केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti

Government of India

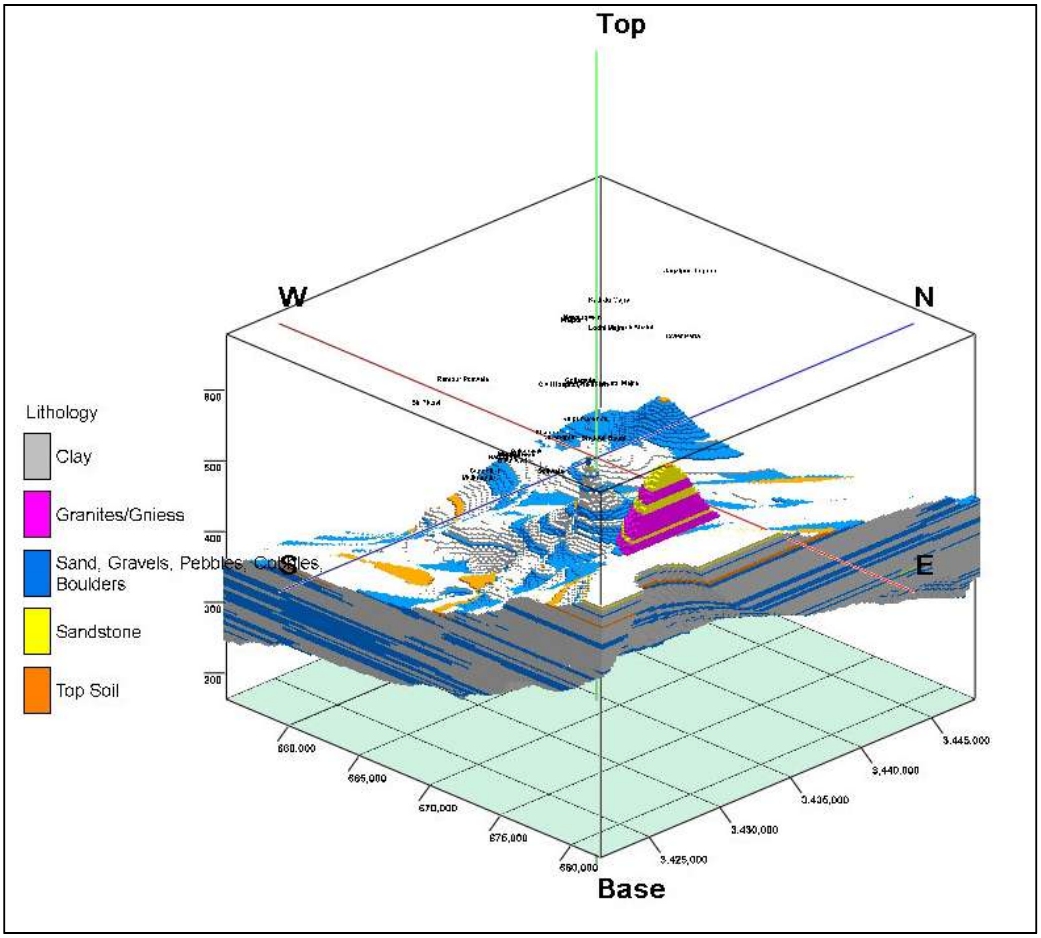
AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

NALAGARH VALLEY, DISTRICT SOLAN, HIMACHAL PRADESH

उत्तरी हिमालयी क्षेत्र, धर्मशाला

Northern Himalayan Region, Dharamshala

AQUIFER MAPPING AND MANAGEMENT PLAN OF NALAGARH VALLEY, DISTRICT SOLAN, HIMACHAL PRADESH



CENTRAL GROUND WATER BOARD

Northern Himalayan Region

Ministry of Water Resources, River Development and Ganga Rejuvenation

Government of India

2018

AQUIFER MAPPING AND MANAGEMENT PLAN OF

NALAGARH VALLEY, DISTRICT SOLAN, HIMACHAL PRADESH

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AQUIFER MAPPING AND MANAGEMENT PLAN OF NALAGARH VALLEY, DISTRICT SOLAN, 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 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.

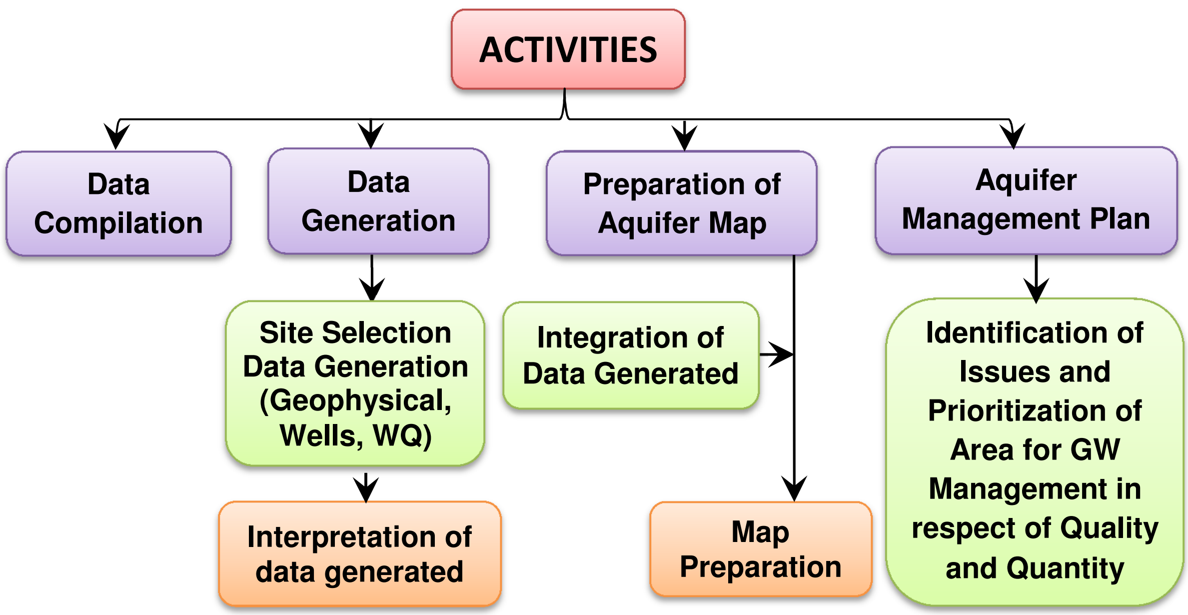
1.1 Objectives

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 a sense 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 Nalagarh valley of Solan District of Himachal Pradesh under the Annual Action Programme 2014-15. 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, 27 key observation wells both Dugwells and borewells (Dugwells: 20 Nos. and springs: 7 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

The study area Nalagarh valley forms a South-Eastern narrow prolongation of a great outer-most Himalayan intermountain valley area of about 838 sq.km carved in the Tertiary formations and extending SE-NW direction between northern latitudes of 30°45’ to 31°15’ and eastern longitudes of 76°36’ to 77°5’ which falls in the Survey of India Toposheet no. 53 A/12, A/16, 53 B/9, B/13 and 53 F/1. The valley is delimited between the Siwalik hills with NE and Sirsa nadi in SW. The valley is well connected by tar roads and is approachable both from Ropar and Pinjor. Pinjor-Nalagarh road runs through the heart of the area. Nalagarh, a tehsil headquarter is located at the NW fringe of the valley. Pinjor is located on Chandigarh-Shimla highway is the nearest railhead of the area. From Pinjor-Nalagarh-Swarghat road there are numerous fair-weather vehicular tracks to approach the villages located in the valley.

1.4 Administrative Divisions and Demographic Particulars

Administratively, Solan town is the head quarter of the district. The study area comprises of 5 Blocks viz., Kasauli, Krishan Garrh, Nalagarh, Ramshahr and Solan Kandaghat, Nalagarh and Solan. Administrative divisions are shown in the Fig.1.1.

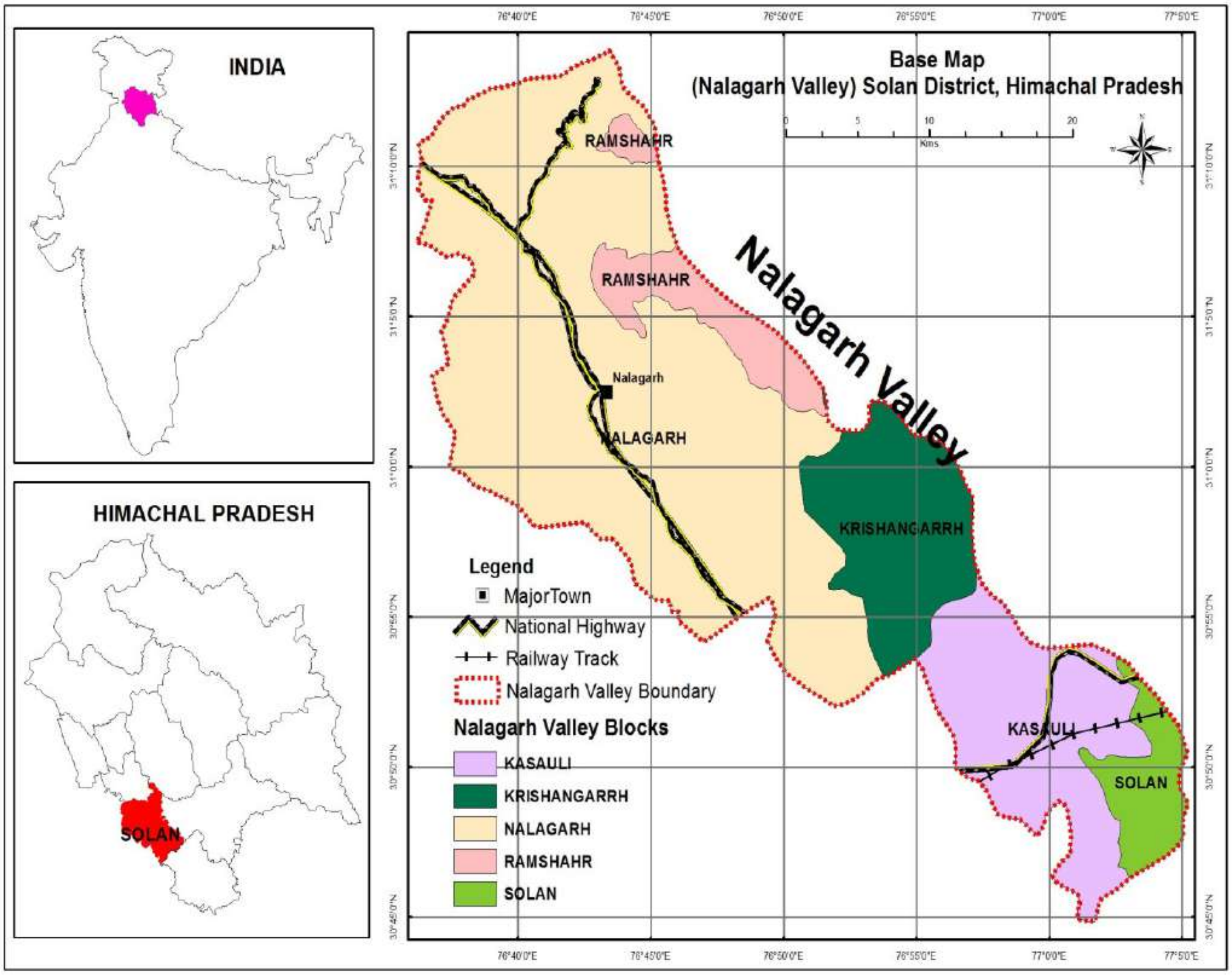


Fig 1.1: The Administrative Division of the Study Area

1.5 Data Gap Analysis

The Data gap analysis was done on the basis of NAQUIM & EFC guidelines in Aquifer Mapping Study area of 838 sq.kms in Nalagarh Valley, District Solan of Himachal Pradesh. The study area falls in Survey of India Toposheets No.53 A/12, A/16, 53 B/9, B/13 and 53 F/1 covering full or partial area of 18 quadrants (Figure -1.2 -Toposheet Index Map). The Data Gap analysis of all the attributes are given in Table 1.1.

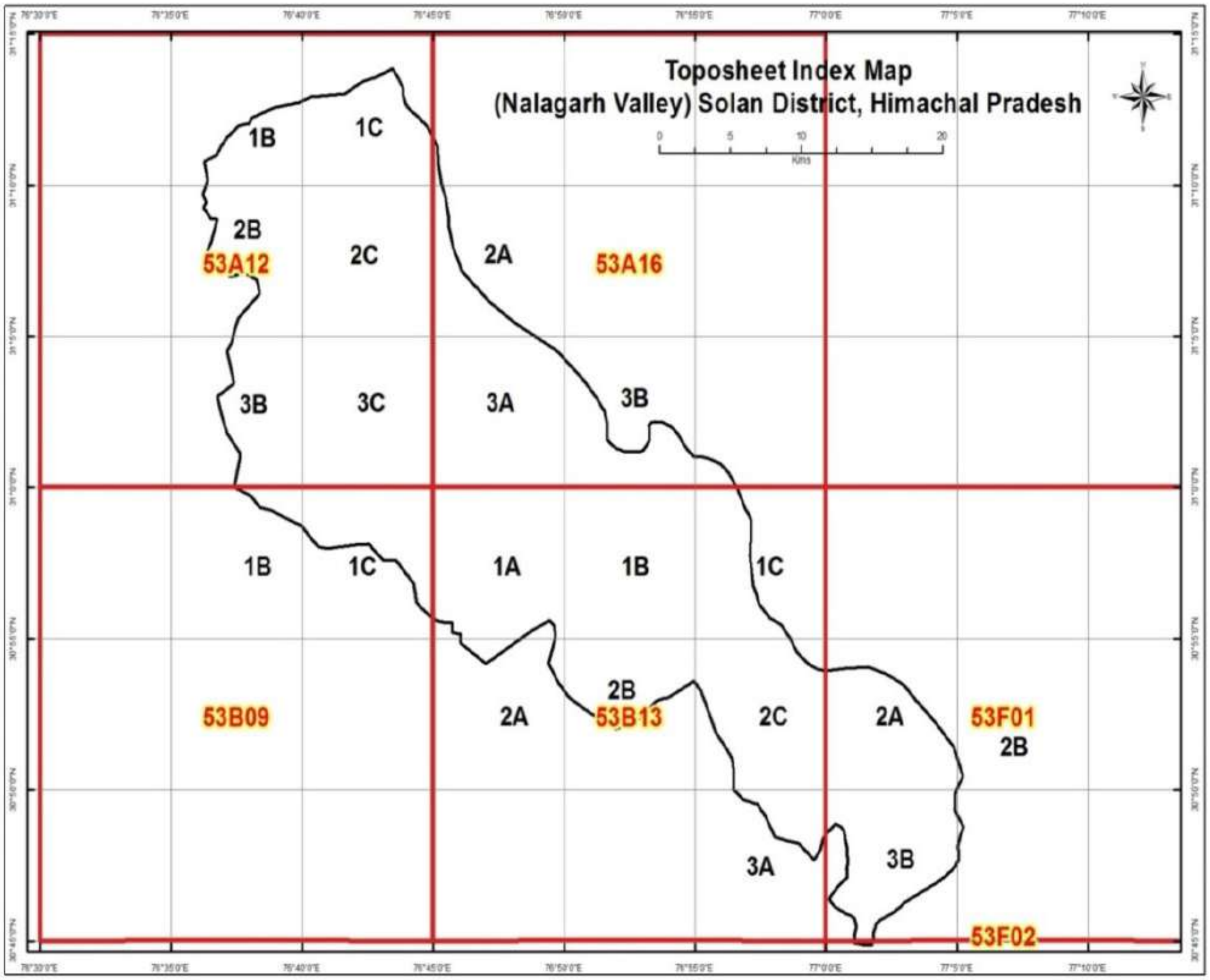


Fig.1.2 Toposheet Index Map - Nalagarh Valley, Solan District

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-1.3 and Table No.1.1

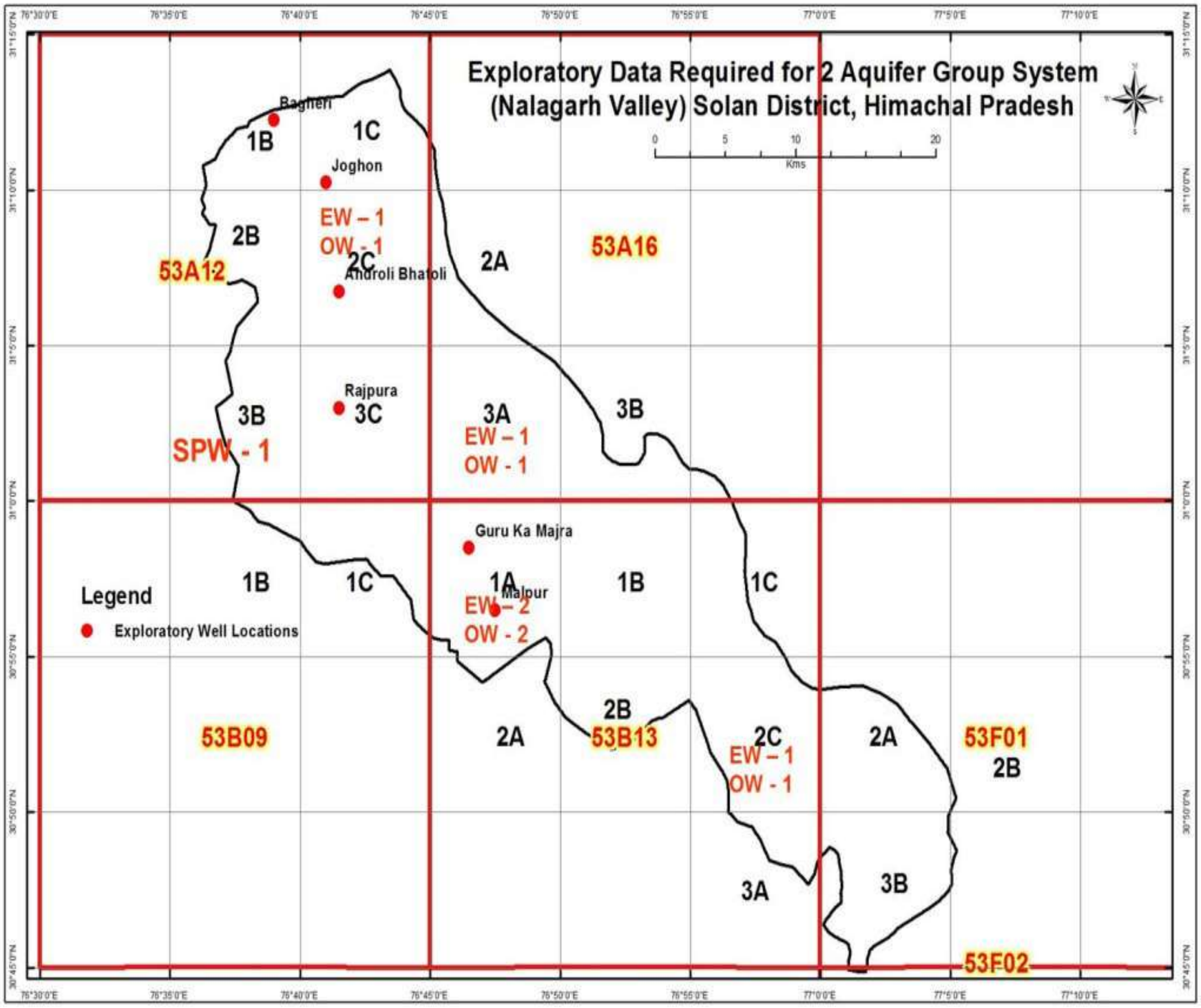


Fig.1.3 Exploratory Data Required Map - Nalagarh Valley, Solan District

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 30 Nos. The quadrant-wise existing and recommended VES sites is presented and shown as square diagram in the figure -1.4.

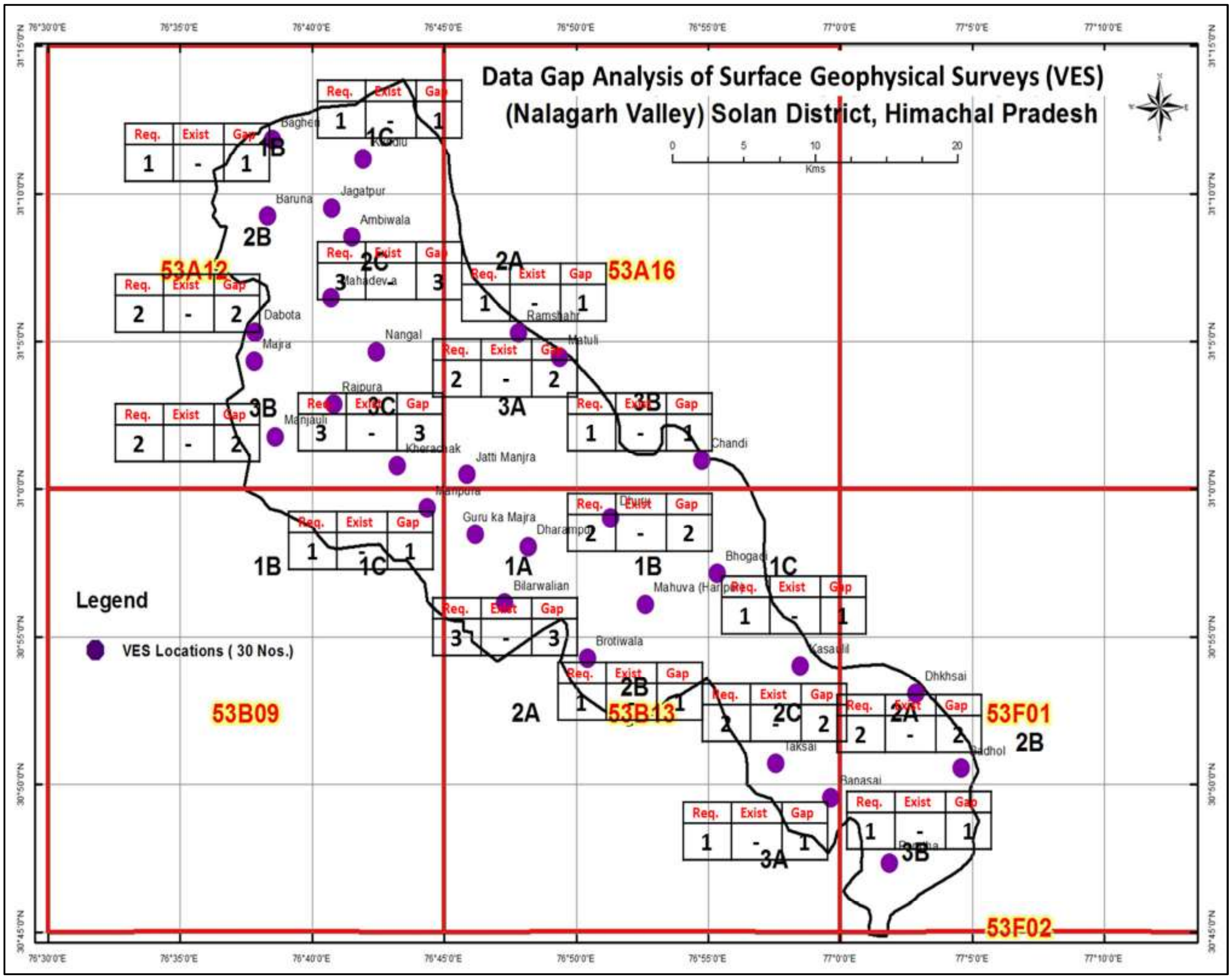


Fig.1.4 Data Gap Analysis of Surface Geophysical Surveys
Nalagarh Valley, Solan District

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 and shown as square diagram in the figure -1.5.

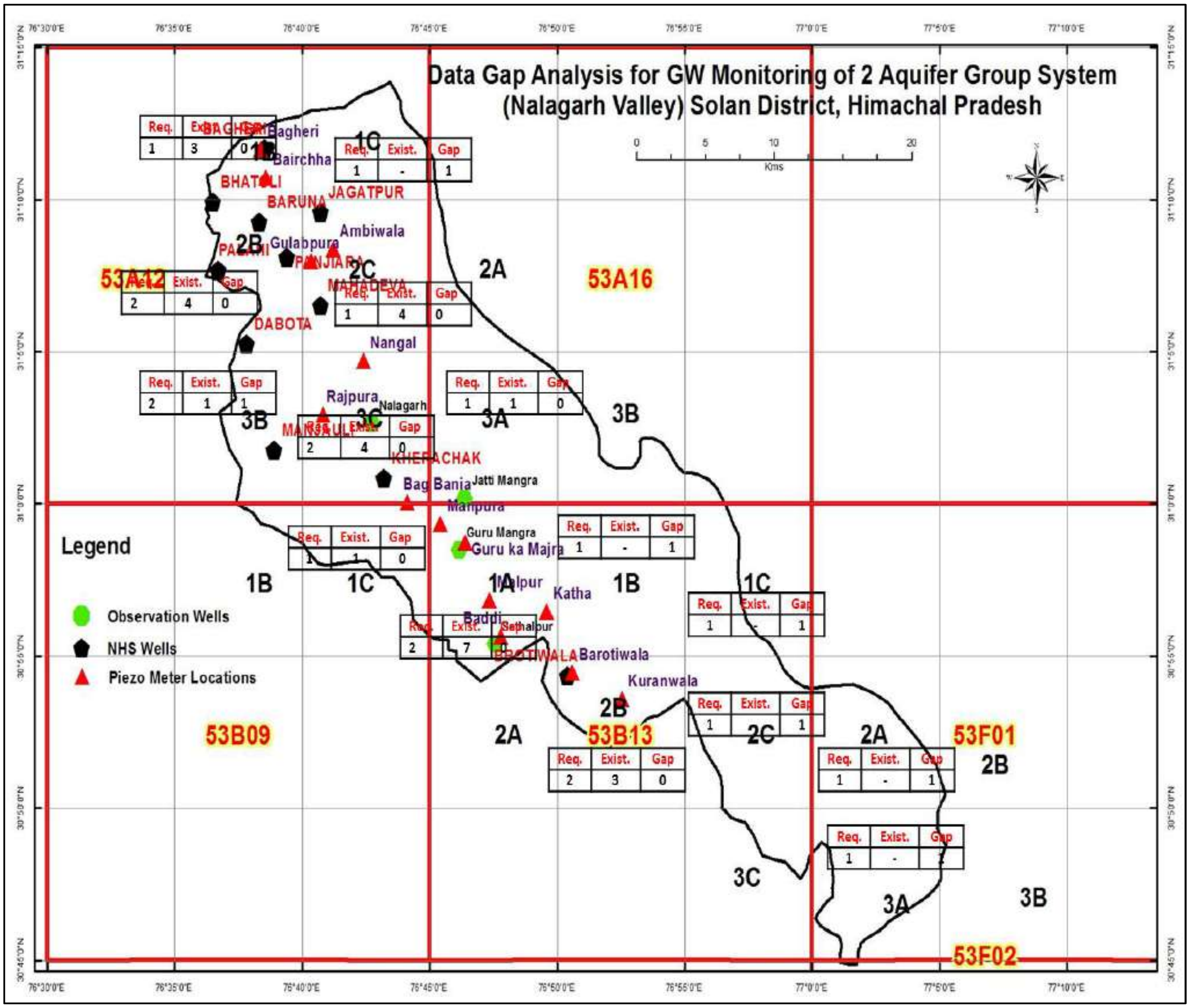


Fig.1.5 Data Gap Analysis for Ground Water Monitoring - Nalagarh Valley, Solan District

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 are required, it will be monitored through NHS, Key well observation stations, hand pumps, existing and proposed E/Ws, and Pzs. The quadrant-wise and aquifer-wise existing and recommended ground water quality monitoring stations are shown as square diagram in the figure -1.6.

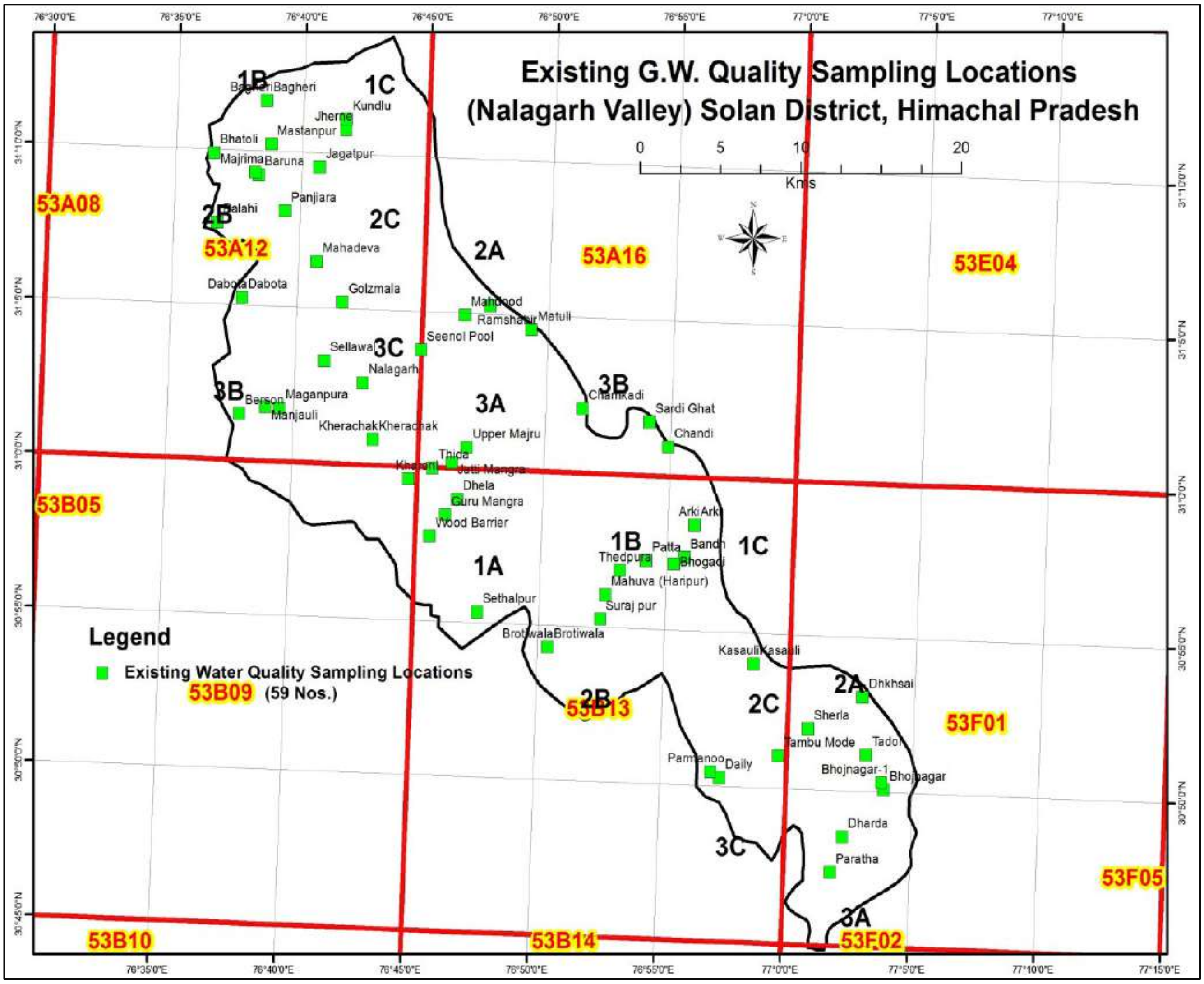


Fig.1.6 Existing Ground Water Quality Locations - Nalagarh Valley, Solan District

1.5.5 Rate of Infiltration

The amount of recharge to ground water depends on the infiltration rates 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, 39 nos. of infiltration tests are required. On the basis of data gap analysis, quadrant-wise existing and recommended infiltration tests are presented and shown as square diagram in the figure -1.7.

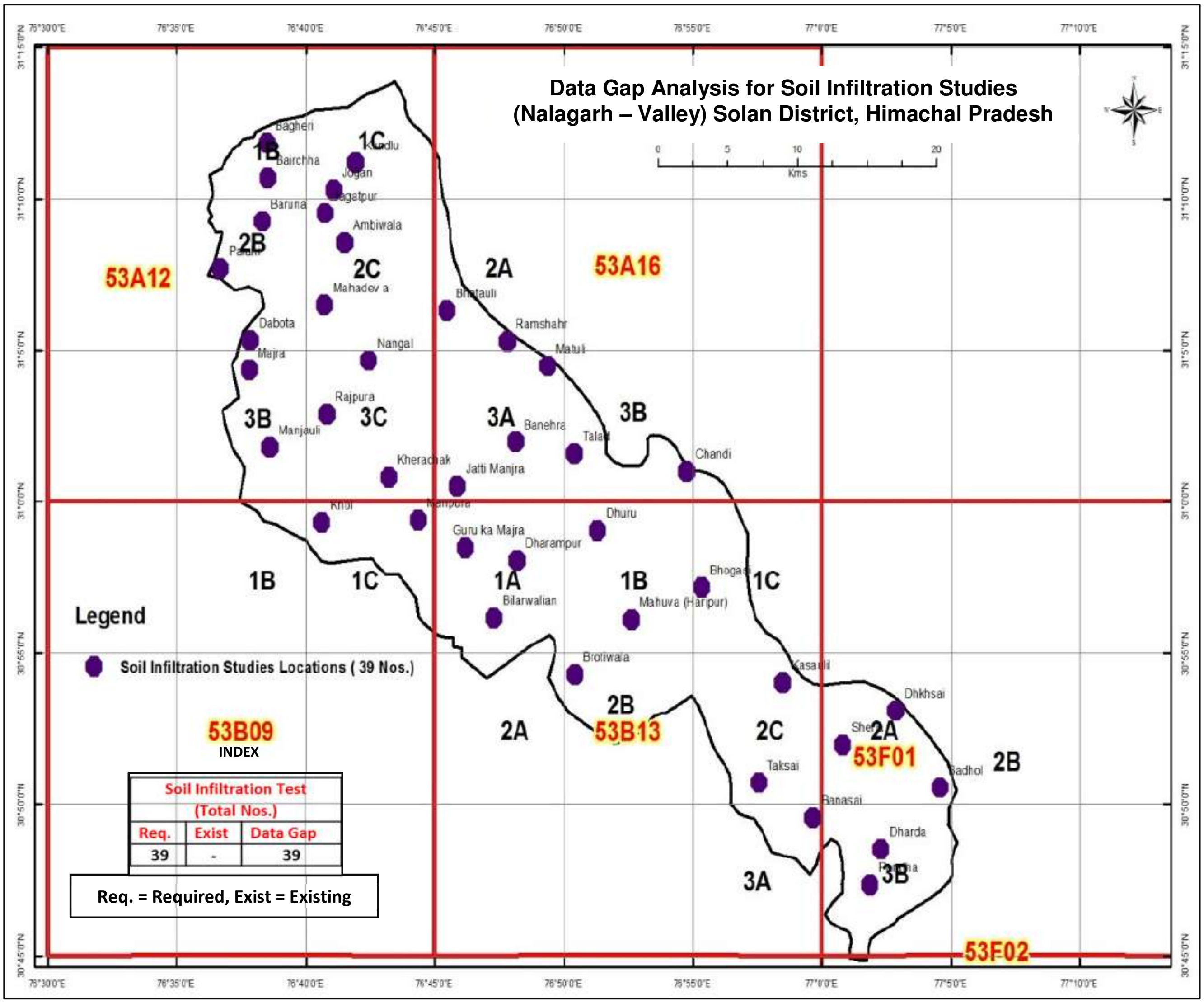


Fig.1.7 Data Gap Analysis for Soil Infiltration Studies - Nalagarh Valley, Solan District

1.5.6 Spring discharge

The spring monitoring (discharge and quality) is essential to know the inflow and outflow of the water in the study area and its quality for domestic and other use. In the study area, 7 Nos. springs have been located (Annexure -1). The quadrant-wise existing springs and discharge data available are presented and shown as square diagram in the figure -1.8.

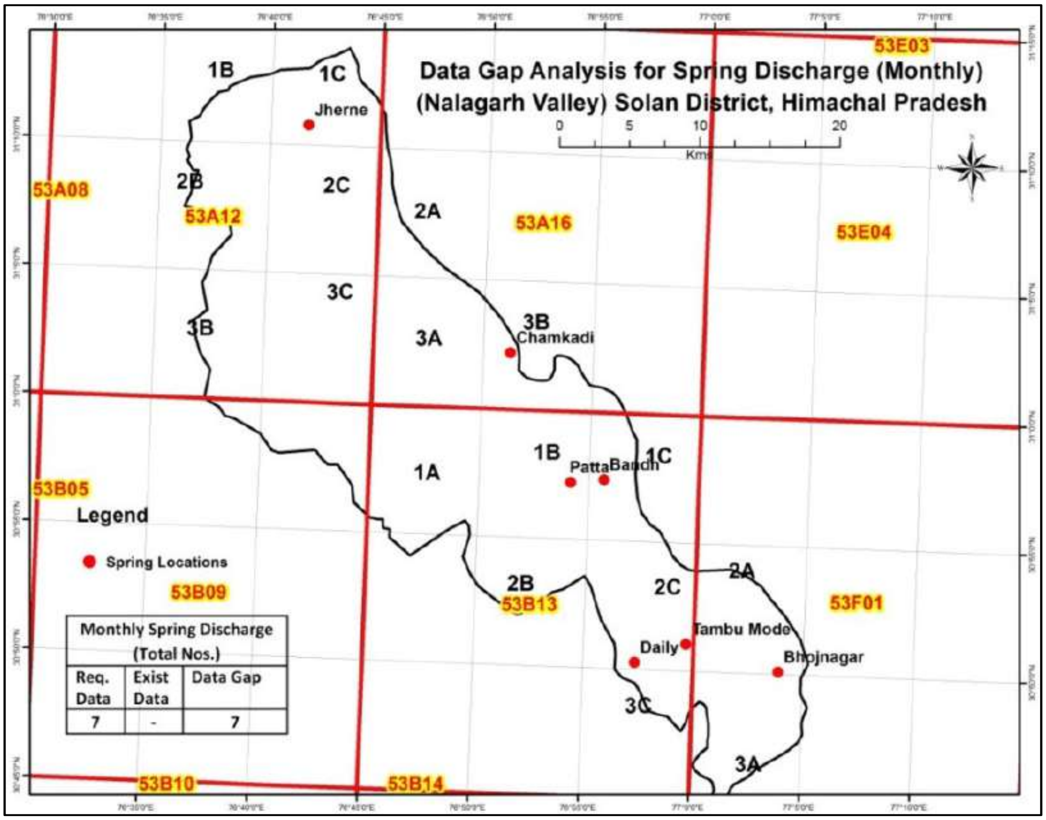


Fig.1.8 Data Gap Analysis for Spring Discharge - Nalagarh Valley, Solan District

DATA GAP ANALYSIS, NALAGARH VALLEY (2014-15)

Toposheet No: - 53A/12, 53A/16, 53B/9, 53B/13 & 53F/1

Quadrant no.	No. of additional EWs Required		No. of additional OWs Required		No. of additional Special Purpose Wells Required (EW / SPW)		No. of additional VES Required		No. of additional water level monitoring stations Required		Monthly Discharge of Existing Springs Required	No. of Soil infiltration test Required
	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II		
53A/12-1B	0	0	0	0	0	0	0	1	0	0	0	2
53A/12-1C	0	0	0	0	0	0	1	0	0	0	1	2
53A/12-2B	0	0	0	0	0	0	0	2	0	0	0	3
53A/12-2C	1	0	1	0	0	0	0	3	0	0	0	3
53A/12-3B	0	0	0	0	0	1	0	2	0	0	0	2
53A/12-3C	0	0	0	0	0	0	0	3	0	0	0	3
53A/16-2A	0	0	0	0	0	0	1	0	0	0	0	2
53A/16-3A	1	0	1	0	0	0	2	0	0	0	0	3
53A/16-3B	0	0	0	0	0	0	1	0	0	0	1	2
53B/9-1B	0	0	0	0	0	0	0	0	0	0	0	0
53B/9-1C	0	0	0	0	0	0	0	1	0	0	0	2
53B/13-1A	1	1	1	1	0	0	0	3	0	0	0	3
53B/13-1B	0	0	0	0	0	0	2	0	1	0	1	2
53B/13-1C	0	0	0	0	0	0	1	0	0	0	0	1
53B/13-2B	0	0	0	0	0	0	0	1	0	0	0	1
53B/13-2C	1	0	1	0	0	0	2	0	0	0	1	2
53B/13-3C	0	0	0	0	0	0	1	0	0	0	0	1
53F/1-2A	0	0	0	0	0	0	2	0	1	0	1	3
53F/1-3A	0	0	0	0	0	0	1	0	1	0	0	2
TOTAL	**4**	**1**	**4**	**1**	**0**	**1**	**14**	**16**	**3**	**0**	**5**	**39**

1.6 Physiography

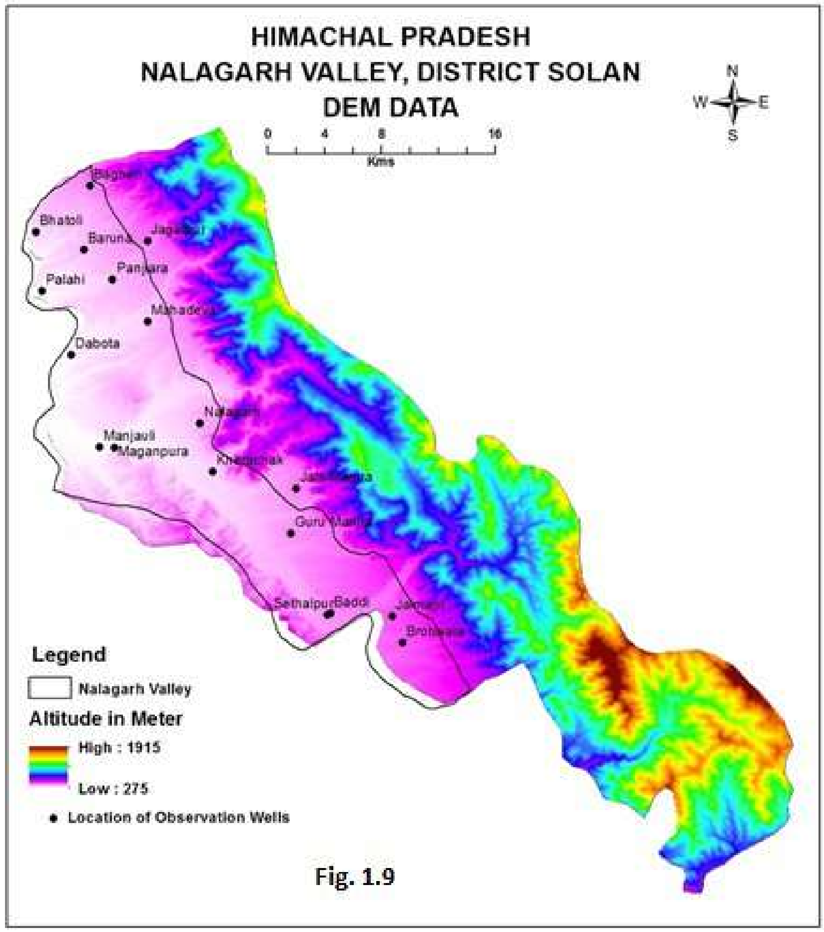


Fig. 1.9

The detailed study area, Nalagarh valley located in the outer part of lesser Himalayas, which has been formed in the last phase of upheaval of the Himalayas. The valley runs in NW-SE parallel to the main strike direction. The valley is located between two almost parallel hill ranges of Siwalik formation in the South and Kasauli formation in the north-eastern side slopping towards west. Average width & length of the valley is about 8 kilometers and 30 kilometers respectively. The valley floor gain elevation from 305 m above mean sea level at the confluence of Sirsa and Chikni khad near Nalagarh in the West to 609 m above mean sea level at the divide between Jharha river near Pinjore. Most of the parts, ridges along the North-Eastern flank of the valley attain heights above1000 m amsl.

In the valley fill deposits a number of erosional terraces formed by the Sirsa nadi upto its confluence with Chikni khad. The area between Chikni khad and Luhund khad shows huge thickness of horizontally stratified beds with occasional lenses of sand and gravel with clay. These deposits have been dissected to low-lying areas and flood planes by the various tributaries of Sutluj river. The ground slope in South-Eastern part is towards Sirsa Nadi whereas the master slope of the valley is towards North-West direction upto the confluence of the Sirsa nadi along Chikni khad. The master slope of the area between Luhund khad and Chikni khad drained by Sutluj river is towards South-West. Geomorphic features like meander scrolls, point bars, paleo-channels etc. are well preserved in the valley (Fig. 1.9).

1.7 Drainage

The area lies within the catchments expense of Sirsa nadi and few tributaries of Sutluj river drainage system. Sirsa is a tributary of Sutlej river and joins with it about 10 kms upstream of Ropar. Sirsa nadi always keeps its course confined toward the South-Western flank of the valley. It originates from the SW shoulder of Kasauli dhar and flows across the valley upto its SW flank. From there it takes a right angle bend to flow along the general trend of the valley. The valley is drained by numerous perennial and ephemeral streams emerging from the NE flank of it. These streams transversal flow across the valley, to join with the Sirsa nadi. Important streams among them are Chikni khad, Phali Nadi, Ratta nala, Balad nadi and Surajpur choa.

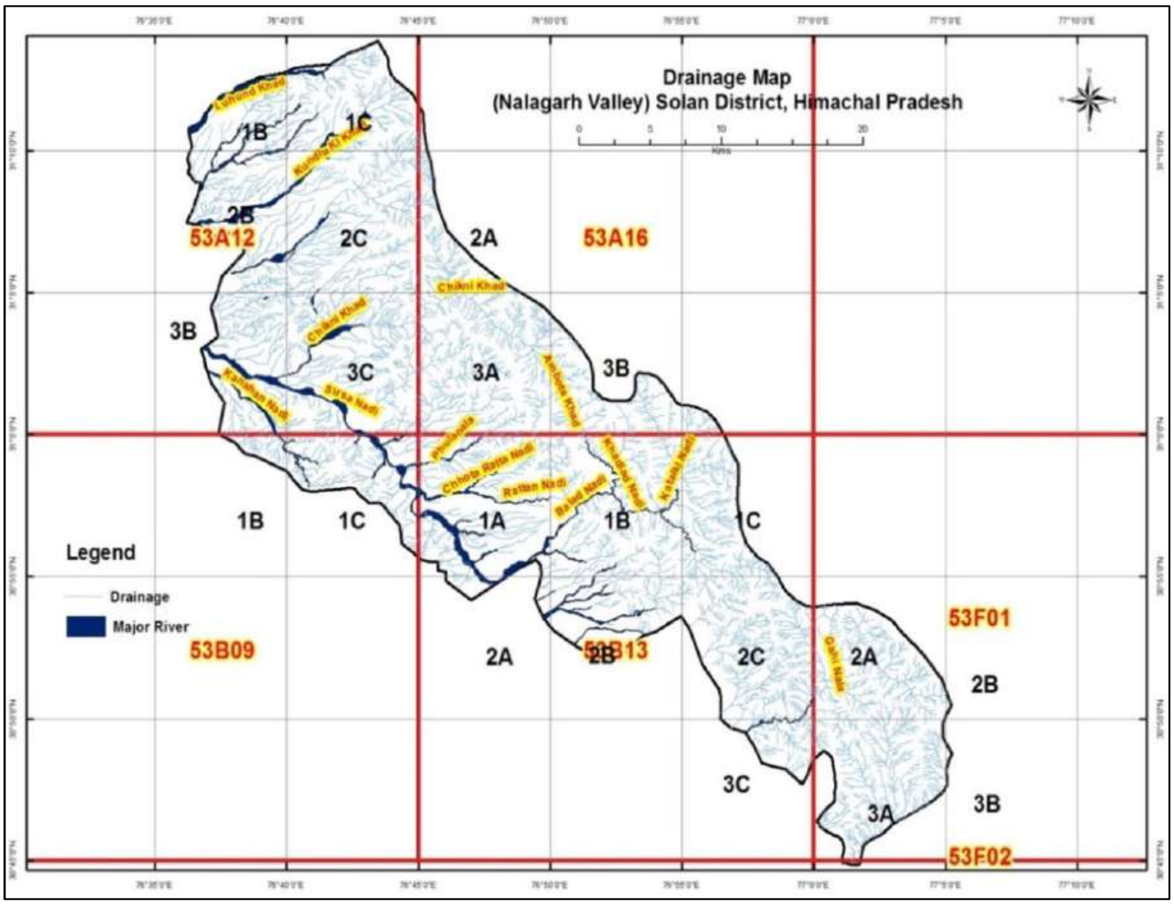


Fig 1.10 The Drainage Map - Nalagarh Valley, Solan District

There are also some other streams other than the tributary of Sirsa nadi, namely Mahadeo khad, Luhund khad, Kundulu khad, Phalai nala, Kalayanpur khad etc., are tributaries of Sutluj river which flows Southwest in the Northwestern parts of the valley. These streams are fed by numerous secondary nalas, which form a dendritic type of drainage pattern. The discharge in the streams fluctuates in accordance with the climatic conditions. During the monsoon, the streams are flooded and carry enormous load of rock particles and deposit them in their flood plains in the valley. All the streams are wither fed by the stream channel and again reappearing some distance downstream is a common feature. The Drainage Map of the study area was prepared on 1:50,000 scale the same was shown in Fig.1.10.

1.8 Geology

Geologically, the rock formations occupying the district range in age from PreCambrian to Quaternary. The detailed geological succession encountered in the district is given below in table 1.2.

Table 1.2 Geological Succession, Solan District.

<table>
<tr><th>Era</th><th>Period</th><th>Group</th><th>Formation</th><th colspan="2">Description of Lithology</th></tr>
<tr><td rowspan="2">Post Tertiary</td><td>Recent</td><td></td><td>Alluvium</td><td colspan="2">Grey to dark grey iron stained fine to coarse sand with pebble and clay</td></tr>
<tr><td>Pleistocene</td><td></td><td>Older Alluvium</td><td colspan="2">Multiple fill cyclic sequence of medium to coarse grained grey sand and grit with pebble of sandstone and lenses of clay</td></tr>
<tr><td rowspan="6">Tertiary</td><td rowspan="3">Pliocene – Middle Miocene</td><td rowspan="3">Siwalik system</td><td>Upper Siwalik</td><td colspan="2">Sand stone, boulder conglomerate, clay and grit stone</td></tr>
<tr><td>Middle Siwalik</td><td colspan="2">Grey sandstone, gravel beds, shale, clay</td></tr>
<tr><td>Lower Siwalik</td><td colspan="2">Micaceous sandstone, purple clay, mudstone</td></tr>
<tr><td rowspan="3">Lower Miocene-Oligocene</td><td rowspan="3">Subathu group</td><td>Kasauli</td><td colspan="2">Grey sandstone, shale, clay;</td></tr>
<tr><td>Dagshai</td><td colspan="2">Grey/green sandstone, red nodular clay</td></tr>
<tr><td>Subathu</td><td colspan="2">Grey/green splintery shale, sandstone and limestone bands</td></tr>
<tr><td rowspan="17">Pre Tertiary</td><td rowspan="3">Upper Proterozoic-III</td><td rowspan="3">Krols</td><td>Krol</td><td colspan="2">Sand stone, red shale, dolomite;</td></tr>
<tr><td>Infra Krol</td><td colspan="2">Carbonaceous shale, slate, greywacke;</td></tr>
<tr><td>Blaini</td><td colspan="2">Tillitoids, shale, slate, quartzite, dolomitic limestone.</td></tr>
<tr><td rowspan="4">Lower Proterozoic –III</td><td rowspan="4">Simla Group /Jaunsar Group</td><td>Sanjauli</td><td>Shale, siltstone, slate, greywacke, quartzite, sandstone, conglomerate,</td><td rowspan="4">Undifferentiated jaunsar quartzite, slate, phyllite, conglomerat, greywacke, limestone, dolaomite and metavolcanics</td></tr>
<tr><td>Chhaosa</td><td>Shale, siltstone, quartzite, greywacke;</td></tr>
<tr><td>Kunihar</td><td>Shale, siltstone and limestone</td></tr>
<tr><td>Basantpur</td><td>Limestone, shale, quartzite and sporadic conglomerate</td></tr>
<tr><td rowspan="6">Proterozoic-II</td><td rowspan="5">Shali Group</td><td>Parnali</td><td colspan="2">Cherty dolomite, quartzite, limestone</td></tr>
<tr><td>Makri</td><td colspan="2">Purple/pale greenish and grey shale, slate, quartzite and cherty dolomite</td></tr>
<tr><td>Tattapani</td><td colspan="2">Pink and grey dolomite, phylitised shale</td></tr>
<tr><td>Sorghawari</td><td colspan="2">Pink and grey limestone, sporadic shale</td></tr>
<tr><td>Khaira</td><td colspan="2">Pink and white quartzite with a thin band of red shale along the upper contact</td></tr>
<tr><td>Sundernagar</td><td>Sundernagar</td><td colspan="2">Shale, slate, phyllite, quartzite and meta-volcanices,</td></tr>
<tr><td rowspan="3">Proterozoic-Undifferentiated</td><td rowspan="3">Jutogh Group</td><td>Bhotli</td><td colspan="2">Shale, phyllitc, garnetiferous, schist, staurolite quartzite, dolomite and amphibolite</td></tr>
<tr><td>Manal</td><td colspan="2">Pale white to grey quartzite, schist, carbonaceous dolomite</td></tr>
<tr><td>Panjerli</td><td colspan="2">Carbonaceous slate, phyllite, schist with limestone and quartzite.</td></tr>
</table>

Source: Geological Survey of India

Stratigraphically the Nalagarh valley and its flanks are bounded by the tertiary formations. Structurally these are highly disturbed. The rock types of the area can be broadly grouped into two tectonic zones striking and trending NW-SE direction. Their position from North to South is as follows; Belt of lower and middle tertiary occurring along the NE flank of the valley (Para-autochthonous) and Belt of upper tertiary confined to the valley and along its SW flank (Autochthonous). The contact of these zones is marked by a major fault (Nalagarh thrust).

Tectonically, the area is highly disturbed, two major thrust trending NE-SW are Nalagarh and Sirsa thrusts. Nalagarh thrust is formed between Kasaulies and middle Siwaliks whereas Sirsa thrust separates upper and middle Siwaliks (Fig.1.11). The lithology map of the study area was prepared with the help of Himachal Pradesh Atlas map on 1:250,000 scale.

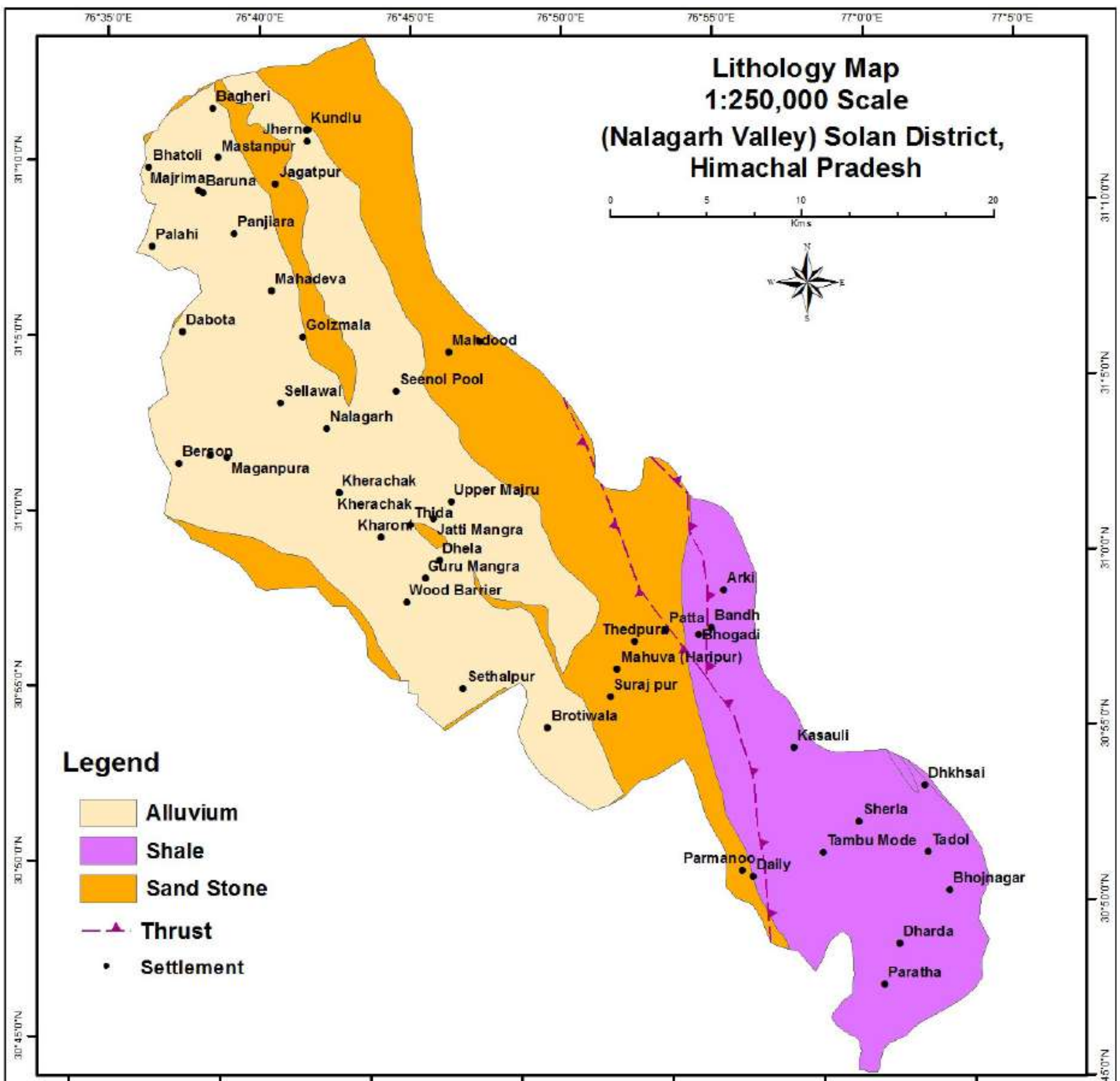


Fig 1.11 Lithology Map of Nalagarh Valley, Solan District

1.9 Hydrogeology

In valley area of Nalagarh, the ground water occurs in porous unconsolidated alluvial formation (valley fills) comprising, sand, silt, gravel, cobbles/pebbles etc. Ground water occurs both under phreatic & confined conditions. The thickness of such deposits is again restricted to 60 to 100 m below ground level. The ground water in the valley also occurs under preached water table conditions at places. Water table rises after monsoon period and intersects the ground surface at the contact between two terraces giving rise to a number of springs. However, the water table drops with the advent of summer and these springs to dry. Intersection of water table in various tributary khads at suitable places maintained their perennial flow. The Sirsa nadi is mainly ground water fed river during the non-monsoon period. Ground water intersects the Sirsa Khad bed near village Charuian in Nalagarh valley and the whole length further downstream upto the confluence of Sirsa nadi with Chikni khad is effluent in nature. Other khads in the Nalagarh valley drain in into Sutlej river also show effluent of ground water in their beds and are perennial in their lower reaches (Fig. 1.11).

Wells and tube wells are the main ground water abstraction structures. Ground water is being developed in the area by medium to deep tube wells, dug wells, and dug cum bored wells. Depth of open dug wells and dug cum bored well in area ranges from 2.00 to 60.00 m bgl wherein depth to water level varies from near ground surface to more than 35 m bgl. Yield of shallow aquifer is moderate with well discharges up to 10 lps.

Deeper semi-confined aquifers are being developed by tube wells ranging in depth from 65 to 120 m tapping 25-35 m granular zones. The well discharges vary from about 10 to 30 lps. Central Ground Water board has drilled/constructed > 9 exploratory wells in the valley area in the depth range of 72.00 to 155.15 m bgl. Static water level of the tube wells ranges from 2.2 to 43.20 mbgl and discharge ranged from 12.616 to 1400.00 lpm for drawdown of 2 to 24 m. Transmissivity ranges from 39.24 m^2/day to 128.34 m^2/day.

The recharge of the ground water body in the valley is chiefly affected through the influent stream seepage and percolation of surface precipitation and irrigation waters. Influent stream seepage occurs mainly in the upper higher portions of the valley adjacent to foothills, their large quantities of water from the streams percolate down into the porous and highly permeable valley-fill deposits.

The discharge of ground water is both natural and induced. a natural discharge is chiefly effected through evapo-transpiration and effluent seepage into the major streams. The induced discharge is mainly through draft from the open wells used for domestic, irrigation and industrial water supplies.

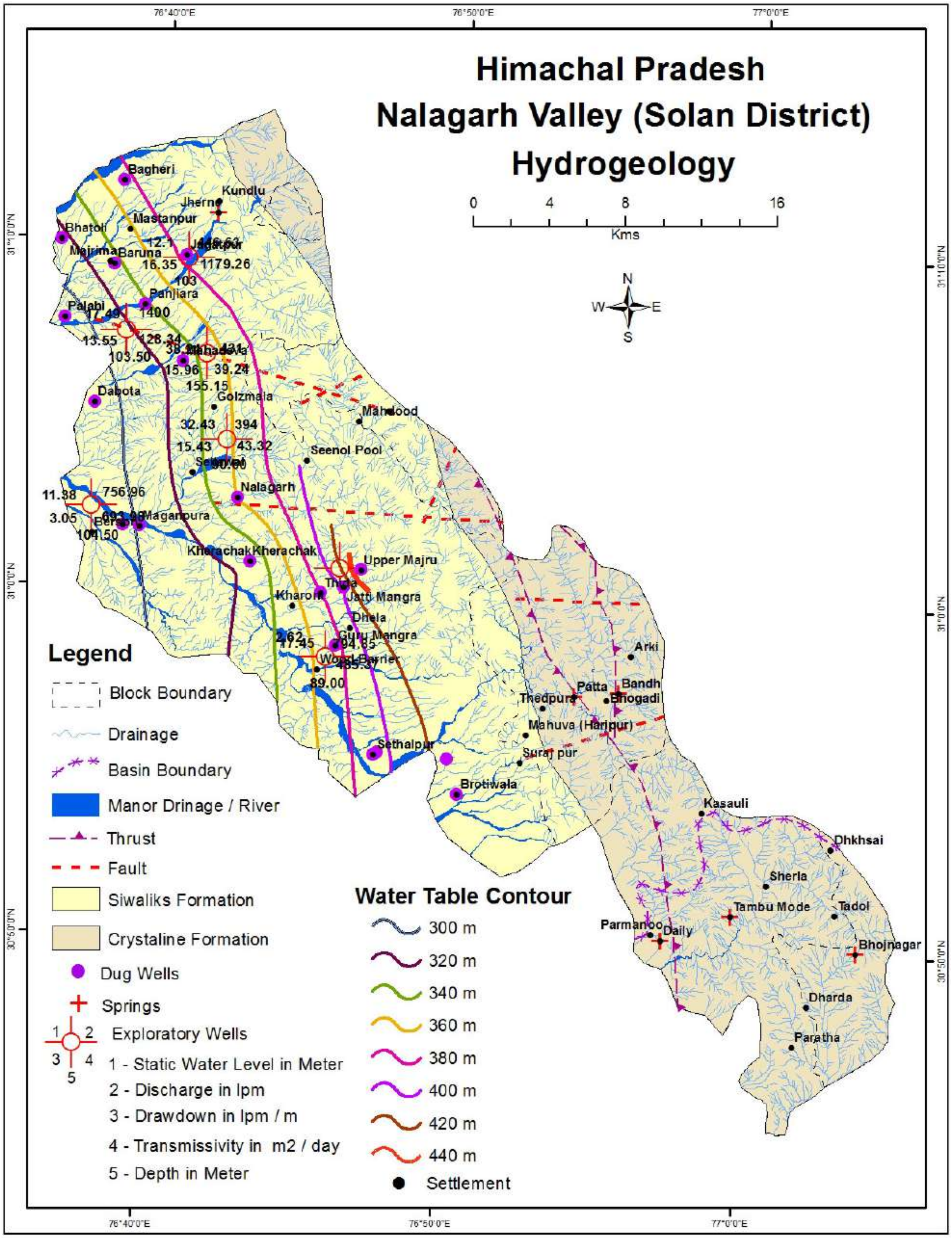


Fig 1.12 Hydrogeology Map of Nalagarh Valley, Solan District

1.10 Geomorphology

The geomorphological map was interpreted from survey of India topographic sheets and IRS P6 LISS - IV satellite imagery. The geomorphic units represented in the study area are Structural hills and river alluvium shown in fig.1.12.

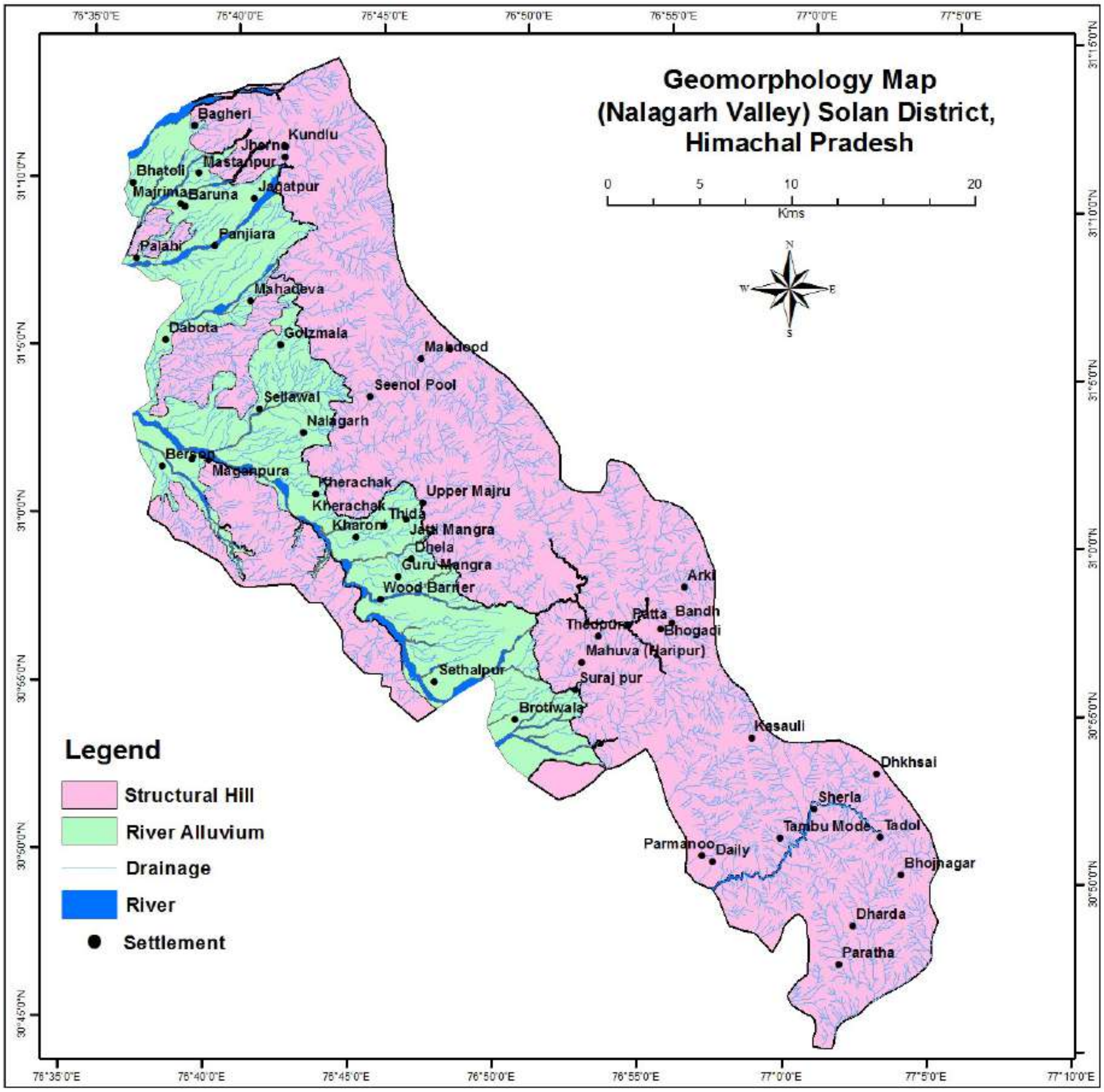
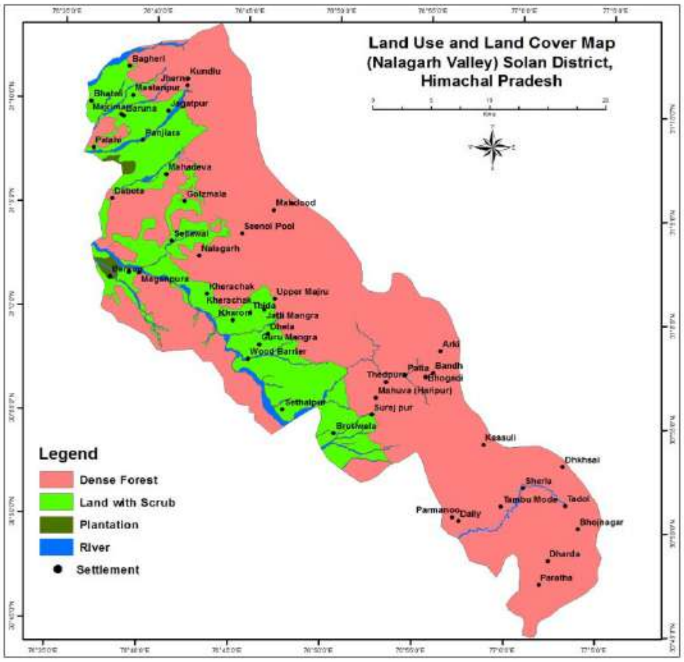


Fig. 1.13 Geomorphology Map of Nalagarh Valley, Solan District

1.11 Land use and Land Cover

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 Dense Forest, Land with scrub, Plantation and River (fig.1.13 (a)). Similarly Forest Area map was prepared with the help of processed satellite imagery, the same has been shown in fig. 1.13 (b).



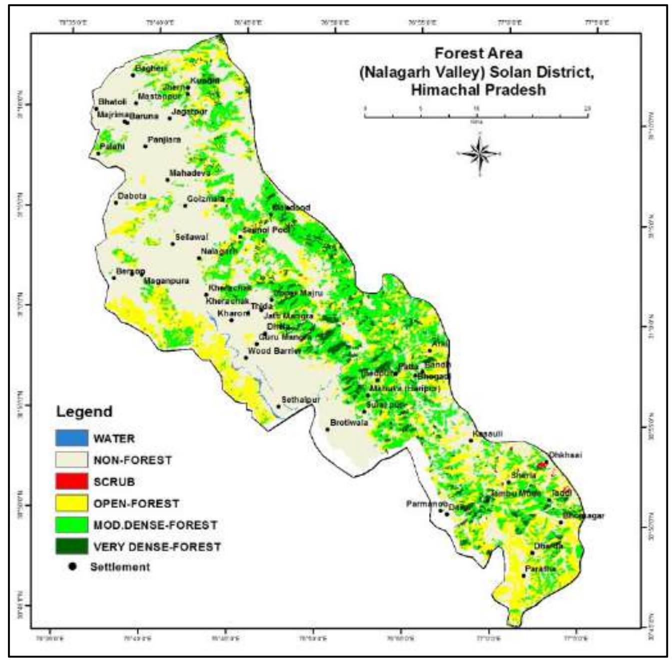


Fig. 1.14 (a) Land Use & Land Cover **(b) Forest Area**

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. 1.14

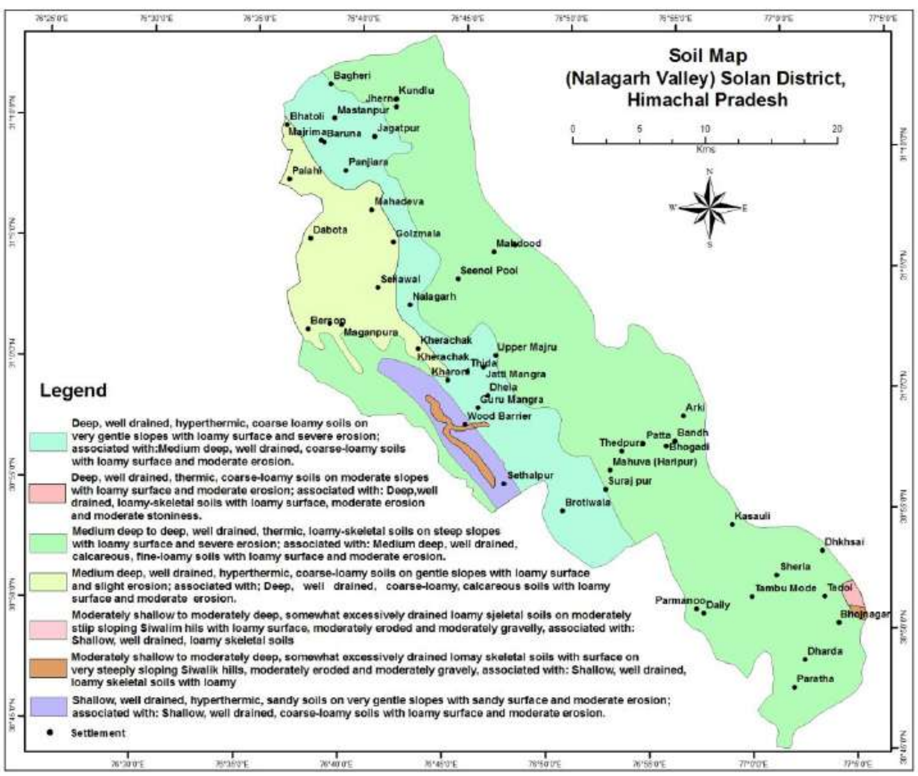


Fig. 1.15 Soil Map of Nalagarh Valley, Solan District

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 Solan district during various field seasons.

Central Ground Water Board, NHR, Dharamshala has also carried out preliminary Pollution studies in Urban clusters of Nalagarh, Baddi and Parwanoo of Solan District and ground water exploration studies in the area.

CGWB NHR, Dharamshala is monitoring ground water levels from National Hydrograph Network observations and aquifer mapping wells (Table 1.3) 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 1.3 National Hydrograph Network observations and aquifer mapping wells of Nalagarh Valley, Solan District, Himachal Pradesh

Sl.No	Name of Village/site	Latitude	Longitude	Estt. Date	RL (mamsl)	Total Depth of DW (mbgl)	Type (DW/)	Measuring Point (magl)
1	Manjauli	31.0291	76.6482	6/11/2014	294.96	4.2	DW	0.15
2	Kherachak	31.0138	76.7199	5/11/2014	330.47	7.98	DW	0.65
3	Jagatpur	31.1594	76.6785	6/11/2014	407.69	22.65	DW	0.2
4	Bagheri	31.1942	76.6421	6/11/2014	393.1	22.75	DW	0.5
5	Bhatoli	31.1651	76.6082	6/11/2014	328.24	13.62	DW	0.3
6	Baruna	31.1540	76.6384	6/11/2014	357.96	37.56	DW	0.55
7	Palahi	31.1276	76.6118	6/11/2014	293.92	6.72	DW	0.55
8	Mahadeva	31.1084	76.6786	6/11/2014	341.9	14.25	DW	0.45
9	Panjiara	31.1350	76.6566	6/11/2014	364.8	55	DW	0.5
10	Dabota	31.0875	76.6303	6/11/2014	303.86	12.55	DW	0.85
11	Baddi	30.9242	76.7944	5/11/2014	398.23	6.75	DW	1.09
12	Jalmajri	30.9222	76.8333	5/11/2014	425.43	13.62	DW	0.9
13	Brotiwala	30.9055	76.8399	5/11/2014	456		DW	0
14	Jatti Manjra	31.0030	76.7725	5/11/2014	412.3	60	DW	0.55
15	Guru Manjra	30.9746	76.7693	5/11/2014	398	45	DW	0.22
16	Sethalpur	30.9231	76.7925	6/11/2014	398	10	DW	0.3
17	Nalagarh	31.0441	76.7120	6/11/2014	367.8	25	DW	1.4
18	Maganpura	31.0288	76.6575	6/11/2014	308.15	15	DW	0.4
19	Thida	30.9997	76.7601	7/6/2015	386.18	0.32	DW	0.6
20	Upper Majru	31.0115	76.7820	7/6/2015	464.51	8	DW	0.1

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, 17 dug wells have been inventoried for Ground Water Management Studies all over the area. The dug wells are located in and around Nalagarh valley. The water levels were taken during the month of May and November, 2015 & 2016 and on the basis of these data, pre-monsoon, post monsoon and seasonal fluctuation map have been prepared for the Nalagarh valley area. The hydrogeological data of the inventoried dug wells are given in Table 2.1.

In Nalagarh valley depth to water level shows wide variation. During pre-monsoon period (May 2015) it ranges from 1.50 to 35.00 m bgl (Fig. 2.0) and post monsoon period (Nov.2015) ranges from 1.20 to 24.40 m bgl. (Fig. 2.1). In major parts of Nalagarh valley, Seasonal Water Level Fluctuation ranges between less than 0.30 to 20.00 m bgl (Fig.2.2). Whereas in pre-monsoon period of (May 2016) it ranges from 1.95 to 27.50 m bgl (Fig.2.3) and post monsoon period (Nov.2015) ranges from 1.15 to 25.95 m bgl (Fig.2.4) and Seasonal Water Level Fluctuation ranges between -12.25 to 27.00 m bgl (Fig. 2.5).

Table 2.1 Water level data (May & Nov.2015 and May & Nov.2016) GWMS and Aquifer Mapping Wells of Nalagarh Valley, Solan District, Himachal Pradesh

Location	Latitude	Longitude	Water Level, 2015		2015 Fluctuation	Water Level, 2016		2016 Fluctuation
			May 2015	Nov. 2015		May 2016	Nov. 2016	
Kherachak	31.0138	76.7199	6.65	4.85	1.8	6.95	4.85	2.10
Jagatpur	31.1594	76.6785	18	14.20	3.8	21.40	15.85	5.55
Bagheri	31.1942	76.6421	19.3	17.80	1.5	21.60	20.10	1.50
Bhatoli	31.1651	76.6082	12.90	11.30	1.6	13.00	25.25	-12.25
Baruna	31.1540	76.6384	29.25	22.20	7.05	22.95	25.95	-3.00
Palahi	31.1276	76.6118	6.40	5.95	0.45	6.15	3.85	2.30
Mahadeva	31.1084	76.6786	13.35	12.50	0.85	14.15	13.68	0.47
Panjiara	31.1350	76.6566	21.30	19.10	2.2	27.00	0.00	27.00
Dabota	31.0875	76.6303	13.45	12.45	1	13.25	12.90	0.35
Brotiwala	30.9055	76.8399	26.90	24.40	2.5	27.50	23.05	4.45
Jatti Manjra	31.0030	76.7725	12.45	8.4	4.05	12.25	10.4	1.85
Guru Manjra	30.9746	76.7693	35	15.4	19.6	24.28	16.88	7.40
Sethalpur	30.9231	76.7925	6.6	4.2	2.4	7.1	4.25	2.85
Nalagarh	31.0441	76.7120	7.25	7.1	0.15	6.3	4.15	2.15
Maganpura	31.0288	76.6575	6.2	5.85	0.35	5.9	5	0.90
Thida	30.9997	76.7601	6.4	4.2	2.2	6.3	4.6	1.70
Upper Majru	31.0115	76.7820	1.5	1.2	0.3	1.95	1.15	0.80

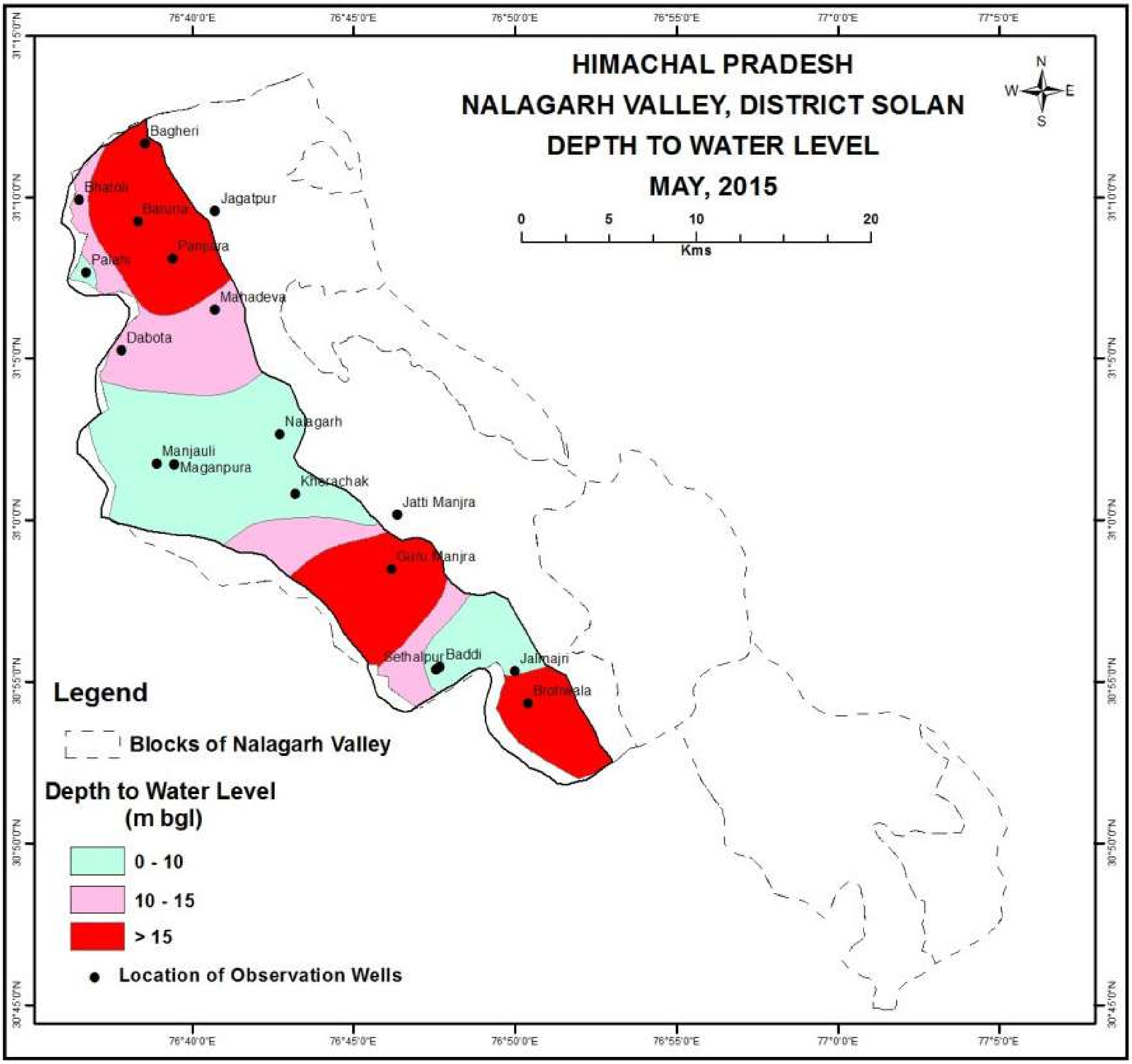


Fig. 2.0 Depth Water Level – May 2015, Nalagarh Valley, Solan District

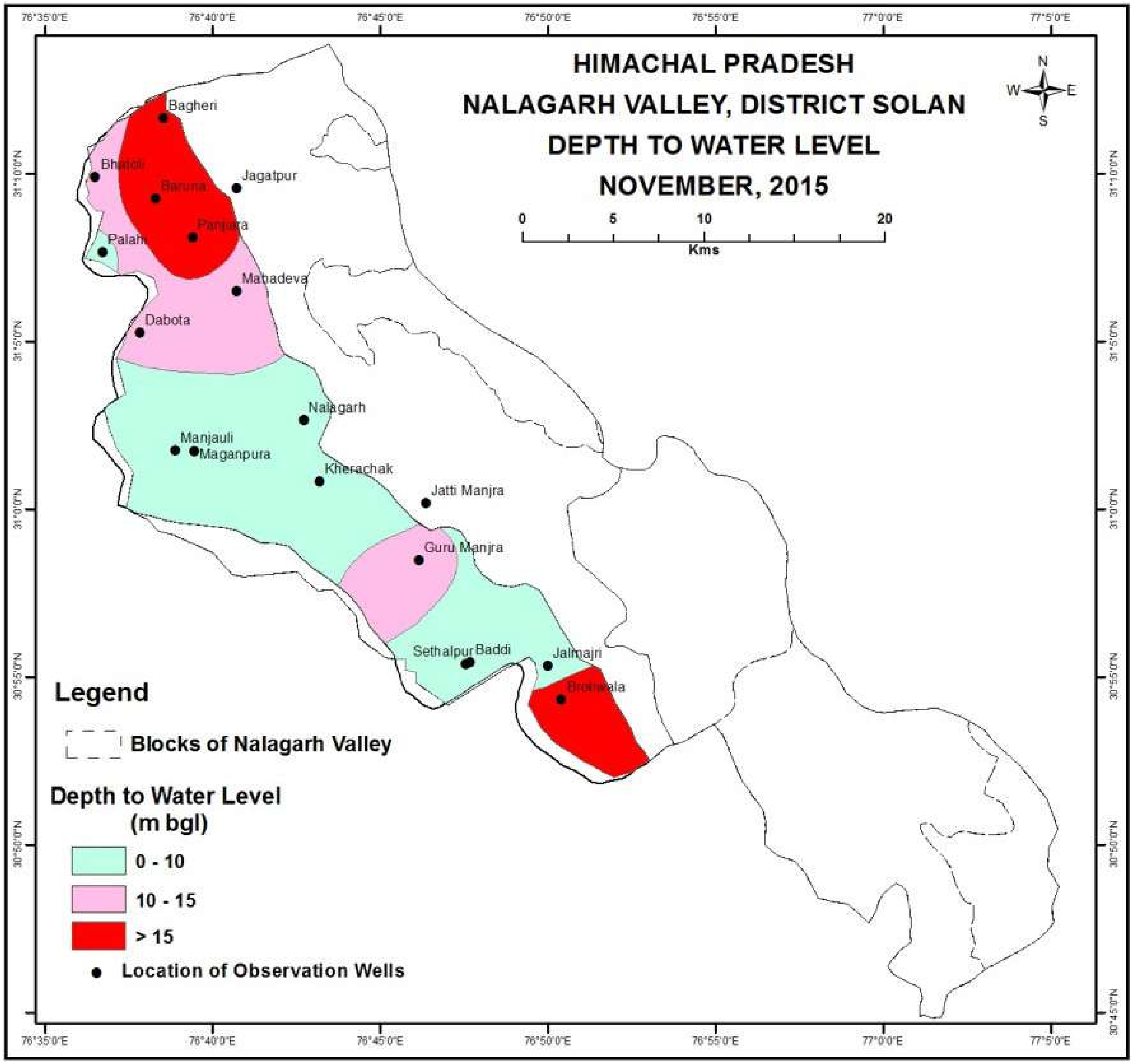


Fig. 2.1 Depth Water Level – November, 2015, Nalagarh Valley, Solan District

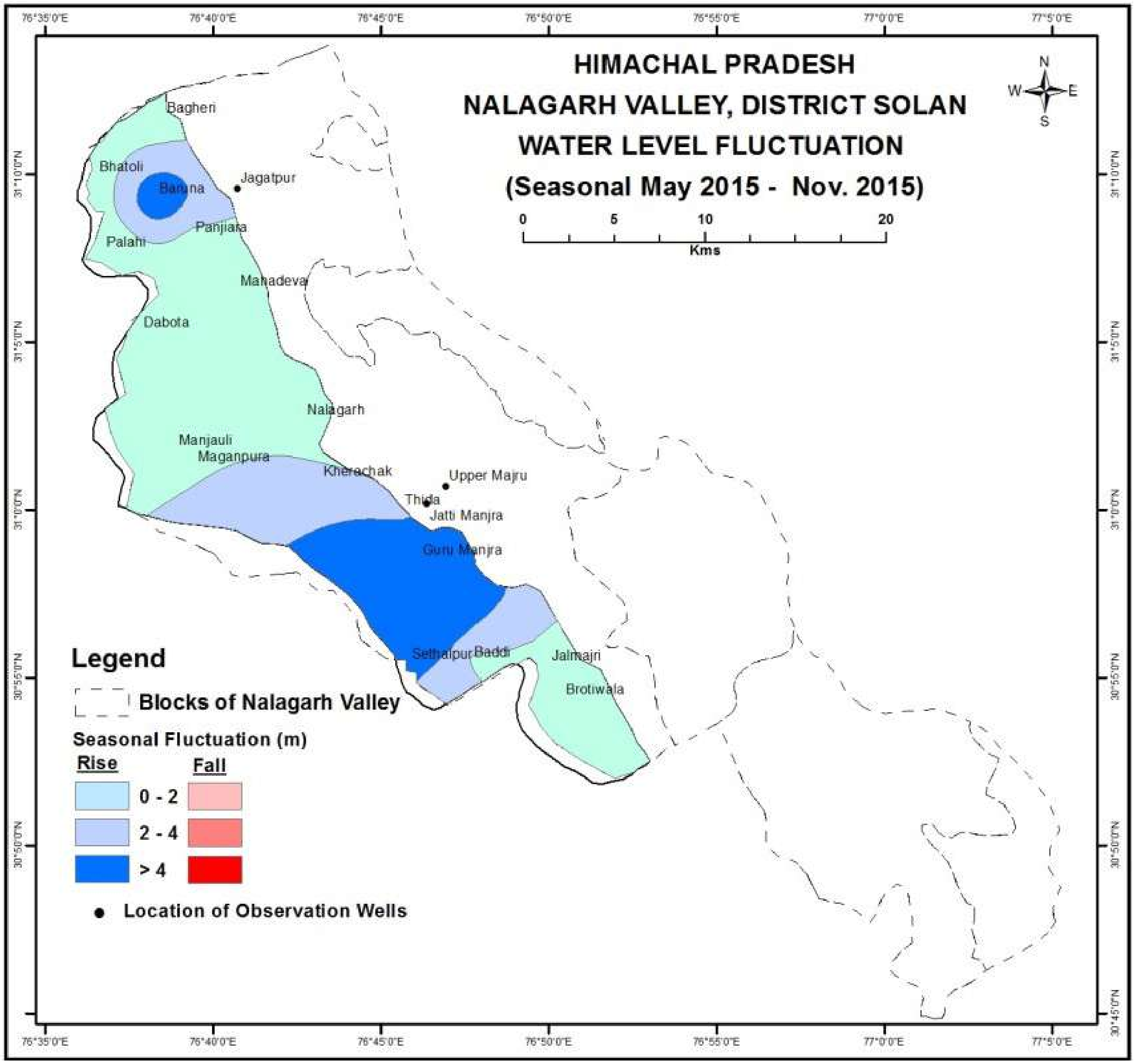


Fig. 2.2 Seasonal Water Level Fluctuation – May 2015 & November 2015, Nalagarh Valley, Solan District

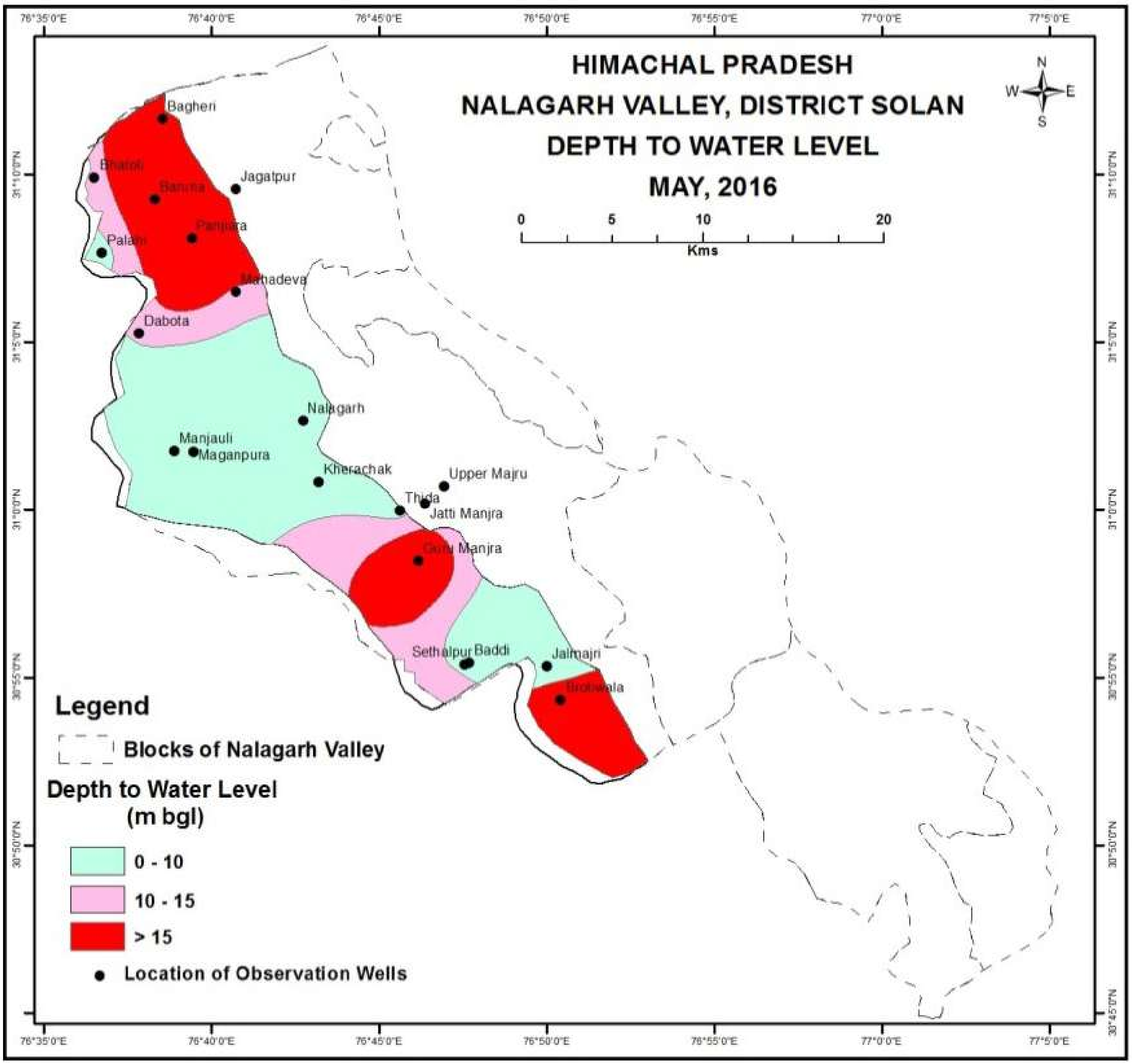


Fig. 2.3 Depth Water Level – May, 2016, Nalagarh Valley, Solan District

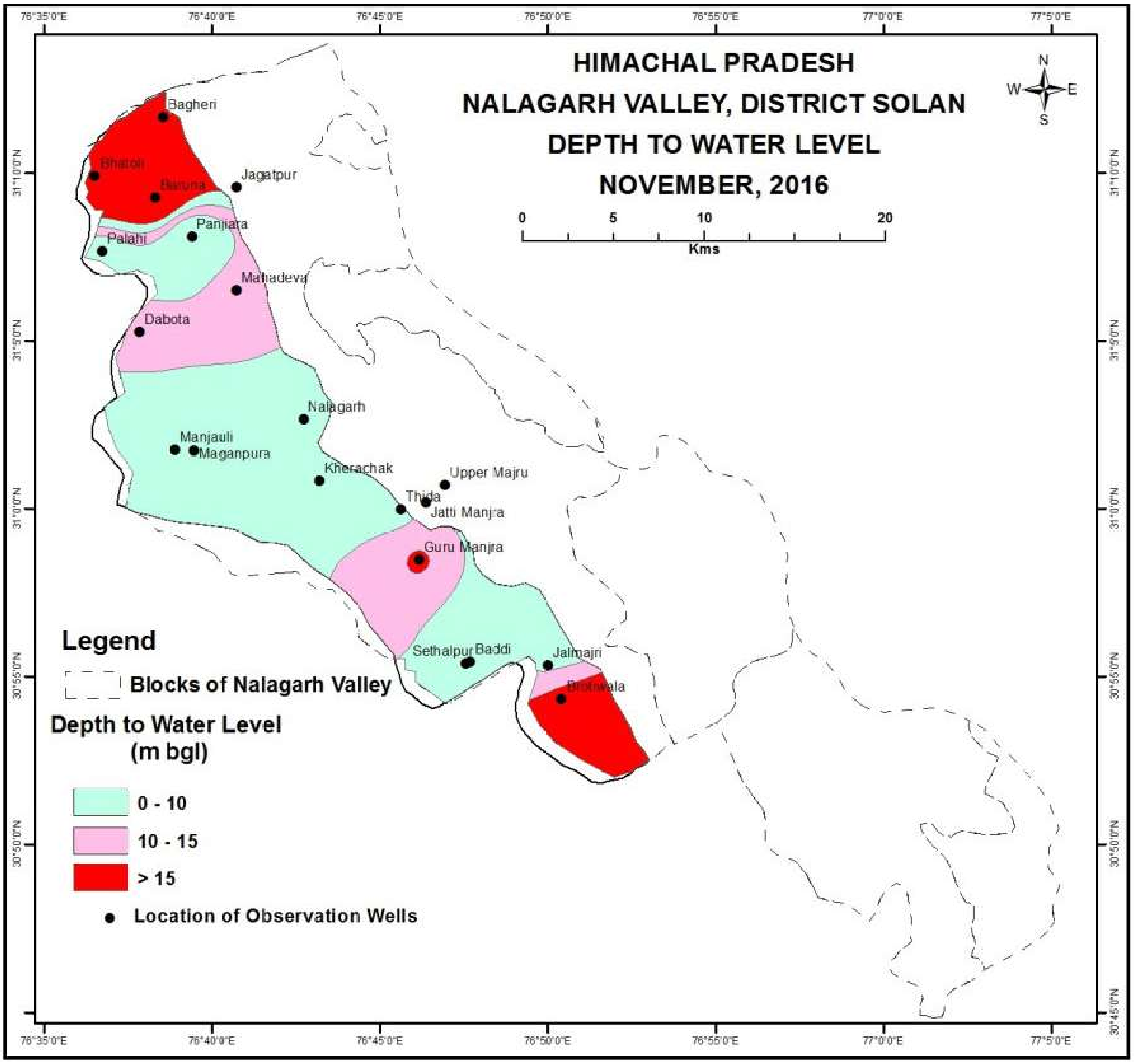


Fig. 2.4 Depth Water Level – November, 2016, Nalagarh Valley, Solan District

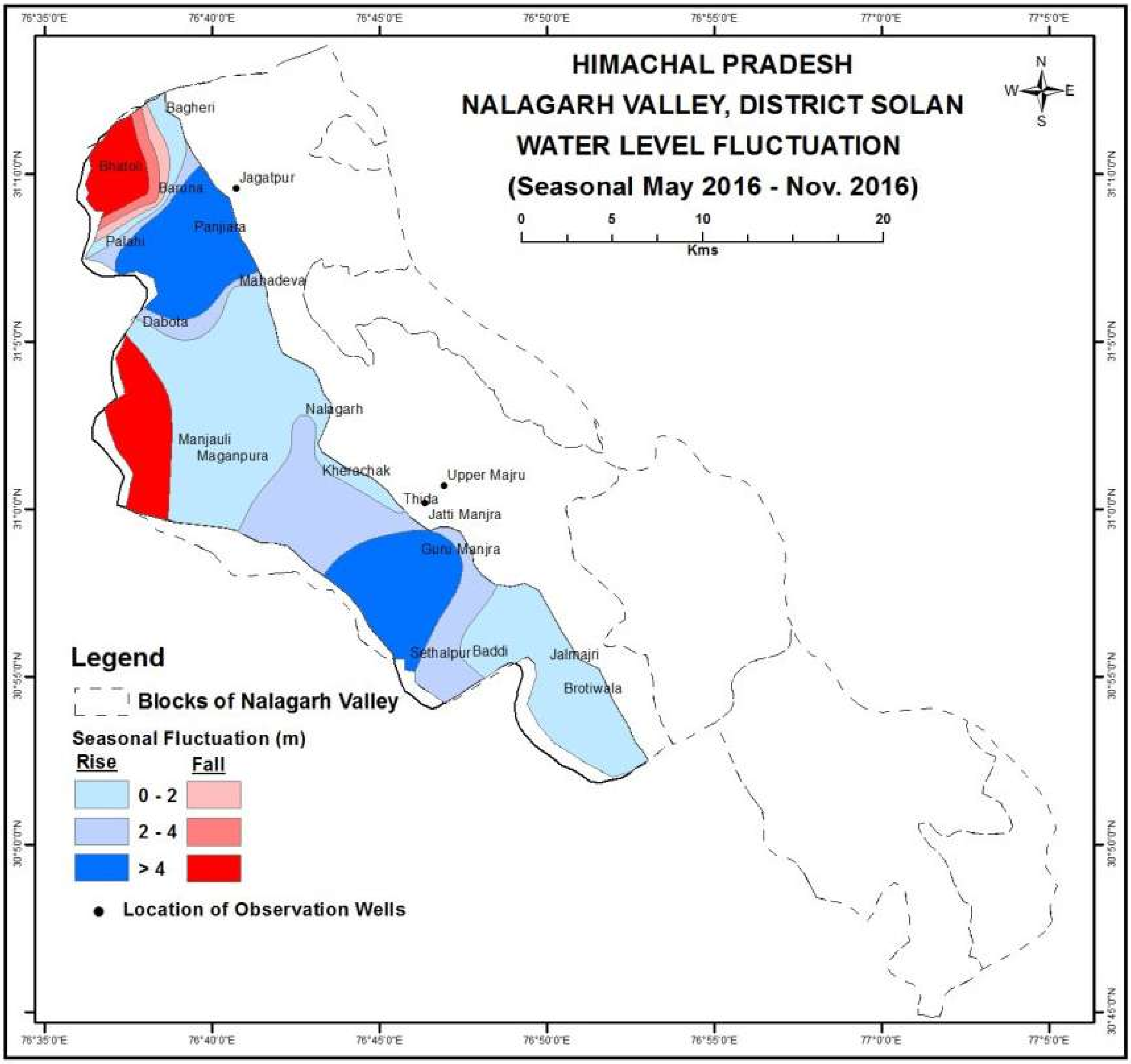


Fig. 2.5 Seasonal Water Level Fluctuation – May 2016 & November 2016, Nalagarh Valley, Solan District

Annual fluctuation in water level of GWMS and Aquifer Mapping Wells during different monitoring periods were analysed and discussed below.

November 2014 & November 2015

To know the annual water level fluctuation and its behavior with respect to time and space, 15 dug wells have been inventoried for Ground Water Management Studies all over the Nalagarh Valley area. The water levels were taken during the month of November, 2014 & November 2015 and on the basis of these data, annual fluctuation map have been prepared for the Nalagarh valley area. The hydrogeological data of the inventoried dug wells are given in Table 2.2.

Table 2.2 Water level data (Nov. 2014 and Nov. 2015) GWMS and Aquifer Mapping Wells of Nalagarh Valley, Solan District, Himachal Pradesh

Location	Latitude	Longitude	November 2014	November 2015	Annual Fluctuation
Kherachak	31.0138	76.7199	5.67	4.85	0.82
Jagatpur	31.1594	76.6785	18.2	14.20	4.00
Bagheri	31.1942	76.6421	16	17.80	-1.80
Bhatoli	31.1651	76.6082	10.66	11.30	-0.64
Baruna	31.1540	76.6384	27.95	22.20	5.75
Palahi	31.1276	76.6118	5.2	5.95	-0.75
Mahadeva	31.1084	76.6786	12.75	12.50	0.25
Panjiara	31.1350	76.6566	19.3	19.10	0.20
Dabota	31.0875	76.6303	11.05	12.45	-1.40
Brotiwala	30.9055	76.8399	25.2	24.40	0.80
Jatti Manjra	31.0030	76.7725	9.85	8.4	1.45
Guru Manjra	30.9746	76.7693	16.18	15.4	0.78
Sethalpur	30.9231	76.7925	5.3	4.2	1.10
Nalagarh	31.0441	76.7120	5.24	7.1	-1.86
Maganpura	31.0288	76.6575	6.5	5.85	0.65

During the period of November 2014 water level ranges from 5.20 to 27.95 m bgl (Fig.2.6) and November 2015 water level ranges from 4.85 to 24.40 m bgl. (Fig.2.7) and Annual Water Level Fluctuation ranges between -1.86 to 5.75 m bgl (Fig. 2.8).

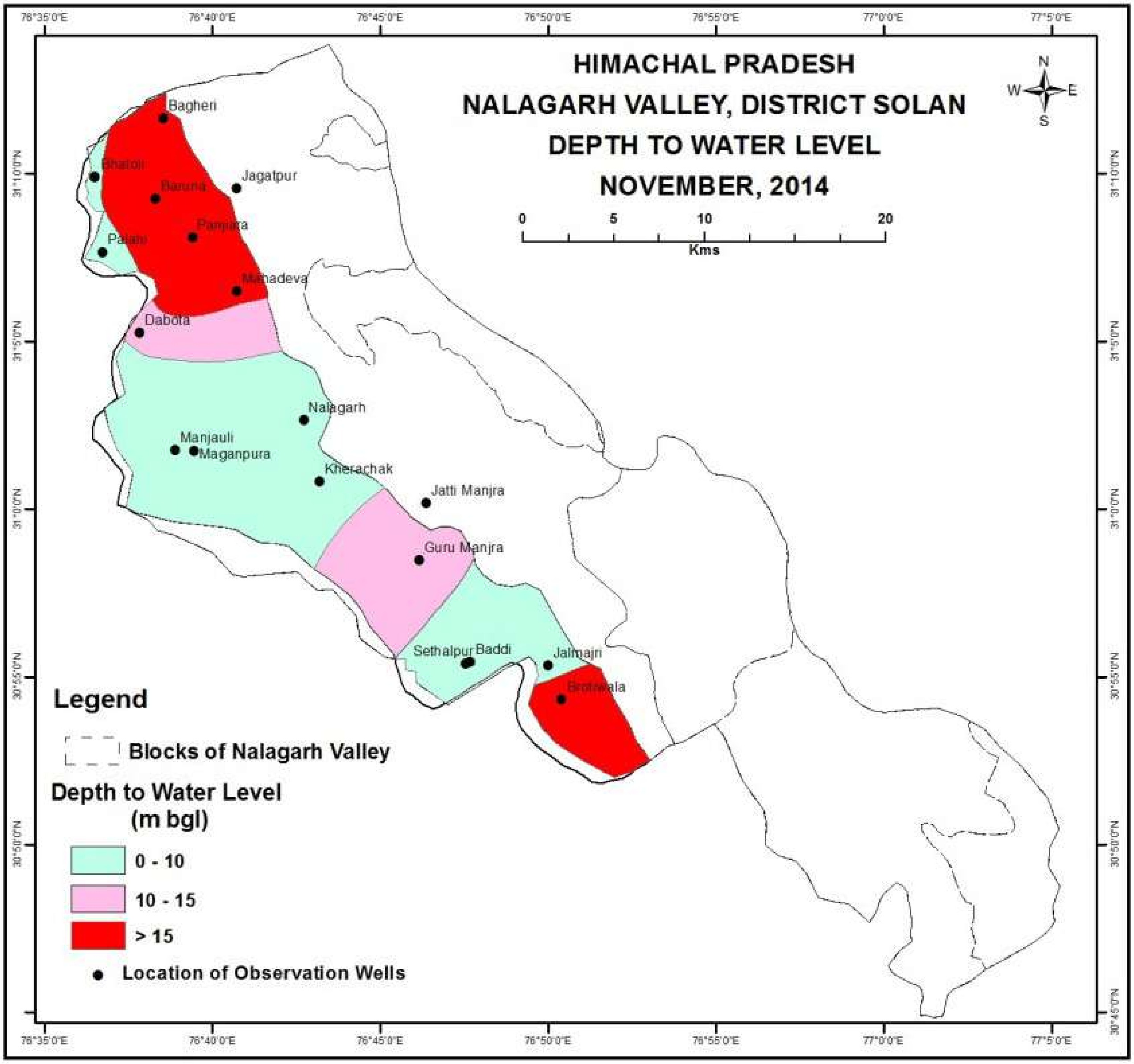


Fig. 2.6 Depth Water Level – November 2014, Nalagarh Valley, Solan District

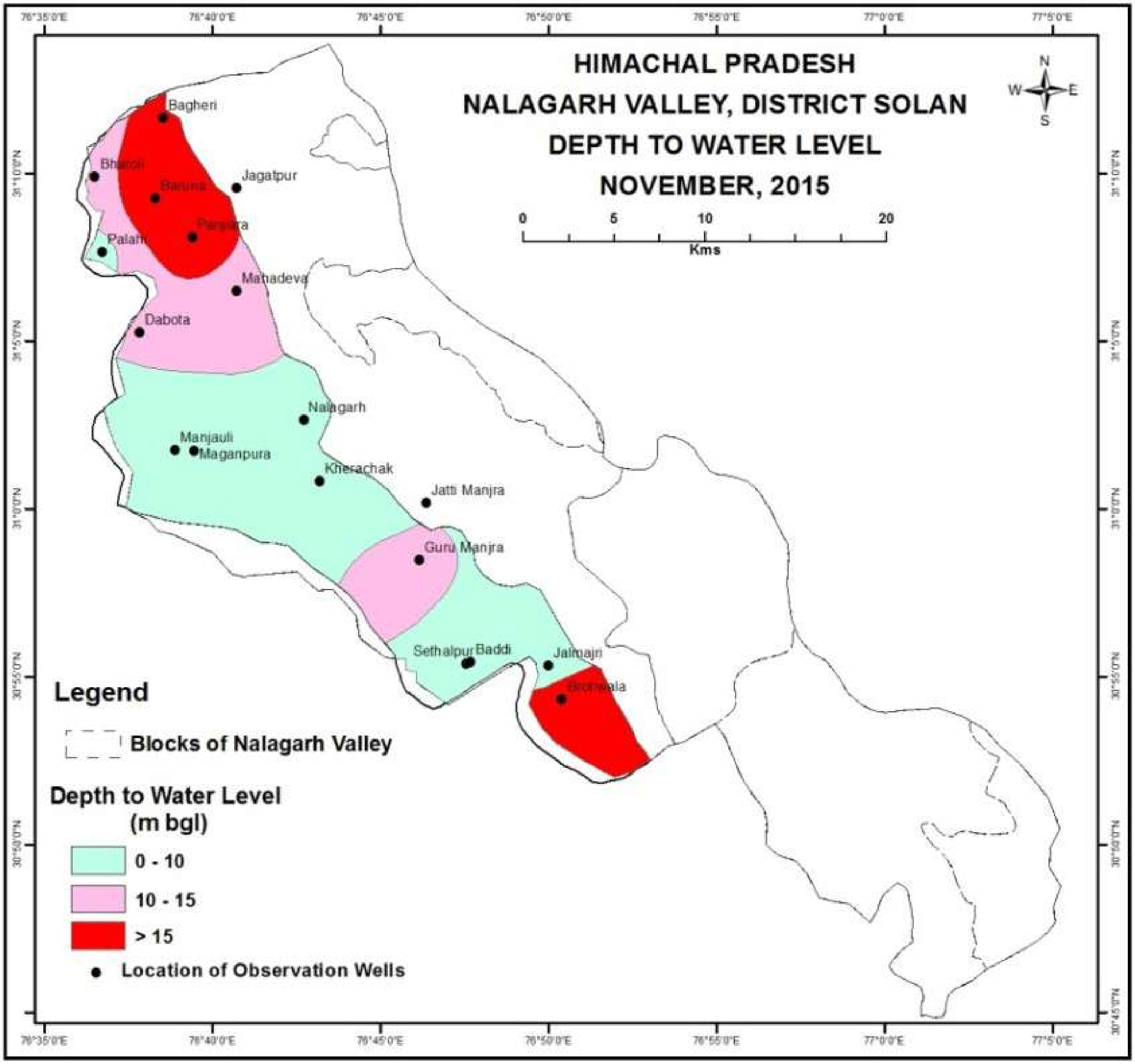


Fig. 2.7 Depth Water Level – November 2015, Nalagarh Valley, Solan District

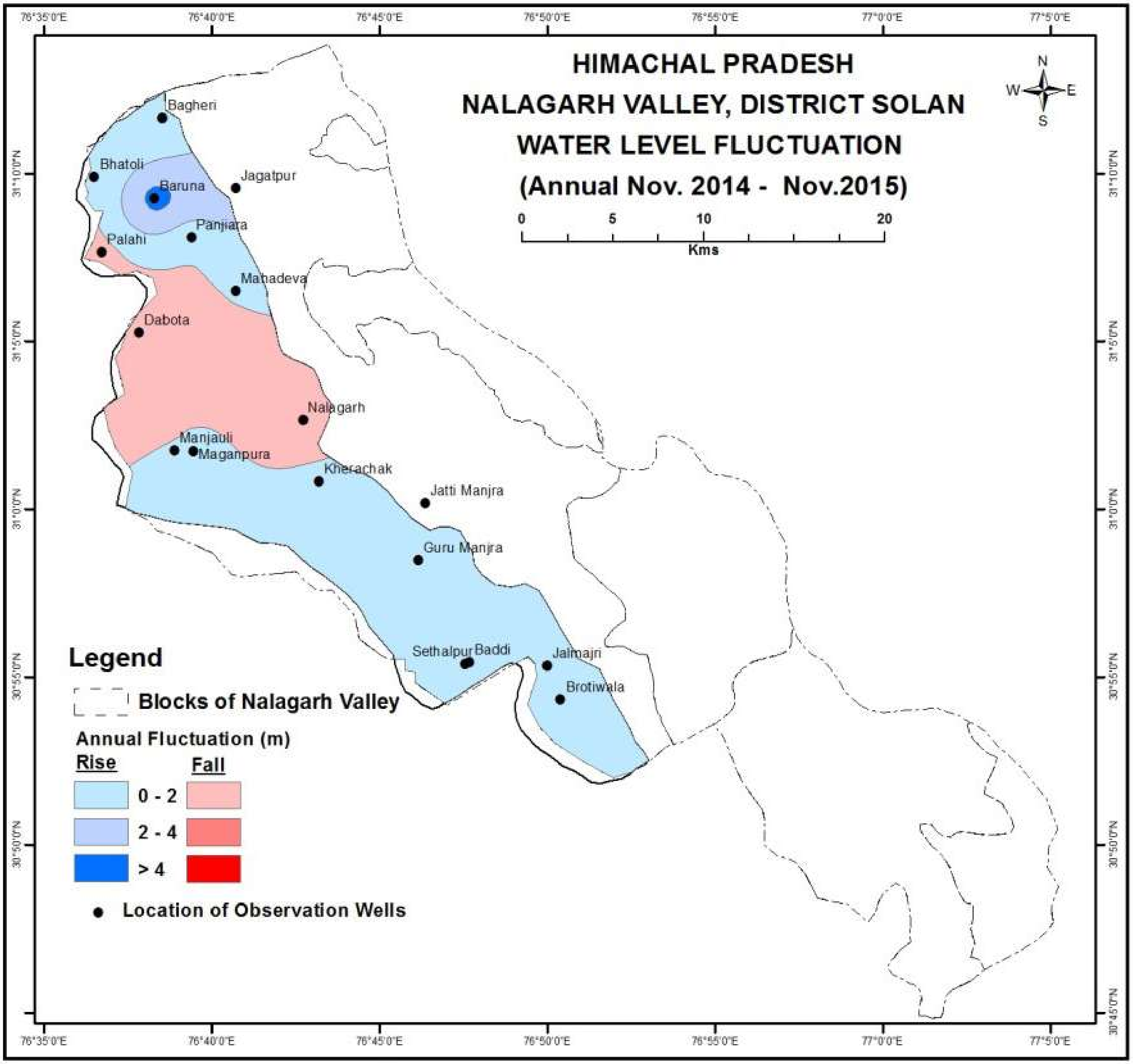


Fig. 2.8 Annual Water Level Fluctuation – November 2014 & November 2015, Nalagarh Valley, Solan District

January 2015 & January 2016

15 Nos. dug well water levels were taken during the month of January, 2015 & January 2016 on the basis of these data, annual fluctuation map have been prepared for the Nalagarh valley area. The hydrogeological data of the inventoried dug wells are given in Table 2.3. During the period of January 2015 water level ranges from 5.50 to 28.75 m bgl (Fig.2.9) and January 2016 water level ranges from 3.30 to 26.85 m bgl. (Fig.2.10) and Annual Water Level Fluctuation ranges between – 4.44 to 4.80 m bgl (Fig. 2.11).

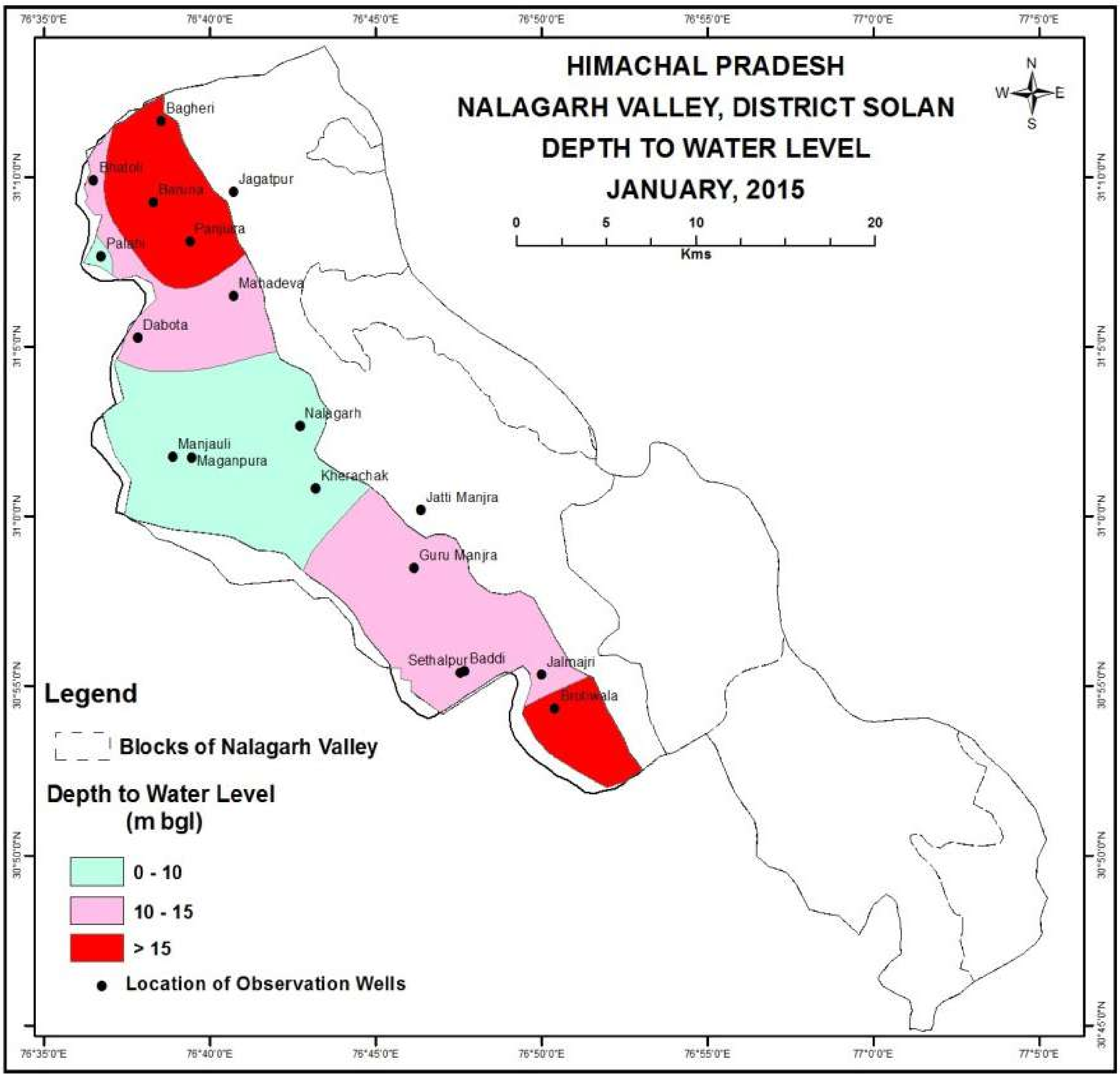


Fig. 2.9 Depth Water Level – January 2015, Nalagarh Valley, Solan District

Table 2.3 Water level data (January. 2015 and January. 2016) GWMS and Aquifer Mapping Wells of Nalagarh Valley, Solan District, Himachal Pradesh

Location	Latitude	Longitude	January 2015	January 2016	Annual Fluctuation
Kherachak	31.0138	76.7199	5.75	6.20	-0.45
Jagatpur	31.1594	76.6785	16.85	18.75	-1.90
Bagheri	31.1942	76.6421	15.46	19.90	-4.44
Bhatoli	31.1651	76.6082	12.90	12.50	0.40
Baruna	31.1540	76.6384	28.75	23.95	4.80
Palahi	31.1276	76.6118	6.28	3.30	2.98
Mahadeva	31.1084	76.6786	12.10	13.35	-1.25
Panjiara	31.1350	76.6566	20.50	20.80	-0.30
Dabota	31.0875	76.6303	12.35	12.65	-0.30
Brotiwala	30.9055	76.8399	26.70	26.85	-0.15
Jatti Manjra	31.0030	76.7725	10.95	11.95	-1.00
Guru Manjra	30.9746	76.7693	18.01	18.79	-0.78
Sethalpur	30.9231	76.7925	6.2	6.8	-0.60
Nalagarh	31.0441	76.7120	5.8	6.1	-0.30
Maganpura	31.0288	76.6575	5.5	5.45	0.05

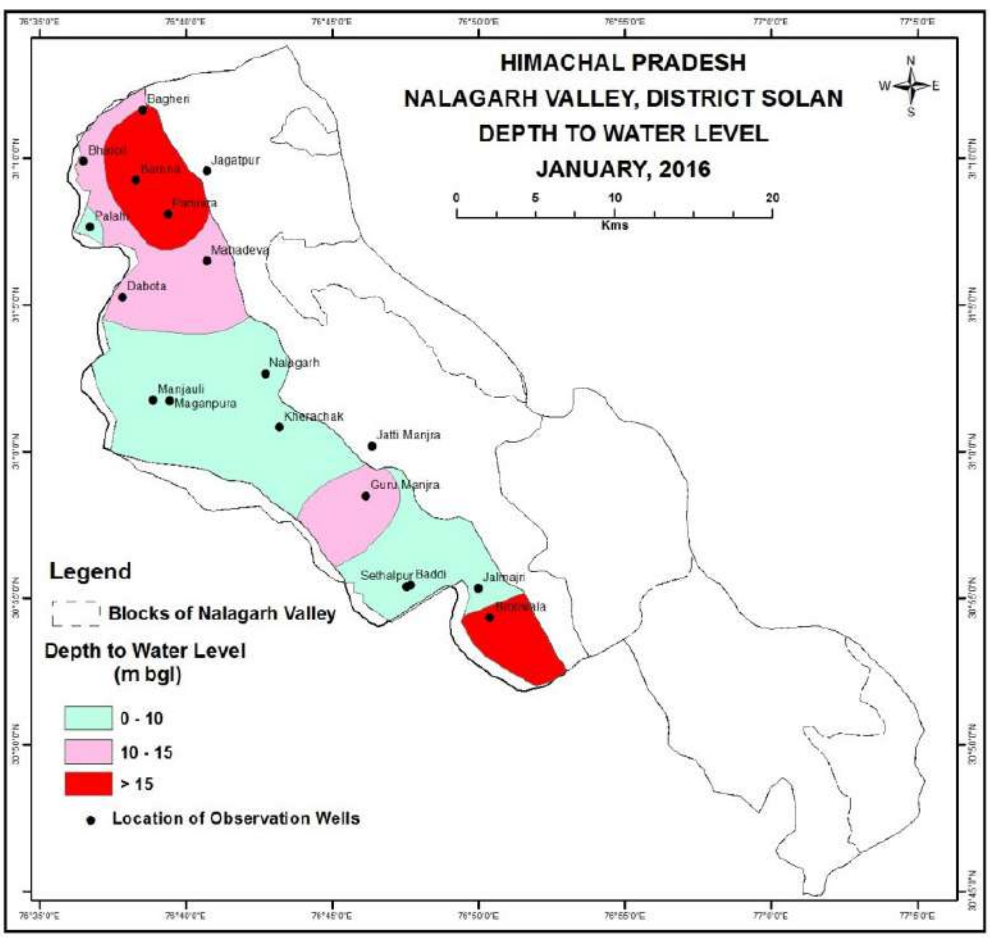


Fig. 2.10 Depth Water Level – January 2016, Nalagarh Valley, Solan District

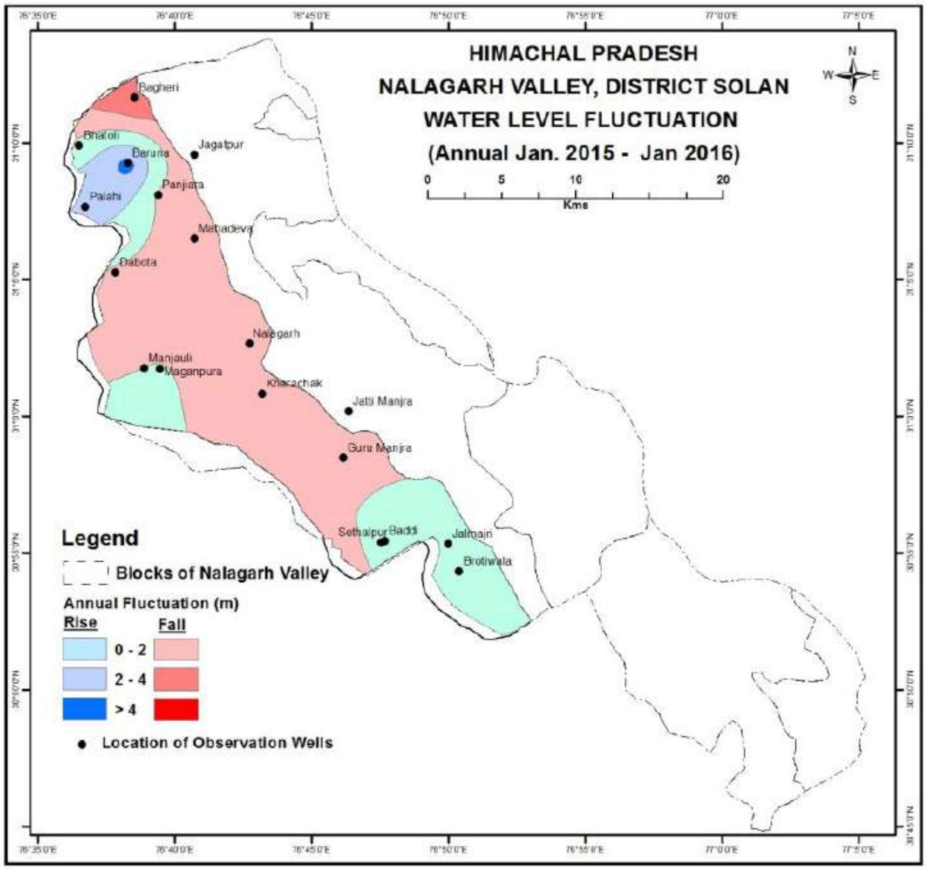


Fig. 2.11 Annual Water Level Fluctuation January 2015 & January 2016, Nalagarh Valley, Solan District

May 2015 & May 2016

17 Nos. dug well water levels were taken during the month of May, 2015 & May 2016 on the basis of these data, annual fluctuation map have been prepared for the Nalagarh valley area. The hydrogeological data of the inventoried dug wells are given in Table 2.4. During the period of May 2015 water level ranges from 1.50 to 35.00 m bgl (Fig.2.12.) and January 2016 water level ranges from 1.95 to 27.50 m bgl. (Fig.2.13.) and Annual Water Level Fluctuation ranges between – 5.70 to 10.72 m bgl (Fig. 2.14).

Table 2.4 Water level data (May 2015 and May 2016) GWMS and Aquifer Mapping Wells of Nalagarh Valley, Solan District, Himachal Pradesh

Location	Latitude	Longitude	May 2015	May 2016	Annual Fluctuation
Kherachak	31.0138	76.7199	6.65	6.95	-0.30
Jagatpur	31.1594	76.6785	18	21.40	-3.40
Bagheri	31.1942	76.6421	19.3	21.60	-2.30
Bhatoli	31.1651	76.6082	12.90	13.00	-0.10
Baruna	31.1540	76.6384	29.25	22.95	6.30

Palahi	31.1276	76.6118	6.40	6.15	0.25
Mahadeva	31.1084	76.6786	13.35	14.15	-0.80
Panjiara	31.1350	76.6566	21.30	27.00	-5.70
Dabota	31.0875	76.6303	13.45	13.25	0.20
Brotiwala	30.9055	76.8399	26.90	27.50	-0.60
Jatti Manjra	31.0030	76.7725	12.45	12.25	0.20
Guru Manjra	30.9746	76.7693	35	24.28	10.72
Sethalpur	30.9231	76.7925	6.6	7.1	-0.50
Nalagarh	31.0441	76.7120	7.25	6.3	0.95
Maganpura	31.0288	76.6575	6.2	5.9	0.30
Thida	30.9997	76.7601	6.4	6.3	0.10
Upper Majru	31.0115	76.7820	1.5	1.95	-0.45

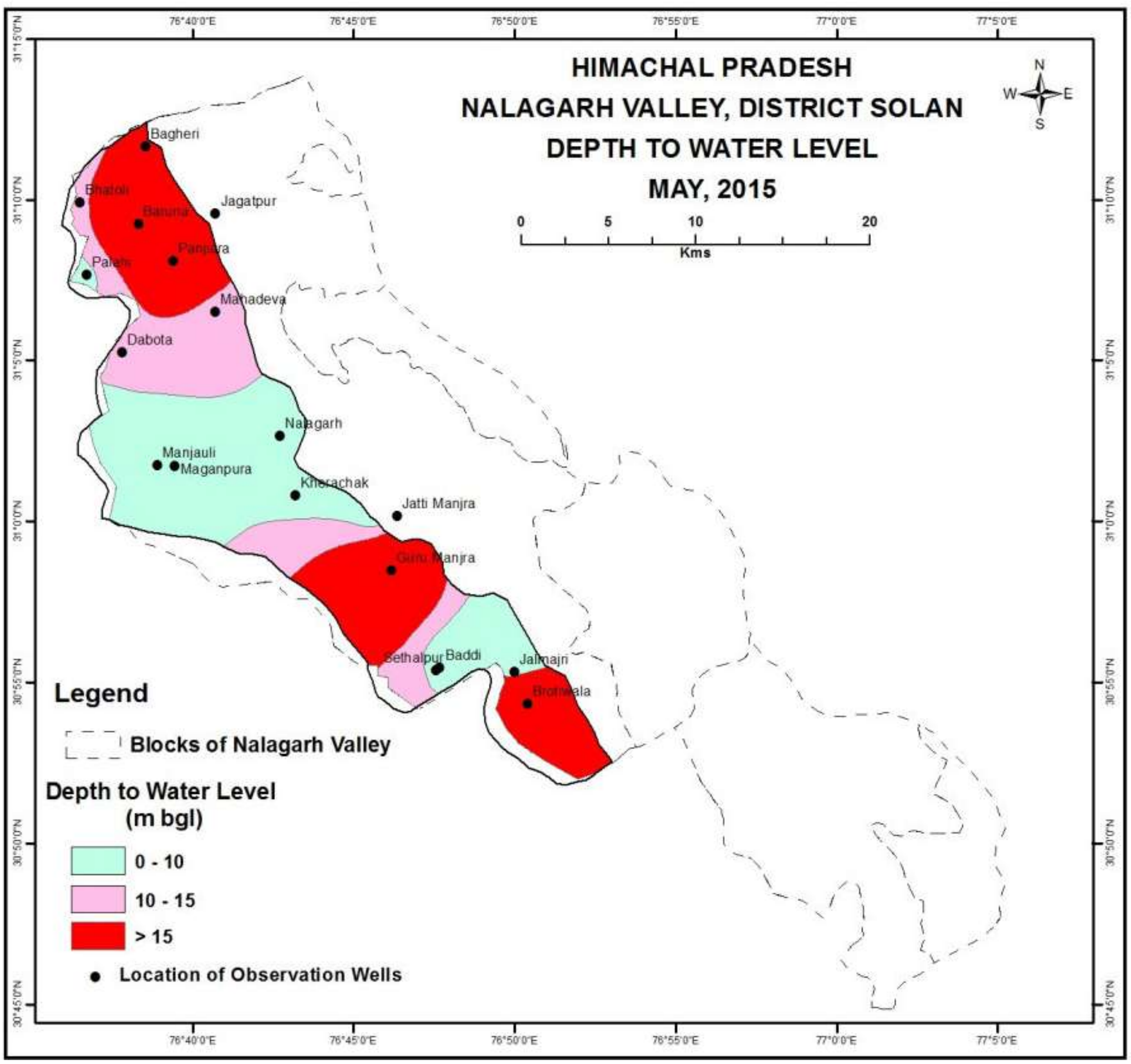


Fig. 2.12 Depth Water Level – May, 2015, Nalagarh Valley, Solan District

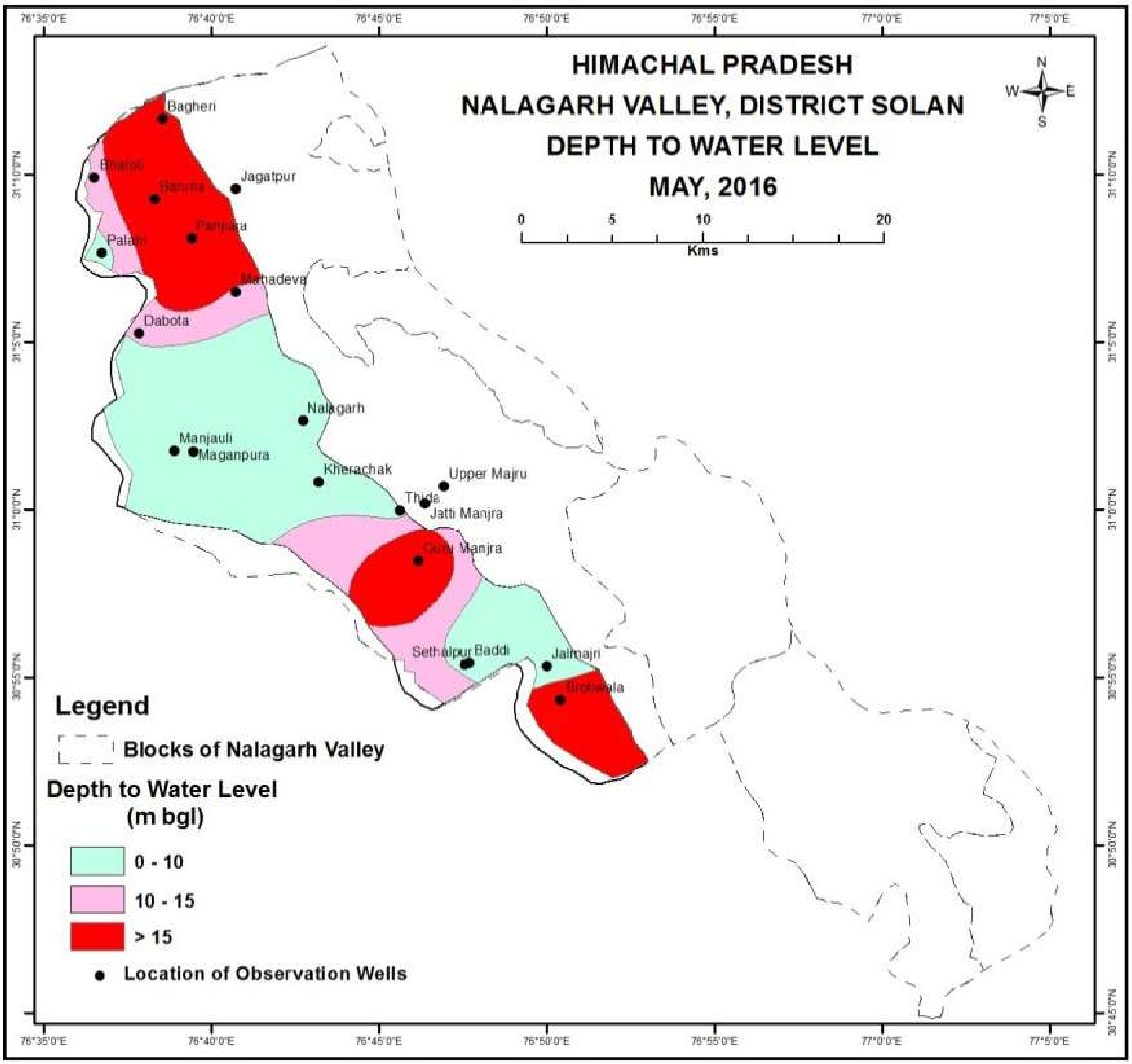


Fig. 2.13 Depth Water Level – May, 2016, Nalagarh Valley, Solan District

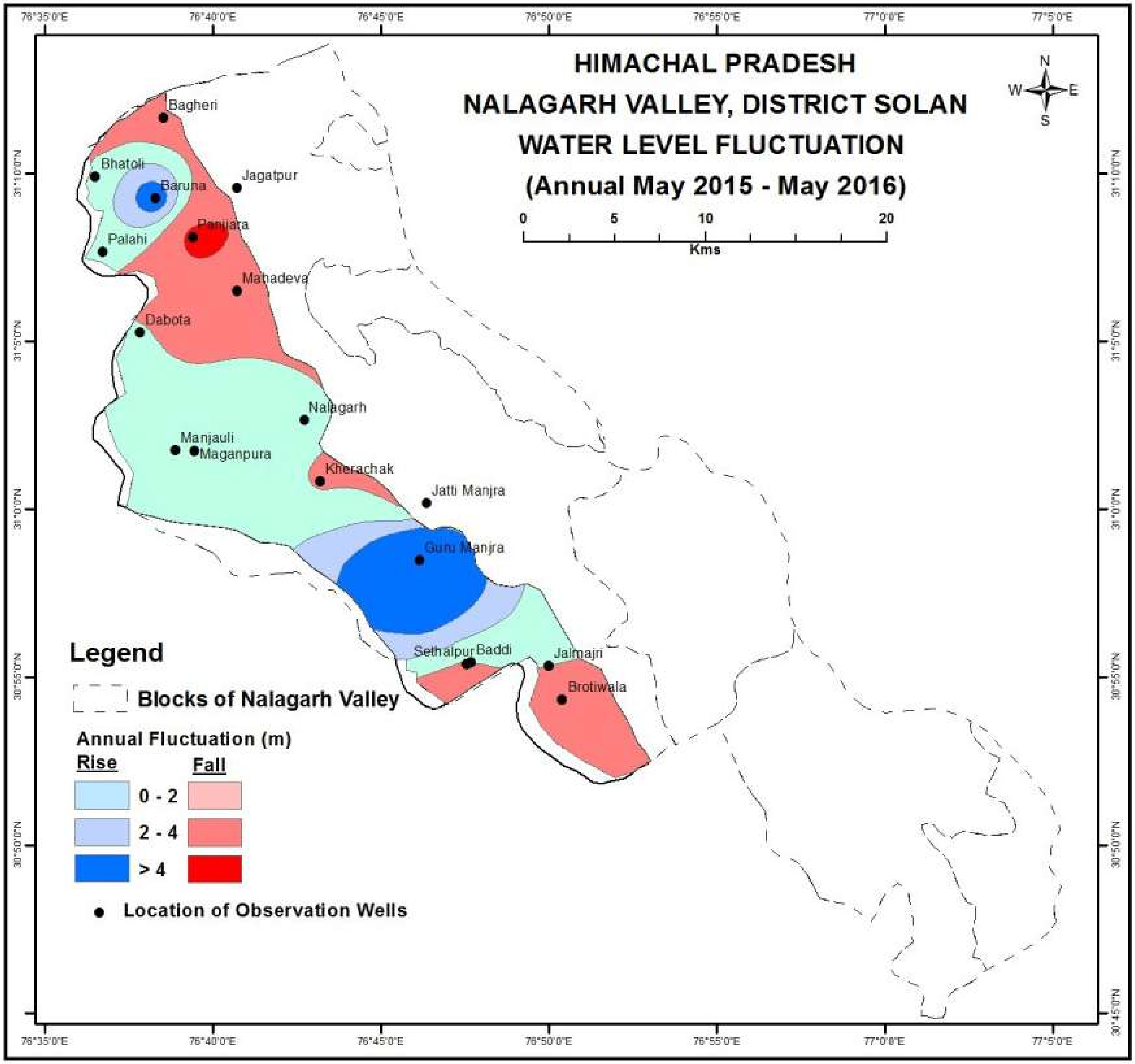


Fig. 2.14 Annual Water Level Fluctuation May 2015 & May 2016, Nalagarh Valley, Solan District

August 2015 & August 2016

19 Nos. dug well water levels were taken during the month of August, 2015 & August 2016 on the basis of these data, annual fluctuation map have been prepared for the Nalagarh valley area. The hydrogeological data of the inventoried dug wells are given in Table 2.5. During the period of August 2015 water level ranges from 1.00 to 24.05 m bgl (Fig.2.15.) and August 2016 water level ranges from 0.00 to 27.40 m bgl. (Fig.2.16.) and Annual Water Level Fluctuation ranges between – 15.85 to 19.30m bgl (Fig. 2.17).

Table 2.5 Water level data (August 2015 and August 2016) GWMS and Aquifer Mapping Wells of Nalagarh Valley, Solan District, Himachal Pradesh

Location	Latitude	Longitude	August 2015	August 2016	Annual Fluctuation
Manjauli	31.0291	76.6482	2.35	0.00	2.35
Kherachak	31.0138	76.7199	4.15	4.80	-0.65
Jagatpur	31.1594	76.6785	12.65	19.95	-7.30
Bagheri	31.1942	76.6421	17.40	21.41	-4.01
Bhatoli	31.1651	76.6082	10.60	26.45	-15.85
Baruna	31.1540	76.6384	24.05	27.40	-3.35
Palahi	31.1276	76.6118	2.65	4.75	-2.10
Mahadeva	31.1084	76.6786	10.20	13.68	-3.48
Panjiara	31.1350	76.6566	19.30	0.00	19.30
Dabota	31.0875	76.6303	12.75	13.25	-0.50
Baddi	30.9242	76.7944	5.30	5.65	-0.35
Brotiwala	30.9055	76.8399	22.10	23.48	-1.38
Jatti Manjra	31.0030	76.7725	8.65	10.63	-1.98
Guru Manjra	30.9746	76.7693	17.28	19.34	-2.06
Sethalpur	30.9231	76.7925	3.2	4.35	-1.15
Nalagarh	31.0441	76.7120	3.23	4.72	-1.49
Maganpura	31.0288	76.6575	5.04	5.7	-0.66
Thida	30.9997	76.7601	2.9	4.04	-1.14
Upper Majru	31.0115	76.7820	1	0.9	0.10

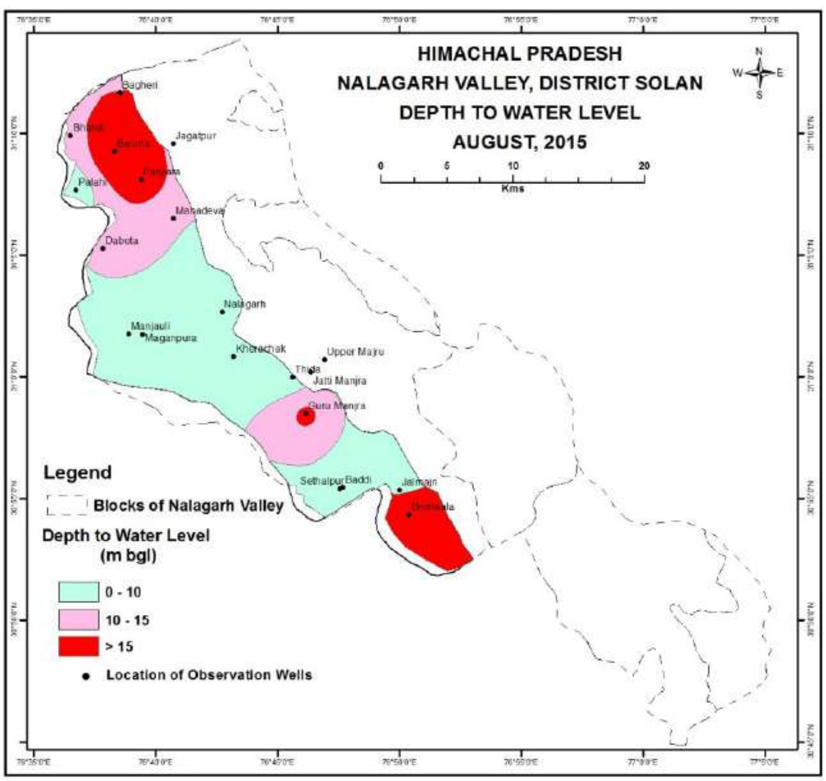


Fig. 2.15 Depth Water Level – August, 2015, Nalagarh Valley, Solan District

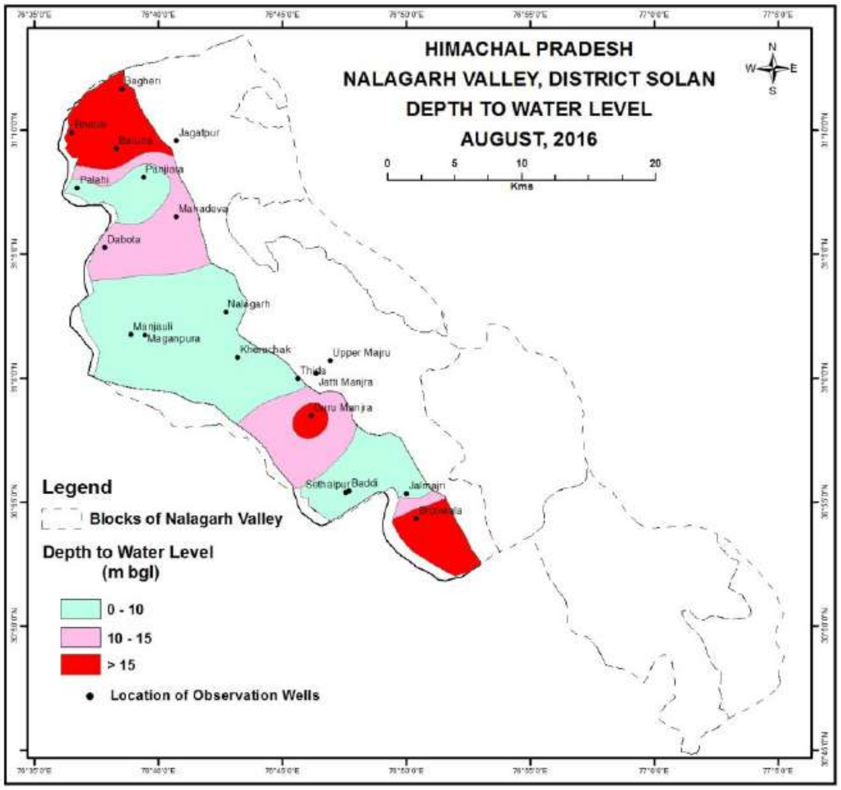


Fig. 2.16 Depth Water Level – August, 2016, Nalagarh Valley, Solan District

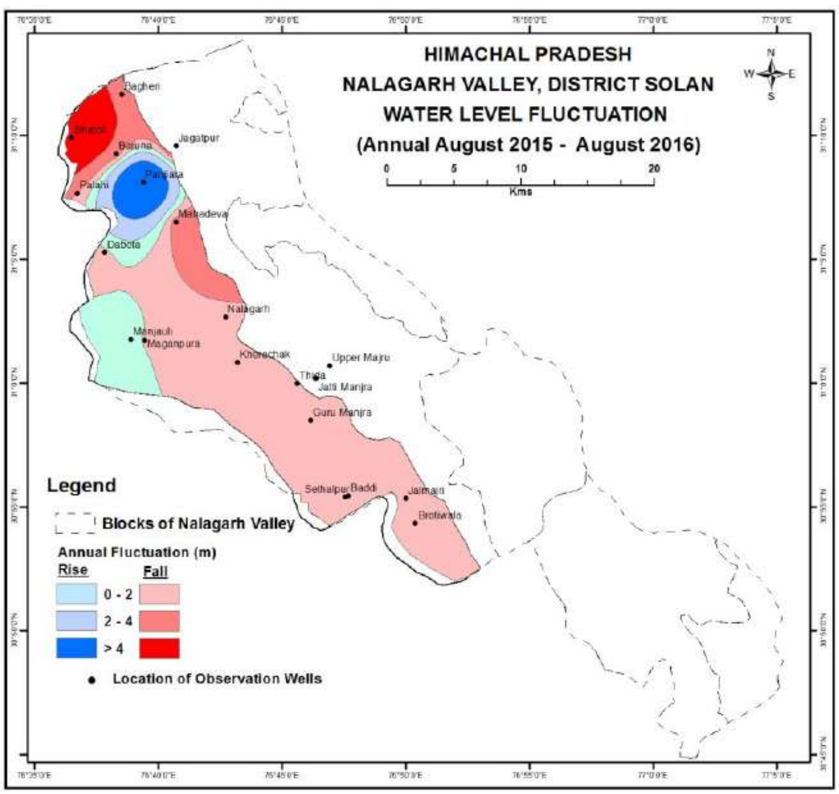


Fig. 2.17 Annual Water Level Fluctuation August 2015 & August 2016, Nalagarh Valley, Solan District

2.2. Exploratory Drilling – CGWB & I& PH Wells

The Lithologs 25 Nos. of Exploratory Well productive wells of CGWB, Irrigation and Public Health Department (I &PH) have been collected and those supported electrical logs 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 2.6 Data availability of exploration wells in Nalagarh Valley, Solan District.

Table of Wells, Nalagarh Valley			
Agency	**Well Depth (meters)**		
	<100	**100-150**	**>150**
CGWB	2	6	1
I & PH	4	12	-
Total	**6**	**18**	**1**

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 2.8 respectively. 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 6×10^{-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 2.10 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.

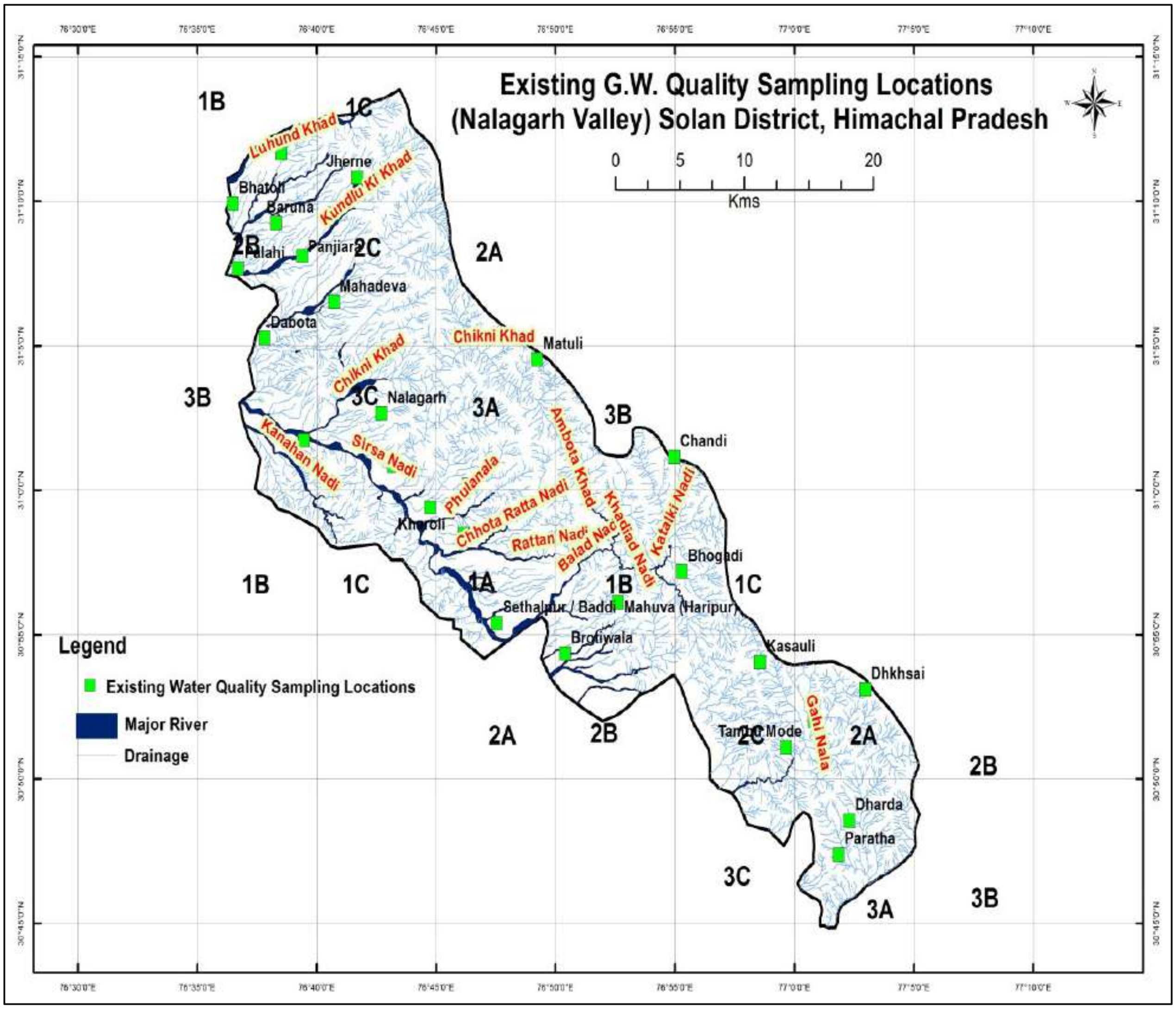


Fig-2.18 Locations of Water Samples for Ground Water Quality Nalagarh Valley, Solan District.

Table 2.11 Ground Water Quality Results (2014) in Nalagarh Valley, Solan District.

Location	PH	EC (us/cm)	TA	TDS	TH	Ca	Mg	Na	K	HCO_3	CL	SO_4	NO_3	F
	(mg/l)													
Kherachak	6.95	710	210	369	235	54	24	79	6.6	256	89	46	32	0.19
Brotiwala	7.23	890	320	463	375	120	18	47	2.2	391	60	7	83	0.07
Dabota	7.16	890	295	463	310	70	33	65	2	360	53	49	40	0.07
Mahadeva	7.36	830	245	432	245	46	32	86	2	299	92	37	26	0.08
Jagatpur	7.51	480	190	250	160	40	16	45	3	232	21	14	29	0.17
Panjiara	7.62	390	175	203	145	38	12	30	3.8	214	11	22	2	0.32
Baruna	7.99	740	350	385	330	96	22	30	2.4	427	32	2	1	0.03
Bagheri	7.43	1180	335	614	390	116	24	96	1.4	409	96	1	160	0.26
Bhatoli	7.4	590	265	307	250	34	40	30	2	323	18	0	35	0.04
Palahi	7.81	680	330	354	255	48	33	46	2.3	403	14	1	8	0.25

Jatti Majra	7.83	570	140	296	220	44	27	29	1	171	36	47	57	0.06
Guru Majra	7.76	480	150	250	195	30	29	33	2	183	36	49	22	0.17
Sethalpur/Baddi	7.78	580	135	302	230	44	29	38	2.4	165	71	54	30	0.12
Nalagarh	7.8	920	195	478	280	30	50	92	0.51	238	117	54	80	0.37
Maganpura	6.98	1100	289	572	340	72	39	96	5.4	353	167	2	35	0.15
Tambu Mode	7.83	290	150	151	135	36	11	13	1.3	183	7	4	0	0.17
Jherne	7.93	610	235	317	185	24	30	59	5.8	287	21	41	16	0.18
Sherla	8.16	600	280	312	250	52	29	20	3.7	341	11	2	0	0.2
Dharda	8.28	680	325	354	285	22	56	28	3.8	397	14	3	2	0.11
Paratha	7.95	460	225	239	205	36	28	17	1.3	274	11	3	0	0.12
Dhkhsai	7.7	790	170	411	345	68	43	26	1.3	208	75	116	9	0.34
Kasauli	8	480	175	250	210	50	21	26	1.3	214	21	52	11	0.27
Kharoli	7.68	780	250	406	285	54	37	72	2.3	305	64	58	55	0.05
Haripur	8.04	540	225	281	170	32	22	47	3.3	275	18	25	0	0.06
Bhogadi	6.9	590	205	307	105	30	7	83	5.3	250	18	10	65	0.72
Chandi	6.99	730	185	380	330	58	22	46	1.5	226	87	77	51	0.07
Matuli	8.24	590	260	307	120	20	17	88	2.6	317	14	32	1	0.04

To assess the impact of ground water quality, 27 numbers of water samples were collected from the study area of Nalagarh Valley of district Solan in 2014, as per the list below:

Sr.No	Type of Source	Total Nos.
1	Dug Well	15 Nos.
2	Hand Pump	10 Nos.
3	Spring	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 2.12 General ranges of water quality parameters of study area

Sr.No	Water Quality Parameters	Minimum	Maximum
1.	PH	6.95	8.28
2.	E.C Sp. Cond. µmhos/cm at 25°C	290	1180
3.	CO_3 (mg/l)	0	
4.	HCO_3 (mg/l)	165	427
5.	CL (mg/l)	7	167
6.	NO3(mg/l)	0	160
7.	F (mg/l)	0.03	0.72
8.	Ca (mg/l)	20	120
9.	Mg (mg/l)	7	56
10.	Na (mg/l)	13	96
11.	K (mg/l)	0.51	6.6
12.	TH (mg/l)	105	390

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 6.9 (Bhogadi) to 8.28 (Dharda). Ground water of the area is alkaline in nature (Fig-2.19).

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 1180 micromhos /cm is determined in the sample collected from Bagheri, Solan District (Fig-2.20).

Bicarbonate

Overall value of Bicarbonate varies from 165 (Sethalpur/ Baddi) to 427(Baruna) mg/l. Maximum concentration of Bicarbonate is noticed in all samples collected from Shallow depth (Fig-2.21).

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 7 mg/l (Tambu Mode) to 167 mg/l (Maganpura) (Fig-2.22).

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, Nitrate concentration varies from minimum 0 to a maximum concentration of Nitrate 160 (Bagheri) mg/l (Fig-2.23).

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 0.03 (Baruna) and 0.72 mg/l (Bhogadi) (Fig-2.24).

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-2.25).

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.

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-2.26).

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 0.03 (Baruna) and 0.72 mg/l (Bhogadi) (Fig-2.27).

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 0.03 (Baruna) and 0.72 mg/l (Bhogadi) (Fig-2.28).

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 105 mg/l (Bhogadi) to 390mg/l (Bagheri) (Fig-2.29).

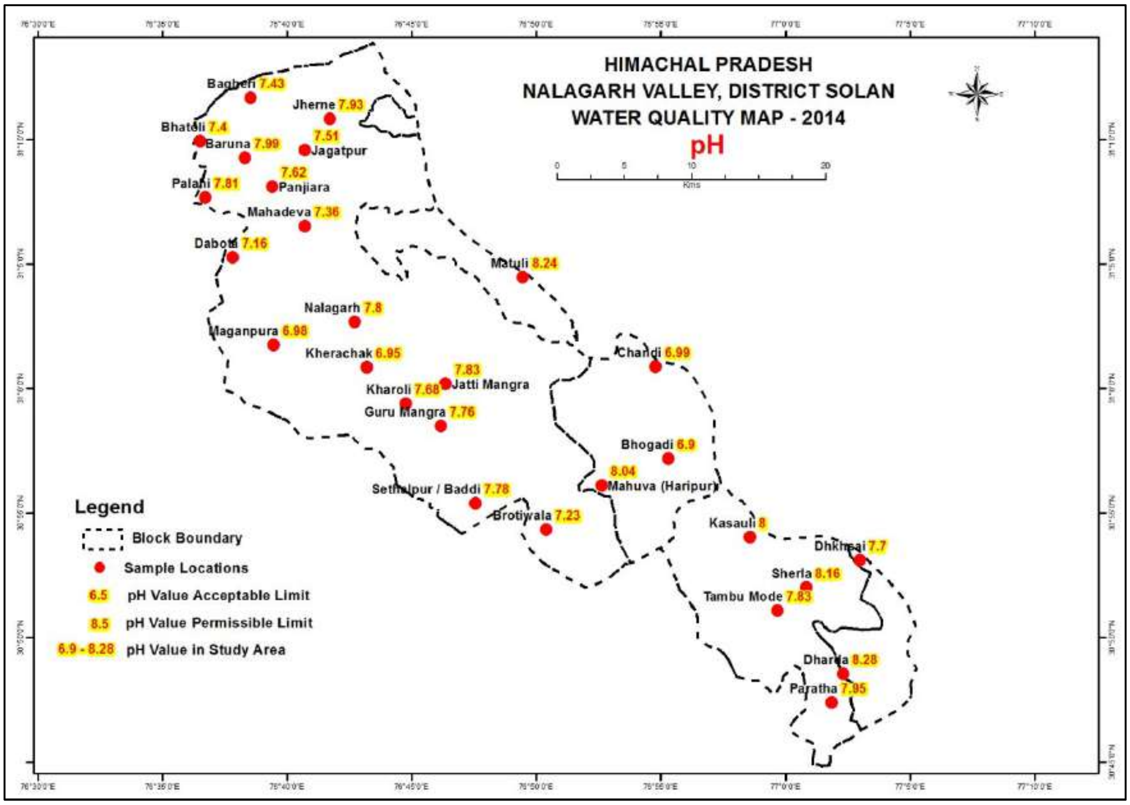


Fig-2.19 pH (2014) Nalagarh Valley, Solan District

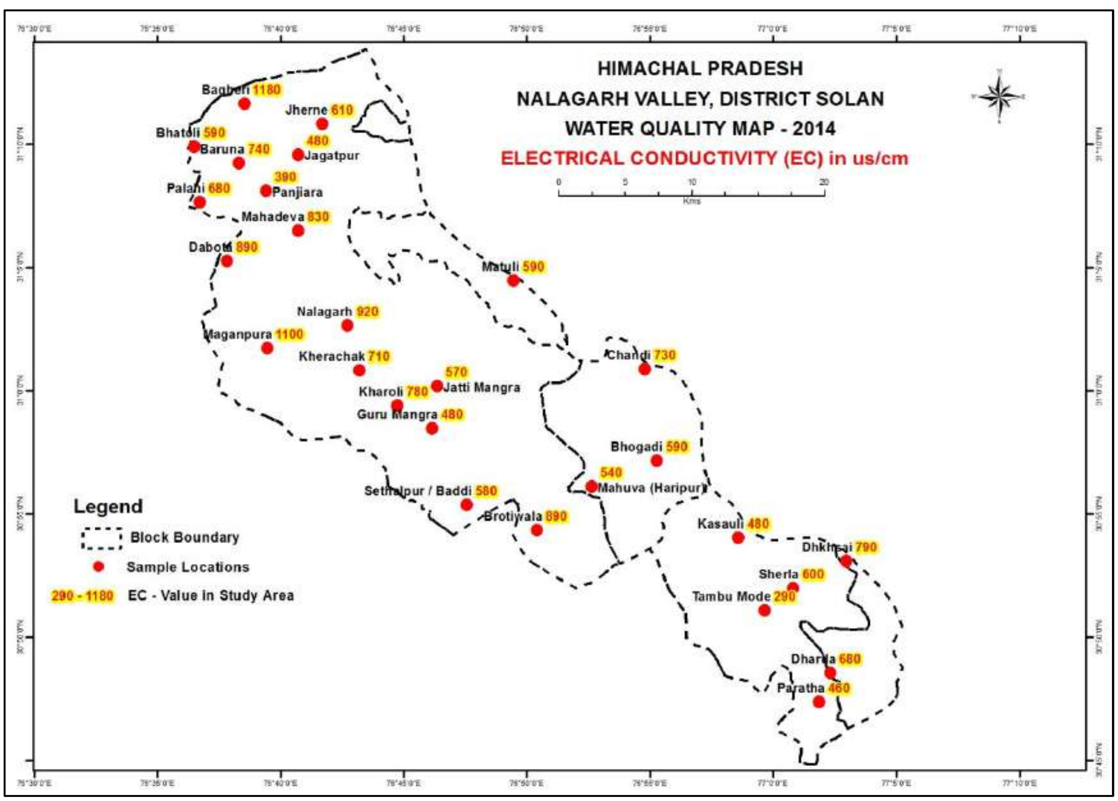


Fig-2.20 Electrical Conductivity (2014) Nalagarh Valley, Solan District

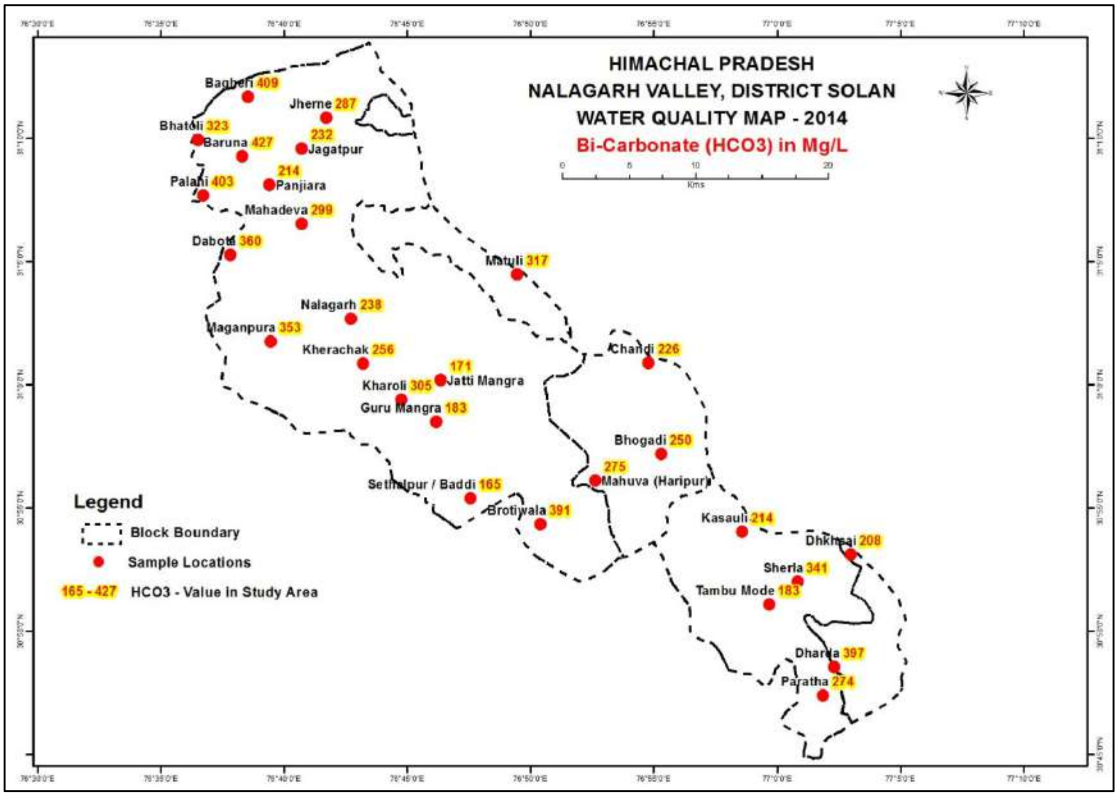


Fig. 2.21 Bi-Carbonate (2014) Nalagarh Valley, Solan District

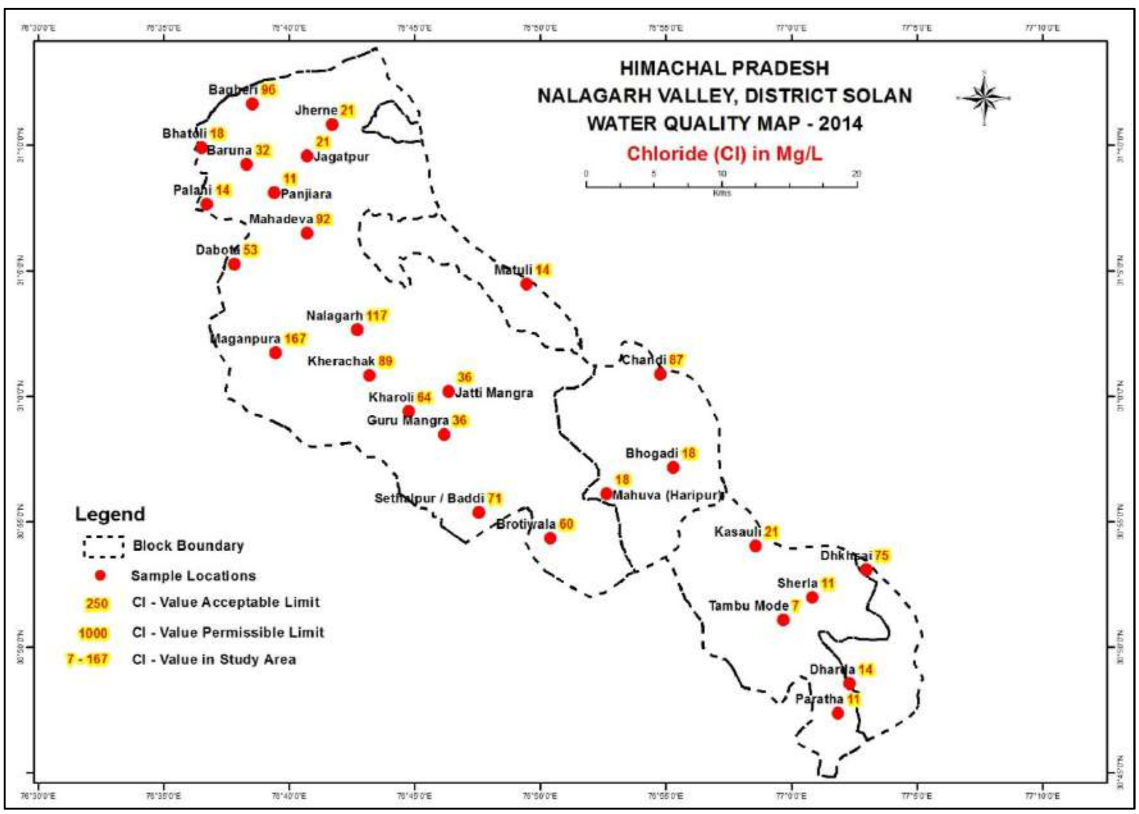


Fig 2.22 Chloride (2014) Nalagarh Valley, Solan District

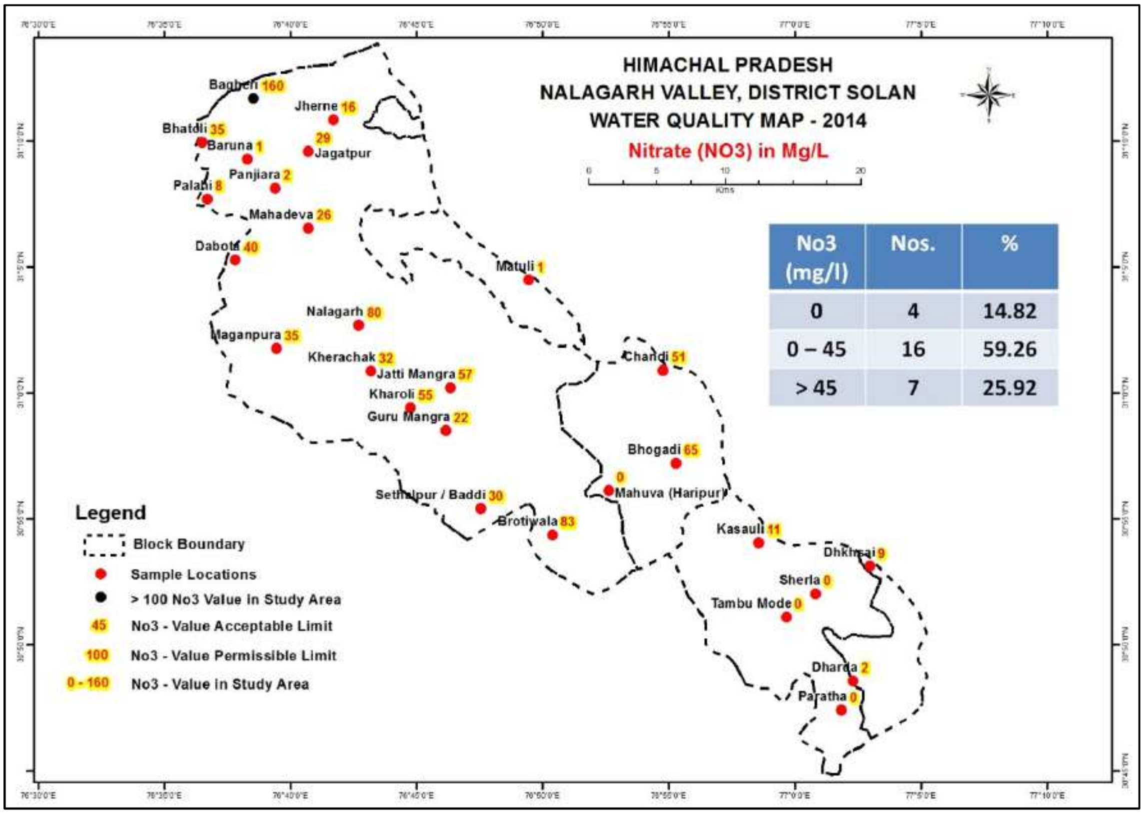


Fig-2.23 Nitrate (2014) Nalagarh Valley, Solan District

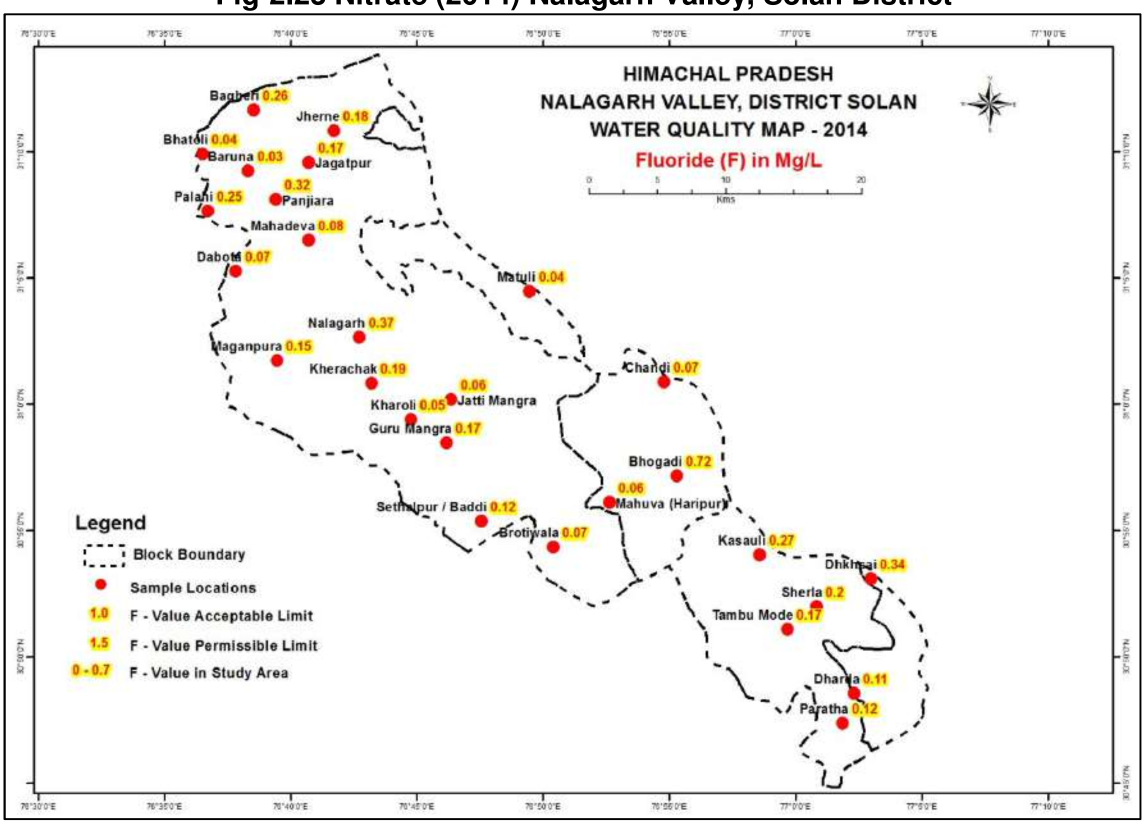


Fig- 2.24 Fluoride (2014) Nalagarh Valley, Solan District

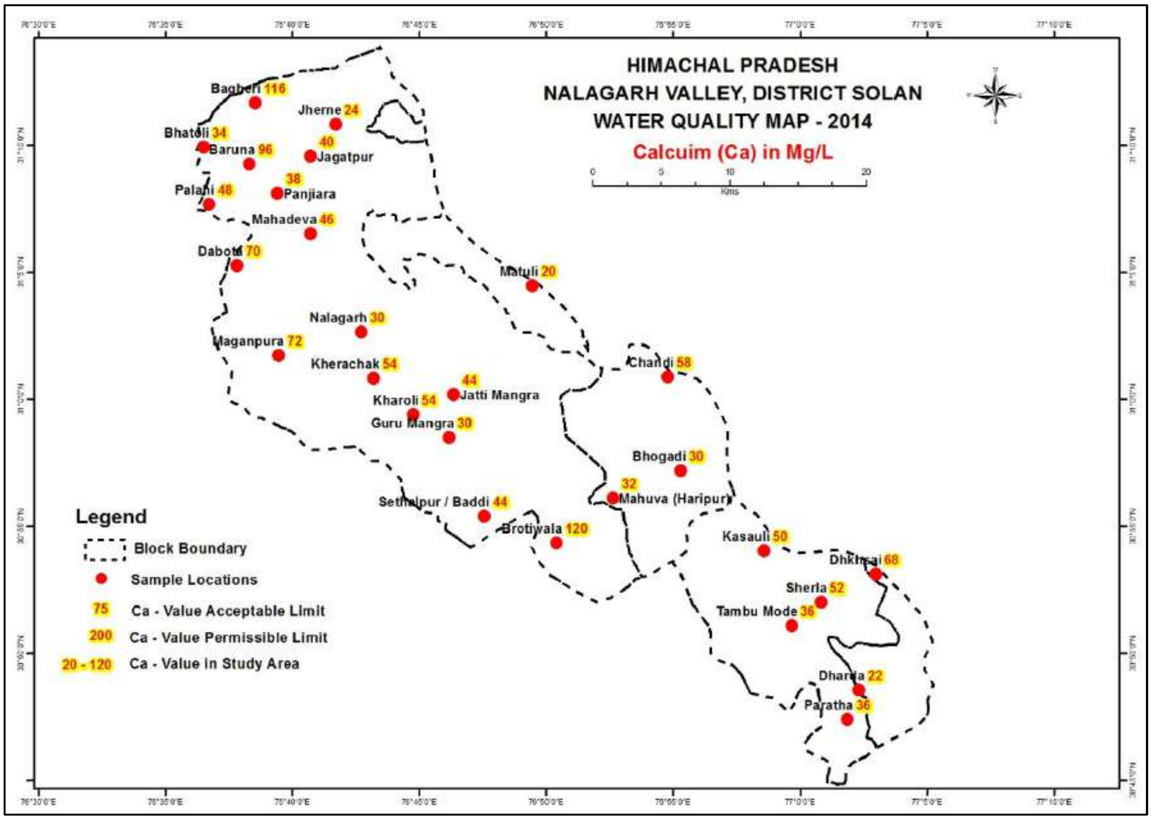


Fig- 2.25 Calcium (2014) Nalagarh Valley, Solan District

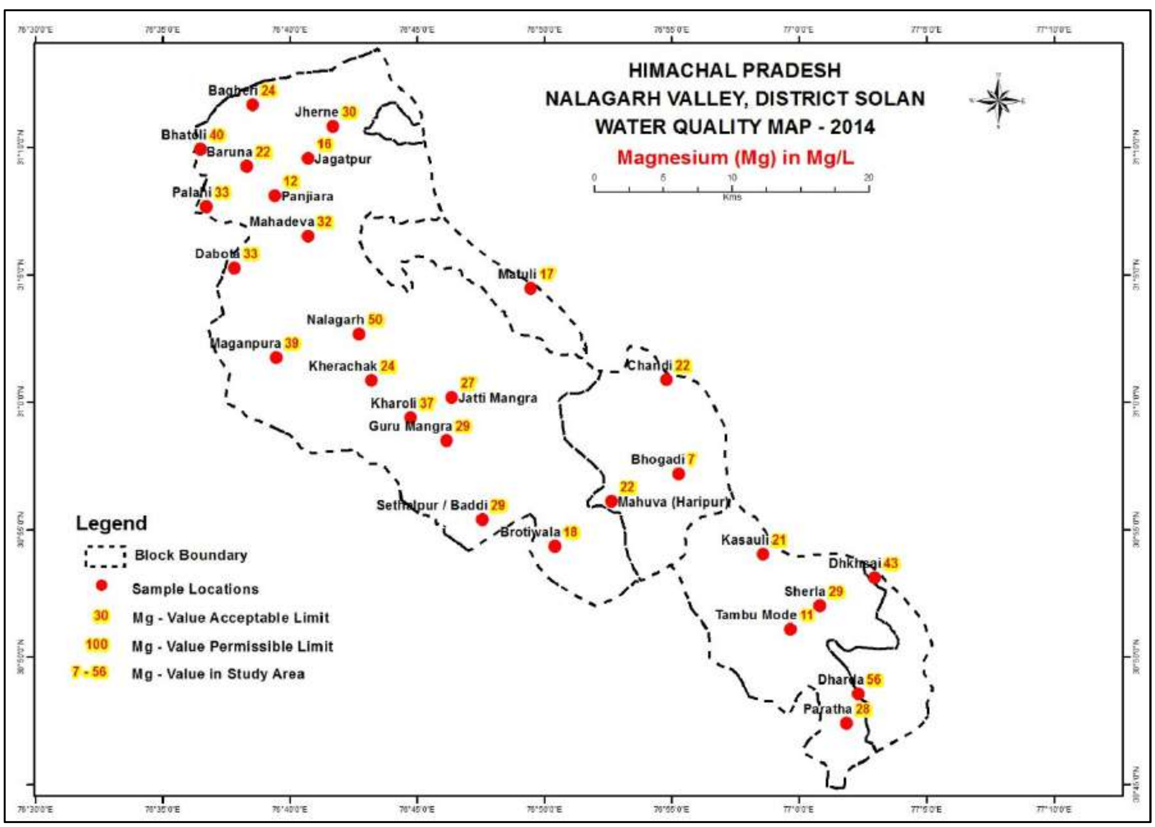


Fig- 2.26 Magnesium (2014) Nalagarh Valley, Solan District

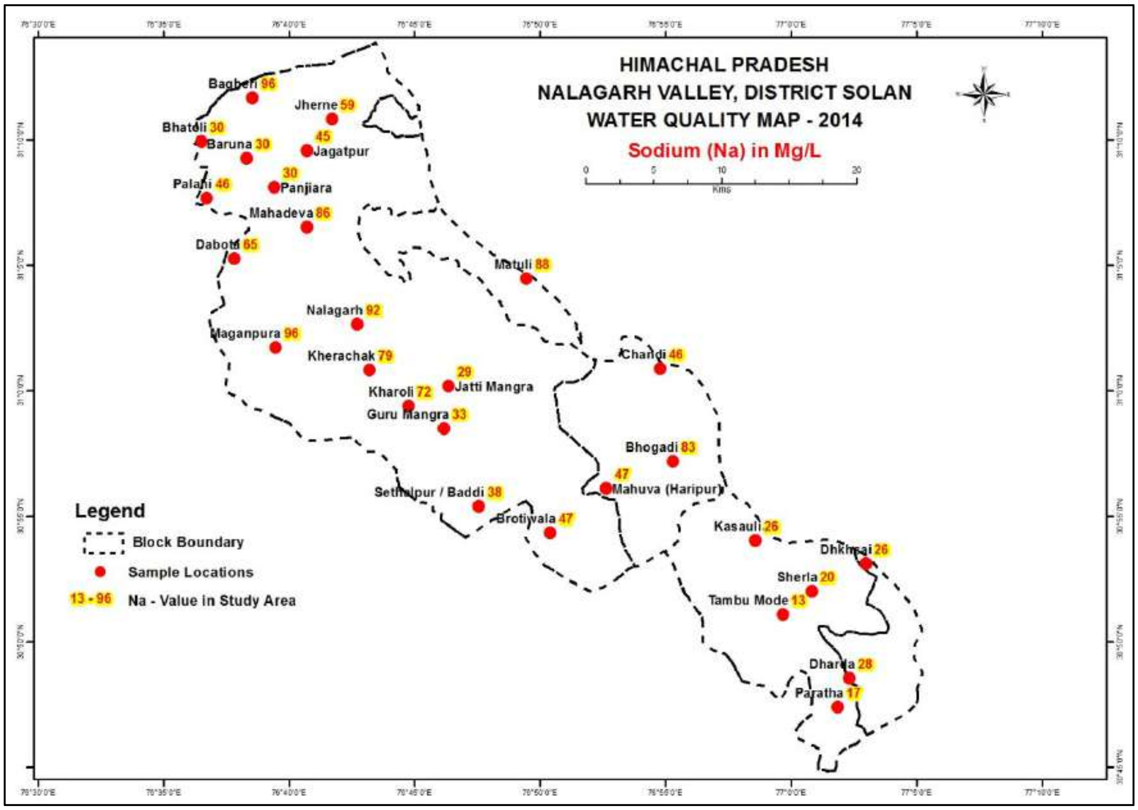


Fig-2.27 Sodium (2014) Nalagarh Valley, Solan District

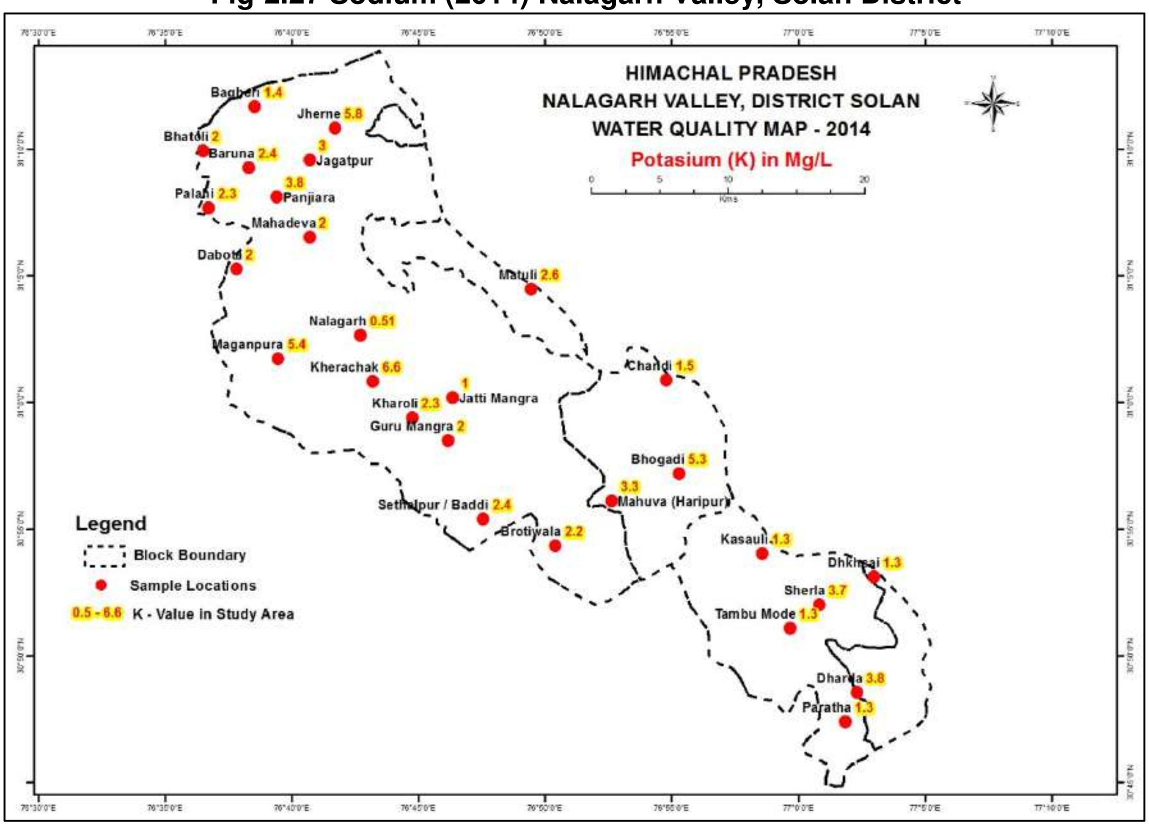


Fig- 2.28 Potasium (2014) Nalagarh Valley, Solan District

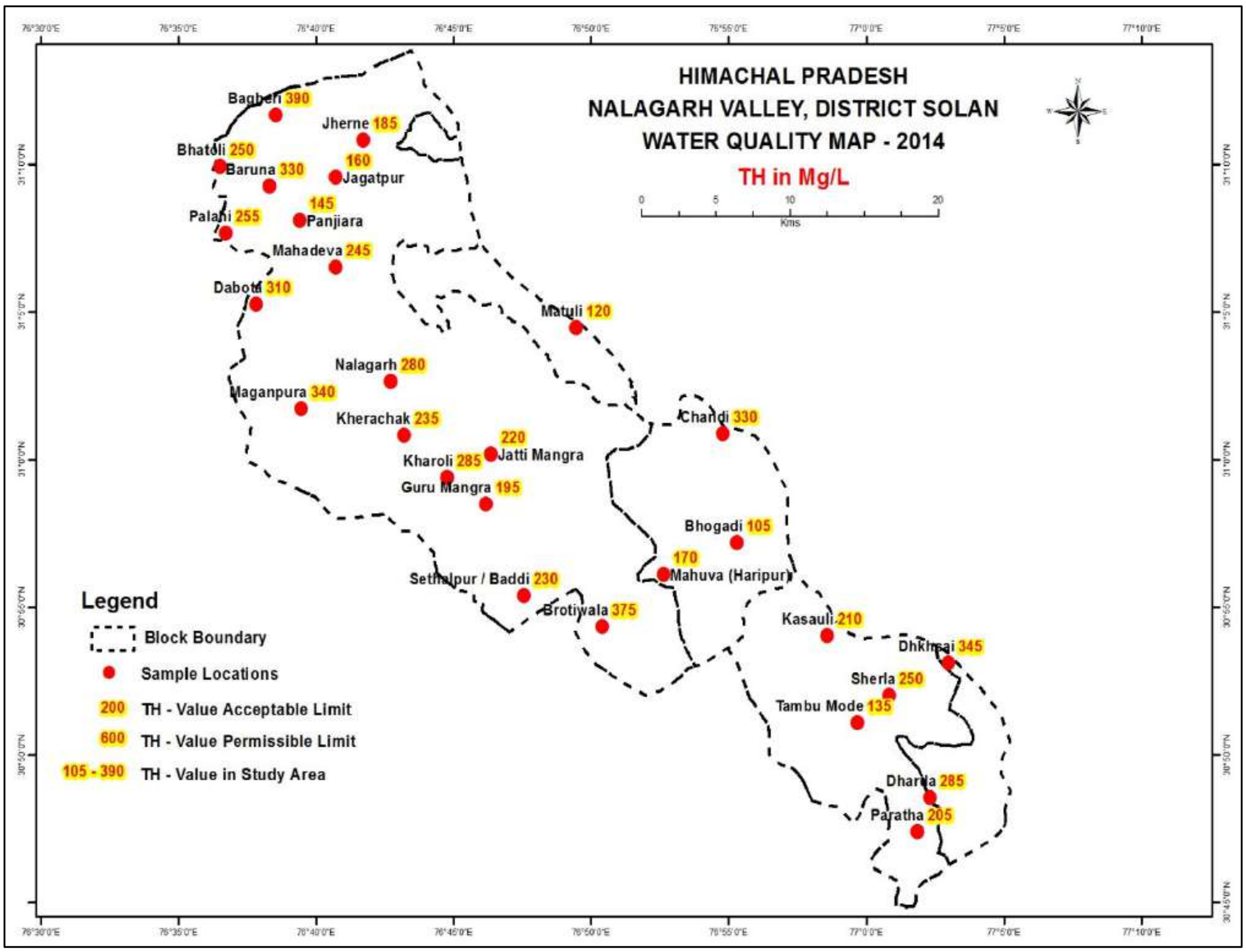


Fig-2.29 TH (2014) Nalagarh Valley, Solan District

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-2.30 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.

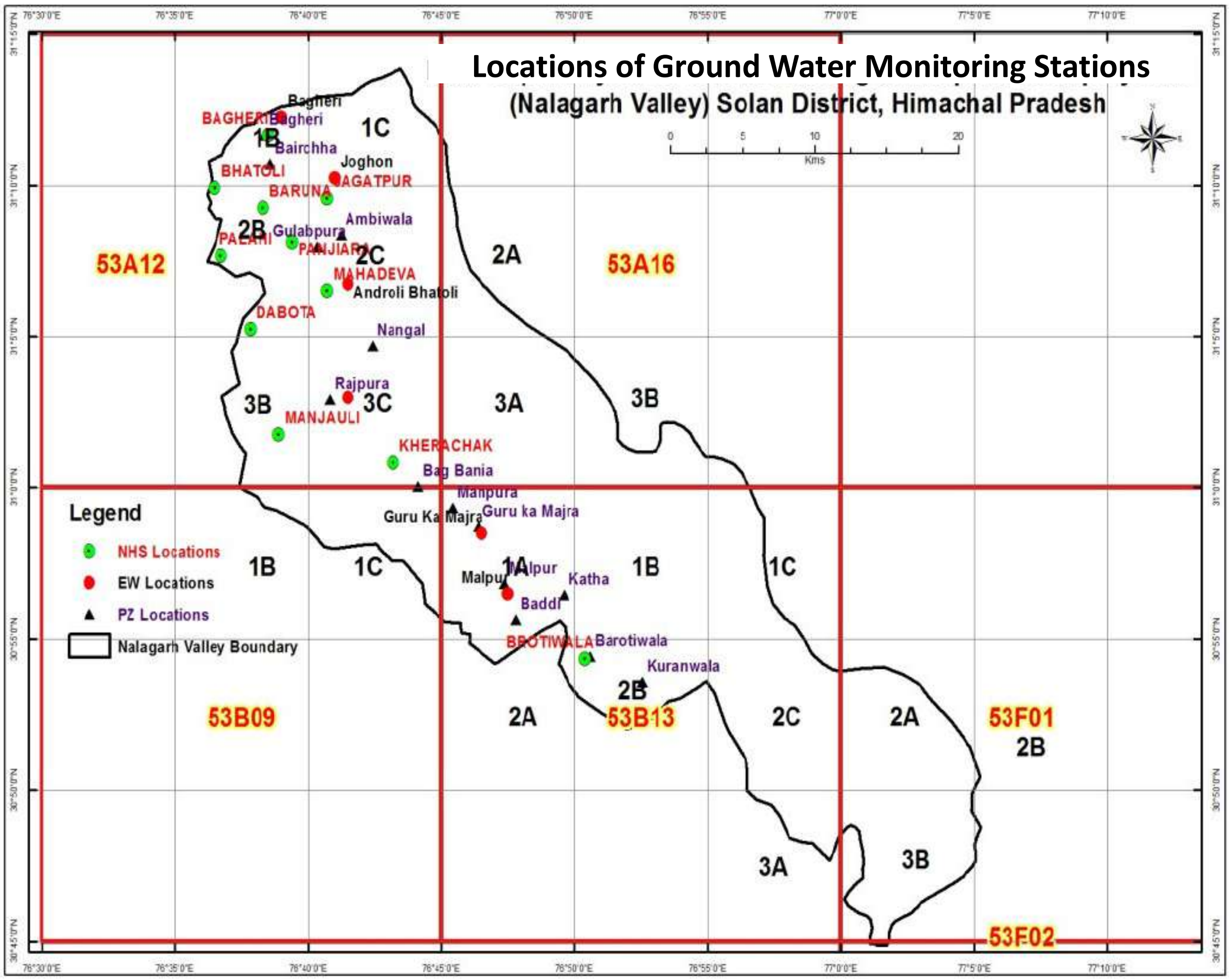


Fig. 2.30 Locations of GWMS in Nalagarh Valley, Solan District

3.0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

All the available data have been validated and optimised for consideration to generate the aquifer map in Nalagarh Valley, Solan District. The wells optimisation part is done based on the maximum depth & litholog (Annexure – I). 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-3.0.

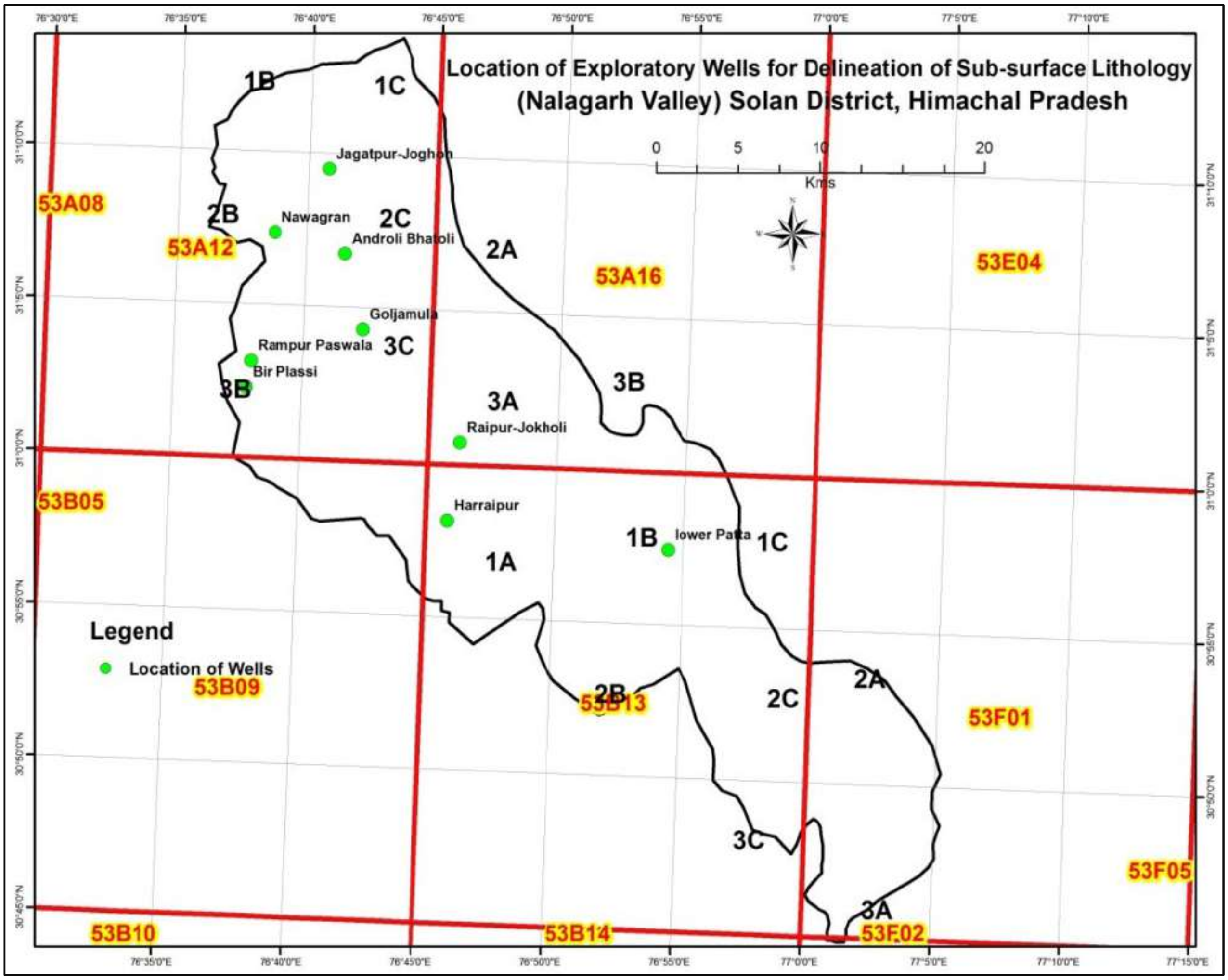


Fig. 3.0 Locations of Exploratory Wells for delineation of Sub-Surface Lithology Nalagarh Valley, Solan District.

3.1 Aquifer Parameter Ranges

In Nalagarh Valley, District Solan (H.P) the exploration drilling was carried out by CGWB, the aquifer parameters range extracted and given in below Table-2.13.

Table 2.13 Summary of exploration and hydraulic details in Nalagarh Valley, Solan District

Exploratory Well	T (m2/day)	Specific Capacity (lpm/m)	Discharge (lpm)	Well Depth
Bir Plassi	693.98	248.18	12.616	104.50
Harraipur	485.37	303.37	794.85	89.00
Raipur-Jokholi	9.046	14.01	240.00	102.00
Jagatpur-Joghon	1179.26	27.32	446.63	103.00
Goljamula	43.32	25.53	394.00	90.60
Rampur Paswala	38.78	26.71	484.48	149.00
Nawagran	128.34	103.32	1400.00	103.50

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. 3.2 & 3.3) & 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-3.1. The 3D lithological fence diagram has been prepared along with distribution of wells are shown in Fig-3.1.

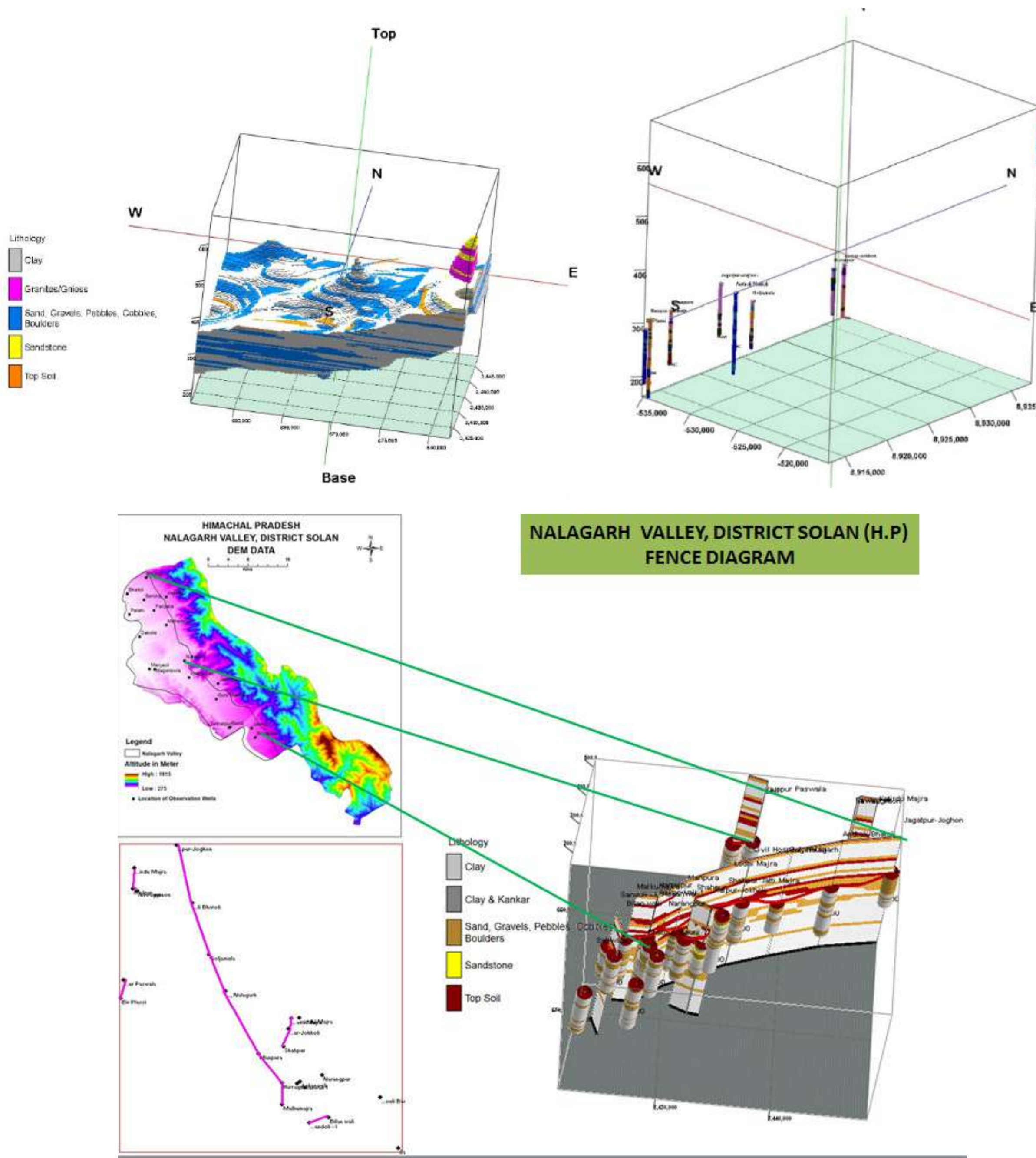


Fig.3.1 3-Dimension Lithological Model of Nalagarh Valley, Solan District

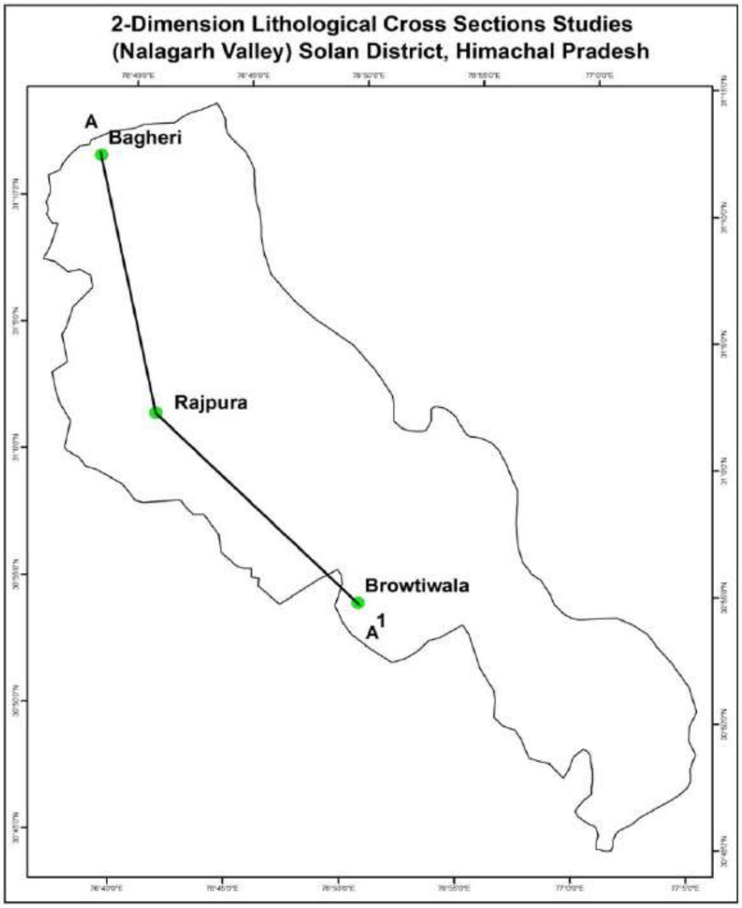


Fig.3.2 2-Dimension Lithological Cross Sections Studies.

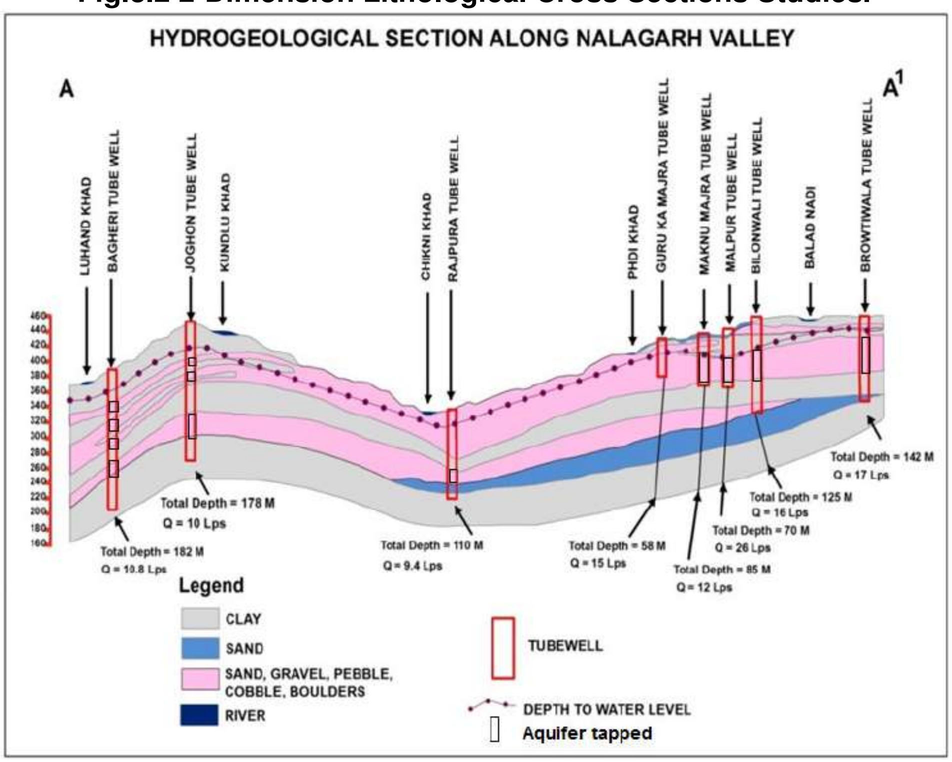


Fig.3.3 Hydrogeological section along Nalagarh Valley, Solan District.

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 Nalagarh valley consists of valley areas with an area of 238 sq.km as well as hilly terrain with an area of 600 sq.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 Nalagarh valley area of the Solan district have been computed and details of the Dynamic ground water resource of Nalagarh valley are as given below:

1.	Area of Nalagarh valley considered for GW Assessment	238	Sq. km.
2.	Net Ground water Availability	8189.74	Ham
3.	Existing Gross Ground Water Draft for Irrigation	1612.64	-do-
4.	Existing Gross Ground Water Draft for Domestic & Industrial Supply	2286.40	-do-
5.	Existing Gross Ground Water Draft	3899.04	-do-
6.	Demand for Domestic and Industrial uses (Projected up to 2025)	1916.03	-do-
7.	Net Ground Water Development for future Irrigation Development	4661.07	-do-
8.	Stage of Ground Water Development	47.61	%

The stage of ground water development of Nalagarh valley is 47.61% as on March, 2013 and falls under **"Safe Category".** This suggests that further ground water development can take place in the valley area.

5.0 GROUND WATER RELATED ISSUES

In Nalagarh valley major cultivation is Rice, Wheat & Maize. 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 is 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 Nalagarh 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.

6.0 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.

6.1 Plan for Sustainable Management of the Resource

Supply Management

- Since the Nalagarh valley area falls in **Safe Category** as per Ground Water Resource Estimation. The solan district receives good rainfall (1293.3 mm), intensity and also having good recharge. So, in the present valley area the construction of 121 Nos. shallow tube wells also suggested for extracting the ground water.
- In Industrial Estates - Anthropogenic activities are the major cause of ground water pollution. Occurrence of nitrate has been reported near drains, agricultural lands and landfill sites. Near Nalagarh to Baddi & Browtiwala areas.
- Landfills should be designed scientifically so that no leachate percolates to reach and contaminate ground water. There should be strict monitoring of waste disposal in industrial belts. Industrial effluents should be discharged only after proper treatment.
- Presence of heavy metals (beyond permissible limits) is mostly restricted to industrial areas, landfill sites in Nalagarh Valley Drainages.
- Agriculture oriented Management Plan - Aberrant erratic behaviour of monsoon and prolonged dry spells during the crop period cause crop failure/low productivity besides drinking water crisis during summers.
- Augmentation of GW through Artificial Recharge structures.
- Ground Water Recharge Practices should be adopted in spring shed area

Hill Area oriented Management Plan

- In present study area proper development of springs is essential as it is observed that most of the spring in the district does not have collection chamber or tanks from where water can be distributed under gravity. The objective of spring development should be to collect the flowing water underground, to protect it from surface contamination and store it for supply. Similarly, seepage springs along hill sides also need to develop for harnessing ground water in such areas.
- 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. Recharge structures feasible in hilly areas are check dams and Gabion structures at suitable locations.
- Ground Water Recharge Practices should be adopted in spring shed area.

Demand Management

Water Use Efficiency method

- To minimize transmission losses, evaporation losses constructing shallow tube wells, shallow dug wells, percolation wells etc. in the farmers field/community.
- Irrigation Practices: Sprinkler / Drip method has higher application and distribution efficiency, saves considerable water and provides complete control on timing and quality of irrigation water to be applied. The Water use efficiency can be much higher as compared to surface method of irrigation.

Annexure – I

Sl.No	Bore	Longitude	Latitude	Elevation	Total Depth
1	Androli Bhatoli	31.1125	76.6917	374.29	155.15
2	Bir Plassi	31.038055	76.63047222	290.17	104.5
3	lower Patta	30.957861	76.90666667	679.09	104.2
4	Harraipur	30.969361	76.76397222	384.35	89
5	Raipur-Jokholi	31.012083	76.77025	402.64	102
6	Jagatpur-Joghon	31.158305	76.67963889	401.42	103
7	Goljamula	31.07166667	76.70472222	348.38	90.6
8	Rampur Paswala	31.0525	76.63333333	311.81	149
9	Nawagran	31.12277778	76.64611111	343.5	103.5

Bore	From	To	Lithology
Androli Bhatoli	0	1	Top Soil
	1	15	Clay
	15	18	Sand
	18	38	Clay
	38	52	Sand
	52	62	Clay
	62	64	Sand
	64	66	Clay
	66	69	Sand
	69	80	Clay
	80	89	Sand
	89	134	Clay
	134	149	Sand
	149	155.15	Clay
Bir Plassi	0	3	Top Soil
	3	20	Clay
	20	27	Sand
	27	33	Clay
	33	37	Sand
	37	43	Clay
	43	47	Sand
	47	72	Clay
	72	75	Sand
	75	104.5	Clay

lower Patta	0	4	Top Soil
	4	16	Silt Stone and Sand Stone
	16	28	Silt Stone and Quartzite
	28	31	Quartzite, Pebbles and Cobbles
	31	43	Quartzite
	43	56	Silt Stone
	56	86	Quartzite
	86	92	Silt Stone
	92	104.2	Quartzite
Harraipur	0	1	Top Soil
	1	3	Clay
	3	6	Sand
	6	9	Cobbles and Pebbles
	9	18	Cobbles and Pebbles and Gravels
	18	24	Clay and Cobbles
	24	30	Cobbles and Silt
	30	36	Clay
	36	42	Cobbles and Pebbles
	42	57	Pebbles and Gravels
	57	75	Pebbles and Sand
	75	81	Gravel, Cobbles and Sand
	81	84	Pebbles and Sand
	84	87	Sand
	87	89	Sand and Clay
Raipur-Jokholi	0	1	Top Soil
	1	4	Gravels and Pebbles
	4	7	Gravels
	7	13	Clay
	13	19	Sand Stone
	19	22	Clay
	22	25	Pebbles, Gravels and Sand
	25	28	Sand Stone, Gravel and Sand
	28	34	Sand and Gravels
	34	37	Pebbles and Gravels
	37	40	Clay and Gravels
	40	43	Sand Stone
	43	46	Gravel, Pebbles and Clay
	46	70	Sand and Clay
	70	73	Sand and Gravels

	73	82	Clay and Sand
	82	88	Clay, Sand and Gravels
	88	102	Sand, Gravel and Clay
Jagatpur-Joghon	0	3	Top Soil
	3	6	Gravels and Pebbles
	6	9	Pebbles, Gravels and Sand
	9	12	Pebbles, Cobbles and Gravels
	12	15	Gravel and Sand
	15	21	Pebbles, Cobbles and Mica Flakes
	21	30	Pebbles, Cobbles and Sand
	30	33	Pebbles, Cobbles and Gravels
	33	42	Pebbles, Cobbles and Sand
	42	45	Sand and Gravels
	45	48	Pebbles, Gravels and Sand
	48	51	Gravel, Pebbles and Sand
	51	57	Gravels and Pebbles
	57	63	Clay, Gravels, Pebbles and Sand
	63	69	Clay, Gravels and Sand
	69	75	Sand and Gravels
	75	81	Clay, Gravel and Sand
	81	84	Sand, Gravels and Pebbles
	84	93	Clay, Sand and Gravels
	93	96	Clay and Gravels
	96	99	Clay, Gravels and Sand
	99	103	Clay and Sand
Goljamula	0	1	Top Soil
	1	6	Boulders, Clay and Sand
	6	7	Clay and Sand
	7	10	Sand, Pebbles and Clay
	10	19	Sand
	19	20	Clay and Sand
	20	22	Sand and Clay
	22	37	Clay and Sand
	37	40	Sand, Gravels and Pebbles
	40	42	Sand
	42	46	Sand and Clay
	46	47	Sand, Clay and Gravels
	47	49	Clay and Sand
	49	51	Sand, Gravels, Pebbles and Clay

	51	58	Clay, Gravel and Sand
	58	59	Sand and Gravels
	59	60	Clay
	60	61	Sand and Clay
	61	66	Clay and Sand
	66	70	Clay
	70	77	Clay, Gravel and Sand
	77	80	Clay and Sand
	80	90.6	Clay
Rampur Paswala	0	1	Top Soil
	1	3	Clay, Sand, Cobbles and Pebbles
	3	12	Clay and Sand
	12	15	Sand and Gravels
	15	19	Clay and Sand
	19	22	Clay, Pebbles and Cobbles
	22	25	Clay and Sand
	25	26	Sand, Gravels and Pebbles
	26	30	Clay, Sand and Gravels
	30	33	Clay and Sand
	33	39	Clay, Sand and Gravels
	39	42	Sand and Clay
	42	47	Clay and Sand
	47	49	Sand
	49	53	Clay and Sand
	53	54	Sand
	54	60	Clay, Silt and Sand
	60	63	Clay and Sand
	63	74	Sand and Clay
	74	77	Clay and Gravels
	77	90	Clay and Silt
	90	94	Clay and Sand
	94	100	Clay
	100	106	Clay, Sand and Gravels
	106	110	Clay
	110	112	Clay and Sand
	112	114	Sand and Clay
	114	133	Clay and Sand
	133	135	Clay, Sand and Gravels
	135	142	Clay and Gravels

	142	143	Sand
	143	149	Clay
Nawagran	0	1	Top Soil
	1	3	Clay and Sand
	3	5	Sand, Pebbles and Cobbles
	5	9	Clay and Sand
	9	16	Sand, Pebbles and Cobbles
	16	18	Clay
	18	21	Sand and Gravels
	21	26	Clay
	26	29	Clay and Sand
	29	33	Sand, Gravels and Pebbles
	33	35	Clay and Sand
	35	37	Clay and Boulders
	37	43	Clay, Sand and Gravels
	43	48	Sand and Clay
	48	55	Clay and Sand
	55	60	Clay, Sand and Gravels
	60	64	Clay, Silt and Sand
	64	66	Clay, Sand and Gravels
	66	72	Clay and Silt
	72	78	Clay and Gravels
	78	80	Clay and Sand
	80	103.5	Clay and Sand Stone