केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation

Government of India

Report

on

AQUIFER MAPPING AND MANAGEMENT PLAN

Kapurthala District, Punjab

उत्तरी पश्चिम क्षेत्र, चंडीगढ़

North Western Region, Chandigarh

1.0 INTRODUCTION

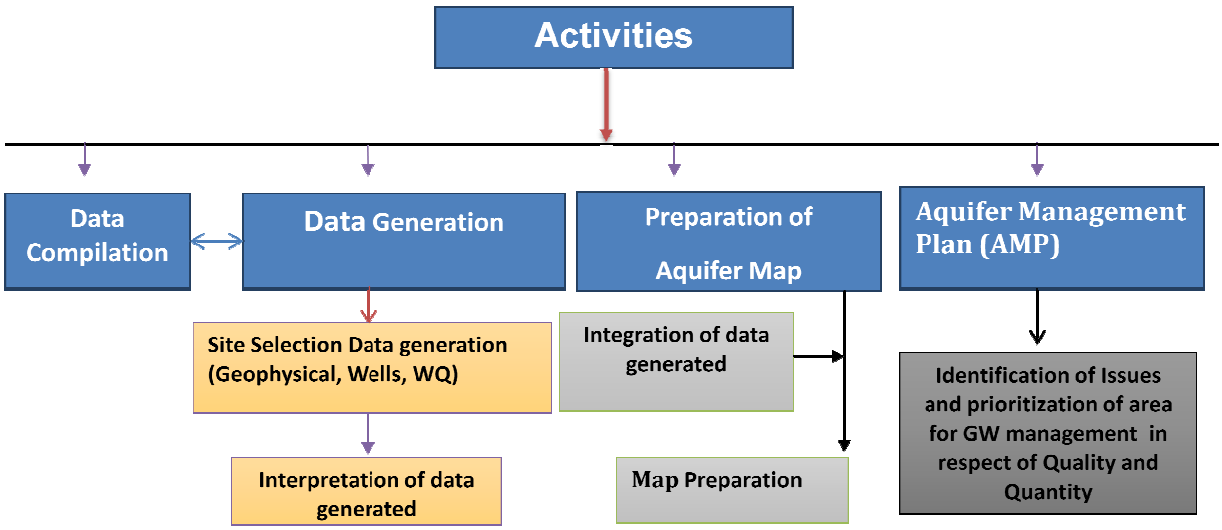
The primary objective of the Aquifer Mapping can be summed up as "Know your Aquifer, Manage your Aquifer". Demystification of Science and thereby involvement of stake holders is the essence of the entire project. The involvement and participation of the community will infuse a sense of ownership amongst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

Kapurthala District located in the north- central part of the state forms of the part of the Bist Doab region (interfluvial plain of Sutlej And Beas rivers).it spans over an area of 1633 Sq.Km (Fig.1). and occurs in two non- contiguous parts adjoining the eastern as well as the western sides of Jalandhar District, about 32 kilometers apart. While the western part comprising Tehsils of Kapurthala, Sultanpur Lodhi and Bholath is bounded by North latitudes 31^0 07' and 31^0 39' and East longitude 74^0 56' and 75^0 36'and the eastern part comprising Phagwara Tehsil is bounded by North latitudes 31^0 15' and 31^0 22' and East longitude 75^0 40' and 75^0 55', falling in Survey of India Degree Sheets 44 M & 44 I. Administratively, Kapurthala district has been divided into four Tehsils namely Kapurthala, Sultanpur Lodhi ,Bholath and Phagwara. The district is well connected by rail and road, with National Highway No.1 passing through the northern part of the district. Western part of the district is bounded by Hoshiarpur and Gurdaspur in North, Ferozpur in South, Tarn Taran and Amritsar in West of Jalandhar district and parts of SBS Nagar, Jalandhar and Hoshiarpur bounded in South, West and East of the Phagwara block of the district. The elevation of land surface ranges between 245m above m.s.l. in northwest to 212 m a.msl at towards southeast. Topographically, it is a leveled plain sloping towards south - south east direction.

There are five administrative development blocks namely Nadala, Dhilwan, Kapurthala, Phagwara & Sultanpur Lodhi. Total number of villages exists in the district is 687 (Inhabited village is 608 and Uninhabited village is 79).

The total population of the district is 8,15,168 as per 2011 census which constitutes 3% of the state population. The total rural population is 5,32,706 and the urban population is 2,82,462 and the decennial growth rate is 8.04 % (2001-2011). Population density of district is 499 persons/sq. km. The literacy rate in the district is around 80.2%.

1.5 Climatic Conditions: Rainfall and Climate

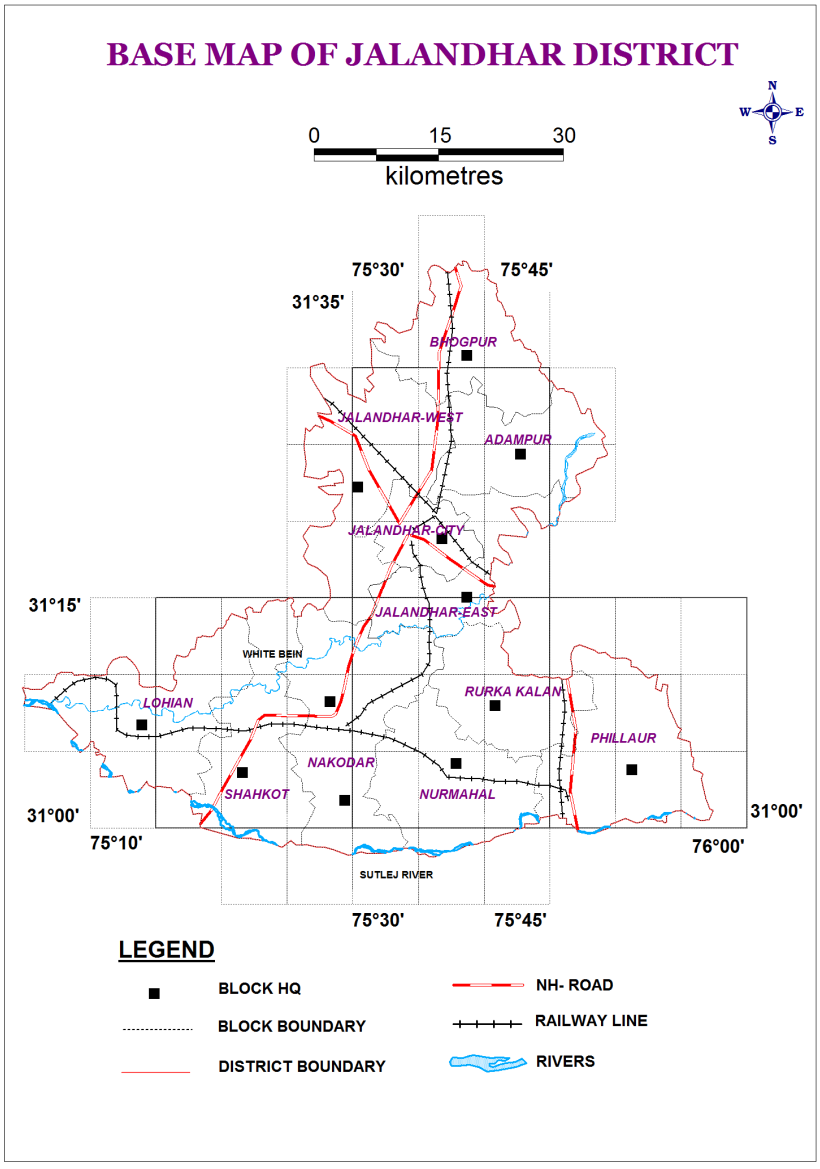
The climate of the district is classified as tropical steppe and hot which is mainly dry except in rainy months and characterized by intensely hot summer and cold winter. There are four seasons in a year namely the cold season from November to March, hot season from April to June, monsoon season from last week of June to the middle of September followed by post monsoon season till the beginning of November. During cold season, a series of western disturbances affect the climate of the city during the summer months i.e. from April to June, weather is very hot, dry and uncomfortable. The weather becomes humid and cloudy during July to September due to penetration of moist air of oceanic origin into the atmosphere. In summer, maximum and minimum temperatures are about 41 ^{0} C to 27^0 C and the maximum temperature may occasionally reach upto 45^0 C (in May/June) and In cold winter, maximum and minimum temperatures are about 19^0 C and 6^0 C in December/January.

The normal annual rainfall is 779 mm in 33 days which is unevenly distributed over the district and normal monsoonal rainfall is 584 mm. The average annual rainfall in the district is 640.37 mm. The south west monsoon which contributes 75% sets in last week of June and withdrawn in middle of September, July and August receive maximum rainfall. Rest 25% of annual rainfall occurs in the non-monsoon months in the wake of western disturbances and thunder storms. The rainfall in the district in general increases from the south-west towards the

Monthly wise rainfall is given in below table.

Monthly wise Rainfall of Kapurthala District in mm (Source: IMD, Chandigarh)												
Year	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
2012	2012	90.4	1.6	1.7	36.2	1	0.8	76.9	118.4	261.2	1.7	0.7
2013	2013	6	73.7	12.7	8.8	3.6	234.1	128	171.3	26.1	13.1	0.3
2014	2014	43.9	41.4	37.5	48.5	9	11.2	93.8	129.2	150.1	19.9	0.2
2015	2015	16	49.4	106.7	49.7	44.2	66.5	182.4	92.2	52.1	0	0
2016	2016	7.4	5.8	56.8	0.5	24.3	58.7	195.8	297.4	44	0.3	1.3

Fig.1: Base map of Kapurthala District



1.6 Geomorphology & Soil Type

The study area is a part of Bist Doab Tract, which is inter alluvial plain between Beas and Satluj River and has almost flat topography with gentle slope towards southwest. The Phagwara region consists of the Sirowal, Dhak and Manjki tracts lying roughly in the North-East, middle and South-East of the tehsils. Sirowal possesses the characteristics of the 'Bet. The numerous hill streams coming down from Hoshiarpur District keep the soil moist all the year round. Some of these streams are silt laden and at first deposit fertile soil though their later deposits are more and more sandy. Due to the existence of these drainage channels patches and strata's of hard clay are also to be found.

The regional altitude in the north east is approximately 231 m above msl and in the south west is approximately 209 m above msl defining an average slope of 0.30m.km. Physiographically, the district is divisible in the following two distinct geomorphic unit's namely *Upland plains and Low land unit*. These land forms are delineated on the basis of relief, pedological, lithological and vegetation variations (GSI, 2005-2006).

Upland Plain unit: This is the oldest and dominant geomorphologic unit of the area. It is higher in elevation and has almost a flat topography occasionally punctuated by the presence of a few sand dunes and manmade sand –dump hills. Older Alluvial plains are basically the aggradational product of the fluvial action of the ancestral rivers of the Indus System. These plains are presently being modified by erosional action of the various forces as well as anthropogenic activities. These plains are well drained, they have fertile soils and also its groundwater conditions are favorable for the development of tubewell irrigation, thus making them agriculturally the most productive. The different *land forms* developed over the Upland plains include sand dunes and aeolian sheets.

Sand dunes: Sand dunes occur in the form of low mounds. The morphology of these dunes has been modified by human activity. At number of places these have been leveled by the local people to reclaim land for cultivation.

Aeolian sheet**:** It comprises of thin veneer (approx 0.10 to 0.15 m) of Aeolian sand over the Older Alluvium and represents the end geomorphic product of the Aeolian action on dunes. The original slope and form of the Aeolian sheets has been highly modified by the agricultural activities of the farmers.

Low land unit: It is the youngest geomorphic unit developed in Holocene times and comprises older and active flood plains of the river Beas and active channels of the East and West Bein. The major portion of this region lies in the river tract falling between the Beas and Black Bein and is called 'BET'. To the south of the Black Bein lies the tract known as 'Dona'. The word 'Dona' means that the soil is formed of two constituents, sand and clay, with sand predominating. The Low Land Unit developed along the Beas River has been sub divided into (i) the active / present flood plains, which are regularly flooded and (ii) the Older Flood Plain, which is only affected when the river carries an enormous discharge of water e.g. in 1988 floods. These two subdisions of the Low land unit are separated by an elevation difference of about one meter (Pahuja and Gupta, GSI, 1992).

Landforms: The landforms include palaeochannel and river bank escarpment, river

channel and point bars developed in the meandering course of the Beas river and the cut off meander loops in the course of West Bein, e.g. west of village Khera. Afew swamps e.g. near Dalla and Bhatnura Labana are located on the Older Flood plain near to the contact with upland plains. Besides, a number of erstwhile water pools (locally known as 'jhils'or 'chhambs') but now dried up and represented by some depressions are reported at Begowal, Khiranwali etc.

The West Bein and the Beas River flow almost parallel, which suggests that the Bein is flowing through an old course of the Beas river, and the main river has shifted to the west.. the presence of a few paleochannels e.g. SSW of Talwandi Choudhrian village which are the courses abandoned by the shifting Beas river in the recent past.

The soils of the study area are generally very deep and well drained. Texturally they range from sandy loam to clayey loam with percentage of sandy soils increasing in the western part.

The Major Soil types found in the district are the arid brown soils and Tropical Arid brown soils. The arid brown soils are found mostly in Southern parts of the district and Tropical Arid brown soils are found in the Northern part and Phagwara block of the district. The arid brown soils are calcareous in nature and Tropical arid brown soil is deficient in nitrogen, potassium and phosphorus.

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 Jalndhar District, Punjab

Type of Land use	Area (hectares)
1. Total Geographical area	263350
2. Forest	5600
3. Land put to non-agricultural use	29350 (11 %)
4. Net area sown	234000 (89 %)
5. Gross cropped area	414000
6. Cropping intensity	177%

(Source: Statistical Abstract, Punjab, 2015)

1.8 River System and Water Resources

The study area located in the interfluvial area of the Beas and the Sutlej rivers is well endowed with water resources. Surface water is available in the area in forms of rivers, choes, lakes, irrigation canals and locally in ponds. The main drainage system of the district forms a part of Beas river system. The flow direction is towards Southwest. West / Black Bein is the main surface water carrier of the western block of the area, the East/White Bein with its tributary /*nalas* defines the main drainage of the eastern part of the area. In Phagwara tehsil East or White Bein Flows westwards and then takes SW turn near western border of the tehsil. It is main drainage system in the tehsil and joins the Sutlej River. The Beas river has tendency to shift westward, there are many small tributaries of Beas Sutlej rivers like Kalna bein, Rau Nala and Kail nala. Drainage and water bodies are shown in Fig.2.

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.

Net area sown in the district is 1,28,479 ha. Area sown more than once is 1,2,1767 ha bringing the total cropped area (Gross sown area) to 2,50,246 ha. Paddy constitutes main kharif crop whereas the wheat is the main Rabi crop.

Net Irrigated area is 1,28,479 ha and Gross Irrigated Area is 2,50,246 ha and Irrigation intensity is 195%.

a. Canal Water Irrigation

The study area is not under canal command irrigation.

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 1,28,000 ha.

1.10 Mineral potential

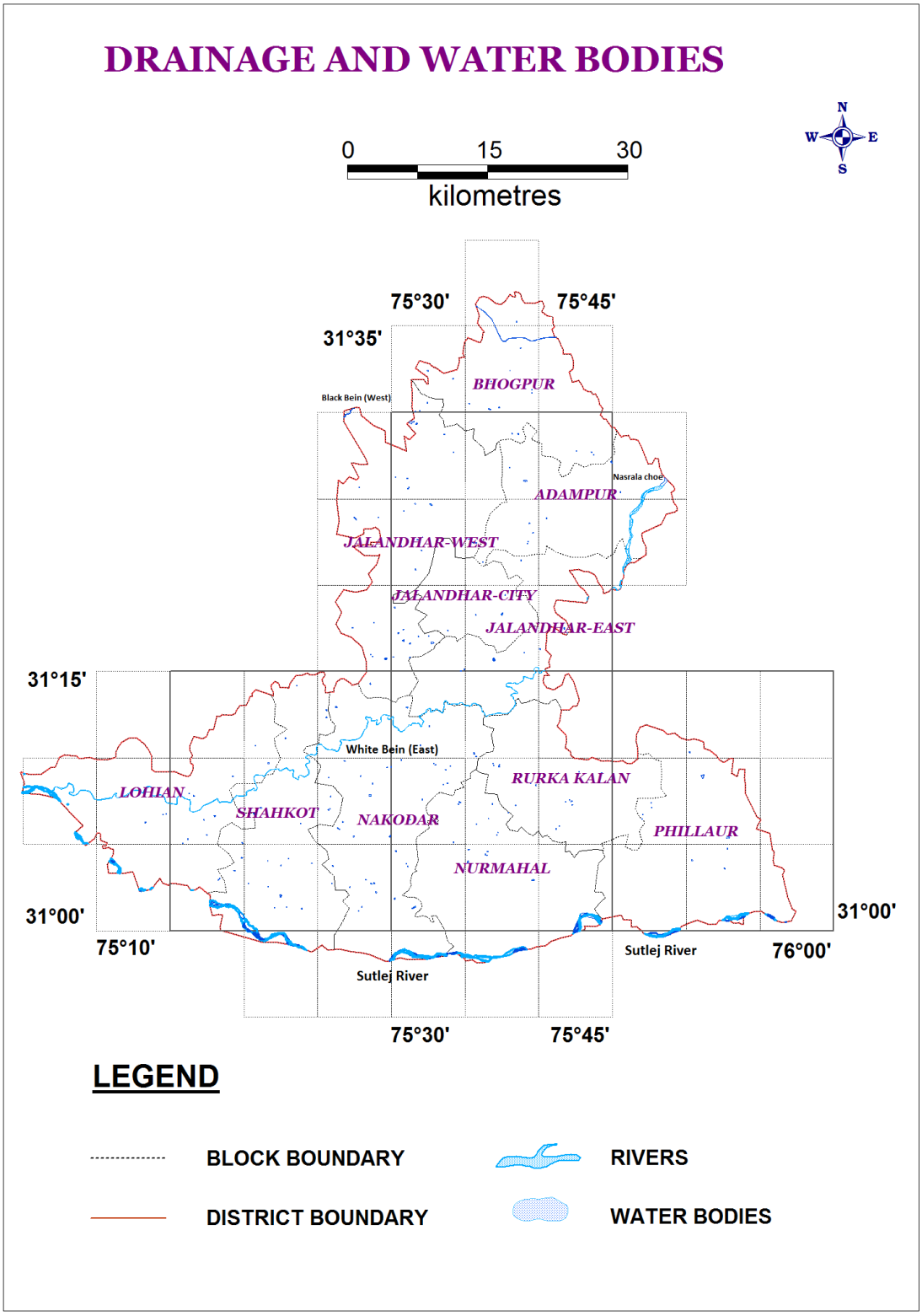
No mineral deposit is known from the district. The minor minerals having economically potential include silty clay, sand ,kankar and salt peter.

1.11 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. In order to arrest further decline in water levels, the roof top and farm pond rainwater harvesting techniques have to be adopted and recharge structures need to be constructed in low lying areas where water gets accumulated during rainy season. 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. This will help in enhancing the recharge to ground water reservoir.

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 Kapurthala District



2.0 DATA COLLECTION AND GENERATION

2.1 Geology and Hydrogeological data:

The Study area forms part of the Punjab basin of the Indus super-basin of the vast Indo-Gangetic Plain and is occupied by Quaternary to present day sediments of fluvial as well as Aeolian origin. These Quaternary sediments unconformably overlie the Siwalik Group of rocks, which in turn overlie the crystalline basement. 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 Lithostratigraphy, Kapurthala District (Pahuja and Gupta, 1991, 92)

Age	***Lithological Unit***	***Lithological Characteristics***
Present to Recent	*Aeolian Sediments(A2 & A3)*	Brownish yellow, micaceous sand with silt, clay and calc. Siliceous concretions Kankar.
	Newer Alluvium (F3)	Pebbly, fine to coarse, grey, micaceous sand, silt with subordinate amounts of clay & kankar
	DIASTEM	
Recent to Sub-Recent	*Newer Alluvium (F2)*	Reddish brown silty sand bed with occasional pebbles.
	DIASTEM	
Sub-Recent to Pleistocene	*Older Alluvium (F1)* *Aeolian (A1)*	Pebbly, fine to coarse, grey, micaceous sand, Alternating bands of golden brown, 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 410 m at village Phagwara. Under Ground water exploration five exploratory wells and eleven piezometers were constructed in the district to delineate and determine potential aquifer zones, evaluation of aquifer characteristics etc. The drilling was carried down to a depth of 410 m and well was constructed down to 397m. The yield of test well was 1983 lpm with draw down of 13.21 m. Ten to eleven granular zones were encountered down to the drilled depth. Transmissivity value of the granular zones in between 278 to 394 m bgl is 987.26 m^2/day. 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 1.08 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.4)

Fig.4: Major Aquifer

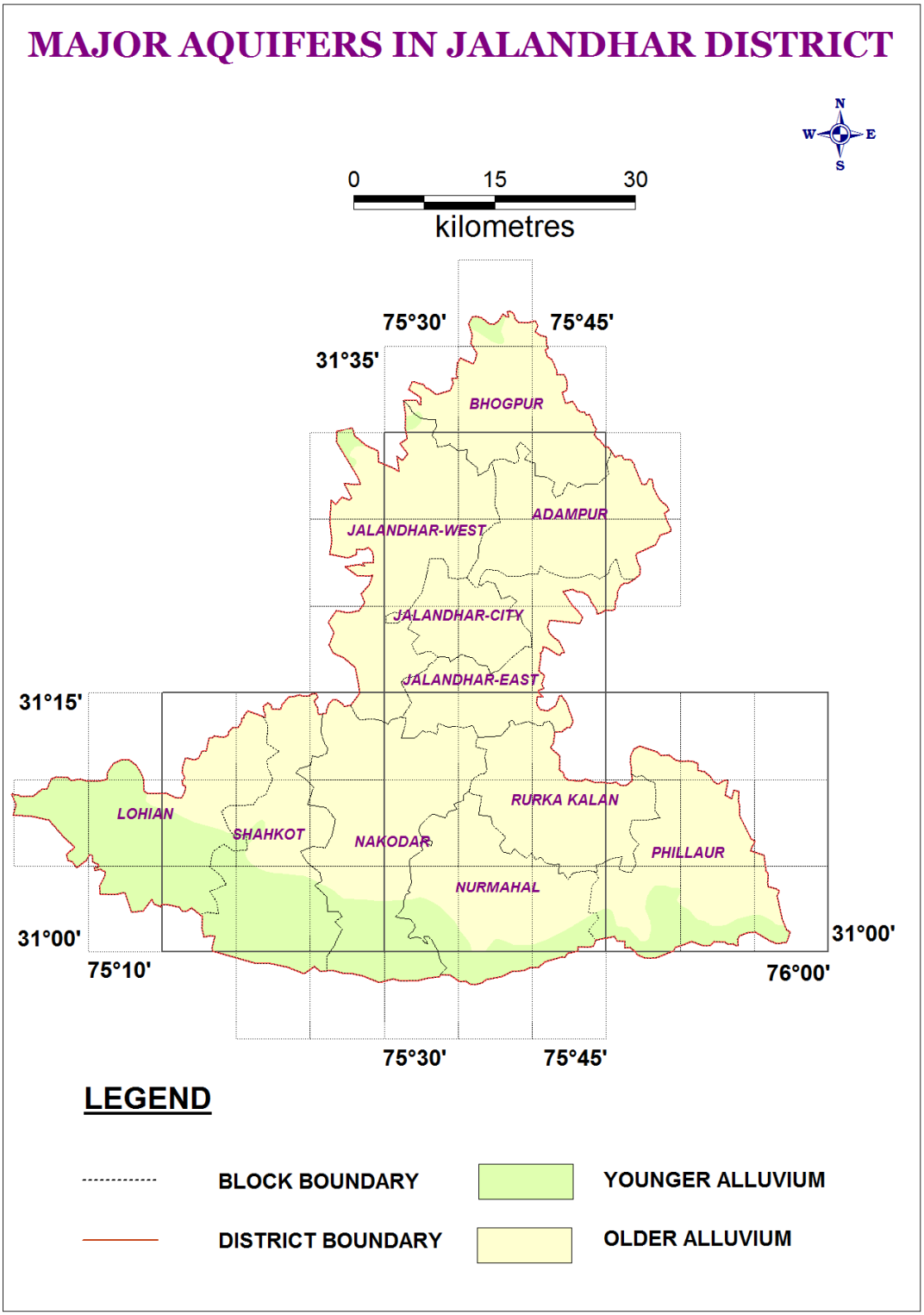
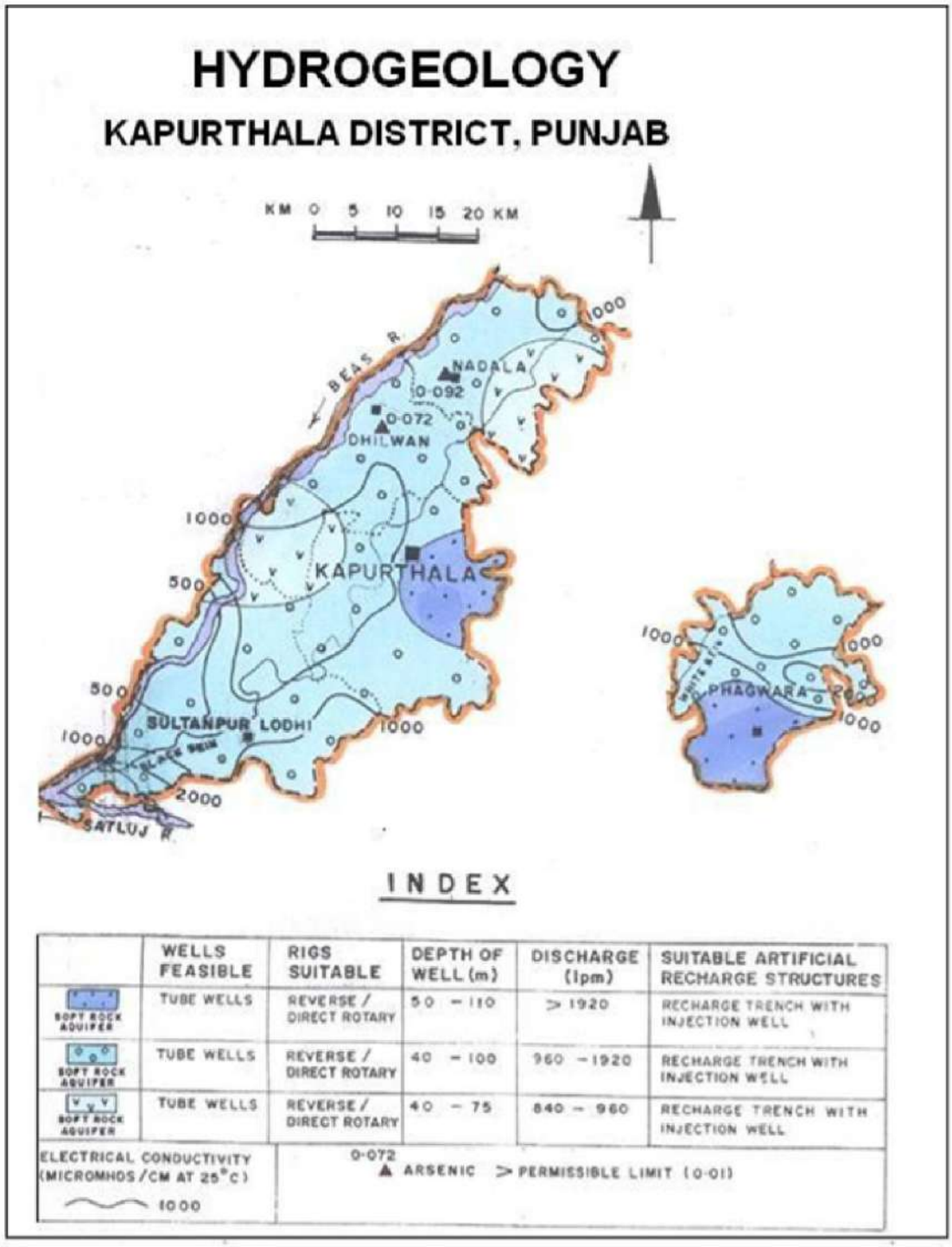


Fig.6: Hydrogeology of Kapurthala District



2.1.1 Water Level Behavior

Fourteen monitoring stations of Central Ground Water Board (CGWB) (12 Piezometers and 2 Dug wells) and *Thirty Seven* monitoring stations (32 Piezometers & 5 Dug wells) of State government departments represent first aquifer. *Six* monitoring stations of CGWB (6 Piezometers) represent Second and Third aquifer. Depth to water level in the area ranges from 7.25 to 35.33 m bgl during pre-monsoon period (Fig.5) and 6.85 to 34.50 m bgl during post monsoon period (Fig.6).

Fig.6: Depth to Water level Pre Monsoon, 2016

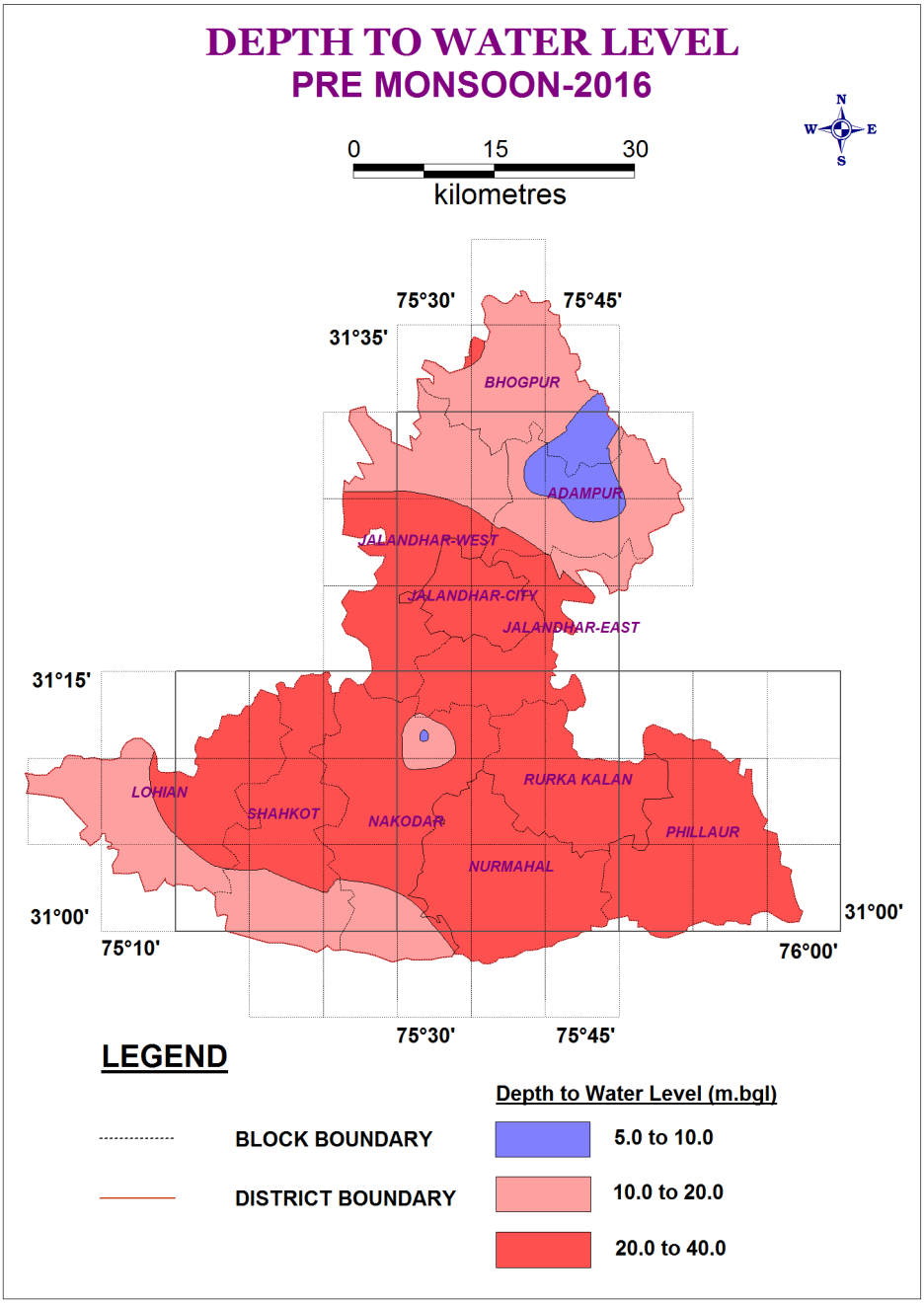
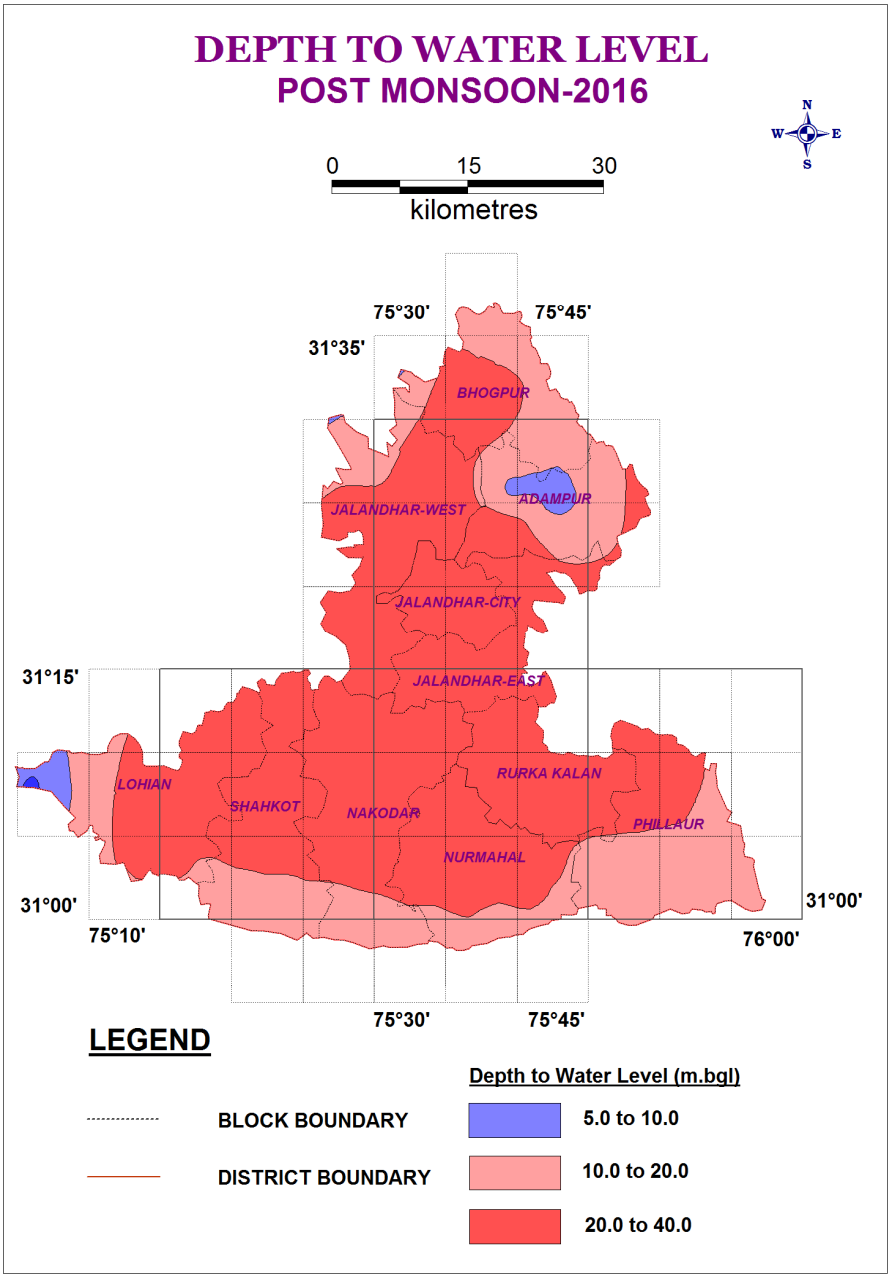


Fig.7: Depth to Water level Post Monsoon, 2016



The major parts (Central ,Western, Eastern and Northern) water levels are >20 m, northern and southern parts having water levels are in the range of 10 to 20 m, in the north 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 2016 (Annexure-I). Net change in water levels Long-term net change of water levels indicates a general decline (negative change) in the large part of the district and it is up to 8.18m. The maximum fall is observed in parts of Nakodar and Shahkot blocks.

2.2 Water Quality Data:

Ground water quality of shallow aquifer (Aquifer-I) is assessed on the basis of chemical data of National Hydrograph Network stations i.e. NHNS monitored during Pre monsoon period. Fifteen groundwater samples are collected and analyzed during NHNS, 2016, given in Annexure-II. The chemical quality of deeper aquifers has to be assessed during ongoing groundwater exploration programme under NAQUIM. An Isotope study having been carried out in the district under Hydrology Project Phase-II by National Institute of Hydrology (NIH) for validation of the aquifer groups, mechanism of recharge to aquifers and for the age determination of the aquifer water.

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, Kapurthala, 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), Kapurthala (4.53) and Amloh (3.87) whereas Arsenic found within permissible limit in all sampling locations (Fig.9).

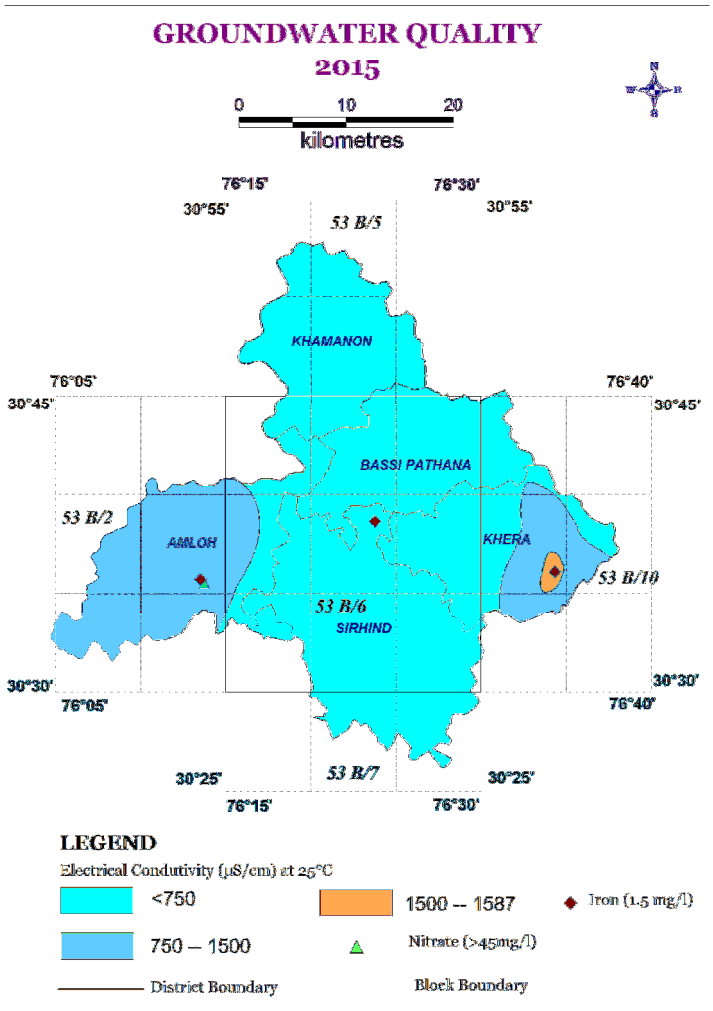
Alkali hazards of irrigation ground waters are estimated through the computation of Residual Sodium Carbonate (RSC), also known as Eaton's Index. Classification based on RSC indicates that 1% of the waters are unsafe for irrigational use. Waters with RSC value <1.25 meq/L are safe for irrigational uses, 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)	

	Potassium (K) Total Dissolved Solids (TDS)	Flame photometric method Flame photometric method 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.9: Groundwater Quality, 2015



2.3 Geophysical data:

Surface and Subsurface geophysical investigations have been carried out in alluvial tracts over parts of Kapurthala 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.

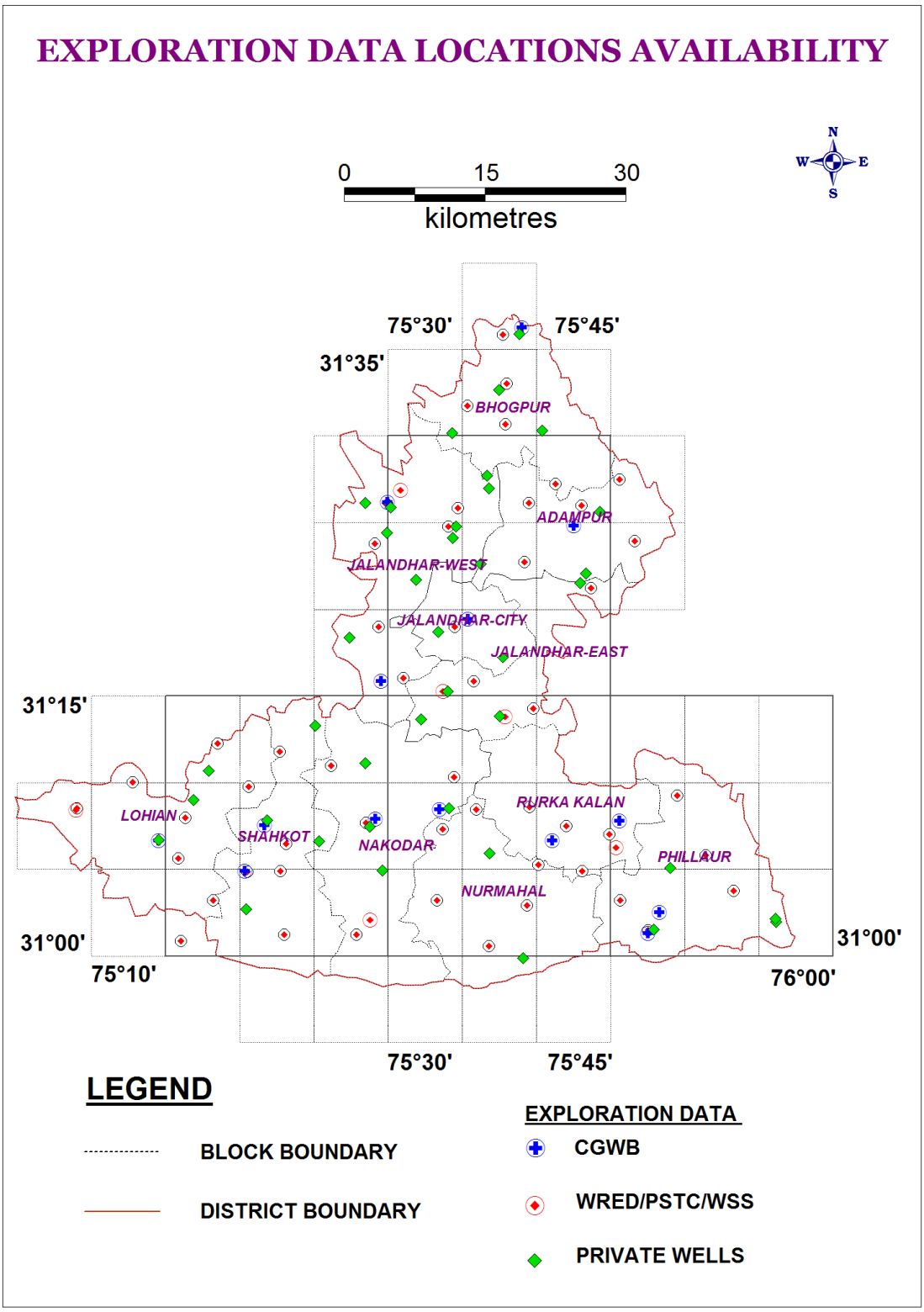
Data Availability of Exploration Wells of Kapurthala district

Sl.No	Source of data	Depth Range (m)				***Total***
		< 100	100-200	200-300	>300	
1	CGWB	5	5	0	6	**16**
2	WRED/WSS/PSTC	0	3	0	3	**06**
3	PRIVATE WELLS	20	3	0	0	**23**
Total		**25**	**11**	**0**	**9**	**45**

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.

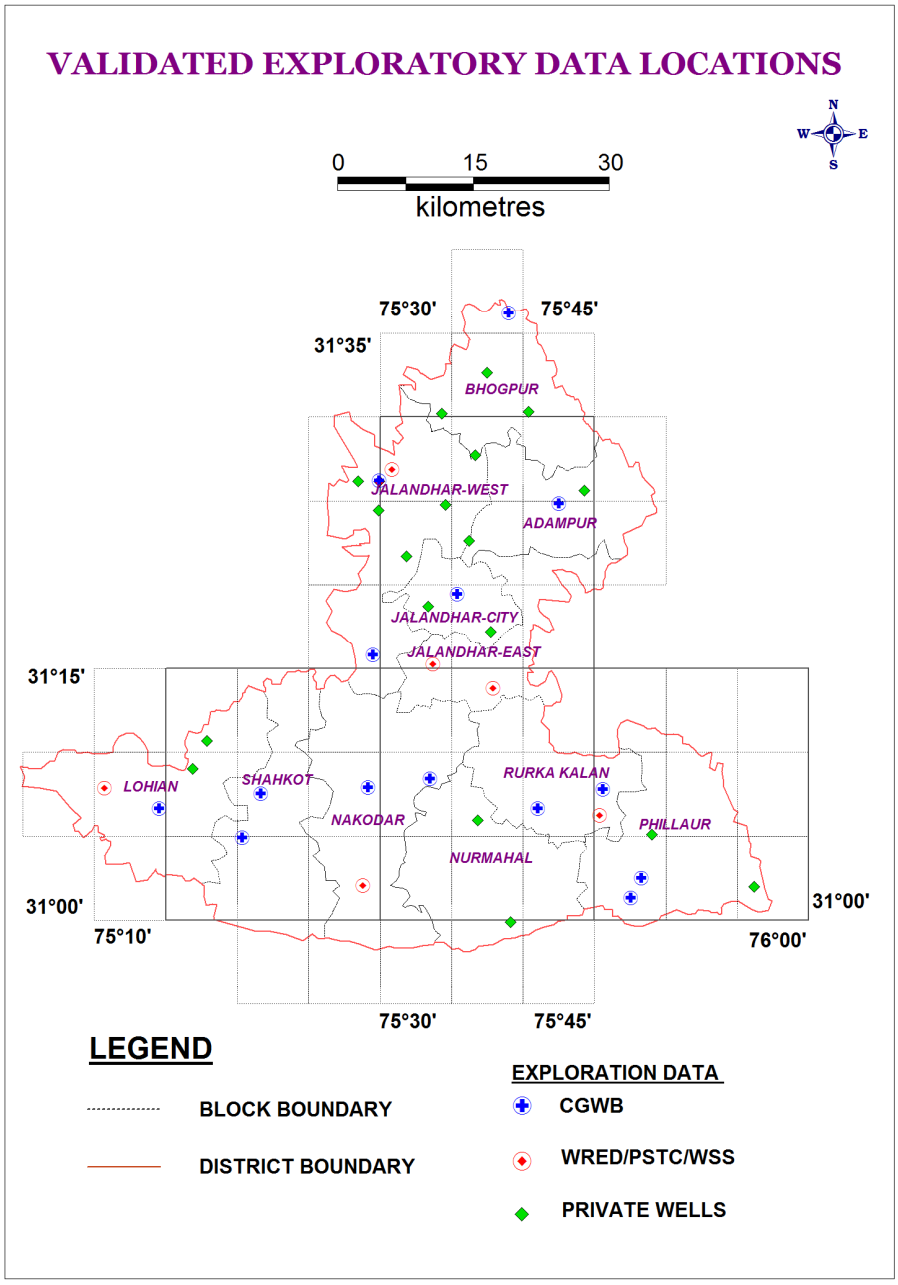
Fig.10: Locations of exploration data availability



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

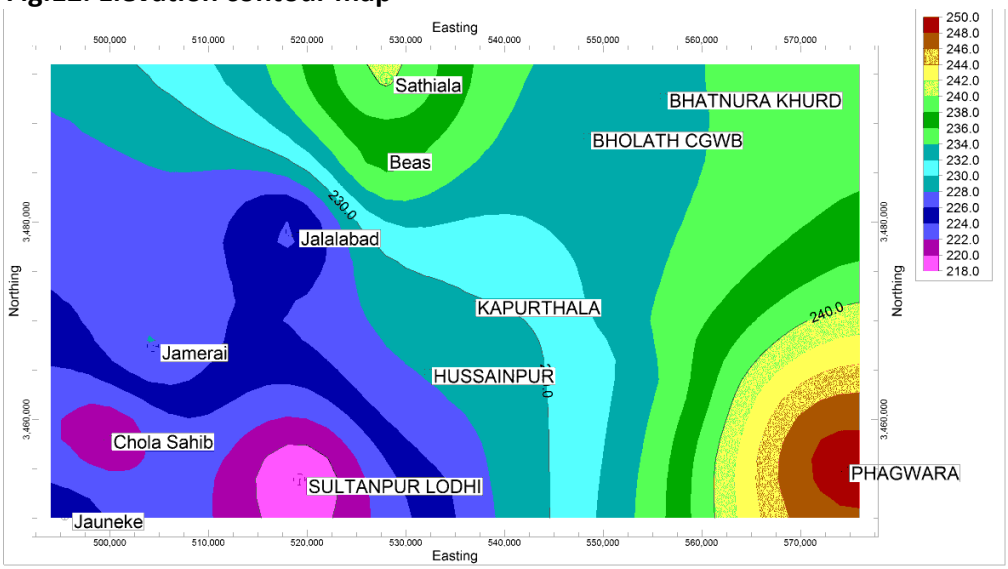
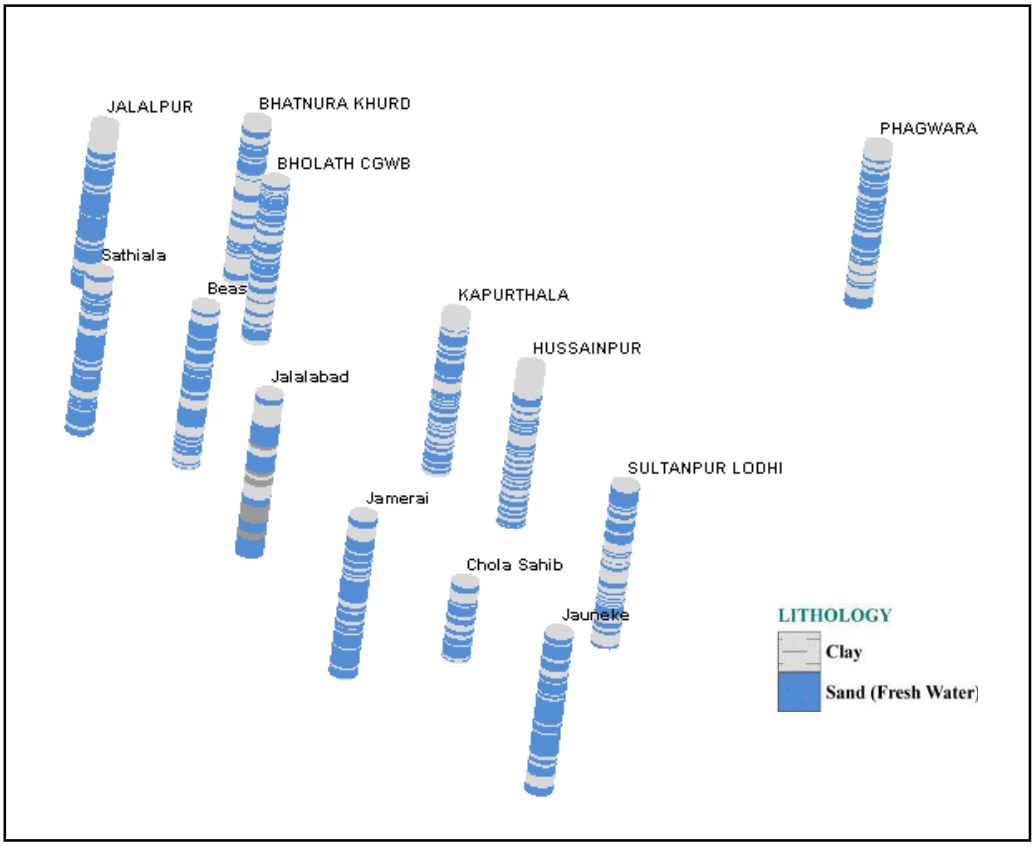


Fig.13: Three dimensional locations of validated exploratory wells with litholog



3.1 Sub Surface Disposition

3.1.1 Previous Work:

Ground water at shallow depth occurs under unconfined to semi confined and confined conditions in deeper aquifers.

The area is underlain by formations of Sub- recent to Quaternary age comprising of alluvium deposits belonging to vast Indus alluvial plains. Sub surface geological formations comprise of sand, gravel, pebbles, Kankar and clay. Ground water is fresh at all levels in the district. Central Ground Water Board has drilled 4 exploratory boreholes along with equal no of observation wells besides 11 piezometers to delineate and determine potential aquifer zones, evaluation of aquifer characteristics etc. Ground water exploration undertaken by CGWB has revealed the presence of 3 aquifer groups down to a depth of 410m. These aquifer groups comprise of fine to medium grained sand.

In alluvium thin granular zones exist down to the entire thickness, the top aquifer ranges from 20 to 45 m. The depth of the top aquifer in the North is upto 40 m., in the south it is upto 45m, in the Central it is 20 m. the top granular zone is interspersed by 2 to 3 thin clay lenses. A thick clay bed of thickness from 15 to 35 m. present beneath the Granular zone. Broadly it indicates 10 to 12 prominent granular horizons exist down to 410 m. and are separated by thick clay layers. The granular material is comprised of fine to coarse sand and at places mixed with gravel and pebble. CGWB has revealed the presence of 3 aquifer groups down to a depth of 350m. These aquifer groups comprise of fine to medium grained sand. Two exploratory wells at Hussainpur and Bhatnura Khurd are tapping medium aquifer (II Aquifer Group) and deep (III Aquifer group). One Piezometer at each of these two sites has been constructed to monitor ground water regime in shallow (I Aquifer group). Water table elevation ranges from 205 m to 240 m above msl. The ground water flow direction is from north east to south west.

Table- 2: The Aquifer Parameters of Kapurthala District

Aquifer Group	**Discharge 'Q' (lpm)**	**Transmissivity 'T' (m^2/day)**	**Storativity**
1st Group	NA	NA	NA
IInd Group			
IInd Group	NA	NA	NA
IIIrd Group	1983	987.26	NA

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

Data Validation of Exploration Wells of Kapurthala District

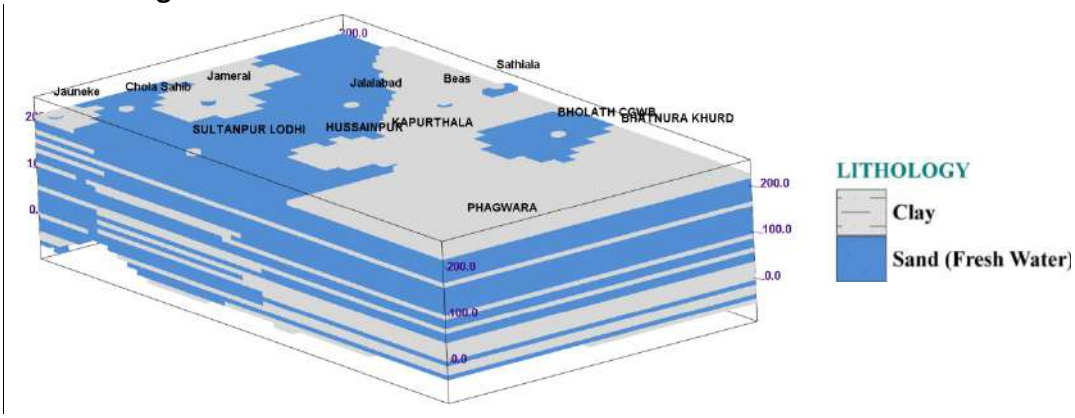
Sl.No	Source of data	Depth Range (m)				***Total***
		< 100	100-200	200-300	>300	
1	CGWB	0	0	0	6	**6**
2	WRED/WSS/PSTC	0	0	0	1	**1**
3	PRIVATE WELLS	16	1	0	0	**17**
Total		**16**	**1**	**0**	**7**	**24**

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.

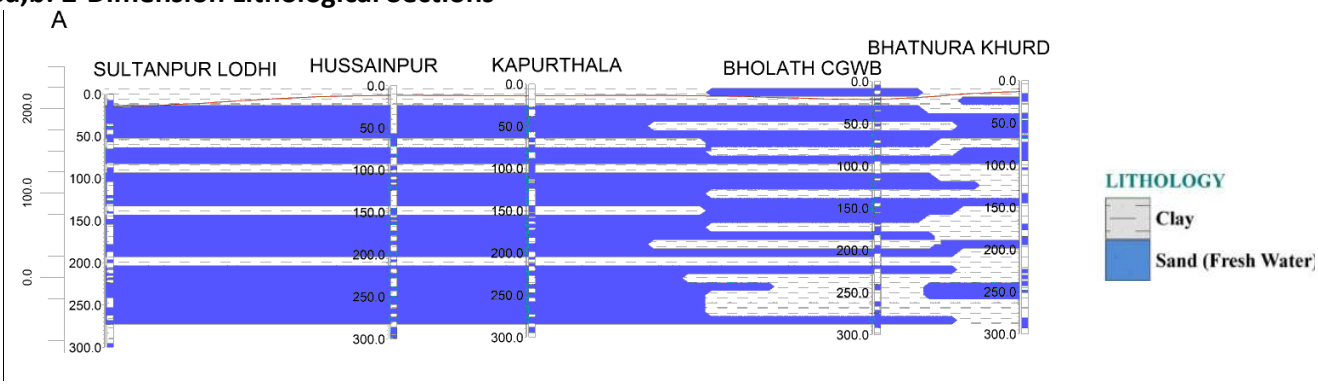
Based on geophysical borehole logging and use of resistivity profiling followed by the depth soundings at few selected places, for the present study and will be referred from time to time as it is obviously the higher resistivity beds represents freshwater zone in contrast in low resistive beds indicating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

Fig.14: 3-Dimension Lithological Model

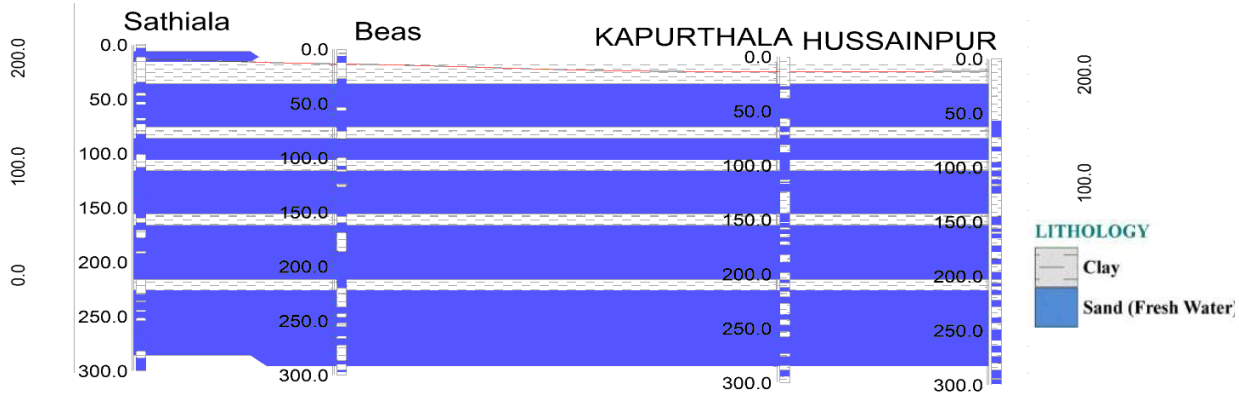


The major aquifer system of the district is quaternary alluvial deposits of Sutlej basin, having older alluvium and newer alluvium mainly comprises of sand, silt and clay admixed with kankars. The top surface layer and soil is mainly silty clay. The lithology shows the variation in lithology thickness i.e. thick clay layers inter bedded with sand except at few locations in Sutlej river basin. In north- eastern 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



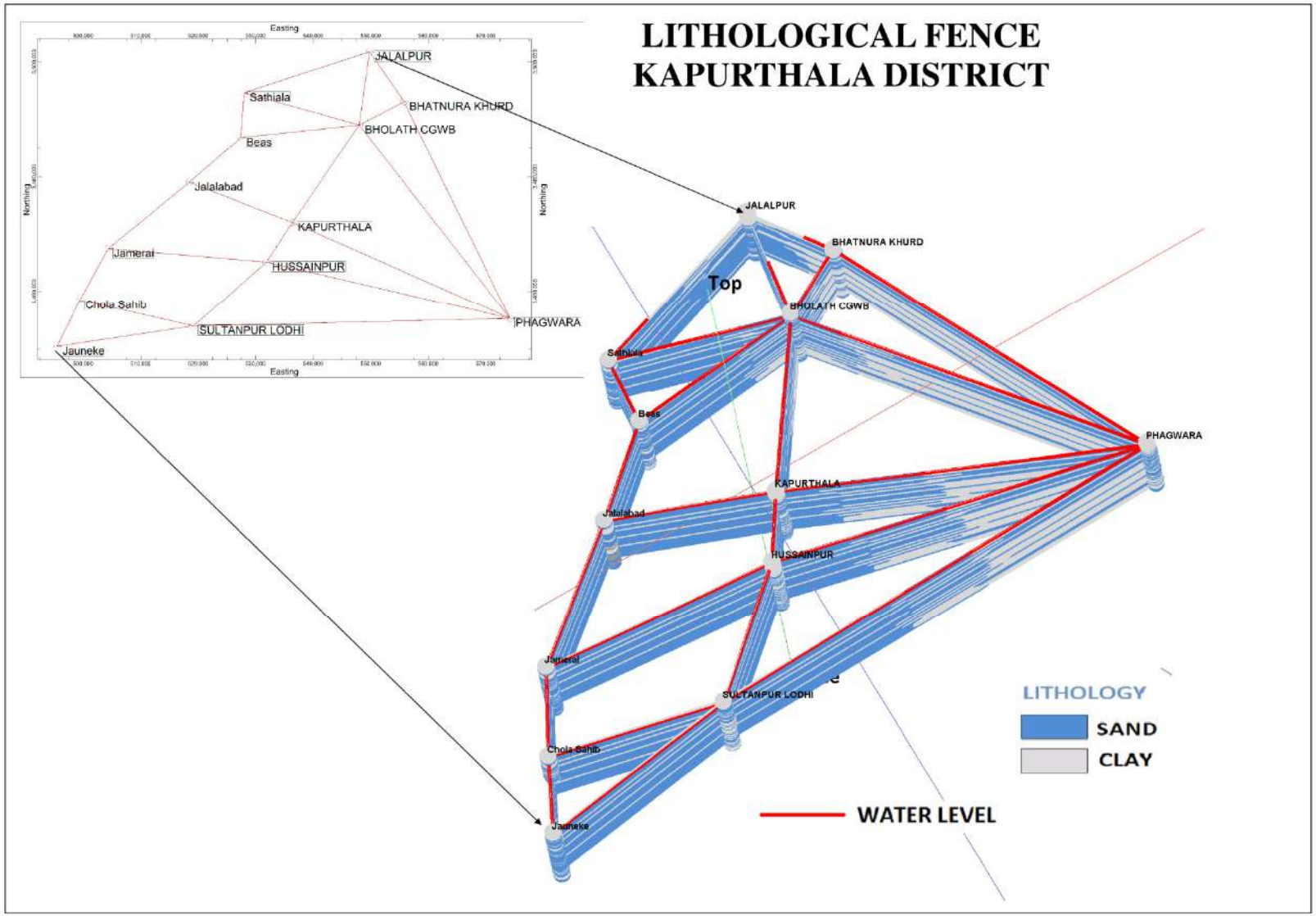
On the basis of lithologs geological sections has been drawn along SW-NE direction i.e. from Sultanpur Lodhi to Bhatnura khurd, indicates that surface soil of 4 to 15 m thickness is an admixture of clay with intercalation of sand lenses is decreasing. There are 5 well defined granular zones up to 50 - 275 m depth separated by laterally extensive clay layers 10 – 20 m thick. 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 locations Bhatnura khurd and Bholath where thick clay layers were identified.



On the basis of lithologs geological sections from Sathiala (Gurdaspur dist.) to Hussainpur indicates that surface soil thickness is an admixture of clay and sand increases from Sathiala. Thicknesses of clay beds are prominent at locations Kapurthala and Huussainpur. There are 5 well defined granular zones up to 300 m depth separated by laterally extensive clay layers 5 – 15 m thick. The lithology shows the variation in thickness i.e. thin clay layers inter bedded with sand except at all locations.

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



3.2 Aquifer Geometry:

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

The first aquifer is water table aquifer and extends all over the area is composed mainly of less coarse sediments as compared to other groups. This aquifer is overlain by a thin clay layer of about 1 to 4 m thick and is also underlain by clayey group which is about more than 12 m depth. Aquifer Group -I extends upto 113 m of depth and below that clay layer starts getting thickened about 12-35 m separating Aquifer Group -II ranges from 143 m to 215 m. Aquifer Group -III exists in this area extends from 246m to 300m separated by highly thick clay zones of 12 to 30 m thickness (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 Kapurthala 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 is also prepared using the aquifer model and are shown in Fig.20. The aquifer grouping, group thickness and granular zones encountered in the groups are given in table below

Aquifer Grouping in Kapurthala District

Aquifer Group	Avg. Range		Avg. Thickness		Avg. Granular Zones	
	From	To	Min	Max	Min	Max
Aquifer I	15	111	67	110	40	61
Aquifer II	122	210	34	90	15	85
Aquifer III	225	300	47	85	30	59

Fig.19: 3D Aquifer disposition Model

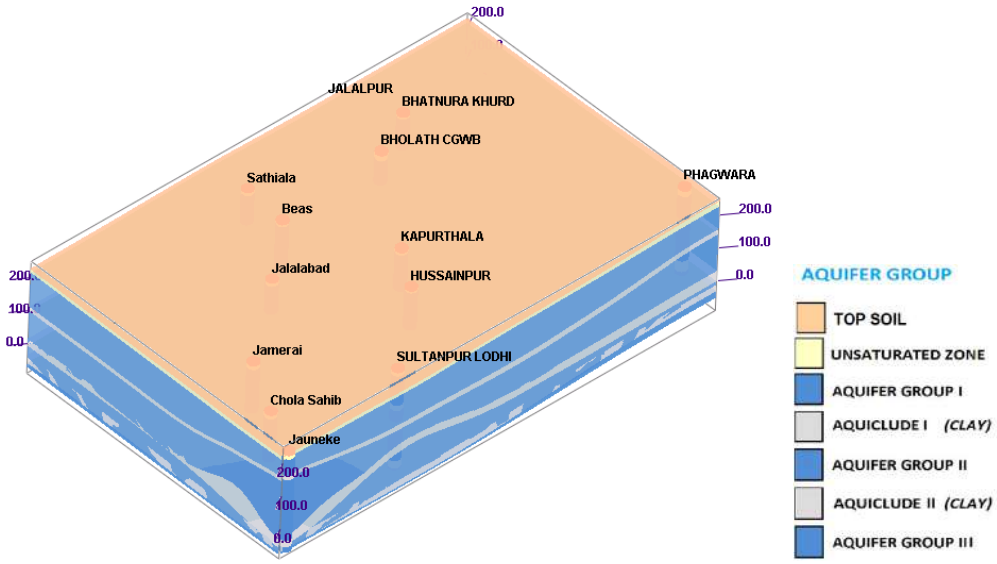
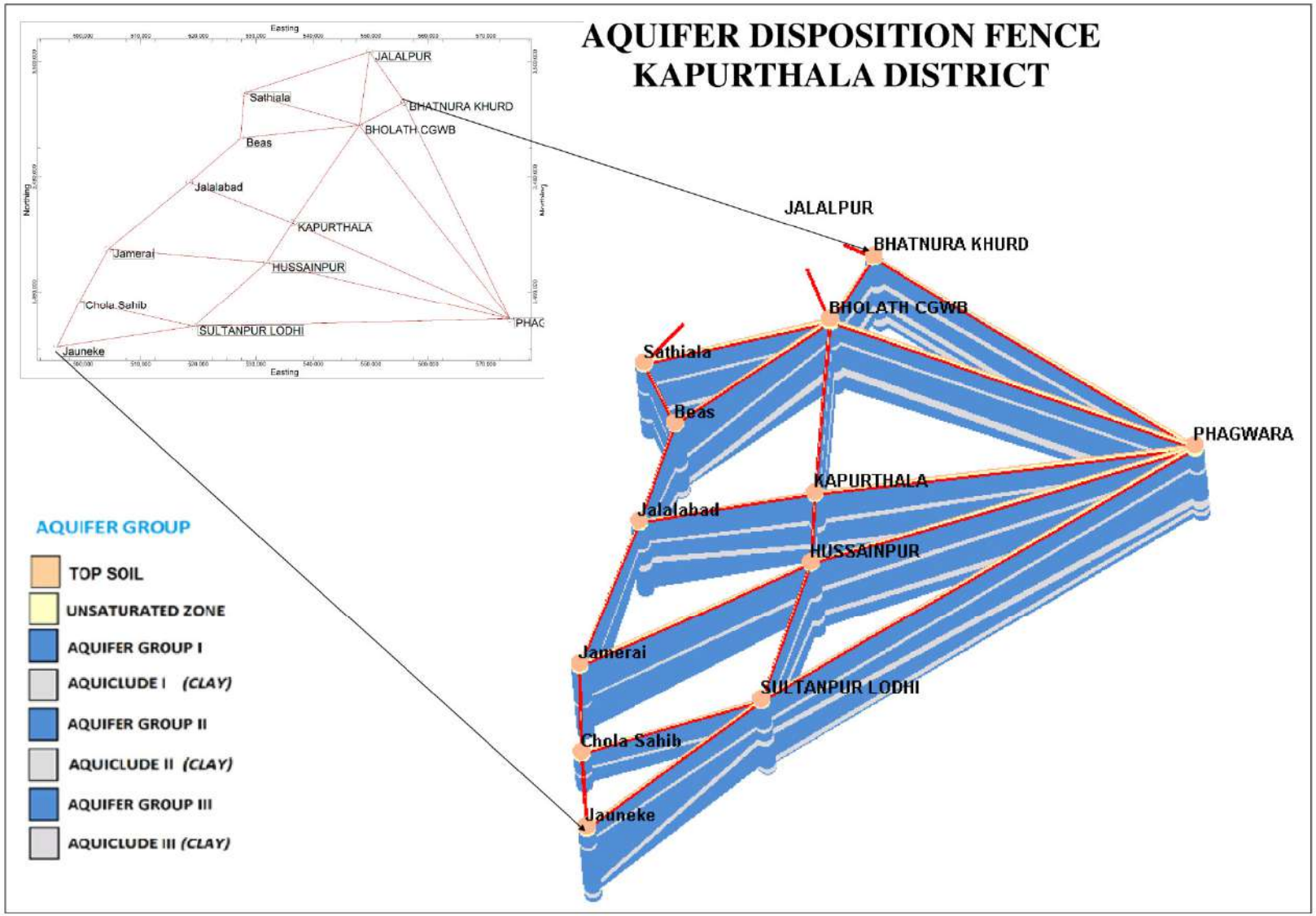


Fig.20: 3D Aquifer Disposition Fence



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 Kapurthala district has been assessed to be 205%. 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*
Nadala	116.98	215.76	3.95	219.71	4.36	-103.13	188	Over Exploited
Dhilwan	139.92	279.67	4.45	284.12	4.97	-144.71	203	Over Exploited
Kapurthala	154.52	264.84	13.94	278.78	15.11	-125.43	180	Over Exploited

Phagwara	135.80	325.89	11.85	337.73	12.97	-203.06	249	Over Exploited
Sultanpur Lodhi	199.41	403.76	3.86	407.62	4.43	-208.78	204	Over Exploited
TOTAL	**746.64**	**1489.91**	**38.06**	**1527.97**	**41.83**	**-785.11**	**205**	**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

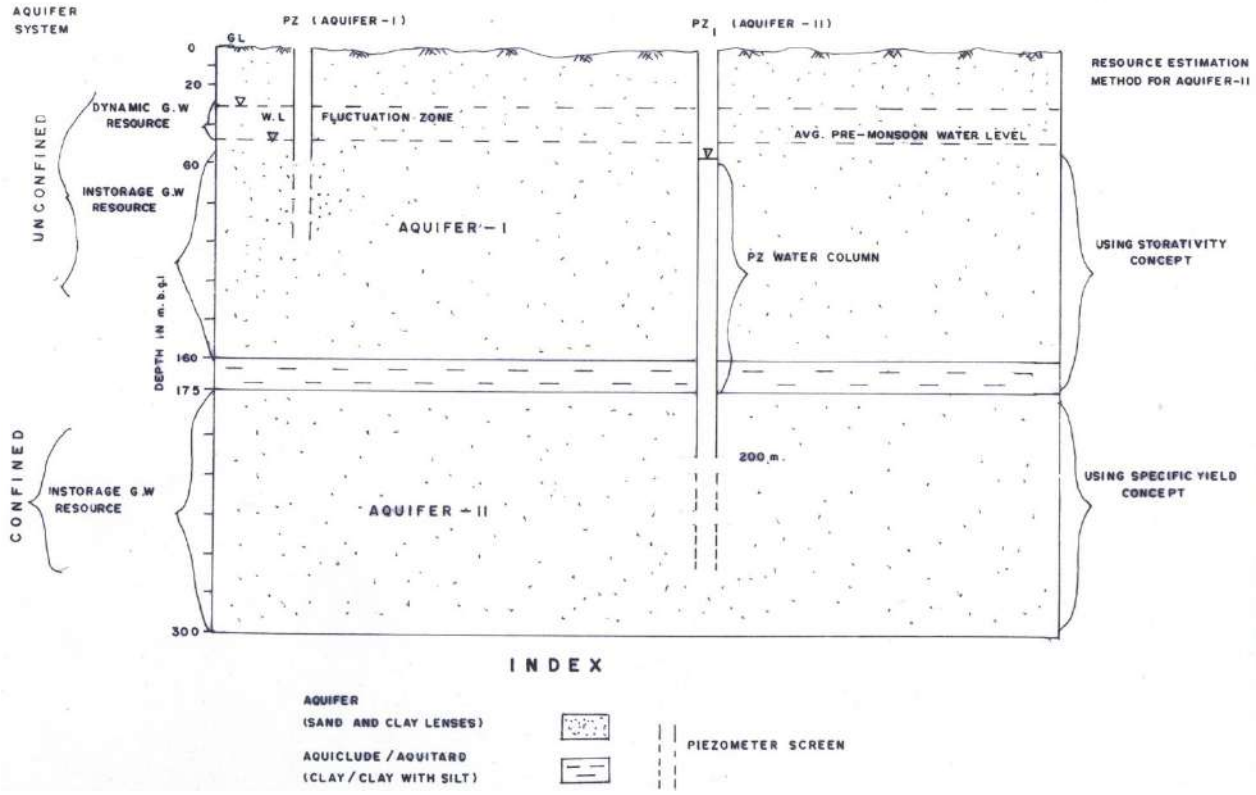


Table-6: Block Wise In storage Ground Water Resources in Unconfined Aquifer –I (Alluvium)

BLOCK WISE INSTORAGE GROUND WATER RESOURCES IN UNCONFINED AQUIFER –I													
Type of Ground Water Assessment Unit (Block):													
Sr. No.	Name of Assessment Unit	Areal extent (Sq.Km.)				Average Pre-monsoon Water Level (m bgl)	Depth to bottom of Aquifer Group I (m bgl)	Total Thickness of formation below Pre-monsoon Water Level (m) (9-8)	Thickness of the Granular Zone in AQUIFER GROUP-I below Pre-monsoon WL (m)	Average Specific Yield	In-Storage Ground Water Resources [(5)*(10)*(11)*] FRESH (ham)	Net Ground water Availability Dynamic Resources (mcm)	Total Aquifer -I Resources (mcm) [12+13]
		Total Geographical Area	Assessment Area										
			Total	Fresh Water	Brackish/ Saline Water								
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Nadala	224.4	224.4	224.4	0	8.70	101	92.3	53	0.072	856	117	973
2	Dhilwan	256.5	256.5	256.5	0	7.48	110	102.5	52	0.072	960	140	1100
3	Kapurthala	392.1	392.1	392.1	0	18.20	119	100.8	60	0.072	1694	155	1848
4	Phagwara	300.4	300.4	300.4	0	22.05	89	67.0	47	0.072	1017	136	1152
5	Sultanpur Lodhi	444.7	444.7	444.7	0	12.29	105	92.7	58	0.072	1857	199	2056
Dist.Total mcm)		**1618.1**	**1618.1**	**1618.1**							**6384**	**747**	**7131**
Dist.Total (bcm)											**6.38**	**0.75**	**7.13**

The data of Dhilwan Block is assessed from adjacent blocks (Nadala & Kapurthala)

mcm: million cubic metre

bcm: billion 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	Areal extent (sq.km)			Top Aquifer II	Depth to bottom of Aquifer II	Piezo-metric Head (m bgl)	Thickness of piezo-metric level(m bgl)	Total Thickness of confined aquifer down to explored depth	Thickness of the Granular Zone in confined aquifer down to explored depth	Average Specific Yield	Average value of Storativity	In-Storage Ground Water Resources (Specific yield concept) [(5)*(11)*(12)]	In-Storage Ground Water Resources (Storativity concept) [(5)*(9)*(13)]	Total in-Storage Ground Water Resources (mcm) (14+15)
		Total Geographical Area	Assessment Area		(m bgl)	(m bgl)			(m)	(m)					
			Total	Fresh Water					(7-6)						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Nadala	224.4	224.4	224.4	121	209	12	197	88	60	0.072	0.000105	969.41	4.64	974
2	Dhilwan	256.5	256.5	256.5	129	210	17	193	81	53	0.072	0.000105	978.80	5.20	984
3	Kapurthala	392.1	392.1	392.1	138	214	21	193	76	48	0.072	0.000105	1355.10	7.95	1363
4	Phagwara	300.4	300.4	300.4	104	218	25	193	114	85	0.072	0.000121	1838.45	7.02	1845
5	Sultanpur Lodhi	444.7	444.7	444.7	120	155	15	140	35	16	0.072	0.000508	512.29	31.63	544
Dist.Total (mcm)		**1618.1**	**1618.1**	**1618.1**									**5654.05**	**56.43**	**5710**
Dist.Total (bcm)													**5.65**	**0.06**	**5.71**

Storativity Value is taken from adjacent blocks of district Jalandhar

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	Areal extent (sq.km)			Top Aquifer III	Depth to bottom of Aquifer III	Thickness of piezo-metric level(m bgl)	Total Thickness of confined aquifer down to explored depth	Thickness of the Granular Zone in confined aquifer down to explored depth	Average Specific Yield	Average value of Storativity	In-Storage Ground Water Resources (Specific yield concept) [(5)*(10)*(11)]	In-Storage Ground Water Resources (Storativity concept) [(5)*(8)*(12)]	Total in-Storage Ground Water Resources (mcm) (13+14)
		Total Geographical Area	Assessment Area		(m bgl)	(m bgl)		(m)	(m)					
			Total	Fresh Water				(7-6)						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Nadala	224.4	224.4	224.4	232	300	211	68	31	0.072	0.000105	500.86	4.97	506
2	Dhilwan	256.5	256.5	256.5	229	300	208	71	41	0.072	0.000105	757.19	5.60	763
3	Kapurthala	392.1	392.1	392.1	227	300	206	73	52	0.072	0.000105	1468.02	8.48	1477
4	Phagwara	300.4	300.4	300.4	233	300	212	67	30	0.072	0.000121	648.86	7.71	657
5	Sultanpur Lodhi	444.7	444.7	444.7	178	300	157	122	58	0.072	0.000508	1857.07	35.47	1893
Dist.Total (mcm)		**1618.1**	**1618.1**	**1618.1**								**5232.00**	**62.23**	**5294**
Dist.Total (bcm)												**5.23**	**0.06**	**5.29**

Storativity Value is taken from adjacent blocks of district Jalandhar
Piezo-metric Head (Aquifer-III) of the district is calculated from adjacent district Jalandhar (21 m bgl)

Table-9: Block Wise Total Availability of Groundwater Resources upto 300 m Depth and

AVAILABILITY OF TOTAL FRESH GROUNDWATER RESOURCES IN KAPURTHALA DISTRICT								
Sl.No	Block	*Volume of Unsaturated Zone up to Pre-monsoon WL (mcm)*	*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)]
								mcm
1	2	*3*	*4*	5	6	7	8	10
1	Nadala	64.63	116.98	856.31	973.29	974	506	2453.17
2	Dhilwan	73.87	139.92	960.34	1100.26	984	763	2847.05
3	Kapurthala	98.81	154.52	1693.87	1848.39	1363	1477	4687.94
4	Phagwara	108.14	135.80	1016.55	1152.35	1845	657	3654.39
5	Sultanpur Lodhi	96.06	199.41	1857.07	2056.48	544	1893	4492.93
Dist. Total (mcm)		**441.51**	**746.64**	**6384.14**	**7130.77**	**5710.48**	**5294.23**	**18135.48**
Dist. Total (bcm)		**0.44**	**0.75**	**6.38**	**7.13**	**5.71**	**5.29**	**18.14**

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 and deep depths and they are the main source of irrigation. This will lead to its deepening of ground water levels in all blocks of Kapurthala 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 & 24) 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 (Shallow Aquifer)

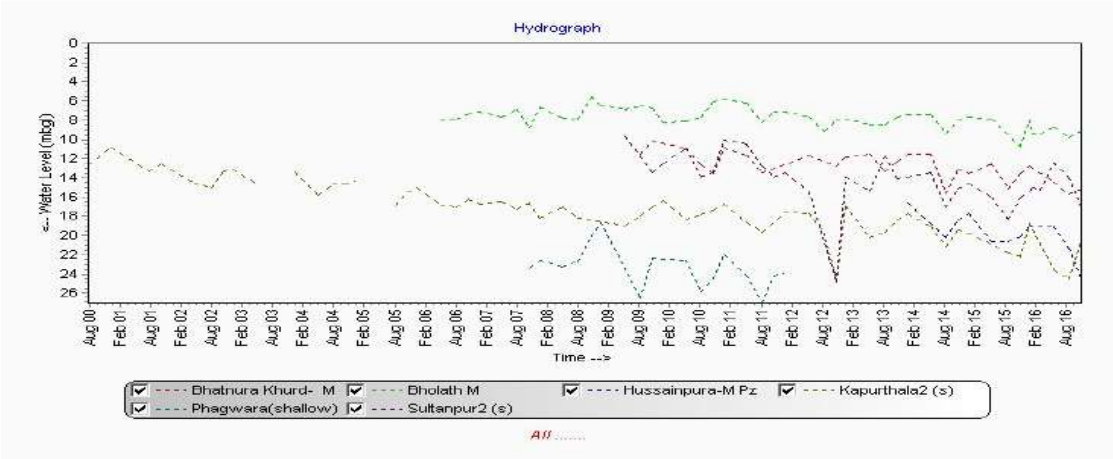
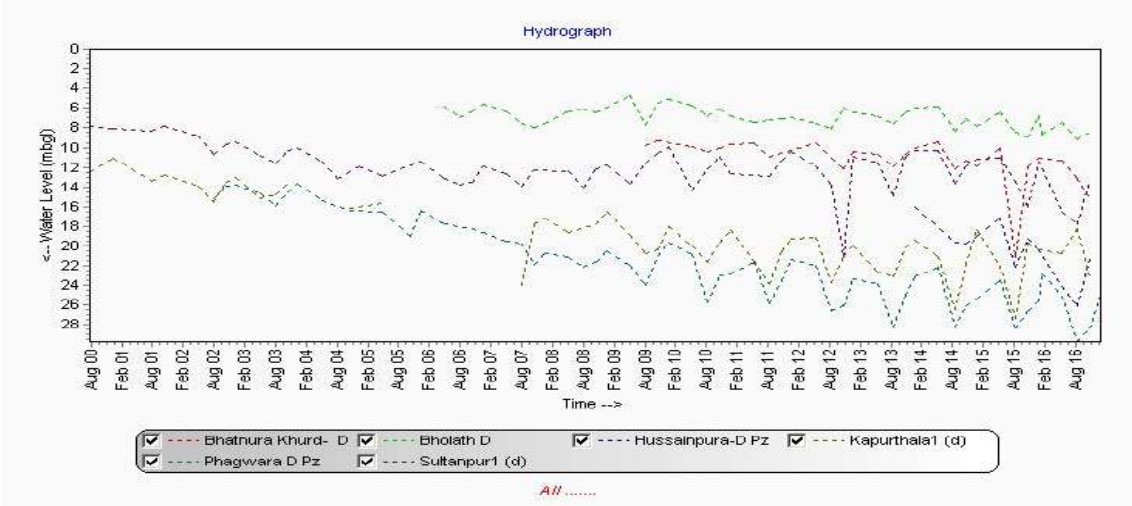


Fig.24: Long term ground water table variation (Deeper Aquifer)



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), Kapurthala (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	3567	9994	23015	13678	1172	193	**51619**
Deep TW	134	408	1467	526	10	0	**2545**
Total	**3701**	**10402**	**24482**	**14204**	**1181**	**154**	**54164**

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	684	29151	10648	11097	1324	1255	5	**54164**
Tubewells (%)	1.26	53.81	19.65	20.48	2.44	2.31	0.01	

Table-12: System of Ground water distribution device

	Open Water Channels			
Lined/pucca	*Unlined/kutcha*	*Underground Pipe*	*Others*	*Total*
6378	46600	1180	6	**54164**

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 Kapurthala District due to very low availability of volume of surplus water (17.92 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 46600 (out of 54164) tube wells (86%) 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 95.22 % 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 1527.97 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 320.44 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 205 % 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-13b).

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		
Nadala	116.98	215.76	188	54.9	2.76	38.8	96.46	95	-
Dhilwan	139.92	279.67	203	71.0	3.43	49.8	124.23	105	5
Kapurthala	154.52	264.84	180	69.70	4.42	32.5	106.62	85	-
Phagwara	135.80	325.89	249	84.40	3.49	84	171.89	95	-
Sultanpur Lodhi	199.41	403.76	204	101.90	3.82	51.5	157.22	121	21
Total	**746.64**	**1489.91**	**205**	**382**	**17.92**	**256.60**	**656.42**	**101**	**-**

Table-13b: Impact on Stage of Development (SOD) after applying various management strategies

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**
Nadala	188	50.49	138	36.73	151	5.92	182
Dhilwan	203	53.86	149	38.71	164	5.57	197
Kapurthala	180	53.71	126	29.64	150	11.47	169
Phagwara	249	71.17	178	70.88	178	11.59	237
Sultanpur Lodhi	204	52.62	151	27.35	177	3.44	201
Total	**205**	**56.61**	**148**	**39.82**	**165**	**7.85**	**197**

By adopting all the management strategies resulting in total reduction in stage of groundwater development is 106%. Hence overall stage of development afterwards is 103 % and is given in Table.14.

Table-14: Overall Stage of Development (SOD) after reduction in Kapurthala 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**
Nadala	188	50.49	36.73	5.92	93.14	95
Dhilwan	203	53.86	38.71	5.57	98.14	105
Kapurthala	180	53.71	29.64	11.47	94.82	85
Phagwara	249	71.17	70.88	11.59	153.64	95
Sultanpur Lodhi	204	52.62	27.35	3.44	83.41	121
Total	**205**	**56.61**	**39.82**	**7.85**	**104.28**	**101**

BLOCK WISE

AQUIFER MAPS

AND

MANAGEMENT PLAN

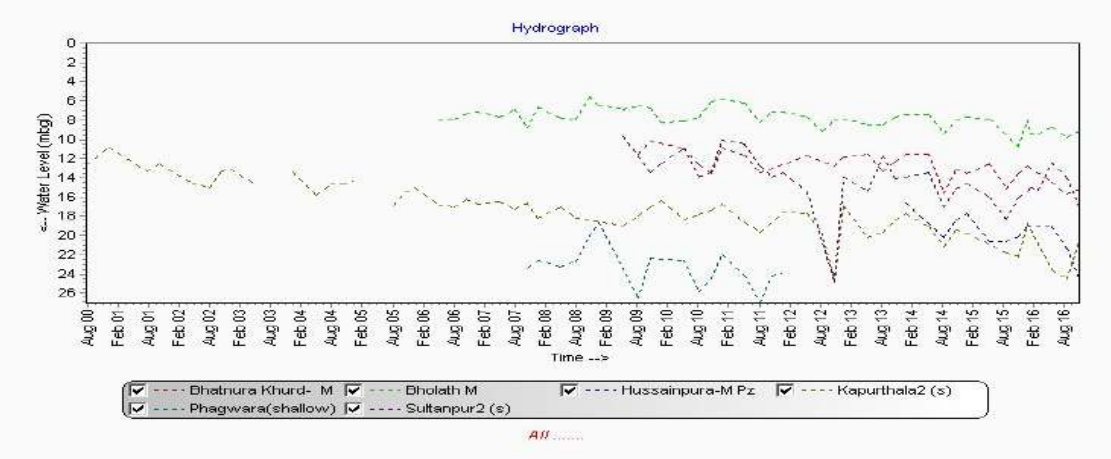
(PART-II)

I. Salient Information of Nadala Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>224.4 sq km</td></tr>
<tr><td>District/ State</td><td>Kapurthala, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 0
Rural Population: 87083
Total population: 87083</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 603mm
Non-monsoon Rainfall : 179 mm
Annual Average Rainfall: 782 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: 365.49 sq km
Net sown area: 180.24 sq km
Irrigation practices: Tube well
Cropping intensity: 203%
<u>Area under</u>
Ground water Irrigation: 180.24 sq km
Surface water irrigation: 0 sq km
Gross Irrigated area: 365.49 sq km
Net Irrigated area: 180.24 sq km
Number and types of abstraction structures: 10985, 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>8.70 – 101.0</td><td>92</td><td>53</td><td>973</td></tr>
<tr><td>Aquifer-II</td><td>121.0 – 209.0</td><td>88</td><td>60</td><td>974</td></tr>
<tr><td>Aquifer-III</td><td>232.0 – 300.0</td><td>68</td><td>31</td><td>506</td></tr>
</table>
Total Ground Water Resources available is 2453 mcm and total potential granular zones available are 144 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: 215.76 mcm Domestic and industrial water supply: 3.95 mcm *Future water demands* Irrigation development potential : (-)103.13 mcm Domestic and industrial water supply up to 2025 years : 4.36 mcm
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 5.68 – 8.72 m bgl Post Monsoon: 6.30 – 9.18 m bgl Seasonal Fluctuation: (-)0.46 – (-)1.93 m/yr **Aquifer-II** Pre Monsoon: 8.87 m bgl Post Monsoon: 9.62 m bgl **Aquifer-III** No Monitoring Station Exist

LONG TERM HYDROGRAPH (DECLINE TREND)



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 (8.70 -101 m)	Quarter-nary Alluvial deposits	Unconfined to confined	53	NA	NA	12 % (0.072)	NA
Aquifer-II (121 - 209 m)		Semi confined to Confined	60				
Aquifer-III (232 - 300 m)		Semi confined to Confined	31	NA	NA	NA	NA

* Well field proposed in adjacent district Jalandhar NA : Not Available

Source: CGWB,2015

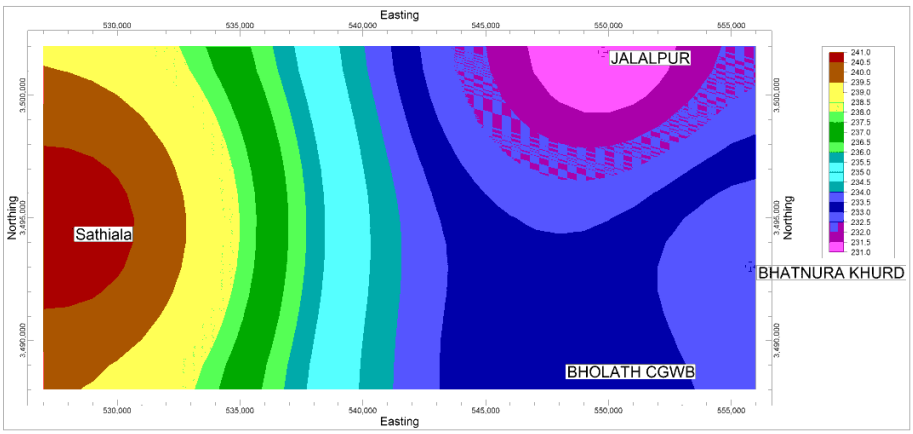
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

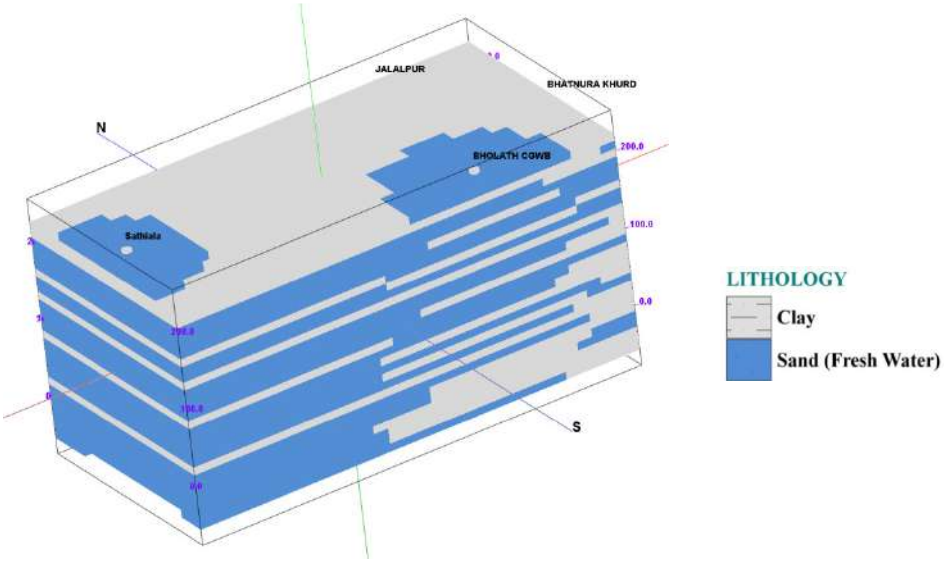
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	0	1	**1**
WRED/PSTC/WSS	0	0	0	0	**0**
PRIVATE	0	0	0	2	**2**
TOTAL	**0**	**0**	**0**	**3**	**3**

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 Nadala Block

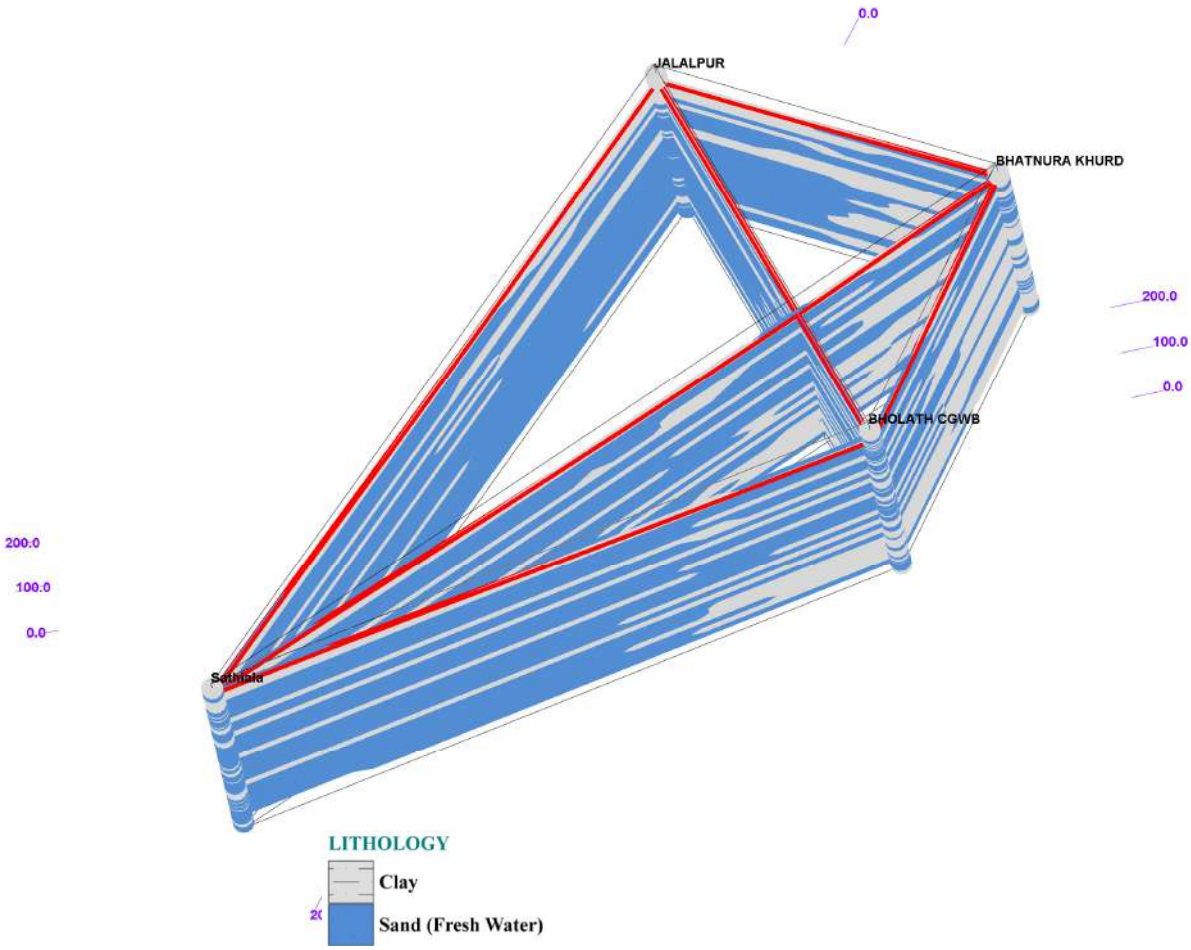


3-D Lithological model of Nadala Block



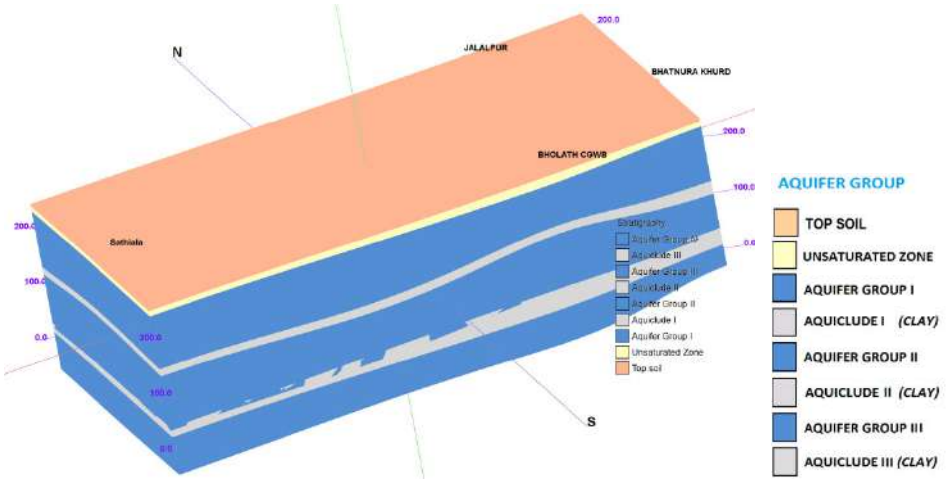
Lithological Cross section from Sathiala to Bhatnura Khurd

3-D Lithological Fence Diagram

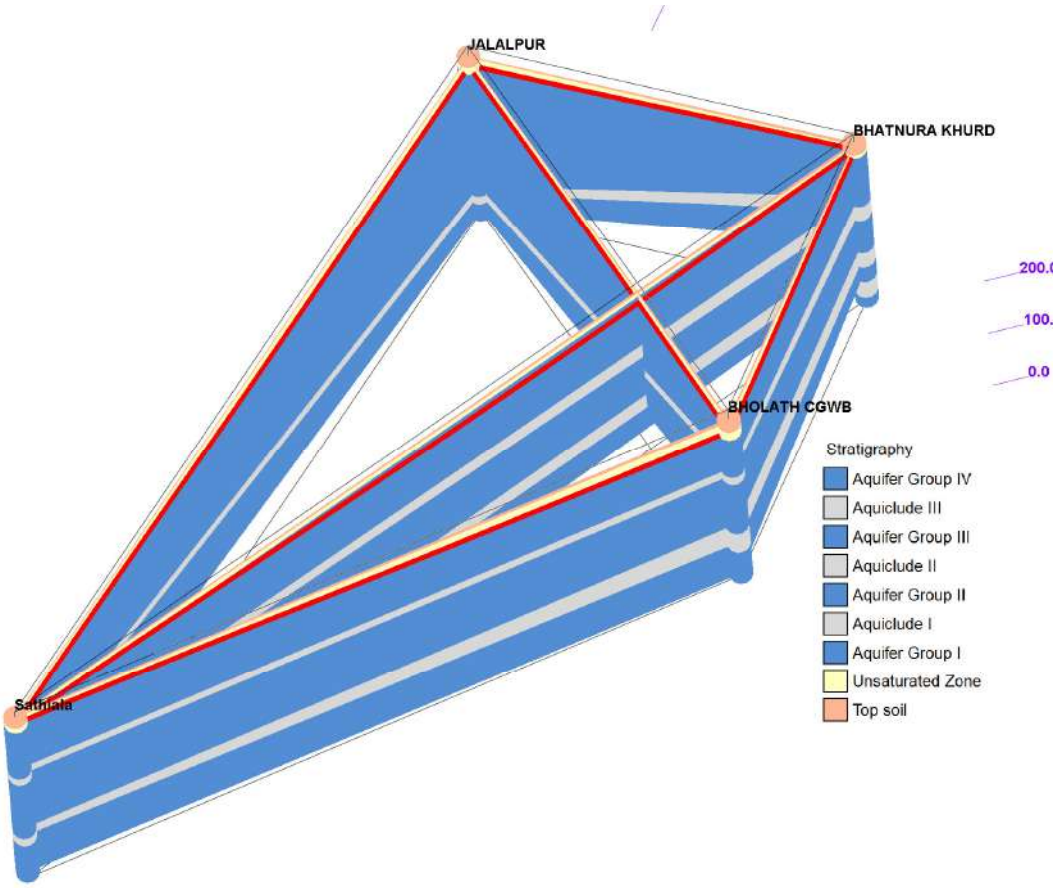


WATER LEVEL

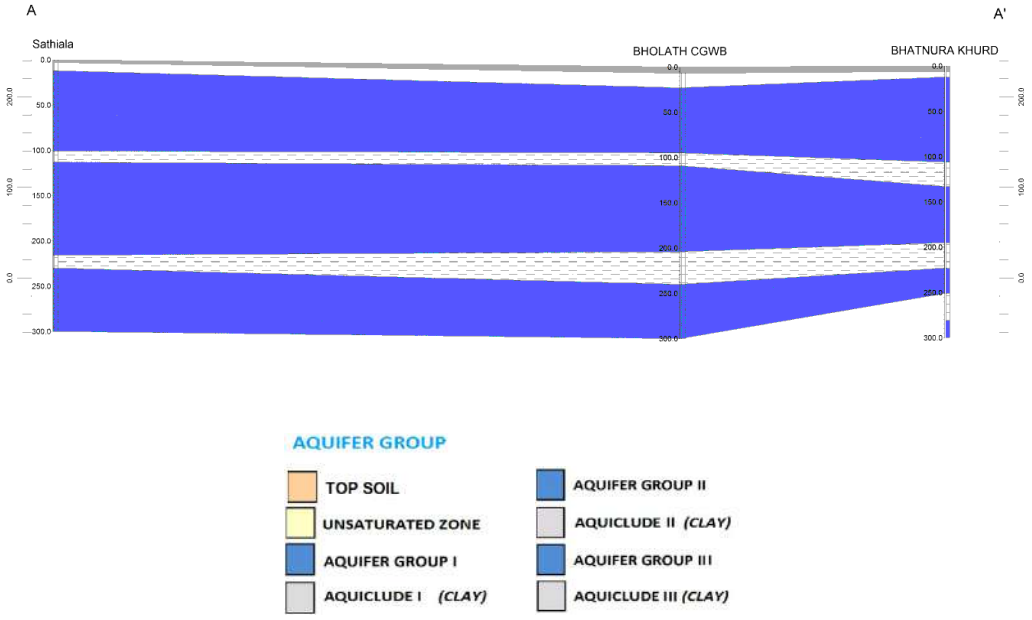
3-D Aquifer Disposition Model of Nadala Block



3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along NW to SE



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

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	116.98 mcm
	In-storage Aquifer-I (Specific Yield Concept)	856 mcm
	In-storage Aquifer-II (Specific Yield Concept)	969.41 mcm
	In-storage Aquifer-II (Storativity Concept)	4.64 mcm
	In-storage Aquifer-III (Specific Yield Concept)	500.86 mcm
	In-storage Aquifer-II (Storativity Concept)	4.97 mcm
	Total Resources	2453.17 mcm
Ground Water Extraction (as per 2013)	Irrigation	215.76 mcm
	Domestic & Industrial	3.95 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		4.36 mcm
Stage of Groundwater Development		188 %
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: 64.63 mcm
Source water requirement/availability for recharge: *Rain, Canal, Irrigation return flow*
Types and number of structures: NA

Other interventions proposed*: Artificial Recharge, Roof top Rainwater harvesting will conserve 3.26 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Nadala Block (224.40 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 54.9 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: *24% of the total rice area needs to change i.e.* 45.35 sq km
Anticipated volume of water to be saved: 45.35 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 (%)*
116.98	215.76	219.71	193	45.35	45.35	174.36	188	38.8	24

Alternate Water sources

Surface water sources: *Tanks, Ponds*
No.of Water tanks: 22
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).

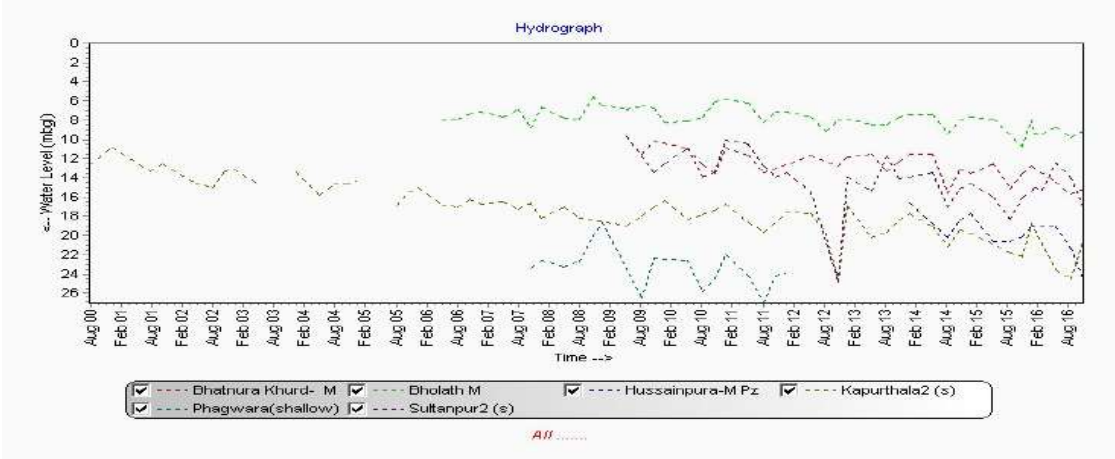
Sl.No	Techniques	Water Saving (%)	Crops
1	Mulching	17	Wheat
2	Bed Planting	18-25	Wheat
3	Use of Sprinkler and drip Irrigation	70-90	Sugarcane, Sunflower, Maize

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 Dhilwan Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>256.50 sq km</td></tr>
<tr><td>District/ State</td><td>Kapurthala, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 0
Rural Population: 89489
Total population: 89489</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 541 mm
Non-monsoon Rainfall : 157 mm
Annual Average Rainfall: 698 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: 429.76 sq km
Net sown area: 216.20 sq km
Irrigation practices: Tube well
Cropping intensity: 199%
<u>Area under</u>
Ground water Irrigation: 216.20 sq km
Surface water irrigation: 0 sq km
Gross Irrigated area: 429.76 sq km
Net Irrigated area: 216.20 sq km
Number and types of abstraction structures: 10636, 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>7.48 – 110.0</td><td>103</td><td>52</td><td>1100</td></tr>
<tr><td>Aquifer-II</td><td>129.0 – 210.0</td><td>81</td><td>53</td><td>984</td></tr>
<tr><td>Aquifer-III</td><td>229.0 – 300.0</td><td>71</td><td>41</td><td>763</td></tr>
</table>
Total Ground Water Resources available is 2847.05 mcm and total potential granular zones available are 146 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: 279.67 mcm Domestic and industrial water supply: 4.45 mcm *Future water demands* Irrigation development potential : (-)144.71 mcm Domestic and industrial water supply up to 2025 years : 4.97 mcm Water Scarcity Villages: 57
Water level behavior	*Aquifer wise water level* *Aquifer wise water level* **Aquifer-I** Pre Monsoon: 6.09 – 13.78 m bgl Post Monsoon: 6.0 – 13.07 m bgl Seasonal Fluctuation: 1.24 – (-)1.18 m/yr **Aquifer-II** Pre Monsoon: 7.80 m bgl Post Monsoon: 9.72 m bgl **Aquifer-III** No Monitoring Station Exist
LONG TERM HYDROGRAPH SHOWING DECLINING WATER TABLE	



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 (7.48-110 m)	Quarter-nary Alluvial deposits	Unconfined to confined	52	NA	NA	12 % *(0.072)*	NA
Aquifer-II (129 - 210 m)		Semi confined to Confined	53	NA	NA	NA	NA
Aquifer-III (229 - 300m)		Semi confined to Confined	41	NA	NA	NA	NA

* Well field proposed in the adjacent block of District Jalandhar, NA : Not Available

Source: CGWB,2015

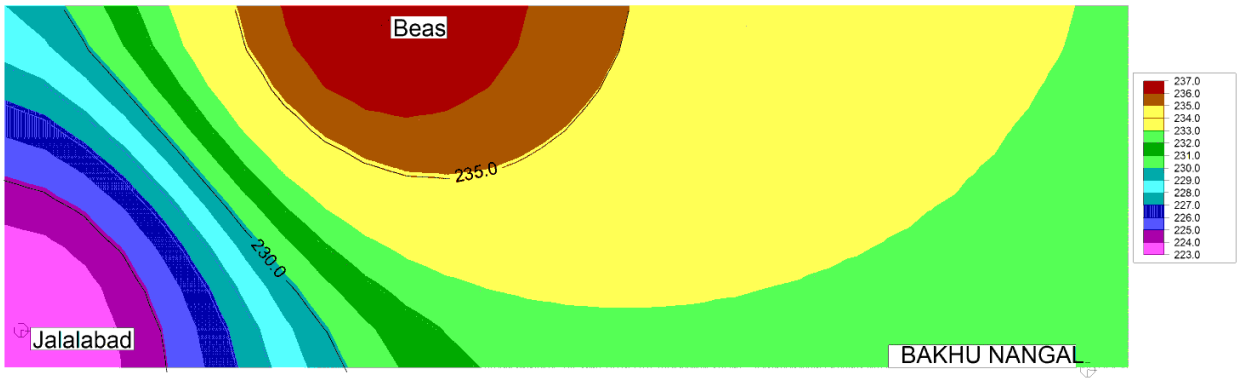
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

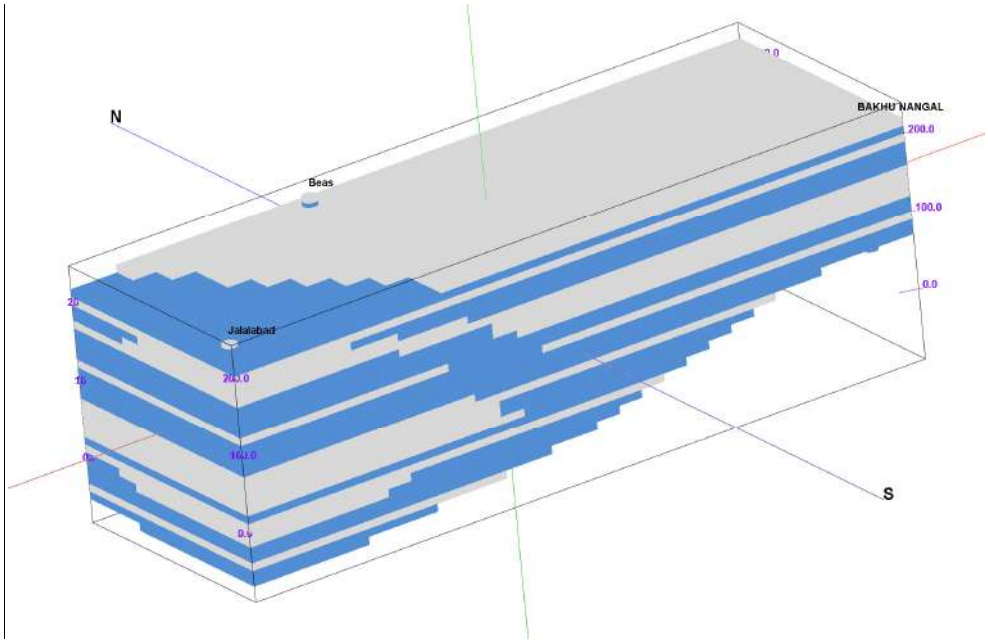
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	1	0	1	**2**
WRED/PSTC/WSS	0	7	0	0	**7**
PRIVATE	0	2	0	0	**2**
TOTAL	**0**	**10**	**0**	**1**	**11**

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.

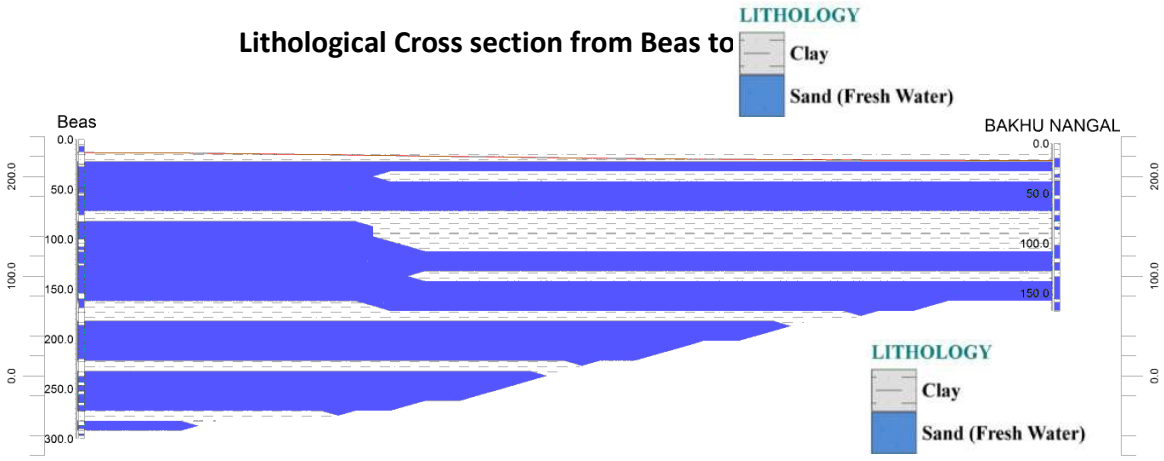
Elevation Map of Dhilwan Block



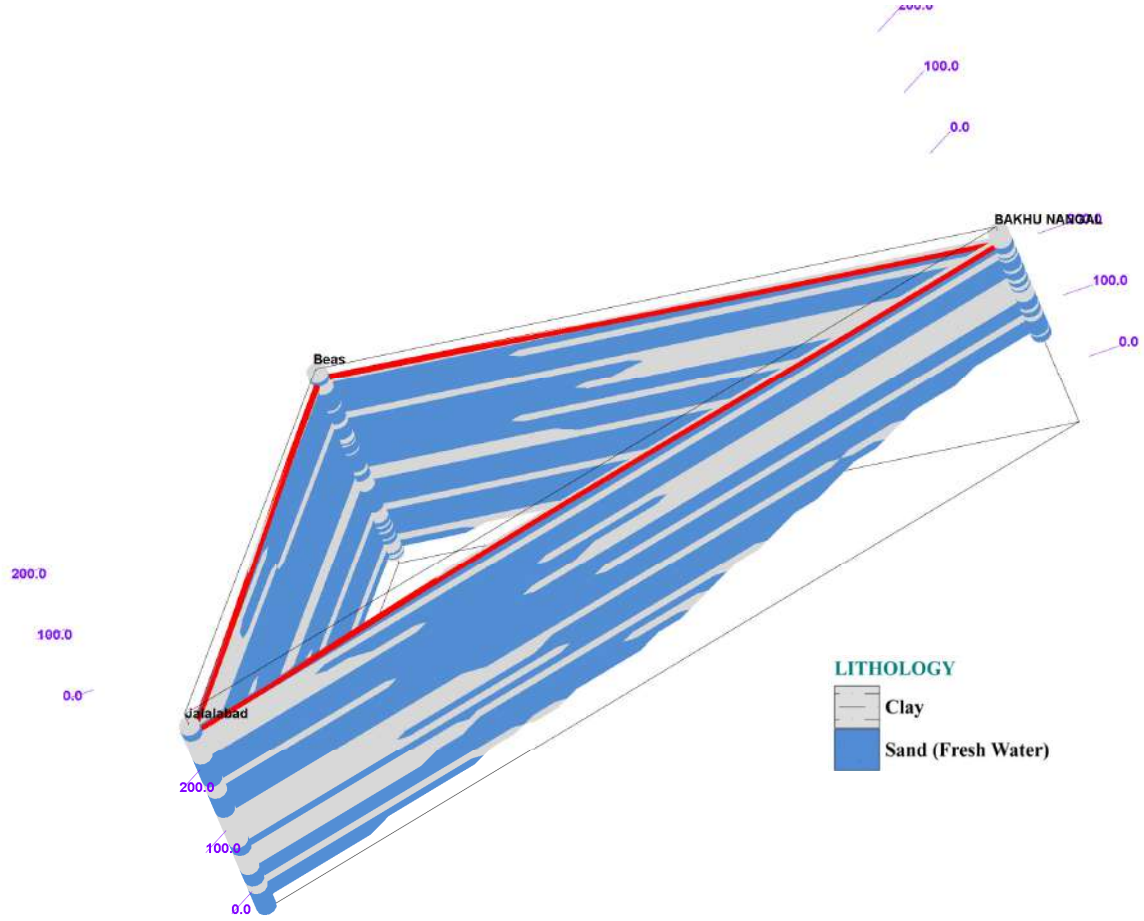
3-D Lithological model of Dhilwan Block



Lithological Cross section from Beas to

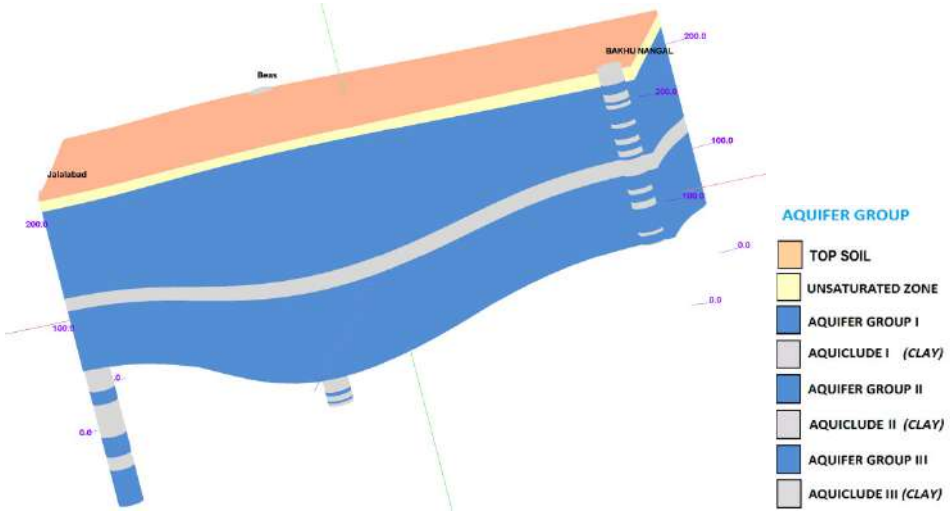


3-D Lithological Fence Diagram

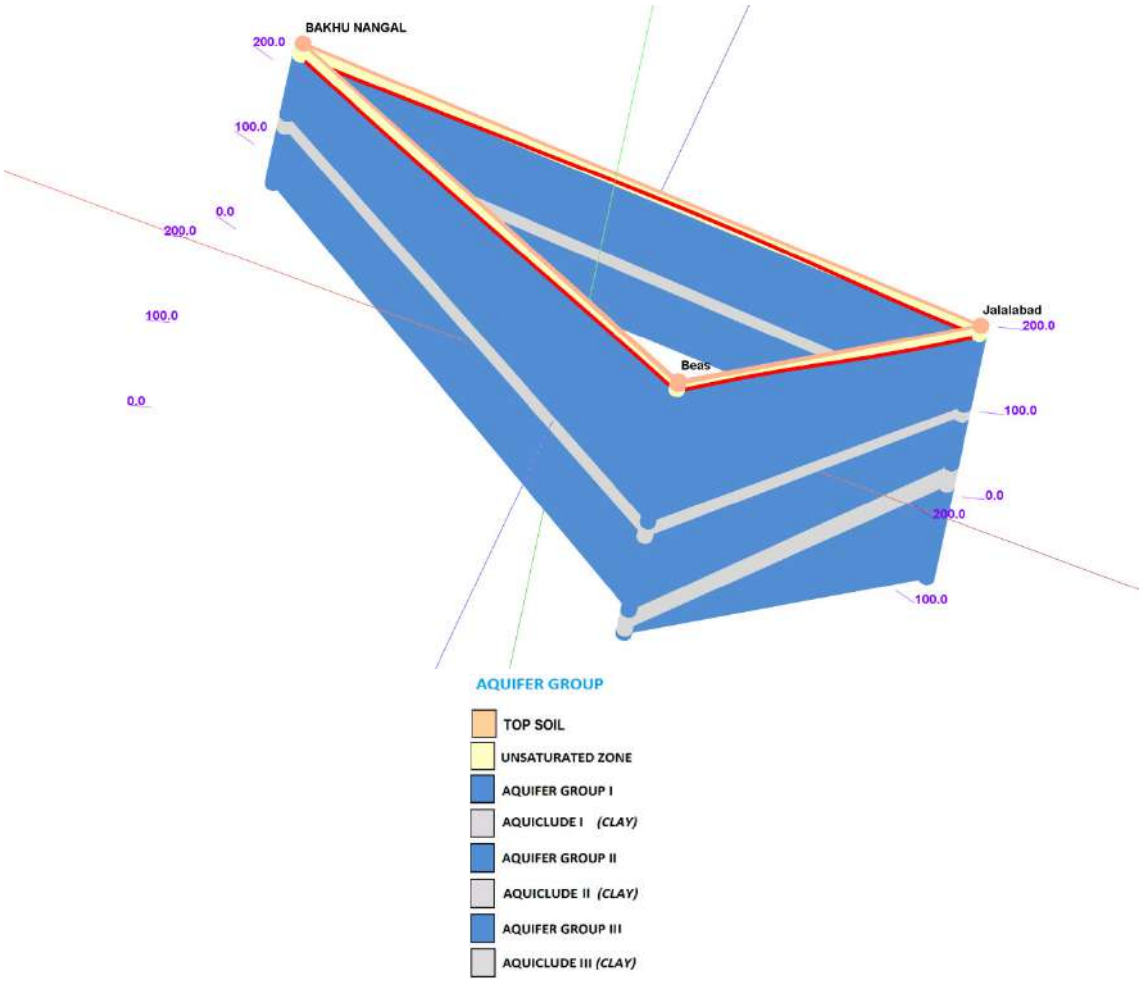


WATER LEVEL

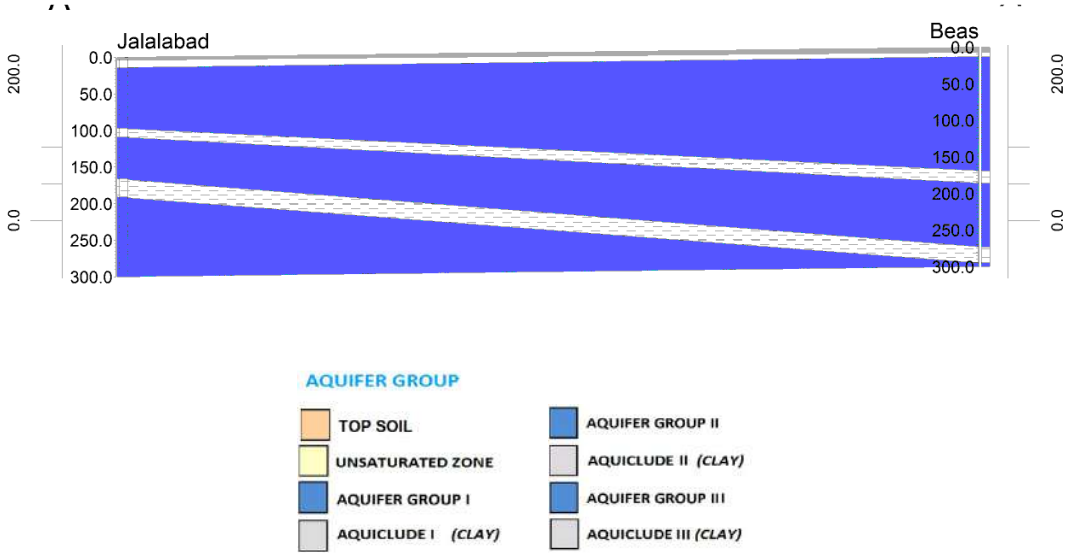
3-D Aquifer Disposition Model of Dhilwan Block



3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along South West to North East



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

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	139.92 mcm
	In-storage Aquifer-I (Specific Yield Concept)	960 mcm
	In-storage Aquifer-II (Specific Yield Concept)	978.80 mcm
	In-storage Aquifer-II (Storativity Concept)	5.20 mcm
	In-storage Aquifer-III (Specific Yield Concept)	757.19 mcm
	In-storage Aquifer-II (Storativity Concept)	5.60 mcm
	Total Resources	2847.05 mcm
Ground Water Extraction (as per 2013)	Irrigation	279.67 mcm
	Domestic & Industrial	4.45 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		4.97 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):*** Kapurthala (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: 73.87 mcm
Source water requirement/availability for recharge: *Rain, Canal, Irrigation return flow*
Types and number of structures: NA
Other interventions proposed*: Artificial Recharge, Roof top Rainwater harvesting will conserve 3.43 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Dhilwan Block (256.50sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 71.0 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:*34% of the total rice area needs to change i.e.* 69.68 sq km
Anticipated volume of water to be saved: 69.68 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 (%)*
105.91	279.67	284.12	208	69.68	69.68	214.44	203	49.8	34

Alternate Water sources

Surface water sources: *Tanks, Ponds*
No.of Water tanks: 17
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	70-90	Sugarcane, Sunflower, Maize

	Irrigation		

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

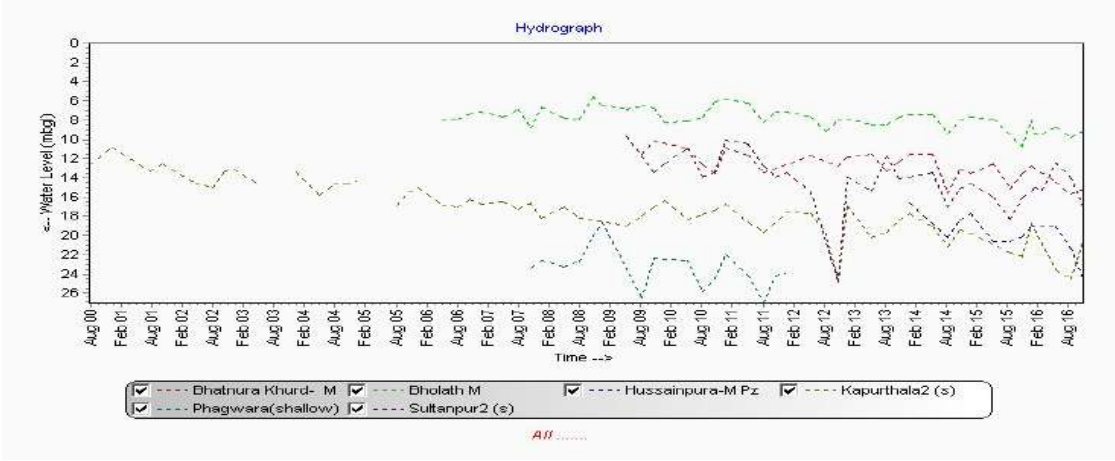
III. Salient Information of Kapurthala Block

Block Area (in Km^2)	**392.10 sq km**
District/ State	Kapurthala, Punjab
Population	Urban Population: 15575 Rural Population: 126101 Total population: 141676
Rainfall	Normal Monsoon: 538 mm Non-monsoon Rainfall : 141 mm Annual Average Rainfall: 679 mm

<table>
<tr><td>Agriculture and Irrigation</td><td>Principal crops: Rice, Wheat, Sugar cane, and Maize
Other crops: Vegetables and Fodder
Gross cropped area: 535.72 sq km
Net sown area: 285.32 sq km
Irrigation practices: Tube well and Canal Irrigation
Cropping intensity: 188%
<u>Area under</u>
Ground water Irrigation: 285.32 sq km
Surface water irrigation: 0 sq km
Gross Irrigated area: 535.72 sq km
Net Irrigated area: 285.32 sq km
Number and types of abstraction structures: 10078, 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 – 119.0</td><td>101</td><td>60</td><td>1848</td></tr>
<tr><td>Aquifer-II</td><td>138.0 – 214.0</td><td>76</td><td>48</td><td>1363</td></tr>
<tr><td>Aquifer-III</td><td>227.0 – 300.0</td><td>73</td><td>52</td><td>1477</td></tr>
</table>
Total Ground Water Resources available is 4687.94 mcm and total potential granular zones available are 160 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>
<tr><td>Existing and future water demands</td><td><u>Existing Gross Ground water Draft as on 2013</u>
Irrigation: 264.84 mcm
Domestic and industrial water supply: 13.94 mcm
<u>Future water demands</u>
Irrigation development potential : (-)125.43 mcm
Domestic and industrial water supply up to 2025 years : 15.11 mcm
Water Scarcity Villages: 45</td></tr>
</table>

Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 19.60 – 28.22 m bgl Post Monsoon: 20.70 – 31.26 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)



Aquifer Disposition

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

Exploratory Data Availability

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

PRIVATE	0	0	0	0	**0**
TOTAL	**2**	**0**	**0**	**1**	**3**

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 -119 m)	Quarter-nary Alluvial deposits	Unconfined to confined	65	NA	NA	12 % *(0.072)*	NA
Aquifer-II (138 - 214 m)		Semi confined to Confined	48	NA	NA		NA
Aquifer-III (227 - 300 m)		Semi confined to Confined	52	NA	NA	NA	NA

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

Source: CGWB,2015 & PSTC,2008

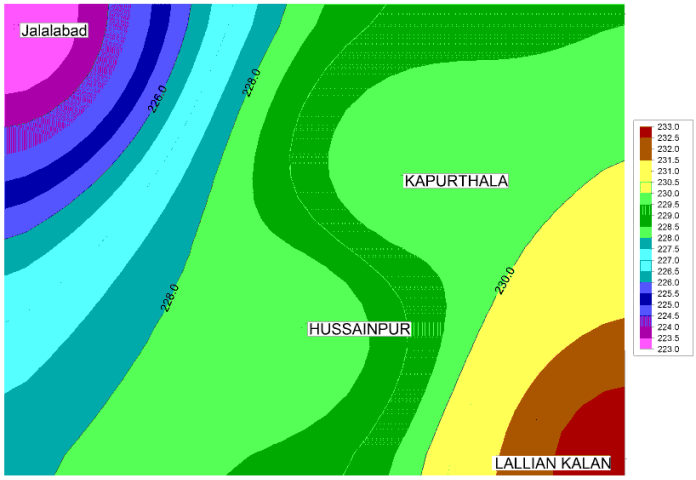
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

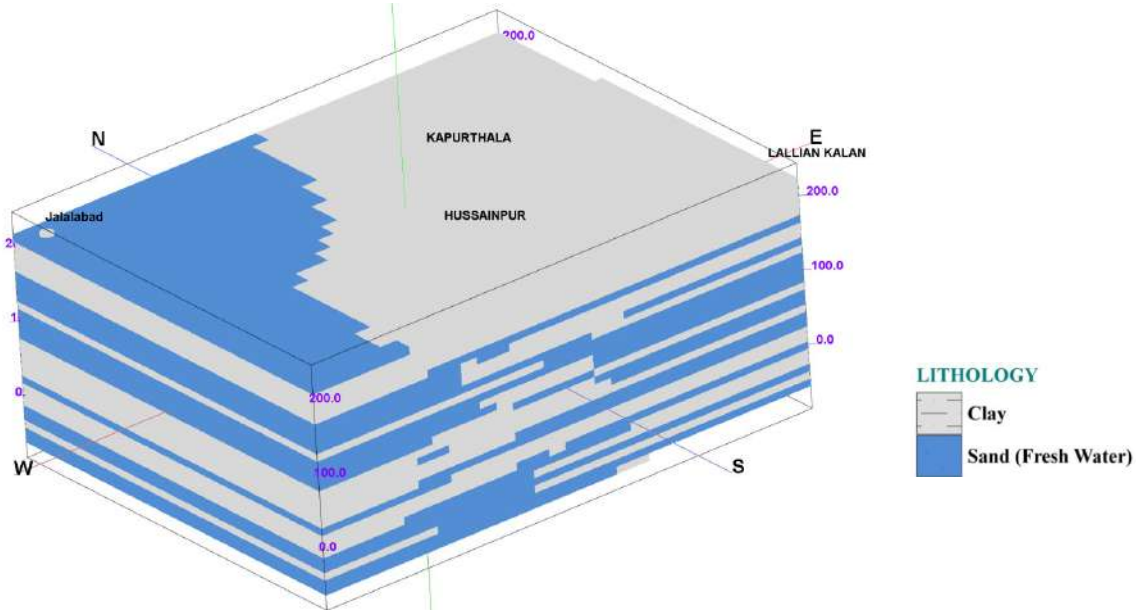
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	0	1	**1**
WRED/PSTC/WSS	2	0	0	0	**2**
PRIVATE	0	0	0	0	**0**
TOTAL	**2**	**0**	**0**	**1**	**3**

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.

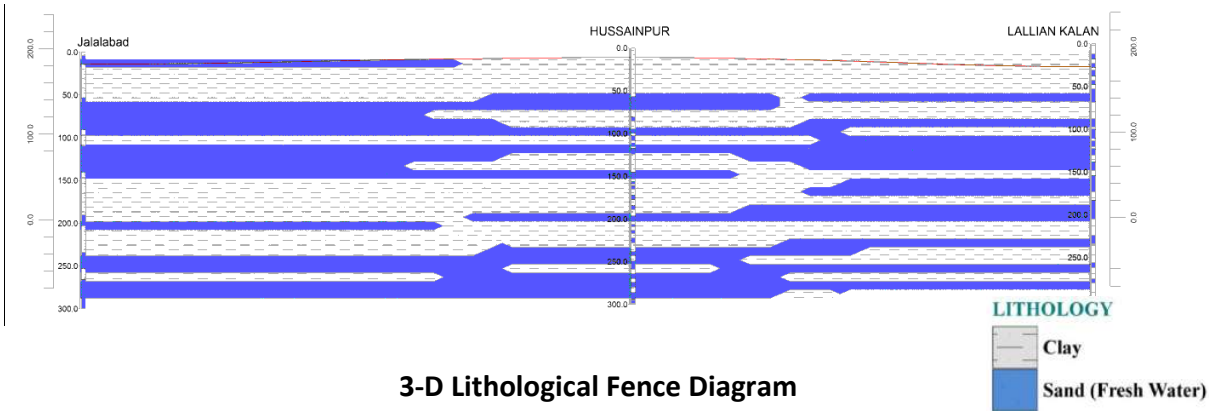
Elevation Map of Kapurthala Block



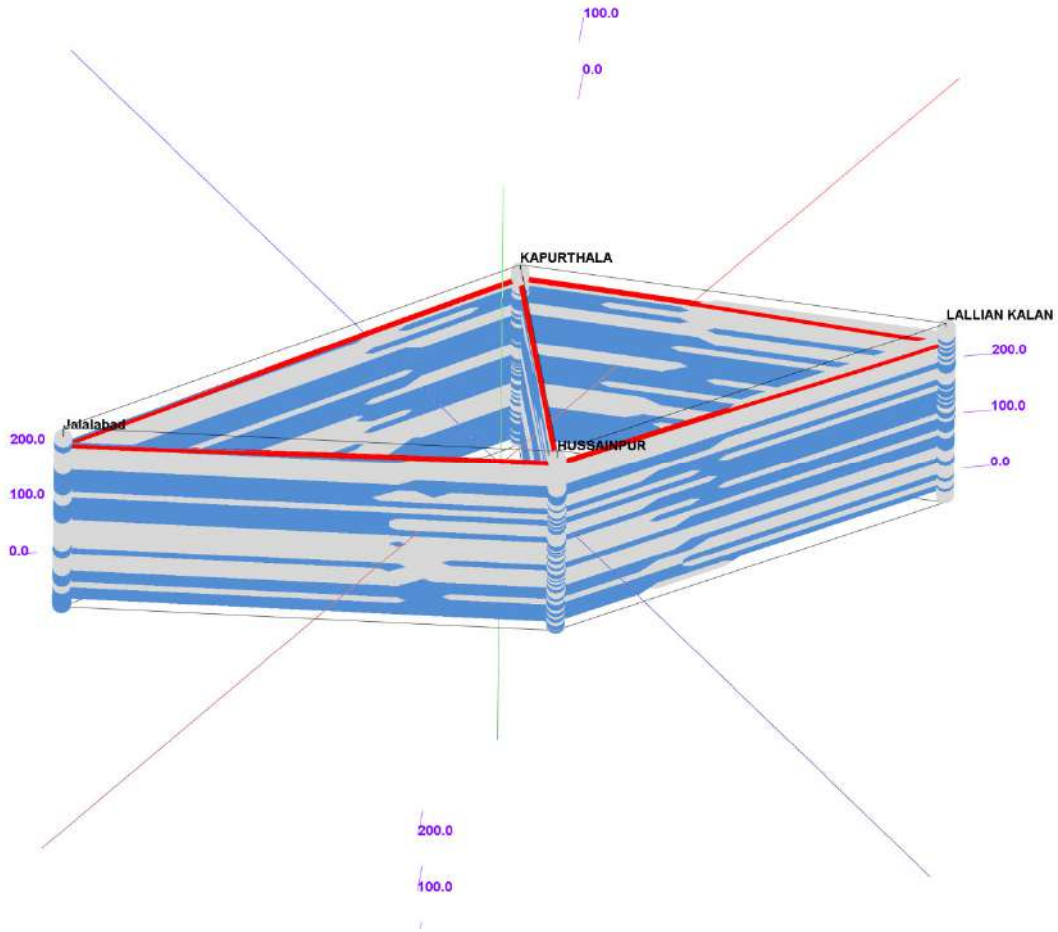
3-D Lithological model of Kapurthala Block



Lithological Cross section from Jalalabad to Lallian kalan



3-D Lithological Fence Diagram



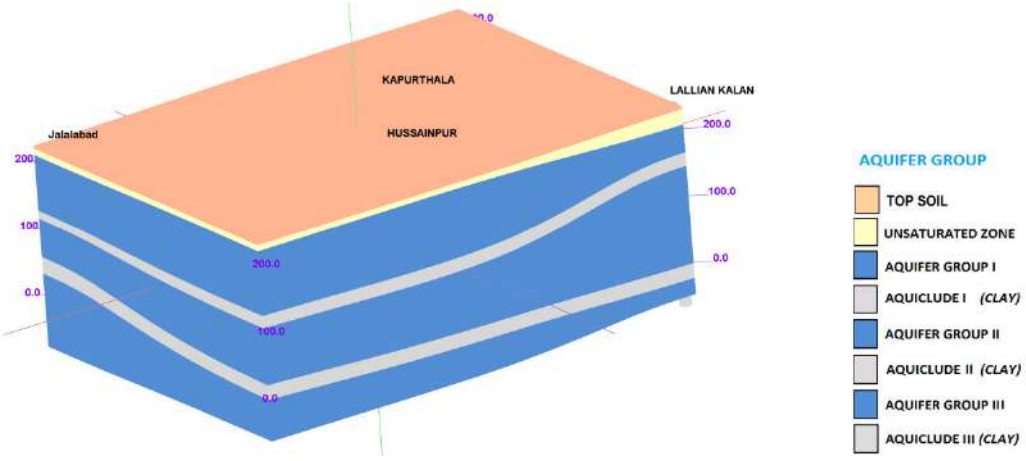
WATER LEVEL

LITHOLOGY

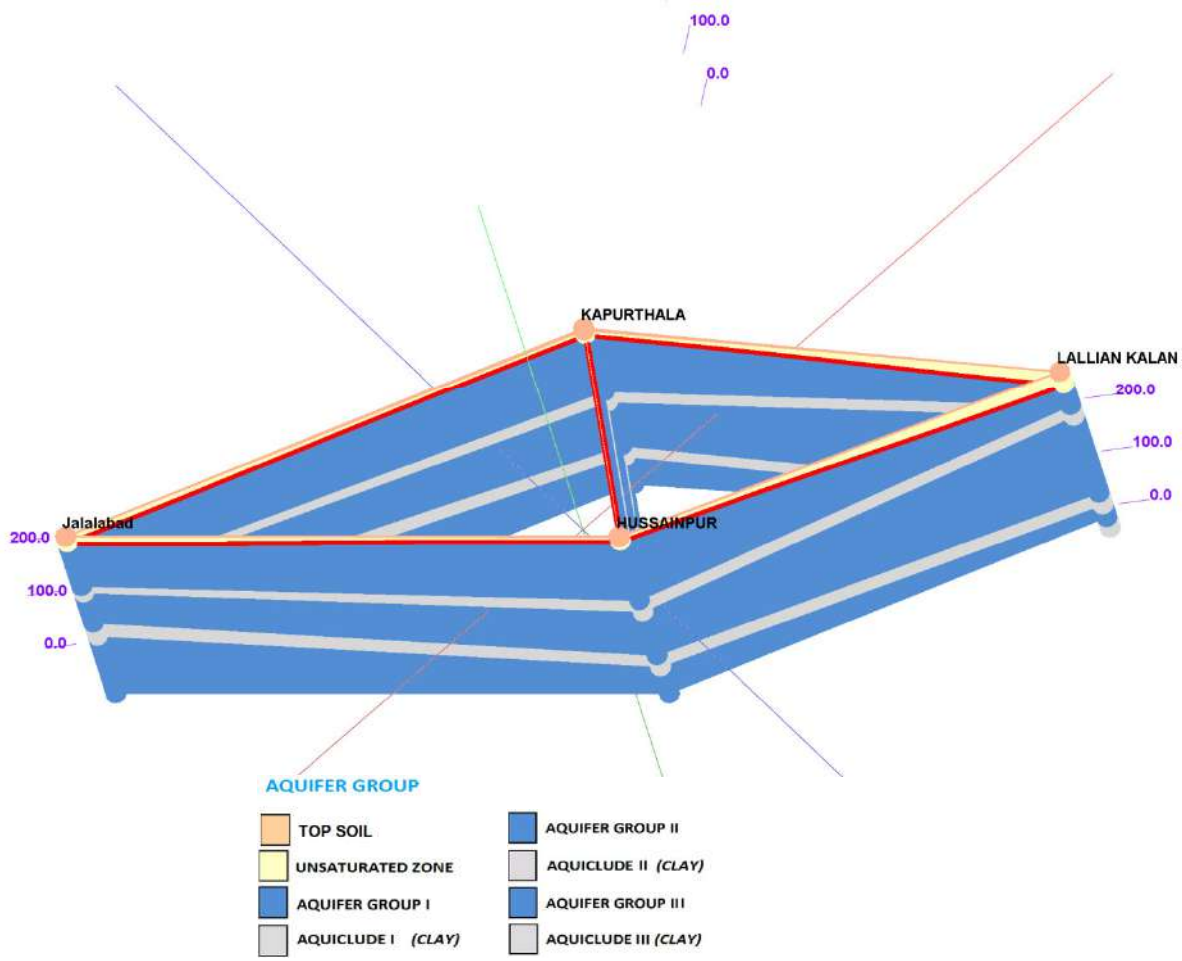
Clay

Sand (Fresh Water)

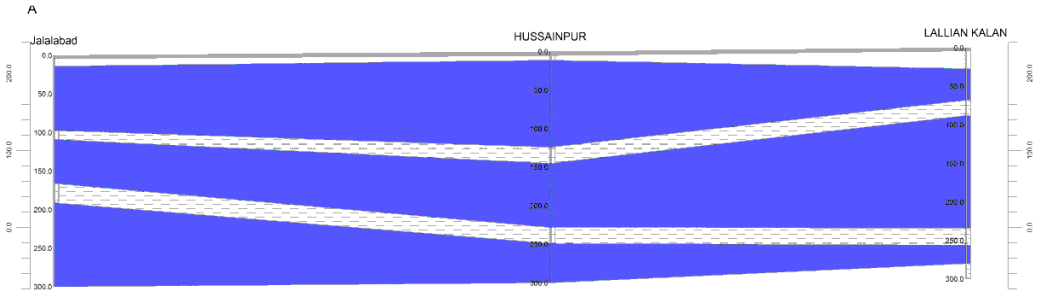
3-D Aquifer Disposition Model of Kapurthala Block



3-D Aquifer Disposition Fence Diagram



Aquifer Cross section from NW to SE



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

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	154.52 mcm
	In-storage Aquifer-I (Specific Yield Concept)	1694 mcm
	In-storage Aquifer-II (Specific Yield Concept)	1355.10 mcm
	In-storage Aquifer-II (Storativity Concept)	7.95 mcm
	In-storage Aquifer-III (Specific Yield Concept)	1468.02 mcm
	In-storage Aquifer-III (Storativity Concept)	8.48 mcm
	Total Resources	4687.94 mcm
Ground Water Extraction (as per 2013)	Irrigation	264.84 mcm
	Domestic & Industrial	13.94 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		15.11 mcm
Stage of Groundwater Development		180 %
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: 98.81 mcm
Source water requirement/availability for recharge: *Rain, Canal, Irrigation return flow*
Types and number of structures: NA
Other interventions proposed*: Artificial Recharge, Roof top Rainwater harvesting will conserve 4.42 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Kapurthala Block (392.10 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 69.70 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: *20% of the total rice area needs to change i.e.* 50.29 sq km
Anticipated volume of water to be saved: 50.29 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 (%)*
154.52	264.84	278.78	254	50.29	50.29	228.49	180	32.5	39

Alternate Water sources

Surface water sources: *Tanks, Ponds*
No.of Water tanks: 24
Location, details and availability from such sources outside the area: Not Available

Regulation and Control:

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

Other interventions proposed, if any

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

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

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

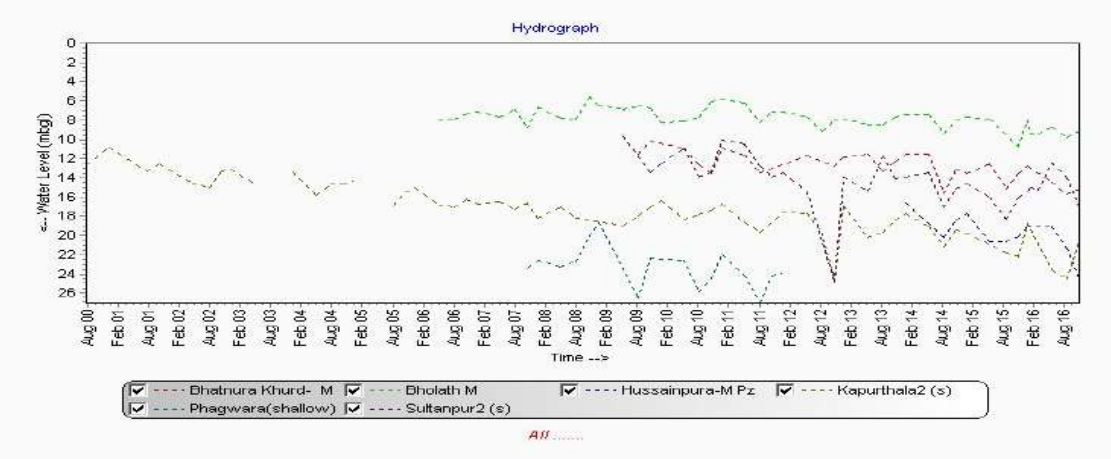
IV. Salient Information of Phagwara Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>300.40 sq km</td></tr>
<tr><td>District/ State</td><td>Kapurthala, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 24409
Rural Population: 125094
Total population: 149503</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 460 mm
Non-monsoon Rainfall : 255 mm
Annual Average Rainfall: 715 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: 438.79 sq km
Net sown area: 234.62 sq km
Irrigation practices: Tube well
Cropping intensity: 172%
<u>Area under</u>
Ground water Irrigation: 234.62 sq km
Surface water irrigation: 0 sq km
Gross Irrigated area: 438.79 sq km
Net Irrigated area: 234.62 sq km
Number and types of abstraction structures: 8730, 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>22.05 – 89.0</td><td>67</td><td>47</td><td>1152</td></tr>
<tr><td>Aquifer-II</td><td>104.0 – 218.0</td><td>114</td><td>85</td><td>1845</td></tr>
<tr><td>Aquifer-III</td><td>233.0 – 300.0</td><td>67</td><td>30</td><td>328</td></tr>
</table>
Total Ground Water Resources available is 3654.39 mcm and total potential granular zones available are 162 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: 325.89 mcm Domestic and industrial water supply: 11.85 mcm *Future water demands* Irrigation development potential : (-)203.06 mcm Domestic and industrial water supply up to 2025 years : 12.97 mcm Water Scarcity Villages: 90
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 26.60 – 35.18 m bgl Post Monsoon: 29.10 – 33.62 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)



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 (22.05 -89 m)	Quarter-nary Alluvial deposits	Unconfined to confined	47	NA	NA	12 % *(0.072)*	NA
Aquifer-II (104 - 218 m)		Semi confined to Confined	85				
Aquifer-III (233 - 300 m)		Semi confined to Confined	67	NA	NA	NA	NA

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

Source: CGWB,2015 & PSTC,2008

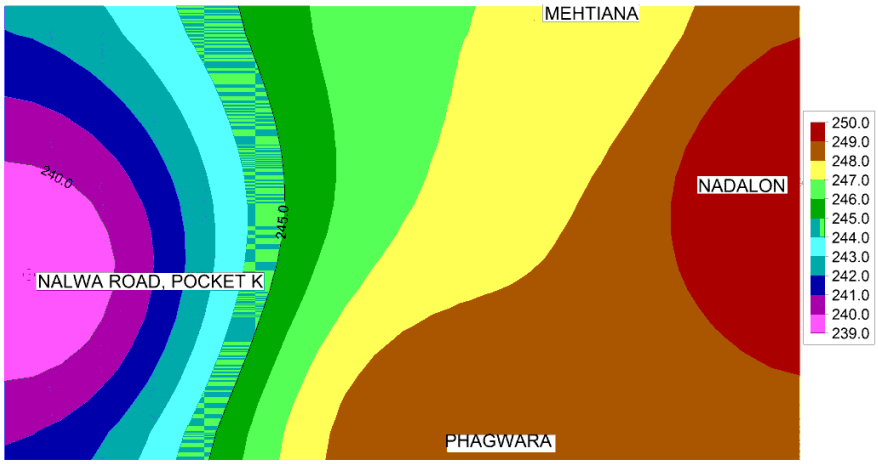
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

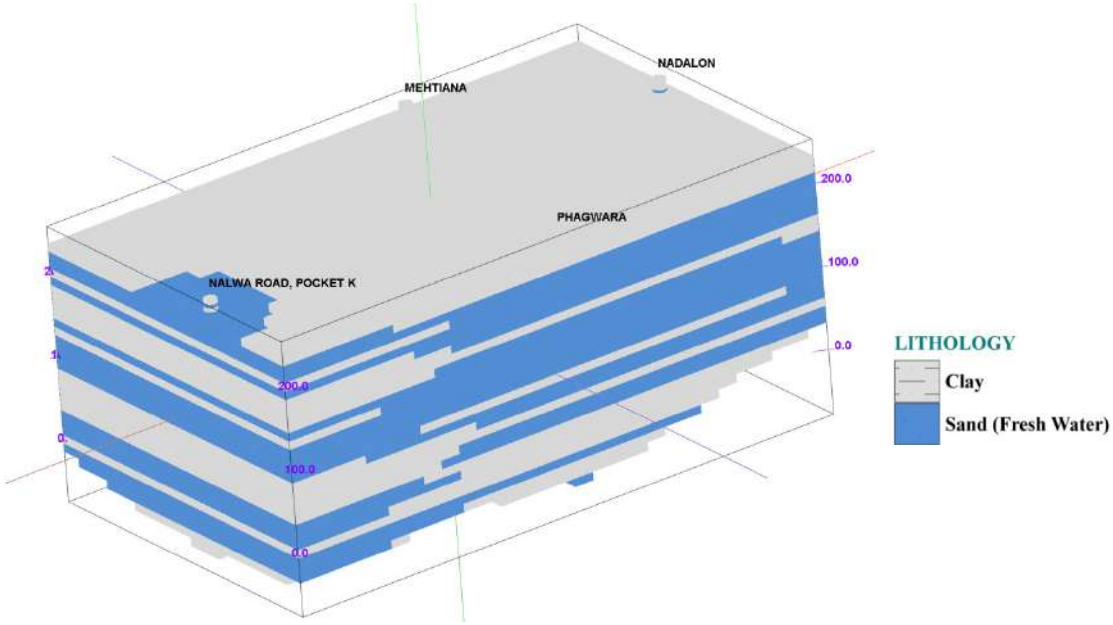
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	0	1	**1**
WRED/PSTC/WSS	0	0	0	0	**0**
PRIVATE	0	0	1	1	**2**
TOTAL	**0**	**0**	**1**	**2**	**3**

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.

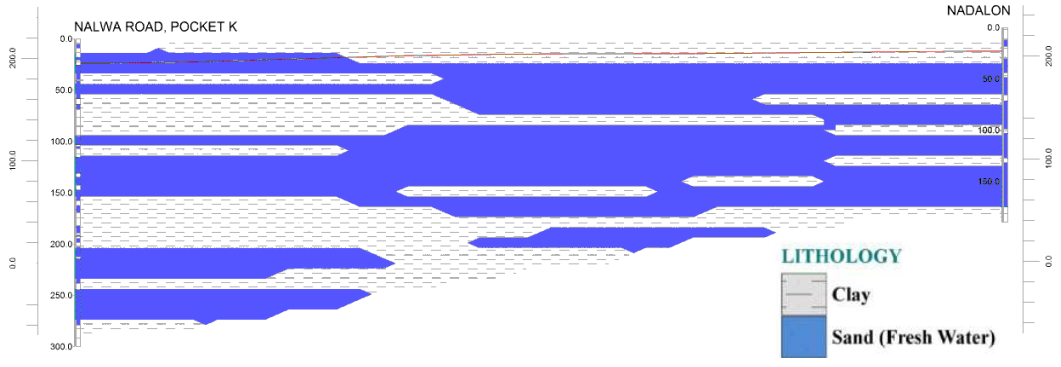
Elevation Map of Phagwara Block



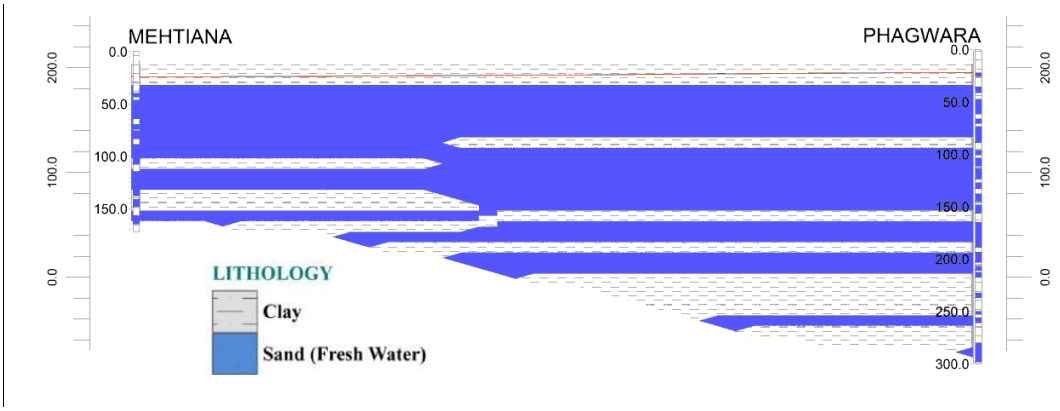
3-D Lithological model of Phagwara Block



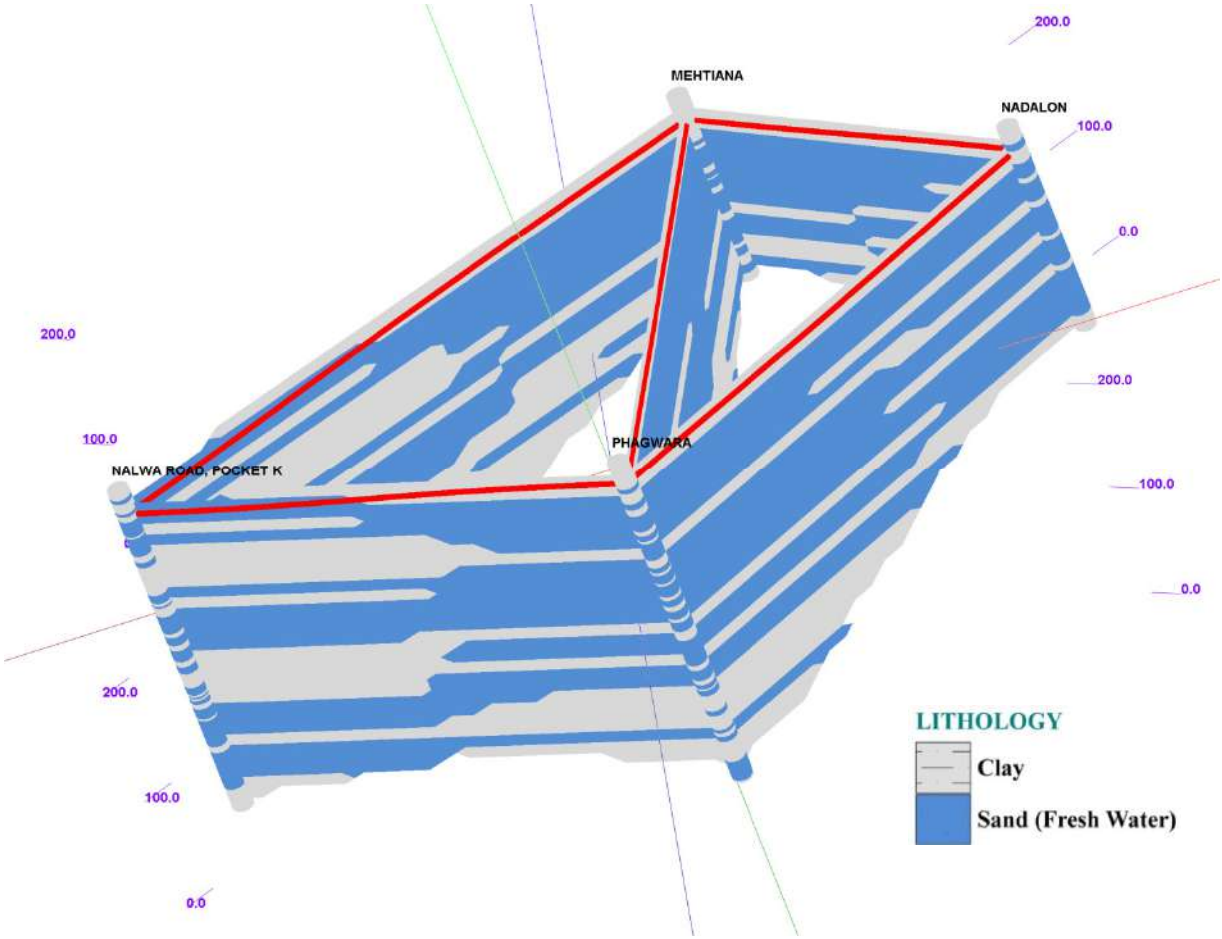
Lithological Cross section from Nalwa to Nadalon



Lithological Cross section from Mehtiana to Phagwara

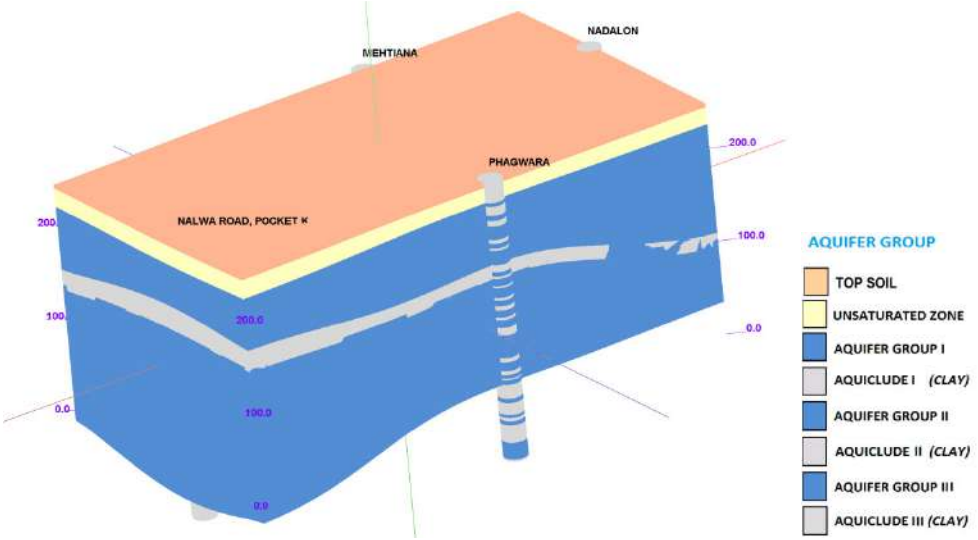


3-D Lithological Fence Diagram

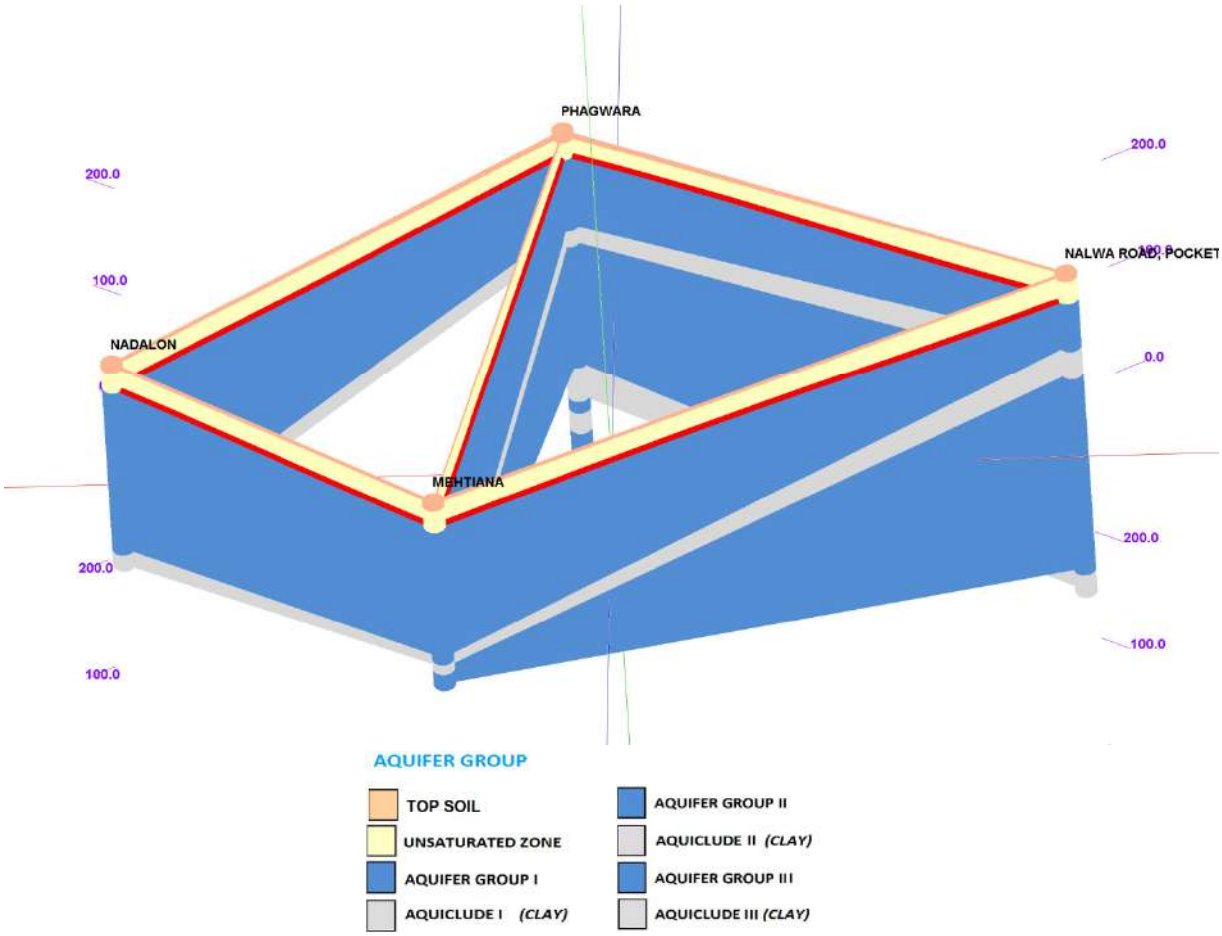


WATER LEVEL

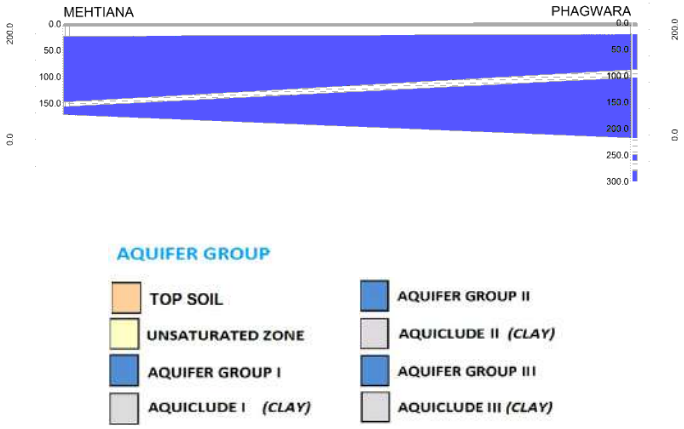
3-D Aquifer Disposition Model of Phagwara Block



3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along Mehtiana to Phagwara



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

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	135.80 mcm
	In-storage Aquifer-I (Specific Yield Concept)	1017 mcm
	In-storage Aquifer-II (Specific Yield Concept)	1838.45 mcm
	In-storage Aquifer-II (Storativity Concept)	7.02 mcm
	In-storage Aquifer-III (Specific Yield Concept)	648.86 mcm
	In-storage Aquifer-II (Storativity Concept)	7.71 mcm
	Total Resources	3654.39 mcm
Ground Water Extraction (as per 2013)	Irrigation	325.89 mcm
	Domestic & Industrial	11.85 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		12.97 mcm
Stage of Groundwater Development		249 %
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: 108.14 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 Phagwara Block (300.40 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 84.40 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:*68% of the total rice area needs to change i.e.* 114.08 sq km
Anticipated volume of water to be saved: 114.08 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 (%)*
135.80	325.89	337.73	169	114.08	114.08	223.65	249	84	68

Alternate Water sources

Surface water sources: *Tanks, Ponds*
No.of Water tanks: 31
Location, details and availability from such sources outside the area: Not Available
Regulation and Control:

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

Other interventions proposed, if any

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

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

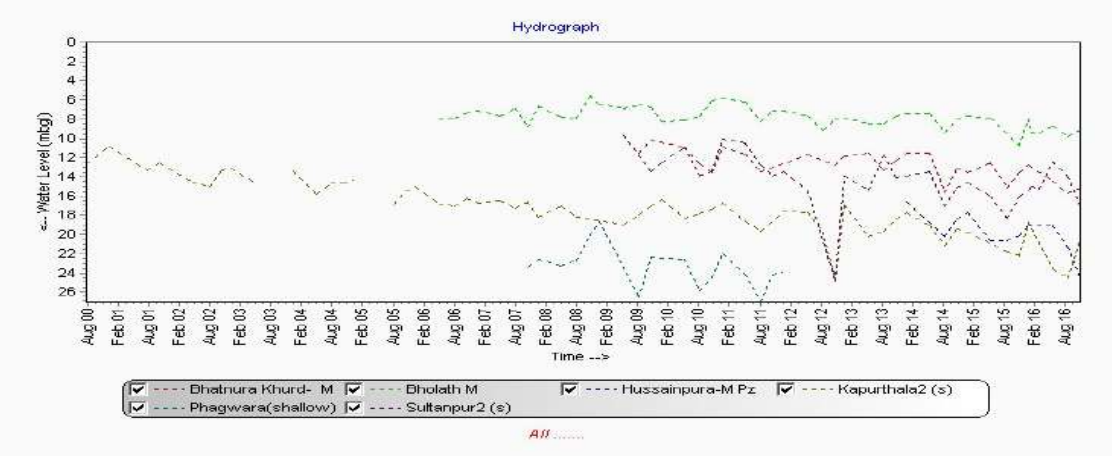
Other than that by 15 days ponding followed by 2 days of drying can lead to 25% saving of water in paddy crop.

V. Salient Information of Sultanpur Lodhi Block

<table>
<tr><td>Block Area
(in Km^2)</td><td>444.70 sq km</td></tr>
<tr><td>District/ State</td><td>Kapurthala, Punjab</td></tr>
<tr><td>Population</td><td>Urban Population: 0
Rural Population: 104939
Total population: 104939</td></tr>
<tr><td>Rainfall</td><td>Normal Monsoon: 432 mm
Non-monsoon Rainfall : 119 mm
Annual Average Rainfall: 551 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: 732.70 sq km
Net sown area: 368.41 sq km
Irrigation practices: Tube well Irrigation
Cropping intensity: 199%
<u>Area under</u>
Ground water Irrigation: 368.41 sq km
Surface water irrigation: 0 sq km
Gross Irrigated area: 732.70 sq km
Net Irrigated area: 368.41 sq km
Number and types of abstraction structures: 13735, 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>12.29 – 105.0</td><td>93</td><td>58</td><td>2056</td></tr>
<tr><td>Aquifer-II</td><td>120.0 – 155.0</td><td>35</td><td>16</td><td>544</td></tr>
<tr><td>Aquifer-III</td><td>178.0 – 300.0</td><td>122</td><td>58</td><td>1893</td></tr>
</table>
Total Ground Water Resources available is 4492.93 mcm and total potential granular zones available are 132 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: 314.50 mcm Domestic and industrial water supply: 9.74 mcm *Future water demands* Irrigation development potential : (-)149.49 mcm Domestic and industrial water supply up to 2025 years : 12.38 mcm Water Scarcity Villages: 136
Water level behavior	*Aquifer wise water level* **Aquifer-I** Pre Monsoon: 18.76 – 32.70 m bgl Post Monsoon: 18.64 – 34.50 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 (12.29 -105 m)	Quarter-nary Alluvial deposits	Unconfined to confined	58	NA	NA	12 % *(0.072)*	NA
Aquifer-II (120 - 155 m)		Semi confined to Confined	16				
Aquifer-III (178- 300 m)		NA	58	1788.8	6276	NA	2.6×10^{-4}

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

Source: Groundwater Exploration Report, CGWB,2015

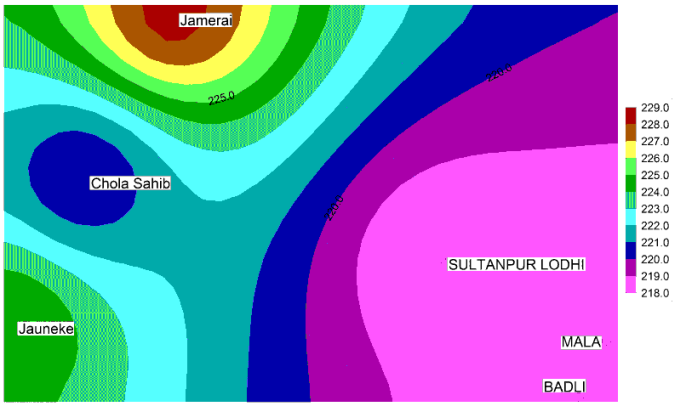
The Aquifer comprises of fresh and saline water and the major aquifer material is sand. The aquiclude and aquitard comprises of clay, clay with silt.

Exploratory Data Validated

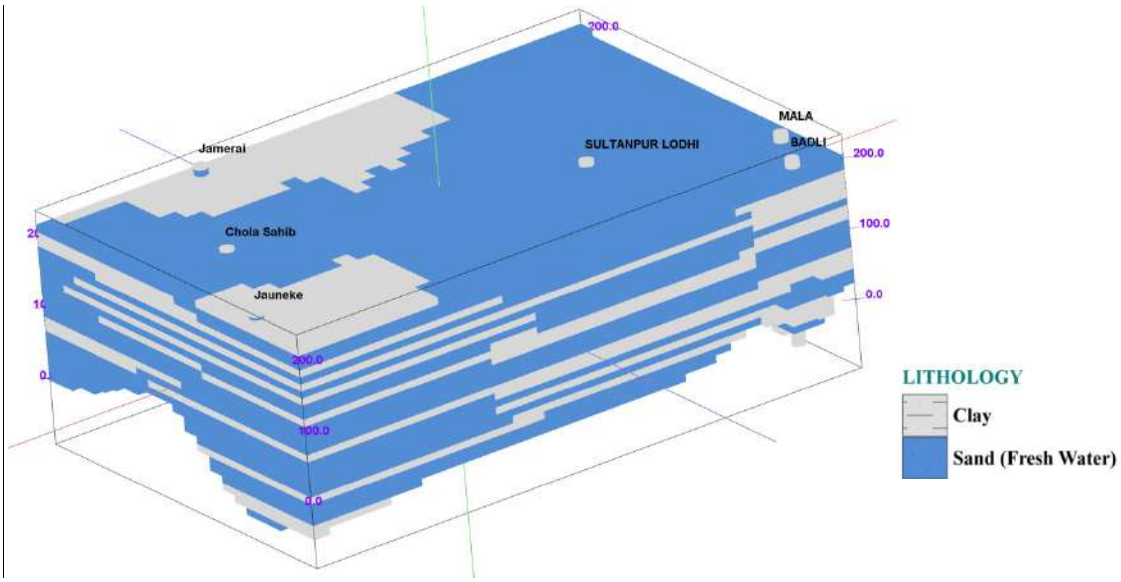
Source of Data	No. of exploration wells as per depth range (m)				Total
	<100	100-200	200-300	>300	
CGWB	0	0	0	1	**1**
WRED/PSTC/WSS	0	0	1	0	**1**
PRIVATE	0	3	2	0	**5**
TOTAL	**0**	**3**	**3**	**1**	**7**

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.

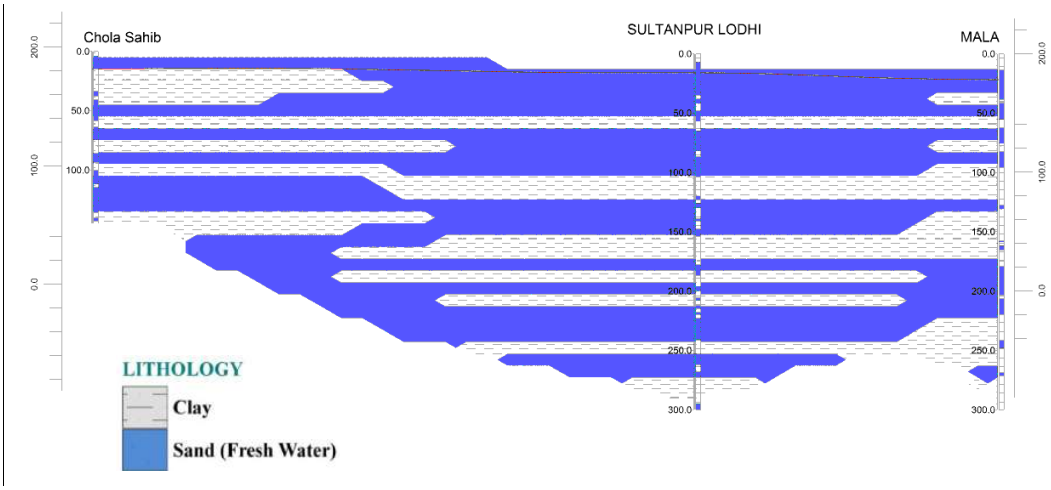
Elevation Map of Sultanpur Lodhi Block



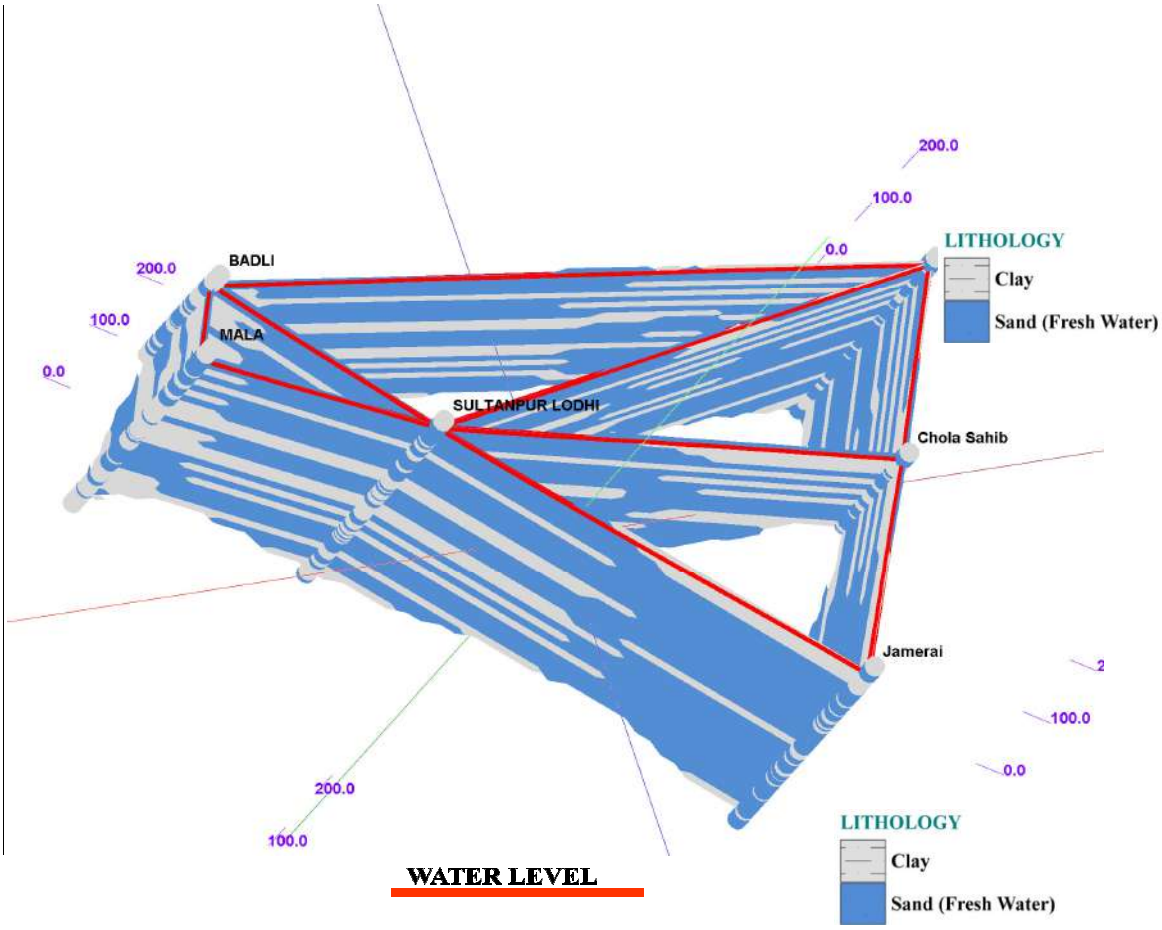
3-D Lithological model of Sultanpur Lodhi Block



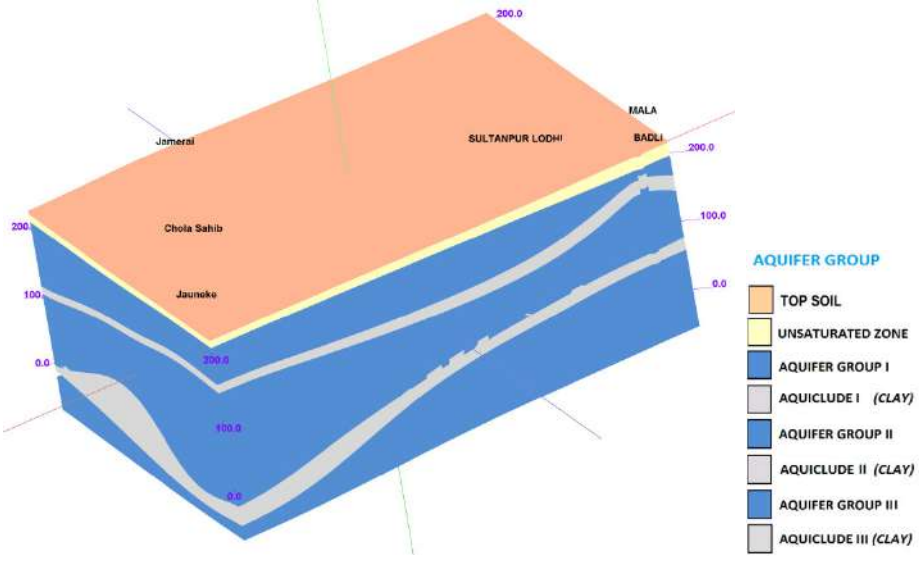
Lithological Cross section from Chola sahib to Mala



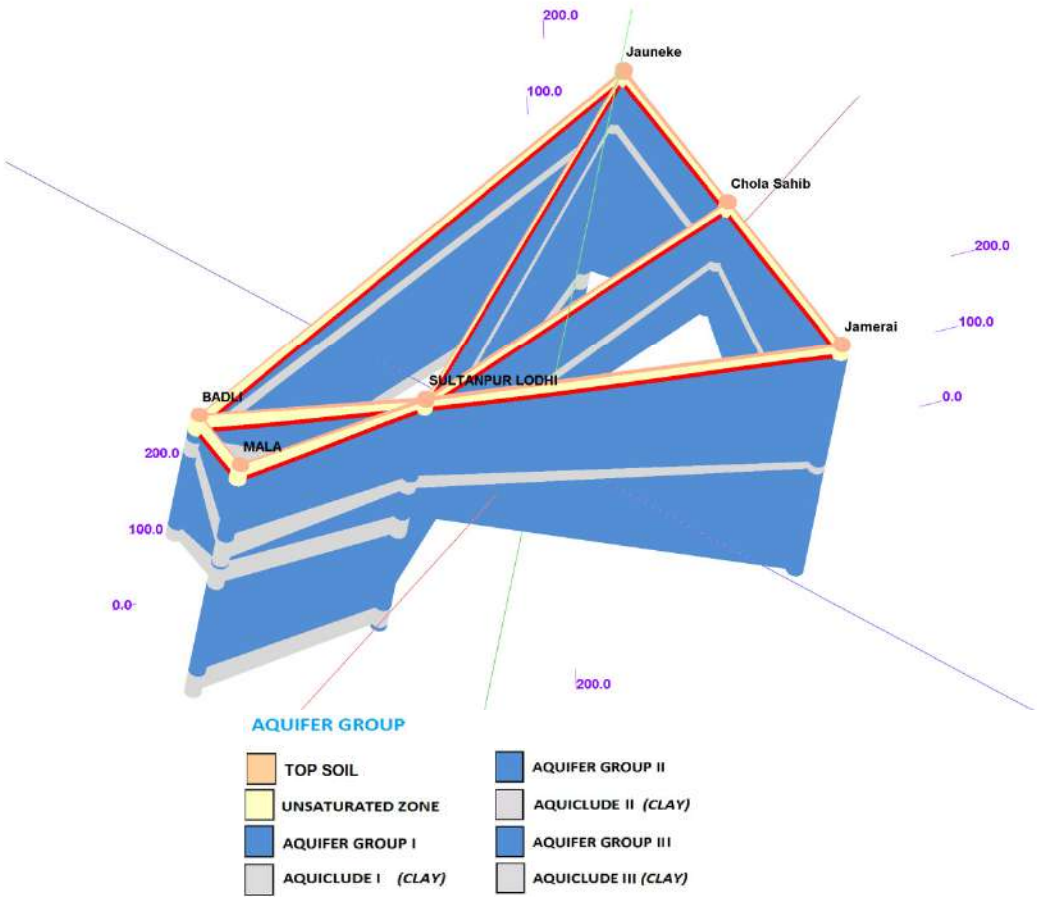
3-D Lithological Fence Diagram



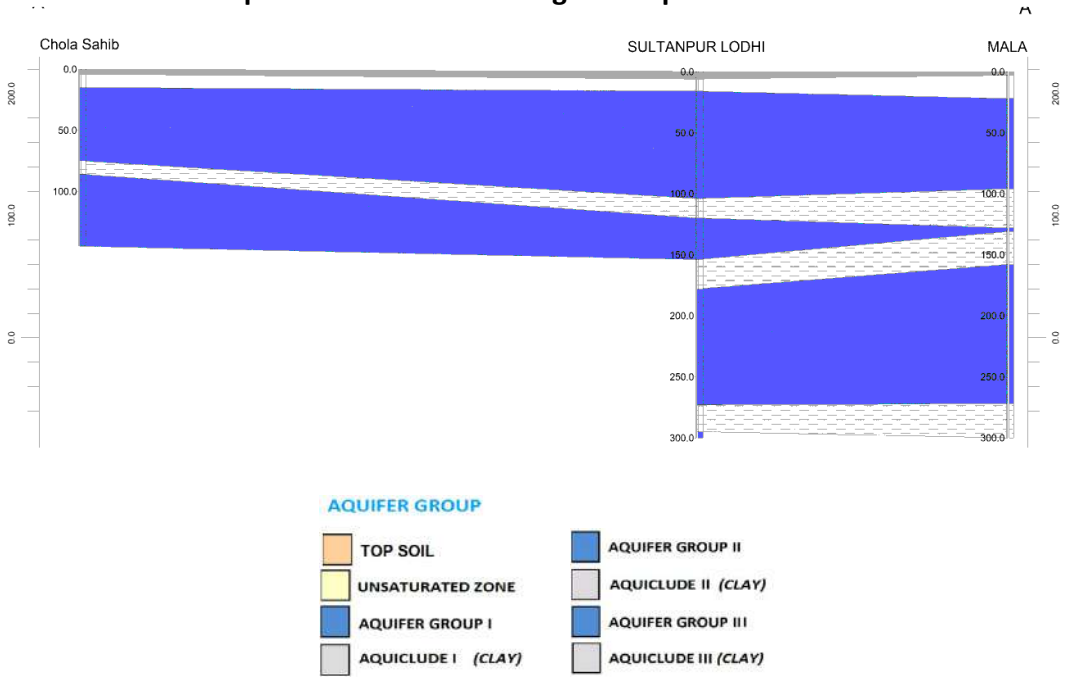
3-D Aquifer Disposition Model of Sultanpur Lodhi Block



3-D Aquifer Disposition Fence Diagram



Aquifer Cross section along Kartar pur to Kot Mohalla



Ground water Resource, Extraction, Contamination and other issues in Sultanpur Lodhi Block

Ground Water Resources upto the depth of 300m	Dynamic Fresh water resources (Aquifer-I)	199.41 mcm
	In-storage Aquifer-I (Specific Yield Concept)	1857 mcm
	In-storage Aquifer-II (Specific Yield Concept)	512.29 mcm
	In-storage Aquifer-II (Storativity Concept)	31.63 mcm
	In-storage Aquifer-III (Specific Yield Concept)	1857.07 mcm
	In-storage Aquifer-III (Storativity Concept)	35.47 mcm
	Total Resources	4492.93 mcm
Ground Water Extraction (as per 2013)	Irrigation	314.50 mcm
	Domestic & Industrial	9.74 mcm
Future Demand for domestic & Industrial sector (2025) (as per 2013)		12.38 mcm
Stage of Groundwater Development		204 %
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: 96.06 mcm
Source water requirement/availability for recharge: *Rain, Canal, Irrigation return flow*
Types and number of structures: NA
Other interventions proposed*: Artificial Recharge, Roof top Rainwater harvesting will conserve 3.82 mcm volume of water*

Demand side interventions

Advanced Irrigation Practices

Area proposed to be covered: Entire Sultanpur Lodhi Block (444.7 sq km)
Volume of Water expected to be conserved under advanced irrigation practices such as lining of underground pipelines (Kutcha channel) etc.: 105.7 mcm

Required Change in cropping pattern

Proposed change in cropping pattern: *Rice to Maize, Soyabean.*
The overexploitation can be managed at sustainable level (100%) by changing the Paddy crop
Area coverage: *29% of the total rice area needs to change i.e.* 102.67 sq km
Anticipated volume of water to be saved: 102.67 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 (%)*
199.41	403.76	407.62	359	102.67	102.67	301.08	204	51.5	29

Alternate Water sources

Surface water sources: *Tanks, Ponds*
No.of Water tanks: 34
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.