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

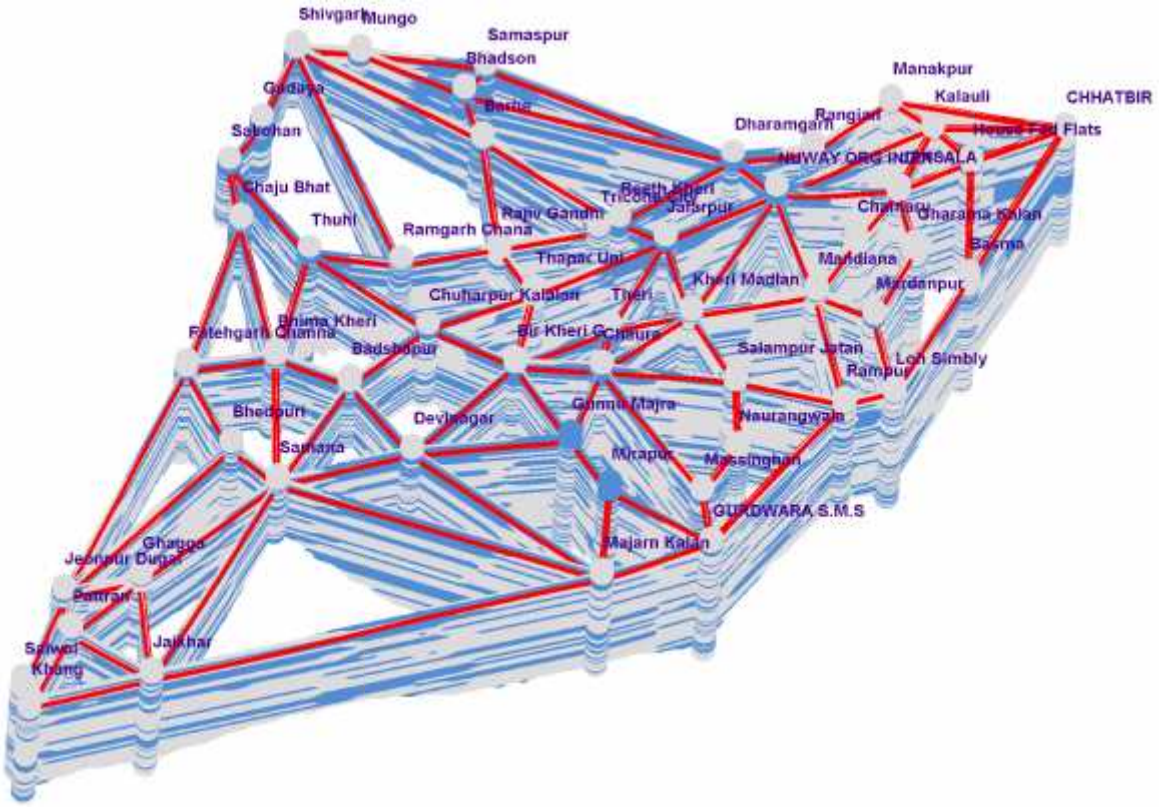
AQUIFER MAPPING AND MANAGEMENT PLAN

Patiala District, Punjab

उत्तरी पश्चिम क्षेत्र, चंडीगढ़

North Western Region, Chandigarh

AQUIFER MAPPING & MANAGEMENT PLAN OF PATIALA DISTRICT, PUNJAB



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2017

AQUIFER MAPPING AND MANAGEMENT PLAN
PATIALA DISTRICT
(3302.70 Sq Km)

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1.0 INTRODUCTION

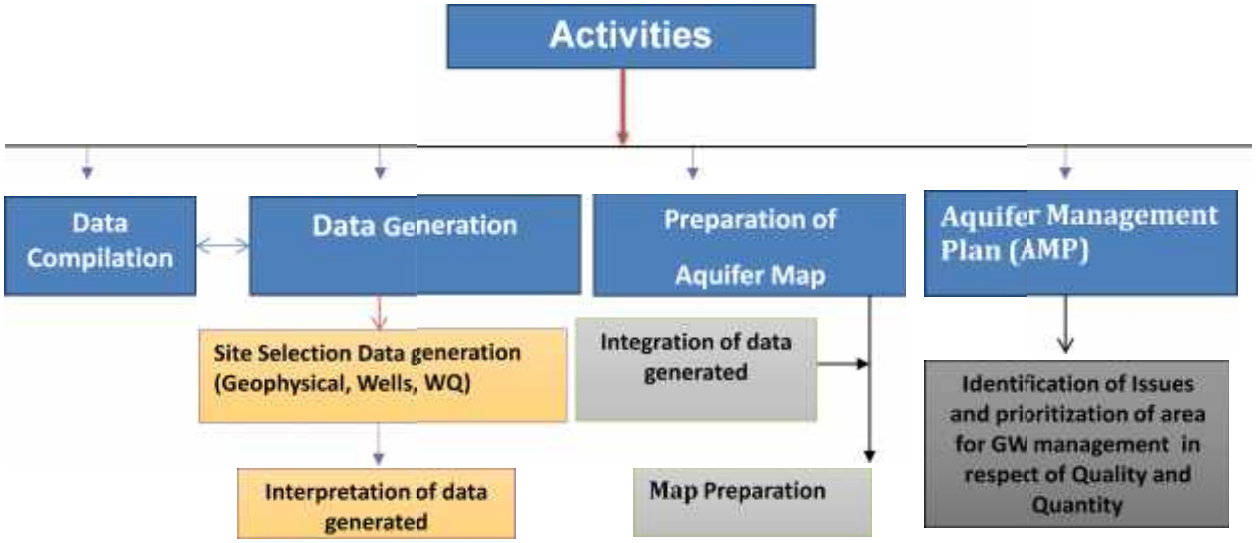
The primary objective of the Aquifer Mapping can be summed up as "Know your Aquifer, Manage your Aquifer". Demystification of Science and thereby involvement of stake holders is the essence of the entire project. The involvement and participation of the community will infuse a sense of ownership amongst 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.

1.2 Scope of the study:

Systematic mapping of an aquifer encompasses a host of activities such as collection and compilation of available information on aquifer systems, demarcation of their extents and their characterization, analysis of data gaps, generation of additional data for filling the identified data gaps and finally, preparation of aquifer maps at the desired scale. This manual attempts to evolve uniform protocols for these activities to facilitate their easy integration for the district as whole.

1.3 Approach and Methodology:

National Aquifer Mapping Programme basically aims at characterizing the geometry, parameters, behaviour of ground water levels and status of ground water development in various aquifer systems to facilitate planning of their sustainable management. The major activities involved in this process include compilation of existing data, identification of data gaps, and generation of data for filling data gaps and preparation of aquifer maps. The overall activities of aquifer mapping are presented in the flow chart below.



1.4 Location and Geographical Units

Patiala district, which is one of the famous princely states of erstwhile Punjab, lies in the south-eastern part of the State. The area falls in the Survey of India Toposheet Nos. 53B/2,3,4,6,7,8,10,11,12 and 53 C/1 lies between 29^0 49' to 30^0 47' North latitude and 75^0 58' to 76^0 54' East longitude covering an area of 3302.70 sq km (Fig.1). It is bounded by Fatehgarh Sahib and SAS Nagar districts in north, Sangrur district in west, Ambala and Kurukshetra districts, neighbouring state of Haryana to north east, and Jind and Kaithal districts of Haryana State in South -South west. The elevation of land surface ranges between 296m above m.s.l. at Chuhar majra in north east to 230 m a.msl at Jogewala (53B/7) towards south west. Topographically, it is a leveled plain sloping towards north - south west direction with a gentle gradient of 0.4 m per km.

The district comprises five sub-divisions (tehsils) namely Patiala, Nabha, Ghanaur, Rajpura and Samana. There are eight administrative development blocks namely Patiala, Nabha, Sanaur, Bhunerheri, Rajpura, Ghanaur, Samana and Patran comprising 855 villages .The district headquarter, Patiala town falls in Patiala Tehsil.

The total population of the district is 1,895,686,as per 2011 census. The total rural population is 1,132,406 (59.74%) and the urban population is 7,63,280 (40.26%) and the decennial growth rate is 19.40 % (2001-2011). Population density of district is 570 persons/sq. km. Patiala has a sex ratio of 888 females for every 1000 males and a literacy rate of 75.28%.

1.5 Climatic Conditions: Rainfall and Climate

The climate of the district is classified as tropical steppe, semi-arid and hot which is mainly dry except in rainy months and characterized by intensely hot summer and cold winter. The temperature ranges from 40.4^0 C (May/June) to 7.1^0 C (December/January).

The normal monsoon and annual rainfall is 547 mm and 677 mm, respectively which is unevenly distributed over the area 29 days .Monsoon rainfall contributes 81% of annual rainfall in the district. The rainfall increases from southwest to northeast in the district. Monthly wise rainfall is given in below table.

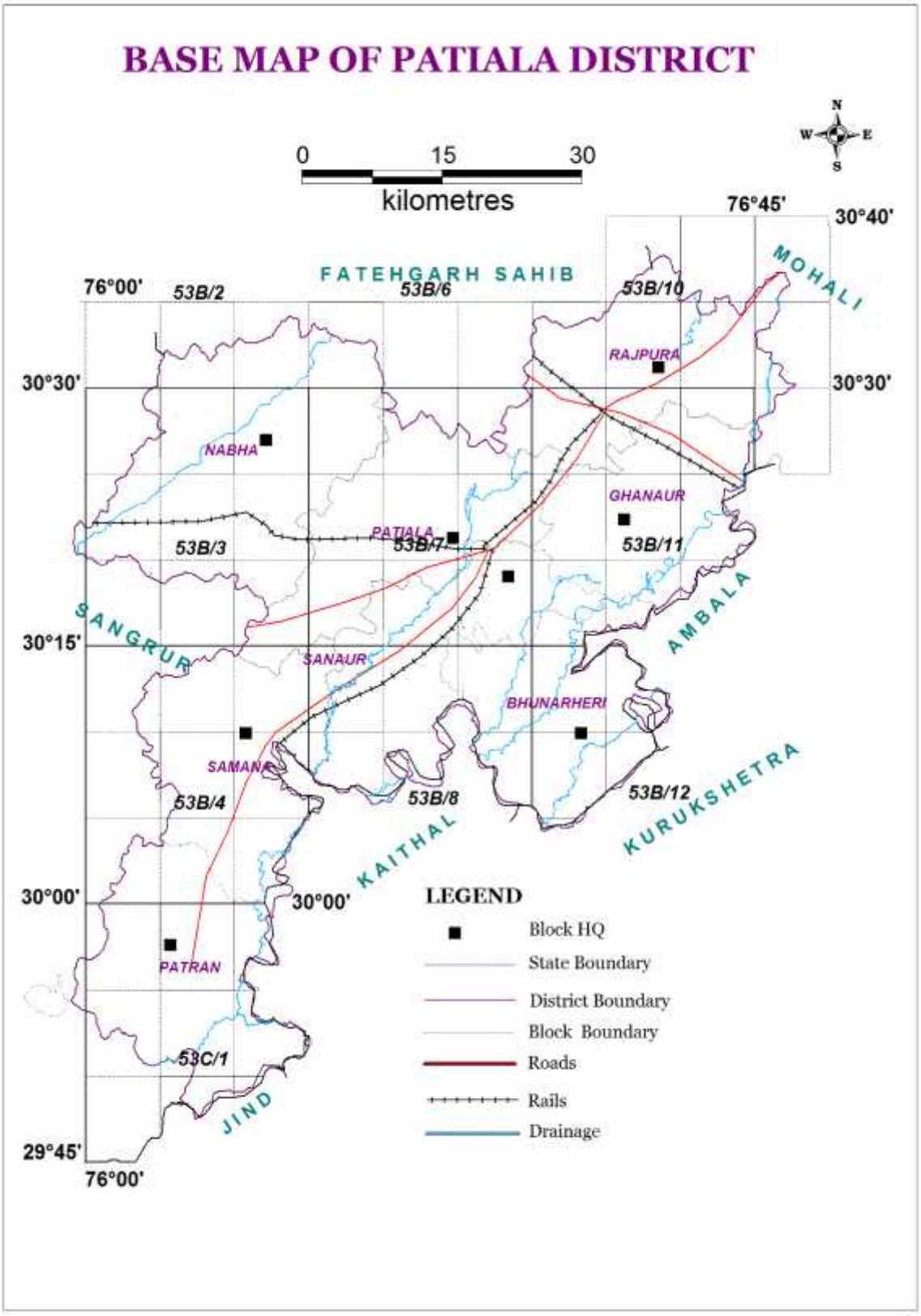
Monthly wise Rainfall of Patiala District in mm (IMD, Chandigarh)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
	Rainfall in mm											
2010	4.9	6.2	0	0.4	1.3	120	363	75.8	188.8	7.2	0	30.4
2011	5.1	21.3	7.7	4.1	10.4	197.2	147.3	142.5	138.9	0	0	5.4
2012	10.4	0.1	0.3	17.9	3.7	18.3	127.4	110.2	74.1	0.5	0.9	7.8
2013	8.2	54.5	16.5	0.7	0.6	87.5	129.4	167	30.3	3.7	1.3	4.1
2014	33.6	32.7	30.1	13.4	20.2	14.7	54.3	19.4	140.2	8	1	28.2

1.6 Geomorphology & Soil Type

The study area is occupied by Indo-Gangetic alluvial plain and forms a part of Sutlej and Ghaggar Basin. It exhibits gradational landforms, mainly fluvial, formed by the deposition of sediments. The area is almost flat terrain without any conspicuous topographical features.

Fig.1: Base map of Patiala District



The main fluvial feature in the area consists of two types of region viz. the Upland plain, and the Floodplain of the Ghaggar River. The elevation of land ranges from 240 to 278 m amsl. Numerous channel bars and point bars have been identified in the flood plains of Ghaggar, Dangri and other stream. The point bars are made up of fine to coarse sediments with filling of clay showing a general fining of these sediments upwards, and exhibit parallel to low angle cross stratification features. The channel bars form longitudinal to transverse bars within the channel, and consists generally of coarse sands exhibiting cross bedding, horizontal parallel lamination, minor cross stratifications etc. Most of these channel bars are cut again by the changing courses of the stream.

In the flood plains of Ghaggar near the concave flanks, both sides of the river, natural levees are noticed due to over flowing or water on top of the channel banks. They consist generally of fine to medium grained sediments. Numerous abandoned channels have been observed in the younger alluvial surface on either side of the present course of Ghaggar.

Due to arid climate, the soils are light coloured. Tropical arid brown soils exist in the major parts of the district. Here soils are deficient in nitrogen, phosphorus and potassium. In Patran and Samana blocks, soils are arid brown soils occur. These are calcareous in nature and in most cases kankar layers occur. The information on soil of the study area is given in below table.

Information on Soil for Patiala District, Punjab (Area in Hectares)

Sr.No	Name of Block	Alluvial					Salt Affected	Deficient in micro nutrient Zn, Mn, Fe, etc.
		Loamy sand	Sandy Loam	Loam	Silt Loam	Clay loam		
1	Patiala	420	25225	8452	8030	0	219	4261
2	Nabha	0	56760	4936	0	0	746	15611
3	Samana	1990	33837	3981	0	0	3	11943
4	Patran	0	4155	33239	0	2077	3	10388
5	Bhunerheri	24692	0	0	6350	4233	1044	328
6	Sanaur	0	12963	7408	11110	5554	714	3825
7	Rajpura	2051	2032	408	30609	6123	219	398
8	Ghanaur	0	0	10937	12262	9942	197	6113
	Total	**29153**	**134972**	**69361**	**68361**	**27929**	**3145**	**52867**

Source: DEIAA, 2016

1.7 Land Use/ Land Cover

The size of operational holdings in this area is generally very small. Small holdings coupled with varying topography are the limiting factors in introduction of mechanized farming. With less than 10% of holdings falling in the size group of 10 ha & above, a strategy wherein technological interventions feasible in small holdings are to be planned for higher and sustainable growth of agriculture.

The main classes are Built Up land, Agricultural land, forestland, Land under non agriculture use, and water body. The land use pattern of the study area is given in below table

Land use pattern of Patiala District, Punjab

Type of Land use	Area (hectares)
1. Total Geographical area	332445
2. Forest	12655
3. Current Fallows	4199
4. Land put to non-agricultural use	39000(12 %)
5. Net area sown	259000(78 %)
6. Gross cropped area	512000
7. Cropping intensity	198%

(Source: Statistical Abstract, Punjab, 2015)

1.8 River System and Water Resources

The study area has a complex drainage system consisting of canals and rivers. Ghaggar River and its major tributaries is the eastern side such as Choa-nadi, Tangauri River, Miranpur Choa, Patialalewali-nadi, Para River, Gadri Nadi and Sirhind choa drain, all flow within the area (Fig.2). These channels exhibit fluvial deposits comprising of sand, silt and clay. Following the regional pattern of the slope of the area, all these streams are ephemeral in nature and flow in south –west direction.

There are three major canals and its branches which pass through the study area (Fig.3). These are Sirhind canal (Patiala and Ghaggar Branch), Bhakra canal (Narwana, Atlana, Bishangarh and Bahmana Branch), and Sutlej Yamuna link (SYL) canal. Of the above Bakhra canal and its branches passes through the central part of the study area in North West of South-Easterly direction.

1.9 Agriculture & Irrigation

Agriculture is the back bone of the study area and an overwhelming 65% of its population lived in rural areas and is engaged in agriculture. The major Kharif crops are Paddy & Maize and the same for Rabi crops are Wheat and Oil Seeds. The study area can legitimately take pride in being one of those districts of Punjab State enjoying the fruits of irrigated agriculture to the maximum extent. Irrigation is an essential input for intensive agriculture and to increase the yields. It is, therefore, necessary to improve the water resources and utilize them properly. Besides, the importance of irrigation to agriculture has become all the more important with the new farm technology. The ground water in 15% of the area in Patiala is suitable for all conditions where as in 29% area; the ground water is unsuitable for Irrigation.

After Independence, there is a significant improvement in the irrigation facilities in this area. The installation of tubewells and extension of canal irrigation from Bhakhra Canal System have led to manifold increase in the irrigated area of the district. Net Irrigated area is 2,71,260 ha and Gross Irrigated Area is 5,12,000 ha and Irrigation intensity is 198 %.

a. Canal Water Irrigation

Canal irrigation is a most important form of irrigation in this area. There is no irrigation by Sirhind canal in this area as it acts only as feeder canal. The Bhakra Main Line canal, the Nawana

Branch and the Ghaggar link provide much needed irrigation water to this area. Before these canals were constructed, Patiala was a water scarce area. These irrigation canals have helped to transform the parched fields into fertile, double crop lands.Sutlej Yamuna link (SYL) is not yet in operation although this canal does not envisage any irrigation in the study area as it is meant to act as a link between the rivers Sutlej and Yamuna. Net area irrigated by canals is 4,000 ha.

b. Ground Water Irrigation

With a large part of the study area is not under canal command the contribution by tube wells is bound to be greater than the surface water irrigation. Net area irrigated by Tubewells and wells are 255,000 ha. Tube wells (96%) are the main source of irrigation. The ground water resources are over exploited due to large scale pumping by tubewells, resulting in decline of water table.

1.10 Industries

Among the industries, there are two sugar mills, 260 saw mills and 279 rice mills in the study area. The Sawmills generates wood chips (11700 MT/year) and saw dust (1950 MT/year) that is being consumed as fuel for nearby industries. Rice is milled in hullers where, husk and bran is in the mixed form, where as modern rice mills separate husk and bran. Residue from hullers is used as fodder, bran from the modern rice mills is also used as fodder, and husk is used as domestic fuel and available as surplus.

1.11 Mineral Resources

The district is poor as regards mineral wealth. The earthen material in Block Ghanour, Rajpura and Bhunarheri is rich in alumina, silica and lime. Therefore, this is very useful as brick earth. In other blocks such as Patiala, Nabha, Samana, Patran and Sanour the earthen material is mostly sandy but in some villages/areas this is useful for bricks manufacturing.

1.12 Water Conservation and Artificial recharge:

Artificial recharge structures may help in arrest decline in which Recharge Trench with injection well structure is the suitable for artificial recharge in all parts of the area due to water level decline trend. Central Ground Water Board (CGWB) has taken up rain water harvesting and artificial recharge studies in the district.

Four pilot projects for artificial recharge to ground water were undertaken and same were completed successfully. These are namely (i). Pilot project for Artificial Recharge from Choe No.1 of Bhakra Main line canal, near village Dhanetha, Samana block (1999-2000), (ii) Pilot study for artificial recharge scheme to ground water from Sirhind Choe, (2000 - 2001), Pilot study for artificial recharge to ground water from Patiala Nadi (2001-2002) and Pilot study for artificial recharge to ground water from Miranpur choe (2001-2002). One Scheme for artificial recharge to roof top rain water harvesting for school buildings were undertaken in the area (2004-2005). Water conservation methods like change in cropping pattern, change in Irrigation policy, lining of unlined channels, timely plantation of paddy, promotion of sprinkler and drip irrigation etc. may be adopted to overcome the ground water decline in the area.

Fig.2: Drainage and Water Bodies of Patiala District

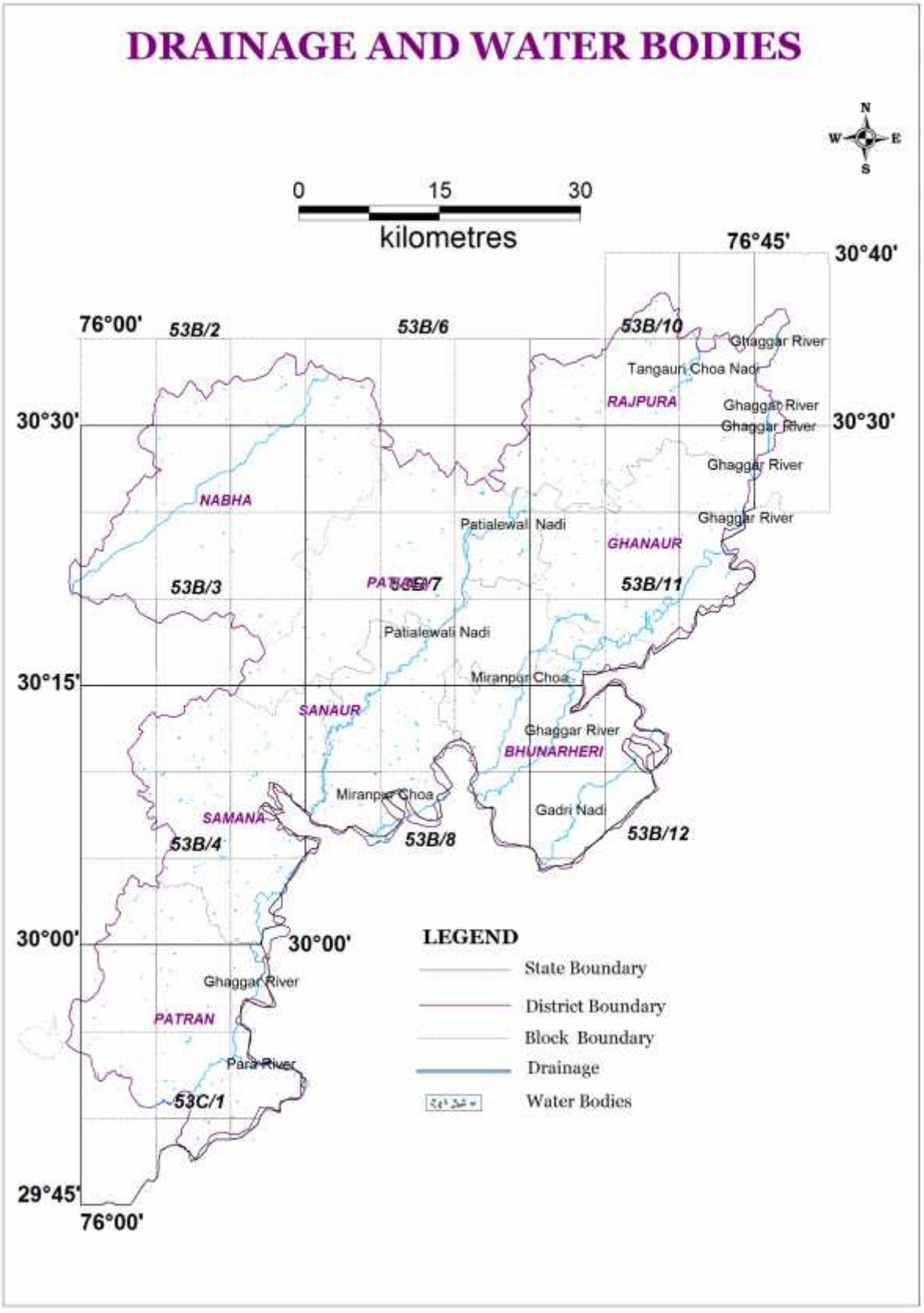
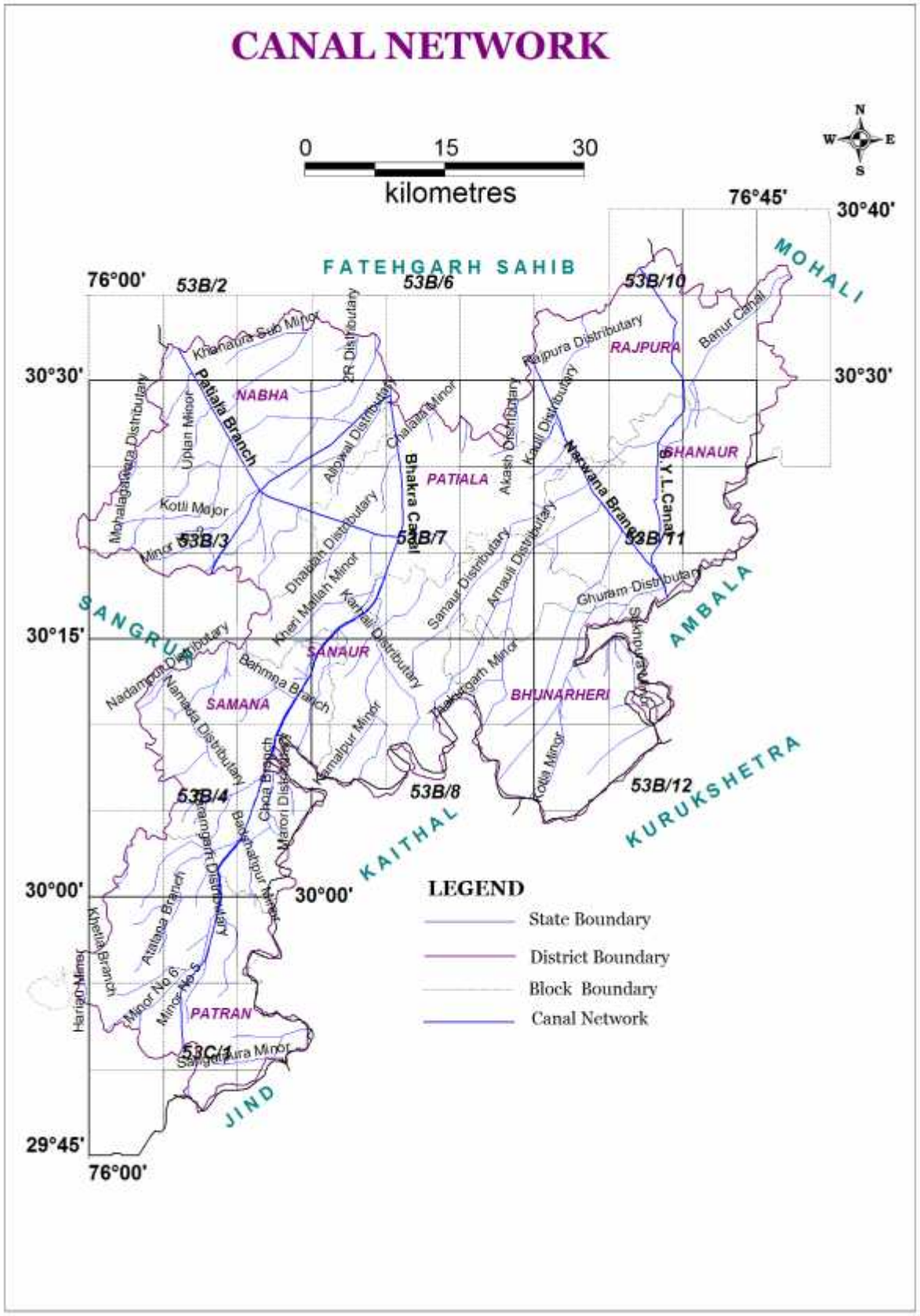


Fig.3: Canal Network of Patiala District



2.0 DATA COLLECTION AND GENERATION

2.1 Geology and Hydrogeological data:

Geologically, the area is occupied by alluvial sediments of Quaternary age, consisting of Indo-Gangetic alluvium. Many of the streams draining the area originate from these Siwalik Hills and the lesser Himalayan range further north of it. The Quaternary sediments in the area, chiefly, comprises of clay, silt, sand and or the mixtures of the above with or without pebbles. The Quaternary alluvial sediments can be broadly classified under two distinct categories based on lithological characteristics viz. Older Alluvium and Younger Alluvium .The Older Alluvium occupy the major part of the area and form relatively higher ground where as the Younger Alluvium form narrow linear low lying tracts in between these Older alluviums. These alluviums are generally confined to the flood plains of the major stream flowing in the area..The generalized stratigraphic sequence of the area is given below,

Generalized Stratigraphy Sequence, Patiala District

Age	***Lithological Unit***	***Lithological Characteristics***
Holocene	*Aeolian deposits*	Fine to medium, well sorted, brownish yellow, micaceous sand.
	Younger Alluvium	Light coloured grey, micaceous sand, silt with subordinate amounts of clay
Mid to Upper Pleistocene	*Older Alluvium*	Alternating bands of yellow, silty clay, sand and silt with Kankar upper horizon is rusty red due to oxidation

-----Basement not exposed----

Sub surface geological formations comprise of fine to coarse grained sand, silt, clay and kankar. Ground water in general is fresh, except around Rajpura city where it is polluted due to industrial effluents. s of finer sediments increases below 100 m in the eastern part of the study area. Water table elevation ranges from 195 m to 287 m above msl. The ground water flow direction is from north east to south west. The gradient of water table elevation is steeped in north east part and gentle in south west part of the study area. Principle Aquifer is Alluvium and Major aquifer in this area is Older Alluvium and Younger Alluvium. (Fig.5)

2.1.1 Water Level Behavior

Twenty three monitoring stations of Central Ground Water Board (CGWB) (19 Piezometers and 4 Dug wells) and *Forty four* monitoring stations (44 Piezometers) of State government departments represent Aquifer-I. Hydrograph of shallow observation wells are shown in Fig.4. *Five* monitoring stations of Central Ground Water Board (CGWB) (5 Piezometers) and *Six* monitoring stations (6 Piezometers) of State government departments represent Aquifer-II and third aquifer is represented by one monitoring station of State government department i.e. (Devigarh) Depth to water level in the area ranges from 5.26 to 39.20 m bgl during pre-monsoon period (Fig.6) and 5.71 to 38.95 m bgl during post monsoon period (Fig.7). The major parts of the area having water levels are >20 m, northern and north

eastern parts having water levels 10 to 20 m, in the eastern and northern part in a portion where, water levels are <10 m bgl. Seasonal water level fluctuation shows a rise and fall in the range of 1.69 to (-) 6.69 meters respectively during the year 2015 (Annexure-I).

Fig.4: Hydrograph of Different Observation Wells of CGWB

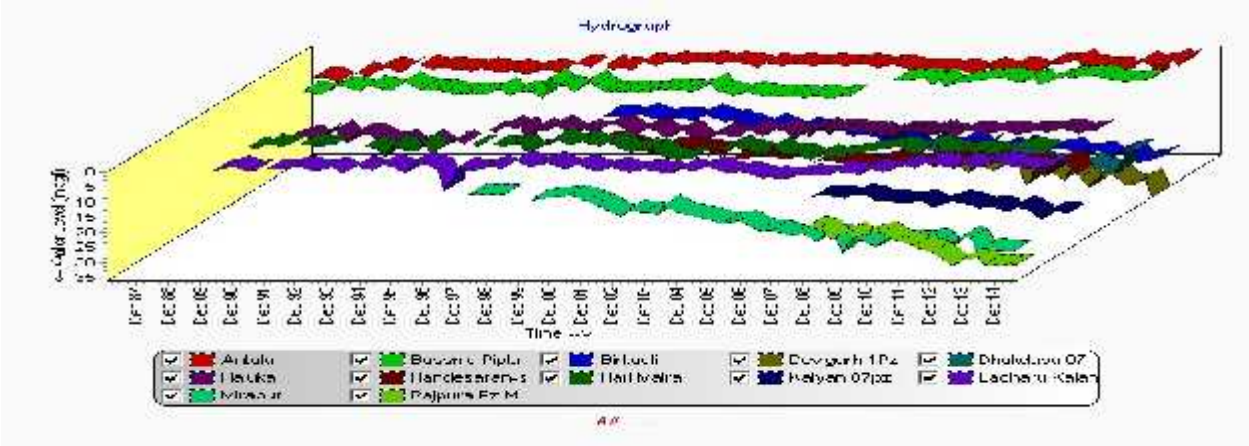


Fig.5: Major Aquifer

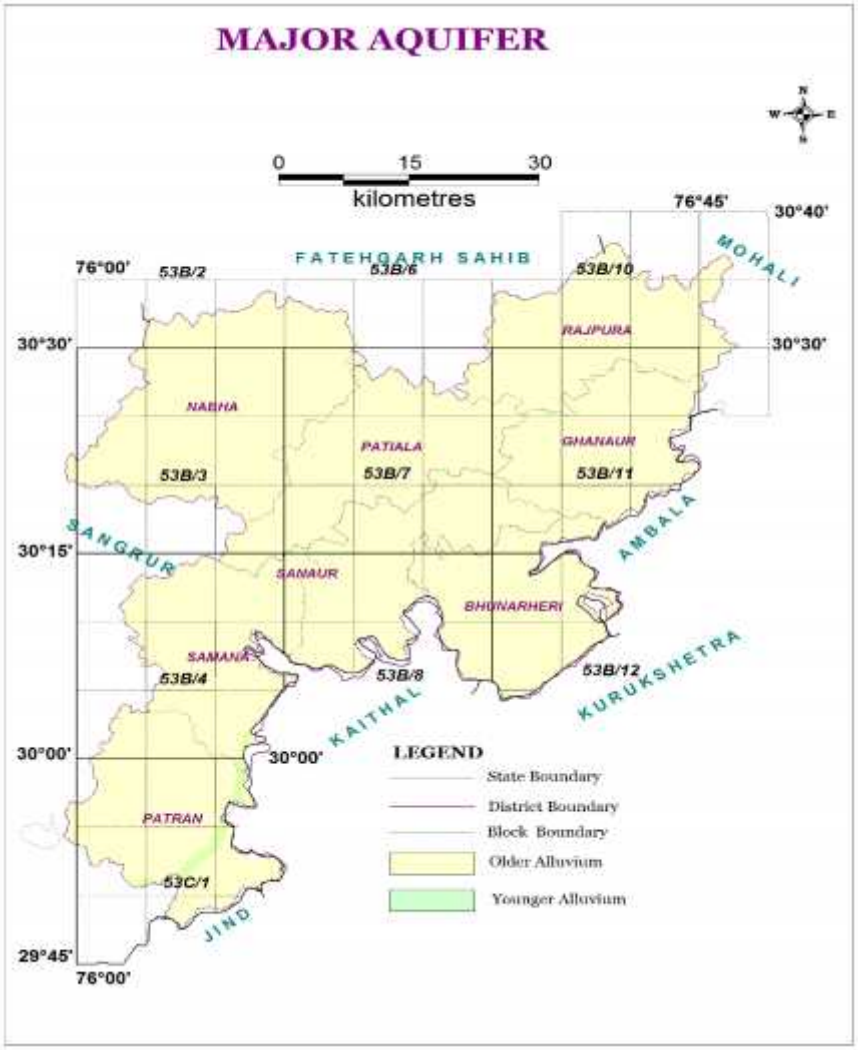


Fig.6: Depth to Water level Pre Monsoon, 2015

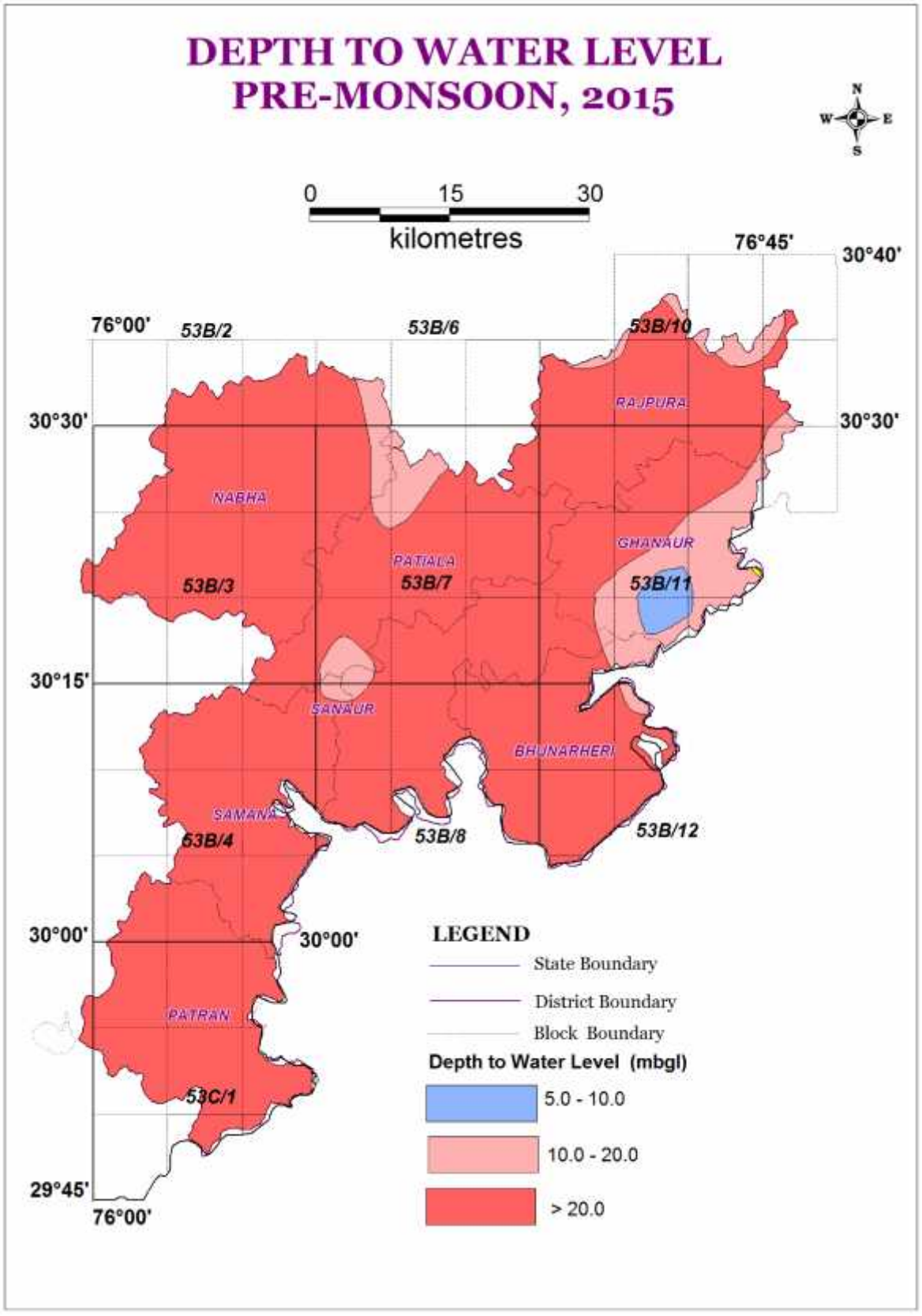
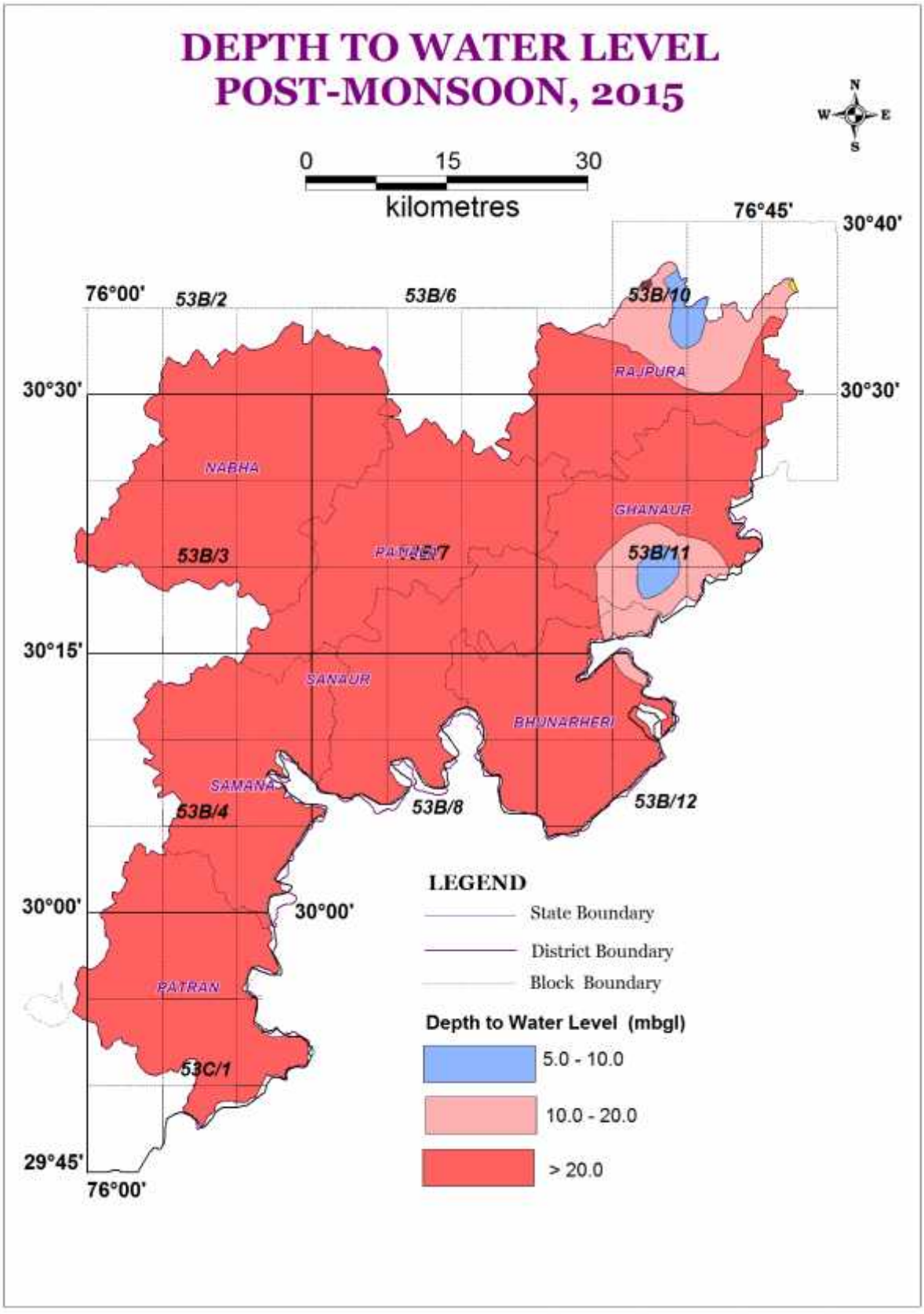


Fig.7: Depth to Water level Post Monsoon, 2015



2.2 Water Quality Data:

Ground water quality of shallow aquifer (Aquifer-I) is assessed based on chemical data of National Hydrograph Network stations i.e. NHNS monitored during Pre monsoon period. *Nineteen* groundwater samples are collected and analyzed during NHNS, 2015, given in Annexure-II. The chemical quality of deeper aquifers has to be assessed during groundwater exploration programme under NAQUIM.

Chemical data of ground water from shallow aquifer indicates that ground water is alkaline in nature where pH value in between 8.25 to 9.05. The Electrical Conductivity (EC) values ranges from 322 to 2595 µS/cm at 25^{o}C and seems to be fresh water. The EC values less than 1000 µS/cm have observed at nine locations i.e. Dhakraba (322), Chat (357), Banur (390), Chehal (449), Bhojo mari (503), Sangatpura Panki (679), Haluka (745), Kalyan (755) and Devigarh (913) respectively. The EC values more than 1000 µS/cm have observed at ten locations i.e. Lachkani (1000), Kami kalan (1044), Bir kauli (1060), Thua (1168), Lachru kalan (1310), Mirpur (1326), Samana (1335), Rajpura (1367), Patran (1588) and Hari majra (2595) (Fig.8).

Salinity, chloride, fluoride and nitrate are the important parameters that are normally considered for evaluating the suitability of ground water for drinking uses. Generally it is suitable for drinking purposes as chemical parameters are within the permissible limits for safe drinking water set by Bureau of Indian Standard (BIS, 2012) except Fluoride and Nitrate at few places. The chloride concentration in ground water varies broadly between 6.9 mg/l at Dhakraba and also 228 mg/l at Patran.

Ground water with Fluoride concentration above permissible limit 1.5 mg/l are found mainly in Rajpura (3.5) and Thua (2.89) and Nitrate concentration above permissible limit 45 mg/l are found mainly in Samana (203) and Patran (81) whereas Arsenic and Iron are found within permissible limit in all sampling locations.

Alkali hazards of irrigation ground waters are estimated through the computation of Residual Sodium Carbonate (RSC), also known as Eaton's Index. Classification based on RSC indicates that 1% of the waters are unsafe for irrigational use. Waters with RSC value <1.25 meq/L are safe for irrigational uses, RSC between 1.25 and 2.5 are marginal and waters with RSC value >2.5 meq/L are unsafe. RSC of ground waters are found to vary from (-2.03) to 6.04 meq/l. Classification based on RSC values indicates that Eight Samples in Safe, Seven Samples in Marginal and Four in Unsafe category for irrigational use. Analysing mechanism and equipments used for chemical analysis are given in table-1.

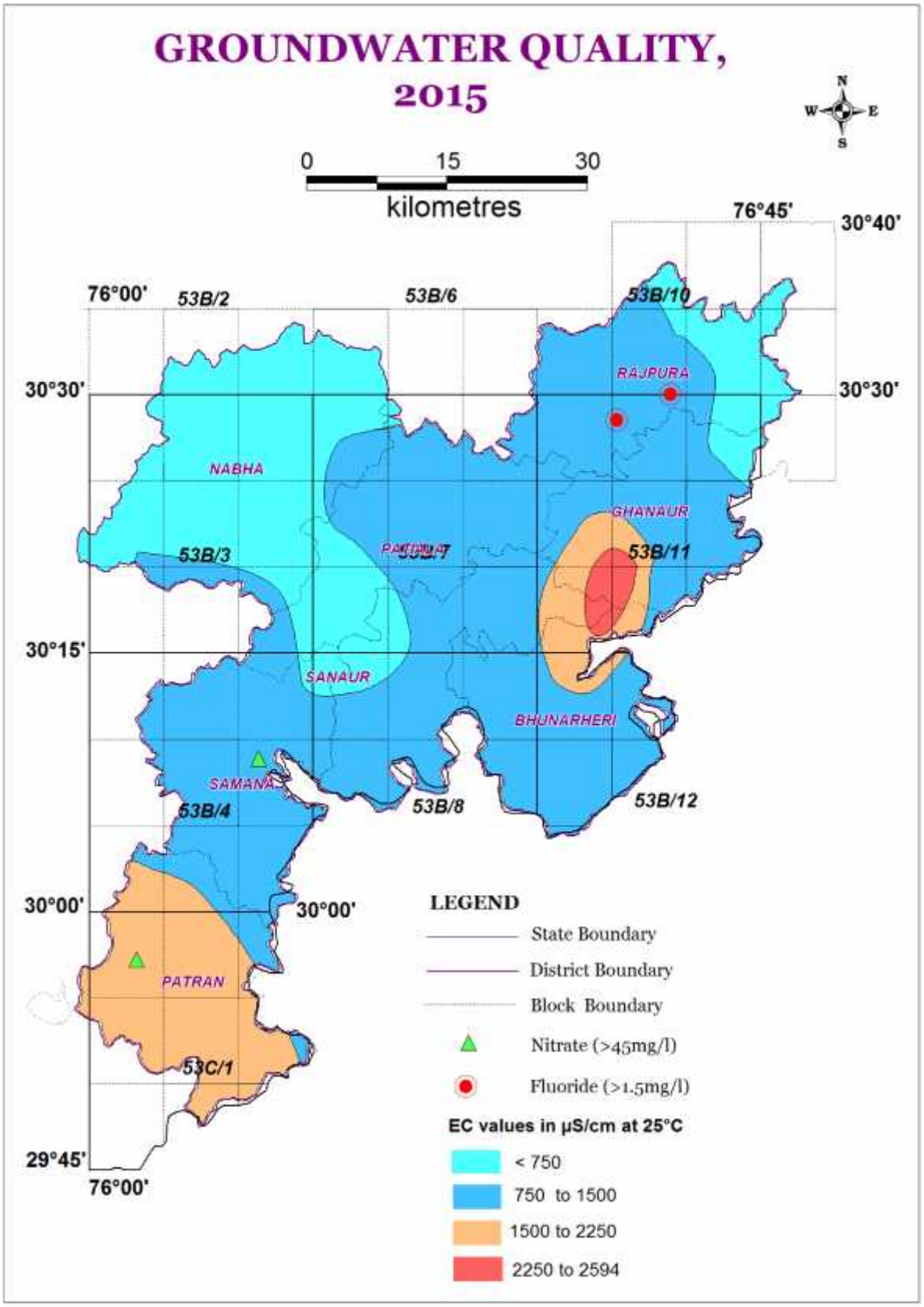
Irrigation Rating of Well Waters of Patiala District
(Based on Eaton's index and USSL Classification)

IRRIGATION SUITABILITY			
EATON's INDEX (RSC in meq/L)			USSL Classification
Safe <1.25	Marginal 1.25-2.5	Unsafe >2.5	
8	7	4	C1S1, C2S1, C3S1, C4S1, C3S2, C4S2 C4S4 C2S3, C3S3

Table-1: Analytical methods and equipments used for chemical analysis.

S. No.	Parameters	Analytical Methods
A.	***Physico-chemical analysis***	
	pH	pH meter
	Conductivity (EC)	Electrometric method
	Carbonate & bicarbonate (CO_3,HCO_3)	Electrical conductivity method
	Chloride (Cl)	Titrimetric method
	Sulphate (SO_4)	Argenotometric method
	Nitrate (NO_3)	Nephloturbidity method
	Fluoride (F)	Spectro-photometric method
	Total hardness (T.H)	Ion metric method
	Calcium (Ca)	EDTA-Titri metric method
	Magnesium (Mg)	EDTA-Titri metric method
	Sodium (Na)	By difference
	Potassium (K)	Flame photometric method
		Flame photometric method
	Total Dissolved Solids (TDS)	Gravimetric
B.	***Trace elements/Heavy metals***	
	Copper (Cu) Cadmium (Cd) Chromium (Cr) Lead (Pb) Manganese (Mn) Nickel (Ni) Cyanide (Cn)	Digestion followed by Atomic Absorption Spectrophotometer (AAS)
	Iron (Fe)	Spectrophotometer method

Fig.8: Groundwater Quality, 2015



2.3 Geophysical data:

The surface geophysical studies (using electrical method) conducted over an area of approximately 3290 sq. km. through 81 numbers of shallow and deep Vertical Electrical Soundings (VES) using ABEM Terrameter have been utilized for interpretation. In Aquifer mapping studies 33 numbers of Shallow VES are conducted in toposheet No. 53B/2 and 7 of an area of 686 sq km. The aim of the survey was to delineate fresh water - saline water interface laterally as well as vertically.

Based on the quantitative interpretation of resistivity data in corroboration with the existing borehole data, following inferences are shown below;

- The ground water occurs in alluvium formations comprising fine to coarse sand, which form the potential aquifers. In the shallow aquifer ground water occurs under unconfined/water table conditions, where as in deeper aquifer, semi-confined/confined conditions exist. The interpretation of EC value reveals that the area is seems to be fresh up to 300m.
- The first layer with resistivity in the range of 100 and 500 ohm m and thickness within 40 to 50m in general corresponds to the topsoil mixed with sand and clay.
- The second layer having resistivity within 100 ohm m corresponds to the geological formation consisting mainly of sand with clay, inferred to be a saturated layer. The thickness of this layer in general has been assessed to be between 60 to 150m comprising intercalations of sand and clay etc.
- The bottom layer with comparatively low resistivity below 26 ohm m characterizes clay predominance with thin intercalations of clay and sand etc.
- The areas adjacent to Patiala city are expected to have sufficient thickness of potential aquifers as compared to the other areas. Some of the areas such as Ghanaur, Patran are reported to be affected with sodicity problem while salinity in shallow aquifer is identified at Gagga.

On the basis of results of surface geophysical investigation and conclusions the study area is fresh upto 300m, the fresh saline interface is not depicted up to 300m depth.

2.4 Exploratory drilling State - Data Availability:

The Lithologs of Exploratory Well/ Observation well/ Piezometer/ productive wells of CGWB, WRED (Water Resources and Environment Directorate), Water Supply and Sanitation (WSS) and Private Wells have been collected and those supported electrical logs have been validated for aquifer map preparation. The details are given in below table.

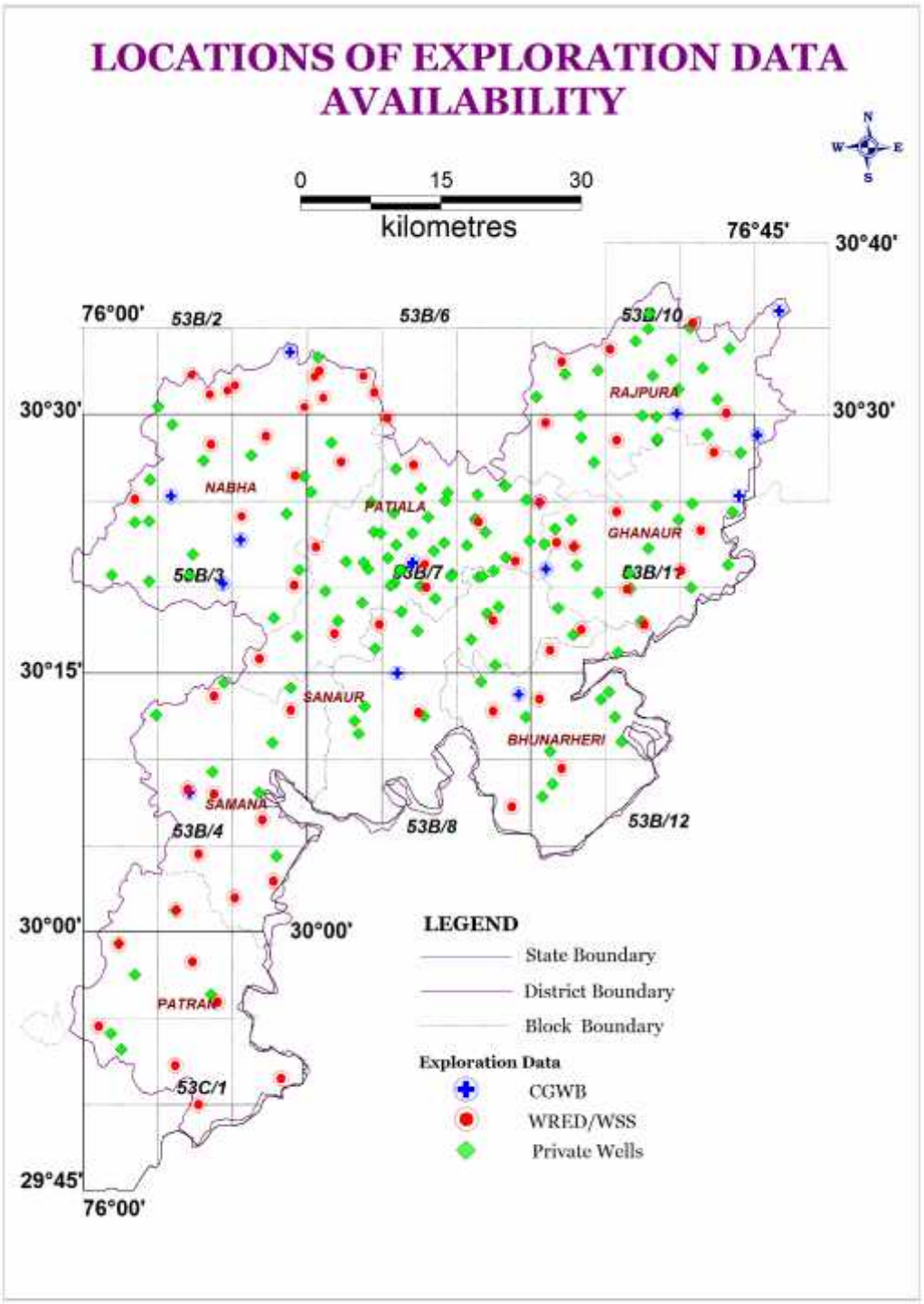
Data Availability of Exploration Wells of Patiala district

Sl.No	Source of data	Depth Range (m)				***Total***
		< 100	100-200	200-300	>300	
1	CGWB	7	7	6	5	**25**
2	WRED/WSS	49	16	0	6	**71**
3	PRIVATE WELLS	2	36	79	31	**148**
Total		**58**	**59**	**85**	**42**	**244**

2.5 Spatial Data Distribution

The actual data of all the wells in the area are plotted on the map of 1:50000 scale with 5'X5'grid (9 x 9) km (Fig. 9). Perusal of table shows that majority of tube wells falls in the in the depth range 200-300 m. The grids/ formations devoid of groundwater exploration are identified as data gaps and these are to be filled by data generation. The physical record of availability of exploration data is given in Annexure-III.

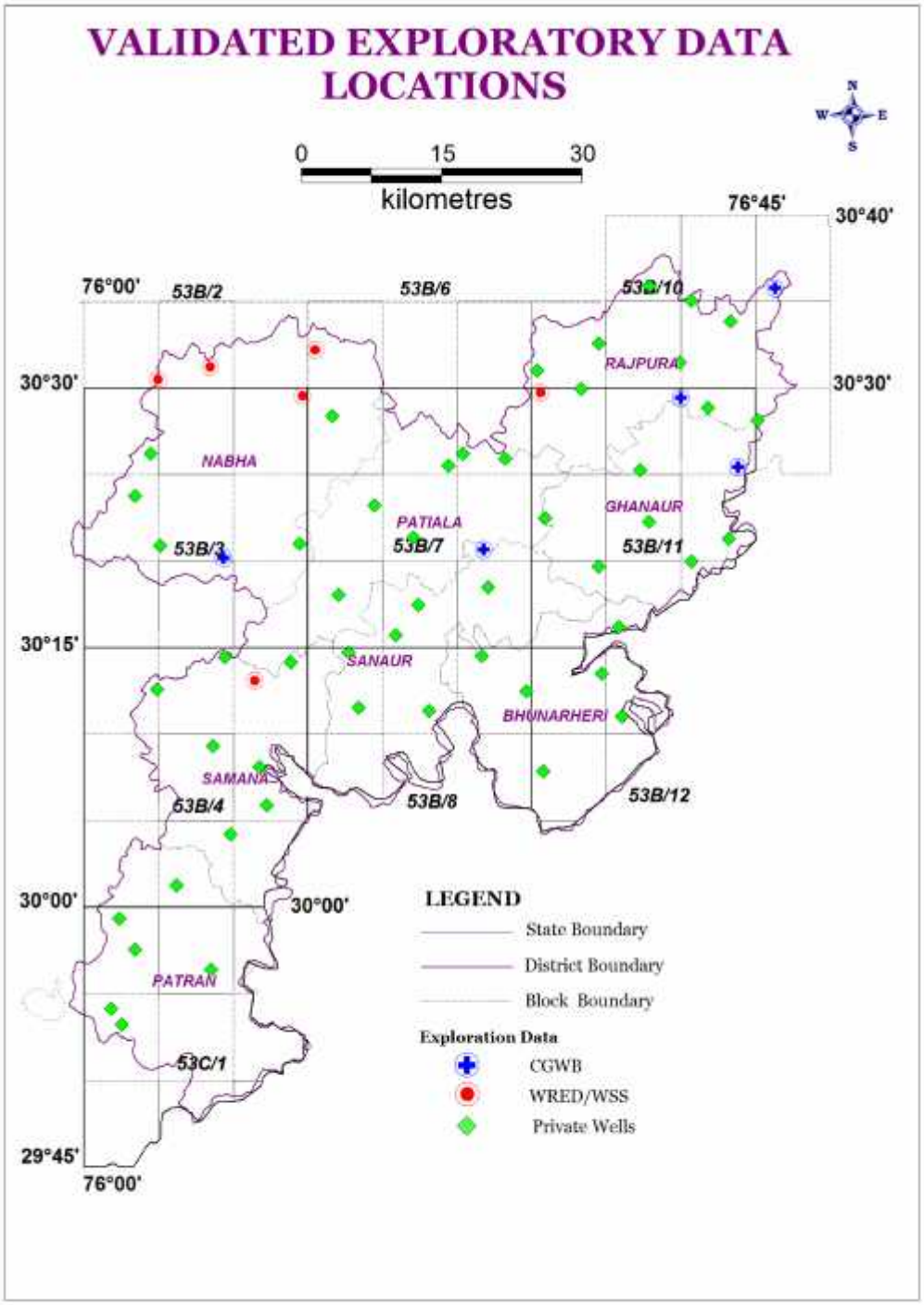
Fig.9: Locations of Exploration Data Availability



3.0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

All the available data have considered and been validated 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 9) km and is shown in Fig.10.

Fig.10: Locations of Validated Exploration Data



The optimized wells of CGWB, WRED (Water Resources and Environment Directorate), Water Supply and Sanitation (WSS) and private wells used to prepare the elevation or collar

elevation map to identify the topographic variations on the ground surface so that it can give the synoptic picture of gradient variations in the water levels. The topographic elevation values have been plotted to prepare the elevation contour map and is in Fig.11. The locations of validated wells in quadrant and toposheet wise distributions in respective blocks are shown in Annexure-IV. Three dimensional locations of validated exploratory wells with litholog are given in Fig.12.

Fig.11: Elevation contour map

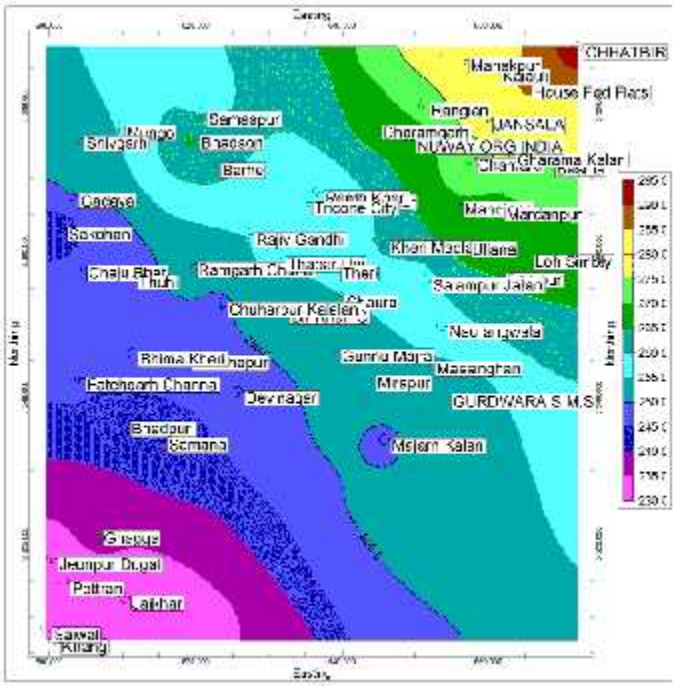
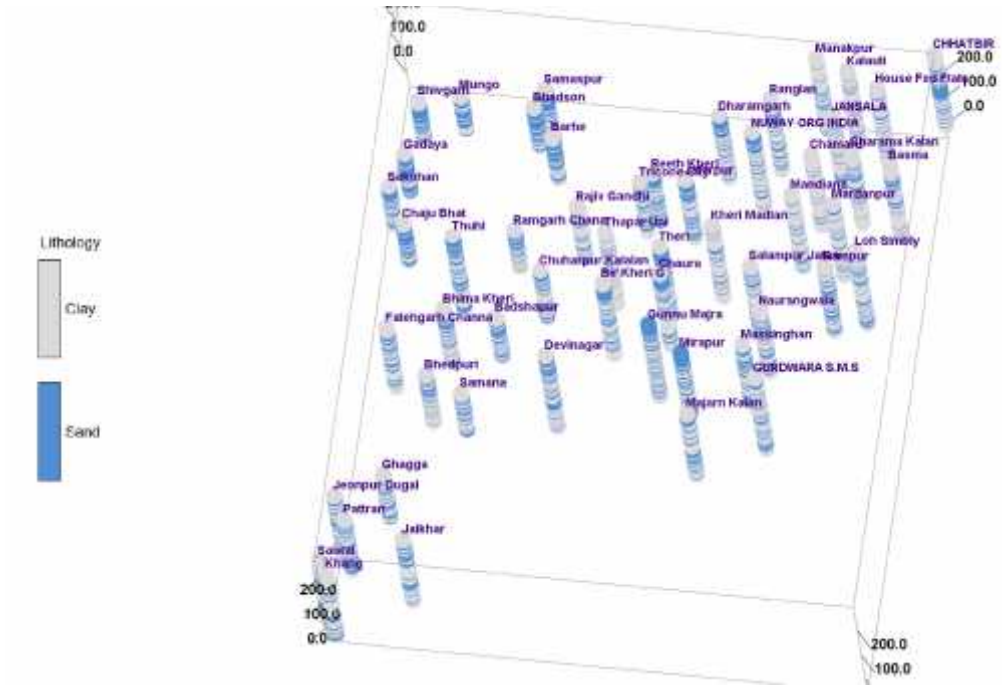


Fig.12: Three dimensional locations of validated exploratory wells with litholog



3.1 Sub Surface Disposition

3.1.1 Previous Work:

The area is underlain by formations of Quaternary age comprising of alluvium deposits belonging to vast Indus alluvial plains. Sub surface geological formations comprise of fine to coarse grained sand, silt, clay and kankar. Ground water at shallow depth occurs under unconfined to semi confined and confined conditions in deeper aquifers.

Exploratory drilling was carried out by CGWB at 13 locations in the district includes 05 Exploratory wells, 02 Slim holes and 06 Piezometers through in-house activities and 04 exploratory wells and 04 piezometers through outsourced by M/s WAPCOS Ltd. to delineate and determine the potential aquifer zones, evaluation of aquifer characteristics etc. The drilling has been done to a maximum depth of about 426.09 m at village Chamaru in Rajpura block and revealed the presence of 15 prominent permeable granular zones. Total thickness of alluvium is expected to be more than 426 m as bed rock has not been encountered up to that depth. The granular zone consists of fine to medium sand. Aquifer characteristics of the study area are given in Table.3.

Further, the study of exploratory boreholes drilled in the district revealed the presence of four aquifer groups up to the maximum drilled depth of 550 m. The first aquifer group forms the shallow water table aquifer (Un confined) occurs maximum down to 141 m bgl and below that clay layer starts getting thickened about 12 -34 m depth and is considered as Unconfined Aquifer. The second and third aquifer behaves as semi-confined to confined aquifer and consisting of thin sand layers alternating with thicker clay layers. Overall flow of ground water is towards south to south-west direction.

Table- 2: The Aquifer Parameters of Patiala District

Aquifer Group	**Discharge 'Q' (lpm)**	**Transmissivity 'T' (m^2/day)**	**Storativity**
Aquifer-I	546 - 3318	900 - 9410	$2.85x10^{-4}$ - $4.7x10^{-3}$
Aquifer-II	2779 - 3373	743 - 1662	$4.30x10^{-4}$ - $1.95 x10^{-3}$
Aquifer-III	1254 - 2699	151 - 1479	NA

The details of validated data on exploration wells is given in below table

Data Validation of Exploration Wells of Patiala District

Sl.No	Source of data	Depth Range (m)				***Total***
		< 100	100-200	200-300	>300	
1	CGWB	0	0	3	5	**8**
2	WRED/WSS	0	7	0	0	**7**
3	PRIVATE WELLS	0	17	48	34	**99**
Total		**0**	**24**	**51**	**39**	**114**

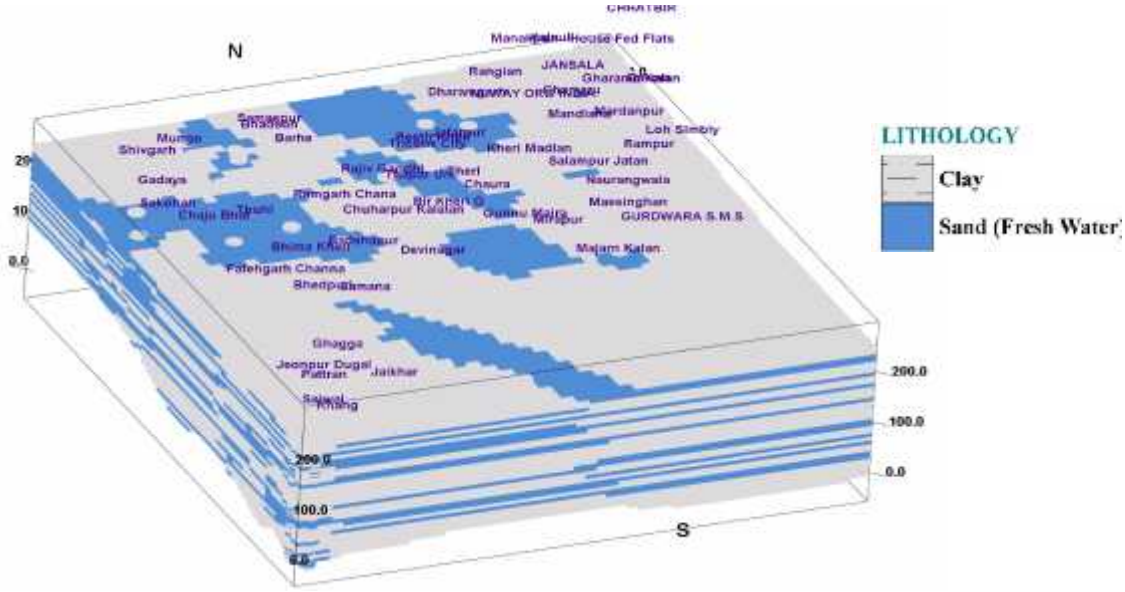
3.1.2 Present NAQUIM Study:

To understand the sub surface disposition in the study area, geological sections and fence diagram have been prepared by synthesizing the various sub-surface sections on the basis

of study of the lithological logs and electrical logs of boreholes drilled by CGWB, WRED and Private Agencies using the RockWorks15 software and a 3D lithological model has been prepared (Fig.13). The 2D lithology sections and 3D lithological fence diagram has been prepared using lithology model and are shown in Fig.14a, b & 15 respectively. The aquifers are composed of fine to medium sand with clay intercalations. The granular zones are extensive.

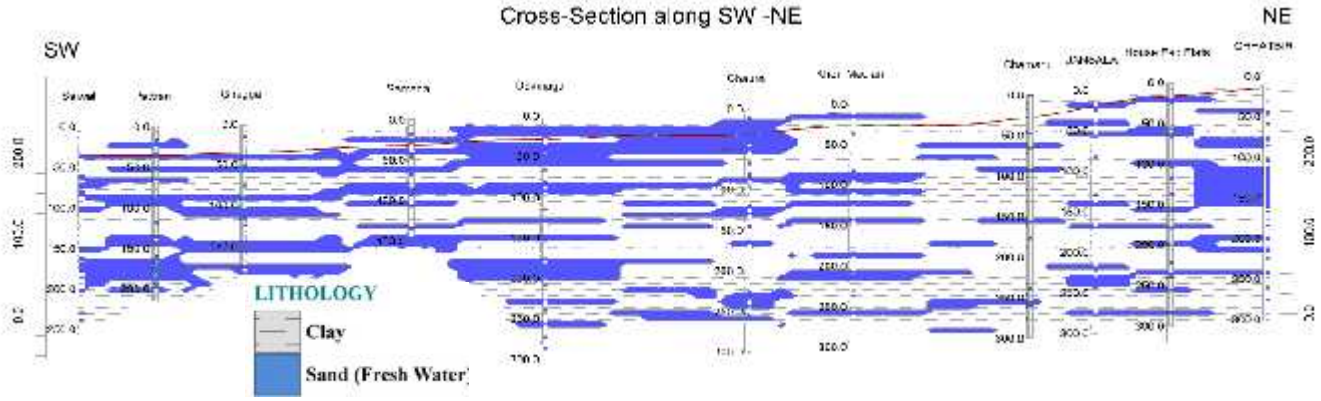
Based on geophysical borehole logging and use of resistivity profiling followed by the depth soundings at few selected places, for the present study and will be referred from time to time as it is obviously the higher resistivity beds represents freshwater zone in contrast in low resistive beds indicating saline groundwater zone. This area is totally represents freshwater zones.

Fig.13: 3-Dimension Lithological Model

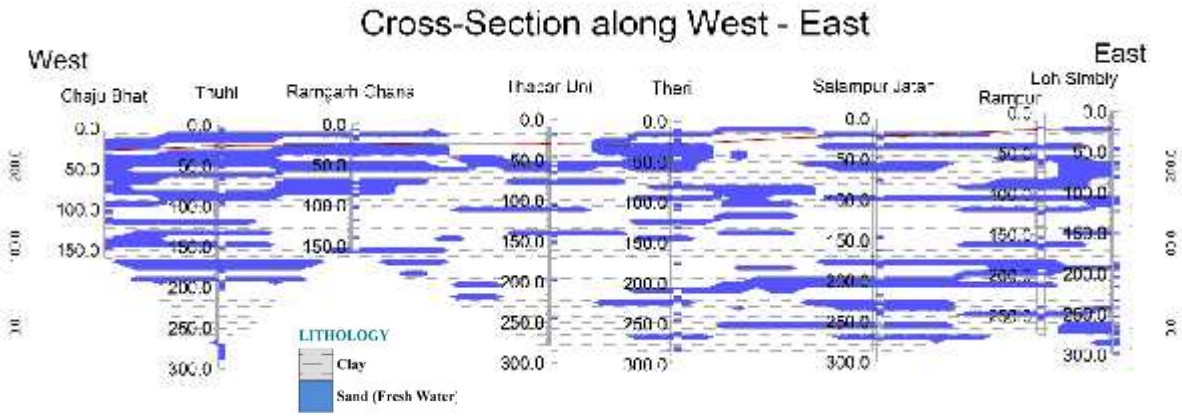


The major aquifer system of this area is quaternary alluvial deposits of Ghaggar basin, having older alluvium which mainly comprises of sand, silt and clay admixed with kankars. The top surface layer and soil is mainly clay. The lithology shows the variation in lithology thickness i.e. thick clay layers inter bedded with sand except at few locations. In northern parts of the district major lithological formations are characterized by layers of fine to coarse sands interbedded with thick layers of clay.

Fig.14a,b: 2-Dimension Lithological Sections



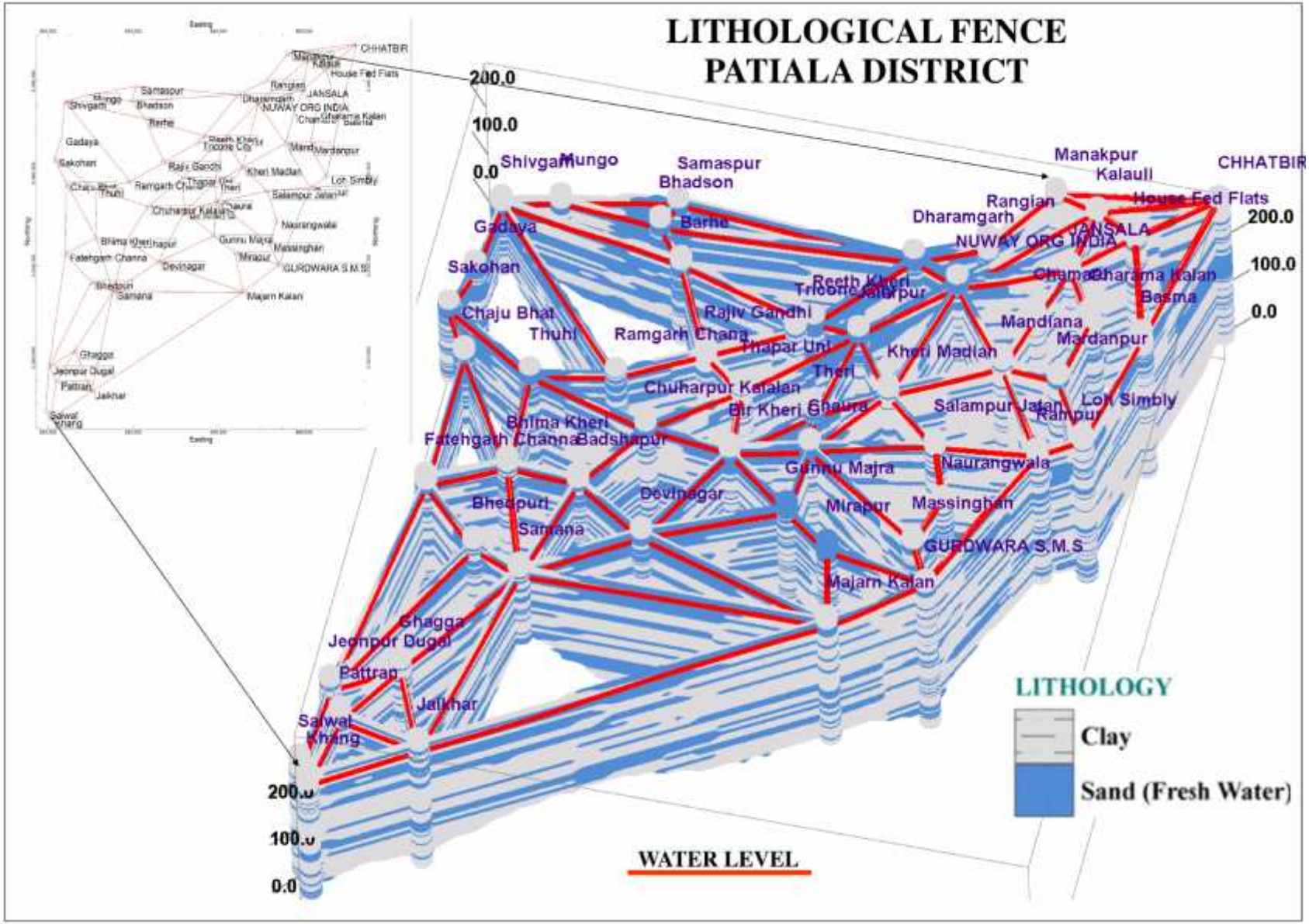
Study of the SW-NE lithological section indicates that surface soil of 8 to 30 m thickness is an admixture of clay with intercalation of sand lenses. There are 4 to 5 well defined granular zones up to 250 m depth separated by laterally extensive clay layers 8 – 30 m thick. The third clay bed occurring at 100 m is alternating with equally extensive thin sand layers shown in borehole Devinagar, Samana, Ghagga and Kheri Madan. Below 250 m there are few granular zones and thick clay. The top sand beds are medium grained while the lower ones are fine to medium in texture. The overall lithological section shows the variation in lithology thickness i.e. thick clay layers inter bedded with sand except at location Devinagar where thin clay layers interbedded with sand were identified. There is inter-layering of sand and thick clay at Chamaru and Jansala towards north- eastern side. The sand percentage increases towards south western direction. Granular zones are more thickened and potential in south western part.



Study of the E-W lithological section indicates that surface soil of 5 to 18 m thickness is an admixture of clay and kankar with intercalation of sand lenses. There are 3 to 4 well defined granular zones up to 200 m depth separated by laterally extensive clay layers 30 m thick in western part while 2 to 3 well defined granular zones separated by thick clayin eastern part t depth up to 300m. The lithology shows the variation in thickness i.e. thin clay layers inter bedded with sand except at location Thappar University where thick clay layers were identified at top depth up to 40 m and at depths 150 mbgl. There is inter-layering of sand with thick clay at Theri and Salampur jatan towards eastern side at a depth below 150 m and 102 m bgl. There is thick inter-layering of sand and clay towards all lithologs except Thappar University, Theri and Salampur jatan shows thin sequence of sand and clay towards Western side.

The geometry and nature of aquifers provide the basic parameters for determining occurrence and movement of ground water. The lithological disposition of the area is given in Annexure-V. The 3D lithological fence will represent the much more clear representation of sub-surface lithology in space.

Fig.15: 3-Dimension Lithological Fence



3.2 Aquifer Geometry:

The aquifer group embodies a number of granular layers alternating with thick or thin clay lenses. A few clay layers intervening these aquifer groups pinch out against the sand zones at a few places. The marker horizons are traced all over the area by connecting their tops and bottoms. Sandy clay layer occurs at the surface covering the unconfined aquifer which is in turn underlain by prominent clay zone. It is composed of mainly of medium sand with thin beds of fine sand.

The first aquifer is water table aquifer and extends all over the area is composed mainly of less coarse sediments as compared to other groups. This aquifer is overlain by a thin clay layer of about 1 to 8 m and is also underlain by clayey group which is about more than 12 m depth. Aquifer -I extends maximum upto 111 m of depth and below that clay layer starts getting thickened about 16 to 43 m separating Aquifer II and 19 to 55 m clay layer separated Aquifer-III upto 300m depth (Annexure VI).

Based on the same criteria, to know the broad picture of the aquifer disposition, inter-relationship of granular zones, nature, geometry and extension of aquifers in the Patiala district, the aquifer grouping has been done using the sub-surface lithology and a three-dimensional aquifer model has been prepared shown in Fig.16. An aquifer disposition 3D fence diagram and 2D Aquifer section are also prepared using the aquifer model and are shown in Fig.17 and Fig.18 a,b. The aquifer grouping, group thickness and granular zones encountered in the groups are given in table below

Aquifer Grouping in Patiala District

Aquifer Group	Range		Thickness		Granular Zones	
	From	To	Min	Max	Min	Max
Aquifer I	23	111	58	90	28	53
Aquifer II	128	195	55	77	24	34
Aquifer III	227	300	58	87	20	46

Fig.16: 3D Aquifer disposition Model

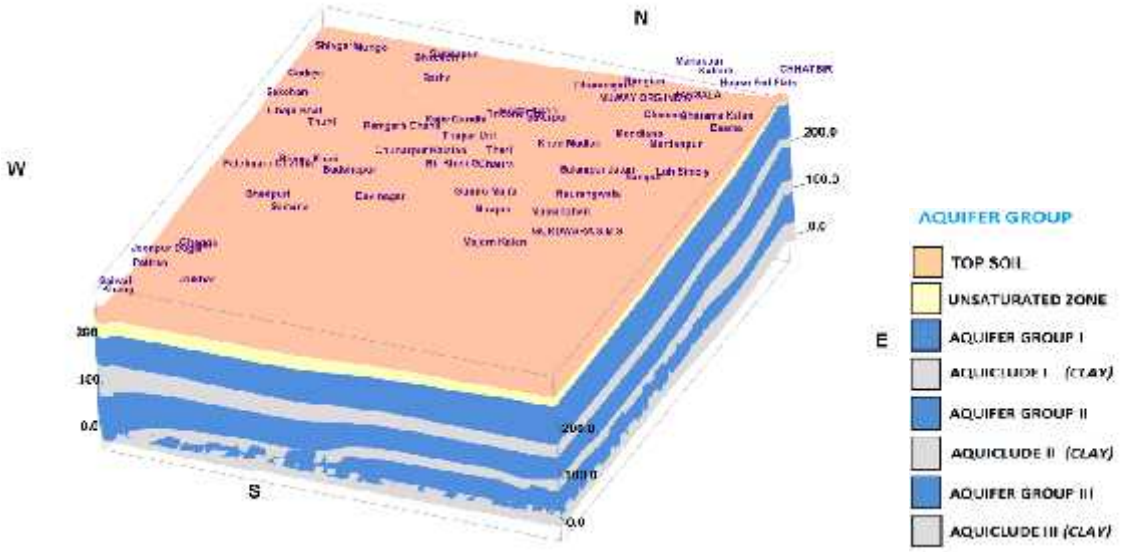


Fig.17: 3D Aquifer Disposition Fence

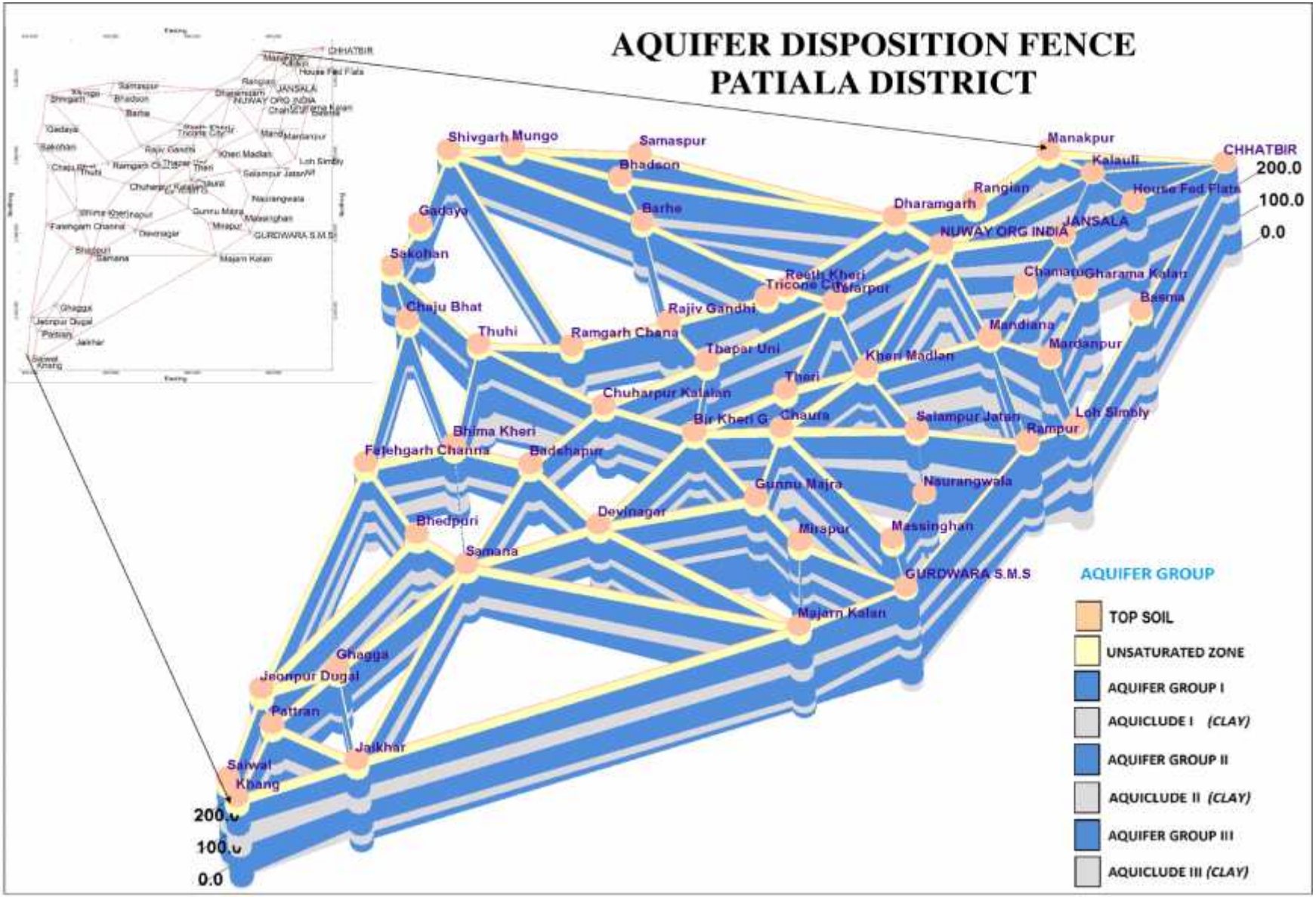


Fig.18a: 2-Dimension Aquifer Sections along Salwal to Chatbir

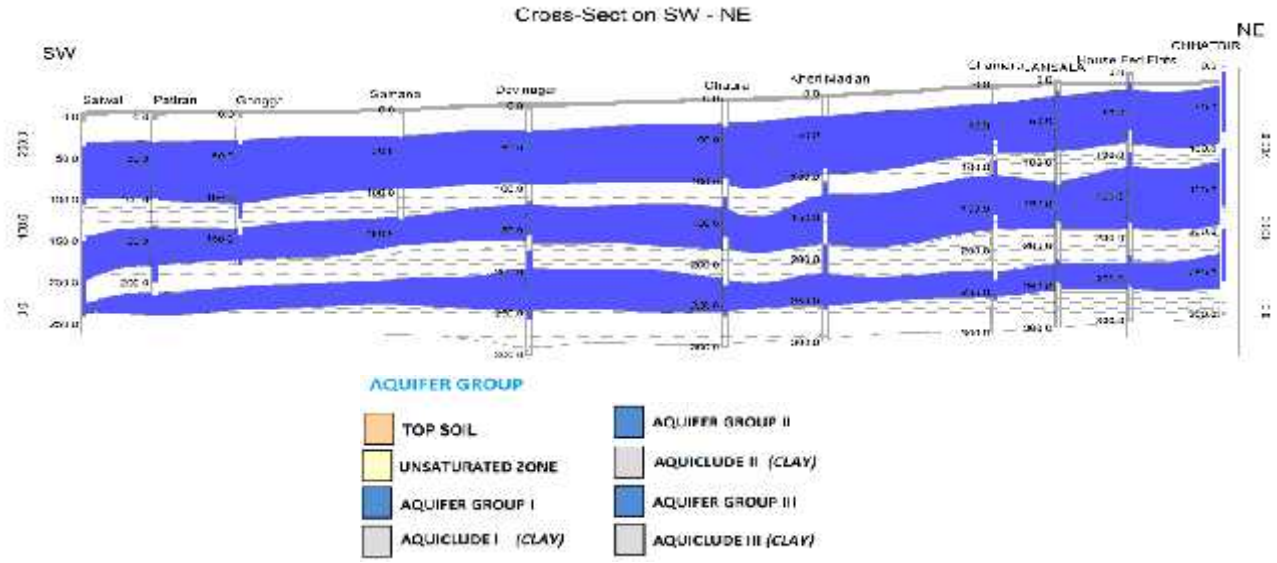
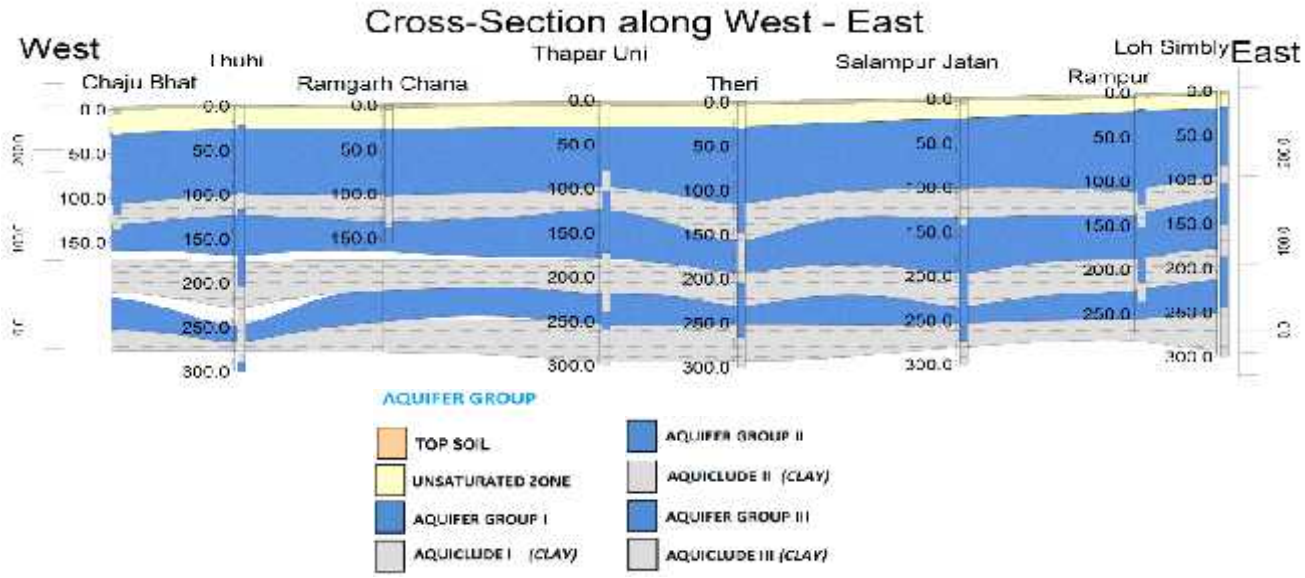


Fig.18b: 2-Dimension Aquifer Sections along Chaju Bhat to Loh Simbly



In the above aquifer sections the Aquifer-I disposition is most prominent in thickness and granular zones encountered than other Aquifer groups.

4.0 GROUND WATER RESOURCES

Ground water resource estimation of the area have been carried out by taking Dynamic and 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 Water Resources and Environment Directorate (WRED), Department of Irrigation, Punjab on the basis of Ground Water Estimation Committee (1997) methodology.

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 ground water resource of this zone has been calculated considering 12% specific yield of the formation. The specific yield value for the unconfined aquifer has been taken as 60% of 0.12 which comes as 0.072 whereas for the confined aquifer, the storativity value has been considered. Since the specific yield is likely to reduce with increase in depth due to compaction of overlying sediments.

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

4.1 Unconfined Aquifers

a. Dynamic Resources:

Block-wise ground water resource potential of the district has been assessed as per GEC-97 as on 31st March 2013. The primary source of recharge in the area is the rainfall. The ground water development in all the blocks has exceeded the available recharge, thus all the blocks have been categorized as over exploited. Stage of ground water development in the Patiala district has been assessed to be 189%. The details are explained in below Table-3.

Table-3: Dynamic Ground Water Resource & Development Potential (31.03.2013) in mcm

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 (11+12)*	*Provision for domestic, and industrial requirement supply to 2025*	*Net Ground Water Availability for future irrigation development (10-11-14)*	*Stage of Ground Water Development {(13/10) * 100} (%)*	*Category*
Bhuner Heri	181.08	377.05	2.72	379.77	4.04	-200.01	210	Over Exploited
Ghanaur	153.79	223.82	3.03	226.84	4.49	-74.52	148	Over Exploited
Nabha	404.44	606.86	7.41	614.27	10.49	-212.91	152	Over Exploited

Patiala	191.53	344.15	13.56	357.71	20.14	-172.76	187	Over Exploited
Rajpura	145.16	244.08	5.73	249.81	8.51	-107.44	172	Over Exploited
Samana	136.65	266.94	3.99	270.93	5.93	-136.22	198	Over Exploited
Sanaur	158.57	338.06	2.95	341.01	4.38	-183.87	215	Over Exploited
Patran	159.86	454.35	3.92	458.27	5.83	-300.32	287	Over Exploited
TOTAL	**1531.08**	**2855.30**	**43.32**	**2898.62**	**63.81**	**-1388.03**	**189**	**Over Exploited**

b. In-storage Ground Water Resources

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

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

4.2 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 19. 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.

i) **Storativity Concept:**

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

ii) **Specific Yield Concept:**

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	×	Specific 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 modeling approach. The Block Wise In storage Ground Water Resources in Unconfined Aquifer –I, Confined Aquifer-II, III and total Groundwater resources (Alluvium) is given in Tables 4, 5, 6 & 7 respectively.

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

Fig 19: Concept for Resource Estimation in Unconfined and Confined Aquifer System

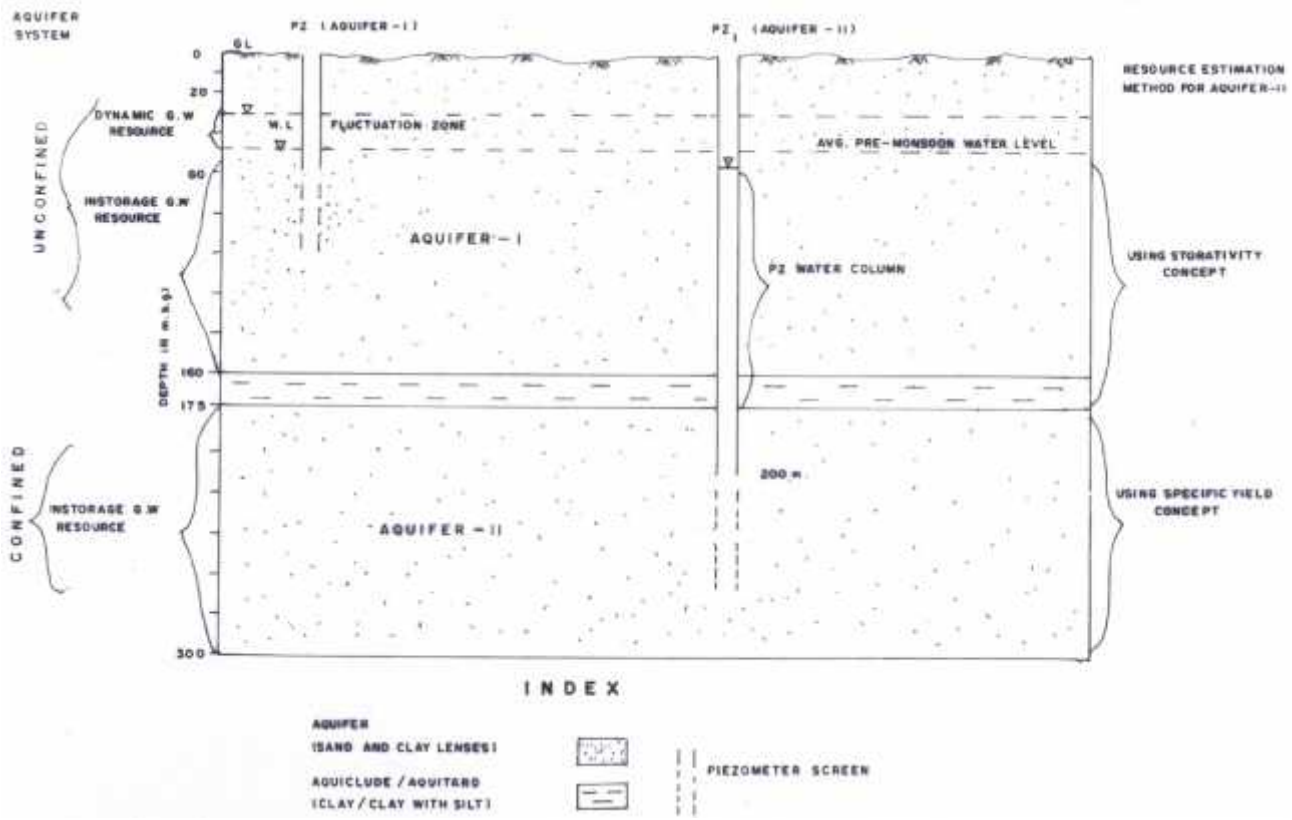


Table-4: Block Wise In storage Ground Water Resources in Unconfined Aquifer –I (Alluvium)

BLOCK WISE INSTORAGE GROUND WATER RESOURCES IN UNCONFINED AQUIFER –I (ALLUVIUM) OF PATIALA DISTRICT											
Sr. No.	Name of Assessment Unit	Areal extent (ha)				Average Pre-monsoon Water Level (m bgl)	Depth to bottom of Aquifer Group I (m bgl)	Total Thickness of formation below Pre-monsoon Water Level (m) Col. (8-7)	Thickness of the Granular Zone in AQUIFER GROUP-I below Pre-monsoon WL (m)	Average Specific Yield	In-Storage Ground Water Resources (ham) Col. [(5)*(10)*(11)]
		Total Geographical Area (ha)	Assessment Area								
			Total	Fresh Water	Brackish/Saline Water						
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1	Bhuner Heri	38020	38020	38020	0	27.77	86	58.23	28	0.072	76648
2	Ghanaur	44320	44320	44320	0	18.91	99	80.09	38	0.072	121260
3	Nabha	54820	54820	54820	0	20.71	111	90.29	53	0.072	209193
4	Patiala	42310	42310	42310	0	20.48	103	82.52	40	0.072	121853
5	Rajpura	39940	39940	39940	0	19.63	86	66.37	27	0.072	77643
6	Samana	39650	39650	39650	0	25.47	94	68.53	34	0.072	97063
7	Sanaur	33980	33980	33980	0	19.75	95	75.25	38	0.072	92969
8	Patran	37230	37230	37230	0	28.81	107	78.19	34	0.072	91139
Dist. Total (ham)		**330270**	**330270**	**330270**							**887769**
Dist. Total (mcm)		**3302.7**	**3302.7**	**3302.7**							**8878**

ham: hectare metre

mcm: million cubic metre

Table-5: Block Wise In storage Ground Water Resources – Confined (Aquifer II)

BLOCK WISE INSTORAGE GROUND WATER RESOURCES – CONFINED (AQUIFER II)															
Sr. No.	Name of Assessment Unit	Total Geogra-phical Area	Areal extent (ha)		Top Aqui-fer II (m bgl)	Depth to bottom of Aquifer II (m bgl)	Peizometer head value for Confined Aquifer-II (m bgl)	Thickness of piezometric level(m bgl) Col.(6-8)	Total Thickness of confined aquifer down to explored depth (m) Col.(7-6)	Thickness of the Granular Zone in confined aquifer down to explored depth (m)	Average Specific Yield	Average value of Storati-vity	In-Storage Ground Water Resources (ham) (Specific yield concept) Col.[(5)*(11)* (12)] FRESH	In-Storage Ground Water Resources (Storativity concept) Col.[(5)*(9)*(13)]	Total in-Storage Ground Water Resources (ham) Col. (14+15)
			Total	Fresh Water											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	Bhuner Heri	38020	38020	38020	116	190	34.75	81.25	74	29	0.072	0.00195	79386	6024	85410
2	Ghanaur	44320	44320	44320	136	200	31.95	104.05	64	28	0.072	0.00195	89349	8992	98342
3	Nabha	54820	54820	54820	133	210	28.8	104.2	77	30	0.072	0.00195	118411	11139	129550
4	Patiala	42310	42310	42310	130	185	26.5	103.5	55	25	0.072	0.00195	76158	8539	84697
5	Rajpura	39940	39940	39940	119	181	37.9	81.1	62	24	0.072	0.00195	69016	6316	75333
6	Samana	39650	39650	39650	128	192	34.6	93.4	64	26	0.072	0.00195	74225	7221	81446
7	Sanaur	33980	33980	33980	117	191	32.5	84.5	74	30	0.072	0.00195	73397	5599	78996
8	Patran	37230	37230	37230	146	210	34.3	111.7	64	34	0.072	0.00043	91139	1788	92927
Dist. Total (ham)		**330270**	**330270**	**330270**									**671081**	**55619**	**726700**
Dist. Total (mcm)		**3303**	**3303**	**3303**									**6711**	**556**	**7267**

ham: hectare metre

mcm: million cubic metre

Table-6: Block Wise In storage Ground Water Resources – Confined (Aquifer III)

BLOCK WISE INSTORAGE GROUND WATER RESOURCES – CONFINED (AQUIFER III)														
Sr. No	Name of Assess-ment Unit	Total Geographical Area	Areal extent (ha)		Top Aquifer III (m bgl)	Depth to bottom of Aquifer III (m bgl)	Thickness of piezo-metric level (m bgl) Col. (6-Avg. Piezo metrice Head)	Total Thicknes s of confined aquifer down to explored depth (m) Col. (7-6)	Thicknes s of the Granular Zone in confined aquifer down to explored depth (m)	Aver-age Specific Yield	Average value of Stora-tivity	In-Storage Ground Water Resources (ham) (Specific yield concept) Col. [(5)*(10)* (11)] FRESH	In-Storage Ground Water Resources (Storativity concept) Col. [(5)*(9)* (12)]	Total in-Storage Ground Water Resources (ham) Col. (13+14)
			Total	Fresh Water										
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	Bhuner Heri	38020	38020	38020	213	300	151.6	87	46	0.072	0.00195	125922	11239	137162
2	Ghanaur	44320	44320	44320	225	300	190.6	75	30	0.072	0.00195	95731	16472	112204
3	Nabha	54820	54820	54820	242	300	207.6	58	23	0.072	0.0038	90782	43246	134028
4	Patiala	42310	42310	42310	232	300	197.6	68	22	0.072	0.00195	67019	16303	83322
5	Rajpura	39940	39940	39940	217	300	182.6	83	21	0.072	0.00195	60389	14221	74611
6	Samana	39650	39650	39650	227	300	192.6	73	20	0.072	0.00195	57096	14891	71987
7	Sanaur	33980	33980	33980	227	300	192.6	73	24	0.072	0.00195	58717	12762	71479
8	Patran	37230	37230	37230	237	260	202.6	23	9	0.072	0.00195	24125	14708	38833
Dist. Total (ham)		**330270**	**330270**	**330270**								**579782**	**143844**	**723626**
Dist. Total (mcm)		**3303**	**3303**	**3303**								**5798**	**1438**	**7236**

The Average Peizometer head value for confined Aquifer - III is 34.40 m.bgl

ham: hectare metre

mcm: million cubic metre

Table-7: Block Wise Total Availability of Groundwater Resources upto 300 m Depth and Volume of Un-saturated granular zone after 3 mbgl upto Average Pre-Monsoon water level.

AVAILABILITY OF TOTAL FRESH GROUNDWATER RESOURCES IN PATIALA DISTRICT									
Sl.No	Block	*Volume of Unsaturated Zone up to Pre-monsoon WL (ham)*	*Dynamic Groundwater Resources (2013) AQUIFER-I*	*In-storage Groundwater Resources AQUIFER-I*	Fresh Groundwater Resources AQUIFER-I [(4)+(5)]	Fresh Groundwater Resources AQUIFER-II	Fresh Groundwater Resources AQUIFER-III	**Total Availabilty of Fresh Groundwater Resources [(6)+(7)+(8)]**	
								ham	mcm
1	2	*3*	*4*	5	6	7	8	9	10
1	Bhuner Heri	40058	18108	76648	94757	85410	137162	317328	3173
2	Ghanaur	28347	15379	121260	136638	98342	112204	347184	3472
3	Nabha	61837	40444	209193	249637	129550	134028	513215	5132
4	Patiala	53818	19153	121853	141006	84697	83322	309025	3090
5	Rajpura	31009	14516	77643	92159	75333	74611	242102	2421
6	Samana	43964	13665	97063	110728	81446	71987	264162	2642
7	Sanaur	43508	15857	92969	108826	78996	71479	259301	2593
8	Patran	36188	15986	91139	107125	92927	38833	238886	2389
Dist. Total (ham)		**338729**	**153108**	**887769**	**1040876**	**726700**	**723626**	**2491203**	**24912**
Dist. Total (mcm)		**3387**	**1531**	**8878**	**10409**	**7267**	**7236**		

ham: hectare metre

mcm: million cubic metre

5.0 GROUND WATER ISSUES

5.1 Ground Water Depletion

The study area is famous for its paddy and non paddy cultivation. The quality of ground water in the area is suitable for irrigation and drinking purposes, therefore, the ground water is constantly being pumped for the irrigation due to its easy access through tube wells at shallow depths and they are the main source of irrigation. This will lead to its deepening of ground water levels in all blocks of Patiala District as the recharge of the groundwater through rainfall and other sources are less than the overall extraction. The hydrographs (Shallow and Deep) also shows the declining water level trend over the years in the district (Fig.20 a,b) and is categorized as over-exploited. This declining water table trend, if not checked, would assume an alarming situation in the near future affecting agricultural production and thus economy. Ground Water Recharge and Conservation may be carried out in these areas to overcome the depletion.

Fig.20a: Long term ground water table variation (Shallow Observation Wells)

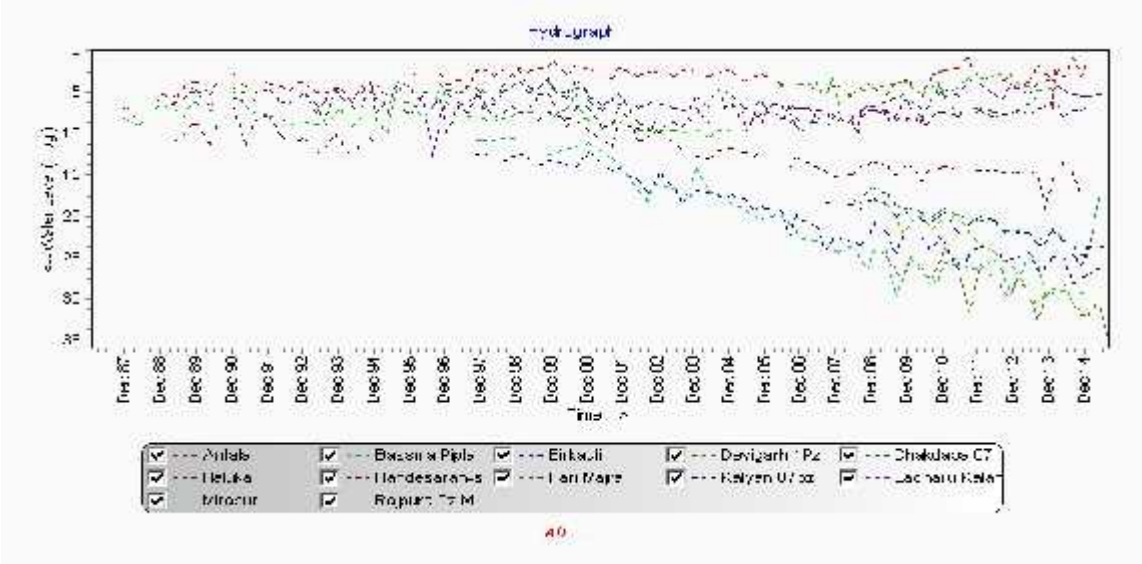
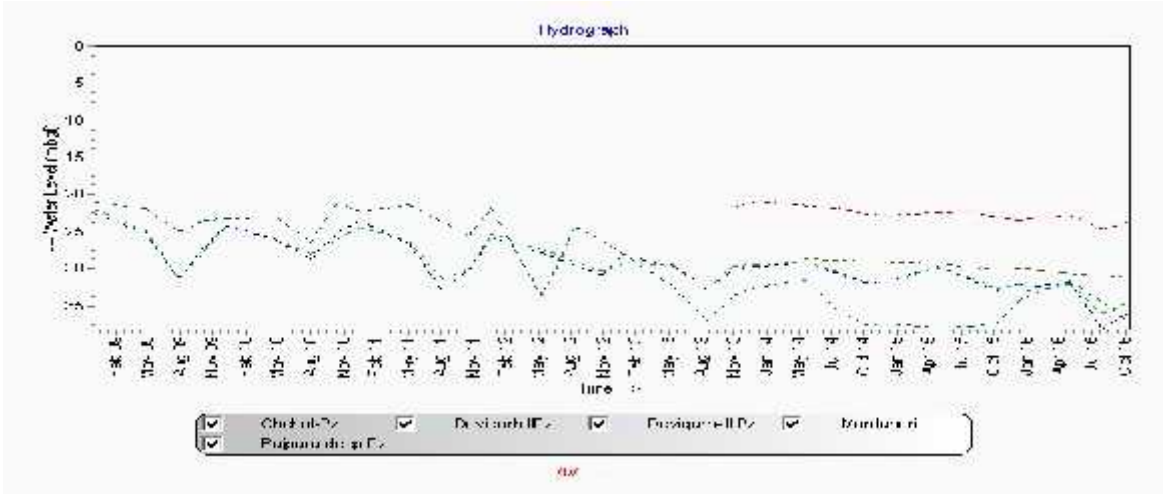


Fig.20b: Long term ground water table variation (Deep Observation Wells)



5.2 Ground Water Quality

The ground water of the study area is alkaline in nature and seems to be fresh. Ground water with Fluoride concentration above permissible limit 1.5 mg/l is found mainly in Rajpura (3.5) and Thua (2.89) and Nitrate concentration above permissible limit 45 mg/l is found in Samana (203) and Patran (81). There is growing concern on deterioration of ground water quality due to geogenic and anthropogenic activities.

5.3 Ground Water Irrigation Scenario

As per the data available from minor irrigation census 2006-07, the detailed number of shallow, deep, tube wells, lined, unlined water distribution system, land holdings of wells are given in Table-8,9 &10 .

Table-8: Distribution of Tube wells According to Well Owner's land holding Size

Type of Tube well (TW)	*Marginal (0-1 ha)*	*Small (1-2 ha)*	*Semi-Medium (2-4 ha)*	*Medium (4-10ha)*	*Big (>10ha)*	*Owned by other than individual farmers*	*Total*
Shallow TW	1375	8586	27111	27871	6002	10	**70955**
Deep TW	19	565	2262	4480	1753	0	**9079**
Total	**1394**	**9151**	**29373**	**32351**	**7755**	**10**	**80034**

Table-9: Distribution of Tube wells According to Depth

Depth of Tubewells in metres								**Total depth Range 0-150m**
Depth range	0-20 m	20-40 m	40-60 m	60-70 m	70-90m	90-150m	>150 m	
Tubewells	738	2876	4172	63166	5687	3360	35	**80034**
Tubewells (%)	0.92	3.59	5.21	78.92	7.11	4.20	0.04	

Table-10: System of Ground water distribution device

	Open Water Channels			
Lined/pucca	*Unlined/kutcha*	*Underground Pipe*	*Others*	*Total*
968	77704	853	509	**80034**

6.0 MANAGEMENT STRATEGIES AND AQUIFER MANAGEMENT PLAN

Aquifer mapping is leads to groundwater management plans to be implemented by including demand side-management and Ground Water Use Efficiency.

An outline of the Aquifer Management Plan for each block is given in Part-II. This includes details regarding population, rainfall, average annual rainfall, agriculture and irrigation, water bodies, ground water resource availability, ground water extraction and water level behavior. Aquifer disposition and various cross sections have also been given. Ground water resources, extraction and other issues including ground water resource enhancement and demand side innervations have been given.

Artificial recharge plan is less feasible in the Patiala District due to very low availability of volume of surplus water (31.03 mcm) (Table-11a). 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) in over exploited blocks of the 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.

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 in the state of Punjab, particularly in overexploited blocks.

There are around 77704 (out of 80034) tube wells (97.08 %) operated by farmers for irrigation through unlined/Kutcha open channel system in study area (Table-10) where water from the tube well is discharge to the agricultural field. In this process, huge (around 25 %) (RKVY, 2015) quantity of ground water is wasted in soil moisture and evaporation losses.

Around 88.65 % of the tube wells are of shallow depth (20 to 70m) and remaining wells are deeper depth (70 to >150 m) existed in the area (Table-9). Thus, majority of wells are tapping shallow aquifer which is under stress.

Dynamic ground water resources (2013) indicate that Gross ground water draft for irrigation in the district is estimated at 2855.30 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 gross draft will be reduced to 251 mcm (Table-11a) assuming that there is a need of crop diversification by the farmers.

The benefit will lead to saving of precious ground water resources in overexploited blocks. The measure if implemented will bring down the ground water overdraft from 189 % to

144%. The category of the blocks will also improve resulting in boosting of agriculture and industrial development otherwise not sustainable in over-exploited blocks (Table-11b).

The tube wells also consume enormous electricity which is subsidized and government incur 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. It is expected to save 1% of the agricultural land occupied by open channels which can be utilized for cultivation purpose. Heavy ground water overdraft can be reduced by these efforts. This will ensure ***more crops per drop.***

6.3 Water saving Potential from Crop Diversification-Change Paddy to Maize/Soya-bean:

As the requirement of water for paddy is much high therefore by changing paddy to maize/soya-bean 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.

The block wise saving of water in mcm by applying various management strategies such as crop diversification, Under Ground Pipe lines (UGPL) in individual land and artificial recharge methods are given in tables 11.a, b.

Table-11a: Scope of Quantitative Impact on Stage of Development after applying various management strategies in mcm

Block	*Net Ground Water Availability (mcm)*	*Total Irrigation Draft (mcm*	*Total Draft (mcm)*	*Present Stage of draft (SOD) (%) (As per 2013)*	*Reduction in draft by different water saving method*				*SOD afterwards (%)*
					Replace water courses by UG Pipes (mcm)	*Adopt Artificial recharge (mcm)*	*Change Paddy to Maize/ Soyabean (mcm)*	*Total (mcm) (2+3+4)*	
				1	2	3	4	5	
Bhunerheri	181.08	377.05	379.77	210	91.51	3.79	103.62	198.92	99.87
Ghanaur	153.79	223.82	226.84	148	54.32	3.88	15.275	73.48	99.72
Nabha	404.44	606.86	614.27	152	147.28	5.80	57.375	210.45	99.85
Patiala	191.53	344.15	357.71	187	83.53	4.11	78.68	166.32	99.93
Rajpura	145.16	244.08	249.81	172	59.24	3.36	42.036	104.64	100.01
Samana	136.65	266.94	270.93	198	64.79	3.52	66.008	134.32	99.97
Sanaur	158.57	338.06	341.01	215	82.05	3.42	96.968	182.43	100.00
Patran	159.86	454.35	458.27	287	110.27	3.15	185.176	298.60	99.88
Total	**1531.08**	**2855.30**	**2898.62**	**189**	**692.98**	**31.03**	**645.138**	**1369.15**	**99.89**

Table-11b: Impact on Stage of Development (SOD) after applying various management strategies in Patiala District

Block	*Present SOD (%) as on 2013*	*Reduction in SOD (%) after unlined channel (%)*	*Resultant SOD (%) Col.(2 - 3)*	*Reduction in Stage of development after crop diversification by Maize/Soyabean (%)*	*Resultant SOD (%) Col.(2 - 5)*	*Reduction in Stage of development after Artificial recharge (%)*	*Resultant SOD (%) Col.(2 - 7)*
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Bhunerheri	210	50.53	159.47	57.2	152.8	2.09	207.91
Ghanaur	148	35.32	112.68	9.9	138.1	2.52	145.48
Nabha	152	36.42	115.58	14.2	137.8	1.43	150.57
Patiala	187	43.61	143.39	41.1	145.9	2.15	184.85
Rajpura	172	40.81	131.19	29	143	2.32	169.68
Samana	198	47.41	150.59	48.3	149.7	2.58	195.42
Sanaur	215	51.74	163.26	61.2	153.8	2.15	212.85
Patran	287	68.98	218.02	115.8	171.2	1.97	285.03
Total	**189**	**45.26**	**143.74**	**42.76**	**146.24**	**2.03**	**186.97**

By adopting all the management strategies resulting in total reduction in stage of groundwater development is 90.05%. Hence overall stage of development afterwards is 100 % and is given in Table.12.

Table-12: Overall Stage of Development (SOD) after reduction in Patiala District

Block	*Present Stage of development (%) as on 2013*	*Reduction in stage of development after unlined channel (%)*	*Reduction in Stage of development after crop diversification by Maize/Soyabean (%)*	*Reduction in Stage of development after Artificial recharge (%)*	*Total Reduction in Stage of development (%) (3 +4+5)*	*Stage of development afterwards (%) (2-6)*
1	**2**	**3**	**4**	**5**	**6**	**7**
Bhunerheri	210	50.53	57.2	2.09	109.82	100
Ghanaur	148	35.32	9.9	2.52	47.74	100
Nabha	152	36.42	14.2	1.43	52.05	100
Patiala	187	43.61	41.1	2.15	86.86	100
Rajpura	172	40.81	29	2.32	72.13	100
Samana	198	47.41	48.3	2.58	98.29	100
Sanaur	215	51.74	61.2	2.15	115.09	100
Patran	287	68.98	115.8	1.97	186.75	100
Total	**189**	**45.26**	**42.76**	**2.03**	**90.05**	**99**

BLOCK WISE

AQUIFER MAPS

AND

MANAGEMENT PLAN

(PART-II)

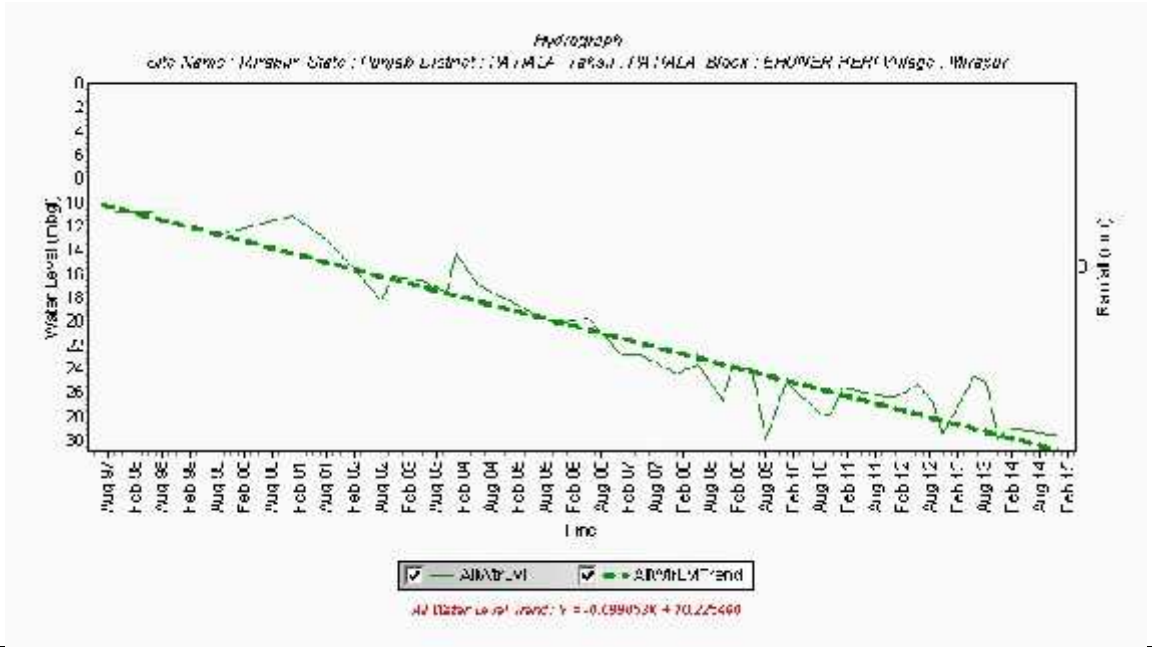
I. Salient Information of Bhunerheri Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>380.20 sq km</td></tr>
<tr><td>District/ State</td><td>Patiala, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 0
Rural Population: 125472
Total population: 125472</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 523 mm
Non-monsoon Rainfall : 124 mm
Annual Average Rainfall: 647 mm</td></tr>
<tr><td>Agriculture and Irrigation</td><td>Principal crops: Wheat, Rice, Maize and Sugar cane
Other crops: Vegetables and Fodder
Gross cropped area: 612.11 sq km
Net sown area: 309.02 sq km
Irrigation practices: Tube well and Canal Irrigation
Cropping intensity: 198%
<u>Area under</u>
Ground water Irrigation: 283.86 sq km
Surface water irrigation: 48.41 sq km
Gross Irrigated area: 608.94 sq km
Net Irrigated area: 307.43 sq km
Intensity of Irrigation: 198%
Number and types of abstraction structures: 10081, Tubewells</td></tr>
<tr><td>Ground Water Resource Availability and Extraction</td><td><u>Ground water Resources Availability</u>
Ground Water Resources are available in the different group of aquifers. The fresh water resources are estimated up to the depth of 300 m on the basis of geophysical interpretations.
<table>
<tr><th>Aquifer Group</th><th>Aquifer Depth range (m)</th><th>Aquifer Thickness (m)</th><th>Granular Zones (m)</th><th>Resources (mcm)</th></tr>
<tr><td>Aquifer-I</td><td>27.77 – 86.0</td><td>58</td><td>28</td><td>947.57</td></tr>
<tr><td>Aquifer-II</td><td>116.0 – 190.0</td><td>74</td><td>29</td><td>854.10</td></tr>
<tr><td>Aquifer-III</td><td>213.0 – 300.0</td><td>87</td><td>46</td><td>1371.62</td></tr>
</table>
Total Ground Water Resources available is 3173.28 mcm and total potential granular zones available are 103 m up to depth of 300 m. Block is categorized as Over-Exploited as per Dynamic Groundwater Resources, 2013 assessment.
<u>Ground water Resources Extraction</u>
Information regarding the abstraction from Aquifer II is not available, but there are drinking water supply wells of State Government tapping combined aquifers. Therefore, the ground water draft could not be assessed for Aquifer-II and III separately.</td></tr>
</table>

Existing and future water demands	Water Scarcity Villages: 142 Small Scale Industries : 113 Large Scale Industries : 0 Total Villages : 148 *Existing Gross Ground water Draft as on 2013* Irrigation: 377.05 mcm Domestic and industrial water supply: 2.72 mcm *Future water demands* Irrigation development potential : (-)200.01 mcm Domestic and industrial water supply up to 2025 years : 4.04 mcm
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 25.55 - 30.16 m bgl Post Monsoon: 28.10 - 32.61 m bgl Seasonal Fluctuation: 0.11 – (-)2.64 m/yr Mean (10 yrs) : (-)0.66– (-)4.53 m/yr *Trends* Pre Monsoon: (-)0.12 – (-)0.94 m/yr Post Monsoon: (-)0.28 – (-)1.22 m/yr **Aquifer-II** Pre Monsoon: 29.64 m bgl Post Monsoon: 32.95 m bgl Seasonal Fluctuation: 0.11 – (-)2.64 m/yr **Aquifer-III** No Monitoring Station

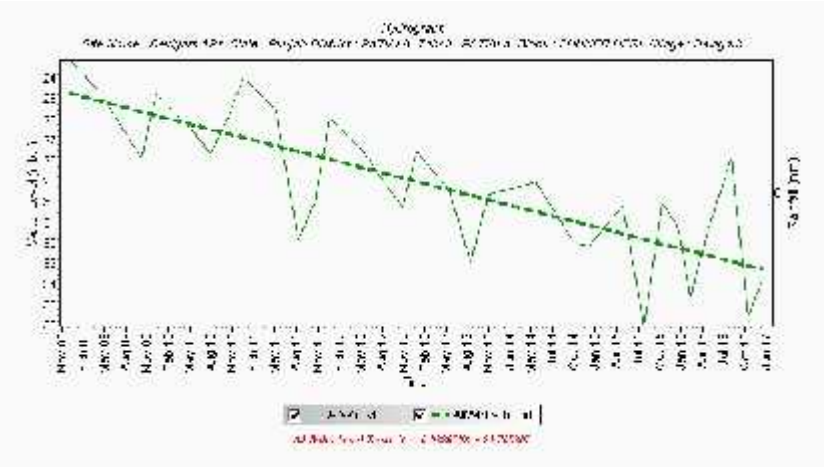
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Mirapur)



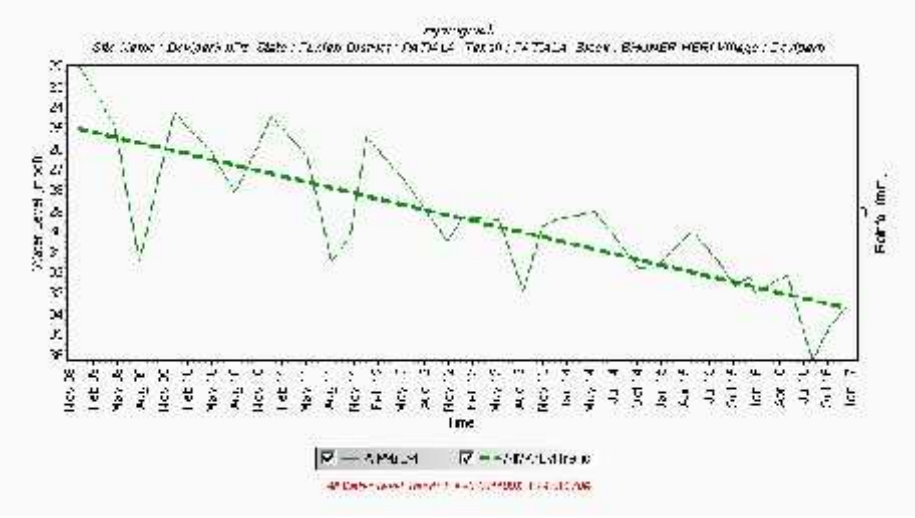
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Devigarh-I)



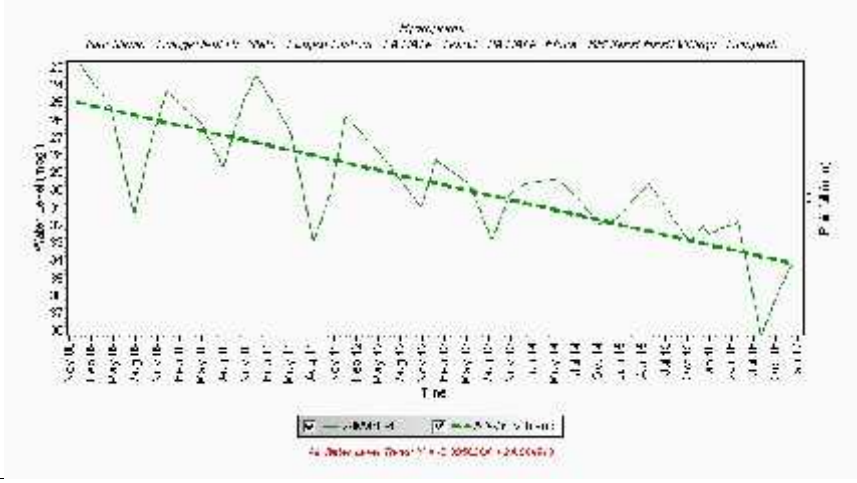
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Devigarh-II)



HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Devigarh-III)



Aquifer Disposition

Number of aquifers	1
Principal aquifer	Alluvium
Major Aquifer	Older Alluvium
Aquifer Disposition	Multiple Aquifer System (Three Aquifer Groups)

Exploratory Data Availability

Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	2	0	0	**2**
WRED/WSS	5	0	0	1	**6**
PRIVATE	0	0	10	0	**10**
TOTAL	**5**	**2**	**10**	**1**	**18**

Aquifer wise Characteristics

Aquifer Group	Geology	Type of Aquifer	Thickness of Granular zones (m)	Transmiss-ivity (m^2/day)	Discharge (m^3/day)	Specific Yield	Storativity
Aquifer –I (27.7 -86 m)	Quarter-nary Alluvial deposits	Unconfined to confined	28	900	3318	12 % *(0.072)*	2.85×10^{-4}
Aquifer-II (116 - 190 m)		Semi confined to Confined	29	NA	NA	NA	NA
Aquifer-III (213 - 300 m)		Semi confined to Confined	46	NA	NA	NA	NA

NA: Not Available

Source: CGWB,2015 & PSTC,2008

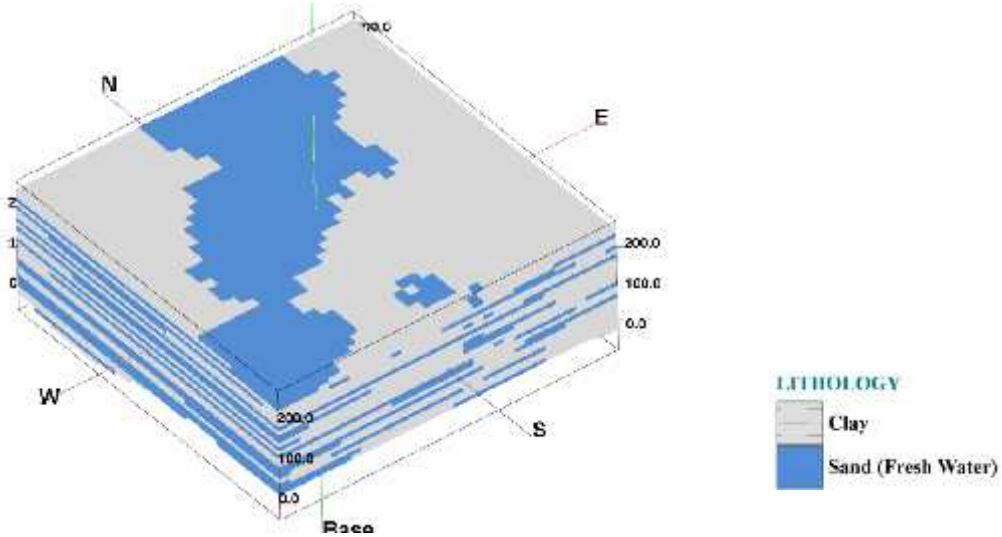
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

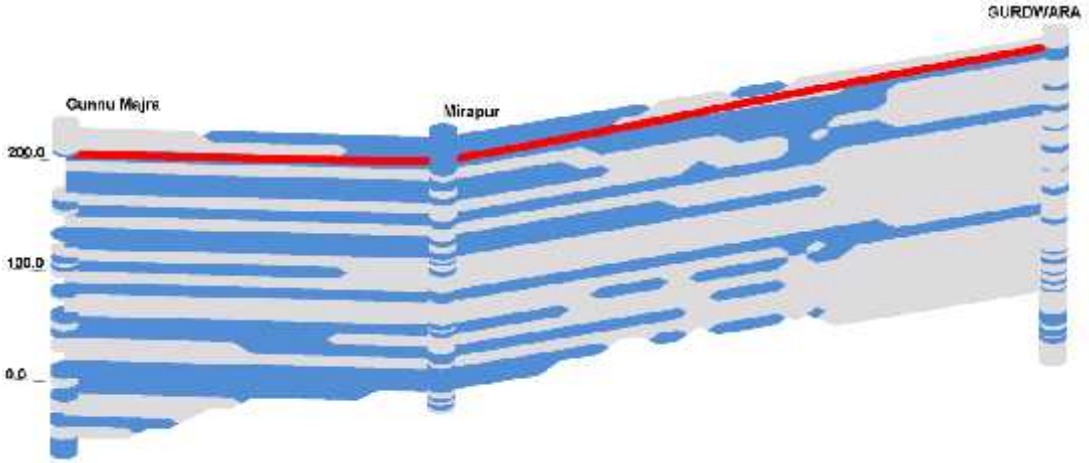
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	0	0	**0**
WRED/PSTC/WSS	0	0	0	0	**0**
PRIVATE	0	0	9	0	**9**
TOTAL	**0**	**0**	**9**	**0**	**9**

The data is validated by selecting the deepest well in each quadrant and used for preparation of 3-D Litho models, 2-D Geological Cross Sections, Fence Diagrams and Aquifer Maps.

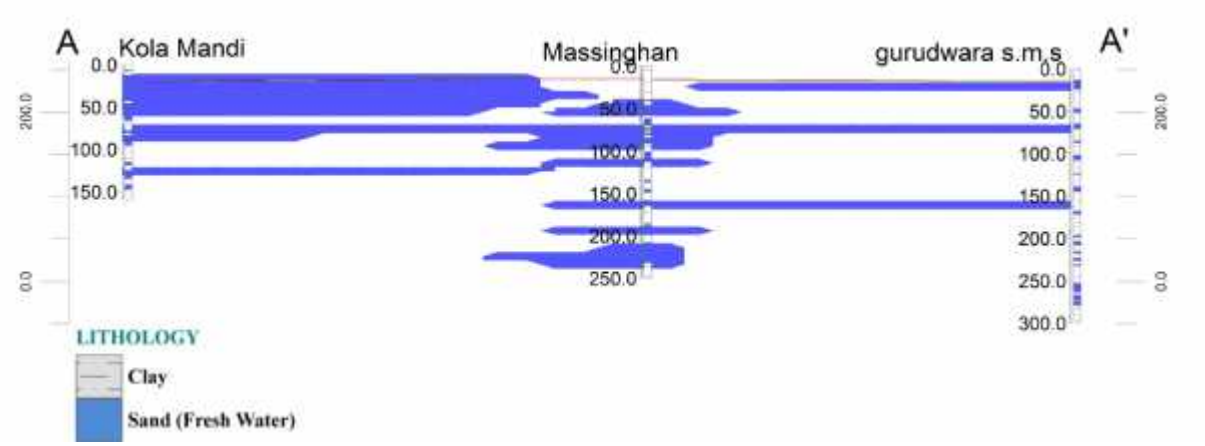
3-D Lithological model of Bhunerheri Block



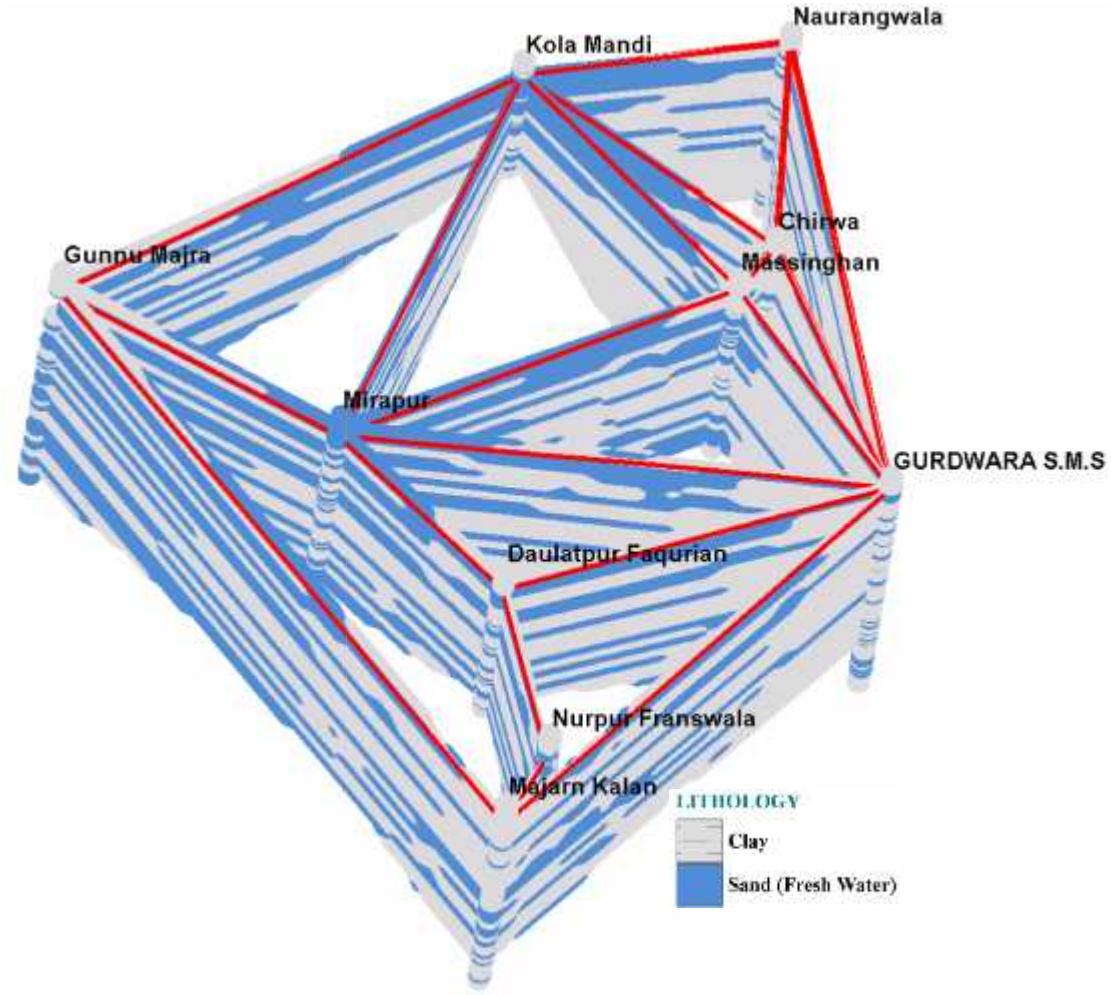
Lithological Cross section from Ghunnu majra to Gurudwara SMS



Lithological Cross section from Kola Mandi to Gurudwara SMS

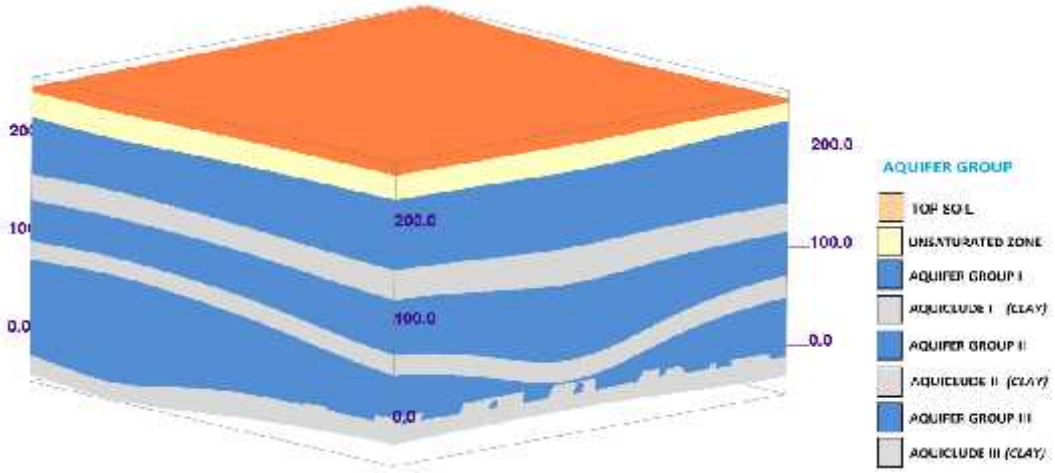


3-D Lithological Fence Diagram

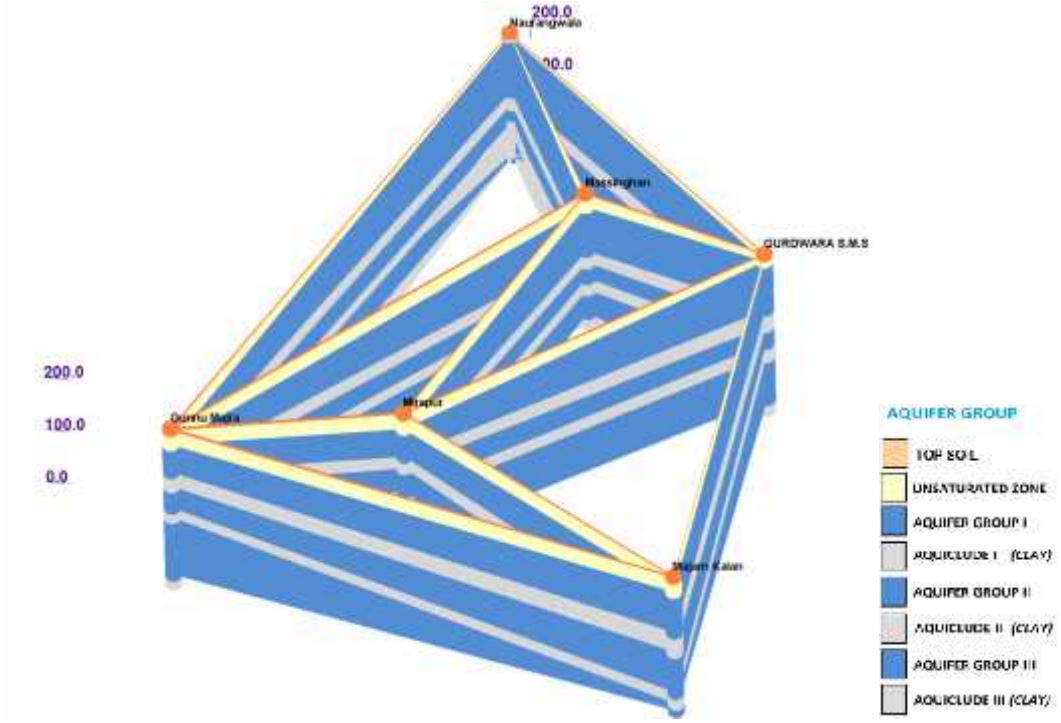


WATER LEVEL

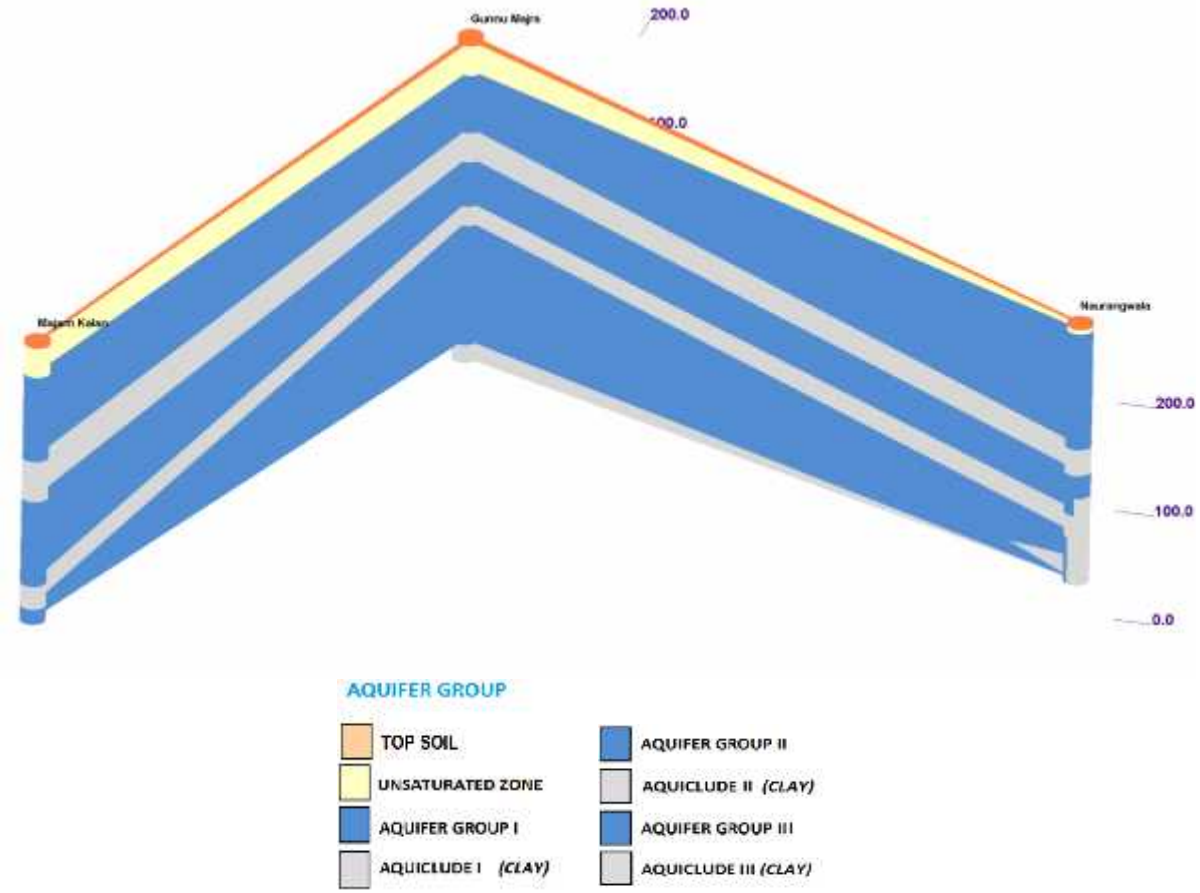
3-D Aquifer Disposition Model of Bhunerheri Block



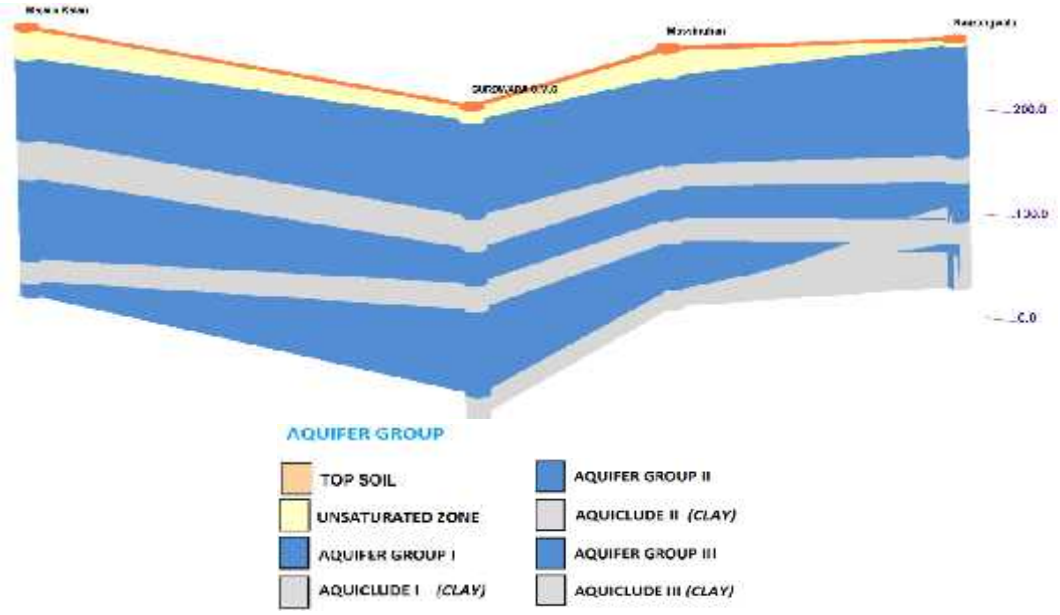
3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along Majari Kalan to Naurangwala



Aquifer Cross section along North to South



Ground water Resource, Extraction, Contamination and other issues in Bhunerheri Block

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	181.08 mcm
	In-storage Aquifer-I (Specific Yield Concept)	766.48 mcm
	In-storage Aquifer-II (Specific Yield Concept)	793.86 mcm
	In-storage Aquifer-II (Storativity Concept)	60.24 mcm
	In-storage Aquifer-III (Specific Yield Concept)	1259.22 mcm
	In-storage Aquifer-II (Storativity Concept)	112.39 mcm
	Total Resources	3173.28 mcm
Ground Water Extraction (as per 2013)	Irrigation	377.05 mcm
	Domestic & Industrial	2.72 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		4.04 mcm
Stage of Groundwater Development		210 %
Chemical Quality of ground water		Ground water in the area is alkaline in nature and pH ranges between 8.66 to 8.91. EC value of the ground water show wide variations and ranges from 913 µS/cm to 1326 µS/cm at 25^0C.

	RSC values are varies from -0.79 to 2.24 meq/L and the area is fit for irrigation.
Ground water Contamination Issues	*NA*
Other issues	Water level decline has been observed in major parts of the block due to in discriminate development of ground water resources.

Ground water Resource Enhancement Potential

Aquifer wise space available for recharge and proposed interventions (Supply Side Measures)

Aquifer-I:

Volume of unsaturated zone after 3m upto a desirable depth: 400.58 mcm
Source water requirement/availability for recharge: *Rain, Canal, Irrigation return flow*
Types and number of structures: NA
Other interventions proposed*: Artificial Recharge, Roof top Rainwater harvesting will conserve 3.79 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Bhunerheri Block (380.20 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 91.51 mcm

Required Change in cropping pattern

Proposed change in cropping pattern: *Rice to Maize, Soyabean.*
The overexploitation can be managed at sustainable level (100%) by changing the Paddy crop
Area coverage: *33% of the total rice area needs to change i.e.* 103.62 sq km
Anticipated volume of water to be saved: 103.62 mcm

Paddy area (Sq km)	*Required Area to be Change from Paddy to Maize/ Soyabean (Sq km)*	*Amount of Water Saved (mcm)*	*Present Stage of develop-ment (%)*	*Reduction in Stage of develop-ment after Maize (%)*	*Crop Diversified area for Maize (%)*	*Reduction in Stage of develop-ment after soya bean (%)*	*Crop Diversified area for Soyabean (%)*	*Reduction in Stage of develop-ment after Maize and Soya bean (%)*	*Crop Diversified area (%)*
314	103.62	103.62	210	39.9	23	17.30	10	57.22	33

Net Annual Ground Water Availability 2013 (mcm)	*Total Irrigat-ion Draft (present) (mcm)*	*Gross Draft all uses (present) (mcm)*	*Paddy area (Sq km)*	*Required Area to be Change from Paddy to Maize/ soya bean (Sq km)*	*Amount of Water Saved (mcm)*	*Gross draft after saving of water (mcm)*	*Present Stage of develop-ment (%)*	*Total Reduction in Stage of develop-ment after Maize/ soya bean (%)*	*Total Crop Diversified area (%)*
181.08	377.05	379.77	314	103.62	103.62	273.43	210	57.22	33

Alternate Water sources

Surface water sources: *Tanks, Ponds*

No.of Water tanks: 38

Location, details and availability from such sources outside the area: Not Available

Regulation and Control:

Punjab Subsoil Act for delay in paddy plantation should continue in the area.

Other interventions proposed, if any

Modern Irrigation Practices be adopted for Rabi crops. Some of the techniques are given in the table below (PAU, Ludhiana).

Sl.No	Techniques	Water Saving (%)	Crops
1	Mulching	17	Wheat
2	Bed Planting	18-25	Wheat
3	Use of Sprinkler and drip Irrigation	70-90	Sugarcane, Sunflower, Maize

Other than that by 15 days ponding followed by 2 days of drying can lead to 25% saving of water in paddy crop.

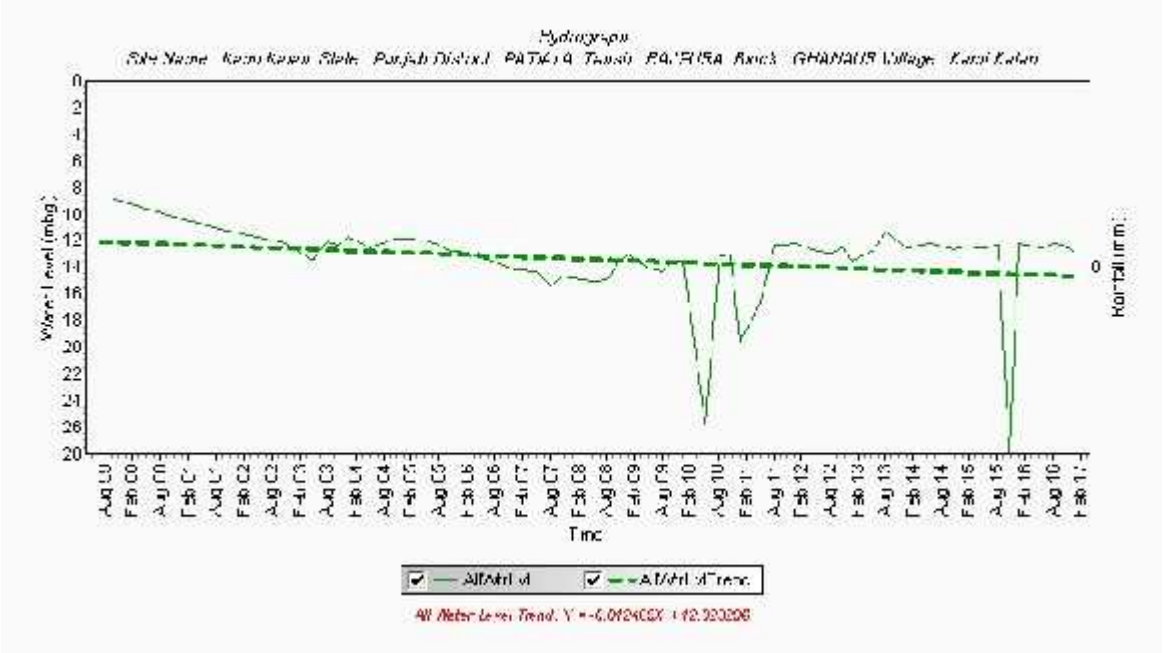
II. Salient Information of Ghanaur Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>443.20 sq km</td></tr>
<tr><td>District/ State</td><td>Patiala, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 0
Rural Population: 138984
Total population: 138984</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 582 mm
Non-monsoon Rainfall : 150 mm
Annual Average Rainfall: 732 mm</td></tr>
<tr><td>Agriculture and Irrigation</td><td>Principal crops: Wheat, Rice, Maize and Sugar cane
Other crops: Vegetables and Fodder
Gross cropped area: 518.50 sq km
Net sown area: 263.68 sq km
Irrigation practices: Tube well and Canal Irrigation
Cropping intensity: 197%
<u>Area under</u>
Ground water Irrigation: 236.73 sq km
Surface water irrigation: 15.55 sq km
Gross Irrigated area: 513.37sq km
Net Irrigated area: 261.12 sq km
Intensity of Irrigation: 197%
Number and types of abstraction structures: 7233, Tubewells</td></tr>
<tr><td>Ground Water Resource Availability and Extraction</td><td><u>Ground water Resources Availability</u>
Ground Water Resources are available in the different group of aquifers. The fresh water resources are estimated up to the depth of 300 m on the basis of geophysical interpretations.
<table>
<tr><th>Aquifer Group</th><th>Aquifer Depth range (m)</th><th>Aquifer Thickness (m)</th><th>Granular Zones (m)</th><th>Resources (mcm)</th></tr>
<tr><td>Aquifer-I</td><td>18.91 – 99.0</td><td>80</td><td>38</td><td>1366.38</td></tr>
<tr><td>Aquifer-II</td><td>136.0 – 200.0</td><td>64</td><td>28</td><td>983.42</td></tr>
<tr><td>Aquifer-III</td><td>225.0 – 300.0</td><td>75</td><td>30</td><td>1122.04</td></tr>
</table>
Total Ground Water Resources available is 3471.84 mcm and total potential granular zones available are 96 m up to depth of 300 m. Block is categorized as Over-Exploited as per Dynamic Groundwater Resources, 2013 assessment.
<u>Ground water Resources Extraction</u>
Information regarding the abstraction from Aquifer II is not available, but there are drinking water supply wells of State Government tapping combined aquifers. Therefore, the ground water draft could not be assessed for Aquifer-II and III separately.</td></tr>
</table>

Existing and future water demands	Water Scarcity Villages: 120 Small Scale Industries : 150 Large Scale Industries : 0 Total Villages : 128 *Existing Gross Ground water Draft as on 2013* Irrigation: 223.82 mcm Domestic and industrial water supply: 3.03 mcm *Future water demands* Irrigation development potential : (-)74.52 mcm Domestic and industrial water supply up to 2025 years : 4.49 mcm
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 5.26 – 31.80 m bgl Post Monsoon: 5.71 – 31.95 m bgl Seasonal Fluctuation: (-)0.15 – (-)0.60 m/yr Mean (10 yrs) : 2.34 – (-)2.13 m/yr *Trends* Pre Monsoon: 0.51 – (-)0.48 m/yr Post Monsoon: 0.21 – (-)0.64 m/yr **Aquifer-II &III** No Monitoring Stations

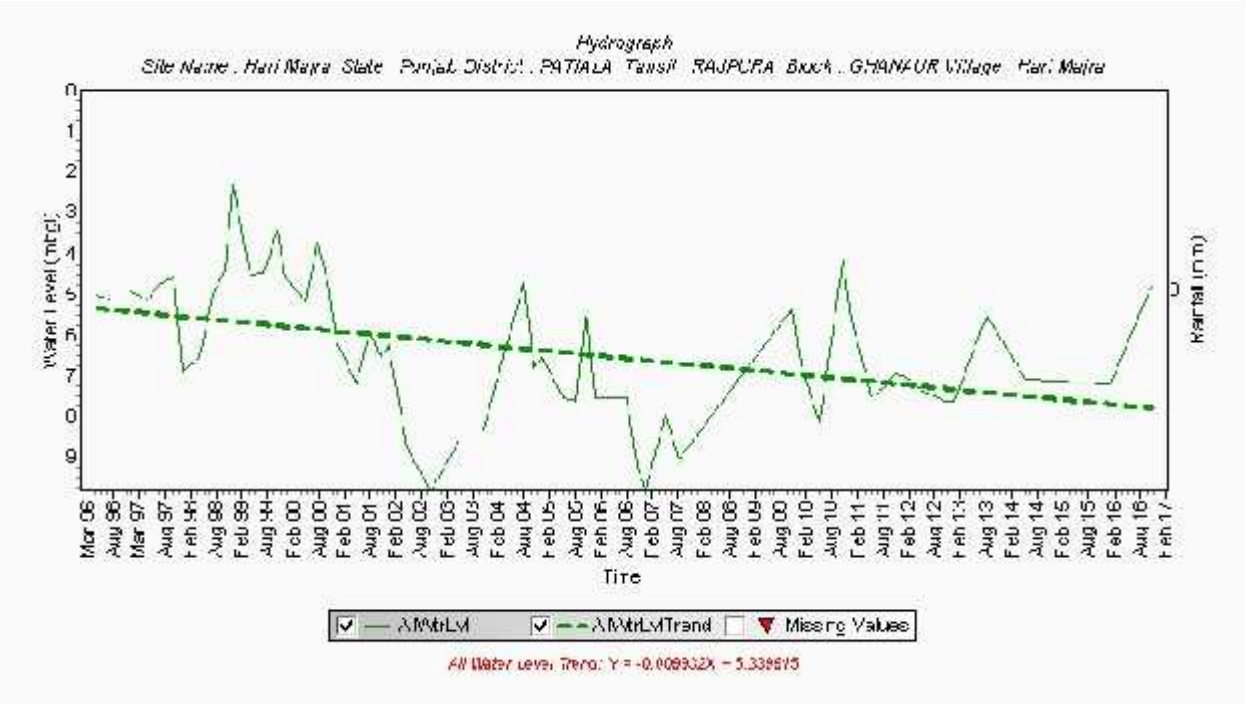
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Kami kalan)



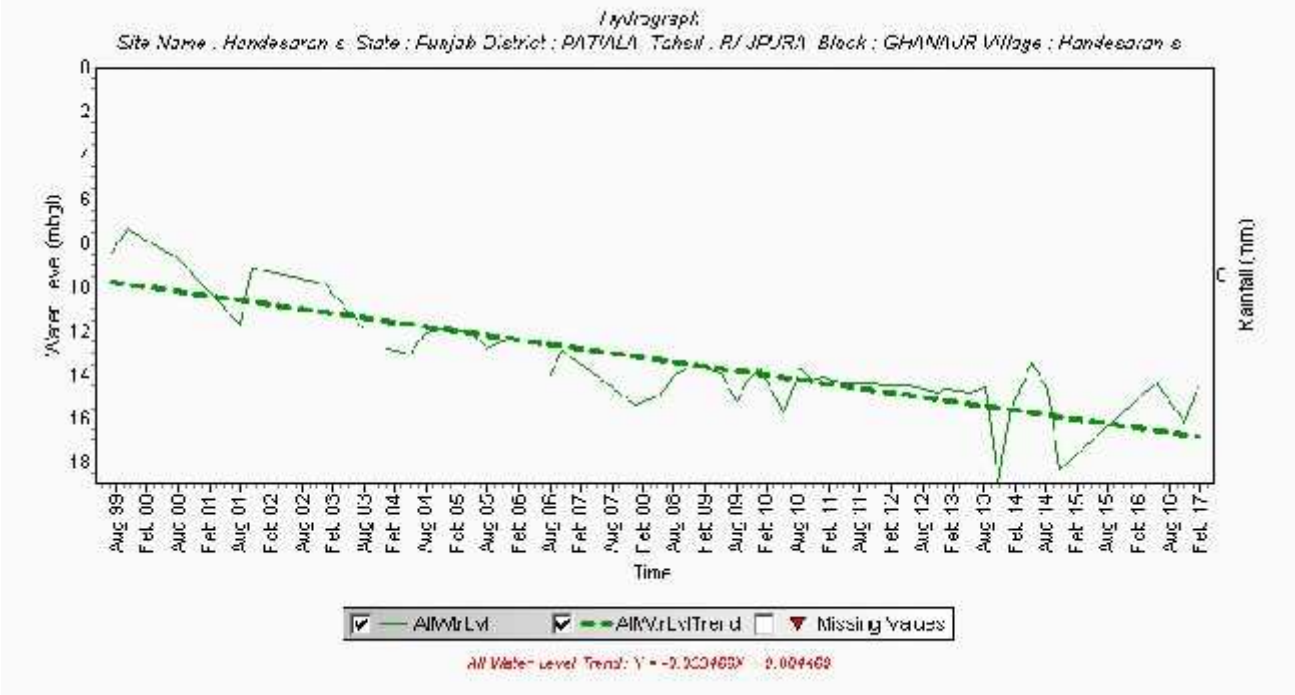
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Hari Majra)



HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Handesaran-S)



Aquifer Disposition

Number of aquifers	1
Principal aquifer	Alluvium
Major Aquifer	Older Alluvium
Aquifer Disposition	Multiple Aquifer System (Three Aquifer Groups)

Exploratory Data Availability

Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	0	2	**2**
WRED/WSS	7	0	0	0	**7**
PRIVATE	0	5	9	13	**27**
TOTAL	**7**	**5**	**9**	**15**	**36**

Aquifer wise Characteristics

Aquifer Group	Geology	Type of Aquifer	Thickness of Granular zones (m)	Transmiss-ivity (m^2/day)	Discharge (m^3/day)	Specific Yield	Storativity
Aquifer –I (18.91- 99 m)	Quarter-nary Alluvial deposits	Unconfined to confined	38	NA	NA	12 % *(0.072)*	NA
Aquifer-II (136 - 200 m)		Semi confined to Confined	28	NA	NA	NA	NA
Aquifer-III (225 - 300 m)		Semi confined to Confined	30	NA	NA	NA	NA

NA: Not Available

Source: CGWB,2015 & PSTC,2008

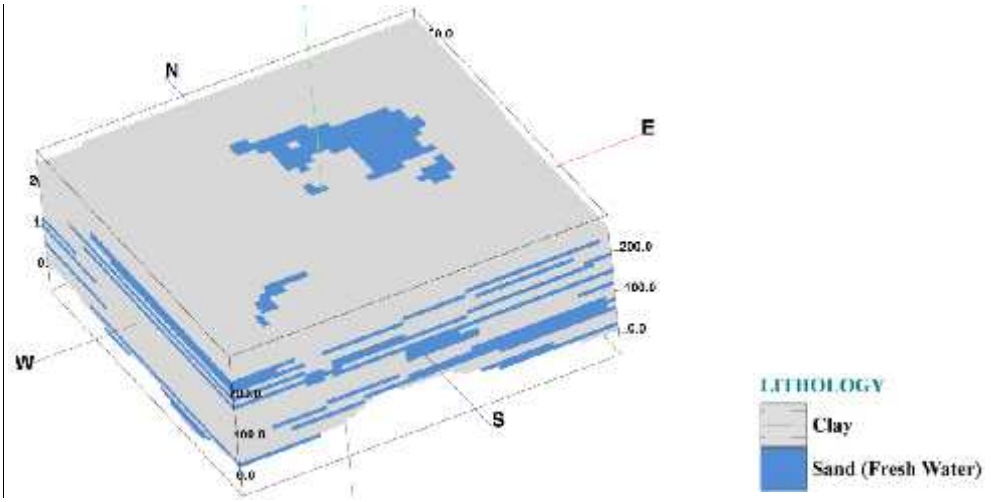
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

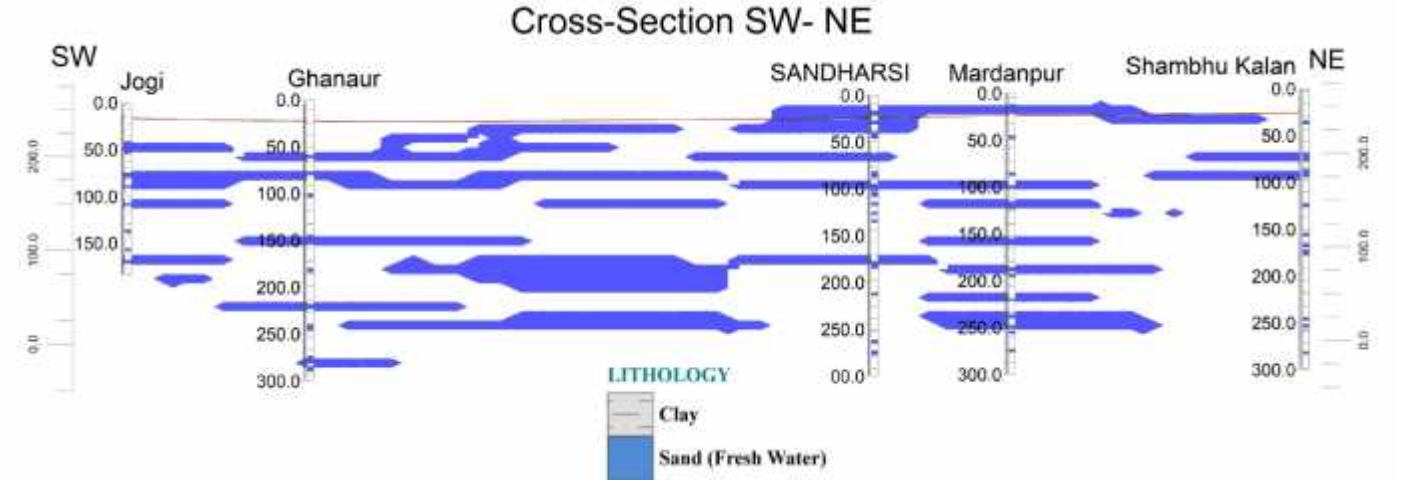
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	0	2	**2**
WRED/WSS	0	0	0	0	**0**
PRIVATE	0	3	2	13	**16**
TOTAL	**0**	**3**	**2**	**15**	**18**

The data is validated by selecting the deepest well in each quadrant and used for preparation of 3-D Litho models, 2-D Geological Cross Sections, Fence Diagrams and Aquifer Maps.

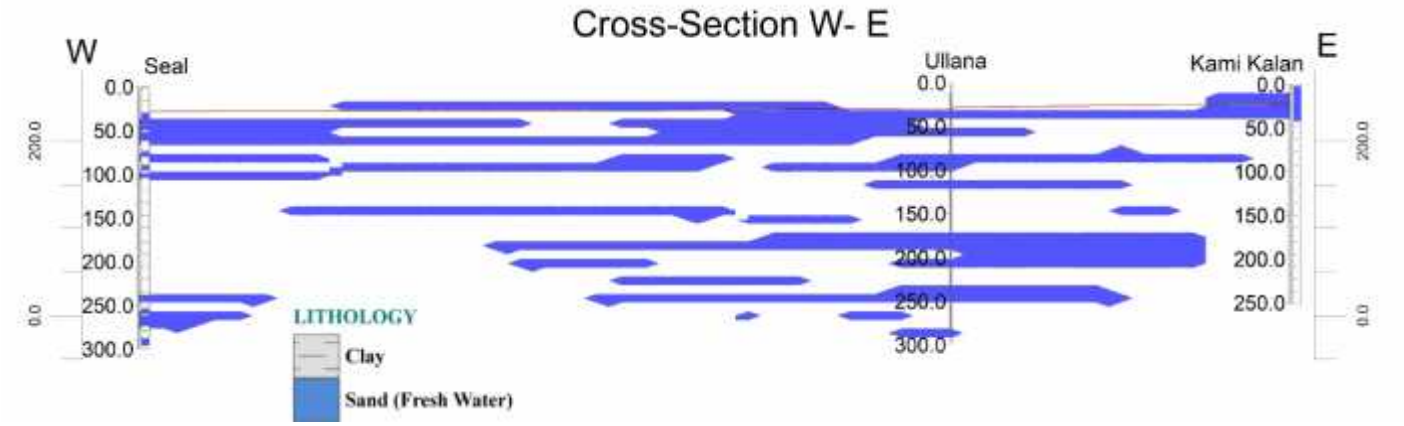
3-D Lithological model of Ghanaur Block



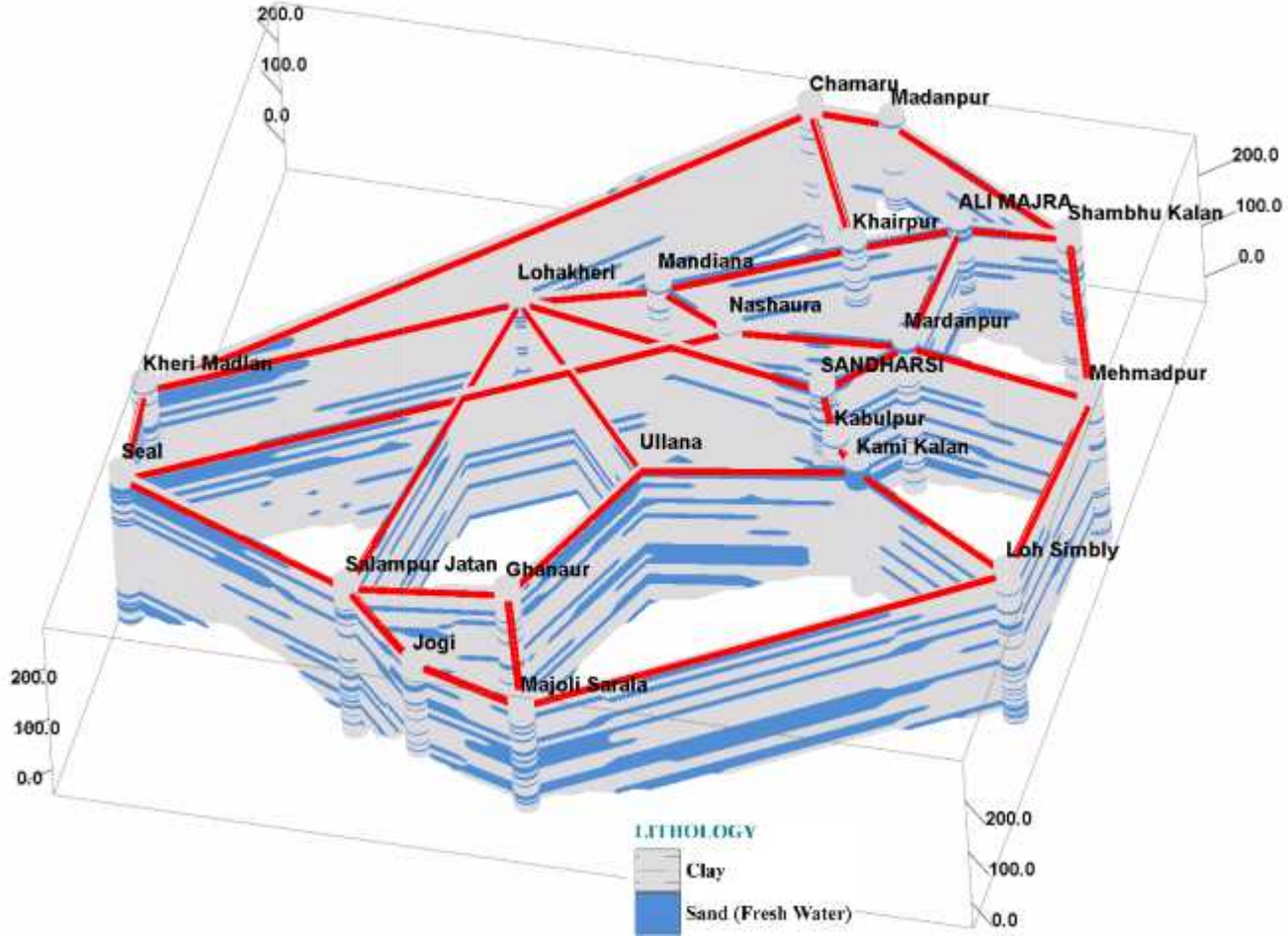
Lithological Cross section from Jogi to Shambhu Kalan



Lithological Cross section from Seal to Kami Kalan SMS

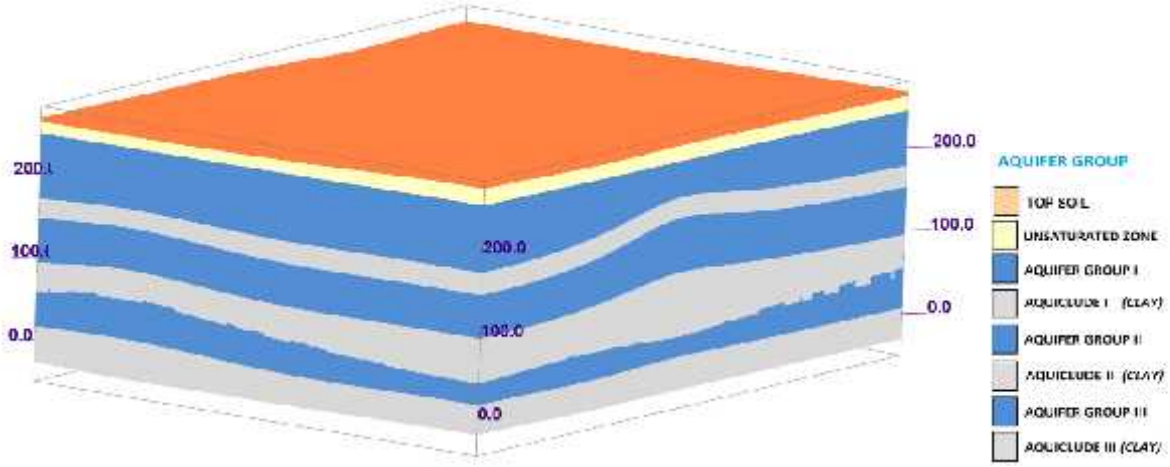


3-D Lithological Fence Diagram

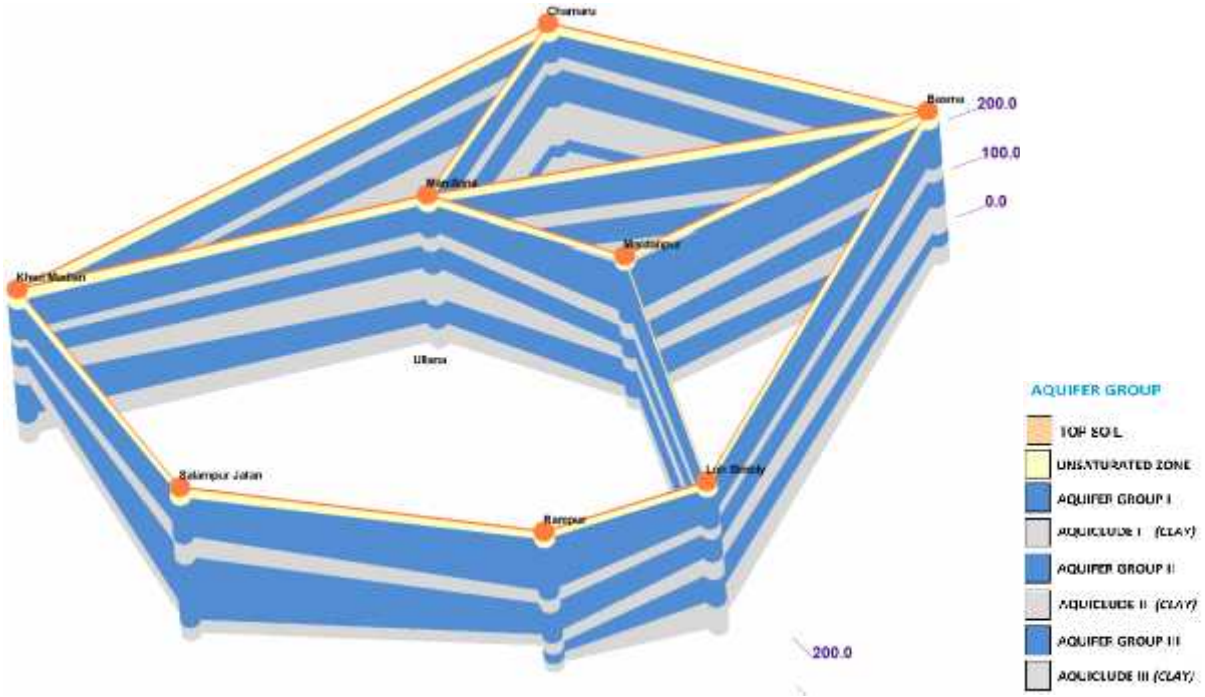


WATER LEVEL

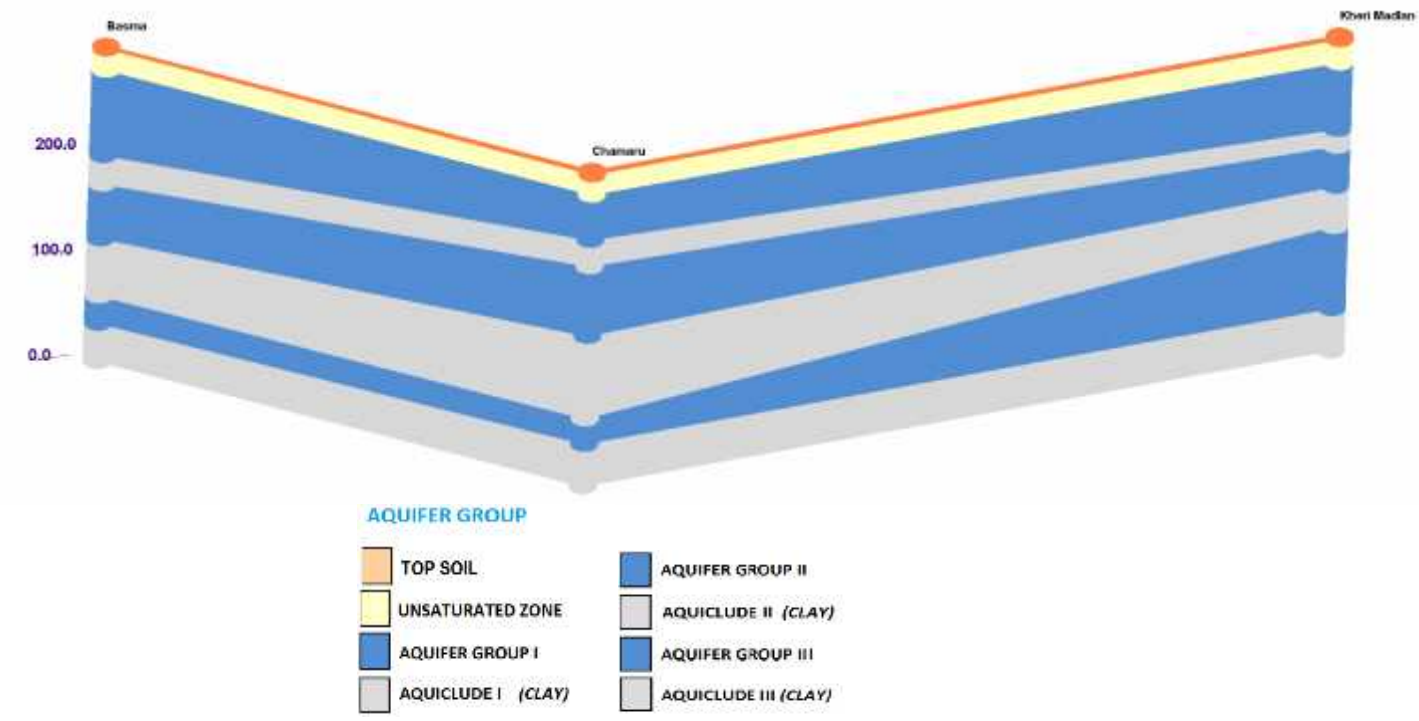
3-D Aquifer Disposition Model of Ghanaur Block



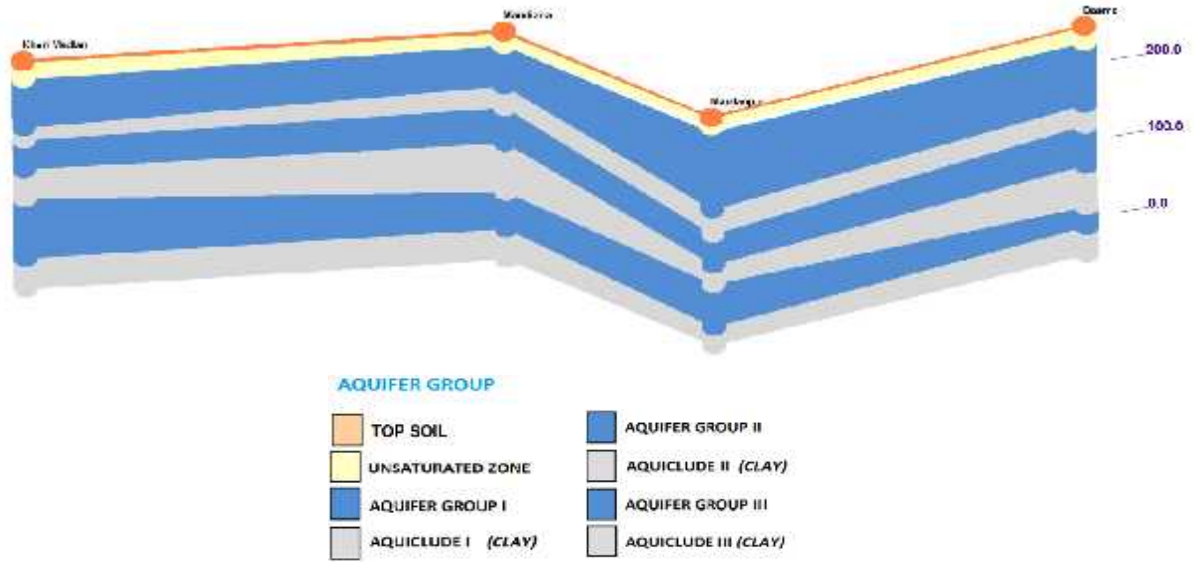
3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along Basma to Kheri Madlan



Aquifer Cross section along North to South



Ground water Resource, Extraction, Contamination and other issues in Ghanaur Block

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	153.79 mcm
	In-storage Aquifer-I (Specific Yield Concept)	1212.60 mcm
	In-storage Aquifer-II (Specific Yield Concept)	893.49 mcm
	In-storage Aquifer-II (Storativity Concept)	89.92 mcm
	In-storage Aquifer-III (Specific Yield Concept)	957.31 mcm
	In-storage Aquifer-II (Storativity Concept)	164.72 mcm
	Total Resources	3471.84 mcm
Ground Water Extraction (as per 2013)	Irrigation	223.82 mcm
	Domestic & Industrial	3.03 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		4.49 mcm
Stage of Groundwater Development		148 %
Chemical Quality of ground water		Ground water in the area is alkaline in nature and pH ranges 8.74 to 8.91. EC value of the ground water show wide variations and ranges from 1044 µS/cm to 2595 µS/cm at 25^0C. RSC values are varies from -1.86 to 5.62

	meq/L and the area is fit for irrigation.
Ground water Contamination Issues	*NA*
Other issues	Water level decline has been observed in major parts of the block due to in discriminate development of ground water resources.

Ground water Resource Enhancement Potential

Aquifer wise space available for recharge and proposed interventions (Supply Side Measures)

Aquifer-I:

Volume of unsaturated zone after 3m upto a desirable depth: 283.47 mcm
Source water requirement/availability for recharge: *Rain, Canal, Irrigation return flow*
Types and number of structures: NA
Other interventions proposed*: Artificial Recharge, Roof top Rainwater harvesting will conserve 3.88 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire GhanaurBlock (443.20 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 91.51 mcm

Required Change in cropping pattern

Proposed change in cropping pattern: *Rice to Maize, Soyabean.*
The overexploitation can be managed at sustainable level (100%) by changing the Paddy crop
Area coverage: *7 % of the total rice area needs to change i.e.* 15.28 sq km
Anticipated volume of water to be saved: 15.28 mcm

Paddy area (Sq km)	*Required Area to be Change from Paddy to Maize/ Soyabean (Sq km)*	*Amount of Water Saved (mcm)*	*Present Stage of develop-ment (%)*	*Reduction in Stage of develop-ment after Maize (%)*	*Crop Diversified area for Maize (%)*	*Reduction in Stage of develop-ment after soya bean (%)*	*Crop Diversified area for Soyabean (%)*	*Reduction in Stage of develop-ment after Maize and Soya bean (%)*	*Crop Diversified area (%)*
235	15.28	15.28	148	9.93	7	NR	NR	9.93	7

NR: Not Required

Net Annual Ground Water Availability 2013 (mcm)	*Total Irrigat-ion Draft (present) (mcm)*	*Gross Draft all uses (present) (mcm)*	*Paddy area (Sq km)*	*Required Area to be Change from Paddy to Maize/ soya bean (Sq km)*	*Amount of Water Saved (mcm)*	*Gross draft after saving of water (mcm)*	*Present Stage of develop-ment (%)*	*Total Reduction in Stage of develop-ment after Maize/ soya bean (%)*	*Total Crop Diversified area (%)*
153.79	223.82	226.84	235	15.28	15.28	208.54	148	9.93	7

Alternate Water sources

Surface water sources: *Tanks, Ponds*

No.of Water tanks: 24

Location, details and availability from such sources outside the area: Not Available

Regulation and Control:

Punjab Subsoil Act for delay in paddy plantation should continue in the area.

Other interventions proposed, if any

Modern Irrigation Practices be adopted for Rabi crops. Some of the techniques are given in the table below (PAU, Ludhiana).

Sl.No	Techniques	Water Saving (%)	Crops
1	Mulching	17	Wheat
2	Bed Planting	18-25	Wheat
3	Use of Sprinkler and drip Irrigation	70-90	Sugarcane, Sunflower, Maize

Other than that by 15 days ponding followed by 2 days of drying can lead to 25% saving of water in paddy crop.

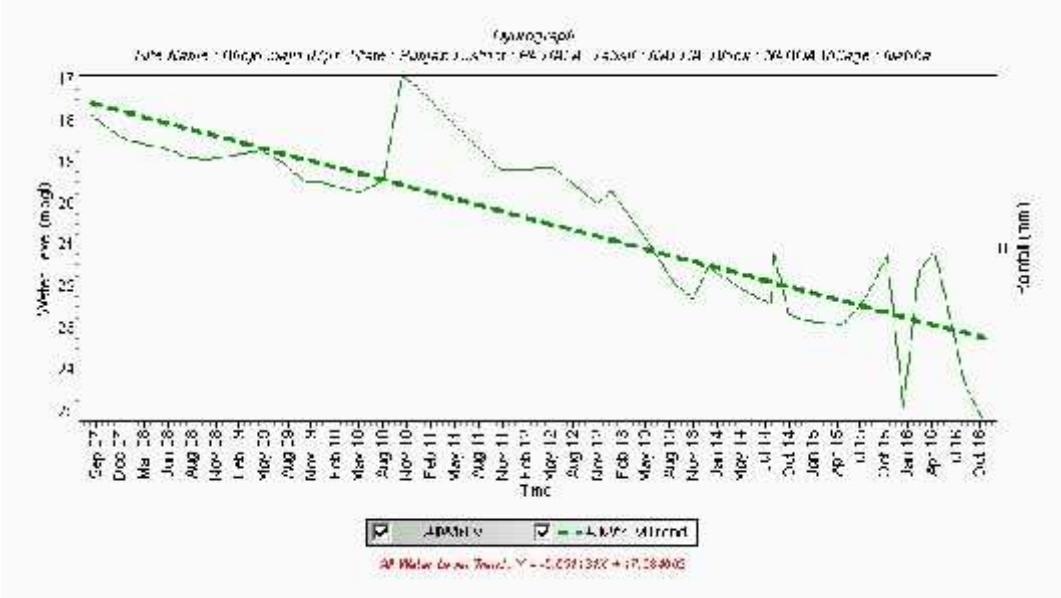
III. Salient Information of Nabha Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>548.20 sq km</td></tr>
<tr><td>District/ State</td><td>Patiala, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 10218
Rural Population: 191786
Total population: 202004</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 478 mm
Non-monsoon Rainfall : 122mm
Annual Average Rainfall: 600 mm</td></tr>
<tr><td>Agriculture and Irrigation</td><td>Principal crops: Rice, Wheat, Maize and Sugar cane
Other crops: Vegetables and Fodder
Gross cropped area: 999.67 sq km
Net sown area: 501.48 sq km
Irrigation practices: Tube well and Canal Irrigation
Cropping intensity: 199%
<u>Area under</u>
Ground water Irrigation: 458.40 sq km
Surface water irrigation: 75.00 sq km
Gross Irrigated area: 999.67 sq km
Net Irrigated area: 501.48 sq km
Intensity of Irrigation: 199%
Number and types of abstraction structures: 18017, Tubewells</td></tr>
<tr><td>Ground Water Resource Availability and Extraction</td><td><u>Ground water Resources Availability</u>
Ground Water Resources are available in the different group of aquifers. The fresh water resources are estimated up to the depth of 300 m on the basis of geophysical interpretations.
<table>
<tr><th>Aquifer Group</th><th>Aquifer Depth range (m)</th><th>Aquifer Thickness (m)</th><th>Granular Zones (m)</th><th>Resources (mcm)</th></tr>
<tr><td>Aquifer-I</td><td>20.71 – 111.0</td><td>90</td><td>53</td><td>2496.37</td></tr>
<tr><td>Aquifer-II</td><td>133.0 – 210.0</td><td>77</td><td>30</td><td>1295.50</td></tr>
<tr><td>Aquifer-III</td><td>242.0 – 300.0</td><td>58</td><td>23</td><td>1340.28</td></tr>
</table>
Total Ground Water Resources available is 5132.15 mcm and total potential granular zones available are 106 m up to depth of 300 m. Block is categorized as Over-Exploited as per Dynamic Groundwater Resources, 2013 assessment.
<u>Ground water Resources Extraction</u>
Information regarding the abstraction from Aquifer II is not available, but there are drinking water supply wells of State Government tapping combined aquifers. Therefore, the ground water draft could not be assessed for Aquifer-II and III separately.</td></tr>
</table>

Existing and future water demands	Water Scarcity Villages: 170 Small Scale Industries : 111 Large Scale Industries : 2 Total Villages : 171 *Existing Gross Ground water Draft as on 2013* Irrigation: 606.86 mcm Domestic and industrial water supply: 7.41 mcm *Future water demands* Irrigation development potential : (-)212.91 mcm Domestic and industrial water supply up to 2025 years : 10.49 mcm
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 22.94 – 26.18 m bgl Post Monsoon: 21.25 – 26.18 m bgl Seasonal Fluctuation: 1.69 – (-)0.88 m/yr Mean (10 yrs) : 1.49 – (-)3.40 m/yr *Trends* Pre Monsoon: (-)0.58 – (-)0.72 m/yr Post Monsoon: (-)0.67 – (-)0.92 m/yr **Aquifer-II** Pre Monsoon: 22.51 m bgl Post Monsoon: 23.10 m bgl Seasonal Fluctuation: (-)0.59 m/yr **Aquifer-III** No Monitoring Stations

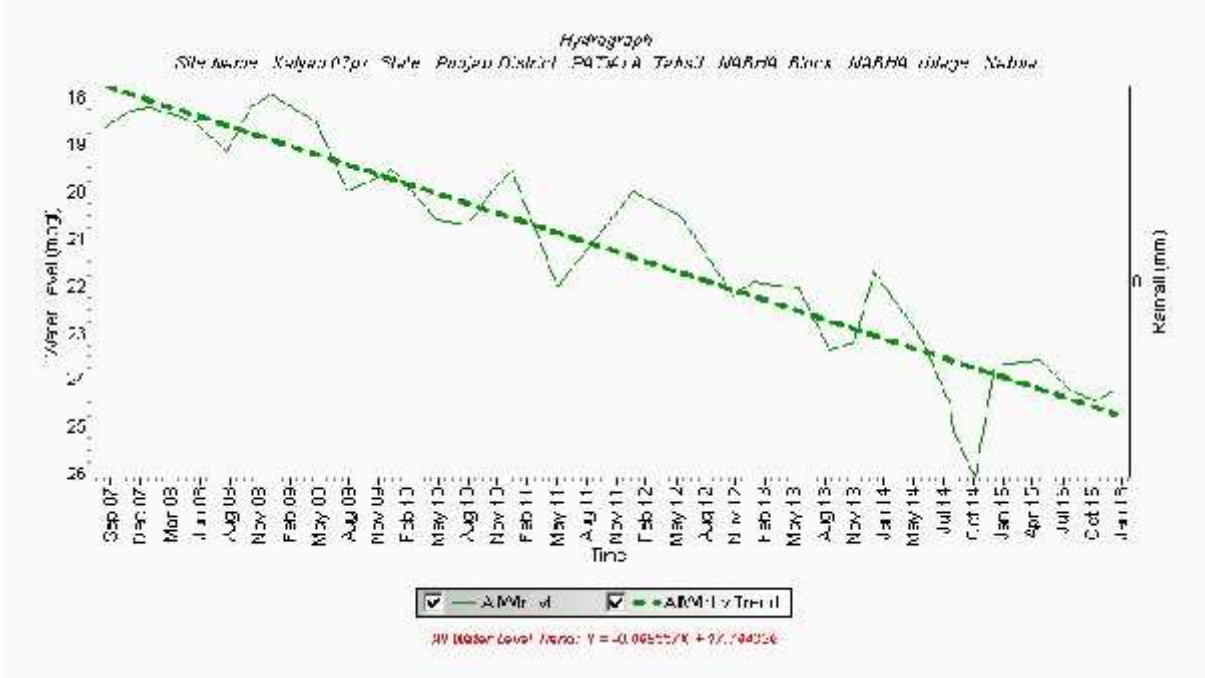
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Bhojomajri)



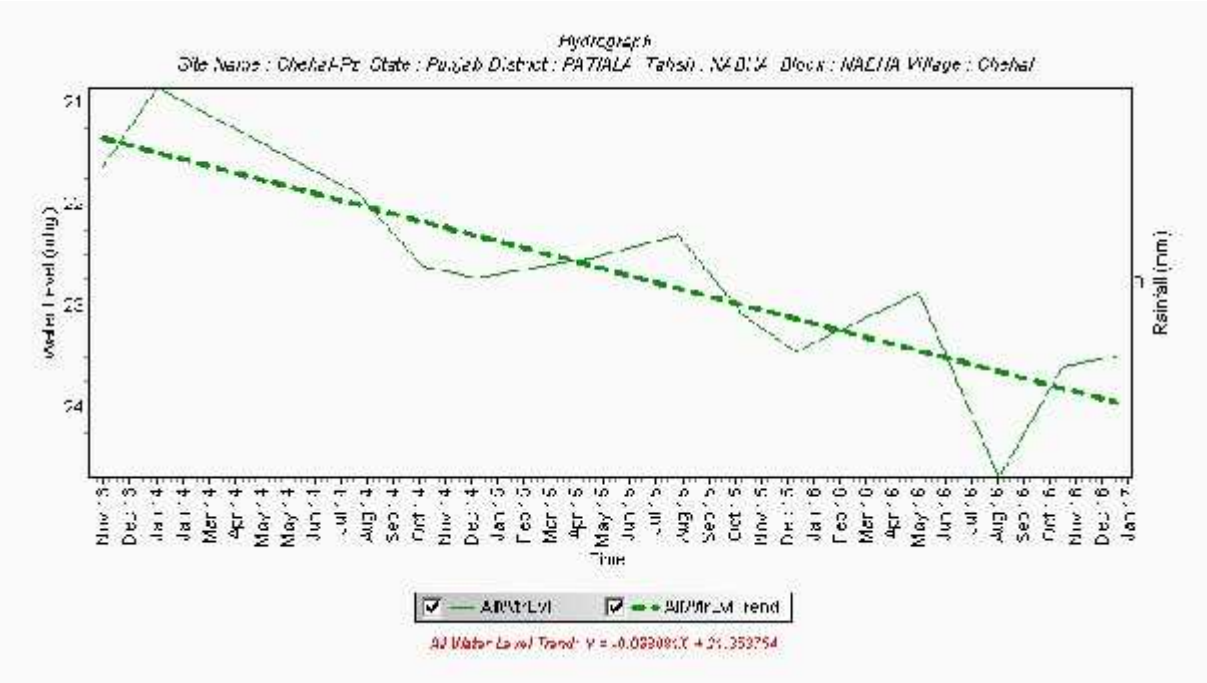
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Kalyan)



HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Chehal)



Aquifer Disposition

Number of aquifers	1
Principal aquifer	Alluvium
Major Aquifer	Older Alluvium
Aquifer Disposition	Multiple Aquifer System (Three Aquifer Groups)

Exploratory Data Availability

Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	1	3	0	1	**5**
WRED/WSS	7	14	0	1	**22**
PRIVATE	0	6	0	0	**6**
TOTAL	**8**	**23**	**0**	**2**	**33**

Aquifer wise Characteristics

Aquifer Group	Geology	Type of Aquifer	Thickness of Granular zones (m)	Transmiss-ivity (m^2/day)	Discharge (m^3/day)	Specific Yield	Storativity
Aquifer –I (20.71- 111 m)	Quarter-nary Alluvial deposits	Unconfined to confined	53	1662	546	12 % *(0.072)*	
Aquifer-II (133 - 210 m)		Semi confined to Confined	30	1476	2779	NA	$3.8x10^{-3}$
Aquifer-III (242 - 300 m)		Semi confined to Confined	23	NA	NA	NA	NA

NA: Not Available

Source: CGWB,2015 & PSTC,2008

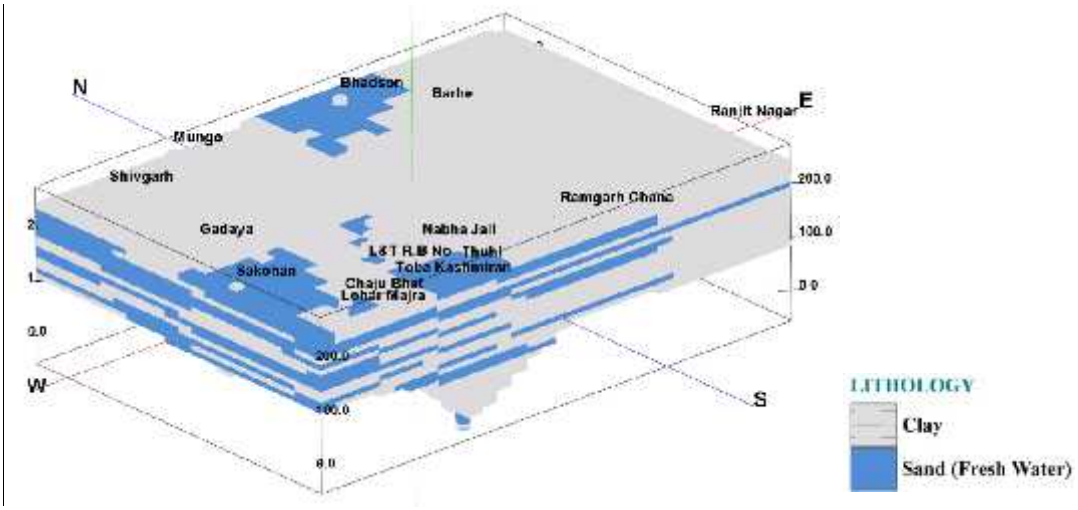
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

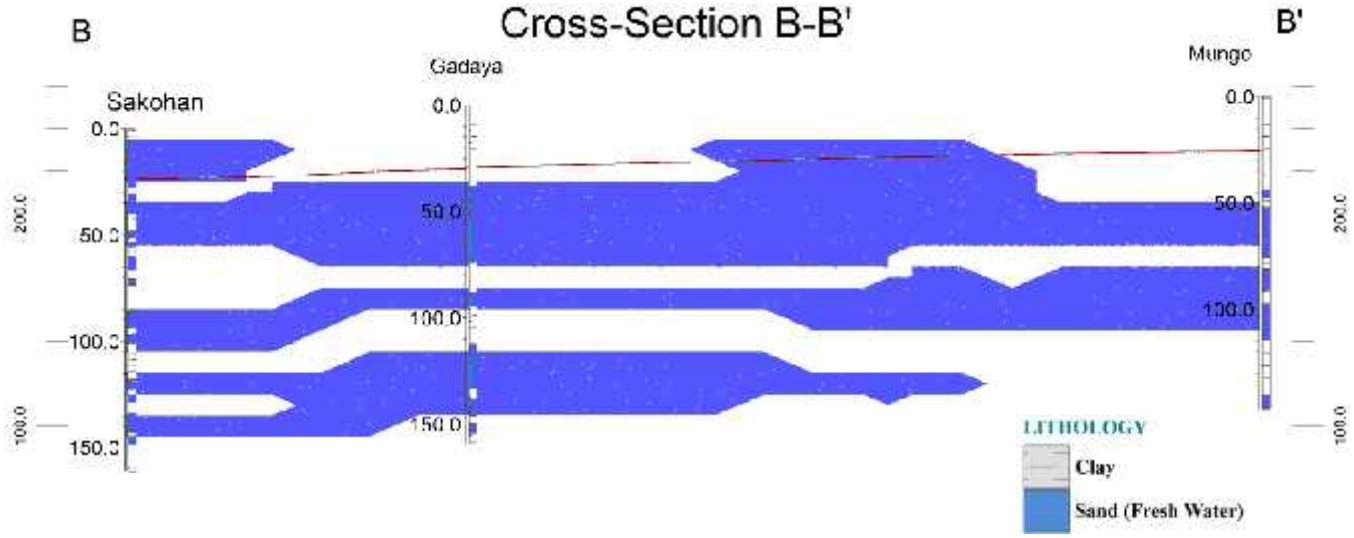
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	0	1	**1**
WRED/WSS	0	14	0	0	**14**
PRIVATE	0	6	0	0	**6**
TOTAL	**0**	**20**	**0**	**1**	**21**

The data is validated by selecting the deepest well in each quadrant and used for preparation of 3-D Litho models, 2-D Geological Cross Sections, Fence Diagrams and Aquifer Maps.

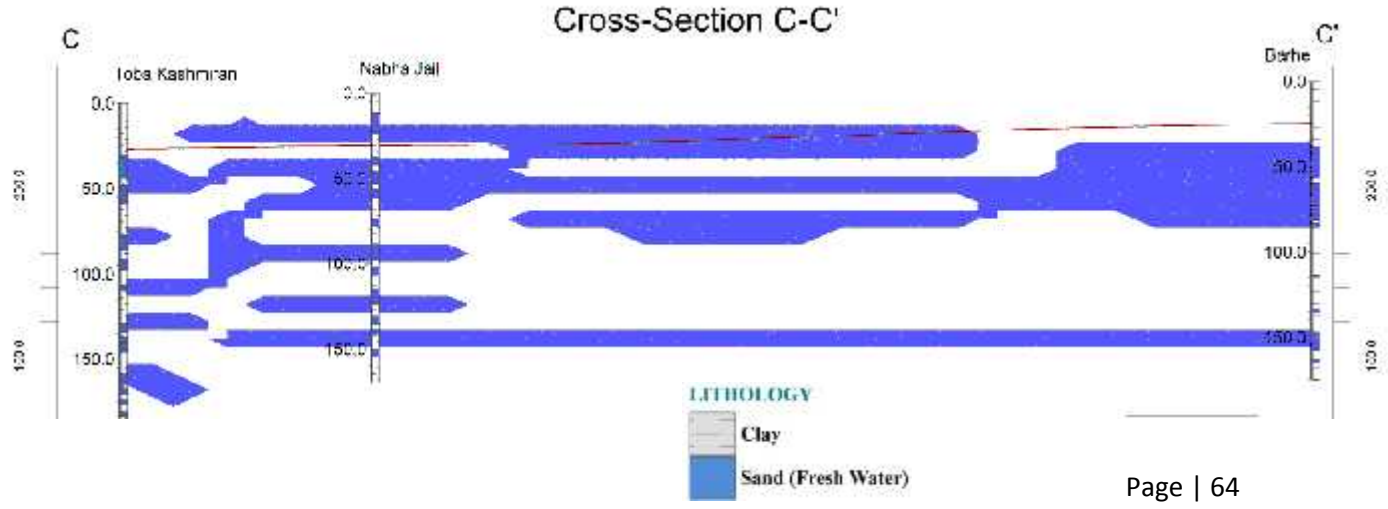
3-D Lithological model of Nabha Block



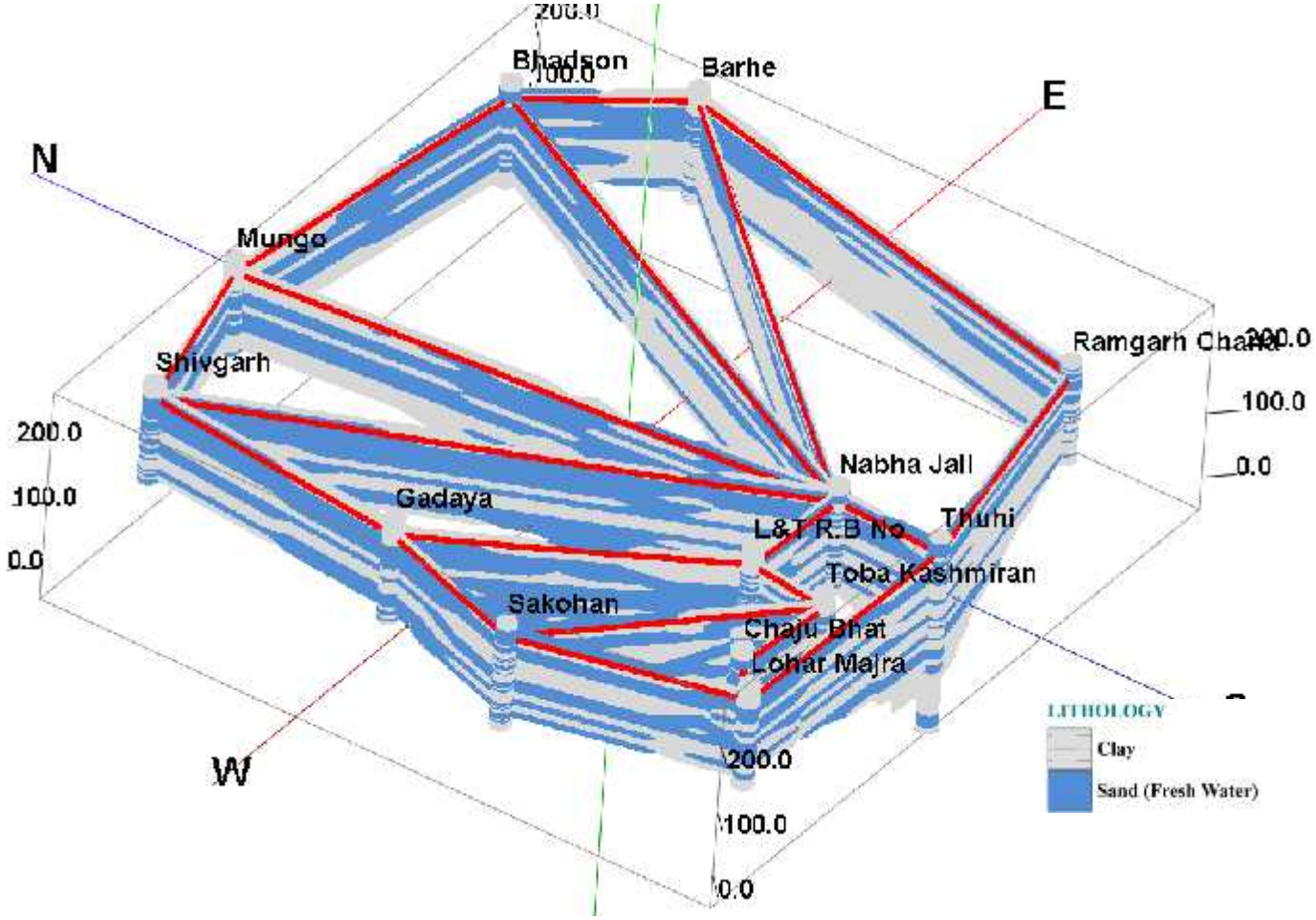
Lithological Cross section from Sakohan to Mungo



Lithological Cross section from Toba Kashmirian to Barhe

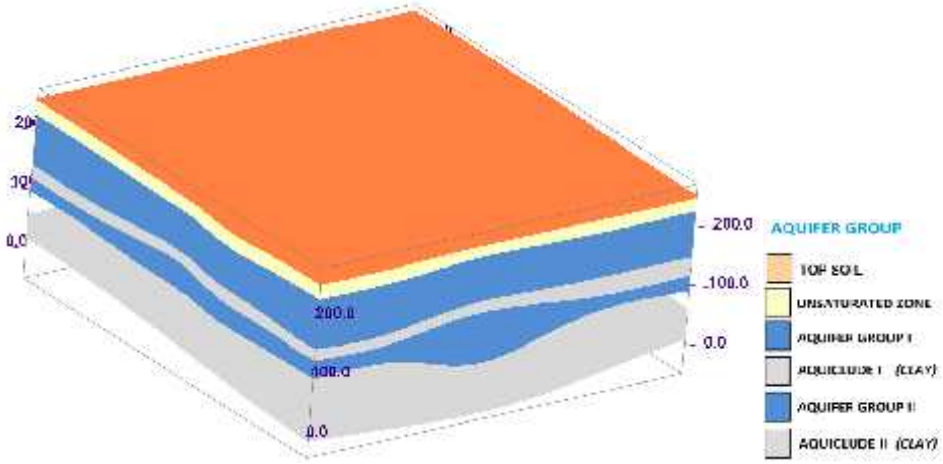


3-D Lithological Fence Diagram

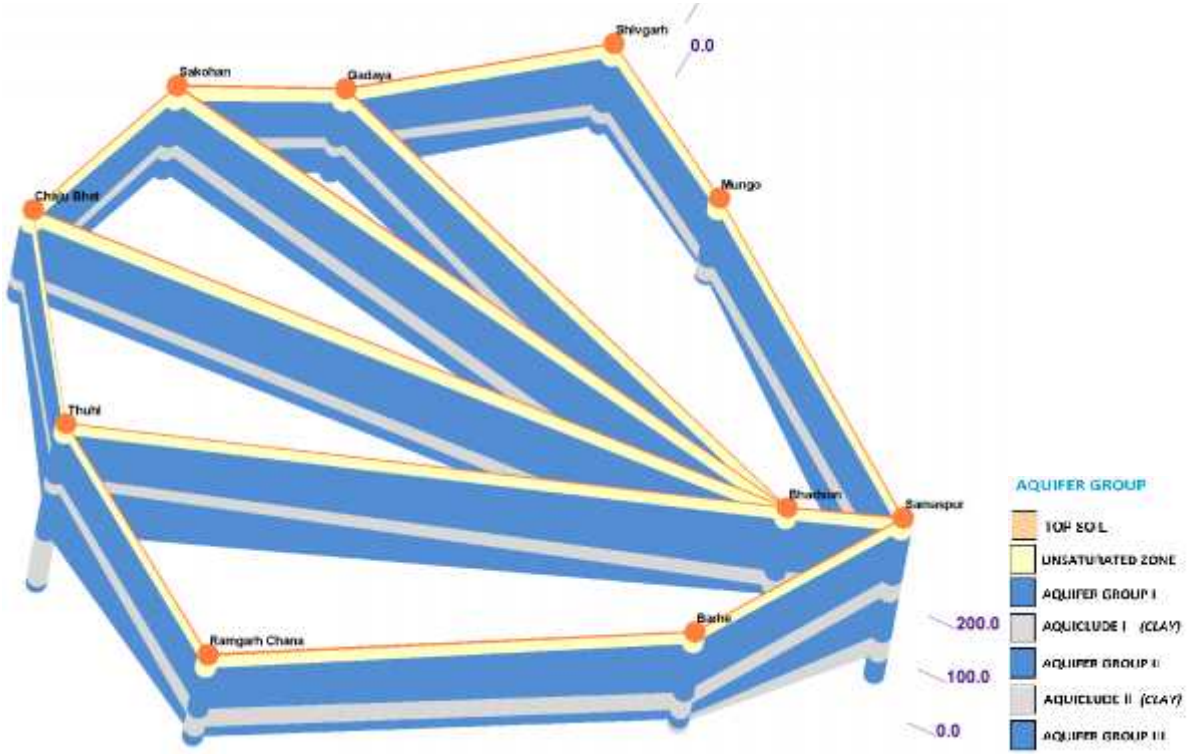


WATER LEVEL

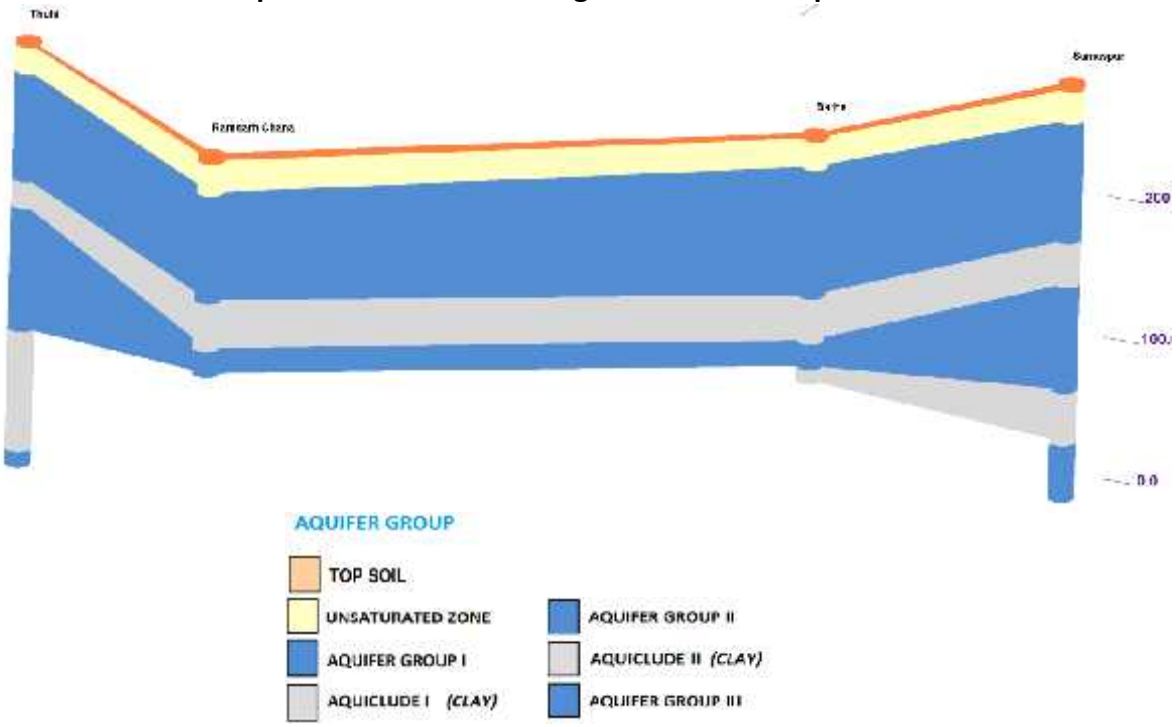
3-D Aquifer Disposition Model of Nabha Block



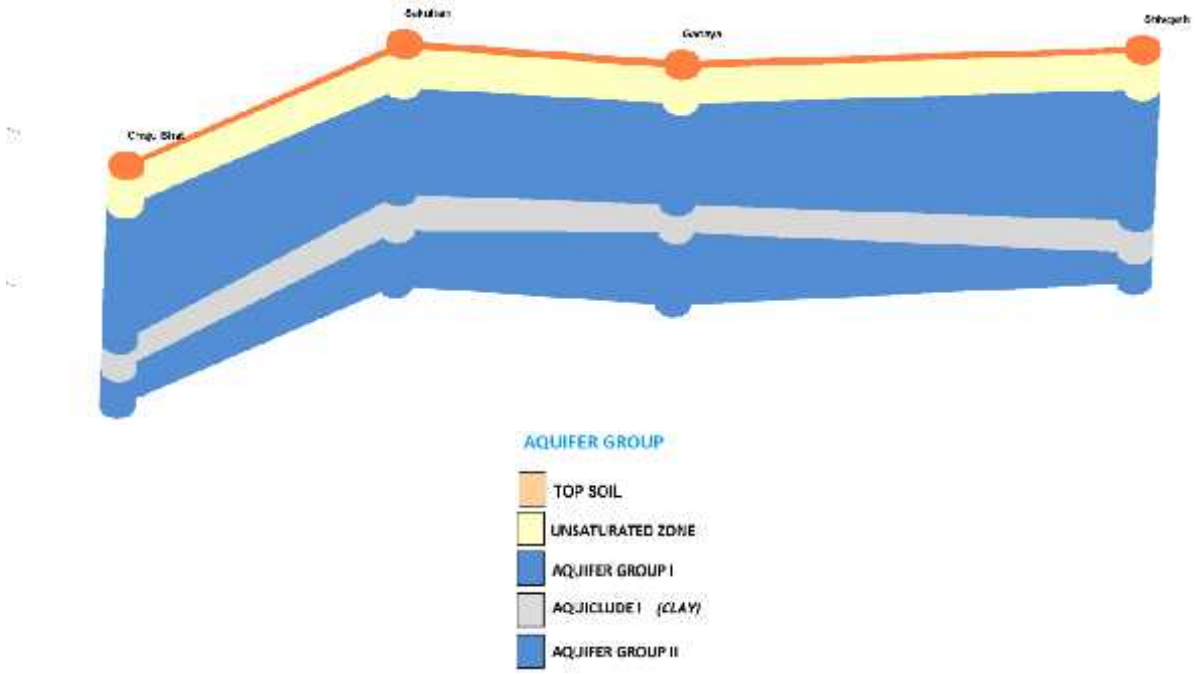
3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along Thuhi to Samaspur



Aquifer Cross section along Chaju Bhat to Shivgarh



Ground water Resource, Extraction, Contamination and other issues in Nabha Block

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	404.44 mcm
	In-storage Aquifer-I (Specific Yield Concept)	2091.93 mcm
	In-storage Aquifer-II (Specific Yield Concept)	1184.11 mcm
	In-storage Aquifer-II (Storativity Concept)	111.39 mcm
	In-storage Aquifer-III (Specific Yield Concept)	907.82 mcm
	In-storage Aquifer-II (Storativity Concept)	432.46 mcm
	Total Resources	5132.15 mcm
Ground Water Extraction (as per 2013)	Irrigation	606.86 mcm
	Domestic & Industrial	7.41 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		10.49 mcm
Stage of Groundwater Development		148 %
Chemical Quality of ground water		Ground water in the area is alkaline in nature and pH ranges between 8.70 to 8.90. EC value of the ground water show wide variations and ranges from 449

	µS/cm to 755 µS/cm at 25^0C. RSC values are varies from 1.19 to 1.69 meq/L and the area is fit for irrigation.
Ground water Contamination Issues	*NA*
Other issues	Water level decline has been observed in major parts of the block due to in discriminate development of ground water resources.

Ground water Resource Enhancement Potential

Aquifer wise space available for recharge and proposed interventions (Supply Side Measures)

Aquifer-I:

Volume of unsaturated zone after 3m upto a desirable depth: 618.37 mcm
Source water requirement/availability for recharge: *Rain, Canal, Irrigation return flow*
Types and number of structures: NA
Other interventions proposed*: Artificial Recharge, Roof top Rainwater harvesting will conserve 5.80 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Nabha Block (548.20 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 147.28 mcm

Required Change in cropping pattern

Proposed change in cropping pattern: *Rice to Maize, Soyabean.*
The overexploitation can be managed at sustainable level (100%) by changing the Paddy crop
Area coverage: *12.5% of the total rice area needs to change i.e.* 57.38 sq km
Anticipated volume of water to be saved: 57.38 mcm

Paddy area (Sq km)	*Required Area to be Change from Paddy to Maize/ Soyabean (Sq km)*	*Amount of Water Saved (mcm)*	*Present Stage of develop-ment (%)*	*Reduction in Stage of develop-ment after Maize (%)*	*Crop Diversified area for Maize (%)*	*Reduction in Stage of develop-ment after soya bean (%)*	*Crop Diversified area for Soyabean (%)*	*Reduction in Stage of develop-ment after Maize and Soya bean (%)*	*Crop Diversified area (%)*
459	57.38	57.38	152	14.20	12.5	NR	NR	14.20	12.5

NR: Not Required

Net Annual Ground Water Availability 2013 (mcm)	*Total Irrigat-ion Draft (present) (mcm)*	*Gross Draft all uses (present) (mcm)*	*Paddy area (Sq km)*	*Required Area to be Change from Paddy to Maize/ soya bean (Sq km)*	*Amount of Water Saved (mcm)*	*Gross draft after saving of water (mcm)*	*Present Stage of develop-ment (%)*	*Total Reduction in Stage of develop-ment after Maize/ soya bean (%)*	*Total Crop Diversified area (%)*
404.44	606.86	614.27	459	57.38	57.38	549.48	152	14.19	12.50

Alternate Water sources

Surface water sources: *Tanks, Ponds*

No.of Water tanks: 42

Location, details and availability from such sources outside the area: Not Available

Regulation and Control:

Punjab Subsoil Act for delay in paddy plantation should continue in the area.

Other interventions proposed, if any

Modern Irrigation Practices be adopted for Rabi crops. Some of the techniques are given in the table below (PAU, Ludhiana).

Sl.No	Techniques	Water Saving (%)	Crops
1	Mulching	17	Wheat
2	Bed Planting	18-25	Wheat
3	Use of Sprinkler and drip Irrigation	70-90	Sugarcane, Sunflower, Maize

Other than that by 15 days ponding followed by 2 days of drying can lead to 25% saving of water in paddy crop.

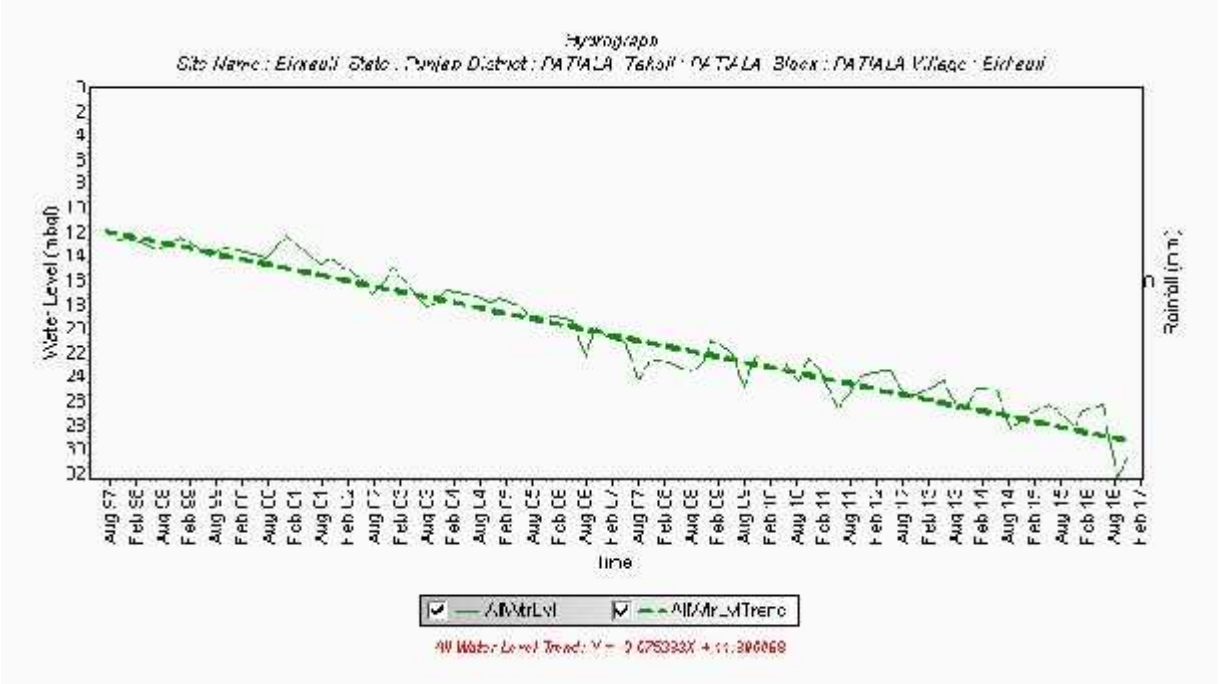
IV. Salient Information of Patiala Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>423.10 sq km</td></tr>
<tr><td>District/ State</td><td>Patiala, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 42253
Rural Population: 166056
Total population: 123803</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 535 mm
Non-monsoon Rainfall : 97 mm
Annual Average Rainfall: 632 mm</td></tr>
<tr><td>Agriculture and Irrigation</td><td>Principal crops: Wheat, Rice, Maize and Sugar cane
Other crops: Vegetables and Fodder
Gross cropped area: 591.1 sq km
Net sown area: 300.36 sq km
Irrigation practices: Tube well and Canal Irrigation
Cropping intensity: 197%
<u>Area under</u>
Ground water Irrigation: 283.34 sq km
Surface water irrigation: 23.37 sq km
Gross Irrigated area: 589.10sq km
Net Irrigated area: 299.36 sq km
Intensity of Irrigation: 197%
Number and types of abstraction structures: 10052, Tubewells</td></tr>
<tr><td>Ground Water Resource Availability and Extraction</td><td><u>Ground water Resources Availability</u>
Ground Water Resources are available in the different group of aquifers. The fresh water resources are estimated up to the depth of 300 m on the basis of geophysical interpretations.
<table>
<tr><th>Aquifer Group</th><th>Aquifer Depth range (m)</th><th>Aquifer Thickness (m)</th><th>Granular Zones (m)</th><th>Resources (mcm)</th></tr>
<tr><td>Aquifer-I</td><td>20.48 – 103.0</td><td>83</td><td>40</td><td>1410.06</td></tr>
<tr><td>Aquifer-II</td><td>130.0 – 185.0</td><td>55</td><td>25</td><td>846.97</td></tr>
<tr><td>Aquifer-III</td><td>232.0 – 300.0</td><td>68</td><td>22</td><td>833.22</td></tr>
</table>
Total Ground Water Resources available is 3090.25 mcm and total potential granular zones available are 87 m up to depth of 300 m. Block is categorized as Over-Exploited as per Dynamic Groundwater Resources, 2013 assessment.
<u>Ground water Resources Extraction</u>
Information regarding the abstraction from Aquifer II is not available, but there are drinking water supply wells of State Government tapping combined aquifers. Therefore, the ground water draft could not be assessed for Aquifer-II and III separately.</td></tr>
</table>

Existing and future water demands	Water Scarcity Villages: 105 Small Scale Industries : 240 Large Scale Industries : 8 Total Villages : 108 *Existing Gross Ground water Draft as on 2013* Irrigation: 344.15 mcm Domestic and industrial water supply: 13.56 mcm *Future water demands* Irrigation development potential : (-)172.76 mcm Domestic and industrial water supply up to 2025 years : 20.14 mcm
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 19.4 – 26.21 m bgl Post Monsoon: 21.25 – 28.10 m bgl Seasonal Fluctuation: (-)1.85 – (-)1.89 m/yr Mean (10 yrs) : (-)2.13 – (-)2.92 m/yr *Trends* Pre Monsoon: (-)0.56 m/yr Post Monsoon: (-)0.88 m/yr **Aquifer-II &III** No Monitoring Stations

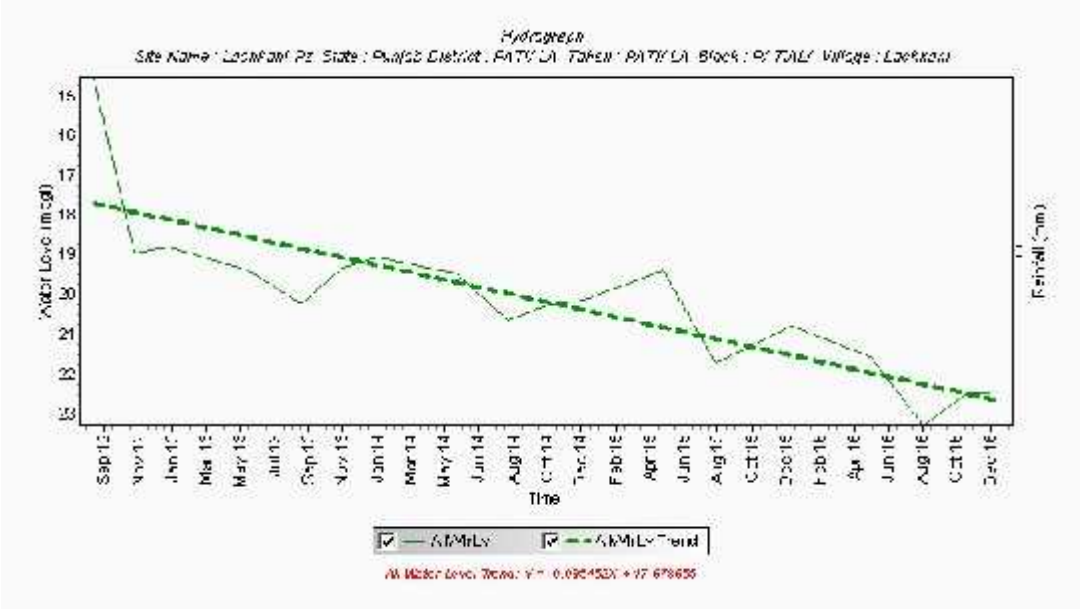
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Birkauli)



HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Lachkani)



Aquifer Disposition

Number of aquifers	1
Principal aquifer	Alluvium
Major Aquifer	Older Alluvium
Aquifer Disposition	Multiple Aquifer System (Three Aquifer Groups)

Exploratory Data Availability

Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	2	1	2	1	**6**
WRED/WSS	6	0	0	1	**7**
PRIVATE	1	18	39	3	**61**
TOTAL	**9**	**19**	**41**	**5**	**74**

Aquifer wise Characteristics

Aquifer Group	Geology	Type of Aquifer	Thickness of Granular zones (m)	Transmiss-ivity (m^2/day)	Discharge (m^3/day)	Specific Yield	Storativity
Aquifer –I (20.48- 103 m)	Quarter-nary Alluvial deposits	Unconfined to confined	40	9410	NA	12 % *(0.072)*	4.7×10^{-3}
Aquifer-II (130 - 185 m)		Semi confined to Confined	25	1150	NA	NA	1.95×10^{-3}
Aquifer-III (232 - 300 m)		Semi confined to Confined	22	239	2479	NA	NA

NA: Not Available

Source: CGWB,2015 & PSTC,2008

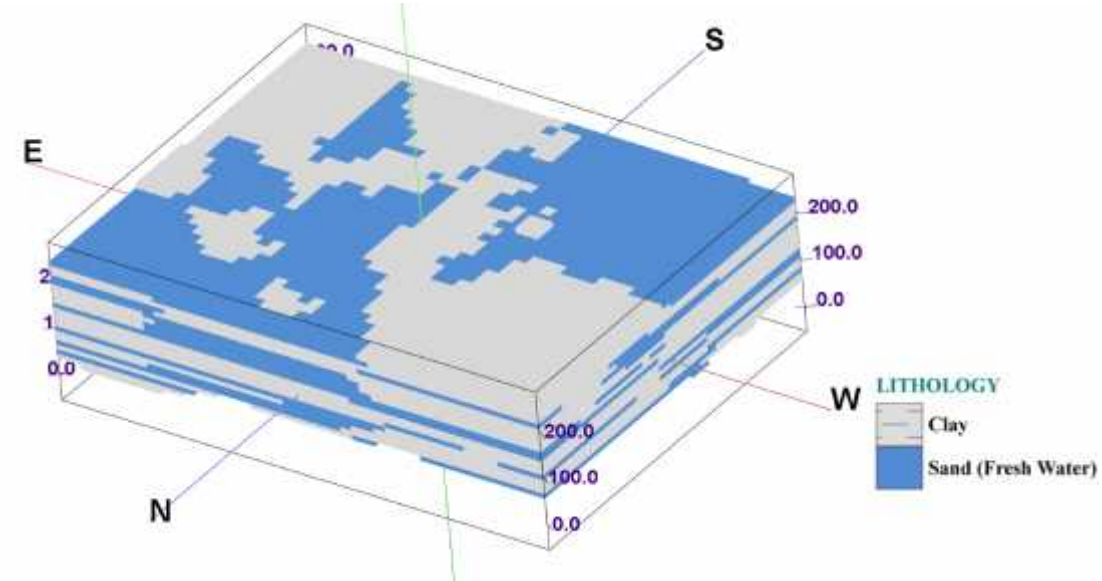
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

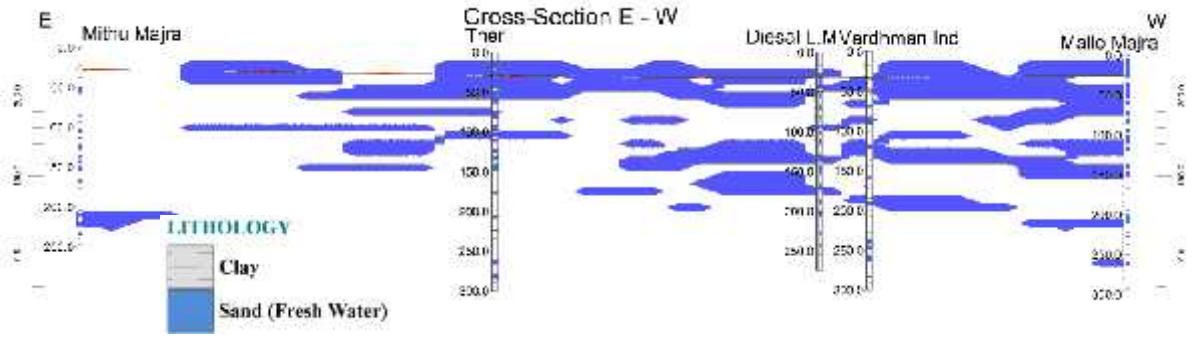
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	1	1	**2**
WRED/WSS	0	0	0	0	**0**
PRIVATE	0	0	10	3	**13**
TOTAL	**0**	**0**	**11**	**4**	**15**

The data is validated by selecting the deepest well in each quadrant and used for preparation of 3-D Litho models, 2-D Geological Cross Sections, Fence Diagrams and Aquifer Maps.

3-D Lithological model of Patiala Block

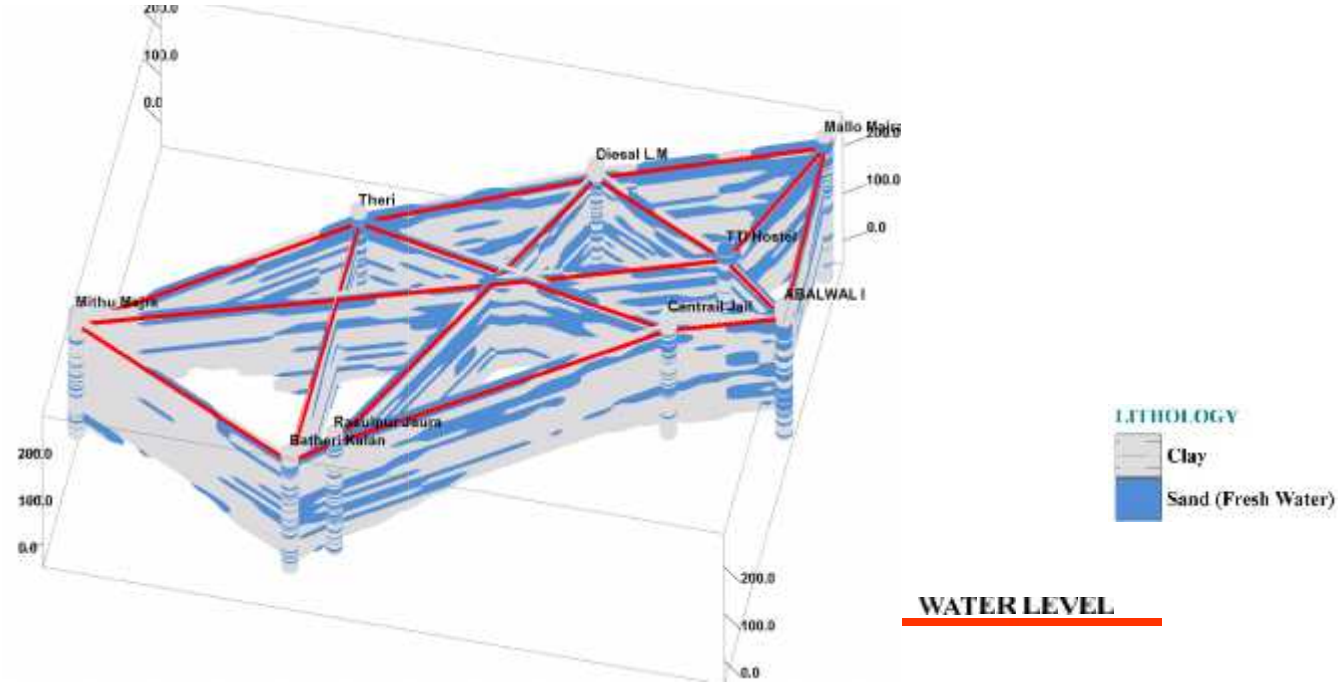


Lithological Cross section from Mithu Majra to Mallo Majra

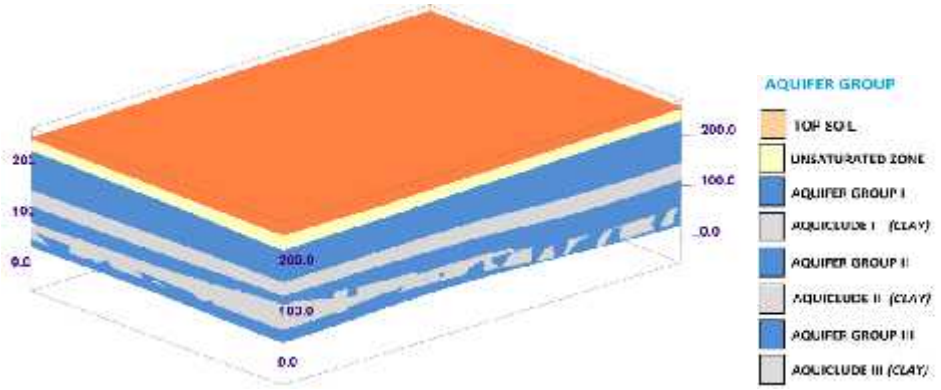


Lithological Cross section from Batheri Kalan to Mallo Majra

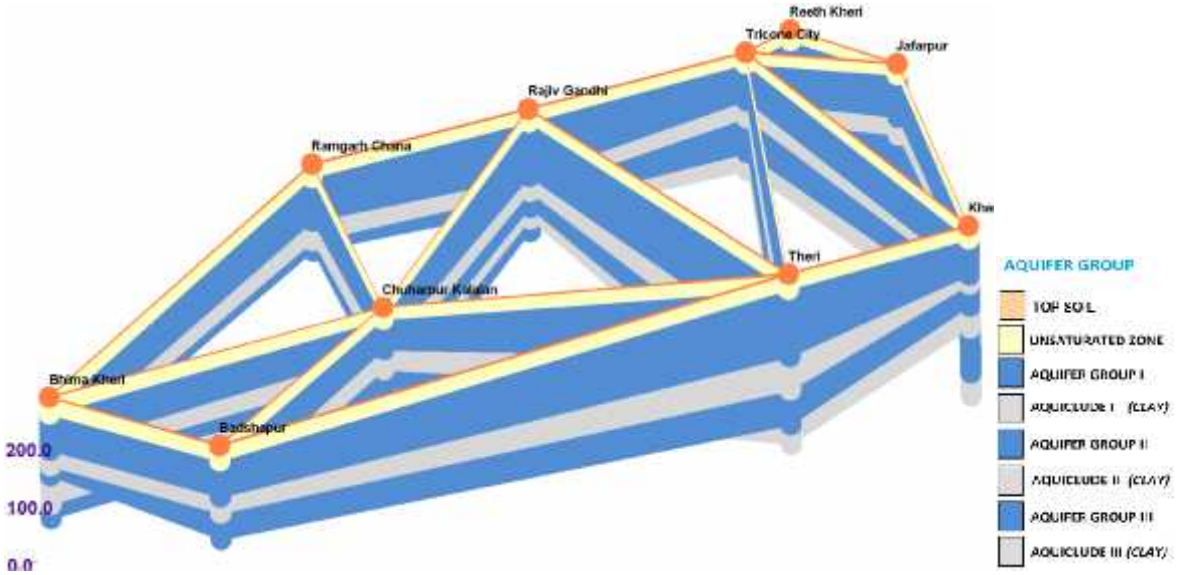
3-D Lithological Fence Diagram



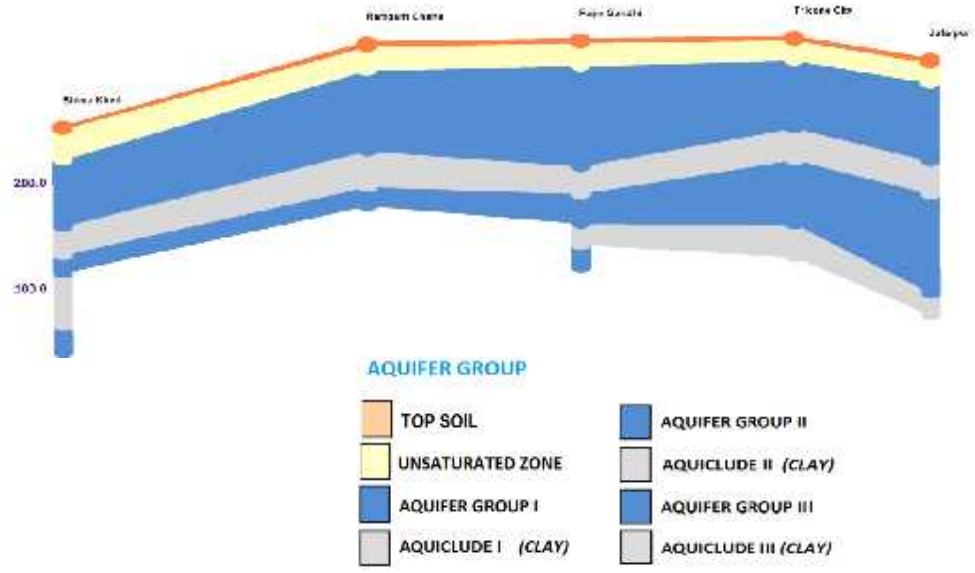
3-D Aquifer Disposition Model of Patiala Block



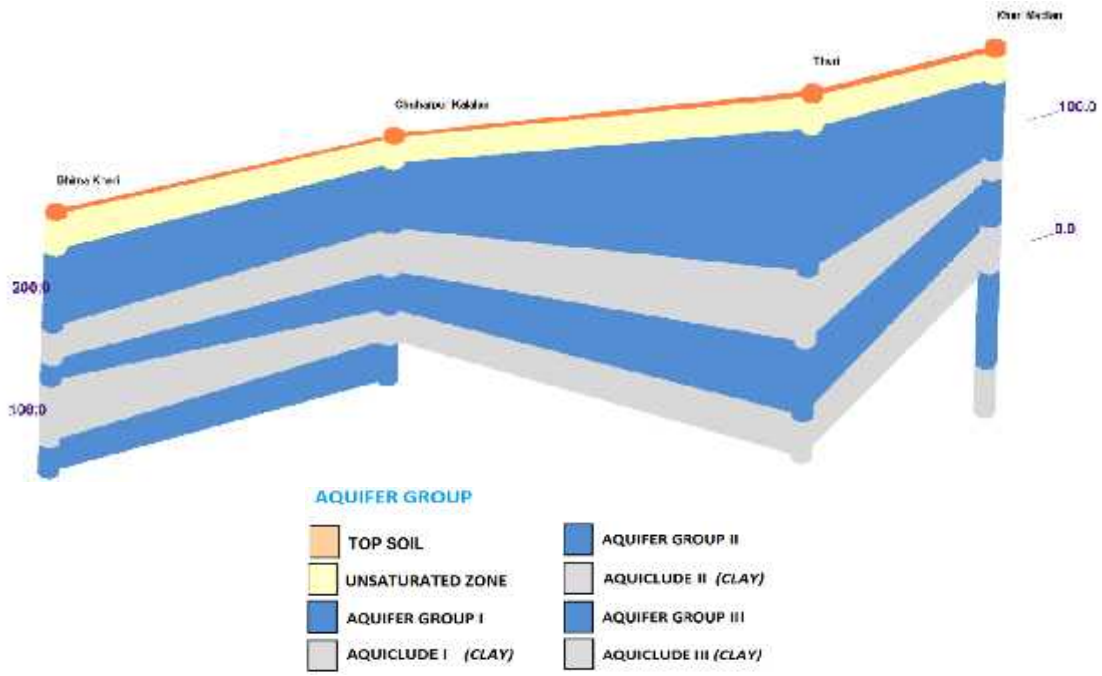
3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along Bhima Kheri to Jafarpur



Aquifer Cross section along Bhima Kheri to Kheri Madhan



Ground water Resource, Extraction, Contamination and other issues in Patiala Block

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	191.53 mcm
	In-storage Aquifer-I (Specific Yield Concept)	1218.53 mcm
	In-storage Aquifer-II (Specific Yield Concept)	761.58 mcm
	In-storage Aquifer-II (Storativity Concept)	85.39 mcm
	In-storage Aquifer-III (Specific Yield Concept)	670.19 mcm
	In-storage Aquifer-II (Storativity Concept)	163.03 mcm
	Total Resources	3090.25 mcm
Ground Water Extraction (as per 2013)	Irrigation	344.15 mcm
	Domestic & Industrial	13.56 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		20.14 mcm
Stage of Groundwater Development		187 %
Chemical Quality of ground water		Ground water in the area is alkaline in nature and pH ranges 8.25 to 8.85. EC value of the ground water show variations and ranges from 1000 µS/cm

	to 1060 µS/cm at 25^{0}C. RSC values are varies from 0.88to 2.13 meq/L and the area is fit for irrigation.
Ground water Contamination Issues	*NA*
Other issues	Water level decline has been observed in major parts of the block due to in discriminate development of ground water resources.

Ground water Resource Enhancement Potential

Aquifer wise space available for recharge and proposed interventions (Supply Side Measures)

Aquifer-I:

Volume of unsaturated zone after 3m upto a desirable depth: 538.18 mcm
Source water requirement/availability for recharge: *Rain, Canal, Irrigation return flow*
Types and number of structures: NA
Other interventions proposed*: Artificial Recharge, Roof top Rainwater harvesting will conserve 4.11 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Patiala Block (423.10 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 83.53 mcm

Required Change in cropping pattern

Proposed change in cropping pattern: *Rice to Maize, Soyabean.*
The overexploitation can be managed at sustainable level (100%) by changing the Paddy crop
Area coverage: *28 % of the total rice area needs to change i.e.* 78.68 sq km
Anticipated volume of water to be saved: 78.68 mcm

Paddy area (Sq km)	*Required Area to be Change from Paddy to Maize/ Soyabean (Sq km)*	*Amount of Water Saved (mcm)*	*Present Stage of develop-ment (%)*	*Reduction in Stage of develop-ment after Maize (%)*	*Crop Diversified area for Maize (%)*	*Reduction in Stage of develop-ment after soya bean (%)*	*Crop Diversified area for Soyabean (%)*	*Reduction in Stage of develop-ment after Maize and Soya bean (%)*	*Crop Diversified area (%)*
281	78.68	78.68	187	40.10	27.3	1.0	0.7	41.08	28

NR: Not Required

Net Annual Ground Water Availability 2013 (mcm)	*Total Irrigat-ion Draft (present) (mcm)*	*Gross Draft all uses (present) (mcm)*	*Paddy area (Sq km)*	*Required Area to be Change from Paddy to Maize/ soya bean (Sq km)*	*Amount of Water Saved (mcm)*	*Gross draft after saving of water (mcm)*	*Present Stage of develop-ment (%)*	*Total Reduction in Stage of develop-ment after Maize/ soya bean (%)*	*Total Crop Diversified area (%)*
191.53	344.15	357.71	281	78.68	78.68	265.47	187	41.08	28

Alternate Water sources

Surface water sources: *Tanks, Ponds*

No.of Water tanks: 47

Location, details and availability from such sources outside the area: Not Available

Regulation and Control:

Punjab Subsoil Act for delay in paddy plantation should continue in the area.

Other interventions proposed, if any

Modern Irrigation Practices be adopted for Rabi crops. Some of the techniques are given in the table below (PAU, Ludhiana).

Sl.No	Techniques	Water Saving (%)	Crops
1	Mulching	17	Wheat
2	Bed Planting	18-25	Wheat
3	Use of Sprinkler and drip Irrigation	70-90	Sugarcane, Sunflower, Maize

Other than that by 15 days ponding followed by 2 days of drying can lead to 25% saving of water in paddy crop.

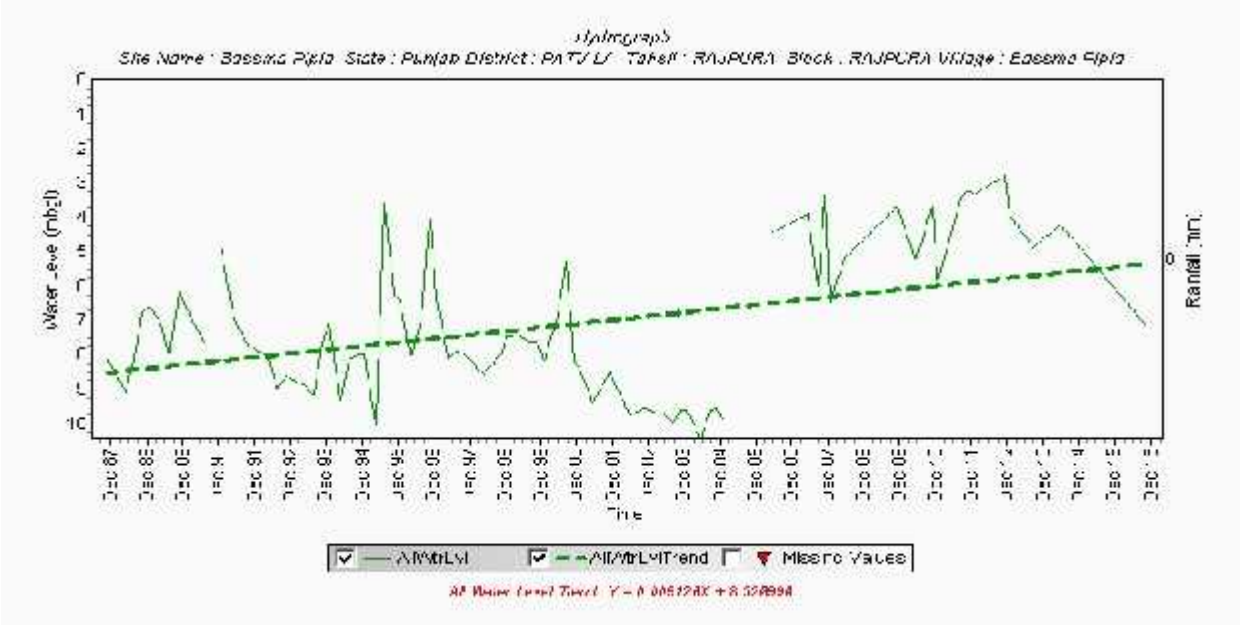
V. Salient Information of Rajpura Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>399.40 sq km</td></tr>
<tr><td>District/ State</td><td>Patiala, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 8391
Rural Population: 144350
Total population: 152741</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 593 mm
Non-monsoon Rainfall : 137 mm
Annual Average Rainfall: 730 mm</td></tr>
<tr><td>Agriculture and Irrigation</td><td>Principal crops: Wheat, Rice, Maize and Sugar cane
Other crops: Vegetables and Fodder
Gross cropped area: 462.13 sq km
Net sown area: 237.60 sq km
Irrigation practices: Tube well and Canal Irrigation
Cropping intensity: 194%
<u>Area under</u>
Ground water Irrigation: 226.04 sq km
Surface water irrigation: 14.33 sq km
Gross Irrigated area: 463.81sq km
Net Irrigated area: 236.24 sq km
Intensity of Irrigation: 196%
Number and types of abstraction structures: 7806, Tubewells</td></tr>
<tr><td>Ground Water Resource Availability and Extraction</td><td><u>Ground water Resources Availability</u>
Ground Water Resources are available in the different group of aquifers. The fresh water resources are estimated up to the depth of 300 m on the basis of geophysical interpretations.
<table>
<tr><th>Aquifer Group</th><th>Aquifer Depth range (m)</th><th>Aquifer Thickness (m)</th><th>Granular Zones (m)</th><th>Resources (mcm)</th></tr>
<tr><td>Aquifer-I</td><td>19.63 – 86.0</td><td>66</td><td>27</td><td>921.59</td></tr>
<tr><td>Aquifer-II</td><td>119.0 – 181.0</td><td>62</td><td>24</td><td>753.33</td></tr>
<tr><td>Aquifer-III</td><td>217.0 – 300.0</td><td>83</td><td>21</td><td>746.11</td></tr>
</table>
Total Ground Water Resources available is 2421.02 mcm and total potential granular zones available are 72 m up to depth of 300 m. Block is categorized as Over-Exploited as per Dynamic Groundwater Resources, 2013 assessment.
<u>Ground water Resources Extraction</u>
Information regarding the abstraction from Aquifer II is not available, but there are drinking water supply wells of State Government tapping combined aquifers. Therefore, the ground water draft could not be assessed for Aquifer-II and III separately.</td></tr>
</table>

Existing and future water demands	Water Scarcity Villages: 114 Small Scale Industries : 87 Large Scale Industries : 2 Total Villages : 115 *Existing Gross Ground water Draft as on 2013* Irrigation: 244.08 mcm Domestic and industrial water supply: 5.73 mcm *Future water demands* Irrigation development potential : (-)107.44 mcm Domestic and industrial water supply up to 2025 years : 8.51 mcm
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 7.32 – 39.20 m bgl Post Monsoon: 7.56 – 38.95 m bgl Seasonal Fluctuation: 0.47 – (-)5.20 m/yr Mean (10 yrs) : 0.42 – (-)4.69 m/yr *Trends* Pre Monsoon: 0.08 – (-)2.10 m/yr Post Monsoon: 0.06 – (-)2.64 m/yr **Aquifer-II** Pre Monsoon: 37.90 m bgl Post Monsoon: 37.40 m bgl Seasonal Fluctuation: 0.50 m/yr **Aquifer-III** No Monitoring Stations

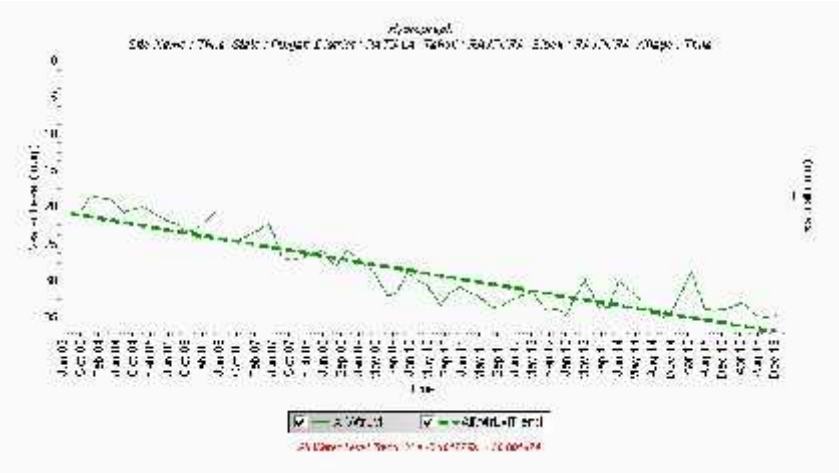
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Bassma Pipla)



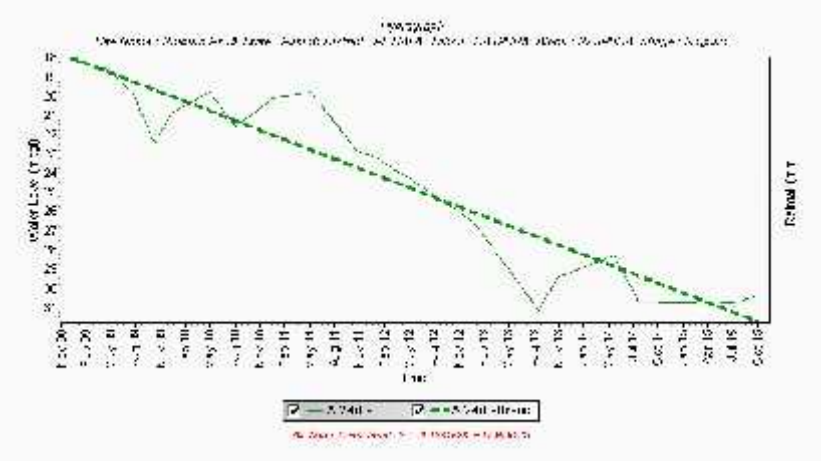
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Thua)



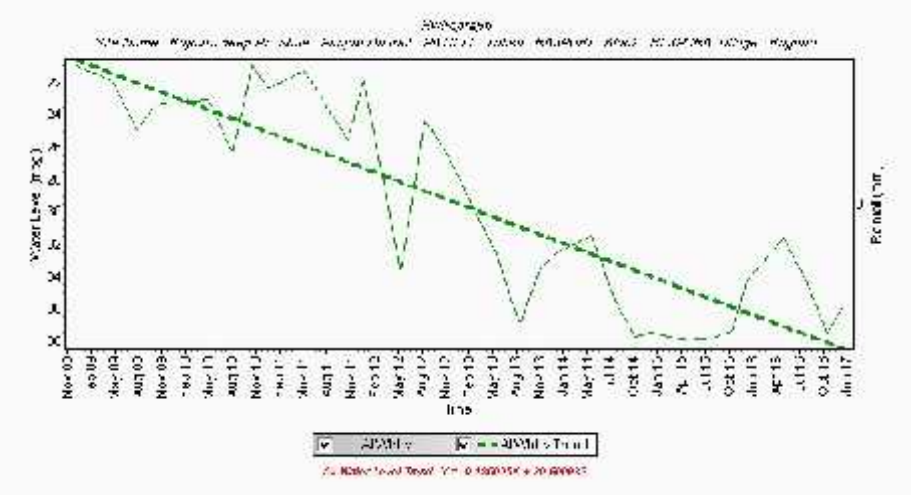
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Rajpura- M)



HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Rajpura - D)



Aquifer Disposition

Number of aquifers	1
Principal aquifer	Alluvium
Major Aquifer	Older Alluvium
Aquifer Disposition	Multiple Aquifer System (Three Aquifer Groups)

Exploratory Data Availability

Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	3	0	1	1	**5**
WRED/ WSS	6	2	0	2	**10**
PRIVATE	1	3	9	12	**25**
TOTAL	**10**	**5**	**10**	**15**	**40**

Aquifer wise Characteristics

Aquifer Group	Geology	Type of Aquifer	Thickness of Granular zones (m)	Transmiss-ivity (m^2/day)	Discharge (m^3/day)	Specific Yield	Storativity
Aquifer –I (19.63 - 86 m)	Quarter-nary Alluvial deposits	Unconfined to confined	27	NA	NA	12 % *(0.072)*	NA
Aquifer-II (119 - 181 m)		Semi confined to Confined	24	NA	NA	NA	NA
Aquifer-III (217 - 300 m)		Semi confined to Confined	21	151	1254	NA	NA

NA: Not Available

Source: CGWB,2015 & PSTC,2008

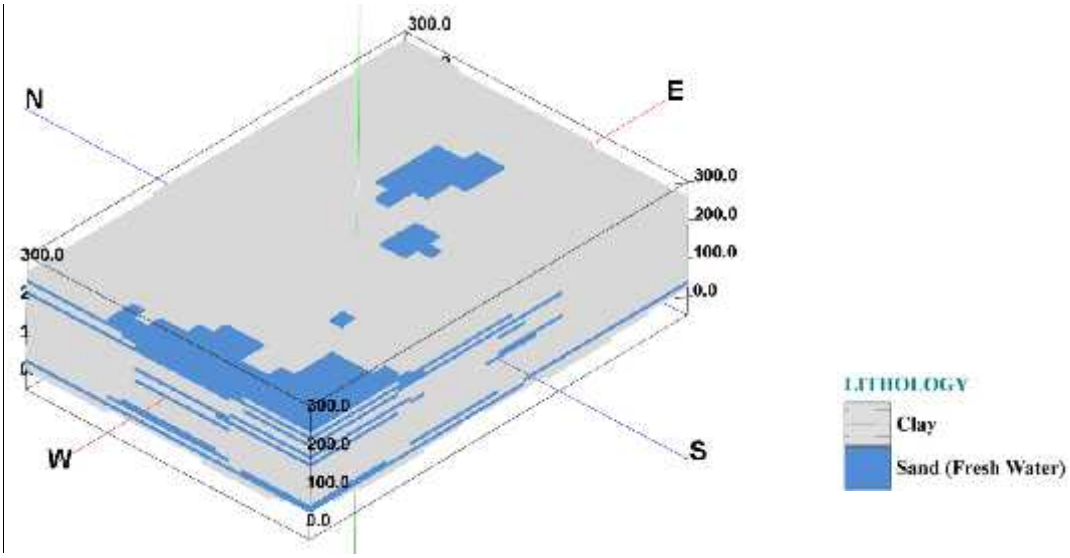
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

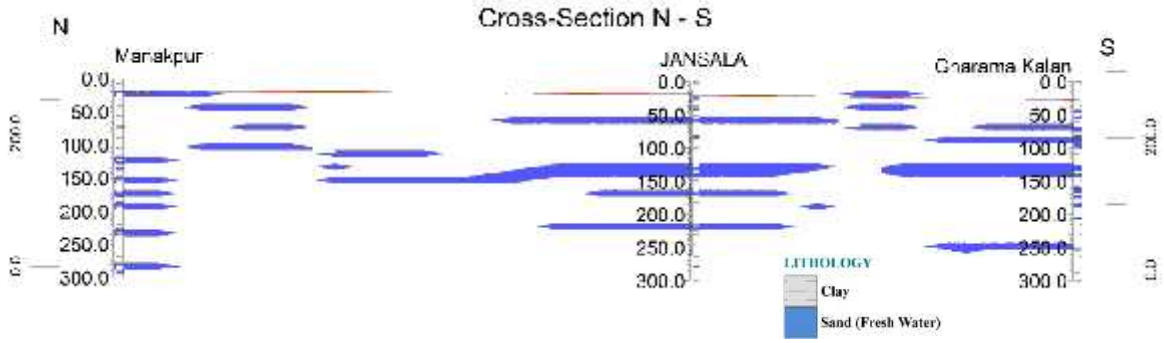
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	1	1	**2**
WRED/WSS	0	0	0	0	**0**
PRIVATE	0	0	6	12	**18**
TOTAL	**0**	**0**	**7**	**13**	**20**

The data is validated by selecting the deepest well in each quadrant and used for preparation of 3-D Litho models, 2-D Geological Cross Sections, Fence Diagrams and Aquifer Maps.

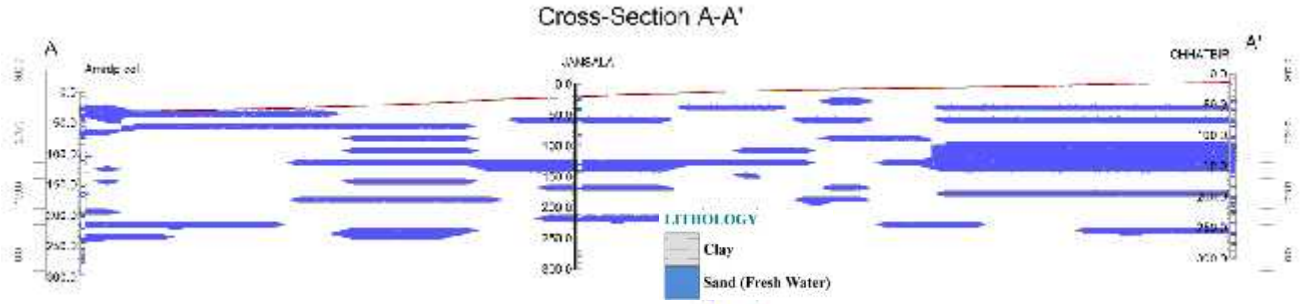
3-D Lithological model of Rajpura Block



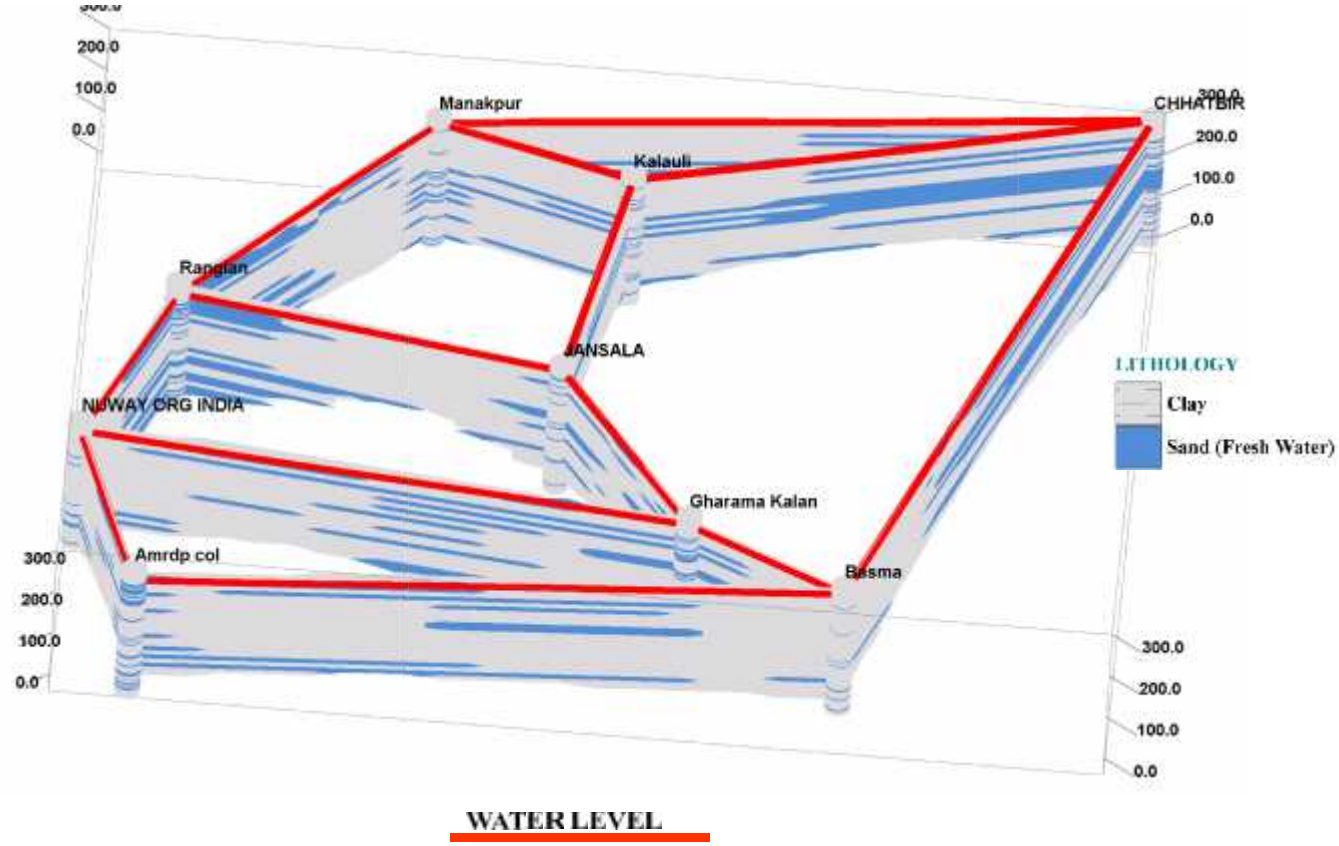
Lithological Cross section from Manakpur to Gharama Kalan



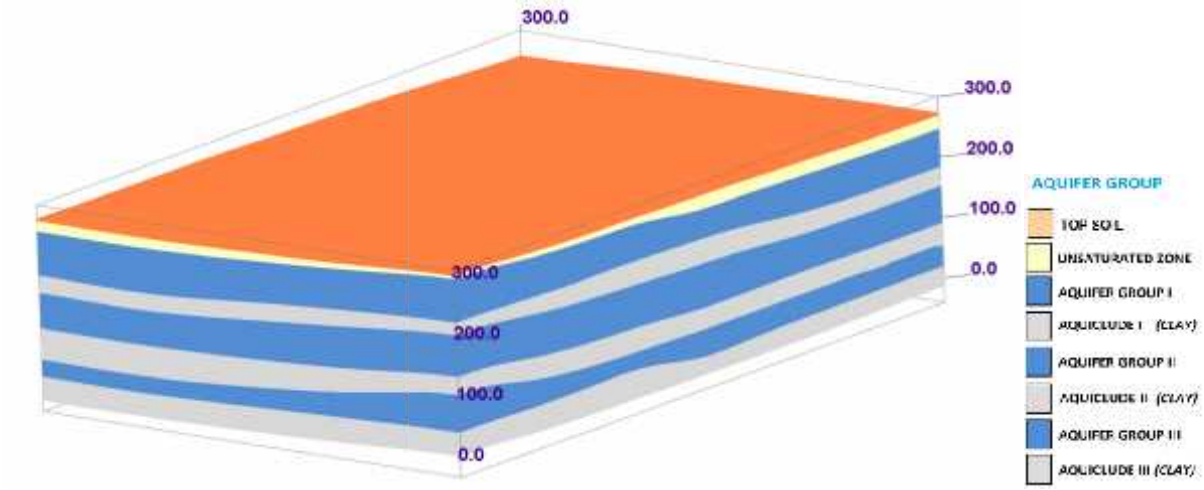
Lithological Cross section from Arm RDP Col to Chhatbir



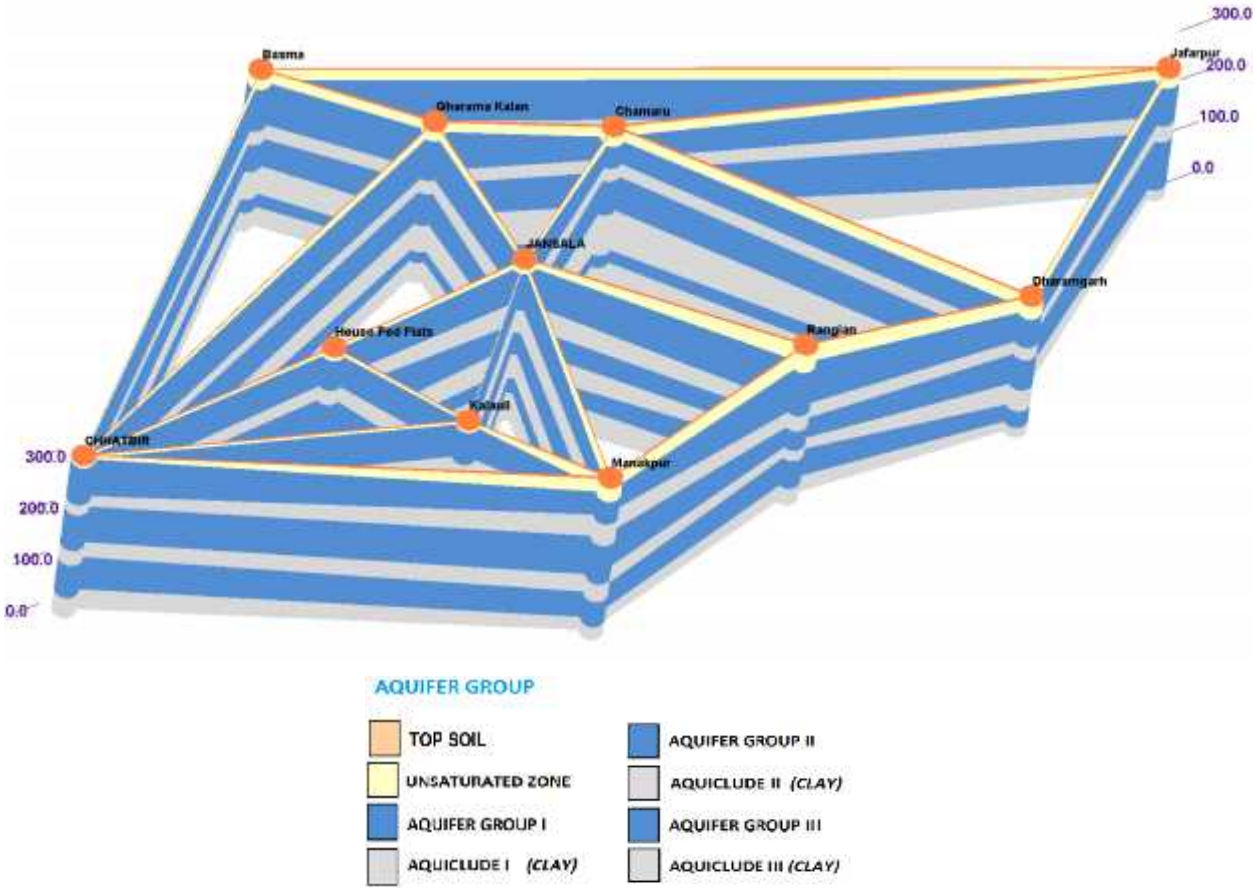
3-D Lithological Fence Diagram



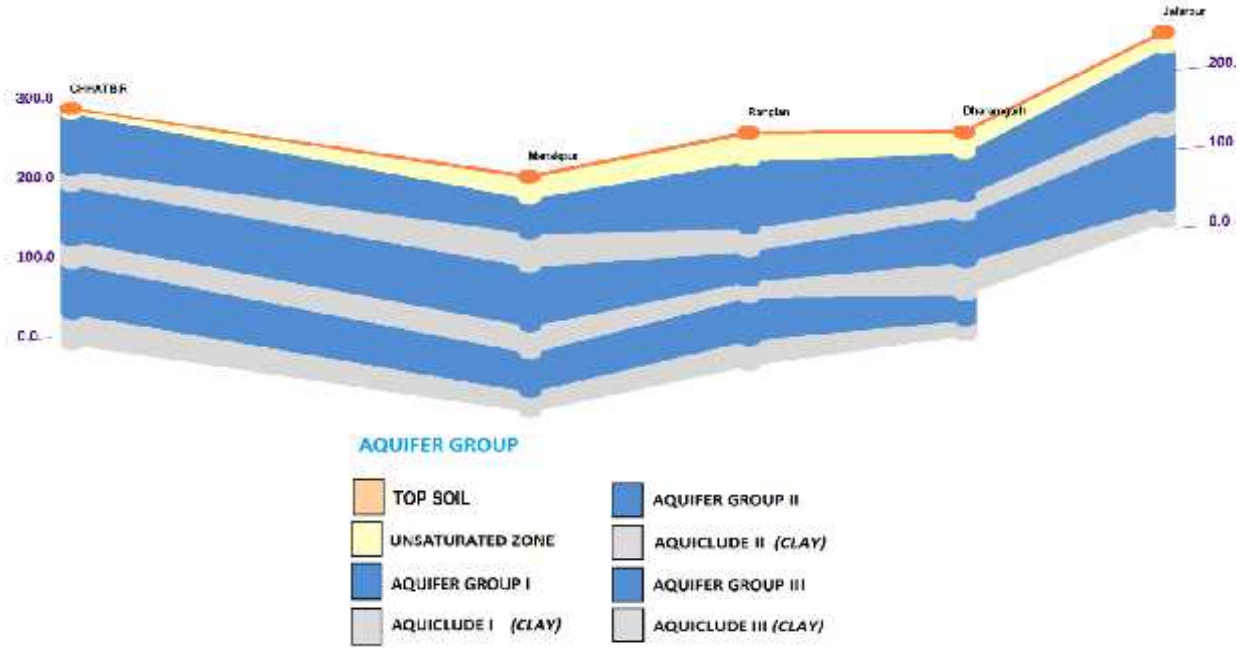
3-D Aquifer Disposition Model of Rajpura Block



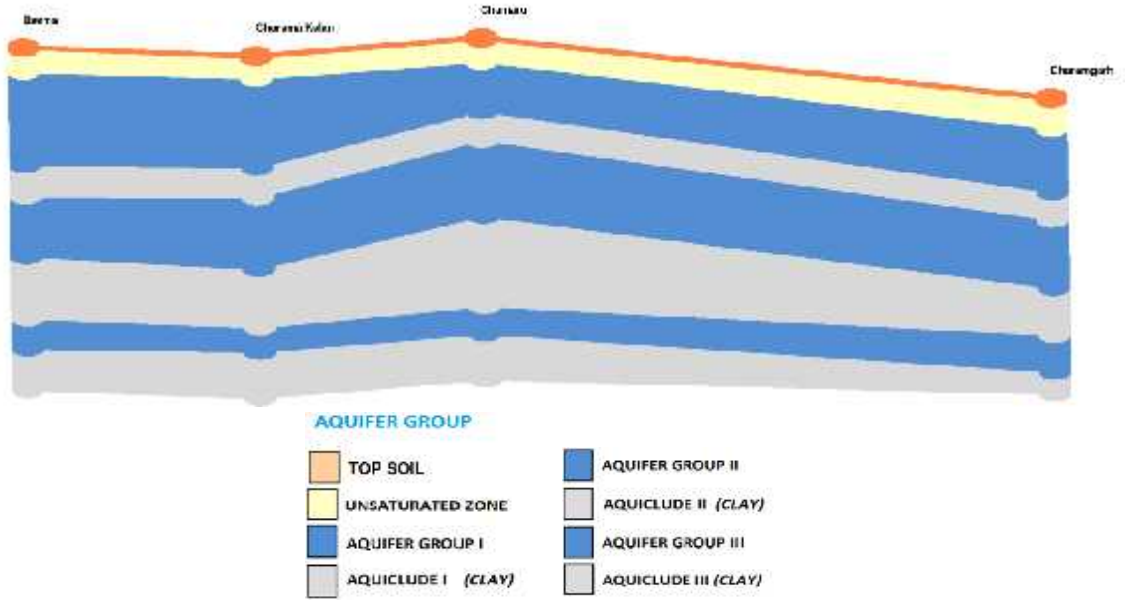
3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along Chhatbir to Jafarpur



Aquifer Cross section along Bassma to Dharamgarh



Ground water Resource, Extraction, Contamination and other issues in Patiala Block

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	145.16 mcm
	In-storage Aquifer-I (Specific Yield Concept)	776.43 mcm
	In-storage Aquifer-II (Specific Yield Concept)	690.16 mcm
	In-storage Aquifer-II (Storativity Concept)	63.16 mcm
	In-storage Aquifer-III (Specific Yield Concept)	603.89 mcm
	In-storage Aquifer-II (Storativity Concept)	142.21 mcm
	Total Resources	2421.02 mcm
Ground Water Extraction (as per 2013)	Irrigation	244.08 mcm
	Domestic & Industrial	5.73 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		8.51 mcm
Stage of Groundwater Development		172 %
Chemical Quality of ground water		Ground water in the area is alkaline in nature and pH ranges 8.59 to 9.05. EC value of the ground water show wide variations and ranges from 357 µS/cm to 1367 µS/cm at 25^0C.

	RSC values are varies from 1.03 to 6.04 meq/L and the area is fit for irrigation.
Ground water Contamination Issues	***Flouride(mg/l):*** Rajpura (3.5), Thua (2.89)
Other issues	Water level decline has been observed in major parts of the block due to in discriminate development of ground water resources.

Ground water Resource Enhancement Potential

Aquifer wise space available for recharge and proposed interventions (Supply Side Measures)

Aquifer-I:

Volume of unsaturated zone after 3m upto a desirable depth: 310.09 mcm
Source water requirement/availability for recharge: *Rain, Canal, Irrigation return flow*
Types and number of structures: NA
Other interventions proposed*: Artificial Recharge, Roof top Rainwater harvesting will conserve 3.36 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Rajpura Block (399.40 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 59.24 mcm

Required Change in cropping pattern

Proposed change in cropping pattern: *Rice to Maize, Soyabean.*
The overexploitation can be managed at sustainable level (100%) by changing the Paddy crop
Area coverage: *29% of the total rice area needs to change i.e.* 42.04 sq km
Anticipated volume of water to be saved: 42.04 mcm

Paddy area (Sq km)	*Required Area to be Change from Paddy to Maize/ Soyabean (Sq km)*	*Amount of Water Saved (mcm)*	*Present Stage of develop-ment (%)*	*Reduction in Stage of develop-ment after Maize (%)*	*Crop Diversified area for Maize (%)*	*Reduction in Stage of develop-ment after soya bean (%)*	*Crop Diversified area for Soyabean (%)*	*Reduction in Stage of develop-ment after Maize and Soya bean (%)*	*Crop Diversified area (%)*
186	42.04	42.04	172	28.96	22.60	NR	NR	28.96	22.6

NR: Not Required

Net Annual Ground Water Availability 2013 (mcm)	*Total Irrigat-ion Draft (present) (mcm)*	*Gross Draft all uses (present) (mcm)*	*Paddy area (Sq km)*	*Required Area to be Change from Paddy to Maize/ soya bean (Sq km)*	*Amount of Water Saved (mcm)*	*Gross draft after saving of water (mcm)*	*Present Stage of develop-ment (%)*	*Total Reduction in Stage of develop-ment after Maize/ soya bean (%)*	*Total Crop Diversified area (%)*
145.16	244.08	249.81	186	42.04	42.04	202.04	172	28.96	22.60

Alternate Water sources

Surface water sources: *Tanks, Ponds*

No.of Water tanks: 47

Location, details and availability from such sources outside the area: Not Available

Regulation and Control:

Punjab Subsoil Act for delay in paddy plantation should continue in the area.

Other interventions proposed, if any

Modern Irrigation Practices be adopted for Rabi crops. Some of the techniques are given in the table below (PAU, Ludhiana).

Sl.No	Techniques	Water Saving (%)	Crops
1	Mulching	17	Wheat
2	Bed Planting	18-25	Wheat
3	Use of Sprinkler and drip Irrigation	70-90	Sugarcane, Sunflower, Maize

Other than that by 15 days ponding followed by 2 days of drying can lead to 25% saving of water in paddy crop.

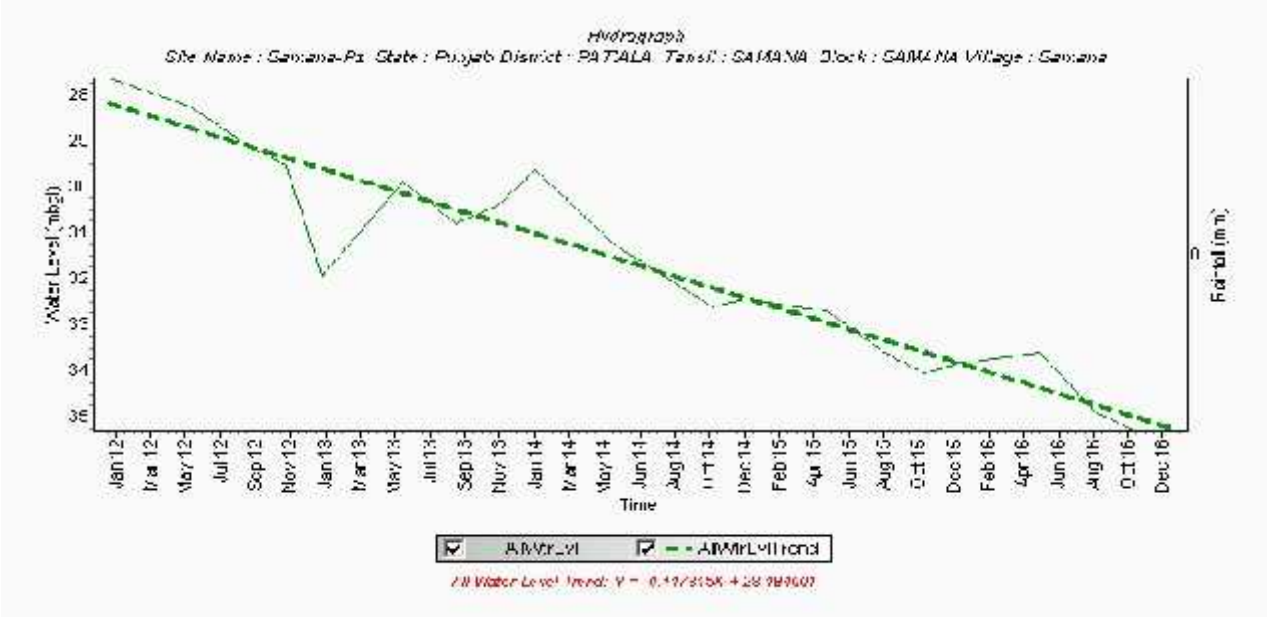
VI. Salient Information of Samana Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>396.50 sq km</td></tr>
<tr><td>District/ State</td><td>Patiala, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 0
Rural Population: 128676
Total population: 128676</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 415 mm
Non-monsoon Rainfall : 130 mm
Annual Average Rainfall: 545 mm</td></tr>
<tr><td>Agriculture and Irrigation</td><td>Principal crops: Wheat, Rice, Maize and Sugar cane
Other crops: Vegetables and Fodder
Gross cropped area: 685.98 sq km
Net sown area: 346.16 sq km
Irrigation practices: Tube well and Canal Irrigation
Cropping intensity: 198%
<u>Area under</u>
Ground water Irrigation: 253.77 sq km
Surface water irrigation: 61.53 sq km
Gross Irrigated area: 685.98 sq km
Net Irrigated area: 346.16 sq km
Intensity of Irrigation: 198%
Number and types of abstraction structures: 9284, Tubewells</td></tr>
<tr><td>Ground Water Resource Availability and Extraction</td><td><u>Ground water Resources Availability</u>
Ground Water Resources are available in the different group of aquifers. The fresh water resources are estimated up to the depth of 300 m on the basis of geophysical interpretations.
<table>
<tr><th>Aquifer Group</th><th>Aquifer Depth range (m)</th><th>Aquifer Thickness (m)</th><th>Granular Zones (m)</th><th>Resources (mcm)</th></tr>
<tr><td>Aquifer-I</td><td>25.47 – 94.0</td><td>69</td><td>34</td><td>1107.28</td></tr>
<tr><td>Aquifer-II</td><td>128.0 – 192.0</td><td>64</td><td>26</td><td>814.46</td></tr>
<tr><td>Aquifer-III</td><td>227.0 – 300.0</td><td>74</td><td>20</td><td>719.87</td></tr>
</table>
Total Ground Water Resources available is 2641.62 mcm and total potential granular zones available are 80 m up to depth of 300 m. Block is categorized as Over-Exploited as per Dynamic Groundwater Resources, 2013 assessment.
<u>Ground water Resources Extraction</u>
Information regarding the abstraction from Aquifer II is not available, but there are drinking water supply wells of State Government tapping combined aquifers. Therefore, the ground water draft could not be assessed for Aquifer-II and III separately.</td></tr>
</table>

Existing and future water demands	Water Scarcity Villages: 79 Small Scale Industries : 215 Large Scale Industries : 8 Total Villages : 80 *Existing Gross Ground water Draft as on 2013* Irrigation: 266.94 mcm Domestic and industrial water supply: 3.99 mcm *Future water demands* Irrigation development potential : (-)136.22 mcm Domestic and industrial water supply up to 2025 years : 5.93 mcm
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 17.30 – 34.90 m bgl Post Monsoon: 23.99 – 36.10 m bgl Seasonal Fluctuation: (-)0.90 – (-)6.69m/yr Mean (10 yrs) : (-)3.08 – (-)6.51 m/yr *Trends* Pre Monsoon: (-)0.69 – (-)1.28 m/yr Post Monsoon: (-)1.15 – (-)1.20 m/yr **Aquifer-II** Pre Monsoon: 29.25m bgl Post Monsoon: 30.05 m bgl Seasonal Fluctuation: (-)0.80 m/yr **Aquifer- III** No Monitoring Stations

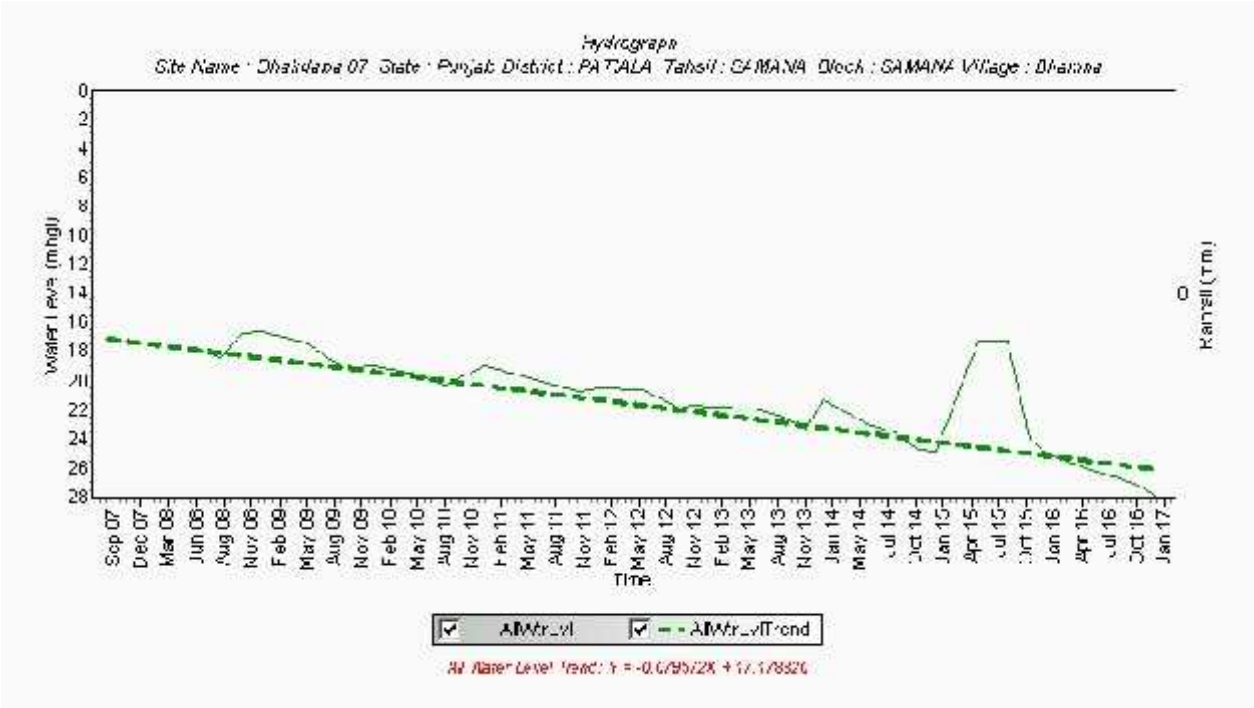
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Samana)



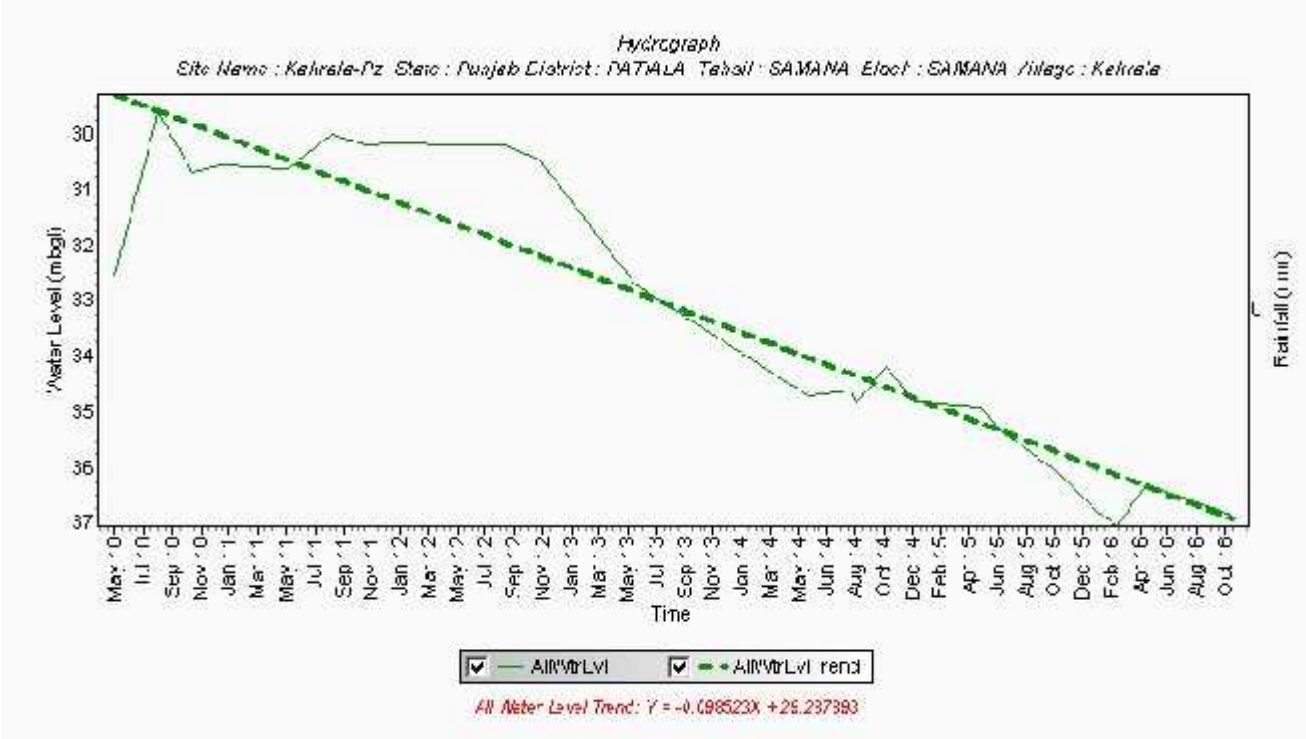
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Dhakraba)



HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Kakrala)



Aquifer Disposition

Number of aquifers	1
Principal aquifer	Alluvium
Major Aquifer	Older Alluvium
Aquifer Disposition	Multiple Aquifer System (Three Aquifer Groups)

Exploratory Data Availability

Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	1	1	0	0	**2**
WRED/WSS	6	0	0	0	**6**
PRIVATE	0	3	2	0	**5**
TOTAL	**7**	**4**	**2**	**0**	**13**

Aquifer wise Characteristics

Aquifer Group	Geology	Type of Aquifer	Thickness of Granular zones (m)	Transmiss-ivity (m^2/day)	Discharge (m^3/day)	Specific Yield	Storativity
Aquifer –I (25.47 - 94 m)	Quarter-nary Alluvial deposits	Unconfined to confined	34	NA	NA	12 % *(0.072)*	NA
Aquifer-II (128 - 192 m)		Semi confined to Confined	26	NA	NA	NA	NA
Aquifer-III (227- 300 m)		Semi confined to Confined	20	NA	NA	NA	NA

NA: Not Available

Source: Groundwater Exploration Report, Punjab CGWB, 2015

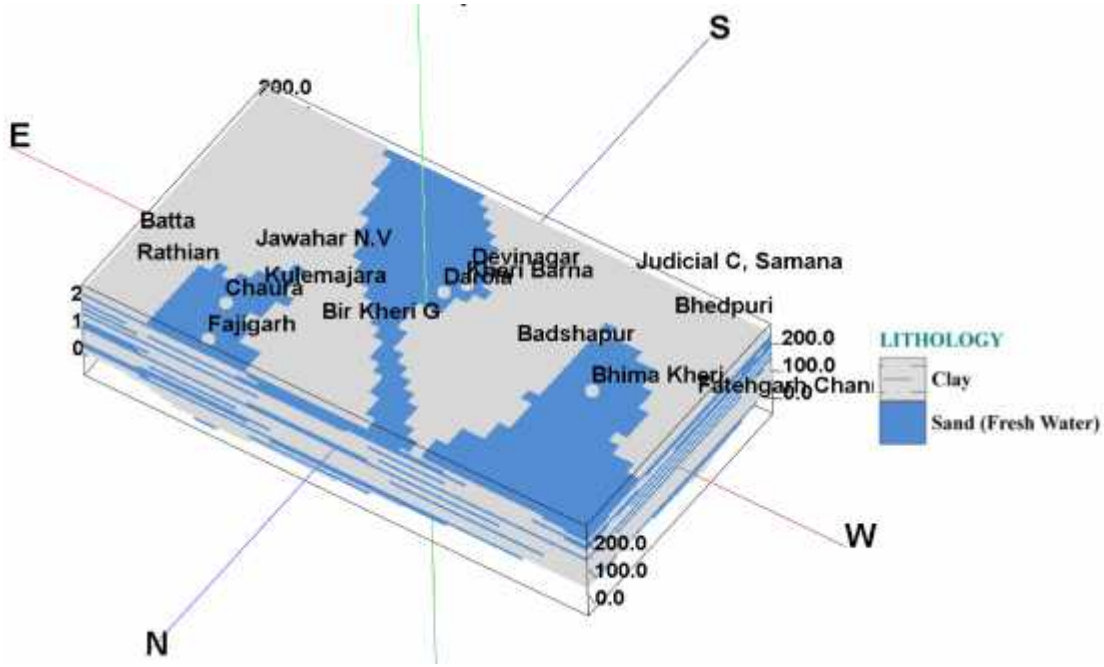
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

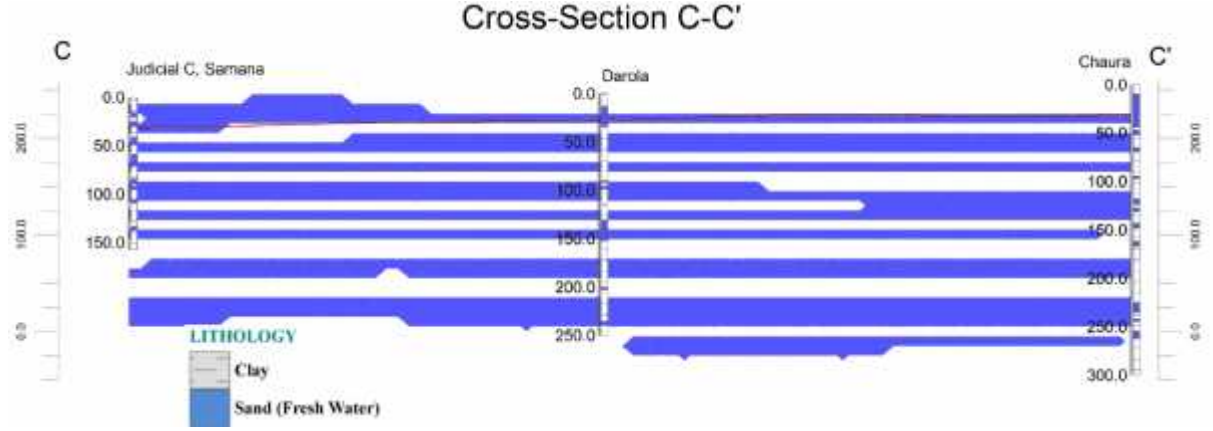
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	0	0	**0**
WRED/WSS	0	0	0	0	**0**
PRIVATE	0	3	2	0	**5**
TOTAL	**0**	**3**	**2**	**0**	**5**

The data is validated by selecting the deepest well in each quadrant and used for preparation of 3-D Litho models, 2-D Geological Cross Sections, Fence Diagrams and Aquifer Maps.

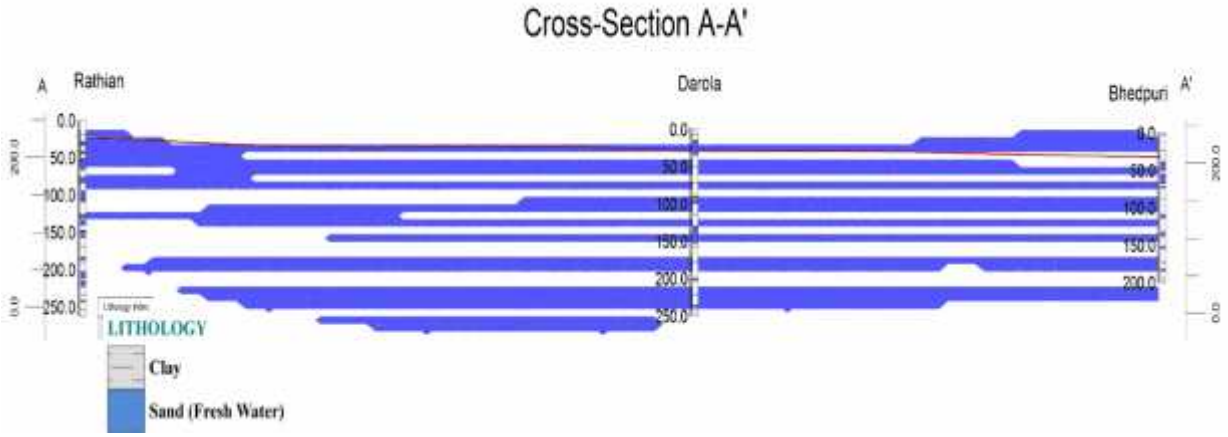
3-D Lithological model of Samana Block



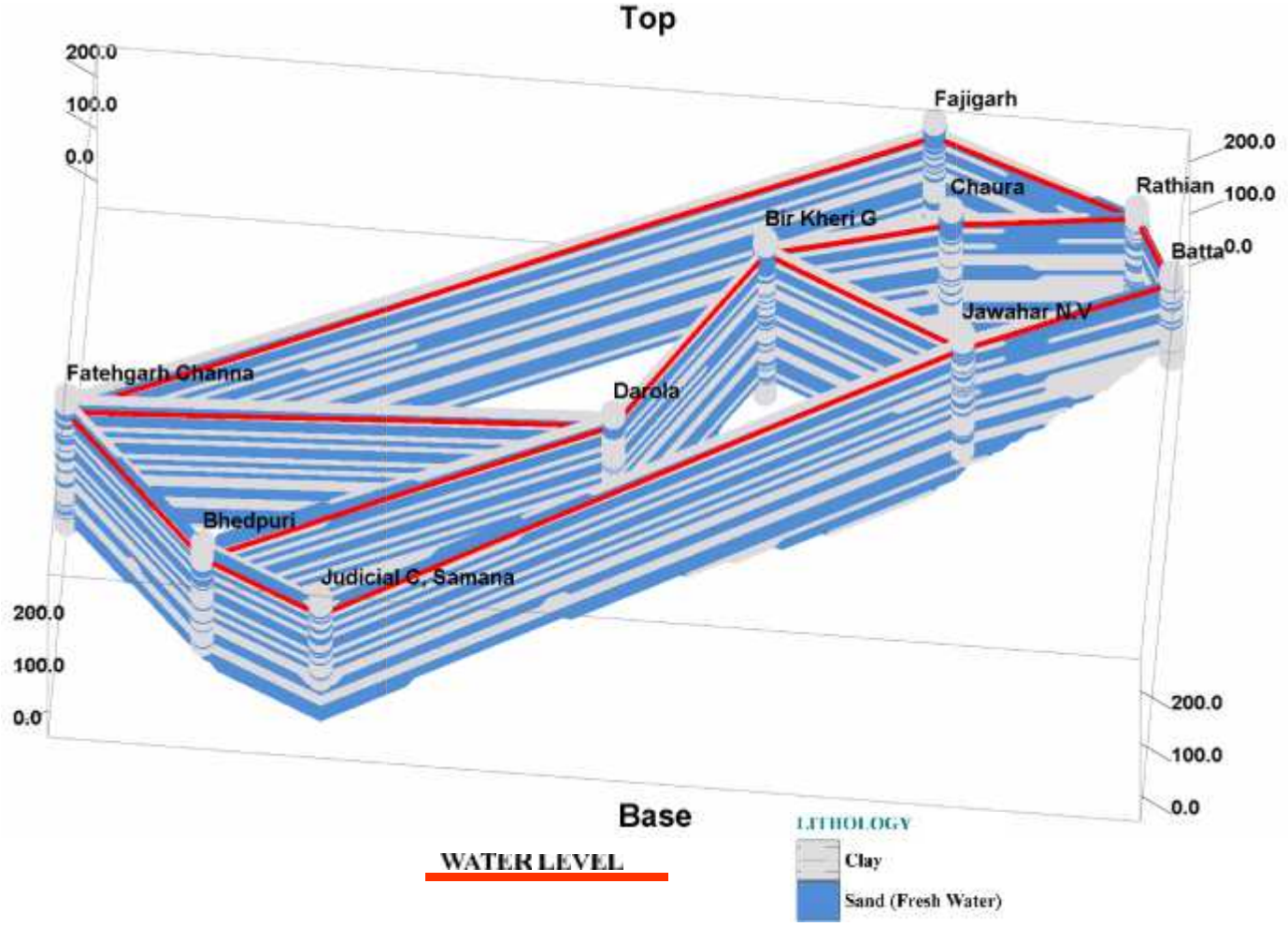
Lithological Cross section from Judicial Samana to Chaura



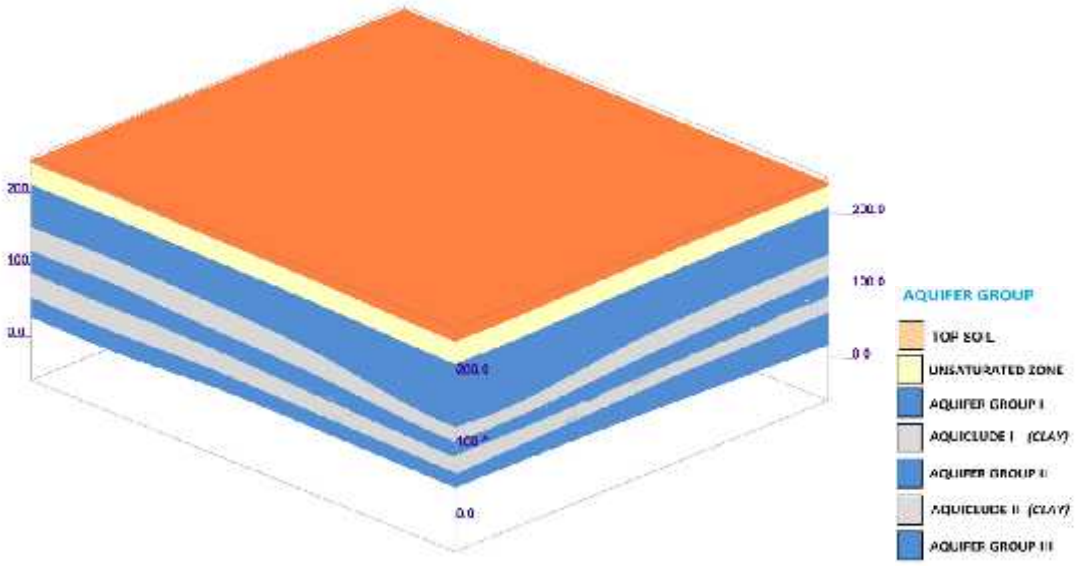
Lithological Cross section from Batheri Kalan to Mallo Majra



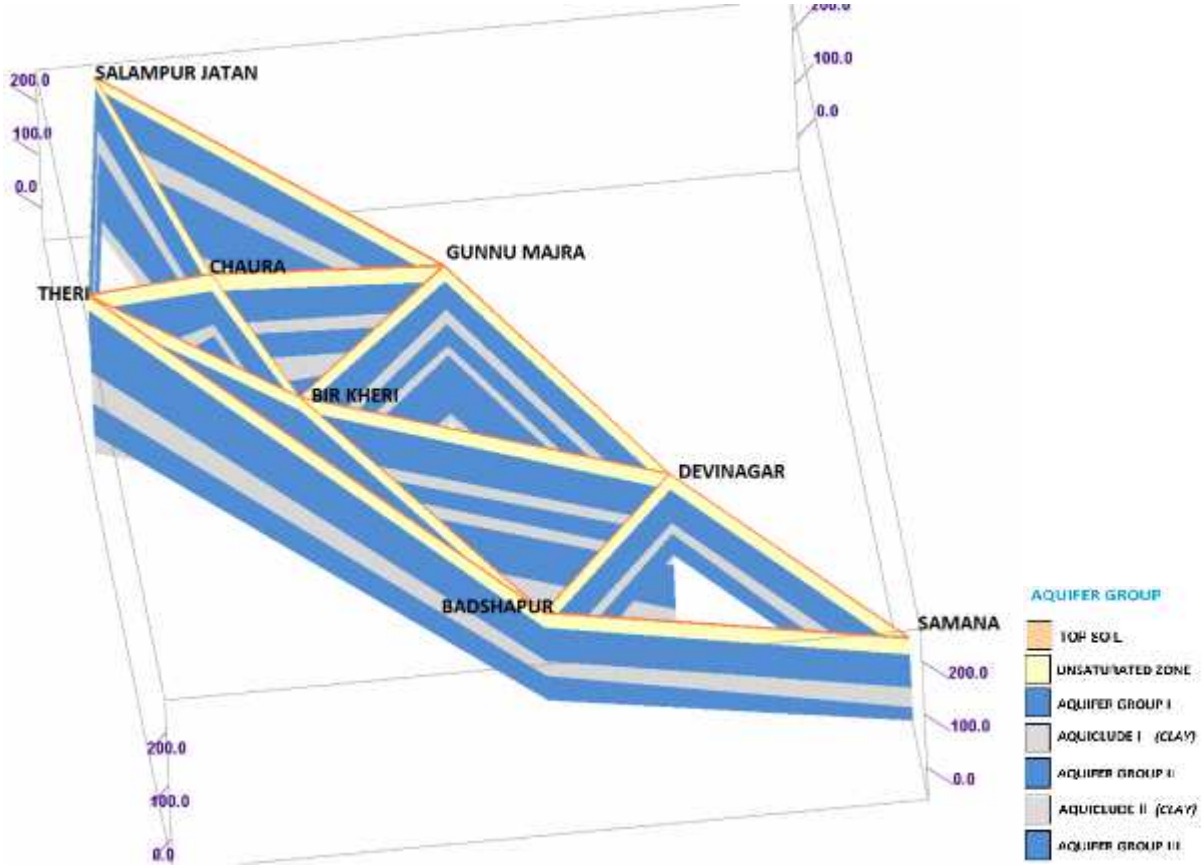
3-D Lithological Fence Diagram



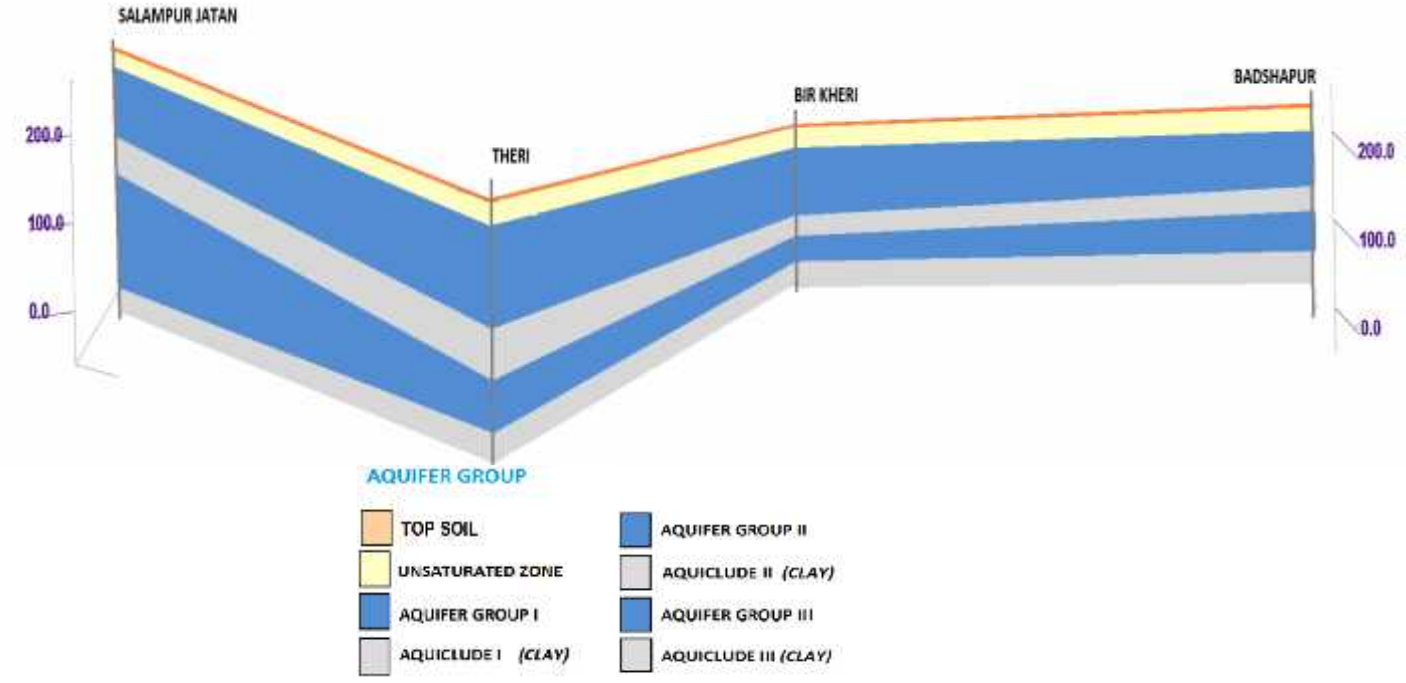
3-D Aquifer Disposition Model of Samana Block



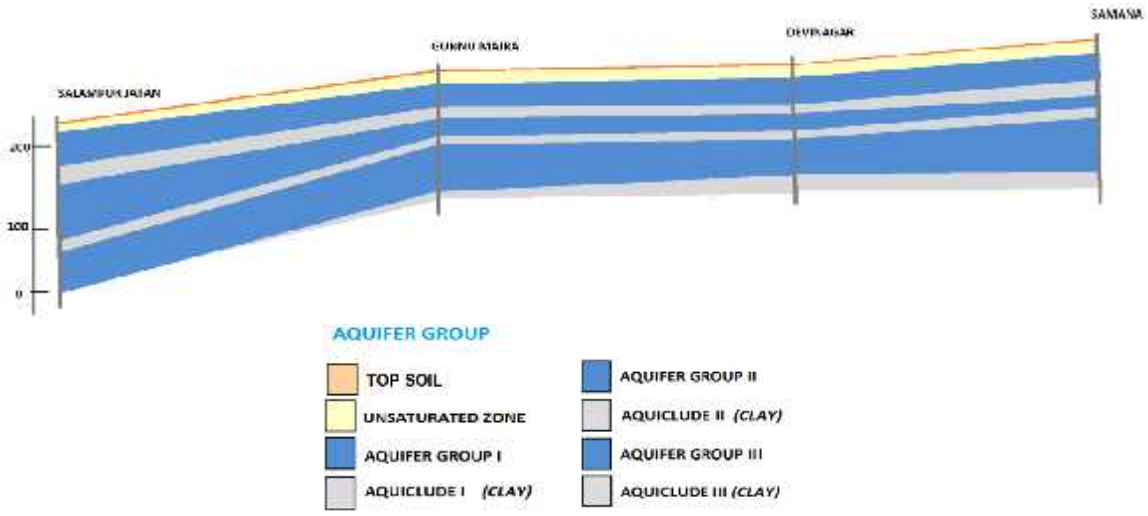
3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along Salampur Jatan to Badhshapur



Aquifer Cross section along Salampur Jatan to Samana



Ground water Resource, Extraction, Contamination and other issues in Samana Block

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	136.65 mcm
	In-storage Aquifer-I (Specific Yield Concept)	970.63 mcm
	In-storage Aquifer-II (Specific Yield Concept)	742.25 mcm
	In-storage Aquifer-II (Storativity Concept)	72.21 mcm
	In-storage Aquifer-III (Specific Yield Concept)	570.96 mcm
	In-storage Aquifer-II (Storativity Concept)	148.91 mcm
	Total Resources	2641.62 mcm
Ground Water Extraction (as per 2013)	Irrigation	266.94 mcm
	Domestic & Industrial	3.99 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		5.93 mcm
Stage of Groundwater Development		198 %
Chemical Quality of ground water		Ground water in the area is alkaline in nature and pH ranges 8.45 to 8.60. EC value of the ground water show wide variations and ranges from 322 µS/cm to 1335 µS/cm at 25^0C. RSC values are varies from (-) 0.94 to (-) 2.03 meq/L and the area is fit for irrigation.

Ground water Contamination Issues	***Nitrate(mg/l):*** Samana (203)
Other issues	Water level decline has been observed in major parts of the block due to in discriminate development of ground water resources.

Ground water Resource Enhancement Potential

Aquifer wise space available for recharge and proposed interventions (Supply Side Measures)

Aquifer-I:

Volume of unsaturated zone after 3m upto a desirable depth: 439.64 mcm
Source water requirement/availability for recharge: *Rain, Canal, Irrigation return flow*
Types and number of structures: NA
Other interventions proposed*: Artificial Recharge, Roof top Rainwater harvesting will conserve 3.52 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Samana Block (396.50 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 64.79 mcm

Required Change in cropping pattern

Proposed change in cropping pattern: *Rice to Maize, Soyabean.*
The overexploitation can be managed at sustainable level (100%) by changing the Paddy crop
Area coverage: *22.3 % of the total rice area needs to change i.e.* 66.01 sq km
Anticipated volume of water to be saved: 66.01 mcm

Paddy area (Sq km)	*Required Area to be Change from Paddy to Maize/ Soyabean (Sq km)*	*Amount of Water Saved (mcm)*	*Present Stage of develop-ment (%)*	*Reduction in Stage of develop-ment after Maize (%)*	*Crop Diversified area for Maize (%)*	*Reduction in Stage of develop-ment after soya bean (%)*	*Crop Diversified area for Soyabean (%)*	*Reduction in Stage of develop-ment after Maize and Soya bean (%)*	*Crop Diversified area (%)*
296	66.01	66.01	198	39.90	18.40	8.40	3.9	48.30	22.30

Net Annual Ground Water Availability 2013 (mcm)	*Total Irrigat-ion Draft (present) (mcm)*	*Gross Draft all uses (present) (mcm)*	*Paddy area (Sq km)*	*Required Area to be Change from Paddy to Maize/ soya bean (Sq km)*	*Amount of Water Saved (mcm)*	*Gross draft after saving of water (mcm)*	*Present Stage of develop-ment (%)*	*Total Reduction in Stage of develop-ment after Maize/ soya bean (%)*	*Total Crop Diversified area (%)*
136.65	266.94	270.93	296	66.01	66.01	200.93	198	48.30	22.30

Alternate Water sources

Surface water sources: *Tanks, Ponds*

No.of Water tanks: 31

Location, details and availability from such sources outside the area: Not Available

Regulation and Control:

Punjab Subsoil Act for delay in paddy plantation should continue in the area.

Other interventions proposed, if any

Modern Irrigation Practices be adopted for Rabi crops. Some of the techniques are given in the table below (PAU, Ludhiana).

Sl.No	Techniques	Water Saving (%)	Crops
1	Mulching	17	Wheat
2	Bed Planting	18-25	Wheat
3	Use of Sprinkler and drip Irrigation	70-90	Sugarcane, Sunflower, Maize

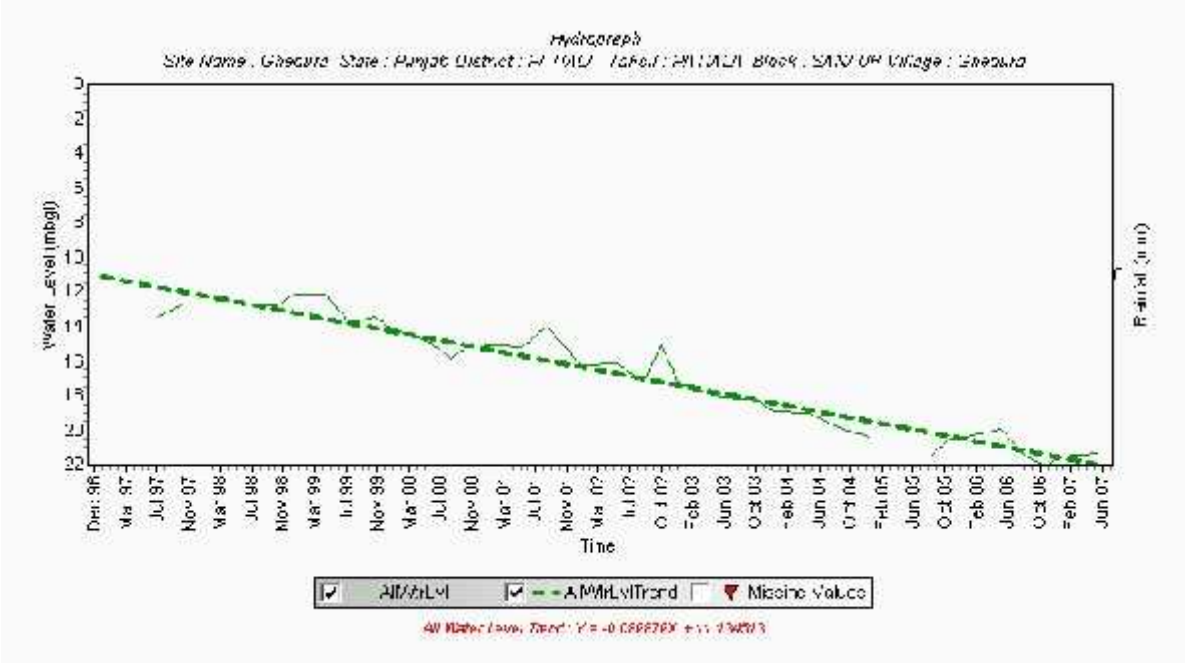
Other than that by 15 days ponding followed by 2 days of drying can lead to 25% saving of water in paddy crop.

VII. Salient Information of Sanaur Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>339.80 sq km</td></tr>
<tr><td>District/ State</td><td>Patiala, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 8310
Rural Population: 138248
Total population: 146558</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 483 mm
Non-monsoon Rainfall : 127 mm
Annual Average Rainfall: 610 mm</td></tr>
<tr><td>Agriculture and Irrigation</td><td>Principal crops: Wheat, Rice, Maize and Sugar cane
Other crops: Vegetables and Fodder
Gross cropped area: 549.46 sq km
Net sown area: 277.39 sq km
Irrigation practices: Tube well and Canal Irrigation
Cropping intensity: 198%
<u>Area under</u>
Ground water Irrigation: 273.41 sq km
Surface water irrigation: 28.37 sq km
Gross Irrigated area: 549.46 sq km
Net Irrigated area: 277.39 sq km
Intensity of Irrigation: 197%
Number and types of abstraction structures: 9029, Tubewells</td></tr>
<tr><td>Ground Water Resource Availability and Extraction</td><td><u>Ground water Resources Availability</u>
Ground Water Resources are available in the different group of aquifers. The fresh water resources are estimated up to the depth of 300 m on the basis of geophysical interpretations.
<table>
<tr><th>Aquifer Group</th><th>Aquifer Depth range (m)</th><th>Aquifer Thickness (m)</th><th>Granular Zones (m)</th><th>Resources (mcm)</th></tr>
<tr><td>Aquifer-I</td><td>19.75 – 95.0</td><td>83</td><td>38</td><td>1088.26</td></tr>
<tr><td>Aquifer-II</td><td>117.0 – 191.0</td><td>55</td><td>30</td><td>789.96</td></tr>
<tr><td>Aquifer-III</td><td>227.0 – 300.0</td><td>68</td><td>24</td><td>714.79</td></tr>
</table>
Total Ground Water Resources available is 2593.01 mcm and total potential granular zones available are 92m up to depth of 300 m. Block is categorized as Over-Exploited as per Dynamic Groundwater Resources, 2013 assessment.
<u>Ground water Resources Extraction</u>
Information regarding the abstraction from Aquifer II is not available, but there are drinking water supply wells of State Government tapping combined aquifers. Therefore, the ground water draft could not be assessed for Aquifer-II and III separately.</td></tr>
</table>

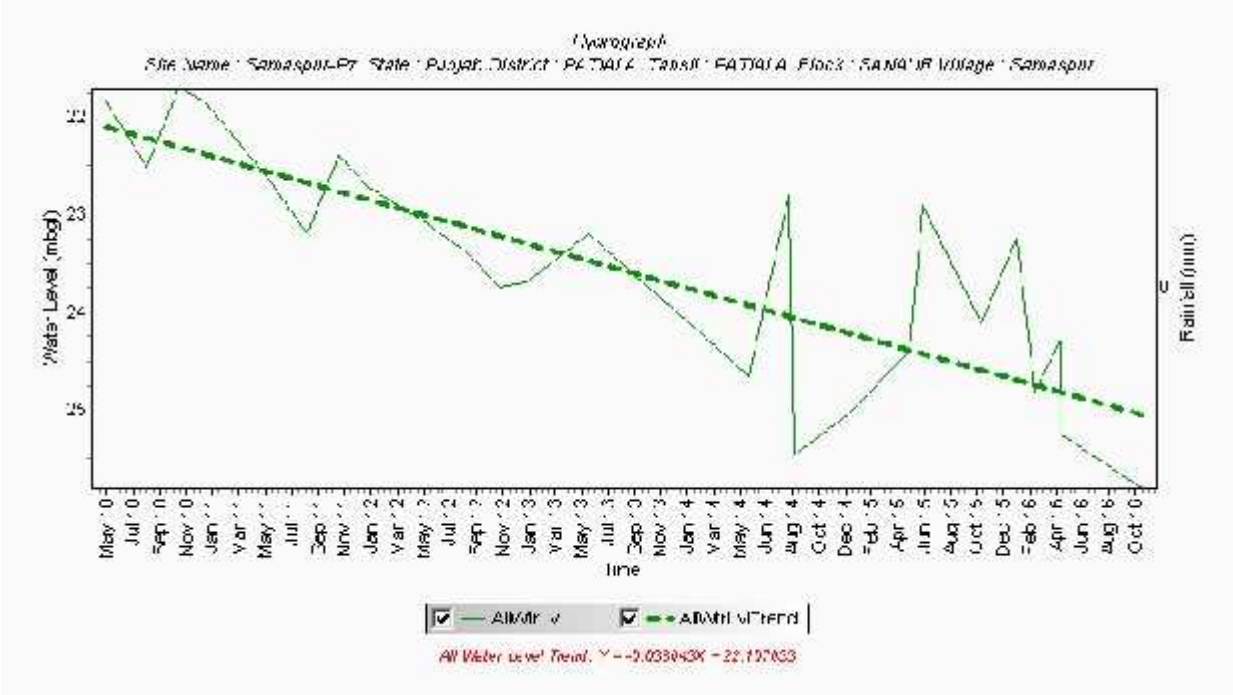
Existing and future water demands	Water Scarcity Villages: 99 Small Scale Industries : 4 Large Scale Industries : 0 Total Villages : 108 *Existing Gross Ground water Draft as on 2013* Irrigation: 338.06 mcm Domestic and industrial water supply: 2.95mcm *Future water demands* Irrigation development potential : (-)183.87 mcm Domestic and industrial water supply up to 2025 years : 4.38 mcm
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 17.20 – 24.40 m bgl Post Monsoon: 16.95 – 24.10 m bgl Seasonal Fluctuation: (-)0.45 – (-)0.85 m/yr Mean (10 yrs) : (-)1.95 m/yr *Trends* Pre Monsoon: (-)0.54 m/yr Post Monsoon: (-)0.60 m/yr **Aquifer-II &III** No Monitoring Stations

HYDROGRAPH SHOWING DECLINING WATER TABLE
(Location: Gheoura)



HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Samaspur)



Aquifer Disposition

Number of aquifers	1
Principal aquifer	Alluvium
Major Aquifer	Older Alluvium
Aquifer Disposition	Multiple Aquifer System (Three Aquifer Groups)

Exploratory Data Availability

Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	0	1	**1**
WRED/WSS	5	1	0	0	**6**
PRIVATE	0	1	5	4	**10**
TOTAL	**5**	**2**	**5**	**5**	**17**

Aquifer wise Characteristics

Aquifer Group	Geology	Type of Aquifer	Thickness of Granular zones (m)	Transmiss-ivity (m^2/day)	Discharge (m^3/day)	Specific Yield	Storativity
Aquifer –I (19.75 - 95 m)	Quarter-nary Alluvial deposits	Unconfined to confined	38	NA	NA	12 % *(0.072)*	NA
Aquifer-II (117 - 191m)		Semi confined to Confined	30	NA	NA	NA	NA
Aquifer-III (227 - 300 m)		Semi confined to Confined	24	766	2699	NA	NA

NA: Not Available

Source: CGWB,2015 & PSTC,2008

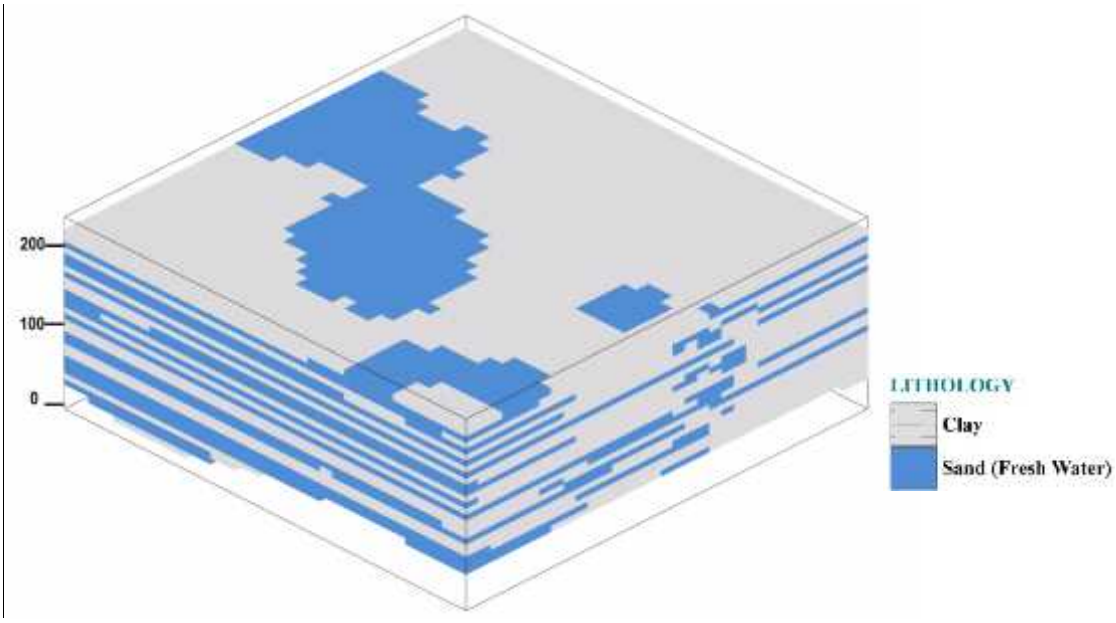
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

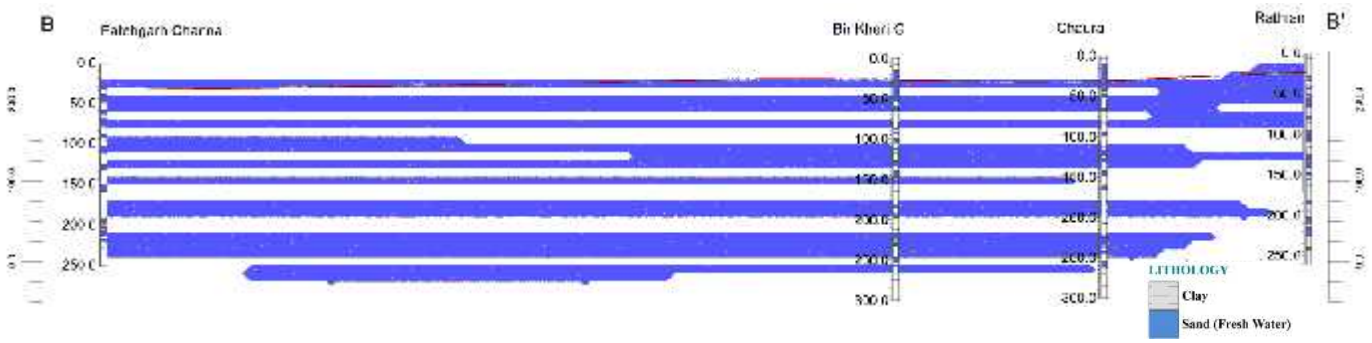
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	0	1	**1**
WRED/WSS	0	0	0	0	**0**
PRIVATE	0	1	5	4	**10**
TOTAL	**0**	**1**	**5**	**4**	**11**

The data is validated by selecting the deepest well in each quadrant and used for preparation of 3-D Litho models, 2-D Geological Cross Sections, Fence Diagrams and Aquifer Maps.

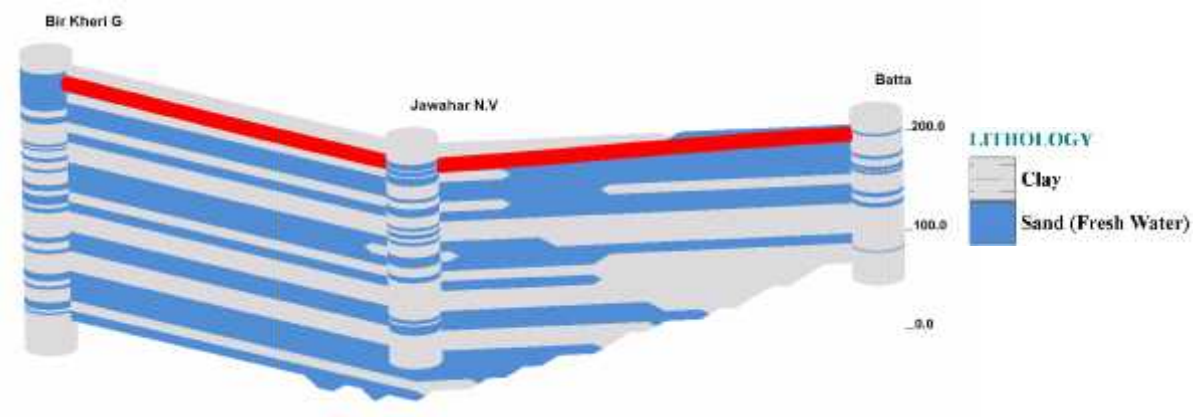
3-D Lithological model of Sanaur Block



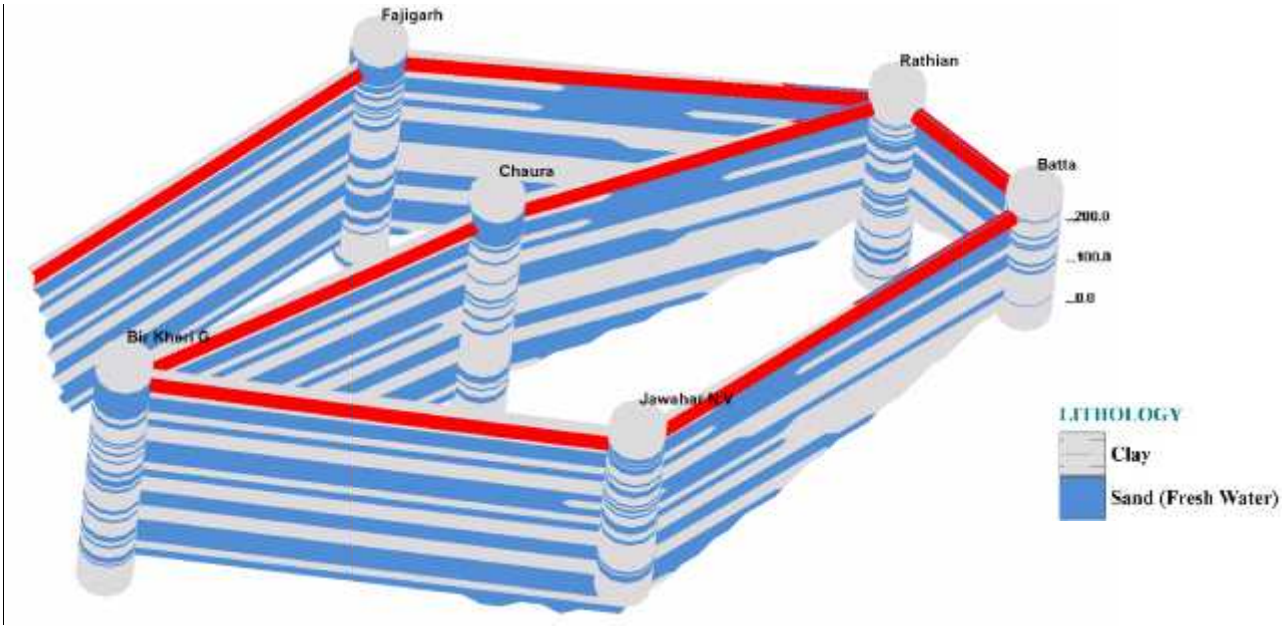
Lithological Cross section from Fatehgarh Channa to Rathian



Lithological Cross section from Batheri Kalan to Mallo Majra

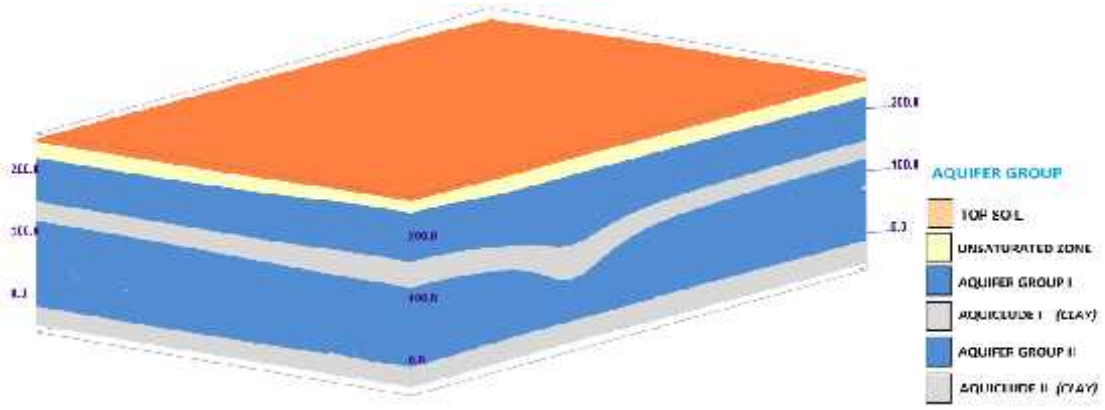


3-D Lithological Fence Diagram

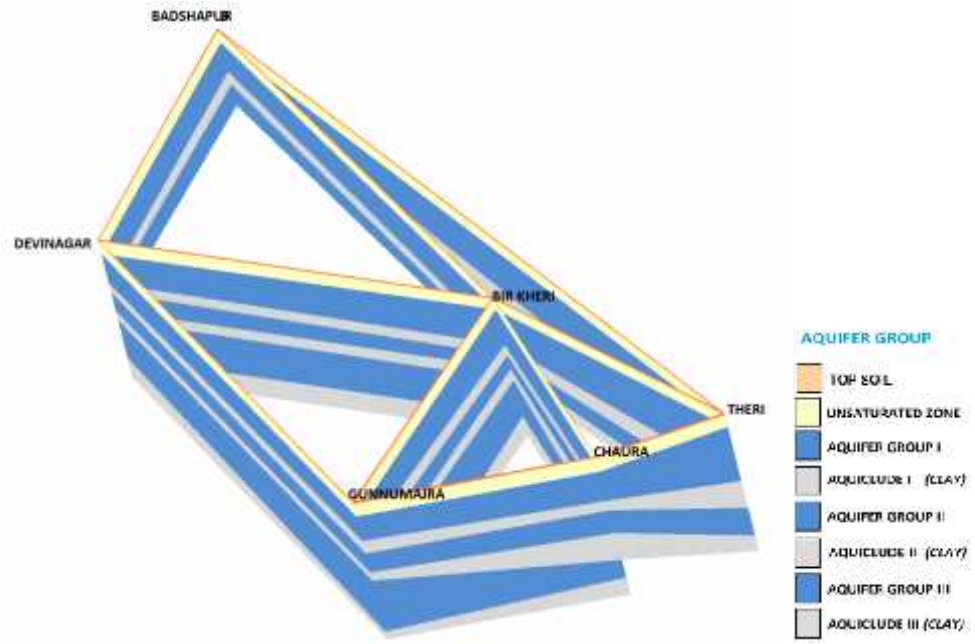


WATER LEVEL

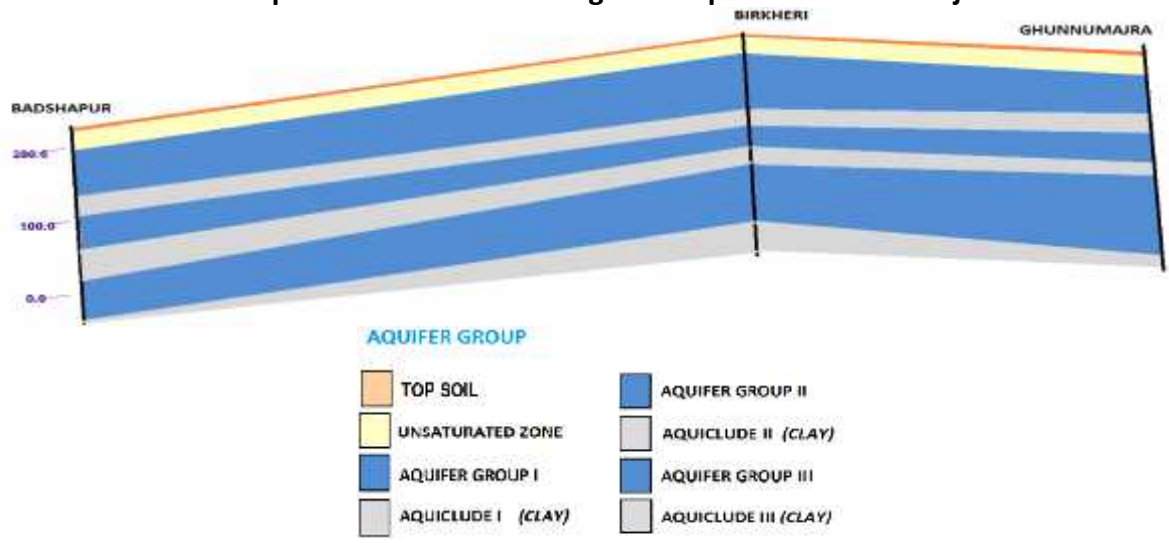
3-D Aquifer Disposition Model of Sanaur Block



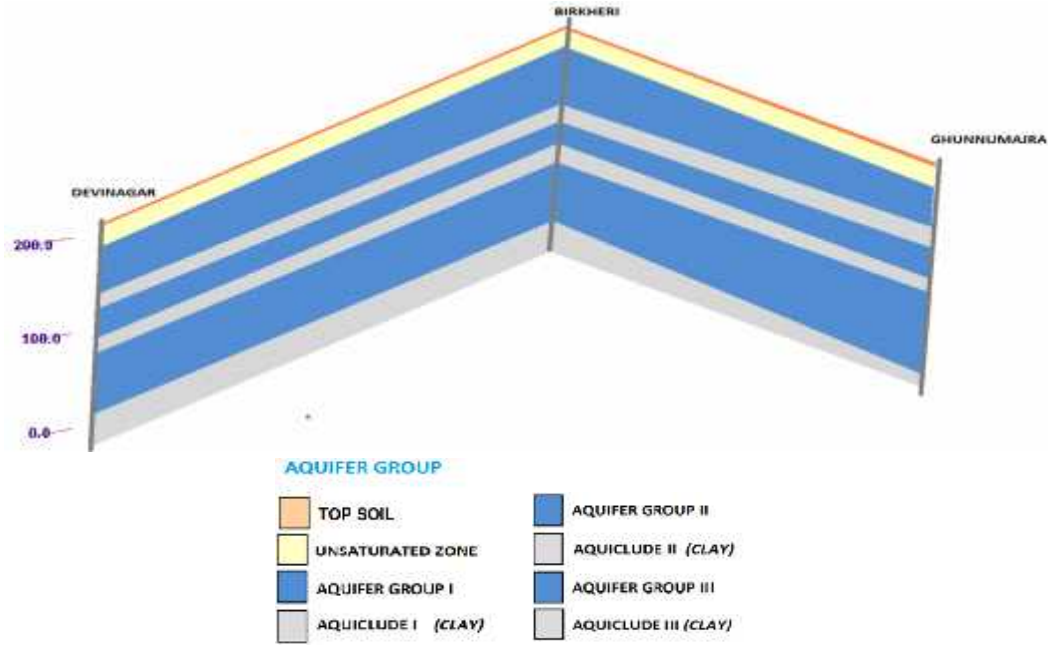
3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along Badshapur to Ghunnu Majra



Aquifer Cross section along Devinagar to Ghunnu Majra



Ground water Resource, Extraction, Contamination and other issues in Patiala Block

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	158.57 mcm
	In-storage Aquifer-I (Specific Yield Concept)	929.69 mcm
	In-storage Aquifer-II (Specific Yield Concept)	733.97 mcm
	In-storage Aquifer-II (Storativity Concept)	55.99 mcm
	In-storage Aquifer-III (Specific Yield Concept)	587.17 mcm
	In-storage Aquifer-II (Storativity Concept)	127.62 mcm
	Total Resources	2593.01 mcm
Ground Water Extraction (as per 2013)	Irrigation	338.06 mcm
	Domestic & Industrial	2.95 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		4.38 mcm
Stage of Groundwater Development		215 %
Chemical Quality of ground water		Ground water in the area is alkaline in nature and the area is fit for irrigation.
Ground water Contamination Issues		*NA*

Other issues	Water level decline has been observed in major parts of the block due to in discriminate development of ground water resources.

Ground water Resource Enhancement Potential

Aquifer wise space available for recharge and proposed interventions (Supply Side Measures)

Aquifer-I:

Volume of unsaturated zone after 3m upto a desirable depth: 435.08 mcm
Source water requirement/availability for recharge: *Rain, Canal, Irrigation return flow*
Types and number of structures: NA
Other interventions proposed*: Artificial Recharge, Roof top Rainwater harvesting will conserve 3.42 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Sanaur Block (339.80 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 82.05 mcm

Required Change in cropping pattern

Proposed change in cropping pattern: *Rice to Maize, Soyabean.*
The overexploitation can be managed at sustainable level (100%) by changing the Paddy crop
Area coverage: *39.10 % of the total rice area needs to change i.e.* 96.97 sq km
Anticipated volume of water to be saved: 96.97 mcm

Paddy area (Sq km)	*Required Area to be Change from Paddy to Maize/ Soyabean (Sq km)*	*Amount of Water Saved (mcm)*	*Present Stage of develop-ment (%)*	*Reduction in Stage of develop-ment after Maize (%)*	*Crop Diversified area for Maize (%)*	*Reduction in Stage of develop-ment after soya bean (%)*	*Crop Diversified area for Soyabean (%)*	*Reduction in Stage of develop-ment after Maize and Soya bean (%)*	*Crop Diversified area (%)*
248	96.97	96.97	215	40	25.60	21.20	13.50	61.15	39.10

Net Annual Ground Water Availability 2013 (mcm)	*Total Irrigat-ion Draft (present) (mcm)*	*Gross Draft all uses (present) (mcm)*	*Paddy area (Sq km)*	*Required Area to be Change from Paddy to Maize/ soya bean (Sq km)*	*Amount of Water Saved (mcm)*	*Gross draft after saving of water (mcm)*	*Present Stage of develop-ment (%)*	*Total Reduction in Stage of develop-ment after Maize/ soya bean (%)*	*Total Crop Diversified area (%)*
158.57	338.06	341.01	248	96.97	96.97	241.09	215	61.15	39.10

Alternate Water sources

Surface water sources: *Tanks, Ponds*

No.of Water tanks: 33

Location, details and availability from such sources outside the area: Not Available

Regulation and Control:

Punjab Subsoil Act for delay in paddy plantation should continue in the area.

Other interventions proposed, if any

Modern Irrigation Practices be adopted for Rabi crops. Some of the techniques are given in the table below (PAU, Ludhiana).

Sl.No	Techniques	Water Saving (%)	Crops
1	Mulching	17	Wheat
2	Bed Planting	18-25	Wheat
3	Use of Sprinkler and drip Irrigation	70-90	Sugarcane, Sunflower, Maize

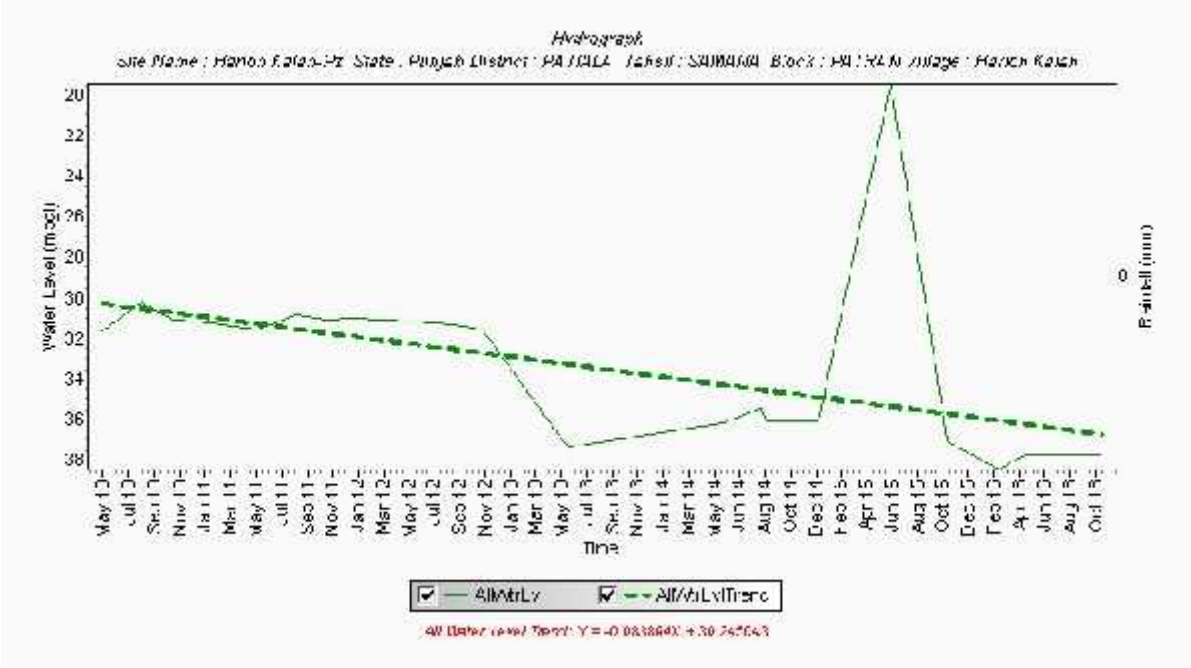
Other than that by 15 days ponding followed by 2 days of drying can lead to 25% saving of water in paddy crop.

VIII. Salient Information of Patran Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>372.30 sq km</td></tr>
<tr><td>District/ State</td><td>Patiala, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 0
Rural Population: 141087
Total population: 141087</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 369 mm
Non-monsoon Rainfall : 128 mm
Annual Average Rainfall: 497 mm</td></tr>
<tr><td>Agriculture and Irrigation</td><td>Principal crops: Wheat, Rice, Maize and Sugar cane
Other crops: Vegetables and Fodder
Gross cropped area: 636.91 sq km
Net sown area: 335.35 sq km
Irrigation practices: Tube well and Canal Irrigation
Cropping intensity: 190%
<u>Area under</u>
Ground water Irrigation: 323.11 sq km
Surface water irrigation: 18.18 sq km
Gross Irrigated area: 636.91 sq km
Net Irrigated area: 335.35 sq km
Intensity of Irrigation: 190%
Number and types of abstraction structures: 11535, Tubewells</td></tr>
<tr><td>Ground Water Resource Availability and Extraction</td><td><u>Ground water Resources Availability</u>
Ground Water Resources are available in the different group of aquifers. The fresh water resources are estimated up to the depth of 300 m on the basis of geophysical interpretations.
<table>
<tr><th>Aquifer Group</th><th>Aquifer Depth range (m)</th><th>Aquifer Thickness (m)</th><th>Granular Zones (m)</th><th>Resources (mcm)</th></tr>
<tr><td>Aquifer-I</td><td>28.81 – 107.0</td><td>83</td><td>34</td><td>1071.25</td></tr>
<tr><td>Aquifer-II</td><td>146.0 – 210.0</td><td>55</td><td>34</td><td>929.27</td></tr>
<tr><td>Aquifer-III</td><td>237.0 – 300.0</td><td>68</td><td>9</td><td>388.33</td></tr>
</table>
Total Ground Water Resources available is 2388.86 mcm and total potential granular zones available are 77m up to depth of 300 m. Block is categorized as Over-Exploited as per Dynamic Groundwater Resources, 2013 assessment.
<u>Ground water Resources Extraction</u>
Information regarding the abstraction from Aquifer II is not available, but there are drinking water supply wells of State Government tapping combined aquifers. Therefore, the ground water draft could not be assessed for Aquifer-II and III separately.</td></tr>
</table>

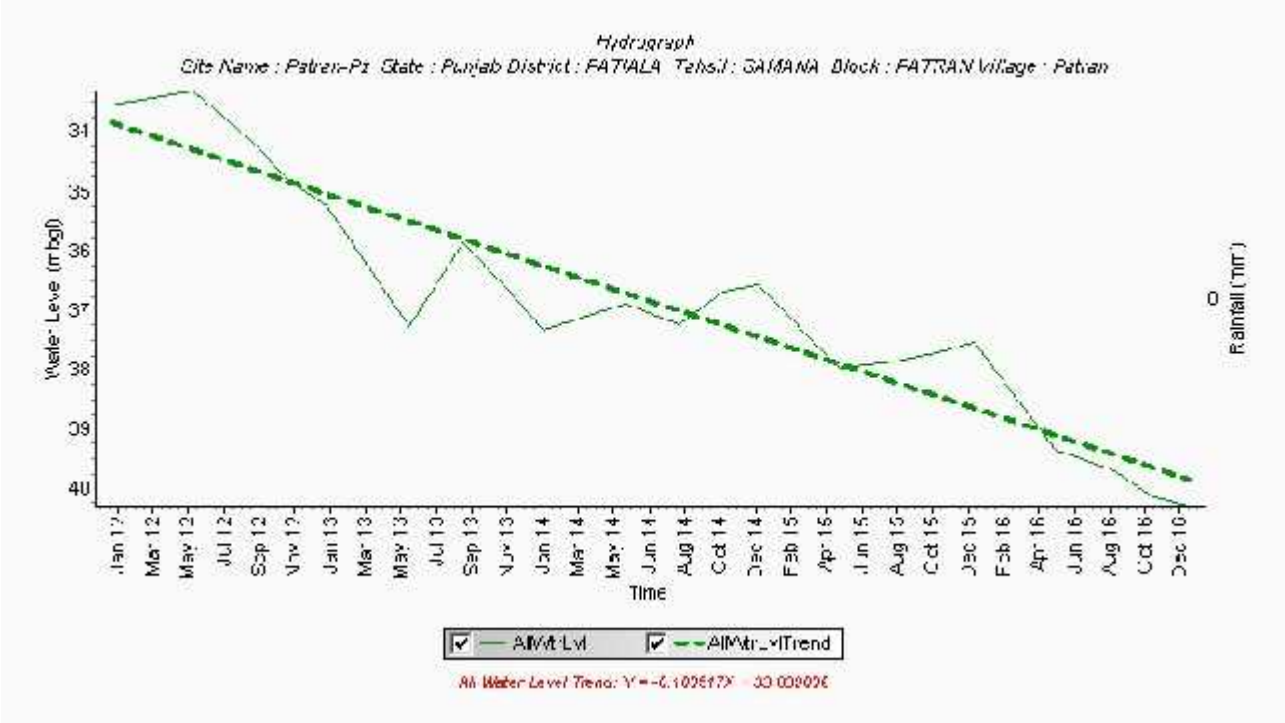
Existing and future water demands	Water Scarcity Villages: 57 Small Scale Industries : 204 Large Scale Industries : 1 Total Villages : 57 *Existing Gross Ground water Draft as on 2013* Irrigation: 454.35 mcm Domestic and industrial water supply: 3.92 mcm *Future water demands* Irrigation development potential : (-)300.32 mcm Domestic and industrial water supply up to 2025 years : 5.83 mcm
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 37.75 – 37.97 m bgl Post Monsoon: 37.10 – 37.73 m bgl Seasonal Fluctuation: 0.24 – 0.65 m/yr Mean (10 yrs) : (-)2.99 – (-)4.17 m/yr *Trends* Pre Monsoon: (-)1.23 m/yr Post Monsoon: (-)1.29 m/yr **Aquifer-II &III** No Monitoring Stations

HYDROGRAPH SHOWING DECLINING WATER TABLE
(Location: Harion Kalan)



HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Patran)



Aquifer Disposition

Number of aquifers	1
Principal aquifer	Alluvium
Major Aquifer	Younger and Older Alluvium
Aquifer Disposition	Multiple Aquifer System (Three Aquifer Groups)

Exploratory Data Availability

Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	1	0	0	0	**1**
WRED/WSS	7	0	0	1	**8**
PRIVATE	0	1	5	0	**6**
TOTAL	**8**	**1**	**5**	**1**	**15**

Aquifer wise Characteristics

Aquifer Group	Geology	Type of Aquifer	Thickness of Granular zones (m)	Transmiss-ivity (m^2/day)	Discharge (m^3/day)	Specific Yield	Storativity
Aquifer –I (28.81- 107 m)	Quarter-nary Alluvial deposits	Unconfined to confined	34	NA	NA	12 % *(0.072)*	NA
Aquifer-II (146 - 210m)		Semi confined to Confined	34	743	3373	NA	$4.30*10^{-4}$
Aquifer-III (237 - 300 m)		Semi confined to Confined	9	NA	NA	NA	NA

NA: Not Available

Source: CGWB,2015 & PSTC,2008

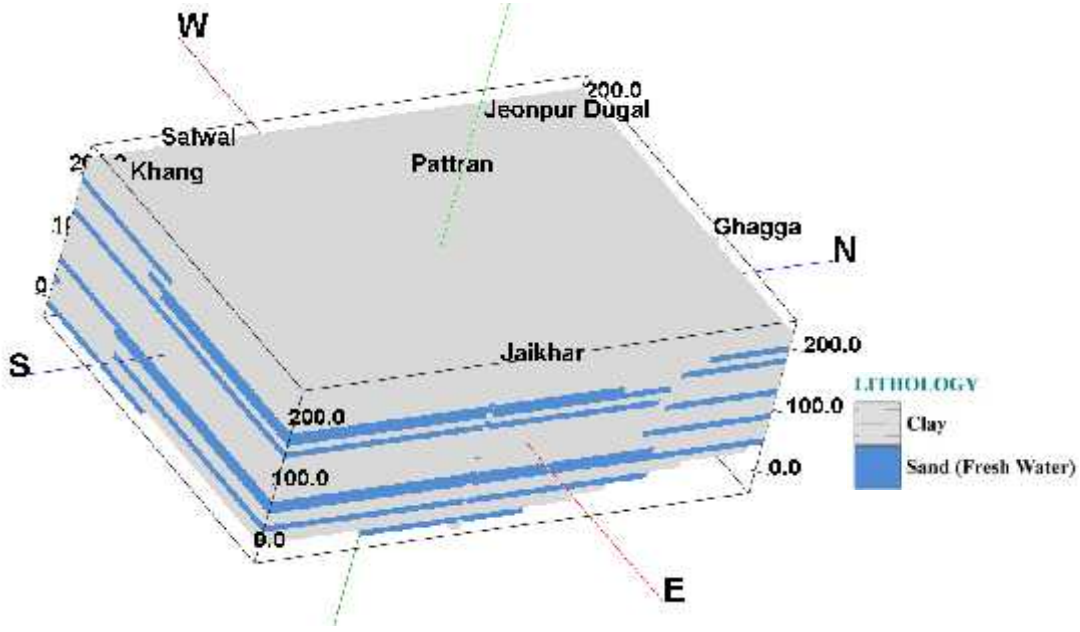
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

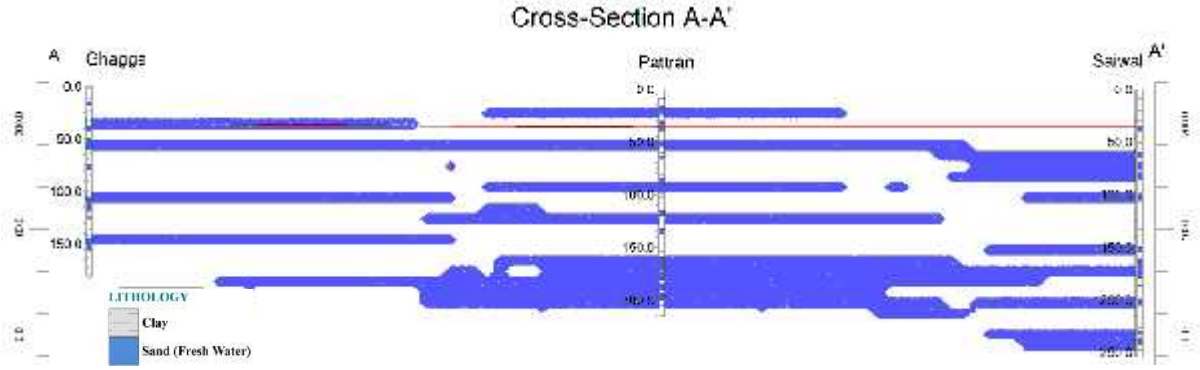
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	0	0	**0**
WRED/WSS	0	0	0	1	**1**
PRIVATE	0	0	5	0	**5**
TOTAL	**0**	**0**	**5**	**1**	**6**

The data is validated by selecting the deepest well in each quadrant and used for preparation of 3-D Litho models, 2-D Geological Cross Sections, Fence Diagrams and Aquifer Maps.

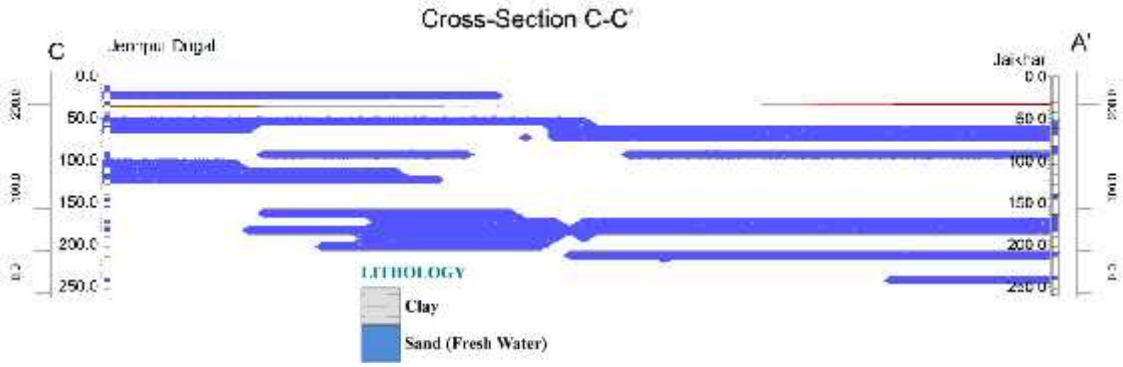
3-D Lithological model of Patran Block



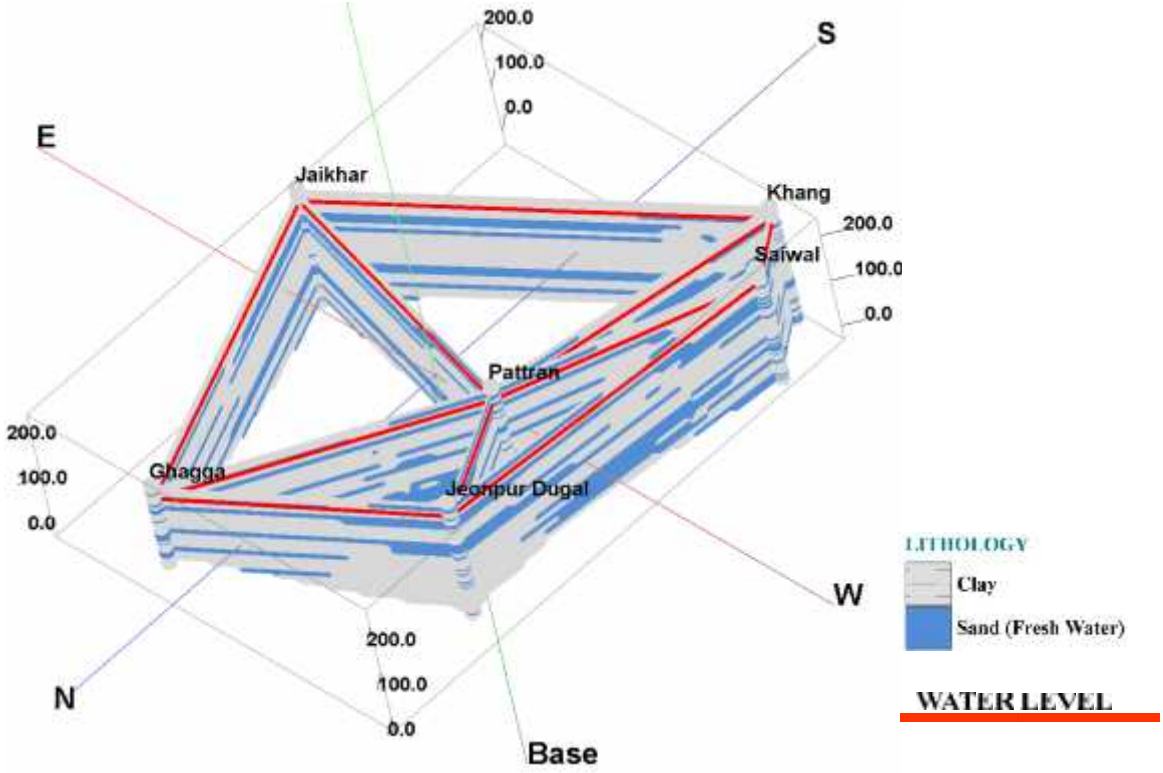
Lithological Cross section from Ghagga to Saiwal



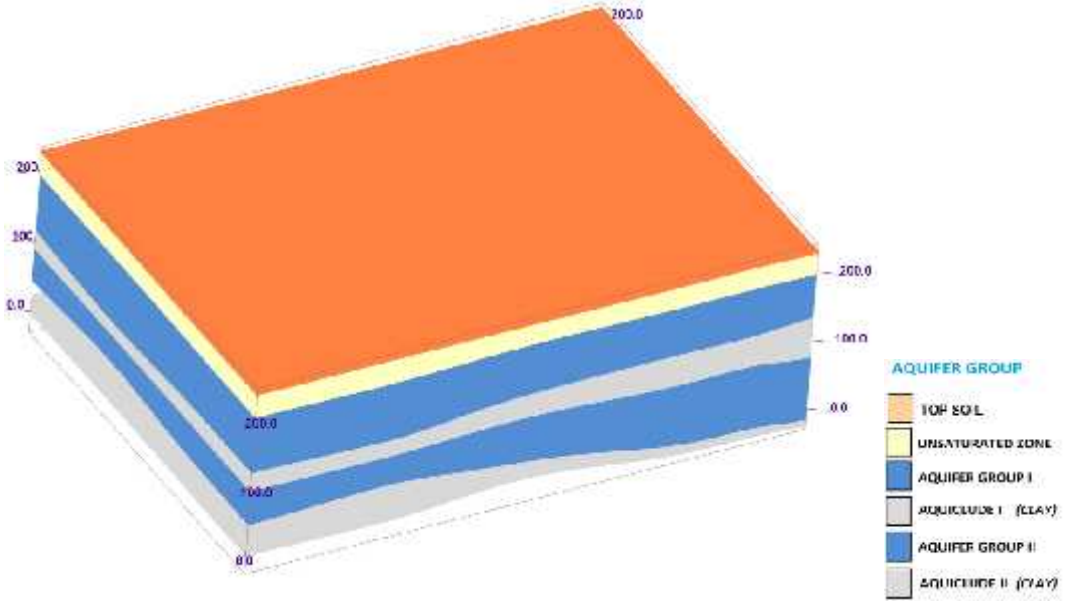
Lithological Cross section from Batheri Kalan to Mallo Majra



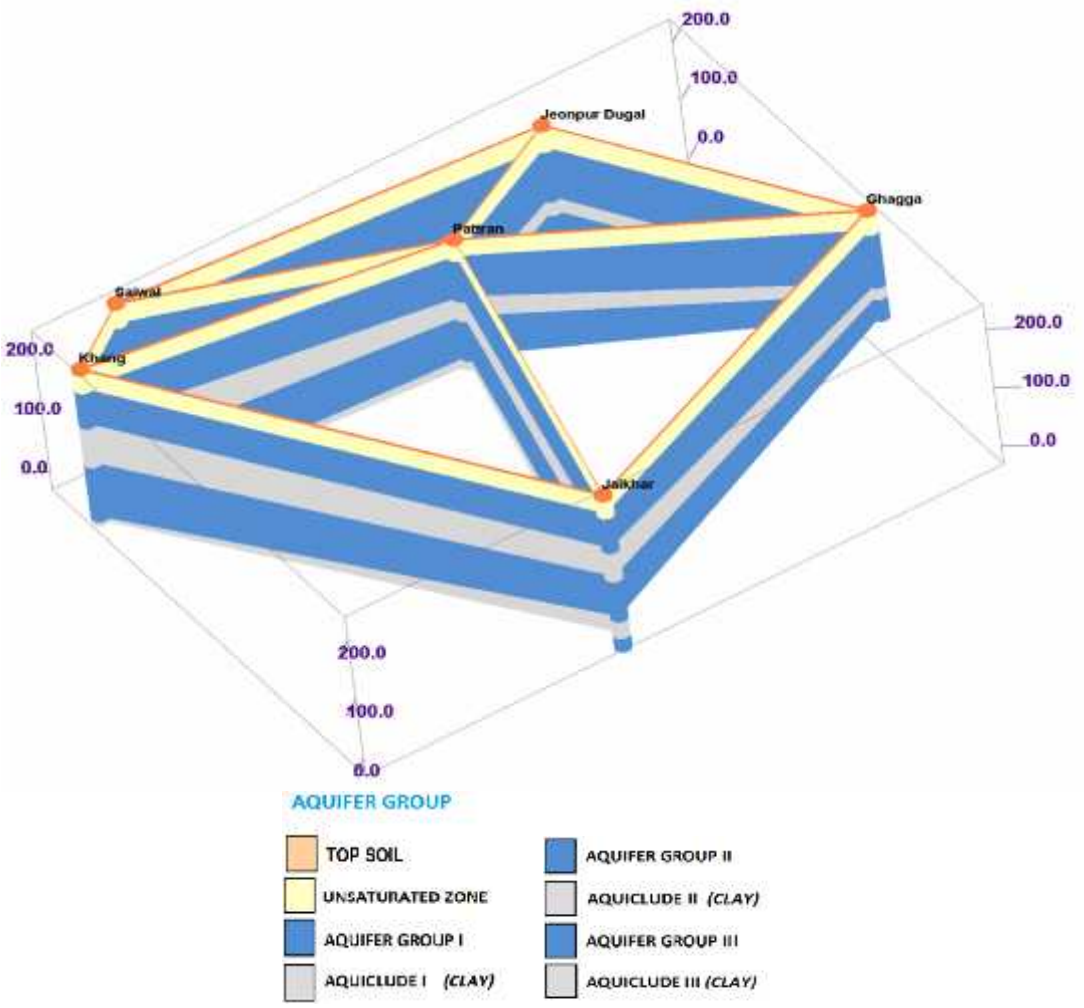
3-D Lithological Fence Diagram



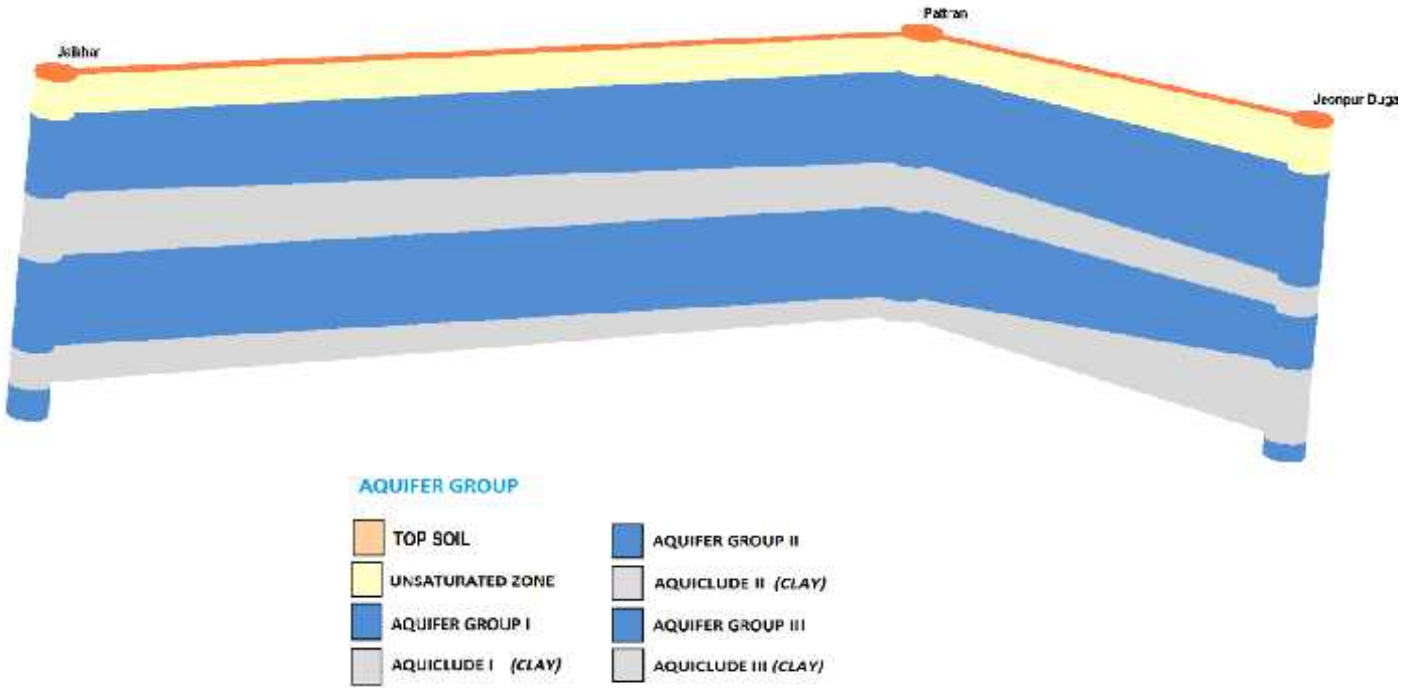
3-D Aquifer Disposition Model of Patran Block



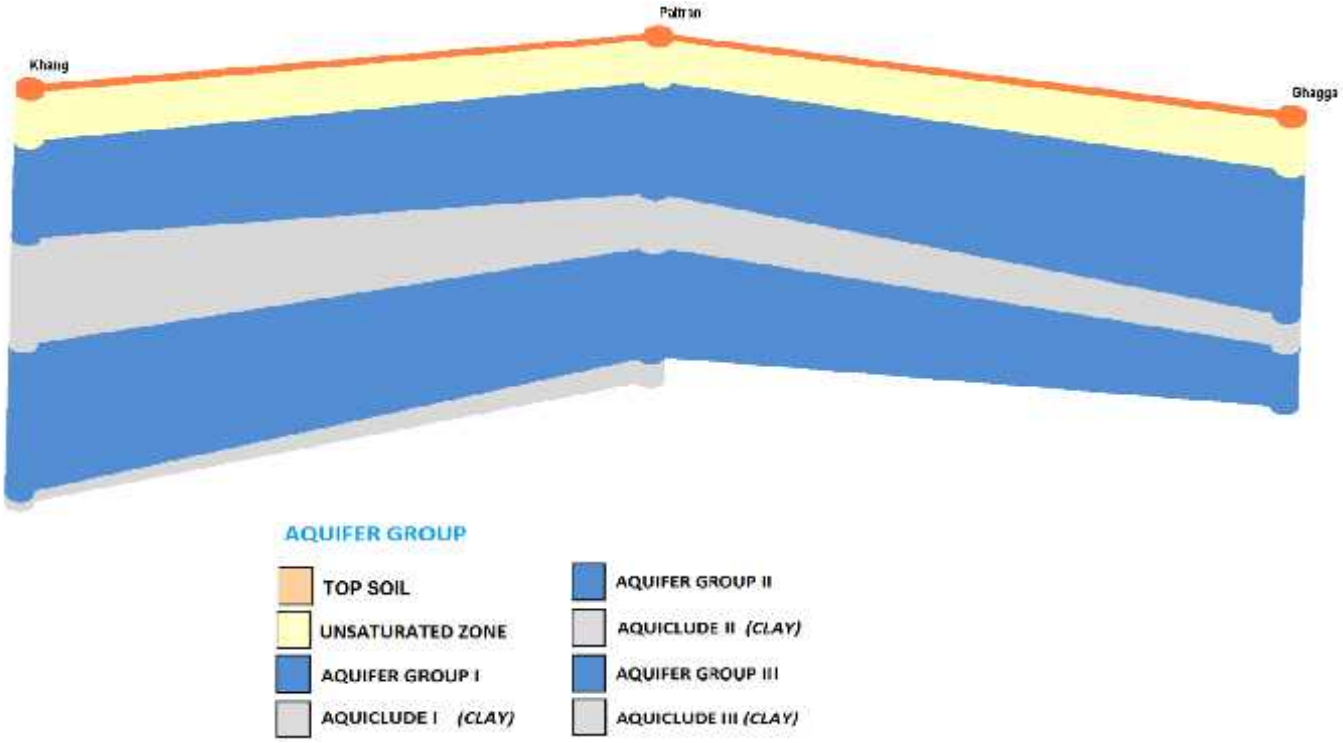
3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along Jakhar to Jeonpur Duga



Aquifer Cross section along Khang to Ghaagga



Ground water Resource, Extraction, Contamination and other issues in Patran Block

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	159.86 mcm
	In-storage Aquifer-I (Specific Yield Concept)	911.39 mcm
	In-storage Aquifer-II (Specific Yield Concept)	911.39 mcm
	In-storage Aquifer-II (Storativity Concept)	17.88 mcm
	In-storage Aquifer-III (Specific Yield Concept)	241.25 mcm
	In-storage Aquifer-II (Storativity Concept)	147.08 mcm
	Total Resources	2388.86 mcm
Ground Water Extraction (as per 2013)	Irrigation	454.35 mcm
	Domestic & Industrial	3.92 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		5.83 mcm
Stage of Groundwater Development		287 %
Chemical Quality of ground water		Ground water in the area is alkaline in nature pH value is 8.9, EC value Patran (1588) µS/cm at 25^0C. RSC value is 0.52 and the area is fit for irrigation.
Ground water Contamination Issues		***Nitrate (mg/l)*** Patran (81)
Other issues		Water level decline has been observed in major parts of the block due to in discriminate development of ground water resources.

Ground water Resource Enhancement Potential

Aquifer wise space available for recharge and proposed interventions (Supply Side Measures)

Aquifer-I:

Volume of unsaturated zone after 3m upto a desirable depth: 361.88 mcm
Source water requirement/availability for recharge: *Rain, Canal, Irrigation return flow*
Types and number of structures: NA
Other interventions proposed*: Artificial Recharge, Roof top Rainwater harvesting will conserve 3.15 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Patran Block (372.30 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 110.27 mcm

Required Change in cropping pattern

Proposed change in cropping pattern: *Rice to Maize, Soyabean.*
The overexploitation can be managed at sustainable level (100%) by changing the Paddy crop
Area coverage: *58.60 % of the total rice area needs to change i.e.* 185.18 sq km
Anticipated volume of water to be saved: 185.18 mcm

Paddy area (Sq km)	*Required Area to be Change from Paddy to Maize/ Soyabean (Sq km)*	*Amount of Water Saved (mcm)*	*Present Stage of develop-ment (%)*	*Reduction in Stage of develop-ment after Maize (%)*	*Crop Diversified area for Maize (%)*	*Reduction in Stage of develop-ment after soya bean (%)*	*Crop Diversified area for Soyabean (%)*	*Reduction in Stage of develop-ment after Maize and Soya bean (%)*	*Crop Diversified area (%)*
316	185.18	185.18	287	40.50	20.50	75.30	38.10	115.84	58.60

Net Annual Ground Water Availability 2013 (mcm)	*Total Irrigat-ion Draft (present) (mcm)*	*Gross Draft all uses (present) (mcm)*	*Paddy area (Sq km)*	*Required Area to be Change from Paddy to Maize/ soya bean (Sq km)*	*Amount of Water Saved (mcm)*	*Gross draft after saving of water (mcm)*	*Present Stage of develop-ment (%)*	*Total Reduction in Stage of develop-ment after Maize/ soya bean (%)*	*Total Crop Diversified area (%)*
159.86	454.35	458.27	316	185.18	185.18	269.17	287	115.84	58.60

Alternate Water sources

Surface water sources: *Tanks, Ponds*
No.of Water tanks: 27
Location, details and availability from such sources outside the area: Not Available

Regulation and Control:

Punjab Subsoil Act for delay in paddy plantation should continue in the area.

Other interventions proposed, if any

Modern Irrigation Practices be adopted for Rabi crops. Some of the techniques are given in the table below (PAU, Ludhiana).

Sl.No	Techniques	Water Saving (%)	Crops
1	Mulching	17	Wheat
2	Bed Planting	18-25	Wheat
3	Use of Sprinkler and drip Irrigation	70-90	Sugarcane, Sunflower, Maize

Other than that by 15 days ponding followed by 2 days of drying can lead to 25% saving of water in paddy crop.