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

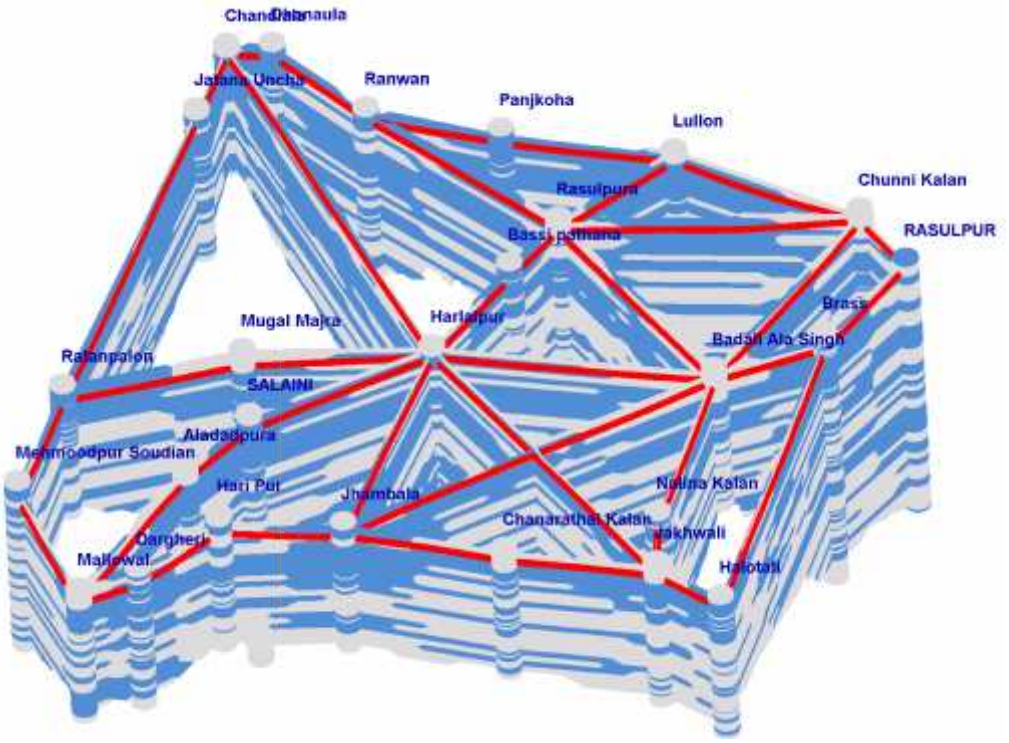
AQUIFER MAPPING AND MANAGEMENT PLAN

Fatehgarh Sahib District, Punjab

उत्तरी पश्चिम क्षेत्र, चंडीगढ़

North Western Region, Chandigarh

AQUIFER MAPPING & MANAGEMENT PLAN OF FATEHGARH SAHIB DISTRICT, PUNJAB



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2017

AQUIFER MAPPING AND MANAGEMENT PLAN
FATEHGARH SAHIB DISTRICT
(1116.70 Sq Km)

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1.0 INTRODUCTION

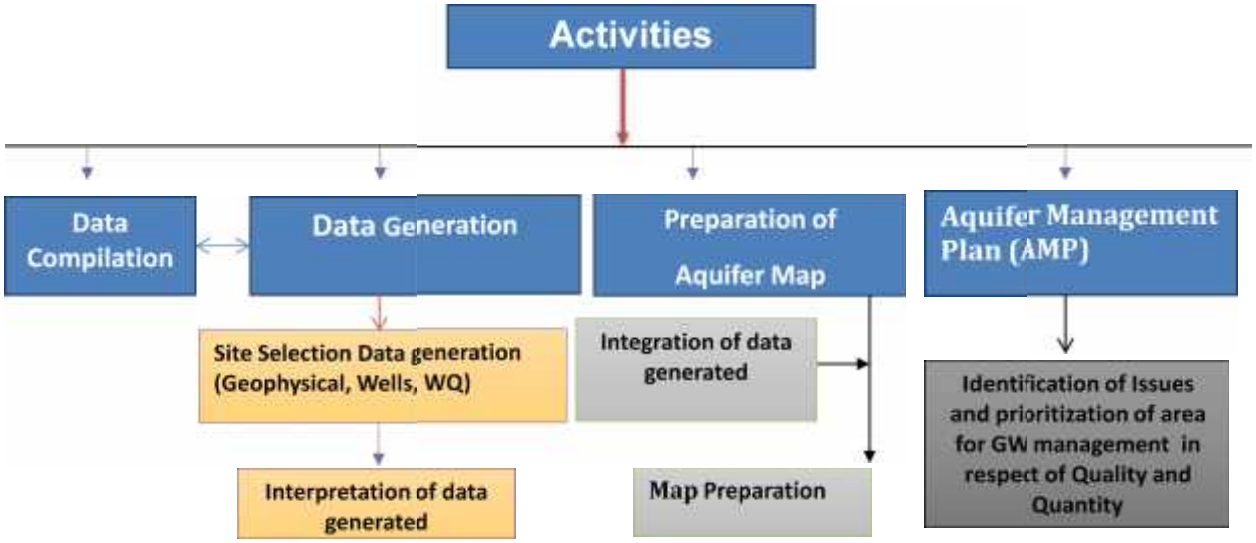
The primary objective of the Aquifer Mapping can be summed up as "Know your Aquifer, Manage your Aquifer". Demystification of Science and thereby involvement of stake holders is the essence of the entire project. The involvement and participation of the community will infuse a sense of ownership amongst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

Fatehgarh Sahib District is located in south-eastern part of Punjab state. The area falls in the Survey of India Toposheet Nos. 53B/2, 5, 6, 7 and 10, lies between 30^0 25' 00" to 30^0 45' 45" North latitude and 76^0 04' 30" to 76^0 35' 00" East longitude covering an area of 1116.7 sq km (Fig.1). It is bounded by Ludhiana and Ropar in North, Patiala in South, parts of Ropar and Patiala in East and parts of Ludhiana and Sangrur in West. The elevation of land surface ranges between 278m above m.s.l. at Hawara and Rattangarh (53B/5) in northwest to 253m a.msl at Lang village (53B/7) towards south. Topographically, it is a leveled plain sloping towards south - south west direction with a gentle gradient of 0.4 m per km.

The district comprises four Tehsils namely Fatehgarh sahib, Amloh, Khamanon & Bassi Pathana. Gobindgarh is the only Sub Tehsil in the district. There are five administrative development blocks namely Sirhind, Amloh, Khamanon, Khera & Bassi Pathana. Total number of villages exists in the district is 456.

The total population of the district is 6,00,163 as per 2011 census which constitutes 2.2% of the state population. The total rural population is 4,14,681 and the urban population is 1,85,482 and the decennial growth rate is 11.39 % (2001-2011). Population density of district is 456 persons/sq. km.

The district came into existence on 13th April 1992, Baisakhi Day and derives its name from Sahibzada Fateh Singh, the youngest son of 10th Guru Gobind Singh, who along with his brother was bricked-up alive on the orders of Suba Sirhind, Wazir Khan in 1704, and which is now the site of the 'Gurudwara Fatehgarh Sahib'.

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 45^0 C (in May/June) to 4^0 C in December/January.

The normal annual rainfall is 692 mm in 28 days which is unevenly distributed over the district. Monsoon rainfall contributes 79% of annual rainfall in the district. The rainfall increases from southwest to northeast in the district. Monthly wise rainfall is given in below table.

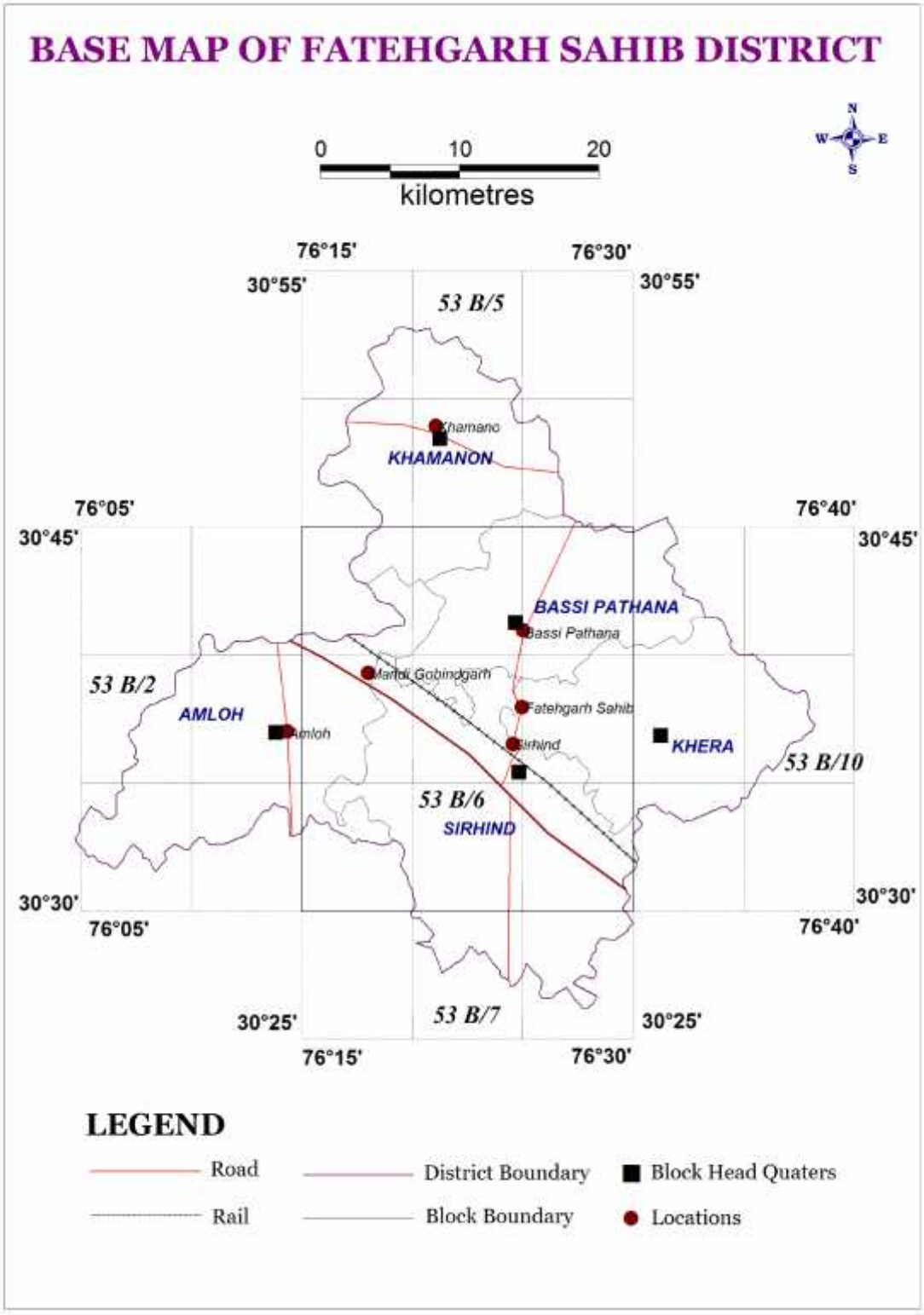
Monthly wise Rainfall of Fatehgarh Sahib District in mm (IMD, Chandigarh)

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
2010	7	13	0	0	0	23.5	128	5	106.4	0	0	22
2011	1	6.4	0	8	36.2	110.3	83.6	217.4	149.3	0	0	2.3
2012	0.5	0	0	8.5	0	3.5	19.9	14.9	5.3	5	0.3	7
2013	15	49.5	51.3	4	8.5	259.5	84.3	148.9	31.3	28	8	7
2014	34	6	2	0	0	14.6	47.7	30.5	98	4.5	0	27

1.6 Geomorphology & Soil Type

The study area occupies in south eastern part of Punjab Plain and forms a part of Sutlej Basin. It exhibits gradational landforms, mainly fluvial, formed by the deposition of sediments. The Study area falls in Cis-Sutlej Doab between the rivers Sutlej and Yamuna. The area is almost flat terrain without any conspicuous topographical features. The main fluvial feature in the area is the Upland Plain, which consists of a part of Older Alluvium deposited by Sutlej River.

Fig.1: Base map of Fatehgarh Sahib District



Geomorphologically, the area exhibits three types of land forms i.e.

1. Alluvium flat
2. Aeolian dunes (Stabilised, Semi stabilised dunes) and
3. Younger Alluvial surface

These land forms are delineated on the basis of relief, pedological, lithological and vegetation variations (GSI, 1998-2000).

a. Alluvial Flat: This surface is widespread and ranges in elevation from 278 meters to 253 meters above m.s.l. It is almost a flat with gentle slope towards southwest. The Patiali Rao, Sirhind choe and other small choes in the area flow in this direction. The Sirhind choe and Patiali Rao constitute the principal drainage of the surface. All the major suburbs and towns including Fatehgarh Sahib, Sirhind, Bassi, Amloh, Mandi Gobindgarh are located on this surface. This surface constitutes very fertile, cultivated fields.

b. Aeolian Dunes: Aeolian surface consist of yellowish brown, compact to loose sand, stabilized and semi-stabilized dunes of various shape and sizes constitute this surface. The height of the dunes varies from 2 to 5 meters and is generally surrounded by sand sheets. Newer Dunes are rarely observed in the area. This surface is mostly of localized nature and prominently developed along the Paleo channel course. Large parts of this surface are also under cultivation due to improved irrigation facilities by tube wells or canals in the area.

c. Younger Alluvial Surface: This surface is restricted to the present course of the Sirhind choe and Patiali Rao. It supports very little vegetation and is represented by grass. Elephant grass and some thorny shrubs. There are no human settlements on this surface. Due to intensive cultivation at places it becomes difficult to distinguish this surface from Alluvial flat.

Soils in the study area are loamy sand at the surface and calcareous sandy loam in subsurface layers. Sand constitutes 80% in the soil profile. Silt constitutes 11% and clay 9% in the soils.

1.7 Land Use/ Land Cover

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

Land use pattern of Fatehgarh Sahib District, Punjab

Type of Land use	Area (hectares)
1. Total Geographical area	117000
2. Forest	1020
3. Land put to non-agricultural use	12000(10 %)
4. Net area sown	102000(90 %)
5. Gross cropped area	192000
6. Cropping intensity	188%

(Source: Statistical Abstract, Punjab, 2015)

1.8 River System and Water Resources

There are two major streams which drain the study area. Of the two streams, Patiali Rao drains the eastern parts and flowing in south-west direction, where as Sirhind choe drains the central and western parts of the which flows also in southwesterly direction. Both these streams are ephemeral, draining monsoon water. Drainage and water bodies are shown in Fig.2.

The river Sutlej which flows at a distance of about 45 km North of Sirhind in westerly direction, is recorded to have flown through Sirhind and Patiala, (Uppal 1978 in Srivastava, 1998). It is recorded that in the past it did not join the Indus which it does now. Before 1000 A.D. it was a tributary of the Hakra river (Pakistan) joining directly the Arabian Sea. By 1245, the river shifted its course west and further shifts occurred between 1593 and 1796. Thus the Sutlej shifted its course from Sirhind-Patiala to Bathinda and then towards Faridkot. At the end of the 18^{th} century it took a course to Ferozepur. Since 1800 A.D. it has not changed its course. The shifting of Sutlej River in the historic past towards north and then west is corroborated by the existence of Palaeo channels now buried as well as abandoned. These channels exhibit fluvial deposits comprising of and, silt and clay. The orientation of these channels is along north-east to south-west direction.

There are four major canals which pass through the study area (Fig.3). These are Sirhind canal, Bhakra canal (main line), Narwana branch (Bhakra canal) and Sutlej Yamuna link (SYL) canal. Of the above Sirhind canal passes through the western flank of the district in North West of South-Easterly direction. This canal is one of the oldest in the country which was commissioned in 1831.

1.9 Agriculture & Irrigation

Agriculture is the main stay of the people of this area and its inhabitants depend heavily for their livelihood on agriculture and its allied occupations.

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.

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 1,01,000 ha and Gross Irrigated Area is 1,91,000 ha and Irrigation intensity is 189 %.

a. Canal Water Irrigation

Canal irrigation is a most important form of irrigation in this area. The district receives water from Bhakhra Main Line Canal. The length of Bhakhra Canal in the district is 37.68 Km.There is no irrigation by Sirhind canal in this area as it acts only as feeder canal. The Narwana branch of Bhakhra Main line also does not have any distributary and as such, there is no contribution towards irrigation. 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 11,000 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 90,000 ha.

1.10 Industries

Gobindgarh is the most flourishing industrial town in Fatehgarh Sahib District and is known as 'Steel Town' of India and is having a large number of steel rolling mills. Nearly 200 rolling mills are serving 25% of the secondary steel market of the country. There are about 48 Induction Furnaces producing raw material for the rolling mills. There are about 12 forging units catering to the needs of steel rolling mills, sugar and paper industry. There are 40 foundry units, 90 scrap cutting units and 12 oxygen plants catering the local requirements of the industry. Besides, there are another 67 units associated with the main industry.

1.11 Mineral Resources

The district is poor as regards mineral wealth. A few minor minerals are kankar popularly known as Rore, occurs mainly as nodules. The soil zones containing nodular variety of Kankar range in thickness from 50 centimetres to a metre. It occurs mostly in the form of isolated beds and pockets. It can be used for white washing and road metalling. Occurrences of gravels at depth have been identified in Bhadson, Rurki areas.

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. A pilot project was implemented in Deputy Commissioner Office covering Administrative complex and Judicial complex at Fatehgarh sahib. In Administrative complex total area of 63438 m^2 covering rooftop area, pavement area and area of officer's colony has been covered for artificial recharge to ground water. It is expected that 22515 m^3 water will be recharge to the ground per year. In Judicial complex 2171 m^2 rooftop area has taken in to consideration and expected recharge to groundwater is 1141 m^3/year. At both the places filtration chambers cum recharge wells of 55 m to 58 m depth have been constructed. Rooftop rain water harvesting can be adopted in all buildings of the district. Types of recharge structures suitable are; Trenches and injection wells. Injection wells of 40 to 60 m depth can be constructed depending upon the local hydrogeological conditions.

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 Fatehgarh Sahib District

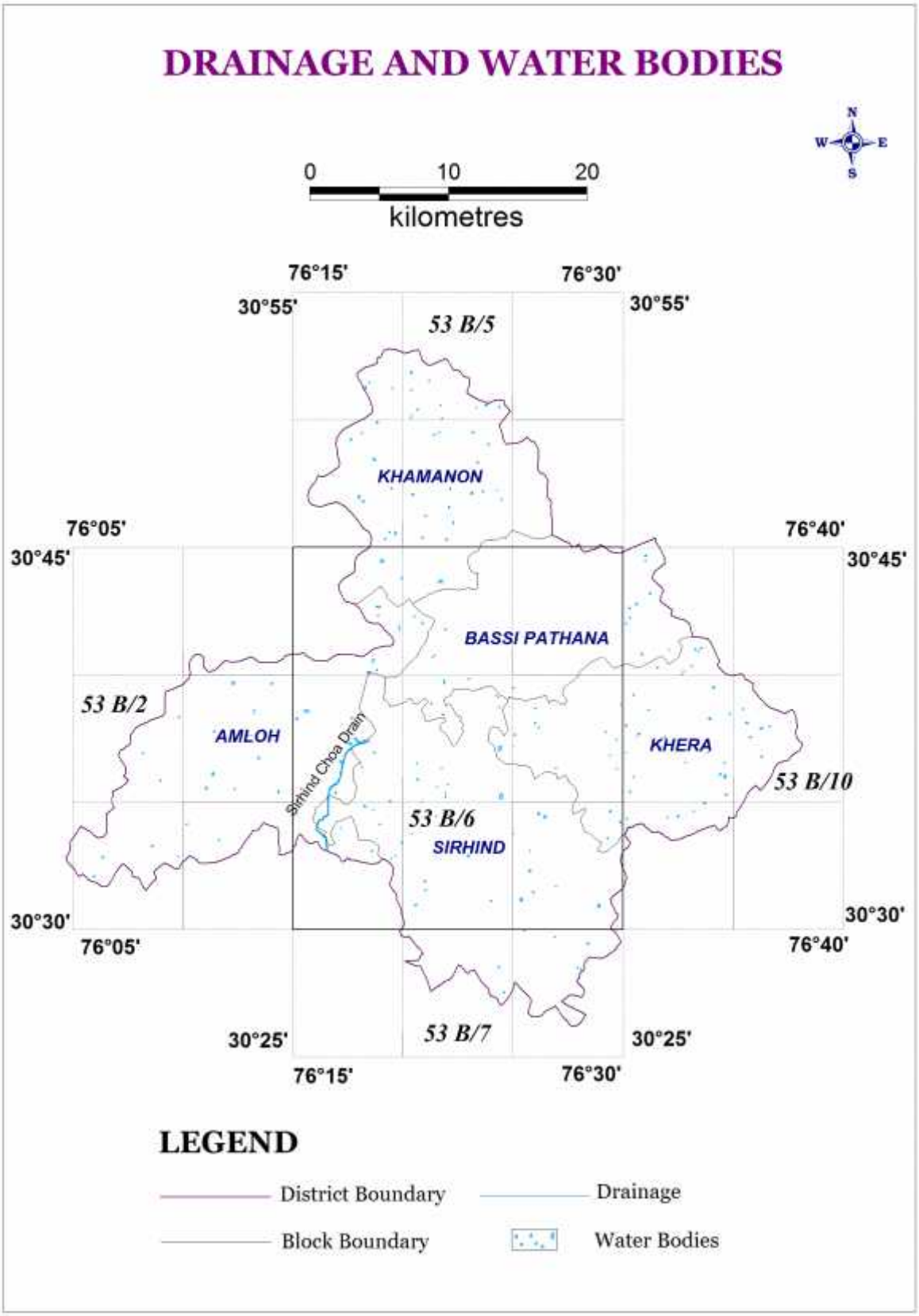
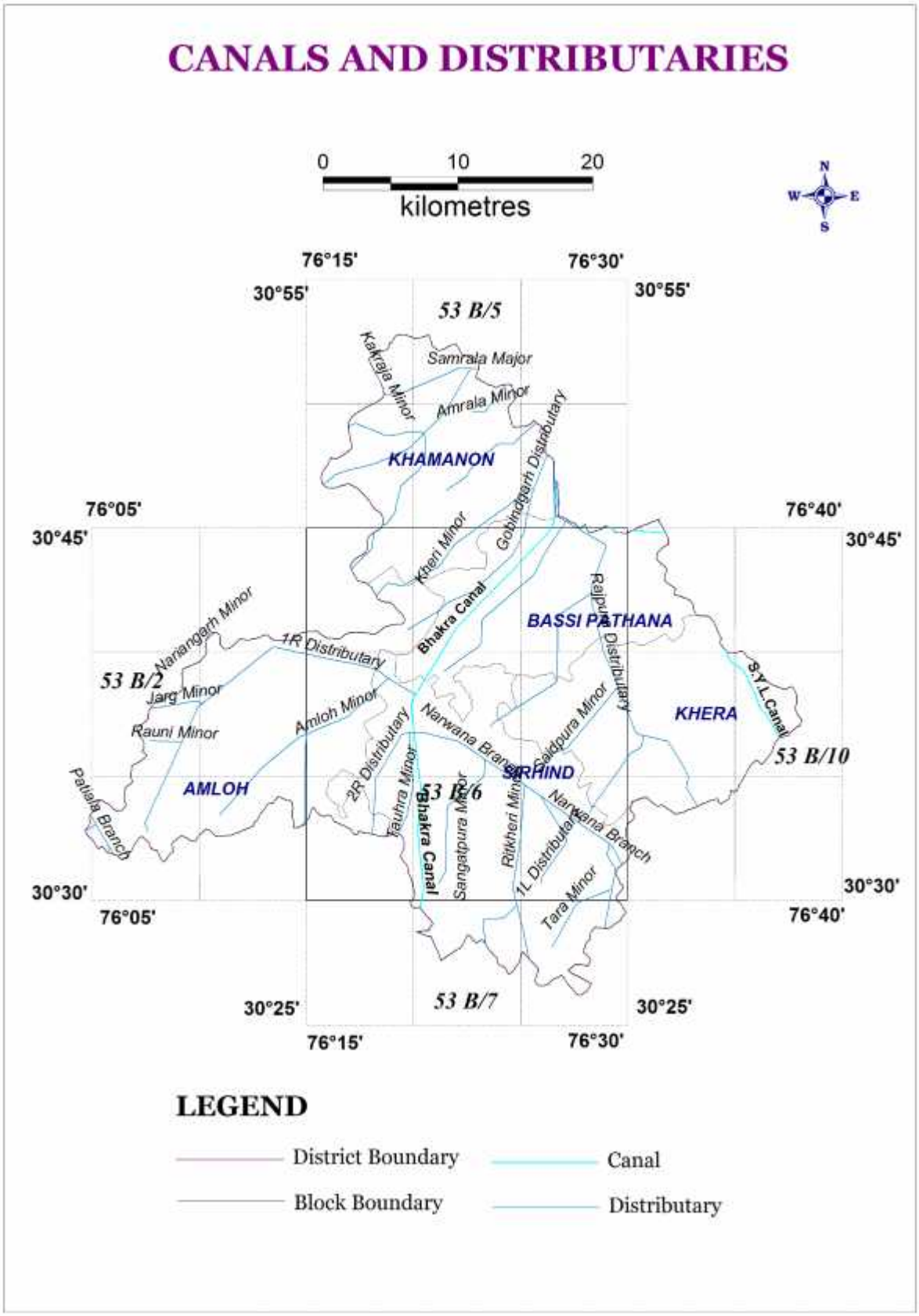


Fig.3: Canal and Distributaries of Fatehgarh Sahib District



2.0 DATA COLLECTION AND GENERATION

2.1 Geology and Hydrogeological data:

The Study area is underlain by formations of Quaternary age comprising of alluvium deposits belonging to vast Indus alluvial plains. The Quaternary deposit can be broadly classified under two distinct categories viz., Fluvial deposits and Aeolian deposits. The former can be further classified into (i) Older Alluvium and (ii) Younger Alluvium. The Aeolian deposits occur as sand dunes and sheets .The generalized stratigraphic sequence of the area is given below,

Generalized Stratigraphy, Fatehgarh Sahib District (Kumar and Dorka, 1989)

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. CGWB has carried out ground water exploration up to a depth of 550 meters at village Rasulpur in Khera block. Total thickness of alluvium is expected to be more than 550 m as bed rock has not been encountered up to that depth. Subsurface geological formations show the existence of a top layer of 10 to 15 m of clay, kankar with sand lenses. This layer is followed by granular zones of 20 to 30 m in thickness and under laid by clay bed of 10 to 20 m in thickness. At a depth of 90 to 120 m another clay bed of 25 to 30 m in thickness exists. In general, the thickness of finer sediments increases below 100 m in the eastern part of the study area.

Water table elevation ranges from 246 m to 266 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. The gradient of ground water table is 1.36 m/km in north east and 0.45 m/km in south west. Principle Aquifer is Alluvium and Major aquifer in this area is Older Alluvium (Fig.5)

2.1.1 Water Level Behavior

Ten monitoring stations of Central Ground Water Board (CGWB) (5 Piezometers and 5 Dug wells) (Fig.4) and *twenty seven* monitoring stations (27 Piezometers) of State government departments represent first aquifer. Second and third aquifer is represented by one monitoring station of CGWB i.e. (Inayatpur). Depth to water level in the area ranges from 5.22 to 33.50 m bgl during pre-monsoon period (Fig.6) and 3.50 to 35.78 m bgl during post monsoon period (Fig.7). The major parts (Western, north eastern and southern) water levels are >20 m, northern and central parts having water levels are in the range of 10 to 20 m, in the eastern

part in a portion where, water levels are <10 m bgl. Seasonal water level fluctuation shows a rise and fall in the range of 2.10 to (-) 2.22 meters respectively during the year 2015 (Annexure-I).

Fig.4: Hydrograph of Different Observation Wells of CGWB

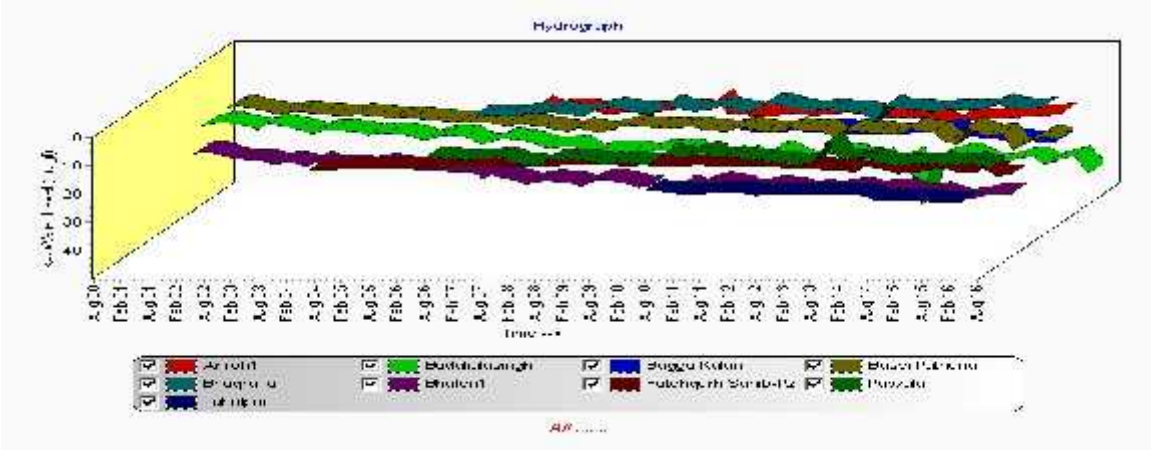


Fig.5: Major Aquifer

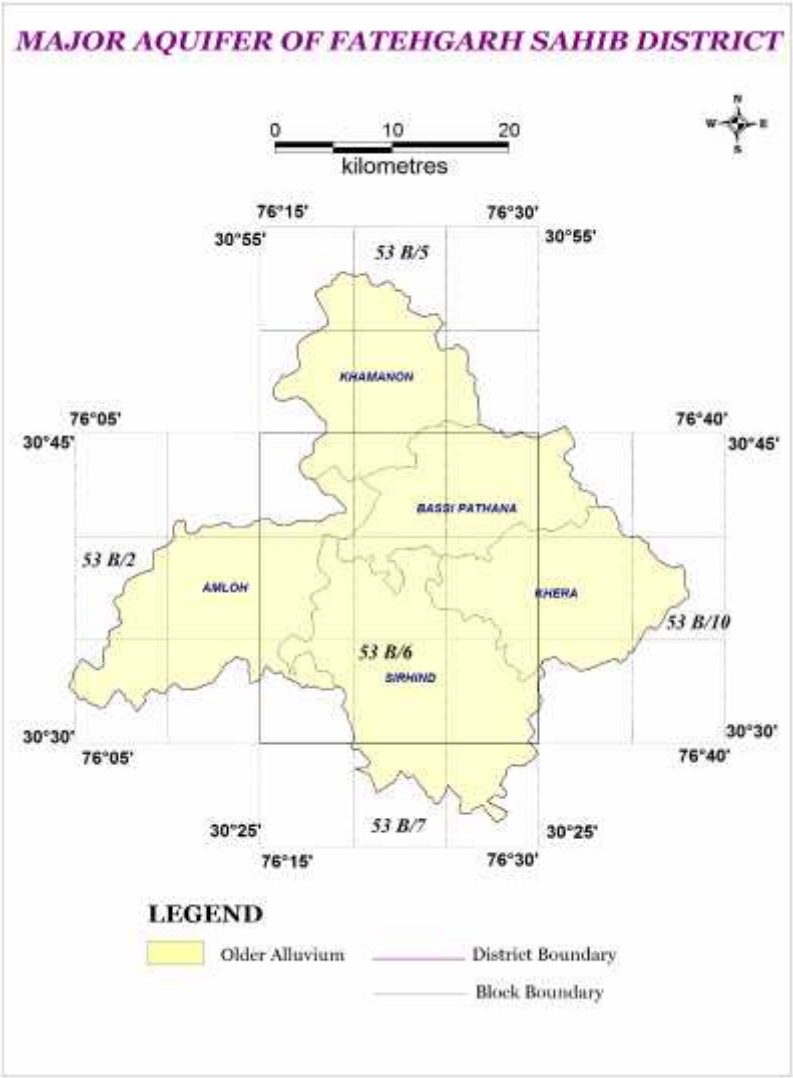


Fig.6: Depth to Water level Pre Monsoon, 2015

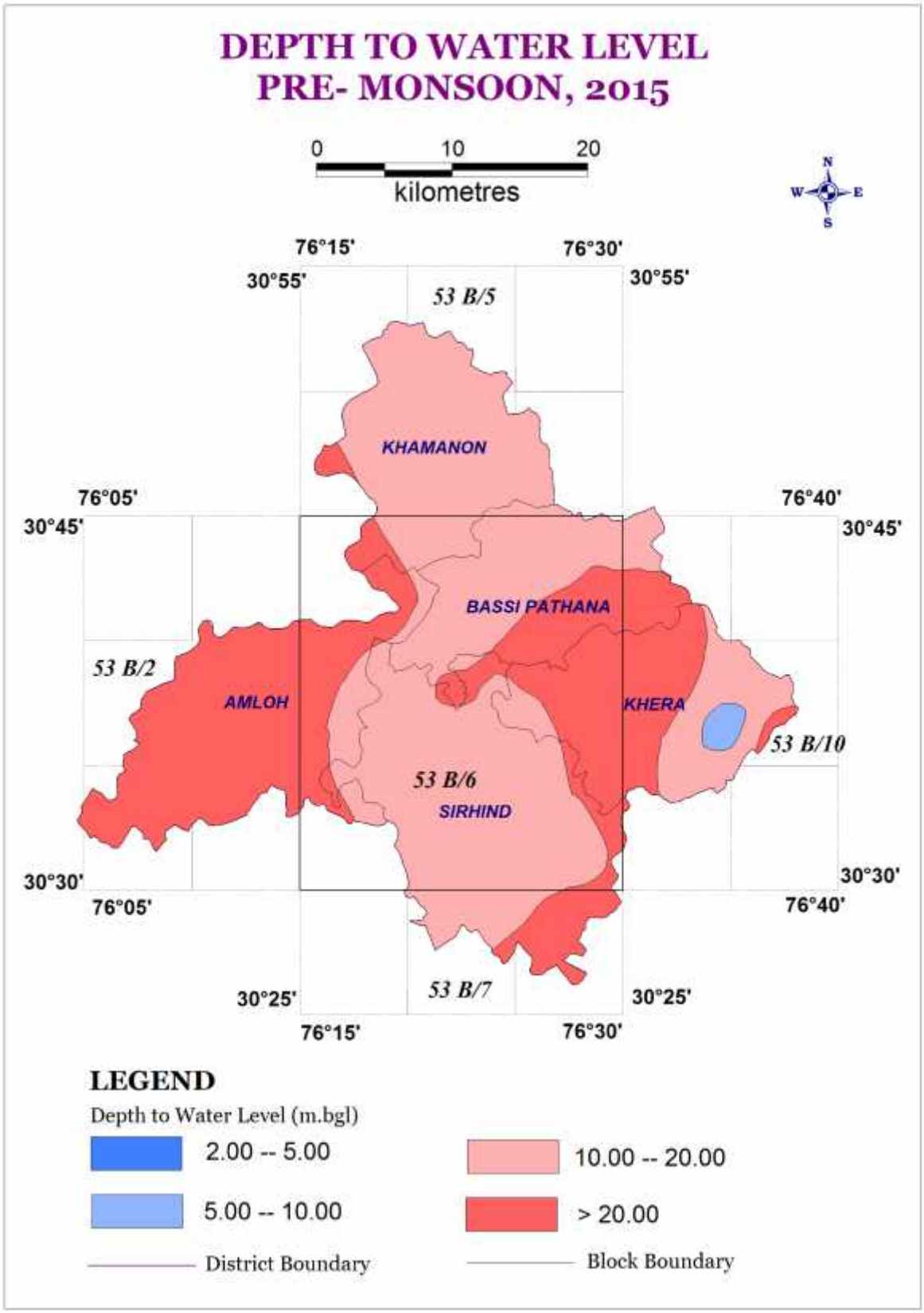
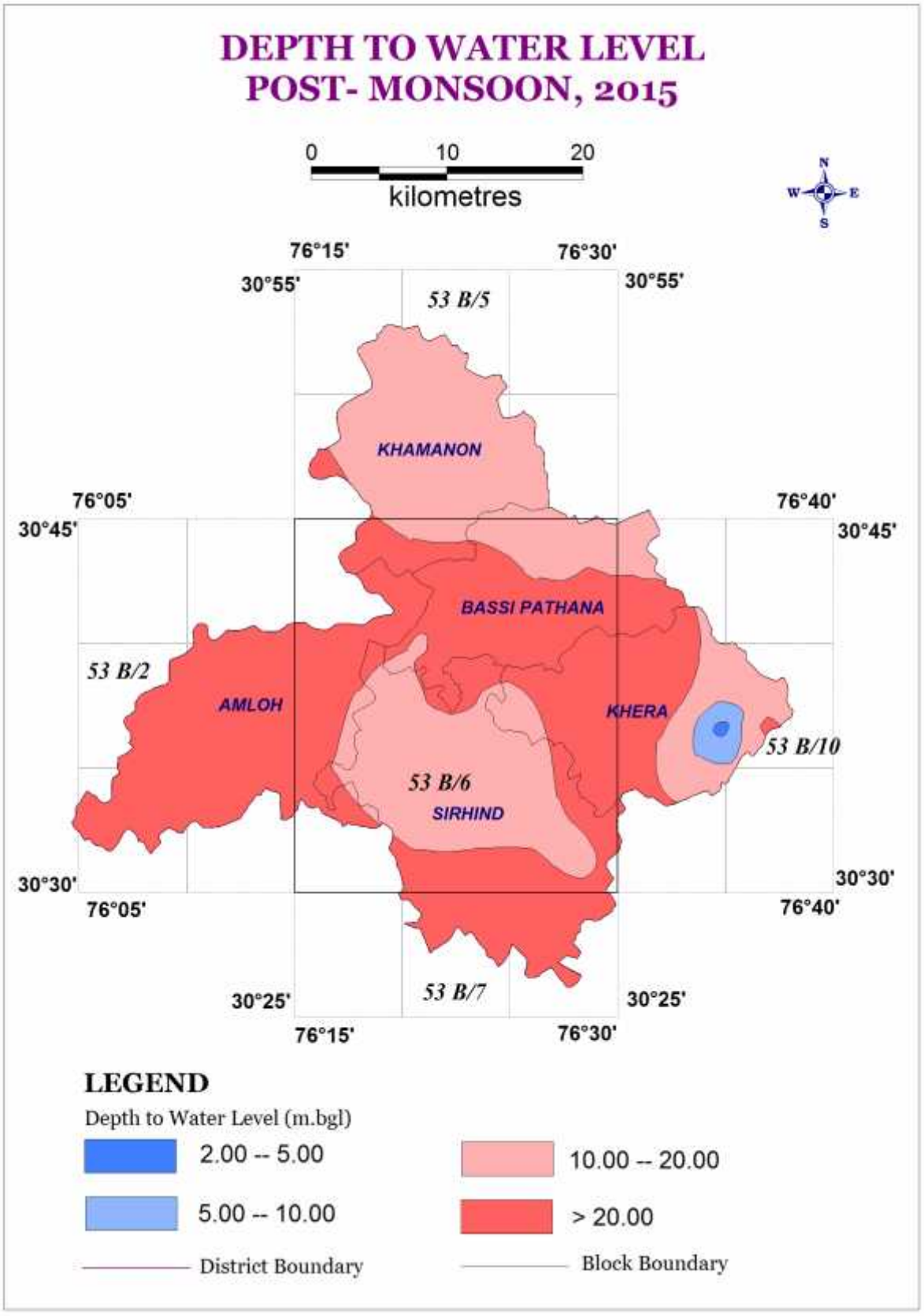


Fig.7: Depth to Water level Post Monsoon, 2015



2.2 Water Quality Data:

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

Chemical data of ground water from shallow aquifer indicates that ground water is alkaline and fresh (Fig.8). The electrical conductivity (EC) values ranges from 456 to 1587 µS/cm at 25^{o}C. The EC values less than 1000 µS/cm have observed at eight locations i.e. Bhatria, Bir Bharmasi, Fatehgarh Sahib, Badali ala singhwala, Nalini, Pawala, Amloh and Chunni kalan and where the EC value is 456, 541, 562, 597, 601, 661, 923 and 982 µS/cm at 25^{o}C respectively. 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 for iron at few places. The chloride concentration in ground water varies broadly between 10 mg/l at Bhatria and also 277 mg/l at Bhagrana. Ground water with iron concentration above permissible limit 1.5 mg/l are found mainly in Bhagrana (1304), Fatehgarh Sahib (4.53) and Amloh (3.87) whereas Arsenic found within permissible limit in all sampling locations (Fig.9).

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 (-3.05) to 3.28 meq/l. Analysing mechanism and equipments used for chemical analysis are given in table-1.

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

S. No.	Parameters	Analytical Methods
A.	***Physico-chemical analysis***	
	pH	Electrometric method
	Conductivity (EC)	Electrical conductivity method
	Carbonate & bicarbonate (CO_3,HCO_3)	Titrimetric method
	Chloride (Cl)	Argenotometric method
	Sulphate (SO_4)	Nephloturbidity method
	Nitrate (NO_3)	Spectro-photometric method
	Fluoride (F)	Ion metric method
	Total hardness (T.H)	EDTA-Titri metric method
	Calcium (Ca)	EDTA-Titri metric method
	Magnesium (Mg)	By difference
	Sodium (Na)	Flame photometric method
	Potassium (K)	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: Hill-Piper diagram for Groundwater Quality of Shallow Aquifer of Fatehgarh Sahib District

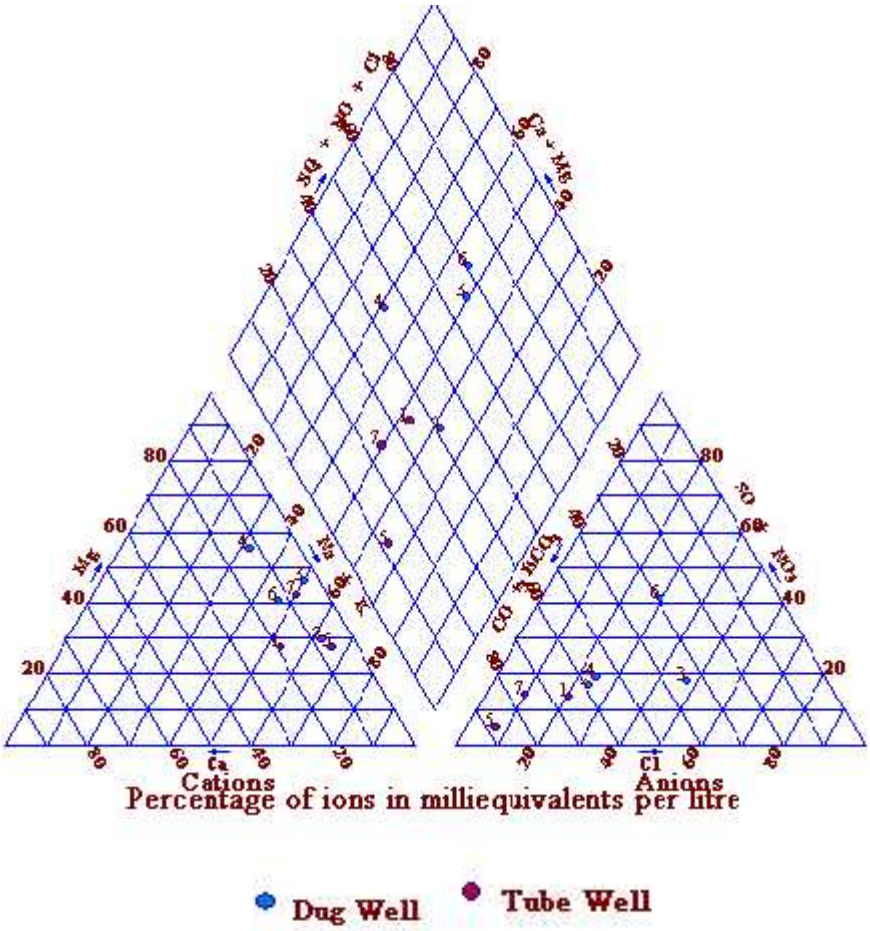
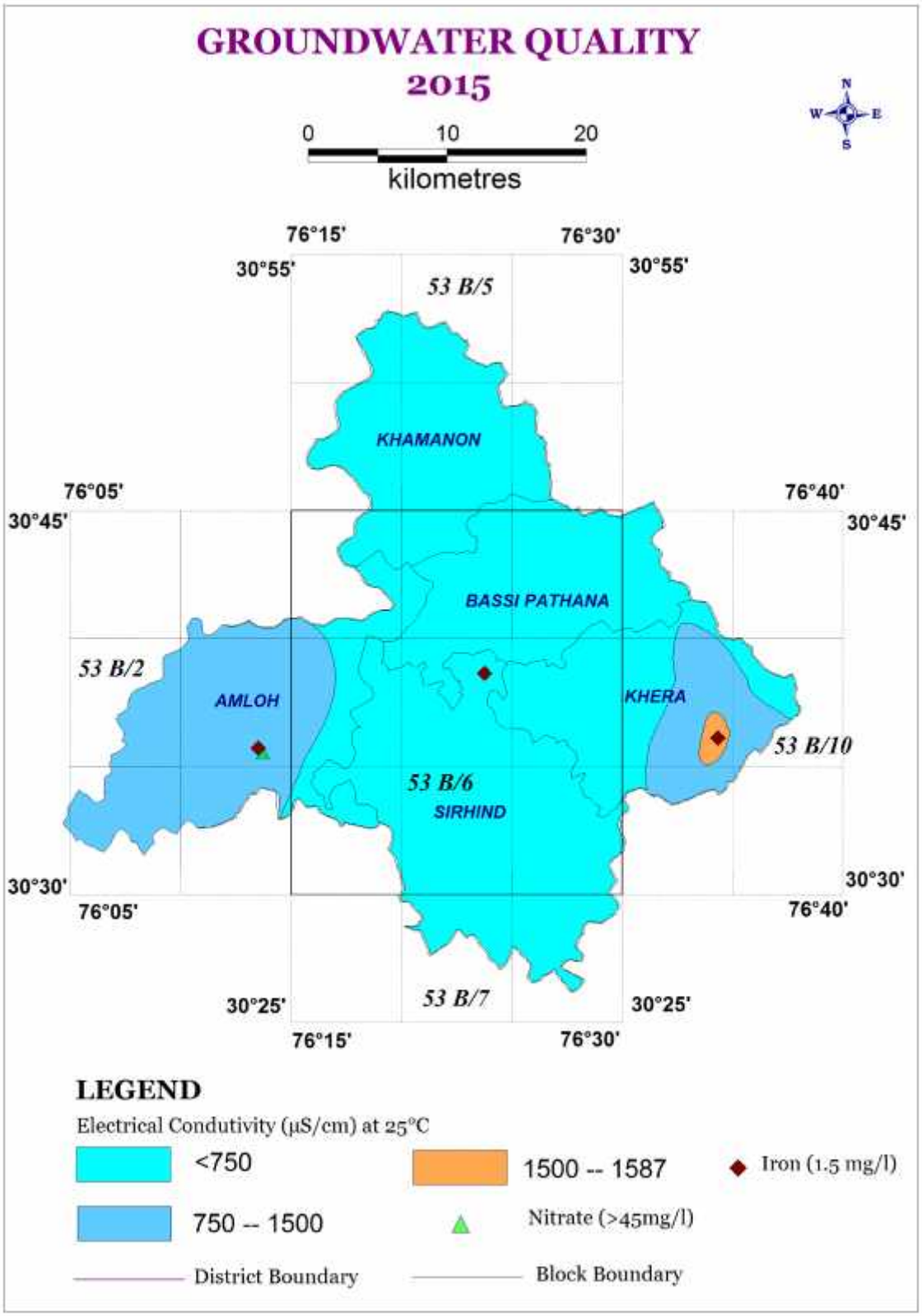


Fig.9: Groundwater Quality, 2015



2.3 Geophysical data:

Surface and Subsurface geophysical investigations have been carried out in alluvial tracts over parts of Fatehgarh Sahib district in toposheet no 53B/2 & 6. In Surface geophysical investigations, total 30 VES in an area of 800 sq km were conducted with current electrical separation of 600 to 1000 m .The aim of the survey was to delineate fresh water - saline water interface laterally as well as vertically.

2.4 Exploratory drilling State - Data Availability:

The Lithologs of Exploratory Well/ Observation well/ Piezometer/ productive wells of CGWB, Punjab State Tubewell Corporation (PSTC) now as Punjab Water Resources Development and Management (PWRDM) , 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.

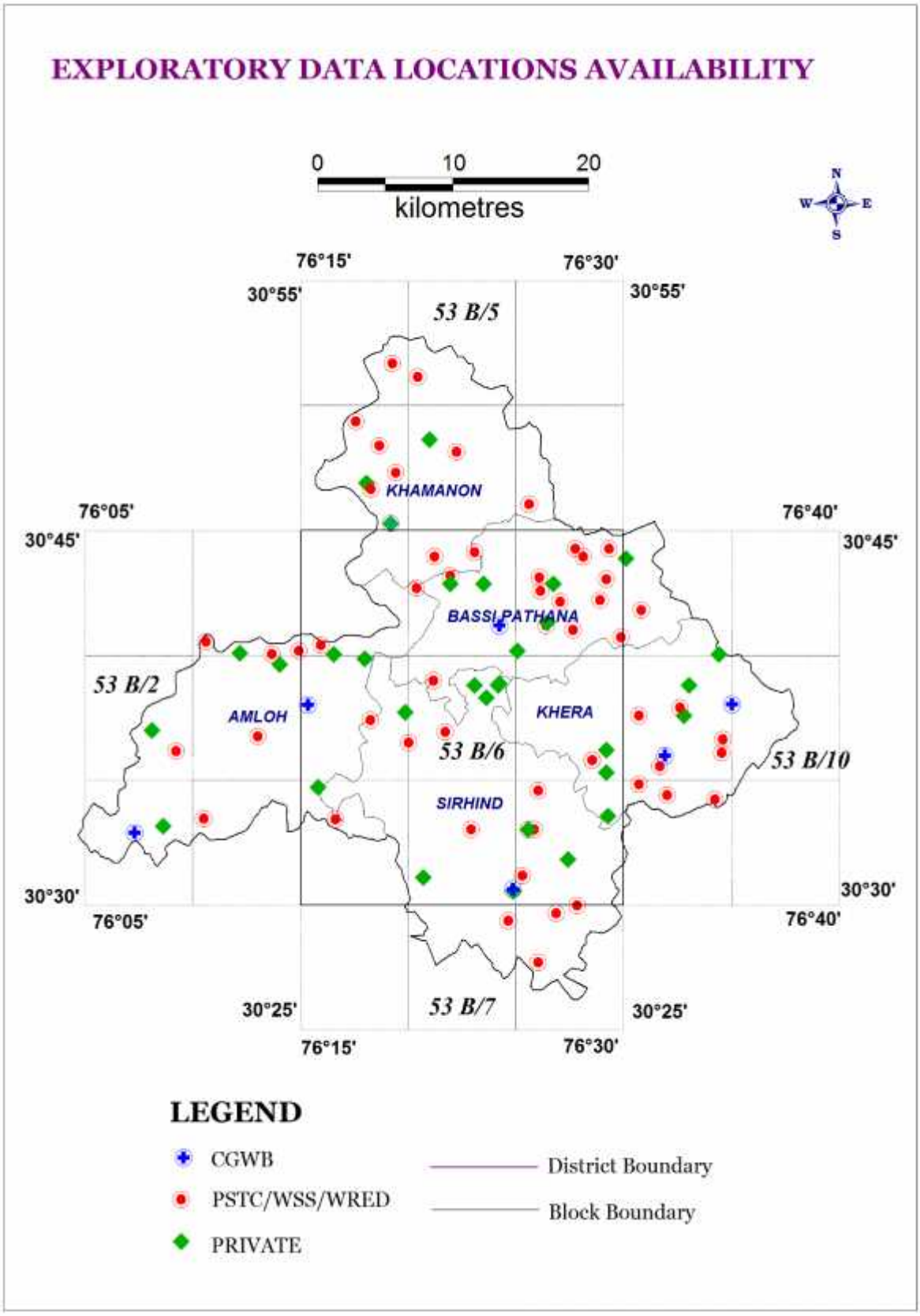
Data Availability of Exploration Wells of Fatehgarh Sahib district

Sl.No	Source of data	Depth Range (m)				***Total***
		< 100	100-200	200-300	>300	
1	CGWB	1	2	3	3	**9**
2	WRED/WSS/PSTC	25	52	2	3	**82**
3	PRIVATE WELLS	0	27	3	3	**33**
Total		**26**	**81**	**8**	**9**	**124**

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. 10). Perusal of table shows that majority of tube wells falls in the Aquifer-I and the depth more than 300m. 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.

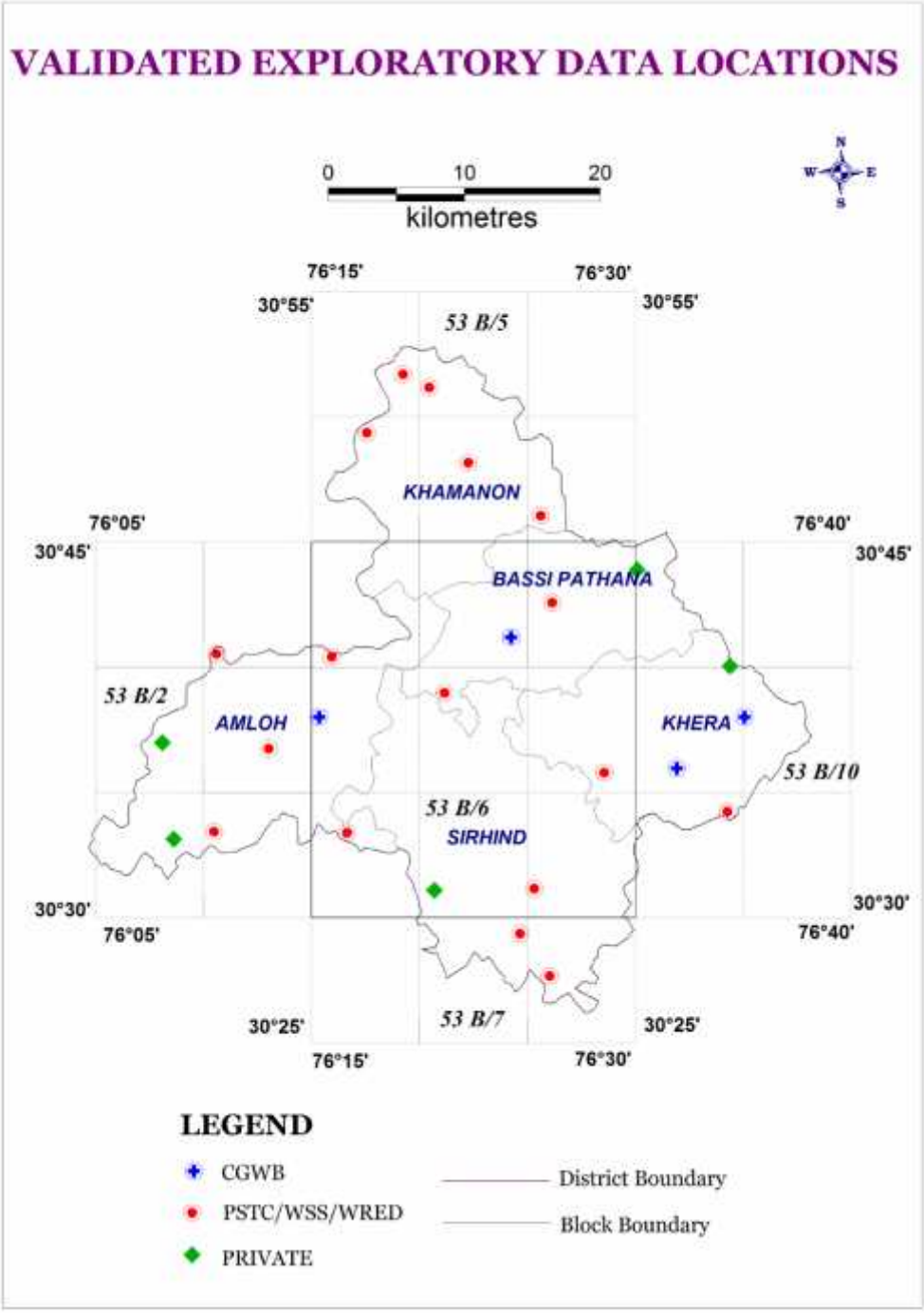
Fig.10: Locations of exploration data availability



3.0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

All the available data have been validated for consideration to generate aquifer map. The deepest well in each quadrant is selected and plotted on the map of 1.50000 scale with 5'X5'grid (9 x 9) km and is shown in Fig.11.

Fig.11: 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.12. 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.13.

Fig.12: Elevation contour map

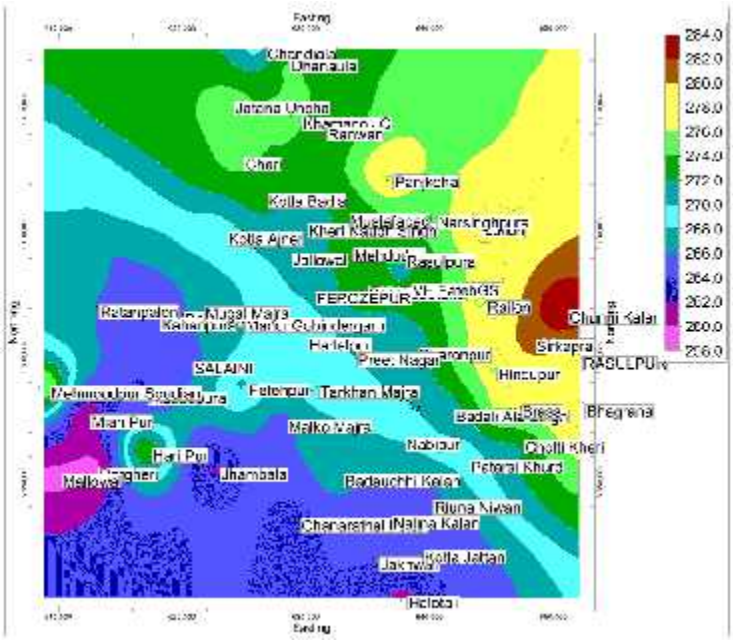
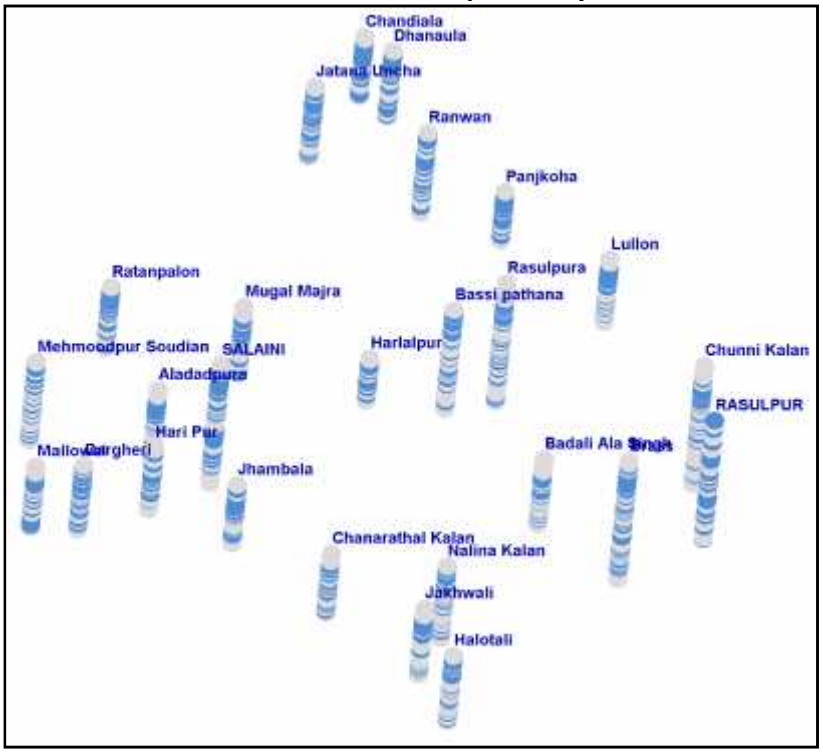


Fig.13: Three dimensional locations of validated exploratory wells with litholog



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 02 locations in the district includes 01 exploratory well and 01 slim hole through in-house activities and 03 exploratory wells and 02 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 550.47 m at village Rasulpur in Khera block and revealed the presence of 25 prominent permeable granular zones. Total thickness of alluvium is expected to be more than 550 m as bed rock has not been encountered up to that depth. The granular zone consists of fine to medium sand. Subsurface geological formations show the existence of a top layer of 10 to 15 m of clay, kankar with sand lenses. This layer is followed by granular zones of 20 to 30 m in thickness and under laid by clay bed of 10 to 20 m in thickness. At a depth of 90 to 120 m another clay bed of 25 to 30 m in thickness exists. In general, the thickness of finer sediments increases below 100 m in the eastern part. 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 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 Fatehgarh Sahib District

Aquifer Group	**Discharge 'Q' (lpm)**	**Transmissivity 'T' (m^2/day)**	**Storativity**
1st Group	2500 - 4243	1555 - 4222	$1.26x10^{-3}$ - $1.50 x10^{-3}$
IInd Group			
IIIrd Group	1874- 2256	425 - 1675	NA

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

Data Validation of Exploration Wells of Fatehgarh Sahib District

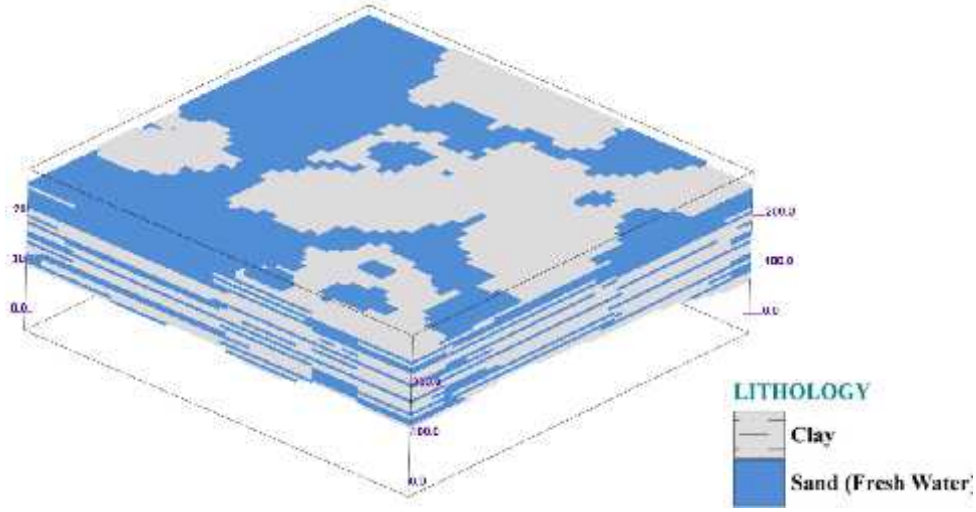
Sl.No	Source of data	Depth Range (m)				***Total***
		< 100	100-200	200-300	>300	
1	CGWB	0	1	2	3	**6**
2	WRED/WSS/PSTC	0	26	2	2	**30**
3	PRIVATE WELLS	0	15	2	3	**20**
Total		**0**	**42**	**6**	**8**	**56**

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.14). The 2D lithology sections and 3D lithological fence diagram has been prepared using lithology model and are shown in Fig.15a, b & 16 respectively. The aquifers are composed of fine to medium sand with clay intercalations. The granular zones are extensive.

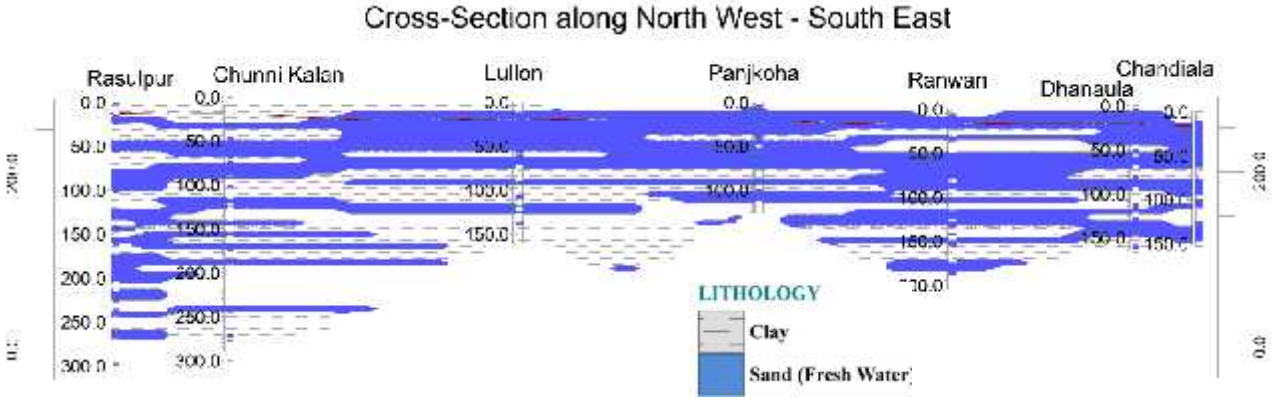
Based on geophysical borehole logging and use of resistivity profiling followed by the depth soundings at few selected places, for the present study and will be referred from time to time as it is obviously the higher resistivity beds represents freshwater zone in contrast in low resistive beds indicating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

Fig.14: 3-Dimension Lithological Model

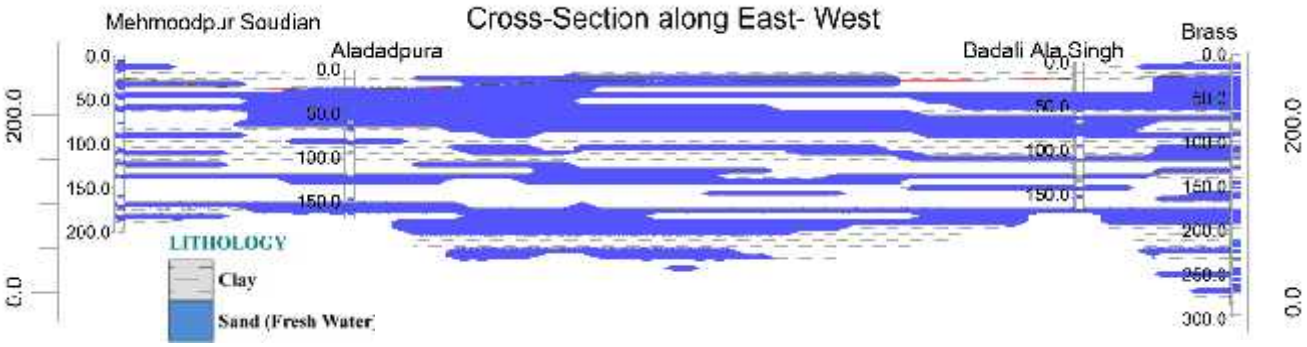


The major aquifer system of the district is quaternary alluvial deposits of Sutlej basin, having older alluvium which mainly comprises of sand, silt and clay admixed with kankars. The top surface layer and soil is mainly silty clay. The lithology shows the variation in lithology thickness i.e. thick clay layers inter bedded with sand except at few locations in Sutlej river basin. 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.15a,b: 2-Dimension Lithological Sections



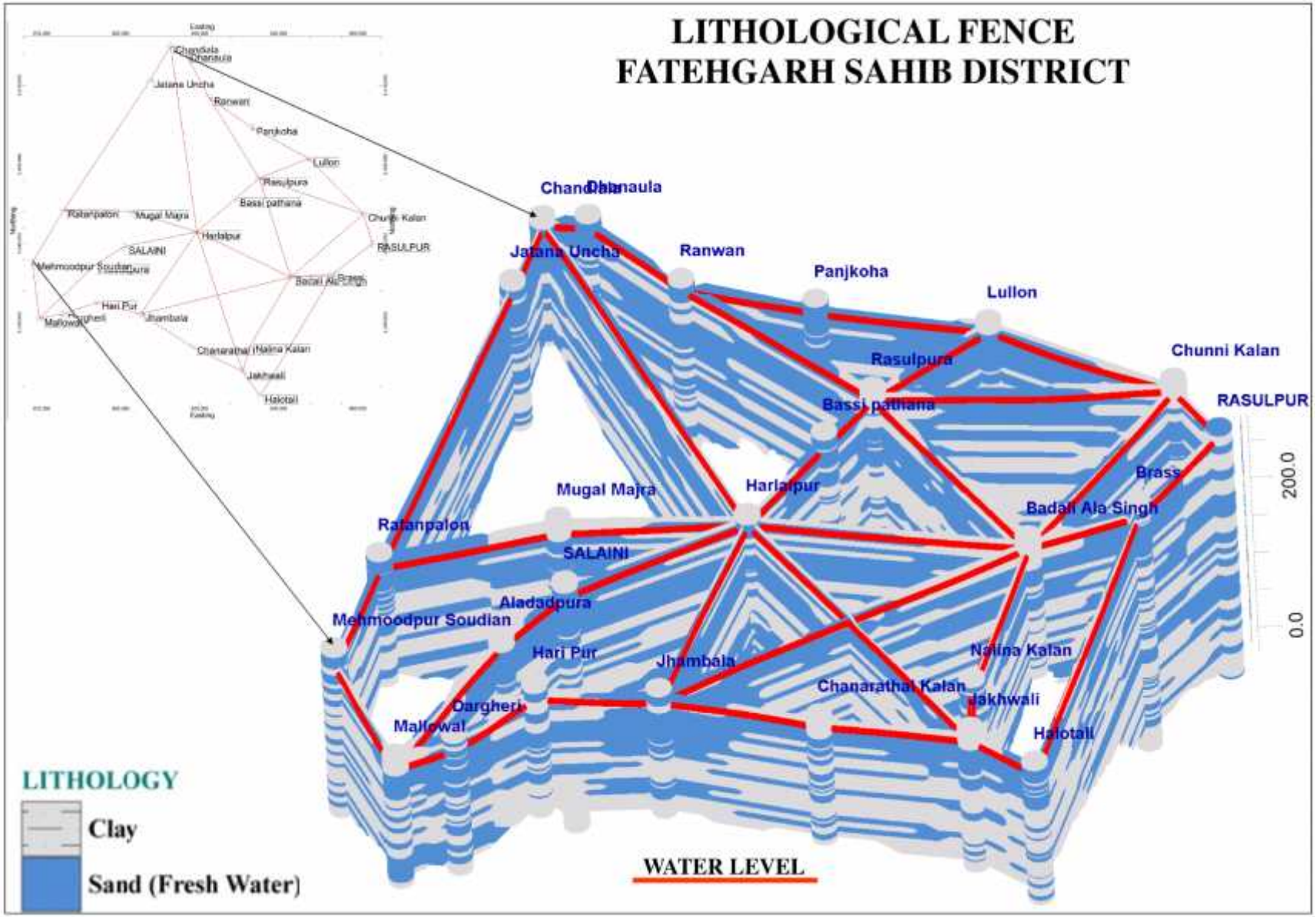
On the basis of lithologs geological sections has been drawn along NW-SE and E-W direction. Study of the NW-SE lithological section indicates that surface soil of 7 to 12 m thickness is an admixture of clay with intercalation of sand lenses. There are 5 well defined granular zones up to 175 - 225 m depth separated by laterally extensive clay layers 5 – 30 m thick. The third clay bed occurring at 100 m is alternating with equally extensive thin sand layers shown in borehole Rasulpur. Below 225 m there are few granular zones and thick clay. The top sand beds are fine to medium grained while the lower ones are medium to coarse in texture. The overall lithological section shows the variation in lithology thickness i.e. thin clay layers inter bedded with sand except at location Chunni Kalan where thick clay layers were identified at top depth up to 30m and at bottom depths 190 and 245 mbgl. There is inter-layering of sand and clay with thick clay at Lullon and Ranwan towards south- eastern side at a depth below 125m and 156m bgl.



Study of the E-W lithological section indicates that surface soil of 10 to 25m thickness is an admixture of clay and kankar with intercalation of sand lenses. There are 3 well defined granular zones up to 195 - 225 m depth separated by laterally extensive clay layers 5 – 30 m thick. The third clay bed occurring at 193 m is alternating with equally extensive thin sand layers. Below 270 m there are no aquifers only aquiclude i.e. clay. The top sand beds are fine to medium grained while the lower ones are medium to coarse in texture. The lithology shows the variation in thickness i.e. thin clay layers inter bedded with sand except at location Aladapura where thick clay layers were identified at top depth up to 20m and at depths 96 and 130 mbgl. There is inter-layering of sand and clay with thick clay at Brass and Badali Ala Singh towards western side at a depth below 97 m and 193 m bgl. There is thick inter-layering of sand and clay towards all lithologs except Mehmoodpur Soudian shows thin sequence of sand and clay towards Eastern 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.16: 3-Dimension Lithological Fence



3.1.3 Ground Water Exploration under NAQUIM and Group wise Aquifer Parameters

Ground water exploration was carried out in study area under NAQUIM. A well field consisting of 3 Exploratory Wells and 3 Observation wells tapping Aquifer –I, Aquifer –II & Aquifer-III has been constructed at site Inayatpur of Sirhind Block. Lay out plan of Well field is shown in Fig.17.

Multiple Aquifer System encountered in well field site, Inayatpur (3 Aquifer System) lithological variation is shown in Fig 18. The litholog of well field site Inayatpur is shown in table.3

Fig.18: Lithological Variation of Exploratory wells (I, II, III) in Inayatpur

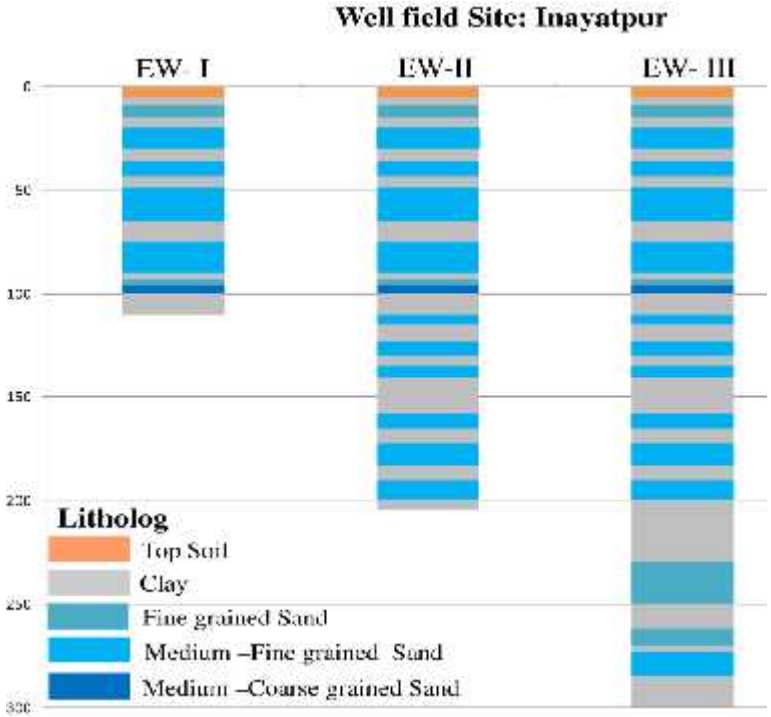


Table-3: Litholog of Well Field Site- Inayatpur

Location: Inayatpur *(Anayatpura)*	**Long:** $76^0$25'19"	**Lat:** $30^0$37'05"	**RL:** 269 amsl
Block: Sirhind		**District:** Fatehgarh Sahib	

Litholog	**From**	**To**	**Thickness**
Top soil	0	5	5
Sandy clay	5	9	4
Sand	9	15	6
Clay, mixed with little fine grained sand	15	20	5
Sand, fine to medium grained	20	30	10
Clay, mixed with little fine sand	30	36	6
Sand, fine to medium grained	36	43	7
Clay	43	49	6
Sand, medium to coarse grained	49	65	16
Clay, mixed with little fine to medium grained sand	65	75	10
Sand, fine to medium grained	75	90	15
Clay, mixed with little fine sand grained	90	93	3
Clay, mixed with little fine to medium grained sand	93	96	3
Sand, medium to coarse grained	96	100	4
Clay, mixed with little fine sand grained	100	110	10
Sand, medium to fine grained	110	115	5
Clay	115	123	8
Sand, medium to fine grained	123	130	7
Clay, mixed with little fine sand grained	130	135	5
Sand, medium to fine grained	135	140	5
Clay	140	158	18
Sand, medium to fine grained	158	165	7
Clay, mixed with little fine sand grained	165	172	7
Sand, medium to fine grained	172	183	11
Clay, mixed with little fine sand grained	183	190	7
Sand, medium to fine grained	190	200	10
Clay, mixed with little fine sand grained	200	230	30
Sand, fine grained with clay	230	250	20
Clay	250	262	12
Sand, fine grained with clay	262	270	8
Clay	270	273	3
Sand, medium to fine grained	273	285	12
Clay	285	300	15

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 0.5 to 4.5 m thick and is also underlain by clayey group which is about more than 12 m depth. Aquifer -I extends maximum upto 156 m of depth and below that clay layer starts getting thickened about 12-34 m separating Aquifer II to a maximum depth of 203 m. Multi aquifers System (Four Aquifer Groups) exists in this area separated by highly thick clay zones of 13 to 42 m thickness 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 Fatehgarh Sahib district, the aquifer grouping has been done using the sub-surface lithology and a three-dimensional aquifer model has been prepared shown in Fig.19. An aquifer disposition 3D fence diagram and 2D Aquifer section are also prepared using the aquifer model and are shown in Fig.20 and Fig.21 a,b. The aquifer grouping, group thickness and granular zones encountered in the groups are given in table below

Aquifer Grouping in Fatehgarh Sahib District

Aquifer Group	Range		Thickness		Granular Zones	
	From	To	Min	Max	Min	Max
Aquifer I	18	156	55	122	28	93
Aquifer II	102	203	20	88	6	46
Aquifer III	213	300	27	58	7	33
Aquifer IV	270	300	6	40	5	12

Fig.19: 3D Aquifer disposition Model

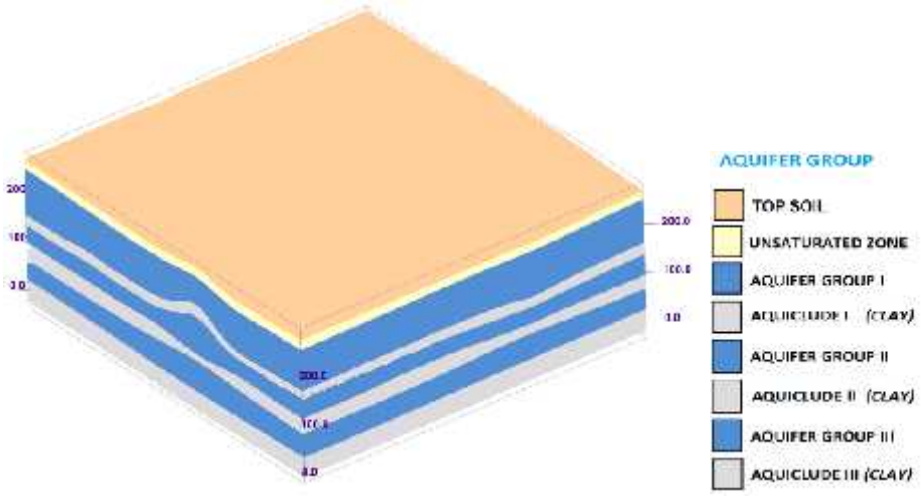


Fig.20: 3D Aquifer Disposition Fence

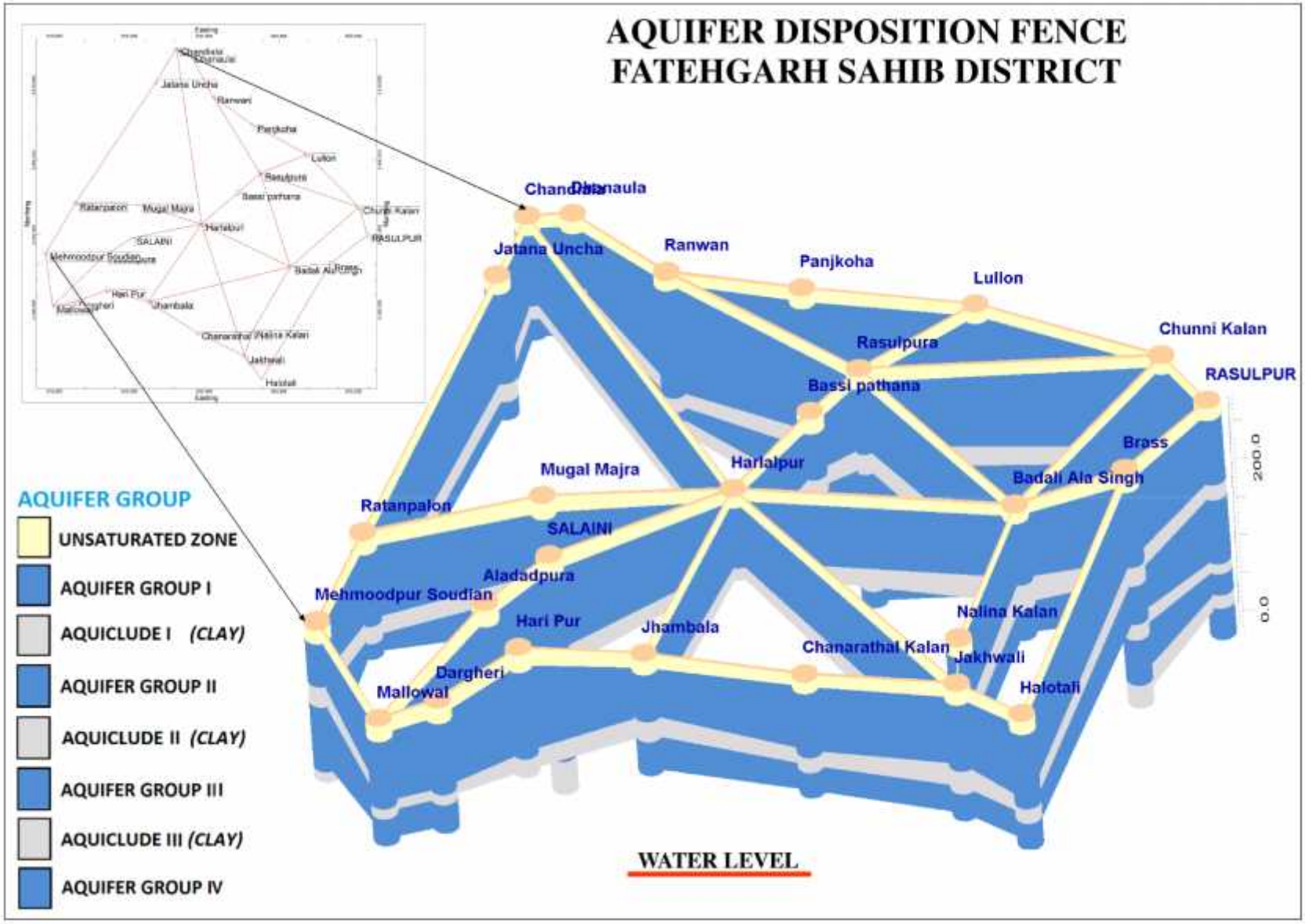


Fig.21a: 2-Dimension Aquifer Sections along Mallowal to Lullon

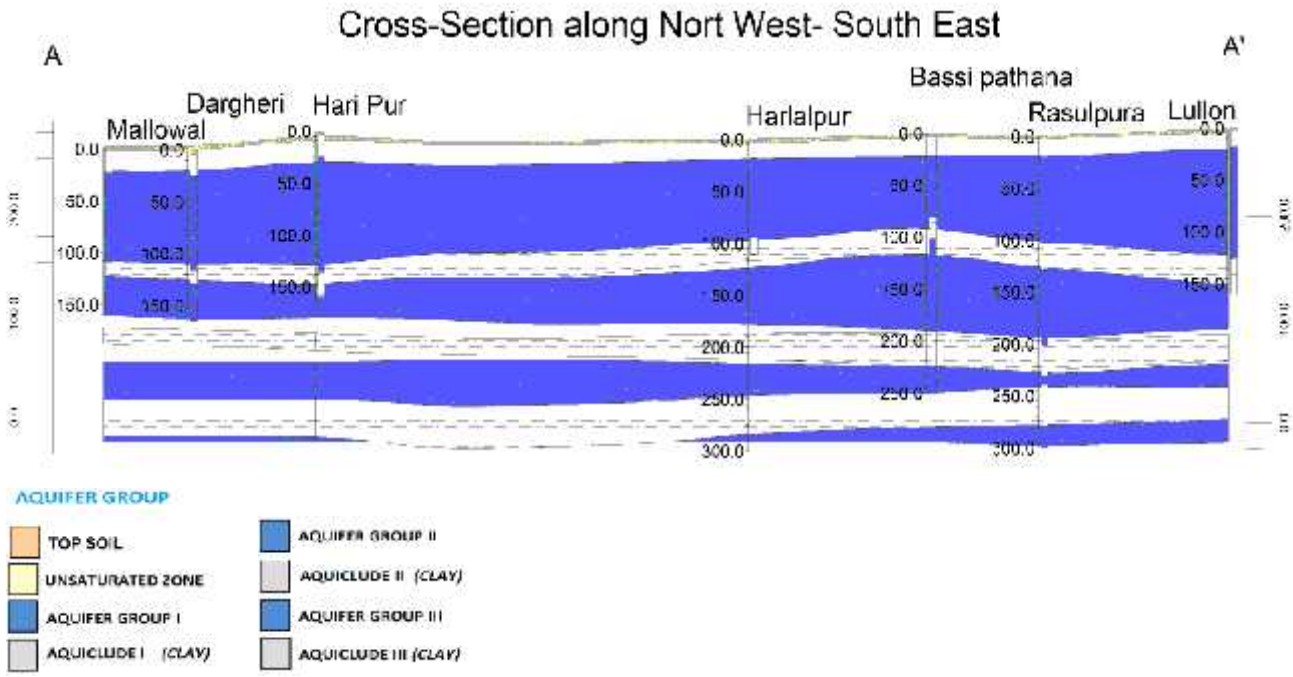
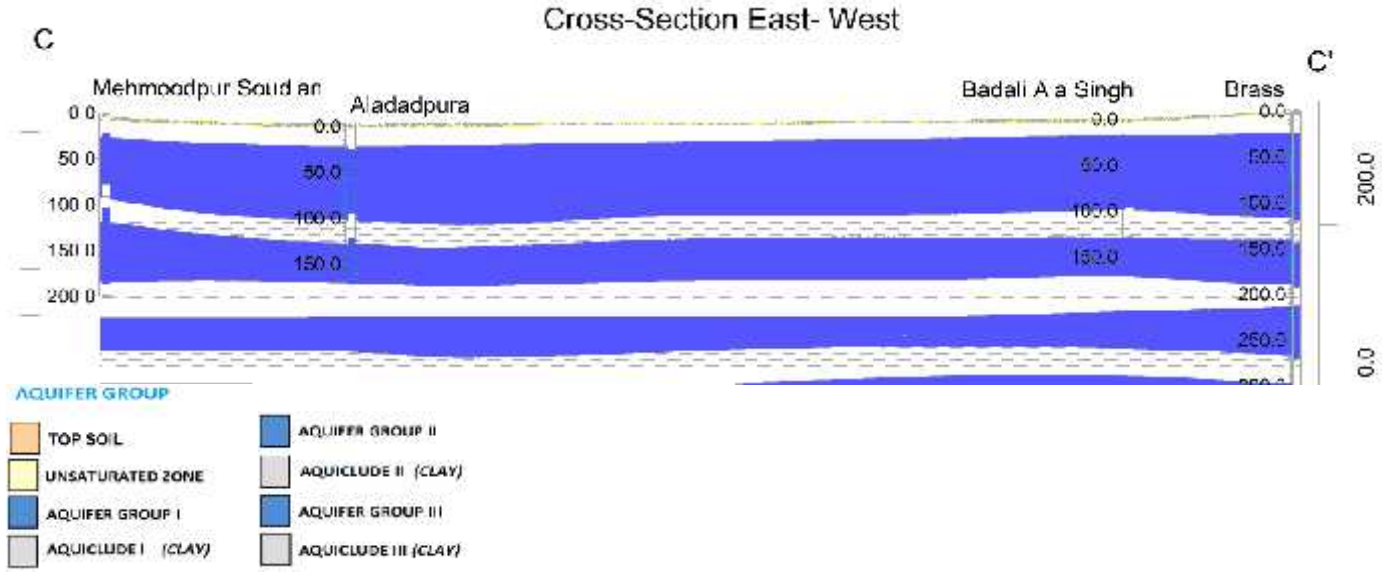


Fig.21b: 2-Dimension Aquifer Sections along Mehmoodpur Soundian to Brass



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

3.2.1 Aquifer Parameters of Well field site

To know the aquifer parameters of all three exploratory wells, Step Drawdown Test (SDT) and Aquifer Performance Test (APT) were carried out. Aquifer parameters obtained as a result of pumping test is given in Table-4.

Table-4: Aquifer Parameters of Well field site-Inayatpur

Aquifer Group	Name of the location	Zones Tapped (below ground level)	Aquifer Parameters						
			Transmi-ssivity (m^2/day)	Strorati-vity	Hydraulic Conduct-ivtiy (m/day)	Static Water level (mbgl)	Disch-arge (lpm)	Draw-down (m)	Specific Capacit y lpm/m
Aquifer- I	*Inayat-pur*	*54- 60, 97-100*	*630*	*1.2×10^{-4}*	*63*	*20.34*	*795*	*2.37*	*335.44*
Aquifer-II	*Inayat-pur*	*111-115, 160-164, 174-176, 191-195*	*849*	*1.5×10^{-3}*	*61*	*22.40*	*1325*	*5.71*	*232.04*
Aquifer-III	*Inayat-pur*	*274-285*	*500*	*6.94×10^{-4}*	*42*	*25.50*	*1325*	*14.15*	*93.63*

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

3.2.2 Ground Water Quality of Well Field Site (Inayatpur)

Chemical quality of different aquifers is assessed during ground water exploration under NAQUIM. Aquifer wise ground water quality of well field Inayatpur is given below.

Aquifer -I

Ground water sampling for Aquifer Group-I, has been carried out from Exploratory well tapping shallow aquifer (i.e. Aquifer-I) at well field site (Inayatpur), in which Basic parameters, Heavy metals, Arsenic , Iron, Pesticide, Microbiological, BOD/COD has been carried out .

The Ground water samples of Aquifer-I is suitable for drinking purposes as chemical parameters are well within the permissible limits for safe drinking water set by Bureau of Indian standard (BIS:10500-2012). For Pesticides, 18 parameters are tested through outsourced by M/s Interstellar Testing Centre Pvt. Ltd. and all parameters are within the permissible range. For Microbiological and Bacteriological Examination, 1L sample was analyzed through outsourced by M/s Environ Tech. Lab and the results are given in table below respectively which indicate that Aquifer –I is free from any Microbiological, and BOD/COD is also <1. For Heavy metals, Arsenic and Iron results are awaited.

Location	Parameters	Result	Test method	Remarks
Inayatpur EW-I	E.Coli	Absent	IS: 5887 (Part-1)	
	T.Coliform	Absent	IS: 5401 (Part-1)	
	BOD at 27^0C for 3 days mg/l	Nil	IS: 3025 (Part-44) 2003/ APHA 22nd Edition 2012	
	COD mg/l	Nil	IS: 3025 (Part-58) 2006/ APHA 22nd Edition 2012	

Aquifer -II

Ground water of Aquifer-II is analyzed during ground water exploration at Inayatpur-II. Generally it is suitable for drinking purposes as chemical parameters are well within the permissible limit. For Heavy metals, Arsenic and Iron results are awaited.

Aquifer –III

Ground water of Aquifer-III is analyzed and suitable for drinking purposes as chemical parameters are well within the permissible limits for safe drinking water set by Bureau of Indian standard (BIS) at Inayatpur-III. For Heavy metals, Arsenic and Iron results are awaited.

The details of chemical analysis (Basic Parameters) in different Aquifers (I, II, III) of well field –Inayatpur under NAQUIM is shown in Annexure-VII.

An Isotope study with NIH has been taken up by CGWB in the district for validation of the aquifer groups, mechanism of recharge to aquifers and for the age determination of the aquifer water. Three samples are collected from all the three aquifer groups and send to NIH for isotope analysis.

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 Fatehgarh Sahib district has been assessed to be 191%. The details are explained in below Table-5.

Table-5: 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*
Khera	95.67	192.22	1.59	193.81	2.04	-98.60	203	Over Exploited
Sirhind	165.93	304.40	3.52	307.92	4.49	-142.96	186	Over Exploited
Amloh	129.88	239.28	11.25	250.52	12.53	-121.93	193	Over Exploited

BassiPathana	96.49	177.41	1.75	179.17	2.25	-93.18	186	Over Exploited
Khamanon	99.41	186.64	2.23	188.87	2.81	-90.04	190	Over Exploited
TOTAL	**587.37**	**1099.95**	**20.34**	**1120.28**	**24.12**	**-536.70**	**191**	**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 22. 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	×	Sp. Yield of the aquifer	×	Areal extent of the confined aquifer group

Preliminary assessment of the ground water resources in confined aquifer does not imply that the assessed resource is available for exploitation. The objective of this exercise is to

have an overview of the ground water regime in the particular confined aquifer. It should be kept in mind that any significant ground water withdrawal from confined aquifer may invoke serious environmental degradation problem. Therefore, in case the preliminary assessment reveals that ground water is being withdrawn in significant quantity for any confined aquifer, that particular aquifer should be identified for detailed assessment using numerical 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 6,7,8,9 respectively.

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

Fig 22: Concept for Resource Estimation in Unconfined and Confined Aquifer System

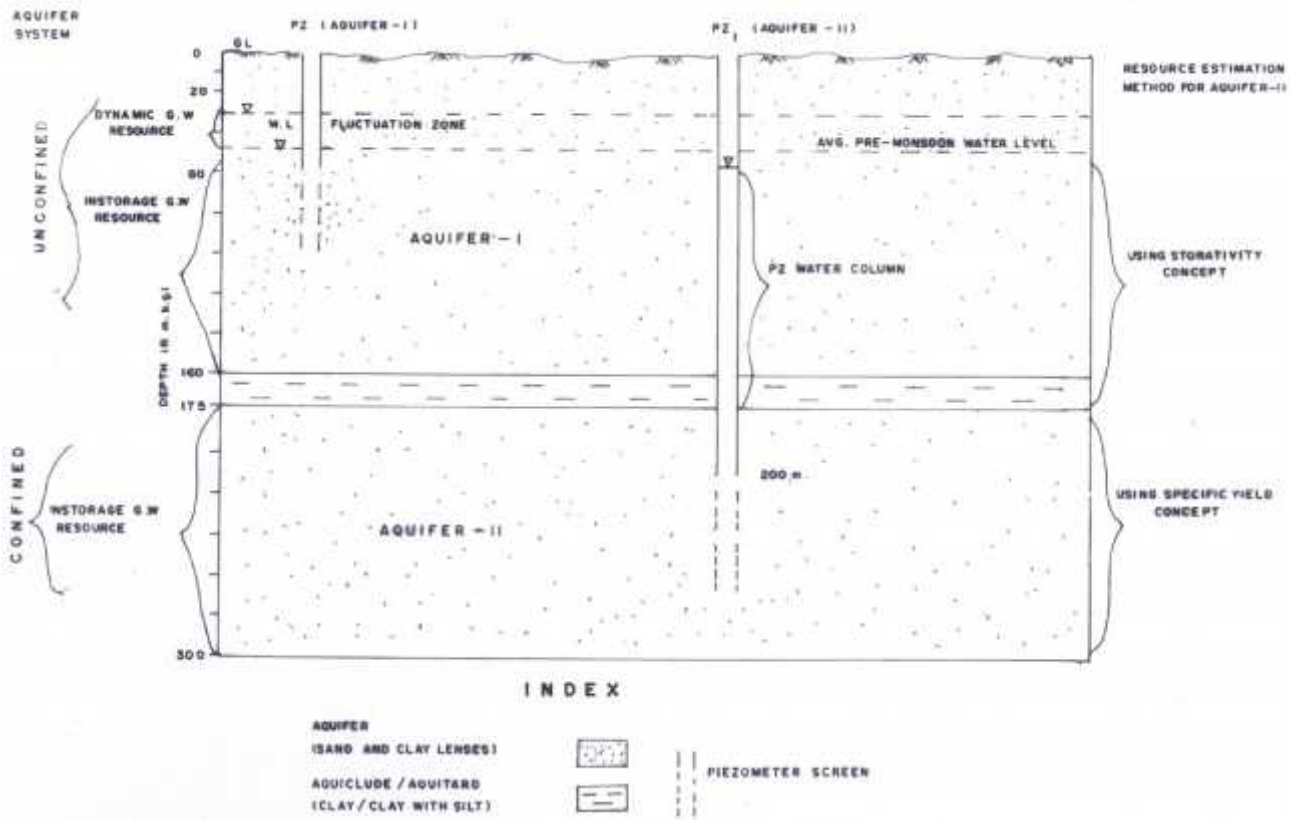


Table-6: Block Wise In storage Ground Water Resources in Unconfined Aquifer –I (Alluvium)

BLOCK WISE INSTORAGE GROUND WATER RESOURCES IN UNCONFINED AQUIFER –I											
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) (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) [(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	Khera	18080	18080	18080	0	17.01	106	88.99	48	0.072	62484
2	Sirhind	37240	37240	37240	0	17.89	107	89.11	52	0.072	139427
3	Amloh	22200	22200	22200	0	20.46	109	88.54	60	0.072	95904
4	Bassi Pathana	18650	18650	18650	0	18.20	105	86.80	55	0.072	73854
5	Khamanon	15500	15500	15500	0	15.82	121	105.18	76	0.072	84816
Dist. Total (ham)		**111670**	**111670**	**111670**							**456485**
Dist. Total (mcm)											**4565**

ham: hectare metre

mcm: million cubic metre

Table-7: 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 Aquifer II (m bgl)	Depth to bottom of Aquifer II (m bgl)	Thickness of piezo-metric level(m bgl)	Total Thickness of confined aquifer down to explored depth (m) (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) [(5)*(10*(11)] FRESH	In-Storage Ground Water Resources (Storativity concept) [(5)*(8)*(12)]	Total in-Storage Ground Water Resources (ham) (14+15)
			Total	Fresh Water										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Khera	18080	18080	18080	128	196	173.6	68	40	0.072	0.00126	52070	3955	56025
2	Sirhind	37240	37240	37240	129	194	143.6	65	28	0.072	0.0015	75076	8021	83097
3	Amloh	22200	22200	22200	123	179	156.6	56	40	0.072	0.00126	63936	4380	68316
4	Bassi Pathana	18650	18650	18650	123	190	167.6	67	32	0.072	0.00126	42970	3938	46908
5	Khamanon	15500	15500	15500	142	205	182.6	63	21	0.072	0.00126	23436	3156	26592
Dist. Total (ham)		**111670**	**111670**	**111670**								**227488**	**23451**	**280939**
Dist. Total (mcm)			**1116.70**	**1116.70**								**2275**	**235**	**2809**

The Average Peizometer head value for Confined Aquifer-II is 22.40 m.bgl

ham: hectare metre

mcm: million cubic metre

Table-8: Block Wise In storage Ground Water Resources – Confined (Aquifer III)

BLOCK WISE INSTORAGE GROUND WATER RESOURCES – CONFINED (AQUIFER III)														
Sr. No.	Name of Assessment Unit	Total Geogra-phical Area	Areal extent (ha)		Top Aquifer III (m bgl)	Depth to bott-om of Aquifer III (m bgl)	Thickness of piezo-metric level(m bgl)	Total Thickn-ess of confined aquifer down to explored depth (m) (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) [(5)*(10*(11)] FRESH	In-Storage Ground Water Resources (Storativity concept) [(5)*(8)*(12)]	Total in-Storage Ground Water Resources (ham) (14+15)
			Total	Fresh Water										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Khera	18080	18080	18080	217	300	192.17	83	28	0.072	0.00126	36449	4378	40827
2	Sirhind	37240	37240	37240	230	300	205.17	70	24	0.072	0.0015	64351	11461	75812
3	Amloh	22200	22200	22200	208	300	183.17	92	29	0.072	0.00126	46354	5124	51477
4	Bassi Pathana	18650	18650	18650	227	300	202.17	73	22	0.072	0.00126	29542	4751	34292
5	Khamanon	15500	15500	15500	0	0	0	0	0	0.072	0.00126	0	0	0
Dist. Total (ham)		**111670**	**111670**	**111670**								**176695**	**25713**	**202408**
Dist. Total (mcm)		**111670**	**111670**	**111670**								**1767**	**257**	**2024**

The Average Peizometer head value for confined Aquifer - III is 24.83 m.bgl

ham: hectare metre

mcm: million cubic metre

Table-9: Block Wise Total Availability of Groundwater Resources upto 300 m Depth and Volume of unsaturated granular zone after 3m upto water level.

AVAILABILITY OF TOTAL FRESH GROUNDWATER RESOURCES IN FATEHGARH SAHIB 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 In-storage Groundwater Resources AQUIFER-II	Fresh In-storage Groundwater Resources AQUIFER-III	Total Availability of Fresh Groundwater Resources [(6)+(7)+(8)]	
								ham	mcm
1	2	*3*	*4*	5	6	7	8	9	10
1	Khera	17357	9567	62484	72051	56025	40827	168904	1689
2	Sirhind	40219	16593	139427	156020	83097	75812	314928	3149
3	Amloh	26640	12988	95904	108892	68316	51477	228686	2287
4	Bassi Pathana	24618	9649	73854	83503	46908	34292	164703	1647
5	Khamanon	20460	9941	84816	94757	26592	0	121349	1213
Dist. Total (ham)		**129294**	**58737**	**456485**	**515222**	**280939**	**202408**	**998569**	**9986**
Dist. Total (mcm)		**1293**	**587**	**4565**	**5152**	**2809**	**2024**		

ham: hectare metre

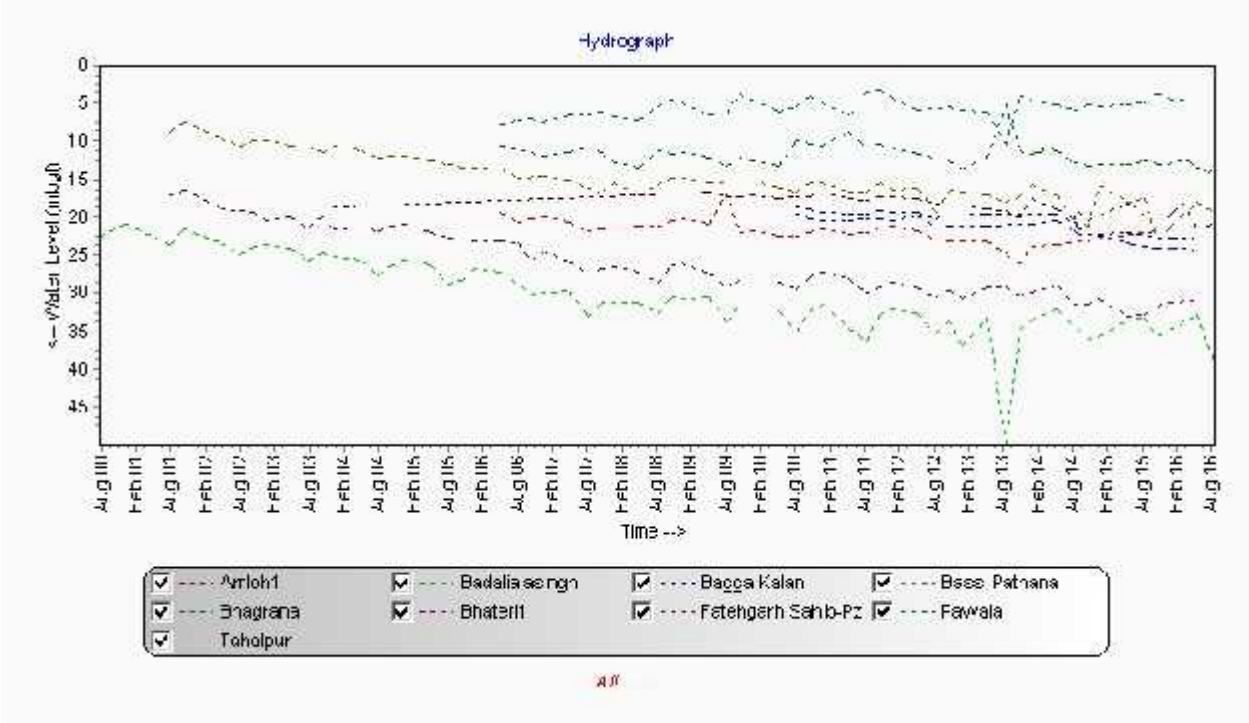
mcm: million cubic metre

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 Fatehgarh Sahib District as the recharge of the groundwater through rainfall and other sources are less than the overall extraction. The hydrographs also shows the declining water level trend over the years in the district (Fig.23) 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.23: Long term ground water table variation



5.2 Ground Water Quality

The ground water of the study area is alkaline in nature. Ground water in the area is fresh. Ground water with iron concentration above permissible limit 1.5 mg/l is found mainly in Bhagrana (13.04), Fatehgarh Sahib (4.53) and Amloh (3.87). 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-10,11 &12 .

Table-10: 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	1559	4265	13092	13165	3259	42	**35382**
Deep TW	7	14	106	201	104	0	**432**
Total	**1566**	**4279**	**13198**	**13366**	**3363**	**42**	**35814**

Table-11: 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	75	8930	2882	23495	279	153	0	**35814**
Tubewells (%)	0.21	24.93	8.05	65.60	0.78	0.43	0.00	

Table-12: System of Ground water distribution device

	Open Water Channels			
Lined/pucca	*Unlined/kutcha*	*Underground Pipe*	*Others*	*Total*
125	32685	2992	12	**35814**

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 Fatehgarh Sahib District due to very low availability of volume of surplus water (12.91 mcm) (Table-13a). 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 32685 (out of 35814) tube wells (91.26 %) operated by farmers for irrigation through unlined/Kutcha open channel system in study area (Table-12) 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 98.80 % 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-11). 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 1099.95 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-13a) 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 191 % to 148%. 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 13.a, b.

Table-13a: 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)*	*Present Stage of draft (SOD) (%) (As per 2013)*	*Reduction in draft by different water saving method*				*SOD afterwards (%)*	*Change of paddy cultivation area (% of existing)*
				Replace water courses by UG Pipes (mcm)	*Adopt Artificial recharge (mcm)*	*Change Paddy to Maize (mcm)*	*Total (mcm) (2+3+4)*		
			1	2	3	4	5		
Khera	95.67	192.22	203	43.85	2.36	50.18	96.39	113	13
Sirhind	165.93	304.40	186	69.45	3.09	70.08	142.62	100	Not Required
Amloh	129.88	239.28	193	54.59	2.93	52.65	110.17	108	8
Bassi Pathana	96.49	177.41	186	40.48	2.25	42.28	85.01	101	1
Khamanon	99.41	186.64	190	42.58	2.27	43.50	88.35	105	5
Total	**587.37**	**1099.95**	**191**	**250.95**	**12.91**	**248.26**	**512.12**	**105**	5

Table-13b: Impact on Stage of Development (SOD) after applying various management strategies in Fatehgarh Sahib 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**
Khera	203	46.26	156.74	54.53	148.47	2.89	200.11
Sirhind	186	52.28	133.72	31.59	154.41	2.29	183.71
Amloh	193	42.14	150.86	49.31	143.69	2.37	190.63
Bassi Pathana	186	42.27	143.73	45.95	140.05	2.65	183.35
Khamanon	190	42.84	147.16	46.01	143.99	2.29	187.71
Total	**191**	**43.00**	**148.00**	**46.00**	**145.00**	**2.47**	**188.53**

By adopting all the management strategies resulting in total reduction in stage of groundwater development is 91.47%. Hence overall stage of development afterwards is 100 % and is given in Table.14.

Table-14: Overall Stage of Development (SOD) after reduction in Fatehgarh Sahib 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**
Khera	203	46.26	54.53	2.89	103.68	99
Sirhind	186	52.28	31.59	2.29	86.16	100
Amloh	193	42.14	49.31	2.37	93.82	99
Bassi Pathana	186	42.27	45.95	2.65	90.87	95
Khamanon	190	42.84	46.01	2.29	91.14	99
Total	**191**	**43.00**	**46.00**	**2.47**	**91.47**	**100**

BLOCK WISE

AQUIFER MAPS

AND

MANAGEMENT PLAN

(PART-II)

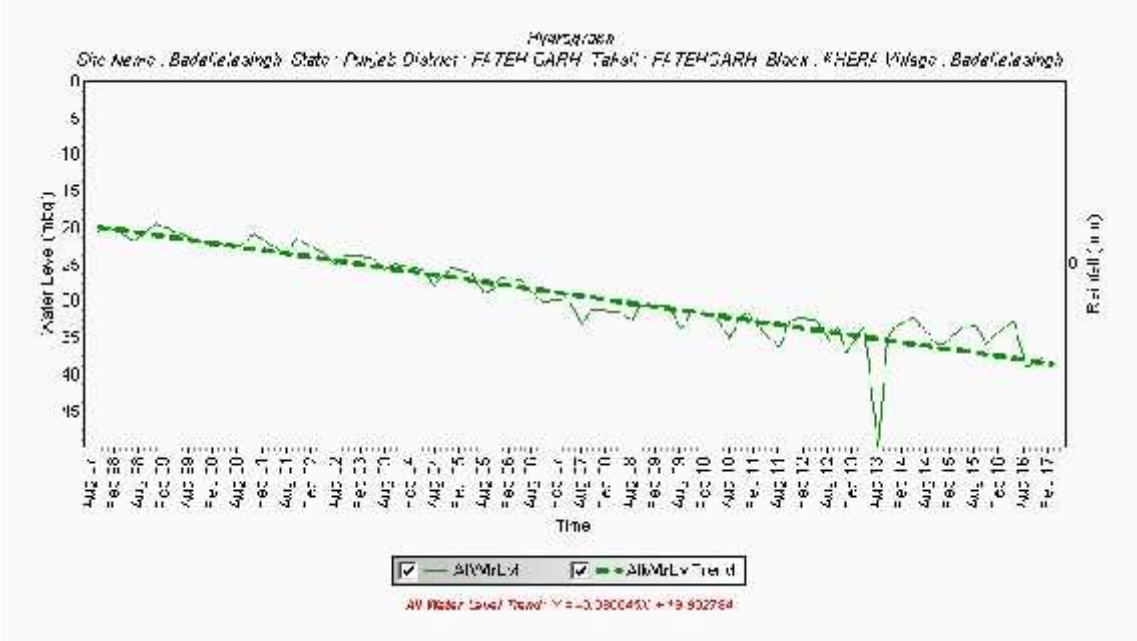
I. Salient Information of Khera Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>180.80 sq km</td></tr>
<tr><td>District/ State</td><td>Fatehgarh Sahib, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 0
Rural Population: 71417
Total population: 71417</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 538 mm
Non-monsoon Rainfall : 184 mm
Annual Average Rainfall: 722 mm</td></tr>
<tr><td>Agriculture and Irrigation</td><td>Principal crops: Wheat, Rice, Sugar cane, and Maize
Other crops: Vegetables and Fodder
Gross cropped area: 352.76 sq km
Net sown area: 181.53 sq km
Irrigation practices: Tube well and Canal Irrigation
Cropping intensity: 194%
Area under
Ground water Irrigation: 170.49 sq km
Surface water irrigation: 3.88 sq km
Gross Irrigated area: 348.48 sq km
Net Irrigated area: 181.48 sq km
Number and types of abstraction structures: 6204, 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>17.01 – 106.0</td><td>89</td><td>56</td><td>720.51</td></tr>
<tr><td>Aquifer-II</td><td>128.0 – 196.0</td><td>68</td><td>40</td><td>560.25</td></tr>
<tr><td>Aquifer-III</td><td>217.0 – 300.0</td><td>83</td><td>28</td><td>408.27</td></tr>
</table>
Total Ground Water Resources available is 1689.04 mcm and total potential granular zones available are 124 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	*Existing Gross Ground water Draft as on 2013* Irrigation: 192.22 mcm Domestic and industrial water supply: 1.59 mcm *Future water demands* Irrigation development potential : (-)98.60 mcm Domestic and industrial water supply up to 2025 years : 2.04 mcm Water Scarcity Villages: 83
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 5.22 – 33.56 m bgl Post Monsoon: 3.50 – 35.78 m bgl Seasonal Fluctuation: 2.10 – (-)2.22 m/yr Mean (10 yrs) : 2.32 – (-)1.78 m/yr *Trends* Pre Monsoon: 0.21 – (-)0.35m/yr Post Monsoon: 0.11 – (-)0.78 m/yr **Aquifer-II &III** No Monitoring Stations

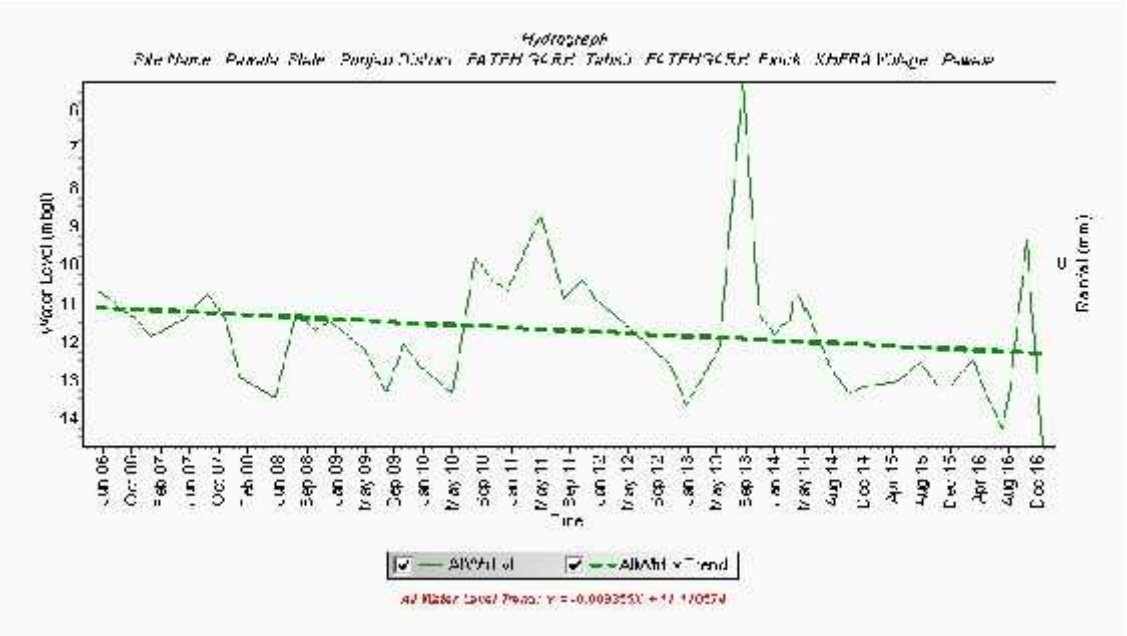
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Badali ala Singh)



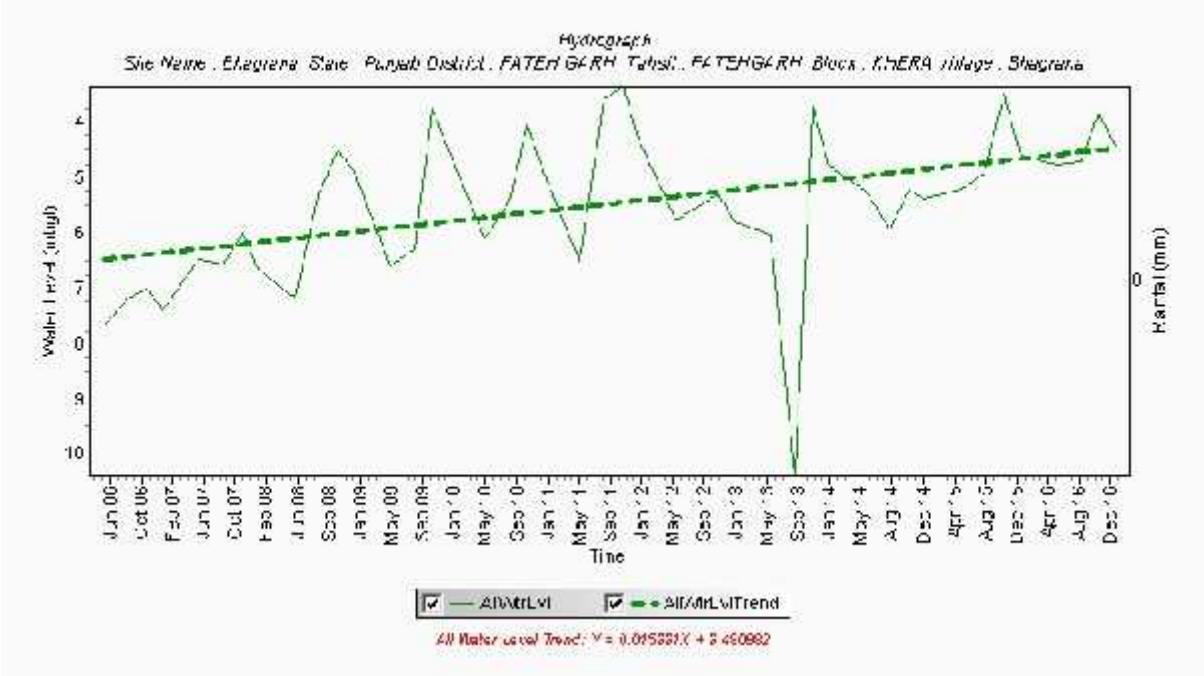
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Pawala)



HYDROGRAPH SHOWING RISING WATER TABLE

(Location: Bhagrana)



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/PSTC/WSS	4	7	0	1	**12**
PRIVATE	0	6	0	2	**8**
TOTAL	**4**	**13**	**0**	**5**	**22**

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 (17.01 -106 m)	Quarter-nary Alluvial deposits	Unconfined to confined	56	1780	3600	12 % *(0.072)*	1.26×10^{-3}
Aquifer-II (128 - 196 m)		Semi confined to Confined	40				
Aquifer-III (217 - 300 m)		Semi confined to Confined	28	NA	NA	NA	NA

* Well field proposed in adjacent block , NA : Not Available

Source: CGWB,2015 & PSTC,2008

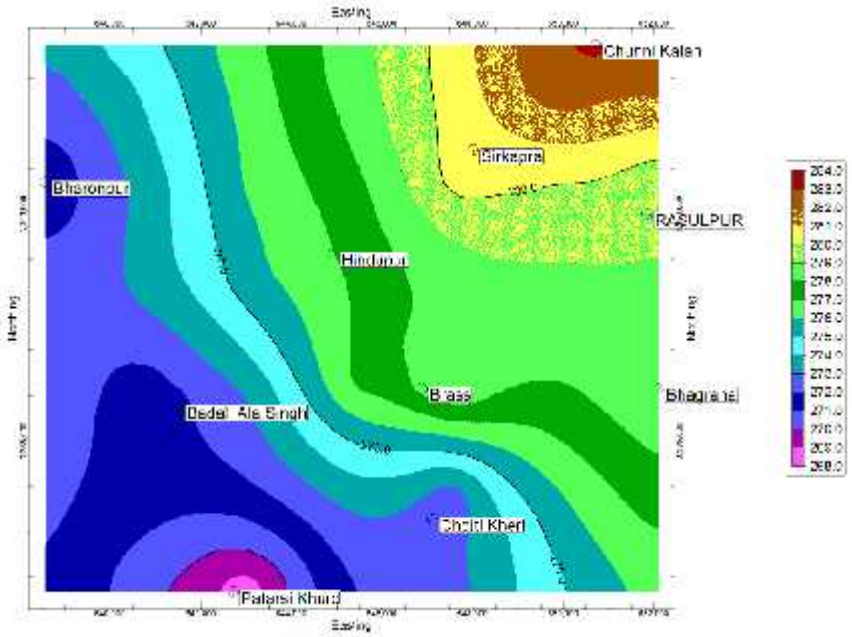
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

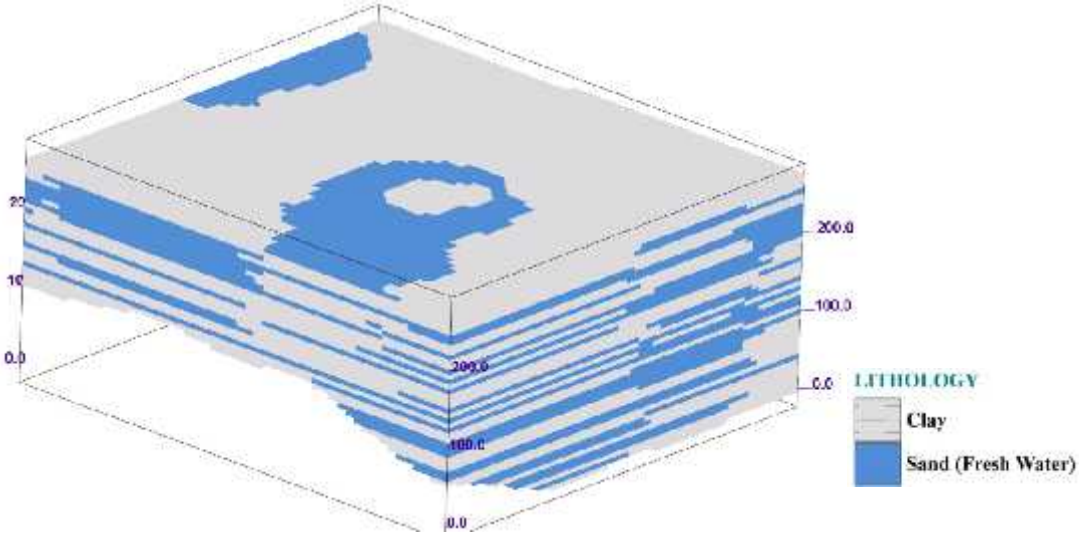
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	0	2	**2**
WRED/PSTC/WSS	0	5	0	1	**6**
PRIVATE	0	1	0	2	**3**
TOTAL	**0**	**6**	**0**	**5**	**11**

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

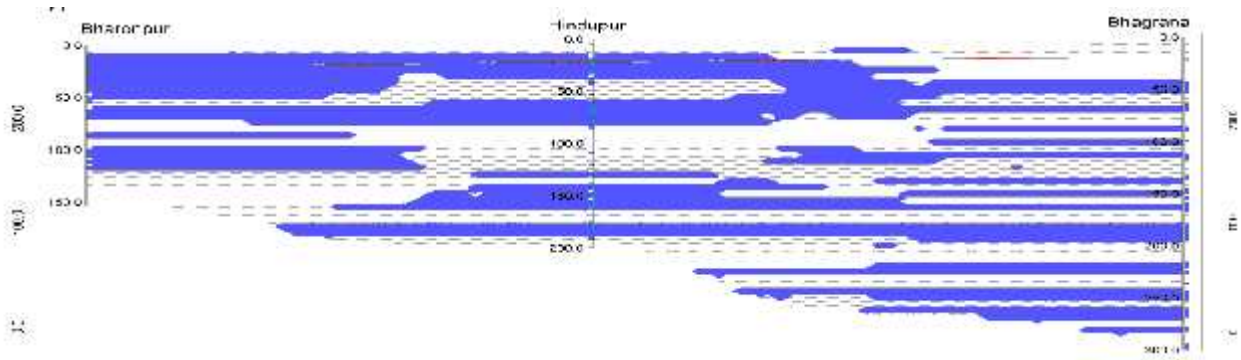
Elevation Map of Khera Block



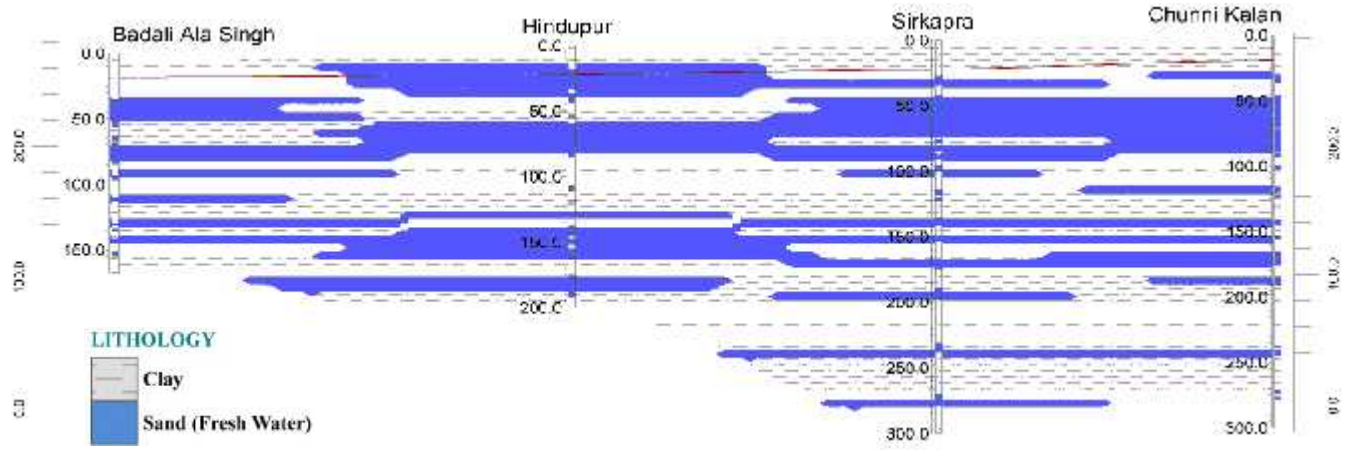
3-D Lithological model of Khera Block



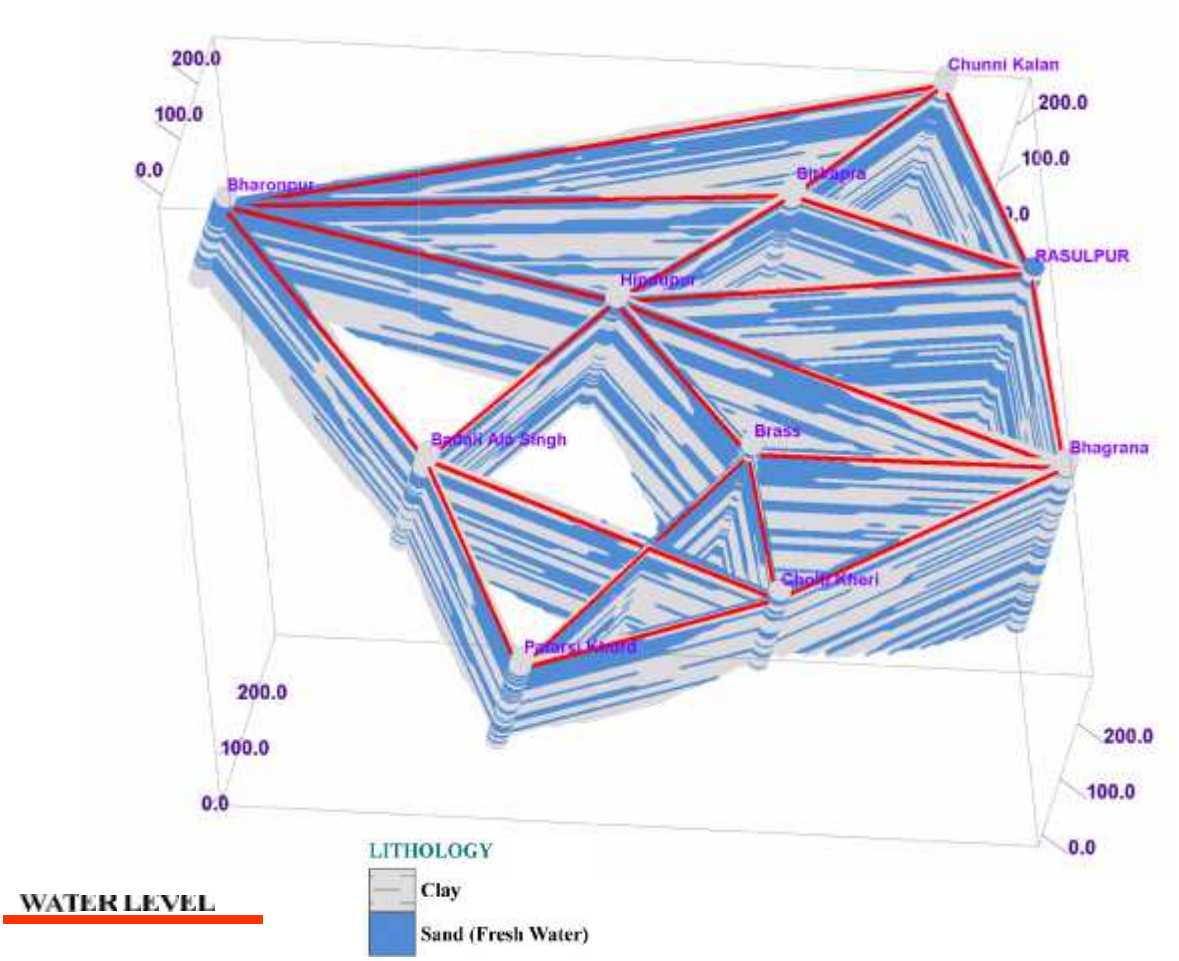
Lithological Cross section from Bharonpur to Bhagrana



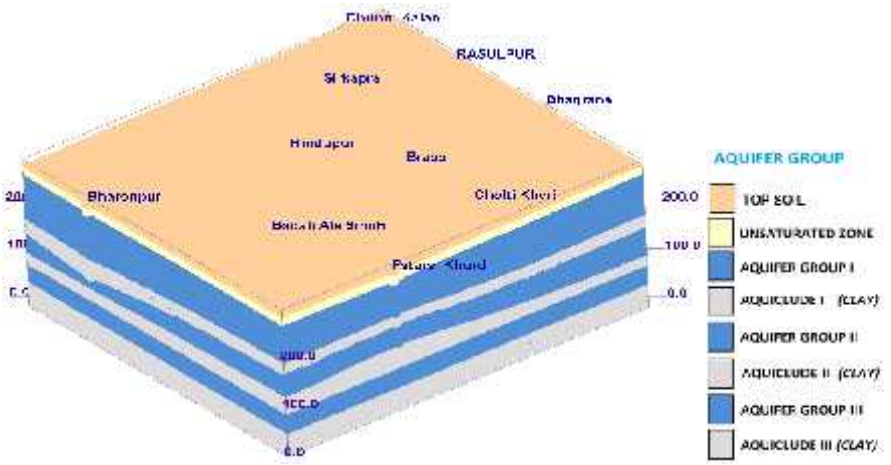
Lithological Cross section from Badali Ala Singh to Chunni Kalan



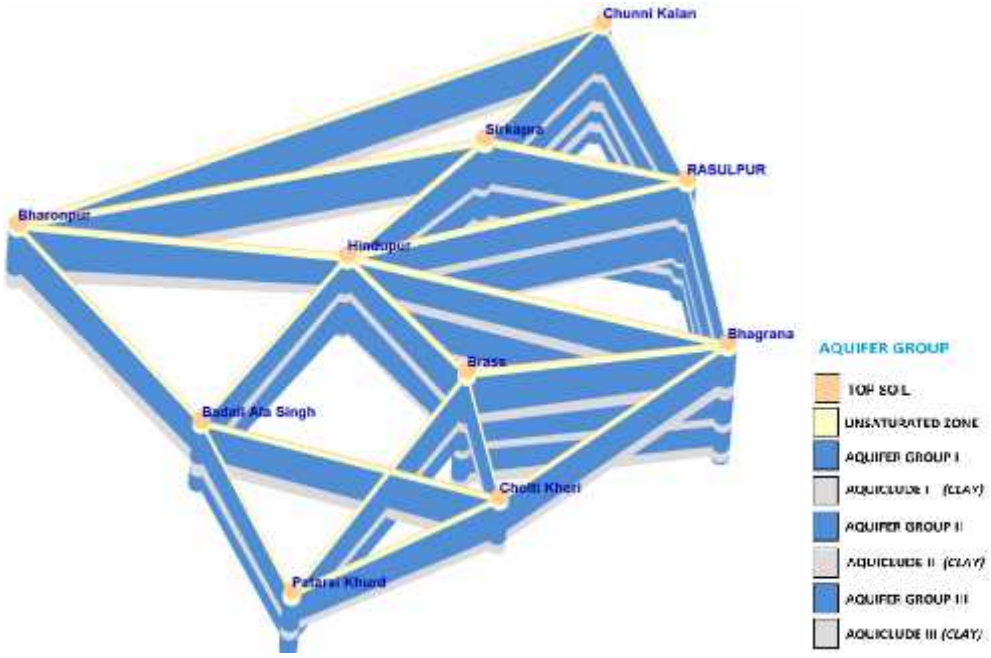
3-D Lithological Fence Diagram



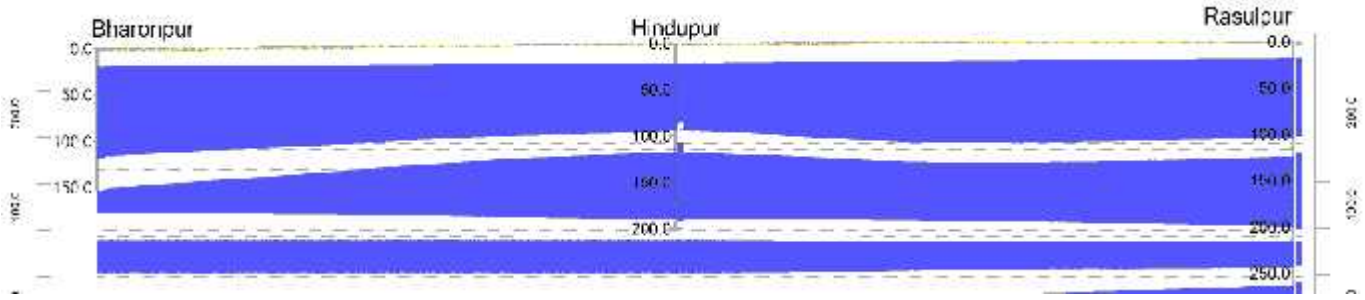
3-D Aquifer Disposition Model of Khera Block



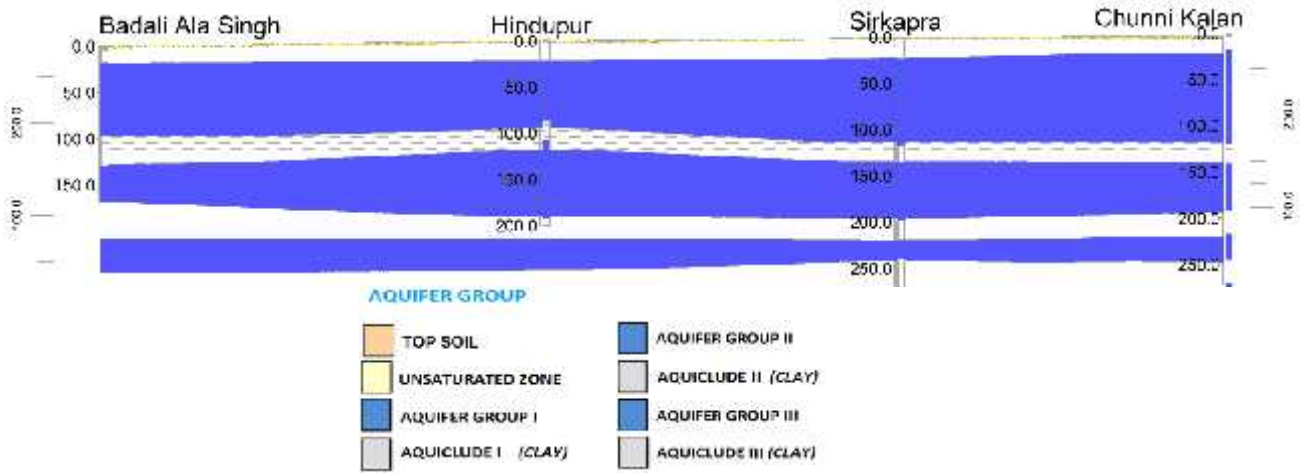
3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along East to West



Aquifer Cross section along North West to South East



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

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	95.67 mcm
	In-storage Aquifer-I (Specific Yield Concept)	624.84 mcm
	In-storage Aquifer-II (Specific Yield Concept)	520.70 mcm
	In-storage Aquifer-II (Storativity Concept)	39.55 mcm
	In-storage Aquifer-III (Specific Yield Concept)	364.49 mcm
	In-storage Aquifer-II (Storativity Concept)	43.78 mcm
	Total Resources	1689.04 mcm
Ground Water Extraction (as per 2013)	Irrigation	192.22 mcm
	Domestic & Industrial	1.59 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		2.04 mcm
Stage of Groundwater Development		203 %
Chemical Quality of ground water		Ground water in the area is alkaline in nature and pH ranges between 8.63 to 8.93. EC value of the ground water show wide variations and ranges from 597 µS/cm to 1587 µS/cm at 25^0C. RSC values are varies from -3.05 to 3.28 meq/L and the area is fit for irrigation.

Ground water Contamination Issues	***Iron(mg/l):*** Bhagrana (13.04)
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: 173.57 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 2.36 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Khera Block (180.80 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 43.85 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: *35% of the total rice area needs to change i.e.* 50.18 sq km
Anticipated volume of water to be saved: 50.18 mcm

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 (%)*	*Reduction in Stage of develop-ment after Maize/ soya bean (%)*	*Crop Diversified area (%)*
95.67	192.22	193.81	132.04	50.18	50.18	142.04	203	54.53	35

Alternate Water sources

Surface water sources: *Tanks, Ponds*
No.of Water tanks: 45
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.

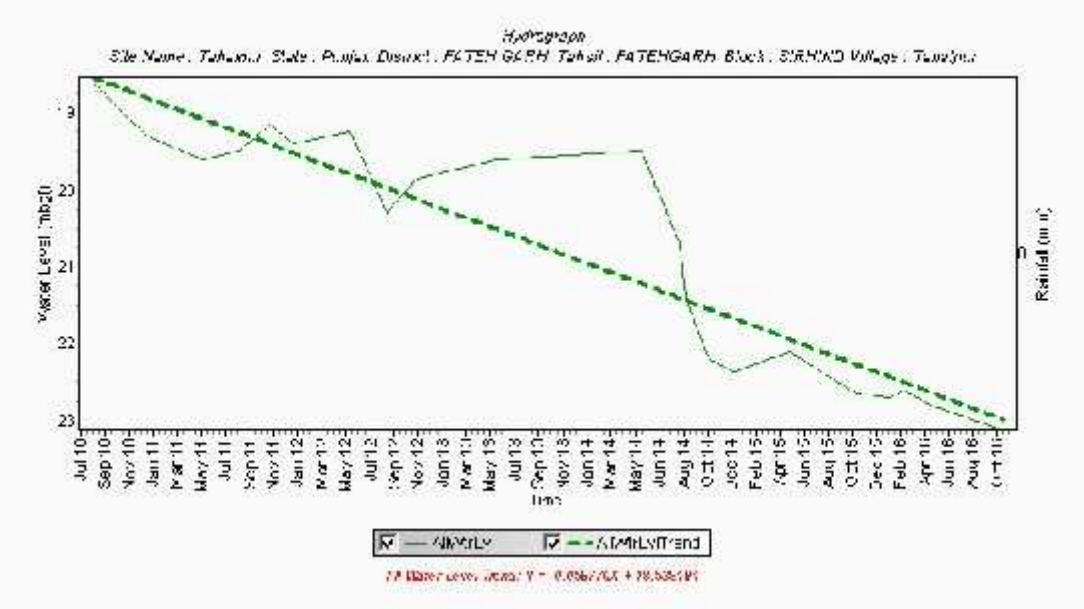
II. Salient Information of Sirhind Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>372.40 sq km</td></tr>
<tr><td>District/ State</td><td>Fatehgarh Sahib, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 0
Rural Population: 95543
Total population: 95543</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 530 mm
Non-monsoon Rainfall : 119 mm
Annual Average Rainfall: 649 mm</td></tr>
<tr><td>Agriculture and Irrigation</td><td>Principal crops: Wheat, Rice, Sugar cane, and Maize
Other crops: Vegetables and Fodder
Gross cropped area: 478.21 sq km
Net sown area: 242.57 sq km
Irrigation practices: Tube well and Canal Irrigation
Cropping intensity: 197%
<u>Area under</u>
Ground water Irrigation: 236.67 sq km
Surface water irrigation: 11.76 sq km
Gross Irrigated area: 477.68 sq km
Net Irrigated area: 264.82 sq km
Number and types of abstraction structures: 10630, 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 300m 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>17.89 – 107.0</td><td>89</td><td>61</td><td>1560.2</td></tr>
<tr><td>Aquifer-II</td><td>129.0 – 194.0</td><td>65</td><td>28</td><td>830.97</td></tr>
<tr><td>Aquifer-III</td><td>230.0 – 300.0</td><td>70</td><td>24</td><td>758.12</td></tr>
</table>
Total Ground Water Resources available is 3149.29 mcm and total potential granular zones available are 113 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	*Existing Gross Ground water Draft as on 2013* Irrigation: 304.40 mcm Domestic and industrial water supply: 3.52 mcm *Future water demands* Irrigation development potential : (-)142.96 mcm Domestic and industrial water supply up to 2025 years : 4.49 mcm Water Scarcity Villages: 103
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 17.00 – 24.40 m bgl Post Monsoon: 17.22 – 24.60 m bgl Seasonal Fluctuation: (-)0.20 – (-)1.55 m/yr Mean (10 yrs) : (-)0.70 – (-)3.35 m/yr *Trends* Pre Monsoon: (-)0.69 m/yr Post Monsoon: (-)0.76 m/yr **Aquifer-II** Pre Monsoon: 22.10 m bgl Post Monsoon: 22.40 m bgl **Aquifer-III** Pre Monsoon: 24.24 m bgl Post Monsoon: 24.83 m bgl

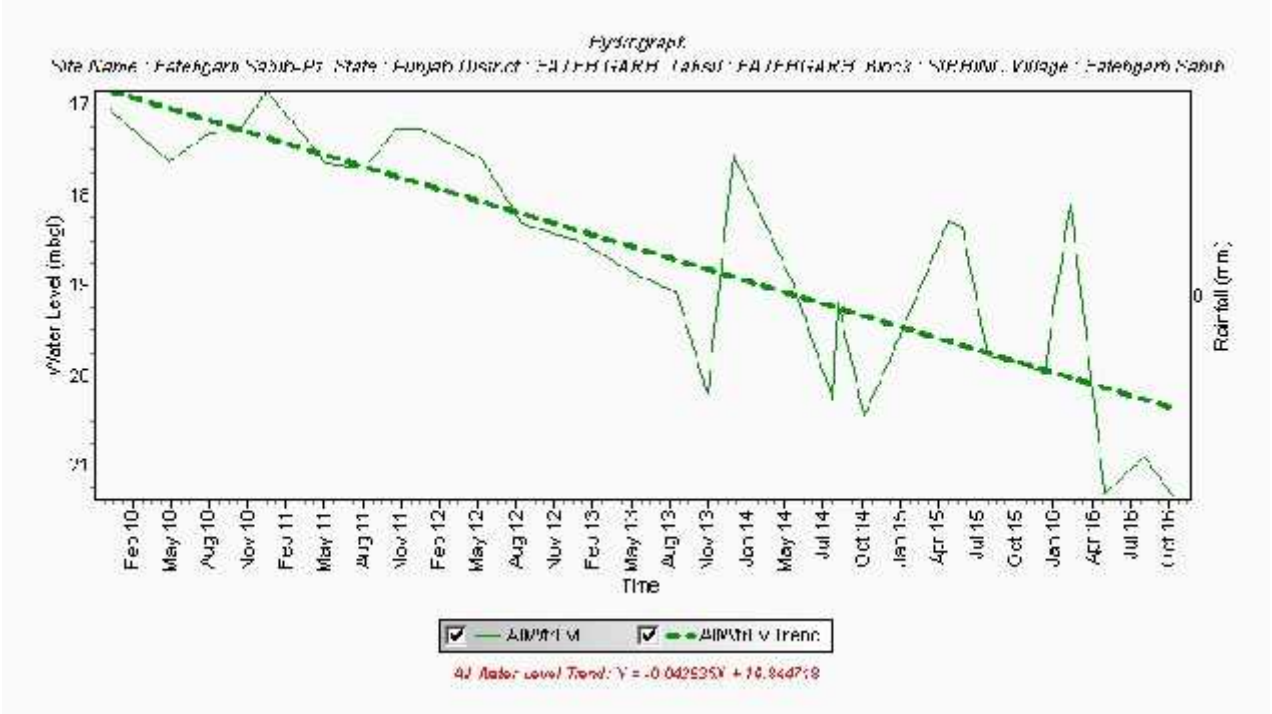
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Tahalpur)



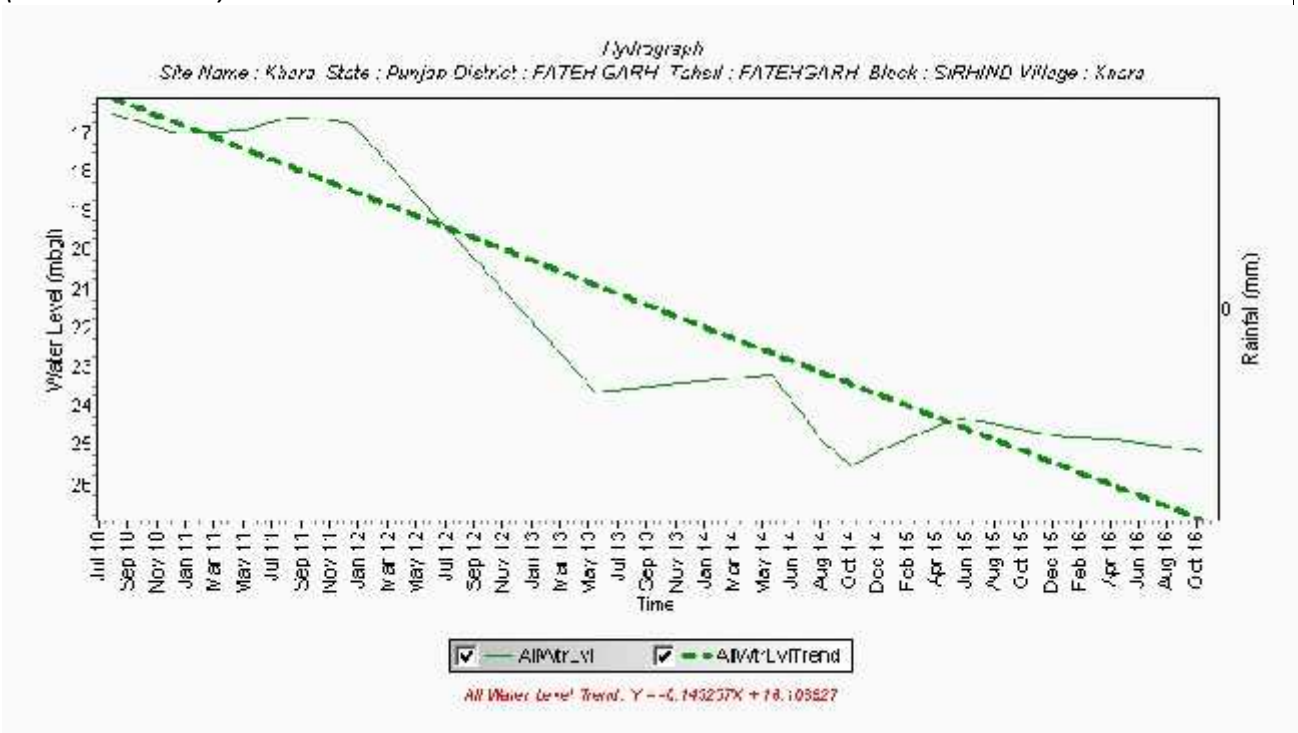
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Fatehgarh sahib)



HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Khara)



Aquifer Disposition

Number of aquifers	1
Principal aquifer	Alluvium
Major Aquifer	Older Alluvium
Aquifer Disposition	Multiple Aquifer System (Two 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	1	1	**4**
WRED/PSTC/WSS	7	12	0	1	**20**
PRIVATE	0	6	0	0	**6**
TOTAL	**8**	**19**	**1**	**2**	**30**

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 (17.89 -107 m)	Quarter-nary Alluvial deposits	Unconfined to confined	61	4222	4693	12 % *(0.072)*	1.50×10^{-3}
Aquifer-II (129 - 194 m)		Semi confined to Confined	28				
Aquifer-III (230 - 300m)		Semi confined to Confined	24	500	1325	NA	6.94×10^{-4}

* Well field proposed in this block (Site: Inayat pur), NA : Not Available

Source: CGWB,2015 & PSTC,2008

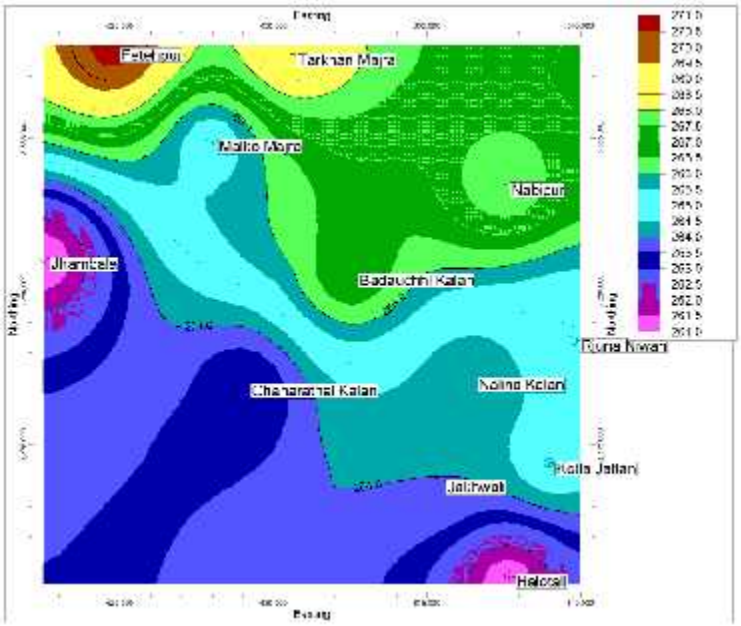
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

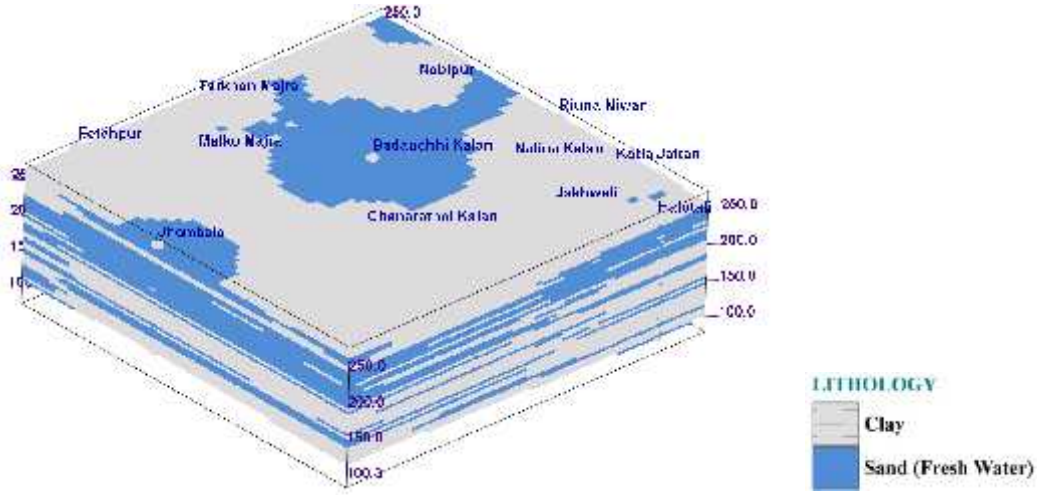
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	1	0	1	**2**
WRED/PSTC/WSS	0	7	0	0	**7**
PRIVATE	0	2	0	0	**2**
TOTAL	**0**	**10**	**0**	**1**	**11**

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

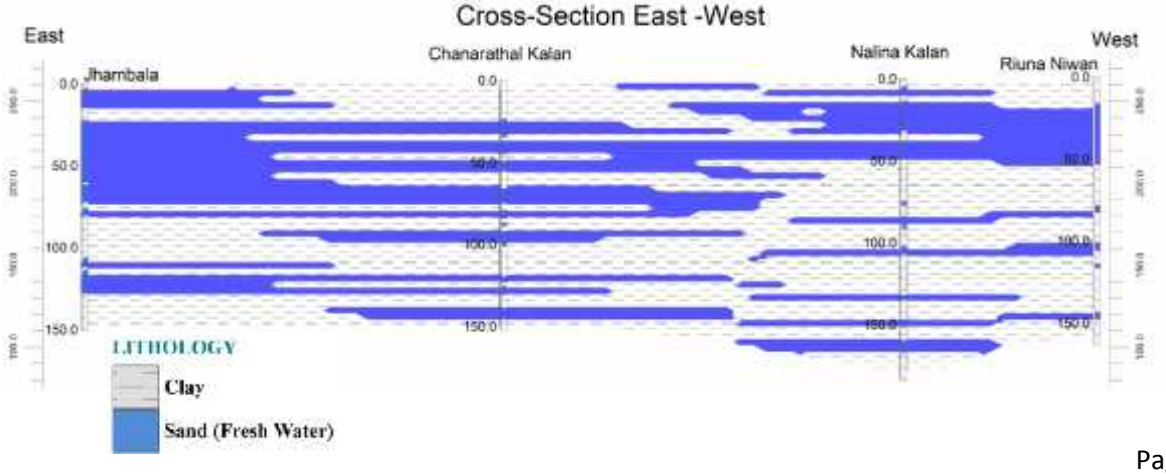
Elevation Map of Sirhind Block



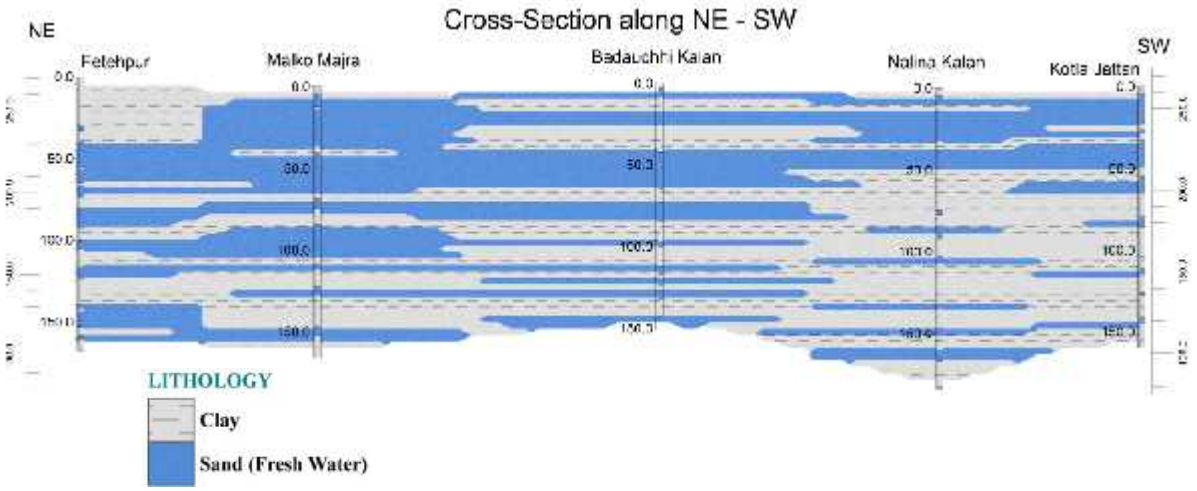
3-D Lithological model of Sirhind Block



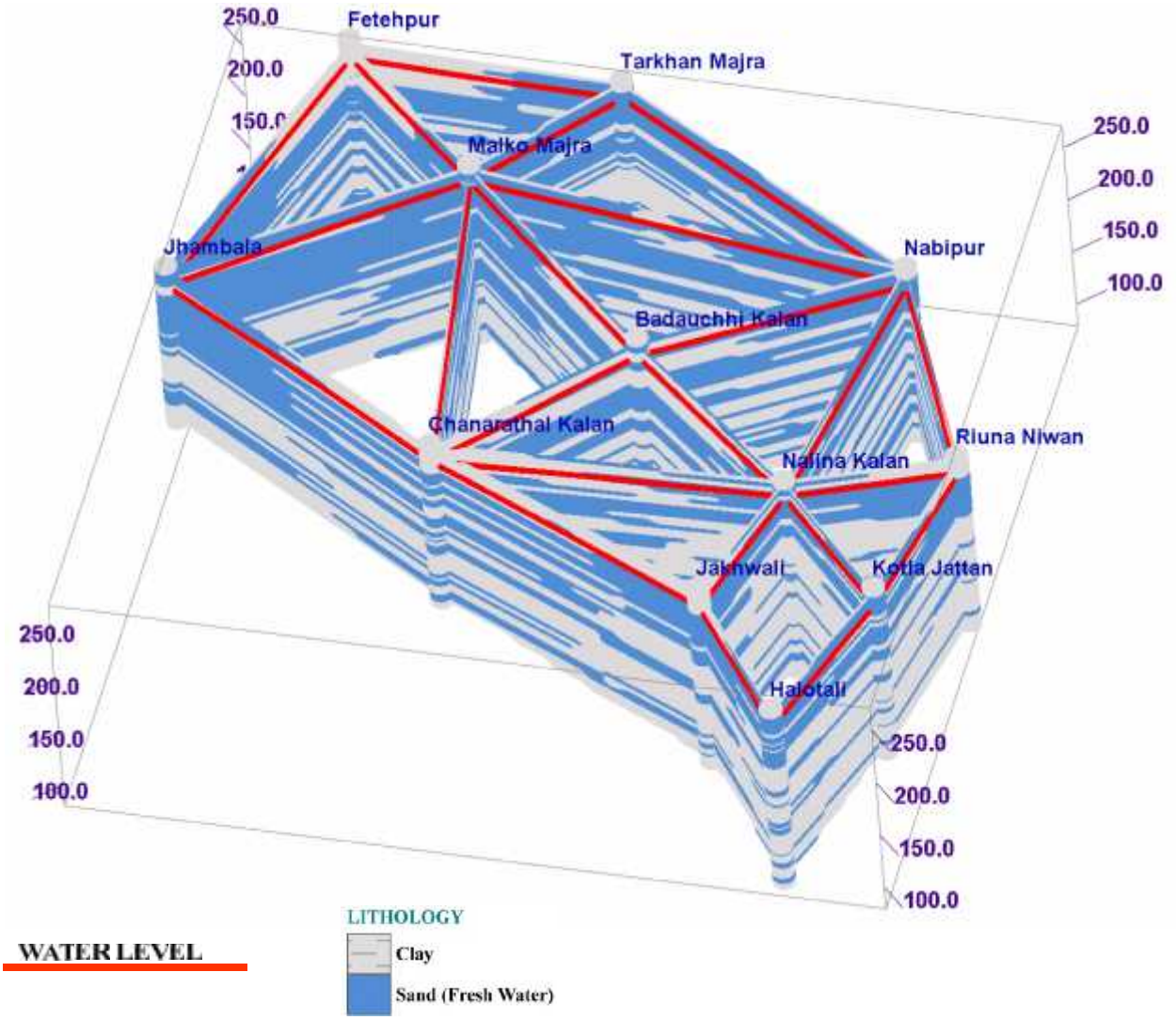
Lithological Cross section from Jhambala to Riuna Niwan



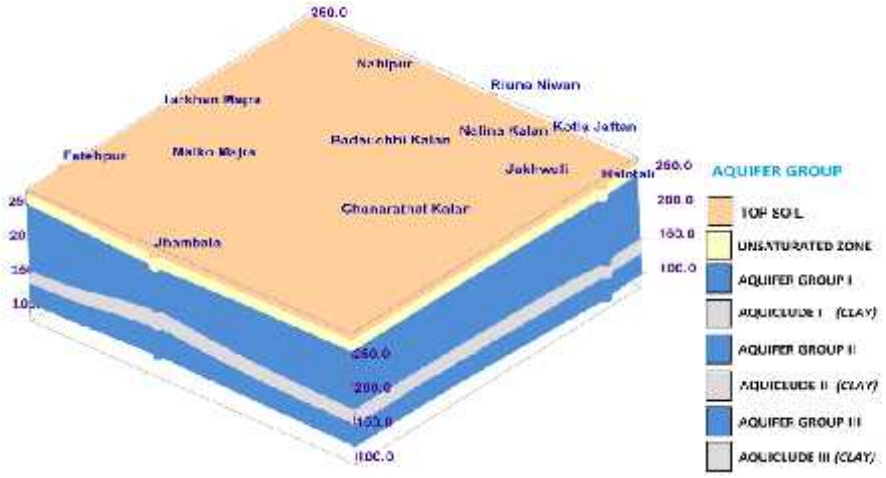
Lithological Cross section from Fatehpur to Kotla Jattan



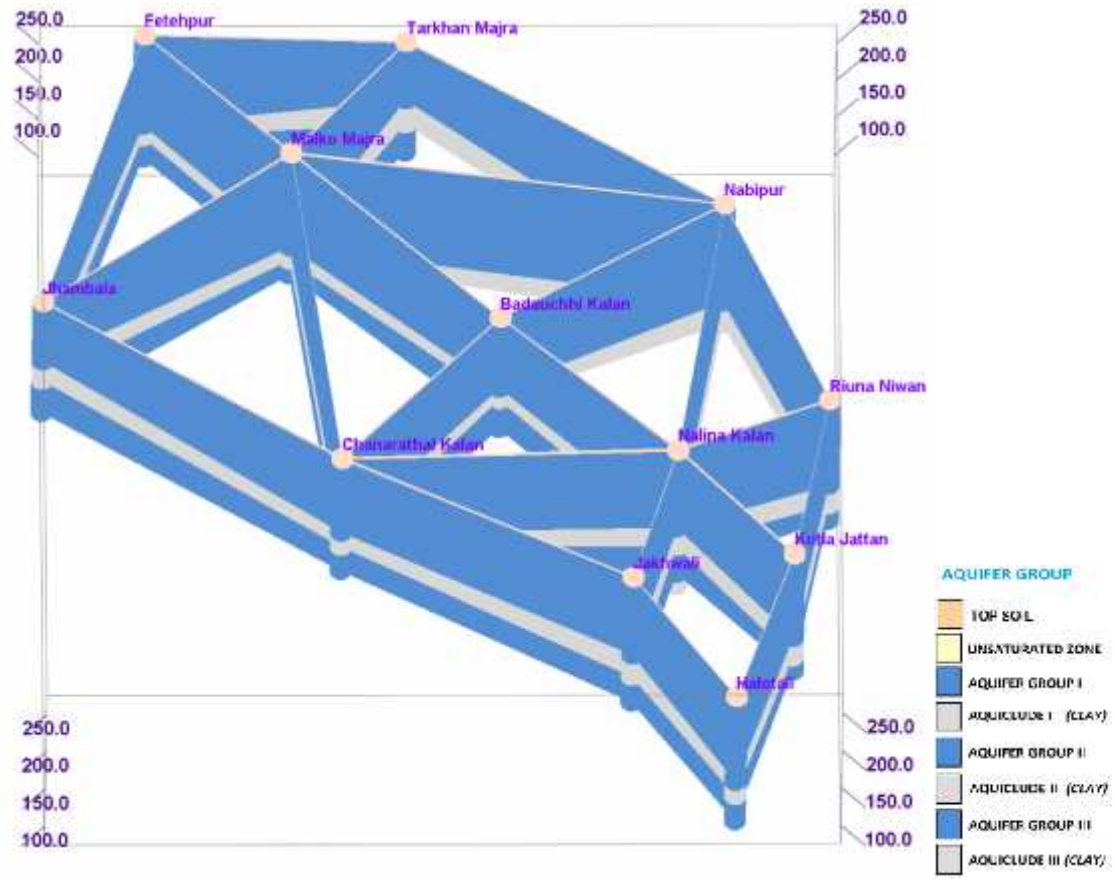
3-D Lithological Fence Diagram



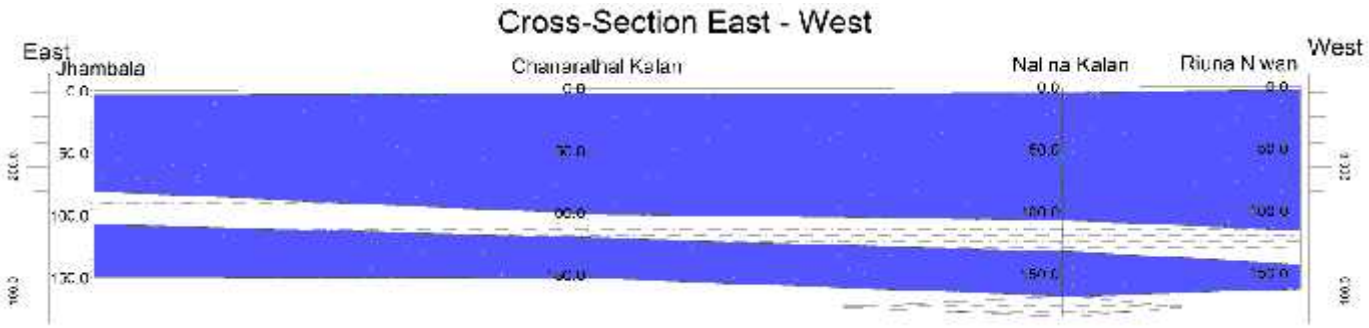
3-D Aquifer Disposition Model of Sirhind Block



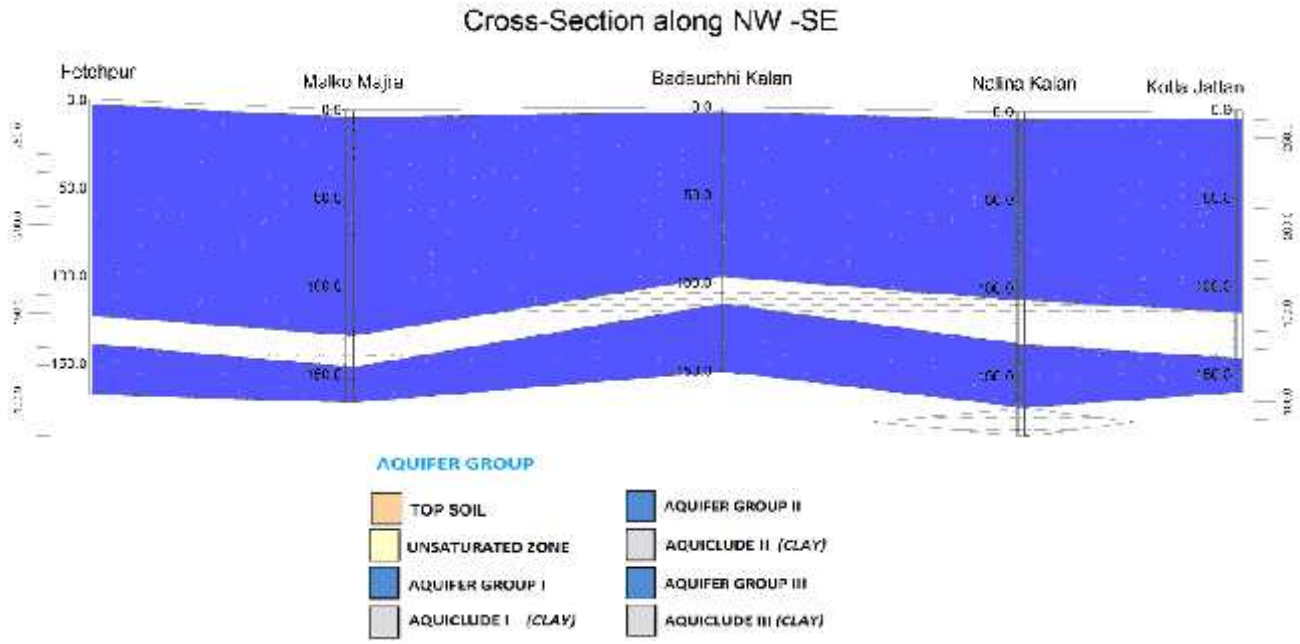
3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along East to West



Aquifer Cross section along North West to South East



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

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	165.93 mcm
	In-storage Aquifer-I (Specific Yield Concept)	1394.27 mcm
	In-storage Aquifer-II (Specific Yield Concept)	429.00 mcm
	In-storage Aquifer-II (Storativity Concept)	80.21 mcm
	In-storage Aquifer-III (Specific Yield Concept)	0 mcm
	In-storage Aquifer-II (Storativity Concept)	0 mcm
	Total Resources	2069.42 mcm

Ground Water Extraction (as per 2013)	Irrigation	304.40 mcm
	Domestic & Industrial	3.52 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		4.49 mcm
Stage of Groundwater Development		203 %
Chemical Quality of ground water		Ground water of Aquifer-I is alkaline in nature and pH ranges between 8.84 to 8.86. EC value of the ground water ranges from 541 μS/cm to 601 μS/cm at 25^0C. RSC values are varies from 1.08 to 2.08 meq/L and the area is fit for irrigation. Ground water of Aquifer-II is alkaline in nature, potable for drinking and fit for irrigation. Ground water of Aquifer-III is alkaline in nature, potable for drinking and fit for irrigation.
Ground water Contamination Issues		***Iron(mg/l):*** Fatehgarh Sahib (4.53)
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: 402.19mcm
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 3.09 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Sirhind Block (372.4 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 69.45 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: *35% of the total rice area needs to change i.e.* 48.18 sq km

Anticipated volume of water to be saved: 48.18 mcm

Net Annual Ground Water Availability 2013 (mcm)	*Total Irrigation 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 development (%)*	*Reduction in Stage of development after Maize/ soya bean (%)*	*Crop Diversified area (%)*
165.93	304.40	307.92	219	48.18	48.18	256.22	186	31.59	22

Alternate Water sources

Surface water sources: *Tanks, Ponds*

No.of Water tanks: 51

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

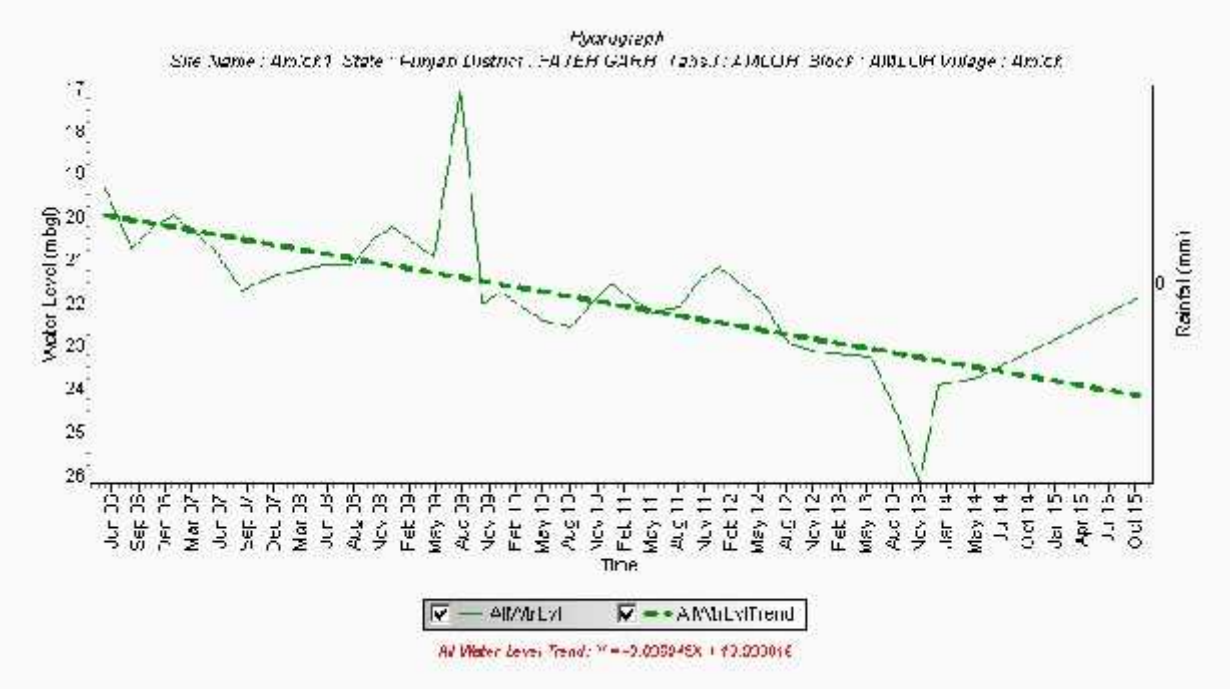
Other than that by 15 days ponding followed by 2 days of drying can lead to 25% saving of water in paddy crop.

III. Salient Information of Amloh Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>222 sq km</td></tr>
<tr><td>District/ State</td><td>Fatehgarh Sahib, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 9136
Rural Population: 106090
Total population: 115226</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 510 mm
Non-monsoon Rainfall : 151 mm
Annual Average Rainfall: 661 mm</td></tr>
<tr><td>Agriculture and Irrigation</td><td>Principal crops: Rice, Wheat, Sugar cane, and Maize
Other crops: Vegetables and Fodder
Gross cropped area: 422.04 sq km
Net sown area: 215.54 sq km
Irrigation practices: Tube well and Canal Irrigation
Cropping intensity: 196%
<u>Area under</u>
Ground water Irrigation: 220.94 sq km
Surface water irrigation: 4.11 sq km
Gross Irrigated area: 420.58 sq km
Net Irrigated area: 219.69 sq km
Number and types of abstraction structures: 7907, 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>20.46 – 109.0</td><td>89</td><td>70</td><td>1088.92</td></tr>
<tr><td>Aquifer-II</td><td>123.0 – 179.0</td><td>56</td><td>40</td><td>683.16</td></tr>
<tr><td>Aquifer-III</td><td>208.0 – 300.0</td><td>29</td><td>29</td><td>514.77</td></tr>
</table>
Total Ground Water Resources available is 2286.86 mcm and total potential granular zones available are 139 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>

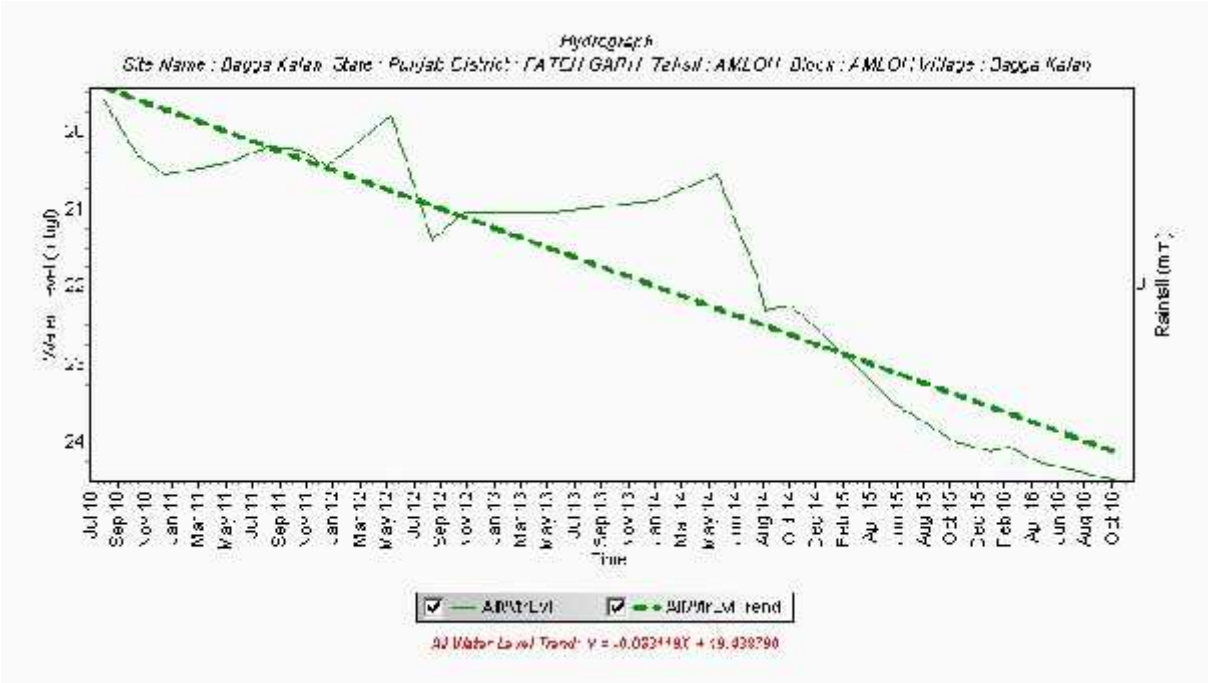
Existing and future water demands	*Existing Gross Ground water Draft as on 2013* Irrigation: 239.28 mcm Domestic and industrial water supply: 11.25 mcm *Future water demands* Irrigation development potential : (-)121.93 mcm Domestic and industrial water supply up to 2025 years : 12.53 mcm Water Scarcity Villages: 97
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 20.45 – 23.35 m bgl Post Monsoon: 20.95 – 24.00 m bgl Seasonal Fluctuation: (-)0.30 – (-)0.65 m/yr Mean (10 yrs) : (-)1.72 – (-)3.22 m/yr *Trends* Pre Monsoon: (-)0.35 – (-)0.83m/yr Post Monsoon: (-)0.33 – (-)0.75 m/yr **Aquifer-II &III** No Monitoring Stations

HYDROGRAPH SHOWING DECLINING WATER TABLE
(Location: Amloh)



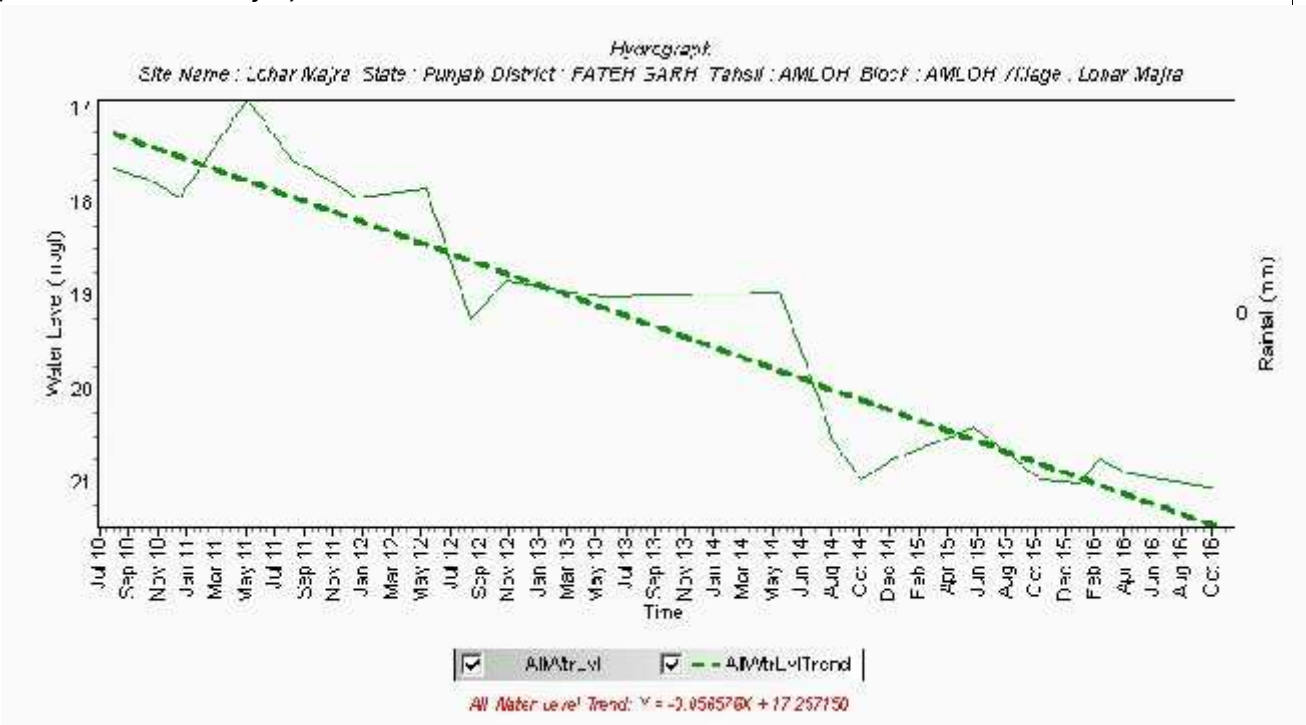
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Bagga Kalan)



HYDROGRAPH SHOWING RISING WATER TABLE

(Location: Lohar majra)



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	1	1	0	**2**
WRED/PSTC/WSS	5	10	0	0	**15**
PRIVATE	0	6	1	0	**7**
TOTAL	**5**	**17**	**2**	**0**	**24**

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 (20.46 -109 m)	Quarter-nary Alluvial deposits	Unconfined to confined	70	NA	NA	12 % *(0.072)*	NA
Aquifer-II (123 - 179 m)		Semi confined to Confined	40				
Aquifer-III (208 - 300 m)		Semi confined to Confined	29	NA	NA	NA	NA

* Well field proposed in adjacent block , NA : Not Available

Source: CGWB,2015 & PSTC,2008

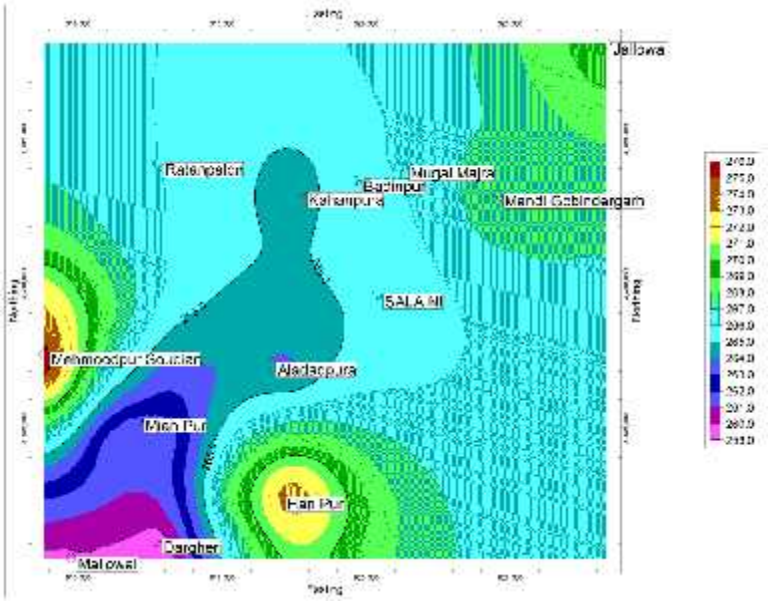
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

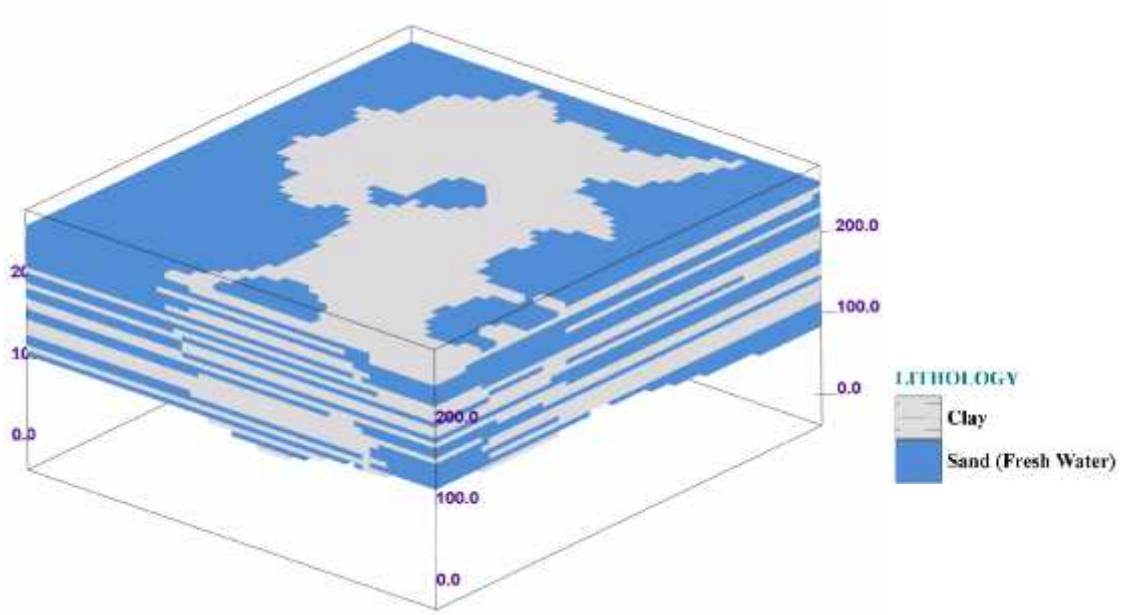
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	1	0	**1**
WRED/PSTC/WSS	0	8	0	0	**8**
PRIVATE	0	5	0	0	**5**
TOTAL	**0**	**13**	**1**	**0**	**14**

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

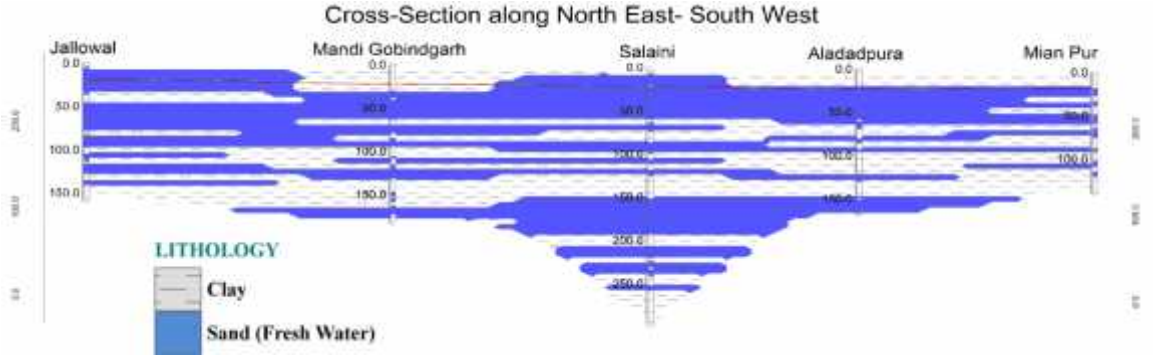
Elevation Map of Amloh Block



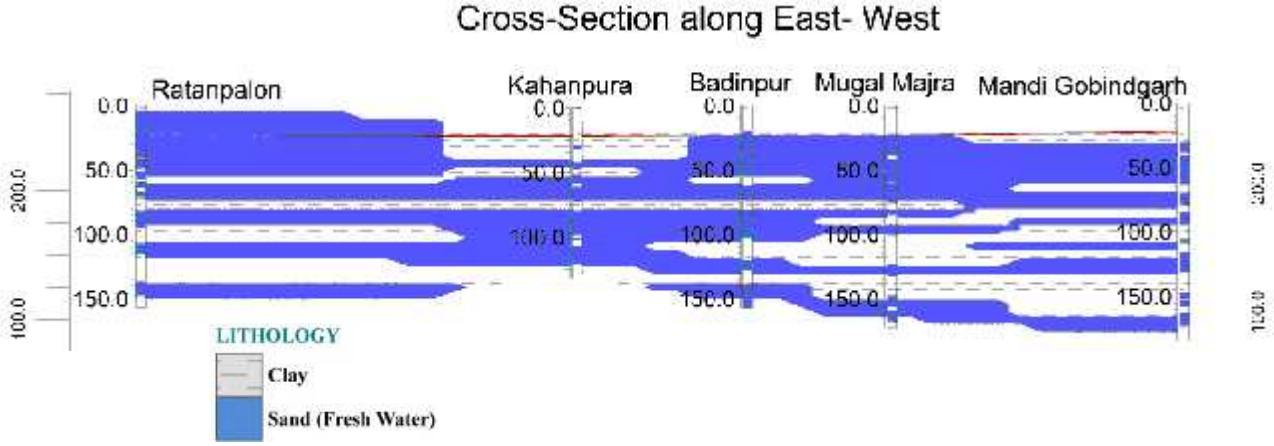
3-D Lithological model of Amloh Block



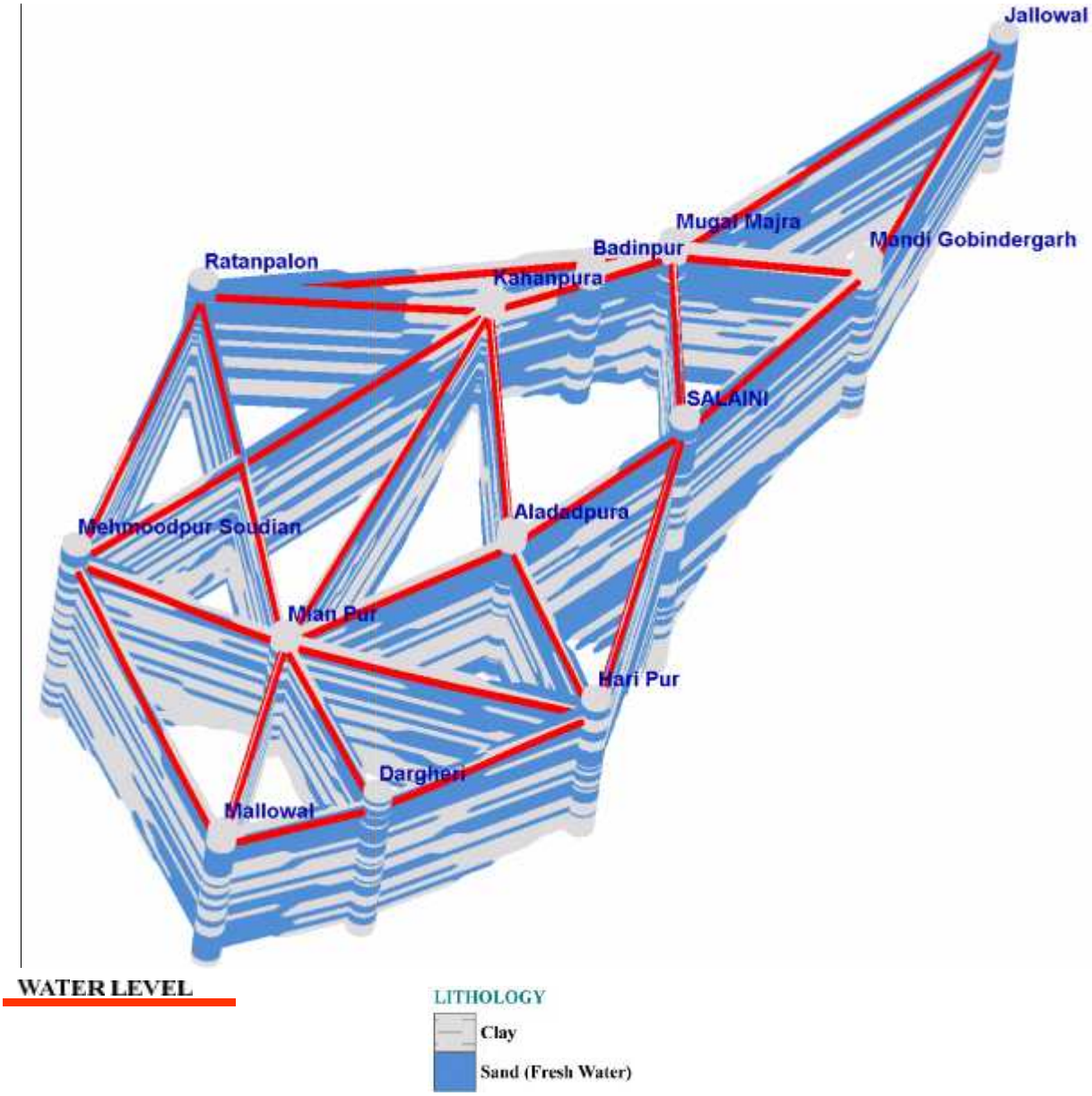
Lithological Cross section from Jallowal to Mianpur



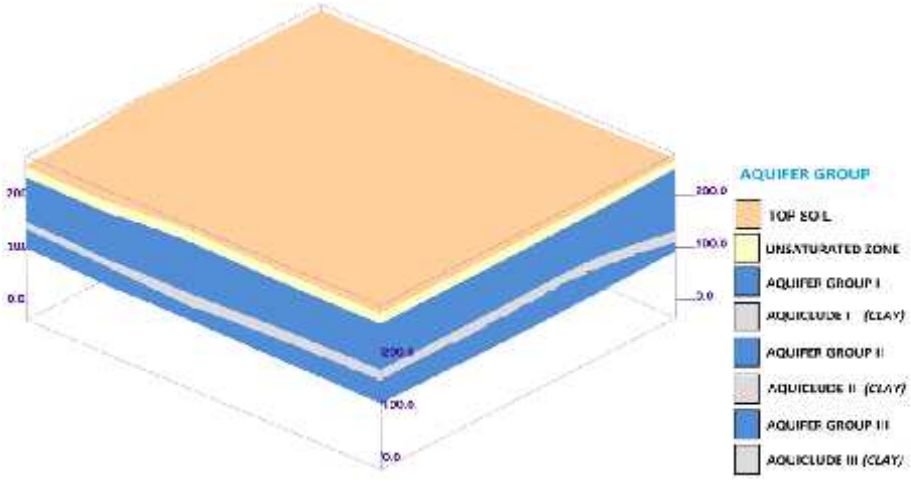
Lithological Cross section from Badali Ala Singh to Chunni Kalan



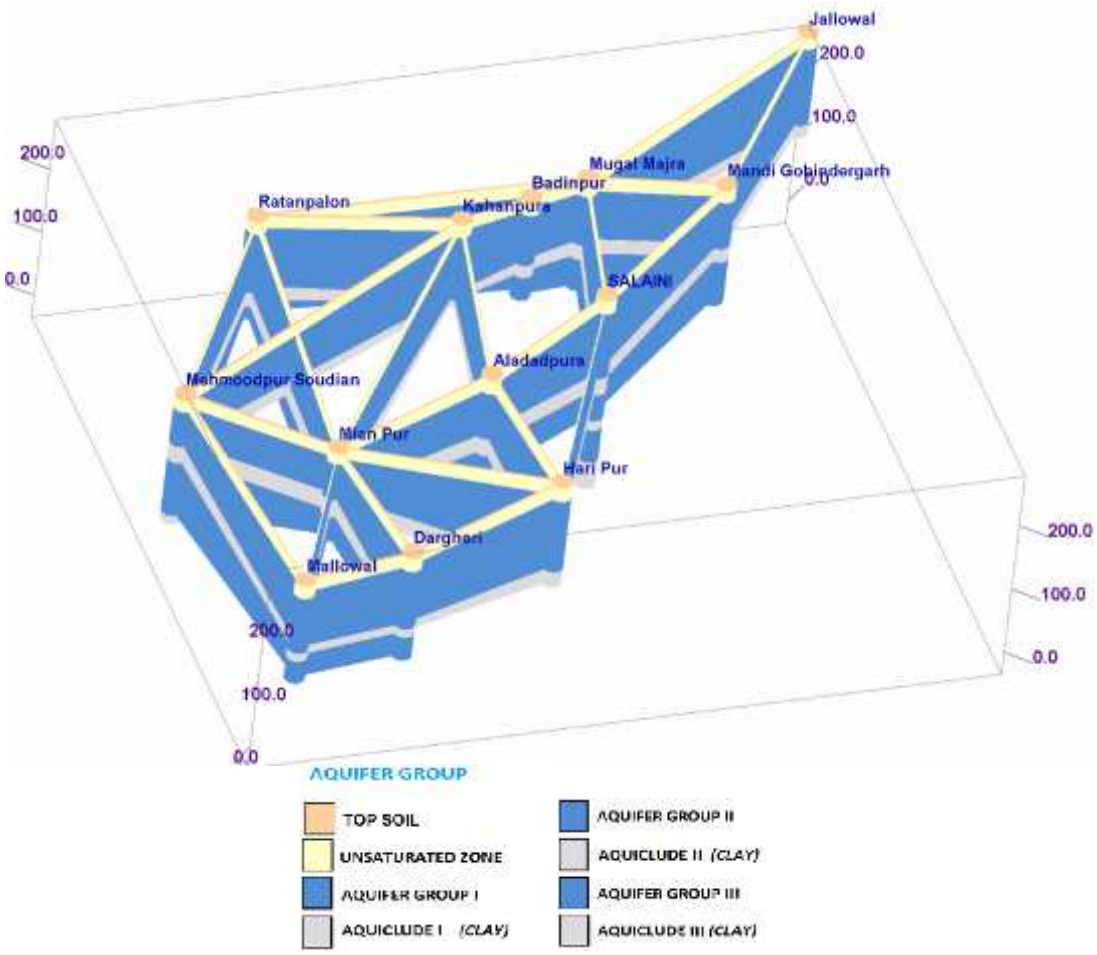
3-D Lithological Fence Diagram



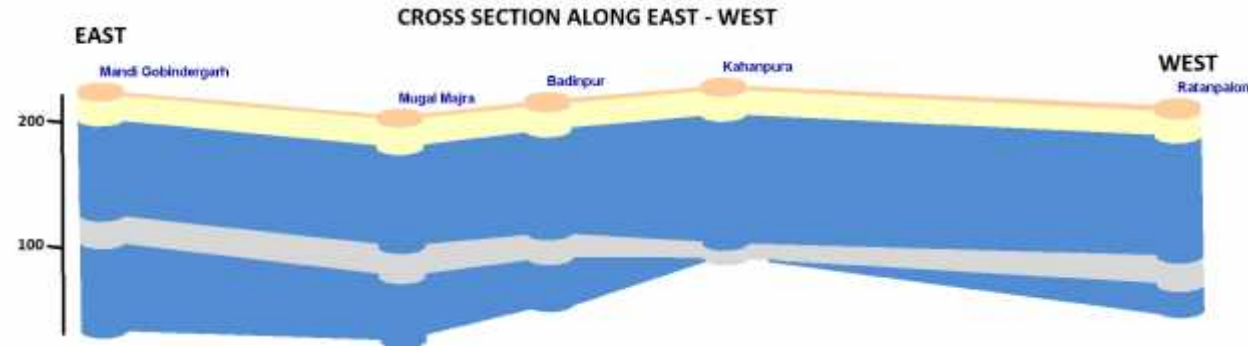
3-D Aquifer Disposition Model of Amloh Block



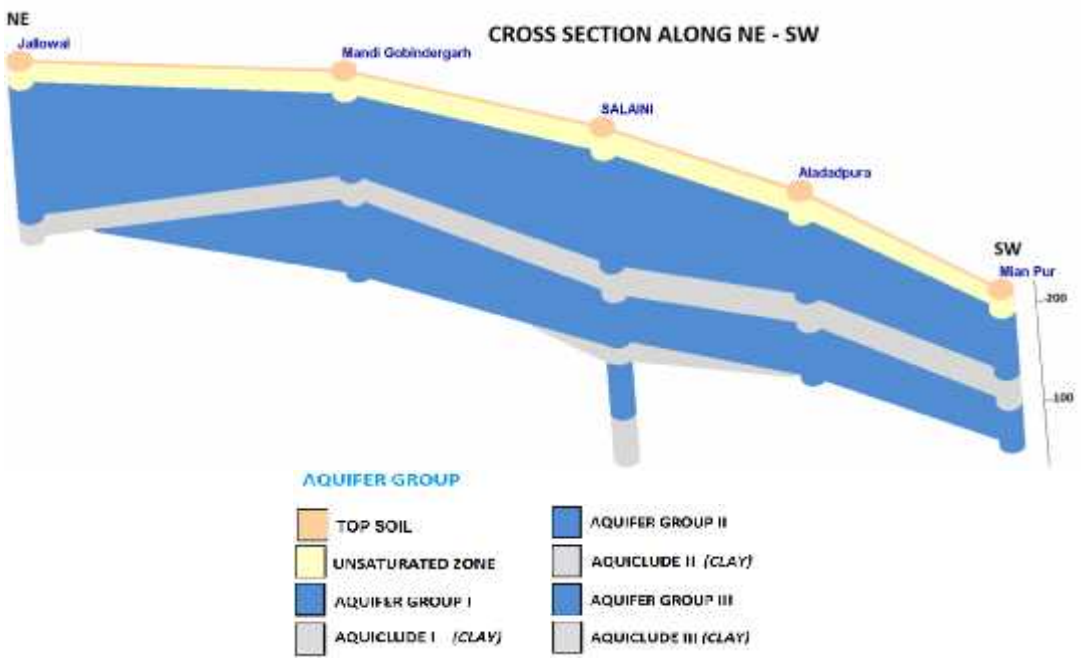
3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along East to West



Aquifer Cross section along North West to South East



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

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	129.88 mcm
	In-storage Aquifer-I (Specific Yield Concept)	959.04 mcm
	In-storage Aquifer-II (Specific Yield Concept)	639.36 mcm
	In-storage Aquifer-II (Storativity Concept)	43.80 mcm
	In-storage Aquifer-III (Specific Yield Concept)	463.54 mcm
	In-storage Aquifer-II (Storativity Concept)	51.24 mcm
	Total Resources	2286.86 mcm

Ground Water Extraction (as per 2013)	Irrigation	239.28 mcm
	Domestic & Industrial	11.25 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		12.53 mcm
Stage of Groundwater Development		193 %
Chemical Quality of ground water		Ground water in the area is alkaline in nature and pH value is 8.49 EC value of the ground water is 923 μS/cm at 25^0C. RSC value is -2.33 meq/L and the area is fit for irrigation.
Ground water Contamination Issues		***Iron(mg/l):*** Amloh (3.87) ***Nitrate(mg/l):*** Amloh (207)
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: 266.40 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 2.93 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Amloh Block (222 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 54.59 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: *35% of the total rice area needs to change i.e.* 46.80 sq km
Anticipated volume of water to be saved: 46.80 mcm

Net Annual Ground Water Availability 2013 (mcm)	*Total Irrigation 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 development (%)*	*Reduction in Stage of development after Maize/ soya bean (%)*	*Crop Diversified area (%)*
129.88	239.28	250.22	195	46.80	46.80	192.48	193	44.80	24

Alternate Water sources

Surface water sources: *Tanks, Ponds*

No.of Water tanks: 52

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 Bassi Pathana Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>186.50 sq km</td></tr>
<tr><td>District/ State</td><td>Fatehgarh Sahib, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 0
Rural Population: 60728
Total population: 60728</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 586 mm
Non-monsoon Rainfall : 158 mm
Annual Average Rainfall: 744 mm</td></tr>
<tr><td>Agriculture and Irrigation</td><td>Principal crops: Wheat, Rice, Sugar cane, and Maize
Other crops: Vegetables and Fodder
Gross cropped area: 320.89 sq km
Net sown area: 163.61 sq km
Irrigation practices: Tube well and Canal Irrigation
Cropping intensity: 196%
<u>Area under</u>
Ground water Irrigation: 154.43 sq km
Surface water irrigation: 10.71 sq km
Gross Irrigated area: 321.86 sq km
Net Irrigated area: 161.11 sq km
Number and types of abstraction structures: 6742, 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>18.20 – 105.0</td><td>87</td><td>66</td><td>835.03</td></tr>
<tr><td>Aquifer-II</td><td>123.0 – 190.0</td><td>67</td><td>32</td><td>469.08</td></tr>
<tr><td>Aquifer-III</td><td>227.0 – 300.0</td><td>73</td><td>22</td><td>342.92</td></tr>
</table>
Total Ground Water Resources available is 1647.03 mcm and total potential granular zones available are 120 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>

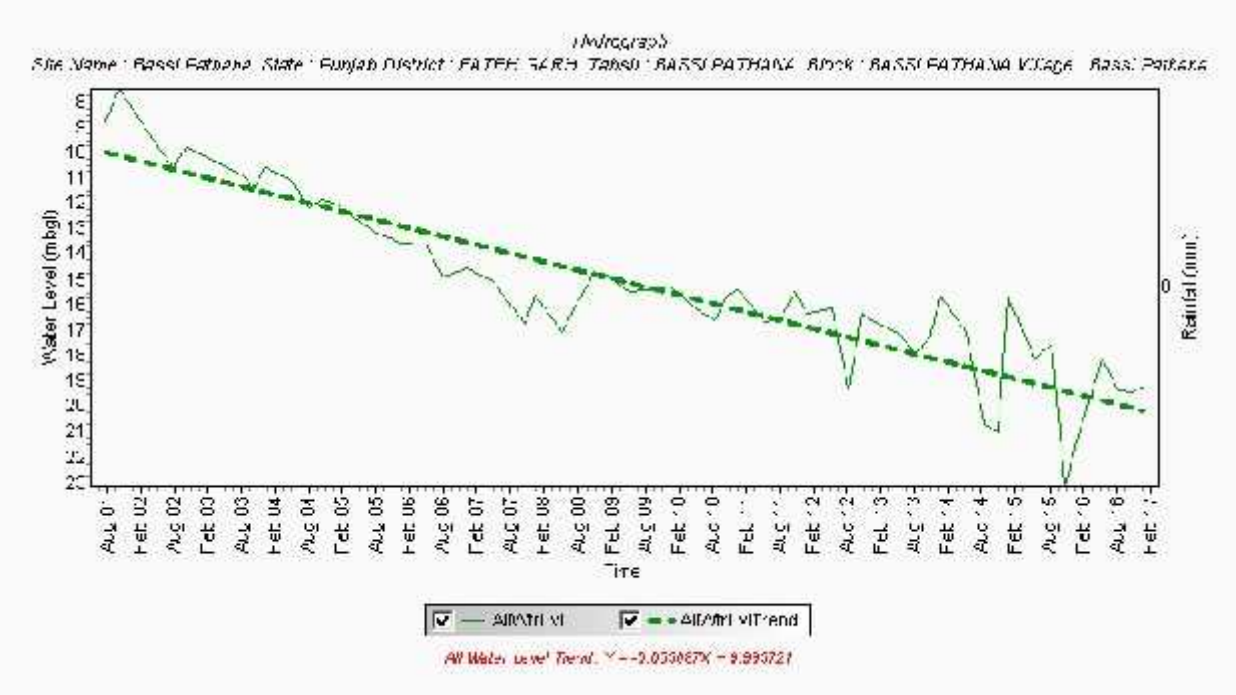
Existing and future water demands	*Existing Gross Ground water Draft as on 2013* Irrigation: 177.41 mcm Domestic and industrial water supply: 1.75 mcm *Future water demands* Irrigation development potential : (-)83.18 mcm Domestic and industrial water supply up to 2025 years : 2.25 mcm Water Scarcity Villages: 87
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 16.55 – 33.10 m bgl Post Monsoon: 16.95 – 31.62 m bgl Seasonal Fluctuation: 0.10 – (-)0.45 m/yr Mean (10 yrs) : (-)1.15 – (-)1.22 m/yr *Trends* Pre Monsoon: (-)0.32 – (-)0.59m/yr Post Monsoon: (-)0.40 – (-)0.70 m/yr **Aquifer-II &III** No Monitoring Stations

HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Bhateri)

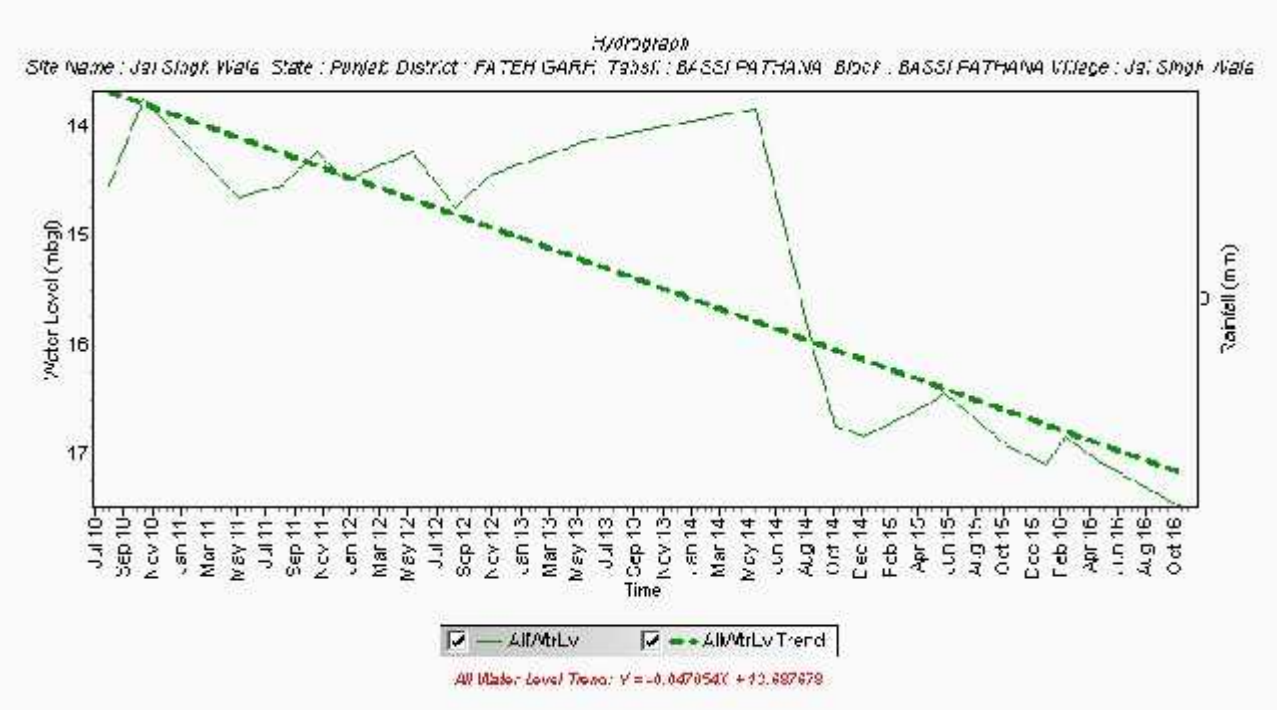
HYDROGRAPH SHOWING DECLINING WATER TABLE

(Location: Bassi Pathana)



HYDROGRAPH SHOWING RISING WATER TABLE

(Location: Jai Singh Wala)



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	1	0	**1**
WRED/PSTC/WSS	5	14	1	1	**21**
PRIVATE	0	6	1	1	**8**
TOTAL	**5**	**20**	**3**	**2**	**30**

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 (18.20 -105 m)	Quarter-nary Alluvial deposits	Unconfined to confined	66	1555	6110	12 % *(0.072)*	$1.2x\ 10^{-1}$
Aquifer-II (123 - 190 m)		Semi confined to Confined	32				
Aquifer-III (227 - 300 m)		Semi confined to Confined	22	NA	NA	NA	NA

* Well field proposed in adjacent block , NA : Not Available

Source: CGWB,2015 & PSTC,2008

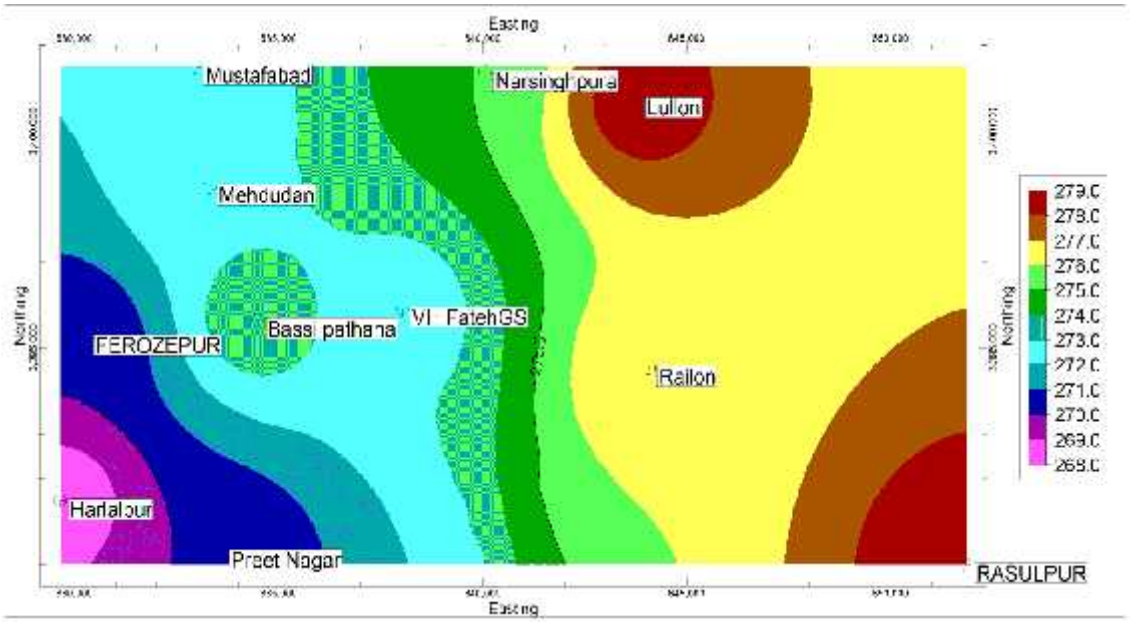
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

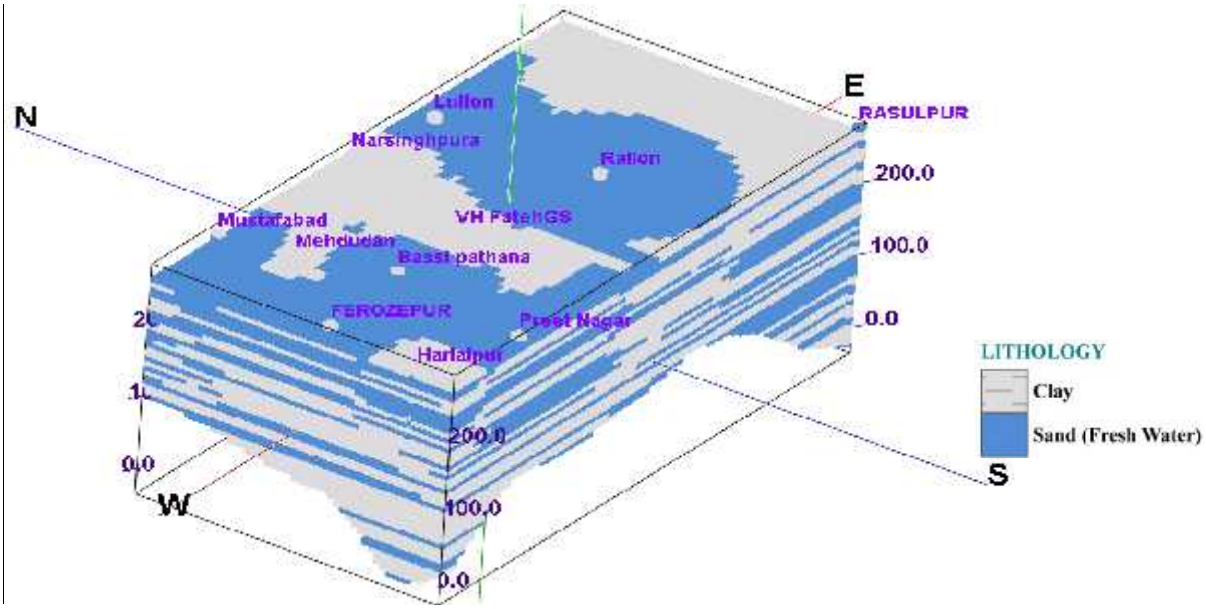
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	1	0	**1**
WRED/PSTC/WSS	0	1	1	1	**3**
PRIVATE	0	4	1	1	**6**
TOTAL	**0**	**5**	**3**	**2**	**10**

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

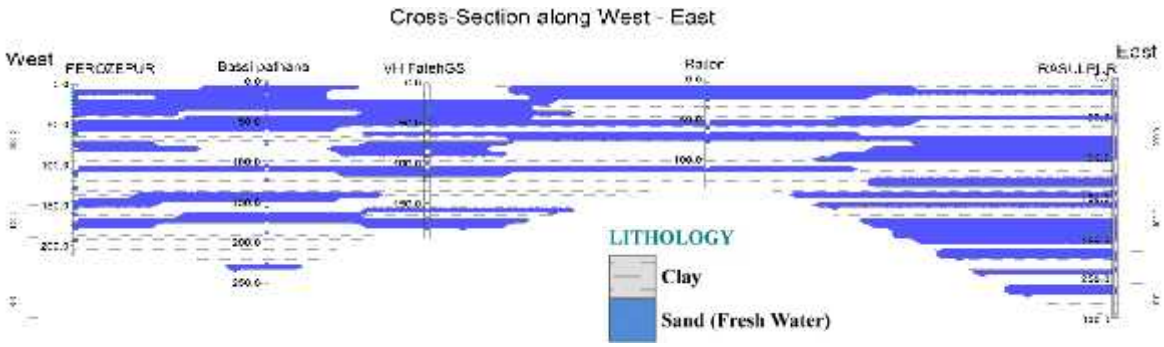
Elevation Map of Bassi Pathana Block



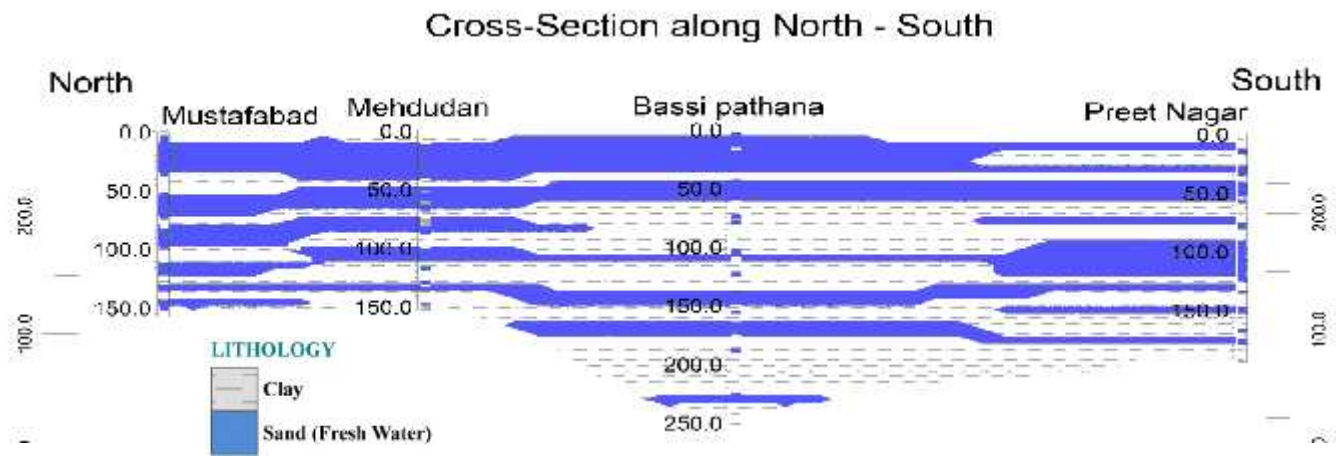
3-D Lithological model of Bassi Pathana Block



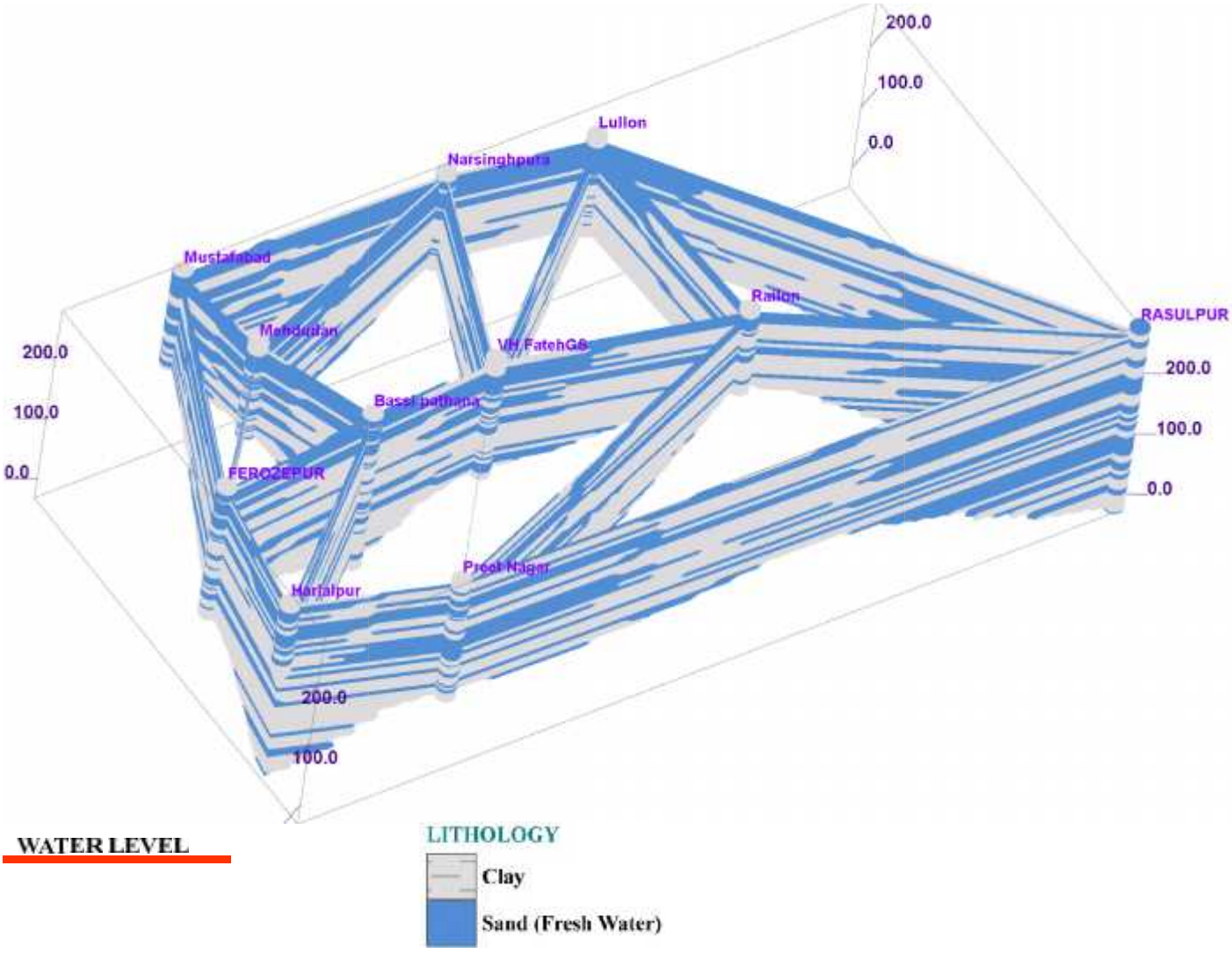
Lithological Cross section from Ferozpur to Rasulpur



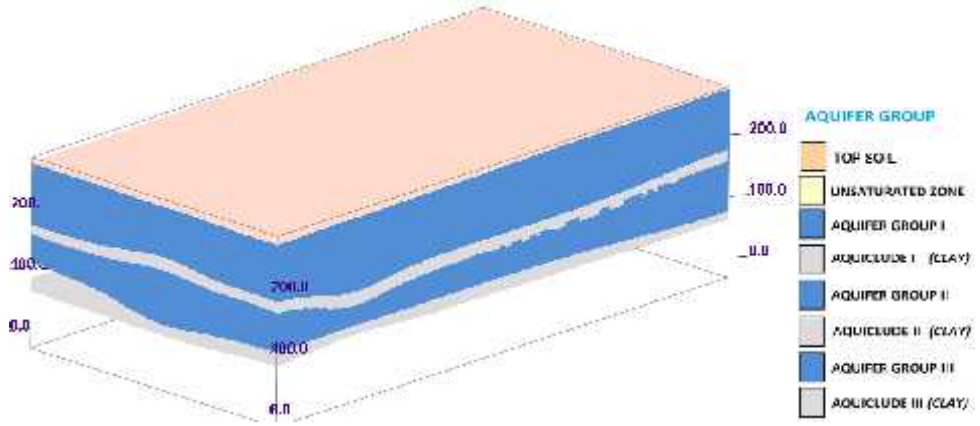
Lithological Cross section from Mustafabad to Preet Nagar



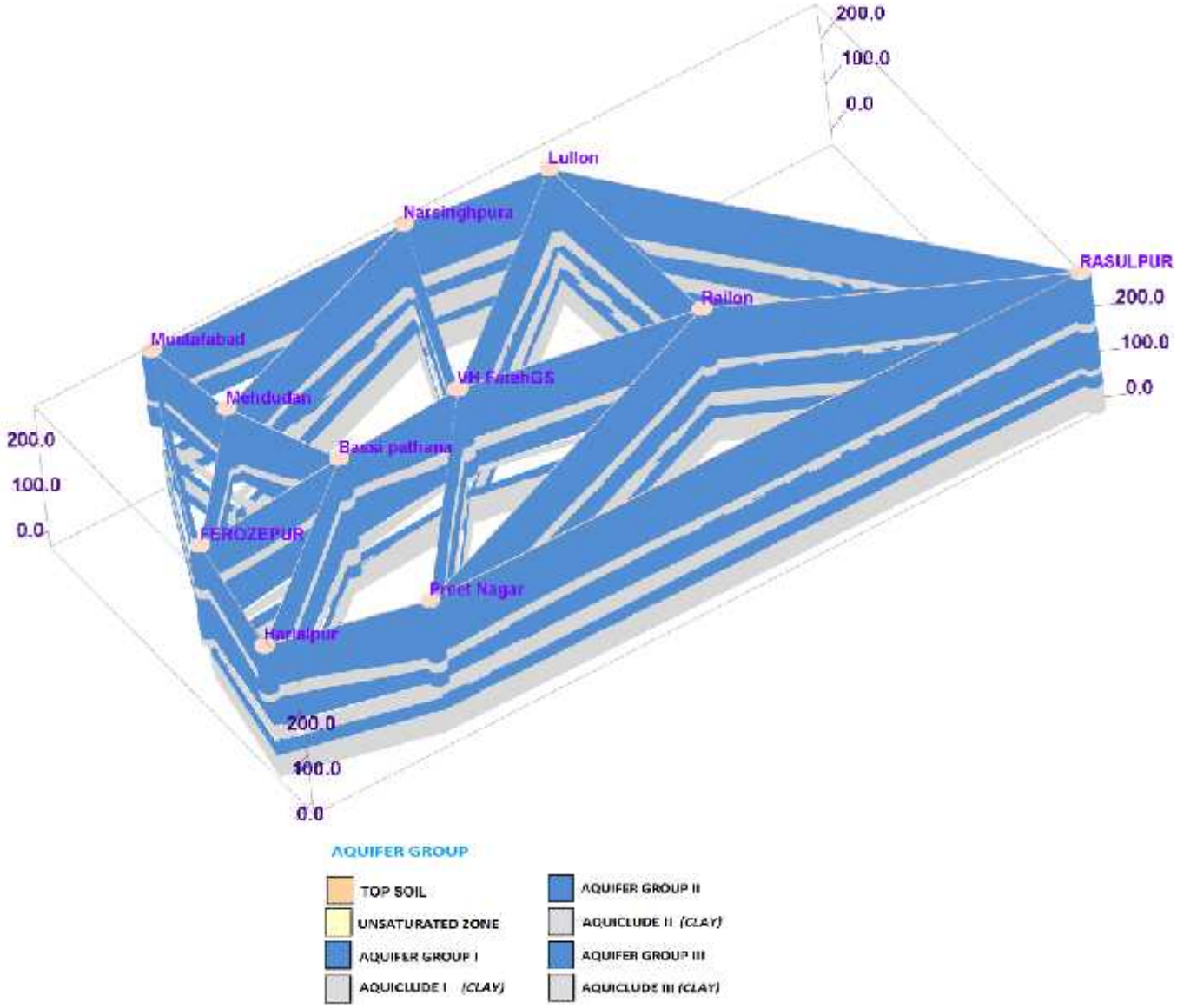
3-D Lithological Fence Diagram



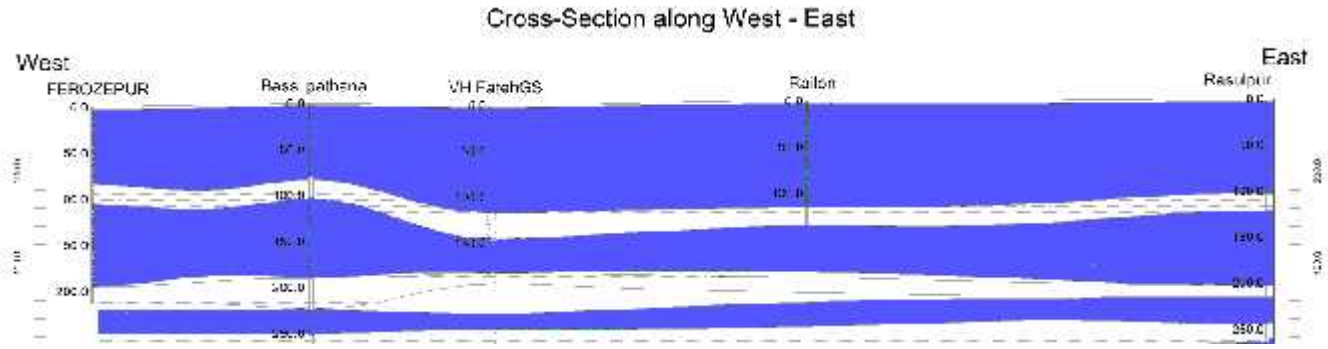
3-D Aquifer Disposition Model of Bassi Pathana Block



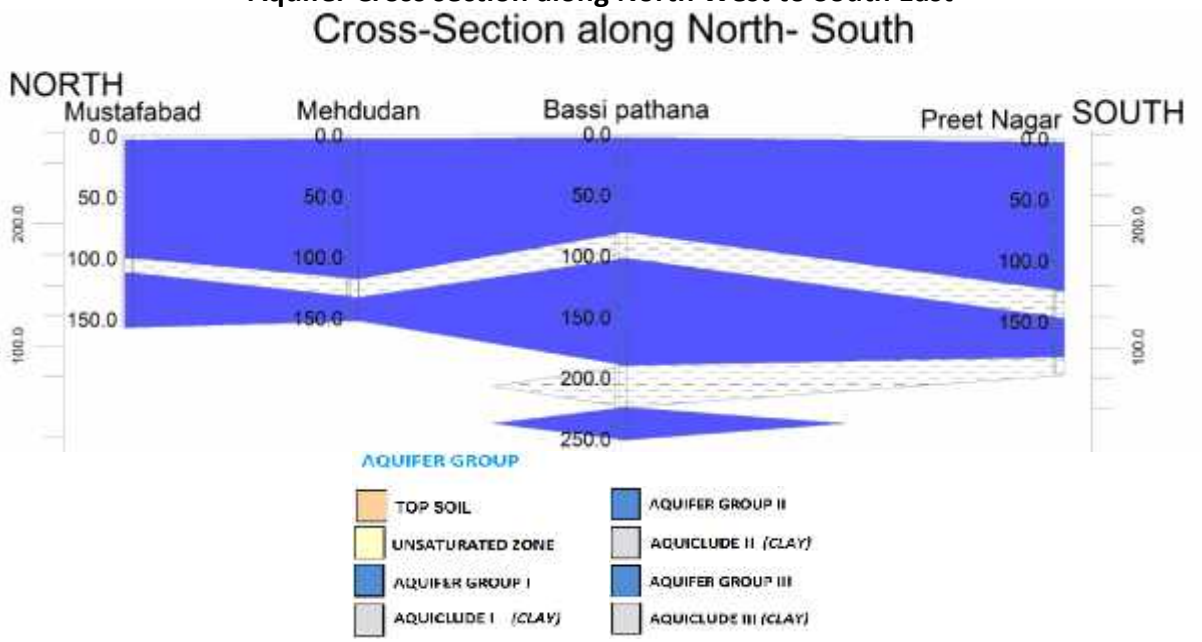
3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along East to West



Aquifer Cross section along North West to South East



Ground water Resource, Extraction, Contamination and other issues in Bassi PathanaBlock

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	96.49 mcm
	In-storage Aquifer-I (Specific Yield Concept)	738.54 mcm
	In-storage Aquifer-II (Specific Yield Concept)	429.70 mcm
	In-storage Aquifer-II (Storativity Concept)	39.38 mcm
	In-storage Aquifer-III (Specific Yield Concept)	295.42 mcm
	In-storage Aquifer-II (Storativity Concept)	47.51 mcm
	Total Resources	1647.03 mcm

Ground Water Extraction (as per 2013)	Irrigation	177.41 mcm
	Domestic & Industrial	1.75 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		2.25 mcm
Stage of Groundwater Development		186 %
Chemical Quality of ground water		Ground water in the area is alkaline in nature and pH value is 8.82 .EC value of the ground water is 456 μS/cm at 25^0C. RSC value is 1.38 meq/L and the area is fit for irrigation.
Ground water Contamination Issues		Not Available (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: 246.18 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 2.25 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Bassi Pathana Block (186.50 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 40.48 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: *35% of the total rice area needs to change i.e.* 42.28 sq km
Anticipated volume of water to be saved: 42.28 mcm

Net Annual Ground Water Availability 2013 (mcm)	*Total Irrigation 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 development (%)*	*Reduction in Stage of development after Maize/ soya bean (%)*	*Crop Diversified area (%)*
96.49	177.41	179.17	302	42.28	42.28	135.13	186	45.95	14

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

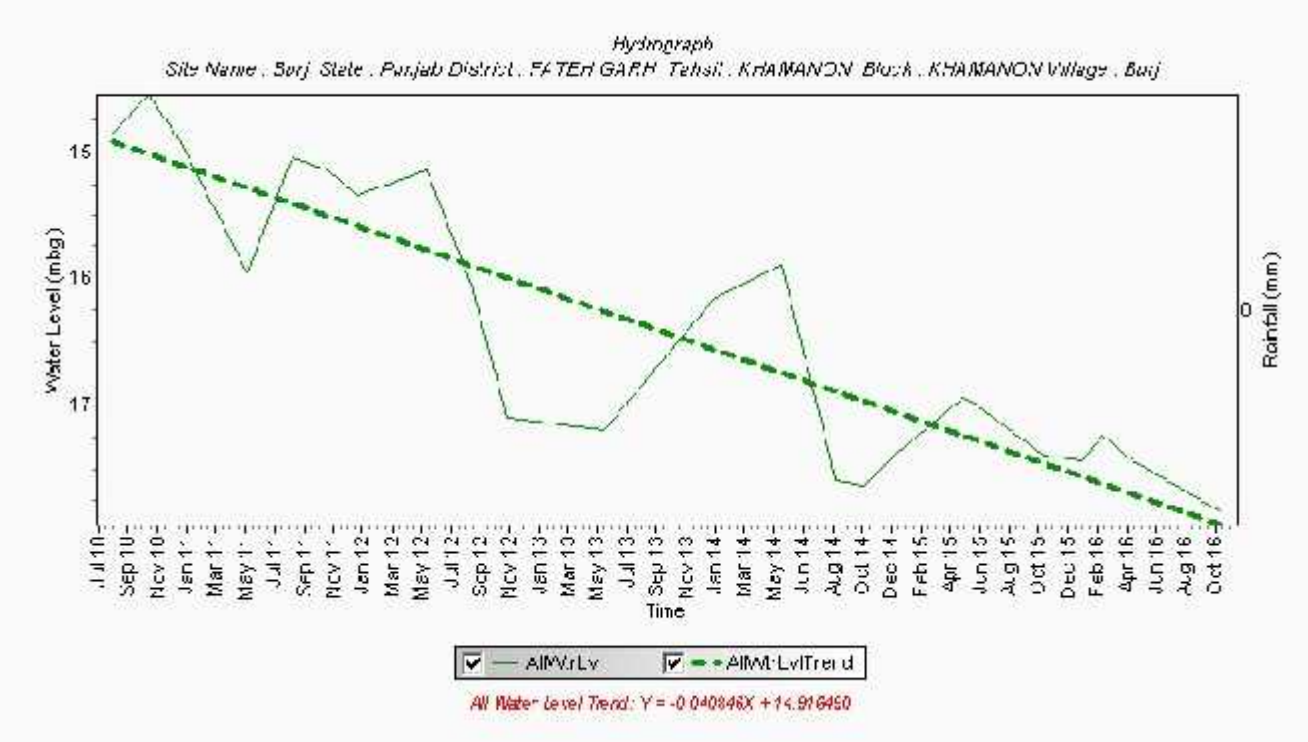
Other than that by 15 days ponding followed by 2 days of drying can lead to 25% saving of water in paddy crop.

V. Salient Information of Khamanon Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>155 sq km</td></tr>
<tr><td>District/ State</td><td>Fatehgarh Sahib, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 0
Rural Population: 60728
Total population: 60728</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 540 mm
Non-monsoon Rainfall : 158 mm
Annual Average Rainfall: 698 mm</td></tr>
<tr><td>Agriculture and Irrigation</td><td>Principal crops: Rice, Wheat, Sugar cane, and Maize
Other crops: Vegetables and Fodder
Gross cropped area: 320.31 sq km
Net sown area: 171.31 sq km
Irrigation practices: Tube well and Canal Irrigation
Cropping intensity: 187%
Area under
Ground water Irrigation: 165.83 sq km
Surface water irrigation: 3.67 sq km
Gross Irrigated area: 320.25 sq km
Net Irrigated area: 171.31 sq km
Number and types of abstraction structures: 6933, 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 205 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>15.82 – 121.0</td><td>105</td><td>87</td><td>947.57</td></tr>
<tr><td>Aquifer-II</td><td>142.0 – 205.0</td><td>63</td><td>21</td><td>265.92</td></tr>
<tr><td>Aquifer-III</td><td>Not Explored</td><td>-</td><td>-</td><td>-</td></tr>
</table>
Total Ground Water Resources available is 1213.49 mcm and total potential granular zones available are 109 m up to depth of 205 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	*Existing Gross Ground water Draft as on 2013* Irrigation: 186.64 mcm Domestic and industrial water supply: 2.23 mcm *Future water demands* Irrigation development potential : (-)90.04 mcm Domestic and industrial water supply up to 2025 years : 2.81 mcm Water Scarcity Villages: 72
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 16.95 – 18.50 m bgl Post Monsoon: 17.40 – 18.40 m bgl Seasonal Fluctuation: 1.48 – (-)0.45 m/yr Mean (10 yrs) : (-)1.08 – (-)2.82 m/yr *Trends* Pre Monsoon: (-)0.33m/yr Post Monsoon: (-)0.53 m/yr **Aquifer-II &III** No Monitoring Stations

HYDROGRAPH SHOWING DECLINING WATER TABLE
(Location: Burj)



Aquifer Disposition

Number of aquifers	1
Principal aquifer	Alluvium
Major Aquifer	Older Alluvium
Aquifer Disposition	Multiple Aquifer System (Two 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	0	**0**
WRED/PSTC/WSS	4	9	1	0	**14**
PRIVATE	0	3	1	0	**4**
TOTAL	**4**	**12**	**2**	**0**	**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 (15.82 -121 m)	Quarter-nary Alluvial deposits	Unconfined to confined	87	NA	NA	12 % *(0.072)*	NA
Aquifer-II (142 - 205 m)		Semi confined to Confined	21				
Aquifer-III Not Explored		NA	NA	NA	NA	NA	NA

* Well field proposed in adjacent block , NA : Not Available

Source: Groundwater Exploration Report, CGWB,2015

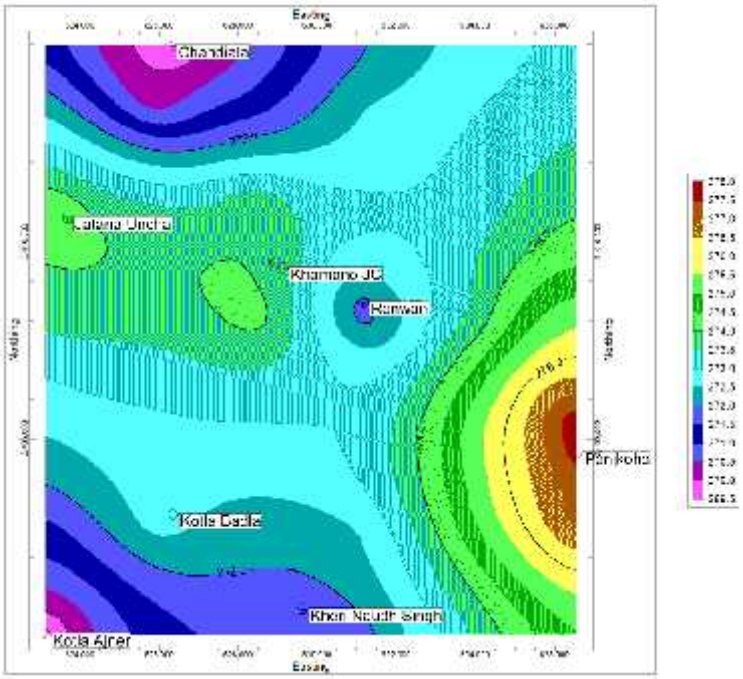
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

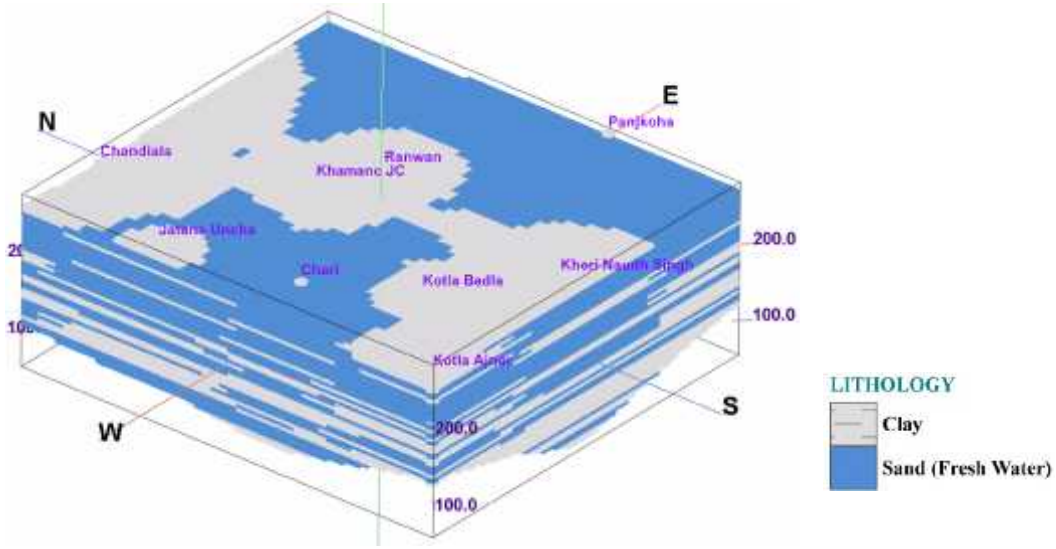
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	0	0	**0**
WRED/PSTC/WSS	0	5	1	0	**6**
PRIVATE	0	3	1	0	**4**
TOTAL	**0**	**8**	**2**	**0**	**10**

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

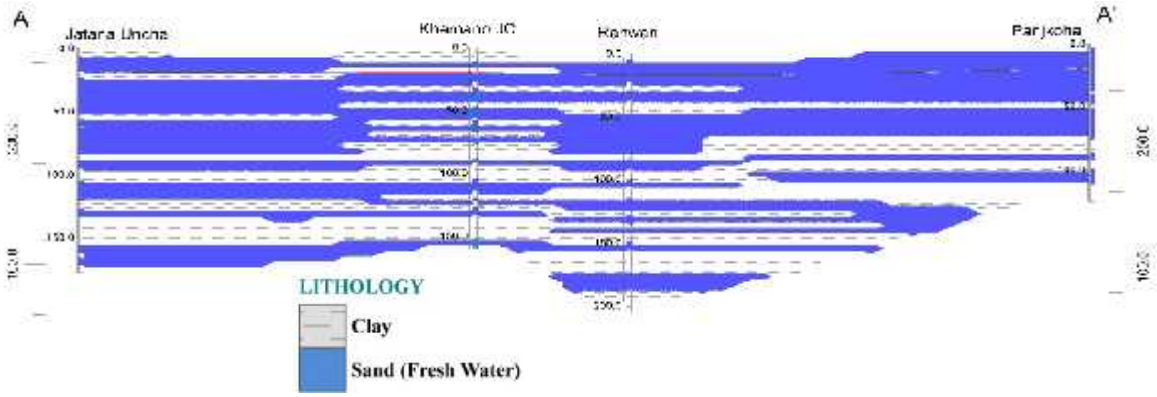
Elevation Map of Khamanon Block



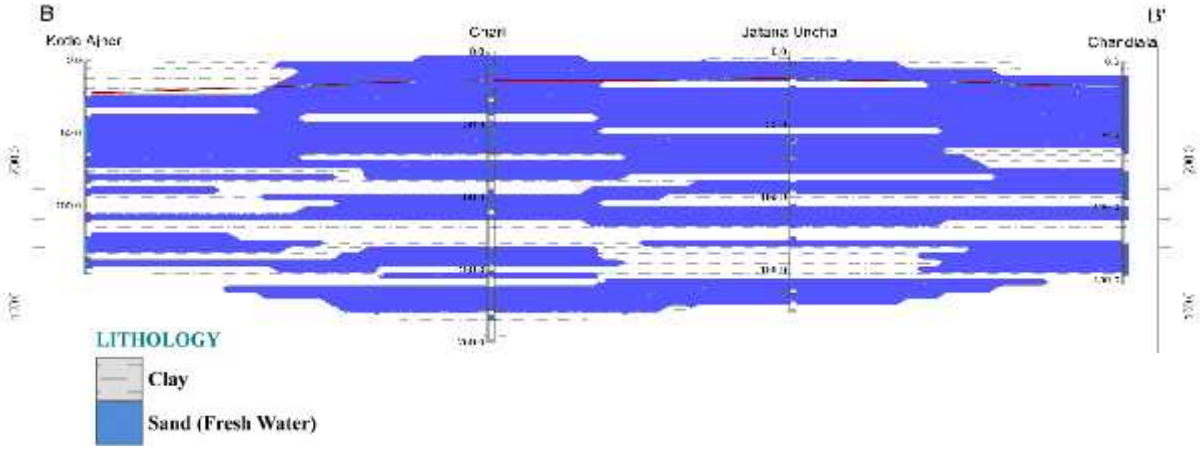
3-D Lithological model of Khamanon Block



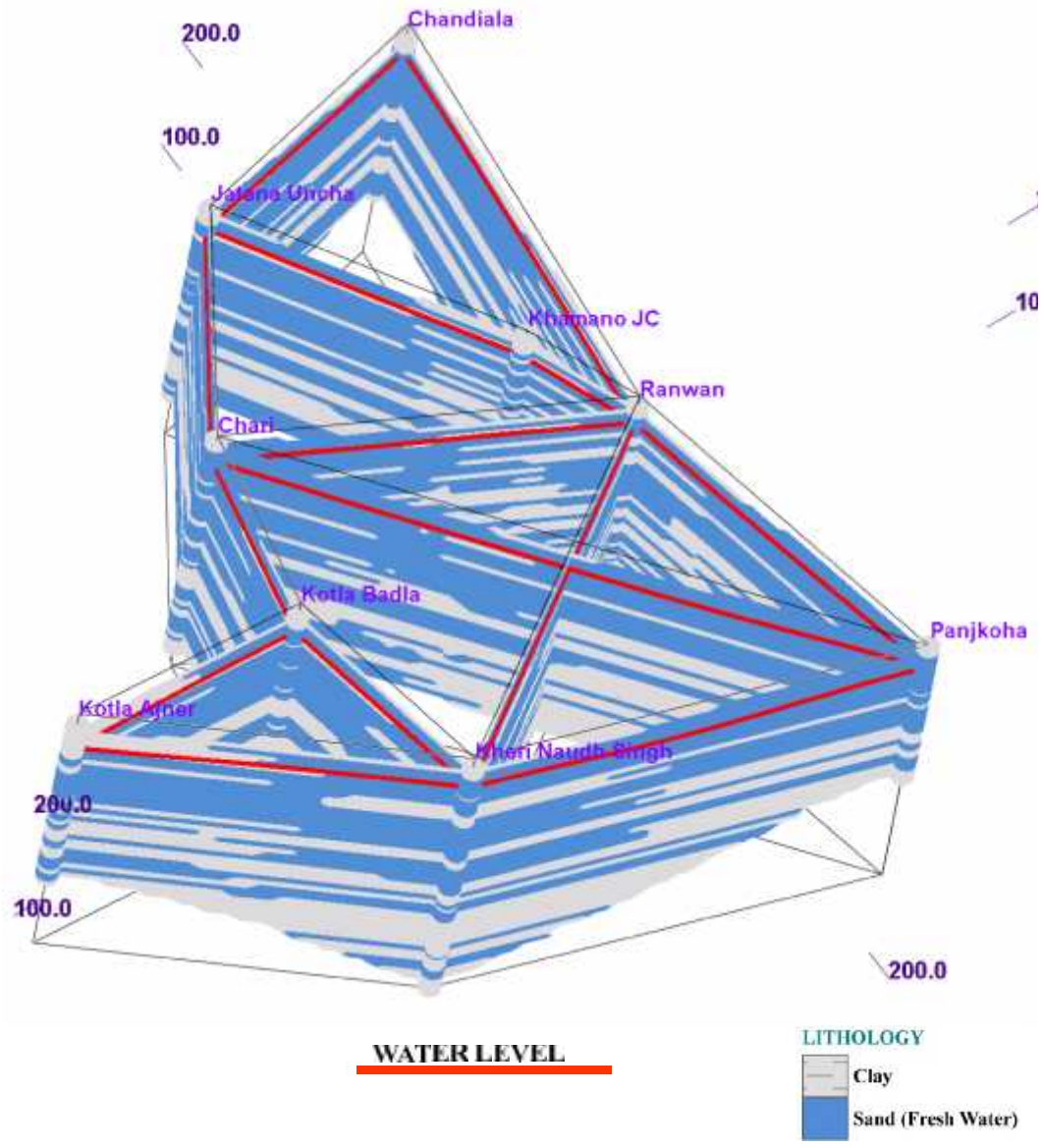
Lithological Cross section from Jatana Uncha to Panjkhoha



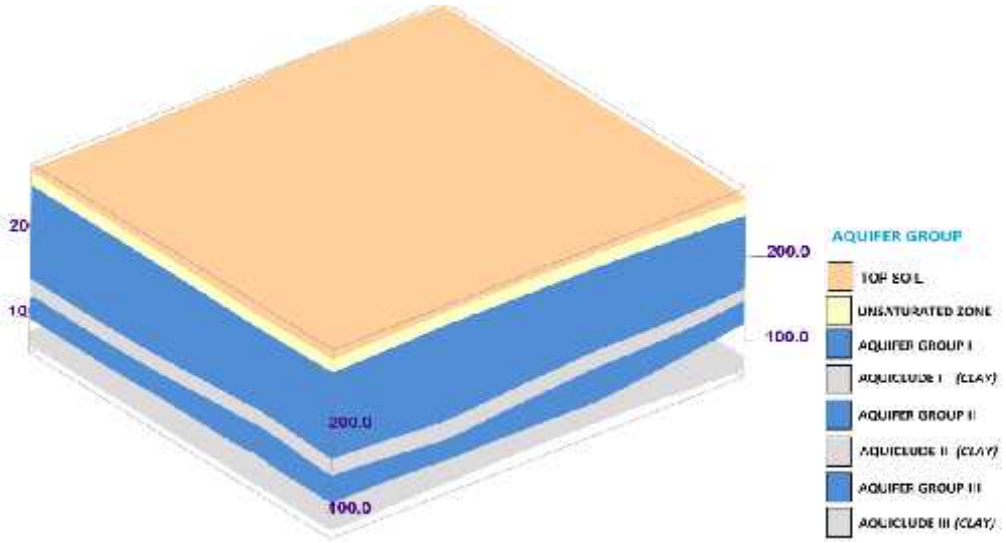
Lithological Cross section from Kotla Ajner to Chandiala



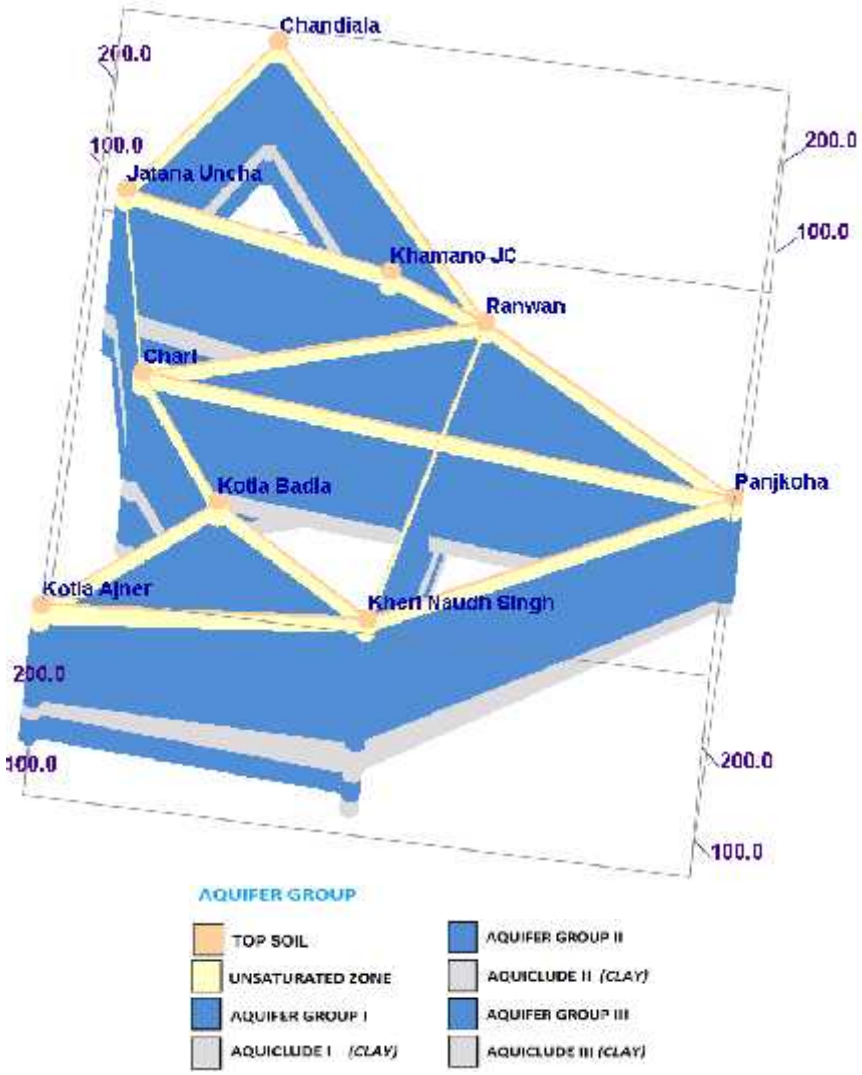
3-D Lithological Fence Diagram



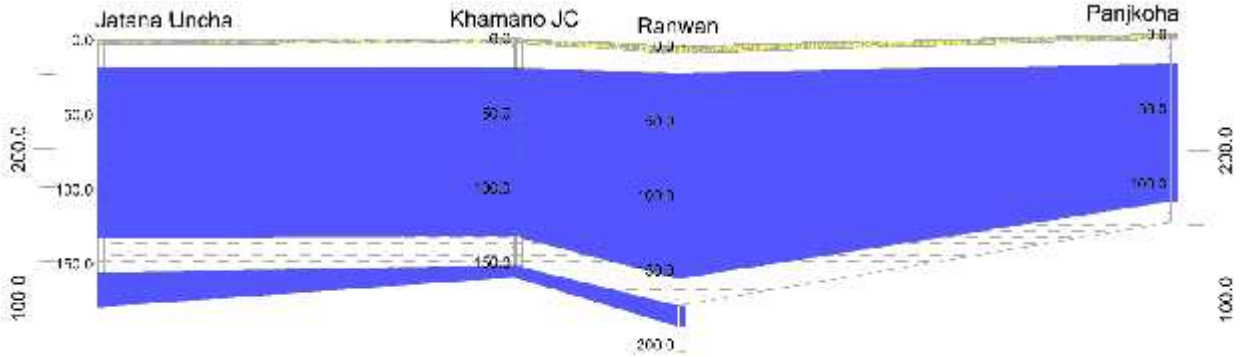
3-D Aquifer Disposition Model of Khamanon Block



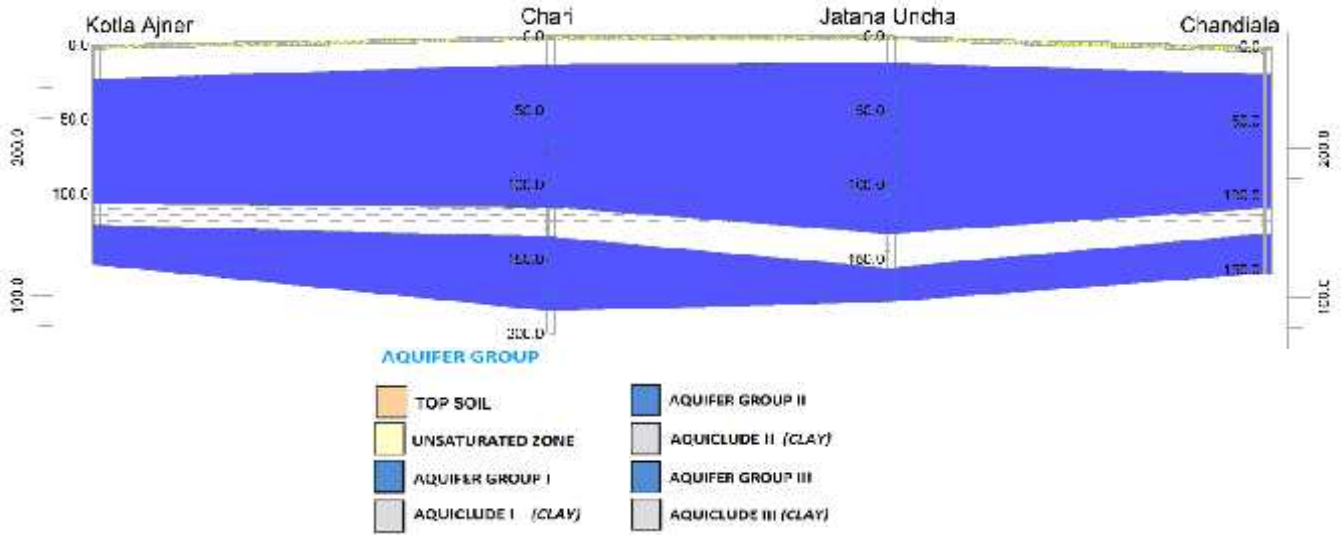
3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along Jatana Uncha to Panjkoha



Aquifer Cross section along Kotla Ajner to Chandiala



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

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	99.41 mcm
	In-storage Aquifer-I (Specific Yield Concept)	848.16 mcm
	In-storage Aquifer-II (Specific Yield Concept)	234.36 mcm
	In-storage Aquifer-II (Storativity Concept)	31.56 mcm
	In-storage Aquifer-III (Specific Yield Concept)	0 mcm
	In-storage Aquifer-II (Storativity Concept)	0 mcm
	Total Resources	1213.49 mcm

Ground Water Extraction (as per 2013)	Irrigation	186.64 mcm
	Domestic & Industrial	2.23 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		2.81 mcm
Stage of Groundwater Development		190 %
Chemical Quality of ground water		Ground water in the area is alkaline in nature, suitable for drinking and is fit for irrigation.
Ground water Contamination Issues		Not Available (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: 204.60 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 2.27 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Khamanon Block (150 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 43.50mcm

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: *30% of the total rice area needs to change i.e.* 46.01 sq km
Anticipated volume of water to be saved: 46.01 mcm

Net Annual Ground Water Availability 2013 (mcm)	*Total Irrigation 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 development (%)*	*Reduction in Stage of development after Maize/ soya bean (%)*	*Crop Diversified area (%)*
99.41	186.64	188.87	145	43.50	43.50	143.14	190	46.01	30

Alternate Water sources

Surface water sources: *Tanks, Ponds*

No.of Water tanks: 36

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.