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Central Ground Water Board,
Department of Water Resources, River Development and Ganga Rejuvenation,
Ministry of Jal Shakti, Government of India

जलभृत मानचित्रण और प्रबंधन योजना
इंदौरा घाटी, जिला कांगड़ा, हिमाचल प्रदेश

AQUIFER MAPPING AND MANAGEMENT PLAN OF INDAURA VALLEY, DISTRICT KANGRA, 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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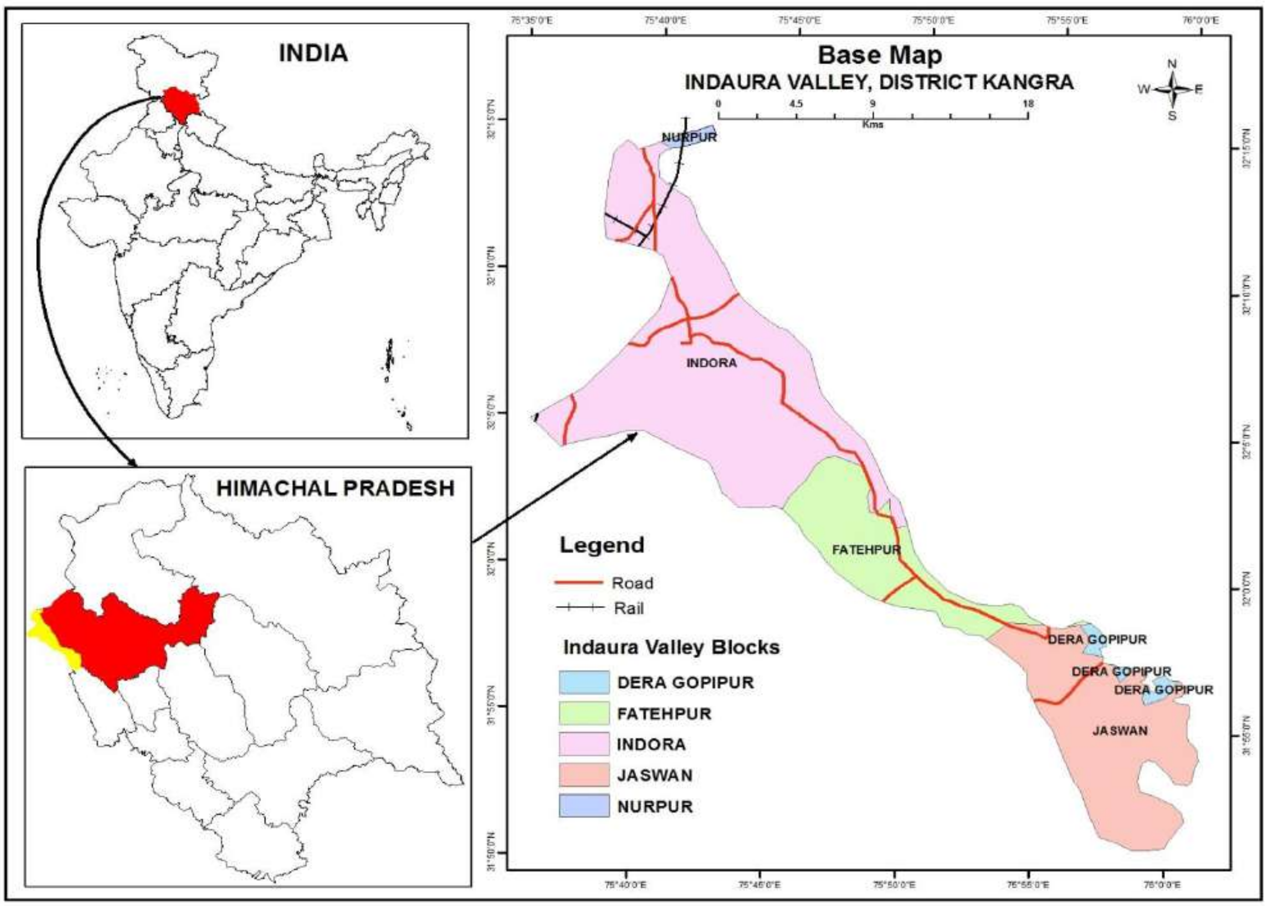

Indaura Valley at a Glance

Northern Himalayan Region, Dharamshala

2019

MAPPING AND MANAGEMENT PLAN OF INDAURA VALLEY, DISTRICT KANGRA, HIMACHAL PRADESH

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AQUIFER MAPPING AND MANAGEMENT PLAN OF INDAURA VALLEY, DISTRICT kANGRA, HIMACHAL PRADESH

1. INTRODUCTION

Aquifer mapping is a process wherein 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 hydro geological 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.

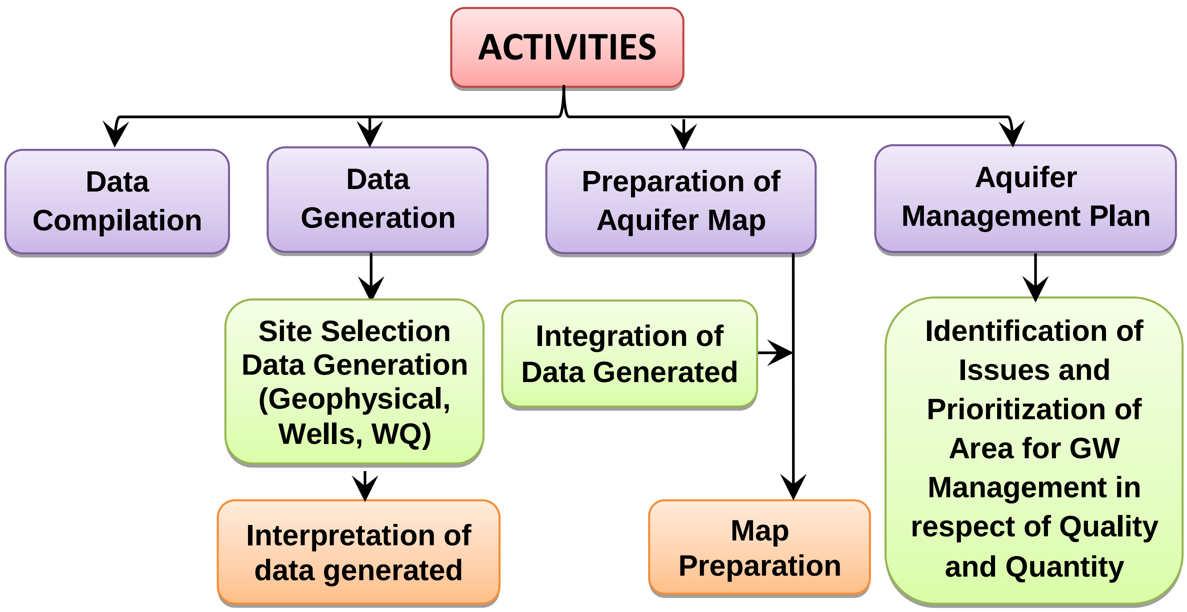
1.1 Objectives

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 rmapping programme with a clear-cut groundwater management purpose. This will ensure that aquifermapping does not remain an academic exercise and that it will seamlessly flow into a participatorygroundwater management programme. The aquifer mapping approach can help integrate ground wateravailability with ground water accessibility and quality aspects.

Aquifer Mapping studies in parts of Kangra district were taken up as per the AAP 2013-2014 of Northern Himalayan Region, Central Ground Water Board. Out of a total area of 5739 sq.km of the district, 320 sq. km was assigned to carry out the Aquifer mapping studies. The area of study was mostly located in the valley part of the mountainous tract.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

Kangra district occupies the western most part of the state located between latitude 31o 45' and 32o 28' and longitudes 75o 35' and 77o 05'and covers an area of 5739 sq.kms. It is bounded by Chamba and Lahaul & Spiti in the north, Kulu and Mandi in the east, Hamirpur and Una in the south, and Gurdaspur & Hoshiarpur districts of Punjab in the west. The important towns of the district are Dharamshala, Kangra, Palampur, Baijnath , Nurpur, Jawali, Dehra and Jawalamukhi. The headquarter of the district is at Dharamshala. All these towns are well connected by metalled roads. A meter gauge railway line from Pathankot to Jogindernagar passes through the district. An airport also exists at Gaggal about 9 kms from Kangra and 15 kms From Dharamshala. The Study area is situated western part of the Kangra district it is about 100 km from Dharamshala. Base map of the study area is given in figure 1.

1.4 Administrative Divisions and Demographic Particulars

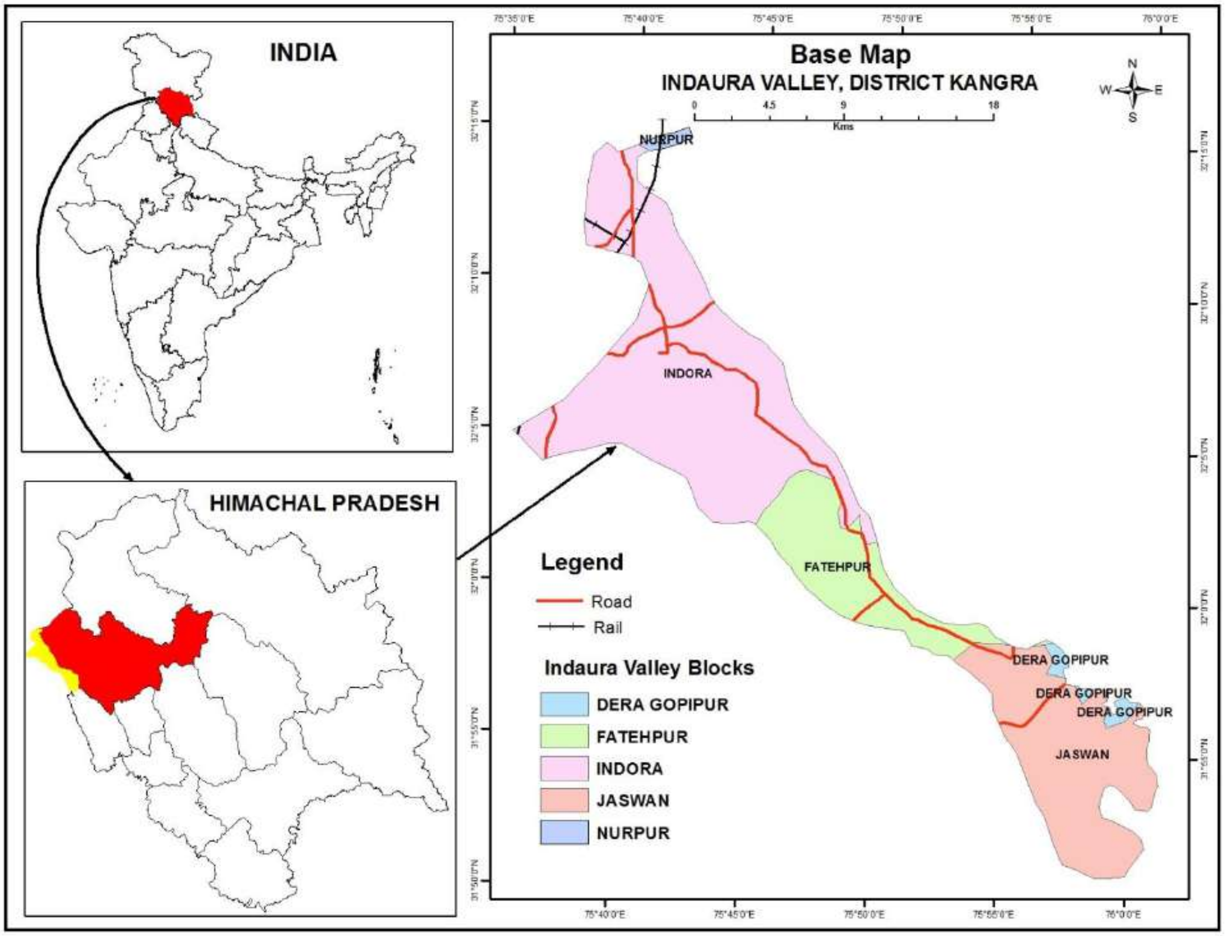


Fig 1: The Administrative Division of the Study Area

1.5 Data Gap Analysis

The Data gap analysis was done in Aquifer Mapping Study area of about 320sq.kms in the Indora Valley of Himachal Pradesh. The study area falls in Survey of India Toposheets No. 53 P/12, 53P/16, 44M/13, & 53A/01 covering full or partial area of 10 quadrants.

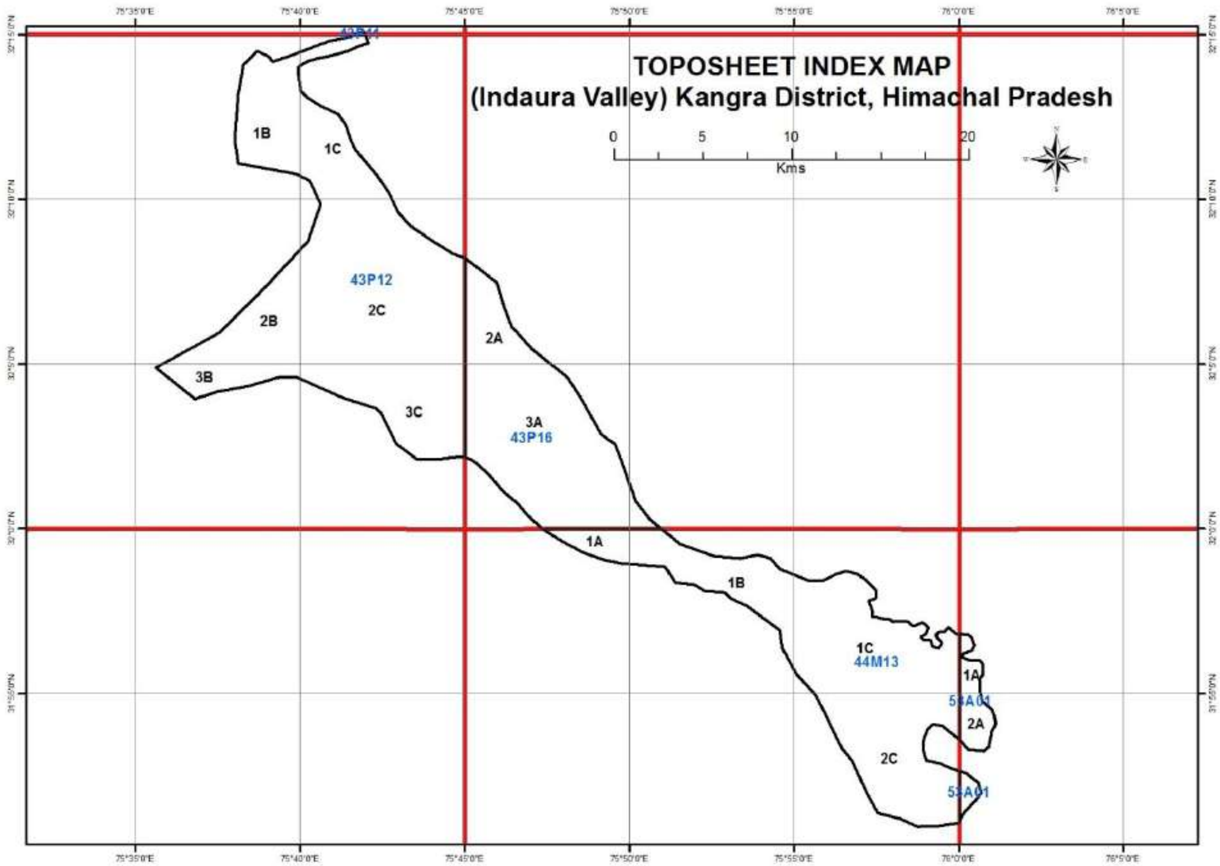


Fig.2 Toposheet Index Map - Indaura Valley, Kangra District

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 in the figure -3. and Table No.1.1

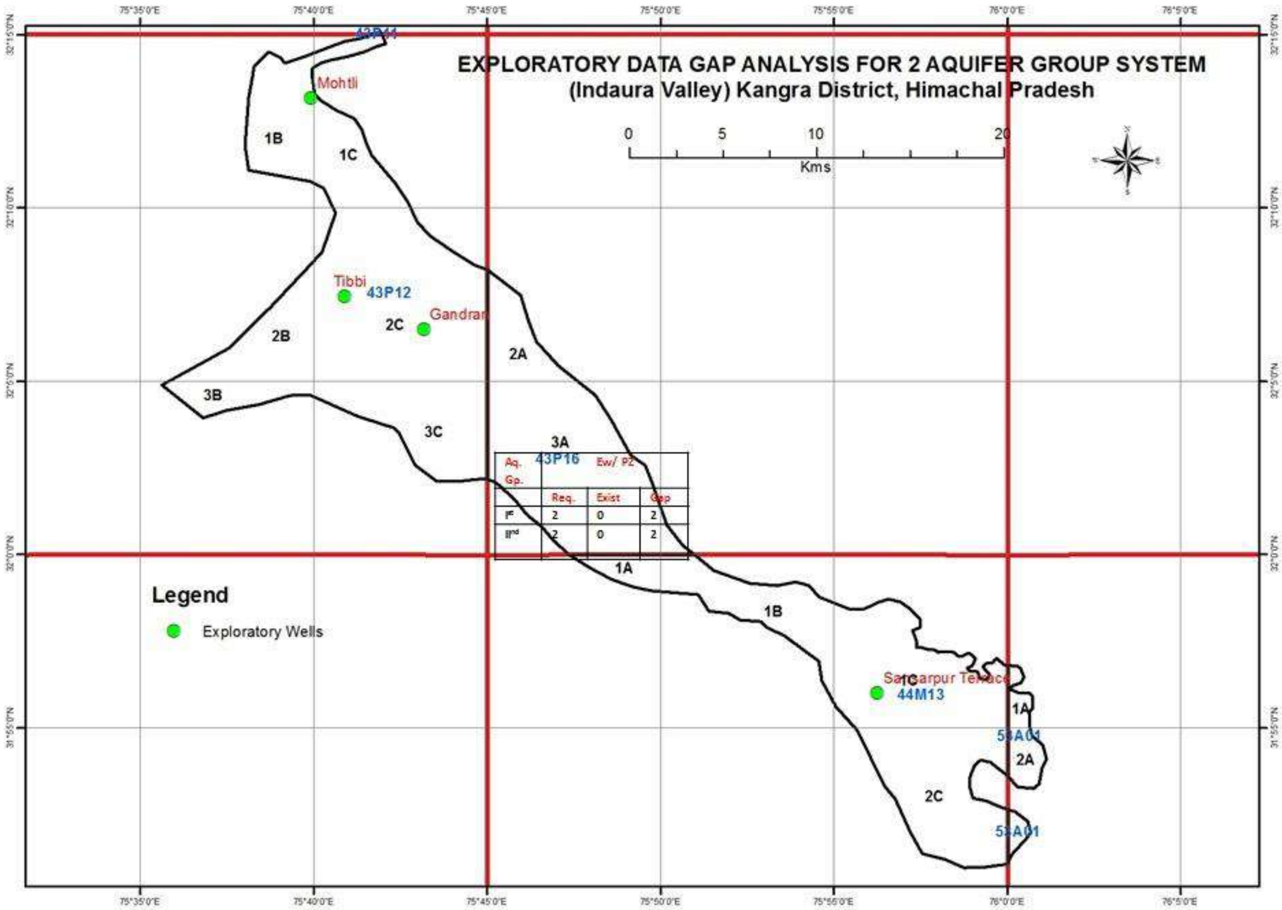


Fig.3 Exploratory Data Required Map – Indaura Valley, Kangra District

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 11 Nos. The quadrant-wise existing and recommended VES sites is presented in the figure 3.0.

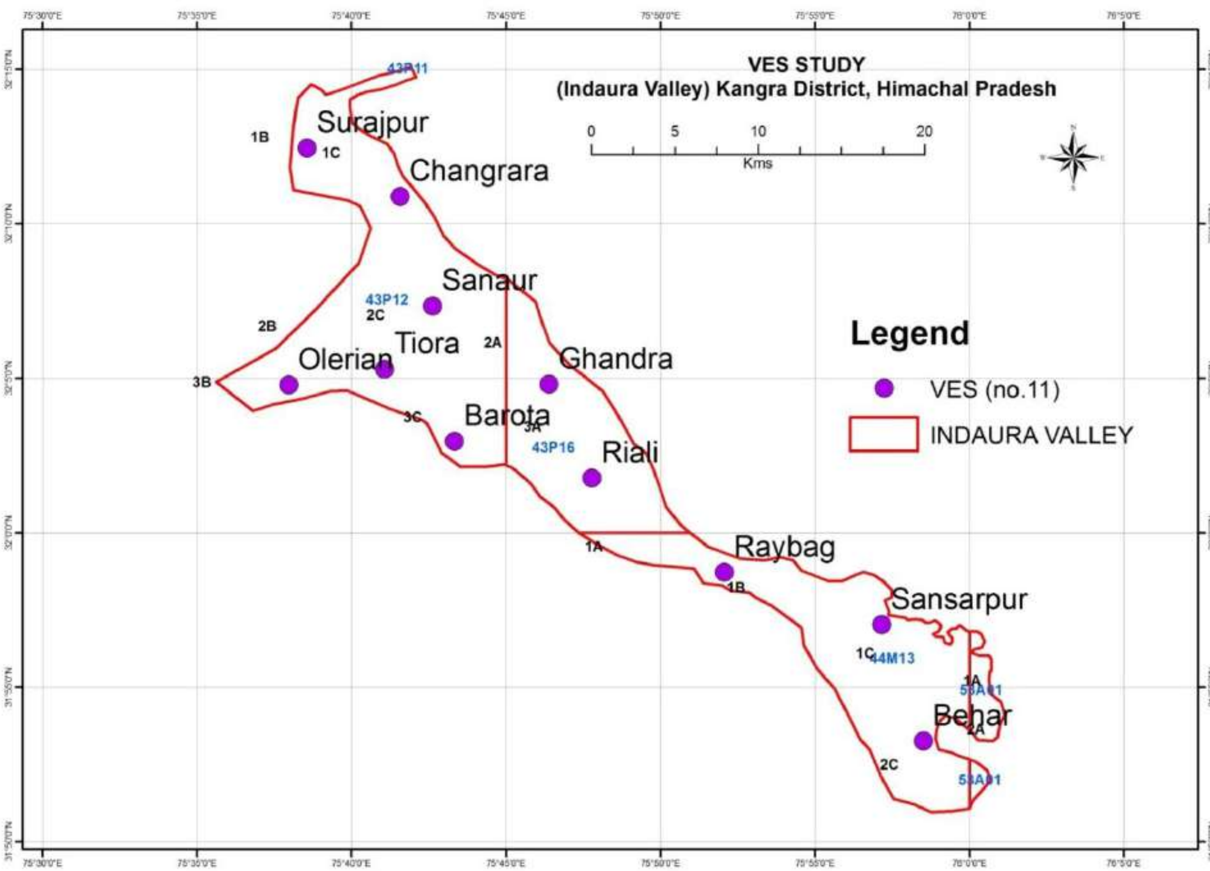


Fig.4 Data Gap Analysis of Surface Geophysical Surveys Indaura Valley, Kangra District

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 in the figure -5. The additional 2 nos. Pzs are required for ground water monitoring.

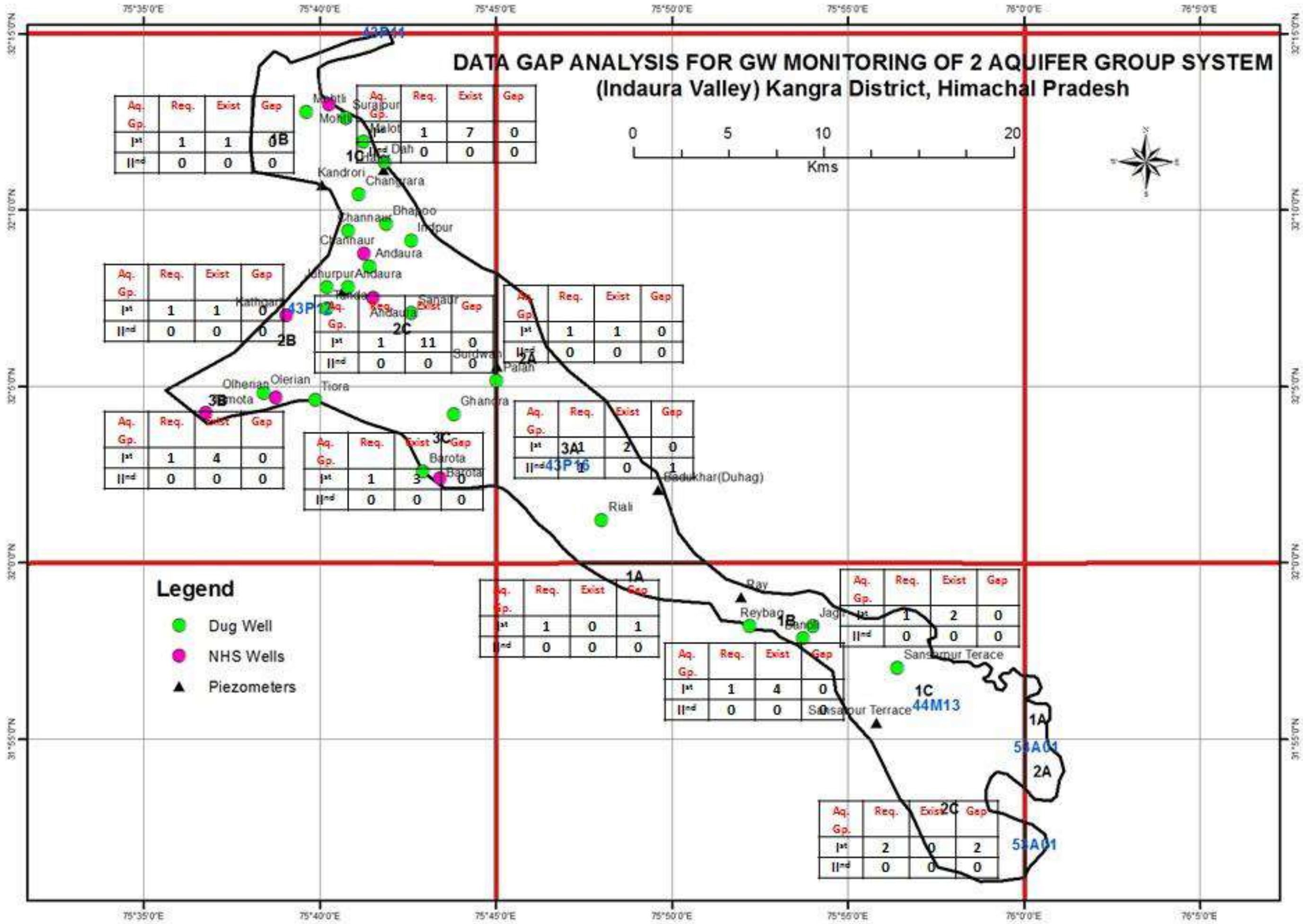


Fig.5 Data Gap Analysis for Ground Water Monitoring – Indaura Valley, Kangra District

1.5.4 Ground Water Quality Monitoring Stations (GWQMS)

Most of the ground water quality monitoring, NHS and Key well observation stations in the area tap the unconfined aquifer. Wells constructed by CGWB and hand pumps by the state agencies tapping the deeper and shallow aquifers are utilised to monitor the quality of ground water in the deeper and shallow aquifers. On the basis of data gap analysis, no additional GWQMS will require, it will be monitored through NHS, Key well observation stations, hand pumps, existing and proposed E/Ws, O/Ws and Pzs. The quadrant-wise and aquifer-wise existing and recommended ground water quality monitoring stations are shown in the figure -6

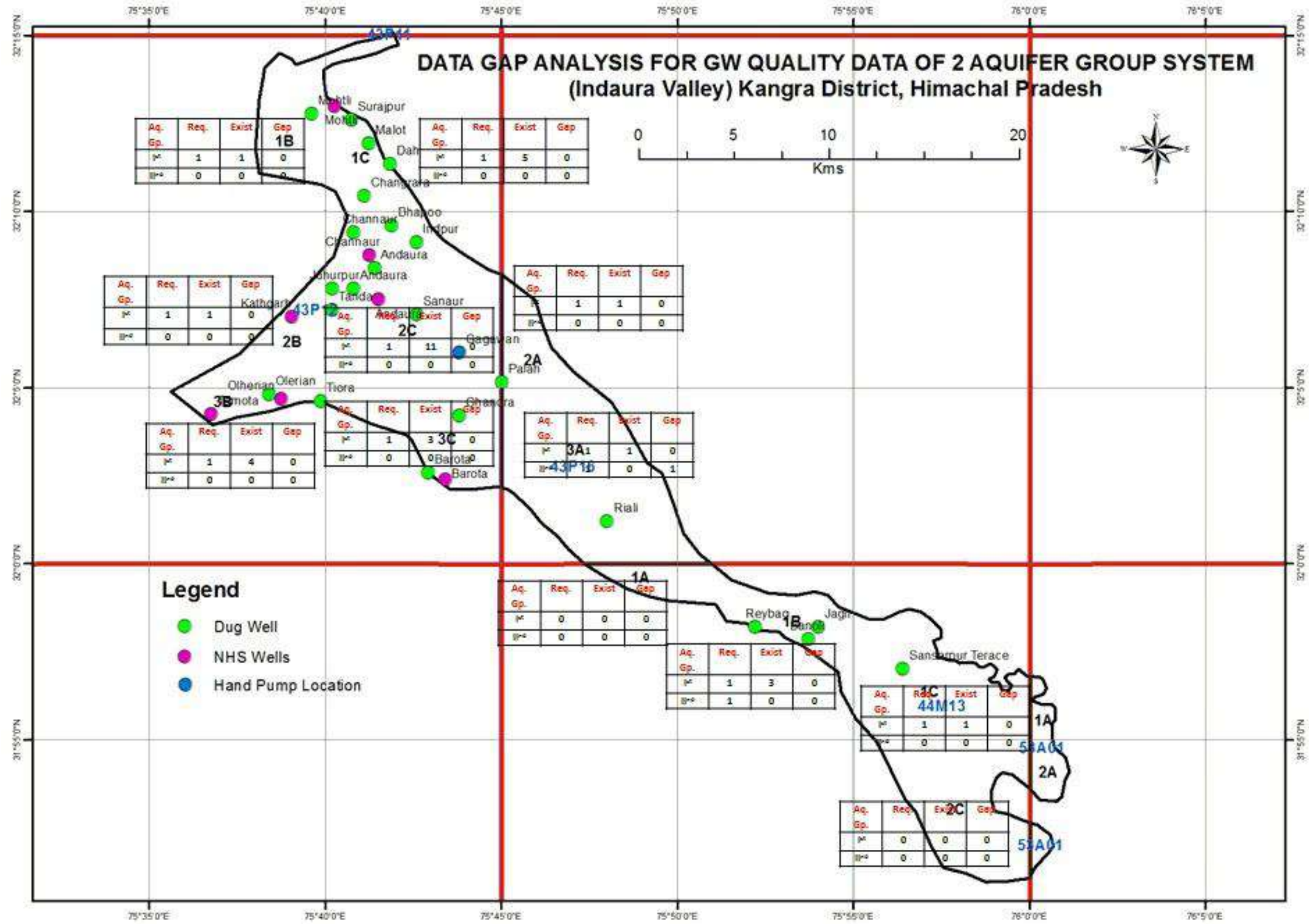


Fig. 6 Ground Water Quality Locations - Indaura Valley, kangra District

1.5.5 Rate of Infiltration

The amount of recharge to ground water depends on the infiltration rate of the soils. No infiltration tests have been conducted in previous surveys by CGWB and even this data is not available with state agencies. To know the infiltration characteristics of the soil in the study area, 19 nos. of infiltration tests are required. On the basis of data gap analysis, quadrant-wise existing and recommended infiltration tests are presented diagram in the figure -

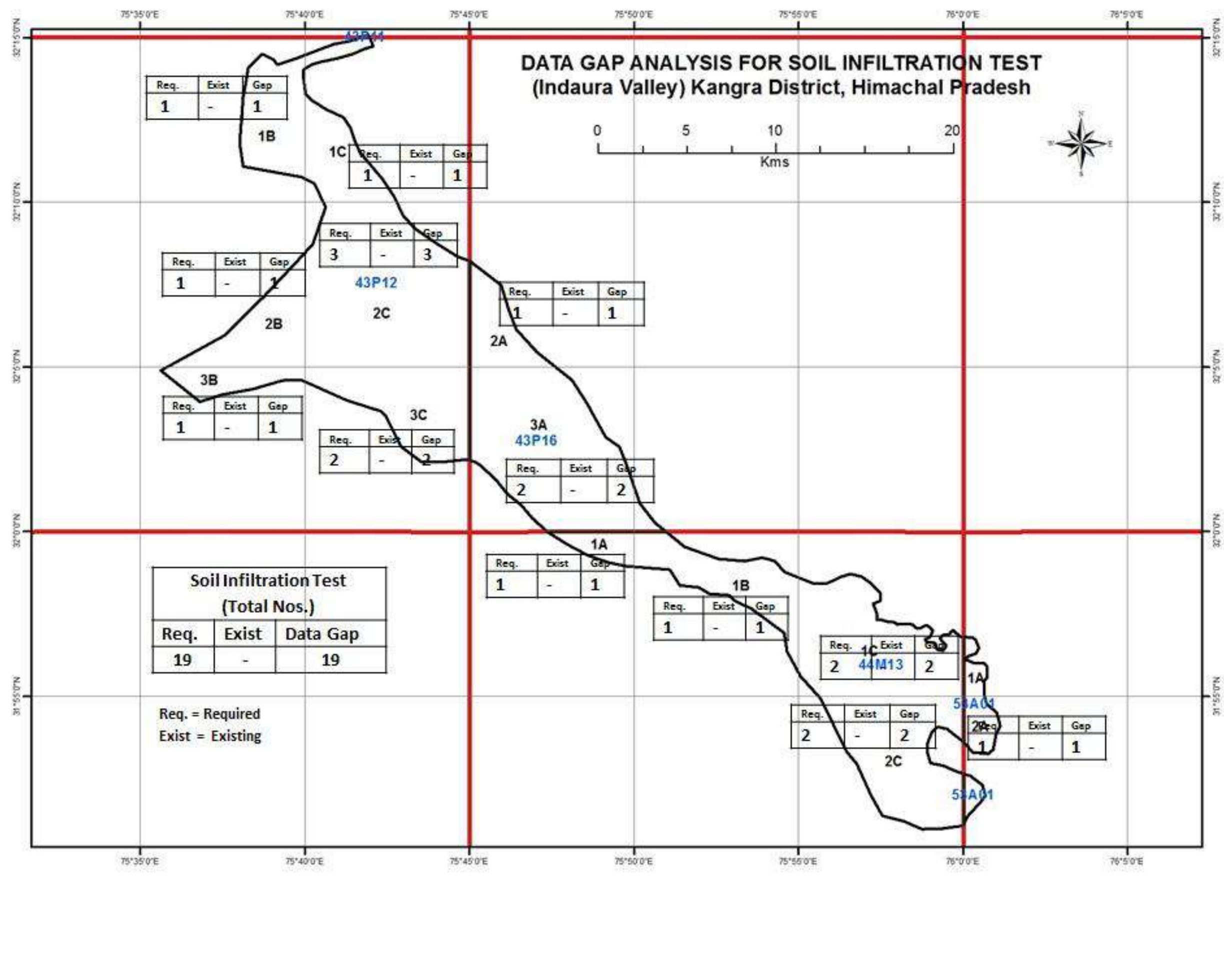


Fig.7 Data Gap Analysis for Soil Infiltration Studies - Indaura Valley, kangra District

Table 1.1 DATA GAP ANALYSIS, INDAURA VALLEY (2013-14)

Toposheet No: - 43P/12, 43P/16, 44M/13, 53A/01

Quadrant no.	No. of additional EW's Required		No. of additional OW's Required		No. of Soil Infilteration test Required	No. of VES/TM Required	No. of Pesticides Required	No. of Isotope Study Required	No. of Carbon Dating Required
	Aq- I	Aq- II	Aq- I	Aq- II	Aq- I				
43P/12 1B					1	1			
43P/12 2B					1				
43P/12 3B					1	1			
43P/12 1C					1	1	1	1	
43P/12 2C					1	2	1	1	
43P/12 3C					1	1	1	1	
43P/16 2A					1				
43P/16 3A	1	1	1	1	1	2	1	1	
44M/13 1A					1				
44M/13 1B					1	1		1	
44M/13 1C					2	1			
44M/13 2C					2	1	1	1	1
53A/01 1A					1				
Total	**1**	**1**	**1**	**1**	**15**	**11**	**5**	**6**	**1**

1.6 PPHYSIOGRAPHY AND DRAINAGE

Geomorphologic features and Land Forms

Based on the physiography, the study area can be divided into the following categories:

1.6.1 **Flood Plain:** All along the river Beas and major khads alluvial terraces of varying dimension are deposited. The most extensive terraces are deposited along river Beas in the western parts of the study area i.e. Indora area.

1.6.2 **Piedmont Plain:** It occupies the area of Jassur to Kandwal area and lower parts of Chakki Khad watershed.

1.6.3 **Valley fills/terraces:** The most extensive terraces are deposited along river Beas from Dehra Gopipur- NagrotaSurian-Jawali-Fatehpur and Raja ka Talab-Jassur and indaura valley belong to a system deposited both by Beas River and Chakki/Jabbarkhads. The westernly shift of Chakki/Jabber khad and southernly sift of Beas river has resulted in the

1.6.4 **Alluvial Terraces:** All along the river Beas and major khads alluvial terraces of varying dimension are deposited. The most extensive terraces are deposited along river Beas from Lambagram and Harsipattan in the east to Dehra Gopipur, Nagrota Surian and Terrace in west. These terraces generally have three to four major levels.

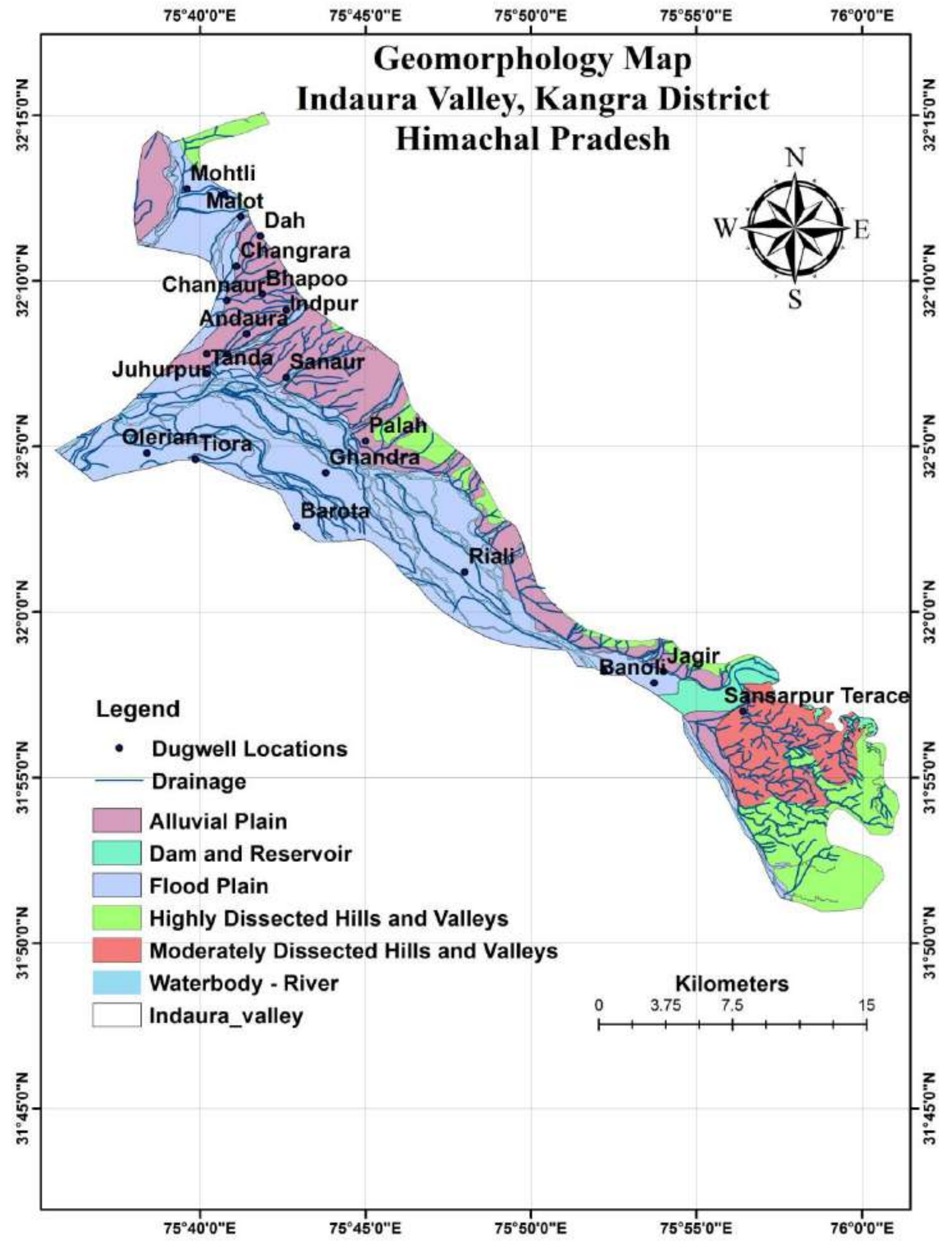


Fig. 8 Geomorphology Map of Indaura Valley

1.7 Drainage & Morphometric features

Drainage & Morphometric features The Beas River, one of the perennial rivers of India, forms the southern border of the district. The Chakki River, tributary of Beas Rivers, forms the northwestern border of the district. The Beas River is fed by Gaj, Neogal, Manjhi, Ikka, Baner, Naker, Deharkhads. All these khads are perennial and snow fed. These khads have deep valleys in the hilly area. The valleys are wide in the Kangra valley region where the slope/gradient of the river is gentle. The courses of these rivers are structurally controlled. The gradient and flow are being utilized both of irrigation and power generations. A number of micro hydel projects are under construction on these khads. The water of these rivers are also being used for irrigation by diverting its flows through Kuhls/irrigational channels.

The northerly flowing tributaries are ephemeral and have flash floods during the monsoons. The width of these streams channel varies from less than a kilometer to more than 2 kms. The channel areas are generally devoid of vegetation. The important (khads) are Pragpur, Nalsuha, Chanour and Dada .The Beas River has been bounded at Pong reservoir resulting in a vast body of water covering about 26,400 hectares of land at maximum storage level.

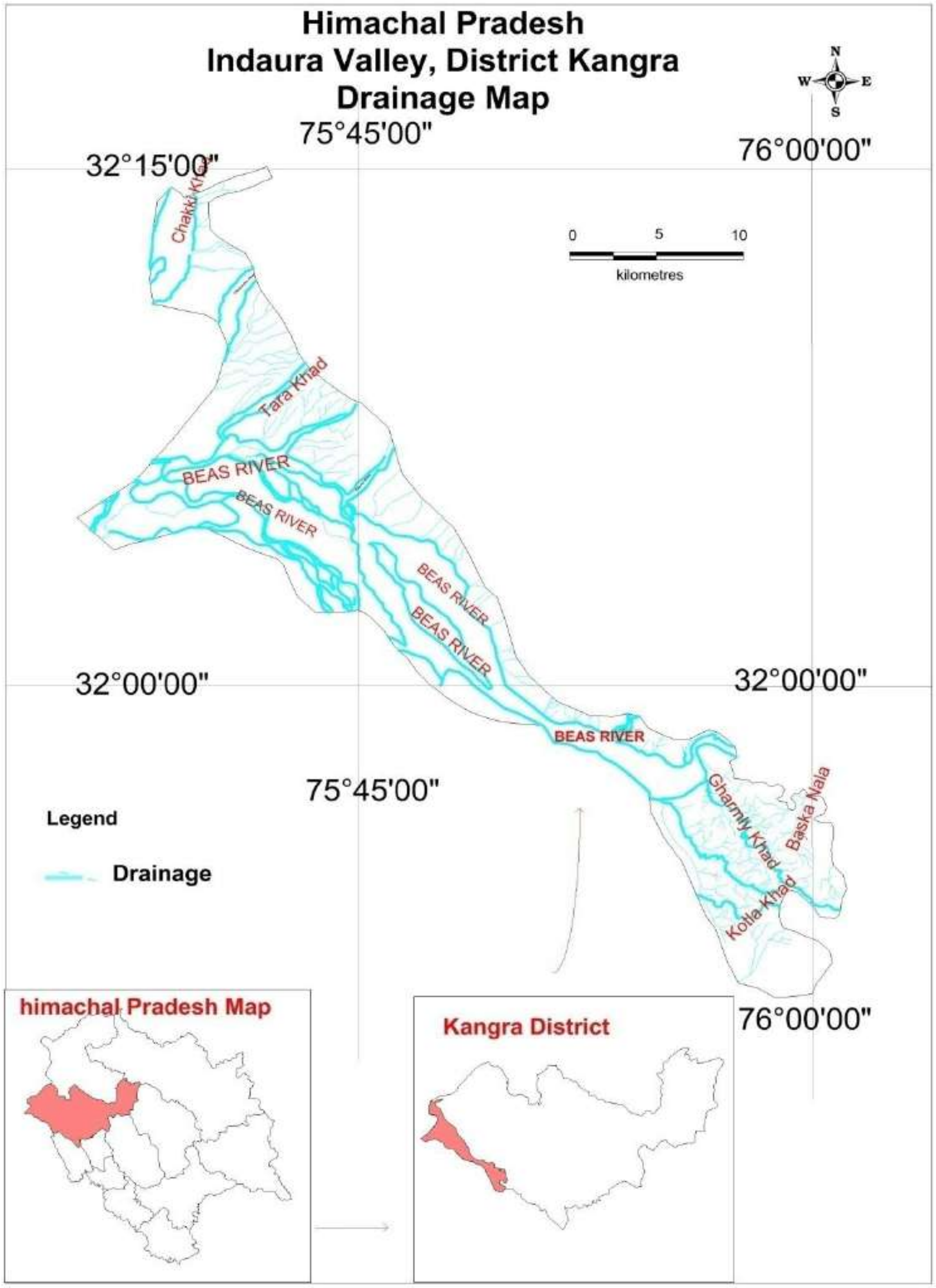


Fig .9 The Drainage Map - Indaura Valley, Kangra District

1.8 Geology

Geologically, the rock formations occupy the study area in age from Tertiary to Quaternary period. The detailed geological succession in the study area is given below in table no.2.

The study area can broadly be divided into Tertiary and Post Tertiary (Quaternary deposits). The valley fills occurs mainly in the western part and as isolated deposits along the terraces/rivers/streams and Tertiary in most of the part. All the formation is trending in NE-SW direction.

Table No. 2. Geological succession of Study area

Period	Age	Formation	Description of Lithology
Quaternary	Recent	Alluvium	Grey to dark grey iron stained fine to coarse sand with pebble and clay
	Pleistocene	Older alluvium	Multiple fill cyclic sequence of medium to coarse grained grey sand and grit with pebble of sandstone and lenses of clay
Tertiary	Pliocene	Upper Siwalik	Boulder conglomerates, clay, sands, pebbly grit.
	Upper Miocene	Middle Siwalik	Micaceous sandstone and shales
	Middle Miocene	Lower Siwalik	Hard, compact, purple sandstone intercalated with brown clays/shales

Source: Geological Survey of India

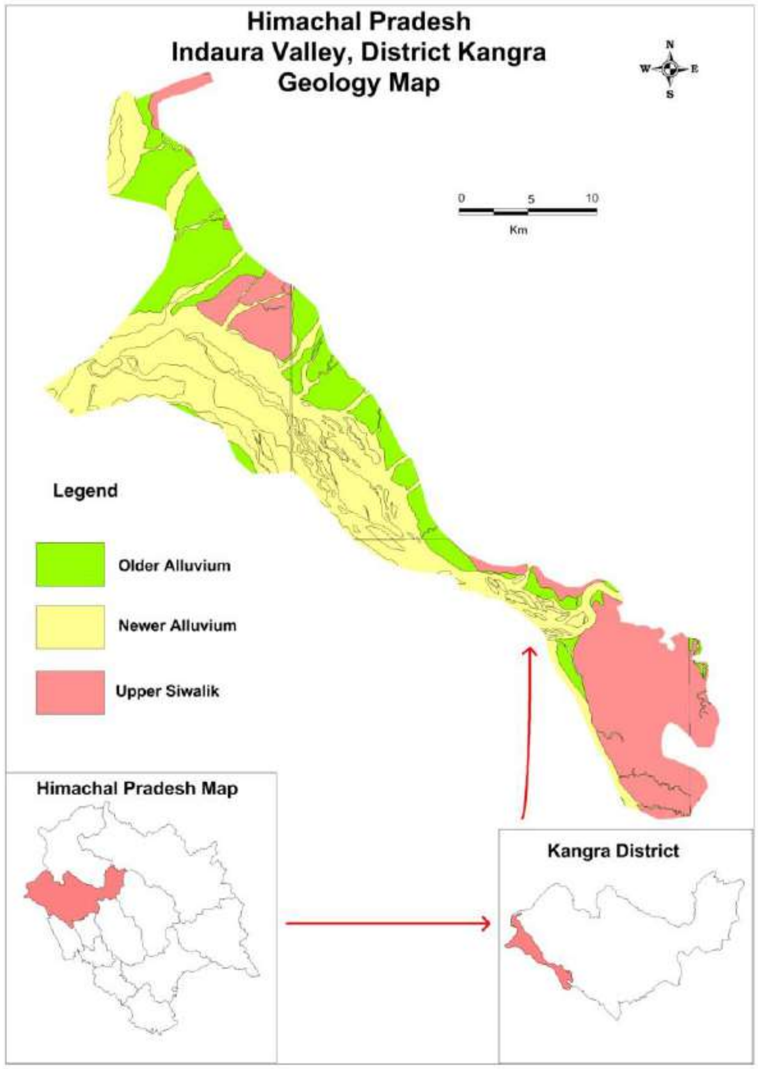


Fig .10 Geology Map of Indaura Valley, Kangra District

1.8.1 Tertiary formation:

The Tertiary formations cover a major part of the district and represent a relatively lower topography. Lower Siwaliks are consisting of massive dark grey sandstones and purple shales. These are conformably overlain by micaceous sandstone and grey clays/shales of middle siwaliks. Upper siwaliks are consisting of conglomerates, coarse grained sandstones interbedded with grey and pink clays silts and lenses of pebble beds.

1.8.2 Post Tertiary Sediments (Quaternary Deposits):

Quaternary deposits, forming valley fill deposits represents fluvio-glacial, fluvial, lacustrine and loessic deposits. These deposits rest unconformable over the Siwaliks. The sediments are deposited in different glacial stages.

1.8.3 Riverine Deposits:

Riverine sediments are distributed in the lower topography areas in lower reaches of rive/khad systems. These sediments are composed of sand, gravel, pebble and boulders and are loose to semi-consolidated. These deposits can be divided into older and younger choe deposits.

1.8.4 Older alluvial deposits are widely distributed in the area between Nadaun, Dehra in the east and indaura Terrace in the west. Older alluvium is also occurring along Beas in the upper reaches and a long other tributaries as micro-valley fill deposits. Thickness of these deposits varies from less than 20m to more than 150 meters. The meander scrolls, Palaeo-Channels and other feature are well defined. The important valley fills are:

1. Nadaun-Ghalour
2. Pragpur-Dada-Siba
3. Nagrota Surian-Fatehpur-Jassur
4. Indaura-Terrace
5. Kunalihar (Naker khad)
6. Gangath valley (Gangath khad)

1.8.5 Younger Alluvial deposits are occurring either along the active channels or adjacent to it. The width of these deposits vary from few metres to more than 1 kilometre and thickness ranges upto 15 meters. These are distributed long all the major and minor stream/river.

1.9 Hydrogeology

The hydrogeological frame work of the district is essentially controlled by the geological setting, distribution of rainfall, snow fall, and facilities of circulation and movement of water through inter-connected primary and secondary porosities of the rocks constituting the aquifers. Based on the geological diversities and relative ground water potentialities of different geological formations the district can broadly be divided into two broad units.

i. Fissured formation

ii. Porous formations

i. Fissured formations

Fissured formations are constituted by hard rock formations belonging to Siwalik system. These formations are consisting of sandstones, conglomerates and shales. These rocks are generally massive and consolidated and devoid of primary porosity. Secondary porosity has developed due to the tectonic activities along the fractured joints and fault zones. Weathered zone rarely form an aquifer because of the less thickness of the weathered mantle. In this hard rock terrain ground water is distributed either along structurally week zones, viz., fracture zones, faults, joints and landslide zones or along the contacts of different formations. The ground water in such areas is discharged through the springs in the topographically favorable areas.

In the Siwalik formations the contact zones of various formations and fault zones form the potential ground water horizons between Nadaun in the east and Nurpur in the west. Important springs at Trilokpur (30 lps) and Nagni (25 lps) are located at the intersection of Jawalamukhi thrust and North-south trending faults.

Compact conglomeratic formations are generally devoid of water but handpumps have been successfully installed in low topography area and along fractured zones. The borehole drilled for installing handpumps has yielded from less than 1 lps to about 15 lps. Discharge is generally higher in Jawalamukhi area along the thrust zone. Depth to water varies from free flowing condition at Darshanpur (Trilokpur) to about 30 meter in the bored wells. Depth to water in shallow zones (Dugwell) generally varies from less than one meter to 10 meters. Water level in shallower in topographic areas are low.

ii. **Porous formations:**

Quaternary sediments as fluviatile deposits are occurring as valley fill deposits overlying the older rocks. Fluviatile deposits are occurring either along Beas river or its tributaries in low altitude areas.

Fluviatile deposits: Fluviatile deposits are represented by both younger (Newer) and older alluvial deposits. These deposits are widely distributed along the river/stream courses and older flood plains. These sediments are loose to semi consolidated comprising sand, clay, silt, gravel, pebbles and boulders.

a. Andaura(Indora) valley fill:

This valley fill covers an area of about 320 sq.kms, is distributed between Damtal, Andaura, Terrace and Talwara. The area on the southern banks of Beas is also called Mand area and used to remain flooded prior to the damming of Beas River at Pong. Ox-bows lakes and intensive braiding of the river existed in this area. Oxbow lakes are shrinking in size and menace of flooding has been controlled with the regulation of Beas river water. The waste lands are being transformed into rich agriculture land.

Thickness of the alluvium increases toward west, its ranges from 20m to more than 200m. The thickness of the upper aquifer varies from 30 to 45 meter and is separated from the lower aquifer by a thick clay bed. Ground water occurs under both unconfined and confined conditions. On the northern part depth to water varies from near surface conditions to 40 meters below ground level. Ground water flow is towards the river in general. On the southern part, depth to water varies from 2m above ground level to about 10 metres below ground level.

The yield of the shallow aquifer developed through shallow percolation and cavity wells ranges between 5 lps to 15 lps. The artesian free flow at Rattangarh tubewell (Depth 50 metres) reportedly varies from 8 lps in summer to 15 lps in rainy season. On the northern and western part artesian free flow condition are also existed with discharge varying from 2 lps to 8 lps. Seasonal artesian flow conditions also occur during and after the rainy season around Andaura.

In Andaura area the yield of the tubewell varies from 15 lps to 35 lps for a drawdown of 6 m to 10 meters. In this tract Central Ground Water Board has constructed many exploratory tubewells ranging in depth from 145 m to 429.50m. Yield of these tubewells ranged between 674 lpm and 2574 lpm. Apart from this, State Government has also constructed many tubewells for irrigation and domestic purposes.

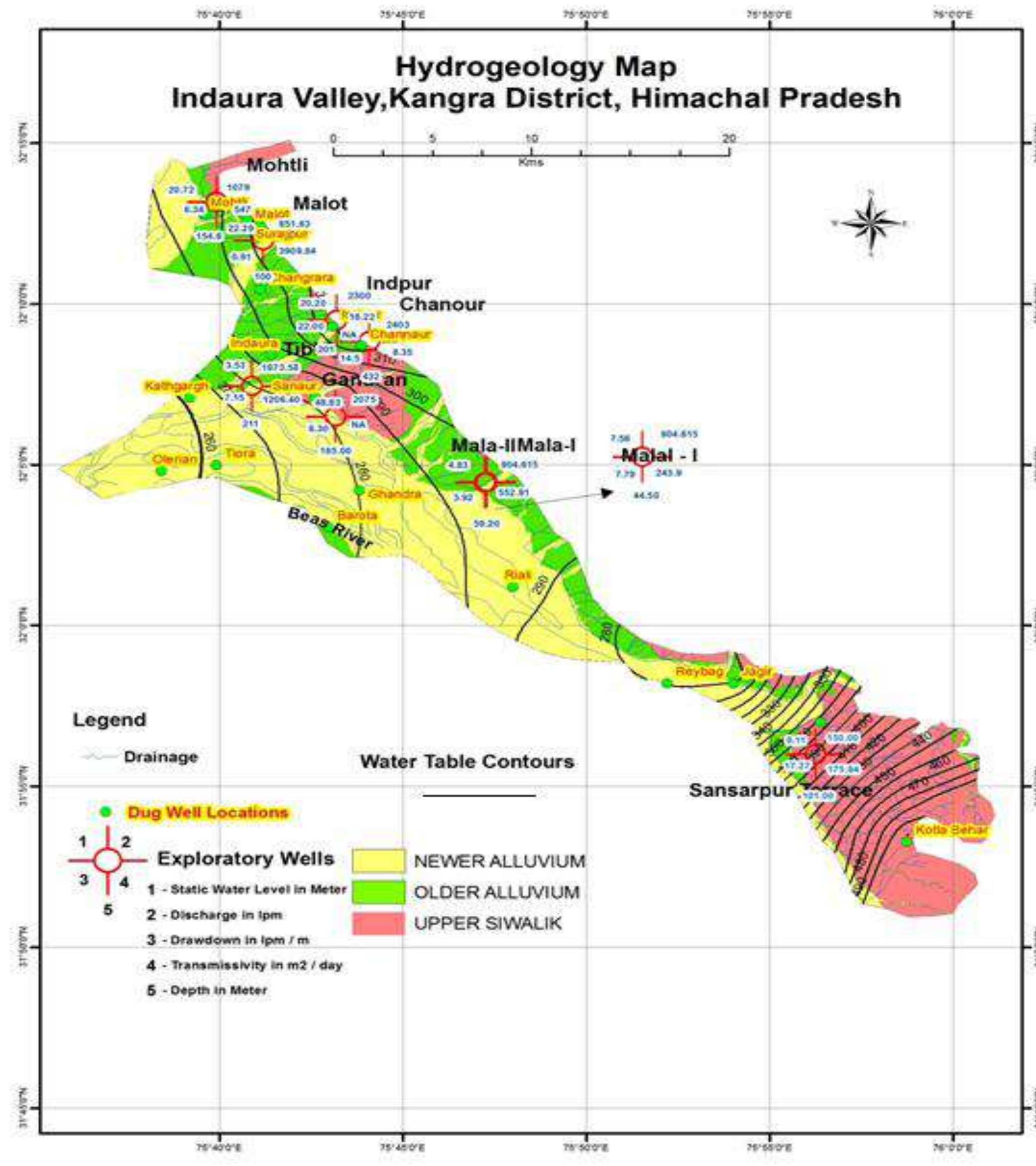


Fig.11 Hydrogeology Map of Indaura Valley, kangra District

1.11 Land use

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.12).

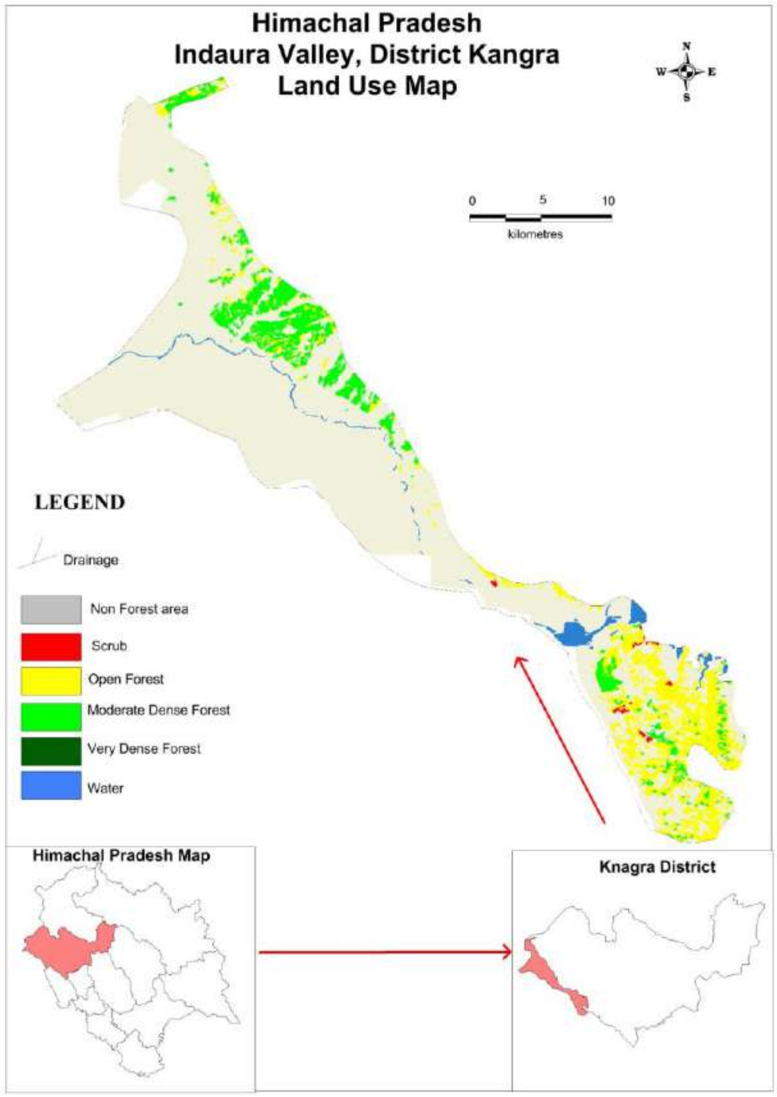


Fig:12 Land Use Map, Indaura valley, District kangra

1.12 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. The different soil types are shown in fig. 13

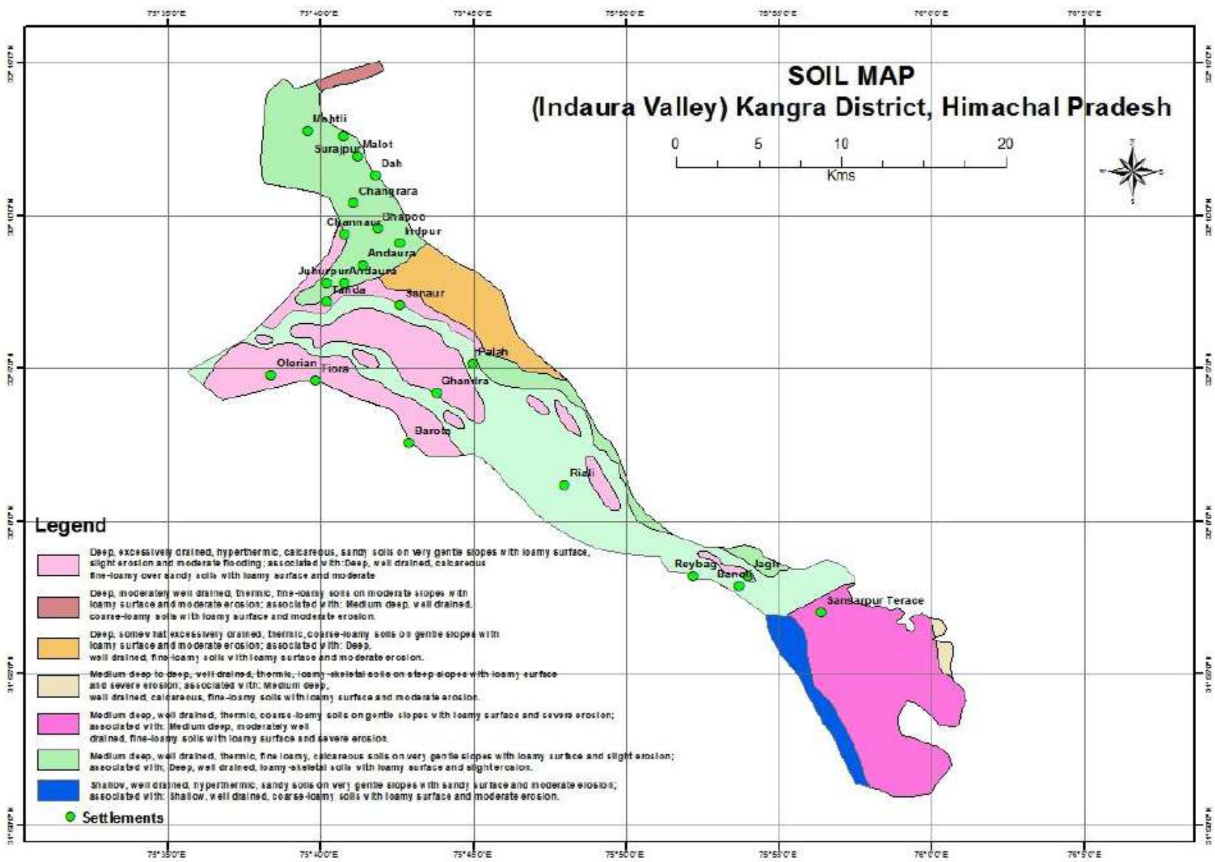


Fig. 13. Soil Map of Indaura Valley, kangra District

1.13 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 hydro geological surveys were carried out by CGWB in Kangra district during various field seasons.

CGWB NHR, Dharamshala is monitoring ground water levels from National Hydrograph Network observations and aquifer mapping wells (Table 3) 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 from those observation wells during the month of May.

Table 3. National Hydrograph Network observations and aquifer mapping wells of Indaura Valley, Kangra District, Himachal Pradesh

Sl.No	Name of Village/site	Latitude	Longitude	Estt. Date	Type (DW/)	Measuring Point (magl)
1	Indaura	32.14	75.69	26.05.2013	DW	
2	Channaur	32.16	75.67	26.05.2013	DW	0.38
3	Olerian	32.08	75.64	26.05.2013	DW	0.60
4	Tiora	32.06	75.65	26.05.2013	DW	0.12
5.	Barota	32.04	75.71	26.05.2013	DW	0.50
6.	Riali	32.02	75.8	26.05.2013	DW	0.00
7.	Reybag	31.97	75.87	26.05.2013	DW	0.32
8.	Jagir	31.97	75.9	26.05.2013	DW	0.30
9.	Ghandra	32.07	75.73	26.05.2013	DW	0.75
10.	Sanaur	32.118	75.71	26.05.2013	DW	0.60
11.	Indpur	32.152	75.71	26.05.2013	DW	0.23

12.	Changrara	32.174	75.685	**26.05.2013**	**DW**	0.30
13.	Malot	32.204	75.696	**26.05.2013**	**DW**	0.40
14.	Surajpur	32.21	75.679	**26.05.2013**	**DW**	0.43
15.	Mohtli	32.213	75.66	**26.05.2013**	**DW**	0.75
16.	Kathgargh	32.12	75.64	**26.05.2013**	**DW**	0.60
17.	Kotla Behar	31.8879	75.9891	**26.05.2013**	**DW**	0.27
18.	Tanda	32.1209	75.6693	**26.05.2013**	**DW**	0.30

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, 22 dug wells have been inventoried for Ground Water Management Studies all over the area. The dug wells are located in and around Indaura valley. The water levels were taken during the month of May and November, 2014 & 2015 and on the basis of these data, pre-monsoon, post monsoon and seasonal fluctuation map have been prepared for the Indaura valley area. The hydrogeological data of the inventoried dug wells are given in Table 4.

In Indaura valley depth to water level shows wide variation. During pre-monsoon period (May 2014) it ranges from 1.65 to 11.83 bgl (Fig. 2.0) and post monsoon period (Nov.2015) ranges from 1.19 to 10.11m bgl.(Fig. 2.1).In major parts of Indaura valley, Seasonal Water Level Fluctuation ranges between less than 0.14 to 2.96 m bgl (Fig.2.2).Whereas in pre-monsoon period of (May 2015)it ranges from 0.70 to 5.43 m bgl(Fig.2.3) and post monsoon period (Nov.2015) ranges from 0.69 to 5.60 m bgl(Fig.2.4) and Seasonal Water Level Fluctuation ranges between 0.01 to 0.90 m bgl (Fig. 2.5).

Table .4 Water level data (May & Nov.2014 and May& Nov.2015) GWMS and Aquifer Mapping Wells of Indaura valley, Kangra District, Himachal Pradesh

S.No	Location	Latitude	Longitude	Water Level, 2014		2014 Fluctuation	Water Level, 2015		2015 Fluctuation
				May 2014	Nov. 2014		May 2015	Nov. 2015	
1.	INDAURA	32.14	75.69	3.76	2.64	1.12	2.75	2.23	0.52
2.	KATHGARH	32.118	75.653	4.12	3.67	0.45	3.82	3.74	0.08
3.	CHANAUR	32.145	75.731	4.32	2.84	1.48	2.88	2.40	0.48
4.	MOHATLI	32.213	75.66	Dry	10.27	10.27	3.50	3.35	0.15
5.	ULLEHERIAN	32.08	75.64	3.34	3.02	0.32	3.00	2.50	0.50
6.	BAROTA	32.051	75.716	6.72	4.54	2.18	6.58	4.17	2.41
7.	RIYALI	32.02	75.8	4.00	3.37	0.63	4.52	3.60	0.92
8.	JAGIR	31.9729	75.903	3.32	2.95	0.37	6.43	3.14	3.29
9.	INDPUR	32.155	75.718	2.73	2.45	0.28	3.16	2.30	0.86
10.	SANAUR	32.118	75.71	8.1	8.94	-0.84	8.42	8.77	-0.35

11.	GHANDRA	32.07	75.73	4.29	3.25	1.04	4.35	3.13	1.22
12.	TANDA	32.1209	75.6693	7.2	6.2	1	7.35	6.24	1.11
13.	CHANGARA	32.174	75.685	2.32	1.79	0.53	2.15	1.68	0.47
14.	MALOT	32.207	75.685	7.32	8.36	-1.04	10.37	8.92	1.45
15.	SURAJPUR	32.2125	75.679	12.98	11.93	1.05	11.83	10.11	1.72
16.	TIORA	32.083	75.665	4.2	3.96	0.24	3.73	3.36	0.37
17.	REYBAGH	31.97	75.87	5.95	5.42	0.53	6.43	5.46	0.97
18.	KOTLA BEHAR	31.888	75.979	5.06	3.99	1.07	5.97	5.51	0.46

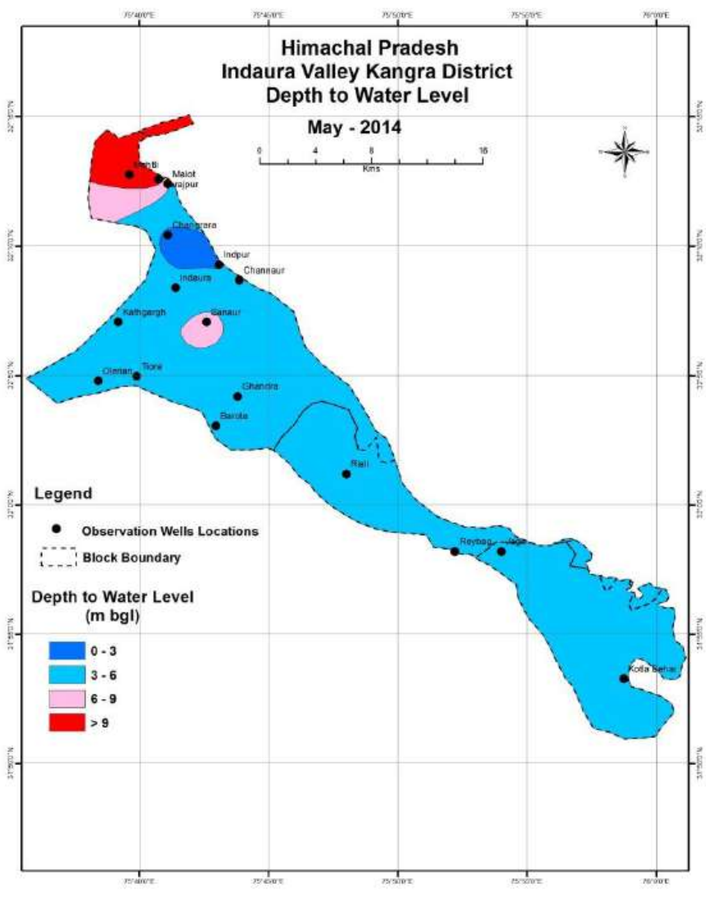


Fig. 14 Depth Water Level – May 2014, Indaura Valley, Kangra District

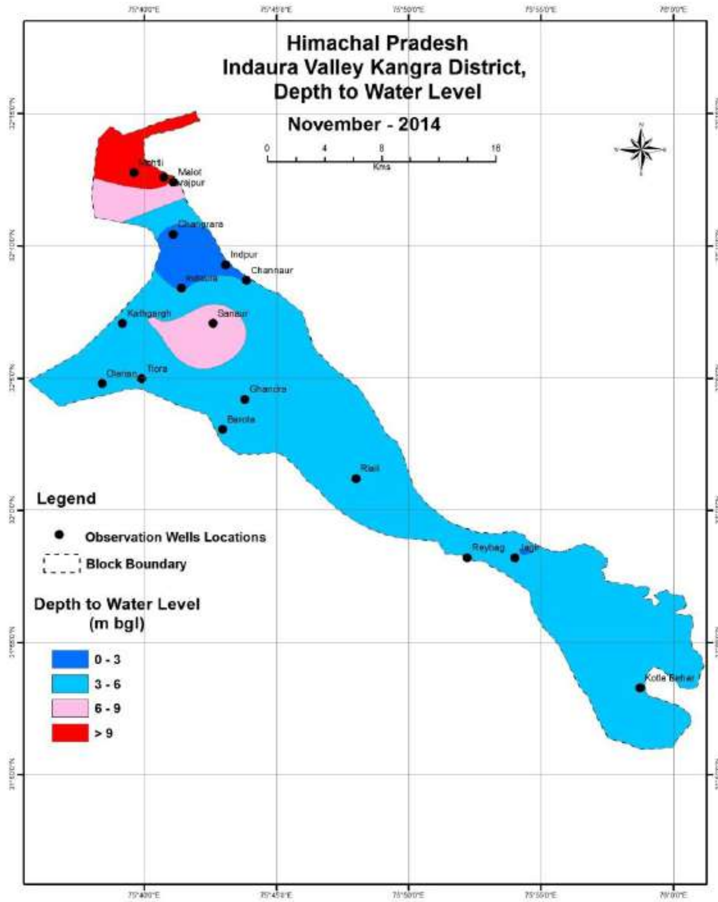


Fig. 15 Depth Water Level – November 2014, Indaura Valley, Kangra District

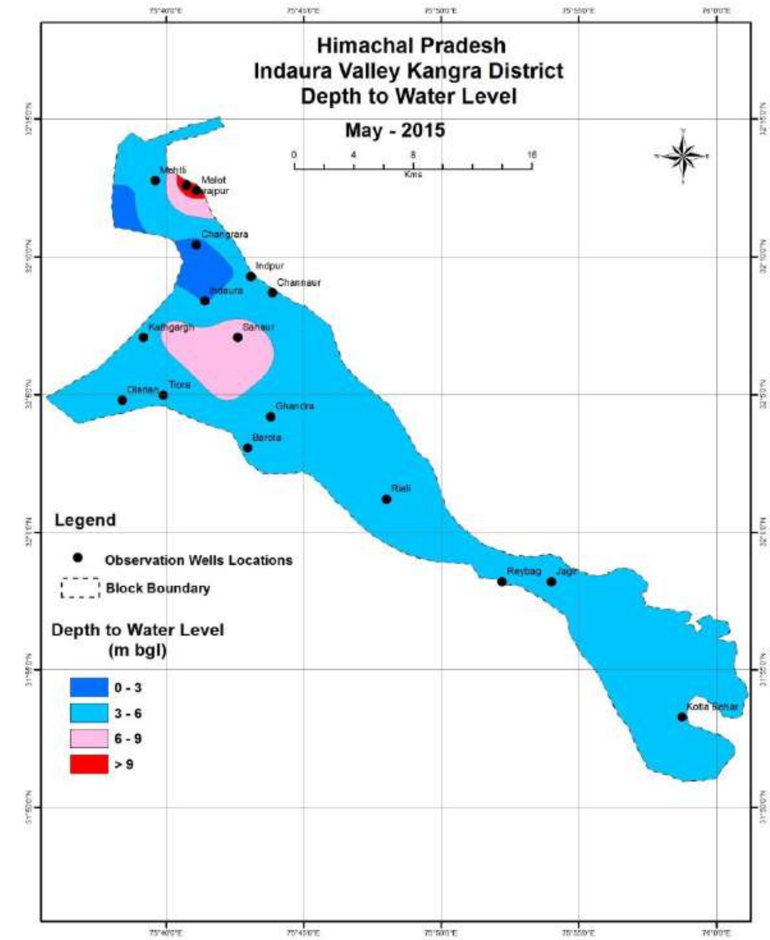


Fig. 16 Depth Water Level – May 2015, Indaura Valley, Kangra District

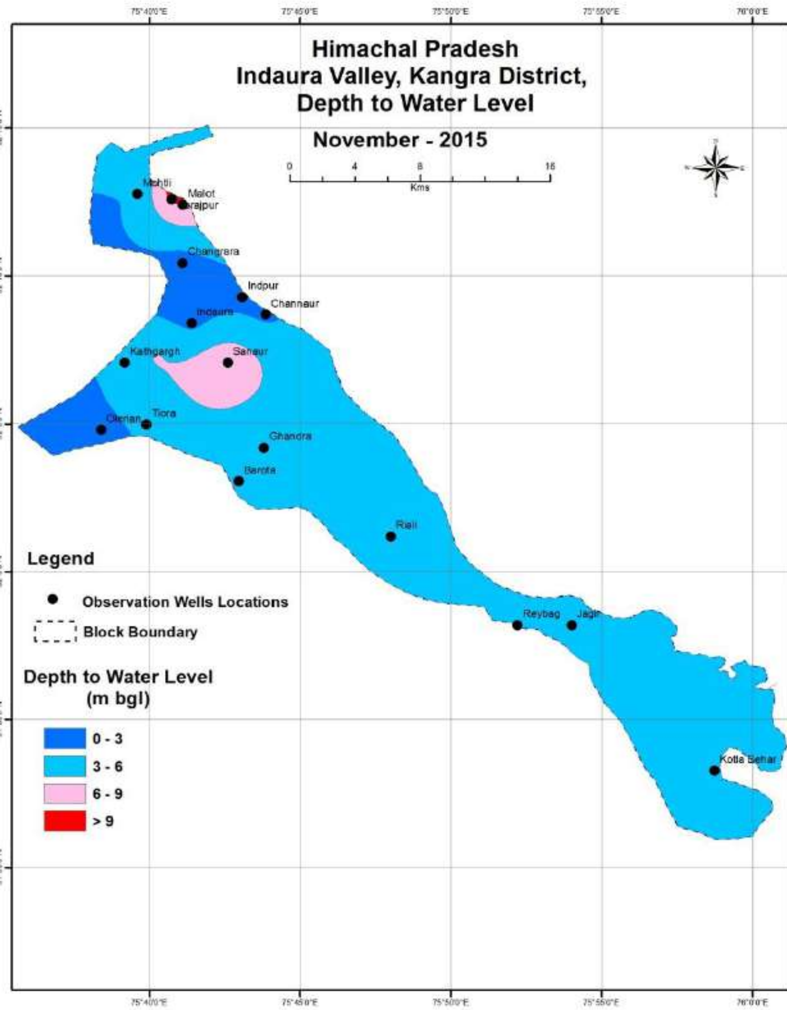


Fig. 17. Depth to Water Level – November, 2015, Indaura Valley, Kangra District

2.2. Exploratory Drilling– CGWB & I& PH Wells

The Lithology 08 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 .5 Data availability of exploration wells in Indaura Valley, Kangra District.

Table of Wells, Indaura Valley			
Agency	**Well Depth (meters)**		
	<100	**100-150**	**>150**
CGWB	8	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 2.7 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 2.8 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 2.9 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 2.10Bacteriological 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 . 6 Ground Water Quality Results (2016) in Indaura Valley, Kangra 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)													
KOTLA	8.40	407	<0.1	25	155	21	25	20	1.80	128	21	15	14	0.36
INDAURA	9.06	381	<0.1	50	164	25	25	33	1.40	128	28	0	0	0.19
KATHGARH	8.81	765	<0.1	76	308	41	50	41	36	295	43	0	18	0.40
CHANAUR	8.52	595	<0.1	25	205	37	27	66	1.00	295	35	0	22	0.31
MOHATLI	8.39	353	<0.1	38	134	33	13	30	1.70	64	57	0	15	0.13
ULLEHERIAN	8.75	998	<0.1	88	287	62	32	59	104	282	71	38	26	0.35
BAROTA	8.44	354	<0.1	38	154	25	22	15	6.00	77	35	19	0.00	0.02
JAGIR	8.40	860	<0.1	25	164	33	20	122	6.50	128	191	0	12	0.00

To assess the impact of ground water quality,11 numbers of water samples were collected from the study area of Indaura Valley of district Kangra in 2016, as per the list below:

Sr.No	Type of Source	Total Nos.
1	Dug Well	11 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 7 .General ranges of water quality parameters of study area

Sr.No	Water Quality Parameters	Minimum	Maximum
1.	PH	8.39	9.06
2.	E.C Sp. Cond. µmhos/cm at 25°C	266	998
3.	CO_3 (mg/l)	25	88
4.	HCO_3 (mg/l)	64	295
5.	CL (mg/l)	21	191
6.	NO3(mg/l)	0	26
7.	F (mg/l)	0	0.40
8.	Ca (mg/l)	21	62
9.	Mg (mg/l)	7.42	50
10.	Na (mg/l)	12	122
11.	K (mg/l)	1.00	104
12.	TH (mg/l)	144	308

pH

The pH is a numerical scale which express the degree of acidity or alkalinity of solution and represented by the equation pH= log1/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 8.39 (Mohatli) to 9.06(Indaura). 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. Maximum value of EC 998 micromhos /cm is determined in the sample collected from ULLEHERIAN, Indaura District (Fig-1.12).

Bicarbonate

Overall value of Bicarbonate varies from 25 (JAGIR) to 88(ULLEHERIAN) 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 (kotla) to191 mg/l (Jagir)(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 0.00 to a maximum concentration of Nitrate 26mg/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 0.40mg/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 8th 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 12 to 122mg/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 1.00 and 104 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 144 mg/l to 308mg/l .(Fig-2.0).

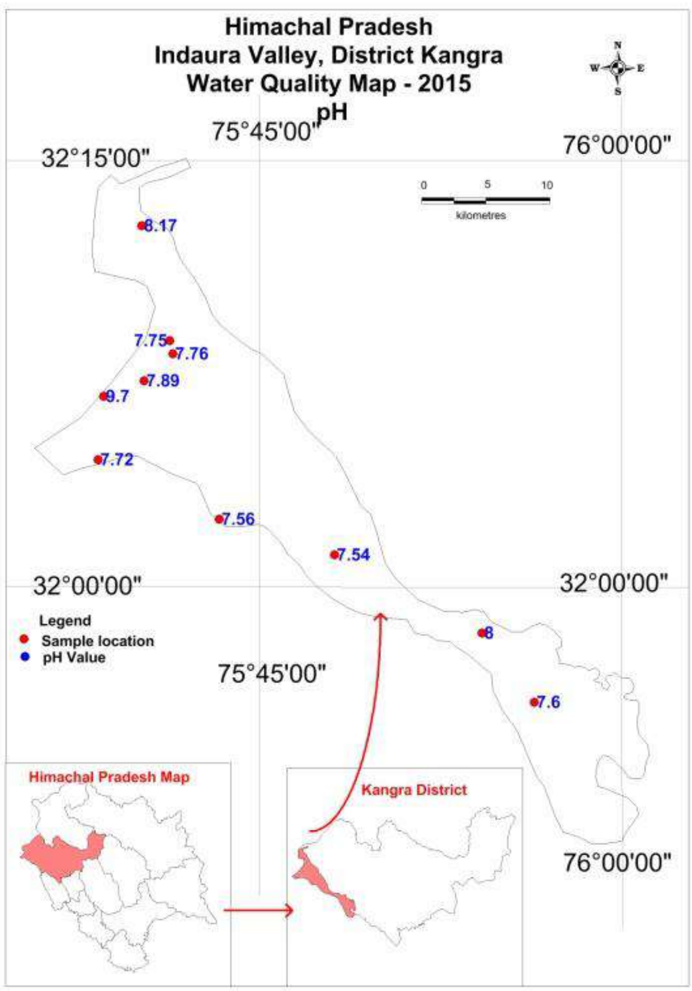


Fig-18 pH (2015) Indaura Valley, Kangra District

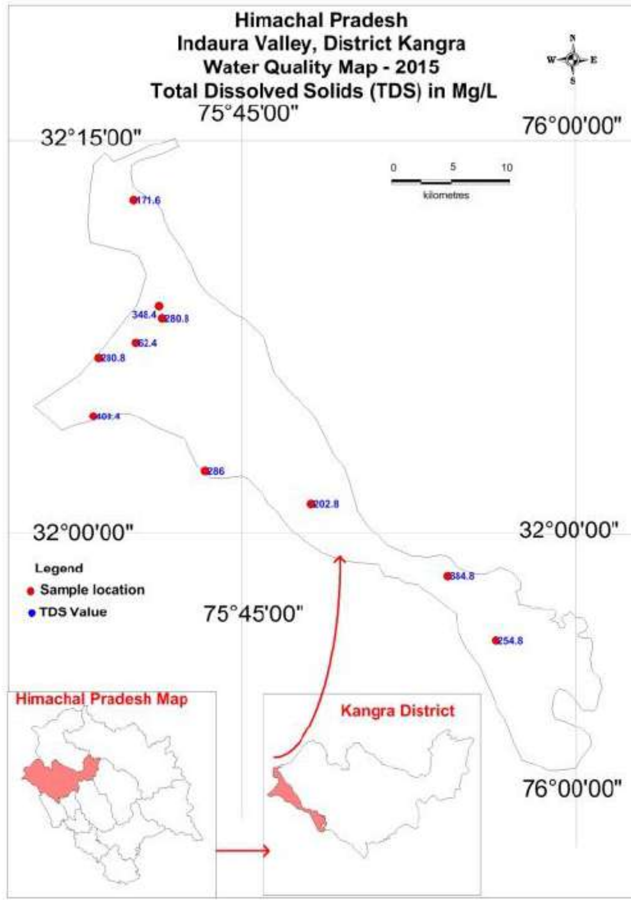


Fig- 19 TDS (2015) Indaura Valley, Kangra District

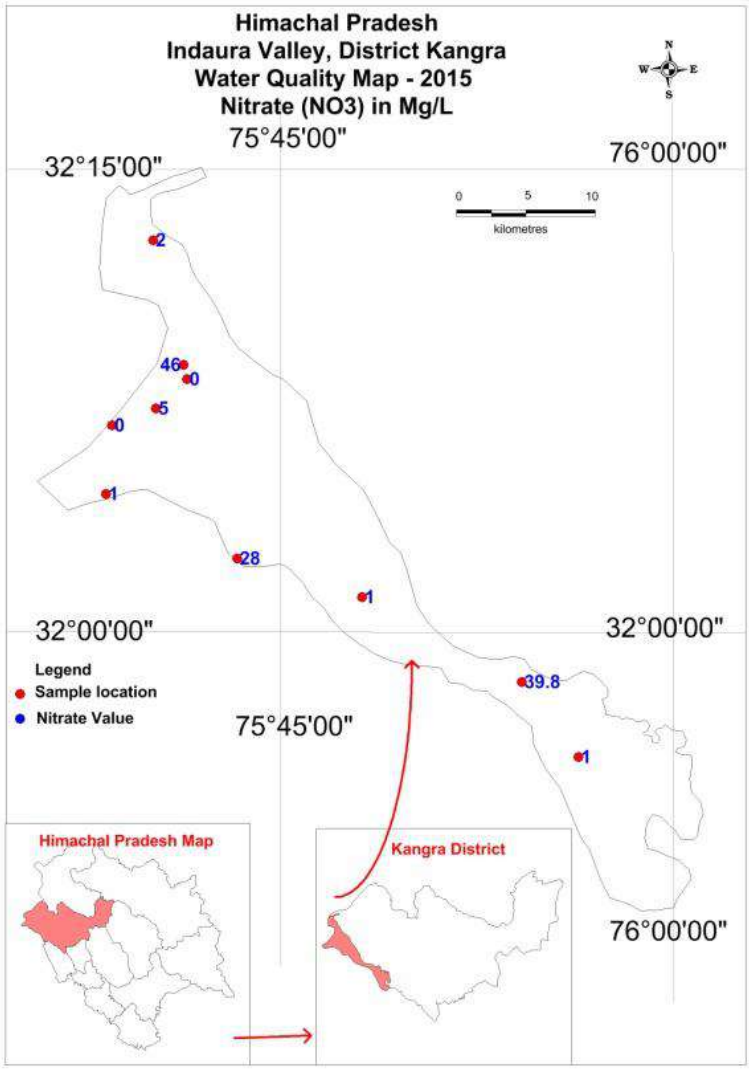


Fig. 20 Nitrate (2015) Indaura Valley, Kangra District

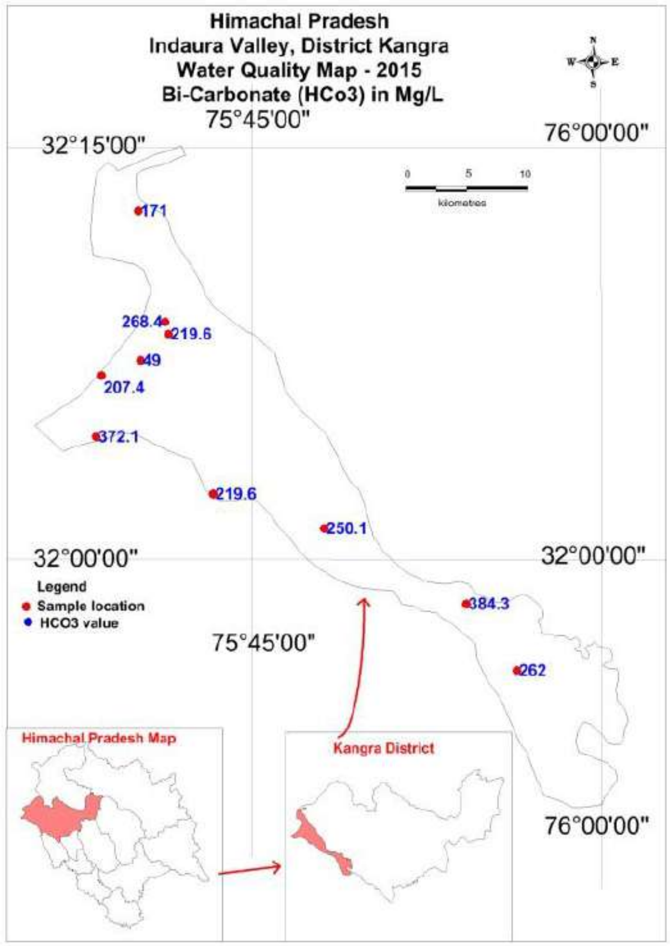


Fig. 21 Bi-Carbonate (2015) Indaura Valley, Kangra District

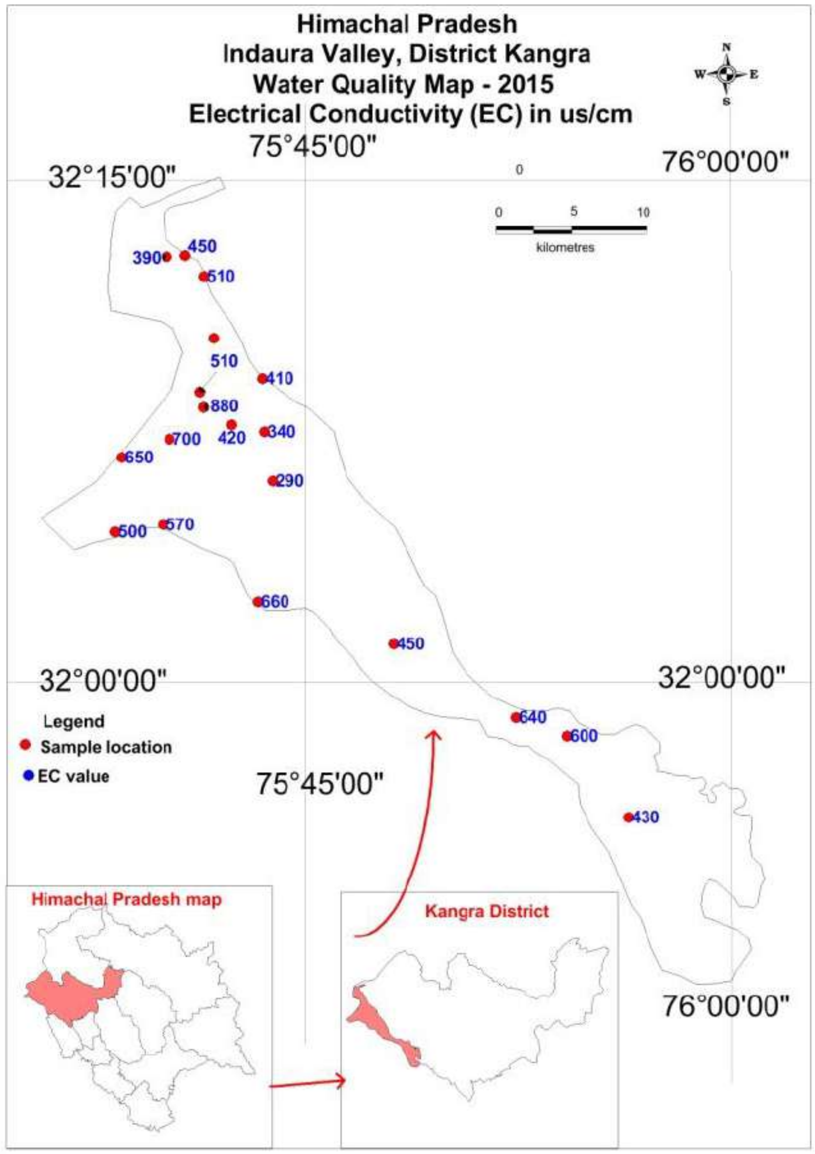


Fig. 22 Electrical Conductivity (2015) Indaura Valley, Kangra District

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-23 respectively. The exploration data shows that majority of tube wells falls in the Ist Aquifer and IInd Aquifer. The grids/ formations devoid of EW/ DW and PZ are identified as data gaps and these are to be filled by data generation.

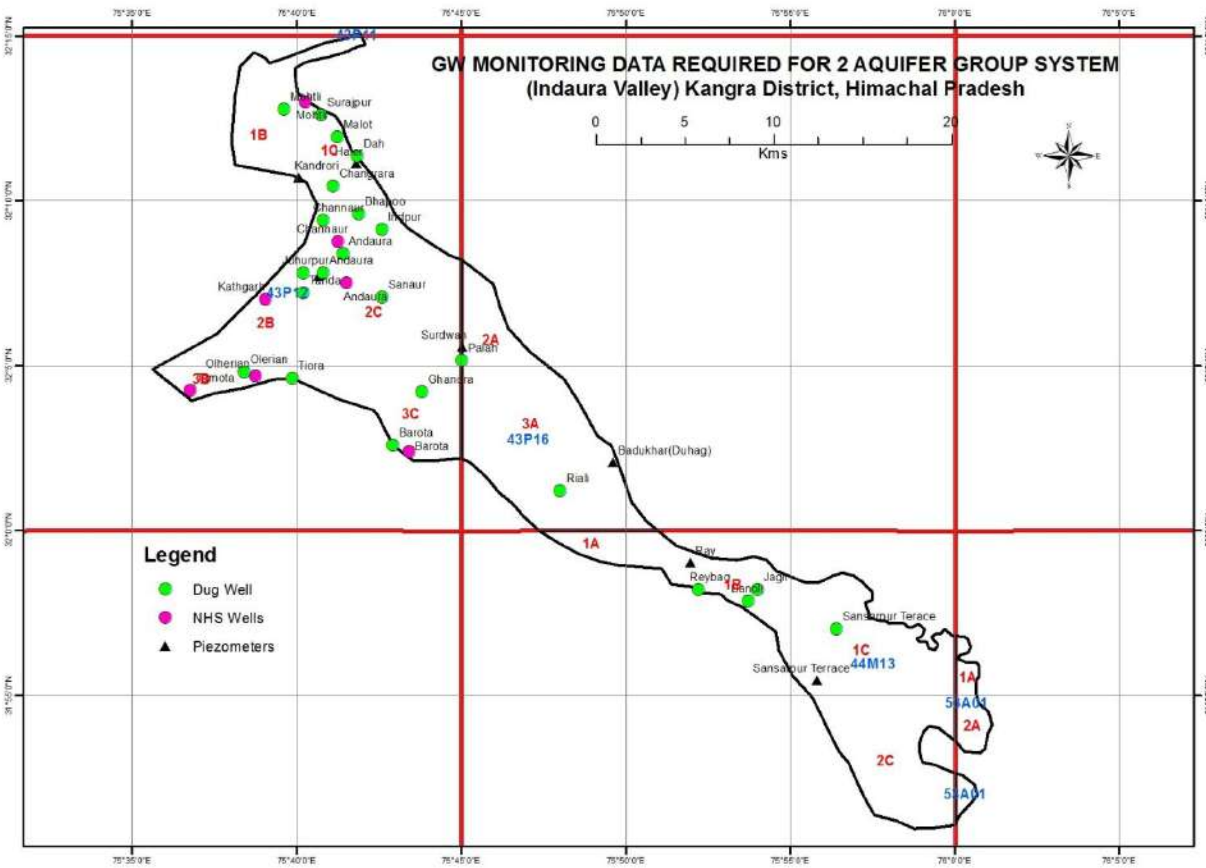


Fig. 23 Locations of GWMS in Indaura Valley, Kangra District

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 Indaura Valley, Kangra 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- 24.

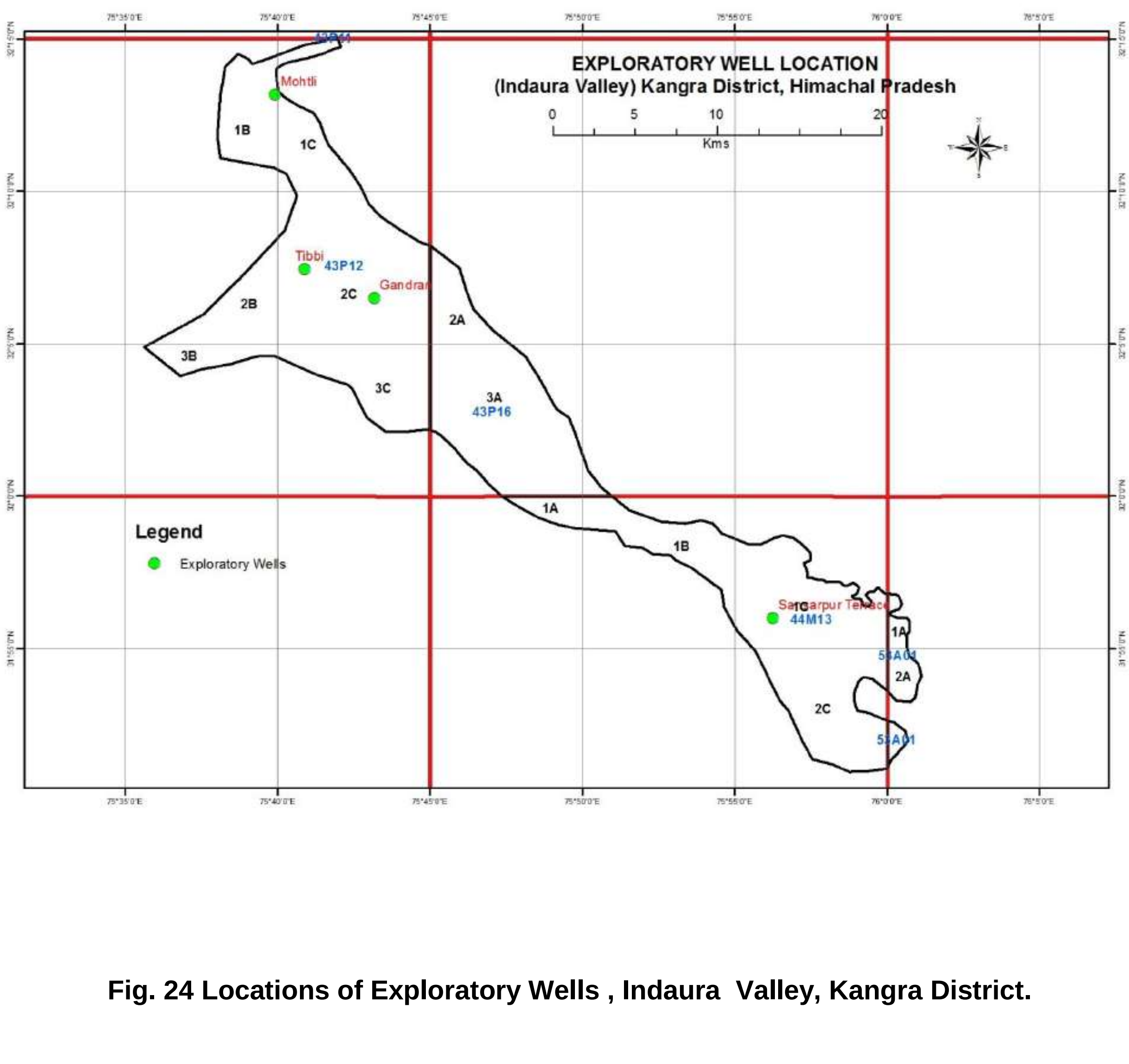


Fig. 24 Locations of Exploratory Wells , Indaura Valley, Kangra District.

3.1 Aquifer Parameter Ranges

In Indaura Valley, District Kangra (H.P) the exploration drilling was carried out by CGWB, the aquifer parameters range extracted and given in below Table-8.

Table .8 Summary of exploration and hydraulic details in Indaura Valley, Kangra District.

Exploratory Well	Lattitude	Longitude	T (m2/day)	Specific Capacity (lpm/m)	Discharge (lpm)	Well Depth(m)
Malot	32.19941667	75.68638889	3909	4.590	851.63	100.00
Malal-I	32.07433333	75.78819444	298.65	116.12	904.61	44.56
Malal-II	32.07405556	75.78708333	554.09	230.67	904.61	59.20
Chanour	32.15833333	75.72	8.35	0.00347	2403	432
Indpur	32.14722222	75.73472222	NA	NA	2300	201
Ghandran	32.10833333	75.71944444	NA	NA	2075	165
Mohtli	32.21944444	75.66527778	547.00	0.506	1079	154.60
Sansarpur terrace	31.93333333	75.9375	175.84	1.3526	130	101
Tibbi	32.12416667	75.68138889	1206.40	0.6439	1873.58	211
Amroh	31.87481	75.95281	1482.7	220.42	729.60	82.00
Ray	31.98988888	75.85847222	507.87	186.99	385.20	86.00
Badukhar	32.027805	75.8216111	11881.79	2500	900	52.38

3.2 Aquifer Geometry and Disposition

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. 26) & 3D synoptic picture by using the Arc GIS and RockWorks16 software. The lithological model has been prepared along with distribution of wells are shown in Fig-25. The 3D lithological fence diagram has been prepared along with distribution of wells are shown in Fig-25.

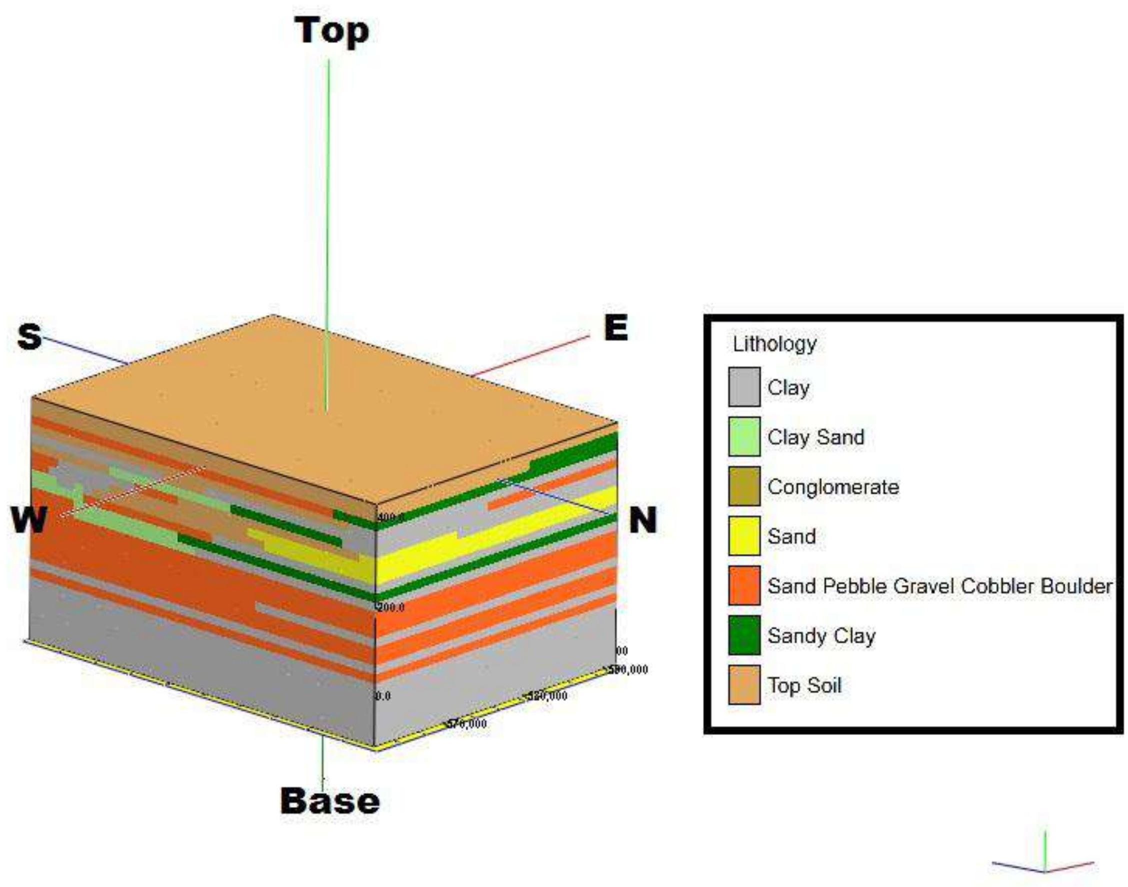
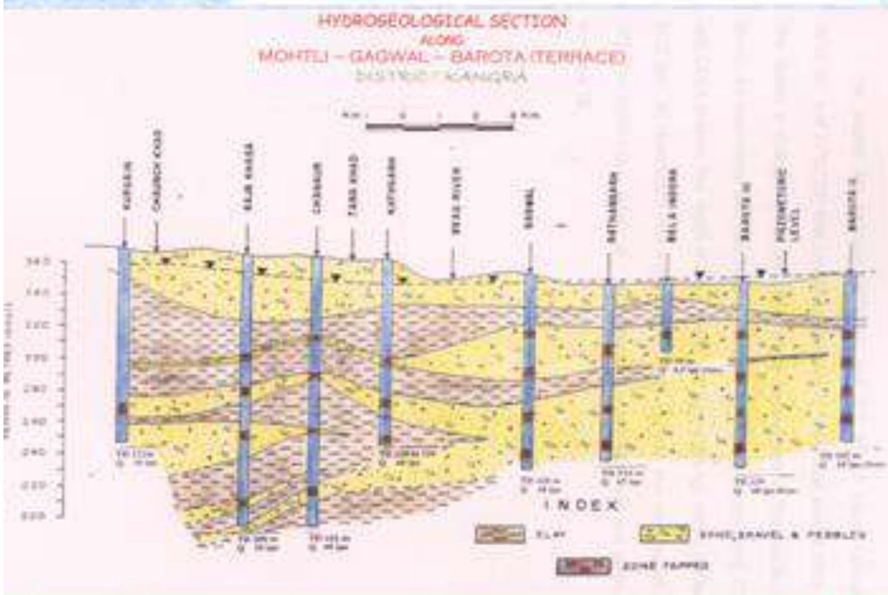
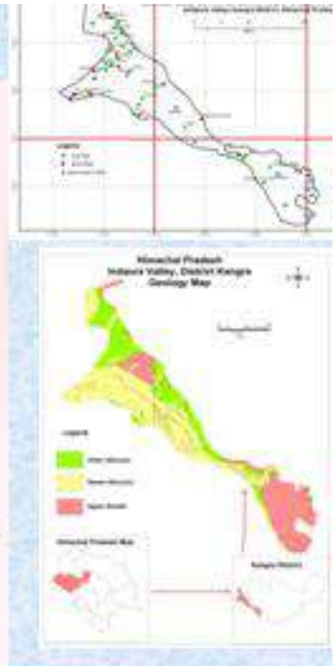


Fig.25. 3Dimension Lithological Model of Indaura Valley, Kangra District

Aquifer Disposition -2D SECTION





Aquifer	Type Lithology	Depth(m)	T (m2/day)	Discharge (LPM)	Suitabilty
1st	Unconsol idate/ Sand	0-70	243.9-3909.84	720.00-2403	Y

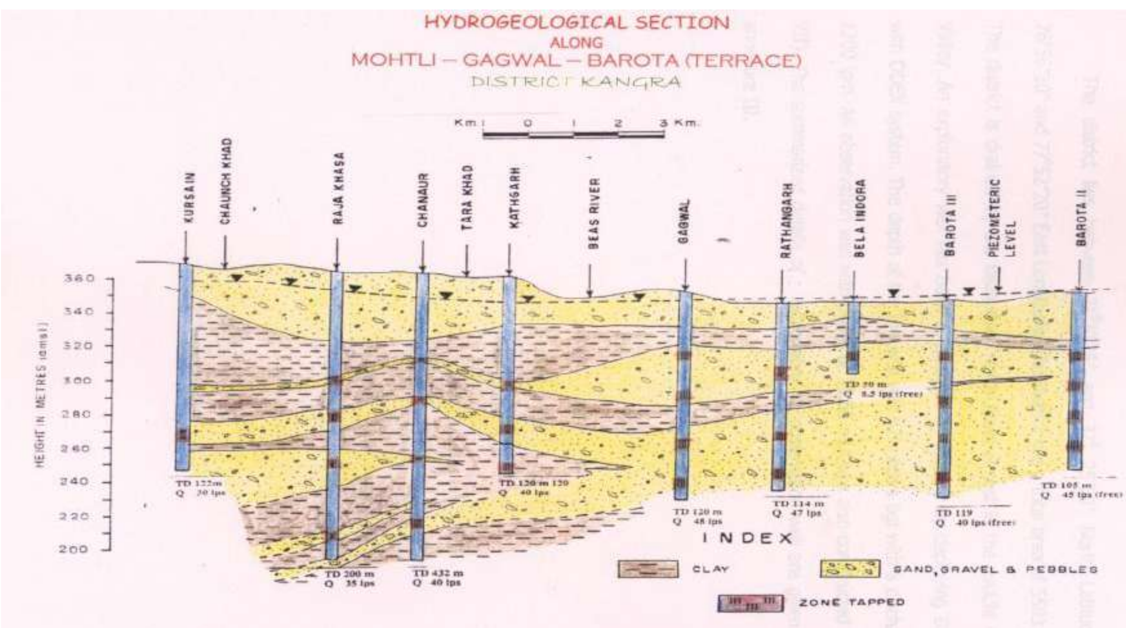


Fig.26. Hydrogeological section along Indaura Valley,Kangra District

4.0 GROUND WATER RESOURCES

Rainfall is the major source recharge to the groundwater body apart from the influent seepage from the rivers, irrigated fields and inflow from upland areas. The discharge from ground water mainly takes place from wells and tube wells; effluent seepages of ground water in the form of springs and base flow in streams.

Aquifer mapping area of Indaura valley consists of valley areas with an area of 101sq.km. Which have slopes of more than 20%. Hence as per GEC 1997 methodology, no ground water resource estimation can be carried out only for valley areas by neglecting hilly areas. Ground water resources and irrigation potential for Indaura valley area of the Kangra district have been computed and details of the Dynamic ground water resource of Indaura valley are as given below:

1.	Area of Indaura valley considered for GW Assessment	320	Sq. km.
2.	Net Ground water Availability	11198.50	Ham
3.	Existing Gross Ground Water Draft for All uses	13223.60	-do-
4.	Net Ground Water Development for future Irrigation Development	0.00	-do-
5.	Stage of Ground Water Development	118.00	*%*

The stage of ground water development of Indaura valley is 118.00% as on March, 2017 and falls under **"Over Exploited".** This suggests that further ground water development can take place in the valley area.

5.0 GROUND WATER RELATED ISSUES

In Indaura valley major cultivation is Wheat, paddy, maize, onion, garlic, vegetables and fruits like Plum, Mango, litchi. The quality of ground water in the area is potable for both the drinking and irrigation purposes. Therefore, ground in valley area is constantly being pumped for the irrigation due to its easy occurs through tube wells which are the main source of irrigation.

This will lead to its major ground water issues which are deepening of ground water level if the recharge of ground water through rainfall and other sources are less than overall extraction.

In the hilly areas i.e. at the marginal areas of Indaura Valley, ground water extractions are done through shallow bore wells fitted with hand pumps and spring water is being used as a source of water supply for domestic uses. The discharge of the spring water is also decreasing with the passage of time or during the non – monsoon period.

Area is occupied by Undulating Topography, flanked by hills on northern side and plains towards south.

- The area falls under OE category (118%) as per GWRE as on March, 2017.
- Yield potential and sustainability of sources is low.
- Decline in water levels in some parts.
- GW quality (Arsenic) issues in some isolated pockets/ sources (Olherian: 0.03 mg/l).
- Rainfall is 1163 mm/year but high runoff.
- Cropping pattern not suitable to temporal distribution of rainfall.

6.0AQUIFER 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:

6.1 Supply side Management

ARTIFICIAL RECHARGE /CONSERVATION MEASURES		Numbers
Artificial Recharge Structures Proposed	**Check dams :** **Nala bunds :** **Recharge shafts (Ponds: 197) :**	**27** **203** **197**
	Expected recharge :	**20.83 MCM**
Roof Top Rain Water Harvesting (35078*144cm= 50,51,232 CM		**5.05 MCM**
Expected outcome	**Arrest Decline in Groundwater levels (or)** **Increase in sustainability of well yield**	
(OR) Decrease in Stage of GW withdrawal : Around 23 %		

6.2 Demand side Management

A.) Area under GW Irrigation : 133.08 sq.km (Per Season)

B.) Water intensive crops

Paddy

Wheat

Sugarcane

(WIC– 204.59 sq.km)

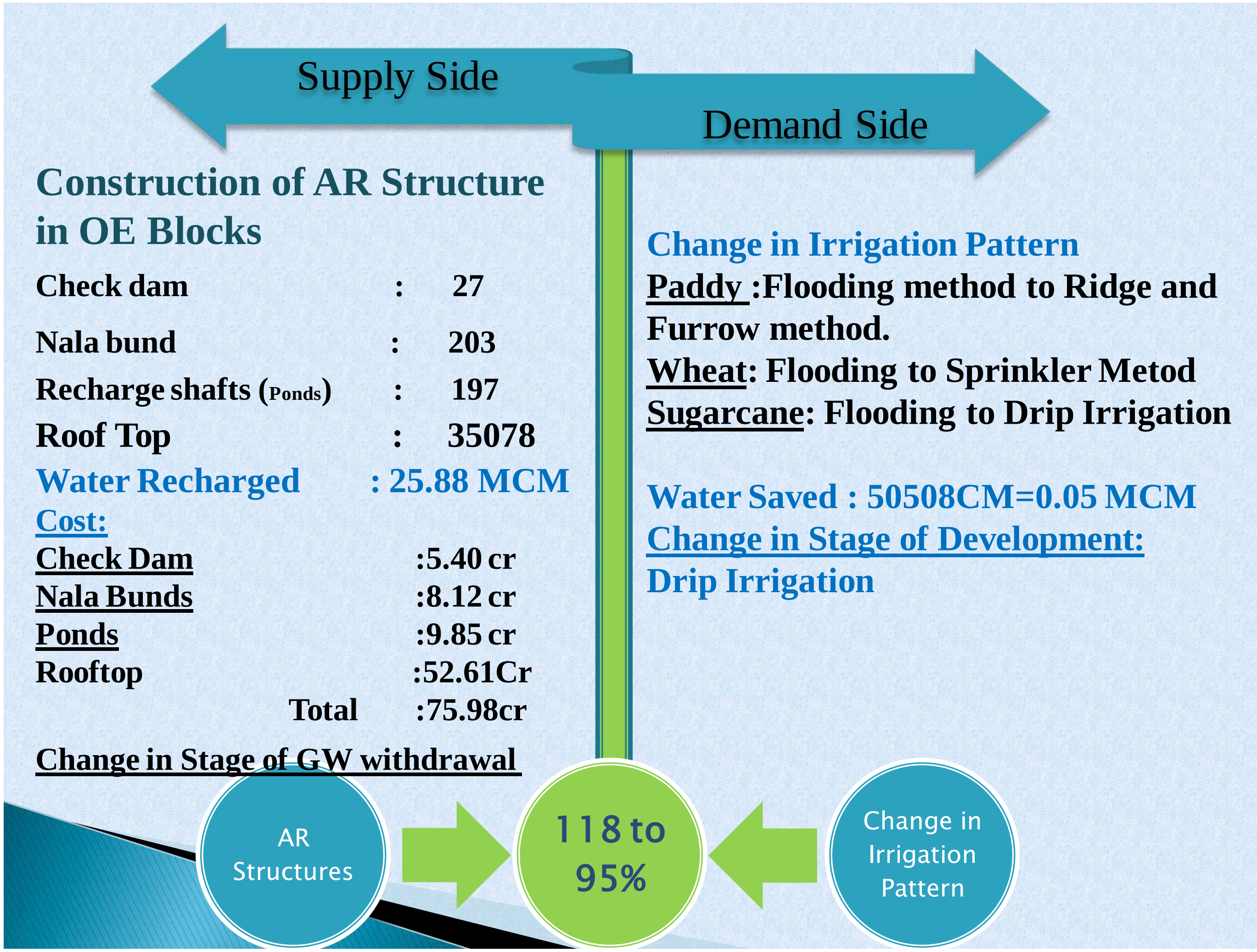
Paddy:

- **Area** : 75.61 sq.km – - flooding Method practiced
- **Ridge and furrow method** – 24952 CM can be saved

Wheat:

- **Area : 104.78 sq.km -** flooding Method practiced
- **Sprinkler Method –** 19070 CM can be saved
- **Sugarcane:**
- **Area :** 10.82 sq.km - Flooding Method practiced
- **Drip Irrigation method –** 6486 CM can be saved

6.3 Conclusion & Recomendation



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