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

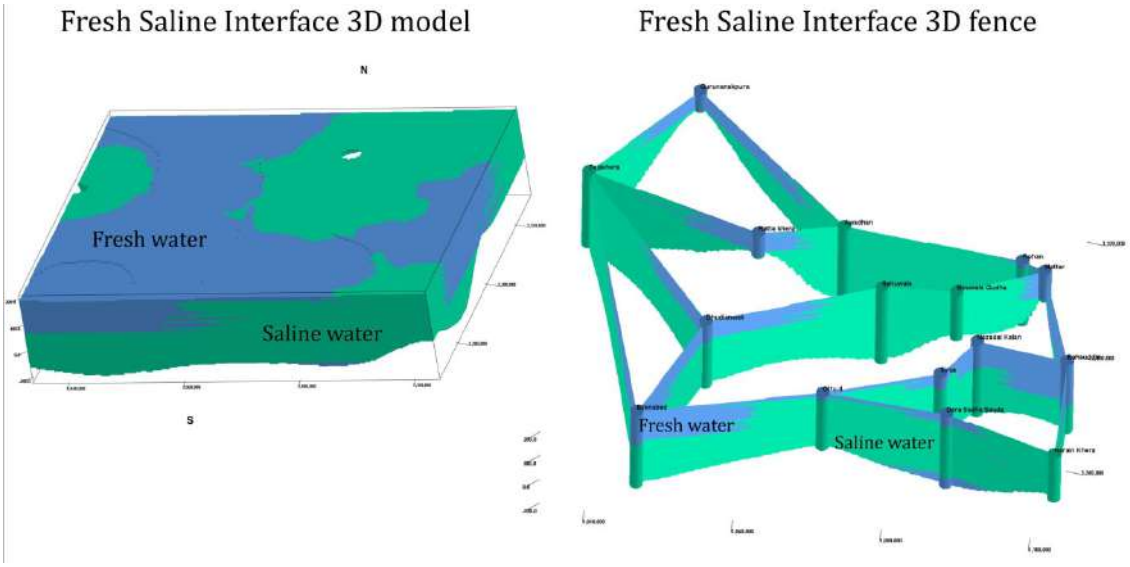
AQUIFER MAPPING AND MANAGEMENT PLAN

Sirsa District, Haryana

उत्तरी पश्चिम क्षेत्र, चंडीगढ़

North Western Region, Chandigarh

राष्ट्रीय जलभृत मानचित्रण एवम प्रबंधन योजना
सिरसा जिला
हरियाणा



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उत्तर पश्चिमी क्षेत्र, चंडीगढ़

जल संसाधन मंत्रालय, नदी विकास एवम् गंगा संरक्षण

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2017

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AQUIFER MAPPING AND MANAGEMENT PLAN

SIRSA DISTRICT (4276 Sq Km)

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1. INTRODUCTION

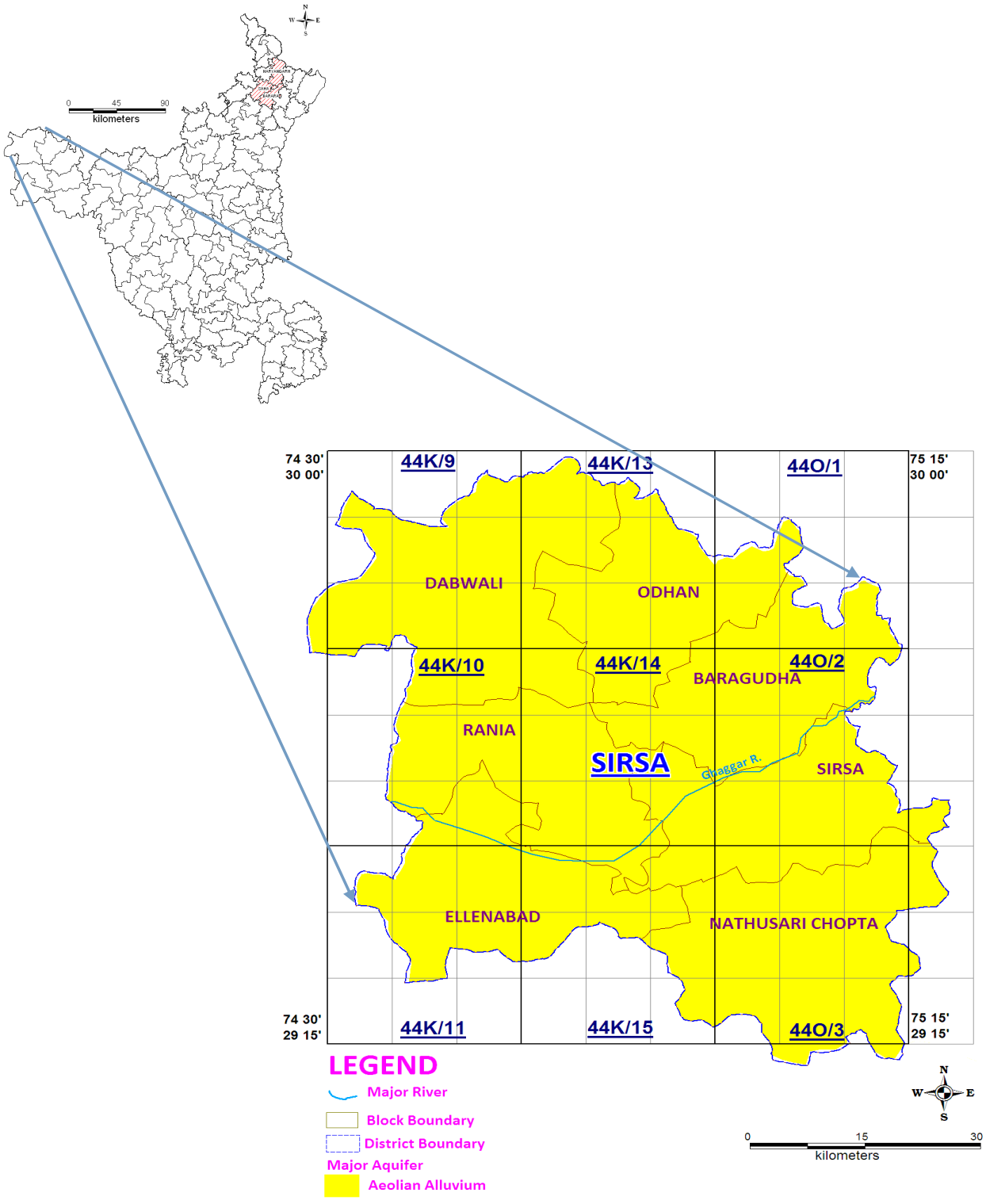
1.1 Introduction & Physiographic Setup

Sirsa is the north western district of Haryana State with a total geographical area of 4276 sq. km and is located between 29^{o} 13': 29^{o} 59' N latitudes and 74 ^{o} 30':75 ^{o} 7' E longitudes (Fig 1). It is surrounded by Muktsar, Bathinda & Mansa districts of Punjab in the north, Ganganagar & Hanumangarh districts of Rajasthan in West and South, Fatehabad and Hisar districts of Haryana in north east and south east respectively. The district is under control of Hisar division and administratively divided into seven development blocks namely Sirsa, Dabwali, Odhan, Baragudha, NathusariChoupta, Rania & Ellenabad. As per 2011 census the total population of the district is 1295114. Out of total population 683242 are males and 611872 are females. In Sirsa district rural population is settled in 321 villages and the rest of population is concentrated in five towns.

1.2 Hydrology & Drainage Network

The Ghaggar, an important seasonal river in the district is a major drainage of the area. It enters the district near village Ranga (Block- Baragudha) and flows through the central part of the district (covering Sirsa, Rania, Ellenabad and part of Baragudha blocks) in south westerly direction but about 1.5 km downstream of Ottu Weir (renamed as Ch. Devi Lal Weir), it takes a sharp turn towards west and flows in the westerly direction. The river leaves the district a little to the south west of village Kariwali (block- Ellenabad) and enters Rajasthan & finally lost in the arid belt (thardesert) of Rajasthan. The river is dammed at Ottu from where two prominent canals namely northern ghaggar and southern ghaggar takes off. The river sometimes gets flooded during monsoon and causes extensive damage to crops and property. The total length of Ghaggar River in the district is about 85 km. Besides, the area is also drained by the artificial drains, which are used during heavy rains by pumpage to the canals. In water-logged area, these artificial drains have also been proposed to combat with the water logging problems in the area.

Fig 1: Base Map of Sirsa District.



1.3 Agriculture & Cropping Patterns

Sirsa District is known as “the cotton belt of Haryana”. There are many type of industries in the district which are engaged in the manufacturing of various items such as Seed Processing, Wrapping Papers, Milk Chilling, Rice Shelling, Chemicals, Iron and Steel Fabrication, Agriculture Implements, Leather Good, Hard and Straw Board etc. The main resource of the district is agro products. There are many Medium and Large Units established with the pass of time procuring the services of local Micro & Small Scale Units.

1.4 Rainfall & Climate

The normal annual rainfall of the district is 318 mm which is unevenly distributed over the area 20 days and the normal monsoon rainfall is 253mm. The south west monsoon sets in from last week of June and withdraws in end of September, contributing about 80% of annual rainfall. July and August are the wettest months. Rest 20% rainfall is received during non-monsoon period in the wake of western disturbances and thunder storms. Generally rainfall in the district increases from southwest to northeast.

Temperature: - Mean Maximum: 41.1°C (May & June) & Mean Minimum: 5.1 °C (January)

The climate of Sirsa district is of tropical desert type arid and hot which is mainly dry hot summer and cold winter except during monsoon period season when moist air of oceanic origin penetrate 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 south- west monsoon which lasts up to September. The transition period from September to October forms the post-monsoon season. The winter season starts late in November and remains up to first wek of March.

1.5 Soils

The type of soil is an important factor for the growth of plants and crops in any area. The soil system has various criteria to classify the soils of a region such as geology, humidity, rainfall pattern, soil texture, soil salinity etc. The district has two types of soils viz Sierozem and Desert soils. The sierozem soils are found in major parts of the district and

desert soils are comparatively found in smaller part of the district especially in southern part of the district. Sierozem Soil are found in the areas where the normal annual rainfall varies from 300 to 500 mm. These soils vary from sandy loam to loamy sands in texture and are marginally fertile. Degree of salinity and alkali hazards is highly variable, though salinity is majorhazaed. These soils occur mainly in northern parts of the district i.e. Odhan, Baragudha & Sirsa blocks and parts of Dabwali, Nathusari Choupta& Rania blocks. Desert Soil are generally found in the areas where the annual rainfall is less than 300 mm. These soils are sandy and extensively cover southern parts of the district vizEllenabad block and parts of Dabwali, Rania & NathusariChoupta blocks. According to the classifications followed by Soil Testing & Research Laboratory, Sirsa, the soils of the district are sandy to sandy loam in texture.

1.6 Geomorphology

Physiographically, the district is characterised by three distinct features i.e. Upland plain, alluvial bed (flood plain) of river Ghaggar and Sand dune clusters. The area as a whole is almost flat with a gentle slope towards south west direction. The district is mainly drained by the river Ghaggar and some artificial drains.

1.7 Topography

The topography values ranges between 190 to 210m amsl and has been plotted to prepare the elevation contour map (fig 2).

1.8 Land Use and Land Cover

Land use and and cover of the study area are prepared based on the visual interpretation of satellite data and toposheet and is shown in fig 3 (Source: IJSETR,Jan 2015). The main classes are agriculture land, forest land, water land and surface water bodies. The agriculture land, classified in the study area is being done all along the drainage course. The major portion of Land is covered under Agriculture. The area covered under different land use pattern is given in table 1.

Table 1: Area covered under different land use pattern.

Land use	Area in Sq. km.
Built up	102.24
Agriculture	4019.92
Plantations	41.37
Wasteland	81.61
Water Bodies	23.06
Total	4268.20

Source: (IJSETR,Jan 2015)

Fig 2: Elevation Contour Map – Sirsa district

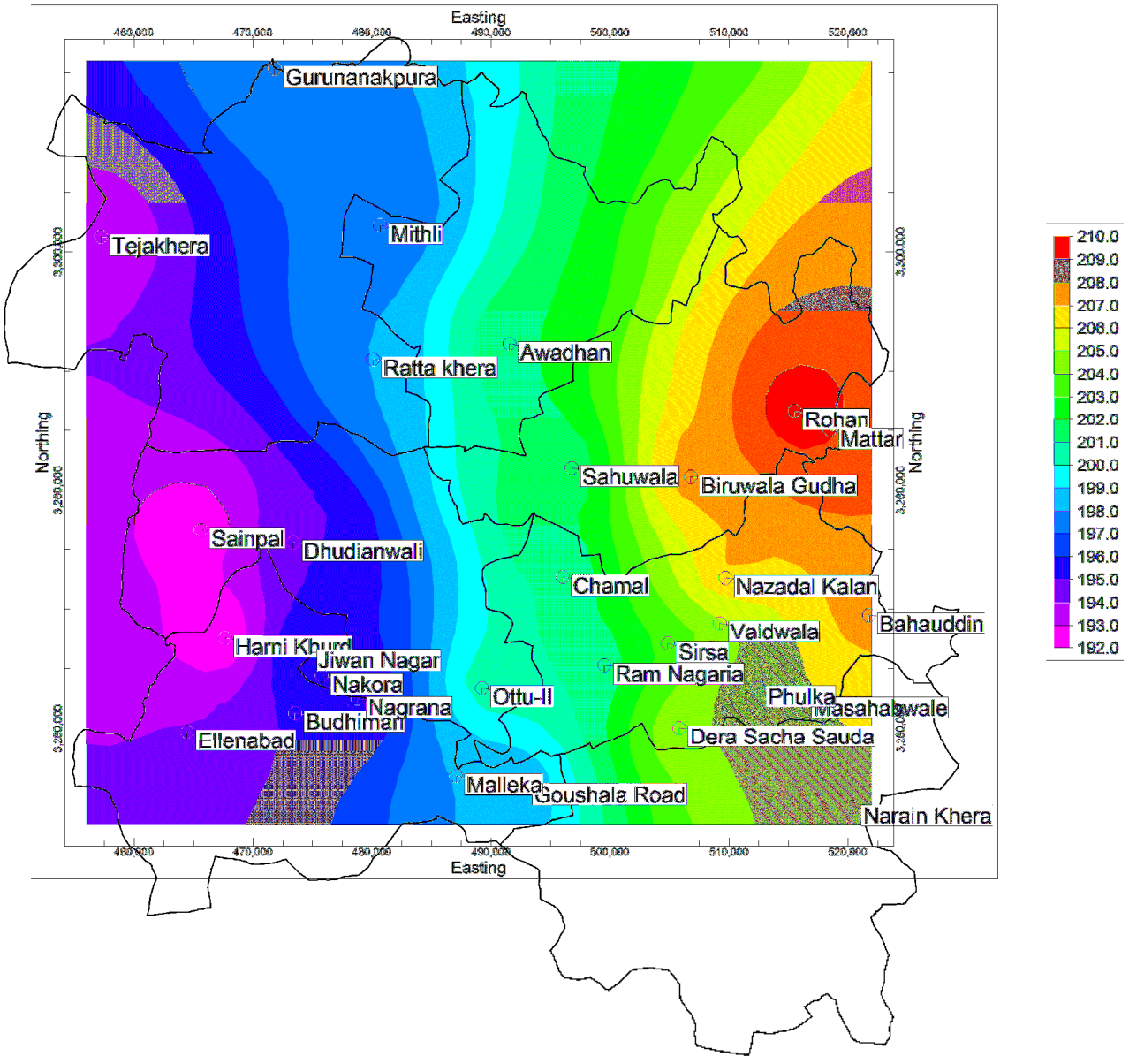
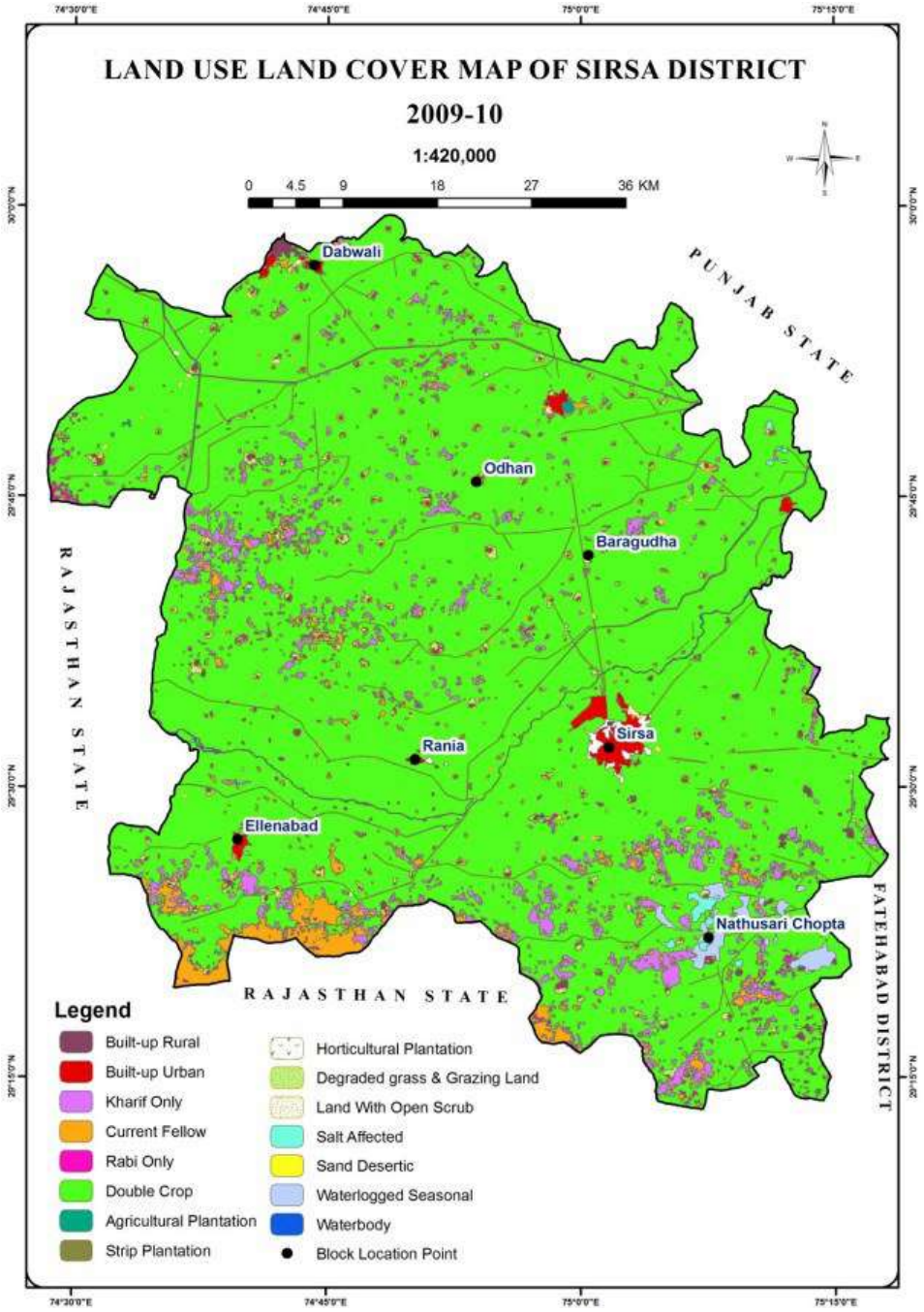


Fig 3: Land Use-Land Cover Map of Sirsa District



Source: (IJSETR,Jan 2015)

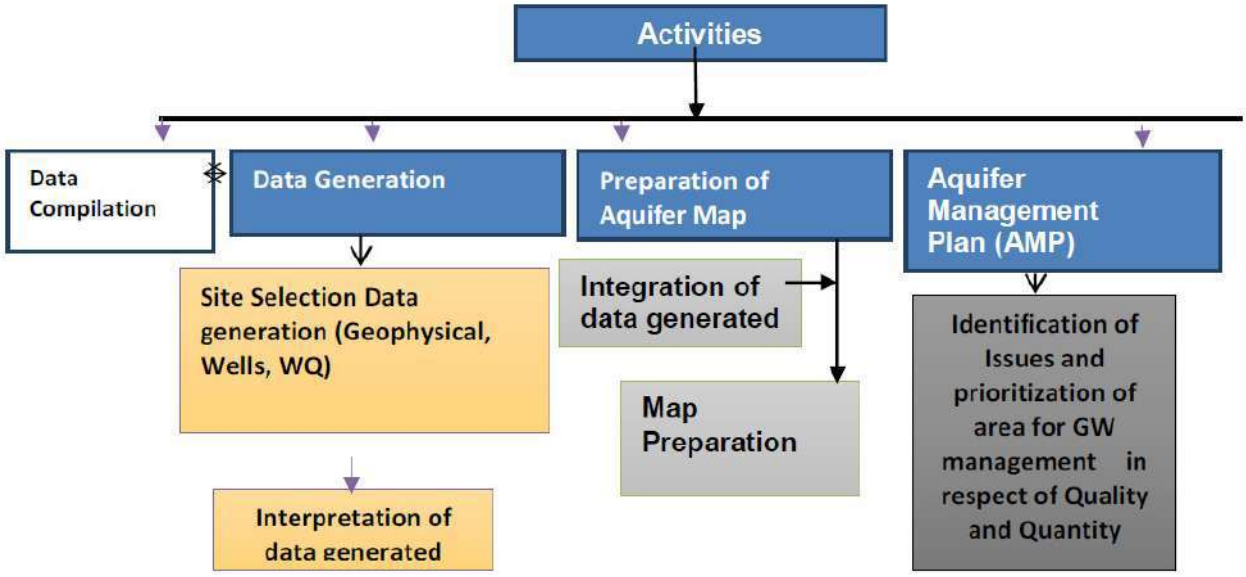
1.9 Objective, Scope of Study & Methodology

The primary objective of the Aquifer Mapping Exercise can be summed up as "Know your Aquifer, Manage your Aquifer". Demystification of Science and thereby involvement of

stake holders is the essence of the entire project. The involvement and participation of the community will infuse a sense of ownership amongst the stakeholders.

This is an activity where the Government and the Community work in tandem. Greater the harmony between the two, greater will be the chances of successful implementation and achievement of the goals of the Project. As per the Report of the Working Group on Sustainable Ground Water Management, "It is imperative to design an aquifer mapping programme with a clear-cut groundwater management purpose. This will ensure that aquifer mapping does not remain an academic exercise and that it will seamlessly flow into a participatory groundwater management programme. The aquifer mapping approach can help integrate ground water availability with ground water accessibility and quality aspects.

Methodology: Various activities of NAQUIM are as follows:



1.10 Data Availability, Data Adequacy, Data Gap Analysis & Data Generation

The data of CGWB wells (Fig 4) and all the wells from PHED and Private in the area are plotted on the map of 1:50000 scale with 5'X5'grid (9 x 9km) and is shown in fig 5 & 6 respectively. The grids/ formations devoid of SH/PZ/EW are identified as data gaps and these are to be filled by data generation.

Fig 4: Location of CGWB wells

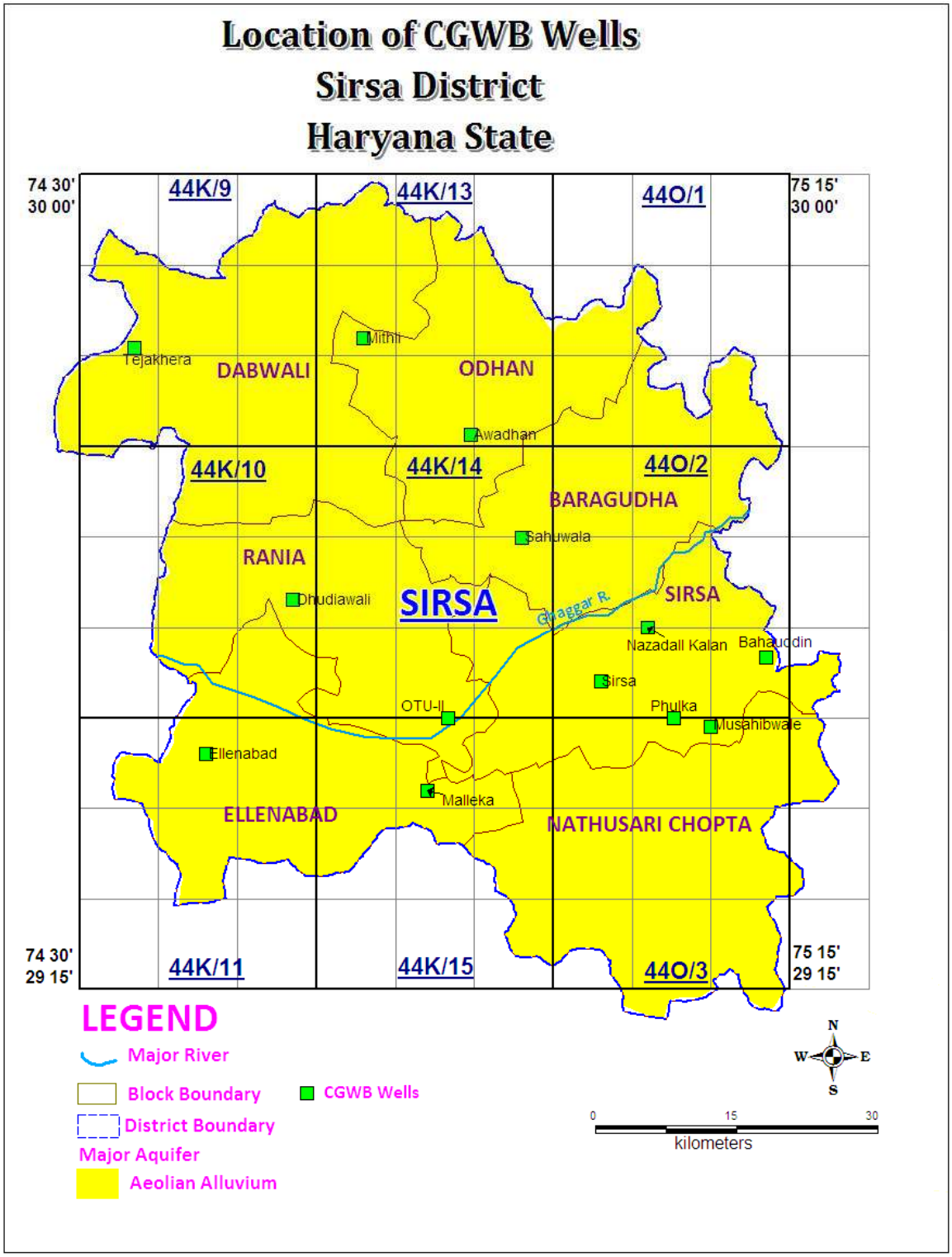


Fig 5: Location of PHED wells

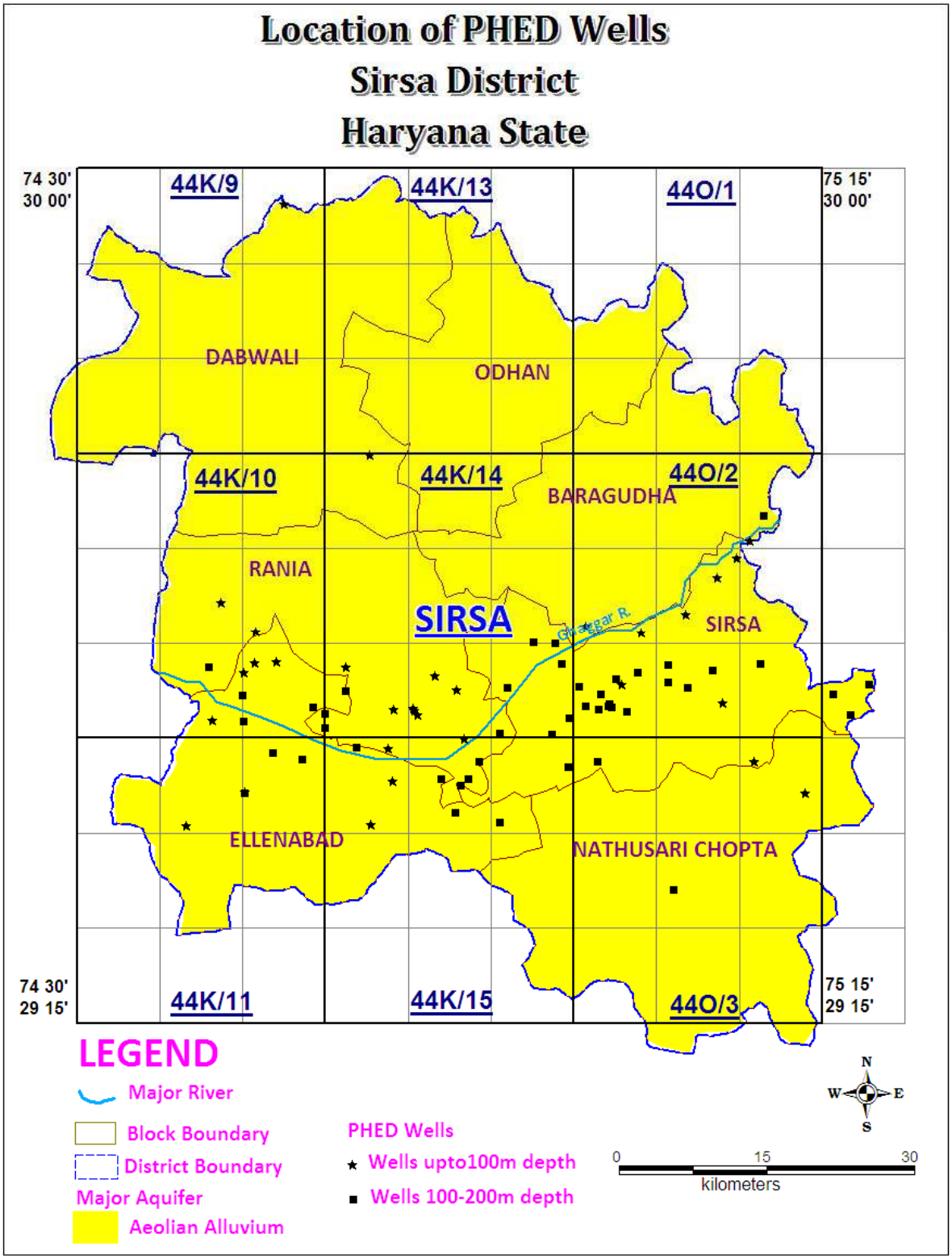
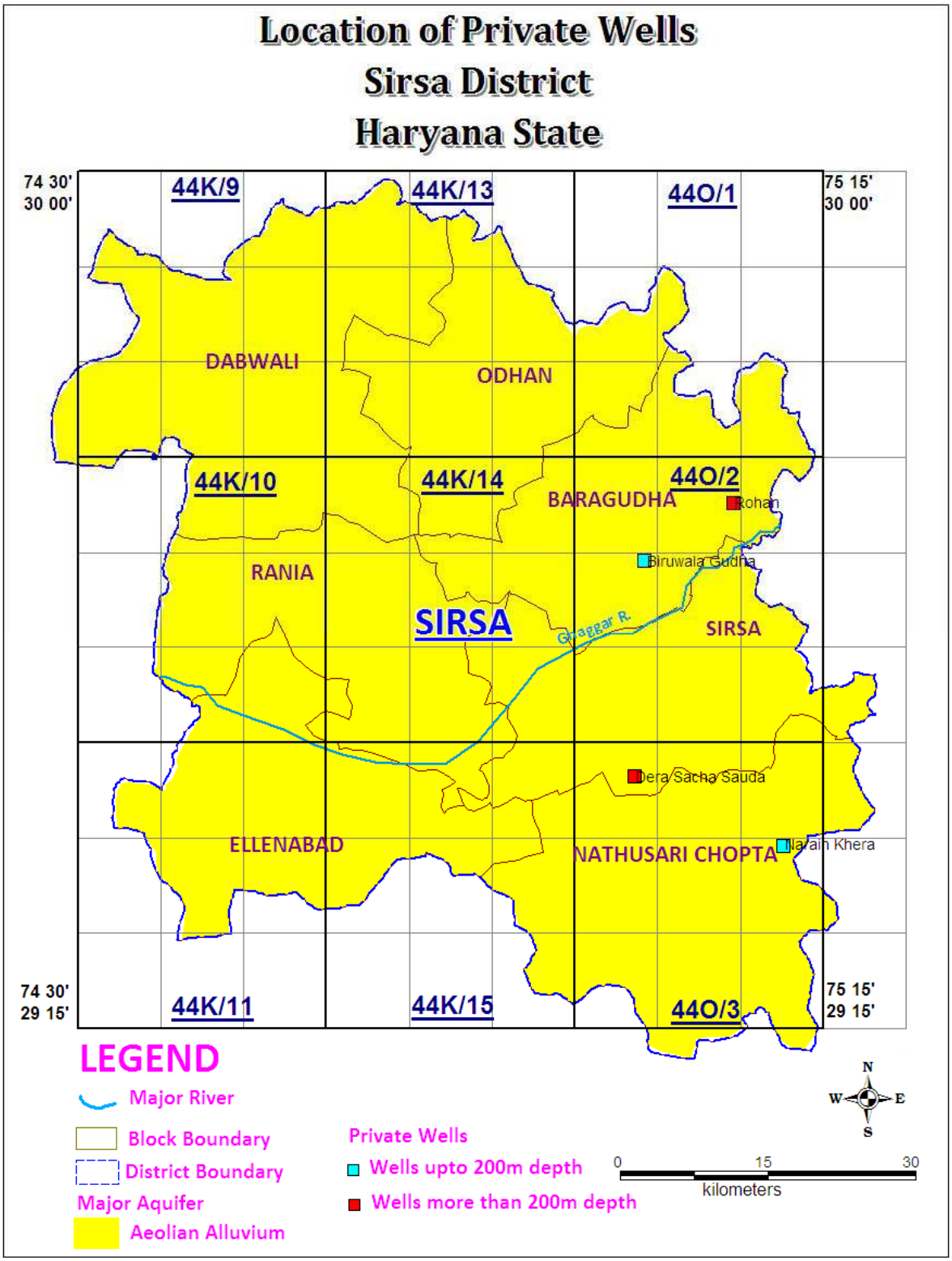


Fig 6: Location of Private Wells



2. DATA COLLECTION AND GENERATION

2.1 Hydrogeological Data

2.1.1 Geology of the Area

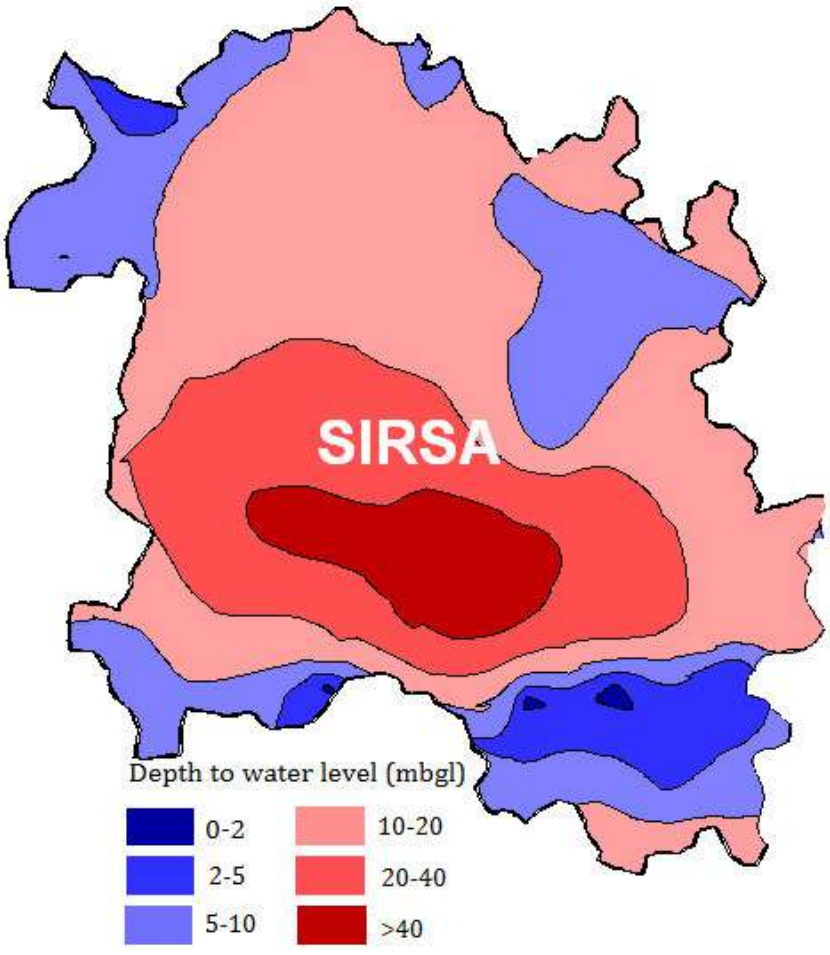
The geological formations are unconsolidated alluvial deposits of Quaternary age. The alluvial deposits comprises of sand, silt, clay associated with kankar. Fine to medium grained sand horizon forms the potential aquifer in the area. The major source of recharge to ground water in the area is inflow of ground water from north eastern and northern parts, rainfall, seepage from canals, return seepage through irrigation and percolation from surface water bodies. The area has both unconfined and confined aquifers. In general the unconfined aquifers occurs down to 60 m depth below ground level in the district. The alluvium acts as ground water reservoir and principal aquifer material comprises fine to medium sand and sand mixed with kankar. This aquifer is either in the form of isolated lenses of sand embedded in clay beds or well connected granular zones that have a pinching and swelling disposition and are quite extensive in nature. The ground water in unconfined condition is abstracted through hand pumps and shallow tubewells where as in deep and confined aquifer through medium and deep tubewells. the thickness of the alluvium deposit varies from 200 to 300 m. The thickness of alluvial formation increases towards northwest. Perusal of the data of the exploratory tubewell drilled in Ghaggar Basin indicate that tubewells tapping water bearing zone with in 100 to 200 m depth yield 1500 lpm to 3000 lpm for draw down of 5 to 17 m. Aquifer parameters viz transmissivity (T), storativity (S), hydraulic conductivity(K) and yield (discharge) of the test well have been determined on the basis of Aquifer Performance Test (APT) conducted on exploratory wells. In the area, 11 exploratory boreholes down to a maximum depth of 306.71m were drilled to determine the aquifer parameters. The yield (discharge) of the test well ranges from 120 lpm to 3000 lpm with a drawdown of 3.66m to 17.47m. The transmissivity value of the aquifers ranged from 327 m2 /day to 2600 m2 /day. The hydraulic conductivity ranged from 5.83m to 83 m/day. The value of the storage coefficient ranges between 0.638x10-3 and 27x10-3. Shallow tubewells constructed in the district have discharge range between 300 and 1000 lpm with a drawdown of 1.0 to 3.5m. Whereas, perusal of data of deeper tubewell/ borewells

constructed in Ghaggar basin tapping water bearing zone in depth range 100m to 260m yield 1500 to 3000 lpm with 5 to 17 m of draw down. Hence it can be said that tubewells constructed in vicinity of Ghaggar river has enormous groundwater potential.

2.1.2 Water Level Behaviour (2015)

The depth to water level ranges from 1.6m bgl at Darba Kalan to 63.50m bgl at Mangala during pre-monsoon (fig 7) and 1.53m bgl to 67.87m bgl during post-monsoon at Gudia Khera and Mangala respectively. The water level fluctuation shows both rise and fall in the water level equally. During post-monsoon, the rise in the water level ranges from 0.05m at Kairanwali to 2.64m at Panniwala Mota and fall in the water level ranges from 0.08m at Bhahu Khera to 4.62m at Sirsa.. The depth to water level data and its fluctuation is given in Annexure I.

Fig 7: Depth to water level map (Pre-monsoon, 2015).

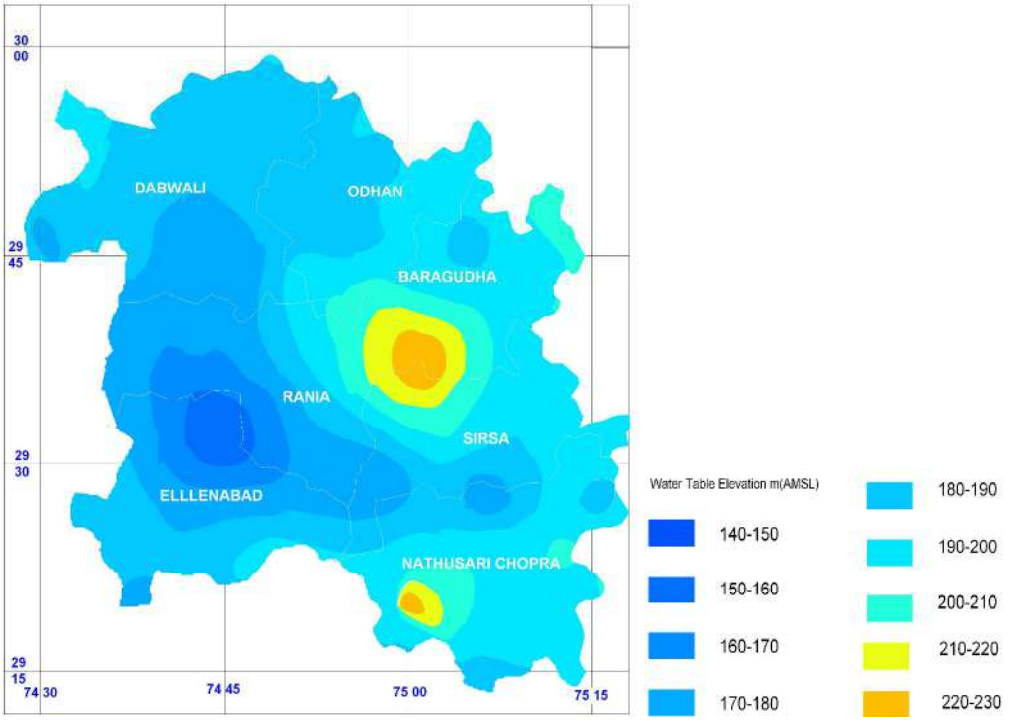


The long term trend in the water level reflected by water level hydrographs is indicative of the change in ground water storage in phreatic zone with time. The ground water observation wells (GWOW) which are indicating a rise in water level trend, this may be due to local hydrological conditions prevailing in the area. Whereas hydrographs showing declining water level trend may be due to over-exploitation of good quality ground water and these area require careful management of surface water and conjunctive use of surface water and ground water. Some of the hydrographs neither showing any substantial rise nor major decline thus indicating that the dynamic storage of phreatic aquifer is being maintained which is being utilized before the monsoon and gets recharged post monsoon.

2.1.3 Ground Water Flow

The major ground water flow is towards the centre of the district i.e. towards Rania and Sirsa Block (fig 8). This is due to high extraction rate in these blocks because of good quality of ground water at the shallow depths. The ground water table varies from 134m amsl in the centre line to 201m amsl in the southern and northern part of the district which also indicates the flow towards the central portion of the district.

Fig 8: Ground Water Flow Map (May, 2016)



2.1.4 Exploratory & Geophysical Data

The Lithologs of Exploratory Well/ Observation well/ Piezometer/ productive wells of CGWB, Public Health and Engineering Department (PHED) & private wells have been collected and those supported electrical logs have been validate for aquifer map preparation. Deeper well data of CGWB is available. The details are shown in table 2. The compromised logs derived from lithologs and geophysical well loggings have been taken as reliable data base.

Table 2: Data availability of Exploration Wells in Sirsa District

S. No.	Source	No. of wells	Depth (in mbgl)			
			0-100	100-200	200-300	>300
1	CGWB	14	1	0	7	6
2	Private	4	0	2	2	0
3	PHED	77	31	46	0	0
	Total	**95**	**32**	**48**	**9**	**6**

2.2 Geophysical Studies

A total of 22 numbers of Vertical Electrical Sounding (VES) were conducted in eastern part of the district covering NS Chopta, Baraguda and Sirsa blocks of Sirsa district, Haryana to delineate fresh/Saline ground water interface (Fig 9). The ABEB Terrameter was used for field investigation. Almost the entire study area is occupied with saline water except at few locations like Theri Rasulpur, Bajike and Jodhka where high resistivity values in the range of 130 to 150 ohm m are observed indicating the presence of fresh ground water sediments. At these location the last is having low resistivity values in the ranges of 5 to 12 ohm m indicating the presence of saline ground water having unknown thickness. At other locations like Shakkarmandhauri, Kutiyana, Gigorani, Kirarkot, Kharika and Khiraj, low resistivity values are recorded from shallow depth which lies in the range of less than 10 Ohm m which represents the presence of saline water.

Fig 9: Map showing VES locations in Sirsa District

2.3 Hydrochemical

The distribution of chemical constituents in ground water as per ground water observation wells data 2015 is tabulated in annexure II. The ground water is alkaline in nature. The pH values range from 7.63 at Dabwali to 9.15 at Mangiana. The EC of ground water ranges from 270 µS/cm atDabwali to 7210 µS/cm at 25°C at Rasalia Khan. In most of the water samples, EC is above 1000µS/cm. The hardness value of ground water ranges from 129 mg/l at Dabwali to 1486 mg/l at Kalawali Man. Among cations, the concentration of calcium ranges between 20mg/l at Mangian to 253 mg/l at Rasalia Khan. Magnesium concentration ranges between 13 mg/l at Nuhian wali to 308 mg/l at Kalawali Man. In majority of the ground water samples, calcium and magnesium concentrations are less than 100 mg/l except at these sites i.e. Rasalia Khan, Panniwala and Kalawali Man. The sodium content varies widely from 10mg/l at Dabwali to 1660 mg/l at Rasalia Khan whereas potassium content ranges from 3.2 mg/l at Nuhian wali to 26 mg/l at . Rasalia Khan. Among anions, carbonate is found to be less in quantity as compared to bicarbonate concentration which ranges between 53 mg/l at Kalawali Man to 499 mg/l Phaggu & Rori. The chloride concentration in ground water samples is more than the desirable range of 250mg/l (BIS 2012) at 5 sites as well as sulphate concentration is also found more than the desirable limit of 400mg/l in majority of the samples. The maximum sulphate content found is 2833 mg/l at Rasalia Khan. The nitrate (NO^3) concentration ranges from 0.1 mg/l at Dabwali to 115 mg/l at Ding. The fluoride (F) content in ground water of the district ranges from 0.29 at Dabwali to 4.5 mg/l at Mangiana.

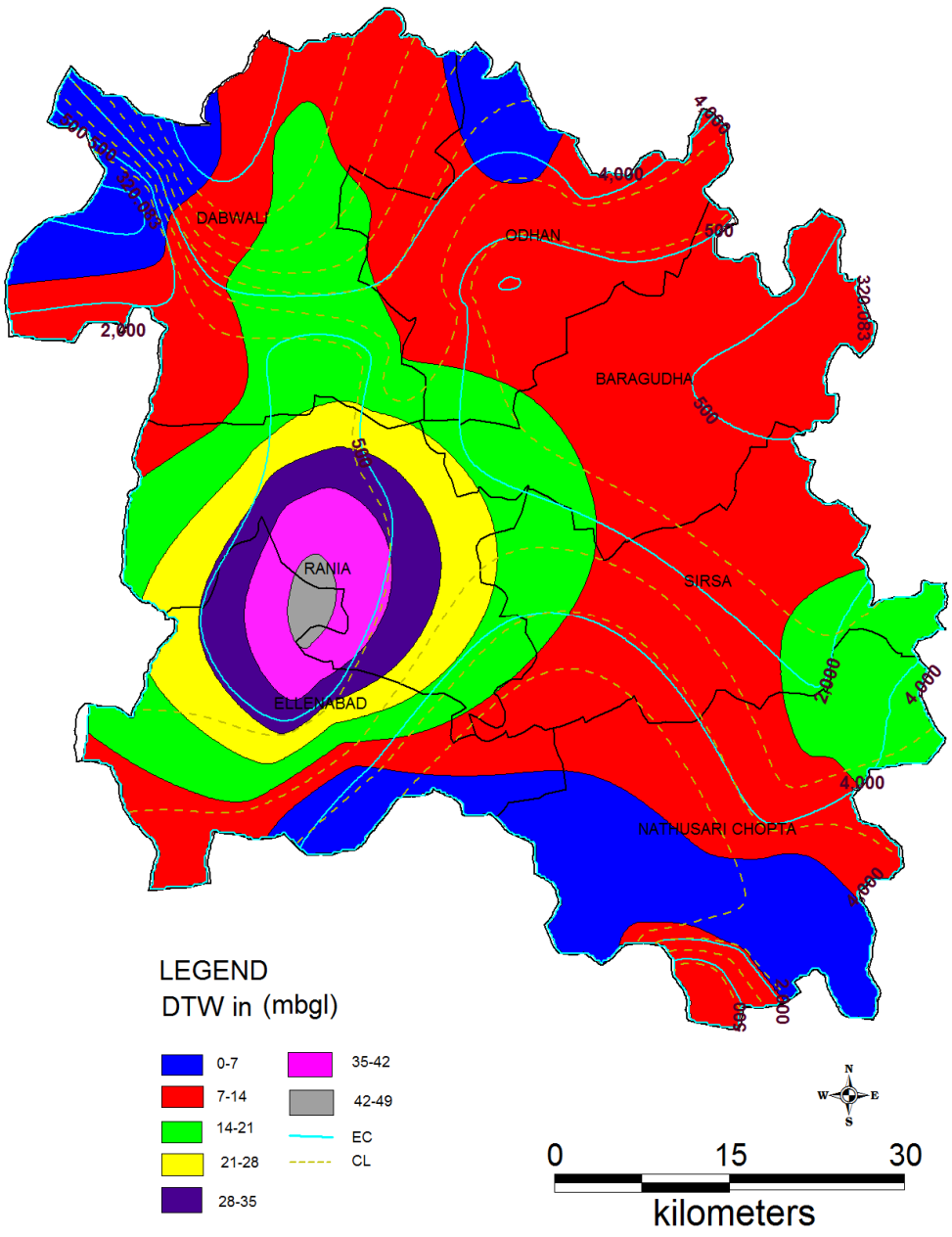
Trace Elements in Ground Water

Arsenic: Its concentration is found to be less than the permissible limit of 0.05 mg/l in all the ground water samples.

Iron: Its concentration in ground water ranges from below detection limit to 0.15 mg/l and it is more than the permissible limit of 0.3 at only one site i.e. Kalawali Man with a value of 0.51 mg/l.

The quality map was prepared using two parameters viz. the Electrical Conductivity and Chlorides showing in Fig 10. The water quality map shows that the ground water is fresh in Rania block and in parts of Ellanabad and Sirsa blocks where the electrical conductivity value is <500 µS/cm. In north western part of the district the ground water quality is marginally saline as the electrical conductivity varies between 500-2000 µS/cm. In rest of the district the ground water quality is saline and the electrical conductivity values are more than the 2000 µS/cm.

Fig 10: Water Quality Map of Sirsa District



Type of Water

The analyzed data on the hydro-chemical facies of ground water in Sirsa district has been presented in trilinear diagrams (Fig 11) which indicate distribution of hydro-chemical types present in respective area. Among cations, sodium is the dominant cation in 72%, Ca+Mg in 9% and in the remaining samples mixed cationic character prevails. Among anions, chloride is dominant in majority of samples followed by sulphate.

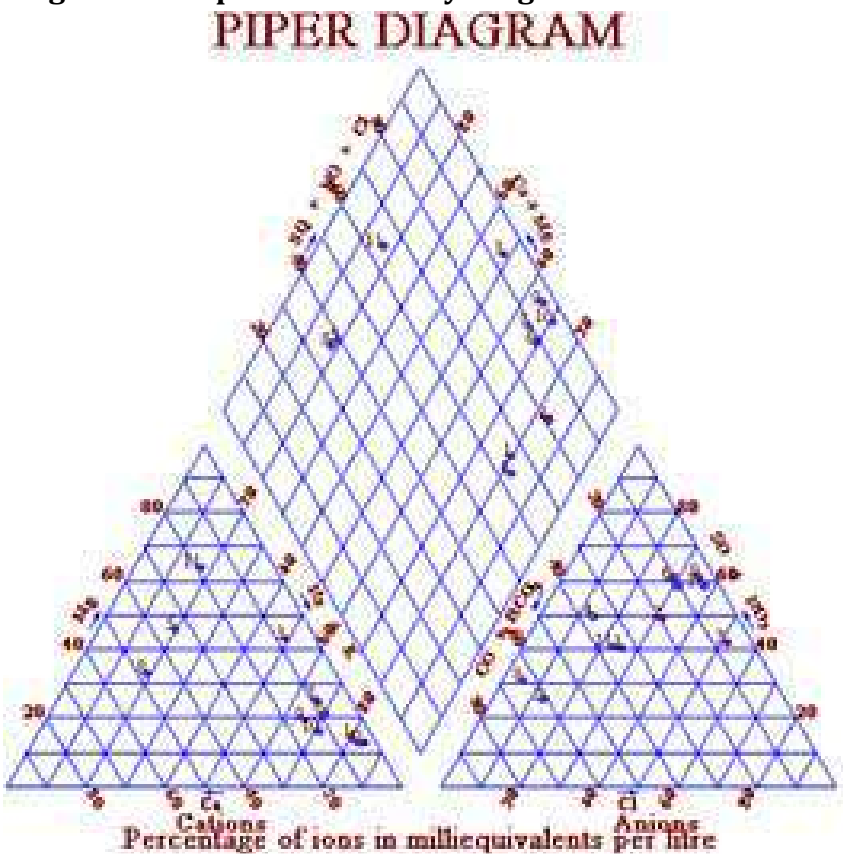
Suitability for Drinking Purposes

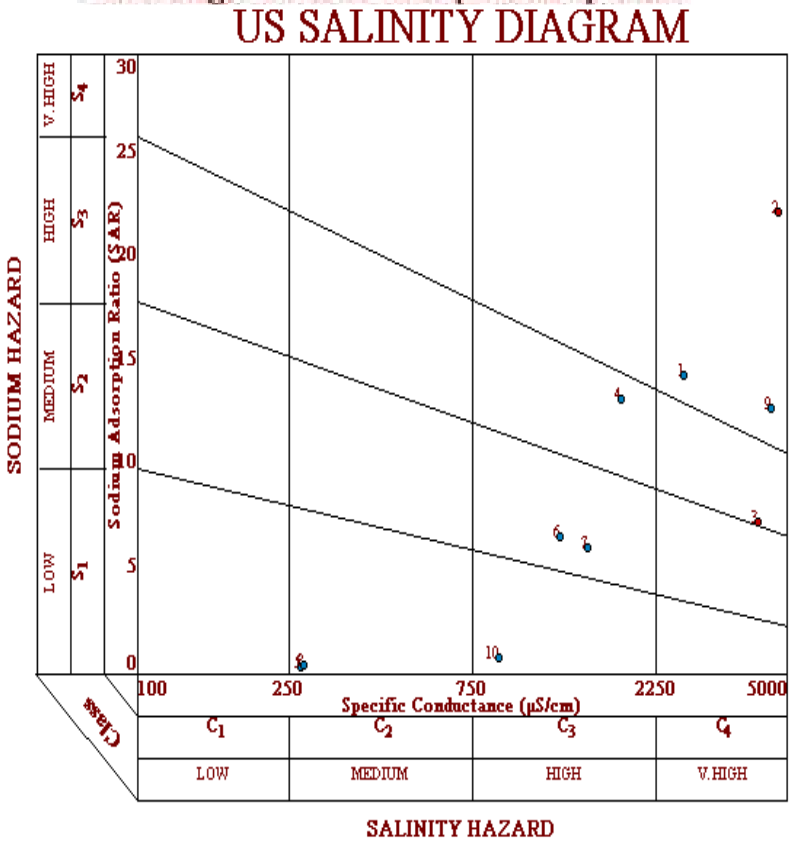
On comparison with drinking water standards given by BIS, it is found that most of the waters have concentration of one or more chemical constituents above the permissible limit and thus are not suitable for drinking use. The constituents that make them unfit for drinking are mainly NO3, F, EC, or combination of these. Only 27% ground waters are potable. High arsenic (0.02 mg/l) is observed at Kalawali Man making it unsuitable for domestic use.

Suitability for Irrigation Purposes

Plot in the USSL staff (1954) diagram indicates that 50% waters fall under C2S1, C3S1 and C3S2 classes of irrigation rating (Fig 11). Such waters may create medium to very high salinity hazards and low to very high sodium hazards when used for irrigation under customary irrigation. Remaining 50% ground waters falling C3S3, C4S2 and C4S4 classes are unsuitable for irrigation. However, these waters can be used for irrigating salt tolerant crops grown on soils with adequate permeability, only after addition of appropriate amounts of gypsum. Classification based on RSC indicates that only 73% of waters are safe, 9% are marginal and the remaining 18% waters are unsafe for irrigation use.

Fig 11: Hill Piper & US Salinity Diagram of Sirsa District



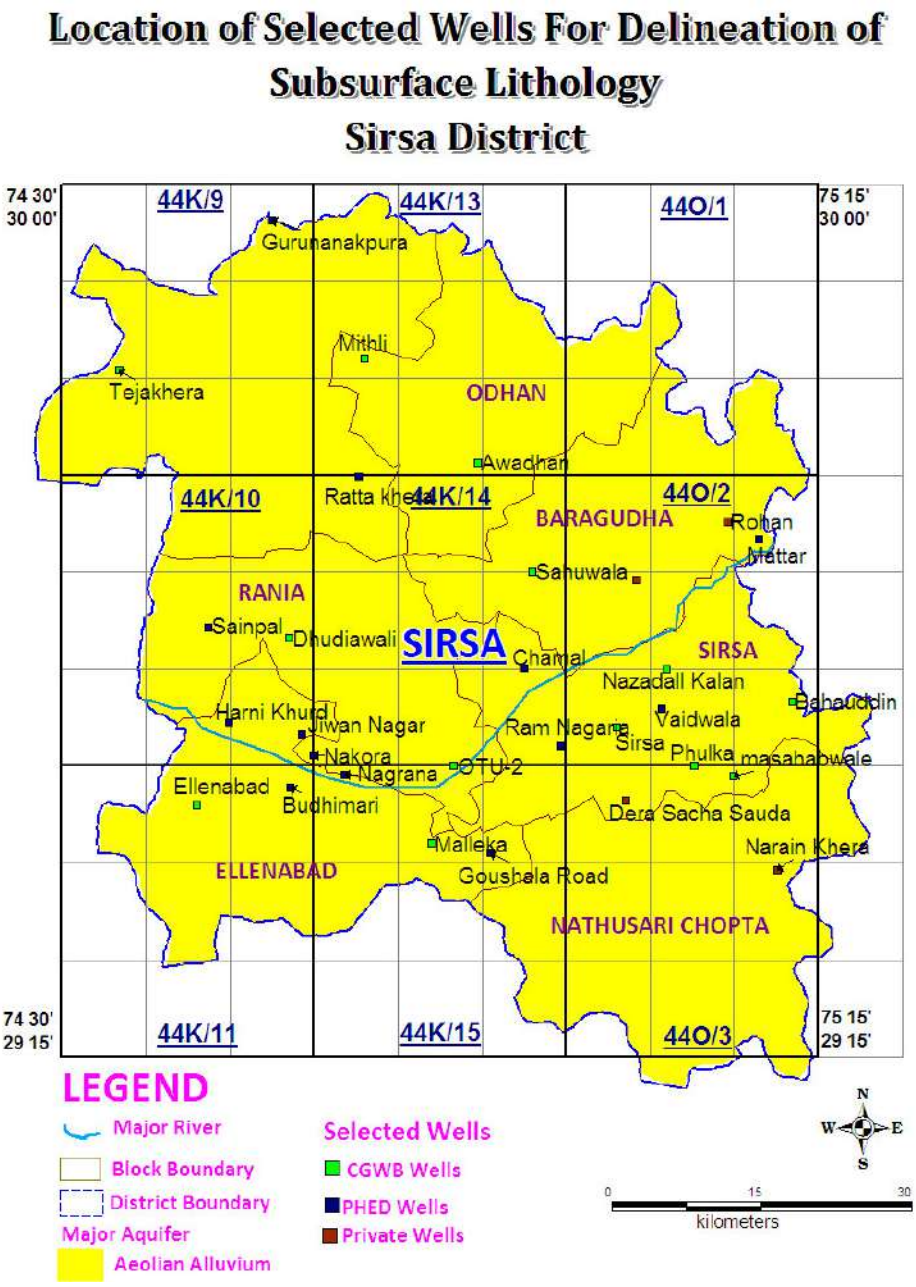


3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 Hydrogeological Interpretation & Results

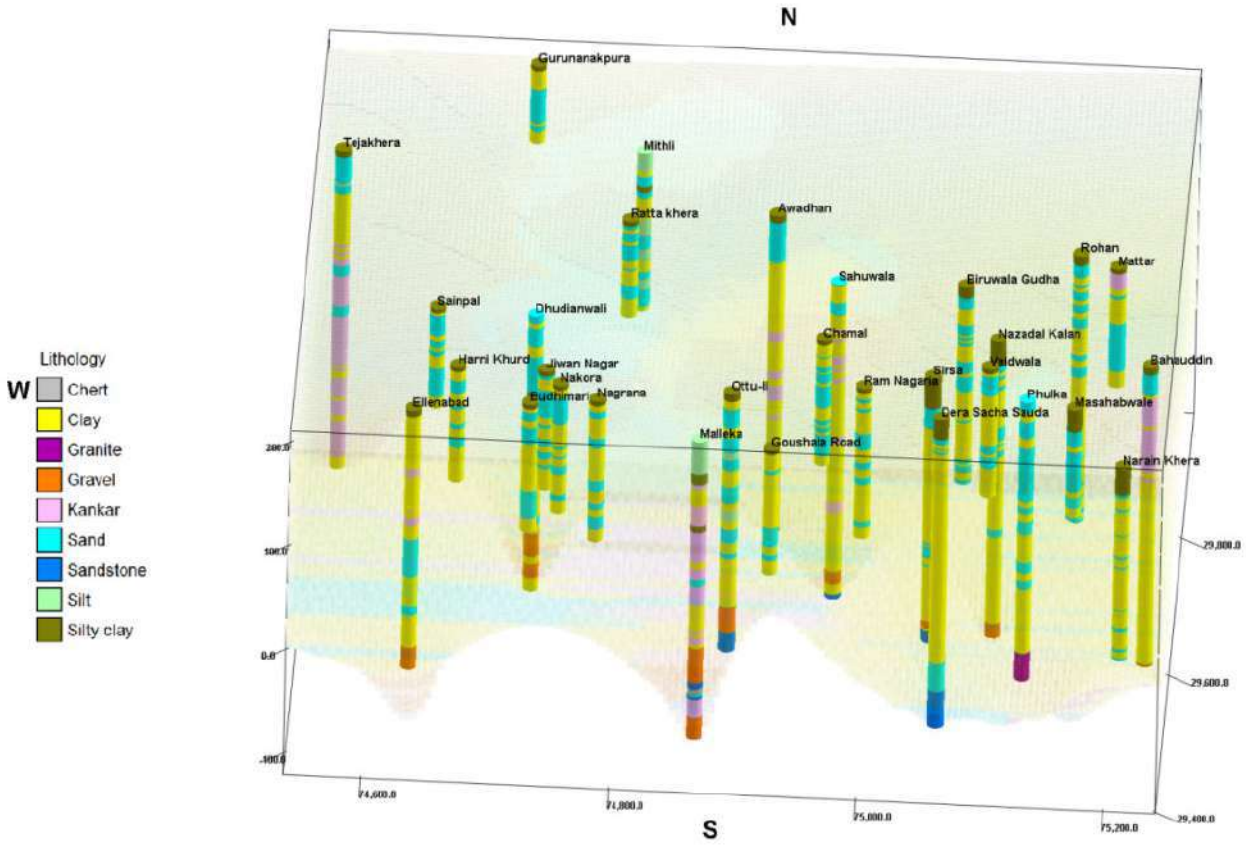
All the available data have been validated for consideration to generate aquifer map. The deepest well in each quadrant is selected and plotted on the map of 1.50000 scale with 5'X5'grid (9 x 9km) and is shown in Fig 12. Details are given in Annexure III.

Fig 12: Validated Exploration Data of Sirsa District



The locations of validated wells are plotted and litholog is shown in fig 13.

Fig 13: 3Dimension location of validated Exploratory Wells with litholog



Summarized details of the validated and optimized wells are given in table 3.

Table 3: Summary of optimized exploration wells

Block	Toposheet		Well Details & Depth				Remarks
			>300	200-300	100-200	<100	
Dabwali		1C	-	-	-	1	Gurunanakpura(74.7m)
		2A	1	-	-	-	Tejakhera(306.34m)
		2B	-	-	-	-	-
		2C	-	-	-	-	-
		3A	-	-	-	-	-
		3B	-	-	-	-	-
	44K/9	3C	-	-	-	-	-
		1B	-	-	-	-	-
	44K/10	1C	-	-	-	-	-

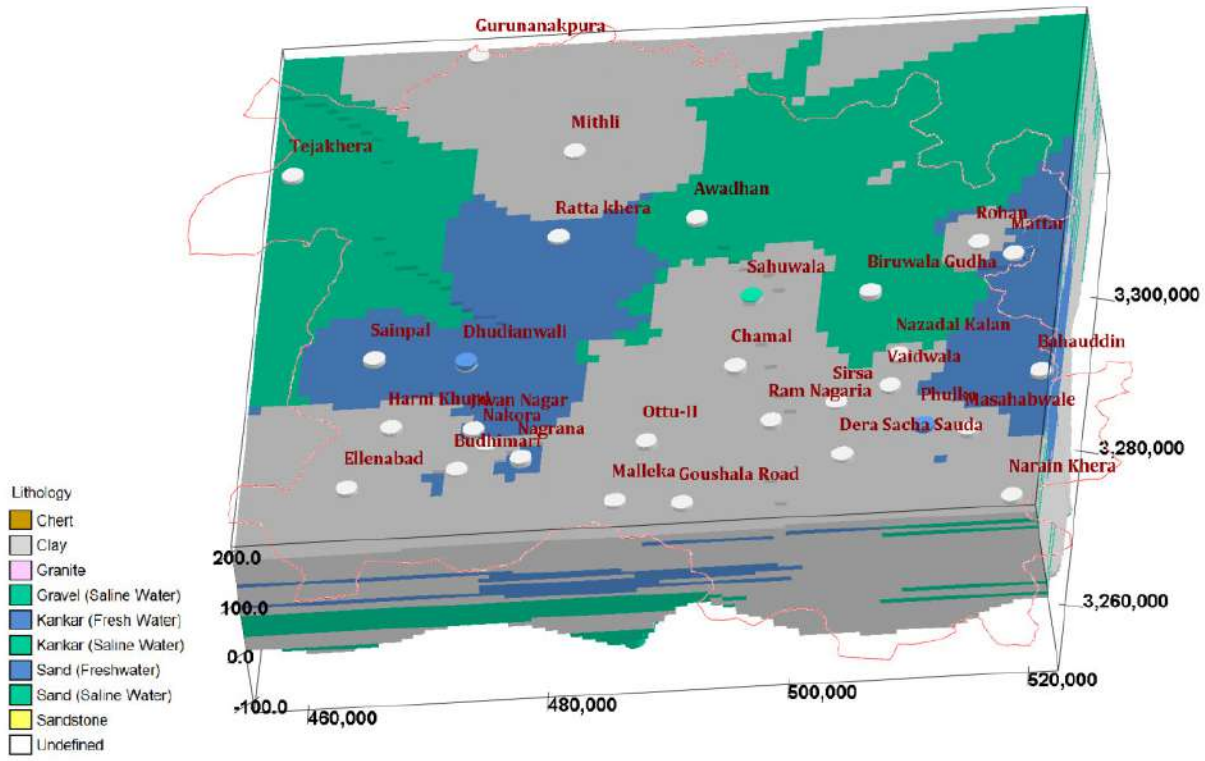
		1A	-	-	-	-	-
		2A	-	-	-	-	-
	44K/13	3A	-	-	-	-	-
	44K/14	1A	-	-	-	1	Ratta Khera(93m)
Odhan		2A	-	-	1	-	Mithli(151m)
		2B	-	-	-	-	-
		2C	-	-	-	-	-
		3A	-	-	-	-	-
		3B	1	-	-	-	Awadhan(306.71m)
	44K/13	3C	-	-	-	-	-
	44K/14	1B	-	-	-	-	-
		2A	-	-	-	-	-
	44O/1	3A	-	-	-	-	-
Rania		2B	-	-	-	1	Sainpal(93m)
		2C	-	1	-	-	Dhudiawali(265.14m)
	44K/10	3B	-	-	-	-	-
		2A	-	-	-	-	-
		2B	-	-	-	-	-
		3A	-	-	1	-	Nakora(123.47m)
	44K/14	3B	-	1	-	-	OUT-2(226m)
Baragudha		3A	-	-	-	-	-
		3B	-	-	-	-	-
	44O/1	3C	-	-	-	-	-
		1C	1	-	-	-	Sahuwala(303.58m)
		2B	-	-	-	-	-
	44K/14	2C	-	-	-	-	-
		1A	-	-	-	-	-
		1B	-	1	-	-	Rohan(257m)
		1C	-	-	1	-	Mattar(114.82m)
		2A	-	-	-	-	-
	44O/2	2B	-	-	-	-	-
Ellanabad		3B	-	-	1	-	Harni Khurd(111.28m)
	44K/10	3C	-	-	1	-	Jiwan Nagar(114.32m)
		1B	1	-	-	-	Ellanabad(304.8m)
		1C	-	-	1	-	Budhimari(123.47m)
		2B	-	-	-	-	-
	44K/11	2C	-	-	-	-	-
		1A	-	-	1	-	Nagrana(135.67m)
	44K/15	1B	-	1	-	-	Malleka(287.12m)

		1C	-	-	1	-	Goushala Road(120.4m)
		2A	-	-	-	-	-
Sirsa		2C	-	-	1	-	Chamal(120.4m)
	44K/14	3C	-	-	1	-	Ram Nagaria(144.8m)
	44K/15	1C	-	-	-	-	-
		2B	1	-	-	-	Nazadall Kalan(301.14m)
		2C	-	-	-	-	-
		3A	-	1	-	-	Sirsa(298.14m)
		3B	-	-	1	-	Vaidwala(123.5m)
	44O/2	3C	-	1	-	-	Bahuddin(288.304m)
		1A	-	1	-	-	Dera Sacha Sauda(297m)
		1B	-	1	-	-	Phulka(268.7m)
	44O/3	1C	1	-	-	-	Masahebwale(304.8m)
Nathusari Chopta	44K/15	2C	-	-	-	-	-
		1A	-	-	-	-	-
		1B	-	-	-	-	-
		1C	-	-	-	-	-
		2A	-	-	-	-	-
		2B	-	-	-	-	-
		2C	-	-	1	-	Narain Khera(186m)
		3A	-	-	-	-	-
		3B	-	-	-	-	-
	44O/3	3C	-	-	-	-	-

3.1.1 Aquifer Geometry & Disposition

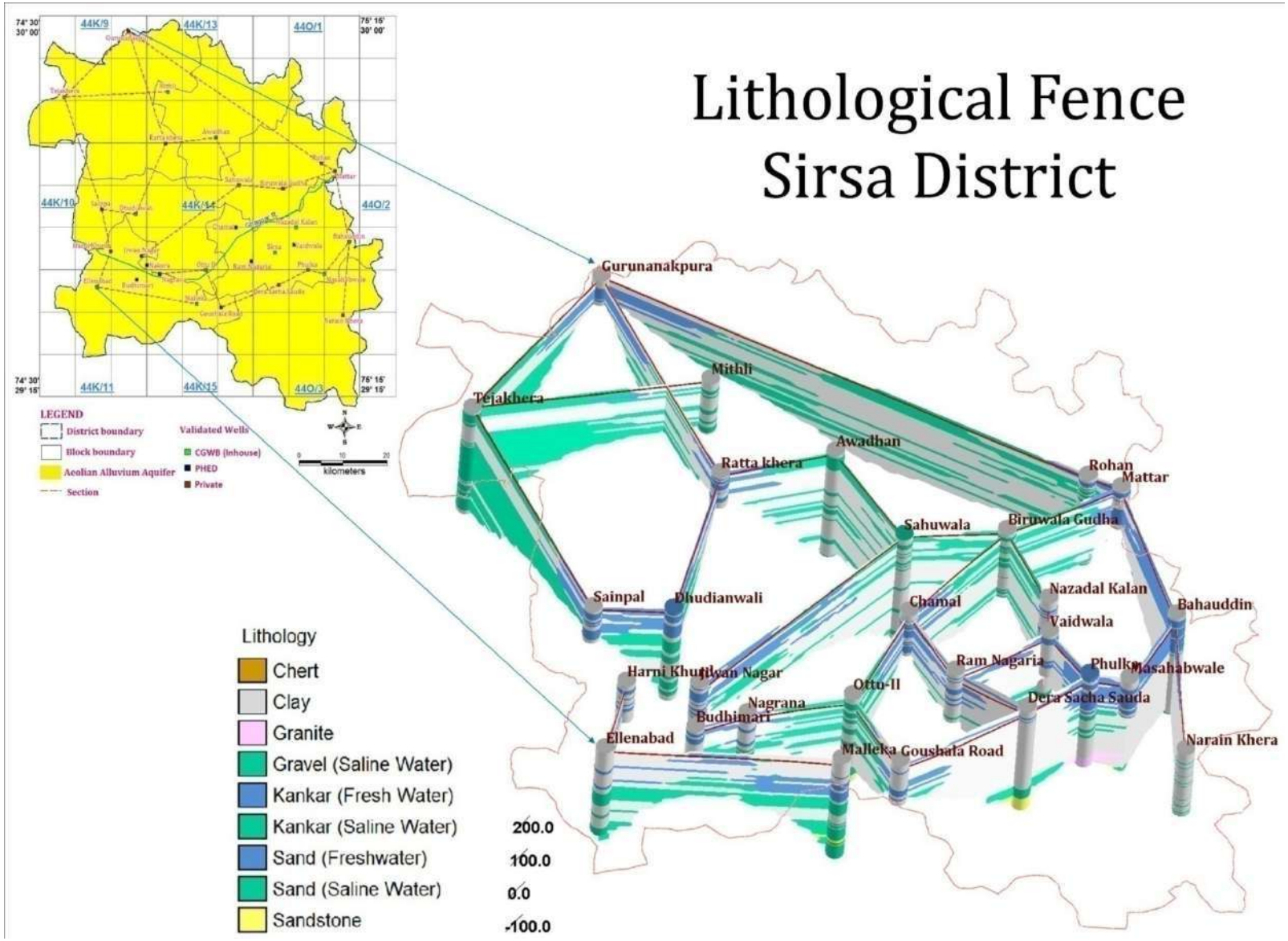
To understand the sub surface lithology and its disposition, the lithological data of the optimized wells drilled by CGWB, PHED and Private Agencies is plotted using the RockWorks15 software and a lithological model has been prepared and is shown in fig 14. The 3D lithological fence diagram has been prepared using the lithology model and is shown in fig 15.

Fig 14: 3-Dimension Lithological Model of Sirsa District



The aquifer material and non-aquifer material in the district is highly variable. The major aquifer material is sand, kankar and gravel and the non-aquifer material is majorly clay, sandstone, chert and granite. The sandstone, chert and granite are found at deeper depth starting from 230m bgl.

Fig 15: 3Dimension Lithological Fence of Sirsa District



3.2 Geophysical Interpretation

On the basis of results of geophysical survey, three numbers of Geo electric cross section and a fence diagram were prepared. The direction of sections is shown in fig 16.

Cross Section AA': This 35 km long North West-South East section begins from VES No.61(Bahrakhera) and finally terminates at VES No.45(Kukarthana).Six numbers of VES locations fall over this section. The entire section is occupied with saline ground water sediments except VES No.46 (Rajpura Kairwali) where fresh sediments are present at shallow depth. This section is shown in Fig 17.

Cross Section BB': This section is 54 km long in North South direction. This section begins form VES No.61 (Bahrakhera) and terminates at VES No.62 (Thiraj).This section is also occupied with saline ground water except at VES No.44(Phulka) where fresh water is indicated at shallow depth. This section is shown in Fig 18.

Cross Section CC': This section originates from VES No. (Kharika) and finally terminates at VES No.54 (Charwal).This section is 46km long. Fresh sediments are observed at VES No. 44(Phulka) and VES No.54 (Charwal) at a shallow depth (25meters) .Length of this section is 46 Km. this section is shown in Fig 19.

3D Fence: On the basis of results of geophysical survey, fence diagram has been prepared. In North Western part, fresh ground sediments are present at deeper depths (around 150 meters).Similarly North East part is also occupied with fresh ground water sediments followed by saline ground water sediments. Fence diagram is shown in Fig 20.

Fig 16 Map showing the direction of the geo-electric sections

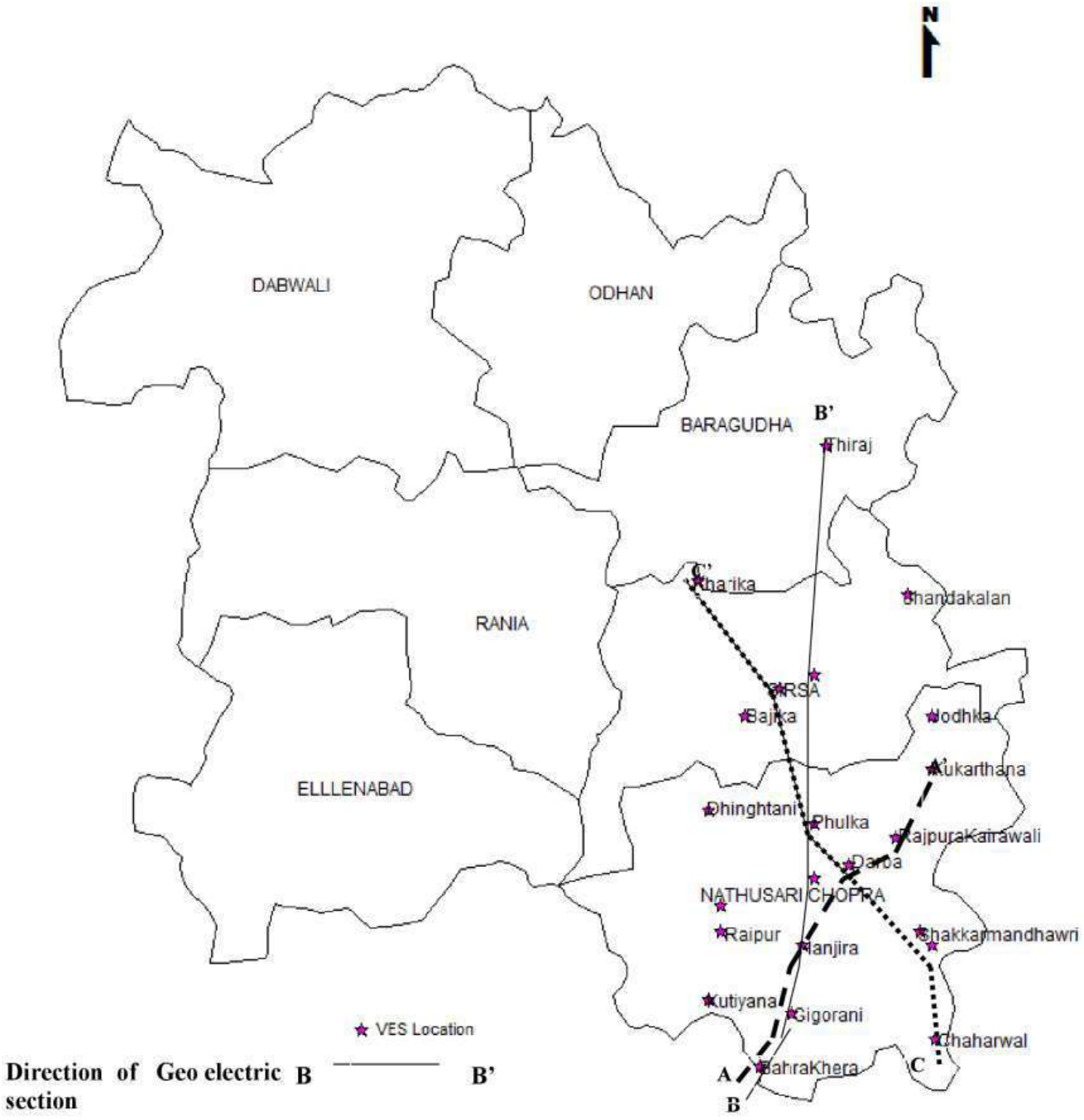


Fig 17: Geo-electrical section along AA'

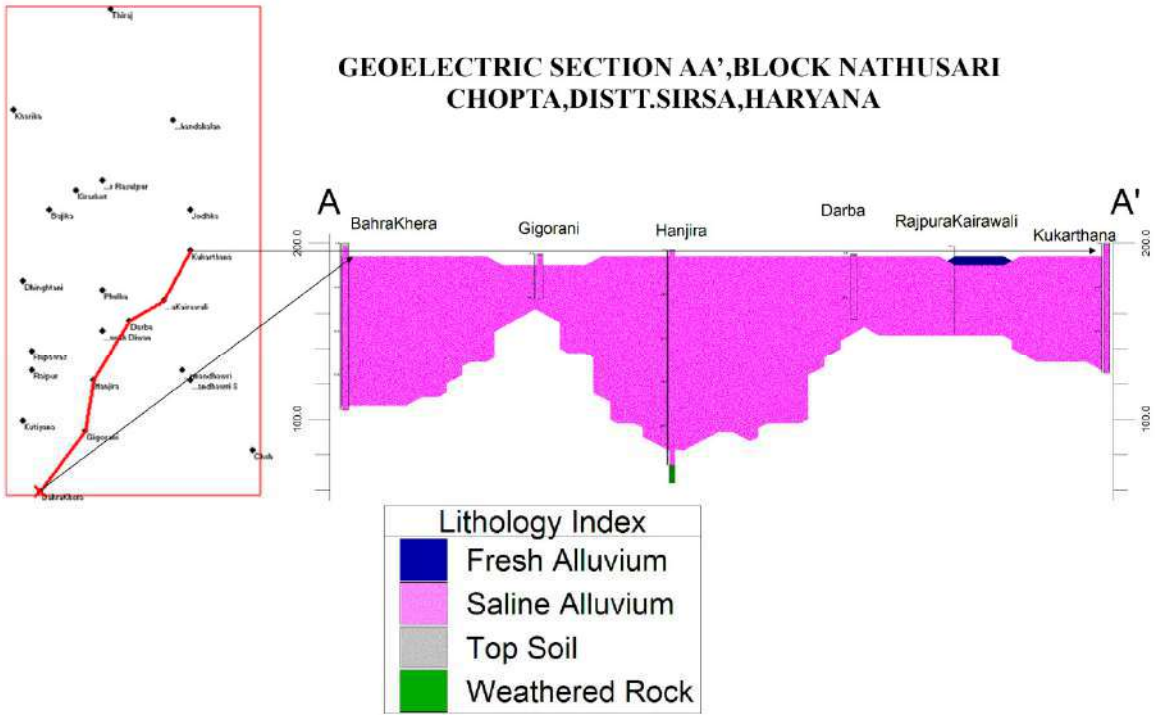


Fig 18: Geo-electrical section along BB'

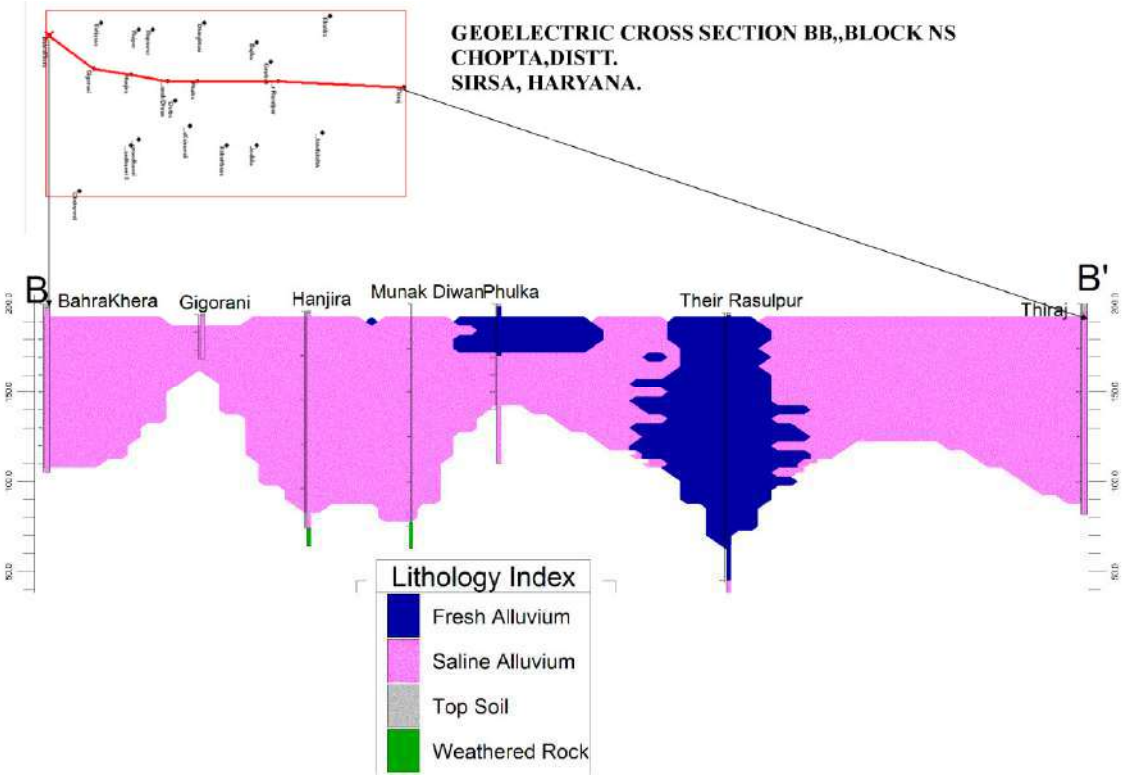


Fig 19: Geo-electrical section along CC'

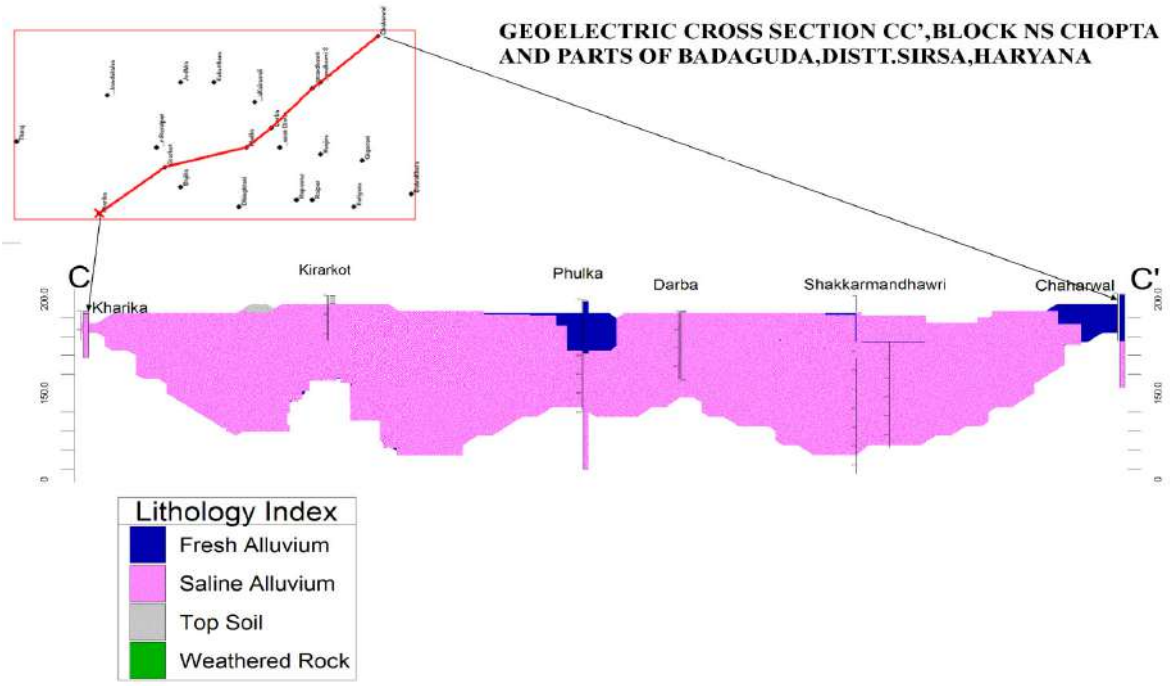
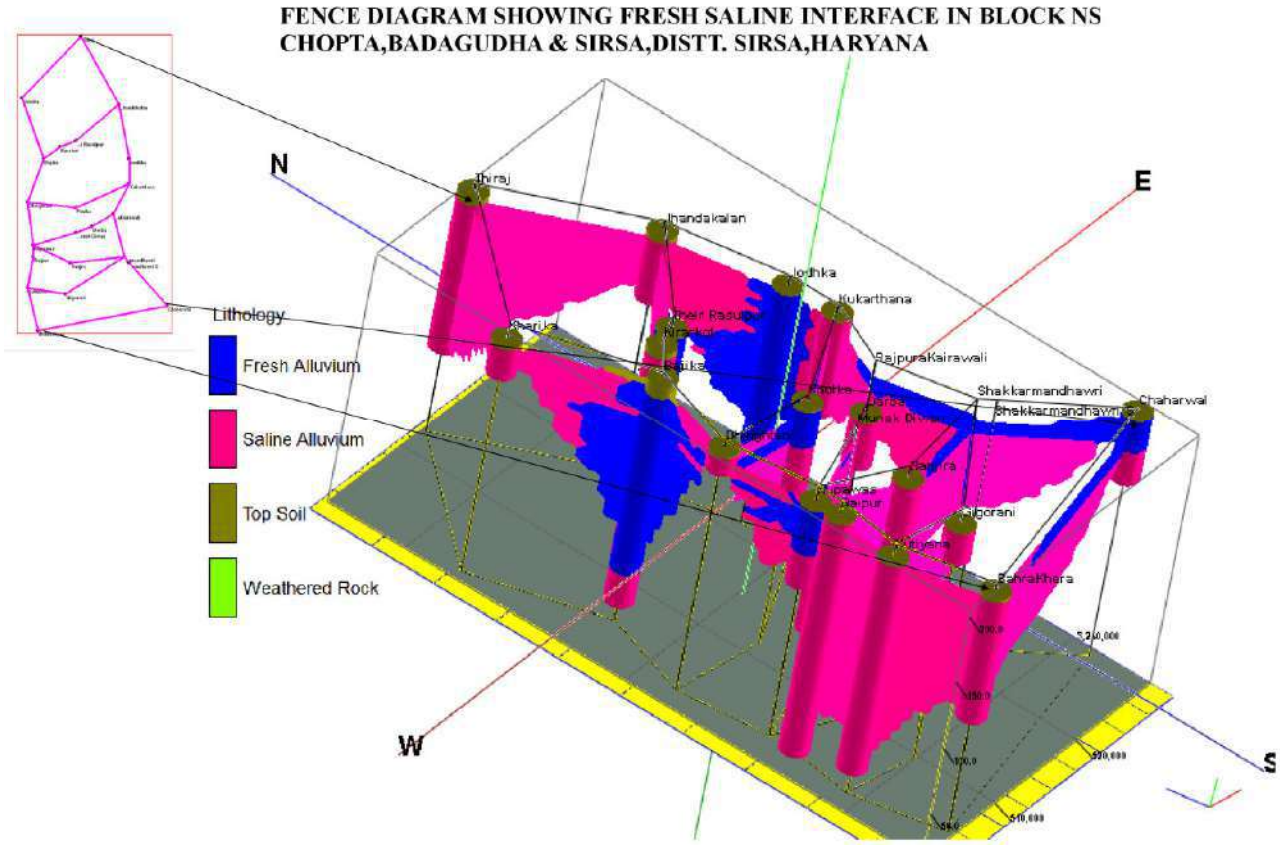


Fig 20: 3-D Fence of Fresh Saline interface in Sirsa District



4. GROUND WATER RESOURCES

4.1 Ground Water Resources of Multiple Aquifer up to 300m Depth

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) upto 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 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.

4.1.1 Unconfined aquifers- Dynamic Resources

The assessment of total availability of ground water resources encompasses two components namely dynamic resources and in-storage resources. Block wise dynamic resource figures so obtained based on GEC, 1997 norms have been taken as the 1st

component for unconfined aquifer. Further in pursuance to the methodology recommended by CGWB to assess total availability of Ground Water Resources, the following procedure has been adopted to calculate in-storage resources and total availability of Ground Water Resources.

The block wise ground water resource potential in the district has been assessed as per GEC-97 as on March 2013.The stage of ground water development ranges between 113% (block-Dabwali) to 323% (block- Rania). The total replenishable ground water resource in the district is 636.78 mcm. The net ground water draft is 1116 mcm. The stage of ground water development in the district is 175% (Table 4).

Table4:Dynamic Ground Water Resource&Development Potential (as on 31.03.13)

Assessment Unit/ Block	Net Annual Ground Water Availability	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	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} (%)
Baraguda	118.10	133.74	0.10	133.84	0.10	-15.74	113
Dabwali	94.98	235.48	0.42	235.90	0.42	-140.92	248
Ellenabad	125.83	182.85	1.55	184.40	1.55	-58.57	147
Ns Chopta	90.34	112.34	0.36	112.70	0.36	-22.36	125
Odhan	63.06	78.50	0.40	78.90	0.40	-15.84	125
Rania	55.87	178.85	1.78	180.63	1.78	-124.76	323
Sirsa	88.60	185.75	3.88	189.63	3.88	-101.03	214
Total	**636.78**	**1107.51**	**8.49**	**1116.00**	**8.49**	**-479.22**	**175**

*all the given figures are in mcm

4.1.2 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 21. 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 modelling approach.

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

Block wise fresh and saline in-storage ground water resources up to fresh-saline interface in unconfined aquifer is given in table 5 & 6 respectively. Block wise saline in-storage ground water resources below the fresh-saline interface in unconfined aquifer is given in table 7 and Total block wise ground water resources are given in table 8.

Fig 21: Methodology for Resource Estimation in Unconfined and Confined Aquifer System

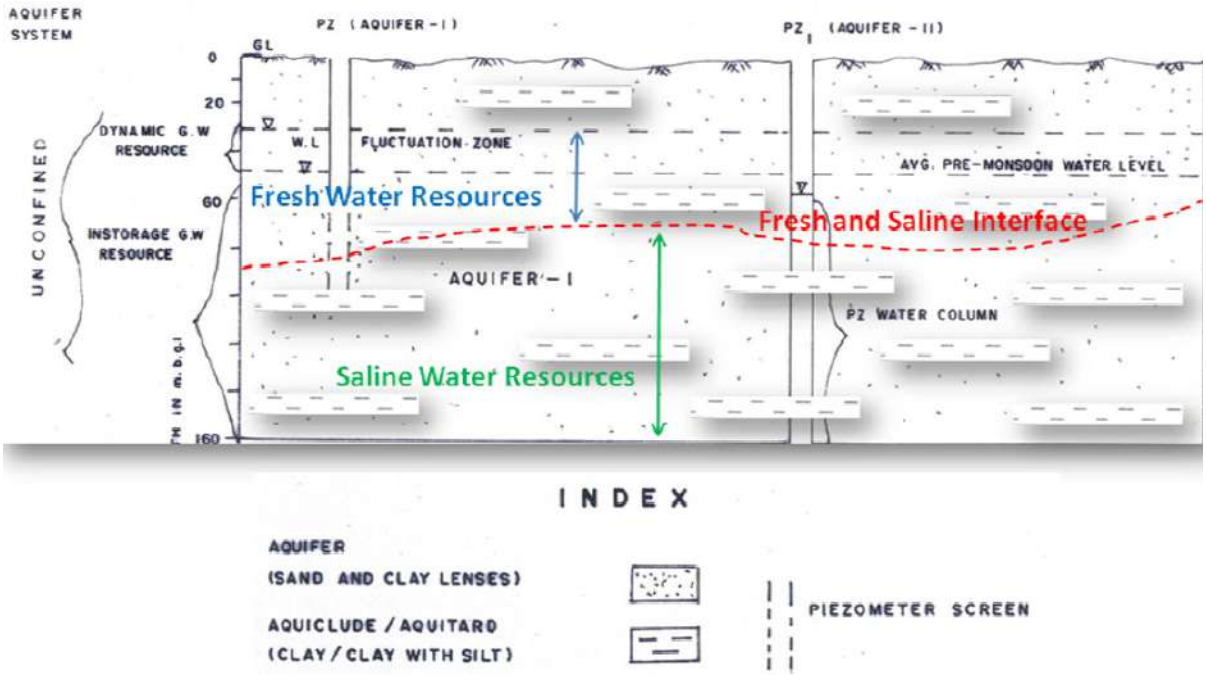


Table 5: Block Wise Instorage Fresh Ground Water Resources in Unconfined Single Aquifer System up to the Fresh-Saline Interface

Name of Assessment Unit	Type of rock formation	Areal extent (sq km)		Fresh-Saline Interface (m bgl)	Average Pre-monsoon Water Level (m bgl)	Total Thickness of formation below Pre-monsoon Water Level up to Fresh-Saline Interface (m) (5-6)	Thickness of the Granular Zone below Pre-monsoon WL up to Fresh Saline Interface (Fresh) (m)	Average Specific Yield	In-Storage Ground Water Resources [4*8*9] FRESH (mcm)
		Total Geo-graphical Area	**Fresh Water Area**						
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Baraguda	Alluvium	520.91	483.82	105	7	98	57.45	0.072	2001.27
Dabwali	Alluvium	838.92	661.42	78	10.28	67.72	30.87	0.072	1470.10
Ellenabad	Alluvium	549.35	479.74	175	16.5	158.5	67	0.072	2314.27
N S Chopta	Alluvium	723.94	554.07	100	10	90	6	0.072	239.36
Odhan	Alluvium	490.22	326.18	90	10.85	79.15	33	0.072	775.00
Rania	Alluvium	575.46	446.53	100	18.51	81.49	46.76	0.072	1503.34
Sirsa	Alluvium	577.20	577.20	105	28	77	39	0.072	1620.78
Distt. Total		**8552.01**	**3528.96**						**9924.12**

Table 6: Block Wise Instorage Saline Ground Water Resources in Unconfined Single Aquifer System up to the Fresh-Saline Interface

Name of Assessment Unit	Type of rock formation	Areal extent (sq km)		Fresh-Saline Interface (m bgl)	Average Pre-monsoon Water Level (m bgl)	Total Thickness of formation below Pre-monsoon Water Level/Fresh-Saline Interface (m) (5-6)	Thickness of the Granular Zone below Pre-monsoon WL/Fresh Saline Interface (Saline) (m)	Average Specific Yield	In-Storage Ground Water Resources [4*8*9] BRACKISH / SALINE (mcm)
		Total Geo-graphical Area	**Brackish /Saline Water**						
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Baraguda	Alluvium	520.91	37.09	105	7	98	57.45	0.072	153.42
Dabwali	Alluvium	838.92	177.50	78	10.28	67.72	30.87	0.072	394.52
Ellenabad	Alluvium	549.35	69.61	175	16.5	158.5	67	0.072	335.80
N S Chopta	Alluvium	723.94	169.87	100	10	90	6	0.072	73.38
Odhan	Alluvium	490.22	164.04	90	10.85	79.15	33	0.072	389.76
Rania	Alluvium	575.46	128.93	100	18.51	81.49	46.76	0.072	434.07
Sirsa	Alluvium	577.20	0	105	28	77	39	0.072	0
Distt. Total		**8552.01**	**577.17**						**1780.95**

Table 7: Block Wise Instorage Ground Water Resources below Fresh-Saline Interface (Up To 300m Depth)

Name of Assessment Unit	Type of rock formation	Areal extent (sq km)	Fresh-Saline Interface (m bgl)	Average Explored Depth (m bgl)	Total Thickness of formation below Fresh-Saline Interface (m) (5-6)	Thickness of the Granular Zone below Fresh Saline Interface (Saline) (m)	Average Specific Yield	In-Storage Ground Water Resources [(7)*(11)*(12)*] BRAKISH / SALINE (mcm)
		Total Area below Fresh Saline Interface						
1	2	3	4	5	6	7	8	9
Baraguda	Alluvium	520.91	105	265	160	33	0.072	1237.68
Dabwali	Alluvium	838.92	78	306	228	172.1	0.072	10395.23
Ellenabad	Alluvium	549.36	175	250	75	57	0.072	2254.53
N S Chopta	Alluvium	723.94	100	287	187	123	0.072	6411.21
Odhan	Alluvium	490.22	90	306	216	60.4	0.072	2131.87
Rania	Alluvium	575.46	100	265	165	66	0.072	2734.59
Sirsa	Alluvium	577.20	105	299	194	29	0.072	1205.19
Dist. Total		8552.01						**26370.30**

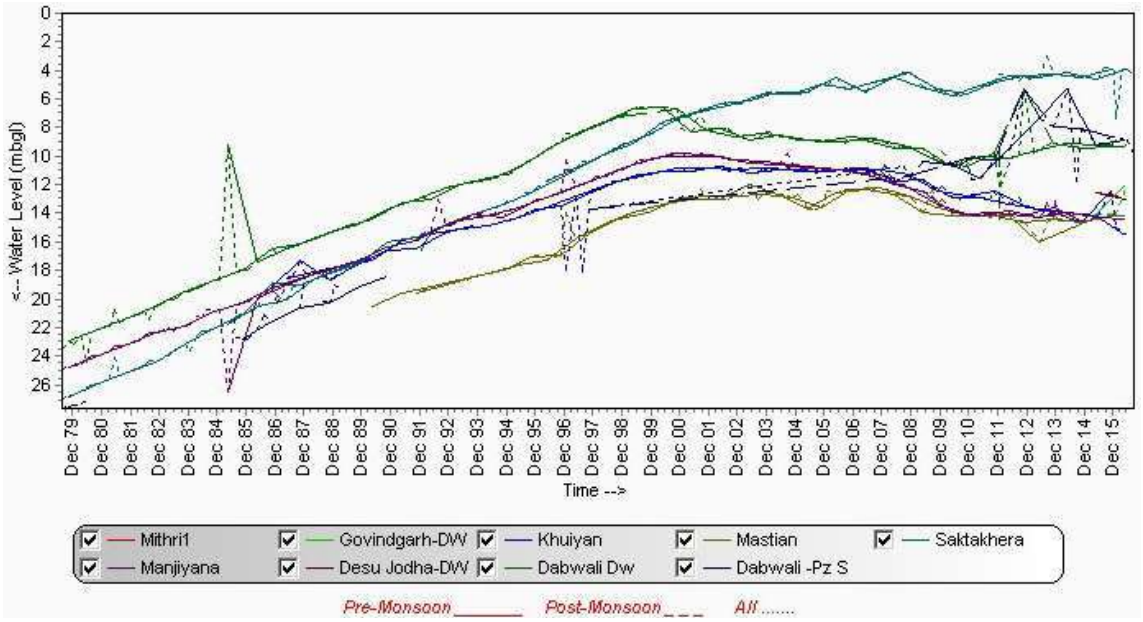
Table 8: Block Wise Total Available Ground Water Resources in Aquifer up to 300m Depth

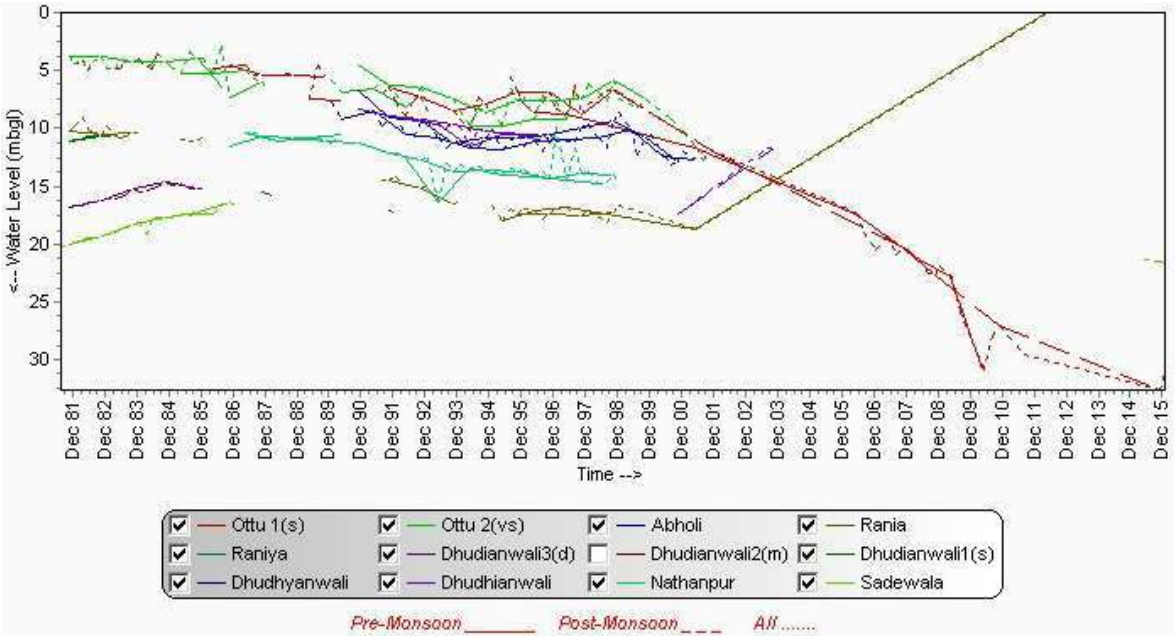
Assessment Unit/Block	Dynamic Ground water Resources (2013)	In-storage Groundwater Resources UPTO FRESH WATER ZONE	Total Groundwater Resources upto Avg. Depth of Fresh Water zone [(2)+(3)]	Total Saline Groundwater Resources up to the depth of wells available in each block	Total Availability of Fresh and Saline Groundwater Resources [(4)+(5)]	Volume of Unsaturated Granular Zones (above Water Level) for Natural Recharge (Considered below 3m bgl to WL)	Unsaturated Zone (in m)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Baraguda	118.1	2001.27	2119.37	1391.10	3510.47	93.76	1.50
Dabwali	94.98	1470.10	1565.08	10789.74	12354.82	302.01	3.00
Ellenabad	125.83	2314.27	2440.10	2590.33	5030.43	395.53	6.00
Ns Chopta	90.34	239.36	329.70	6484.60	6814.29	0.00	0.00
Odhan	63.06	775.00	838.06	2521.63	3359.69	185.30	3.15
Rania	55.87	1503.34	1559.21	3168.66	4727.87	331.46	4.80
Sirsa	88.6	1620.78	1709.38	1205.19	2914.57	865.80	12.50
Total	**636.78**	**9924.12**	**10560.90**	**28151.25**	**38712.15**	**2173.88**	

5. GROUND WATER RELATED ISSUES

The major issue in the district is deteriorated ground water quality (saline water), water logging and high extraction rate where the ground water quality is more or less fresh or marginal. The water logging and the declining water level trend can be seen in the hydrograph shown in fig 22.

Fig 22: Hydrographs of various sites in Sirsa district.





5.1 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 below in table , 10 and shown in fig 23.

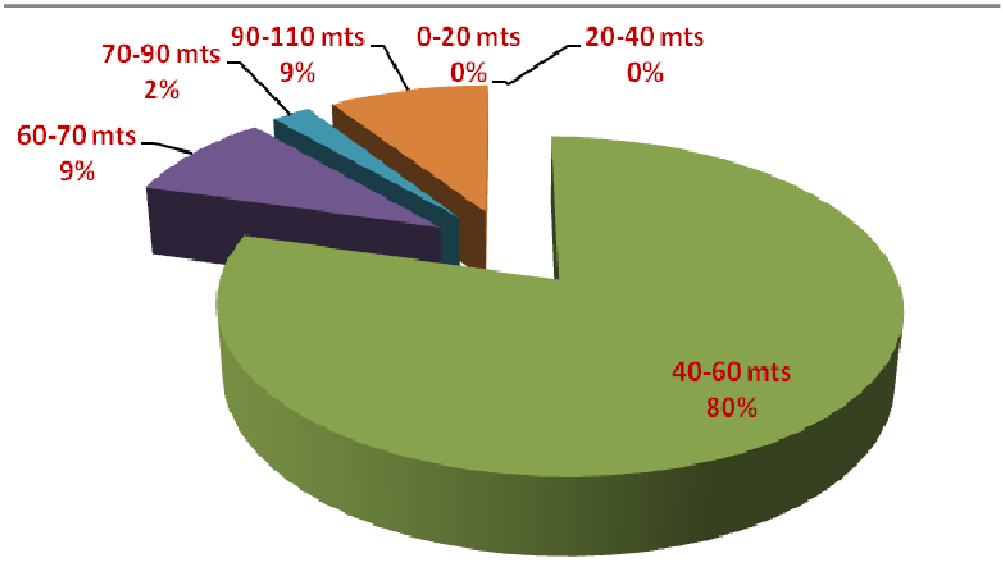
Table 9: Distribution of Tube wells According to Owner's land Holding Size

Marginal (0-1 ha)	Small (1-2 ha)	Semi-Medium (2-4 ha)	Medium (4-10ha)	Public	Group of Farmers	Total
102	1343	6841	4002	880	14588	27756

Table 10: Type of Ground water distribution device

Open Water Channel		
Lined/pucca	Unlined/kutcha	Total
20527	7229	27756

Fig 23: Irrigation tubewells as per depth range.



6. AQUIFER MANAGEMENT PLAN

Another focus has been given to minimize the gross draft by enhancing ground water use efficiency in irrigation system after replacing the water distribution system from unlined/kutcha channel to Under Ground Pipeline System (UGPS) for the whole Sirsa district.

6.1 Scope of Implementation

This plan is focusing on the technical aspects of the ground water recharge through various means 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. Artificial recharge plan for rural and urban areas, and through recharge pits is given in Table 11, 12 & 13 respectively.

Table 11: Artificial Recharge in Rural Area

Name of CD block	Total households (2011 census)	No of Houses taken for Artificial Recharge (10% of total households)	Total No of AR Structures (one structure for 10 households)	Annual Rainfall runoff Available for recharge (MCM) (No of households x avg rooftop area(200 sqm) x runoff coefficient (80%) x rainfall, 228mm)
Baraguda	21598	2160	2160	0.059
Dabwali	31629	3163	3163	0.071
Ellenabad	23409	2341	2341	0.058
Odhan	**19902**	1990	1990	0.052
Rania	24643	2464	2464	0.089
Sirsa	32079	3208	3208	0.122
NSChopta	30235	3024	3024	0.115
Total	**153260**	**15326.2**	**15326.2**	**0.452**

Table 12: Artificial Recharge in Urban Area

Name of **Block**	**Total Households**	**Housholds taken for Atificial Recharge (10%)**	**Total Roof Top Area (sqm)(=200 SQ.MT PER HOUSEHOLD)**	**Vol of water available for recharge (MCM)**
Dabwali	10770	1077	215400	0.032
Odhan	4431	443	88620	0.015
Sirsa	36191	3619	723820	0.184
Rania	4874	487	97480	0.023
Ellenabad	6810	681	136200	0.023

Table 13: Artificial Recharge through Recharge Pits in Farm

Block Name	Total Geographical Area (in Hectares)	10%of village area taken for farm recharge (sq m)	Total number of recharge pits (1 recharge pit / hector) for 10% area	Annual recharge (MCM)= (Area*Runoff 15%*Rainfall in mm/1000000)
Baraguda	53803	49989000	4999	1.710
Dabwali	81383	79074000	7907	2.230
Ellenabad	54696	54696000	5470	1.698
Odhan	48752	48752000	4875	1.587
Rania	56384	56384000	5638	2.546
Sirsa	53762	53762000	5376	2.564
N S Chopta	73431	73431000	7343	3.016
Total	**422211**	**416088000**	**41609**	**15.351**

6.2 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 7229 (out of 27756) tubewells (26%) operated by farmers for irrigation through unlined/Katcha open channel system in Sirsa district where water from the tubewell is discharge to the agricultural field. In this process huge (up to 20 %) quantity of ground water is wasted in soil moisture and evaporation losses. Around 80% of the tube wells are of shallow depth (40- 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 (2013) indicate that Gross ground water draft for irrigation in Sirsa district is estimated at 1116 MCM. It is expected that around 25% of over draft can be brought down by switching over to underground/surface pipeline based distribution from the prevailing unlined open channels. Thereby draft will be reduced up to 1023 MCM assuming there is no crop diversification by the farmers.The benefit will lead to saving of precious ground water resources in the area. The measure if implemented will bring down the stage of ground water development from 175% to 116%. The category of the blocks will also improve drastically resulting in boosting of agriculture and industrial development which may be otherwise not sustainable for future.

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. Reduction in stage of development after construction of Pucca channels in irrigated land is given in table-14.

6.3 Water Saving Through 3/5 Pond System

The disposal of waste water in rural/villages is a major problem. The stagnant of waste water smells bad and also acts as breading place for mosquitoes resulting in spread of diseases. Therefore proper disposal and reuse of waste water wherever possible will help in controlling diseases as well as meting out scarcity of water. The Seechewal model for treatment of water in natural ways for reuse in irrigation is well adopted. The treated water can also be used for gardening, fodder raising and kitchen gardening.

For the treatment of waste water at village level by natural way, a three pond/ five pond system may be adopted. The grey water of the village collected through the

drains/nallas , collected at a common point and passed through the iron mesh of different sizes and then allowed to pass through large shallow ponds where grey water is stabilize and pond water can be used for irrigation & fishery. The water saving through pond system has been calculated and is given in table 15. The field photographs of this 3/5 pond systems adopted in different villages of Karnal district are given below.

A view of village tanks of five pond / three pond system

6.4 Water Saving Potential from Crop Diversification –

6.4.1 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.

Scope of quantitative impact on stage of development after applying various management strategies is given in Table 16.

Table 14: Reduction in stage of development after construction of Pucca channels in irrigated land

Block	Net Annual Ground Water Availability (mcm)	Gross Irrigation Draft (presenti n mcm)	Gross Ground Water Draft for Domestic & industrial supply (mcm)	Percentage of unlined channel	Wastage through unlined channel, (mcm)	Potential of Reduced irrigation overdraft (3-6) (mcm)	Gross draft after saving of water (mcm)	Present Stage of Development (%)	Reduction in stage of development after constructing pucca channel
Baraguda	118.1	133.74	0.1	26	8.6931	125.05	125.15	113	106
Dabwali	94.98	235.48	0.42	26	15.306	220.17	220.59	248	232
Ellenabad	125.83	182.85	1.55	26	11.885	170.96	172.51	147	137
NSChopta	90.34	112.34	0.36	26	7.3021	105.04	105.4	125	117
Odhan	63.06	78.5	0.4	26	5.1025	73.398	73.798	125	117
Rania	55.87	178.85	1.78	26	11.625	167.22	169	323	303
Sirsa	88.6	185.75	3.88	26	12.074	173.68	177.56	214	200
Total	**636.78**	**1107.51**	**8.49**		**71.988**	**1035.5**	**1044**	**175**	**164**

Table 15: Reduction in stage of development after adopting 3/5 pond system

Block	Net Annual Ground Water Availability (mcm)	Total draft (mcm)	Saving of water through waste water of pond (mcm)	Gross draft after saving of water(mcm)	Existing stage of Development (%)	SOD after wards (%)
Baragudha	118.10	133.84	2.34	131.50	113	111
Dabwali	94.98	235.90	3.42	232.48	248	245
Ellenabad	125.83	184.40	2.57	181.83	147	145
Nathusari chopta	90.34	112.70	3.35	109.35	125	121
Odhan	63.06	78.90	2.17	76.73	125	122
Rania	55.87	180.63	2.70	177.93	323	318
Sirsa	88.60	189.63	3.40	186.23	214	210
TOTAL	**636.78**	**1116.00**	**19.95**	**1096.05**	**175**	**172**

Table 16: Scope of Quantitative Impact on Stage of Development after applying various management strategies

Block	Net Ground Water Availability (mcm)	Total Draft (mcm)	Present Stage of draft (SOD) (%) As per 2013	Reduction in draft by different water saving method				SOD afterwards	% paddy area to be converted to maize/ soyabean
				Replace water courses by UG Pipes (mcm)	Adopt artificial recharge (mcm)	Adopting 3/5 Pond system (mcm)	Crop Divesification to Maize (mcm)	(%)	
Baraguda	118.1	133.84	113	10.43	1.77	2.34	1.2	100	23
Dabwali	94.98	235.9	248	18.37	2.33	3.42	27.44	194	100
Ellenabad	125.83	184.4	147	14.26	1.78	2.57	39.96	100	89
NS Chopta	90.34	112.7	125	8.76	3.13	3.35	7.12	100	60
Odhan	63.06	78.9	125	6.12	1.65	2.17	1.43	107	100
Rania	55.87	180.63	323	13.95	2.66	2.7	105.45	100	95
Sirsa	88.6	189.63	214	14.49	2.87	3.4	80.27	100	93
Total	**636.78**	**1116**	**175**	**86.38**	**16.19**	**19.95**	**262.87**	**115**	

7. BLOCK WISE AQUIFER MAPS

AND

MANAGEMENT PLAN

I. Baragaudha Block (520.91 sq km)

Population (2011)	Rural-114445 Urban-0 Total-114445
Rainfall	Monsoon -163.4mm Non Monsoon-64.20mm
Average Annual Rainfall	227.6mm
Agriculture and Irrigation	Major Crops- Wheat, Rice, Barley& Bajra Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies Net Area Sown-492.41sqkm Total Irrigated Area-445.52sqkm
Water Bodies	11 nos.

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

Water level Behavior(2015):

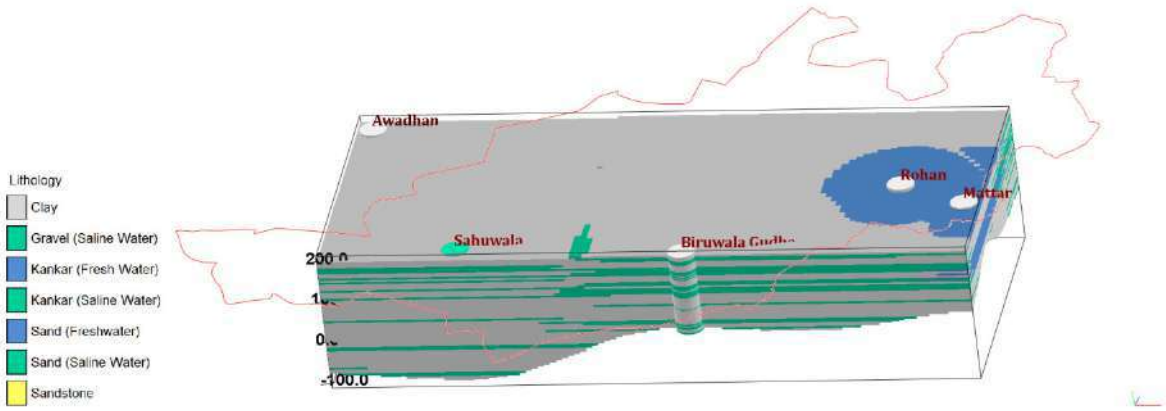
Pre Monsoon-5.5-11.3 mbgl & Post Monsoon-5.1-12.0 mbgl

Aquifer Disposition: Single Aquifer System

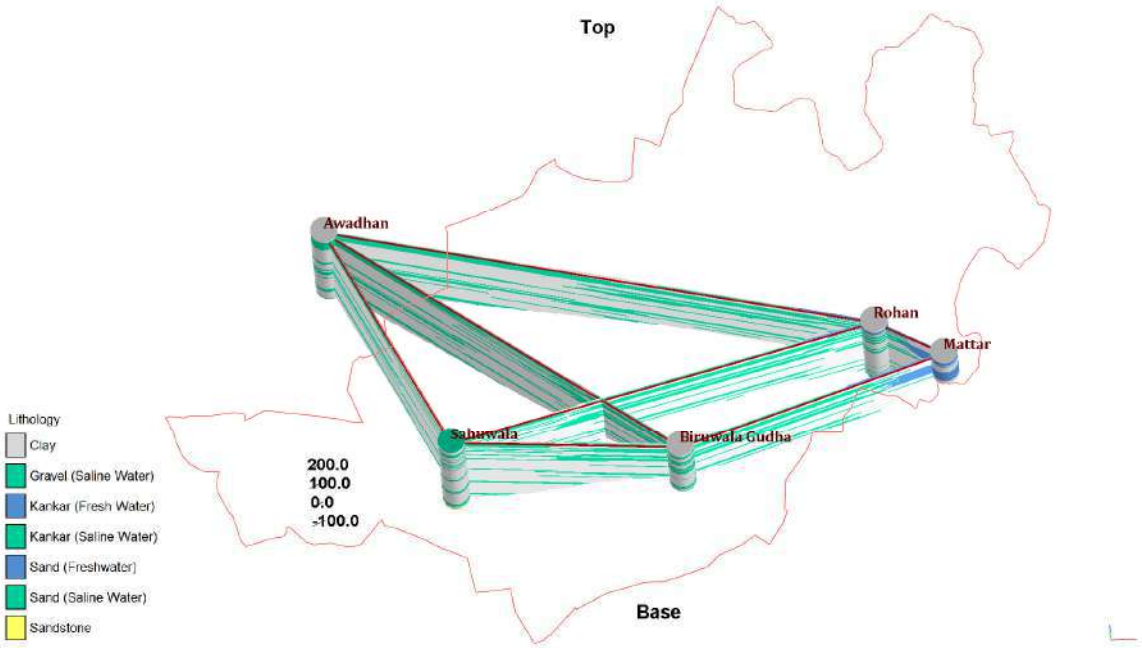
Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand, kankar and gravels. The non-aquifer material comprises of clay. The average depth of the fresh saline interface is at 105m bgl.

Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (5-265m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	92	-	12	NA

3D Lithology model

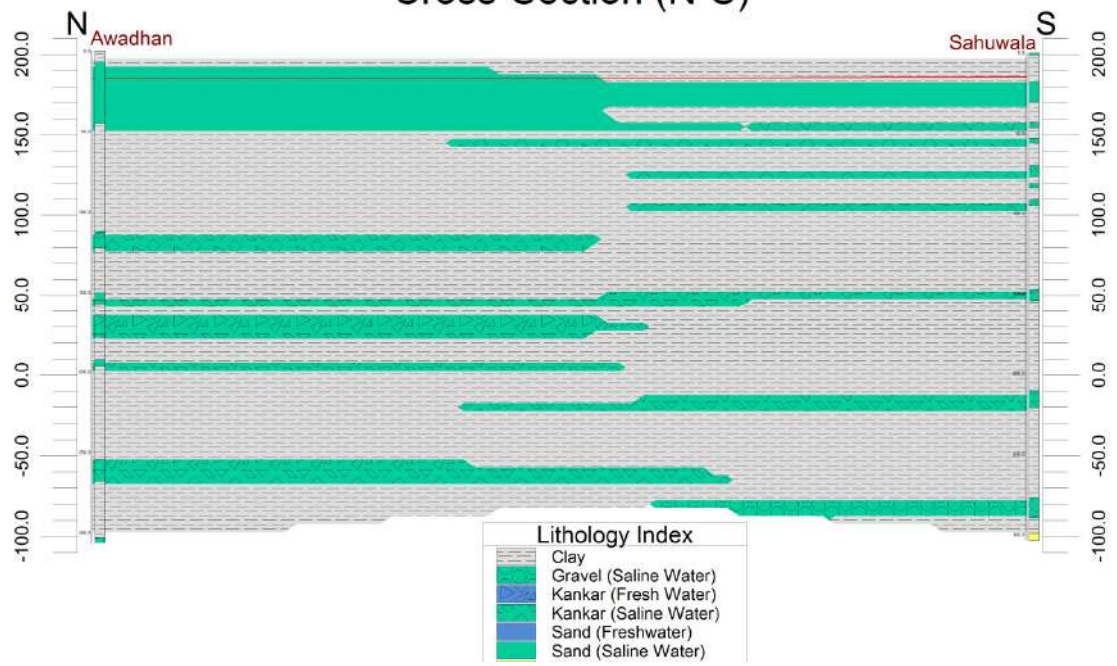


3D Lithology Fence

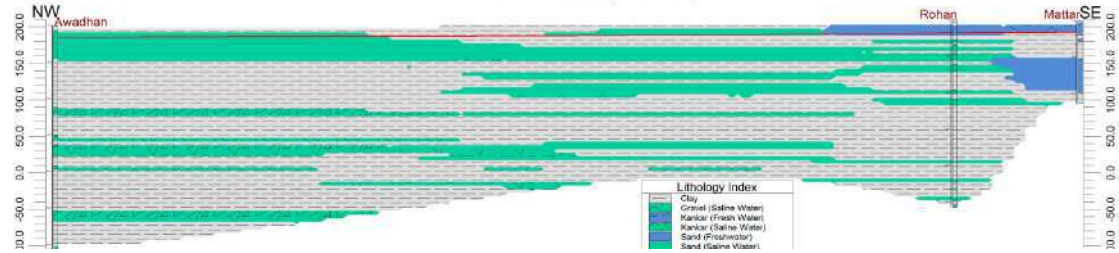


Cross-Section (NE-SW)

Cross-Section (N-S)



Cross-Section (NW-SE)



Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	118.10
	In-storage Aquifer I	3392.37(F=2001.27, S=1391.10)
	Total	3510.47
Ground Water Extraction (mcm)	Irrigation (2013)	133.74
	Domestic & Industrial (2013)	0.10
Future Demand for domestic & Industrial sector (2025) (in mcm)		0.10
Chemical Quality of ground water		Salinity problem in deeper aquifers (Details in ANNEXURE II)
Other issues		Declining ground water level trend (50.8-52.4cm/yr)

Ground Water Resource Enhancement

Aquifer wise space available for artificial recharge and proposed interventions	Volume of unsaturated zone upto the average depth to water level (7m) is 93.76mcm.
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 5.27mcm volume of water wastage
Change in cropping pattern	Proposed change in cropping pattern from Paddy to maize/soyabean in 12% of the total area. Anticipated volume of water to be saved by maize is 3.54 mcm
Alternate water sources	Tanks, ponds and canals
Regulation and Control	No (Not Notified)
Other interventions proposed, if any	-

II. Dabwali Block (838.92 sq km)

Population (2011)	Rural-167176 Urban-52873 Total-220049
Rainfall	Monsoon -135.40mm Non Monsoon-52.80mm
Average Annual Rainfall	188.2mm
Agriculture and Irrigation	Major Crops- Wheat, Rice, Barley& Bajra Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies Net Area Sown-742.59sqkm Total Irrigated Area-664.26sqkm
Water Bodies	0 nos.

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

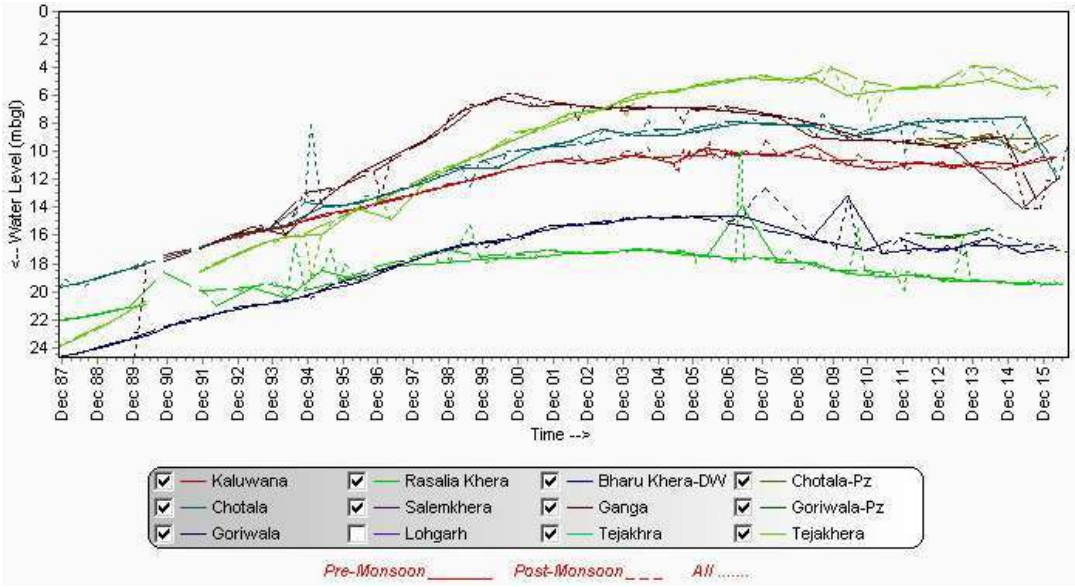
Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

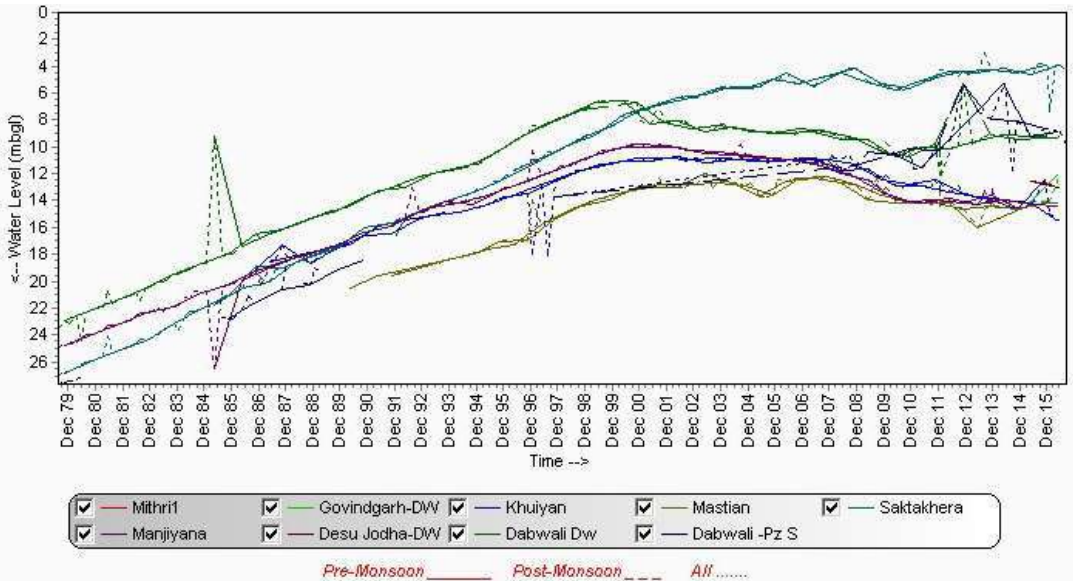
Water level Behavior(2015):

Pre Monsoon-4.6-19.4mbgl&Post Monsoon-3.9-19.6mbgl

Aquifer Disposition: Single Aquifer System

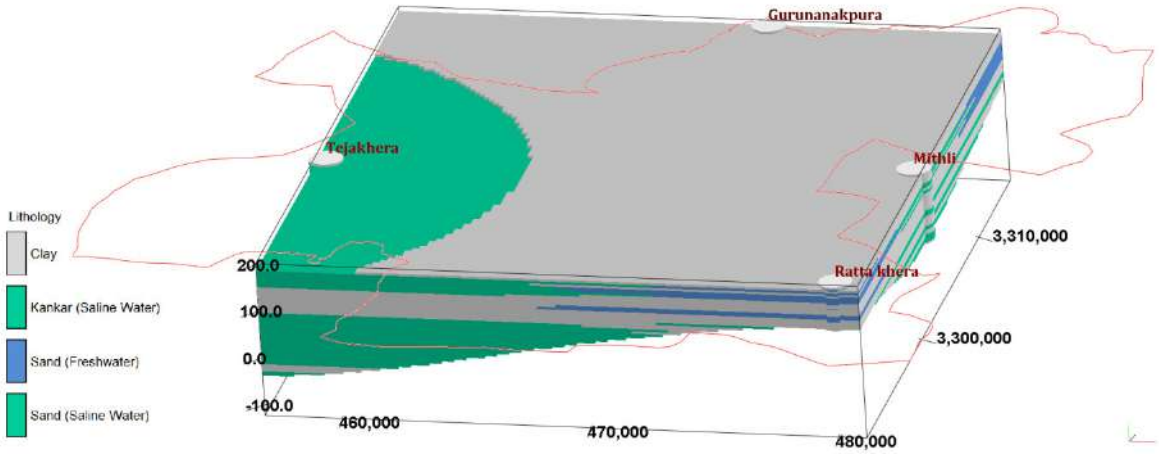
Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand and kankar. The non-aquifer material comprises of clay. The average depth of the fresh saline interface is at 78m bgl.



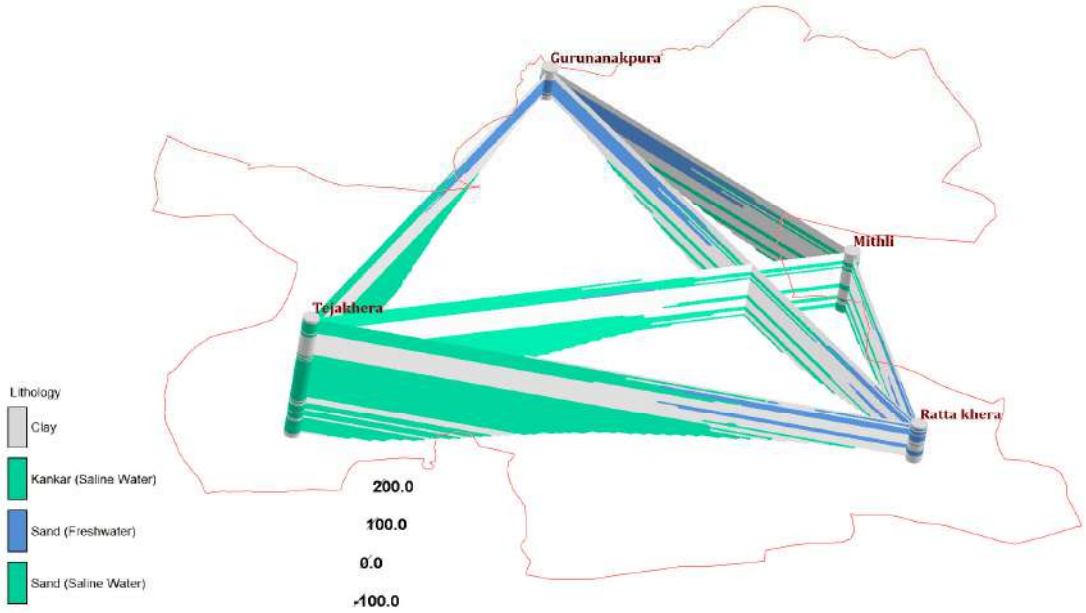


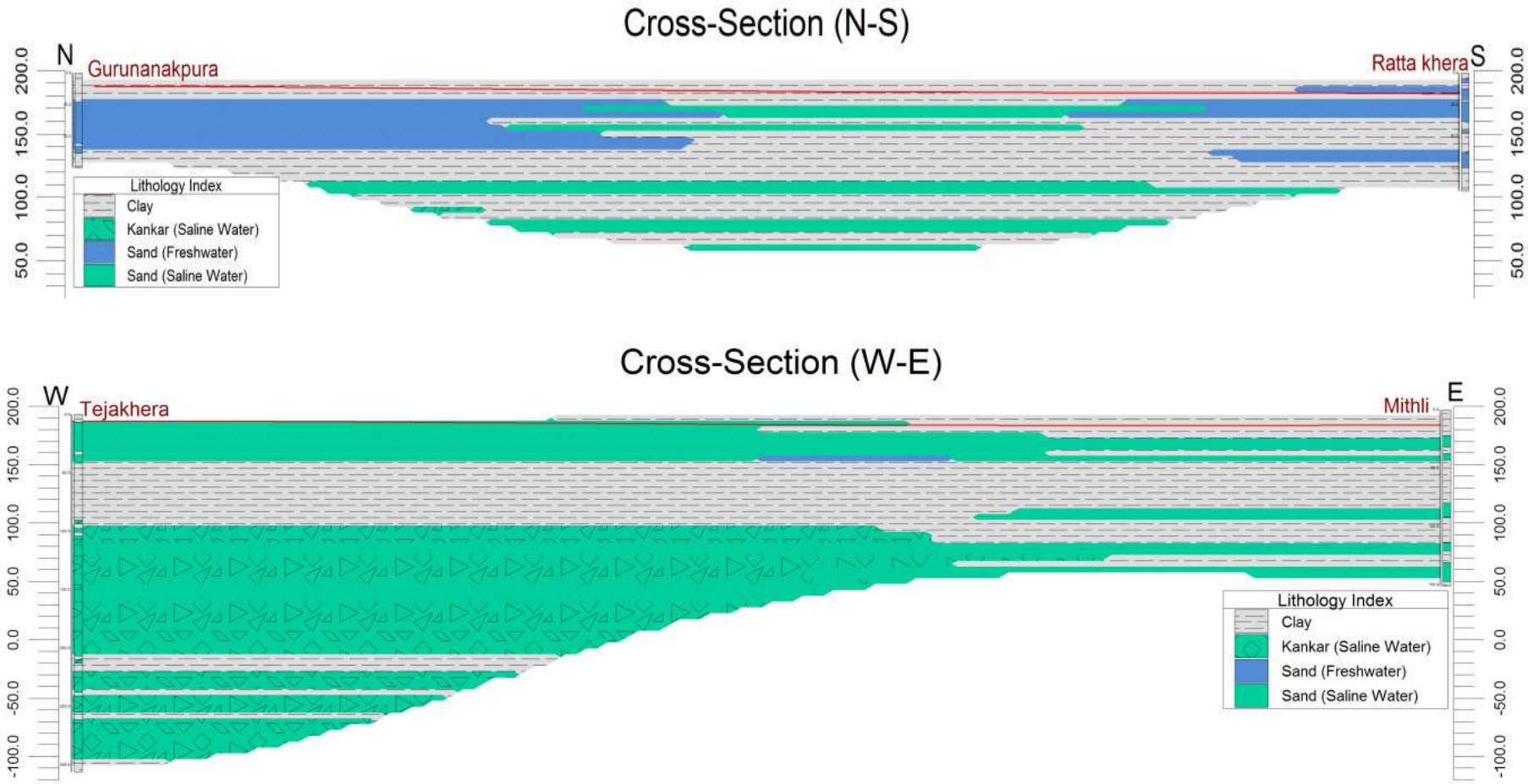
Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (5-306m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	205.97	-	12	NA

3D Lithology model



3D Lithology Fence




Cross-Section (N-S)
N
Gurunanakpura
Ratta khera
S
200.0
150.0
100.0
50.0
Lithology Index
Clay
Kankar (Saline Water)
Sand (Freshwater)
Sand (Saline Water)
Cross-Section (W-E)
W
Tejakhera
Mithli
E
200.0
150.0
100.0
50.0
0.0
-50.0
-100.0
Lithology Index
Clay
Kankar (Saline Water)
Sand (Freshwater)
Sand (Saline Water)

Ground Water Resource, Extraction, Contamination and other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	94.98
	In-storage Aquifer I	12259.84 (F=1470.10, S=10789.74)
	Total	12354.82
Ground Water Extraction (mcm)	Irrigation (2013)	235.48
	Domestic & Industrial (2013)	0.42
Future Demand for domestic & Industrial sector (2025) (in mcm)		0.42
Chemical Quality of ground water		Salinity problem in deeper aquifers (Details in ANNEXURE II)
Other issues		Declining water level trend (17-18cm/yr)

Ground Water Resource Enhancement

Aquifer wise space available for artificial recharge and proposed interventions	Volume of unsaturated zone upto the average depth to water level (10m) is 302mcm.
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 15.31mcm volume of water wastage
Change in cropping pattern	Proposed change in cropping pattern from Paddy to maize/soyabean in 100% area of the block. Anticipated volume of water to be saved by maize is 27.44mcm.
Alternate water sources	Tanks, ponds and canals
Regulation and Control	Not Notified
Other interventions proposed, if any	-

III. Ellanabad Block (125.83 sq km)

Population (2011)	Rural-125868 Urban-36623 Total-162491
Rainfall	Monsoon -146.20mm Non Monsoon-60.80mm
Average Annual Rainfall	207mm
Agriculture and Irrigation	Major Crops- Wheat, Rice, Barley& Bajra Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies Net Area Sown-503.18sqkm Total Irrigated Area-415.71sqkm
Water Bodies	0 nos.

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

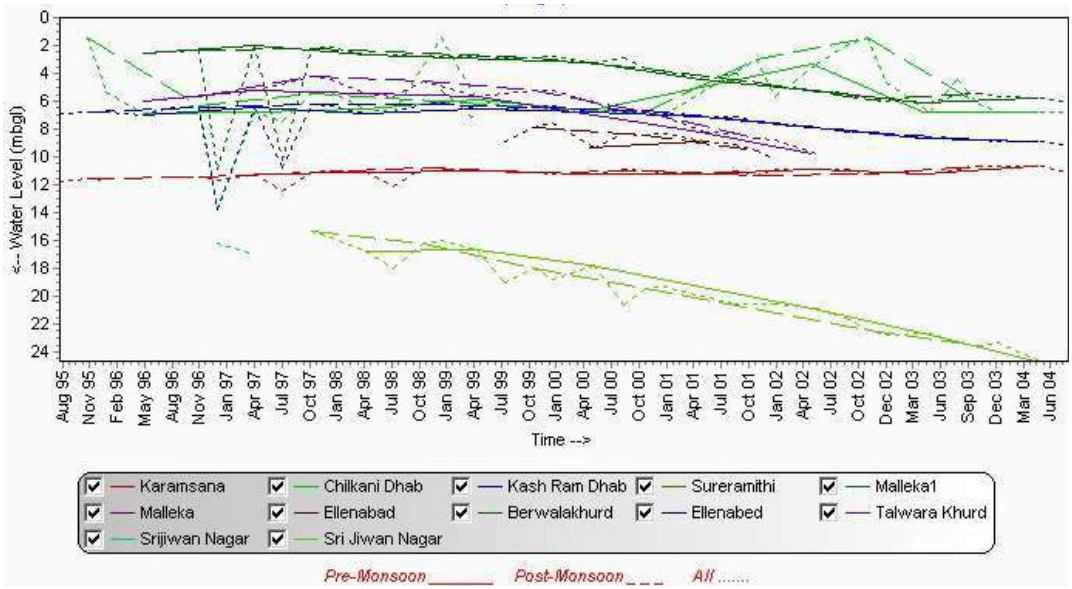
Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

Water level Behavior(2015):

Pre Monsoon-1.7-43.6mbgl&Post Monsoon-1.7-44.8mbgl

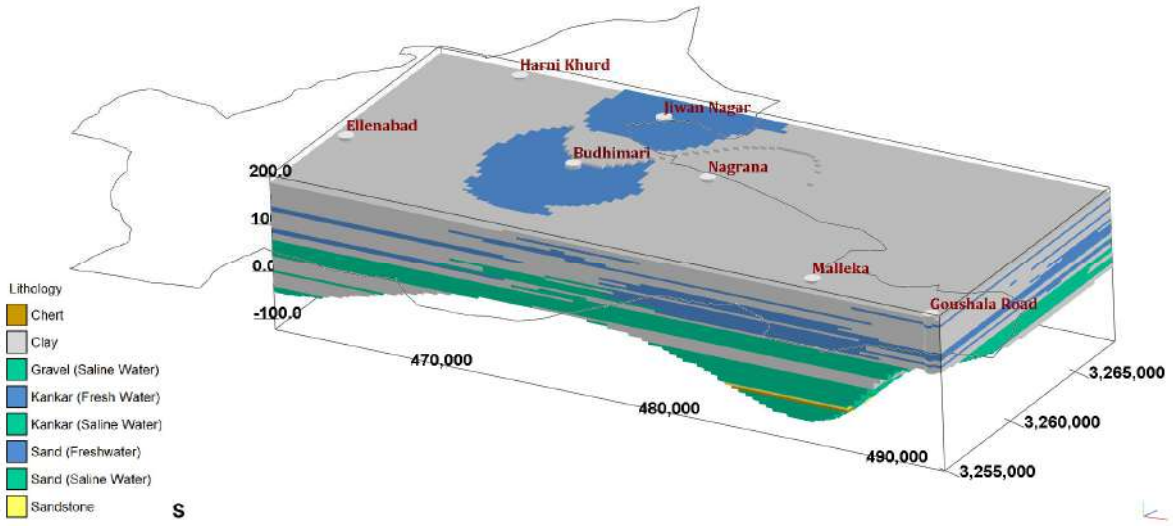
Aquifer Disposition: Single Aquifer System

Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand, kankar and gravels. The non-aquifer material comprises of clay, chert and sandstone. The average depth of the fresh saline interface is at 175m bgl.

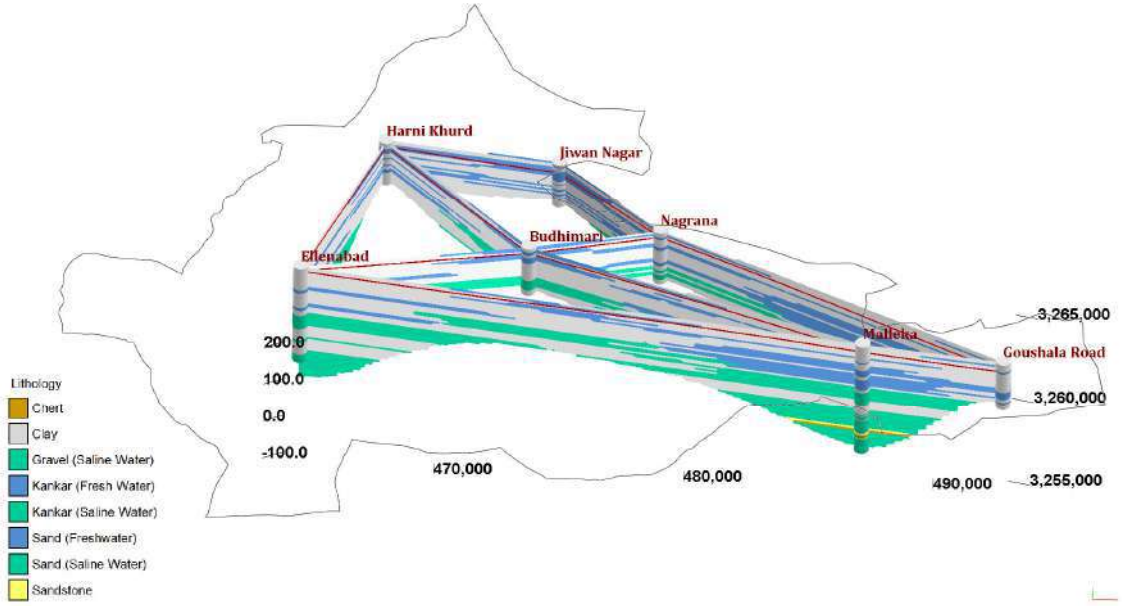


Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (5-250m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	130	375	12	NA

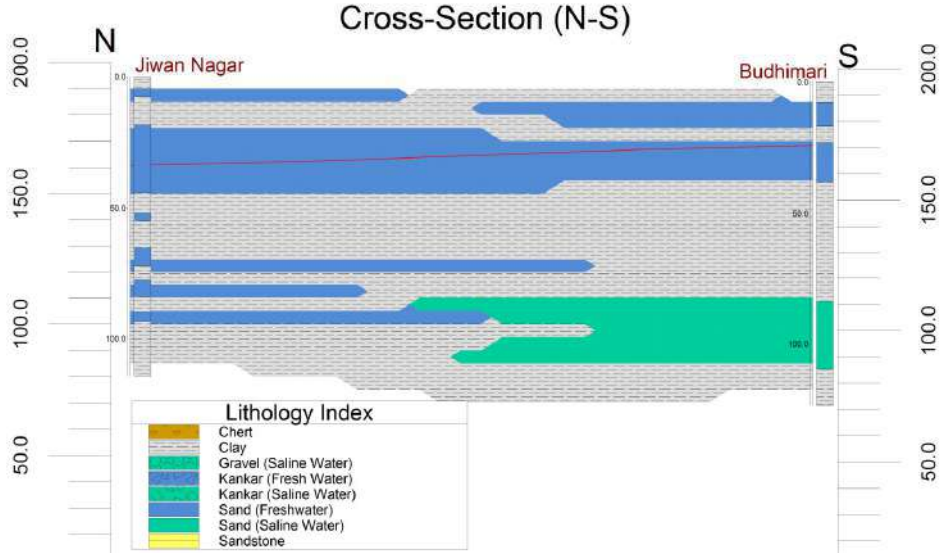
3D Lithology model



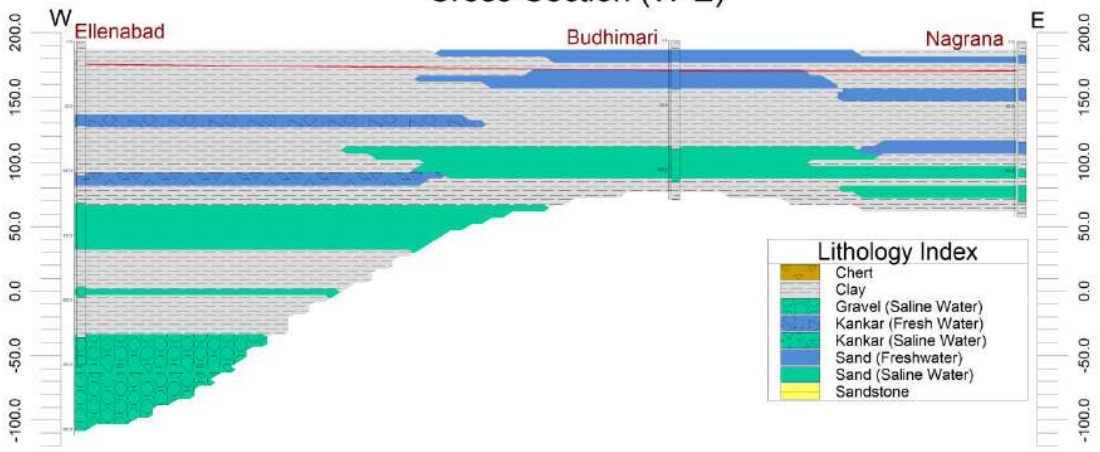
3D Lithology Fence

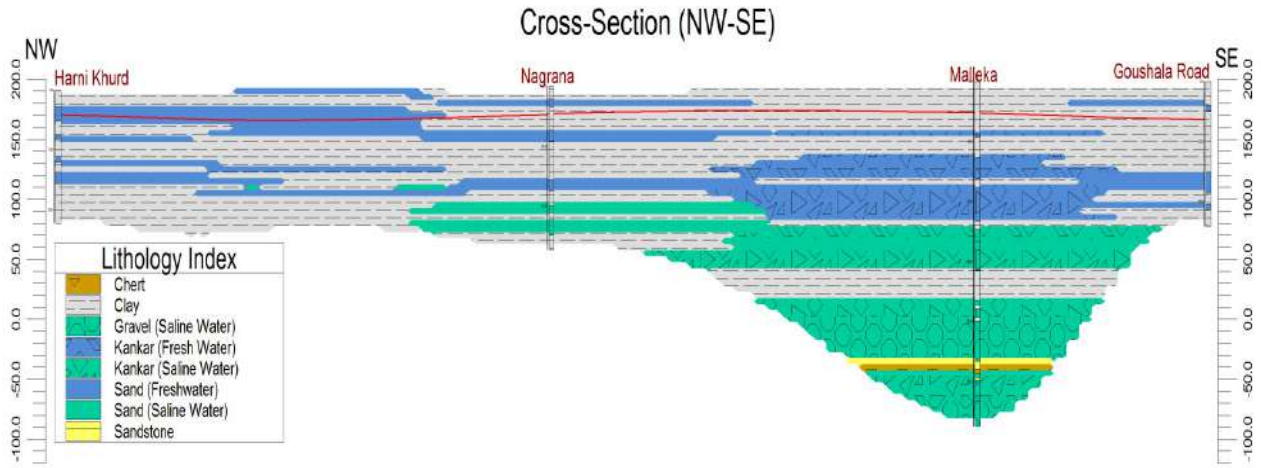


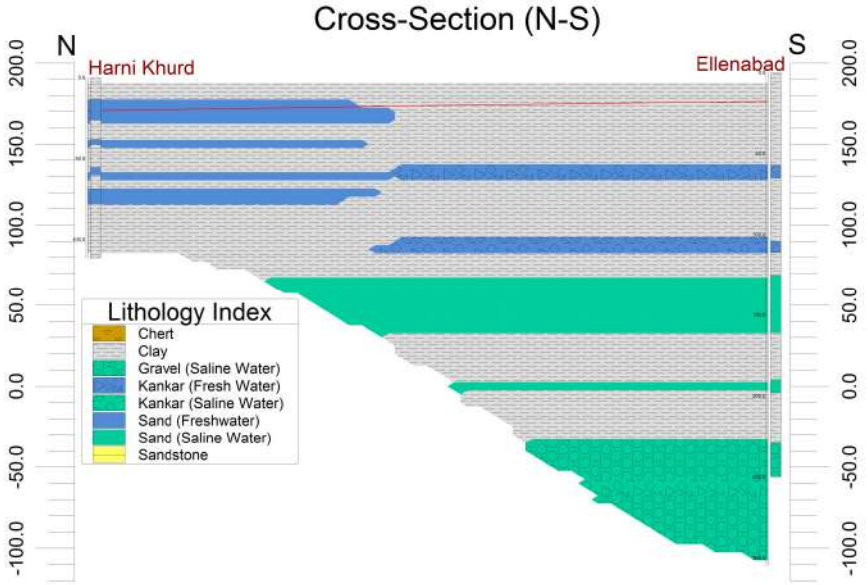
Cross-Section (N-S)

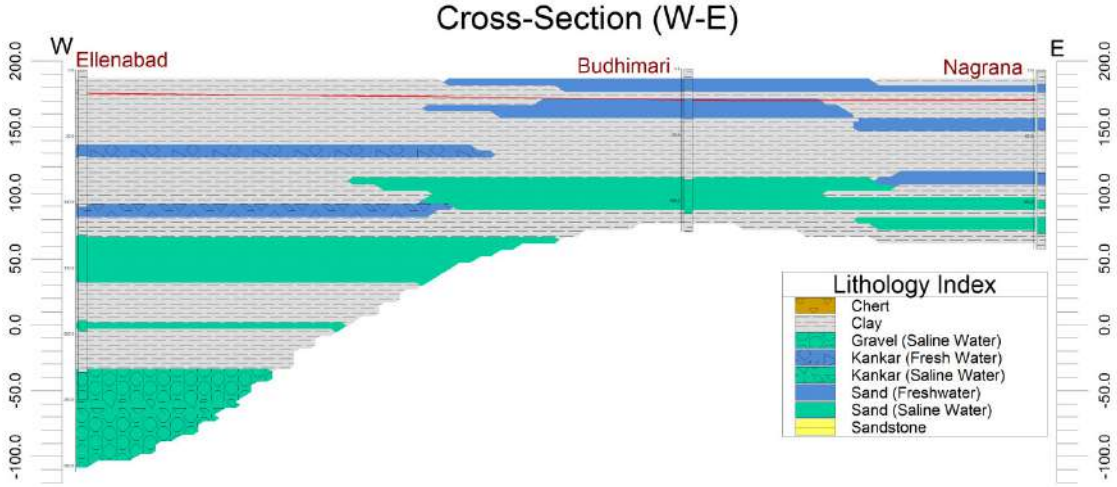


Cross-Section (W-E)




Cross-Section (NW-SE)
NW
SE
Harni Khurd
Nagrana
Malleka
Goushala Road
200.0
150.0
100.0
50.0
0.0
-50.0
-100.0
Lithology Index
Chert
Clay
Gravel (Saline Water)
Kankar (Fresh Water)
Kankar (Saline Water)
Sand (Freshwater)
Sand (Saline Water)
Sandstone


Cross-Section (N-S)
N
S
Harni Khurd
Ellenabad
200.0
150.0
100.0
50.0
0.0
-50.0
-100.0
Lithology Index
Chert
Clay
Gravel (Saline Water)
Kankar (Fresh Water)
Kankar (Saline Water)
Sand (Freshwater)
Sand (Saline Water)
Sandstone


Cross-Section (W-E)
W
E
Ellenabad
Budhimari
Nagrana
200.0
150.0
100.0
50.0
0.0
-50.0
-100.0
Lithology Index
Chert
Clay
Gravel (Saline Water)
Kankar (Fresh Water)
Kankar (Saline Water)
Sand (Freshwater)
Sand (Saline Water)
Sandstone

Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	125.83
	In-storage Aquifer I	49046 (F=2314.27, S=2590.33)
	Total	5030.43
Ground Water Extraction (mcm)	Irrigation (2013)	182.85
	Domestic & Industrial (2013)	1.55
Future Demand for domestic & Industrial sector (2025) (in mcm)		1.55
Chemical Quality of ground water		Salinity problem in deeper aquifers
Other issues		Declining water level trend (134-141cm/yr)

Ground Water Resource Enhancement

Aquifer wise space available for artificial recharge and proposed interventions	Volume of unsaturated zone upto the average depth to water level (17m) is 396mcm.
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 11.89mcm volume of water wastage
Change in cropping pattern	Proposed change in cropping pattern from Paddy to maize/soyabean in 24% area of the block. Anticipated volume of water to be saved by maize is 44.9mcm.
Alternate water sources	Tanks, ponds and canals
Regulation and Control	Notified (2012)
Other interventions proposed, if any	-

IV. Nathusari Chopta Block (723.94 sq km)

Population (2011)	Rural-163943 Urban-0 Total-163943
Rainfall	Monsoon -255.20mm Non Monsoon-62.60mm
Average Annual Rainfall	317.8mm
Agriculture and Irrigation	Major Crops- Wheat, Rice, Barley& Bajra Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies Net Area Sown-643.67sqkm Total Irrigated Area-527.92sqkm
Water Bodies	57 nos.

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

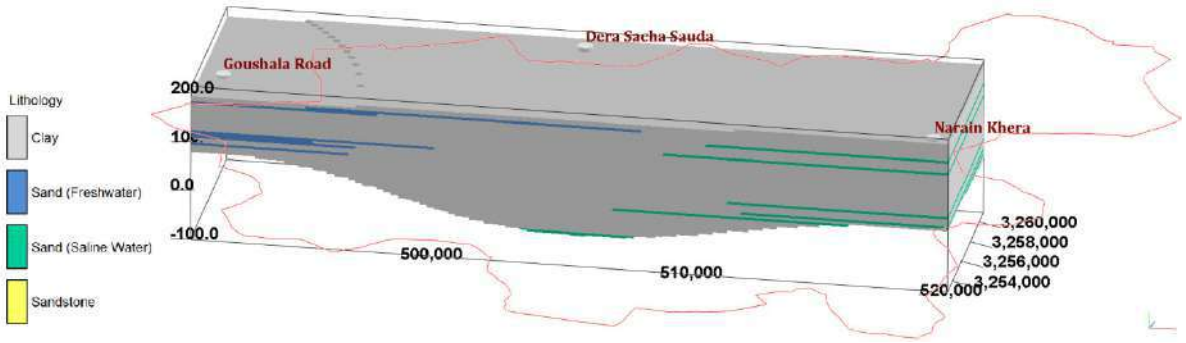
Water level Behavior(2015): Pre Monsoon-1.6-29.2mbgl&Post Monsoon-1.5-29.2mbgl

Aquifer Disposition: Single Aquifer System

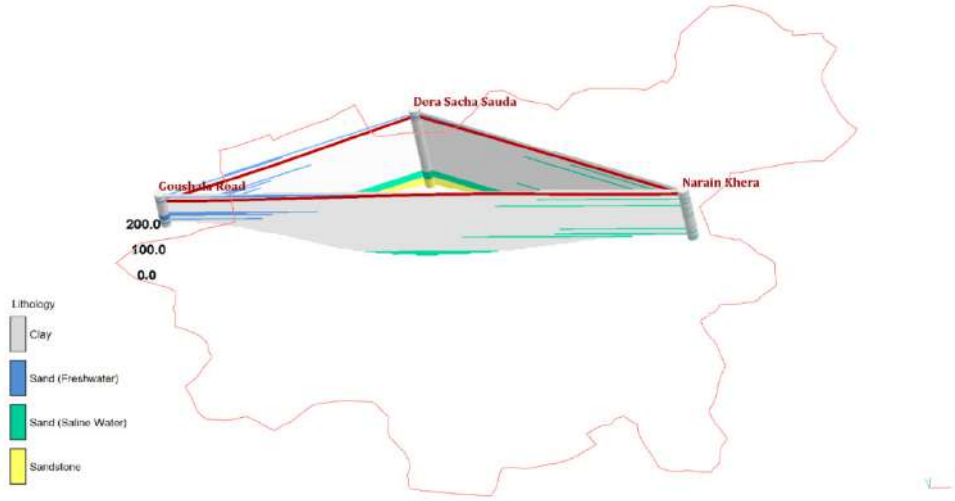
Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand, kankar and gravels. The non-aquifer material comprises of clay. The average depth of the fresh saline interface is at 100m bgl.

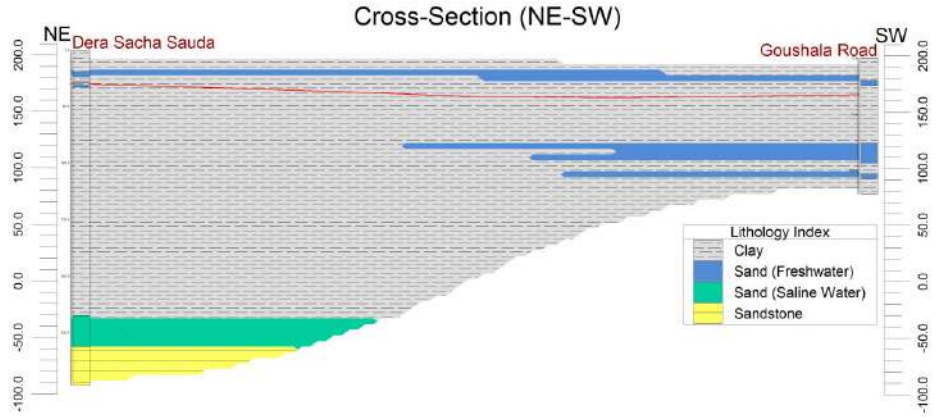
Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (19-287m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	129	2600	12	NA

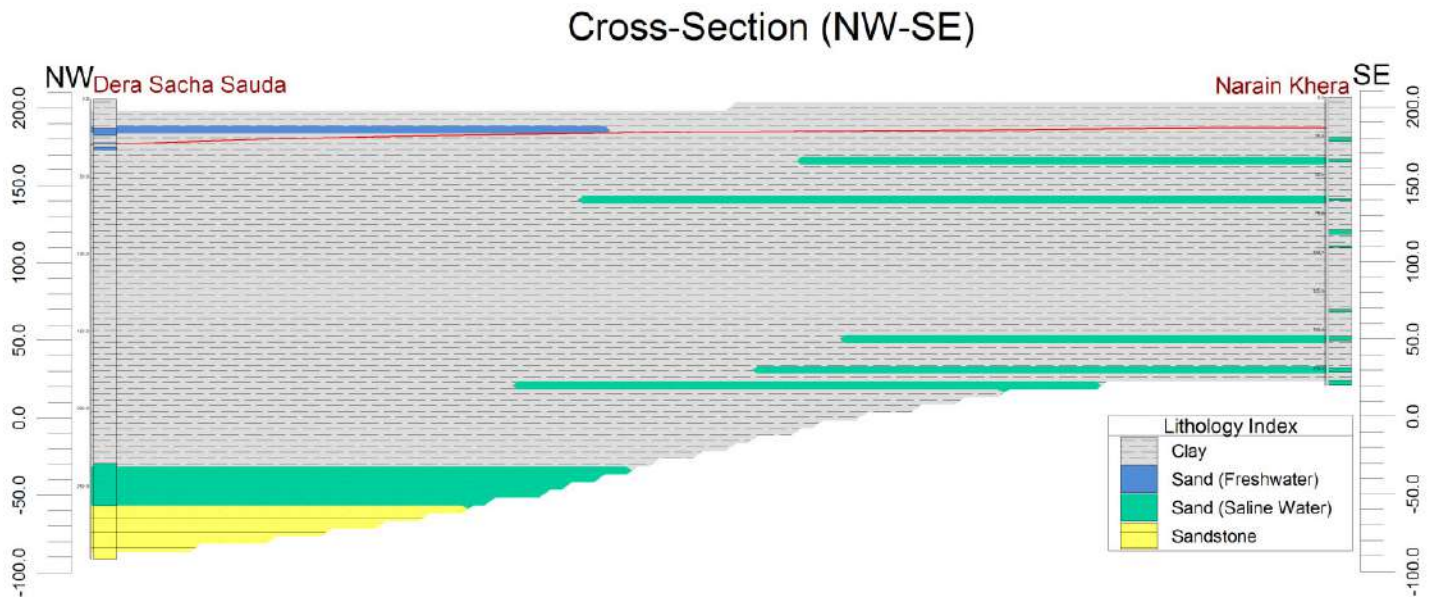
3D Lithology model

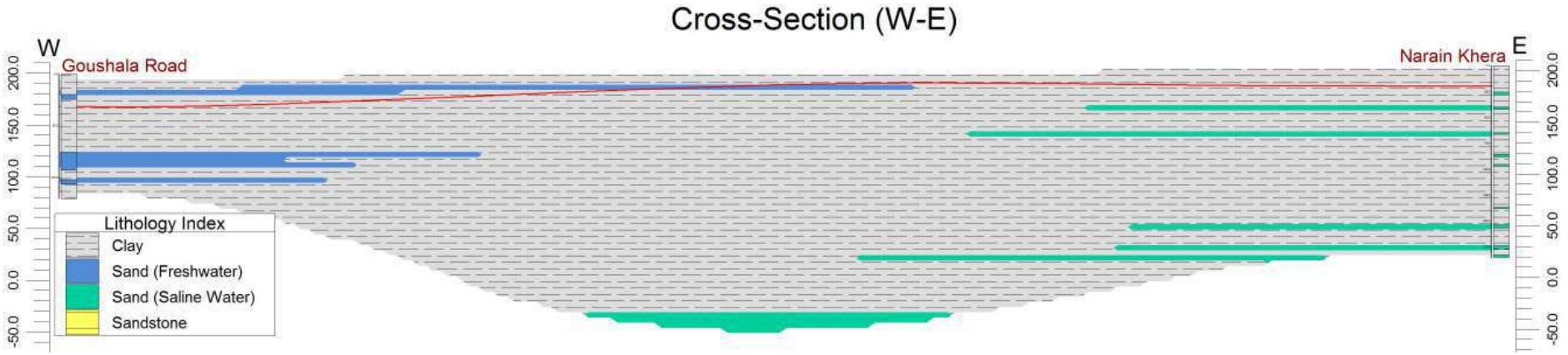


3D Lithology Fence






Cross-Section (NW-SE)
NW
Dera Sacha Sauda
Narain Khera
SE
200.0
150.0
100.0
50.0
0.0
-50.0
-100.0
Lithology Index
Clay
Sand (Freshwater)
Sand (Saline Water)
Sandstone


Cross-Section (W-E)
W
Goushala Road
Narain Khera
E
200.0
150.0
100.0
50.0
0.0
-50.0
Lithology Index
Clay
Sand (Freshwater)
Sand (Saline Water)
Sandstone

Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	90.34
	In-storage Aquifer I	6723.96(F=239.36, S=6484.60)
	Total	68143
Ground Water Extraction (mcm)	Irrigation (2013)	112.34
	Domestic & Industrial (2013)	0.36
Future Demand for domestic & Industrial sector (2025) (in mcm)		0.36
Chemical Quality of ground water		Salinity problem (Details in ANNEXURE II)
Other issues		Declining ground water level trend (21.8-24.9cm/yr)

Ground Water Resource Enhancement

Aquifer wise space available for artificial recharge and proposed interventions	Volume of unsaturated zone upto the average depth to water level (10m) is 0mcm. (based on limited litholog data)
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 8.76mcm volume of water wastage
Change in cropping pattern	Proposed change in cropping pattern from Paddy to maize/soyabean in 29% of the total area. Anticipated volume of water to be saved by maize is 10.47 mcm
Alternate water sources	Tanks, ponds and canals
Regulation and Control	No (Not Notified)
Other interventions proposed, if any	-

V. Odhan Block (490.22 sq km)

Population (2011)	Rural-106120 Urban-0 Total-106120
Rainfall	Monsoon -176.40mm Non Monsoon-40.60mm
Average Annual Rainfall	217mm
Agriculture and Irrigation	Major Crops- Wheat, Rice, Barley& Bajra Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies Net Area Sown-437.07sqkm Total Irrigated Area-397.26sqkm
Water Bodies	2 nos.

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

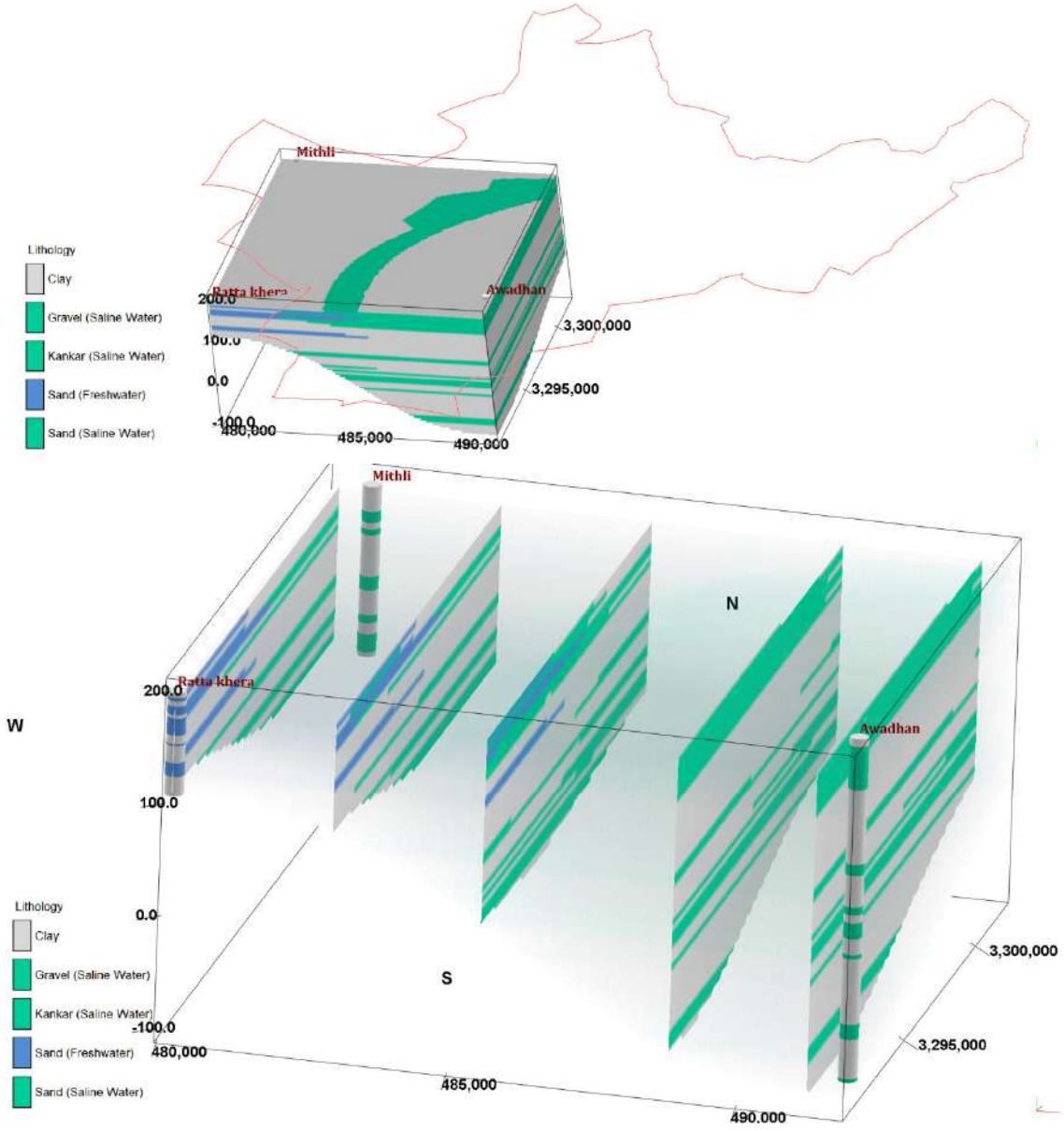
Water level Behavior(2015): Pre Monsoon-6.6-17.6mbgl&Post Monsoon-6.8-17.5mbgl

Aquifer Disposition: Single Aquifer System

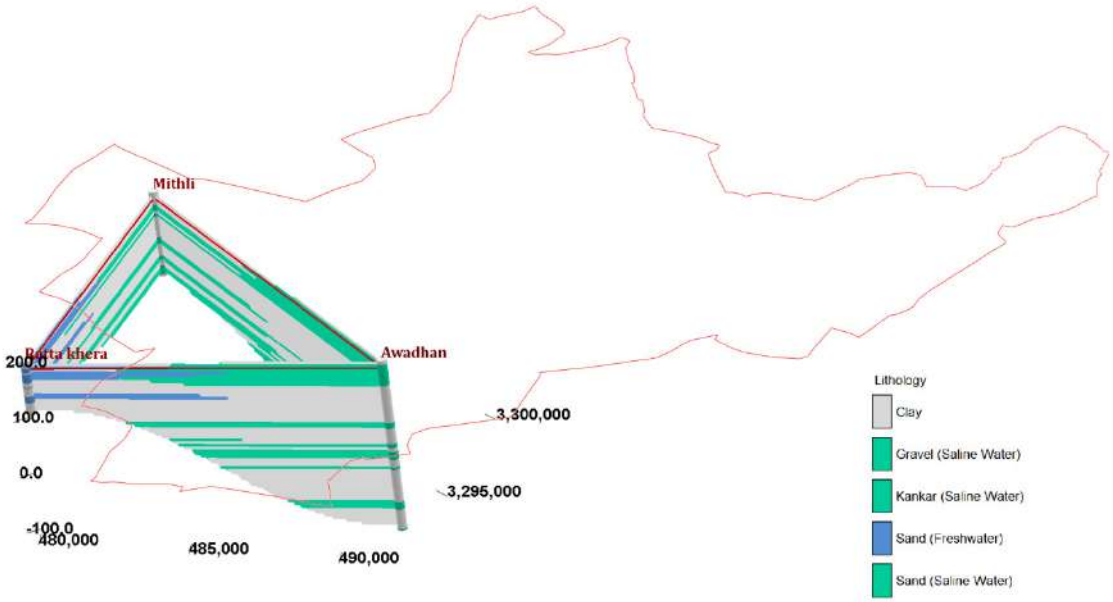
Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand, kankar and gravels. The non-aquifer material comprises of clay. The average depth of the fresh saline interface is at 90m bgl.

Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (5-306m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	96.55	193	12	NA

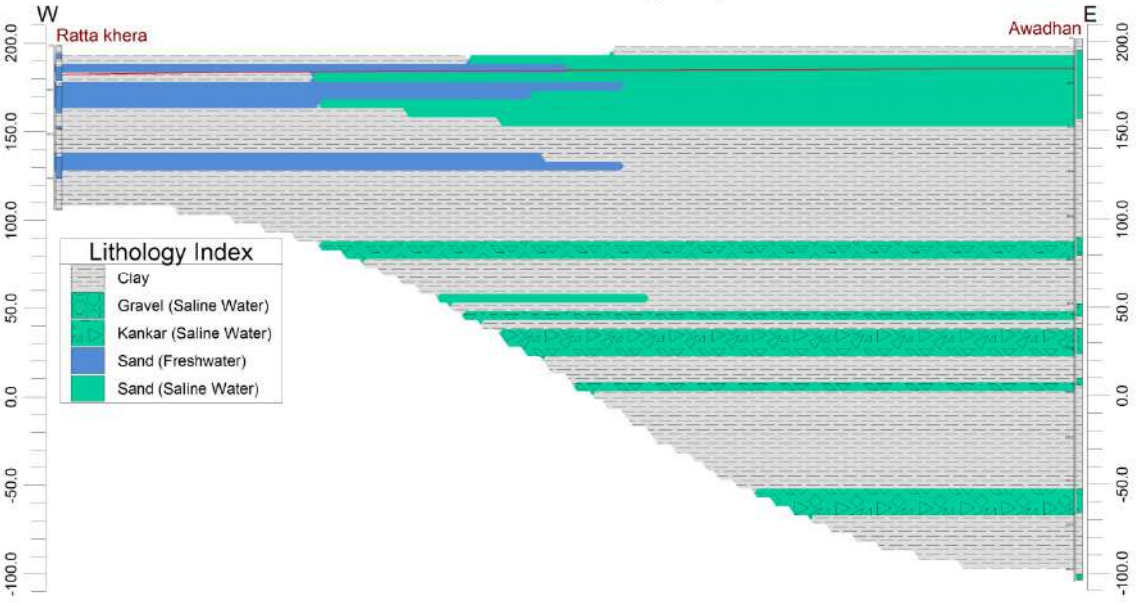
3D Lithology model

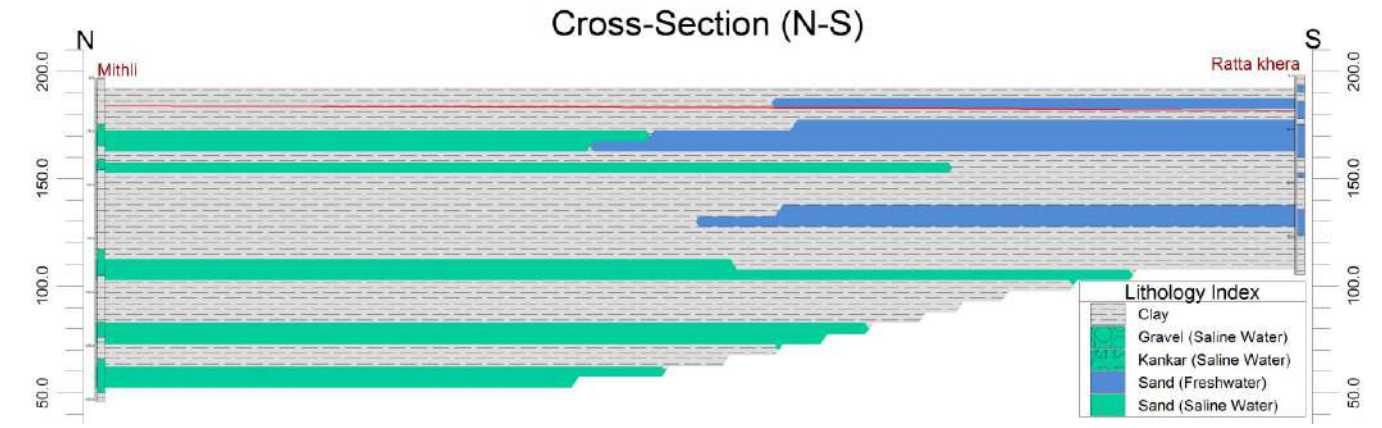


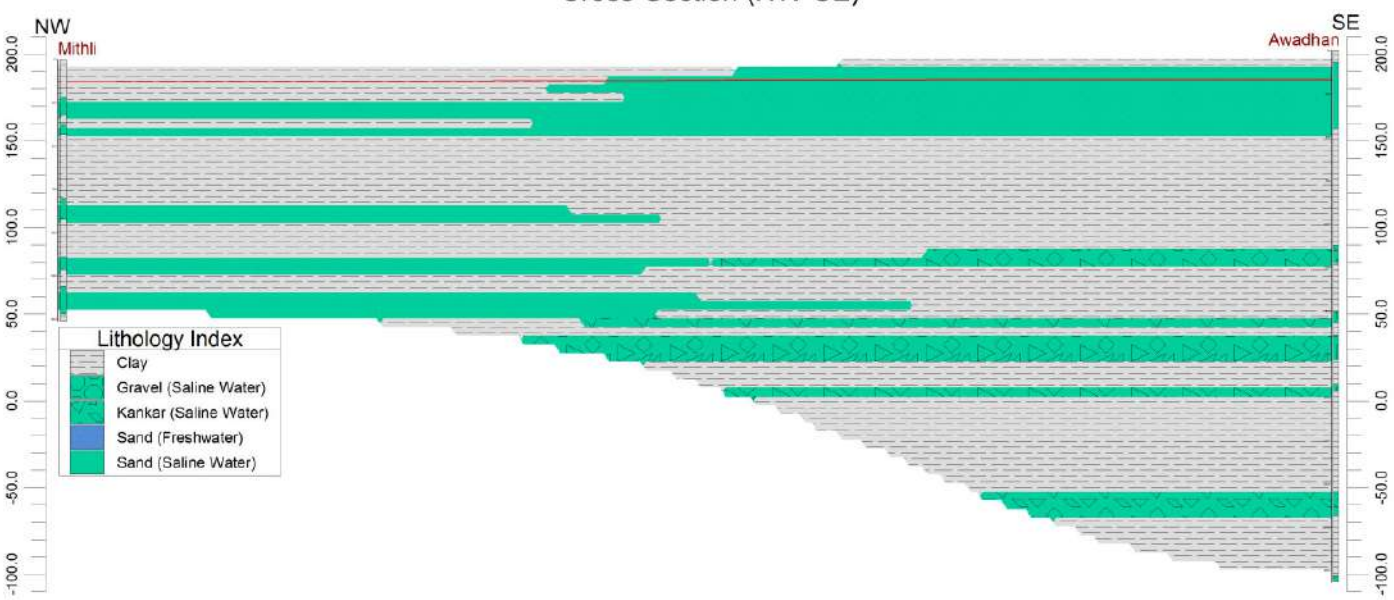
3D Lithology Fence



Cross-Section (W-E)




Cross-Section (N-S)
N
S
Mithli
Ratta khera
200.0
150.0
100.0
50.0
Lithology Index
Clay
Gravel (Saline Water)
Kankar (Saline Water)
Sand (Freshwater)
Sand (Saline Water)


Cross-Section (NW-SE)
NW
SE
Mithli
Awadhan
200.0
150.0
100.0
50.0
0.0
-50.0
-100.0
Lithology Index
Clay
Gravel (Saline Water)
Kankar (Saline Water)
Sand (Freshwater)
Sand (Saline Water)

Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	63.06
	In-storage Aquifer I	3296.63(F=775, S=2521.63)
	Total	3359.69
Ground Water Extraction (mcm)	Irrigation (2013)	78.50
	Domestic & Industrial (2013)	0.40
Future Demand for domestic & Industrial sector (2025) (in mcm)		0.40
Chemical Quality of ground water		Salinity problem (Details in ANNEXURE II)
Other issues		Declining ground water level trend (32.4-34.8cm/yr)

Ground Water Resource Enhancement

Aquifer wise space available for artificial recharge and proposed interventions	Volume of unsaturated zone upto the average depth to water level (9m) is 185.30mcm.
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 6.12mcm volume of water wastage
Change in cropping pattern	Proposed change in cropping pattern from Paddy to maize/soyabean in whole area of the block. Anticipated volume of water to be saved by maize is 1.43 mcm
Alternate water sources	Tanks, ponds and canals
Regulation and Control	No (Not Notified)
Other interventions proposed, if any	-

VI. Rania Block (575.46 sq km)

Population (2011)	Rural-132162 Urban-25123 Total-157285
Rainfall	Monsoon -226.35mm Non Monsoon-75.0mm
Average Annual Rainfall	301.35mm
Agriculture and Irrigation	Major Crops- Wheat, Rice, Barley& Bajra Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies Net Area Sown-497.14sqkm Total Irrigated Area-432.01sqkm
Water Bodies	1 nos.

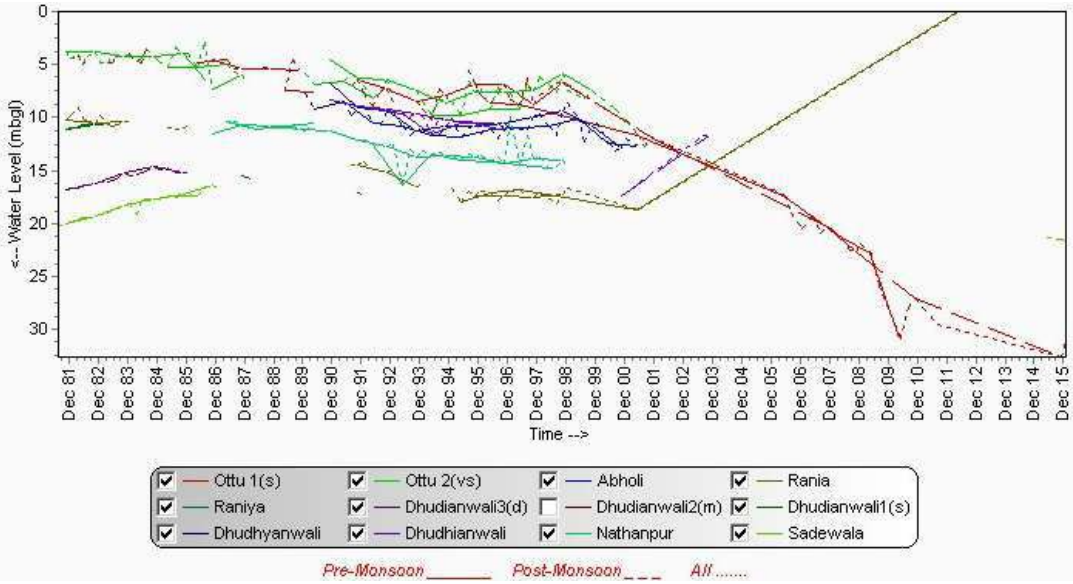
Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

Water level Behavior(2015): Pre Monsoon-19.4-31.4mbgl&Post Monsoon-19.3-32.6mbgl

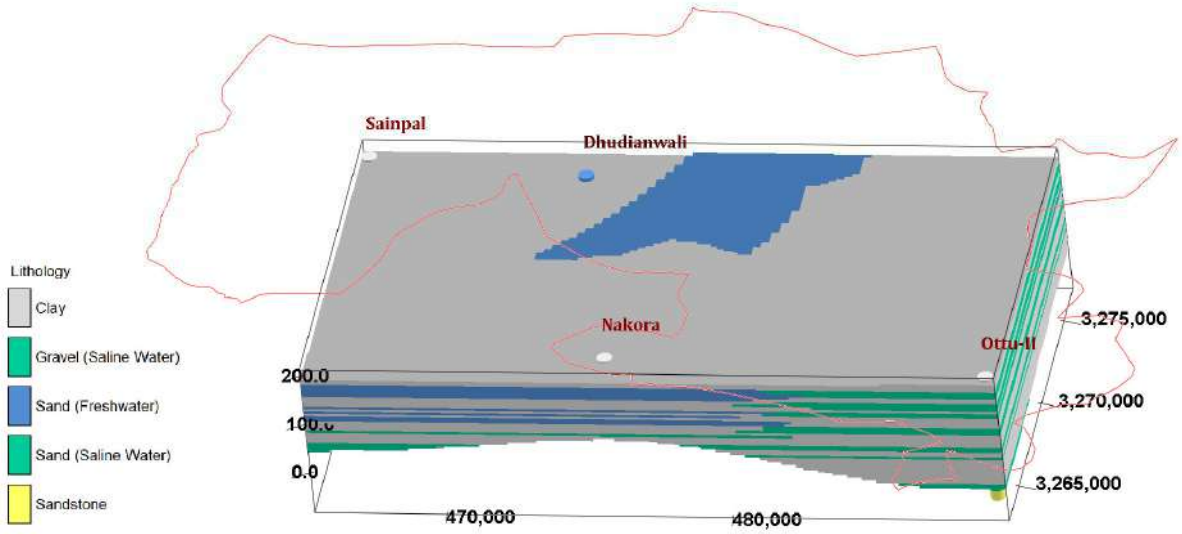
Aquifer Disposition: Single Aquifer System

Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand and gravels. The non-aquifer material comprises of clay and sandstone. The average depth of the fresh saline interface is at 100m bgl.

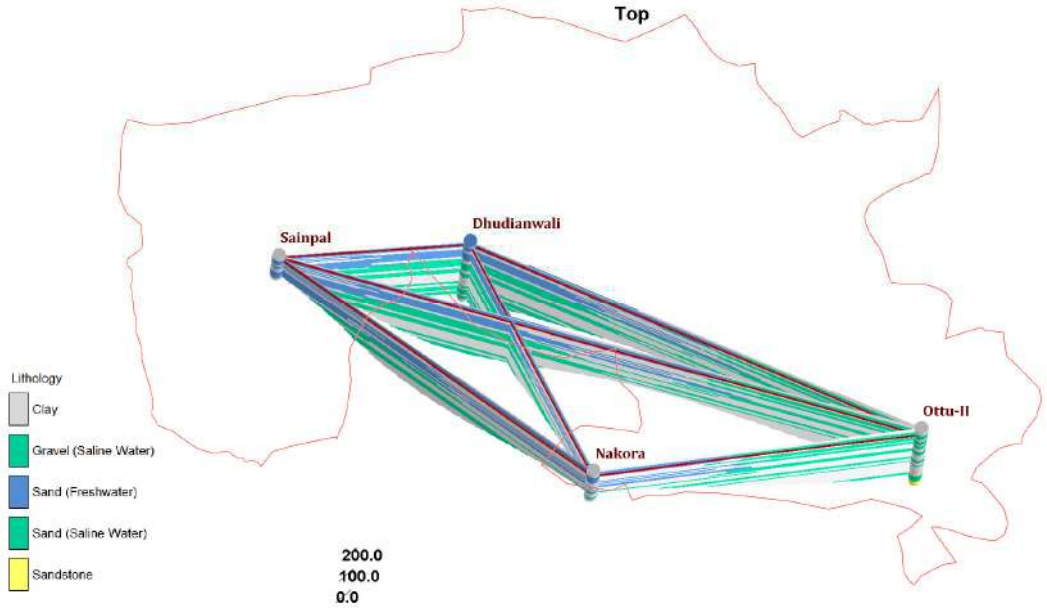


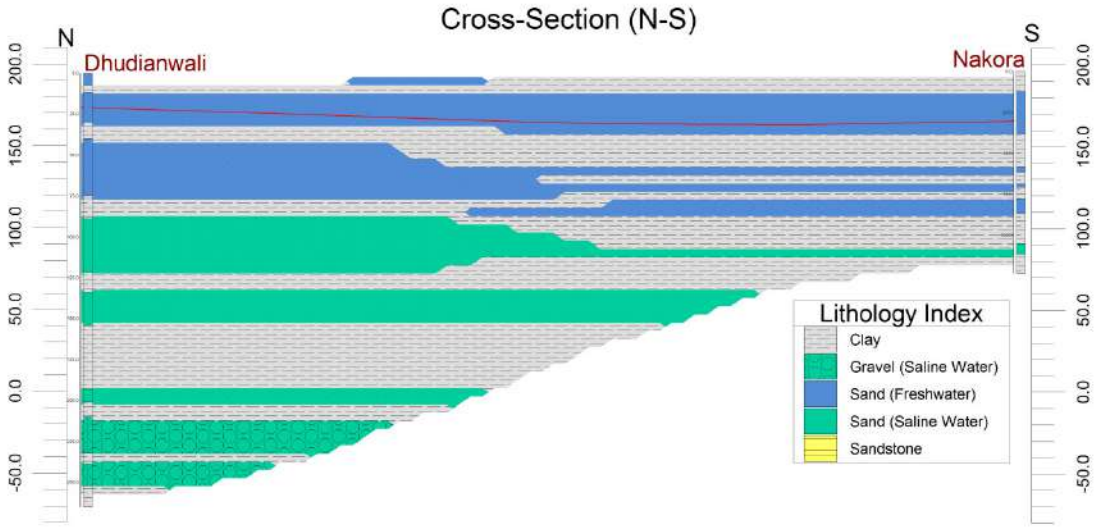
Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (8-265m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	117.56	57-544	12	NA

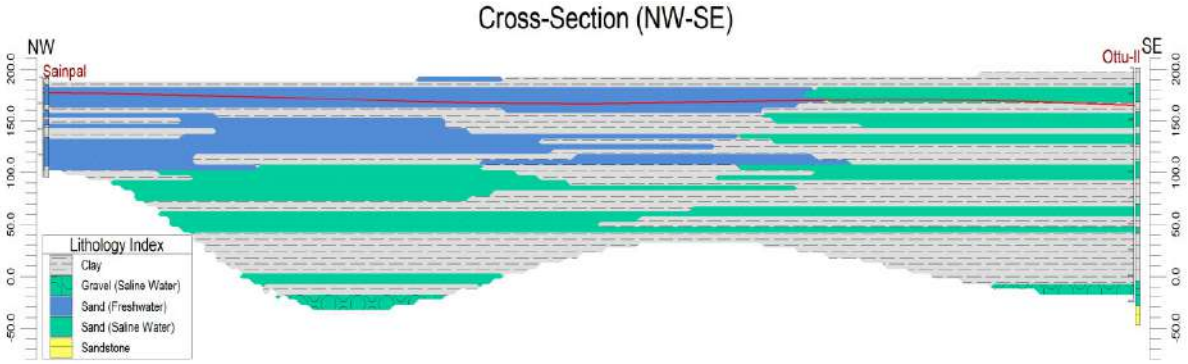
3D Lithology model



3D Lithology Fence







Ground Water Resource, Extraction, Contamination and other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	55.87
	In-storage Aquifer I	4672 (F=1503.34, S=3168.66)
	Total	4727.87
Ground Water Extraction (mcm)	Irrigation (2013)	178.85
	Domestic & Industrial (2013)	1.78
Future Demand for domestic & Industrial sector (2025) (in mcm)		1.78
Chemical Quality of ground water		Salinity problem in deeper aquifers
Other issues		Declining water level trend (121-125cm/yr)

Ground Water Resource Enhancement

Aquifer wise space available for artificial recharge and proposed interventions	Volume of unsaturated zone upto the average depth to water level (19m) is 332mcm.
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 11.63mcm volume of water wastage
Change in cropping pattern	Proposed change in cropping pattern from Paddy to maize/soyabean in 81% area of the block. Anticipated volume of water to be saved by maize is 111mcm.
Alternate water sources	Tanks, ponds and canals
Regulation and Control	Notified (2011)
Other interventions proposed, if any	-

VII. Sirsa Block (577.20 sq km)

Population (2011)	Rural-166227 Urban-204629 Total-370856
Rainfall	Monsoon -257.80mm Non Monsoon-60mm
Average Annual Rainfall	317.8mm
Agriculture and Irrigation	Major Crops- Wheat, Rice, Barley& Bajra Other crops-Gram, Cereals, oilseeds, cotton, Potatoes & Chillies Net Area Sown-485.35sqkm Total Irrigated Area-465.26sqkm
Water Bodies	21 nos.

Ground Water Resource Availability: Ground Water Resources available as a single aquifer system in the block up to a depth of 300m. Block is categorized as Over Exploited as per Dynamic Ground Water Resource assessment (31.3.2013).

Ground water Extraction: Information regarding the abstraction from deeper part of the aquifer is not available, but there are drinking water supply tapping combined aquifer therefore, aquifer could not be assessed separately.

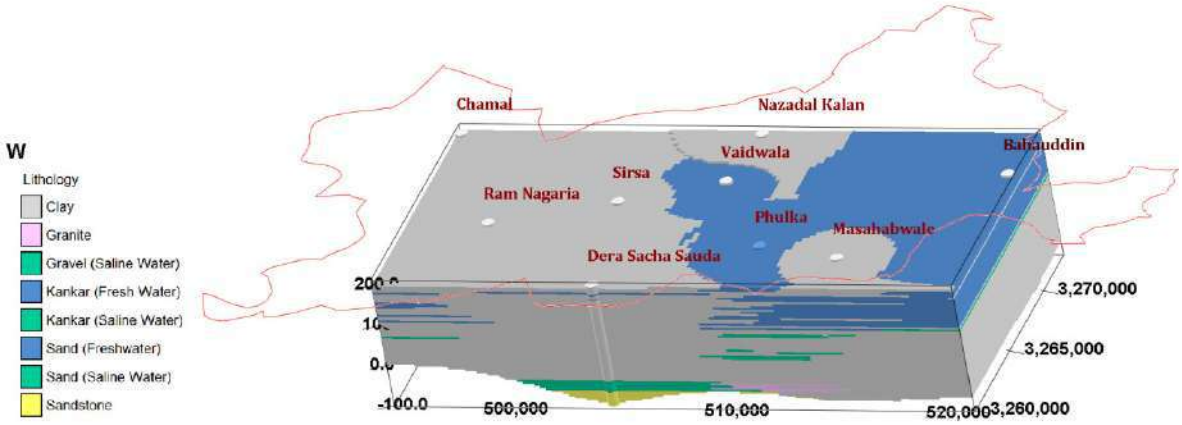
Water level Behavior(2015): Pre Monsoon-32.5-63.5mbgl&Post Monsoon-37.2-67.9mbgl

Aquifer Disposition: Single Aquifer System

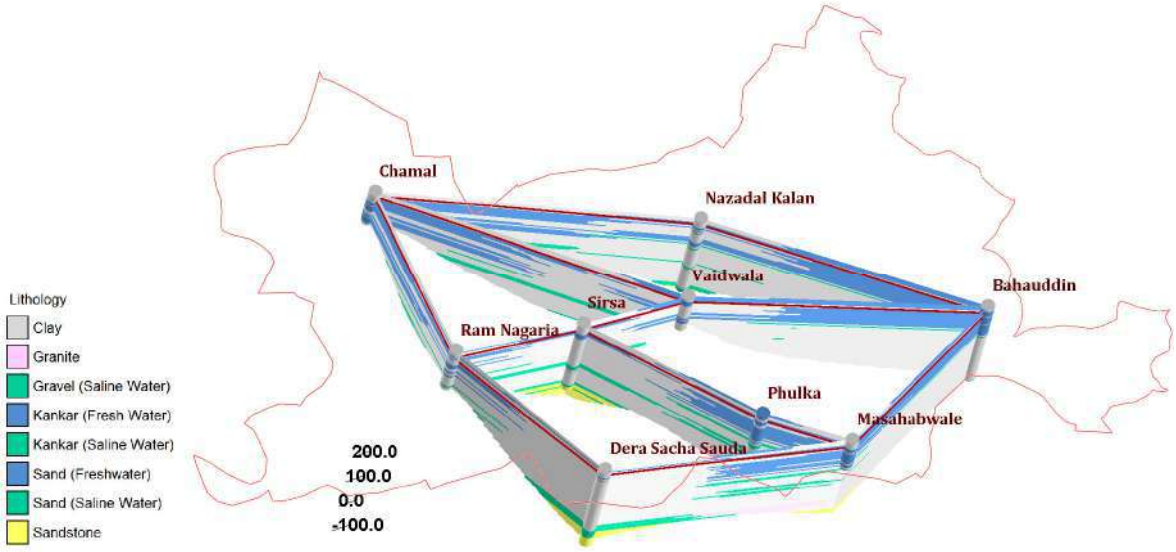
Aquifer comprises of fresh and saline water and the main aquifer formations are mixture of sand, kankar and gravel. The non-aquifer material comprises of clay, sandstone and granite. The average depth of the fresh saline interface is at 105m bgl.

Aquifer	Geology	Type of Aquifer	Thickness of Granular Zones (m)	Transmissivity (m^2/day)	Specific Yield %	Storativity
I (8-299m)	Quaternary Alluvial deposits	Unconfined to Semi-confined	81	375-698	12	NA

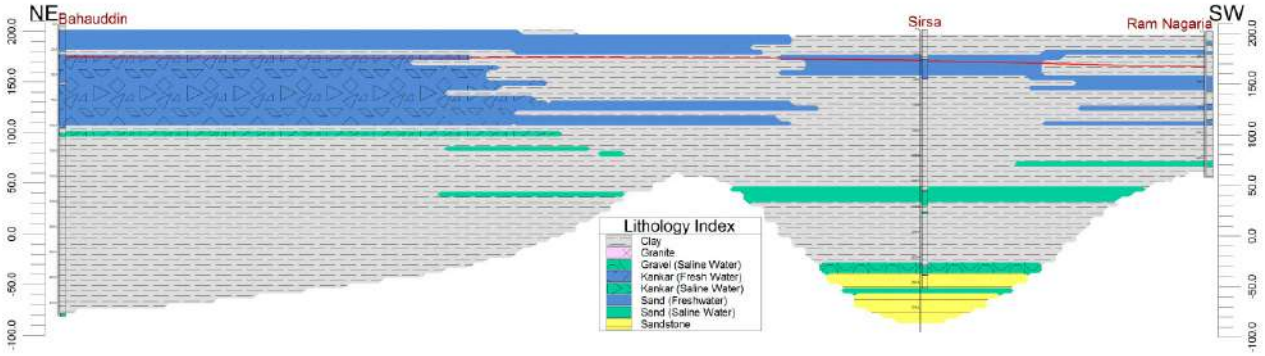
3D Lithology model



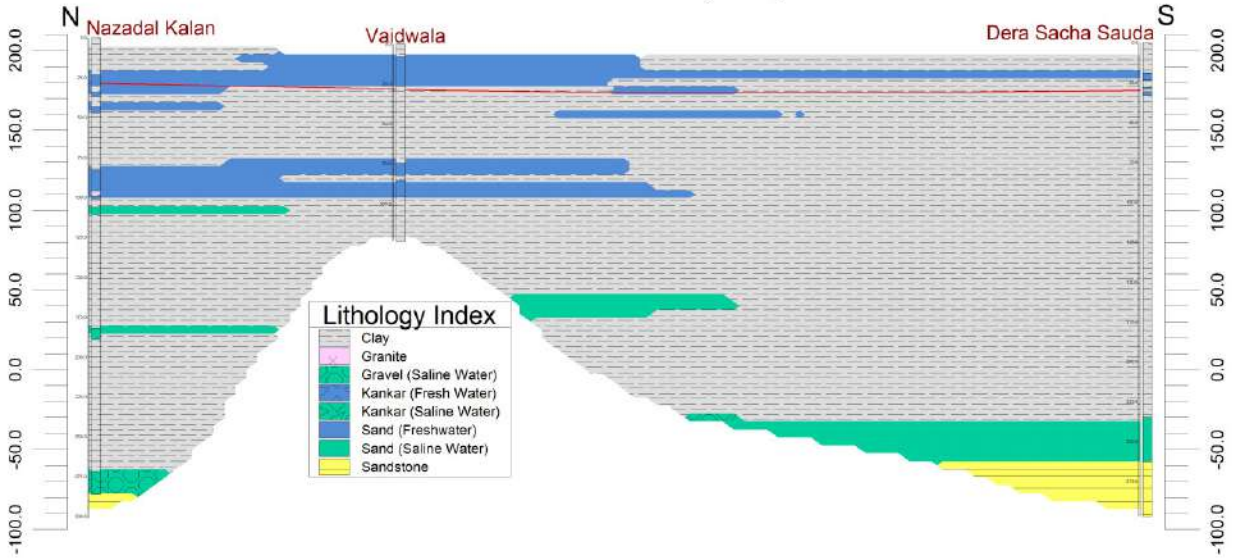
3D Lithology Fence



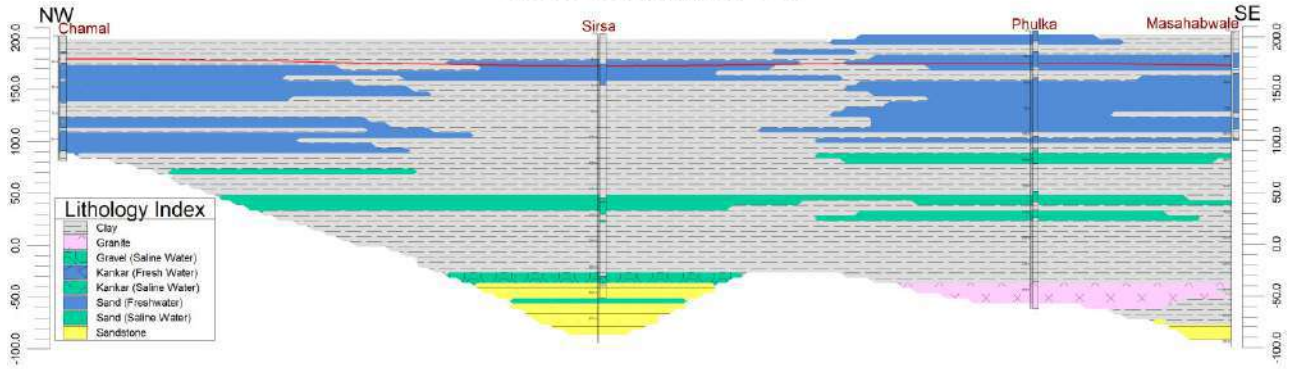
Cross-Section (NE-SW)



Cross-Section (N-S)



Cross-Section (NW-SE)



Ground Water Resource, Extraction, Contamination and Other Issues

Ground Water Resources (in mcm) (2013)	Dynamic Aquifer I	88.60
	In-storage Aquifer I	2825.97(F=1620.78, S=1205.19)
	Total	2914.57
Ground Water Extraction (mcm)	Irrigation (2013)	185.75
	Domestic & Industrial (2013)	3.88
Future Demand for domestic & Industrial sector (2025) (in mcm)		3.88
Chemical Quality of ground water		Salinity problem (Details in ANNEXURE II)
Other issues		Declining ground water level trend (201.6-236.7cm/yr)

Ground Water Resource Enhancement

Aquifer wise space available for artificial recharge and proposed interventions	Volume of unsaturated zone upto the average depth to water level (28m) is 865.8mcm.
Other interventions proposed	NA

Demand Side Interventions

Advanced Irrigation Practices	Lining of underground pipelines (Kutcha channel) will save 14.49mcm volume of water wastage
Change in cropping pattern	Proposed change in cropping pattern from Paddy to maize/soyabean in 40% of the total area. Anticipated volume of water to be saved by maize is 83.67mcm
Alternate water sources	Tanks, ponds and canals
Regulation and Control	Not Notified
Other interventions proposed, if any	-

8. CONCLUSIONS

- Sirsa is the north western district of Haryana State with a total geographical area of 4270 sq. km and is located between 29^{o} 13': 29^{o} 59' N latitudes and 74^{o} 30':75^{o} 7' E longitudes
- Ghaggar River is the major drainage and is dammed at Ottu from where two prominent canals namely northern ghaggar and southern ghaggar takes off. The total length of Ghaggar River in the district is about 85 km.
- Sirsa District is known as "the cotton belt of Haryana". There are many type of industries in the district which are engaged in the manufacturing of various items.
- The climate of Sirsa district is of tropical desert type arid and hot which is mainly dry hot summer and cold winter except during monsoon period season. The normal annual rainfall of the district is 318 mm which is unevenly distributed over the area 20 days.
- Physiographically, the district is characterized by three distinct features i.e. Upland plain, alluvial bed (flood plain) of river Ghaggar and Sand dune clusters
- Geophysical investigation has been carried out to delineate the fresh/Saline ground water interface. Almost the entire study area is occupied with saline water except at few locations like Theri Rasulpur, Bajike and Jodhka where high resistivity values are observed indicating the presence of fresh ground water sediments.
- The depth to water level ranges from 1.6 to 63.50m bgl during pre-monsoon and 1.53 to 67.87m bgl during post-monsoon. The major ground water flow is towards the centre of the district i.e. towards Rania and Sirsa Block
- The ground water is alkaline in nature. More than 50% of the samples are having high EC concentration > 1000 μS/cm indicating the saline water
- Arsenic concentration is within the permissible limit of BIS 2012 whereas Iron concentration is more than the permissible limit (0.05 mg/l) at only one site with a value of 0.51 mg/l.
- The geological formations are unconsolidated alluvial deposits of Quaternary age. The alluvial deposits comprises of sand, silt, clay associated with kankar. The alluvium acts as ground water reservoir and principal aquifer material comprises fine to medium sand and sand mixed with kankar. This aquifer is either in the

form of isolated lenses of sand embedded in clay beds or well connected granular zones that have a pinching and swelling disposition and are quite extensive in nature.

- According to the present NAQUIM study, it has been found that the aquifer material and non-aquifer material in the district is highly variable. The major aquifer material is sand, kankar and gravel and the non-aquifer material is majorly clay, sandstone, chert and granite.
- As per Ground water resource estimation as on March 2013, the stage of ground water development ranges between 113% (block- Baragauda) to 323% (block- Rania). All the blocks of the sirsa district falls in the over-exploited category and out of them 2 blocks (Rania & Sirsa) are notified.
- The net ground water availability is 637 mcm, and existing gross ground water draft for all uses is 1108 mcm and net ground water availability for future irrigation development is 8.5mcm. The stage of ground water development in the district is 175
- The district belongs to single aquifer system upto a depth of 300m. Dynamic & In- storage ground water resources has also been carried for the same for fresh as well as saline.
- There are around 7229 (out of 27756) tubewells (26%) operated by farmers for irrigation through unlined/Katcha open channel system in Sirsa district where water from the tubewell is discharge to the agricultural field. In this process, huge (upto 25%) quantity of ground water is wasted in soil moisture and evaporation losses.
- Around 80% of the tube wells are of shallow depth (40- 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
- There is an overdraft in the district therefore it is suggested that proposed artificial recharge measures, conserving ground water through laying of underground water pipe line, crop diversification and adoption of 3/5 pond system will save 16.19, 86.38, 277.23 & 19.95 mcm of ground water respectively.
- By adopting all the measures stage of development in the district can be reduced to 175% from the present 115%.

9. PHOTOGRAPHS

Water Level Monitoring

Preparation of the report

ANNEXURE I: Depth to water level of GWOW (2015)

S. No.	Location	Latitude	longitude	Water Level		Fluctuation
				May	Nov	
1	Ali Mohmmad	29°27'52'' N	75°06'23'' E	29.20	29.20	0.00
2	Alikan	29°52'39'' N	74°43'40'' E	11.32	12.05	-0.73
3	Bharu Khera-DW	29°45'00'' N	74°36'58'' E	9.37	9.45	-0.08
4	Bhuratwala-Pz	29°25'30'' N	74°46'15'' E	11.45	10.93	0.52
5	Chaharwala	29°17'12'' N	75°12'52'' E	9.08	8.88	0.20
6	Chilkani Dhab	29°23'31'' N	74°48'14'' E	1.70	1.70	0.00
7	Chormar	29°47'00'' N	74°50'30'' E	16.36	16.82	-0.46
8	Chotala	29°46'30'' N	74°31'00'' E	7.56	-	-
9	Chotala-Pz	29°46'25'' N	74°31'30'' E	10.11	9.03	1.08
10	Dabwali Dw	29°57'15'' N	74°44'15'' E	-	9.31	-
11	Dabwali -Pz S	29°57'15'' N	74°44'15'' E	9.27	8.67	0.60
12	Darba Kalan-Pz	29°23'30'' N	75°05'20'' E	1.60	1.60	0.00
13	Desu Jodha-DW	29°56'10'' N	74°51'01'' E	12.58	12.70	-0.12
14	Desu Malkana-DW	29°51'22'' N	74°58'00'' E	14.10	14.10	0.00
15	Dholpalia-DW	29°25'15'' N	74°36'00'' E	8.00	8.30	-0.30
16	Ding	29°27'45'' N	75°15'50'' E	18.01	17.64	0.37
17	Ganga	29°47'00'' N	74°40'20'' E	14.05	14.05	0.00
18	Ghushiana	29°15'10'' N	75°05'00'' E	13.53	14.10	-0.57
19	Gigorani	29°18'00'' N	75°08'40'' E	4.84	5.49	-0.65
20	Goriwala	29°47'30'' N	74°42'30'' E	17.25	16.64	0.61
21	Govindgarh-DW	29°51'20'' N	74°41'05'' E	14.10	14.10	0.00
22	Gudia Khera-DW	29°23'02'' N	75°00'02'' E	1.63	1.53	0.10
23	Hassu	29°53'58'' N	74°56'16'' E	14.63	14.63	0.00
24	Jagiwala-DW	29°16'00'' N	75°14'05'' E	11.44	11.56	-0.12
25	Jamal	29°19'50'' N	74°58'50'' E	4.80	4.51	0.29
26	Jamal- Pz	29°19'40'' N	74°59'10'' E	4.38	4.46	-0.08
27	Kairanwali-DW	29°23'58'' N	75°12'30'' E	2.02	1.97	0.05
28	Kalanwali Mandi-Pz	29°50'20'' N	74°59'20'' E	7.40	8.07	-0.67

29	Kaluwana	29°42'45'' N	74°38'05'' E	10.92	10.37	0.55
30	Karamsana	29°20'25'' N	74°37'48'' E	9.34	7.58	1.76
31	Kash Ram Dhab	29°25'20'' N	74°36'45'' E	-	7.10	-
32	Khuiyan	29°51'30'' N	74°46'10'' E	14.21	12.48	1.73
33	Kurangwali	29°46'38'' N	75°04'6'' E	5.89	5.74	0.15
34	Lohgarh	29°53'58'' N	74°34'06'' E	5.18	5.18	0.00
35	Makhu Shorani	29°22'41'' N	75°10'04'' E	-	2.80	-
36	Mammer Khera-Pz	29°40'20'' N	74°39'25'' E	19.43	19.34	0.09
37	Mangala-Pz	29°28'40'' N	74°57'20'' E	63.50	67.87	-4.37
38	Manjiyana	29°55'15'' N	74°48'15'' E	14.33	-	-
39	Mastian	29°53'10'' N	74°43'12'' E	14.33	14.17	0.16
40	Mithri	29°51'00'' N	74°59'00'' E	16.15	17.52	-1.37
41	Nuhian Wali	29°45'15'' N	74°51'00'' E	14.50	15.43	-0.93
42	Odhan Pz	29°46'00'' N	74°53'50'' E	17.55	15.37	2.18
43	Ottu 1(s)	29°29'59'' N	74°53'22'' E	-	32.63	-
44	Panniwala Mota	29°47'05'' N	74°54'45'' E	12.89	10.25	2.64
45	Phaggu-Pz	29°37'20'' N	75°01'20'' E	5.50	5.06	0.44
46	Rasalia Khera	29°43'00'' N	74°46'00'' E	19.35	19.55	-0.20
47	Rori -DW	29°44'30'' N	75°11'45'' E	9.36	9.93	-0.57
48	Rupana	29°23'51'' N	75°05'44'' E	-	1.72	-
49	Sadewala	29°38'37'' N	74°43'14'' E	21.35	21.50	-0.15
50	Sainpal-Pz	29°36'40'' N	74°41'00'' E	31.35	32.46	-1.11
51	Saktakhera	29°53'30'' N	74°38'10'' E	4.56	3.94	0.62
52	Shergarh-DW	29°55'35'' N	74°40'35'' E	-	8.27	-
53	Sherpura	29°27'15'' N	75°12'15'' E	15.00	14.81	0.19
54	Sirsa-Pz	29°32'09'' N	75°02'58'' E	32.54	37.16	-4.62
55	Sri Jiwan Nagar-B	29°32'15'' N	74°44'30'' E	43.60	44.85	-1.25
56	Sukhchain-DW	29°46'40'' N	75°02'10'' E	9.14	8.08	1.06
57	Taruwana	29°49'30'' N	75°00'30'' E	-	8.12	-
58	Tejakhera	29°50'40'' N	74°33'20'' E	5.50	5.35	0.15
59	Thiraj	29°43'29'' N	75°07'08'' E	9.38	9.38	0.00
60	Tigri-DW	29°55'04'' N	74°54'20'' E	6.55	6.75	-0.20

ANNEXURE II: Results of chemical analysis of water samples from NHS in Haryana (2015)

S. No	Location	Block	pH	EC in µS/cm at 25°C	CO3	HCO3	Cl	SO4	NO3	F	PO4	Ca	Mg	Na	K	SiO2	T.H as CaCO3	As	Fe
					(----------mg/l----------)														
1	Ding	Sirsa	8.29	880	Nil	240	96	132	**115**	0.9	0.1	40	85	39	9	16	450	0.001	BDL
2	Rasalia Khera	Dabwali	8.11	**7210**	Nil	206	**1389**	**2833**	**64**	**3.2**	0.1	**253**	**202**	1660	26	13	**1461**	0.001	0.14
3	Panniwala	Odhan	8.02	**4510**	Nil	123	787	**1844**	19	**2.7**	0.1	192	**156**	983	18	11	**1120**	0.001	0.07
4	Nuhian Wali	Odhan	7.68	273	Nil	126	6.9	48	1.6	0.5	0.1	31	13	12	3	15	131	0.001	0.09
5	Goriwala-Pz	Rania	8.01	1509	Nil	214	179	**400**	**63**	**2.1**	0.1	28	52	263	13	17	282	0.001	0.01
6	Mastian	Dabwali	8.12	1270	Nil	93	145	390	34	1.4	0.1	24	37	222	9	11	212	0.003	0.15
7	Dabwali	Dabwali	7.63	270	Nil	105	14	35	0.1	0.3	0.1	22	18	10	8	9	129	0.001	0.04
8	Mangiana	Dabwali	**9.15**	1847	52	367	109	**489**	29	**4.5**	0.1	20	36	430	8	14	198	0.002	0.01
9	Kalawali Man	Odhan	**8.64**	**4190**	77	53	**1062**	**1122**	**64**	**1.9**	0.1	87	**308**	650	16	16	**1486**	0.020	**0.52**
10	Phaggu-Pz	Baragudha	**9.06**	**4740**	77	499	654	**1336**	26	**2.9**	0.1	32	87	1070	16	16	436	0.003	0.02
11	Rori	Baragudha	**9.01**	**2680**	77	499	299	**575**	**59**	0.7	0.2	32	58	590	14	14	317	0.001	BDL

The values more than the permissible limits (BIS Standard 2012) are shown in red colour.

ANNEXURE III: Lithological data of optimized wells.

Well Name	Zones		LITHOLOGY	THICKNESS
	FROM	TO		
Gurunanakpura	0	23	Clay	23
	23	55	Sand	32
	55	58	Clay	3
	58	63	Sand	5
	63	75	Clay	11
Tejakhera	0	7	Clay	7
	7	32	Sand	25
	32	35	Clay	3
	35	42	Sand	7
	42	91	Clay	49
	91	94	Kankar	3
	94	98	Clay	4
	98	101	Kankar	3
	101	104	Clay	3
	104	111	Kankar	7
	111	121	Sand	10
	121	150	Kankar	29
	150	161	Sand	11
	161	207	Kankar	46
	207	210	Clay	3
	210	213	Kankar	3
	213	220	Clay	7
	220	238	Kankar	18
	238	241	Clay	3
	241	255	Kankar	14
	255	261	Clay	6
	261	295	Kankar	34
	295	306	Clay	11
Sainpal	0	8	Clay	8
	8	26	Sand	18
	26	32	Clay	6
	32	38	Sand	6
	38	41	Clay	3
	41	46	Sand	5
	46	58	Clay	12
	58	85	Sand	27
	85	96	Clay	11
Dhudianwali	0	8	Sand	8
	8	12	Clay	5

	12	30	Sand	18
	30	40	Clay	10
	40	75	Sand	35
	75	89	Clay	14
	89	122	Sand	33
	122	134	Clay	12
	134	154	Sand	20
	154	193	Clay	39
	193	201	Sand	8
	201	210	Clay	9
	210	232	Gravel	22
	232	239	Clay	7
	239	252	Gravel	13
	252	265	Clay	13
Harni Khurd	0	14	Clay	14
	14	26	Sand	12
	26	38	Clay	12
	38	41	Sand	3
	41	55	Clay	14
	55	60	Sand	5
	60	69	Clay	9
	69	78	Sand	9
	78	111	Clay	34
Jiwan Nagar	0	5	Clay	5
	5	8	Sand	3
	8	18	Clay	11
	18	44	Sand	26
	44	52	Clay	8
	52	55	Sand	3
	55	65	Clay	10
	65	72	Sand	7
	72	78	Clay	6
	78	84	Sand	6
	84	90	Clay	6
	90	94	Sand	4
	94	114	Clay	21
Ellenabad	0	57	Clay	57
	57	65	Kankar	8
	65	104	Clay	39
	104	111	Kankar	7
	111	125	Clay	14
	125	161	Sand	36

	161	190	Clay	29
	190	198	Sand	8
	198	229	Clay	31
	229	250	Gravel	21
Budhimari	0	8	Clay	8
	8	17	Sand	9
	17	23	Clay	6
	23	38	Sand	15
	38	84	Clay	46
	84	110	Sand	26
	110	123	Clay	14
Mithli	0	22	Clay	22
	22	32	Sand	10
	32	38	Clay	6
	38	43	Sand	6
	43	80	Clay	37
	80	92	Sand	12
	92	114	Clay	22
	114	121	Sand	7
	121	131	Clay	10
	131	147	Sand	16
	147	151	Clay	4
Awadhan	0	7	Clay	7
	7	45	Sand	38
	45	112	Clay	67
	112	122	Kankar	10
	122	150	Clay	28
	150	157	Kankar	7
	157	164	Clay	7
	164	178	Kankar	14
	178	192	Clay	14
	192	196	Kankar	4
	196	255	Clay	58
	255	268	Kankar	13
	268	303	Clay	35
	303	306	Gravel	3
Ratta khera	0	5	Clay	5
	5	8	Sand	3
	8	12	Clay	5
	12	20	Sand	8
	20	23	Clay	3
	23	38	Sand	15

	38	46	Clay	8
	46	47	Sand	2
	47	63	Clay	15
	63	75	Sand	12
	75	93	Clay	18
Sahuwala	0	2	Sand	2
	2	18	Clay	16
	18	30	Sand	13
	30	43	Clay	13
	43	46	Kankar	3
	47	53	Clay	6
	53	56	Kankar	3
	56	70	Clay	14
	70	77	Kankar	7
	77	81	Clay	4
	81	84	Kankar	3
	84	91	Clay	7
	91	95	Kankar	4
	95	147	Clay	52
	147	154	Kankar	7
	154	210	Clay	56
	210	221	Kankar	11
	221	277	Clay	55
	277	290	Gravel	13
	290	299	Clay	9
	299	304	Sandstone	5
Chamal	0	15	Clay	15
	15	17	Sand	2
	17	26	Clay	9
	26	30	Sand	5
	30	32	Clay	2
	32	41	Sand	9
	41	44	Clay	3
	44	65	Sand	21
	65	78	Clay	13
	78	82	Sand	4
	82	84	Clay	2
	84	89	Sand	5
	89	91	Clay	3
	91	111	Sand	20
	111	120	Clay	9
Nakora	0	12	Clay	12

	12	38	Sand	26
	38	59	Clay	20
	59	62	Sand	3
	62	69	Clay	7
	69	71	Sand	2
	71	78	Clay	7
	78	87	Sand	9
	87	105	Clay	18
	105	112	Sand	6
	112	123	Clay	12
Ottu-II	0	15	Clay	15
	15	33	Sand	18
	33	43	Clay	10
	43	57	Sand	15
	57	64	Clay	7
	64	74	Sand	11
	74	90	Clay	16
	90	106	Sand	16
	106	131	Clay	25
	131	143	Sand	12
	143	154	Clay	11
	154	159	Sand	5
	159	206	Clay	47
	206	230	Gravel	24
	230	248	Sandstone	18
Ram Nagaria	0	11	Clay	11
	11	14	Sand	3
	14	20	Clay	6
	20	23	Sand	3
	23	44	Clay	21
	44	59	Sand	15
	59	72	Clay	12
	72	78	Sand	6
	78	87	Clay	9
	87	93	Sand	6
	93	128	Clay	35
	128	134	Sand	6
	134	145	Clay	11
Nagrana	0	11	Clay	11
	11	17	Sand	6
	17	37	Clay	20
	37	46	Sand	9

	46	78	Clay	32
	78	87	Sand	9
	87	99	Clay	12
	99	105	Sand	6
	105	111	Clay	6
	111	124	Sand	13
	124	136	Clay	12
Malleka	0	42	Clay	42
	42	46	Kankar	4
	46	63	Clay	17
	63	81	Kankar	18
	81	88	Clay	7
	88	116	Kankar	28
	116	123	Clay	7
	123	133	Kankar	10
	133	140	Sand	7
	140	157	Kankar	17
	157	182	Clay	25
	182	186	Kankar	4
	186	189	Clay	3
	189	196	Kankar	7
	196	199	Clay	3
	199	233	Gravel	33
	233	240	Sandstone	7
	240	244	Chert	4
	244	247	Sand	3
	247	249	Sandstone	2
	249	266	Kankar	17
	266	287	Gravel	21
Goushala Road	0	20	Clay	20
	20	24	Sand	5
	24	75	Clay	51
	75	93	Sand	18
	93	102	Clay	9
	102	107	Sand	5
	107	120	Clay	14
Rohan	0	9	Clay	9
	9	21	Sand	12
	21	28	Clay	7
	28	31	Sand	3
	31	35	Clay	4
	35	43	Sand	8

	43	48	Clay	5
	48	55	Sand	8
	55	61	Clay	6
	61	70	Sand	9
	70	96	Clay	26
	96	101	Sand	5
	101	108	Clay	7
	108	117	Sand	9
	117	194	Clay	77
	194	196	Sand	2
	196	219	Clay	23
	219	223	Sand	4
	223	231	Clay	8
	231	233	Sand	2
	233	244	Clay	11
	244	249	Sand	5
	249	254	Clay	5
	254	257	Sand	3
Mattar	0	5	Clay	5
	5	20	Kankar	15
	20	26	Clay	6
	26	29	Sand	3
	29	53	Clay	24
	53	99	Sand	46
	99	114	Clay	15
Biruwala Gudha	0	10	Clay	10
	10	21	Sand	11
	21	37	Clay	16
	37	46	Sand	9
	46	48	Clay	2
	48	52	Sand	4
	52	54	Clay	2
	54	57	Sand	3
	57	72	Clay	15
	72	83	Sand	11
	83	86	Clay	3
	86	101	Sand	14
	101	129	Clay	29
	129	131	Sand	2
	131	166	Clay	35
	166	170	Sand	4
	170	172	Clay	2

	172	179	Sand	7
	179	186	Clay	7
	186	190	Sand	4
Nazadal Kalan	0	23	Clay	23
	23	30	Sand	7
	30	34	Clay	4
	34	37	Sand	3
	37	43	Clay	6
	43	47	Sand	4
	47	83	Clay	36
	83	96	Sand	13
	96	99	Clay	3
	99	101	Sand	2
	101	106	Clay	5
	106	111	Sand	5
	111	182	Clay	71
	182	189	Sand	7
	189	272	Clay	83
	272	286	Gravel	14
Sirsa	0	30	Clay	30
	30	49	Sand	20
	49	159	Clay	110
	159	161	Sand	3
	161	162	Clay	1
	162	174	Sand	12
	174	180	Clay	6
	180	182	Sand	2
	182	234	Clay	52
	234	241	Gravel	7
	241	243	Clay	2
	243	255	Sandstone	12
Vaidwala	0	8	Clay	8
	8	26	Sand	18
	26	75	Clay	49
	75	82	Sand	8
	82	85	Clay	3
	85	96	Sand	11
	96	124	Clay	27
Bahauddin	0	7	Clay	7
	7	27	Sand	20
	27	30	Clay	3
	30	57	Kankar	27

	57	60	Clay	3
	60	102	Kankar	42
	102	107	Clay	5
	107	111	Kankar	3
	111	286	Clay	175
	286	288	Gravel	2
Dera Sacha Sauda	0	19	Clay	19
	19	24	Sand	5
	24	28	Clay	5
	28	29	Sand	1
	29	31	Clay	2
	31	33	Sand	2
	33	235	Clay	202
	235	263	Sand	28
	263	297	Sandstone	35
Phulka	0	10	Sand	10
	10	20	Clay	10
	20	35	Sand	15
	35	45	Clay	10
	45	97	Sand	52
	97	102	Clay	5
	102	108	Sand	6
	108	115	Clay	7
	115	128	Sand	13
	128	155	Clay	27
	155	165	Sand	10
	165	173	Clay	8
	173	181	Sand	8
	181	242	Clay	61
	242	269	Granite	27
Narain Khera	0	26	Clay	26
	26	28	Sand	3
	28	40	Clay	12
	40	42	Sand	2
	42	65	Clay	23
	65	66	Sand	2
	66	86	Clay	19
	86	88	Sand	2
	88	95	Clay	7
	95	97	Sand	2
	97	137	Clay	40
	137	138	Sand	1

	138	154	Clay	16
	154	157	Sand	3
	157	174	Clay	17
	174	177	Sand	3
	177	183	Clay	6
	183	185	Sand	2
Masahabwale	0	22	Clay	22
	22	36	Sand	15
	36	41	Clay	5
	41	79	Sand	38
	79	85	Clay	6
	85	95	Sand	11
	95	104	Clay	9
	104	106	Sand	3