केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

भारत सरकार

Central Ground Water Board

Ministry of Water Resources, River Development and Ganga Rejuvenation

Government of India

Report

on

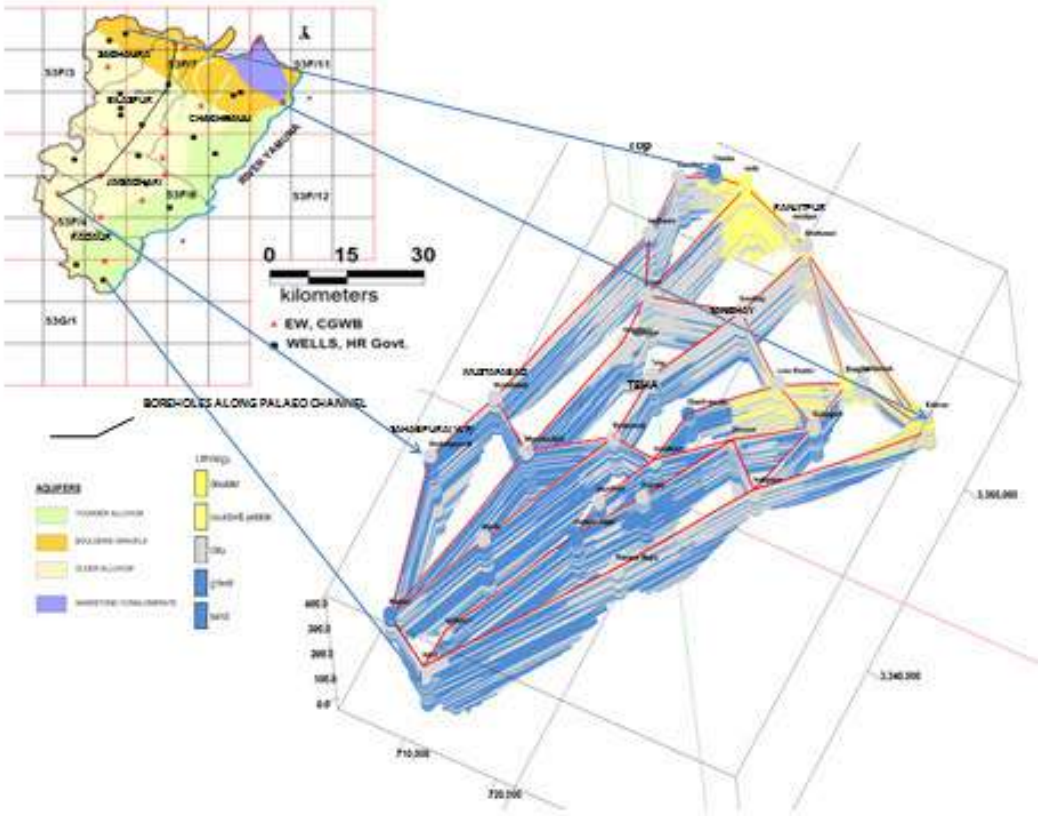
AQUIFER MAPPING AND MANAGEMENT PLAN

Yamuna Nagar District, Haryana

उत्तरी पश्चिम क्षेत्र, चंडीगढ़

North Western Region, Chandigarh

AQUIFER MAPPING & MANAGEMENT PLAN
YAMUNANAGAR DISTRICT
HARYANA



Central Ground Water Board
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2016

AQUIFER MAPPING AND MANAGEMENT PLAN
YAMUNANAGAR DISTRICT
(1756 Sq Km)

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AQUIFER MAPPING AND MANAGEMENT PLAN
YAMUNANAGAR DISTRICT
(1756 Sq Km)

Executive Summary

"Aquifer mapping" is a scientific method that applies hydro-geologic techniques to assess the quantity, quality, and distribution of groundwater in aquifers in horizontal as well as in vertical domains and characterize them, so as to work out the development potential and prepare an aquifer-wise management plan. This program integrates the variety of scientific data including geologic, hydrologic, geophysical, and geochemical with the objectivity and knowledge that the Aquifer Mapping Program possesses.

Yamunanagar is a place of great Historical and Religious importance, revered all over the country for its sacred associations. It is situated in the north eastern part of Haryana state. Saraswati and Markanda are main rivers of the district. The district has been divided into 2 subdivisions namely Thanesar and Pehowa. It has five development blocks viz., Thanesar, Pehowa, Ladwa, Babain & Shahabad.

Aquifer mapping study has been carried out in Yamunanagar district and as a result two to three aquifer systems have been identified up to a depth of 300m. Aquifer I is unconfined in nature and Aquifer II & III are semi-confined to confined in nature. The ground water resource quantity estimation for all the three aquifers has also been assessed. Aquifer I (unconfined) is very prominent in the district and it has been observed that for irrigation and other purposes, the users are tapping mainly Aquifer I. The ground water extraction is quite high which is reflected by the stage of the development of the district i.e. 135% (2013) and district is categorized as over-exploited which leads to the need of the ground water management plan. To reduce the stage of development some management strategies like lining of underground pipelines, crop diversification, roof top rainwater harvesting and artificial recharge has been proposed of which the details are given in the following chapter.

1. INTRODUCTION

1.1 GENERAL

Total geographical area of the district is 1756 sq.km. Administratively, Yamuna Nagar district is divided into one sub-division and six-development blocks viz. Bilaspur, Chachrauli, Jagadhri, Mustafabad, Radaur and Sadhaura. Yamuna Nagar is thickly populated district. The population of the district is 12,14,205 as per 2011 census. The eastern parts of the district falls in the Upper Yamuna Basin and western parts falls in Ghaggar basin. Irrigation is done only by ground water.

The climate of Yamuna Nagar district can be classified as subtropical monsoon, mild &dry winter, hot summer and sub-humid which is mainly dry with hot summer and cold winter except during monsoon season when moist air of oceanic origin penetrates into the district. There are four seasons in a year. The hot weather season starts from mid March to last week of the June followed by the southwest monsoon which lasts up to September. The transition period from September to November forms the post monsoon season. The winter season starts late in November and remains up to first week of March.

The normal annual rainfall of the district is 1107 mm, and is unevenly distributed over the area. The average rainy days are 43. The south west monsoon, sets in from last week of June and withdraws in the end of September, contributing about 81% of normal annual rainfall. July and August are the wettest months. Rest 19% rainfall is received during non-monsoon period in the wake of western disturbances and thunderstorms.

1.2 PHYSIOGRAPHY

The district is divided into five Physiographic units

- Siwaliks Hills
- Dissected Rolling Plains (Kandi)
- Interfluvial Plains
- Active and Recent Flood Plains
- Relict Wedge Plains

Siwaliks Hills – Siwalik hill ranges occupy the northern fringe of Yamuna Nagar district and attain the height up to 950m AMSL. The hills are about 500m high with respect to the adjacent alluvial plains. These are characterized by the broad tableland topography that has been carved into quite sharp slopes by numerous ephemeral streams come down to

the outer slopes of the Siwaliks and spread much of gravels boulders, pebbles in the beds of these streams.

Kandi Belt - A dissected rolling plain in the northern parts of district is a transitional tract between Siwaliks hills and alluvial plains. It is about 25 km wide and elevation varies between 250 and 375m AMSL.

Interfluvial plains - This tract is part of higher ground between Ghaggar and Chautang and includes high mounds and valleys. In general, the slope is from northeast to southwest.

Active and recent flood plains - This plain is narrow tract along river Yamuna in the district.

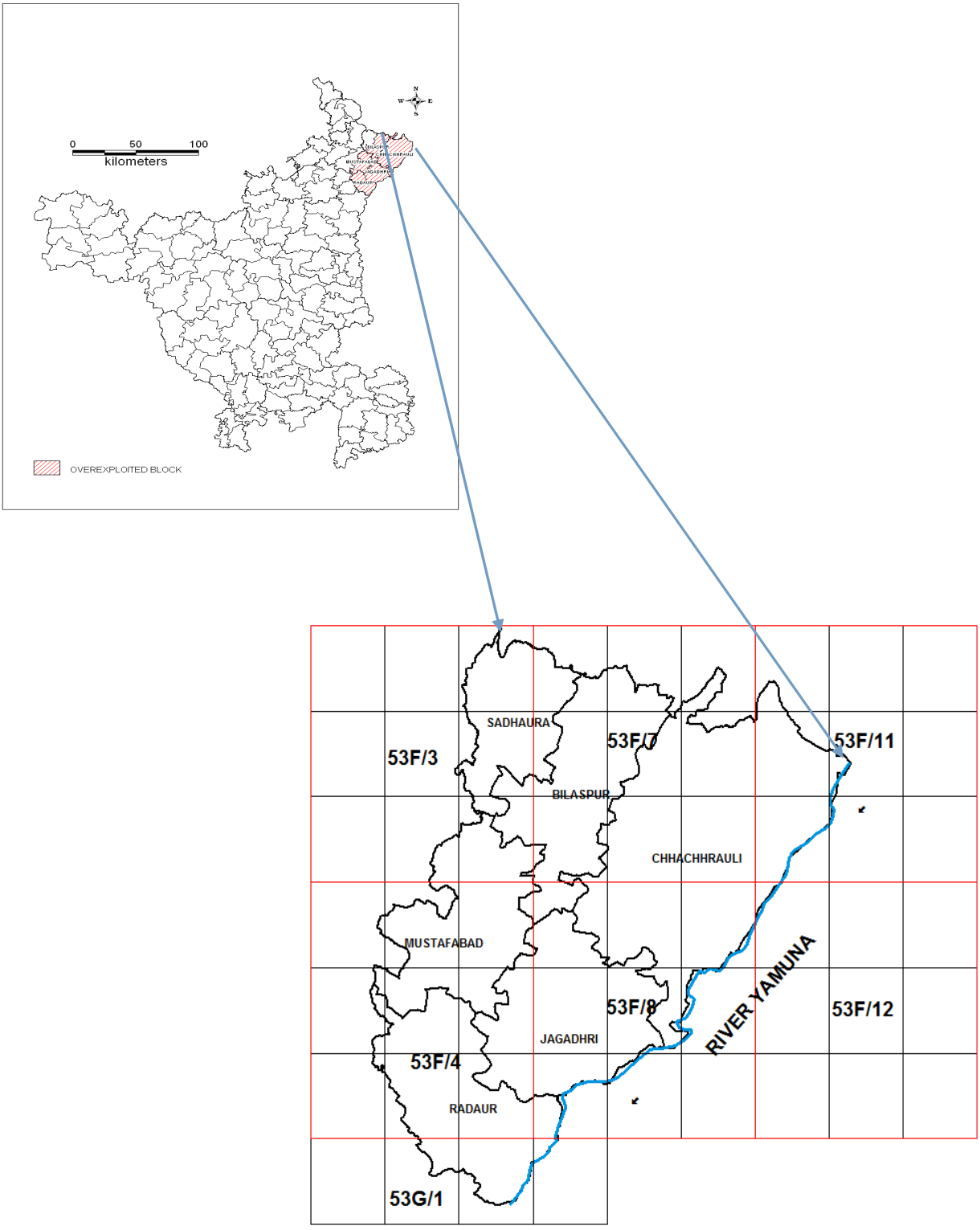
Relict wedge plain - This is almost in alignment to the surface water divide between the westward flowing Ghaggar and eastward flowing Somb river

1.3 SOIL TYPES

- Eurtrochrepts/ Udorthents – These are shallow and loamy sands to fine sandy loams, except in depressions, well-drained, non-saline, non-alkali, non-calcareous, mostly base saturated and are classified as loamy skeletal typic, lithyhic, eurtrochrepts/ udorthents. These soils are found in the Siwalik range.
- Udipsamments/ udorthents – These are loamy sand to sandy loam deep, excessively or well-drained, non-saline, non-alkali. These are placed under the associations of transitional tract between Siwaiks hills and alluvial plains.
- Psammaquents and Haplaquepts – These soils are found in Yamuna Plains
- Haplaquept – These soils are non saline, alkalinity hazards are classified as typic ustochrepts but water logged soils with loam to clay loam texture showing the effect of glazing, are classified as aeric/ typic Haplaquepts. Areas as aeridic soil moisture, moisture have soils classified as camborthics and torropsamments.

  The Yamuna is Perennial River and descending from Himalayas in Uttarakhand and a dam has been constructed at Tajewala to harness water, which is being used for irrigation in west Yamuna canal areas. In Yamuna Nagar district, only 40 Km^2 area is irrigated by this canal system.

Fig 1: Base Map of Yamunanagar District



2 DATA COLLECTION AND GENERATION

2.1 Tube well Logs and Geophysical Data

The Lithologs of Exploratory Well/ Observation well/ Piezometer/ productive wells of CGWB, Public Health and Engineering Department (PHED) and private wells have been collected and those supported electrical logs have been validated for aquifer map preparation. Deeper well data of CGWB is available. The details are shown in table 1. The compromised logs derived from lithologs and geophysical well loggings have been taken as reliable data base.

Table 1: Data availability of exploration wells in Kurukshetra district

S. No.	Source	No. of wells	Depth	
			<200m	>200m
1	CGWB	17	3	14
2	Private	11	11	0
3	PHED	33	33	0

2.2 Ground Water Level Behavior:

Depth to ground water level of district Yamunanagar ranges from 3.10 mbgl at Bilaspur to 50.00 mbgl at Jhiwarheri during Pre monsoon 2015 (Fig-2). The water level data of all Ground Water Monitoring Wells of 2015 are shown in Table-2. Groundwater level is shallow in northern part and deeper in south-western parts of the district which are adjacent to district Karnal and Kurukshetra.

Table-2 Water level data (2015) Ground Water Observation Wells of district Yamunanagar

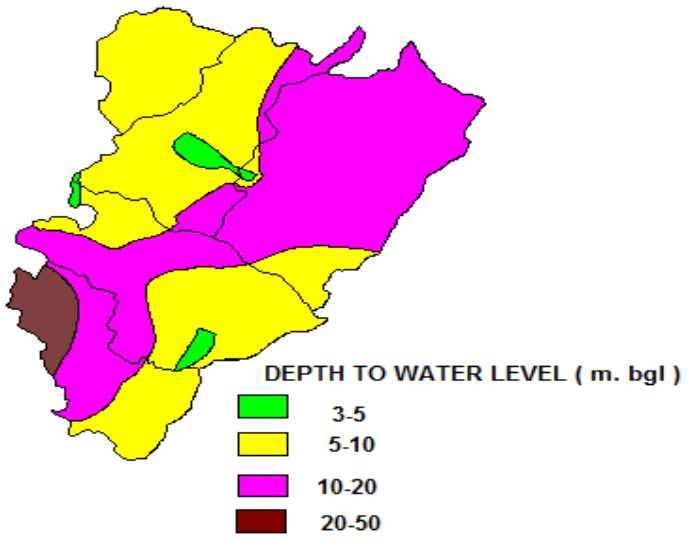
Location	Toposheet	Latitude	Longitude	Depth to water level	RL of GL (mamsl)	WTE (mamsl)
Choli	53 F/7	30°16'45" N	77°20'30" E	10.50	300.28	289.78
Harewa	53 F/7	30°14'00" N	77°23'00" E	4.50	279.87	275.37
Khizrabad	53 F/7	30°18'00" N	77°29'15" E	18.00	302.39	284.39
Nagal Patti	53 F/7	30°19'00" N	77°31'00" E	29.50	313.28	283.78
Dhalaur	53 F/3	30°19'00" N	77°12'00" E	6.00	288.12	282.12
Dhanaura	53 F/4	30°26'00" N	77°23'10" E	14.50	-	-
Bilas Pur	53 F/7	30°18'00" N	77°18'00" E	3.10	305	301.90

Location	Toposheet	Latitude	Longitude	Depth to water level	RL of GL (mamsl)	WTE (mamsl)
Ramgarh	53 F/4	30°23'00" N	77°21'00" E	8.70	311.39	302.69
Amadalpur	53 F/8	30°08'15" N	77°22'00" E	14.50	278.00	263.50
Shadipur	53 F/8	30°06'00" N	77°16'45" E	14.50	-	-
Mustafabad	53 F/4	30°11'45'' N	77°08'45'' E	8.50	279.62	271.12
Radaur S	53 F/4	30°01'30'' N	77°09'00'' E	35.00	260.52	-
Jhiwarheri	53 F/4	30°07'30'' N	77°05'10'' E	50.00	-	-
Hayeli	53 F/3	30°26'00" N	77°13'00" E	7.50	318.96	311.46
Rasulpur	53 F/3	30°26'50" N	77°13'00" E	14.50	-	-
Sabri	53 F/3	30°21'30'' N	77°14'45'' E	14.50	-	-
Sadhaura	53 F/3	30°24'00" N	77°13'15" E	15.00	306.78	291.78
Salehpur	53 F/3	30°27'00" N	77°14'00" E	15.00	323.02	308.02

Fig-2: Depth to water level map of district Yamunanagar

Pre-monsoon, 2015

-



2.2.1 Ground water flow: In general the ground water table varies from 323 to 260 m a.m.s.l. and the regional ground water flow direction is from northwest to southwest.

2.3 GEOPHYSICAL STUDY

In the present study geo electrical resistivity profiling and vertical Electric Soundings methods were utilized along Palaeo- channels in Yamunanagar district. (Fig.3)

Fig-3 LOCATION OF VES POINTS IN DISTRICT YAMUNANAGAR, HARYANA

LEGEND

VES Location

SARASWATI PALAEOCHANNEL

(a) RESISTIVITY PROFILING

Resistivity profiling were conducted using the Gradient Resistivity Profiling techniques(GRP) across the so called buried channels as identified on the basis of photo geological interpretations. In this technique the current electrodes are kept fixed at comparatively infinity distance. The Potential electrodes are moved at different Stations along the line of profiling. The apparent resistivity values are calculated at different Stations. Apparent resistivity value are plotted on Y axis and the locations of Stations are plotted on X axis. In the present study, for the identification of buried channel, high resistivity values are favorable.

VERTICAL ELECTRICAL SOUNDING

Resistivity sounding is a technique of studying the vertical (depth) variations of subsurface resistivity through an estimation of the resistivity's and thickness of various sub surface

layers. In this approach, the center of the configuration is kept stationary and the measurements are made for each of the progressively increasing electrodes spacing. The current is injected into the ground through the outer electrodes and the potential difference is measured between the two inner electrodes. The ratio between the potential difference and the current gives the resistance "R". Apparent sensitivities is calculated by multiplying the value "R" with "K" known as Geometrical factor. The apparent resistivity values thus obtained are plotted on Y- axis and half of the distance between the current electrodes is plotted on X-axis in Log-Log paper. The curve so obtained is known as VES (Vertical Electrical Sounding) Curve. The curve is interpreted with the help of either manually or computer softwares. Interpretated results are in the form of thickness and corresponding true resistivity value. On the basis of true resistivity values ,nature of sub surface layers is determined. This method was adopted to scan the study area. The instrument used for the purpose was Sweden make ABEM Terrameter. Vertical Electrical Soundings (VES) have been conducted current electrode separation in the range of 100m to 200m using Schlumberger configuration. Generally K &KH type multilayered VES curves have been recorded. Generally K & KH type multilayered VES curves have been recorded. K type VES curves represent initial rise and consecutive fall of resistivity in the later part of the curves. The interpretation of VES curves was done by matching the field curves with master curves (Orellana & Moony) to obtain the true resistivity and thickness of different geo-electrical layers. After manual interpretation, the results were corrected with the help of computer soft wares. Due to non availability of sufficient space information for deeper depth could not be obtained. Three electrodes (Half Schlumberger method) were also used at two locations. Due to presence of underground pipe lines cables etc. ,the results of geophysical survey may vary with the actual drilling data. In the present study, Vertical Electrical Soundings was conducted at suitable and selected points where anomaly was expected in resistivity profiling. Resistivity sounding provides variation of resistivity values with depth while resistivity profiling gives variation of resistivity values from point to point (At Different Stations) on same horizontal plane. Schlumberger electrode configuration techniques were used for resistivity soundings. Maximum current electrode separation available was 500 meters. Terrameter SAS 300C was used for measuring apparent resistivity values in the field for both resistivity profiling and Sounding.

DISCUSSION OF RESULTS

Resistivity profiling:

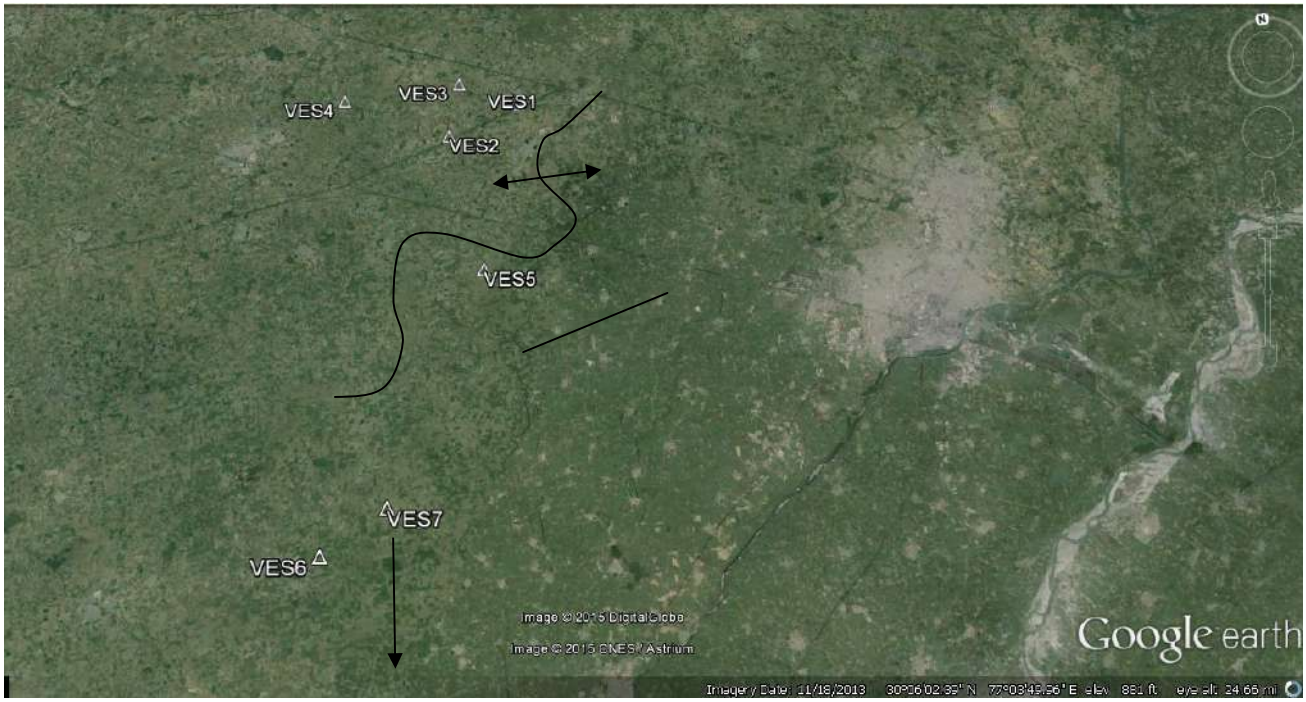
Resistivity profiles were interpreted both qualitative as well as quantitative. Anomalies were identified in resistivity profiles (GRP). Width of anomalous zone could not be o estimated due to non availability limited space. However, at few places, attempt was made to estimate the width of anomalous zone. Resistivity soundings curves were interpreted in terms of resistivity values and thickness of various sub surface layers by using curve matching techniques. Both complete curve matching and partial curve matching techniques were used. The Standard curves based on the tables given by Orellana and Moony (1966) were used for matching with field curves. Later on the interpreted results were refined by Software. Four numbers of VES were conducted in the area to correlate the resistivity values with available litho logical information. The reported borehole data of the area indicates sand and clayey formations often mixed. Sand and clay formation occur alternately. Quality of ground water of the study area is fresh having the EC values in the range of 200 to 400 micro Siemens/liter. No Significant anomaly was expected in the study area due to less contrast in nature of different sub surface layers, However on the basis of past study of the surrounding area following correlation seems to be possible:

Resistivity Order	Probable Lithology
1. 0-20 Ohm m	Clay predominant formation
2. 20-60 Ohm m	Sand and clay formation
3. More than 60 Ohm m	Coarse Sand with kankar, gravel

Gradient Resistivity Profiles

In the study area, GRP (Gradient Resisitivity profiling Techniques) were adopted to explore the deep depth ranges. Station Interval was 10 meters and Potential Electrodes separation was 20 meters.The Current Electrodes separation was 500 meters. Three numbers of GRP were conducted in Yamunanagar district as per data gap (Fig4). The results are given below:

Fig-4 DIRECTION & LOCATION OF GRP (Gradient Resistivity Profile), DISTRICT, YAMUNANAGAR, HARYANA



GRP 3

GRP 1

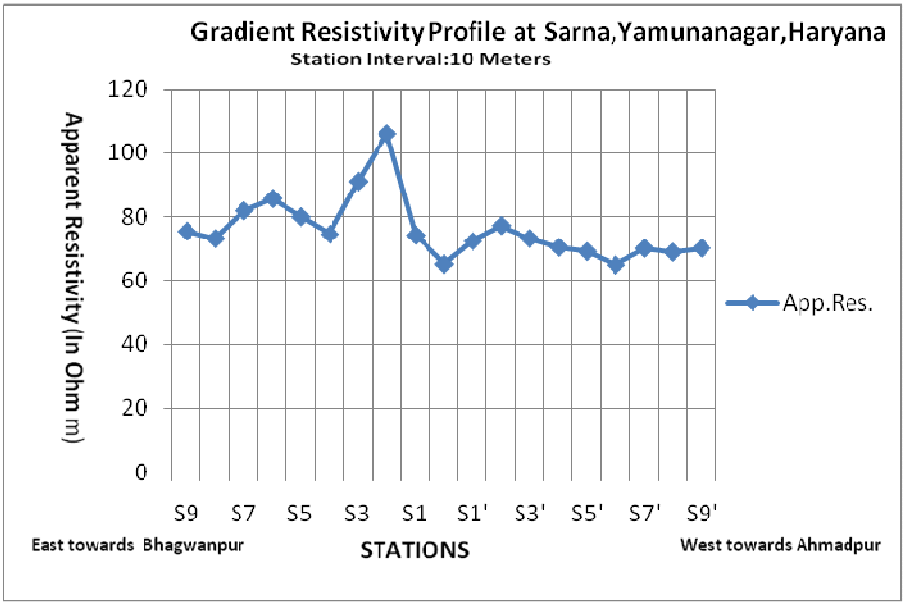
GRP 2

Vertical Electrical Soundings:

GRP 1, village Sarna, Yamunanagar district

GRP 1 has shown variation in apparent resistivity values of the order of 105 Ohm m at Station No S2. The Station Interval was 10 meter and distance between the potential electrodes was 20 meters. The anomaly is obtained at Station S3 and S2 which may be due to the presence of presence of buried channel consisting of coarser sediments .These Stations lies near to so called river Saraswati as inferred on the basis of remote sensing techniques. The direction GRP 1 was East (Bhagwan pur) –West (Ahmad pur)The apparent resistivity values recorded at these location is of the order of around 100 Ohm m. The width of anomalous zone could not be estimated as only one station (S2) has shown the anomaly. The location and direction of GRP 1 is shown in Figure 3and the results are shown in figure 5.

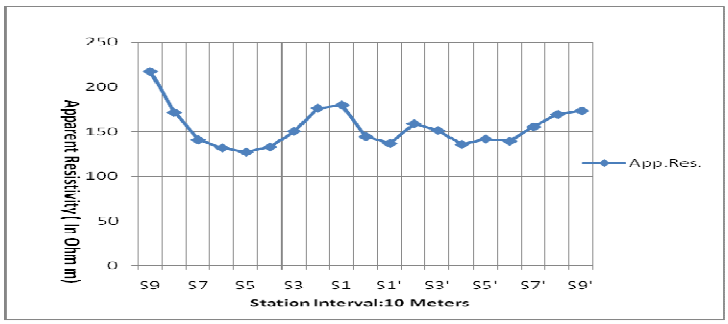
Fig-5



GRP 2, village Gondhana, Yamunanagar district

GRP 2 was conducted in village Gondhana in North East- South West direction. Station Interval was 10 meters and potential electrode separation was 20 meters. Station No.S9 has shown the anomaly of the order of around 217 Ohm m against the average resistivity value of the order of 135 Ohm m. This Station is in the North East direction and near to so called river Saraswati as inferred on the basis of remote sensing techniques. As this was the last Station, width of the anomalous zone could not be estimated. The location and direction of GRP 2 is shown in Figure 4 and the results are shown in figure 6.

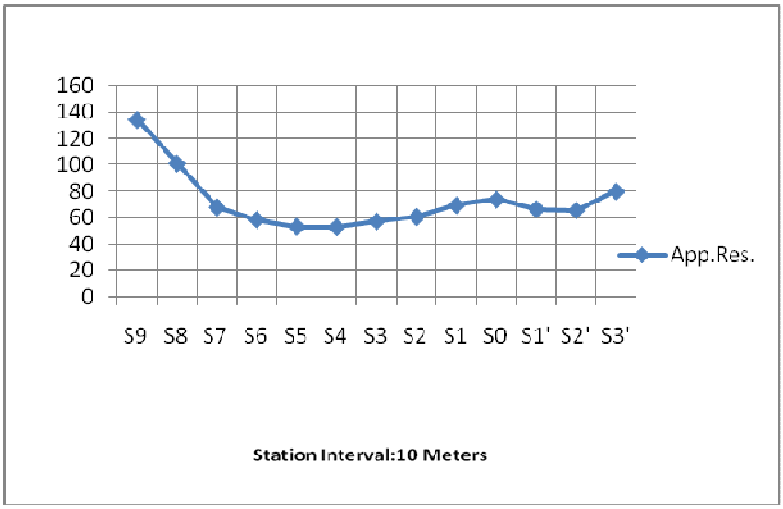
Fig-6



GRP 3, village Gura, Yamunanagar district

GRP3, was conducted in North South direction and neat to village Gura with Station Interval of 10 meters and Potential Electrode separation of 20 meters. Station No.S9 has shown the anomaly of the order of around 135 Ohm m against the average resistivity value of the order of 60 Ohm m. This Station is in the North t direction and towards the river Saraswati.. As this was the last Station, width of the anomalous zone could not be estimated. The location and direction of GRP 3 is shown in Figure 4 and the results are shown in figure 7

Fig-7

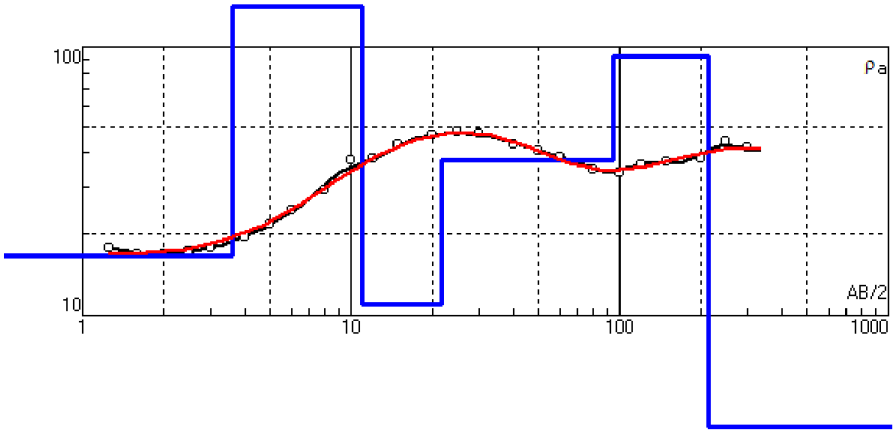


VES at Bhagwanpur, Yamunanagar

On the basis of previous study and geophysical data, it was inferred that the coarser sediments exists below 70 meters. Hence, more emphasis is given to this depth in discussions of interpretation of VES data. The interpreted results at this location indicates the presence of 5 geoelectric layers. The first layer is 3.16 thick with resistivity value if the order of 16.7 Ohm m representing top soil. The fifth layer is 120 m thick with resistivity value of the order of 92.1 ohm m indicating the presence of coarser sediments with thin lenses of finer sediments. Last layer is having a low resistivity value(3.84 Ohm m) which may be due to the presence of finer sediments. Thickness is unknown as this is a last layer. The VES curve along with result is shown in Figure No. 8.

Fig-8

bhagwanpur



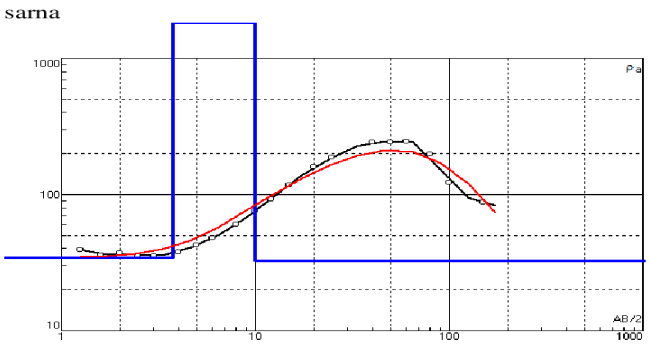
Error = 2.94%

N	ρ	h	d	Alt
1	16.7	3.61	3.61	-3.61
2	142	7.36	11	-10.97
3	11	10.8	21.8	-21.77
4	37.5	73.4	95.2	-95.17
5	92.1	120	215	-215.2

VES at Sarna, Yamunanagar

This VES was conducted neat to village Sarna. Here also presence of coarser sediments along with thin layers of clay is indicated below the depth of 75 meters This is due to the fact that moderate resistivity value (750hmm) is obtained for this layer with unknown thickness. The VES curve obtained at this site is shown in Figure No. 9

Fig-9



Error = 12.5%

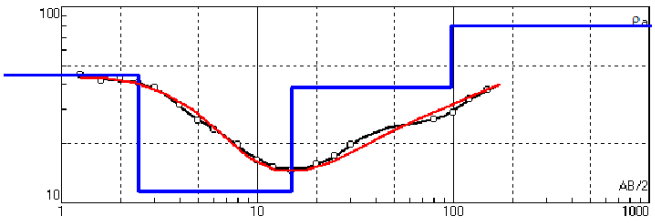
N	ρ	h	d	Alt
1	34.3	3.78	3.78	-3.78
2	1822	6.19	9.97	-9.97
3	32.6			

VES on Gaganpur - Holi Road, Yamunanagar

At this location, deposit of coarser sediments is indicated after the depth of 82.2 meters. This is represented by last layer having moderated resistivity value of the order of 79.5 Ohm m. This is last layer hence its thickness is unknown. Moderate resistivity value also represents the occurrence of thin alternate layers of finer sediments. The VES curve obtained at this location along with results is shown in Figure No. 10

Fig-10

gaganpur



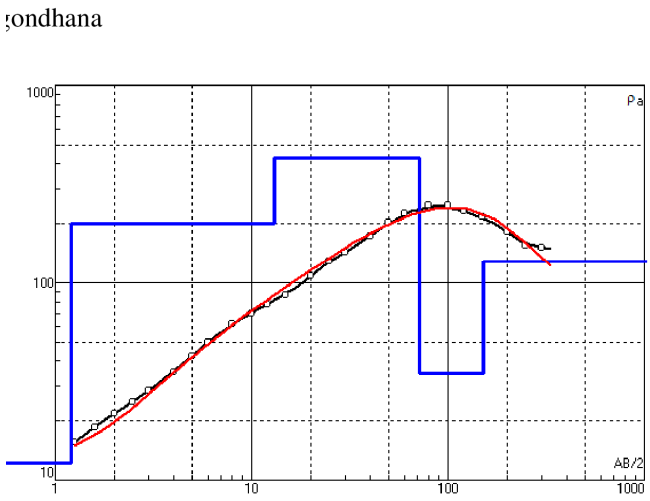
Error = 4.99%

N	ρ	h	d	Alt
1	44.6	2.5	2.5	-2.5
2	11.4	12.5	15	-15
3	38.9	82.2	97.2	-97.2
4	79.5			

VES at Gondhana, Yamunanagar

The results of VES at Village Gondhana indicate the presence of two high resistive layers in the form of third and last layer. Third layer is 58.2 meters thick with resistivity value of the order of 4330hm m. High resistivity value of this layer is due to partial unsaturated nature and presence of coarser sediments. This layer lies in the depth ranges of 13.10 meters to71.2 meters. Last layer is having resistivity value of the order of 129 Ohm m and begins after the depth of 151meters.Thickness of this layer is unknown as this is a last layer. Moderate to high resistivity value of this layer is indicative of presence of coarser sediments. The VES curve obtained at this location along with results is shown in Figure No. 11.

Fig-11



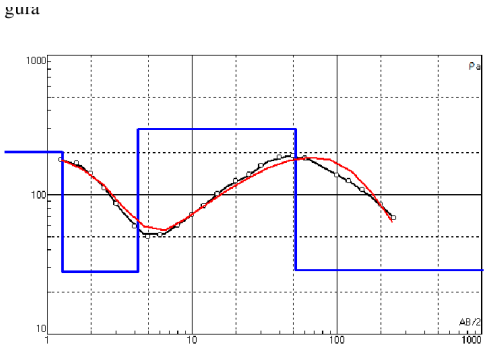
Error = 7.05%

N	ρ	h	d	Alt
1	12.3	1.21	1.21	-1.21
2	200	11.8	13	-13.01
3	433	58.2	71.2	-71.21
4	34.8	79.8	151	-151
5	129			

VES at Gura and Magra- Dandaur Road, Yamunanagar

The total depth of information of VES conducted in village Gura is 52 meters. High resistivity value is obtained for the third layer which is of the order of 294 Ohm m .This is indicative of partial saturation and presence of some coarser material like Sand and gravel with occasional thin clay layers. Thickness of this layer is 47.7 meters and it lies in the depth ranges of 2.96 m to52 meters. last layer is having resistivity value of 28.7 Ohm m indicating the presence of finer sediments. Its vertical extension is unknown as this is last layer. The VES curve obtained at this location along with results is shown in Figure No. 12.

Fig-12



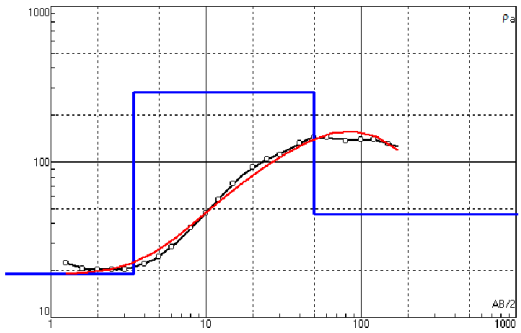
Error = 9.18%

N	ρ	h	d	Alt
1	202	1.27	1.27	-1.27
2	28	2.96	4.23	-4.23
3	294	47.7	51.9	-51.93
4	28.7			

VES conducted on Magra Dandaur Road

Similarly the results of VES conducted on Magra Dandaur Road ,the depth of information n is 50 meters. Second geo electric layer is having high resistivity value if the order of 281 Ohm m .High value is due to the partial saturation of this layer and presence of coarser sediments. Thickness of this layer is 46.6 meters and begins for the depth of 3.43 meters..This layer is underlain by third and layer with moderated resistivity value of the order of 46.2 Ohm m which is indicative of presence of finer to coarser sediments. Thickness of this layer is unknown. The VES curve obtained at this location along with results is shown in Figure No. 13.

Fig-13



Error = 8.19%

N	ρ	h	d	Alt
1	18.9	3.43	3.43	-3.43
2	281	46.6	50	-50.03
3	46.2			

Findings of Geophysical survey

Based on geophysical the following conclusions has been drawn for district Yamunanagar (Toposheet no 5 3 F/4)

1. The anomaly is observed in Gradient Resistivity Profiling (GRP 1) which is of the order of 105 to 217 Ohm m thus indicating good probability of presence of buried channel in deeper depth and at the stations discussed in the previous chapters.

2. The width of anomalous zone could not be assessed precisely however its thickness is around 20 to 30 meters.

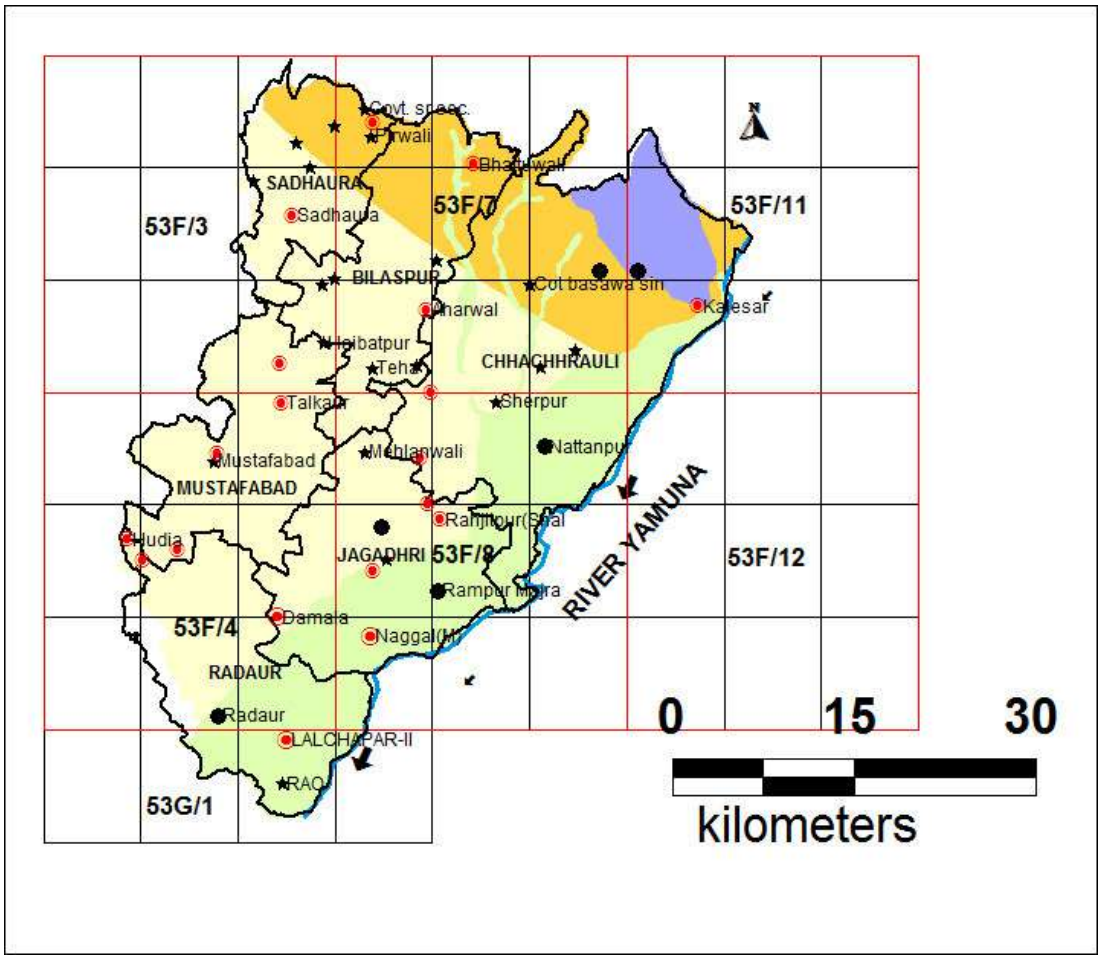
3. On the basis of VES interpretation, the vertical thickness of anomalous zone could not be determined as in some cases thickness of anomalous zone lies in last layer whose thickness is unknown .This is due to "limitation "of geophysical survey techniques.

On the basis of. VES data interpretation, the anomalous zones lies below the depth of around 75 meters.

2.4 SPATIAL DATA DISTRIBUTION

The exploration data of CGWB, drinking water wells from PHED and Privately drilled wells in the area are plotted on the map of 1:50000 scale with 5'X5'grid (9 x 9km) and is shown in Fig 14. The exploration data shows that majority of tube wells fall in the Ist Aquifer and IInd Aquifer. The grids not having any SH/PZ/EW are identified as data gaps and these are being filled by data generation under NAQUIM.

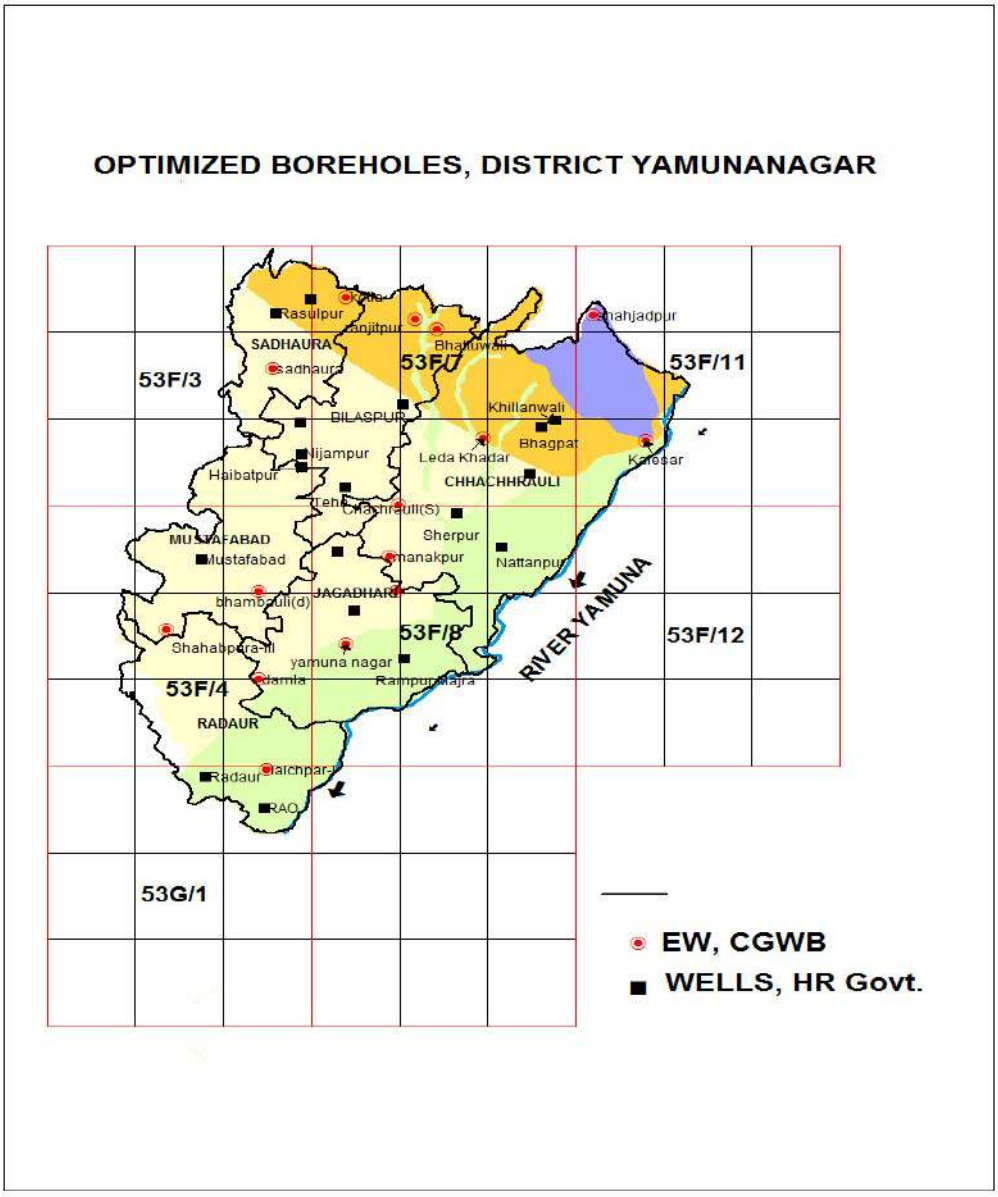
Fig 14. Location of available CGWB Wells, Private Wells and PHED wells.



2.5 Data Interpretation, Integration and Aquifer Mapping

After considering all the available data, only selected 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.15. Summary of optimised exploratory wells/tubewells in Yamunanagar district is given in Table 3.

Fig 15 Location of optimized CGWB Wells, Private Wells and PHED wells.



2.6 SURFACE ELEVATION CONTOUR MAP, DISTRICT YAMUNANAGAR

The topography values has been plotted to prepare the elevation contour map and is shown in figure16 & 3-dimensional location of validated exploratory wells with lithilog is given in Fig.17.

Fig.16

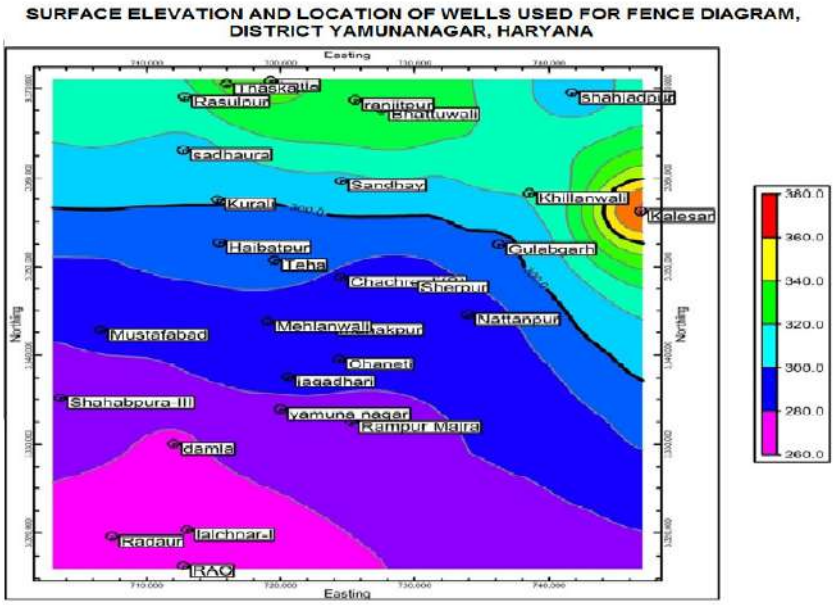


Fig 17: 3-Dimensional location of validated Exploratory Wells with litholog

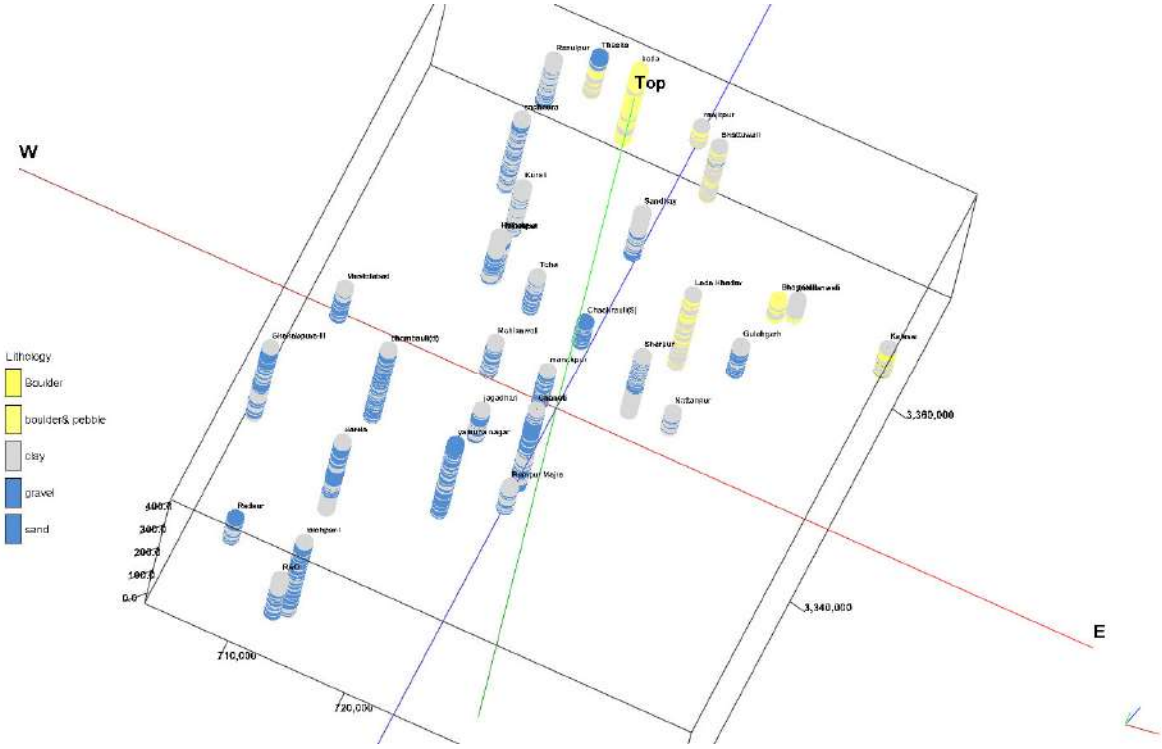


TABLE-3: SUMMARY OF OPTIMIZED EXPLORATORY WELLS/ TUBEWELLS, DISTRICT YAMUNANAGAR

Block	Toposheet and Grid No.		Well Details & Depth (m)				Location with Depth in 'meter'
			>300	200-300	100-200	<100	
Sadhaura	53F/3	C1	-	-	1	-	Rasulpur-p(184m)
		C1	-	-	1	-	Thaska-p(166m)
		C2	1	-	-	-	Sadhaura(402m)
	53F/7	1A	1	-	-	1	Kotla(302m), Ranjit Pur(70m)
Bilaspur	53F/3	C3	-	1	-	-	Kurali-p(198m)
		C3	-	1	-	-	Haibatpur-p(194m)
	53F/7	3A	-	-	1	-	Teha-p(142m)
		1B	-		1	1	Bhattuwali(331m),Ranjitpur(70m)
		2B	-	-	1		Sandhay-p(184m)
Chachrauli	53F/7	3B	-	-	-	1	Chachrauli(97m)
		2C	-	-	1	-	Khillanwali-PHE(130m)
		3C		-	1	-	Gulabgarh-p(137m)
	53F/8	1A	-	-	1	-	Manakpur(146.5m)
		1B		-	1	-	Shepur-p(153m)
		1C		-		1	Nattanpur-PHE(78m)
	53F/11	1A	-	-	1	-	Shahjadapur(165m)
		2A	-	-		1	Bhagpat-PHE(78m)
		3A		-	1		Kalesar(113m)
Jagadhari	53F/4	1B	-	-	1	-	mustafabad-p(140m)
		1C	1	-	-	-	Bhambauli(457m)
		2C	1	-	-		Damla(463m)
	53F/8	1A		-	1	-	Mehlanwala-p(141m)
		2A	1	-	1		Yamunanagar(460m), Jagadhari-PHE(109m)
		2B	-	1	-	1	Chaneti(287m), Rampumajara-PHE (90m)

Block	Toposheet and Grid No.	Well Details & Depth (m)					Location with Depth in 'meter'
		>300	>300	>300	>300	>300	
Radaur	53F/4	2B	-	1	-	-	Shahabpura(302m)
		3B	-		1		Radaur-PHE(100m)
		3C	1	-	-	-	Lalchappar-I(305m)
	53G/1	1C	-	-	1	-	Rao-p(152m)

3. HYDROGEOLOGY

3.1 PREVIOUS WORK

The area belongs to Upper Yamuna and Ghaggar Basins and occupied by geological formations of Quaternary age comprising of recent alluvial deposits of Indus alluvial plains. Ground water at shallow depth occurs under unconfined condition and semi confined to confined conditions in deeper aquifers.

Central Ground Water Board has drilled 12 exploratory wells and 15 piezometers through in house to delineate and determine the potential aquifer zones, evaluation of aquifer characteristics etc. The drilling has been done to a maximum depth of about 463 m and revealed the presence of 3 to 9 prominent permeable granular zones with aggregate thickness varying from 31 to 203 m. The granular zone consists of fine to coarse sand, occasional gravel and pebble.

Further, the study of exploratory boreholes drilled in the district revealed the presence of three distinct aquifer groups up to the maximum drilled depth of 450 m. The first aquifer groups forms the water table aquifer and occurs down to 186 m below ground level. The second aquifer occurs in the depth range of 123 to 324 m depth which behaves as semi-confined to confined and consisting of individual sand and clay layers. The third one exist between 245 and 386 m depth and occurs in confined condition and consisting of thin sand layers alternating with thicker clay layer. The thickness of the alluvium is presumed to be more because bedrock has not been encountered up to 450 m depth in the district. Overall flow of ground water is towards south-west direction.

The Basin wise aquifer parameters were also determined during the ground water exploration work. The aquifer parameters of Upper Yamuna Basin is given in Table-4 and aquifer parameters of Ghaggar river basin is given in Table-5. Western part of the area falls under Ghaggar river basin , whereas eastern part of the area falls under Upper Yamuna basin.

Table 4. The aquifer parameters of Upper Yamuna Basin are as follows

Aquifer Group	DISCHARGE (lpm)	Transmissivity 'T' (m^2/day)	'K' (Lateral) m/day	Storativity
1st Group	3937	2,200	24	0.12
IInd Group	NA	700	7.2	1x10-3
IIIrd Group	1500	525	7.1	4.5x10-4

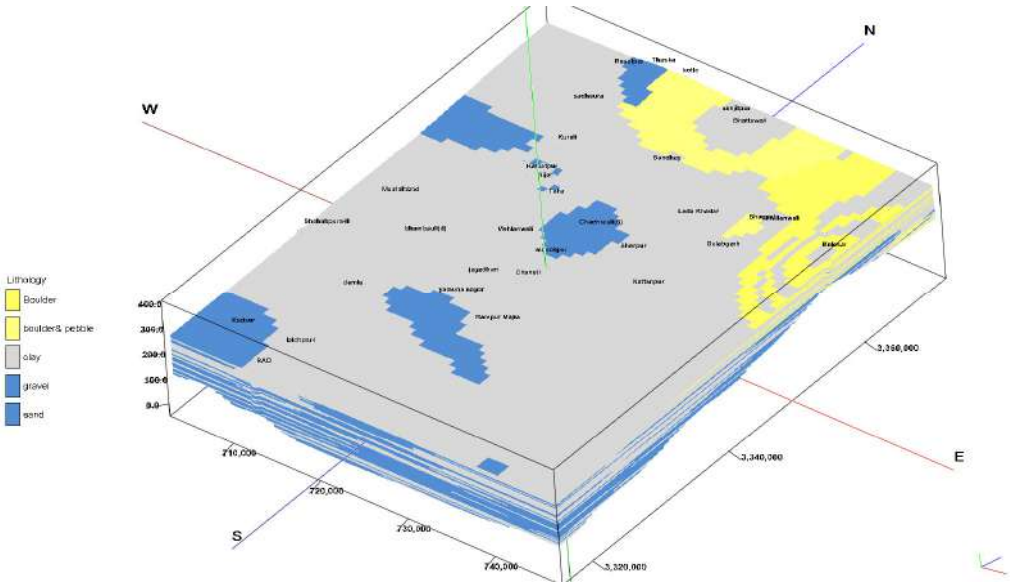
Table 5. The aquifer parameters of Ghaggar river Basin are as follows

Aquifer Group	DISCHARGE (lpm)	Transmissivity 'T' (m^2/day)	'K' (Lateral) m/day	Storativity
1st Group	795 to 4164	874.62 to 2500	18	1.4E-4 TO 2.10E-2
IInd Group	1325	1163.91	18	5.2E-5
IIIrd Group	1325	1745.86	18	3.2 E-4

3.2 Present NAQUIM study

To understand the sub surface lithology and its disposition, the lithological data of the optimized wells drilled by CGWB, PHED and Private Agencies is plotted using the RockWorks15 software and a lithological model has been prepared and is shown in fig 18. The 2D lithological and 3D lithology map fence diagram has been prepared using the lithology model and are shown in 20 & 21 respectively.

Fig 18-3-Dimension Lithological Model of Yamunanagar District



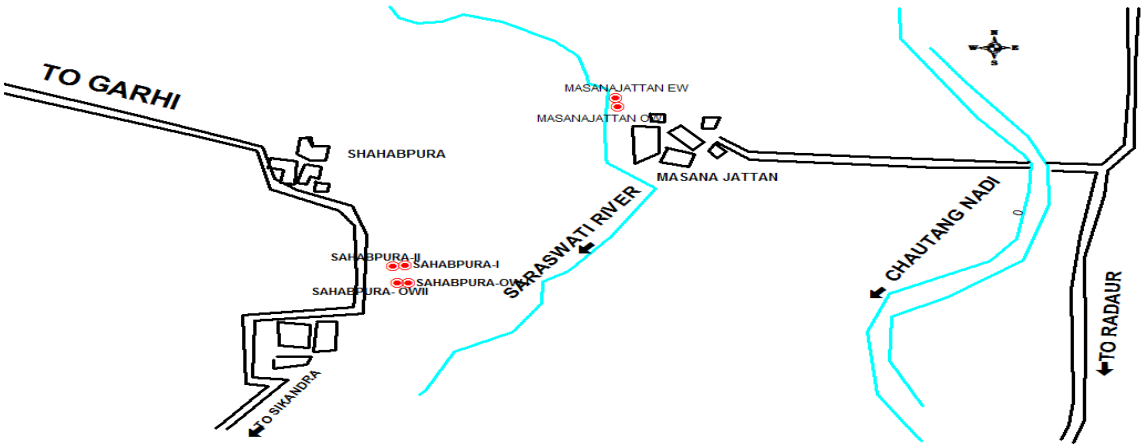
The major aquifer system of the Yamunanagar district is alluvial deposit having older and younger alluvium which mainly comprised of sand, silt and clay. The major lithological formations are sand & clay and silt is found admixed with gravels and kankars. The top surface layer and soil is mainly silty clay. There is inter-layering of sand and clay with thick clay at all locations in Ghaggar river basin eg. Khillanwali, Sandhay, Sahabpura and thin clay at nearly all the location in Yamuna river basin eg. Lal Chappar, Yamunanagar and Chaneti EW sites. The lithology along W-E direction shows the variation in lithology thickness i.e. thin clay layers inter bedded with sand except at few locations in Yamuna river basin. There is thin inter-layering of sand and clay in Ghaggar river basin and thick inter-layering of sand and clay in Yamuna river basin. In northern parts of the district major lithological formations are characterized by layers of Boulder, gravels and Coarse sands interbedded with thick layers of clay.

3.2.1 Ground Water Exploration Under NAQUIM and Group wise Aquifer Parameters

Ground water exploration was carried out in Yamunanagar district under NAQUIM. A well field consisting of 3 Exploratory Wells and 3 Observation wells tapping aquifer –I, Aquifer –II & Aquifer-III has been constructed at site Sahabpura and Masana Jattan of block Radaur. In Masana Jattan exploratory well tapping Aquifer-I has been constructed whereas in Sahabpura site two exploratory wells tapping Aquifer-II and Aquifer –III were constructed Respectively. Lay out plan of Well field is given in fig.19.

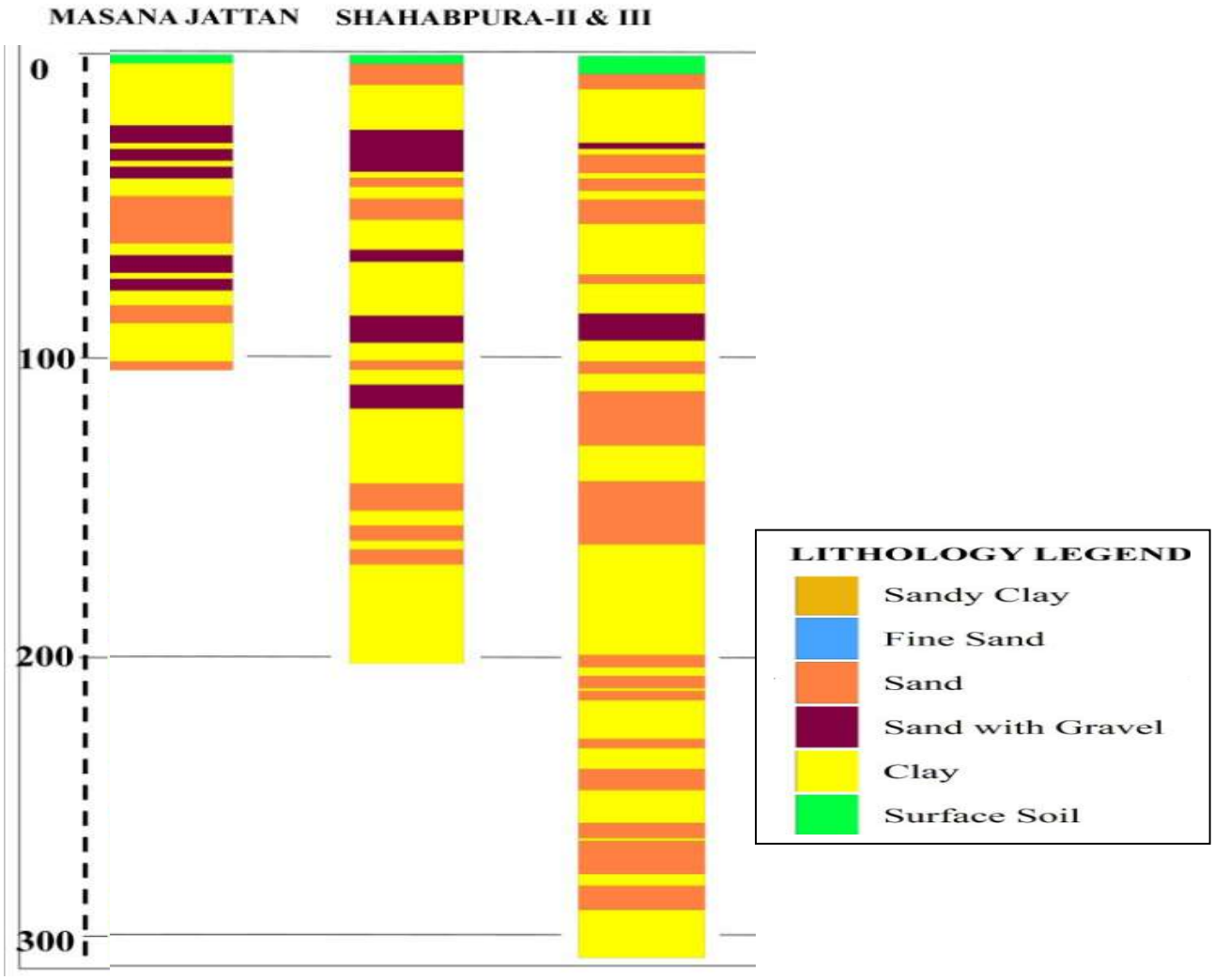
Fig.19

LAY OUT PLAN OF WELL FIELD CONSTRUCTED IN THE VILLAGE MASANAJATTAN AND SHAHABPURA, BLOCK RADAUR, DISTRICT YAMUNANAGAR



Aquifer Disposition: Multiple Aquifer System encountered in well field site (3 Aquifer System) is given in Fig 20

Fig 20



3.2.2 Aquifer Parameters of Exploratory wells

To know the aquifer parameters of all three exploratory wells, Step Drawdown Test (SDT) and Aquifer Performance Test (APT) were carried out. Aquifer parameters obtained as a result of pumping test is given in Table 6 .

Table:6

Aquifer Group	Name of the location	Zones Tapped (below ground level)	Aquifer Parameters						
			Transmissivity (m2/day)	Strorativity	Hydraulic Conductivtiy (m/day)	Static Water level (mbgl)	Discharge (lpm)	Drawdown (m)	Specific Capacity lpm/mt
Aquifer I	Masana Jattan	56-62, 70-73, 86-89	874.62	1.4E-4 *(due to local confining clay condition)*	18	27.60	795	3.1	257
Aquifer-II	Shahabpura-II	144-151, 158-161, 166-169	1163.91	5.2E-5	18	31.87	1325	5.07	261.3
Aquifer-III	Shahabpura-III	207-210, 239-245, 263-269, 277-281	1745.86	3.2 E-4	18	28.57	1325	5.13	258.3

Almost all aquifer parameters obtained from above three exploratory wells are different to each other whereas static water level of all three exploratory wells are also different from each other which exhibits that all three aquifer groups are hydraulically isolated from each other i.e. there is no any hydraulic connection among all three aquifer groups.

3.2.3 WATER LEVEL BEHAVIOUR OF OBSERVATION WELLS TAPPING AQUIFER-I, II AND III

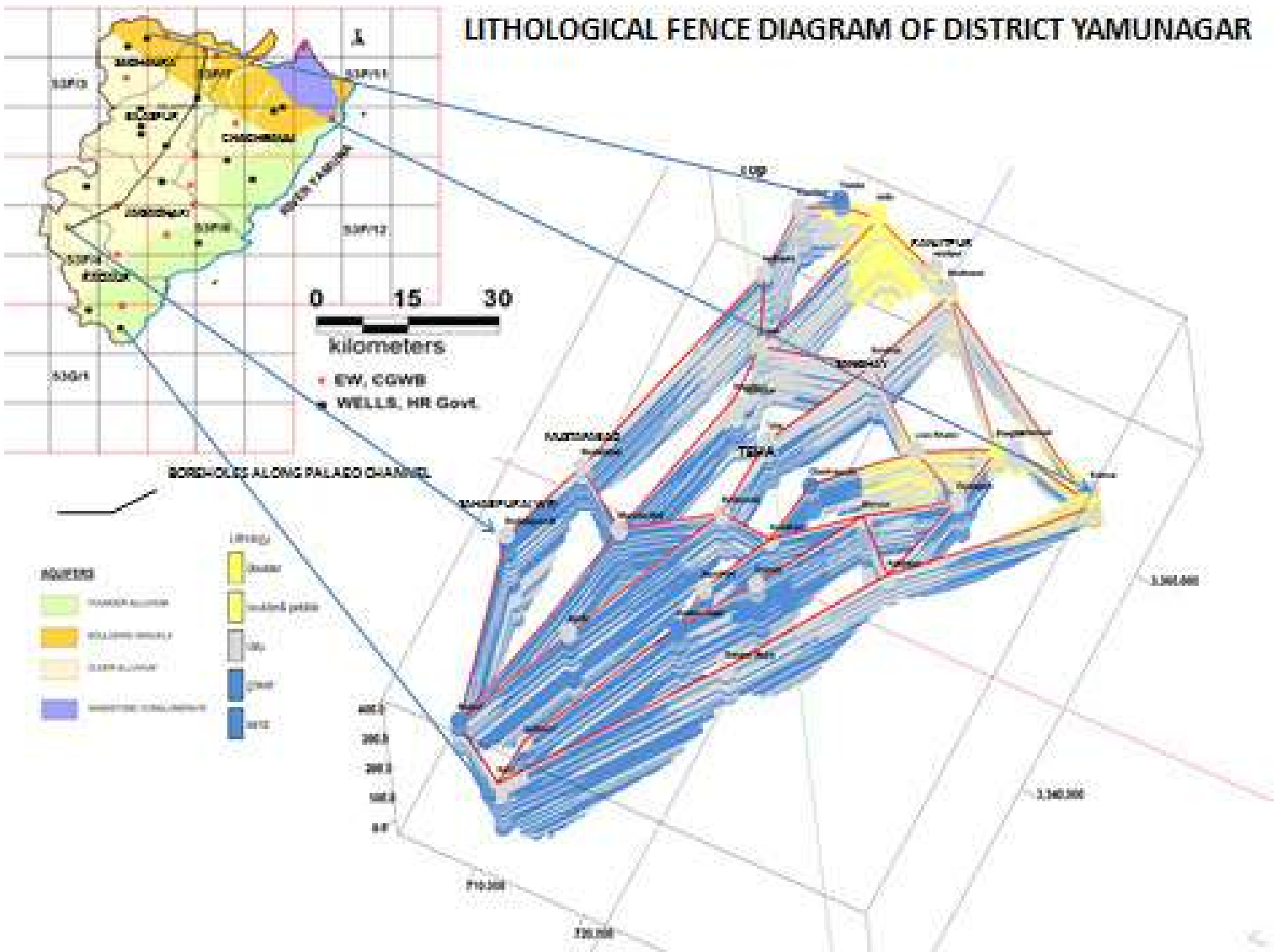
The Ground water level monitoring for all three observation wells has been done and given in Table7.

Table 7

Observation Well	SWL-June 2015 (mbgl)	SWL-Nov. 2015 (mbgl)	SWL-Jan. 2016 (mbgl)	SWL-April 2016 (mbgl)	Fluctuation (April16-June15) (m)
I(100m)	27.76	28.30	28.88	28.52	0.76 m fall
II (200m)	32.04	30.18	30.71	29.10	2.94 m rise
III(300m)	28.64	29.28	29.40	28.42	0.22 m rise

The mixed behavior of water level fluctuation indicates that the tubewells in the area are tapping within the depth of 100-300m and hydraulically all exploratory wells are not connected with each other.

Fig-21


LITHOLOGICAL FENCE DIAGRAM OF DISTRICT YAMUNAGAR
0 15 30
kilometers
EW, CGWB
WELLS, HR Govt.
BOREHOLES ALONG PALAEO CHANNEL
TSHA

3.2.4 Aquifer Geometry

Majority of the Yamunanagar District falls under the Ghaggar River Basin; therefore it belongs to a single aquifer system up to 180 m depth with thin inter-layering of sand and clay and below that clay layer starts getting thickened (Ghaggar River Project Report). Based on the same criteria, to know the broad picture of the aquifer disposition, inter-relationship of granular zones, nature, geometry and extension of aquifers in the Yamunanagar district, the aquifer grouping has been done using the sub-surface lithology and a three-dimensional aquifer model has been prepared (Fig 22). The 2D aquifer map was also prepared using the aquifer model and is shown in fig 23. The aquifer grouping is done and given in Table 8. The first aquifer is water table aquifer and extends all over the area. The aquifer is mainly composed of fine to coarse grained sand.

Table 8: Aquifer Grouping in Yamunanagar District

Aquifer Group	Depth Range(mbgl)		Thickness (m)	
	From	To	Min	Max
Aquifer I	0	180	95	180
Aquifer II	178	300	16	110
Aquifer III	245	300	16	55

Fig 22 : 3-Dimension Aquifer model – Yamunanagar District

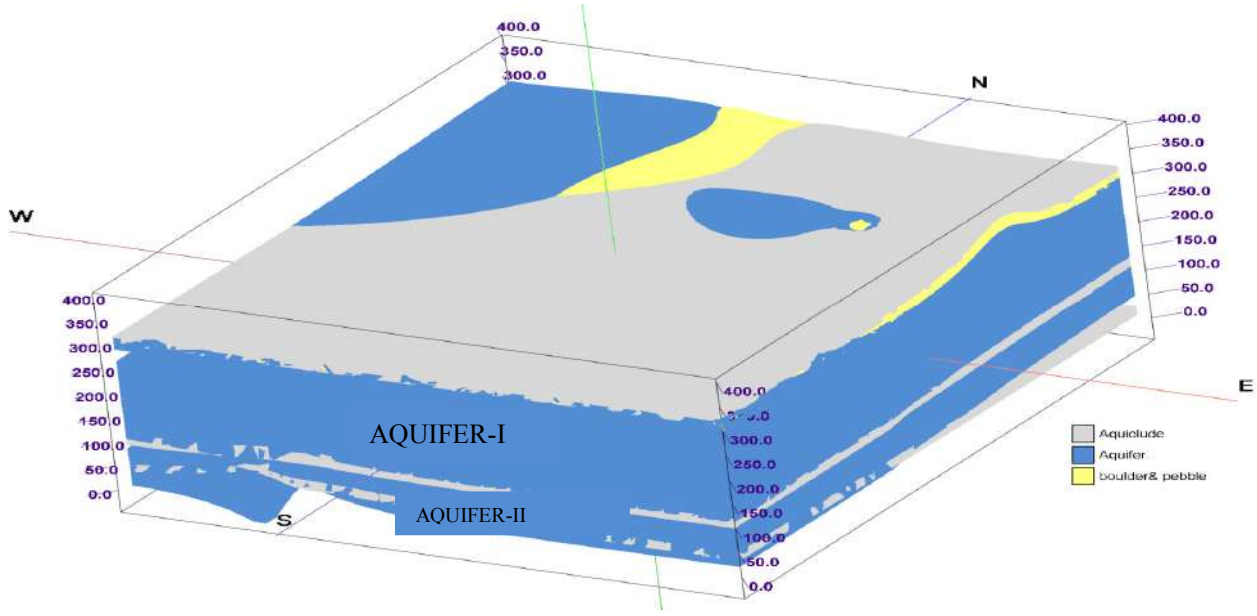
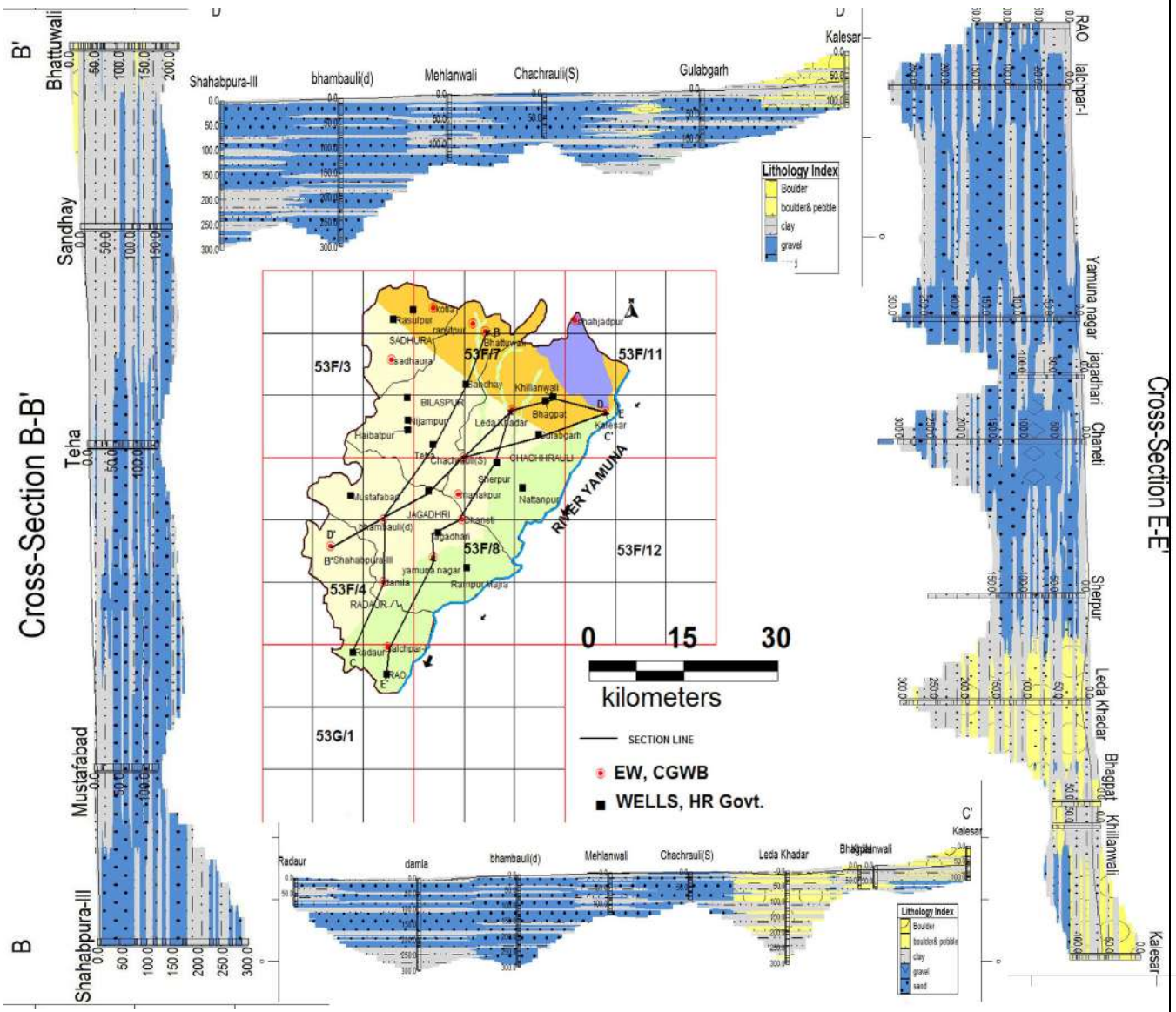


Fig 23: Cross sections of Aquifer Map of Yamunanagar District



4. GROUND WATER QUALITY

Ground water quality of shallow aquifer is assessed based on the chemical data of the ground water observation wells monitored regularly by CGWB on annual basis (Annexure-I & 2) and during special study along palaeo-channels (Annexure-3, 4, 5 & 6). In addition to that chemical quality of different aquifers is assessed during ground water exploration (Annexure-7,8 & 9) under NAQUIM. Aquifer wise ground water quality is given below.

Aquifer –I

1. Ground water quality of the observation wells monitored regularly by CGWB

Ground water of aquifer–I is alkaline with electrical conductivity (EC) values in ground water monitoring stations (Annexure-I) less than 1000 µS/cm at 25^0C, except at one location at Mustafabad where the EC value is 1177 µS/cm at 25^oC. Nitrate is above permissible limit of 135 mg/l only at one location in Bilaspur. Fluoride is below permissible limit in all water samples analyzed. Generally all chemical parameters are well within the permissible limits for safe drinking water set by Bureau of Indian standard (BIS). Ground water sampling at 14 locations has been taken place for Iron and Arsenic (Annexure-2), in which Iron is above permissible limit in five (5) locations with the value of 1.55 (Choli) to 9.56 mg/l (Rasulpur) whereas Arsenic found within permissible limit in all sampling locations.

2. **Ground water quality of the observation wells along palaeo-channels**

Ground water quality monitoring has been carried out along the palaeo-channel at 20 locations. Ground water along the palaeo channel is alkaline with electrical conductivity (EC) values in ground water monitoring stations (Annexure-3 & 4) less than 1000 µS/cm at 25^0C, except at three locations at Mustafabad, Bilaspur and Mandkhera where the EC value is 1177, 1208 and 1120 µS/cm at 25^oC respectively. Nitrate is above permissible limit of 162 mg/l only at one location in Bilaspur. Fluoride is below permissible limit in all water samples analyzed. Generally all chemical parameters are well within the permissible limits for safe drinking water set by Bureau of Indian standard (BIS).

For heavy metal analysis ground water sample has been collected from nine (9) locations along the palaeo-channel in which cadmium (Cd), Chromium (Cr) & Copper (Cu) concentration is at no detectable limit at all 9 locations(Annexure-5). High Iron is reported at four location namely Ranjeetpur (1.48 mg/l), Muglawali ST 2 (2.21 mg/l)), Safilpur (2.85

mg/l) and at Rulla Heri (4.70 mg/l). Lead (Pb) is reported to be below detection limit to 0.016 mg/l whereas Zinc (Zn) is found between the value of 0.027 to 0.522 mg/l. Manganese (Mn) ranges between non-detection limit to 0.172 mg/l.

3. **Ground water quality monitored during ground water exploration**

Ground water sampling for aquifer group-I, has been carried out from exploratory well tapping shallow aquifer at well field site of Masana Jattan in which ground water sampling for complete, pesticide analysis, Microbiological, BOD/COD has been carried out .The results are given in Annexure 6, 7 and 8 respectively which indicate that aquifer –I is free from any Microbiological and Pesticide contamination and BOD/COD is also <1.

Aquifer-II

Ground water of aquifer-II is analyzed during ground water exploration at Shahabpur-II. Generally it is suitable for drinking purposes as chemical parameters are well within the permissible limits except Iron (Fe:3.43) for safe drinking water set by Bureau of Indian standard (BIS). (Annexure 6 & 9)

Aquifer –III

Ground water of aquifer-III in samples analyzed is generally suitable for drinking purposes as chemical parameters are well within the permissible limits for safe drinking water set by Bureau of Indian standard (BIS) at Shahabpura-III. (Annexure 9)

4.1 ISOTOPE STUDY

A Joint Isotope study with BARC has been taken up by CGWB in the district for validation of the aquifer groups, mechanism of recharge to aquifers and for the age determination of the aquifer water. The study is carried jointly with the BARC, Mumbai and CGWB, NWR for the purpose of Aquifer mapping and Paleo-channel studies in the district during 2014 to 2016 in three phases of sample collection. Reconnaissance survey in 2014 (5), October 2015 (6) and June 2016 (4) was carried out and the sampling location is given in Annexure-10. Isotope study reveals that ground water from aquifer-I and aquifer-II is derived from local precipitation and is in dynamic condition, whereas ground water from aquifer-III is old and depleted indication high altitude recharge and long residence time.

GROUND WATER RESOURCES

Ground water resource estimation of the area have been carried out by taking Dynamic and Static/In-storage resources of unconfined aquifer and confined aquifers present upto 300m depth. The assessment of dynamic ground water Resources of the study area have been carried out jointly by CGWB and Ground Water Cell, Department of Agriculture, Haryana on the basis of Ground Water Estimation Committee (1997) methodology based on data available and as per the revised methodology for the year as on 31st March 2013.

The occurrence of potential aquifers (productive granular zones) up to 300 m depth has been demarcated on basis of aquifer wise subsurface mapping. The total saturated thickness of granular zones was derived from the exploratory borehole data of a particular block. The granular zones occurring below the zone of water level fluctuation up to the first confining layer has been considered as static unconfined zone. The ground water resource of this zone has been calculated considering 12% specific yield of the formation. The specific yield value for the unconfined aquifer has been taken as 60% of 0.12 which comes as 0.072 whereas for the confined aquifer, the storativity value has been considered. Since the specific yield is likely to reduce with increase in depth due to compaction of overlying sediments.

Hence, the major data elements considered in this estimation are thickness of granular zones, specific yield/storativity, and area of both fresh water and saline/brackish water. It has been observed that in some of the blocks sufficient data on probable occurrence of granular zones was not available. In those cases, the existing exploratory data of adjoining block/district has been either extrapolated or interpolated to derive such parameters required for estimation. This assessment of total groundwater resources has been computed based on the available data with CGWB & Ground Water Cell, Department of Agriculture, Haryana.

5.1 Unconfined aquifers

Dynamic Resources

The ground water development in all the blocks has exceeded the available recharge, thus all the blocks have been categorized as over exploited (Table-9). Stage of ground water development in the Yamunanagar district has been assessed to be 135%.

Table 9: Dynamic Ground Water Resource & Development Potential (as on 31.03.2013)

Assessment Unit/ District	Net Annual Ground Water Availability [(8)-(9)]	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for domestic and industrial water supply	Existing Gross Ground Water Draft for All uses (11+12)	Provision for domestic, and industrial requirement supply to 2025	Net Ground Water Availability for future irrigation development (10-11-14)	Stage of Ground Water Development {(13/10) * 100} (%)
2	**10**	**11**	**12**	**13**	**14**	**15**	**16**
YAMUNANAGAR							
Bilaspur	**9345**	7817	1665	9482	238	1290	101
Chachrauli	**13043**	13300	1815	15115	394	-651	116
Jagadhri	**8410**	11115	3225	14340	3225	-5930	171
Mustafabad	**7358**	9747	1230	10977	1230	-3619	149
Radour	**8941**	13586	1350	14936	1350	-5995	167
Sadhuara	**3943**	3082	930	4012	117	744	102
Total	**51040**	**58647**	**10215**	**68862**	**6554**	**-14161**	**135**

In storage Ground Water Resources

As per revised guidelines recommended by the Central Level Expert Group on ground water resources assessment, the resources are separately considered as dynamic and in-storage unconfined. In case of alluvial area, the in-storage resources of unconfined aquifer have been computed based on specific yield of the aquifer as detailed below:

In-storage Ground Water resources (unconfined Aquifer)	=	Thickness of the aquifer (granular/productive zone) below the zone of water level fluctuation down to the bottom layer of unconfined aquifer	x	Sp. Yield of the aquifer	x	Areal extent of the aquifer

5.2 Confined Aquifer

The availability of ground water resources in confined aquifer have two components: Storage under pressure (using Storativity concept) and Storage under desaturated (gravity drainage) condition (using Specific Yield concept) (source: Assessment of Ground Water Resources; A Review of International Practices, 2014) and is shown in Fig 24. However, since ground water withdrawals from confined aquifer are known to have serious environmental degradation effects, the preliminary assessment of ground water resources in confined aquifer is restricted to the estimation of ground water storage under pressure conditions only but here the storage under de-saturation is also computed.

Storativity Concept:

ii)	In-storage Ground Water resources (within the Peizometer)	=	Thickness of the water column in Peizometer of particular confined aquifer up to the top layer of same confined aquifer	×	Storativity of the confined aquifer	×	Areal extent of the confined aquifer group

Specific Yield Concept:

ii)	In-storage Ground Water resources (within the aquifer thickness)	=	Thickness of the confined aquifer (granular/ productive zone) down to the bottom layer of confined aquifer or exploitable depth of 300 m	×	Sp. Yield of the aquifer	×	Areal extent of the confined aquifer group

Preliminary assessment of the ground water resources in confined aquifer does not imply that the assessed resource is available for exploitation. The objective of this exercise is to have an overview of the ground water regime in the particular confined aquifer. It should be kept in mind that any significant ground water withdrawal from confined aquifer may invoke serious environmental degradation problem. Therefore, in case the preliminary assessment reveals that ground water is being withdrawn in significant quantity for any confined aquifer, that particular aquifer should be identified for detailed assessment using numerical odeling approach.

Total Availability of Ground Water Resources = Dynamic Resources + In-storage Resources.

Fig 24: Concept for Resource Estimation in Unconfined and Confined Aquifer System

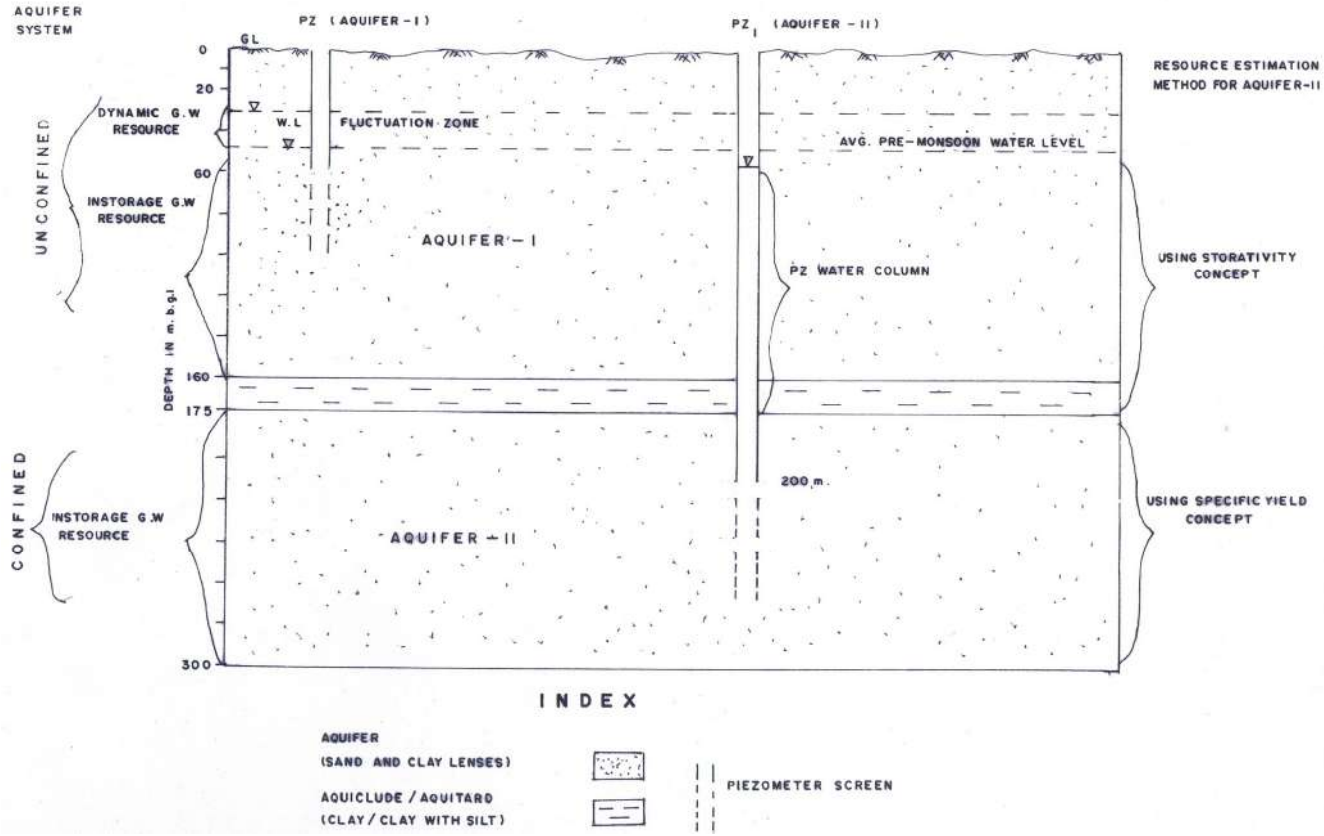


Table 10: BLOCK WISE INSTORAGE GROUND WATER RESOURCES IN UNCONFINED AQUIFER –I (ALLUVIUM)

Sr. No.	Name of Assessment Unit	Areal extent (ha)				Average Pre-monsoon Water Level (m bgl)	Depth to bottom of Aquifer Group I (m bgl)	Total Thickness of formation below Pre-monsoon Water Level (m) (9-8)	Thickness of the Granular Zone in AQUIFER GROUP-I below Pre-monsoon WL (m)	Average Specific Yield	In-Storage Ground Water Resources [(6)*(11)*(12)*] FRESH (ham)
		Total Geographical Area	Assessment Area								
			Total	Fresh Water	Brackish/Saline Water						
1	2	4	5	6	7	8	9	10	11	12	13
	Yamunanagar										
1	Bilaspur	30122	29022	29022	0	8.73	167	158.27	35	0.072	73135
2	Chacharauli	53155	39955	39955	0	10.23	147	136.77	86.78	0.072	249645
3	Jagadhri	27270	27270	27270	0	14.02	180	165.98	113.662	0.072	223169
4	Mustafabad	20682	20682	20682	0	11.34	170	158.66	43.53	0.072	64821
5	Radaur	29101	29101	29101	0	19.95	171	151.05	102.71	0.072	215205
6	Sadhuara	15270	14270	14270	0	7.54	140	132.46	49.046	0.072	50392
	Dist. Total	**175600**	**160300**	**160300**							**876367**

Table 11: BLOCK WISE INSTORAGE GROUND WATER RESOURCES – CONFINED (AQUIFER II)

Sr. No.	Name of Assessment Unit	Areal extent (ha)			Top Aquifer II (m bgl)	Depth to bottom of Aquifer II (m bgl)	Thickness of piezometric level(m bgl)	Total Thickness of confined aquifer down to explored depth (m) (9-8)	Thickness of the Granular Zone in confined aquifer down to explored depth (m)	Average Specific Yield	Average value of Storativity	In-Storage Ground Water Resources (Specific yield concept) [(6)*(12)*(13)*] FRESH (ham)	In-Storage Ground Water Resources (Storativity concept) [(6)*(10)*(14)*] (ham)	Total in-Storage Ground Water Resources (15+16) (ham)
		Total Geographical Area	Assessment Area											
			Total	Fresh Water										
1	2	4	5	6	8	9	10	11	12	13	14	15	16	17
1	Bilaspur	30122	29022	29022	184	200	152.13	16	16	0.072	0.00451	33433	19912.17704	53346
2	Chacharauli	53155	39955	39955	178	197	146.13	19	19	0.072	0.00451	54658	26332.19492	80991
3	Jagadhri	27270	27270	27270	190	300	158.13	110	71.25	0.072	0.00451	139895	19448.045	159343
4	Mustafabad	20682	20682	20682	184	223	152.13	39	30	0.072	0.00451	44673	14190.0505	58863
5	Radaur	29101	29101	29101	200	300	168.13	100	58	0.072	0.00451	121526	22066.3076	143592
6	Sadhuara	15270	14270	14270	187	263	155.13	76	35	0.072	0.00451	35960	9983.810001	45944
7	**Dist. Total**	**175600**	**160300**	**160300**								**430146**	**111932.5851**	**542079**

The average peizometer head of aquifer II is 31.87 m bgl.

Table 12: BLOCK WISE INSTORAGE GROUND WATER RESOURCES – CONFINED (AQUIFER III- upto 300m depth)

Sr. No.	Name of Assessment Unit	Areal extent (ha)			Depth to Top Aquifer III (m bgl)	Depth to bottom of Aquifer III (m bgl)	Thickness of piezometric level(m)	Total Thickness of confined aquifer down to explored depth (m) (m) (9-8)	Thickness of the Granular Zone in confined aquifer down to explored depth(m) (m)	Average Specific Yield	Average value of Storativity	In-Storage Dyanamic Ground Water Resources (Specific yield concept) [(6)*(12)*(13)] (ham)	In-Storage static Ground Water Resources (Storativity concept) [(6)*(10)*(14)] (ham)	Total in-Storage Ground Water Resources (15+16) (ham)
		Total Geographical Area	Assessment Area											
			Total	Fresh Water										
1	2	4	5	6	8	9	10	11	12	13	14	15	16	
1	Bilaspur	30122	29022	29022	0	0		0	0	0.072	0	0	0	0
2	Chacharauli	53155	39955	39955	0	0		0	0	0.072	0	0	0	0
3	Jagadhri	27270	27270	27270	0	0		0	0			0	0	0
4	Mustafabad	20682	20682	20682	245	300	215.36	55	46	0.072	0.00451	68499	20087.8806	88587
5	Radaur	29101	29101	29101	0	0		0	0			0	0	0
6	Sadhuara	15270	14270	14270	284	300	254.36	16	7	0.072	0.00451	16439.00	16370.02457	32809
7	**Dist. Total**	**175600**	**160300**	**160300**								**68499**	**36457.90517**	**121396**

The average Peizometer head value for confined Aquifer III is 29.64 m.bgl

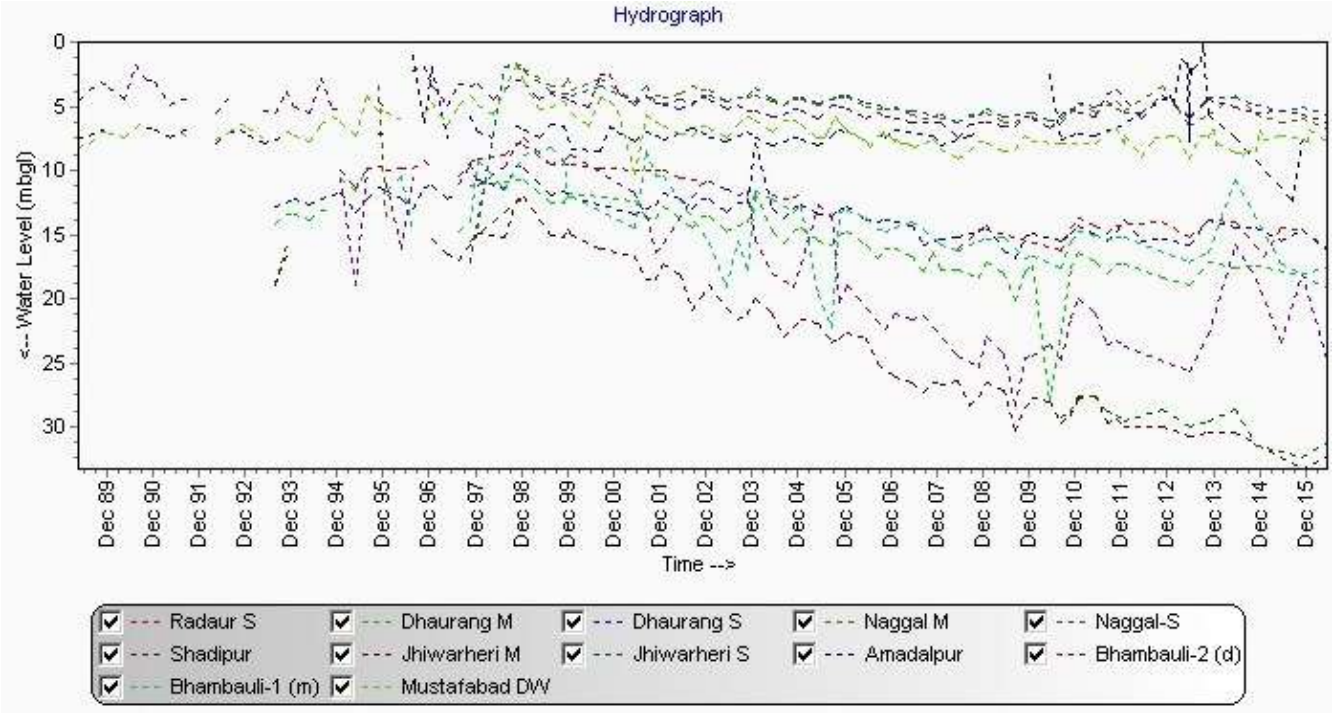
Table 13: BLOCK WISE TOTAL AVAILABLE GROUND WATER RESOURCES IN AQUIFERS UP TO 300m DEPTH

Sl.No	BLOCK	*Dynamic Groundwater Resources (2013) AQUIFER-I*	*In-storage Groundwater Resources AQUIFER-I*	Fresh Groundwater Resources AQUIFER-I [(3)+(4)]	Fresh In-storage Groundwater Resources AQUIFER-II	Fresh In-storage Groundwater Resources AQUIFER-III	Total Availabilty of Fresh Groundwater Resources [(5)+(6)+(7)]	
							ham	mcm
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1	Bilaspur	9345	73135	82480	53346	0	135826	1358
2	Chacharauli	13043	249645	262688	80991	0	343679	3437
3	Jagadhri	8410	223169	231579	159343	0	390922	3909
4	Mustafabad	7358	64821	72179	58863	88587	219629	2196
5	Radaur	8941	215205	224146	143592	0	367738	3677
6	Sadhuara	3943	50392	54335	45944	32809	133088	1331
Dist.Total (ham)		**51040**	**876367**	**927407**	**542079**	121396	**1590882**	**15909**
Dist.Total (mcm)		**510**	**8764**	**9274**	**5421**	**1214**	**15909**	
Dist.Total (bcm)		0.51	8.764	9.274	5.421	1.214	15.9	

5. GROUND WATER ISSUES

Yamunanagar is famous for its paddy cultivation. The quality of ground water in the district is potable for both the drinking and irrigation purposes therefore, the ground water is constantly being pumped for the irrigation due to its easy access through tube wells and they are the main source of irrigation. This will lead to its major ground water issue which is deepening of ground water level as the recharge of the groundwater through rainfall and other sources are less than the overall extraction. The hydrographs **(Fig 23)** also shows the declining water level trend over the years and the district is also categorized as over-exploited.

Fig 25 : Long term ground water table variation



6.1 GROUND WATER IRRIGATION SCENARIO

As per the data available from minor irrigation census 2006-07, the detailed number of shallow, deep, tube wells, lined, unlined water distribution system, land holdings of wells are given in Table 10,11 and 12

Fig 24: Depth wise irrigation tube wells

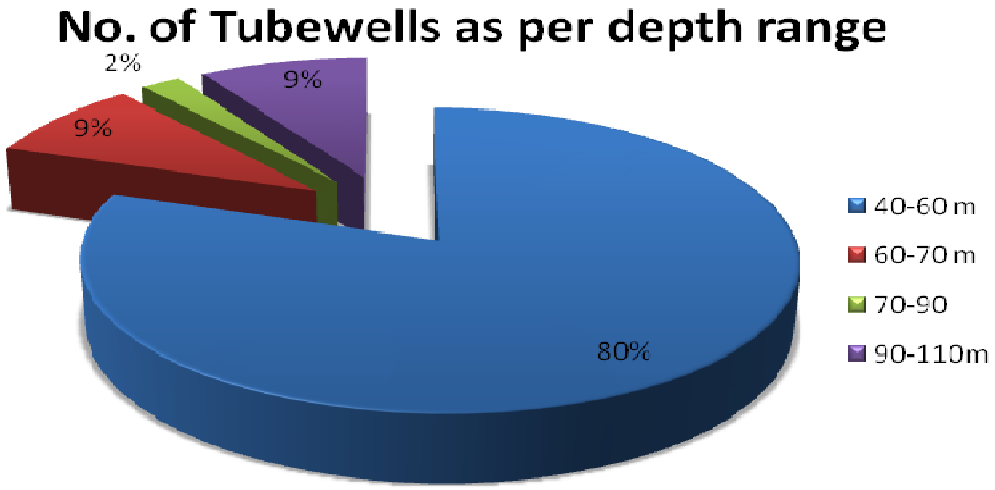


Table 14-Distribution of Tube wells According to Owner's holding Size

Sr.no	District	Marginal (0-1 ha)	Small (1-2 ha)	Semi-Medium (2-4 ha)	Medium (4-10ha)	Public	Group of Farmers	Total
1	Yamunanagar	138	1888	5448	170	202	12658	20504

Table15- Type of Ground water distribution device

Open Water Channel		
Lined/pucca	**Unlined/kutcha**	Total
27357	**5183**	32540

Table 16- Number of Ground Water Schemes and Potential Utilized by water distribution device

Ground Water Schemes according to water Distribution System				
	Open Water Channel			
Sr.no	District	Lined/pucca	Unlined/kutcha	Total
1	YAMUNANAGAR	17171	3333	20504

7. AQUIFER MANAGEMENT PLAN

Artificial recharge plan is not feasible in The Yamunanagar District due to very low availability of volume of surplus water (1.90 mcm). Another approach has been given to minimize the gross draft by enhancing ground water use efficiency in irrigation system after changing the water distribution system from unlined/kutcha channel to lined/pucca channel for the whole Yamunanagar district.

7.1 SCOPE OF IMPLEMENTATION

This plan is focusing on the technical aspects of the ground water savings through lining of unlined channel so that various implementing agencies may get the appropriate technical guidelines. The existing/ongoing schemes of the central or state govt. like MANERGA, IWSP, PMKSY (Prime Minister Krishi Sinchai Yojna), NABARD funded schemes, Urban Development schemes, departmentally funded projects etc. may be benefitted from the recharge plan by incorporating the input in the operational guidelines/ design and for locating the specific sites.

Agriculture university, engineering Collages, Academic and Research Institution, NGO may also take up the pilot or demonstrative projects in the blocks suitable to them to plan at local level as per local conditions.

7.2 POTENTIAL OF ENHANCING THE GROUND WATER USE EFFICIENCY

The micro level transformation in the ground water management have vast impact potential to counter extensive ground water depletion faced by the state of Haryana, particularly in overexploited blocks. There are around 3333 (out of 20502) tubewells (16.26%) operated by farmers for irrigation through unlined/Katcha open channel system in Yamunanagar district where water from the tubewell is discharge to the agricultural field. In this process huge (upto 30%) quantity of ground water is wasted in soil moisture and evaporation losses. Around 85% of the tube wells are of shallow depth (< 60m) and remaining are deeper (60-110 m) depth. Thus majority of wells are tapping Aquifer group-1 which is under stress due to overexploitation. Dynamic ground water resources (2011) indicate that Gross ground water draft for irrigation in

Yamunanagar district is estimated at 666.49 MCM. It is expected that around 30% of over draft can be brought down by switching over to underground/surface pipeline based distribution from the prevailing unlined open channels. Thereby gross draft will be reduced to the tune of 27.52 MCM assuming there is no crop diversification by the farmers. The benefit will lead to saving of precious ground water resources in overexploited blocks. The measure if implemented will bring down the ground water overdraft from 138 % to 131.90%. The category of the blocks will also improve drastically resulting in boosting of agriculture and industrial development otherwise not sustainable in majority of the blocks in the state. The tubewells also consume enormous electricity which is subsidized and government incurs significant revenue on this account. The measures therefore will result in saving of energy and money. Pollution impact will be reduced whenever diesel engines are used by the farmers. The environmental and ecological condition in the irrigated land will improve. Unwanted weed growth will also be controlled inside the farm land. This will also be useful in the waterlogged/ shallow water table areas as the seepage losses in these areas also aggravate the water logging. Government should make/launch a mission mode program for installing the underground pipe lines instead of having katcha channel in the entire Haryana. Heavy ground water overdraft can be reduced by these efforts. This will ensure more crop per drop.

Water Saving Potential from Crop Diversification-Change Paddy to Maize/ Soyabean:

As the requirement of water for paddy is much high therefore by changing paddy to maize/soyabean will help in saving of water. For estimating the water saving by crop diversification it is assumed that one mcm of water will be saved in case of maize or soyabean planted in one sq km of land. In case of pulses even higher amount of ground water can be saved.

Table 17: Scope of Quantitative Impact on Stage of Development after applying various management strategies, Yamunanagar district

Block	Present Stage of development (%) as on 2013	Reduction in stage of development after unlined channel (%)	Reduction in Stage of development after crop diversification by Maize/Soyabean (%)	Reduction in Stage of development after Artificial recharge (%)	Total Reduction in Stage of development (%) (2 +3)	Stage of development afterwards (%) (1-5)	Reduction in Stage of development after crop diversification by Pulses (%)	Total Reduction in Stage of development (%) (1 +7)	Stage of development afterwards (%) (1-8)
	1	2	3	4	5	6	7	8	
Bilaspur	101	3.61	NR	0	3.61	**97**	-	-	**-**
Chachrauli	116	5.09	13.33	0	18.42	**98**	-	-	**-**
Jagadhri	171	6.94	17.23	0	24.17	**147**	39.13	46.07	**125**
Mustafabad	149	6.28	23.76	0	30.03	**119**	55.06	61.34	**88**
Radour	167	7.36	19.61	0	26.97	**140**	45.31	52.67	**114**
Sadhuara	102	4.06	NR	0	4.06	**98**	39.13	43.19	**59**

8 -BLOCK WISE AQUIFER MAPS AND MANAGEMENT PLAN

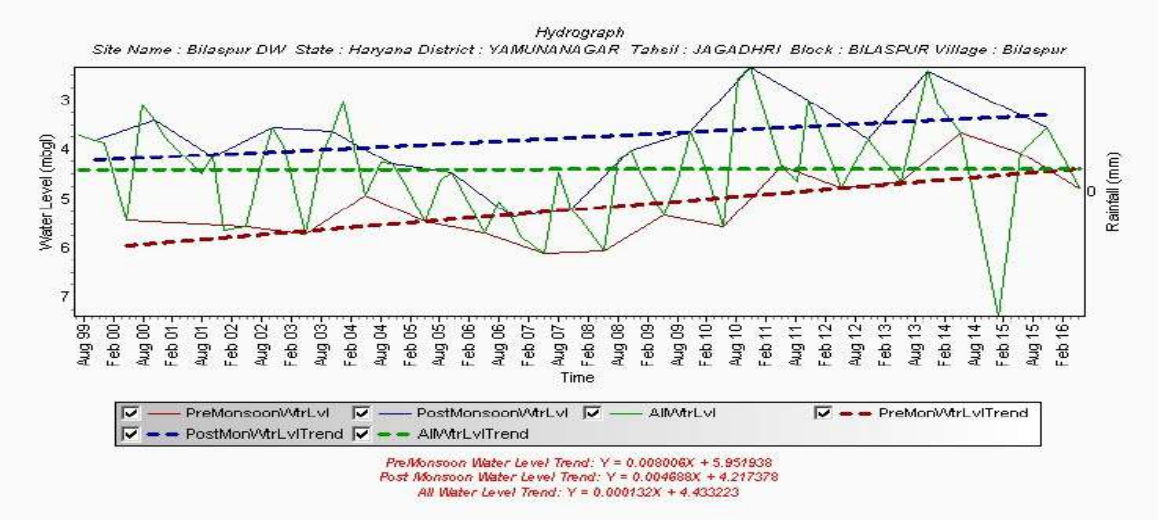
i- BILASPUR BLOCK (301.22 SQ KM)

Population (2011)	Rural-62177 Urban-0 Total-62177
Rainfall	Monsoon -951.20 mm Non Monsoon-175.80 mm
Average Annual Rainfall	1127 mm
Agriculture and Irrigation	Major Crops- Rice, Wheat Other crops-Sugarcane, Potatoes, Pulses, Oilseeds Net Area Sown- 218.31 sqkm Total Irrigated Area-186.04 sqkm
Water Bodies	187

Ground Water Resource Availability: Ground Water Resources available in the different group of aquifers. Aquifer I (167m) is very prominent in terms of thickness and geographic extent. Aquifer II (16 m) are less in thickness as per explored depth . Block is categorized as Over-Exploited as per 2013 assessment.

Ground water Extraction: Information regarding the abstraction from Aquifer II is not available, but there are drinking water supply tapping combined aquifer and separate aquifer could not be assessed separately.

Water level Behavior (2015): Pre Monsoon-~5m bgl & Post Monsoon-~ 4mbgl

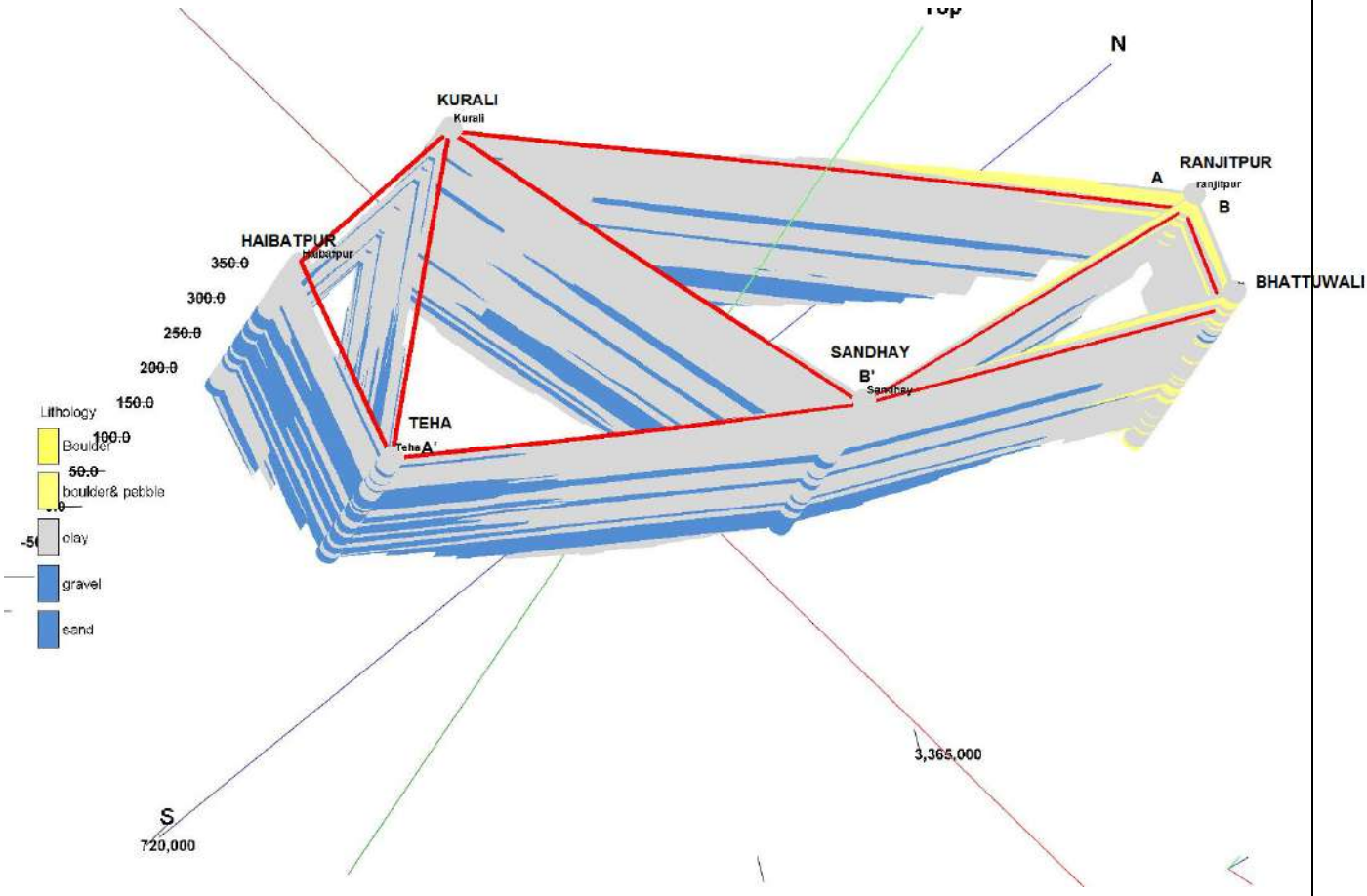


Aquifer Disposition: Multiple Aquifer System (3 Aquifer System)

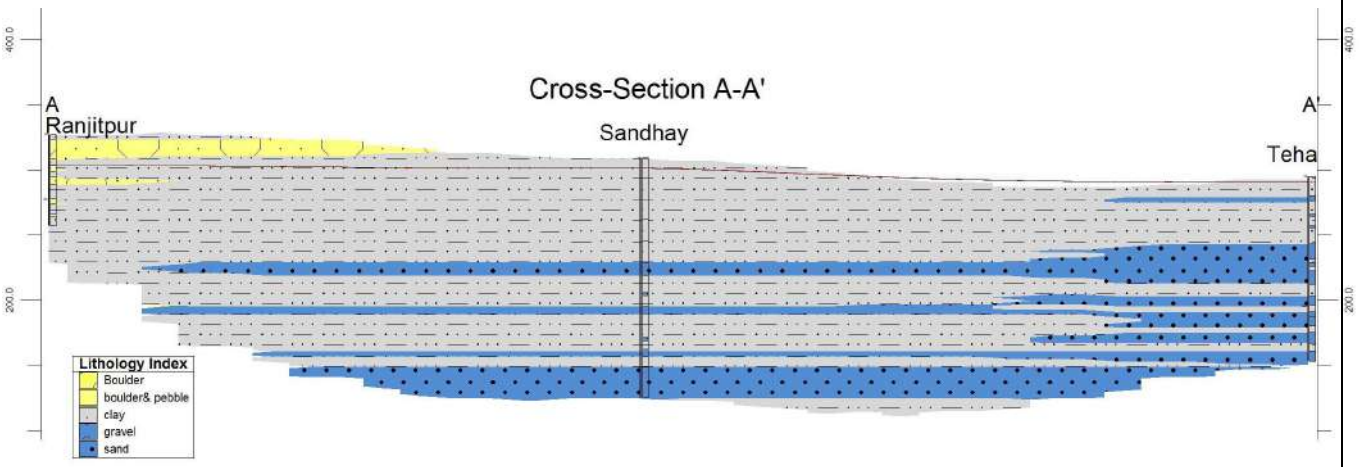
Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
Aq-I (0-167 m)	Quaternary Alluvial deposits	Unconfined	158.27	2200	12	NA
Aq-II (184-200m)		Semi confined to Confined	27	700	-	$6.63x10^{-3}$
Aq-III (200-300)		Semi confined to Confined	28	525	-	$4.5 x10^{-4}$

Aquifer comprises of freshwater only and the main aquifer formation is sand. The non-aquifer material comprise of clay.

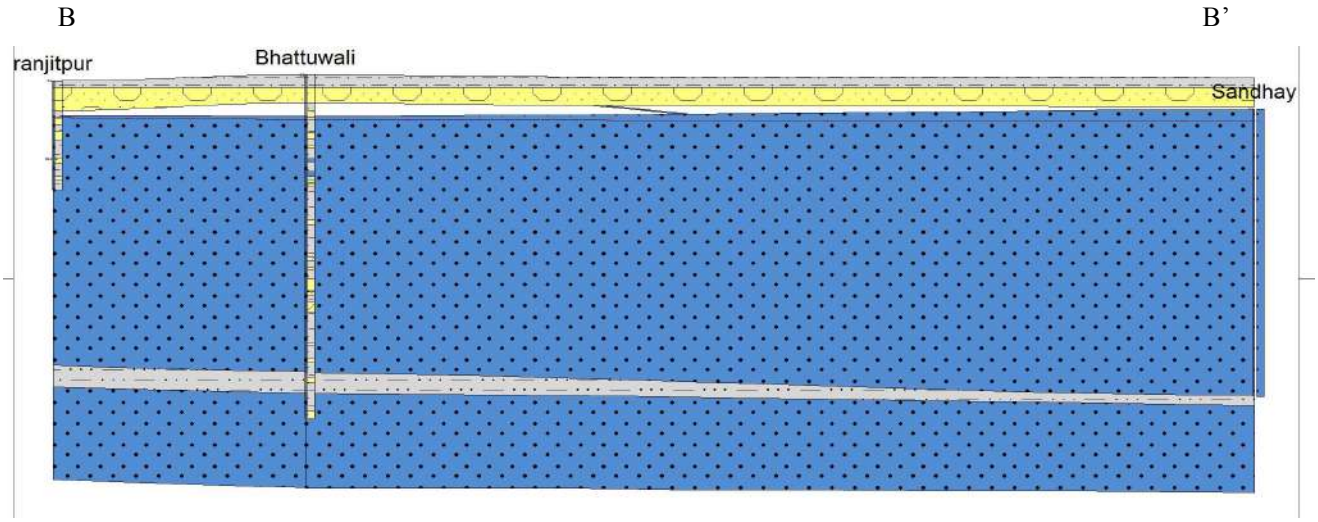
3D Lithology Fence



Lithological Fence Diagram



Aquifer Map along B-B'



Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm)	Dynamic Aquifer I	93.45
	In-storage Aquifer I	731.35
	Dynamic Aquifer II	199.12
	In-storage Aquifer II	334.33
	Dynamic Aquifer III	NA
	In-storage Aquifer III	NA
	Total	1358.25
Ground Water Extraction (in mcm)	Irrigation	78.17
	Domestic & Industrial	16.65
Future Demand for domestic & Industrial sector (2025) (in mcm)		2.38
Chemical Quality of ground water		Potable for drinking and irrigation
Other issues		Overexploitation of groundwater

Ground Water Resource Enhancement

Aquifer wise space available for recharge and proposed interventions	Volume of unsaturated zone up to the average depth to water level (9.11 m) is 180.73 mcm.

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 5.38 mcm volume of water wastage
Change in cropping pattern	Change in cropping pattern from Paddy to maize/soyabean need not required.
Alternate water sources	Tanks, ponds and canals
Regulation and Control	-

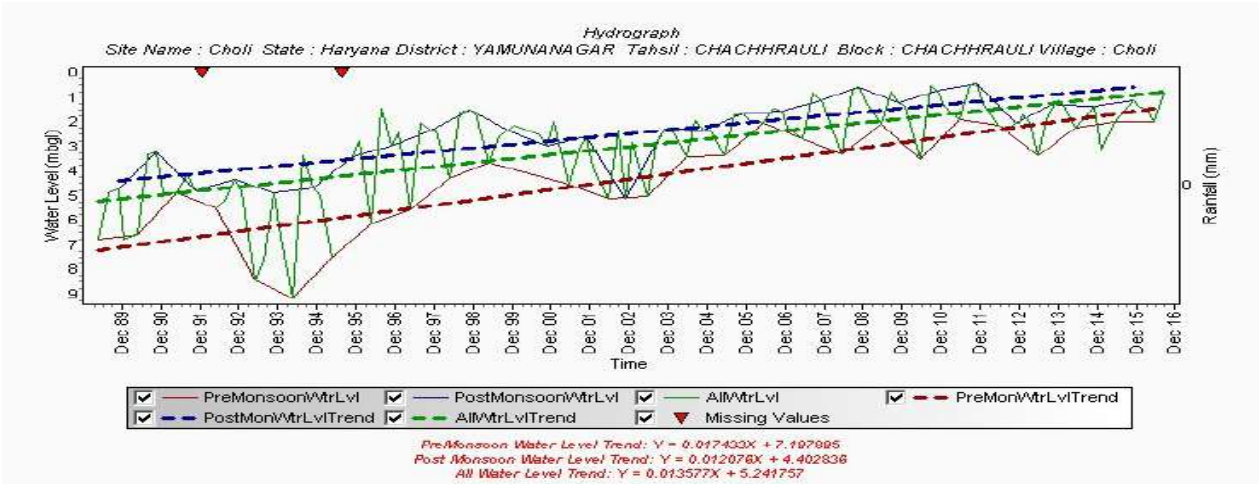
ii.- CHACHRAULI BLOCK (531.55 SQ KM)

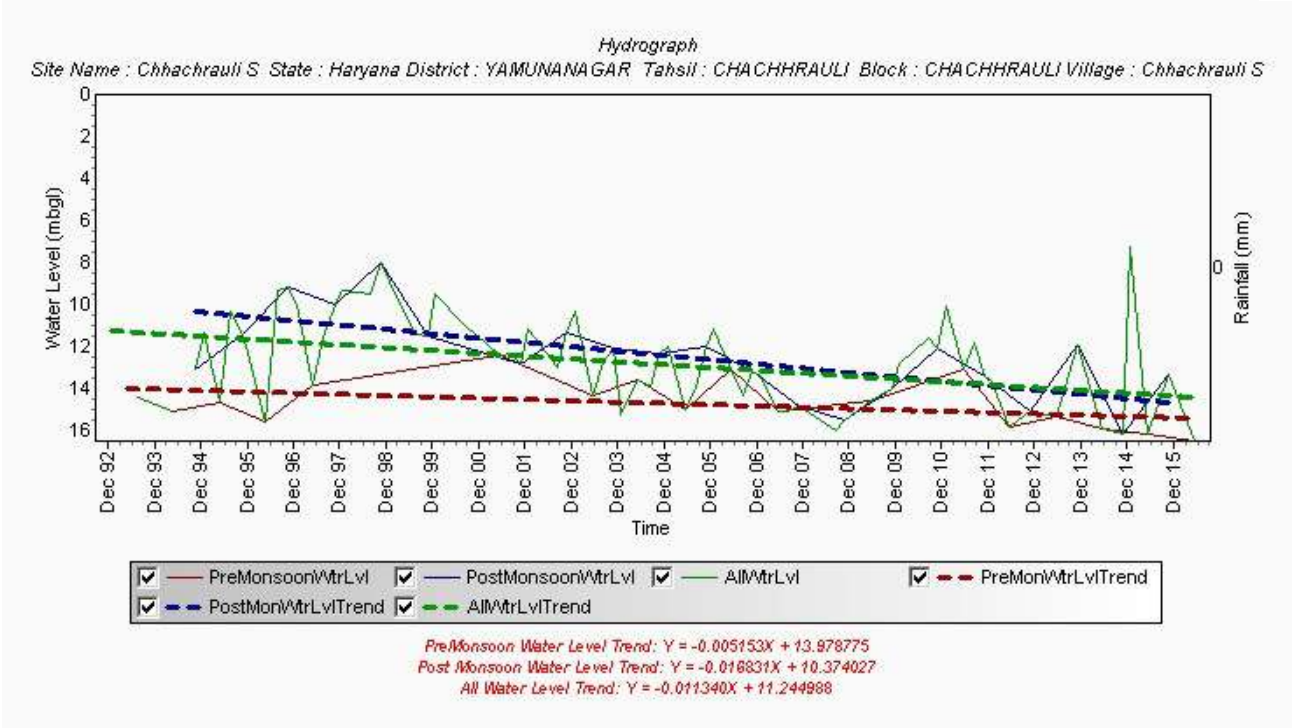
Population (2011)	Rural-203588 Urban-0 Total-203588
Rainfall	Monsoon -951.20 mm Non Monsoon-175.80 mm
Average Annual Rainfall	1127mm
Agriculture and Irrigation	Major Crops- Rice, Wheat Other crops-Sugarcane, Potatoes, Pulses, Oilseeds Net Area Sown-273.89sqkm Total Irrigated Area- 252.23 sqkm
Water Bodies	94

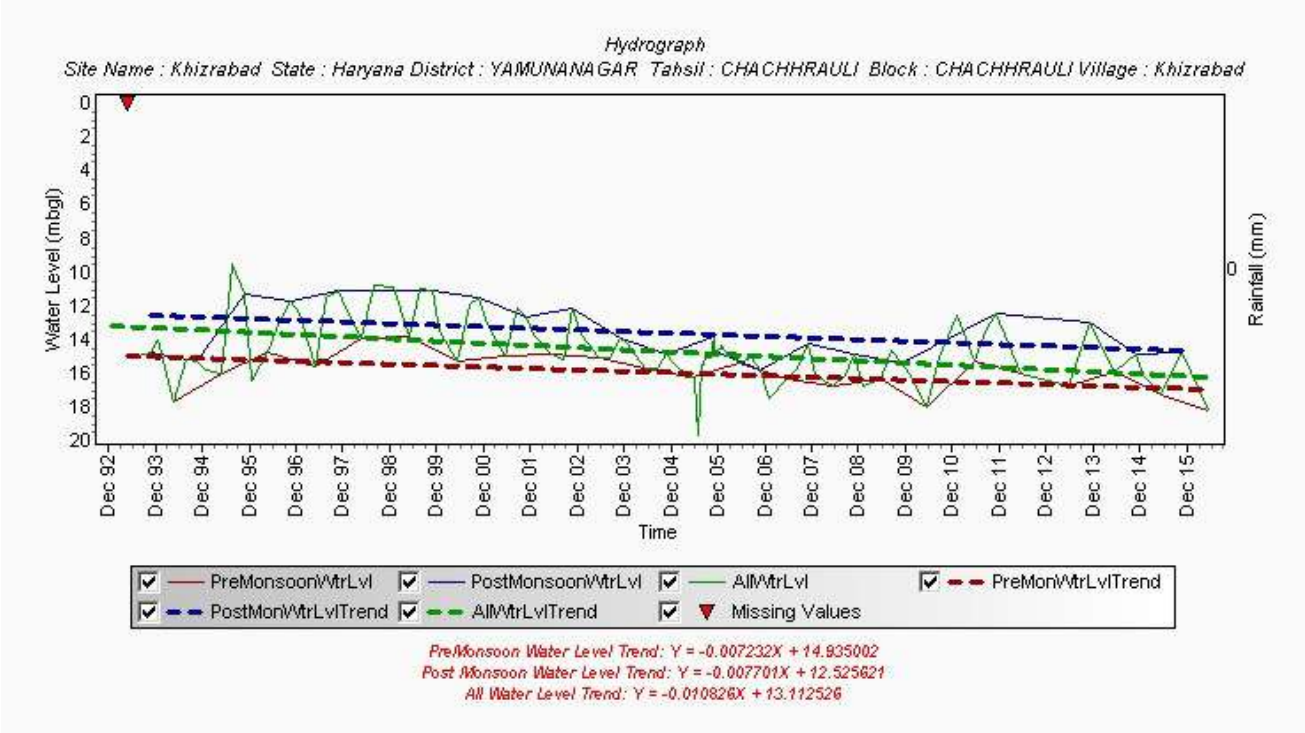
Ground Water Resource Availability: Ground Water Resources available in the different group of aquifers. Aquifer I (147 m) is very prominent in terms of thickness and geographic extent. Aquifer II (19 m) is less in thickness. Block is categorized as Over-Exploited as per 2013 assessment.

Ground water Extraction: Information regarding the abstraction from Aquifer II is not available, but there are drinking water supply tapping combined aquifer and separate aquifer could not be assessed separately.

Water level Behavior (2015): Pre Monsoon-~1.99-17.26 m bgl &Post Monsoon-1.39-16.20 mbgl


Hydrograph
Site Name : Choli State : Haryana District : YAMUNANAGAR Tahsil : CHACHHRAULI Block : CHACHHRAULI Village : Choli
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = 0.017433X + 7.197895
Post Monsoon Water Level Trend: Y = 0.012076X + 4.402836
All Water Level Trend: Y = 0.013577X + 5.241757


Hydrograph
Site Name : Chhachrauli S State : Haryana District : YAMUNANAGAR Tahsil : CHACHHRAULI Block : CHACHHRAULI Village : Chhachrauli S
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.005153X + 13.978775
Post Monsoon Water Level Trend: Y = -0.016831X + 10.374027
All Water Level Trend: Y = -0.011340X + 11.244988

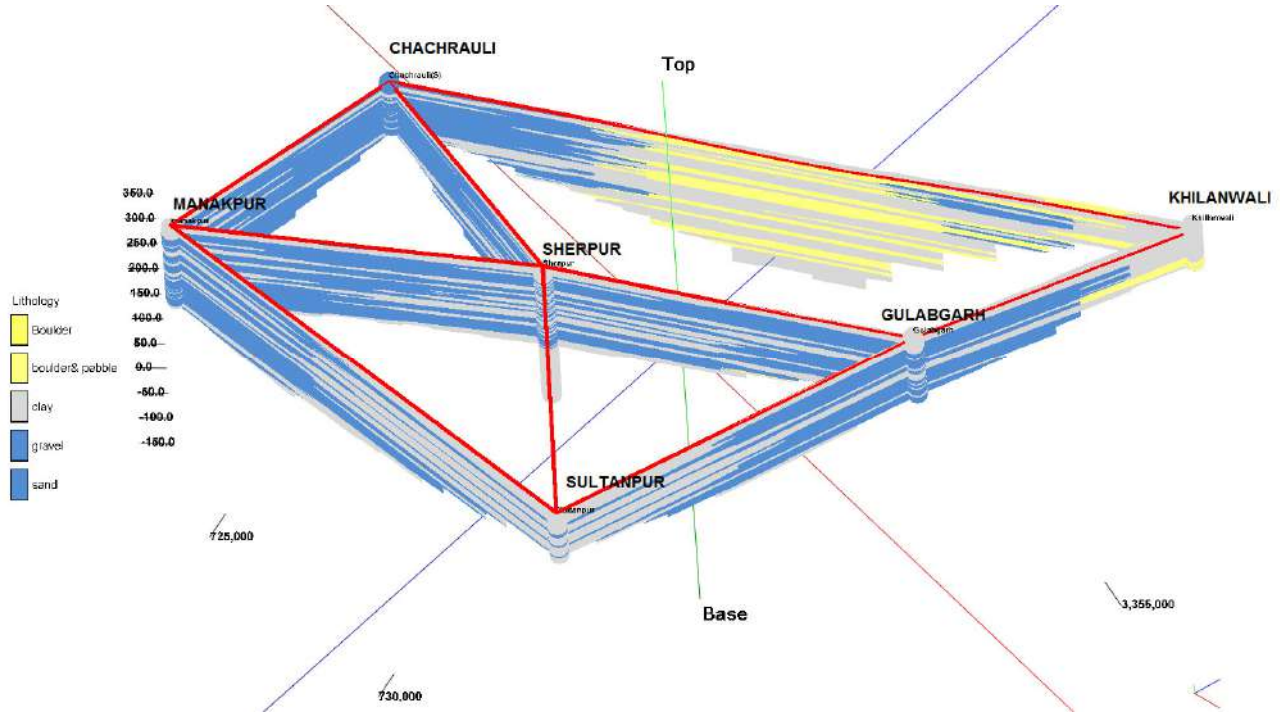


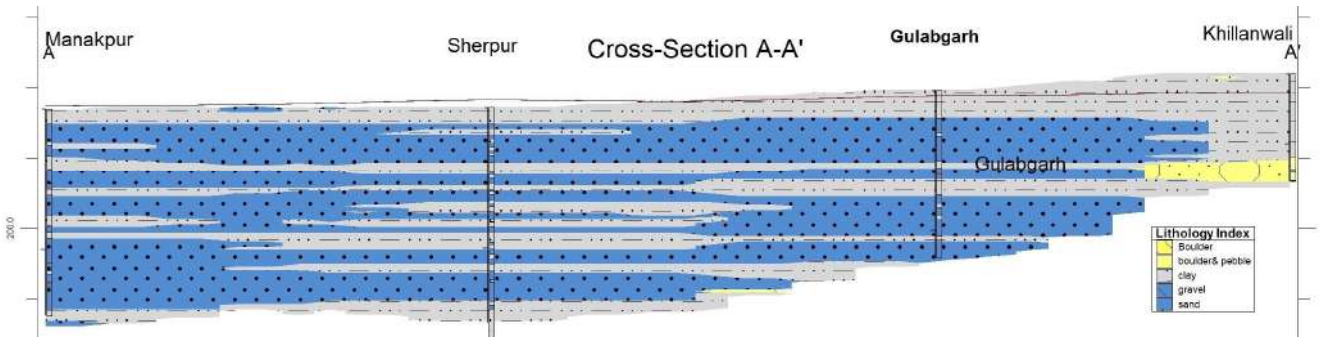
Aquifer Disposition: Multiple Aquifer System (3 Aquifer System)

Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
Aq-I (0-147)	Quaternary Alluvial deposits	Unconfined	147	2200	12	NA
Aq-II (178-197m)		Unconfined to Confined	19	-	-	$1x10^{-3}$
Aq-III (NA)		Semi confined to Confined	-	-	-	NA

Aquifer comprises of freshwater only and the main aquifer formation is sand. The non-aquifer material comprise of clay.

3D Lithology Fence





Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm)	Dynamic Aquifer I	130.43
	In-storage Aquifer I	2496.45
	Dynamic Aquifer II	263.32
	In-storage Aquifer II	546.58
	Dynamic Aquifer III	NA
	In-storage Aquifer III	NA
	Total	3436.78
Ground Water Extraction (in mcm)	Irrigation	133
	Domestic & Industrial	18.15
Future Demand for domestic & Industrial sector (2025) (in mcm)		3.94
Chemical Quality of ground water		Potable for drinking and irrigation
Other issues		Deeper water level (>5m) & declining water level trend (17-72 cm/yr)

Ground Water Resource Enhancement

Aquifer wise space available for recharge and proposed interventions	Volume of unsaturated zone upto the average depth to water level (10.22m) is 605.96 mcm.
Other interventions proposed	-

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 9.15 mcm volume of water wastage
Change in cropping pattern	Proposed change in cropping pattern from Paddy to maize/soyabean. Total area of the block needs to change the crop from paddy to maize. Anticipated reduction in stage of groundwater development after crop diversification(Paddy to maize) is 2%.
Alternate water sources	Tanks, ponds and canals
Regulation and Control	-
Other interventions proposed, if any	-

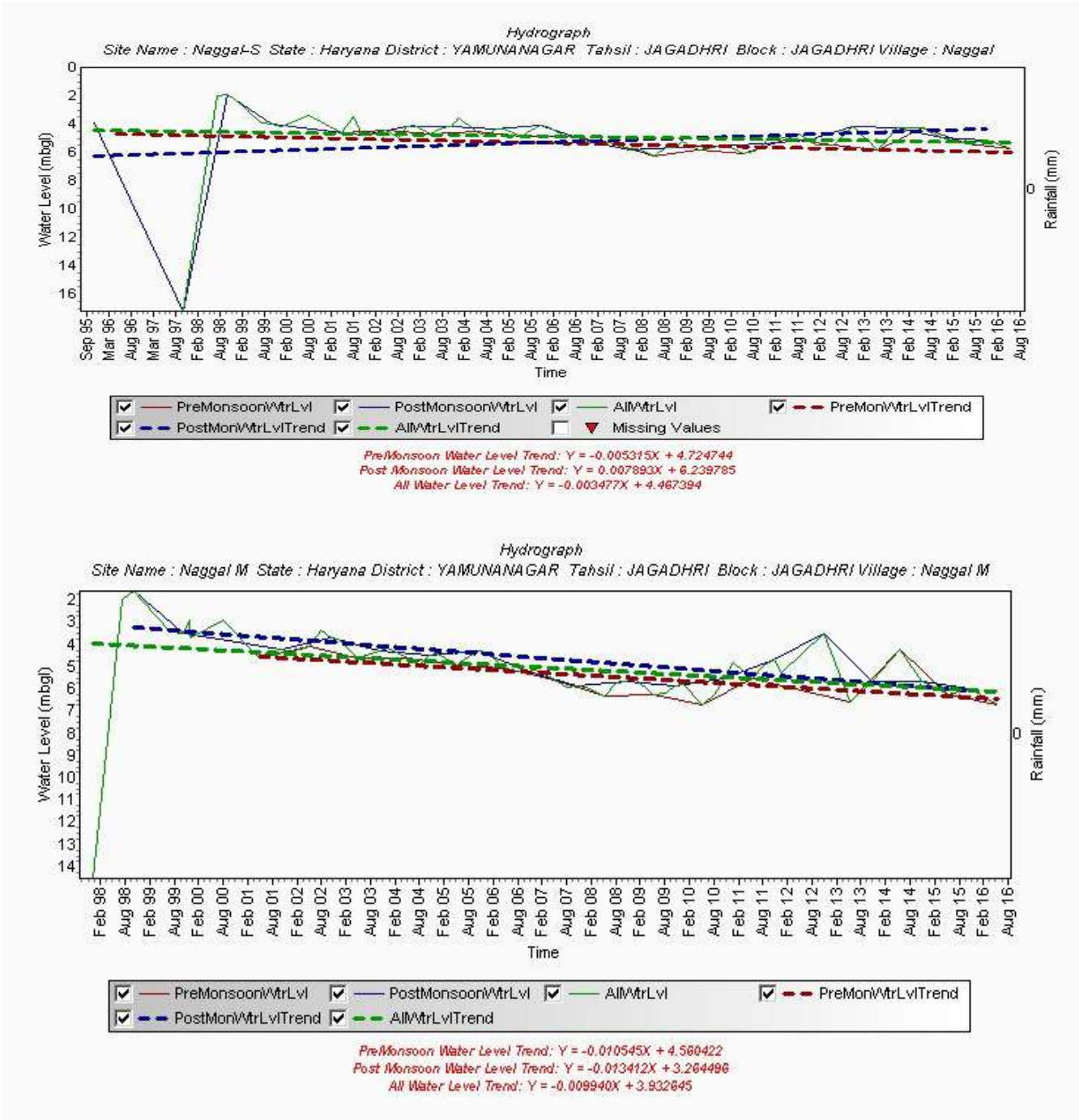
iii. JAGADHARI BLOCK (272.70 SQ KM)

Population (2011)	Rural-111131 Urban-124894(jagadhari)+217071(Yamunanagar) Total-453096
Rainfall	Monsoon -696.60 mm Non Monsoon-89.40 mm
Average Annual Rainfall	786 mm
Agriculture and Irrigation	Major Crops- Rice, Wheat Other crops-Sugarcane, Potatoes, Pulses, Oilseeds Net Area Sown-189.28sqkm Total Irrigated Area-189.26 sqkm
Water Bodies	123

Ground Water Resource Availability: Ground Water Resources available in the different group of aquifers. Only two aquifers have been identified up to 300m depth of which Aquifer I (165.98m) is very prominent in terms of thickness and geographic extent. Aquifer II (110m) is less in thickness. Block is categorized as Over-Exploited as per 2013 assessment.

Ground water Extraction: Information regarding the abstraction from Aquifer II is not available, but there are drinking water supply tapping combined aquifer and separate aquifer could not be assessed separately.

Water level Behavior(2015): Pre Monsoon-5.38-17.25mbgl & Post Monsoon-4.92-14.51 mbgl


Hydrograph
Site Name : Naggal-S State : Haryana District : YAMUNANAGAR Tahsil : JAGADHRI Block : JAGADHRI Village : Naggal
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = -0.005315X + 4.724744
Post Monsoon Water Level Trend: Y = 0.007893X + 6.239785
All Water Level Trend: Y = -0.003477X + 4.467394
Hydrograph
Site Name : Naggal M State : Haryana District : YAMUNANAGAR Tahsil : JAGADHRI Block : JAGADHRI Village : Naggal M
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
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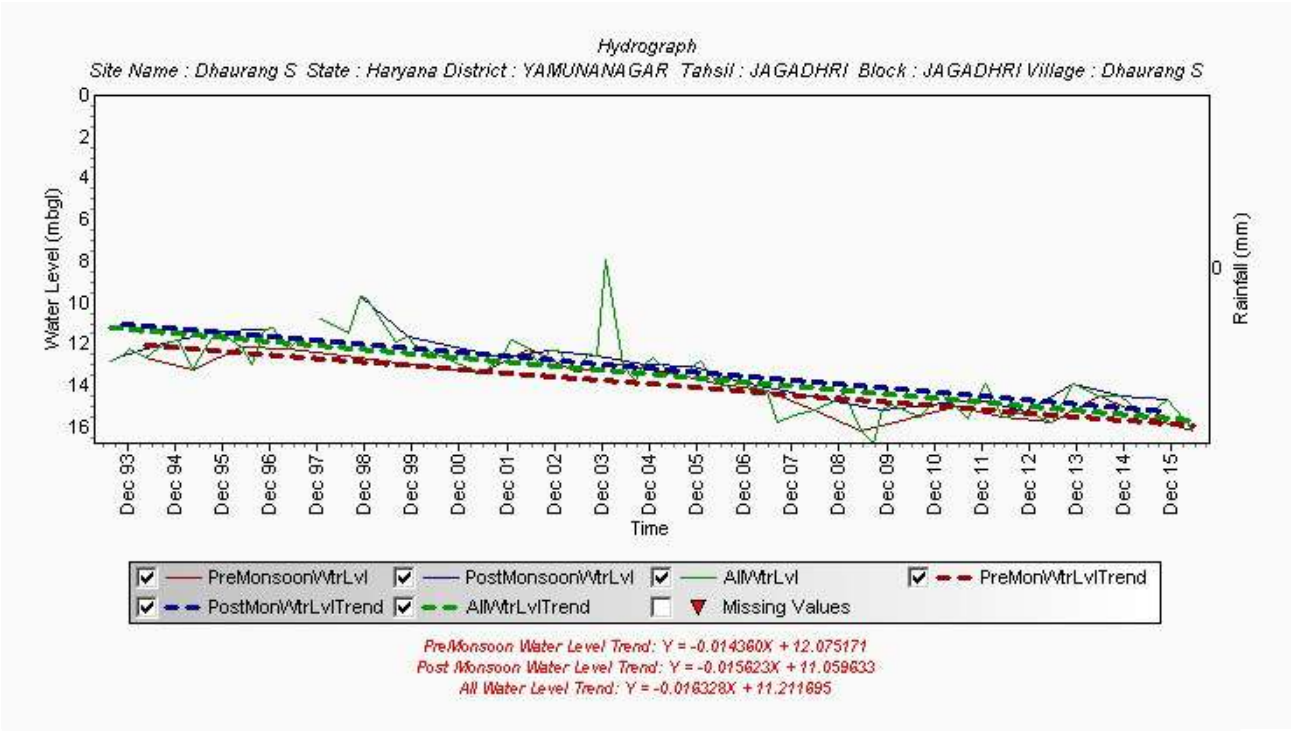
Post Monsoon Water Level Trend: Y = -0.013412X + 3.264496
All Water Level Trend: Y = -0.009940X + 3.932645


Hydrograph
Site Name : Dhaurang S State : Haryana District : YAMUNANAGAR Tahsil : JAGADHRI Block : JAGADHRI Village : Dhaurang S
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = -0.014360X + 12.075171
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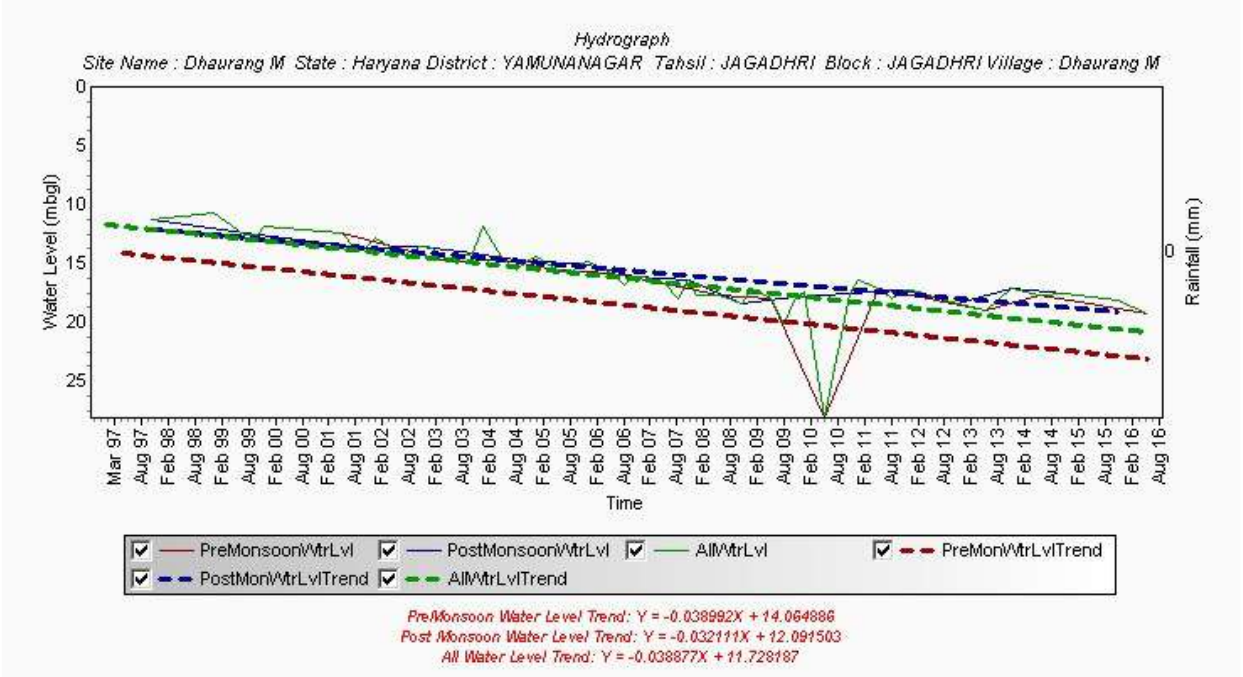
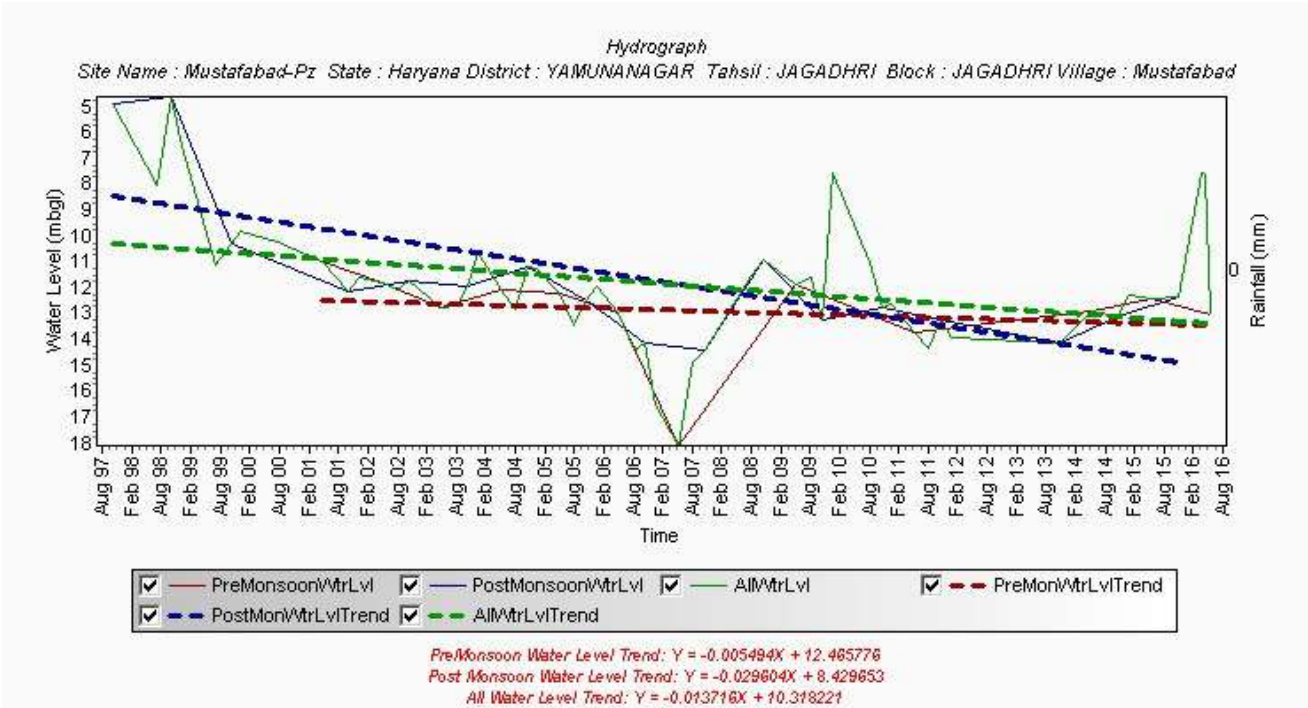
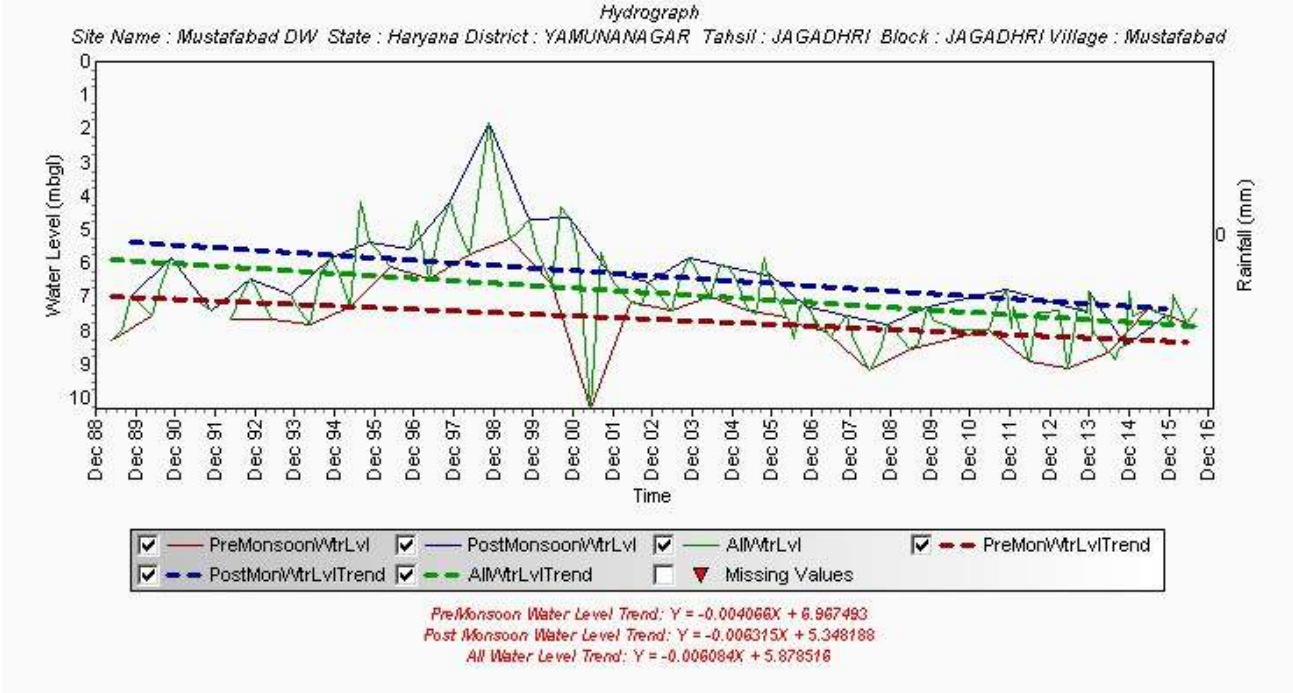
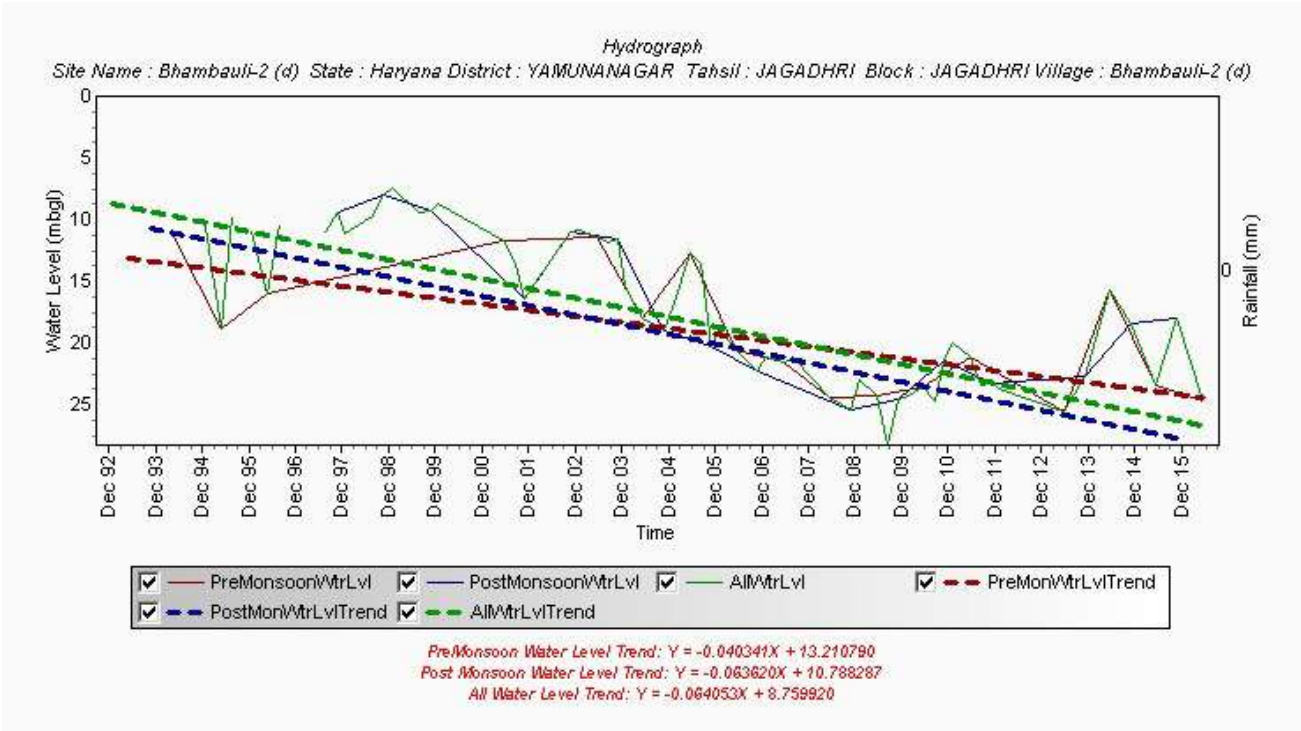
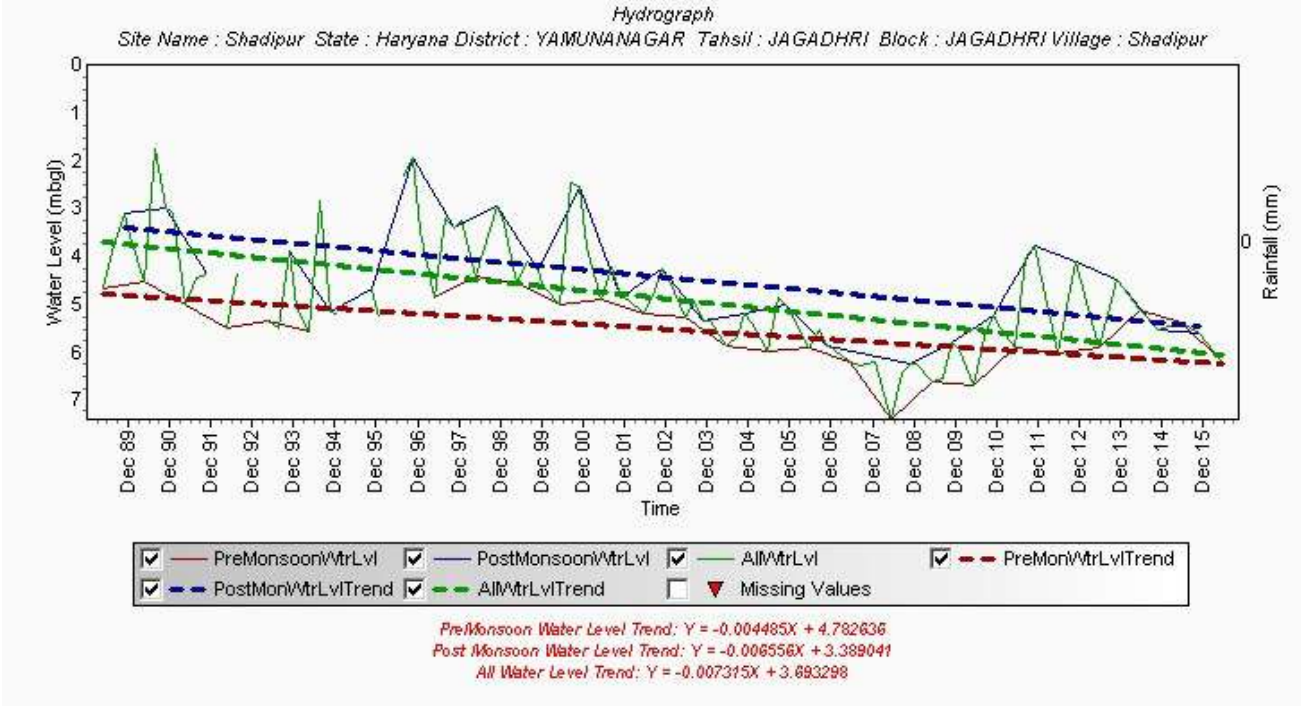
All Water Level Trend: Y = -0.016328X + 11.211695


Hydrograph
Site Name : Dhaurang M State : Haryana District : YAMUNANAGAR Tahsil : JAGADHRI Block : JAGADHRI Village : Dhaurang M
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.038992X + 14.064886
Post Monsoon Water Level Trend: Y = -0.032111X + 12.091503
All Water Level Trend: Y = -0.038877X + 11.728187


Hydrograph
Site Name : Mustafabad-Pz State : Haryana District : YAMUNANAGAR Tahsil : JAGADHRI Block : JAGADHRI Village : Mustafabad
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.005494X + 12.465776
Post Monsoon Water Level Trend: Y = -0.029604X + 8.429653
All Water Level Trend: Y = -0.013716X + 10.318221


Hydrograph
Site Name : Mustafabad DW State : Haryana District : YAMUNANAGAR Tahsil : JAGADHRI Block : JAGADHRI Village : Mustafabad
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = -0.004066X + 6.967493
Post Monsoon Water Level Trend: Y = -0.006315X + 5.348188
All Water Level Trend: Y = -0.006084X + 5.878516


Hydrograph
Site Name : Bhambauli-2 (d) State : Haryana District : YAMUNANAGAR Tahsil : JAGADHRI Block : JAGADHRI Village : Bhambauli-2 (d)
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.040341X + 13.210790
Post Monsoon Water Level Trend: Y = -0.063620X + 10.788287
All Water Level Trend: Y = -0.064053X + 8.759920

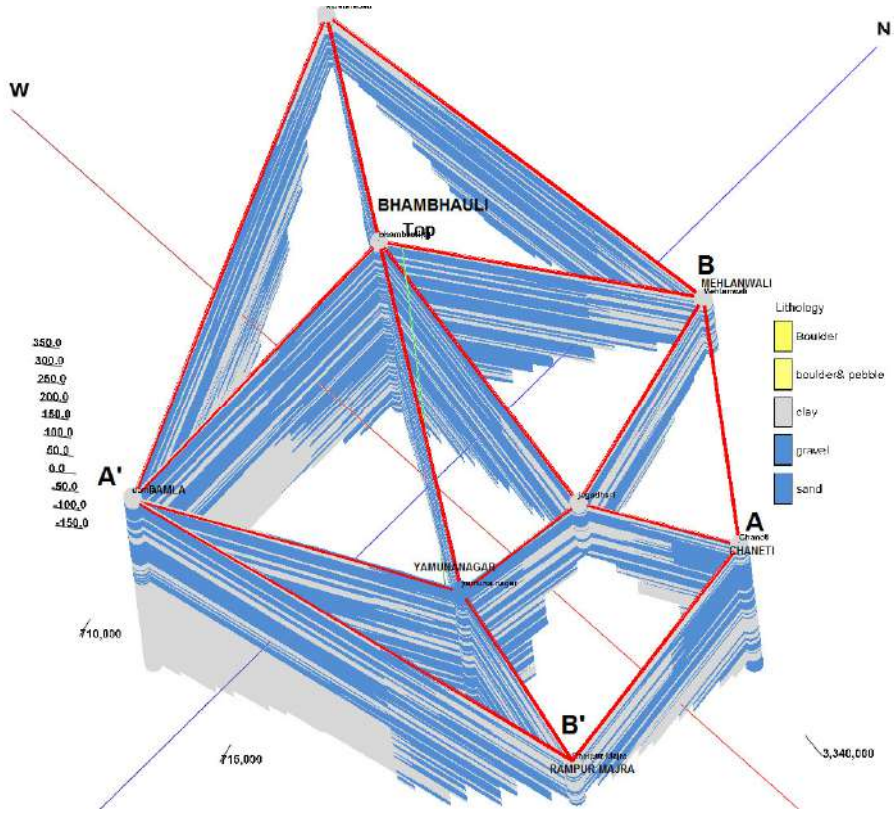

Hydrograph
Site Name : Shadipur State : Haryana District : YAMUNANAGAR Tahsil : JAGADHRI Block : JAGADHRI Village : Shadipur
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = -0.004485X + 4.782636
Post Monsoon Water Level Trend: Y = -0.006556X + 3.389041
All Water Level Trend: Y = -0.007315X + 3.693298

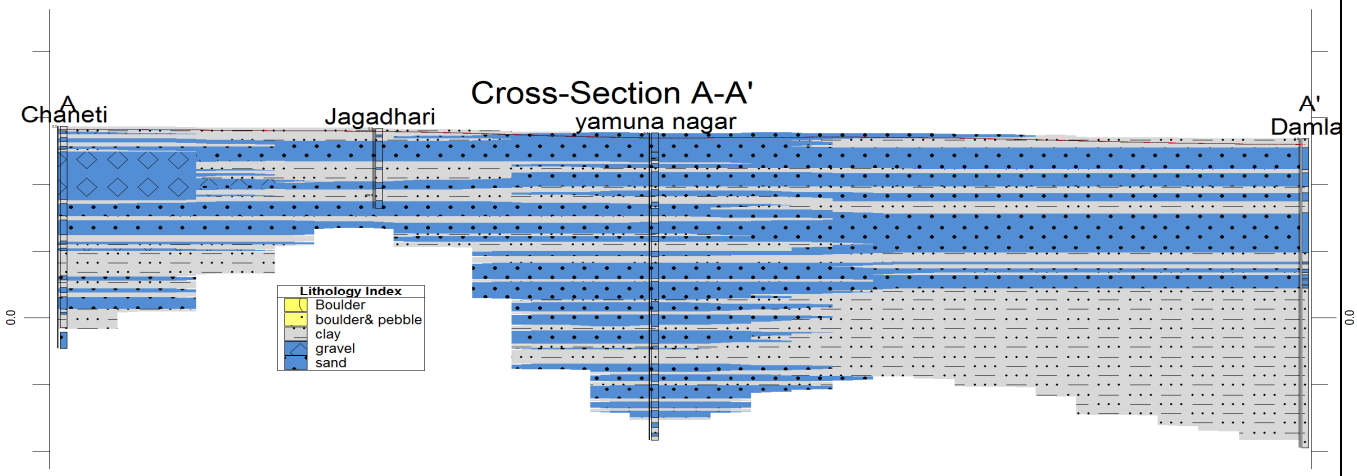
Aquifer Disposition: Multiple Aquifer System (2 Aquifer System)

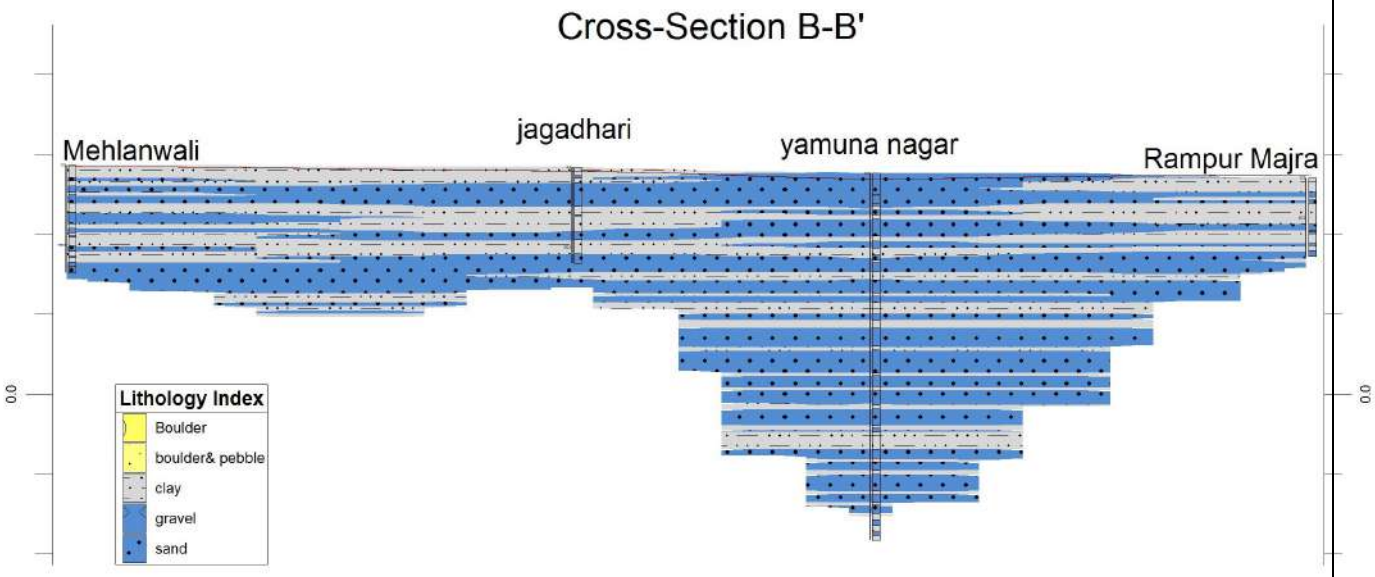
Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
Aq-I (0-180m)	Quaternary Alluvial deposits	Unconfined	113.662	2200	12	NA
Aq-II (190-300m)		Semi confined to Confined	71.25	-	-	$6.63x10^{-3}$

Aquifer comprises of freshwater only and the main aquifer formation is sand. The non-aquifer material comprise of clay.

3D Lithology Fence




Cross-Section A-A'
A
Chaneti
Jagadhari
yamuna nagar
A'
Damla
Lithology Index
Boulder
boulder& pebble
clay
gravel
sand
0.0
0.0


Cross-Section B-B'
Mehlanwali
jagadhari
yamuna nagar
Rampur Majra
Lithology Index
Boulder
boulder& pebble
clay
gravel
sand
0.0
0.0

Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm)	Dynamic Aquifer I	84.10
	In-storage Aquifer I	2231.69
	Dynamic Aquifer II	194.48
	In-storage Aquifer II	1398.95
	Total	3909
Ground Water Extraction (in mcm)	Irrigation	111.15
	Domestic & Industrial	32.25
Future Demand for domestic & Industrial sector (2025) (in mcm)		32.25
Chemical Quality of ground water		Potable for drinking and irrigation
Other issues		Deeper water level (>5m) & declining water level trend (15-99cm/yr)

Ground Water Resource Enhancement

Aquifer wise space available for recharge and proposed interventions	Volume of unsaturated zone upto the average depth to water level (12.83m) is 425.41 mcm.
Other interventions proposed	-

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 7.65mcm volume of water wastage
Change in cropping pattern	Proposed change in cropping pattern from Paddy to maize/soyabean. 44% of the total area needs to change the crop from paddy to maize Anticipated volume of water to be saved by maize is 47.56 mcm
Alternate water sources	Tanks, ponds and canals
Regulation and Control	-
Other interventions proposed, if any	-

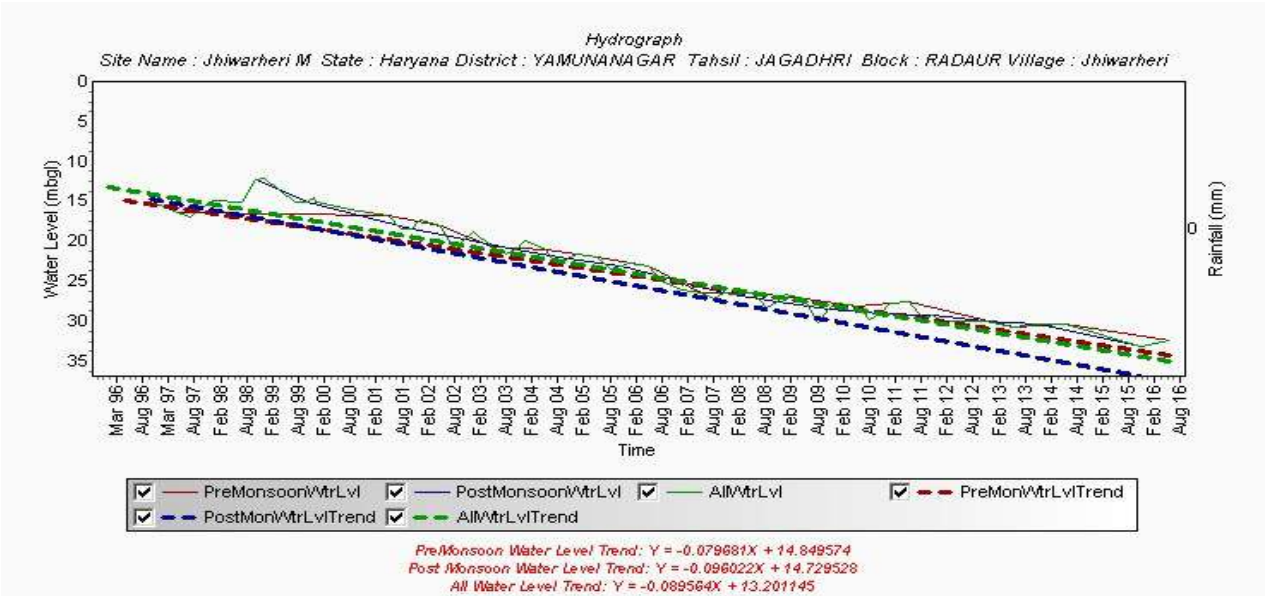
iv. RADAUR BLOCK (291.01 SQ KM)

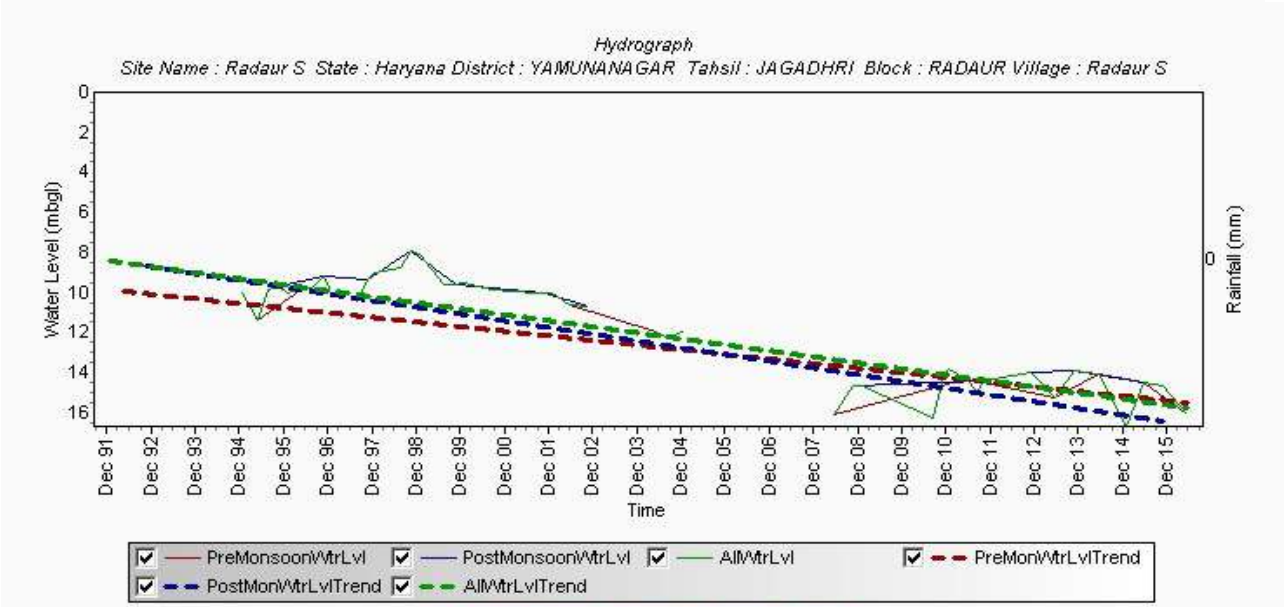
Population (2011)	Rural-116237 Urban-0 Total-116237
Rainfall	Monsoon -731.20 mm Non Monsoon-132 mm
Average Annual Rainfall	863.20 mm
Agriculture and Irrigation	Major Crops- Rice, Wheat Other crops-Sugarcane, Potatoes, Pulses, Oilseeds Net Area Sown-205.54 sqkm Total Irrigated Area-504.96 sqkm
Water Bodies & Canal Irrigation	25

Ground Water Resource Availability: Ground Water Resources available in the different group of aquifers. Aquifer I (171m) is prominent in terms of thickness and geographic extent. Aquifer II (100 m). Block is categorized as Over-Exploited as per 2013 Ground Water Resource estimation.

Ground water Extraction: Information regarding the abstraction from Aquifer II is not available, but there are drinking water supply tapping combined aquifer and separate aquifer could not be assessed separately.

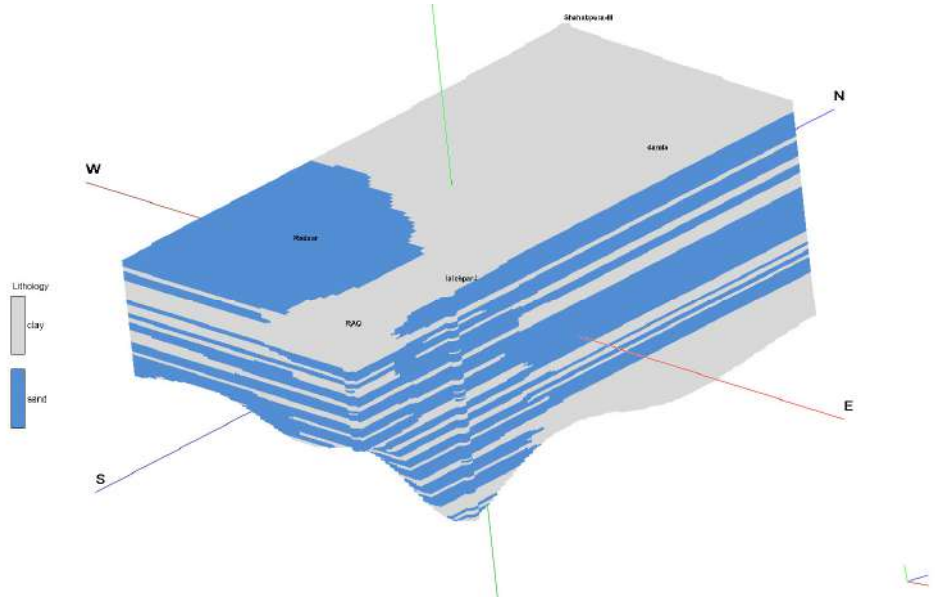
Water level Behavior(2015): Pre Monsoon-~34.48 m bgl & Post Monsoon-~31.50 m bgl


Hydrograph
Site Name : Jhiwarheri M State : Haryana District : YAMUNANAGAR Tahsil : JAGADHRI Block : RADAUR Village : Jhiwarheri
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.079681X + 14.849574
Post Monsoon Water Level Trend: Y = -0.096022X + 14.729528
All Water Level Trend: Y = -0.089564X + 13.201145

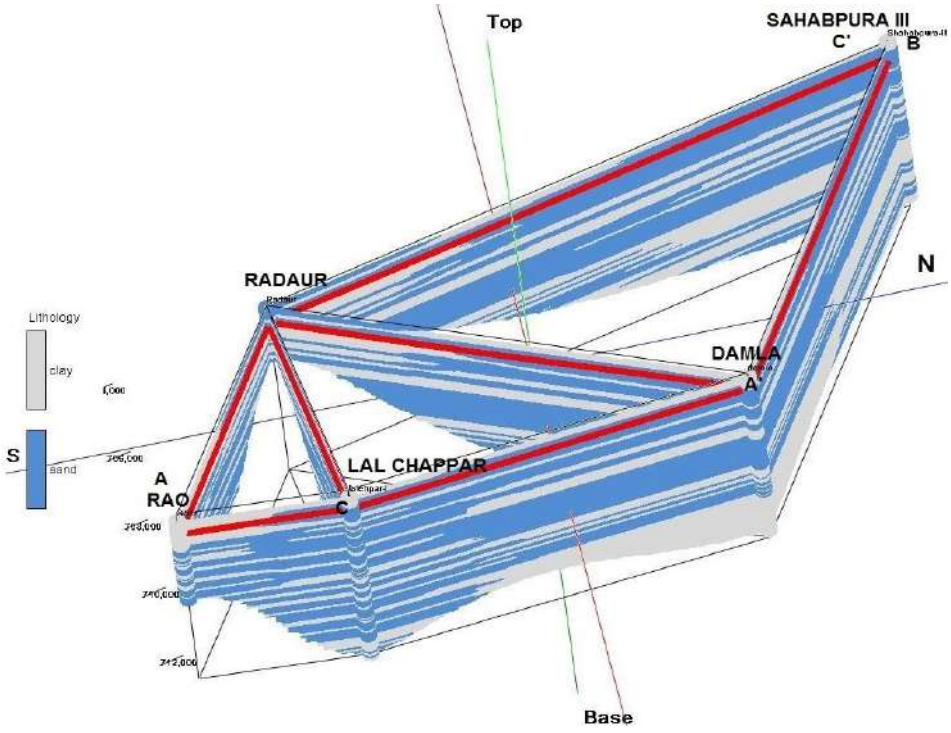

Hydrograph
Site Name : Radaur S State : Haryana District : YAMUNANAGAR Tahsil : JAGADHRI Block : RADAUR Village : Radaur S
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.019106X + 9.949468
Post Monsoon Water Level Trend: Y = -0.027793X + 8.641983
All Water Level Trend: Y = -0.025053X + 8.409512

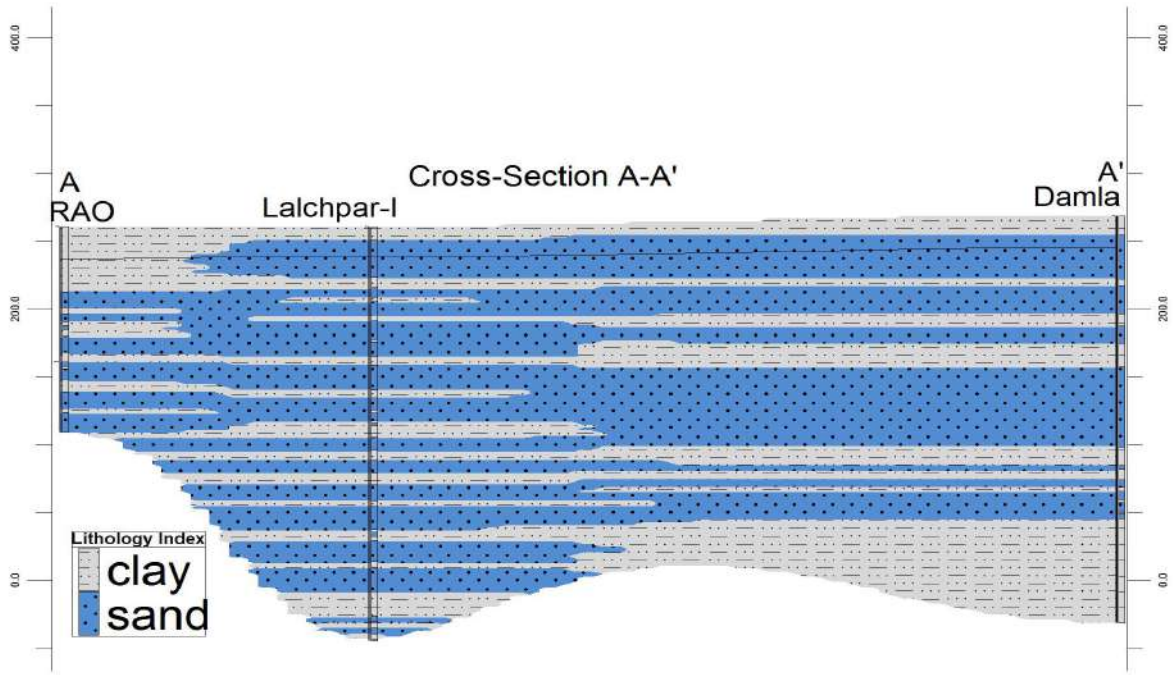
Aquifer comprises of freshwater only and the main aquifer formation is sand. The non-aquifer material comprise of clay.

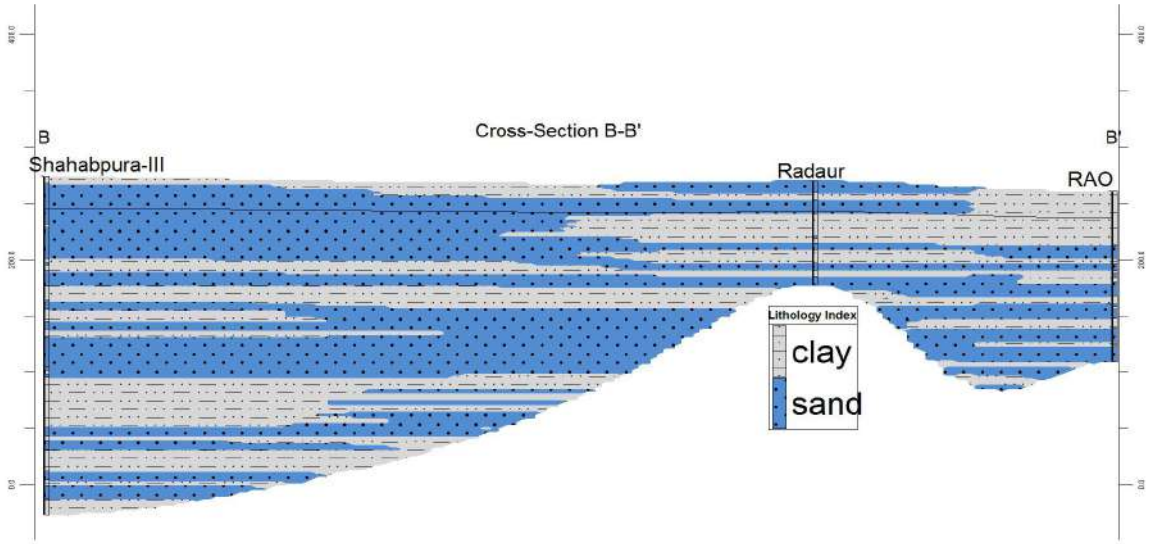
3D Lithology model

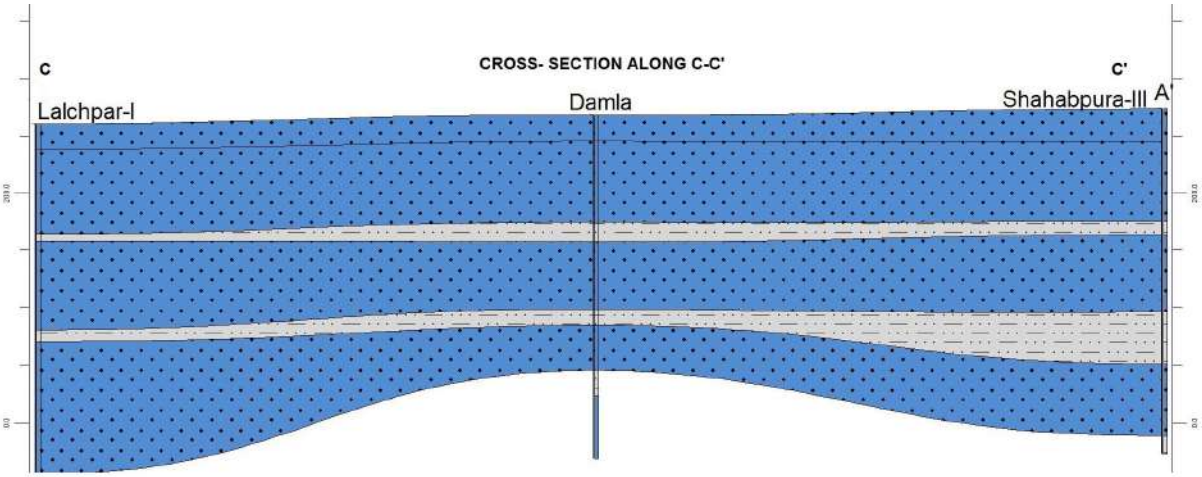


3D Lithology Fence

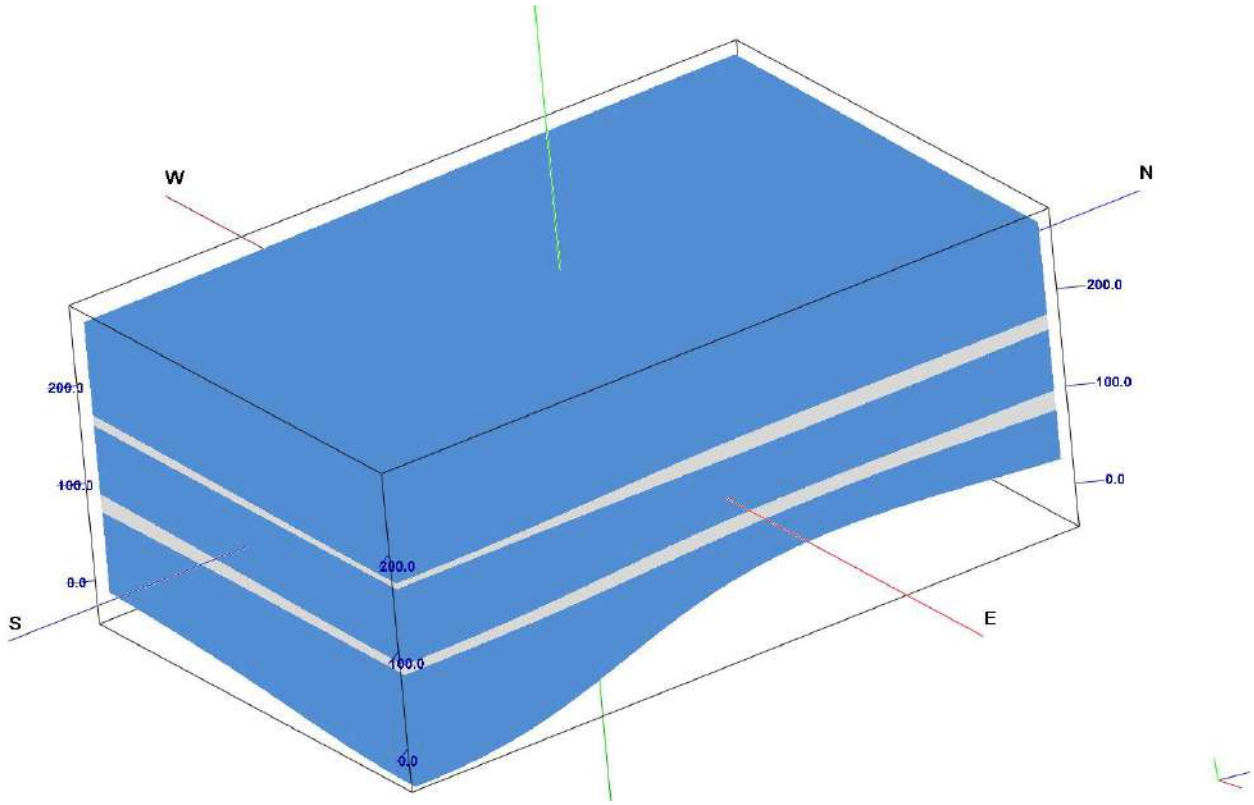



Cross-Section A-A'
A
RAO
Lalchpar-I
A'
Damla
400.0
200.0
0.0
Lithology Index
clay
sand


Cross-Section B-B'
B
Shahabpura-III
Radaur
B'
RAO
Lithology Index
clay
sand



3-D AQUIFER MAP



Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm)	Dynamic Aquifer I	89.41
	In-storage Aquifer I	2152.05
	Dynamic Aquifer II	220.66
	In-storage Aquifer II	1215.26
	Dynamic Aquifer III	-
	In-storage Aquifer III	-
	Total	3677
Ground Water Extraction (in mcm)	Irrigation	135.86
	Domestic & Industrial	13.50
Future Demand for domestic & Industrial sector (2025) (in mcm)		13.50
Chemical Quality of ground water		Potable for drinking and irrigation
Other issues		Deeper water level (>5m) & declining water level trend (2-89cm/yr)

Ground Water Resource Enhancement

Aquifer wise space available for recharge and proposed interventions	Volume of unsaturated zone up to the average depth to water level (19.29m) is 488mcm.
Other interventions proposed	-

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 9.35 mcm volume of water wastage
Change in cropping pattern	Proposed change in cropping pattern from Paddy to maize/soyabean. 35% of the total area needs to change the crop from paddy to maize Anticipated volume of water to be saved by maize is 47.34 mcm
Alternate water sources	Tanks, ponds and canals
Regulation and Control	-
Other interventions proposed, if any	-

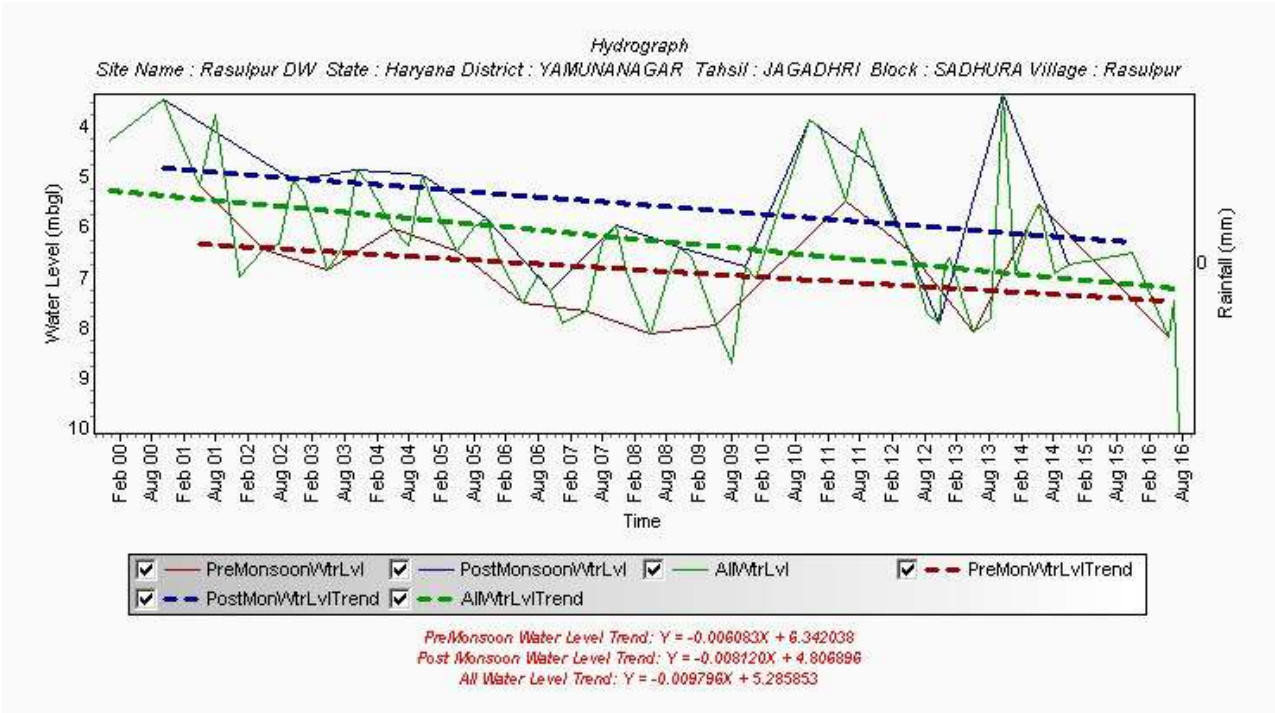
v. SADHAURA BLOCK (152.70 sq. km.)

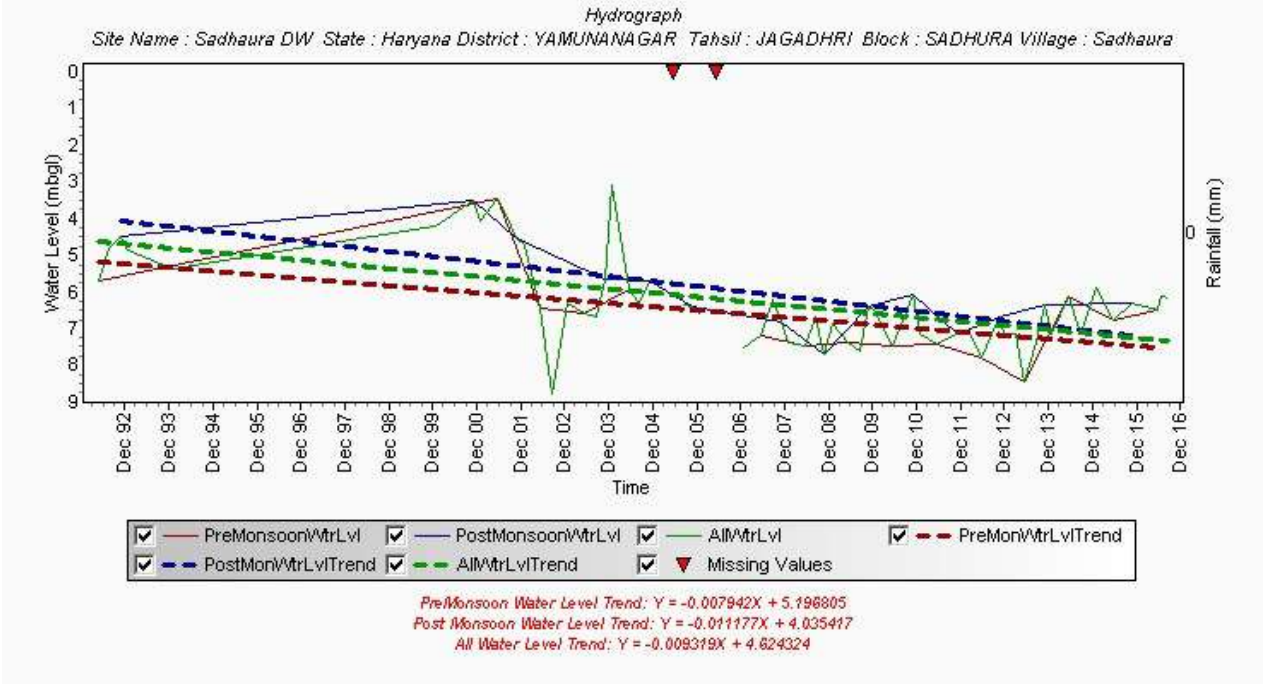
Population (2011)	Rural-69029 Urban-0 Total-69029
Rainfall	Monsoon -1085.40 mm Non Monsoon-190.60 mm
Average Annual Rainfall	1276 mm
Agriculture and Irrigation	Major Crops- Rice, Wheat Other crops-Sugarcane, Potatoes, Pulses, Oilseeds Net Area Sown-103 sqkm Total Irrigated Area-71.11 sqkm
Water Bodies	64

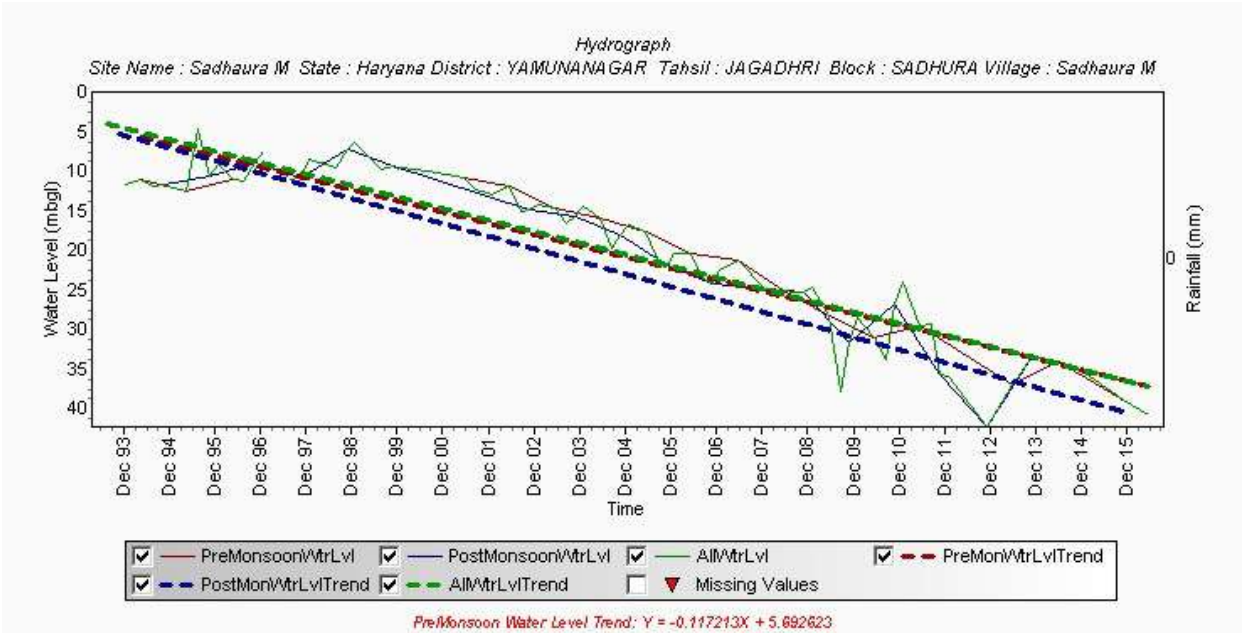
Ground Water Resource Availability: Ground Water Resources available in the different group of aquifers. Only two aquifers have been identified up to 300m depth of which Aquifer I is having a thickness of 140 m and Aquifer II is of 100 m. Block is categorized as Over-Exploited as per 2013 assessment.

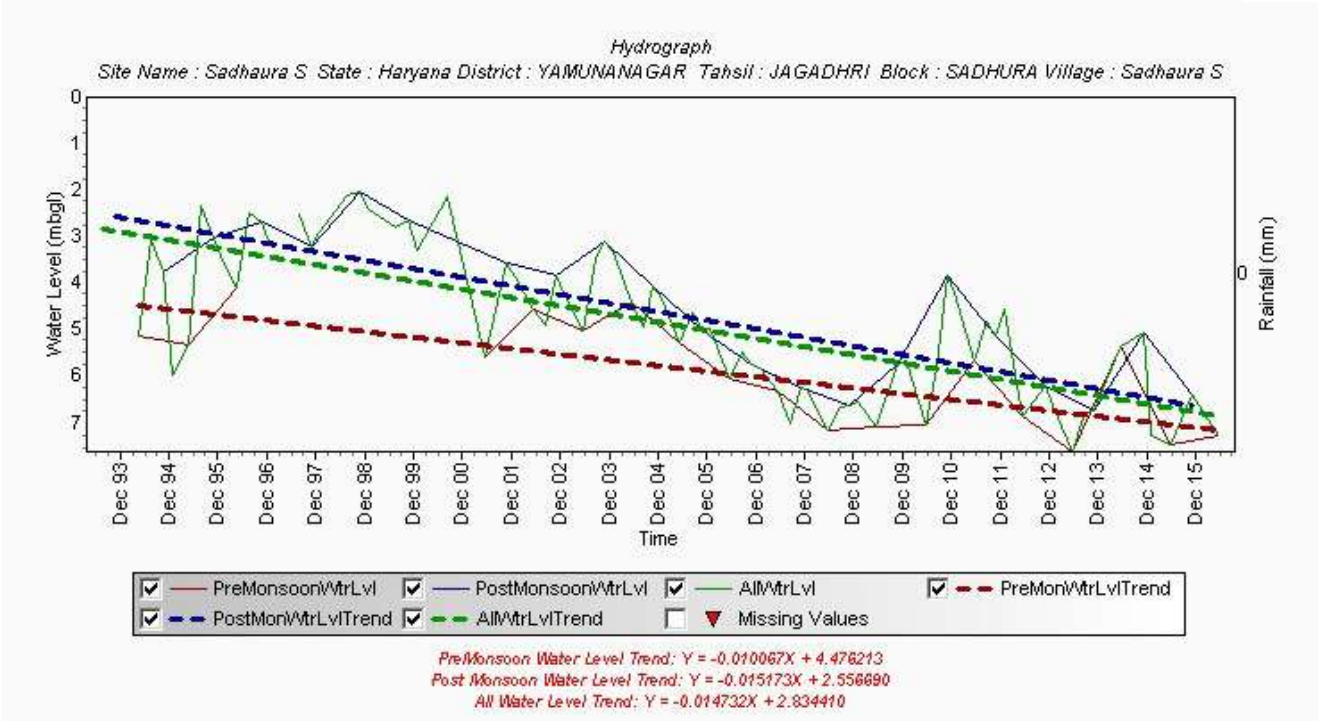
Ground water Extraction: Information regarding the abstraction from Aquifer II is not available, but there are drinking water supply tapping combined aquifer and separate aquifer could not be assessed separately.

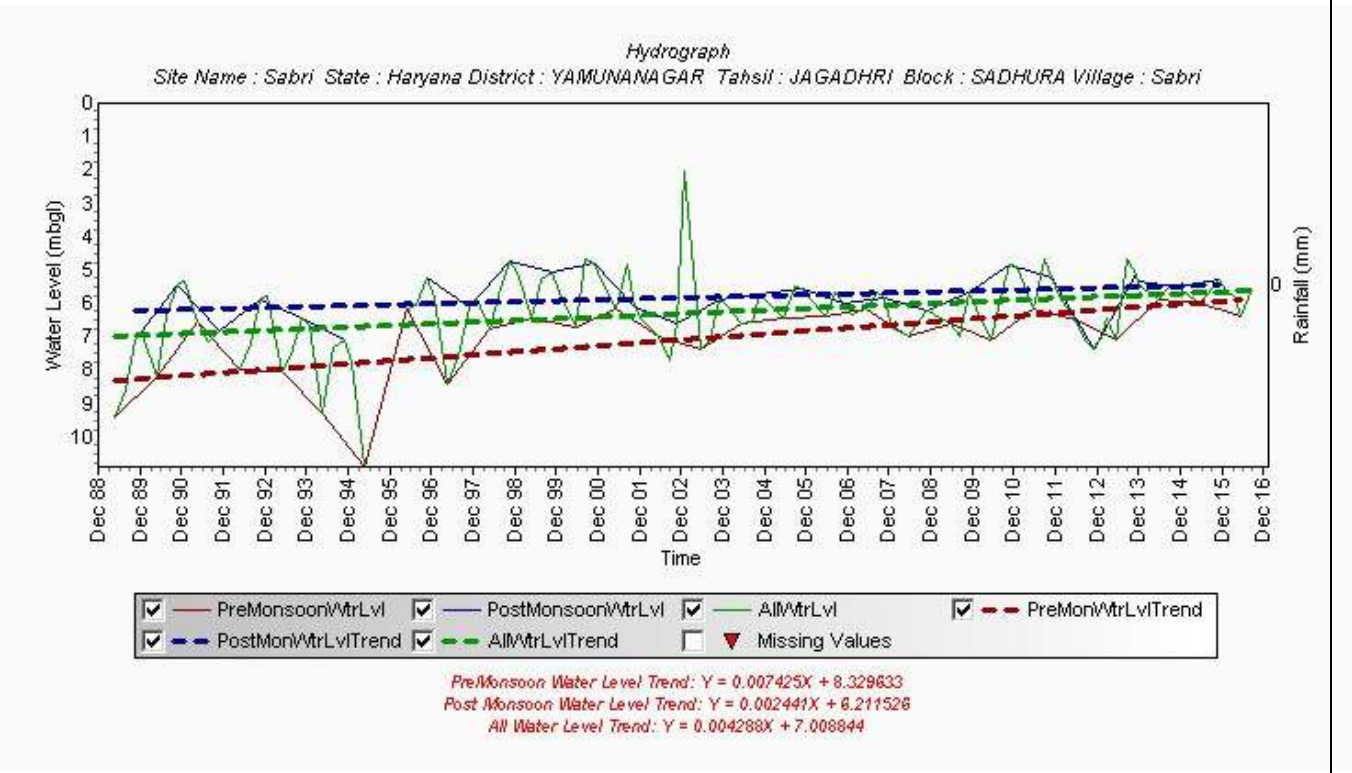
Water level Behavior(2015):Pre Monsoon-7.54 m bgl & Post Monsoon-~5.95 mbgl


Hydrograph
Site Name : Rasulpur DW State : Haryana District : YAMUNANAGAR Tahsil : JAGADHRI Block : SADHURA Village : Rasulpur
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.006083X + 6.342038
Post Monsoon Water Level Trend: Y = -0.008120X + 4.806896
All Water Level Trend: Y = -0.009796X + 5.285853


Hydrograph
Site Name : Sadhaura DW State : Haryana District : YAMUNANAGAR Tahsil : JAGADHRI Block : SADHURA Village : Sadhaura
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = -0.007942X + 5.196805
Post Monsoon Water Level Trend: Y = -0.011177X + 4.035417
All Water Level Trend: Y = -0.009319X + 4.624324


Hydrograph
Site Name : Sadhaura M State : Haryana District : YAMUNANAGAR Tahsil : JAGADHRI Block : SADHURA Village : Sadhaura M
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = -0.117213X + 5.692623
Post Monsoon Water Level Trend: Y = -0.130819X + 5.299601
All Water Level Trend: Y = -0.121238X + 4.102805


Hydrograph
Site Name : Sadhaura S State : Haryana District : YAMUNANAGAR Tahsil : JAGADHRI Block : SADHURA Village : Sadhaura S
Water Level (mbgl)
Rainfall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
Missing Values
PreMonsoon Water Level Trend: Y = -0.010067X + 4.476213
Post Monsoon Water Level Trend: Y = -0.015173X + 2.556690
All Water Level Trend: Y = -0.014732X + 2.834410

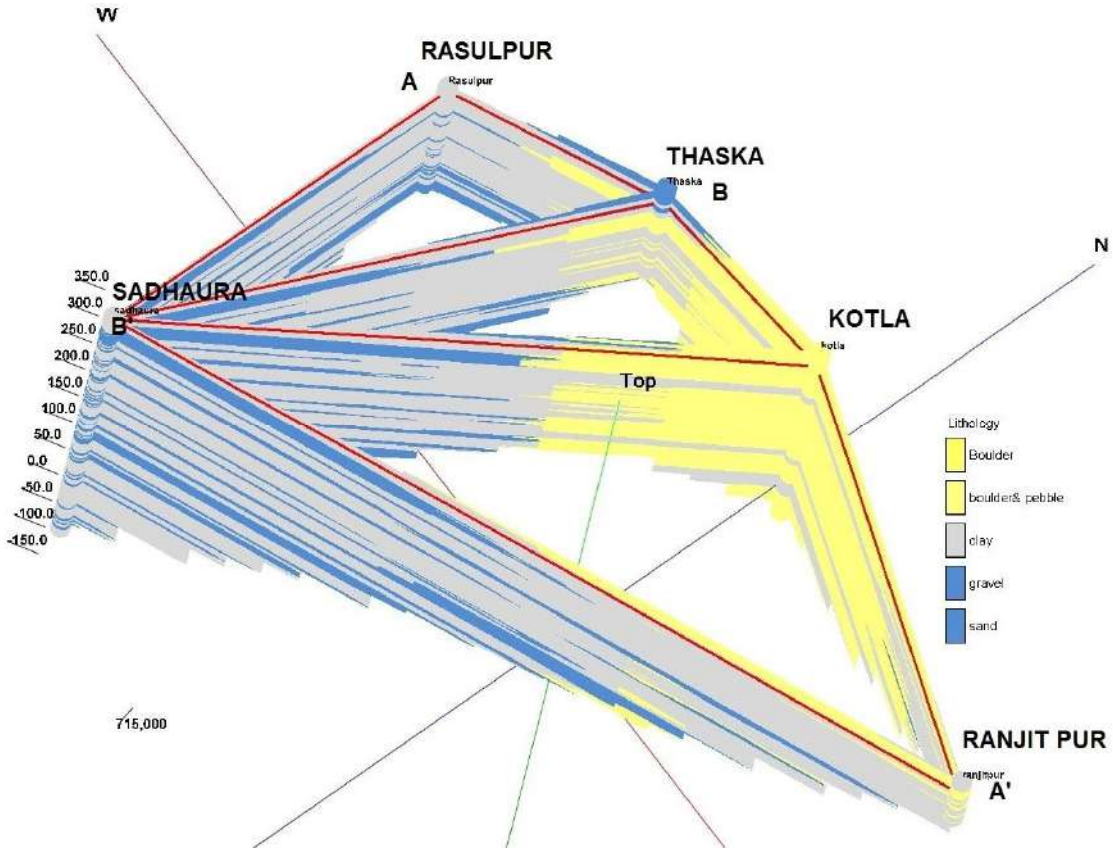


Aquifer Disposition: Multiple Aquifer System (3 Aquifer System)

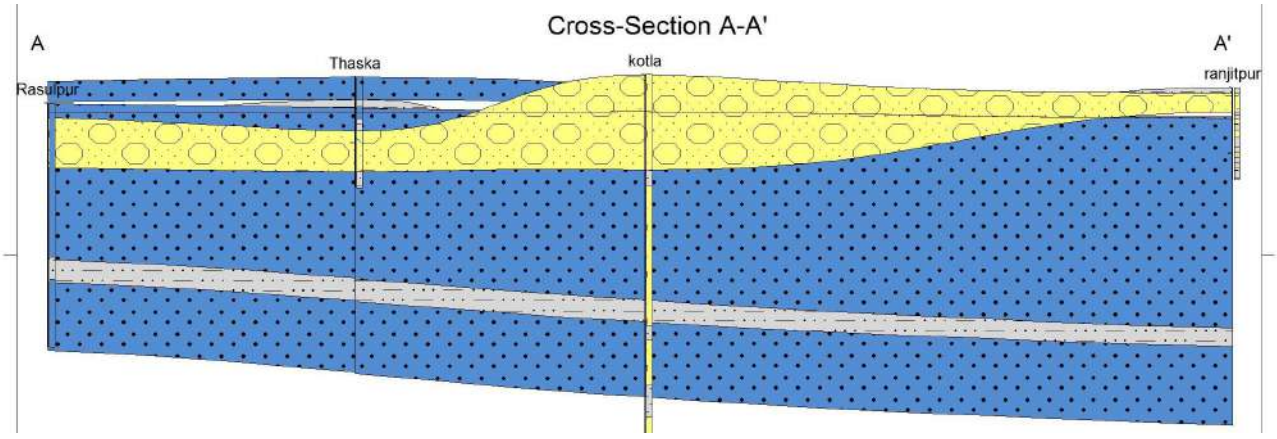
Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
Aq-I (0-140m)	Quaternary Alluvial deposits	Unconfined	49	2200	12	NA
Aq-II (187-263m)		Semi confined to Confined	35	1163	-	$5.2*x10^{-5}$
Aq-III (284-300)		Semi confined to Confined	16	1745	-	$3.2x10^{-4}$

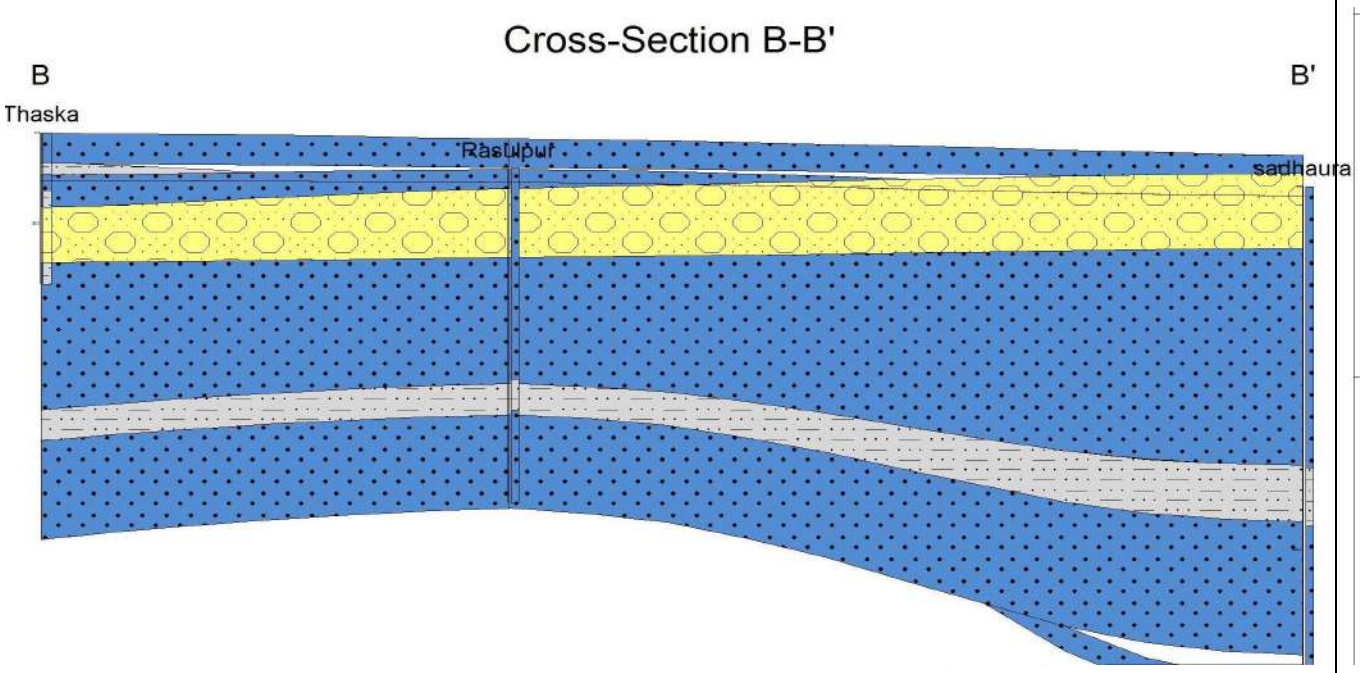
Aquifer comprises of freshwater only and the main aquifer formation is sand

The non-aquifer material comprise of clay.



3D Lithology Fence





Ground Water Resources (in mcm)	Dynamic Aquifer I	39.43
	In-storage Aquifer I	503.92
	Dynamic Aquifer II	99.83
	In-storage Aquifer II	359.60
	Dynamic Aquifer III	163.70
	In-storage Aquifer III	164.39
	Total	1331.00
Ground Water Extraction (in mcm)	Irrigation	30.82
	Domestic & Industrial	9.30
Future Demand for domestic & Industrial sector (2025) (in mcm)		1.17
Chemical Quality of ground water		Potable for drinking and irrigation
Other issues		Deeper water level (>5m) & declining water level trend (up to 112 cm/yr)

Ground Water Resource Enhancement

Aquifer wise space available for recharge and proposed interventions	Volume of unsaturated zone upto the average depth to water level (6.95 m) is 36.64 mcm.
Other interventions proposed	-

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 2.12 mcm volume of water wastage
Change in cropping pattern	No Proposed change in cropping pattern from Paddy to maize/soyabean.
Alternate water sources	Tanks, ponds and canals
Regulation and Control	-
Other interventions proposed, if any	-

vi. MUSTAFABAD BLOCK (206.82 sq. km.)

Population (2011)	Rural-107899 Urban-0 Total-107899
Rainfall	Monsoon -778.40 mm Non Monsoon-85.40 mm
Average Annual Rainfall	863.80 mm
Agriculture and Irrigation	Major Crops- Rice, Wheat Other crops-Sugarcane, Potatoes, Pulses, Oilseeds Net Area Sown-176.53 sq km Total Irrigated Area-176.53 sq km
Water Bodies	60

Ground Water Resource Availability: Ground Water Resources available in the different group of aquifers. Only two aquifers have been identified up to 300m depth of which Aquifer I is having a thickness of 170 m , Aquifer II is of 39 m & Aquifer III of 55 m thickness . Block is categorized as Over-Exploited as per 2013 assessment.

Ground water Extraction: Information regarding the abstraction from Aquifer II is not available, but there are drinking water supply tapping combined aquifer and separate aquifer could not be assessed separately.

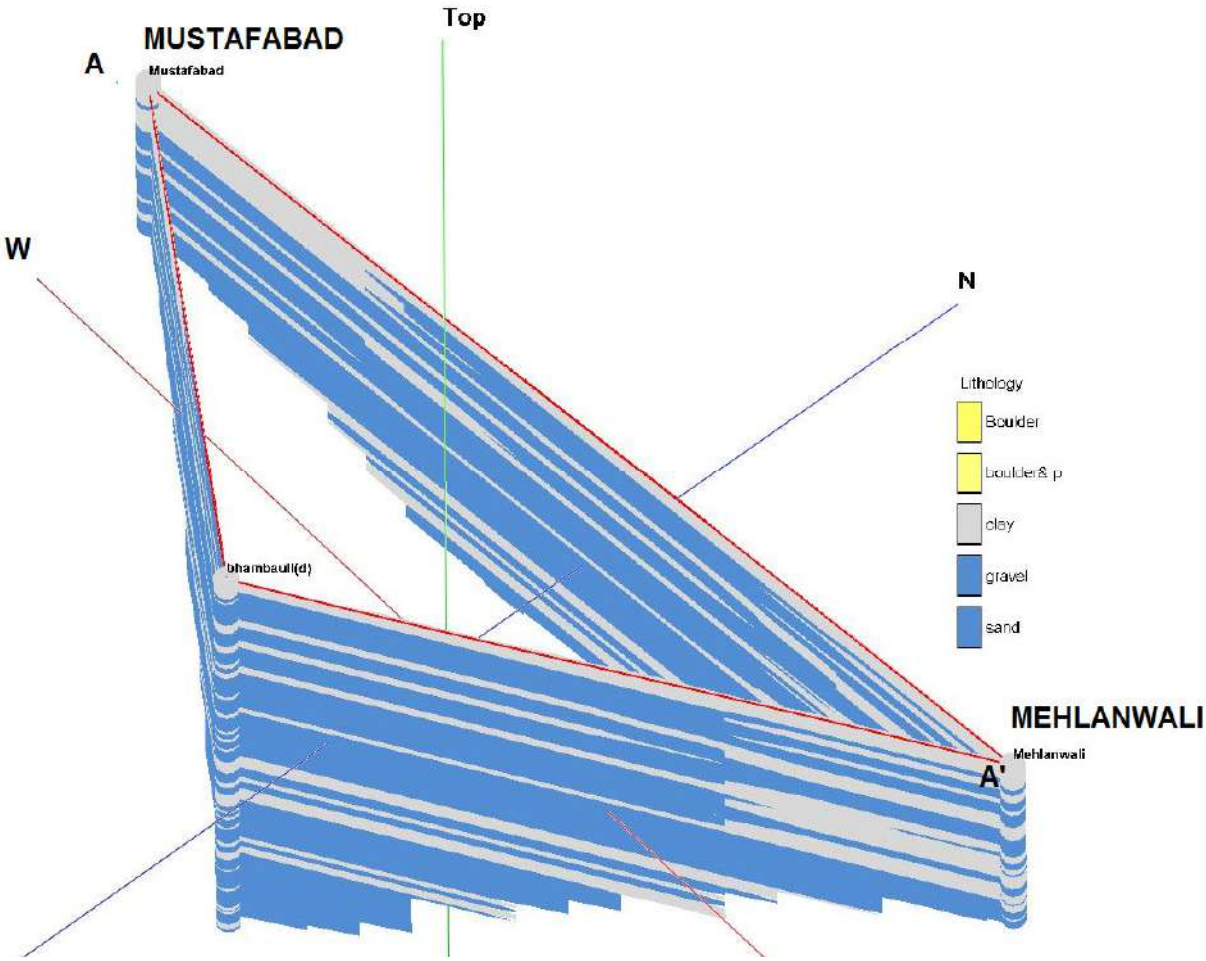
Water level Behavior(2015):Pre Monsoon-11.34 m bgl & Post Monsoon-~9.95 mbgl

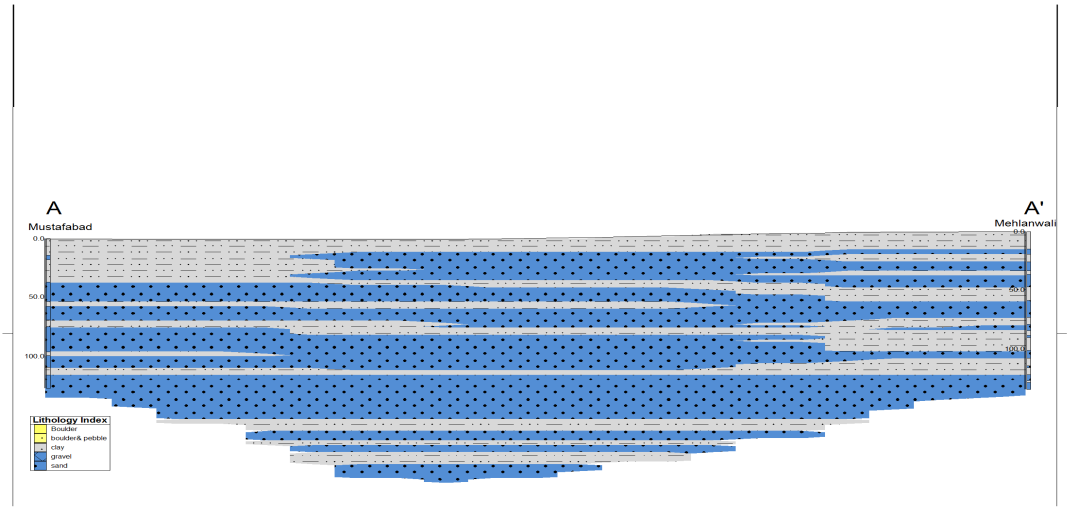
Aquifer Disposition: Multiple Aquifer System (3 Aquifer System)

Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
Aq-I (0-170m)	Alluvial Quaternary deposits	Unconfined	43.53	2200	12	NA
Aq-II (184-223m)		Semi confined to Confined	30	1163	-	$5.2*x10^{-5}$
Aq-III (245-300)		Semi confined to Confined	46	1745	-	$3.2x10^{-4}$

Aquifer comprises of freshwater only and the main aquifer formation is sand. The non-aquifer material comprise of clay.

3-D Lithology Fence





CROSS-SECTION ALONG A-A'

Water Resources (in mcm)	Dynamic Aquifer I	73.58
	In-storage Aquifer I	648.21
	Dynamic Aquifer II	141.90
	In-storage Aquifer II	446.73
	Dynamic Aquifer III	200.87
	In-storage Aquifer III	684.99
	Total	2196.00
Ground Water Extraction (in mcm)	Irrigation	97.47
	Domestic & Industrial	12.30
Future Demand for domestic & Industrial sector (2025) (in mcm)		12.30
Chemical Quality of ground water		Potable for drinking and irrigation
Other issues		Deeper water level (>5m) & declining water level trend (up to 116.9cm/yr)

Ground Water Resource Enhancement

Aquifer wise space available for recharge and proposed interventions	Volume of unsaturated zone upto the average depth to water level (10.04 m) is 124 mcm.

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 6.71 mcm volume of water wastage
Change in cropping pattern	Proposed change in cropping pattern from Paddy to maize/soyabean will save 26.84 mcm volume of water.
Alternate water sources	Tanks, ponds and canals
Regulation and Control	-

9. CONCLUSION

- The area of Yamunanagar district belongs to Upper Yamuna and Ghaggar Basins and occupied by geological formations of Quaternary age.
- The major aquifer system of the Yamunanagar district is alluvial deposit having older and younger alluvium which mainly comprised of sand, silt and clay.
- Three aquifer groups have been identified in the district up to a depth of 300 meters. Aquifer- I ranges from ground level to 180 m bgl with thickness ranges from 95 meters to 180 meters. Aquifer –II ranges from 178 m bgl to 300 m bgl with thickness ranges from 16 to 110 meters. Aquifer –III ranges from 245 m bgl to 300 m bgl with thickness ranges from 16 to 55 meters.
- Electrical Conductivity of Aquifer II & Aquifer –III is better than aquifer-I. Aquifer I shows the presence of Mn, Pb & Zn at few places where as in Aquifer-III Mn is reported at one place. In Aquifer I, II & II, Iron is present above permissible limits, whereas Arsenic is within limits.
- The aquifer –I & II is free from any Microbiological and Pesticide contamination and BOD/COD is also <1.
- Isotope study reveals that ground water from aquifer-I and aquifer-II is derived from local precipitation and is in dynamic condition, whereas ground water from aquifer-III is old and depleted indication high altitude recharge and long residence time.
- As per dynamic ground water resources as on March 2013, all six blocks of the district under over exploited category. Stage of ground water development of the blocks ranges from 101% (Bilaspur block) 171% (Jagadhari block). Over all stage of ground water development of the district is 135%.
- Dynamic & In- storage ground water resources has also been carried out to a depth of 300 meters for all aquifer groups.
- Ground water resources (Dynamic + In- storage) of Aquifer –I is 9274 MCM, Fresh In- storage ground water resources of Aquifer- II is 5421 MCM, whereas Fresh In- storage ground water resources of Aquifer- III is 1049 MCM. Total ground water resources upto 300 m depth in the district is 15909 MCM (15.9

bcm).

- Based on Dynamic ground water resources (as on March 2013) and considering the high ground water abstraction (1021 mcm) and overdraft (1416 mcm), long-term sustainability remains a serious issue owing to which it is suggested to change of the paddy cultivation to Maize/ Soyabean and Pulses in Chachrauli, Jagadhari, Mustafabad, Radaur blocks of Yamunanagar district.
- Other techniques of water saving and modern irrigation technology to be enforced to maximize the per drop of water use in the district.
- Ground water regulation for protecting the Aquifer I from rampant irrigation by the paddy crops in all blocks of the district is needed.

Annexure-1

The Chemical details of the ground water samples collected from the NHS wells in district Yamunanagar

Sl.No.	Location	pH	EC in µS/cm at 25^0C	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	Ca	Mg	Na	K	SiO_2	T.H as CaCO3
				(----------mg/l----------												
1	Sadaura	8.88	763	70	167	83	12	19	0.54	BDL	29	35	85	4.2	18	214
2	Rasulpur	7.05	953	Nil	214	129	129	2.0	0.19	BDL	78	17	105	5.7	17	265
3	Sabri	Leaked														
4	Bilaspur	7.25	795	Nil	131	76	82	**135**	0.24	BDL	33	22	110	0.8	20	174
5	Khijrabad	7.45	355	Nil	167	6.9	58	18	0.24	BDL	25	27	22	2.6	20	174
6	Choli	8.55	300	23	131	14	8	6.0	0.31	BDL	35	5	32	5.0	22	107
7	Mustafabad	8.40	1177	35	286	132	120	2.1	0.53	BDL	18	26	205	10	11	153
8	Shadipur	8.48	325	82	12	6.9	20	BDL	0.14	BDL	25	14	25	5.6	20	117
9	Yamunanagar	8.50	323	12	131	14	25	8.7	0.34	BDL	22	15	28	4.4	18	117
10	Bamboli	8.55	536	23	173	45	42	BDL	0.30	0.01	20	32	45	8.9	23	184
11	Dhaurang	8.57	321	41	101	24	BDL	BDL	0.36	BDL	29	12	28	4.5	24	122
12	Chachhrauli	8.53	403	23	167	14	15	1.4	0.43	0.01	29	17	30	6.7	19	143
13	Naggal	8.35	689	23	178	28	118	5.0	0.18	BDL	41	22	60	25	18	194
14	Radaur	8.53	343	18	89	38	32	5.0	0.48	BDL	29	15	28	4.6	25	133

Annexure-2

Concentration of Arsenic and Iron in Ground Water samples of district Yamunanagar

S. No	Block	Location	As in mg/l	Fe in mg/l
1	Sadaura	Sadaura	0.001	0.0827
2	Sadaura	Rasulpur	0.005	**9.5695**
3	Sadaura	Sabri	0.002	0.3724
4	Jagadri	Bilaspur	BDL	0.4106
5	Chhachroli	Khijrabad	0.001	0.1503
6	Chhachroli	Choli	BDL	**1.5519**
7	Jagadri	Mustafabad	BDL	**2.3837**
8	Jagadri	Shadipur	0.001	0.1694
9	Jagadri	Yamunanagar	0.002	0.0453
10	Jagadri	Bamboli	0.002	BDL
11	Jagadri	Dhaurang	0.002	BDL
12	Chhachroli	Chachhrauli	0.001	**3.5905**
13	Chhachroli	Naggal	0.004	**1.8574**
14	Radaur	Radaur	0.001	0.0146

Annexure-3

The Chemical details of the ground water samples collected from the key wells along Palaeo-channel under NAQUIM

Sr. No	LOCATION	pH	EC in µS/cm at 25^0C	$HCO3^*$	Cl	SO_4^*	NO_3	F	$Po4^*$	Ca	Mg	Na*	K*	SiO_2^*	TH as $CaCO_3$
1	Bada Marwa	7.09	698	445	5.3	6	22	0.05	0.012	105	11	41	1	23	309
2	Bilaspur	6.96	1208	488	64	50	**162.0**	0.22	0.012	151	23	95	1.6	23	471
3	Adi Badri	7.58	708	439	7.1	36	0.0	0.17	0.012	101	25	24	2.6	17	356
4	Barudhara	7.08	5432	311	1659	176	1.2	1.25	0	220	17	1030	6.6	13	617
5	Leda Khadar	6.88	973	586	39	22	3.5	0.13	0	136	33	33	11	22	476
6	Berthala	7.39	526	360	8.9	0	0.0	0.27	0.016	61	20	32	3.6	16	235
7	Mand Khaela	6.76	1120	604	71	29	15.0	0.13	0.042	124	46	64	5.3	24	497
8	Chaneti	6.82	908	464	21	68	63.0	0.27	0	105	42	46	1.5	25	434
9	BILASPUR W/NO-1	8.35	510	5.9	338	14	22	0	0.114	64	21	38	1.5	20	247
10	RANIPUR	8.22	510	0	344	18	7	3.5	0.051	82	11	30	1.4	18	253
11	KATHGARH	8.17	540	0	272	47	0	9.4	0.044	70	3.8	47	2.1	18	191

Annexure-4

Test Report of Chemical Analysis of Ground water samples collected around Muglawali excavation site, Yamunanagar

Sr. No	LOCATION	pH	EC in µS/cm at 25^0 C	CO_3	HCO_3	Cl	SO_4	NO_3	F	Ca	Mg	Na	K	TH as $CaCO_3$
				(←---------- mg/l----------→)										
1	Mugalwali-1, YN	7.50	498	0	282	14	5	20	0.53	69	17	14	2	245
2	Mugalwali-STW 2,	7.45	578	0	376	14	0	0.2	0.16	106	7	14	2.2	296
3	Mugalwali-3,TW	7.70	440	0	282	14	0	0.28	0.16	61	12	22	1.8	204
4	Safilpur –HP	7.22	695	0	443	14	0	22	0.34	131	10	15	0.9	367
5	Safilpur-TW	7.5	468	0	268	6.9	0	20	0.25	74	10	13	0.7	225
6	Rulla Heri –HP	7.75	345	0	201	14	0	4.15	0.22	53	5	17	1.1	153
7	Ranjeetpur-HP	7.15	585	0	349	14	0	19	0.19	102	7	16	1.2	286
8	Adibadri Kund, YN	7.45	680	0	470	14	0	0.58	0.25	98	27	22	3.4	357
9	Kathgarh(HP), YN	7.42	510	0	282	24	0	14	0.25	74	5	33	2.7	204

Annexure-5

Results of sample collected along Muglawali excavation site for trace elements analysis from Districts Yamunanagar

S.No.	Location	Cd	Cr	Cu	Mn	Pb	Zn	Fe
		←----------Concentration mg/l----------→						
1	Mugalwali-1, YN	nd	ND	nd	0.172	nd	0.027	0.74
2	Mugalwali-STW 2,	nd	ND	nd	0.95	0.016	0.033	**2.21**
3	Mugalwali-3,TW	nd	ND	nd	0.016	nd	0.048	0.05
4	Safilpur –HP	nd	ND	nd	0.018	nd	0.222	**2.85**
5	Safilpur-TW	nd	ND	nd	nd	0.01	0.029	0.04
6	Rulla Heri –HP	nd	ND	nd	0.556	0.009	0.522	**4.70**
7	Ranjeetpur-HP	nd	ND	nd	0.03	nd	0.152	**1.48**
	Adibadri Kund, YN							
8		nd	ND	nd	0.03	0.009	0.187	0.06
9	Kathgarh(HP), YN	nd	ND	nd	0.12	0.06	0.11	0.37

Annexure-6

The Chemical details of the ground water samples collected from well fields in block Radaur under NAQUIM

Sr. No	LOCATION	pH	EC in µS/cm at 25^{0} C	CO_3^*	HCO_3^*	Cl	SO_4^*	NO_3	PO_4^*	Ca	Mg	Na*	K*	SiO_2^*	TH as $CaCO_3$
1	MASANA JATTA	7.88	755	0	531	18	2	0	0	82	29	59	6.1	19	325
2	SHAHABPURA-I	8.42	270	5.9	145	3.5	23	1.401	0	19	8.7	34	3.2	22	83
3	SHAHAPURA-II	8.5	365	8.9	254	11	0	0	0.051	43	13	32	5.1	20	158

Annexure -7

Pesticide Analysis of the ground water samples collected from Aquifer –I of the well field at Masana Jatta

S.No.	Parameters(micro gram/l)	Results
1	Alachlor	ND (0.1)
2	Atrazine	ND (0.1)
3	Aldrine / Dialdrin	ND (0.1)
4	Alpha HCH	ND (0.1)
5	Beta HCH	ND (0.1)
6	Butachlor	ND (0.1)
7	Chlorpyriphos	ND (0.1)
8	Delta HCH	ND (0.1)
9	2,4- Dichlorophenoxyacetic acid	ND (0.1)
10	DDT (o,p and p, DDE, p-Isomers of DDT)	ND (0.1)
11	Endosulfan	ND (0.1)
12	Ethion	ND (0.1)
13	Gamma-HCH (Lindane)	ND (0.1)
14	Isoproturon	ND (0.1)
15	Malathion	ND (0.1)
16	Methyl Parathion	ND (0.1)
17	Monocrotophos	ND (0.1)
18	Phorate	ND (0.1)

Above results confirms IS: 10500-2012 for drinking purpose

Annexure -8

Results of Bacretreological Analysis of Aquifer-I at Massana Jattan:

S.No.	Parameters(micro gram/l)	Results
1	Chemical Oxygen Demand	ND (1.0)
2	Bio-Chemical Oxygen Demand (3 days at 27^0C)	ND (1.0)
3	Aldrine / Dialdrin	ND (0.1)
4	*E.Coli*/100 ml	Absent
5	*Total Coliform Bacteria*/ 100 ml	Absent

Annexure -9

Ground water quality of individual Aquifer groups obtained from well field

Aquifers	Basic Analysis		Cd (mg/l)	Cu (mg/l)	Mn (mg/l)	Pb (mg/)	Zn (mg/l)	Fe(mg/l)
	EC µS/cm at 250C	Other Parameters						
Masana Jattan (Aquifer-I)	536	Within permissible limits	0.019	-	0.369	-	-	6.456
Shahabpura-II (Aquifer-II)	270	Within permissible limits	0.006	-	0.318	-	-	3.43
Shahabpura-III (Aquifer-III)	365	Within permissible limits	0.016	-	-	-	-	0.917

Annexure 10

Results of isotopic analysis of samples collected nearby areas of Paleaochannel in district Yamunanagar

Sr.No.	Location	Source & Depth	Parameters	Parameters	Date of Sampling	δ ^{18}O (‰)	δ D (‰)
5	Mugalwali-1, YN	Excavation pit (1.8 mts)	$^{3}_{1}H$ (500ML)	^{18}O & D_2 (60 ML)	05/08/2015	**-5.41**	**-37.96**
6	Mugalwali-2, YN	Shallow Well (6 mts)	$^{3}_{1}H$ (500ML)	^{18}O & D_2 (60 ML)	05/08/2015	**-7.38**	**-47.65**
7	Mugalwali-3, YN	TW (33 mts)	$^{3}_{1}H$ (500ML)	^{18}O & D_2 (60 ML)	05/08/2015	**-7.04**	**-42.99**
8	Adibadri Kund, YN	Kund (Surface)	$^{3}_{1}H$ (500ML)	^{18}O & D_2 (60 ML)	05/08/2015	**-6.68**	**-41.49**
9	Kathgarh(HP), YN	HandPump cum tube well (60 mts)	$^{3}_{1}H$ (500ML)	^{18}O & D_2 (60 ML)	05/08/2015	**-7.18**	**-45.34**

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SAMPLING OF SEEPAGE WATER FROM SARASWATI KUND, ADI BADRI, YAMUNANAGAR

SARASWATI PALAEO-CHANNEL AT MASANA-JATTAN, BLOCK RADAUR

SITE SELECTION OF WELL-FIELD AT SHAHABPURA

RIG DEPLOYMENT AT SHAHABPURA WELL FIELD SITE

VIEW OF PALAEO- CHANNEL DIGGING AT MUGHLAWALI, BLOCK BILASPUR

GROUND WATER SAMPLING FOR ISOTOPE STUDY WITH THE TEAM OF BARC AT VILLAGE RANIPUR

GROUND WATER SAMPLING FOR ISOTOPE STUDY WITH THE TEAM OF BARC AT WELL FIELD SITE