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

UNA, DISTRICT, HIMACHAL PRADESH

उत्तरी हिमालयी क्षेत्र, धर्मशाला

Northern Himalayan Region, Dharamshala

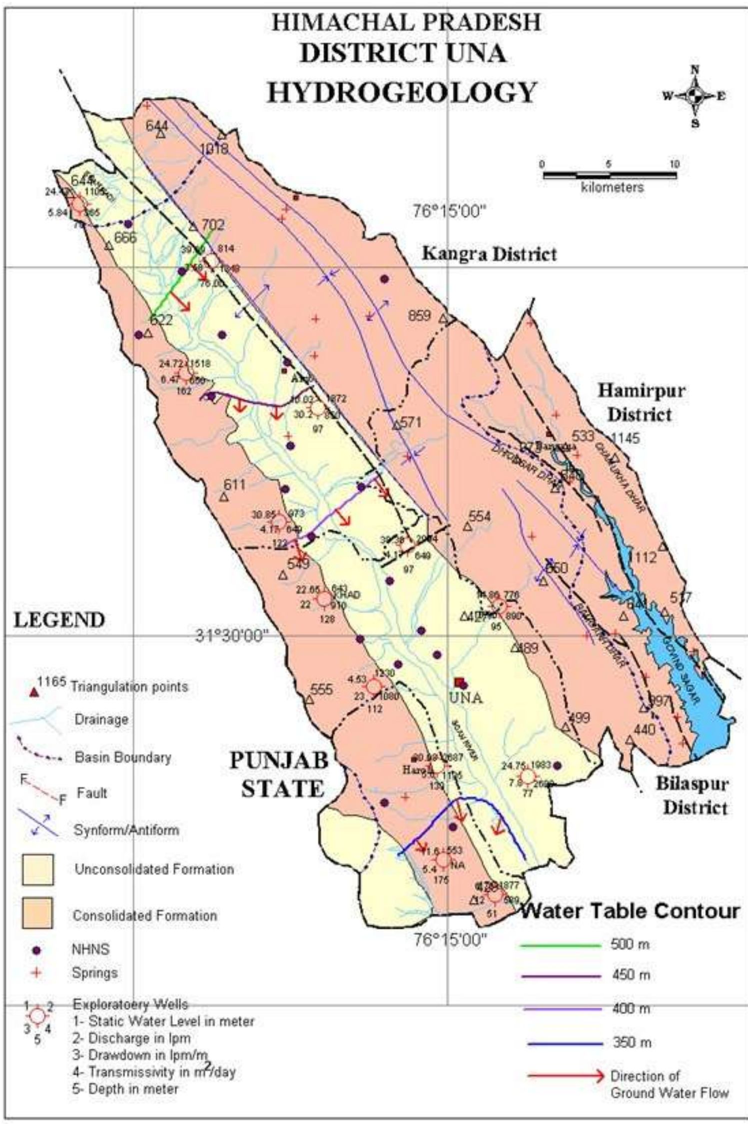
GOVERNMENT OF INDIA

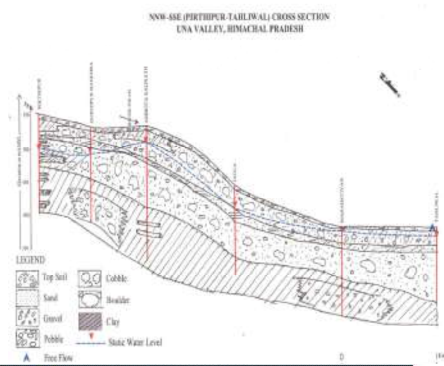
CENTRAL GROUND WATER BOARD

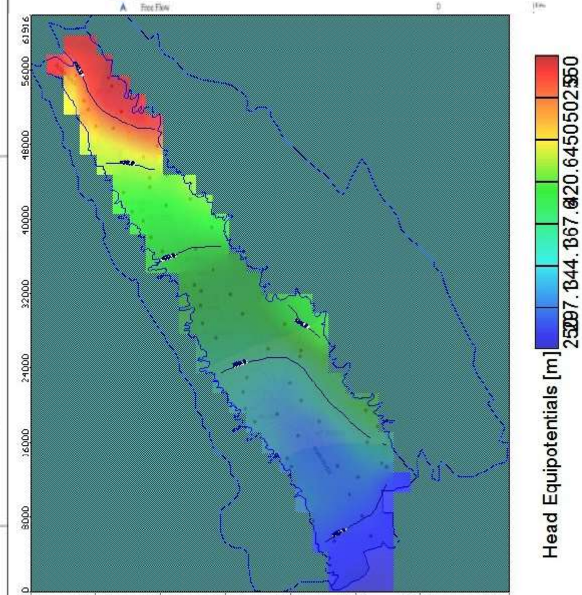
DEPARTMENT OF WATER RESOURCES, RD& GR

MINISTRY OF JAL SHAKTI

AQUIFER MAPPING IN UNA DISTRICT HIMACHAL PRADESH







NORTHERN HIMALAYAN REGION
DHARAMSALA
March, 2020

AQUIFER MAPPING IN UNA DISTRICT
HIMACHAL PRADESH

CONTENTS

AQUIFER MAPPING IN UNA DISTRICT
HIMACHAL PRADESH

(1312 Sq.km Una valley & Parts of Una District)

1. INTRODUCTION

The delineation of aquifers along with their extent and potential through ground water surveys, exploration and monitoring is an on-going activity of Central Ground Water Board. The entire country including the valley areas of Himachal Pradesh has already been covered under Systematic Hydrogeological Surveys to generate basic hydrogeological data. Reappraisal Hydrogeological Surveys/ Ground Water Management Studies have been conducted to study the changes in the groundwater regime over a period of time. The hydrogeological map of the entire country was compiled on 1: 2,000,000 scale and was first published in 1984. Subsequently, it was revised and again published in 2002 based on the data collected by CGWB through ground water survey, investigation and exploration program supported by exploratory drilling, geophysical investigations and hydro chemical studies. Aquifer Atlas of Himachal Pradesh was prepared on 1:250,000 scale.

In today's scenario, increasing population, rapid urbanization and industrial development and human interventions in the ecosystem pose a challenge for water resource managers. Any strategy for management of ground water resources on sustainable basis depends on proper understanding of the characteristics of the aquifer system. In view of the emergent challenges in the ground water sector in the country, an urgent need was felt for comprehensive and realistic information pertaining to various aspects of ground water resources available in different hydro-geological settings through a process of systematic data collection, compilation, data generation, analysis and synthesis.

In view of this the micro level aquifer mapping programme has been taken up by Central Ground Water Board (CGWB) during the XII Five Year Plan. Aquifer mapping is a multidisciplinary scientific process wherein a combination of geological, hydrogeological, geophysical, hydrological and water quality data are integrated to characterize the quantity, quality and movement of ground water in the aquifers. Under the National Aquifer Management Programme (NAQUIM) North Western Himalayan Region had undertaken aquifer mapping of Una District of Himachal Pradesh.

Objectives

The objective of aquifer mapping is delineation of geometry of the underlying aquifer systems in horizontal as well as vertical domain and their characterization, estimating their yield potential and formulation of aquifer management plans to ensure water availability on sustainable basis.

Scope of the study

The scope of the present study is broadly within the framework of NAQUIM being implemented by CGWB. There are four major components of this activity viz.: (i) Data collection /compilation (ii) Data gap analysis (iii) Data generation, and (iv) Preparation of aquifer maps and management plan.

Data compilation included collection, and wherever required procurement, of all the maps from concerned Agencies, such as the Survey of India, Geological Survey of India, State Governments, etc., computerization and analyses of all acquired data, and preparation of a knowledge base.

Identification of Data Gap was included to ascertain the requirement for further data generation in respect of hydrogeological, geophysical, chemical, hydrological studies, etc.

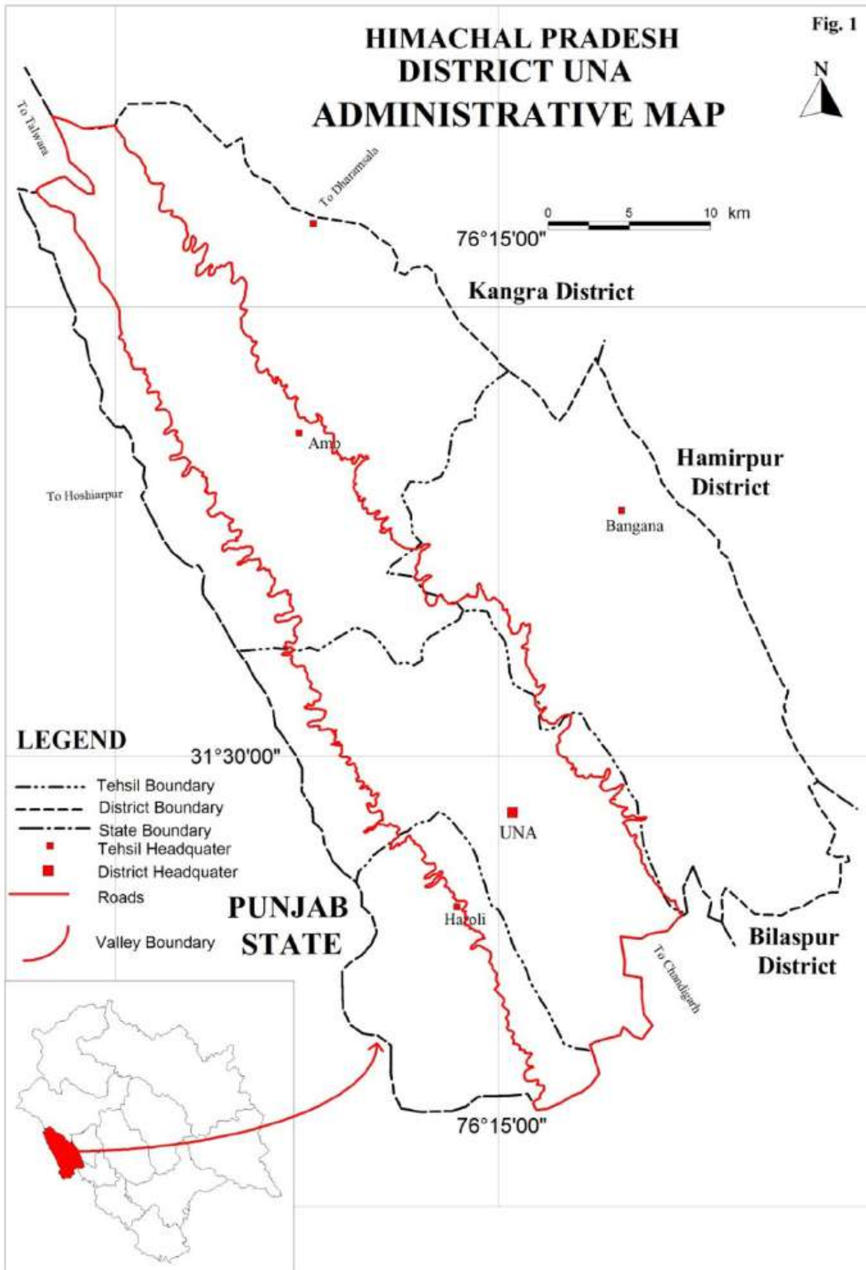
Data generation included those pertaining to exploratory drilling and aquifer characteristics, sub-surface geophysics, chemical quality of ground water and geophysical survey. Generation of chemical quality data of ground water was accomplished by collection of water samples and their laboratory analyses for all major parameters and heavy metals. Sub-surface geophysical studies incorporated Vertical Electrical Sounding and borehole logging.

Based on integration of data generated from various studies of hydrogeology & geophysics, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out Characterization of Aquifers, which can be termed as Aquifer maps providing spatial variation (lateral & vertical), quality, water level and potential (quality & quantity). Finally, a suitable strategy for sustainable development and management of the aquifer in the area has been evolved based on the acquired data.

Approach and Methodology

The study involves collection of existing data from various sources including CGWB records, State Government agencies, available literature and other sources relevant for the purpose of aquifer mapping and management. Central Ground Water Board has been continuous groundwater exploration in the area till date. District Reports and report of Reappraisal Hydrogeological surveys in Una valley and District Ground water Brochures was compiled, analysed, examined, synthesized and interpreted from available sources. Since these sources had predominantly non-computerized data, all the data available and collected was converted into computer based GIS data sets, which were used to prepare various thematic layers. These layers were integrated to generate aquifer maps. Finally an attempt was made to formulate aquifer management plans.

With these aims, Aquifer Mapping Study was carried out in Una valley, district Una under Annual Action Programme 2012-13 and parts of Una district in 2015-16. These surveys are made 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, 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 irrigation facility and sustainability of water resources development. It will also result in better management of vulnerable areas.

During this study, 66 key observation wells (Dug wells) were established. Subsequently, all the available data of ground water from the earlier studies are compiled and integrated with these studies. This report brings out the ground water scenario, lateral & vertical characteristics of the aquifer and suggests better management plan of ground water in scientific manner.

Location, Extent and Accessibility

The Aquifer mapping area, i.e. Una District (Una valley and Parts of Una district) is one of the southwestern district of Himachal Pradesh lying between North latitude 31018’00” & 31055’00” and East longitude 75055’00” & 76028’00” (Fig. 1). It falls in survey of India degree sheet Nos. 44M & 53A and covers area of 1312 sq. km. The area is bounded by Kangra district in north, Hamirpur and Bilaspur districts in northeast and southeast and Punjab State in southwest and south.

The district is well connected by rail and road network. All the tehsil headquarters are connected with metalled roads and State Highway No 23 passes through the area. The nearest airport is at Chandigarh, about 125 km from Una. Goddess temple at Chintpurni, Dera Baba Bhadbhag Singh and Rudru Baba are the important pilgrim centers in the district.

The district has been divided into two sub-divisions namely Una and Amb and comprises of four tehsils viz., Una, Amb, Bangana and Haroli (Fig. 1). For development purposes, the district has been divided in five community development blocks namely Una, Amb, Gagret, Dhundla and Haroli. There are five major towns i.e. Una, Mehtpur Badshera, Gagret, Santhokhgarh and Daulatpur, 758 inhabited villages, 56 uninhabited and 235 Gram Panchayats in the district (Table1).

Table-1 : Administrative Divisions and Population of Una District (Census 2011)

S. No	C.D. Block	Area (sq km)	Population					
			Total	Rural	Urban	SC	ST	Density
1.	Amb	336.24	95,406	95,406	0	23,040	2,649	284
2.	Gagrate	251.98	91,234	83,624	7610	22,104	1,688	362
3.	Bangana	418.51	73,035	73,035	0	20,626	864	145
4.	Una	215.72	1,55,901	1,18,598	37303	22,946	247	723
5.	Haroli	306.28	1,05,597	1,05,597	0	19,330	3,004	345
Total		1540.00	5,21,173	476,260	44,913	1,15,491	8,601	338

Source : Primary Census Abstract, Census, 20011

As per 20011 census, district has a population of 5,21,173 with 338 persons /sq km density of population. The male/female sex ratio is 976. Rural population is about 91% indicating thereby that the district has a agricultural economy. Scheduled caste population constitutes about 22% of the total population.

Land use, irrigation and cropping pattern

In the district, agriculture is the primary occupation of the people. The land utilization of the district for the year 2011-2012 is given in Table-2.

Table-2 : Land Utilization, Una district.

S. No.	Land Use	Area in Hectares
1	Total geographic area of the district:	154200
2	Total forest area:	18165
3	Barren and uncultivated area:	22064
4	Land put to non agricultural use:	18871
5	Net area sown:	41591
6	Area sown more than once:	34463
7	Cultivable waste land:	2360
8	Current fallows:	2668
9	Other fallows:	2340
10	Total cropped area:	76054
11	Total irrigated area:	7800

Ground water is the major source of water in the district for irrigation and domestic use. There are large numbers of water supply wells and tube wells, springs, *kulhs* (water channels) and lift irrigation schemes implemented exclusively for irrigation purposes. About 80 Sq. km area is being irrigated by these sources.

The major irrigation scheme in the area is Bhabaur Sahib Lift Irrigation Scheme and have been implemented under two phases i.e. Phase-I and Phase-II and Nangal dam is the source of water for this scheme. The Phase-I was commenced from year 1993 and it has a CCA of 923 hect. comprising of village Bangarh, Bhatoli, Morebar, Jakhera, Mehtpur, Raipur, Dehlan, Bharolian and Behdala. The Phase-II was commenced from the year 2001 and it has a CCA of 2640 hect. comprising of villages Bangarh, Dehlan, Chattara, Jakhera, Behdala, Raipur, Basdehra, Charatgarh, Jatpur, Ajauli, Udaipur, Lamlehra, Sasan, Nangran, Badehar, Judowal, Pekghubella, Fatehpur and Chhatterpur Dhada

Cropping Pattern

The Kharif and the Rabi are the two principal crops. The kharif crops largely depend on the rainfall. The major crops like maize, wheat, rice, sugarcane and pulses are grown apart from the vegetables in the district. Very limited area is irrigated by the assured irrigation water supply. The area covered under food grain crops is given in Table-3.

Table-3 : Cropping Pattern, Una district

S.No.	Crops	Area (Hectares) (in Hectares)	Production (Tones)
1.	Rice	1538	1124
2.	Wheat	6816	43171
3.	Maize	3270	12254
4.	Pulses	37	28
5.	Sugar cane	154	2572
6.	Potato	698	3239

Source: District at a Glance, 2012

Industrial Activities

There is not much industrial development in the area. However, there are few small and large-scale industries are existing. The major industries are given below:

1. Industries at Industrial area Mehtpur:

i) Rangar Brewries Ltd.

ii) Panjab Lamminations

iii) RM Minerals-Calcium carbide

iv) Him Valves-regulators

v) Pyara raxines

vi) Capson polycots

vii) Hard chem. Agro-induction furnace

2. Industries at Industrial area Tahliwal:

i) Mehk Chemicals- bleaching powder

ii) B.B. Chemicals-detergents and acids

iii) Tara Mandal-blanket

iv) Viran Agro- soap

v) Kosol roller flour mill

vi) Mahindra glass crafting

3. Industries at Industrial area Gagrate:

i) BDM-fruit processing industries

ii) Omid engineering

4. Industries at Industrial area Amb:

i) Him cylinders

ii) International motor cars

iii) Sar silicon

iv) Him alloy

5. Industries at Industrial area Jalehra:

i) Una chemicals

ii) Hari Om Industries

iii) May Fair Biotech- medicine

iv) Par roller mills

v) Nipro polycots

vi) Trinity autofast engineering

Climate

Climate of the district is tropical to temperate in nature as the terrain varies from plains to high hills. Temperature varies from minimum of 4°C in winter to the maximum of 46°C in summer. The winter starts from the November and continues till the middle of March. Thereafter the mercury continues rising till the set of monsoon which starts from the last week of June and continues till the middle of September.

The area receives rainfall during monsoon period extending from June to September and also non-monsoon period (winter). The annual average rainfall in the district is about 1040 mm. There are three rain gauge stations at Una, Amb and Bangana in Una district, monitored by IMD.

Table 4. : The district average rainfalls in mm shown below are the arithmetic average of rainfall of stations under the district.

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
2009	14.6	45.0	31.8	31.2	25.3	44.2	430.9	454.3	84.1	20.6	30.2	0.0
2010	10.8	38.4	2.4	1.3	52.4	79.5	270.4	409.6	217.9	35.1	5.8	58.7
2011	32.4	124.2	42.7	26.9	29.3	166.5	176.1	443.8	203.5	17.8	0.0	9.2
2012	110.4	16.1	7.6	55.1	0.5	29.4	175.0	347.4	255.0	2.8	6.7	43.0
2013	29.6	81.9	35.4	7.5	13.2	293.2	430.4	370.6	95.5	61.1	7.8	31.9

(Source: http://www.imd.gov.in/section/hydro/distrainfall/webrain/hp/una.txt)

Temperature

The temperature in the different parts of the district varies according to the elevations. After the end of February temperature increases gradually till June, which is the hottest month of the year. Over most of the district the summer is hot. With the onset of the monsoon by about the end of June there is decrease in temperature. During the summer maximum temperature ranges between 40^0C and 44^0C and during winter, the maximum and minimum temperatures are 16^0C and 4^0C respectively.

After the withdrawal of the monsoon by about the middle of the September temperatures decrease gradually at first and fairly rapidly after November. January is generally the coldest month in association with cold waves in the wake of western disturbances that affect the district.

Humidity

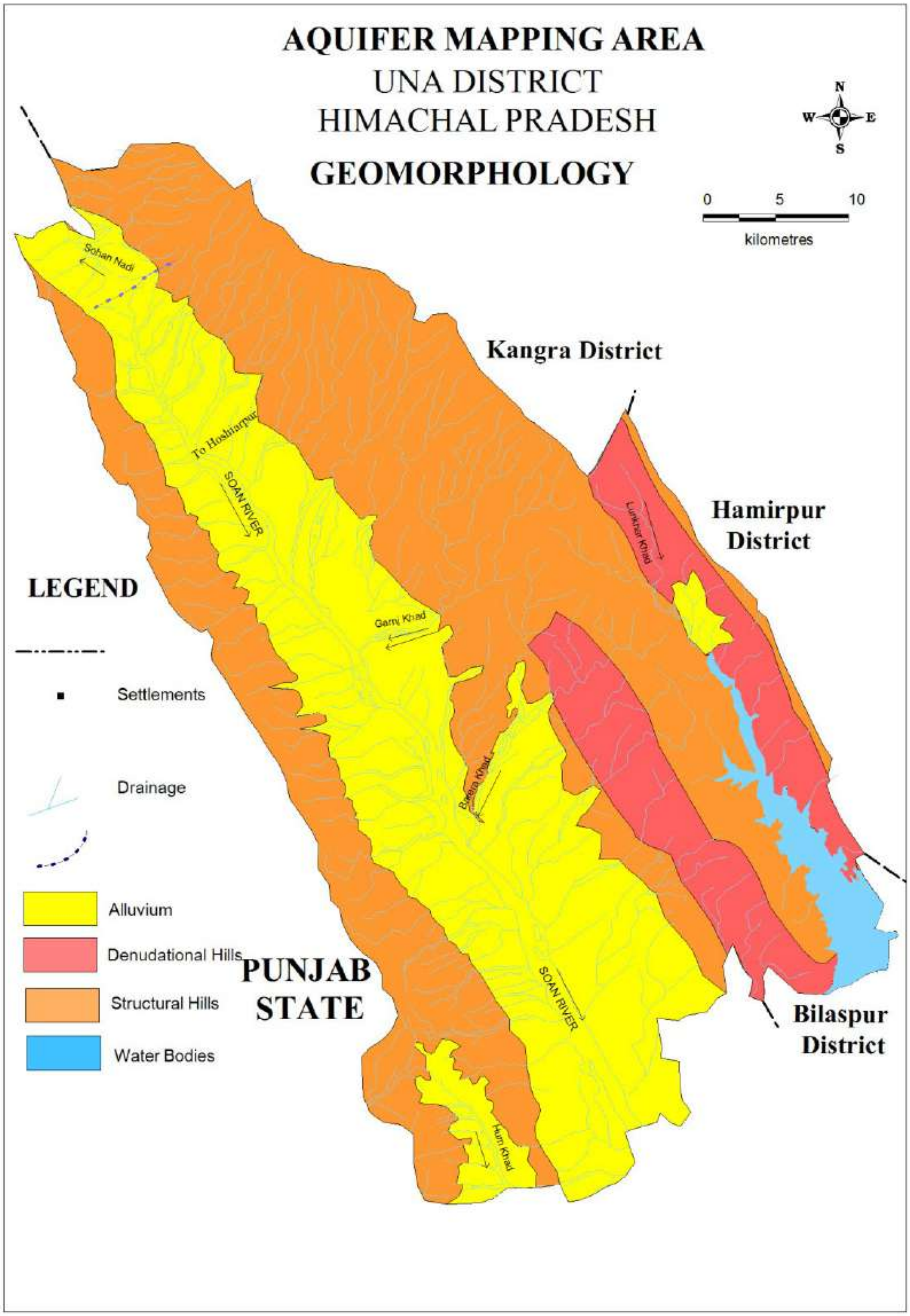
In the southwest monsoon season, the humidity is high. In the post-monsoon, winter and the early part of the summer the humidity is generally low particularly in the higher regions. By June the humidity begins to increase.

Physiography

Una district nestles between Siwalik ranges and forms part of the lesser Himalaya (Fig. 2). It has a diverse landscape made of the hills, valleys with piedmont zone, terraces. The elevations of the land surface in the district vary from 340 m in southeastern part to 1041 m above sea level (amsl) in eastern part of the district. There are three hill ranges i.e. Chamukha Dhar with maximum elevation of 1041m amsl which borders with district Hamirpur, Dhionsar Dhar with maximum elevation of 950m amsl and Ramgarh Dhar with maximum elevation of 997m amsl. In the southwest border with Punjab, Siwalik hill ranges forms hilly area with elevation up to 666 m above mean sea level. The vast area between the northwesterly & southeasterly hill ranges, on both sides of river Swan is the *Una valley*. The undulating to plain fertile Una valley has an area of about 655 sq km and it extends from Daulatpur in the northwest to Santokhgarh in the southeast.

Drainage

The major part of the Una district (80%) is drained by Soan river, Sohan nadi and Lunkhar khad and their tributaries. Soan river a tributary of river Satluj (Fig. 2.) Soan is a seasonal river with its 80% catchments in Una district and divides the district into two parts. Soan River flows in a southeastern direction and has a wide channel and exhibits braided nature. It originates near Daulatpur in the northeastern part and leaves the district near Santokhgarh and subsequently joins Satluj River. About 73 local streams or khads joins the river within the district. During monsoon Soan River gets flooded due to shallow bank heights & large area on both sides are affected. Government has initiated riverbank protection cum flood controls measures and the work is in progress. The main tributaries of Swan river are Sunkaliwali *Khad* (stream), Ambwali khad, Panjoa ki khad, Una di khad, Gubji khad, Barera khad, Khurd ki khad, Barewali khad etc. Siwalik hills run in the north to north-easterly direction to meet Soan river with the tributaries of harer khad, Barwali khad, Parwsati khad, Kalwali khad, Surian ki khad etc.

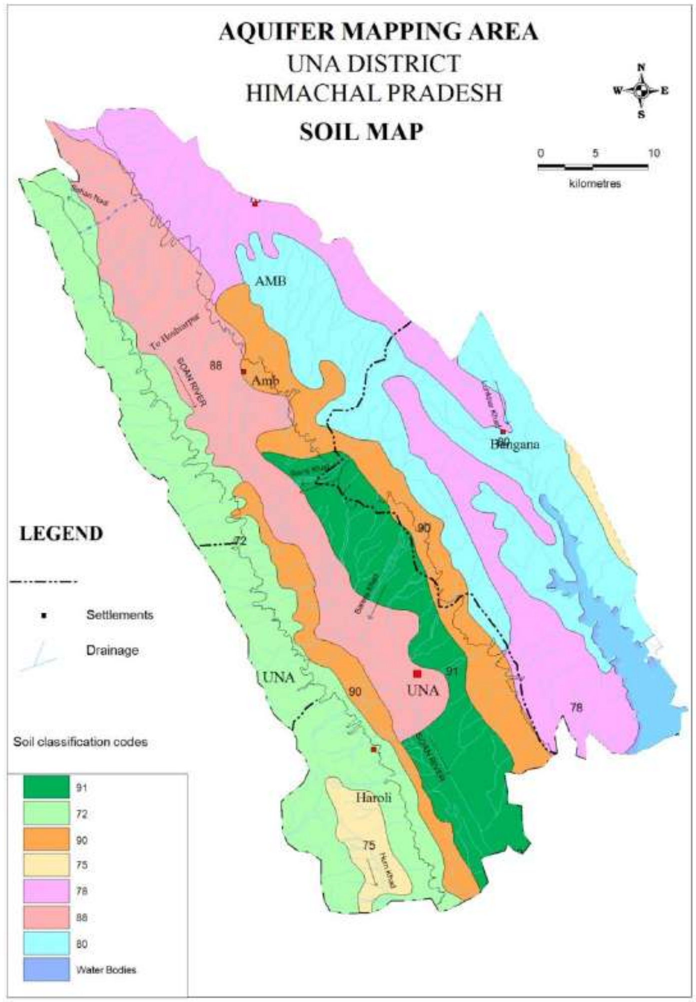


In the Bangana area, another Khad flowing parallel to Soan River is Lunkhar khad, which debouches in the Govind Sagar reservoir. In the extreme northwestern part of the district small area form the catchments of Sohan Nadi, a tributary of Beas river. Hum khad forms the main drainage in the southwestern part of the district.

Soil characteristics

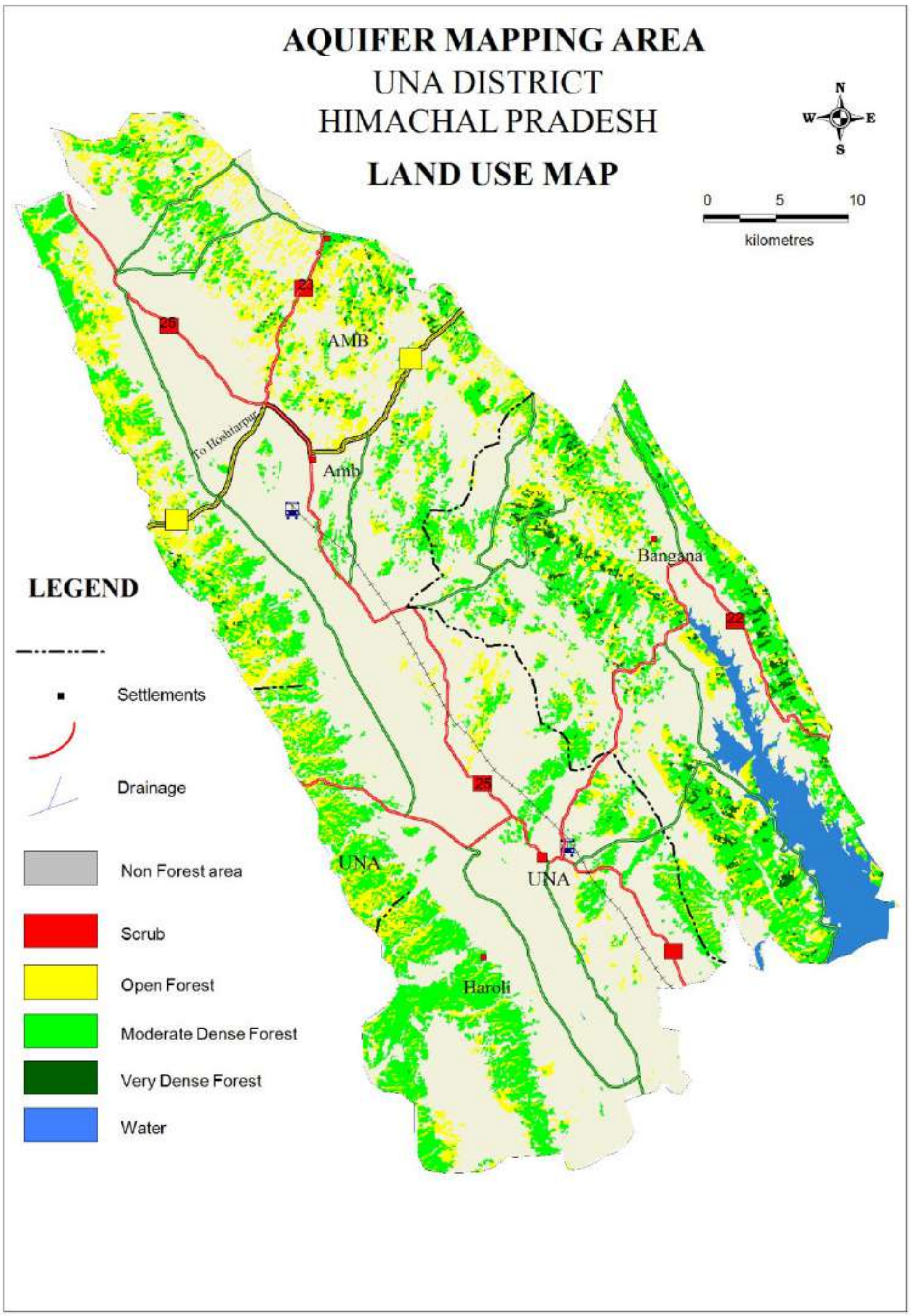
Two types of soils are observed in the district viz., alluvial soil and non-calcic brown soil. Most of the area in district is covered with alluvial soil and only about 25% of the area i.e. hilly area in the district is covered with non-calcic brown soil. These soils are restricted to major drainage courses. They consist of very deep dark brown to dark grayish brown. Silty clayey loams are seasonally submerged. These are well drained and suitable for perennial irrigation. pH is 8.0. They are low in N and P and medium in K.

Soil Classification Code	Soil Description
88	Shallow, well drained, hyperthermic, sandy soils on very gentle slopes with sandy surface and moderate erosion; associated with: Shallow, well drained, coarse-loamy soils with loamy surface and moderate erosion.
72	Medium deep to deep, well drained, thermic, loamy-skeletal soils on steep slopes with loamy surface and severe erosion; associated with: Medium deep, well drained, calcareous, fine-loamy soils with loamy surface and moderate erosion.
80	Medium deep, well drained, thermic, loamy skeletal soils on moderately steep slopes with loamy surface and severe erosion; associated with: Medium deep, well drained, fine-loamy soils with loamy surface and severe erosion.
90	Deep, well drained, hyperthermic, coarse loamy soils on very gentle slopes with loamy surface and severe erosion; associated with: Medium deep, well drained, coarse-loamy soils with loamy surface and moderate erosion.
78	Medium deep, well drained, thermic, coarse-loamy soils on gentle slopes with loamy surface and severe erosion; associated with: Medium deep, moderately well drained, fine-loamy soils with loamy surface and severe erosion.
91	Medium deep, well drained, hyperthermic, coarse-loamy soils on gentle slopes with loamy surface and slight erosion; associated with; Deep, well drained, coarse-loamy, calcareous soils with loamy surface and moderate erosion.
75	Medium deep, well drained, thermic, loamy skeletal soils on very gentle slopes with loamy surface, moderate erosion and moderate stoniness; associated with: Deep, well drained, fine-loamy soils with loamy surface and slight erosion.



Landuse

The district-wise land-use and land-cover map prepared by the National Natural Resource Centre and National Remote Sensing Centre of ISRO, Hyderabad was downloaded from bhuvan-noeda.n rsc.gov.in/theme. It has been observed that major parts of the area are covered by agricultural land. The wasteland, gullied/ravenous land is observed adjoining to the river and drainage channels. Almost whole of the aquifer mapping area has spread of settlements.



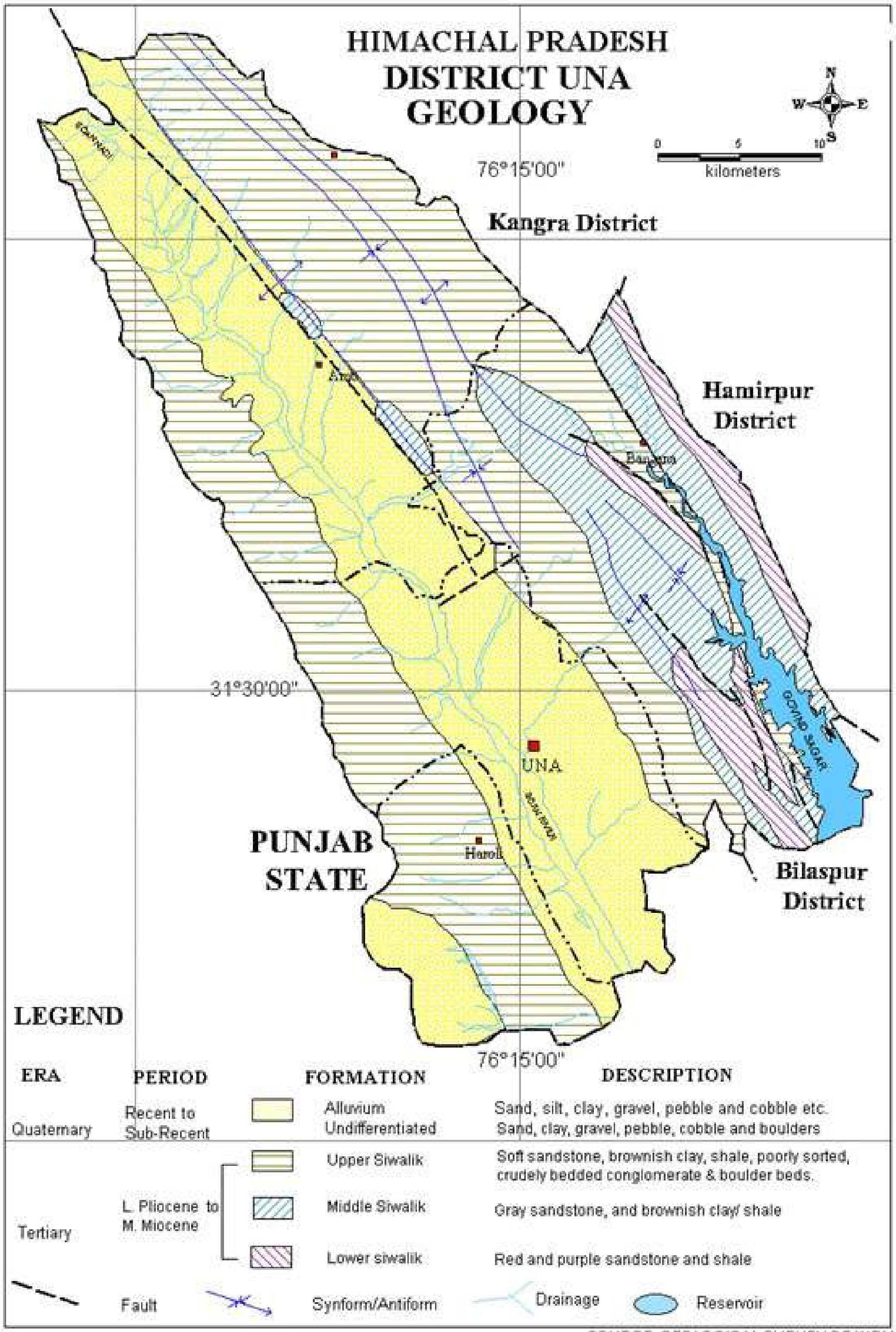
General Geology

The Geology of the area can be described under two broad heads (i) Hilly areas, comprising of upper, middle and lower Siwalik formations.(ii) Quaternary sediments constituting the valley area.

The area is mainly occupied by the Siwalik formation of Tertiary age with narrow longitudinal tectonic valley i.e. Una valley (Fig. 3). The Una valley extends from Daulatpur to Santokhgarh and beyond the northern border of Dun-Syncline in the area is a thrust plane called Soan Thrust. Apart from Una valley, the rest of the area of the district is hilly. Geological sequence is given bellow.

The younger valley fill deposits are Pleistocene to Recent in age and constitute unconsolidated elastic sediments comprising chiefly granular deposits interest ratified in the clays and clay-boulder beds. In the sub-mountain tracts along the Siwalik Hills, the piedmont deposits comprising sand, gravel, pebbles, cobbles and boulders occur. Coarse-grained deposits usually fringe the hills and grade into fine-grained aggregates towards the central parts of the Una valley. The granular beds are interbedded with clays, of varying thickness. In the low lying area of Una valley i.e. Central parts of the valley and the streams traversing the northern part of the valley finer elastic sediments comprising sand, silt and clay chiefly occur.

Era	**Period**	**Formation**	**Lithology**
Quaternary	Recent	Alluvium	Sand, gravel, pebble and cobble
	Lower Pleistocene to Recent	Undifferentiated	Sand, gravel, pebble, cobble and soft sandstone
Tertiary	Lower Pliocene to Lower Pleistocene	Upper Siwalik	Brownish clay, Conglomerate and shale
	Middle Miocene to Lower Pliocene	Middle Siwalik	Gray sandstone, shale and brownish clay
	Lower Miocene to Middle Miocene	Lower Siwalik	Red and purple sandstone and shale

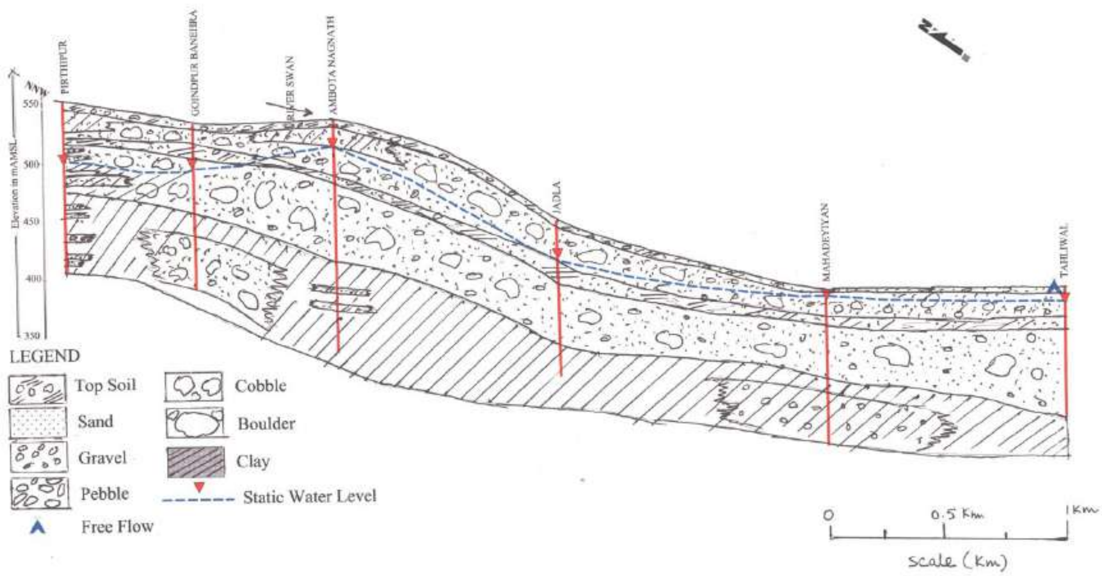


SOURCE: GEOLOGICAL SURVEY OF INDIA

The older valley fill deposits (Terraces) occur along the left bank of the Soan river and on the northern slopes of the valley chiefly comprise gravel, pebbles, boulders interstratified with thin clay lenses. The terrace formations in the Una valley are older than the river alluvium. The piedmont deposits occur along the sub. Mountain tract of Siwalik hills and comprise sand, pebbles, cobbles & boulders.

The upper Siwalik rocks are found in north and south east of the Una valley comprising of indurated sands, sandstones, silts and brown clays. The conglomerate beds also occur at places. Coarser sediments mainly comprise pebbles beds are prominent in the northwestern part of the area. In the southern parts, the boulder bed forms the upper most part, consist of pebbles, cobbles and boulders with intervening thin beds of clays. North of the valley, upper Siwalik formations are chiefly represented by massive sandstone and

NNW-SSE (PIRTHIPUR-TAHLIWAL) CROSS SECTION
UNA VALLEY, HIMACHAL PRADESH



conglomerate with beds of clay and indurate sands. Sandstones are usually soft friable and pebbly.

The middle Siwalik includes hard, gray or brown colour sandstones with small proportion of drab shales, orange clays and occasional beds of gravel. Between Kathaulas-ki-Khad and Panjoa-ki-khad there are two isolated outcrops of middle Siwalik rocks comprising of moderately hard, massive medium to coarse grained micaceous sands tones with the thin intercalations of clays.

The lower Siwalik comprises hard sandstones with clay nodules and purple shale. The sandstone generally forms conspicuous strike ridges. The valley fill comprises unconsolidated fluvial deposits consisting gravels, pebbles, cobbles and boulders intermixed with clays. The various khads emerging on the left bank and joining Soan and formed piedmont deposits and fan deposits those are likely to emerges as potential ground water horizons.

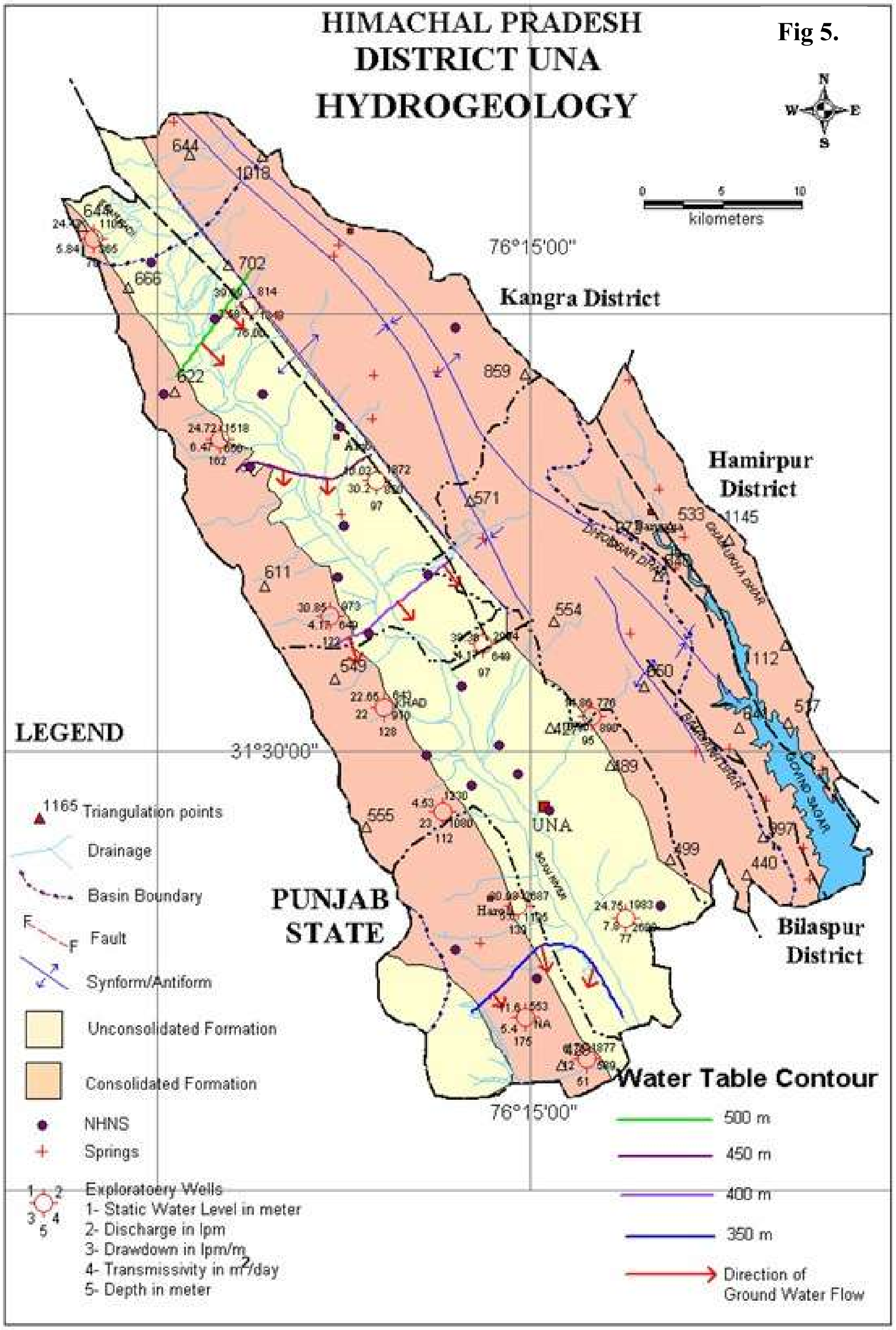
Hydrogeology

Hydrogeologicaly, the entire area of the Una district is divided into two aquifer system i.e. Consolidated and Unconsolidated aquifer system. The hilly areas comprise the rocks belonging to upper, middle and lower Siwalik. The major rocks are sandstones, shale, clay, conglomerate and boulder beds exposed in the upland areas like Bhangana and Bharwain. (Fig.5). Ground Water in these formations are poorly developed by constructing shallow dug wells along the drainage lines in low topography. Dug wells in the area with overburden have depth to water level varying from 2 to about 8 m. and most of these structures dried up during peak summers. Springs exist in the low topographic areas along the lineaments, contact of various formations and along the streams.

The unconsolidated formations are confined to valley areas only. These covers low lying areas of the valleys and upland terrace deposits. These formations consist of pebble, cobble and boulder mixed with varying proportion of sand interstratified with clay and clay boulder bed. Proportion of coarse-grained sediments increases towards the hills and deposits become finer towards the Soan river i.e. central part of the Una valley. In terrace deposits the granular zones are more promising and forms potential water bearing horizons.

Aquifer Parameters

Central Ground Water Board has constructed 45 exploratory tube wells in the Una valley varying in depth from 90 m to 163 m. The static water level varies from artesian 1.45 m agl (Rampur) to 43.20 m bgl at Chalet. The yield of tube wells ranges from 338 lpm (Badehra) to 3430 lpm (Athman). The discharge of the exploratory wells tapping the aquifers between 27m to168m bgl varies from 68 lpm to 3430 lpm for a drawdown of 2 to 40 m. The artesian wells tapping confined aquifers at Bhadsali, Kaloh and Rampur yielded 1230 lpm, 3290 lpm and 886 lpm for drawdown of 24m, 39m and 11 m respectively. Transmissivity in the Valley area



ranges from 150 m^2/day to 2600 m^2/day. The lithological log of the borehole data of exploratory tube wells drilled by CGWB is given in Annexure-1.

Irrigation and Public Health (I&PH) department, Himachal Pradesh has also constructed about 300-tube wells range in depth from 51.0 to 220.0. The water level varies in these tube wells from artesian condition to 45.00 m. The well yields are high with discharge ranging from 553 to 3500 lpm for 7-10 m draw down. Out of 300-tube wells, 270-tube wells are being utilized for water supply and remaining 30 tube wells for irrigation purpose. In all the hilly areas of Una district, I&PH department has drilled some shallow bore-wells (fitted with hand pumps) to provide the clean drinking water to the hamlets. in depth from 45 to 80 m and their yield or discharges are less than 0.5 lps. Dug wells in the overburden with shallow depth (2-8 mbgl) exist in the Bhangana and Bharwain area. The lithological log of the borehole data of .exploratory tube wells drilled by I&PH department is given in Annexure-II.

Occurrence of Ground Water

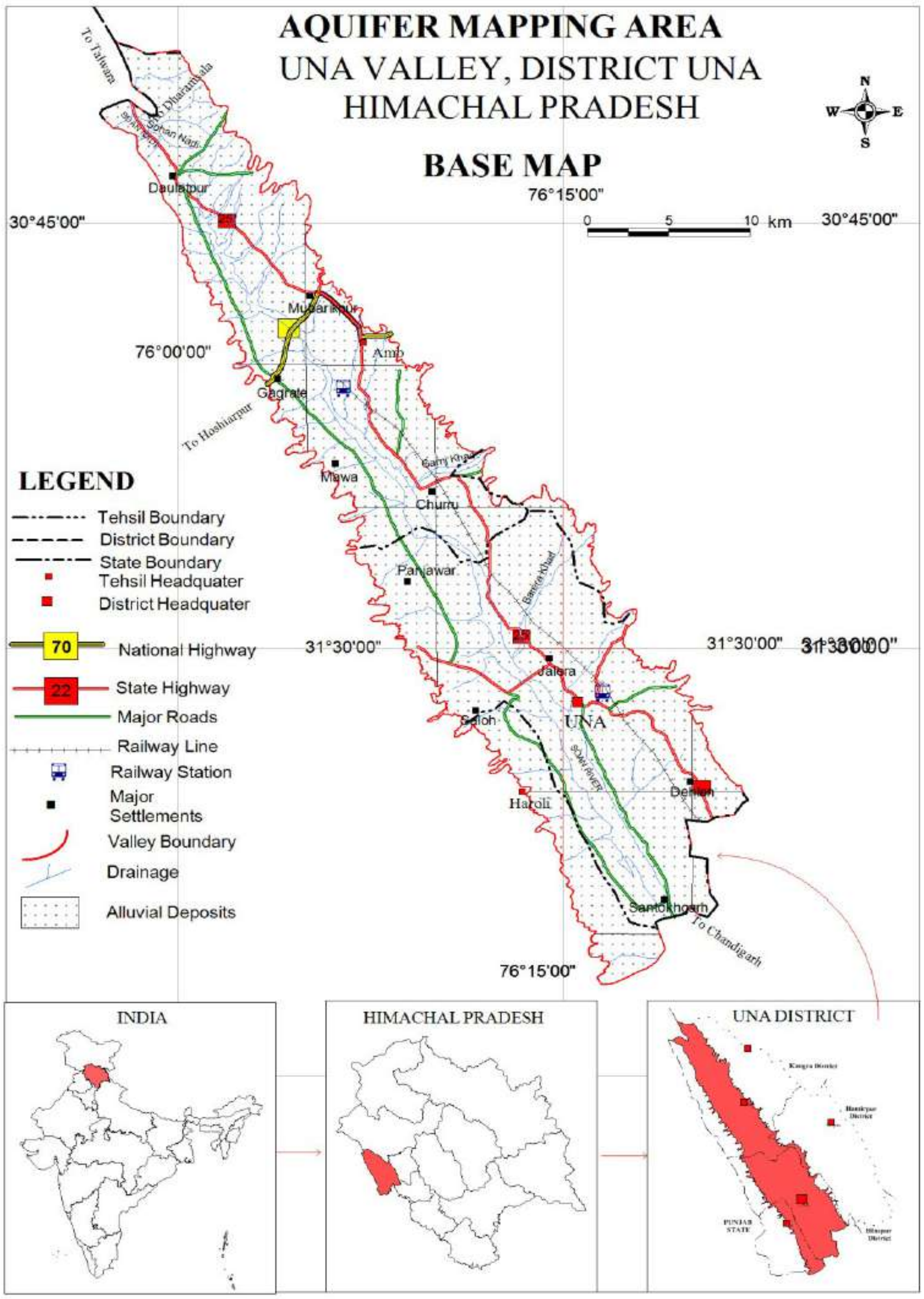
The ground water in the Siwalik group of rocks occur under the unconfined to semi-confined conditions mainly in the arenaceous rocks viz., sandstone, siltstone, gravel boulder beds etc. The occurrence and movement of ground water is controlled by inter granular pore spaces and also the fracture porosity. Siwalik sediments underlie hilly/undulating areas where springs (mostly gravity/contact type) and *bowries* are the main ground water structures apart from the hand pumps. The discharges of the springs, varies from seepages to 0.50 lps. B*owries* are dug well type constructed on the hill slopes/nalas for tapping the seepages from the sediments. In the low lying areas underlain by Siwalik rock, dug wells and hand pumps are the main ground water structures that range in depth from 3.00 to 25.00 m bgl.

In larger part of the Una valley, the ground water occurs in porous unconsolidated/alluvial formation (valley fills) comprising, sand, silt, gravel, cobble/pebble etc. Ground water occurs both under phreatic & confined conditions. Artesion conditions are also observed in the lower part of Soan river. Ground water is being extensively developed in the area by medium to deep tube wells, dug wells, dug-cum-borewells and also by hand pumps. Depth of dug wells and dug- cum-borewell in area ranges from 4.00 to 70.00m bgl.

2. DATA GAP ANALYSIS

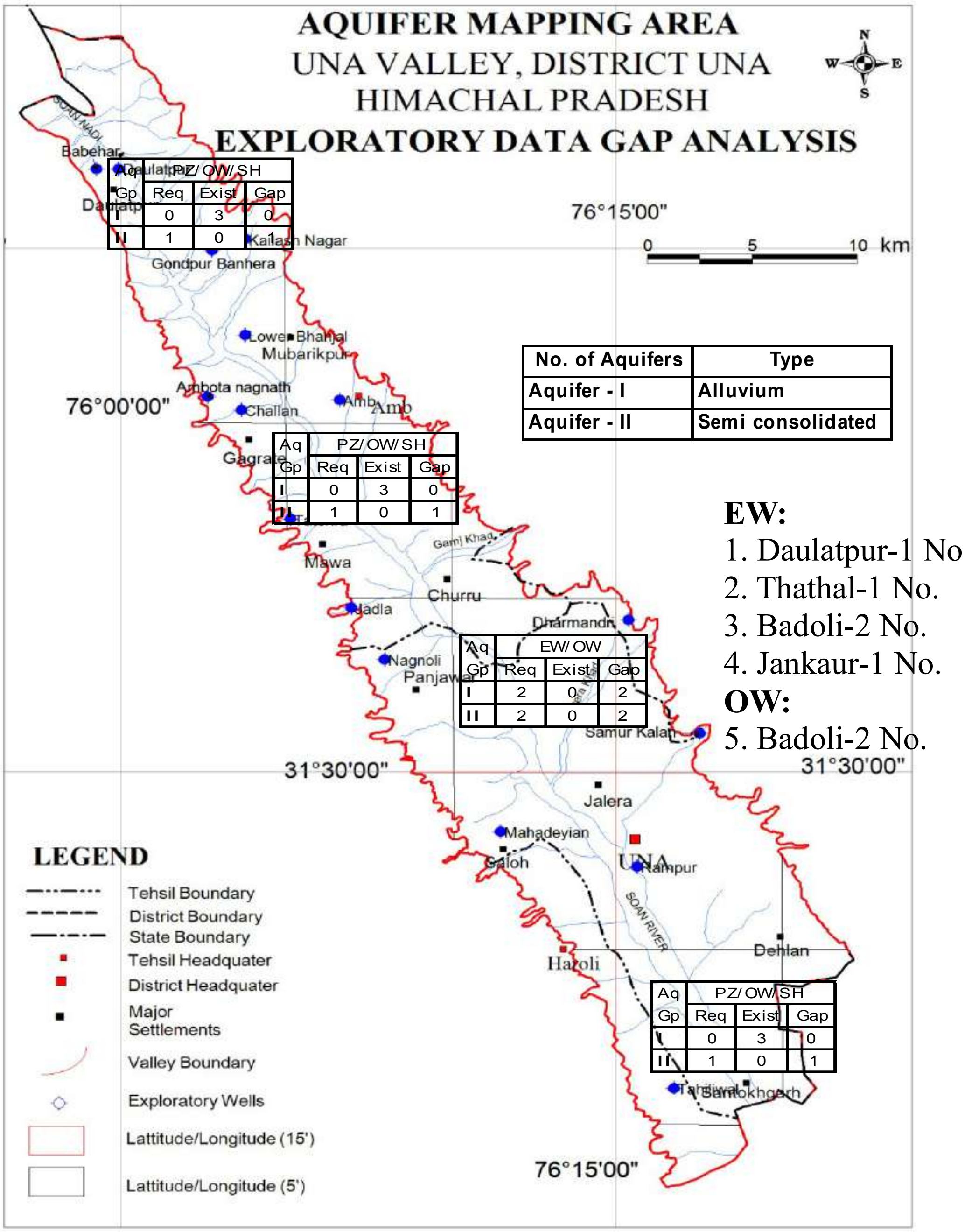
Una Valley

The data gap analysis for Aquifer mapping in Una valley, district Una has been carried out on the basis of EFC guidelines for soft rock area. Una valley is supposed to be a two aquifer system consisting of valley fill alluvium as a first aquifer. The base map for data gap analysis is sown in The analyses done are detailed below:



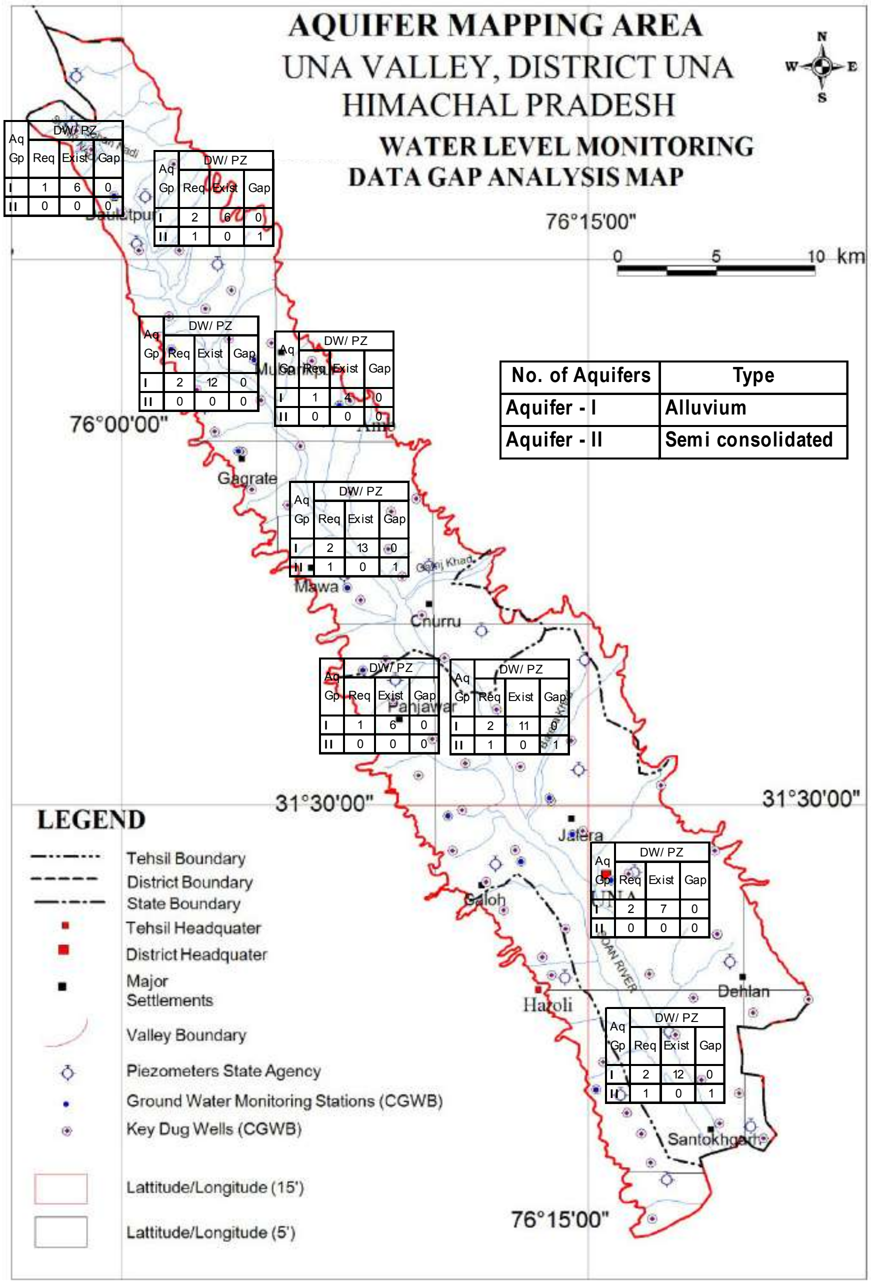
Ground Water Exploration:

As per the EFC guidelines there should be one well field and three special purpose wells i.e. 5 EW and 2 OW. 4 EW for first aquifer and 1 EW & 1 OW for the second aquifer should be constructed. The proposed sites for EW & OW are also given.



Water Level Monitoring:

As per the EFC guidelines there should be 21 No. of monitoring stations. There is no gap for water level monitoring due to the available dug wells for monitoring of first aquifer. The list of observation wells and data gap analysis is shown in fig.



Total 21 No.

EW:

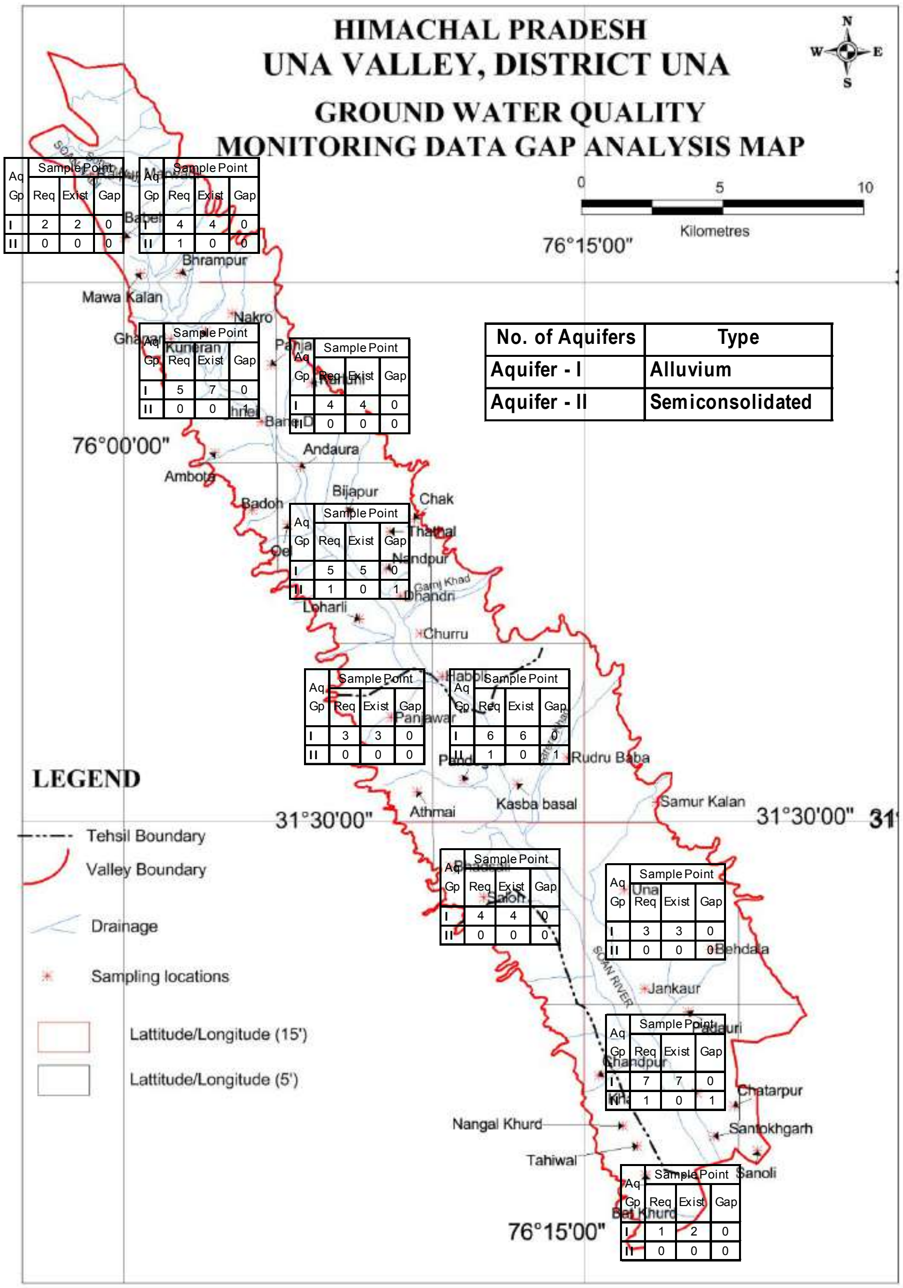
1. Daulatpur
2. Thathal
3. Badoli
4. Jankaur

OW: PZ/GWMS:

5. Dangoh
6. Marwari
7. Mawa
8. Ganehri
9. Singhnei
10. Badoh
11. Panjawar
12. Ishpur
13. Padauri
14. Nangal Khurd.
15. Nangran
16. Una
17. Dehlan
18. Khwaja
19. Bhaira
20. Thathal
21. Andaura

Ground Water Quality:

As per the EFC guidelines there should be 44 No. sampling locations. There is no gap for sampling locations due to the available dug wells. The list of tentative sampling points and data gap analysis is shown.

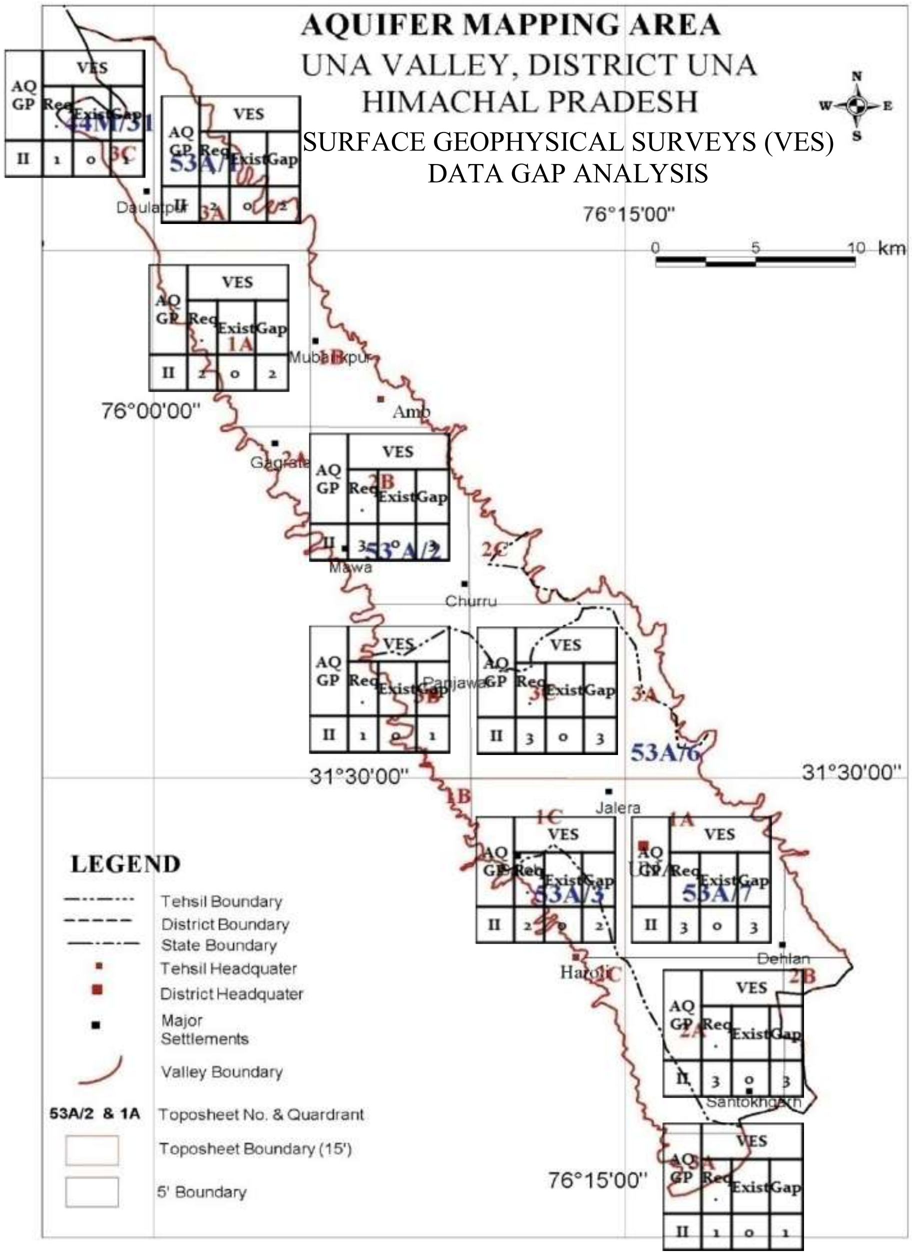


Total 44 No.

1. Daulatpur
2. Thathal
3. Badoli
4. Jankaur
5. Dangoh
6. Marwari
7. Mawa
8. Ganehri
9. Singhnei
10. Badoh
11. Panjawar
12. Ishpur
13. Padauri
14. Nangal Khurd.
15. Nangran
16. Una
17. Dehlan
18. Khwaja
19. Bhaira
20. Thathal
21. Andaura
22. Santokhgarh
23. Bathri
24. Tahliwal
25. Khanpur
26. Jankaur
27. Kahluwal
28. Dharampur
29. Badsali
30. Panoh
31. Khad
32. Athma
33. Guglehr
34. Gagrate
35. Loharli
36. Ambota
37. Karluhi
38. Panjal
39. Mubarikpur
40. Nakro
41. Babehr
42. Marwari
43. Oel
44. Nandpur

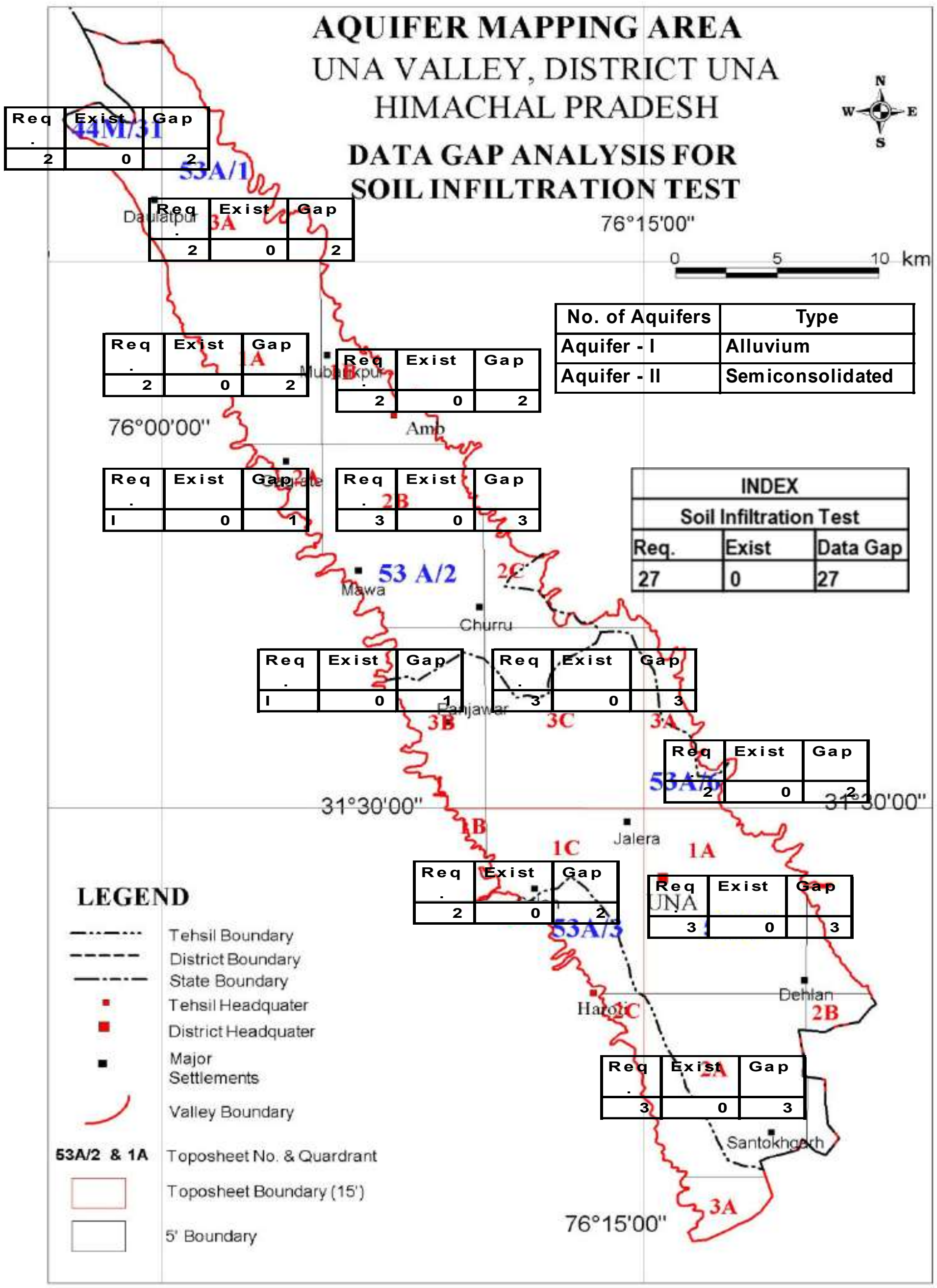
Subsurface Geophysical Survey (VES):

As per the EFC guidelines there should be 21 No. sites for VES for subsurface geophysical survey. The data gap analysis is shown in the Fig.10.



Soil Infiltration:

As per the EFC guidelines there should be 27 No. sites for soil infiltration studies. The data gap analysis is shown in the Fig.



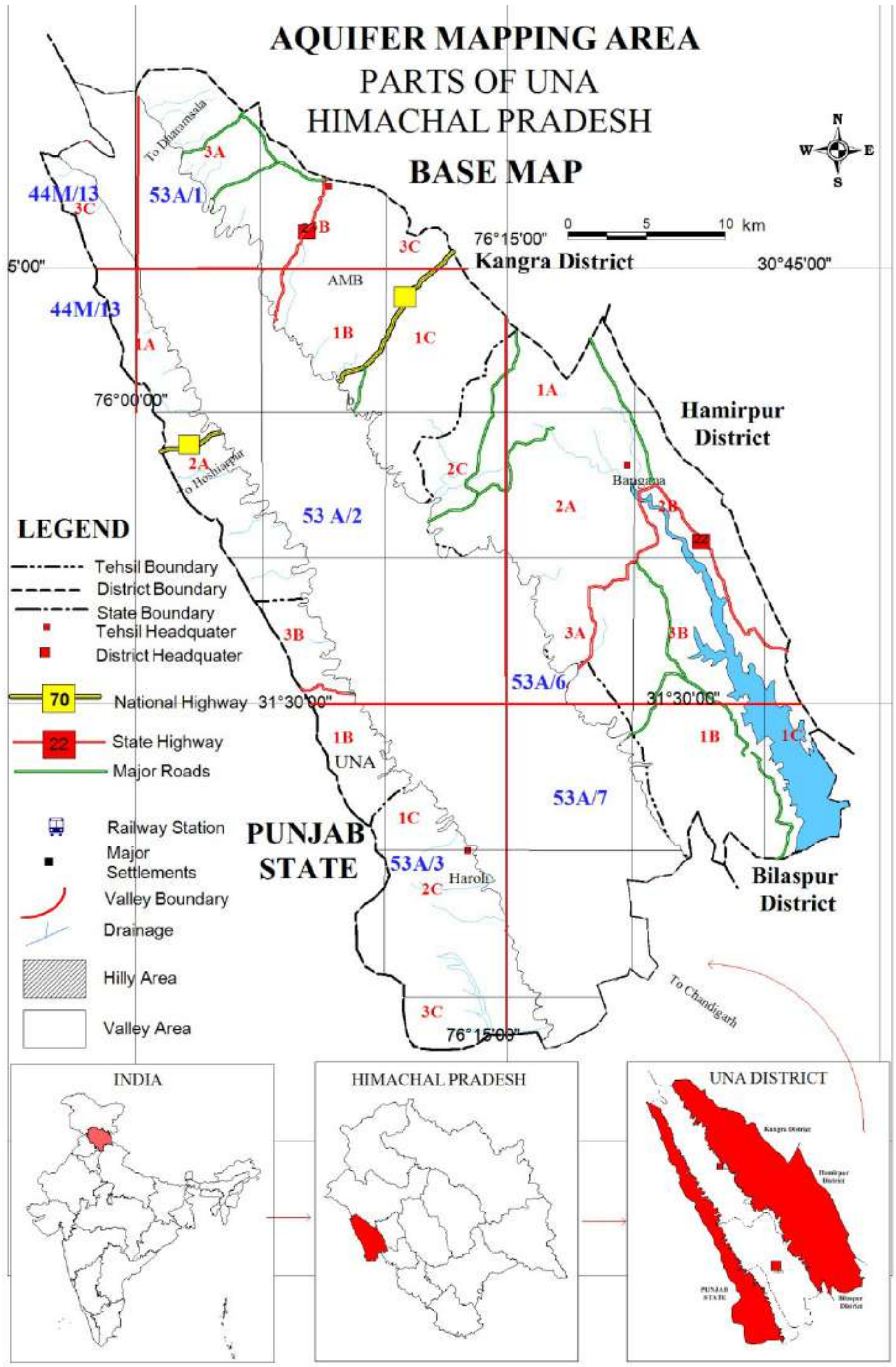
The final Data Gap analysis for Aquifer mapping in Una valley is given in the table 5.

Table 5. Data Gap Analysis for Aquifer Mapping in Una Valley, Una District
Toposheet No: 44M/13, 53A/1, 53A/2, 53 A/3, 53A/6 & 53A/7

Quadrant No.	No. of additional EWs Required		No. of additional OWs Required		No. of additional Special Purpose Wells Required (EW / PZ)		No. of additional VES/TEM Required		No. of additional water level monitoring stations Required		No. of additional Water Quality Stations 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	Aq-I	Aq-II	
44M/13-3C	0	0	0	0	0	0	0	1	0	0	0	0	2
53A/1-3A	0	0	0	0	0	1	0	2	0	0	0	0	2
53A/2-1A	0	0	0	0	0	0	0	2	0	0	0	0	2
53A/2-1B	0	0	0	0	0	0	0	0	0	0	0	0	2
53A/2-2A	0	0	0	0	0	0	0	0	0	0	0	0	1
53A/2-2B	0	0	0	0	0	1	0	3	0	0	0	0	3
53A/2-2C	0	0	0	0	0	0	0	0	0	0	0	0	0
53A/2-3B	0	0	0	0	0	0	0	1	0	0	0	0	1
53A/2-3C	1	1	1	1	0	0	0	3	0	0	0	0	3
53A/6-3A	0	0	0	0	0	0	0	0	0	0	0	0	2
53A/3-1C	0	0	0	0	0	0	0	2	0	0	0	0	2
53A/7-1A	0	0	0	0	0	0	0	3	0	0	0	0	3
53A/7-1B	0	0	0	0	0	0	0	0	0	0	0	0	0
53A/2-2C	0	0	0	0	0	0	0	0	0	0	0	0	0
53A/7-2A	0	0	0	0	0	1	0	3	0	0	0	0	3
53A/7-2B	0	0	0	0	0	0	0	0	0	0	0	0	0
53A/7-3A	0	0	0	0	0	0	0	1	0	0	0	0	1
TOTAL	1	1	1	1	0	3	0	21	0	0	0	0	27

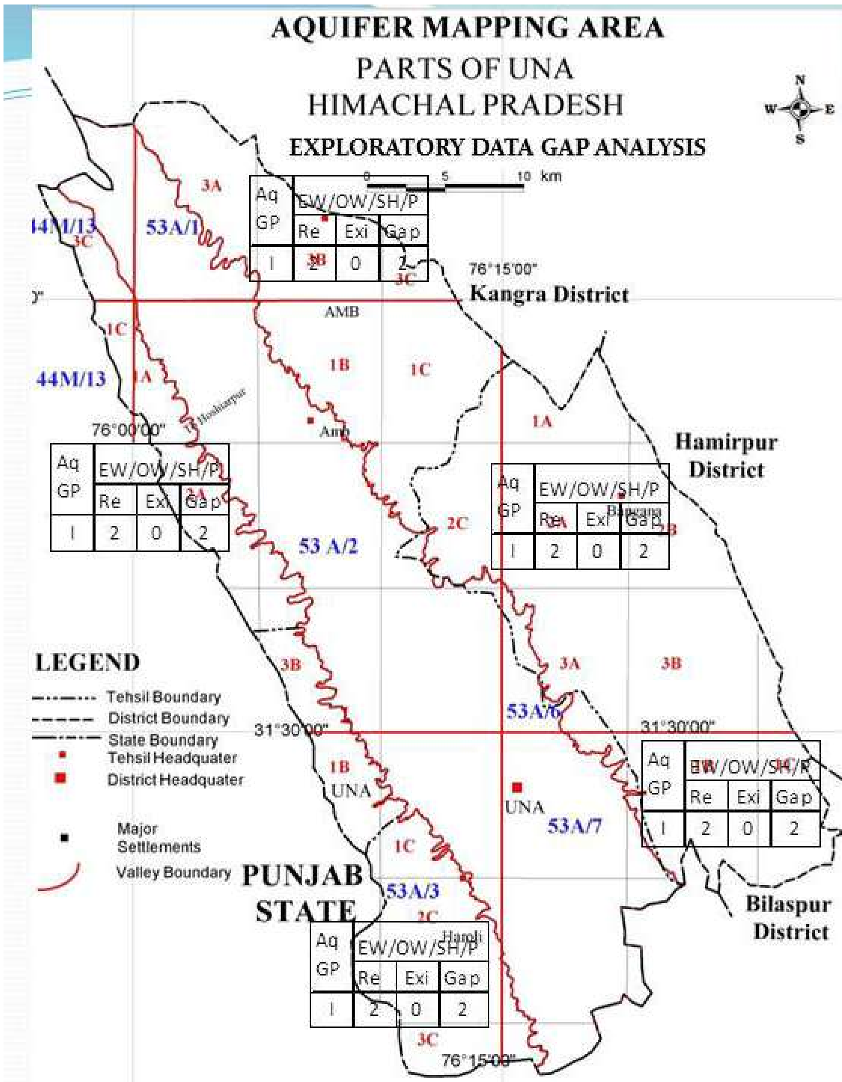
Parts of Una District

The data gap analysis for Aquifer mapping in Una valley, district Una has been carried out on the basis of EFC guidelines for soft rock area. Una valley is supposed to be a two aquifer system consisting of valley fill alluvium as a first aquifer. The base map for data gap analysis is sown in The analyses done are detailed below:



Ground Water Exploration

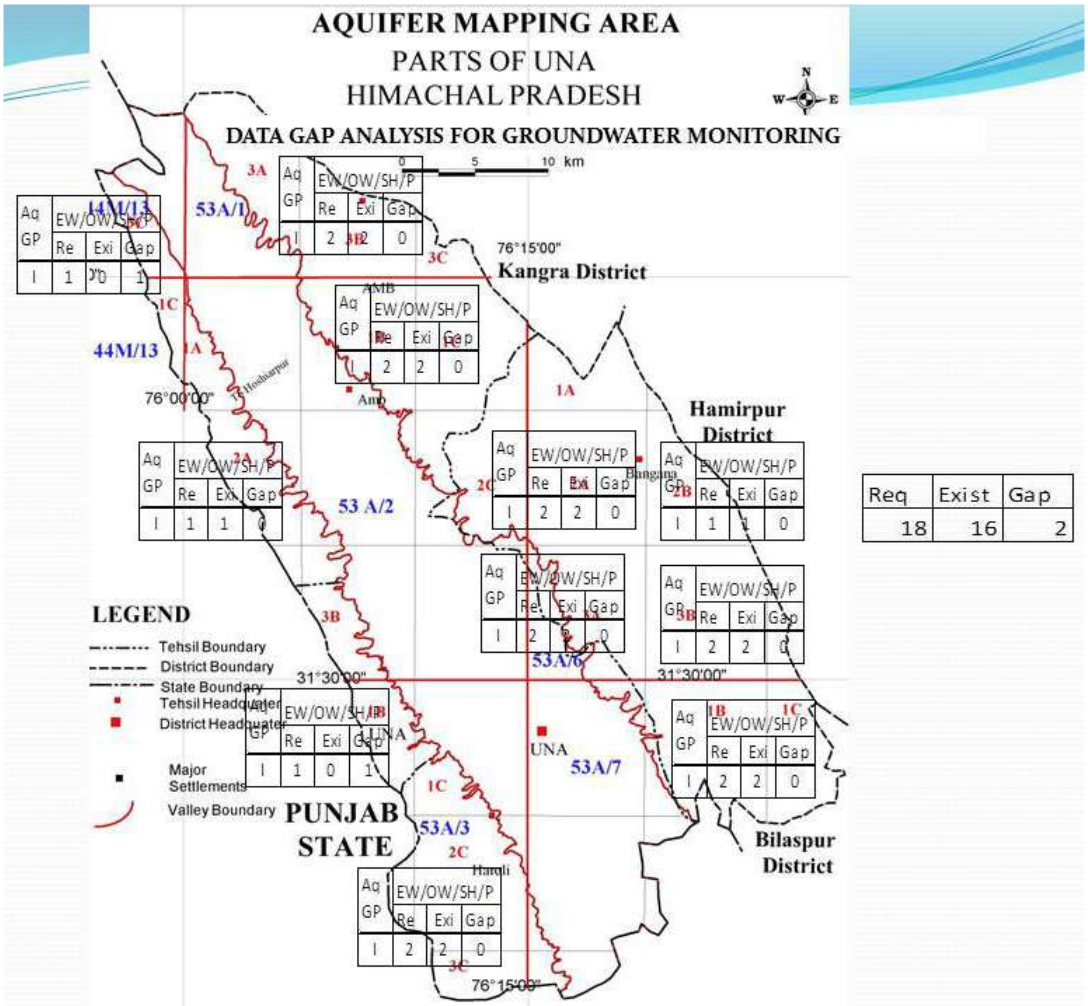
As per the EFC guidelines there should be one well field and three special purpose wells i.e. 5 EW and 5 OW. The proposed sites for EW & OW are also given



Req	Exist	Gap
10	0	10

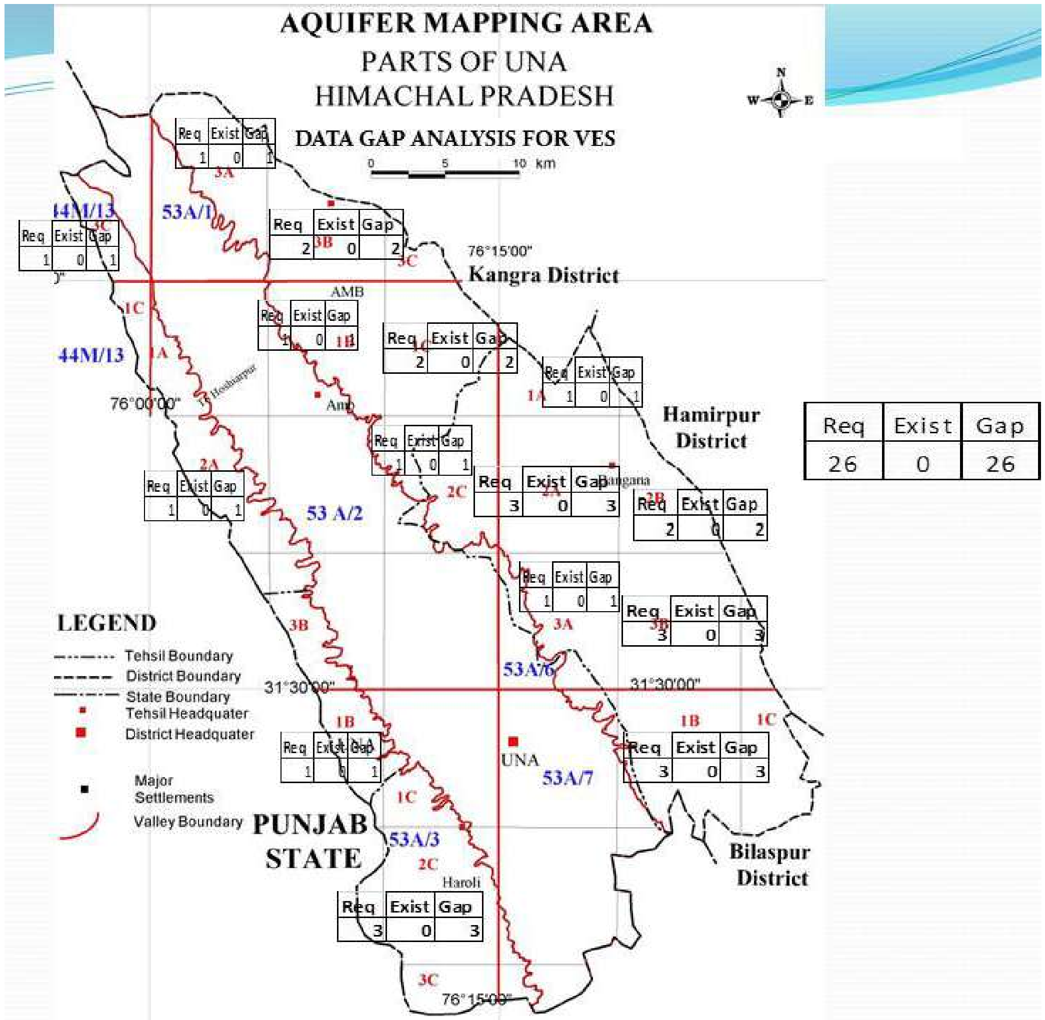
Water Level Monitoring:

As per the EFC guidelines there should be 18 No. of monitoring stations. There is no gap for water level monitoring due to the available dug wells for monitoring of first aquifer. The list of observation wells and data gap analysis is shown in fig



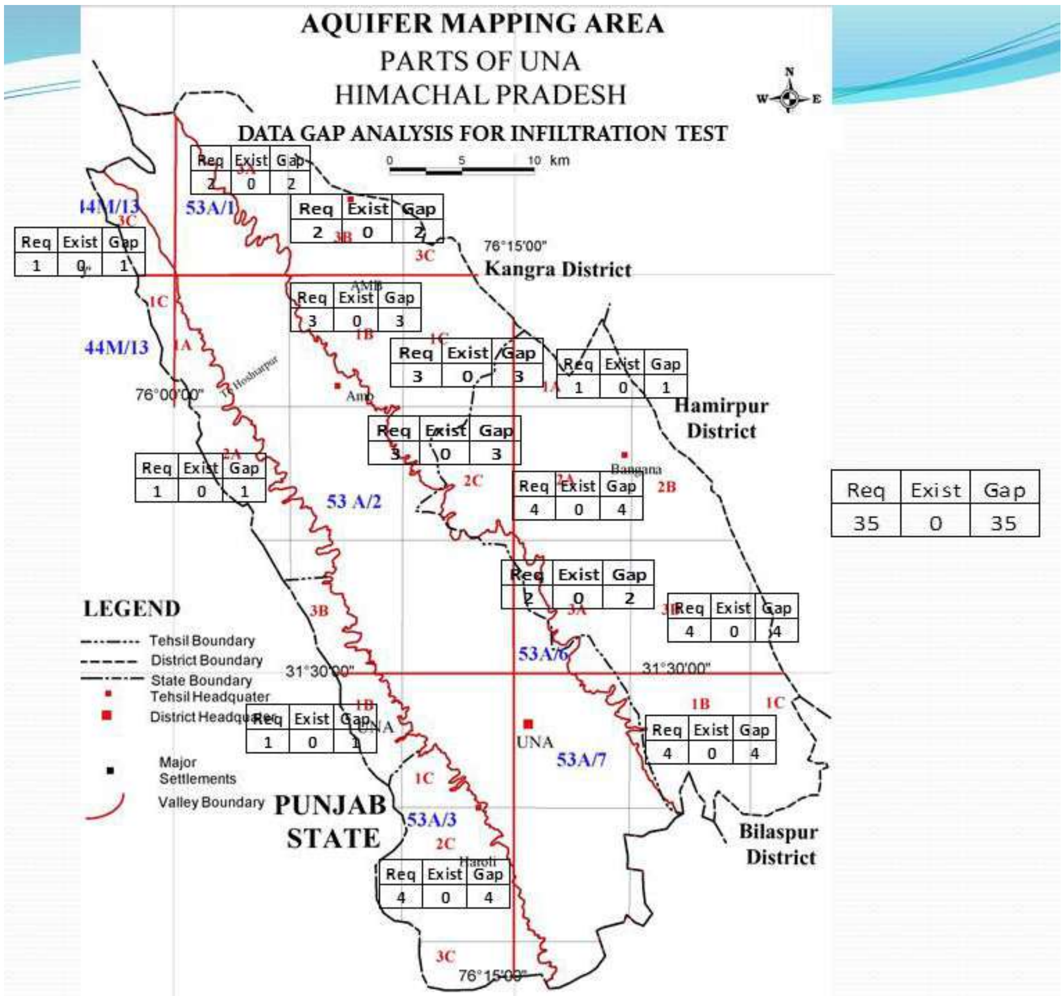
Subsurface Geophysical Survey (VES):

As per the EFC guidelines there should be 26 No. sites for VES for subsurface geophysical survey. The data gap analysis is shown in the Fig..



Soil Infiltration:

As per the EFC guidelines there should be 27 No. sites for soil infiltration studies. The data gap analysis is shown in the Fig.



The final Data Gap analysis for Aquifer mapping in Una valley is given in the table

DATA GAP ANALYSIS
Aquifer Mapping Area, Parts of Una, Una District
Toposheet No: 44M/13, 53A/1, 53A/2, 53 A/3, 53A/6 & 53A/7

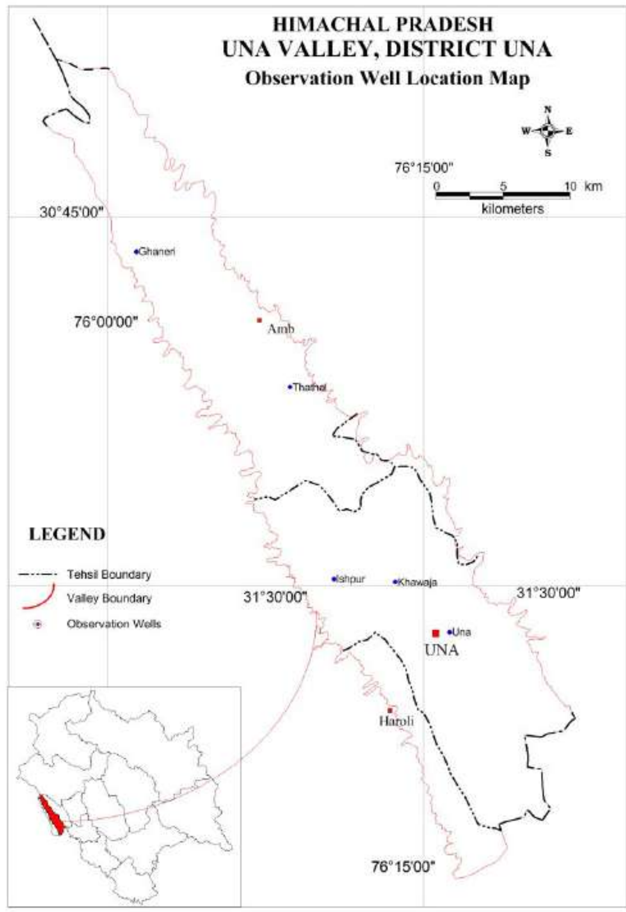
Quadrant No.	No. of additional EWs Required	No. of additional OWs Required	No. of additional water level monitoring stations Required	No. of additional VES Required	No. of Infiltrations
	Aq-I	Aq-I	Aq-I	Aq-I	Aq-I
53A/1-3A	0	0	0	1	2
53A/1-3B	1	1	0	2	2
53A/1-3C	0	0	0	0	0
53A/2-1B	0	0	0	1	3
53A/2-1C	0	0	0	2	3
53A/2-2C	0	0	0	1	1
53A/6-1A	0	0	0	1	3
53A/6-2A	1	1	0	3	4
53A/6-3A	0	0	0	1	2
53A/6-2B	0	0	0	2	0
53A/6-3B	0	0	0	3	4
53A/7-1B	1	1	0	3	4
53A/7-1C	0	0	0	0	0
44M/13-3C	0	0	1	1	1
44M/14-1C	0	0	0	0	0
53A/2-1A	0	0	0	0	0
53A/2-2A	1	1	0	1	1
53A/2-3B	0	0	0	0	0
53A/3-1B	0	0	1	1	1
53A/3-2C	1	1	0	3	4
53A/3-3C	0	0	0	0	0
Total	5	5	2	26	35

3. DATA COLLECTION AND GENERATION

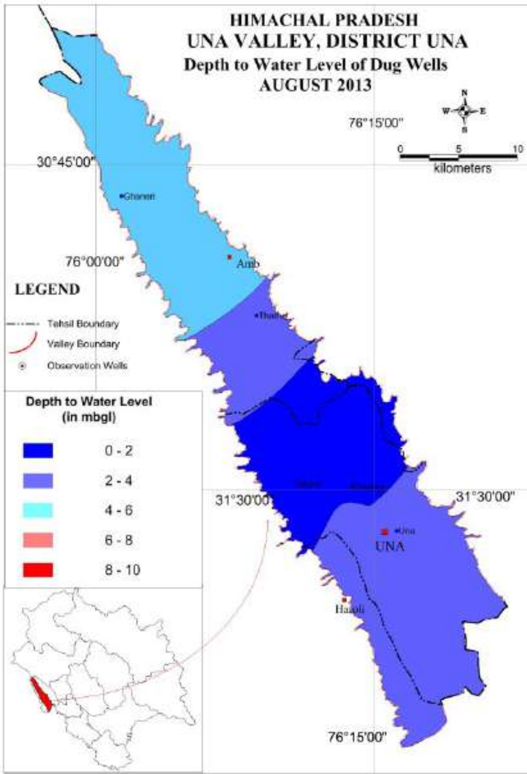
Data on various attributes of Aquifer Mapping has been generated based on the data availability and data gap analysis discussed in previous section. The data generated and data collected from various state government departments.

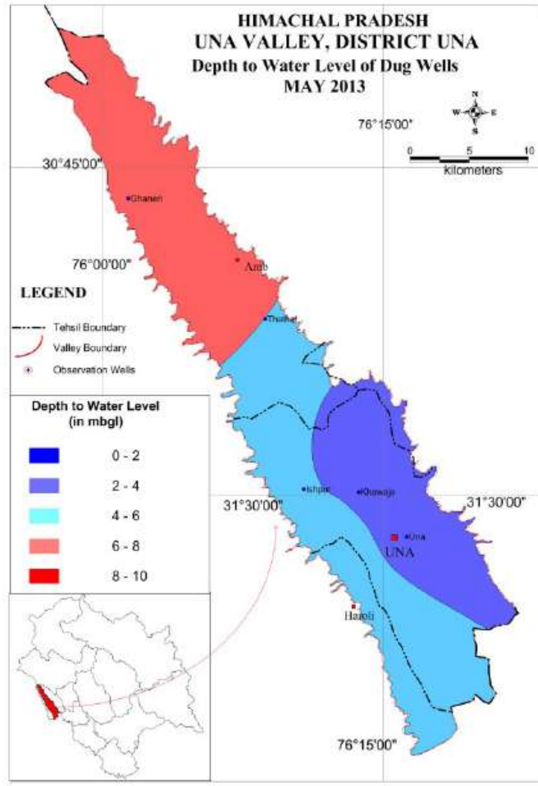
Water Level Monitoring:

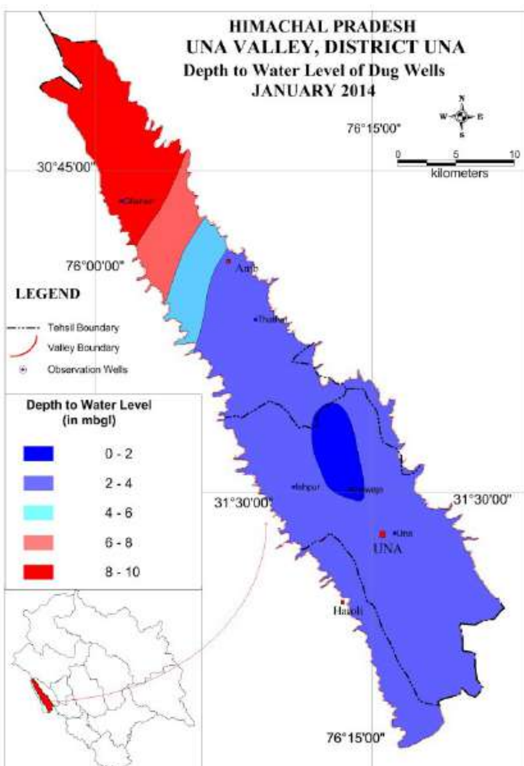
To know the water level and its behavior with respect to time and space, the dug wells have been inventoried Aquifer mapping in Una district (Fig.-). The wells were therefore monitored to study the impact of various development related activities on the ground water regime. The depth to water level contour map was generated for Una Valley only as it is not possible to prepare the contours for the hilly area. Therefore only point values are being given for the well observed in parts of Una district (Fig)

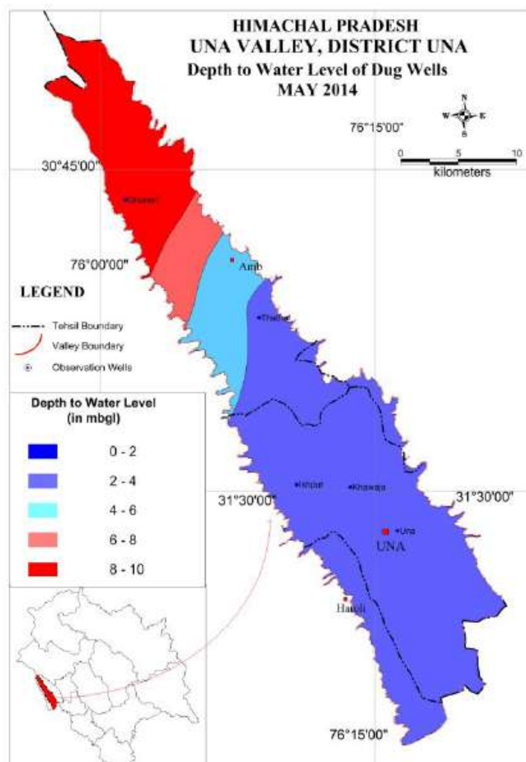


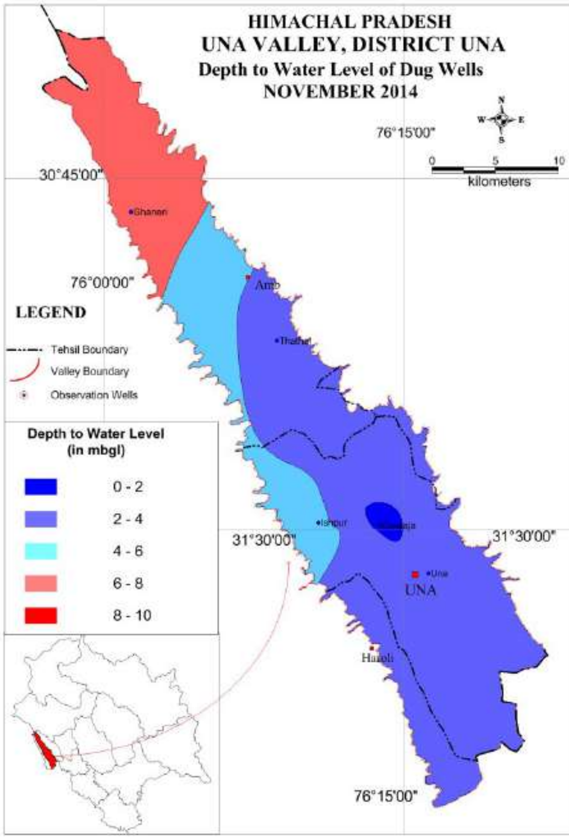
The depth to water level contour map generated during the August, 2013, November, 2013, January, 2014, May, 2014, August, 2014, November, 2014 and January, 2015 are as given in Fig.

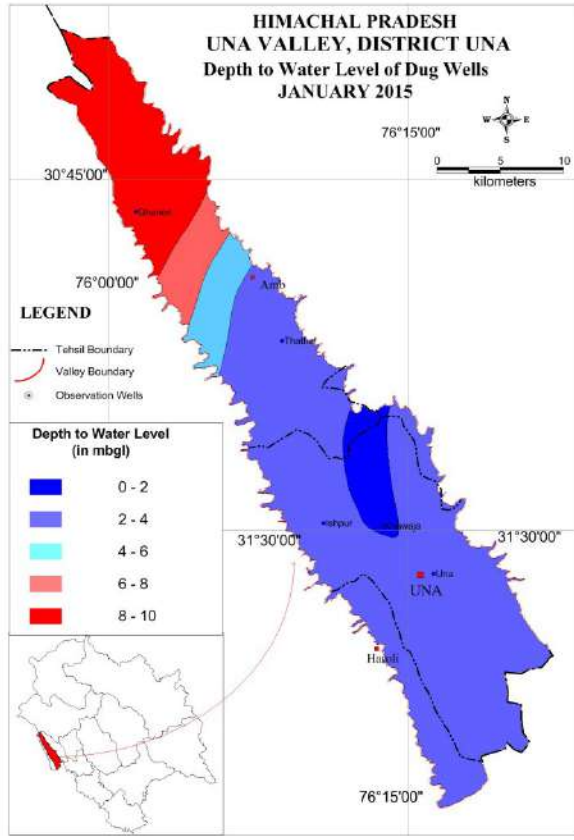

HIMACHAL PRADESH
UNA VALLEY, DISTRICT UNA
Depth to Water Level of Dug Wells
AUGUST 2013
76°15'00"
0 5 10
kilometers
30°45'00"
76°00'00"
Amb
31°30'00"
31°30'00"
UNA
Haroli
76°15'00"
LEGEND
Tehsil Boundary
Valley Boundary
Observation Wells
Depth to Water Level (in mbgl)
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10


HIMACHAL PRADESH
UNA VALLEY, DISTRICT UNA
Depth to Water Level of Dug Wells
MAY 2013
76°15'00"
0 5 10
kilometers
30°45'00"
76°00'00"
Amb
31°30'00"
31°30'00"
UNA
Haroli
76°15'00"
LEGEND
Tehsil Boundary
Valley Boundary
Observation Wells
Depth to Water Level (in mbgl)
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10

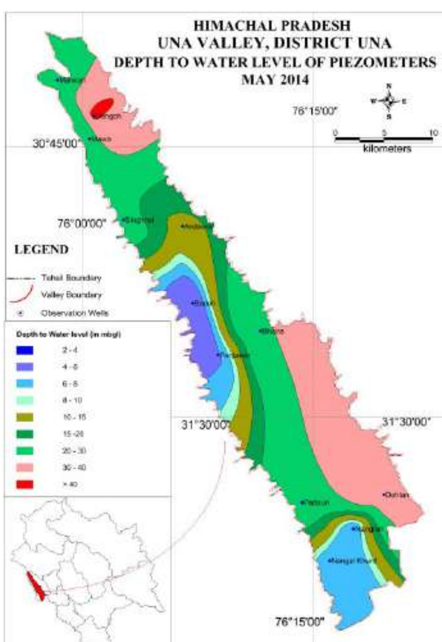

HIMACHAL PRADESH
UNA VALLEY, DISTRICT UNA
Depth to Water Level of Dug Wells
JANUARY 2014
76°15'00"
0 5 10
kilometers
30°45'00"
76°00'00"
Amb
31°30'00"
31°30'00"
UNA
Haroli
76°15'00"
LEGEND
Tehsil Boundary
Valley Boundary
Observation Wells
Depth to Water Level (in mbgl)
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10

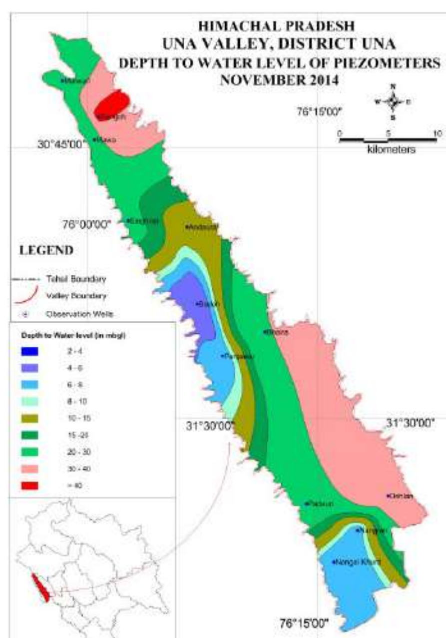

HIMACHAL PRADESH
UNA VALLEY, DISTRICT UNA
Depth to Water Level of Dug Wells
MAY 2014
76°15'00"
0 5 10
kilometers
30°45'00"
76°00'00"
Amb
31°30'00"
31°30'00"
UNA
Haroli
76°15'00"
LEGEND
Tehsil Boundary
Valley Boundary
Observation Wells
Depth to Water Level (in mbgl)
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10



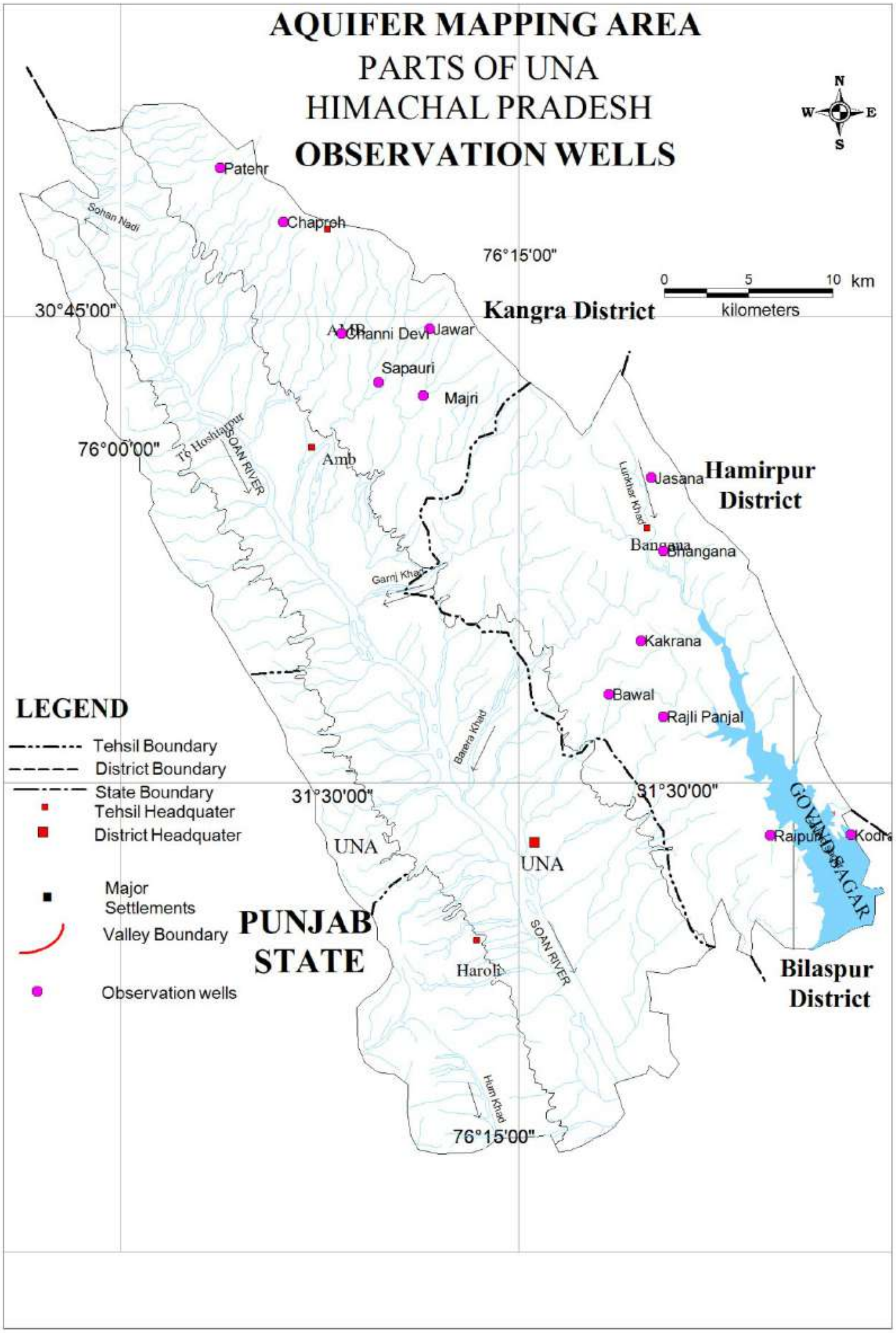


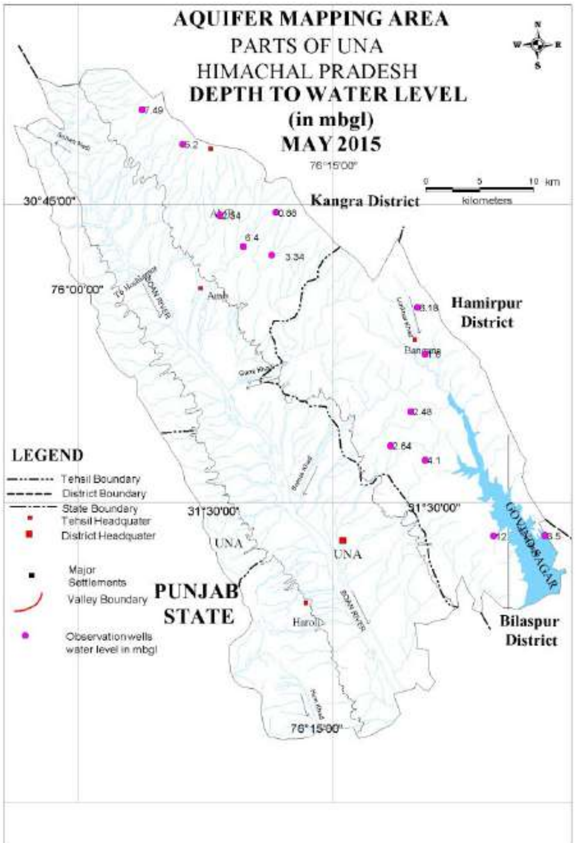
Depth to Water Lebvel map has also een generated on the basis of the Piezometers constructed by state agencies. The location maps of Piezometers is given in Fig.

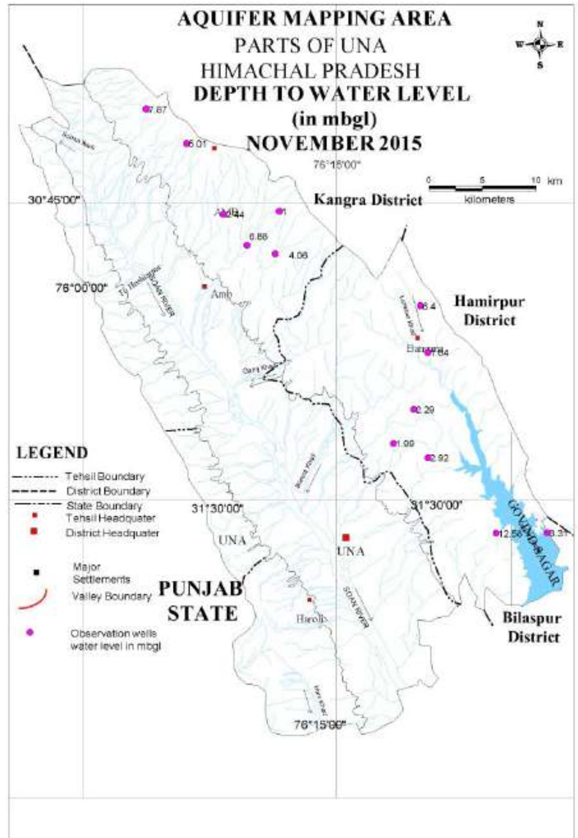


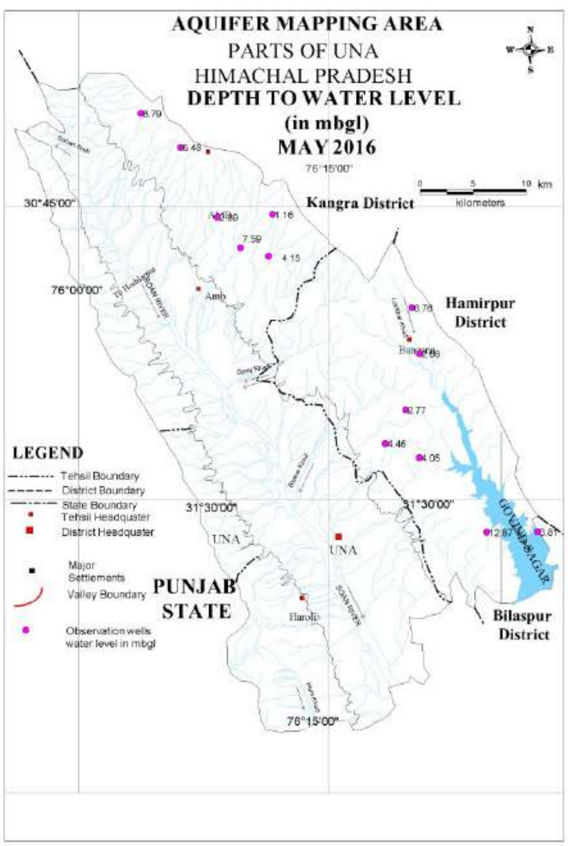


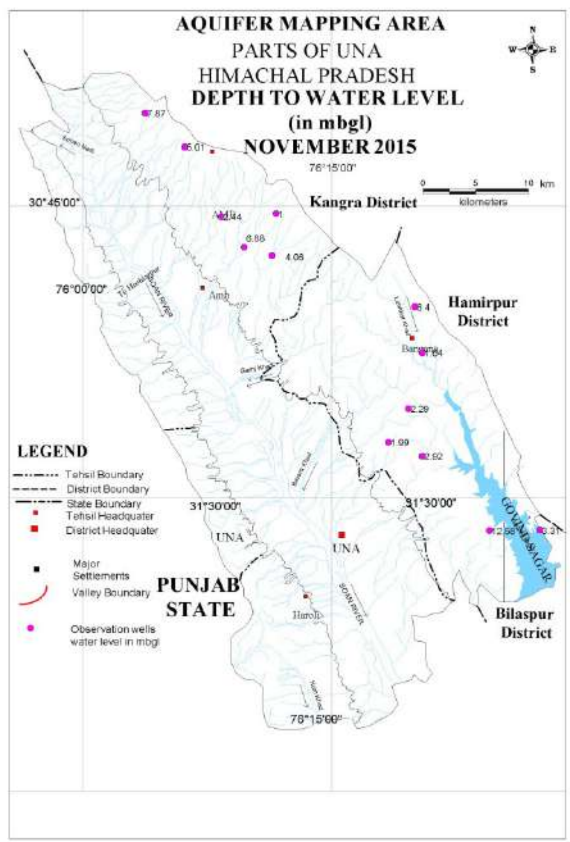
The point values map of the observation well located in Parts of Una District:




AQUIFER MAPPING AREA
PARTS OF UNA
HIMACHAL PRADESH
DEPTH TO WATER LEVEL
(in mbgl)
MAY 2015
Kangra District
Hamirpur District
Bilaspur District
PUNJAB STATE
UNA
Amb
Bangana
Haroli
GOVIND SAGAR
LEGEND
Tehsil Boundary
District Boundary
State Boundary
Tehsil Headquater
District Headquater
Major Settlements
Valley Boundary
Observation wells water level in mbgl
30°45'00"
76°00'00"
31°30'00"
76°15'00"
7.49
5.2
0.66
6.4
3.34
3.18
2.48
2.64
4.1
12
6.5


AQUIFER MAPPING AREA
PARTS OF UNA
HIMACHAL PRADESH
DEPTH TO WATER LEVEL
(in mbgl)
NOVEMBER 2015
Kangra District
Hamirpur District
Bilaspur District
PUNJAB STATE
UNA
Amb
Haroli
GOVIND SAGAR
LEGEND
Tehsil Boundary
District Boundary
State Boundary
Tehsil Headquater
District Headquater
Major Settlements
Valley Boundary
Observation wells water level in mbgl
30°45'00"
76°00'00"
31°30'00"
76°15'00"
7.87
5.01
1
6.88
4.06
8.4
2.29
1.99
2.92
12.56
0.31


AQUIFER MAPPING AREA
PARTS OF UNA
HIMACHAL PRADESH
DEPTH TO WATER LEVEL
(in mbgl)
MAY 2016
Kangra District
Hamirpur District
Bilaspur District
PUNJAB STATE
UNA
Amb
Haroli
GOVIND SAGAR
LEGEND
Tehsil Boundary
District Boundary
State Boundary
Tehsil Headquater
District Headquater
Major Settlements
Valley Boundary
Observation wells water level in mbgl
30°45'00"
76°00'00"
31°30'00"
76°15'00"
8.79
6.48
1.16
7.59
4.15
6.78
2.77
4.46
4.05
12.87
3.81


AQUIFER MAPPING AREA
PARTS OF UNA
HIMACHAL PRADESH
DEPTH TO WATER LEVEL
(in mbgl)
NOVEMBER 2015
Kangra District
Hamirpur District
Bilaspur District
PUNJAB STATE
UNA
Amb
Haroli
GOVIND SAGAR
LEGEND
Tehsil Boundary
District Boundary
State Boundary
Tehsil Headquater
District Headquater
Major Settlements
Valley Boundary
Observation wells water level in mbgl
30°45'00"
76°00'00"
31°30'00"
76°15'00"
7.87
5.01
1
6.88
4.06
8.4
2.29
1.99
2.92
12.56
0.31

Aquifer Characteristics

The data of ground water exploration of Central Ground Water Board in the shape of lithologs was extracted from old files and was computerized in MS Excel. The strata charts from Irrigation & Public Health Department were collected and their co-ordinates and elevations were worked out in the field and on toposheets. This data was also brought into digital form. The unified lithologs were prepared according to the standard legend decided.

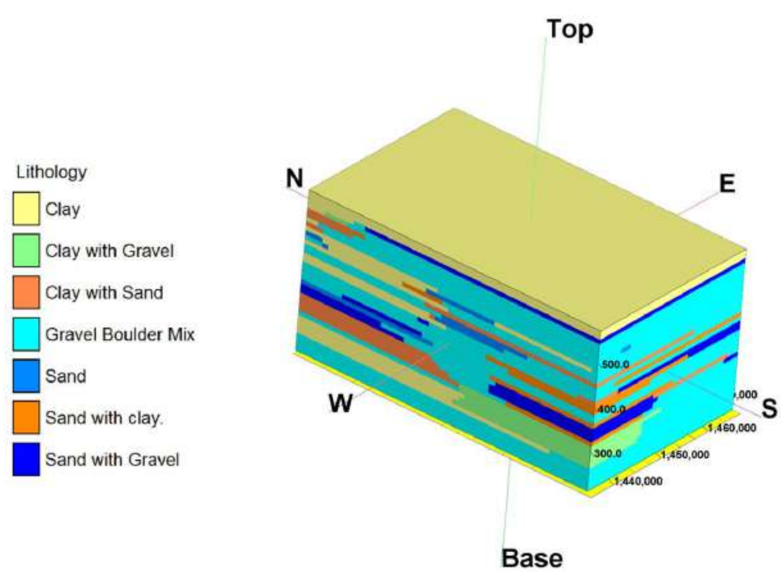
The lithological layers are generated using borehole data. The layers are broadly classified into eight types– sand; clay; shale; sandstone; conglomerate, boulder, cobble, pebble, gravel, sand; boulder, cobble, pebble, gravel, sand; clay with boulder, cobble, pebble, gravel, sand; and sand, boulder, cobble, pebble, gravel.

Lithological Disposition and Aquifer Disposition

The lithological disposition and the aquifer disposition interpreted through the models, fence and cross sections prepared using the rockworks software. The sections drawn for sub-surface formations and aquifers, have vertical and horizontal scales in meters.

The lithological and aquifer model of the complete aquifer mapping area depicts that the northern part is at higher elevations and the depth of exploration is limited to 100 m in this part. There is an abundance of granular horizon but the water levels are deep. The valley part is at shallow elevations and water levels are very shallower in this part. In the hilly area the water bearing zone is very less.

The 3D model of Una valley has been created on the basis of the lithology ia as given in fig.



4. GROUND WATER RESOURCES

Rainfall is the major source of recharge to the groundwater body, apart from the influent seepage from the rivers, irrigated fields and inflow from upland areas, whereas 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 etc.

The quantitative estimation of various inputs to ground water resources and their temporal variation in space and time is imperative for a planned management and development of ground water resources. The resources in the surveyed area are computed on the basis of methodology recommended by the Ground Water Estimation Committee of Ministry of Water Resources, Govt. of India, 1997.

Methodology adopted

The primary source of recharge of groundwater in the Una valley is rainfall. Therefore rainfall infiltration method has been used for estimating the resources. Rainfall recharge factor or Infiltration factor is a recharge parameter that indicates a quantum of water recharged to the groundwater system in relation to the rainfall. It is a function of rate of infiltration and ability of the system to accept the infiltrated water. The infiltration factor can be expressed as follows

IF = (Qi/Qa) X SY,

Where,

IF = Infiltration Factor

Qi = Quantum of water infiltrated over the test period in m

Qa = Quantum of water applied in m

SY = Specific Yield

Recharge of ground water involves several components and the rainfall being the major one. The other components are return irrigation flow from surface water and ground water.

Ground water resources and irrigation potential for Una valley and Hum valley of the district have been computed as per the GEC-97 methodology, the resources for the year 2013 are presented below.

DYNAMIC GROUND WATER RESOURCES (2013)

A. Una valley

• Net Annual Ground Water Draft for all uses	9559.66 ham
• Net Ground Water availability for future Irrigation	4503.63 ham
• Projected Demand for Domestic and industrial Uses up to 2025	1290.67 ham
• Stage of Ground Water Development	74.43%
• Category	Safe

B. Hum valley

• Net Annual Ground Water Draft for all uses	539.46 ham
• Net Ground Water availability for future Irrigation	-33.01ham
• Projected Demand for Domestic and industrial Uses up to 2025	164.32 ham
• Stage of Ground Water Development	90.29 %
• Category	Critical

The stage of ground water development in Una valley and Hum valley of Una district, is 74.43% & 90.29% and both valleys fall under "Critical" category. There is thus no scope for further ground water development.

5. GROUND WATER MODELLING

Three-dimensional mathematical models of regional groundwater flow are beneficial to the management of groundwater resources as they allow the approximation of the components of hydrological processes and provide a mechanistic description of the flow of water in an aquifer.

Numerical three-dimensional groundwater flow model was developed for the Una valley, District Una, Himachal Pradesh with the following objectives:

- To simulate regional groundwater flow to identify the distribution of heads,
- Impact on the aquifer system due to various hydrological stresses.
- To develop few scenarios for proper understanding of the aquifer system.
- For Efficient and sustainable management of the aquifer system.

The conceptual model of the system was arrived from the detailed study of geology, borehole lithology, geophysical resistivity survey &logs, cross section and water level fluctuations in wells. Groundwater of the study area is found to occur in the alluvial formation in the valley area and surrounded by Siwalik formation. Groundwater is found to occur in unconfined conditions in the alluvial formation.

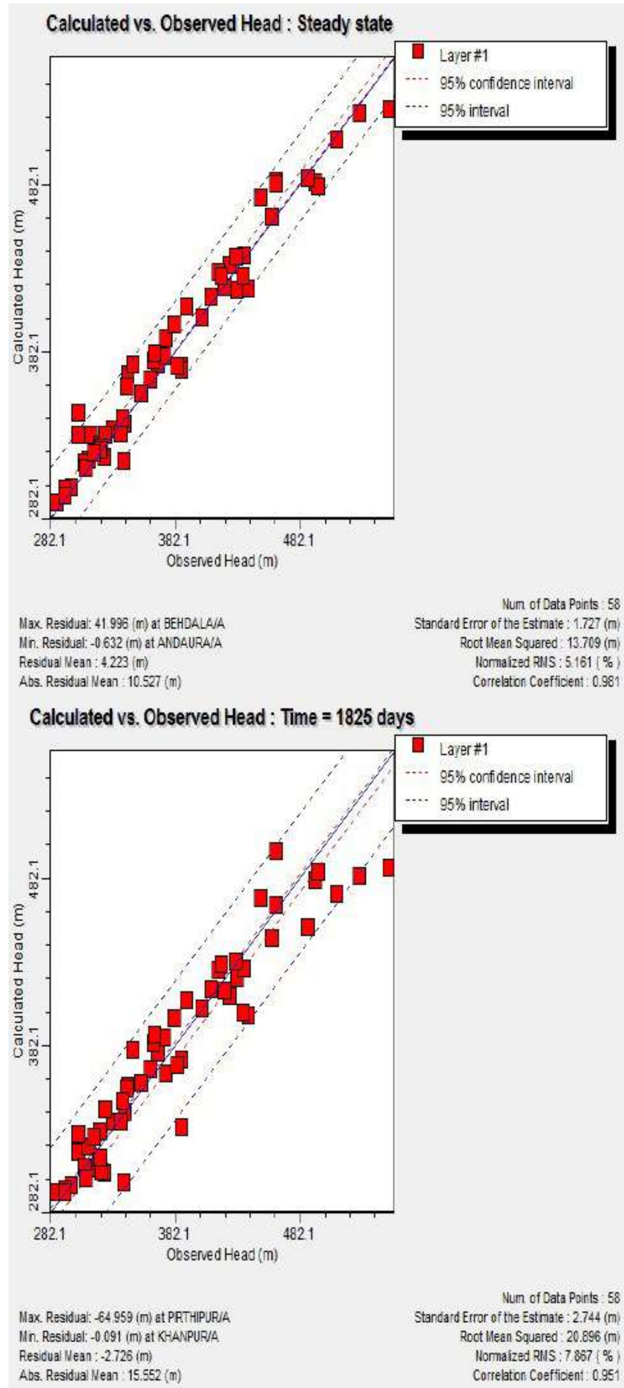
The calibration strategy was to initially vary the best known parameters as little as possible, and vary the poorly known or unknown values the most to achieve the best overall agreement between simulated and observed.

i. Steady state model:

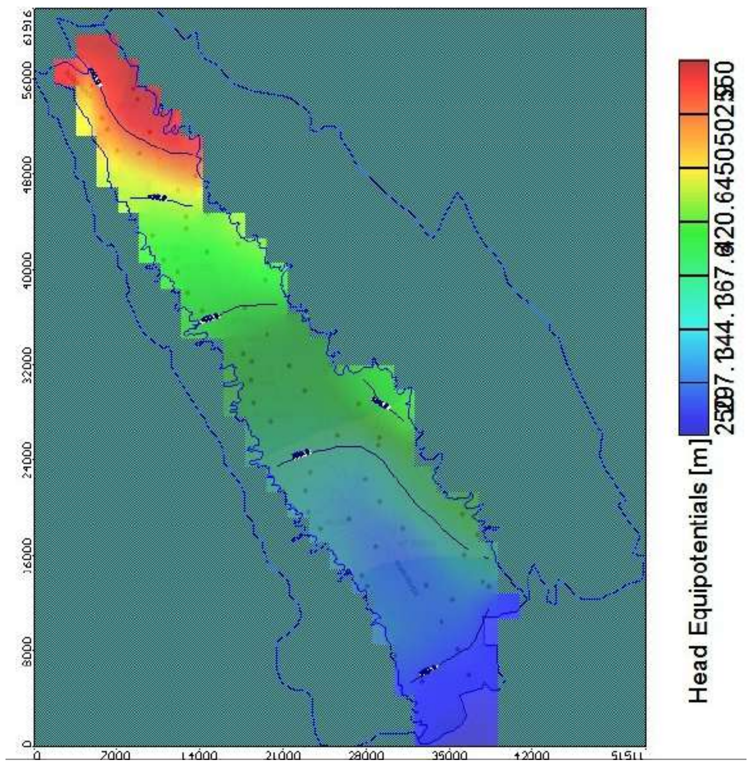
Steady state model calibration was carried out to minimize the difference between the computed and field water level condition. Steady state calibration was carried out with the water level data of May 2013 in 60 wells distributed over the study area. Out of all the input parameters, the Specific yield value is the only poorly known as only 15 pumping tests were available in this area. The lithological variations in the area and borehole lithology of existing wells were studied. Based on this it was decided to vary hydraulic conductivity values upto 10% of the pumping test results for layer in order to get a good match of the computed and observed heads. The figure indicates that there is a very good match between the calculated and observed water heads in most of the wells of the study area. Root mean square error and the mean error were minimized through numerous trial runs.

ii. Transient State Model:

Transient state simulation was carried out for a period of 5 years from Jan 2013 to Dec 2017 with season wise stress periods during monsoon and non-monsoon for 245 days and 120 days respectively. The trial and error process by which calibration of transient model was achieved by several trials until a good match between computed and observed heads over space and time. The hydraulic conductivity and recharge values incorporated in the transient model were modified slightly from those calibrated by the steady state model. Based on the close agreement between measured and computed heads from Jan 2013 to Dec 2017 at 60 observation wells distributed through out the aquifer, the transient models were considered to be calibrated satisfactorily . The sensitivity of the model to input parameters were tested by varying only the parameter of interest over a range of values and monitoring the response of the model by determining the root mean square error of the simulated heads compared to the measured heads.



The model was simulated in transient condition for a period of 5 years from January 2013 to December 2017. There was fairly good agreement between the computed and observed heads (Figure.7). A study of the simulated potentiometric surface of the aquifer indicates that the highest heads are found on the North-western side of the study area, which is a general reflection of the topography. The regional groundwater flow direction is from north-east to south-west. The groundwater flow vectors for the month of December 2012 is given in figure.. The comparison of observed and computed heads . The computed and observed heads for Daulatpur and Amb village clearly shows the match in the pattern and trends (Fig.). The transient simulation clearly shows the matching of pattern of the groundwater head with change in time.



The aquifer response for different input and output fluxes was studied in order to sustainably manage the aquifer system. The model was run for a further period of 05 years from 2017 to 2022. Before commencement of this simulation, the data of normal rainfall, abstraction, and recharge was provided to the model upto 2022.

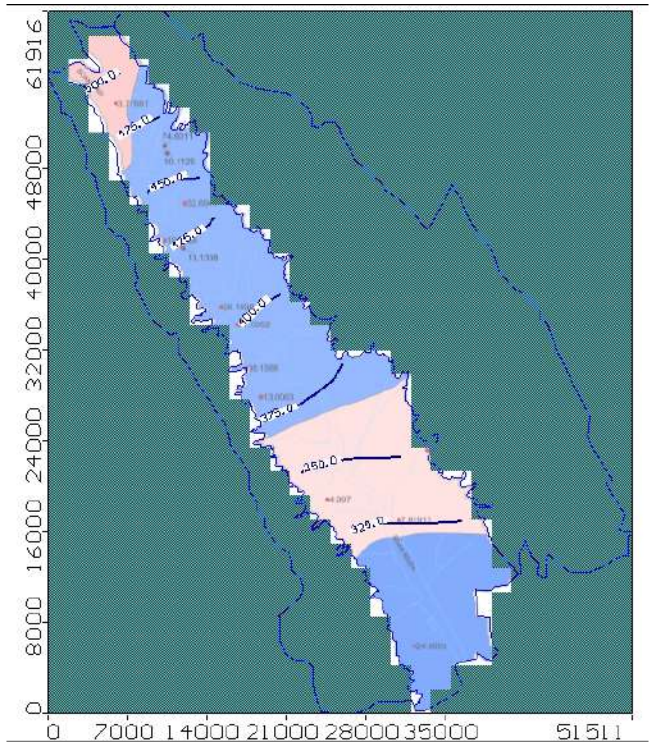
One prediction runs were planned to evolve optimal management schemes.

i. Normal rainfall condition

The model was run to predict the regional groundwater head in this area until the year 2022. For these runs the monthly average rainfall calculated from 05 years rainfall data was used. The present level of groundwater abstraction was considered for this simulation. The simulated regional groundwater head for September 2022 is shown in Figure. There is not much increase or decrease in water level. Such observation is made in most of the locations. This clearly indicates that the model is stable under the present pumping conditions.

ii. Increase in Pumping

The model was run to predict the regional groundwater head in area until the year 2022 with 30 % increase in pumping for which the normal monsoon and non monsoon rainfall data was used. The predicted model indicates that there is uniform decline of ground water head in the aquifer of study area (Figure. 10).



Three-layered finite-difference flow model was used to simulate the groundwater head in the Una aquifer system for a period of 5 years (Jan 2013-Dec 2017) for better understanding of the aquifer system. All the data was inputted into the model and Visual Modflow Classic 4.6.0.166 was used to simulate the model. The model was calibrated for steady and transient state conditions. There was a reasonable match between the computed and observed heads. Based on the modelling results, it is found that this aquifer system is stable at this pumping rate. The transient model was run until the year 2022 to forecast the dynamic groundwater flow under various scenarios of over pumping and less recharge. The model predicts the behavior of this aquifer system under various hydrological stress conditions. The simulated results indicate that this aquifer system is stable under the present conditions. The spatial groundwater head follows the topography. The groundwater water flows from the north to south -south eastern. The computed groundwater head mimics the observed groundwater head in several locations. The model helps in understanding the groundwater head trend and illustrates the impact of changes in hydrological conditions, thus enables the water managers for an effective management tool.

6. ISSUES AND AQUIFER MANAGEMENT STRATAGIES

Major ground water related issues in Una district

- Deeper Water Levels in hilly area or Beet area
- Decline in Water Levels
- Comparatively Steeper slopes
- Large no. of springs
- Open Dug Wells losing their Utility
- Deforestation led to reduced recharge
- Artesian Conditions: Ground water is lost through natural drainages
- Surface flows: Huge volume of unaccounted water flowing waste
- Water Logged Area – Reduced – declining ground water levels
- High NO_3 at a few isolated places

Issues in Una District

1. Deeper Water Levels

There is acute shortage of water in the hilly area of Siwalik formation where the water tables are deep seated. The lithology in the area is less pervious and not capable of receiving large volumes of recharge.

2. Decline in Water Levels in both Hilly and valley area.
3. Comparatively Steeper slopes in hilly area
4. Large number of Ponds

There are a large number of ponds/tanks in Beat area. In earlier days water from these ponds was being used for washing, bathing and even drinking at places. These ponds also acted as recharge structures. With the coming up of piped water supply these ponds have been put to dis-use and have even been encroached upon, and their inlets have been disturbed. Some ponds are being filled up by tubewells installed near them which are putting stress on aquifers.

5. There exist a large number of dug wells (open wells and most of them belong to the village community) in the area, which have lost their utility with the coming up of piped water supply. These dug wells are either being filled up with garbage or they are being covered up with RCC slabs to avoid falling of children and animals in them.

6. High NO_3 and Fe at a few isolated places

Contamination of water from septic tanks occurs under various conditions viz, Poor placement of septic leach fields, high density placement of tanks, leakage from sewer lines. Nitrate is also mostly found in the return flow from the agriculture area.

9. Artesian Conditions:

Huge amount of ground water is lost through the free flow artesian wells. Number of tubewell is being constructed in some part of the valley area of free flow wells for irrigation purposes. The ground water emerging through these free flow tubewells can be channelised and utilized for irrigating the fields. Absence of water and electricity budgeting provisions are a cause of wastage of fresh utilisable ground water.

10. Surface flows: Springs

The entire hilly area of the district consists of springs, which are due to gravitational forces only, and generally springs are contact, fracture or depression in origin. To define the magnitude of springs, Meinzer, 1923 proposed a classification by discharge. The discharge of the spring depends on the area contributing recharge to the aquifer and the rate of recharge.

Magnitude	Mean Discharge
I	>10 m3/sec
II	1-10 m3/sec
III	0.1-1 m3/sec
IV	10-100 lps
V	1-10 lps
VI	0.1-1 lps
VII	10-100 ml/sec
VIII	<10 ml/sec

Most of the springs in the area come under the category VI of Meinzer's classification for springs. The only spring that comes under category V is at spring no. 53A/2-1C1 at Daulidhar has a discharge of 1 lps in pre-monsoon period. The pre- monsoon post-monsoon fluctuation of spring discharge ranges from zero to 0.5 lps at Biru

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.

Plan for Sustainable Management of the Resource

- The major aquifer system of the Una valley is alluvial deposits.
- Valley fill deposits and terraces are to be fully explored by constructing test wells for studying the precise distribution of ground water horizons and scope for development.
- In hard rock area all the weak zones, like thrust, faults, fractures, lineaments, and contact of different formation are to be studied in detail for demarcating the aerial extent and vertical distribution of ground water potential zones by micro level hydrogeological/geophysical studies followed by exploratory drilling based on which suitable ground water structures can be constructed for the development of ground water resources.
- As per GEC 1997 methodology, ground water resources for Una Valley and Hum Valley was estimated and observed that there is a scope for ground water development as the stage of ground water development in Una valley and Hum valley of Una district, is 74.43% & 90.29% and both valleys fall under "Critical" category. There is thus no scope for further ground water development.
- There is need to protect traditional water harvesting structures like ponds, tanks, talavs to utilized these for rain water harvesting and recharging shallow aquifers.
- In hilly and mountainous terrain, traditional ground water sources viz., springs, bowries etc needs to be developed and protected for better health and hygiene with proper scientific intervention.
- Proper development of springs in hilly area 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 in sanitary spring box 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.

- In the district, for most of the households, IPH department supplies water, so the people put their dugwells abandoned without using it. These unused and abandoned dugwells can be used as rainwater harvesting and artificial recharge structure to recharge ground water.
- People's participation is a must for any type of developmental activities. So proper awareness for utilization and conservation of water resources is required.
- Constrictions of bore well near to spring source in hilly area should be avoided as this could lead to drying of the natural water sources.
- Recharge structures feasible in hilly areas are check dams, Gabion structures and staggered contour trends at suitable locations.