesticides/ organic compounds cannot be ignored.

Chemical data of ground water from shallow aquifer indicates that ground water is alkaline, fresh or moderately saline. The ground water samplings are carried out through Ground Water Observation Wells in every year pre-monsoon period by CGWB. The chemical quality data of pre-monsoon, 2014 is used in this report and the main observations are given as follows in Table 2.11. The same has shown in Figure No. 2.18.

Table.14: Ground Water Quality Results (2016) in Kullu Valley, Kullu District.

Location	PH	EC (us/cm)	PO_4	CO_3	TH	Ca	Mg	Na	K	HCO_3	CL	SO_4	NO_3	F
	(mg/l)													
Kullu	8.47	290	<0.1	38	140	48	5.00	3.9	4.90	77	21	0	5.03	0.07
Gadouri	8.36	354	<0.1	25	170	52	10	9	3.70	90	43	0	30	0

To assess the impact of ground water quality 2 numbers of water samples were collected from the study area of Kullu Valley of district Kullu in 2016, as per the list below:

Sr.No	Type of Source	Total Nos.
1	Dug Well	2 Nos.

All the collected samples were analyzed at chemical laboratory of CGWB, North Western Himalayan Region, Jammu, (J&K), by adopting Standard methods of analysis (APHA) and ranges are given below Table 2.12.

Table .15: General ranges of water quality parameters of study area

Sr.No	Water Quality Parameters	Minimum	Maximum
1.	PH	8.36	8.47
2.	E.C Sp. Cond. µmhos/cm at 25°C	290	354
3.	CO_3 (mg/l)	25	38
4.	HCO_3 (mg/l)	77	90
5.	CL (mg/l)	21	43
6.	NO3(mg/l)	5.03	30
7.	F (mg/l)	0	0.07
8.	Ca (mg/l)	48	52
9.	Mg (mg/l)	5	10
10.	Na (mg/l)	3.9	9
11.	K (mg/l)	3.70	4.90
12.	TH (mg/l)	140	170

Table.16: Ground Water Quality Results, Spring (2012) in Kullu Valley, Kullu District.

Location	pH	Sp Cond ms/cm 25°C	CO_3	HCO_3	Cl	SO_4	NO_3	F	Ca	Mg	Na	K	Fe	TH
	(mg/l)													
Babeli	8.10	260	Nil	134	10.7	Tr	13.3	Tr	32.1	9.0	6.0	7.6	N D	115
Raison	7.89	260	Nil	116	17.8	Tr	13.5	0.05	34	3.6	10.4	6.7	N D	100
Raison Bihal	7.32	240	Nil	116	14.2	3.84	2.0	0.07	34	2.4	8.5	6.1	N D	95
Kalath	7.00	140	Nil	73	7.1	Tr	3.8	0.59	18	2.0	6.2	2.5	N D	55
Rawri	6.90	40	Nil	18.3	3.6	Tr	11.4	0.30	6	1.2	2.1	1.3	N D	20
Vashist Chowk Malali	6.52	120	Nil	37	3.6	Tr	20.0	0.39	10	2.0	6.6	3.4	N D	35
Barua	7.85	80	Nil	18	7.1	Tr	11.0	0.2	6	2.0	3.2	3.5	N D	25
Aloe	7.58	190	Nil	37	17.8	Tr	35.8	Tr	20	1.0	10.2	3.9	N D	55
Gojara	7.70	90	Nil	43	7.1	Tr	10.6	0.28	12	1.0	3.8	2.1	N D	35
Mahili	7.80	200	Nil	92	10.7	Tr	8.8	0.22	20	7.0	2.7	4.4	N D	85
Kararsu	7.80	220	Nil	98	3.6	7.2	14.4	0.25	26	4.0	5.1	6.3	N D	85

pH

The pH is a numerical scale which express the degree of acidity or alkalinity of solution and represented by the equation pH= $\log 1/aH^{+}= -\log aH^{+}$ or in other words pH may be defined as negative logarithmic of Hydrogen ion concentration. In study area, the overall range of pH in ground water varies from 8.36 (Gadouri) to 8.47 (Kullu). Ground water of the area is alkaline in nature (Fig-1.11).

Electrical conductivity

Electrical Conductivity can be defined as the ability of a solution to conduct an electric current and measured in micromhos /cm and reported at 25°C. Electrical Conductivity is a function of concentration of ions, charge and ionic mobility Electrical Conductivity is approximately indicative of ionic strength. In study area spring water is least mineralised.

Bicarbonate

Overall value of Bicarbonate varies from 77 (kullu) to 90(Gadouri) mg/l. (Fig-1.13).

Chloride

Chloride is one of the most common constituent in groundwater and very stable as compared to other ions like SO_4, HCO_3, NO_3 etc. It is noticed from the chemical data that, varies from 21 mg/l (kullu) to 43mg/l (Gadouri)(Fig-1.14).

Nitrate

Nitrate is one of the important pollution related parameter. Nitrate is the end product of the aerobic oxidation of nitrogen compounds. Mainly it is contributed by nitrogenous fertilizers, decomposition of organic matter in the soil, fixation of nitrogen by bacteria etc. Human and animal excreta may also add nitrate to water by bacterial decomposition. For drinking water maximum permissible limit of nitrate is 45 mg/l as per BIS 1991-Rev-2007.

In the study area, over all nitrate concentration is less than 45 mg/l. It varies from minimum 5.03 to a maximum concentration of Nitrate 30mg/l (Fig-1.15).

High concentration of nitrate causes infant methaemoglobinaemia (Blue baby disease).Very high concentration of Nitrate causes gastric cancer and affects central nervous and cardiovascular system.

Fluoride

Fluoride is an important water quality parameter for accessing the water quality for drinking purpose. Fluoride is more abundant than chloride in the igneous and as well as sedimentary rocks. Fluoride differs from other halogen members due to high electronegative character.In study area, Fluoride concentration ranges from 0 to 0.07mg/l Fig-1.16).

Calcium

The calcium is a major constituent of various rocks. The precipitates (limestone) contain about 27.2% of calcium ions. It is one of the most common constituent present in natural water. Calcium minerals associated with sodium, aluminium, silica, sulphate, carbonate and Fluoride. Maximum permissible limit for calcium is 200 mg/l(Fig-1.17).

It is observed that all collected samples, are found to have concentration of Calcium, within the maximum permissible limit of BIS for drinking water.

Magnesium

Magnesium is the 8^{th} most abundant element in the solar system. It is available in various rocks .The maximum concentration of Magnesium, 4.53 % is found in the evaporates of sedimentary rocks. The concentration of Magnesium in natural water is mainly controlled by dissolved CO_2. (Fig-1.18).

The concentration of Magnesium in springs, Ground Water Aquifers (Shallow & Deep) are within the maximum permissible of BIS (100 mg/l) for drinking water.

It is observed that all collected samples, are found to have concentration of Magnesium, within the maximum permissible limit of BIS for drinking water (Fig-1.18).

Sodium

Sodium is the abundant of the alkali element in the earth's crust. Most of the Sodium occurs in the Feldspars, Mica, amphiboles and Pyroxenes. In study area, Sodium concentration ranges from 3.9 to 9 mg/l .(Fig-1.19).

Potassium

Potassium in sedimentary rock is more abundant than Sodium. The main potassium minerals containing silicates are Orthoclase, micas. Evaporate beds may contain potassium salts. In study area, Potasium concentration ranges from 3.70 and 4.90 mg/l .(Fig-1.20).

Total Hardness (TH)

High concentration of carbonates, bicarbonates of calcium and magnesium, in ground water causes hardness. It causes scaling in water supply lines. High concentration of hardness in ground water is social economic problem; hence it is also an important water quality parameter. Hardness of water is the capacity to neutralize soap and is mainly caused by carbonates and bicarbonates of calcium, magnesium. In study area the overall value of total hardness varies from 140 mg/l to 170mg/l .

2.5 Spatial Data Distribution

The data of CGWB wells in the area are plotted on the map of 1:50000 scale with 5'X5'grid (9km x 9km) and is shown in Fig-2.10 respectively. The exploration data shows that majority of tube wells falls in the Ist Aquifer and II nd Aquifer. The grids/ formations devoid of EW/ DW and PZ are identified as data gaps and these are to be filled by data generation.

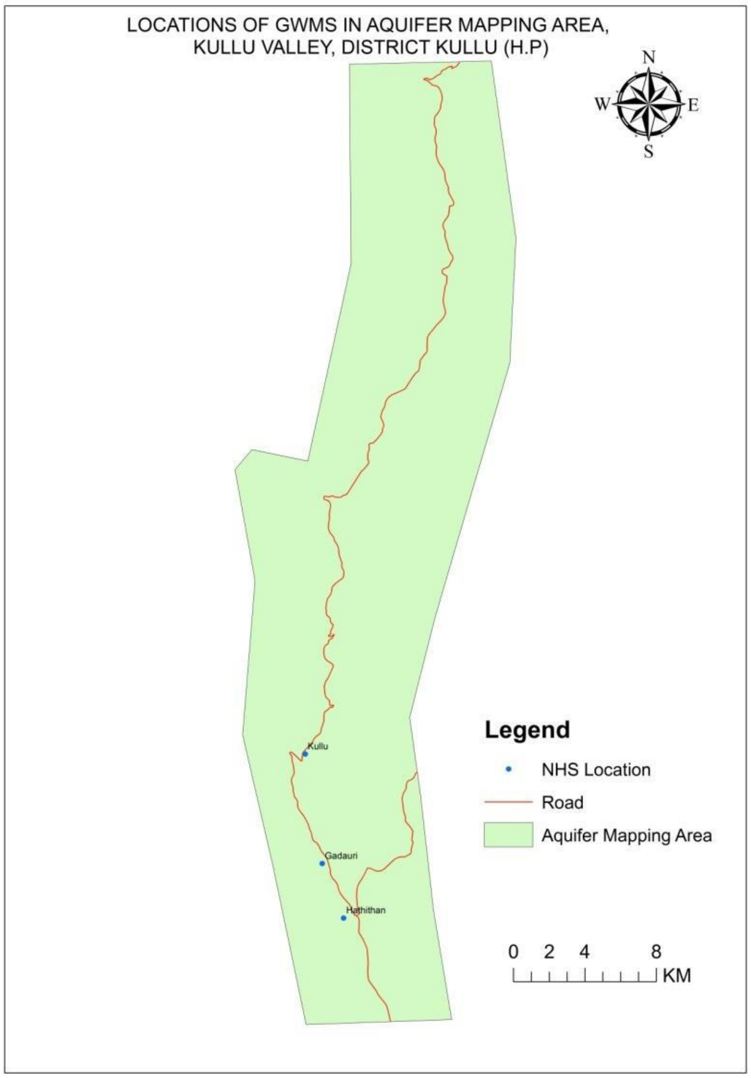


Fig. 21: Locations of GWMS(NHS) in Kullu Valley, Kullu District

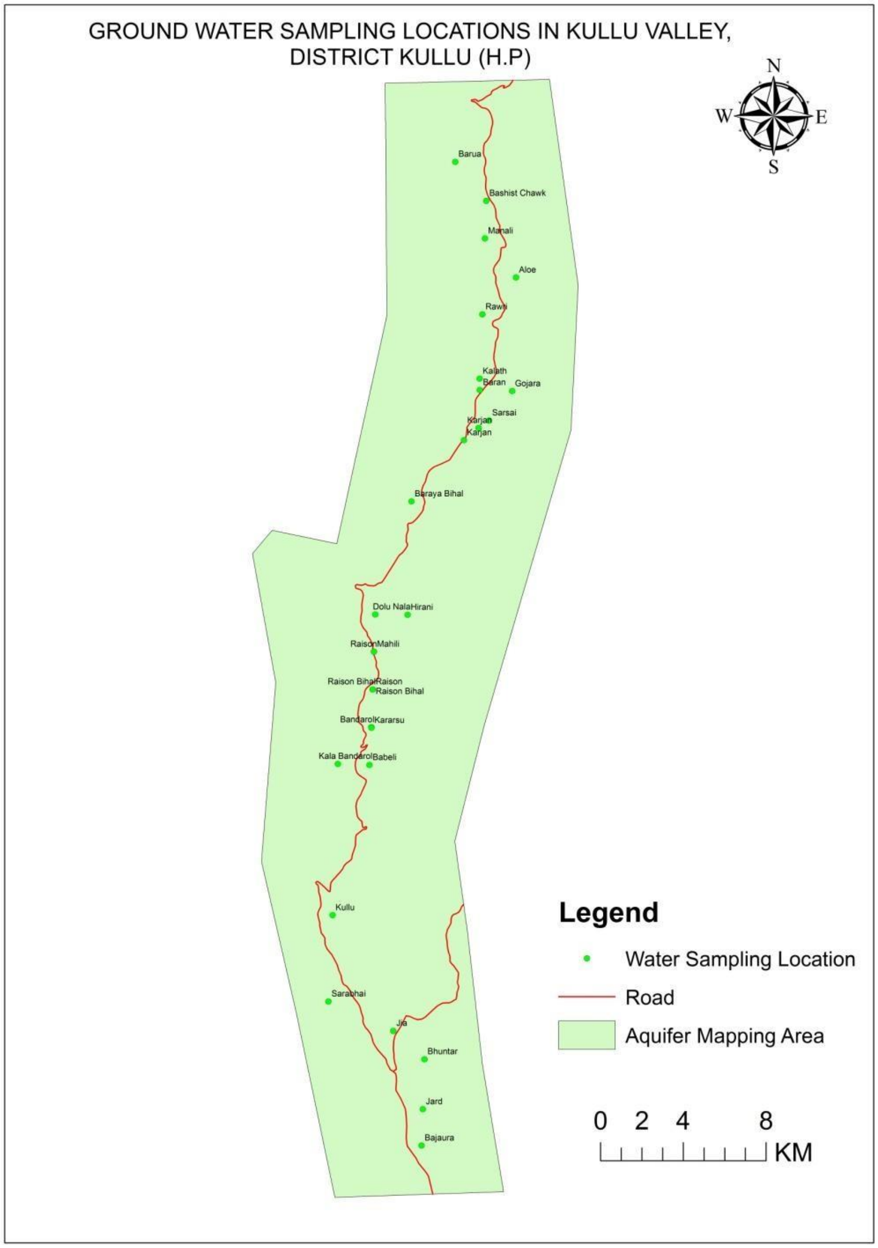


Fig. 22: Locations of GWMS(Spring) in Kullu Valley, Kullu District

Chapter-III

3.0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

All the available data have been validated and optimized for consideration to generate the aquifer map in Kullu Valley, Kullu District. The wells optimization part is done based on the maximum depth & litholog . The deepest well in each quadrant is selected and plotted on the map of 1.50000 scale with 5'X5'grid (9 x 9km) and is shown in Fig- 16.

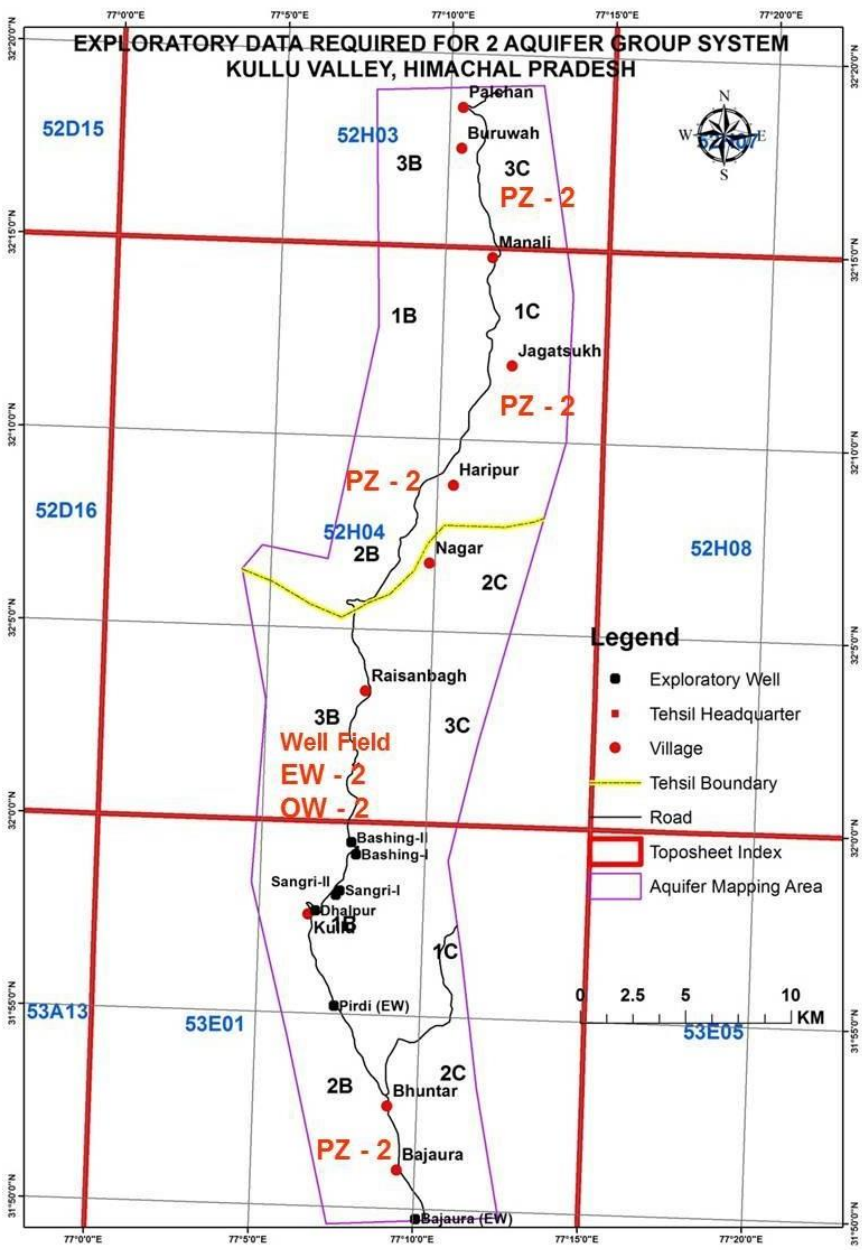


Fig. 23: Locations of Exploratory Wells , Kullu Valley, Kullu District.

3.1 Aquifer Parameter Ranges

In Kullu Valley, District Kullu (H.P) the exploration drilling was carried out by CGWB, the aquifer parameters range extracted and given in below Table-16.

Table.17: Summary of Exploration and Hydraulic details in Kullu Valley, Kullu District

S.No	Exploratory Well	Latitude	Longitude	T (m2/day)	Discharge (lpm)	Well Depth(m)
1.	Bashing	31.96	77.12	669.93	1268	50.00
2.	Dhalpur	31.96111	77.1125	409.79	465.60	97.50
3.	Bajaura	31.829	77.12	NA	1200	62.00
4.	Pirdi	31.92	77.12	270	298.80	92.00
5.	Bandrol	32.038	77.131	68.76	540	58.00
6.	Palchan	32.309	77.166	4916.57	625	79.00
7.	Jard Vihal	31.86	77.1609	NA	60	33.00
8.	Sangri Bagh-II	31.97	77.12	NA	NA	100.70

3.2 Aquifer Geometry

To understand the lithological frame work and aquifer disposition in the sub surface aquifers, the litholog data of wells drilled by CGWB are used to compile, optimized and modeled into 2D (Fig. 2) The 3D lithological fence diagram has been prepared along with distribution of wells are shown in Fig-30 & 31

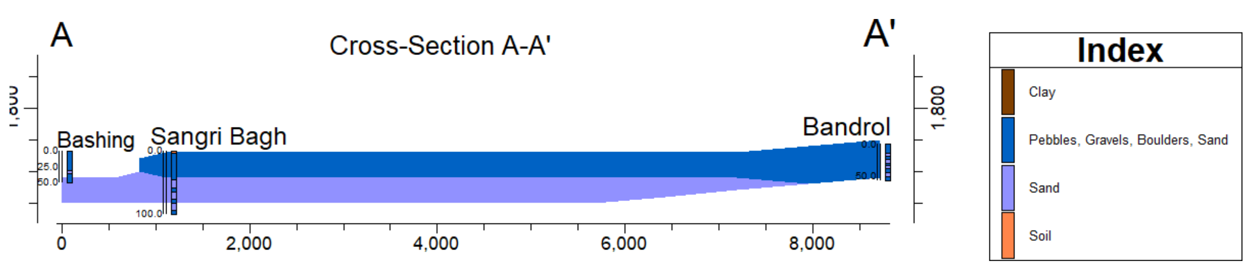


Fig .24: 2D-Cross Section along Bashing – Sangri Bagh - Bandrol EW

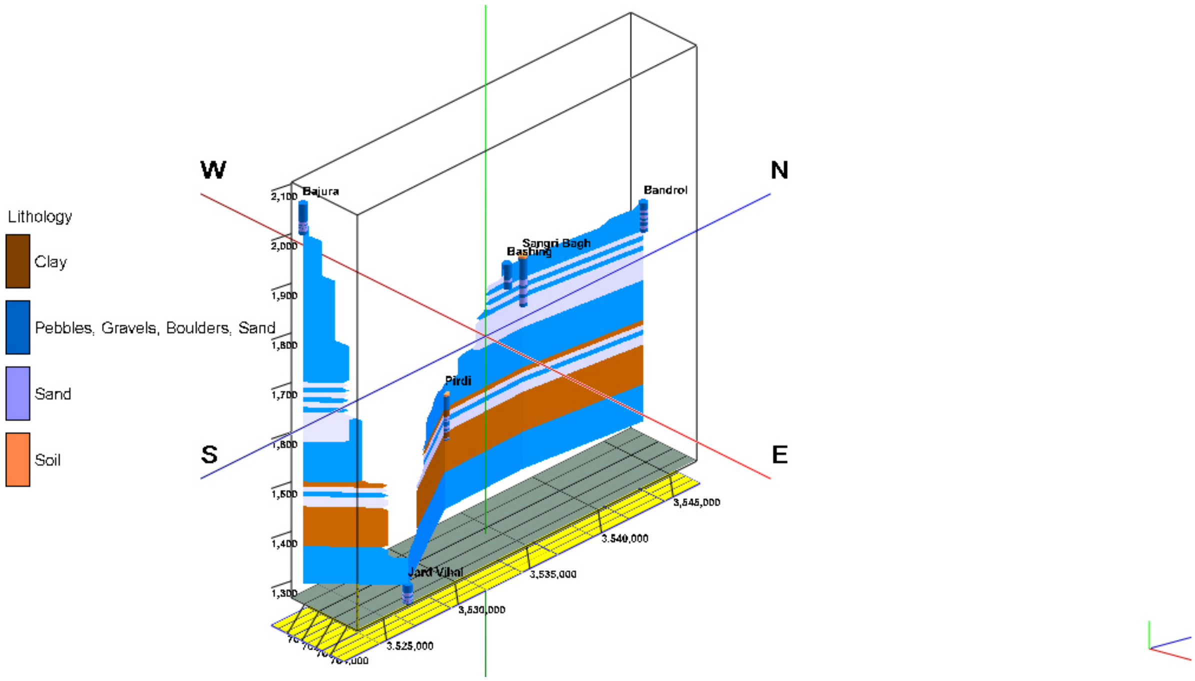


Fig.25 : 3D Lithological Fence Diagram EW

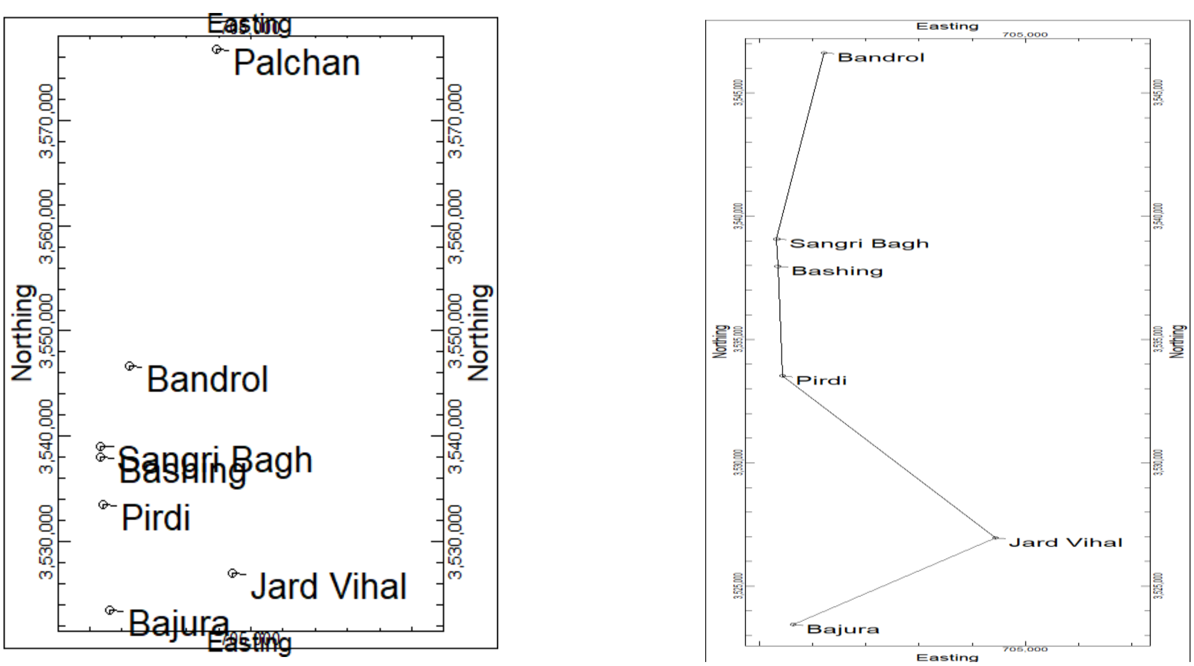


Fig.26 : Locations Map of EW

Chapter-IV

4.0 Ground Water Resources

Ground water resources and irrigation potential for Kullu valley of the district has not been computed as per the GEC-2015 methodology due to hilly terrain and localized aquifers. Snow fall in the higher reaches and rain fall in the lower areas, recharge the ground water. Springs are the other main sources for the irrigation and water supply schemes.

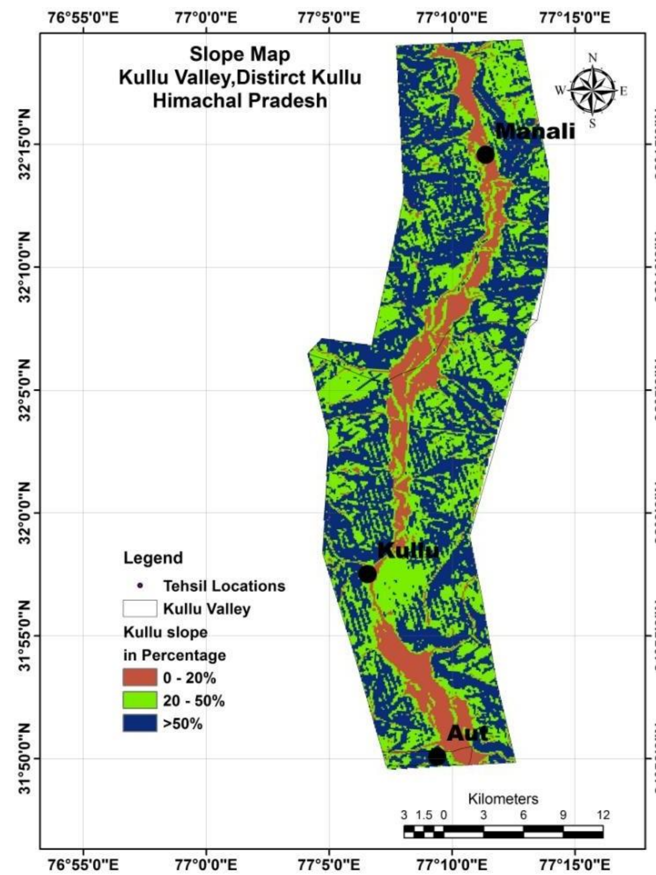


Fig.27 : Slope Map of the study area

5.0 GROUND WATER RELATED ISSUES & PROBLEMS

In Kullu Valley, major water supply schemes are based on springs and surface water. The excess of silt in major rivers, create problems for water supply schemes. Ground water in Kullu district has not been explored fully for its development. Kullu valley, located along the Beas river, Lag valley located along Sarvary khad, Garsa valley-located in the eastern part of Kullu district, Manikaran valley- located along Parbati River and small valleys in Sainj, Banjar, Ani can be explored for the development of ground water for round the year and fresh water supplies to the public and for irrigation purpose.

Major ground water related issues and their manifestation in area are:

1) Siltation of surface Water Bodies

- Due to excessive runoff, topography of the area, and anthropogenic change of land use in areas, all the surface water bodies are receive high level of silt. This siltation hamper the rate of ground water recharge form these bodies as well increase the maintenance cost of these water bodies.

2) High degree of rainfall runoff

- Due to sloping topography of the areas, type of soil, concentrated period of rainfall, most of the precipitation is lost as surface runoff without significant contribution to infiltration.

3) Drying of Springs

- Majority of the springs in the area are losing discharge, especially during lean season. The man culprit behind drying of springs is Energization nearby groundwater abstraction structures to cope with the increasing demand, Change in land use pattern in the watershed as well as recharge area of the springs and ecological degradation caused by human activities.

4) Low Stage of Ground Water Development

- Ground water development in study areas is very low. Most of the population is dependent on surface water for both domestic as well as irrigation use. It is mainly due to reason that groundwater potential in the area is low to moderate.

6.0 GROUND WATER MANAGEMENT STRATEGY

6.1 Ground Water Development

Kullu valley is partly explored and only shallow aquifers are tapped for water supply schemes. All these wells are drilled all along the Beas river and its tributaries in the district. There is a lot of scope for the future ground water development in the district.

In Kullu valley, ground water occurs under water-table to semi-confined conditions. The aquifer zone mainly comprises of sand and fine silt in association with pebbles and boulders in low plains and predominantly boulders, cobbles, pebbles mixed with little clay in terraces. Fissured formation includes the semi-consolidated to consolidated sediments exposed in the district and are of sedimentary, metamorphic and igneous in origin.

Metamorphic and igneous rocks exposed in northeastern parts of the district include quartzites, gneisses, phyllites slates and dolomites. Phyllites interlayer with thin quartzite bands and slates with dolomites form the exposed metamorphic rocks. Springs are reported to exist in the low topography areas along the lineaments and contact of various formations.

Most of the part of Kullu district having Metamorphic and Igneous rocks (consolidated and semi-consolidated) have not been explored due to mountainous terrain and difficulty in approachability as such, their yield potentials are unknown.

6.2 Water Conservation and Artificial Recharge

Average annual rainfall of the district is 1,405.7 mm, out of which 57% occurs during June to Sept. Due to hilly terrain most of the rainfall goes as runoff and a very small quantity enters as ground water. The ground water condition becomes particularly severe in hard rock formations, where scope for recharging the aquifer is low. Only the area, sufficiently traversed by faults/joints/weak zones/ weathered zones get recharged during the monsoon period. Due to high relief, most of the surface water goes as runoff, and hence, there exists a scope for recharging such aquifers.

Taking into consideration the physiography of the area, the following methods for artificial recharge are suggested.

Gabion Structure: - In hard rock areas, marked with fractures/weak zones; such less costly structures can be useful for recharging the surface water.

Contour Bunding: - This practice can be followed efficiently in hilly terrain, tapping the stream water. Here, the ditches are excavated following the ground surface contour of the area. Subsurface dykes: - These types of structures are very useful in arresting the sub-surface flow in a stream and store the water below ground surface, to meet the demands during the period of needs.

Check dams: - Check dams can be constructed across small streams, having gentle slope and are feasible both i.e. hard rock areas as well as alluvial formations. The design of the structure is based on the characteristics of the stream course.

Recharge Shafts: -These are most efficient and cost effective structures to recharge the aquifer directly. In the areas, where source of water is intermittent or perennial e.g. base flow, springs etc., the recharge shaft can be constructed.

Roof top rain water harvesting: - During the monsoon period , the rain water from roof tops can be collected and put into recharge structure for recharging the shallow aquifer. This will help in raising the water level in the area, to some extent. The water can also be used for domestic purposes by collecting it into tanks.

7.0 AQUIFER MANAGEMENT PLAN

An outline of the Aquifer Management Plan includes details regarding population, rainfall, average annual rainfall, agriculture and irrigation, water bodies, ground water resource availability, ground water extraction and water level behavior. Aquifer disposition and various cross sections have also been given. **Plans for Sustainable Management of the Resource**

Table.18: Broad outline of management plan is as follows:

Sr. No	GW Related Issues in Area	Suggested Solution
1.	Low Groundwater Potential	Check runoff thorough various surface storage type recharge structure
2.	Siltation of Surface Water Bodies	Watershed treatment through plantation, restoration/revival and de-silting of existing ponds/tanks etc.
3.	High Degree of Runoff	Surface water storage structures i.e. dams/ponds, Nala bund, Gabions structures etc,
4.	Drying of Springs	A program similar to Dhara Vikas Spring Rejuvenation in Sikkim, India
5	Low Stage of Groundwater Development	Promoting Irrigation through TW/DW in valley areas/ potential zones

In the Study area,

Table.19: Demand and Supply of Drinking water (Providing WSS) year Wise Tehsil Manali (town) District Kullu

S.No.	Year	Demand (in MLD)	Supply(in MLD)
1	2015-2016	1.95	2.05
2	2016-2017	1.95	2.10
3	2017-2018	2.00	2.10
4	2018-2019	4.20	4.80
5	2019-2020	4.80	5.10

Table.20: Demand and Supply of Drinking water (Providing WSS) year Wise Tehsil Kullu (town) District Kullu

S.No.	Year	Demand (in MLD)	Supply(in MLD)
1	2015-2016	2.5	2.55
2	2016-2017	2.8	3.15
3	2017-2018	3.75	4.1
4	2018-2019	4.25	4.35
5	2019-2020	4.32	4.745

7.1 Plan for Sustainable Management of the Resource

- The major aquifer system of the Kullu valley is alluvial deposits. .
- There is need to protect traditional water harvesting structures like ponds, tanks, talavs to utilized these for rain water harvesting and recharging shallow aquifers.
- In hilly and mountainous terrain, traditional ground water sources viz., springs, *bowries* etc needs to be developed and protected for better health and hygiene with proper scientific intervention.
- Roof top rainwater harvesting practices can be adopted in hilly areas and urban areas, since the district receives fair amount of rainfall. Construction of roof top rain water harvesting structures should be made mandatory in all new construction and rain water harvesting in rural areas should be promoted. Traditional water storage systems need to be revived.

- People's participation is a must for any type of developmental activities. So proper awareness for utilization and conservation of water resources is required.
- Construction of bore well near to spring source in hilly area should be avoided as this could lead to drying of the natural water sources.
- Recharge structures feasible in hilly areas are check dams, Gabion structures and staggered contour trends at suitable locations.

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