केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

CHANDIGARH

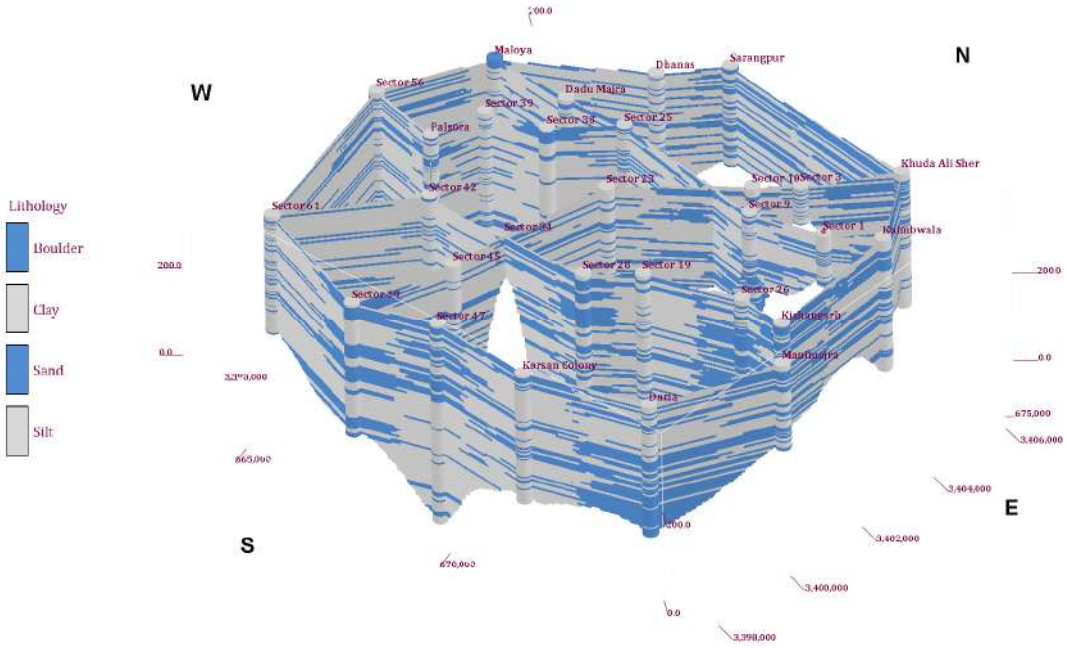
उत्तरी पश्चिमी क्षेत्र, चंडीगढ़

North Western Region, Chandigarh

राष्ट्रीय जलभृत मानचित्रण एवम प्रबंधन योजना

चंडीगढ़

(केंद्र शासित प्रदेश)



केन्द्रीय भूमि जल बोर्ड

उत्तर पश्चिमी क्षेत्र, चंडीगढ़

जल संसाधन मंत्रालय, नदी विकास एवम् गंगा संरक्षण

भारत सरकार

2019

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Report Compiled & Prepared	**Iti Gupta,** **Scientist 'B'**

Geophysics	**Chemical Quality**	**Hydrogeology**
S. C. Kapil Scientist 'D'	K. S. Rawat Scientist B Chemical Lab	Iti Gupta Scientist 'B'

AQUIFER MAPPING AND MANAGEMENT PLAN

CHANDIAGRH (U.T.)

(114 Sq Km)

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1. INTRODUCTION

1.1 Introduction & Physiographic Setup

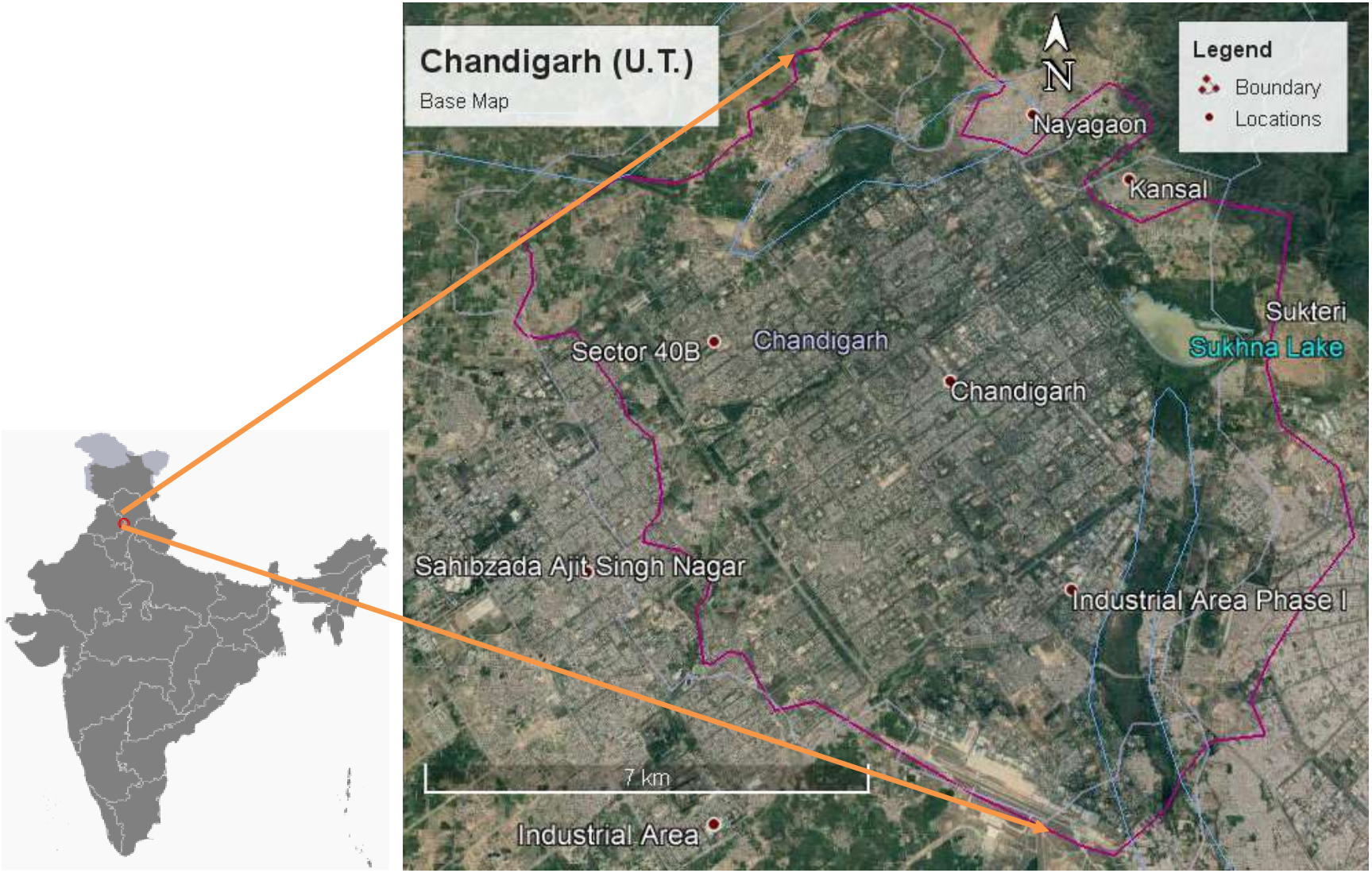
Chandigarh known as "THE CITY BEAUTIFUL" is a Union Territory (U.T.) located at the foothills of the Siwaliks about 250 kms north of Delhi. The city also has the distinction of being the joint capital of Punjab and Haryana states even though it does not form part of any of the two States. It lies between north latitudes 30°40' and 30°46' and east longitudes 76°42' and 76°51' and falls in Survey of India toposheet no. 53B/13 & 53B/14. Punjab state borders the UT in the south and southwestern sides and Haryana state on eastern side. Base map of Chandigarh is shown in fig 1. Chandigarh has an area of 114 km^2, out of which 36 km^2 is rural and remaining 78 km^2, is urban. The city is divided into 55 dwelling sectors. As per census 2011, total population of the city was 10,54,686 persons having a population density of 9252 persons/sq.km. Due to high urbanization, almost 79% of the total area is not available for cultivation. Main crops grown during Kharif are rice, maize and, potato while during Rabi season wheat, gram and oil seeds are grown.

The water requirement of the city for drinking and domestic purposes is 473.62 MLD (million liters per day), which will increase to 523.41 MLD in 2026. A major part of water requirement of the city is met by canal water. Canal water supply to the city is approximately 305 MLD. There are 239 deep tubewells in the city, which contribute a total of 91 MLD of water. Thus there will be a shortfall of about 49.79 MLD.

1.2 Hydrology & Drainage Network

There are no large natural surface water bodies in Chandigarh though small ponds do exist in the rural areas. The Sukhna Choe has been dammed in northeast side of the city, which has given rise to an artificial lake covering an area of about 1.62 sq.km. The lake, known as Sukhna has a water holding capacity of 5 million cubic meters (MCM). UT of Chandigarh falls in the Ghaggar Basin. There are two major streams, Sukhna Choe and Patiali ki Rao that originate from Siwalik Hills ranges and forms the natural drainage of the city. The Sukhna Choe flows north to south, drains the eastern part and joins the Ghaggar River. The other important stream is Patiala-ki Rao, which flows northeast to southwest and drains the northern parts of the city. Both these streams are ephemeral in nature and carry high flows during monsoon. The N-Choe flows through the leisure valley and drains major parts of the city. It flows from northeast to southwest direction and traverses north central part of the city. Another Choe, Choi Nala originates from Sector-31 and drains southern most part of the city.

Fig 1: Base Map of Chandigarh (U.T.)



1.3 Rainfall & Climate

The climate of Chandigarh can be classified as subtropical with hot summer and cold winter except during monsoon season when moist air of oceanic origin reaches the area. There are four seasons in a year. The hot weather season starts from mid March to last week of the June followed by the southwest monsoon, which lasts up to September. The transition period from September to November forms the post monsoon season. The winter season starts late in November and remains up to first week of March.

The normal annual rainfall of the UT is 1061 mm, which is unevenly distributed over the area in 49 days. The southwest monsoon sets in from last week of June and withdraws in end of September, contributes about 80% of annual rainfall. July and August are the wettest months. Rest 20% rainfall is received during non-monsoon period in the wake of western disturbances and thunderstorms. The lowest rainfall, which was 49% less than normal, was recorded in 1987 and the highest rainfall, which was 69% more than normal, was recorded in 1971. Maximum amount of rain received by the city of Chandigarh during monsoon season is 195.5 mm in a single day.

The summers and winters exhibit extreme temperature interspersed by monsoon. The Mean Maximum temperature of the city is 39.1°C (May and June) and the mean Minimum is 6.1 °C (January). The highest recorded temperature in Chandigarh was 46.5 °C on 20 June, 1964 and the minimum was (-) 1.2°C on 26 January, 1964. The highest relative humidity touches 80% during July – August whereas the lowest relative humidity values of 26% are recorded during April-May. Wind velocity is maximum at 8.4 km/hr during May while it is minimum at 3.2 km/hour during September. The average annual evaporation for Chandigarh works is 2110 mm. The lowest monthly evaporation is 7.2 mm during January and highest of 36.3 mm takes place in May.

Rainfall

Normal Annual Rainfall	: 1061 mm
Normal Monsoon Rainfall	: 849 mm
Normal Rainy days	: 49

Temperature

Mean Maximum	: 39.10C (May & June)
Mean Minimum	: 6.10C (January)

The rainfall data of the last 5 years of Chandigarh UT is given below:

Rainfall in mm	2013	2014	2015	2016	2017
	841.7	635.8	572.8	496.4	752.8
Source: https://indianexpress.com/article/cities/chandigarh/chandigarh-breaks-five-year-record-with-883-mm-rain-this-monsoon-5370355/					

1.4Soils

The soils in UT Chandigarh are loamy sand at surface and calcareous sandy loam in subsurface layers. The hard clay forms pan at depths varying between 20 and 30 m. In northern parts the soil is sandy to sandy loam where as it is loamy to silt loam in southern parts. The soils in Chandigarh are light yellowish brown to pale brown in color. Soils are calcareous and normally have kankar. Almost all the soils are deficient in nitrogen, phosphorous and potash.

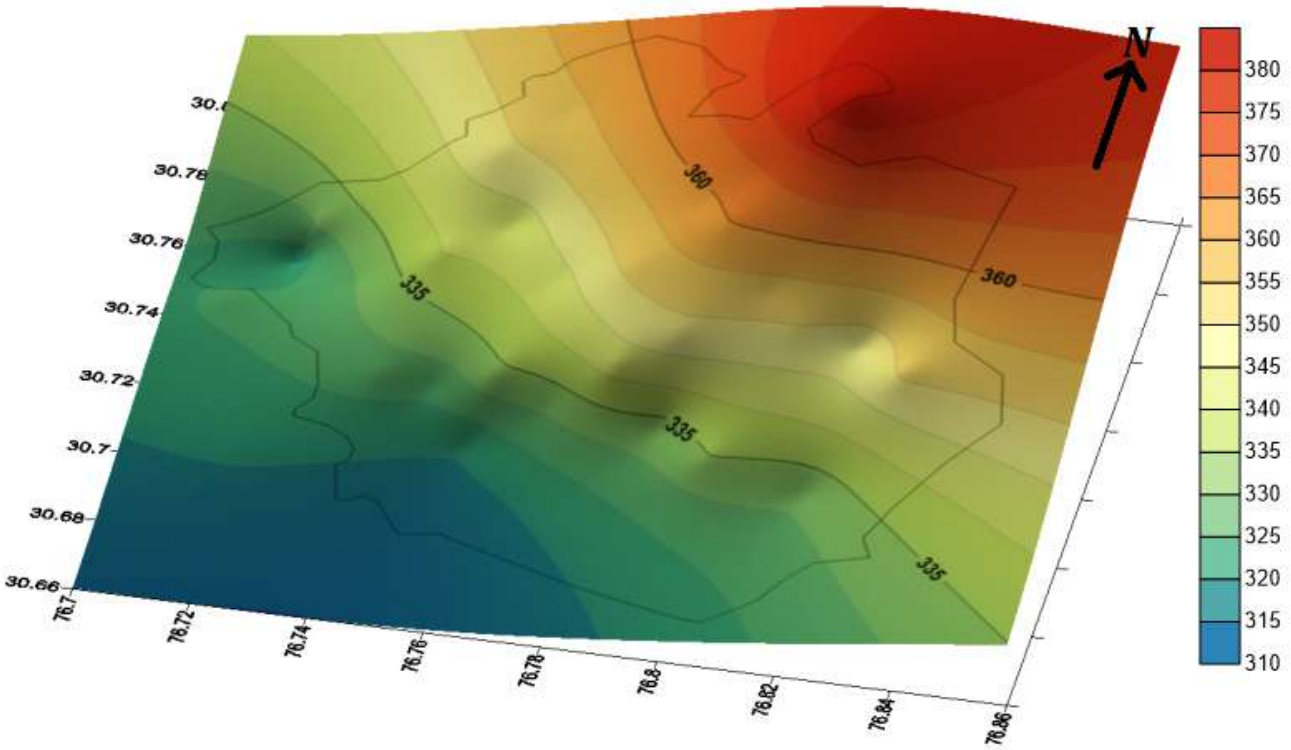
1.5 Geomorphology

Four physiographic units are encountered in Chandigarh; ***The Siwalik range*** trending NW-SE forms the northeastern boundary of Chandigarh and is exposed in a small patch on the northeastern side. Southwestern slopes of the foothills are covered with loose talus material deposited by hill torrents forming alluvial fans. These alluvial fans coalesce to form piedmont ***Kandi formation*** running parallel to the hill ranges. The piedmont deposits comprise of cobble, pebble and boulder, associated with sand, silt and clay. The Kandi formations merge into ***Sirowal formations*** in south and southwest. The Sirowal merges with the main Alluvial plain towards south and southwest. The ***alluvial deposits*** belong to Quaternary age and comprise layers of fine sand and clay. Coarser sediments occur along the Sukhna Choe and Patiali ki Rao whereas relatively finer sediments, thus restricting the aquifer disposition laterally, underlie the area between these two streams. The typical Kandi formations comprising boulders-gravel- coarse sand are not prevalent in the area since the source formations are fine grained.

1.6 Topography

The topography values ranges between 315 to 380m amsl and has been plotted to prepare the elevation contour map (fig 2).

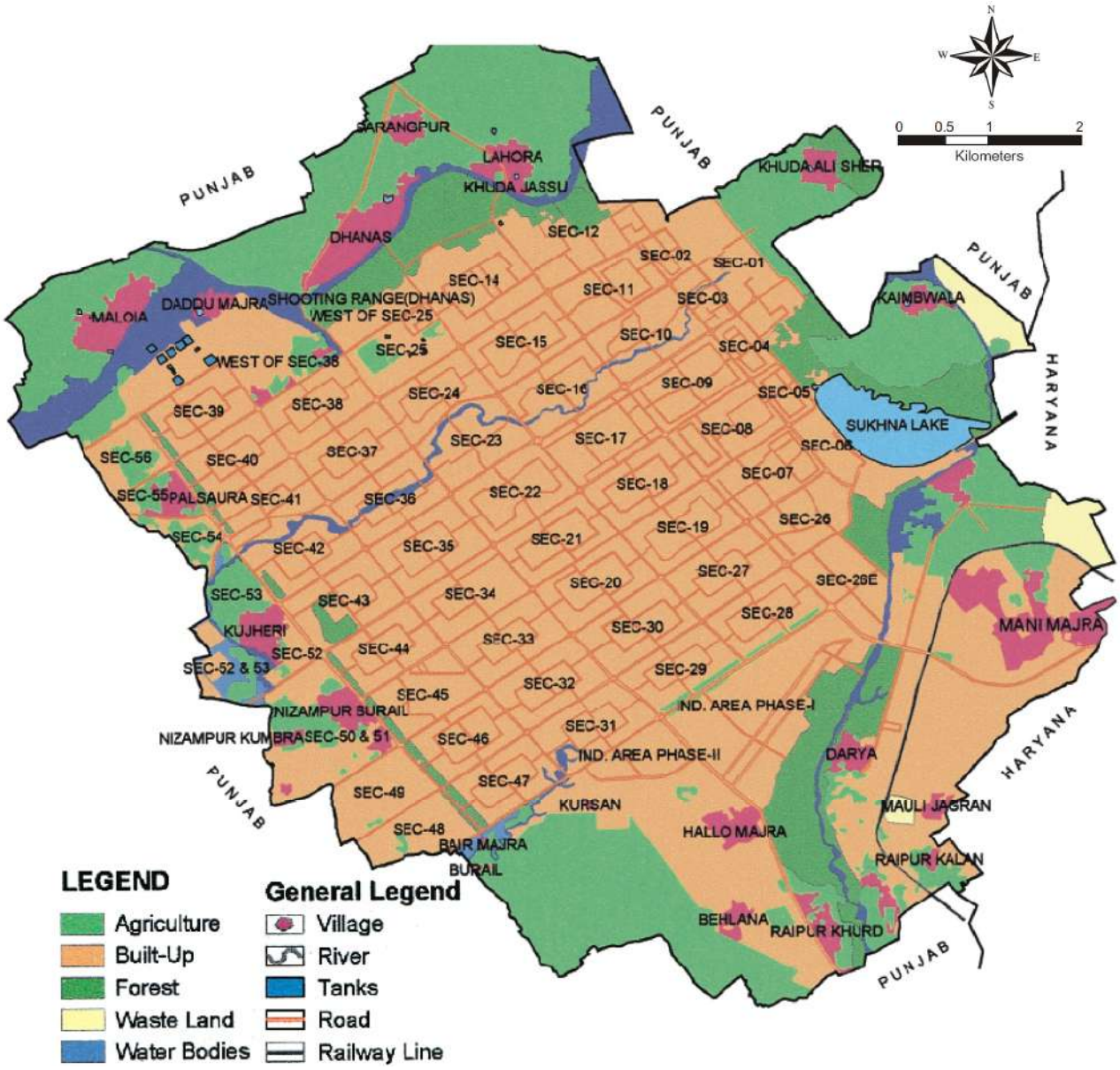
Fig 2: 3-D Elevation Contour Map-Chandigarh (U.T.)



1.7 Landuse & Landcover

The distribution of various land uses prepared by Punjab Remote Sensing Centre, Ludhiana (PRSC) and is shown in fig 3. The data indicates that a large portion of the land (about 69.6%) falls under urban category, 5.4% of the area is under village habitation, 7.2 % of the area is under agricultural use, 7.7% under forests & other plantations, 1.6% is under Sukhna Wetland, 3.1% under other water bodies and rest of the area is under vacant land (3.8%) and miscellaneous uses (1.6%). In addition to the above, 25.42 sq km additional area has been acquired and declared as Sukhna Wetland Sanctuary. Hence, the total area under forests is 32.41 sq km, out of which 26.10 sq km area is under hilly forest, 3.90 sq km is under Sukhna Choe forest & PatialaKi-Rao forest and 1.05 sq km of the area is under Lake forest.

Fig 3: Land use and Land Cover Map



Source: PRSC, Ludhiana http://chandigarhenvis.gov.in/beta/EnvisPdfFiles/18.pdf

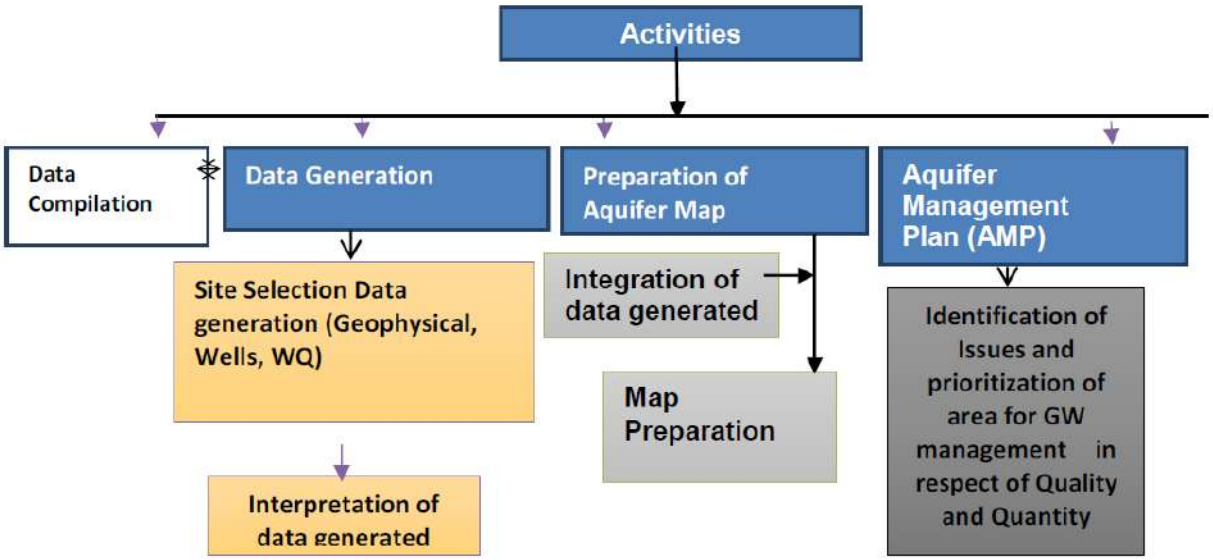
1.8 Objective, Scope of Study & Methodology

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

This is an activity where the Government and the Community work in tandem. Greater the

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

Methodology: Various activities of NAQUIM are as follows:



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

The data of CGWB and all the wells from MCC and Private in the area are plotted on the map of 1:50000 scale with 5'X5'grid (9km x 9km). The exploration data shows that majority of tube wells falls in the Ist Aquifer and IInd Aquifer.

2. DATA COLLECTION AND GENERATION

2.1 Hydrogeological Data

2.1.1 Geology of the Area

The Union Territory of Chandigarh is occupied by semi consolidated formations of upper Siwalik system of middle Miocene age that are exposed in north eastern fringe whereas the rest of the Territory is occupied by Indo-Gangetic plain comprising alluvium of Pleistocene age. The piedmont deposits at the foot of Siwalik Hills comprise cobble, pebble and boulder, associated with

sand, silt and clay. The piedmont deposits are followed by alluvial plain comprised of clay, silt and sand.

The formations have been deposited by the drainage system originating in the Siwaliks. Coarser sediments occur along the Sukhna Choe and Patiali ki Rao whereas relatively finer sediments, thus restricting the aquifer disposition laterally, underlie the area between these two streams. The typical Kandi formations comprising boulders-gravel- coarse sand are not prevalent in the area since the source formations are fine grained. Based on the exploratory drilling carried out by Central Ground Water Board down to a depth of 450 mbgl, it can be concluded that fair to good aquifer horizons occur in most part of Chandigarh except in south-western parts near sectors 37,38,39,40 and 41. An aquifer, 20 meters thick, occurring at a depth of 160 mbgl, comprising medium to coarse sand, occurs in almost all of Chandigarh except around sector 38. It has also been inferred that the sediments are relatively coarse-grained up-to a depth of 180 mbgl below which they become finer. The yields of the deeper aquifers is also lesser as compared to the shallower ones.

The formations encountered in a borehole drilled down to 465 mbgl in sector 28, close to Sukhna Choe, are well-defined coarse sediments up to 240 mbgl. Below this depth the formations are finer grained. Whereas the shallow formations comprise coarse sand to gravel and pebbles intercalated with clays, the deeper ones are fine sands and silts. In sector 47, the aquifer material is coarse up to a depth of 174mbgl below which it becomes finer. The aquifer material encountered at sector 33 is coarse up to 180mbgl. This indicates that the thickness of coarser sediments is greater in northern parts of the city as compared to the southern parts.

Along Sukhna Choe, three prominent sand beds occur (inter-bedded with clay beds) within a depth of about 100 m. The upper sand beds are about 15 m thick and occur 8 m below land surface. Middle sand bed is about 18 m thick and occurs at depths varying from 21 to 38 mbgl. The deeper sand bed occurs at depth varying from 39 to 76mbgl and is about 27m thick. These beds are more persistent in the down-stream direction of Sukhna Choe. The clay percentage varies from 30 to 62% while sand percentage varies from 38 to 70% in various well logs. In the area lying to the west of Industrial Area around sector 27 to 31, thin sand beds of 3 – 6 m thick have been observed up to depth of 100 m. However, in this area thickness of clay beds is more than sand beds.

Along the Patiali-ki-Rao nala a single thick sand bed has been observed. This thick bed is inter-layered with clay lenses in northeast and southwest directions of the nala. The clay

percentage varying from 31 to 88 and sand percentage varying from 12 to 69 have been encountered in various boreholes. This bed continues but thins towards southeast. Further this bed gets split up into two units separated by 20 – 25 m thick clay beds.

Lithological sequence encountered during drilling does not show conformity in aquifer geometry in the area. The sub-surface formations are basically composed of pebbles, gravels and fine to coarse-grained sand with fair proportion of Kankar throughout. In the southern part of the area compact/cemented, poorly permeable silt beds exist below 250 mbgl. The litho logical logs of boreholes drilled indicate presence of saturated granular zones comprising of medium to coarse sand and gravel up to depth of 465 m. A distinct aquifer of around 10-20 m thickness at a depth of about 160 m exists persistently all over the UT area except southwestern parts.

Ground water in the area occurs under water table, confined as well as semi- confined conditions. The pumping test data of the aquifers tested in the city clearly indicates that good confined aquifers occur around sector 10, 33, 38 and 47 while leaky aquifers are encountered around sector 28. One interesting feature is that the aquifers in the southern parts of the city are restricted in aerial extent due to lithological boundaries as deciphered from pumping test data. Ground water occurs under unconfined conditions down to about 80 m in Manimajra area. In other areas the semi-confined conditions prevail up to 20-30 m below land surface. Barring Manimajra area ground water below 20-30 m exist under confined conditions. The depth of the shallow aquifer system is less than 30m below ground level whereas the depth of the deeper aquifer system ranges from 40 to 450 mbgl of explored depth while in Manimajra area confined aquifers occur below 90 m.

During the exploratory drilling operations in the city in the year 1972-74 only deep (100-300 m) exploratory wells were constructed and aquifer performance tests were conducted. The discharge of 6 exploratory wells constructed varies from 83-1880lpm. The transmissivity values for the deeper aquifer system ranges between 74 m^2/day at sector 10 to 590 m^2/day at sector 28. The storativity values ranged between $1.5x10^{-4}$ to $8.6x10^{-4}$ indicating confined nature of aquifer systems. A number of aquifer performance tests were also conducted on the existing shallow tubewells and only the recovery data was used to assess the aquifer parameters. The transmissivity values of shallow aquifers up to 100 m depth range obtained during these tests ranged between 70 and 466 m^2/day.

Two no. of Peizometers have been constructed at IMD, Chandigarh in 2018. The depth of Pz-I is 87m and Pz-II is 180m.

2.1.2 Water Level Behaviour (2018)

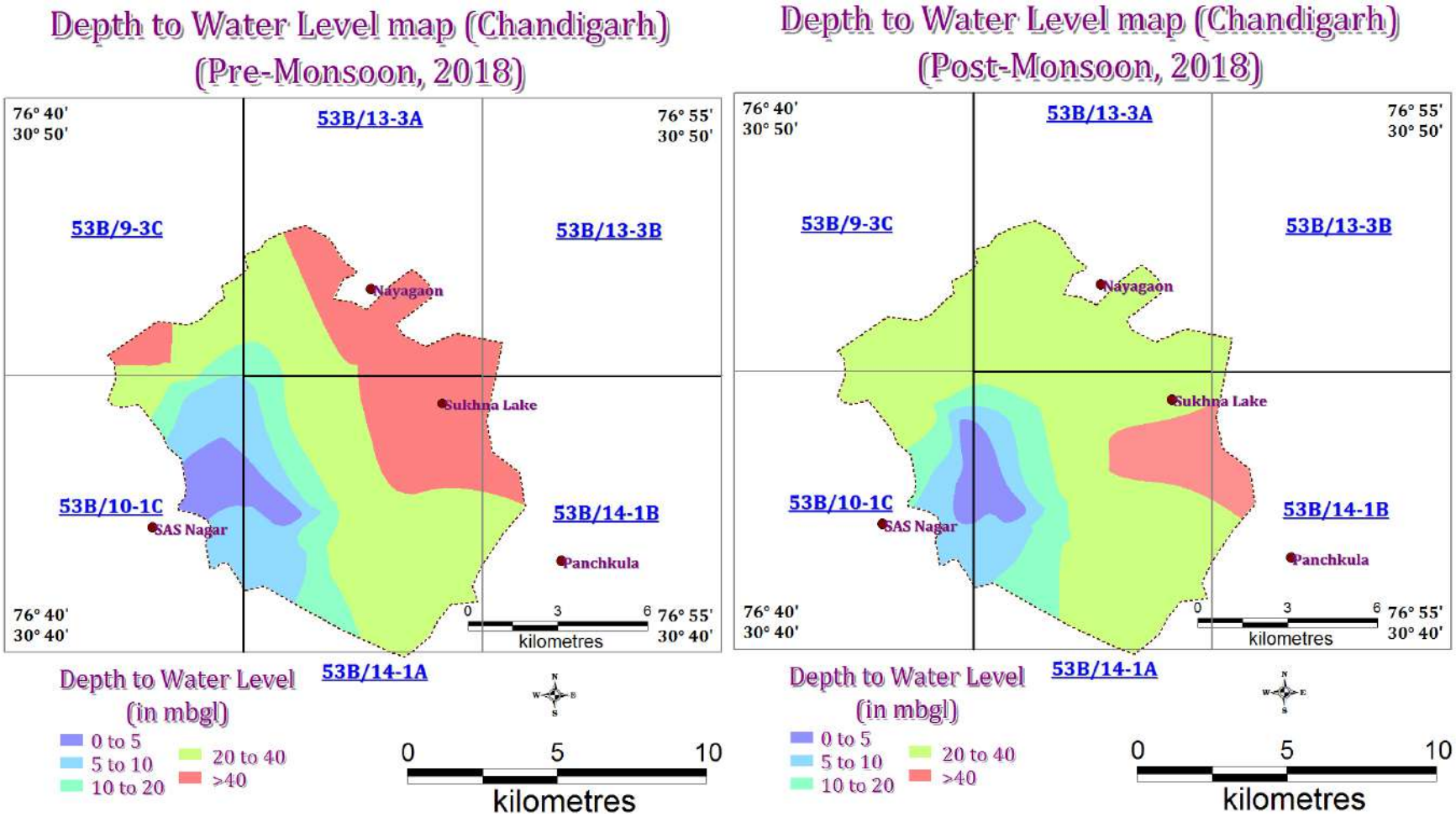
Ground water monitoring has been carried out quarterly in a year i.e. in the month of June, August, October & January. The water level data of June and October represents the pre and post monsoon water level respectively. There are total 26 wells monitored in Chandigarh out of which one is Dug Well and others are Piezometers corresponding to 14 site locations tapping different aquifer system.

During the pre-monsoon, the depth to water level in the shallow aquifer system varies between 2.75mbgl at site Burail (in south-west) to 53.64 mbgl at site in Sector 3 (in north-east) whereas during the post-monsoon, it varies from 2.57 at site Burail to 53.55mbgl at site in Sector 3. The depth to water level map for pre and post-monsoon is shown in fig 4. In the western and south-western part of the city covering sectors 41 to 47 the water level is shallow – less than five meters. This is due to finer nature of sediments and lithological boundaries. In sectors falling along *Madhya Marg*, it is more than 15 m. It gradually deepens as we move from west to east and it is as deep as 30 m in the extreme eastern part covering part of Sector-26 and Manimajra. These are recharge areas with coarser sediments and steeper hydraulic gradients. The water level is deeper in north-east and north-western part and shallower in western part of Chandigarh. In the deep aquifer system the water level ranges from 3.69 mbgl to even more than 100m bgl. In the southwestern part of the city the water level of deep aquifer system is shallower as compared to northeastern part, 70% of the area is having water level of more than 20m bgl in deeper aquifer and only in a very small portion of west is having shallow water level.

The seasonal (Pre-post monsoon) water level fluctuation in the shallow aquifer is not significant. A greater part of the city has shown a rise in water levels, the maximum being 1.35m at sector 46. There is no such decline is encountered during this period but in general it is observed in the south-western part of Chandigarh.

The long term water level fluctuation data of the shallow aquifer system shows that the northern and central parts of the city are having decline in water levels, whereas the rest of the area is having a near static trend except the southern sectors which shows a rising trend. There is a general decline of water levels ranging between 0.49m at Sector 37 to 3.97m at Sector 27 while there is a rise of water level from 0.27 m at Burail to 0.55m at Sector 10 is observed.

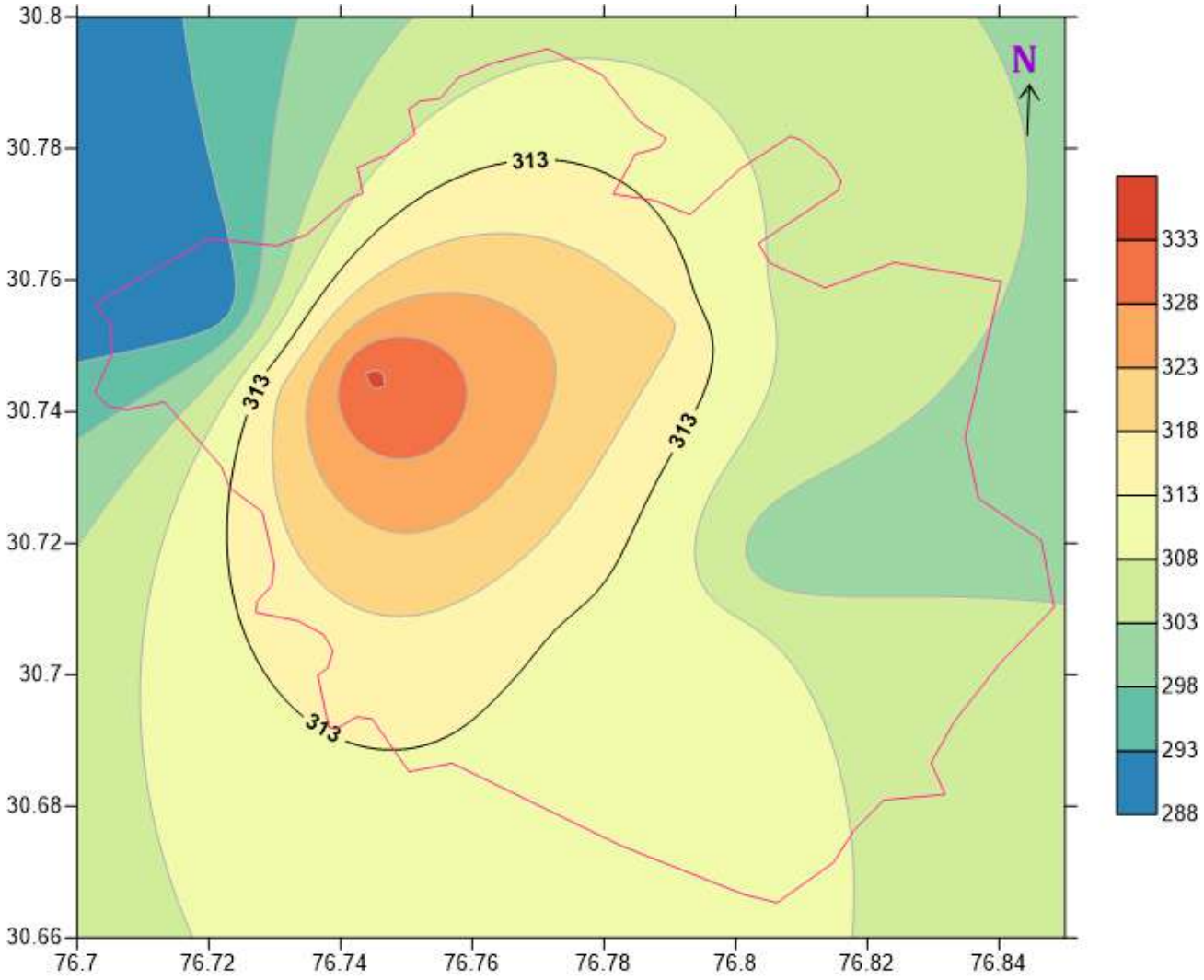
Fig 4: Depth to water level map (Pre & Post-monsoon, 2018)



2.1.3 Ground Water Flow

Water table elevation study reveals that the flow of ground water is from north-south central to west and north-western direction. Water table elevation difference between central and north-western parts is ~40m and lies between 290m amsl and 330m amsl. Due to this hydraulic difference the ground water moves from north-south central to north-western and eastern parts. The hydraulic gradient is steep towards north-western part as compared to eastern part. In western area ground water flow is towards Patiala-ki- Rao and it flows parallel to Sukhna Choe. The recharge in Chandigarh takes place from recharge area running parallel to Siwaliks.

Fig 5: Water Table Elevation Map



2.1.4 Exploratory & Geophysical Data

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

Table 1: Data availability of exploration wells in Chandigarh

S. No.	Source of Data	No of Wells in Depth range (m)					Total Wells
		<100	100-200	200-300	300-400	>400	
1	CGWB	0	2	0	1	4	7
2	MC	0	14	79	34	5	132
3	Others	103	0	0	0	0	103

2.2 Geophysical Studies

Entire area of the Union Territory Chandigarh falls under sedimentary rock formation comprising of coarse to fine grained sand, pebbles, cobbles and gravel, clay horizons and finer sediments alternately. The younger alluvium is restricted to the flood plains of choes and river and older alluvium consists of fine sand, silt and clay. It is located in the foot hills of the Siwalik hill range occupied by kandi in the North-East and Sirowal and alluvium plains in the remaining part. The location of the electrical borehole logging is shown in plate 1.

Geophysical studies carried out in the area shown in map plate III reveals that the first aquifer occurs between the depth range of 10-20 meters and its thickness is 7 to 10 m consisting of sand having resistivity value varies between 30 to 40 ohm-m and terminates at Sector 37 whereas it is about 40 m thick at sector 27 with resistivity value 80 ohm-m representing sand with cobbles and gravels. It is again in the form of sand as represented by a resistivity of 40 ohm-m underlain by thick deposits of clay and fine sand of resistivity value of the order of 15 to 20 ohm-m. The second and third aquifer are 10 to 20 m thick having resistivity of the order of 20 ohm-m representing the presence of finer sediments, shown in section AA' in plate IV.

The first layer of sand dominating at Sector 44 is underlain by a thick deposit of sand and gravel having a moderate value of resistivity of the order of 50 ohm-m. Low resistivity is observed at deeper depths representing clay dominating horizons, shown in section BB' in plate V.

The first aquifer at Sector 39 is in the form of thin layer of sand with resistivity value of 30 ohm-m whereas it is thick (20 m) at sector 44 and Sector 47 and Air Force High Ground but its lateral extension in NW direction is not established. At Air Force High Ground, deposits of sand and gravel are indicative of high resistivity value order of 60 Ohm-m. The second aquifer is comparatively thick about 15 m but is not established beyond Sector 39, shown in section CC' of plate VI.

The granular zones are in the form of thin lenses of sand at Sector 52 except at a depth of 130 m where thick deposit of sand is observed which is underlain by clay having resistivity of the order of 15 Ohm-m. The formation is in the alternate bands of clay and sand. The deposits of sand are more at deeper depth at Sector 33, shown in section DD' plate VII.

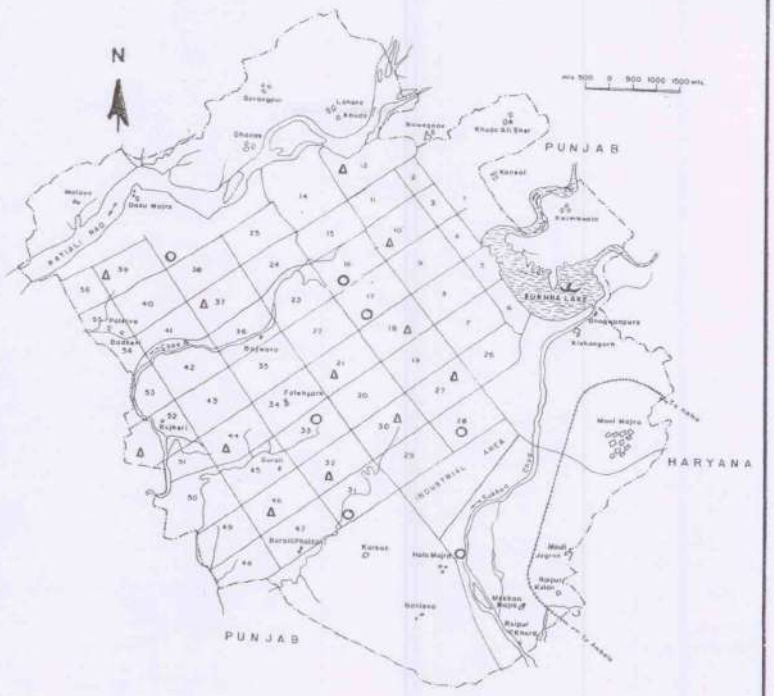
The shallow aquifer is uniformly distributed except Karson Colony with varying thickness maximum at Sector 49 which is about 50 m thick. At Karson Colony it comprises of sand with resistivity value of the order of 40 Ohm-m. The high resistivity value of the order of 80 Ohm-m is indicative of the presence of sand and boulders. The second and third aquifers are also uniformly distributed but pinches out towards Sector 49. This section is generally dominated by clay having resistivity of the order of 15 to 20 Ohm-m, shown in section CC' plate VIII.

It has been observed from the fence diagram based on geophysical studies that the thickness is less in the western part in comparison to the eastern part of the city. In general there is fresh sediments aquifer system are present in and around the city area. The first group occurs between the depth range of 20 to 100 mbgl and its thickness ranges from 10 to 20 m. The second aquifer group is present in the range of 125 to220 m. The third aquifer group is present below 220 m. The aquifer groups are separated with respect to each other by the presence of thin layer of clay and finer sediments.

PLATE I

CHANDIGARH U.T.

MAP SHOWING THE LOCATIONS OF BOREHOLE LOGGING



INDEX

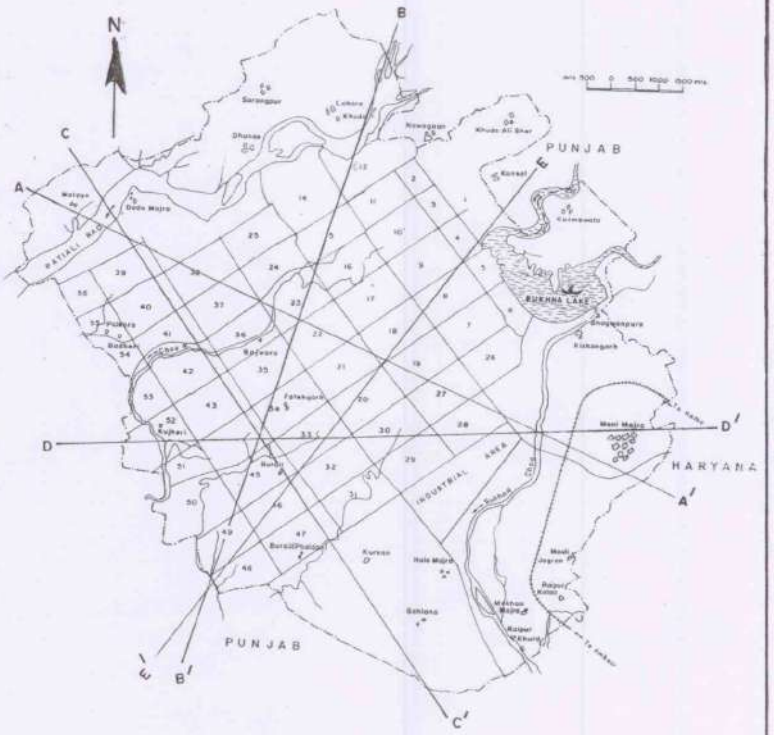
- o EXPLORATORY BOREHOLE C.G.W.B.
- Δ PIEZOMETER
- -·-·- STATE BOUNDARY
- [21] SECTORS

CGWB NWR CH D.O. NO. 2012/107

PLATE II

CHANDIGARH U.T.

MAP SHOWING DIRECTIONS OF GEOELECTICAL SECTIONS



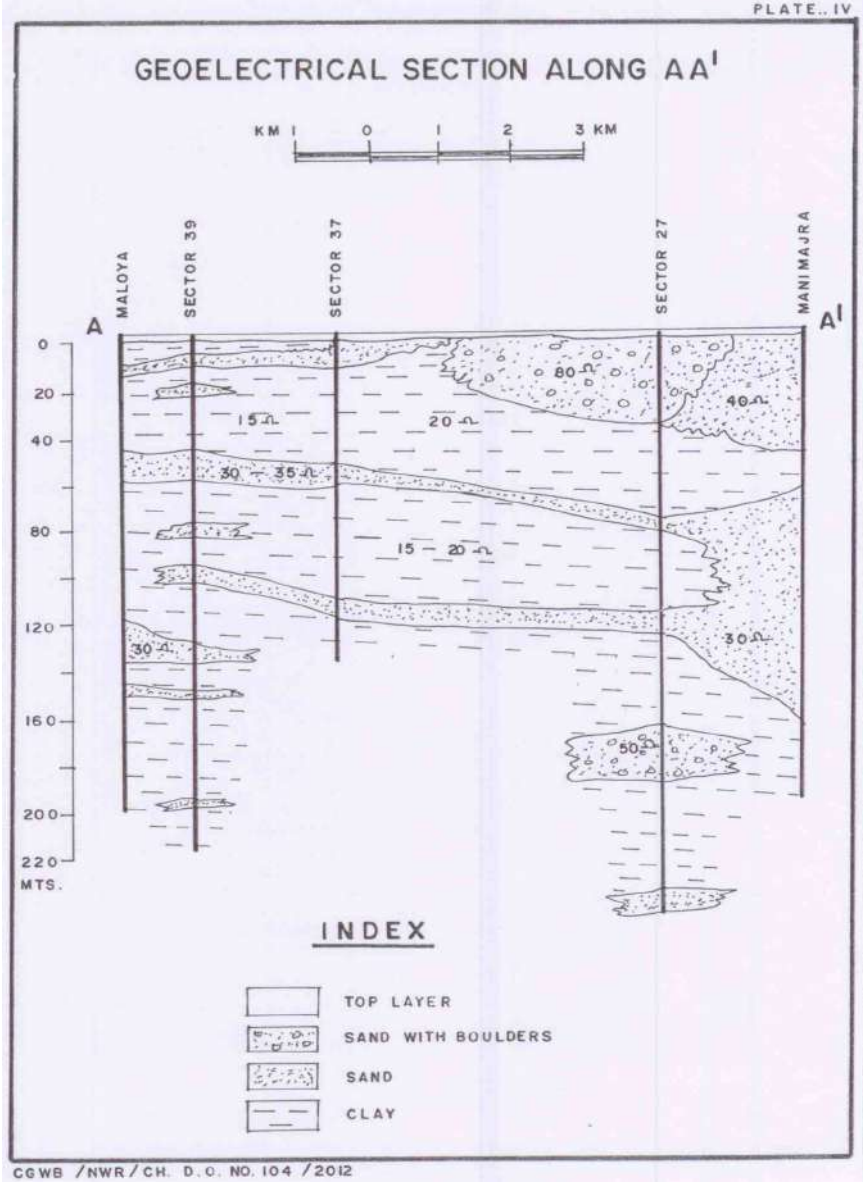
INDEX

CROSS SECTION LINE B ——— B'

CGWB NWR CH D.O. No. 2012/106

PLATE.. IV

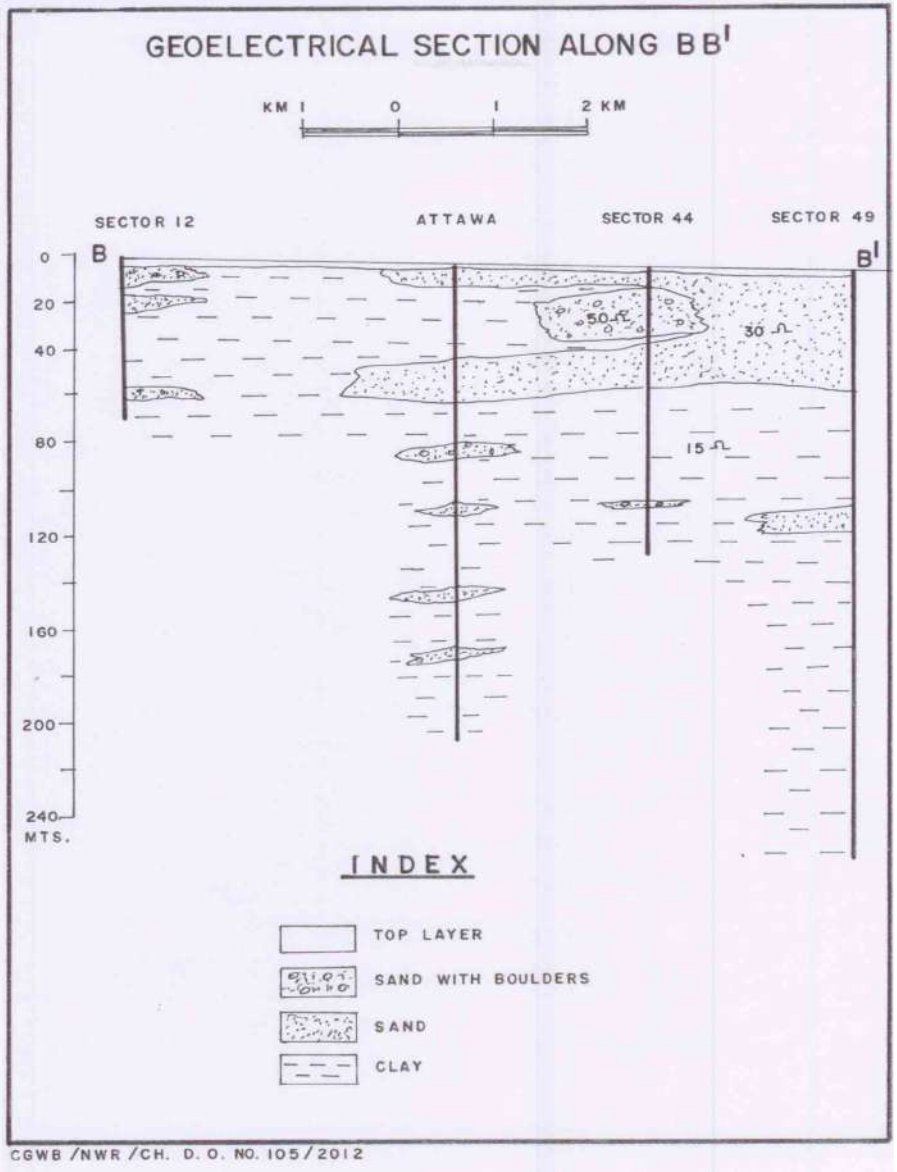
GEOELECTRICAL SECTION ALONG AA'



CGWB /NWR/CH. D.O. NO. 104 /2012

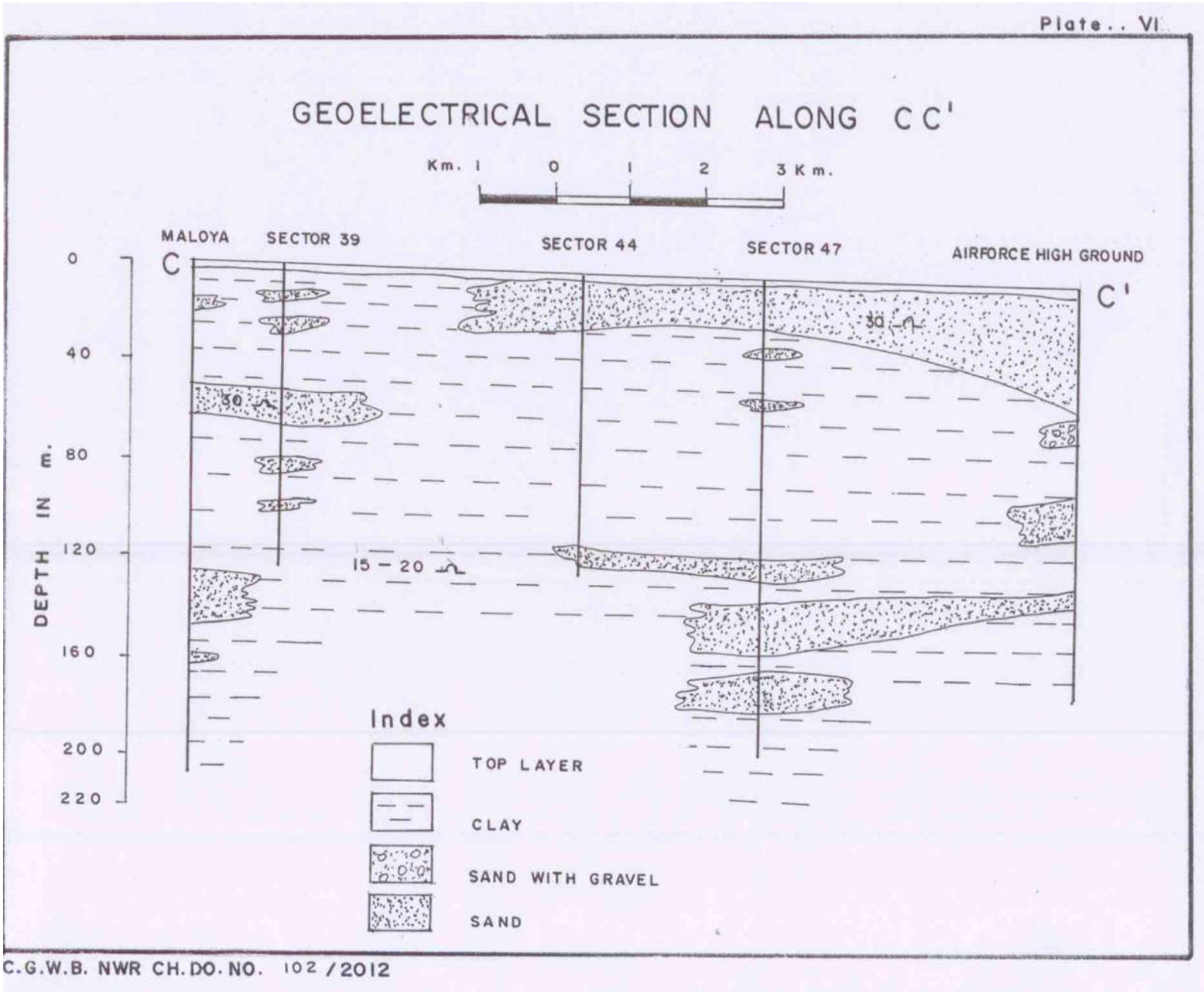
PLATE ... V

GEOELECTRICAL SECTION ALONG BB'



CGWB /NWR/CH. D.O. NO. 105/2012

GEOELECTRICAL SECTION ALONG C C'



C.G.W.B. NWR CH.DO.NO. 102 /2012

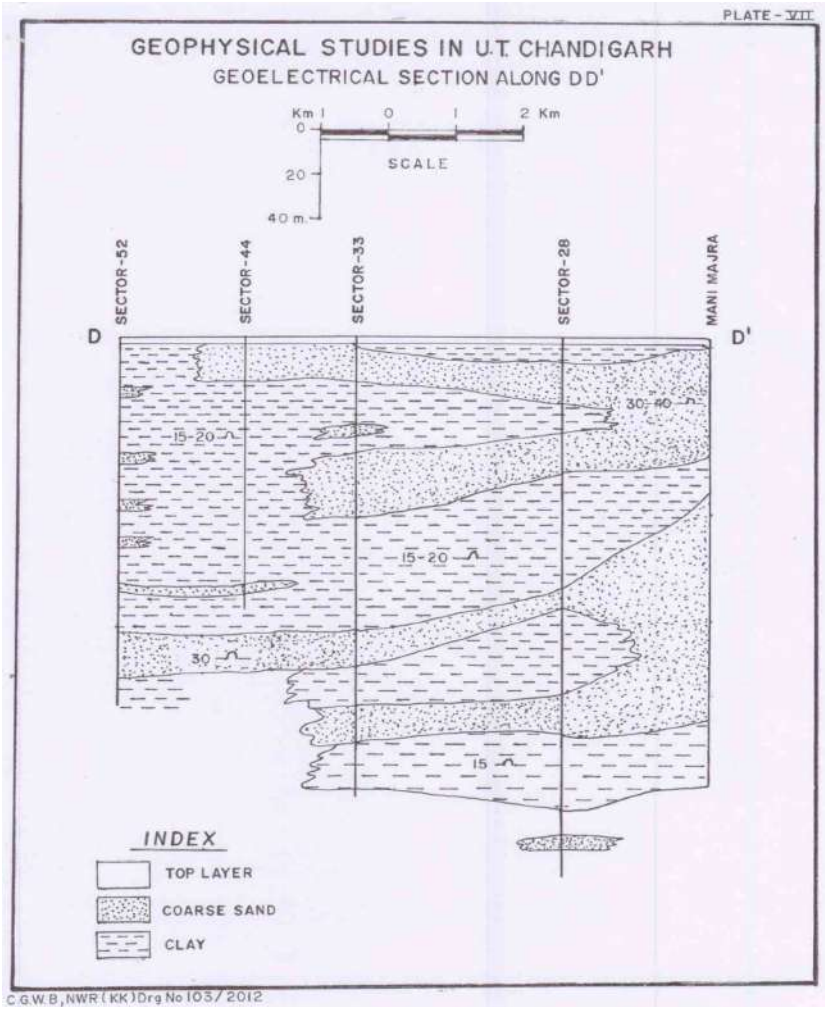


PLATE - VII
GEOPHYSICAL STUDIES IN U.T. CHANDIGARH
GEOELECTRICAL SECTION ALONG DD'
Km 1 0 1 2 Km
SCALE
20
40 m.
SECTOR-52
SECTOR-44
SECTOR-33
SECTOR-28
MANI MAJRA
D
D'
30-40 Ω
15-20 Ω
15-20 Ω
30 Ω
15 Ω
INDEX
TOP LAYER
COARSE SAND
CLAY
C.G.W.B, NWR (KK) Drg No 103/2012

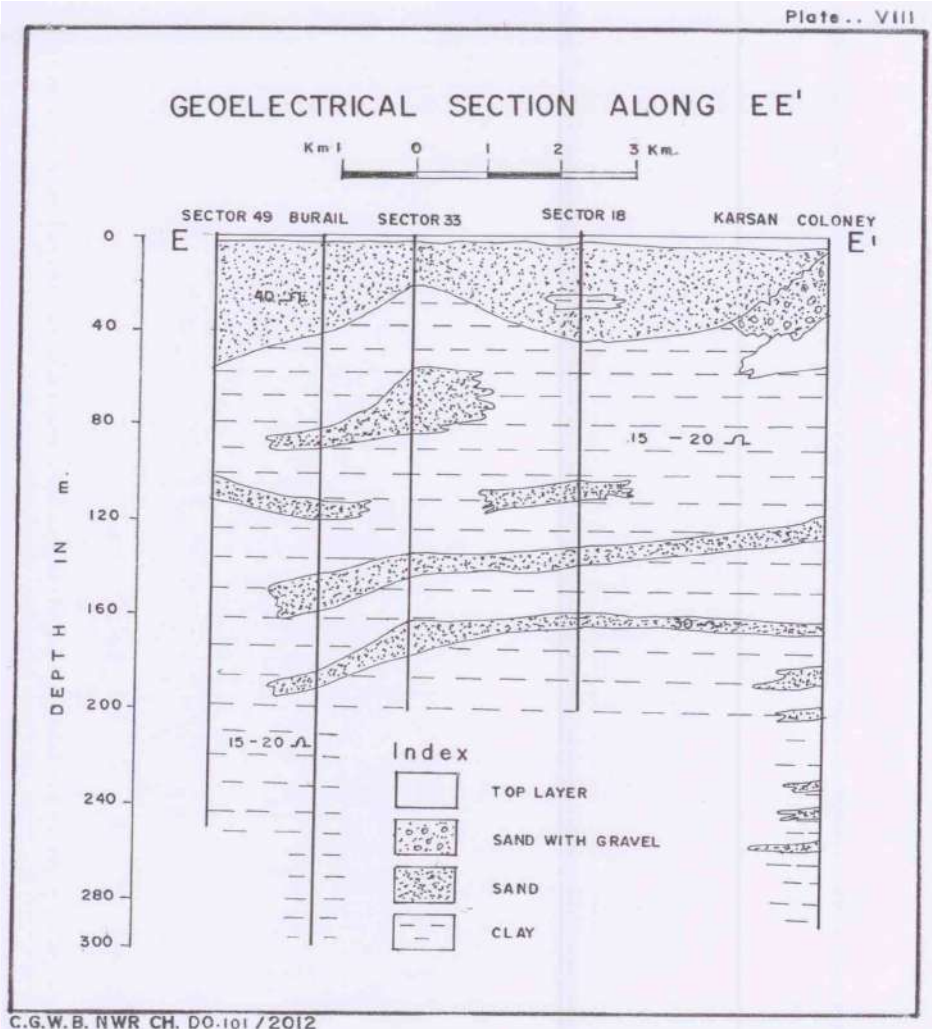


Plate.. VIII
GEOELECTRICAL SECTION ALONG EE'
Km 1 0 1 2 3 Km.
SECTOR 49
BURAIL
SECTOR 33
SECTOR 18
KARSAN COLONEY
E
E'
DEPTH IN M.
0
40
80
120
160
200
240
280
300
40 Ω
15 - 20 Ω
30 Ω
15 - 20 Ω
Index
TOP LAYER
SAND WITH GRAVEL
SAND
CLAY
C.G.W.B. NWR CH. DO.101/2012

2.3 Hydrochemistry

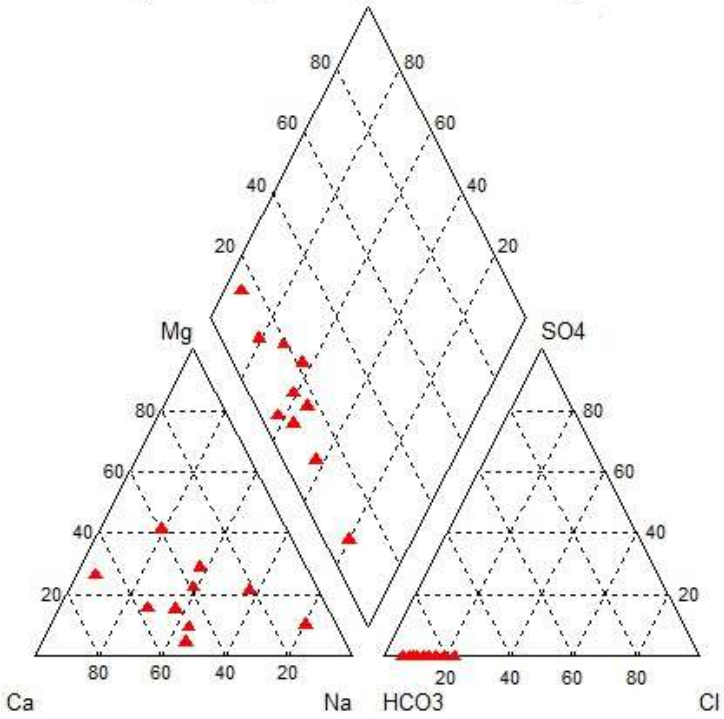
Chemical quality data obtained from the analysis of ground water samples representing shallow aquifers reveals that ground water is alkaline in nature and fresh to moderately saline. The pH value ranges from 7.66 to 8.51. According to BIS 10500, Rev.2012, the 15 basic chemical constituents for safe drinking water are within the permissible limits of all the ground water samples and is suitable for drinking purposes (Annexure-I). Among anions, bicarbonate is the dominant anion and among the cations calcium and sodium are dominated. Arsenic and other trace metals (Cd, Cu, Pb, Mg, Zn, Fe & As) are also within the permissible limit. The min and max value obtained from the samples for different chemical constituents is given in table 2.

Salinity (EC), Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) are the basic parameters considered for ascertaining the irrigational suitability of ground water. Based on the plot of EC and SAR on USSL diagram for rating irrigation water, it is observed that ground water fall under C2S1 and C3S1. The ground water is low to medium saline with low sodium hazard because of low SAR and such waters cause neither major salinity nor major sodium hazards when used for customary irrigation and is suitable for irrigation.

Table 2: Concentration range of chemical constituents

Chemical Constituent	Min	Max	Units
pH	7.66	8.51	-
Specific Conductivity	498	1295	µS/cm at 25°C
CO^3	Nil	76	mg/l
HCO^3	282	666	mg/l
Cl	21	71	mg/l
NO^3	0	0	mg/l
F	0.11	0.85	mg/l
Ca	28	124	mg/l
Mg	7	46	mg/l
Na	6.9	273	mg/l
K	1.1	8.3	mg/l
Total hardness as $CaC0^3$	150	370	mg/l

Fig6: Hill-Piper Diagram for Chandigarh



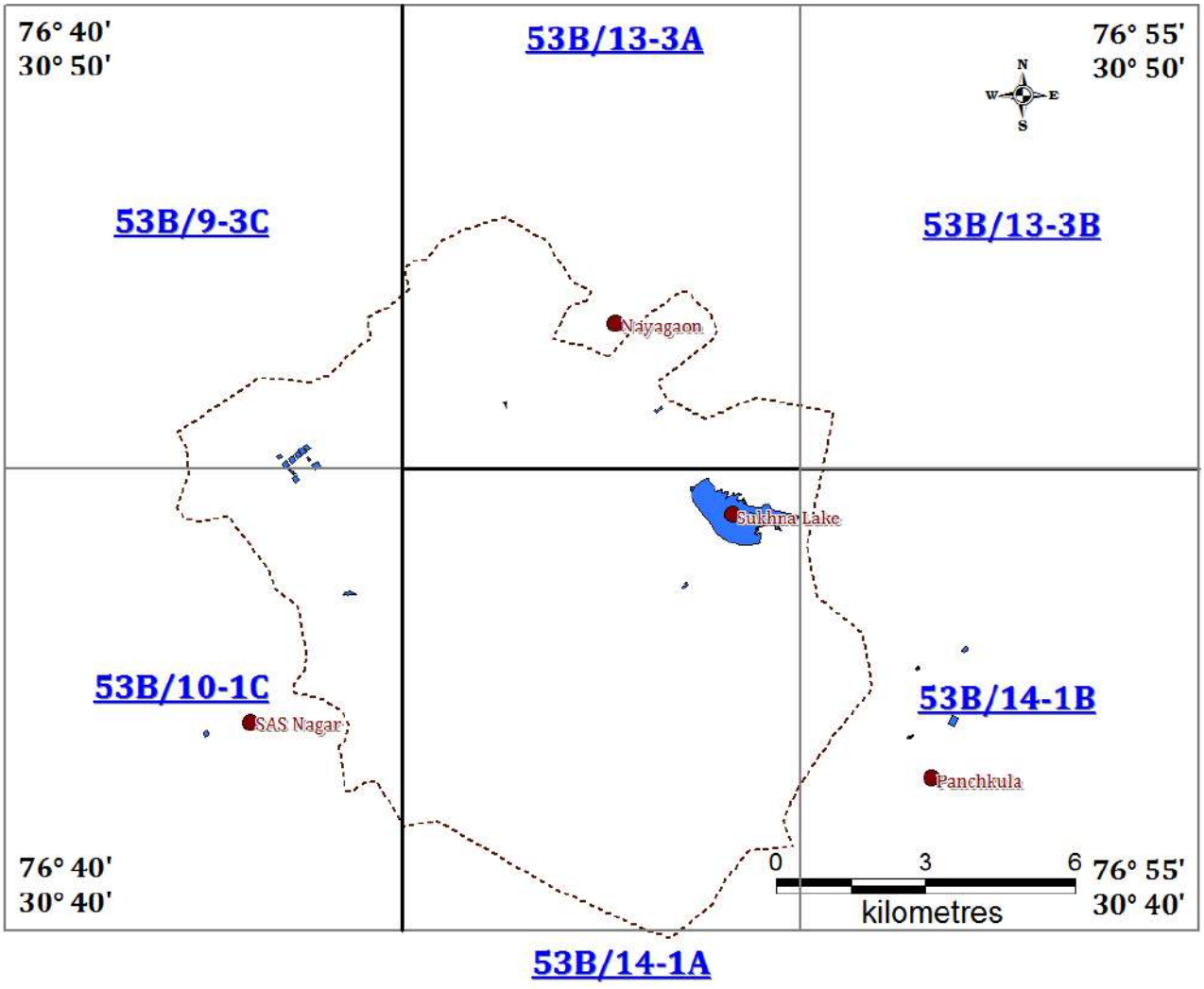
Chemical composition of water

The chemical characters of shallow ground water in the Chandigarh is mostly found Ca+Na+Mg+ HCO^3 and Na-HCO^3 type and is shown in fig 5.

2.4 Water Bodies

There are some small ponds exists in rural areas of Chandigarh and there is an artificially created exists due to damming in northeast side of the covering an area of about 1.62 sq.km and is shown in fig 7.

Fig 7: Water Body Map

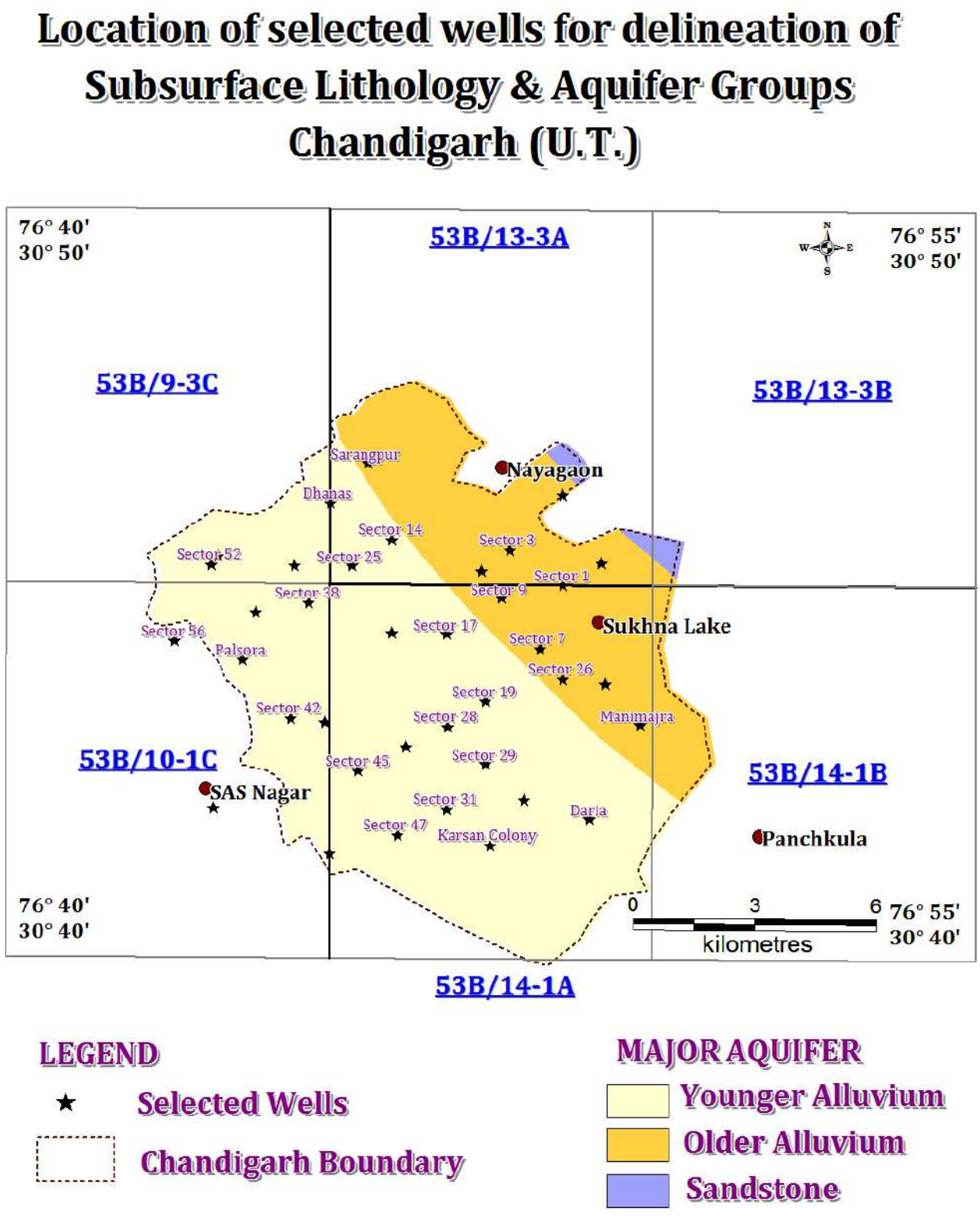


3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 Hydro-geological Interpretation & Results

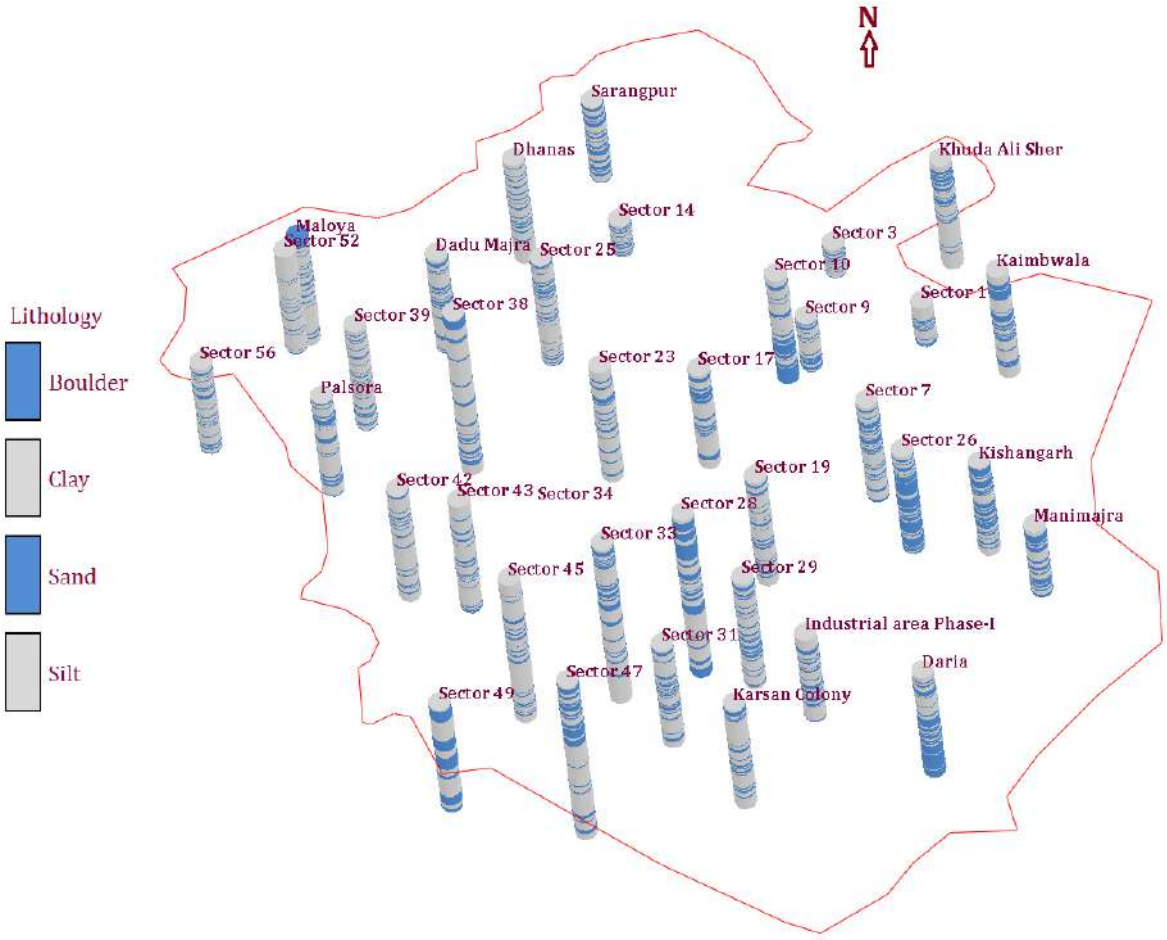
All the available data have been validated for consideration to generate aquifer map. The deepest well in each quadrant is selected and plotted on the map of 1.50000 scale with 5'X5'grid (9 x 9km) and is shown in Fig 8.

Fig 8: Validated Exploration Data of Chandigarh (U.T.)



The locations of validated wells are plotted and litholog is shown in fig 9.

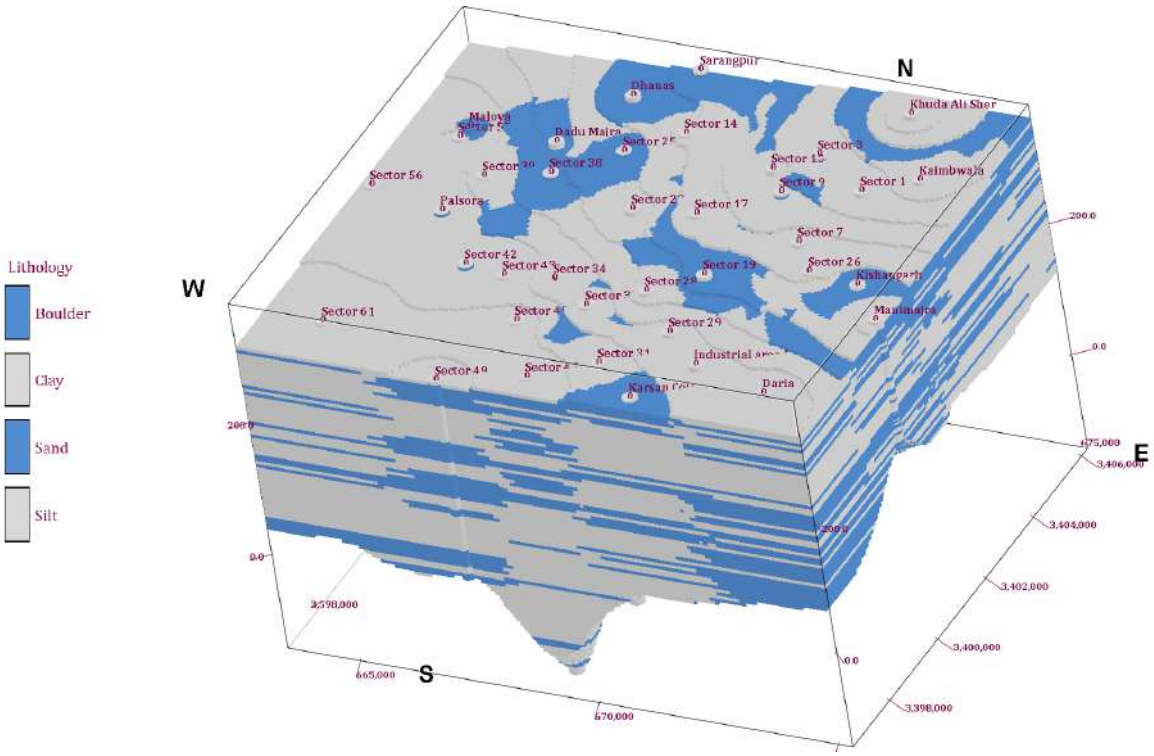
Fig 9: 3Dimension location of validated Exploratory Wells with litholog



3.1.1 Lithology Disposition

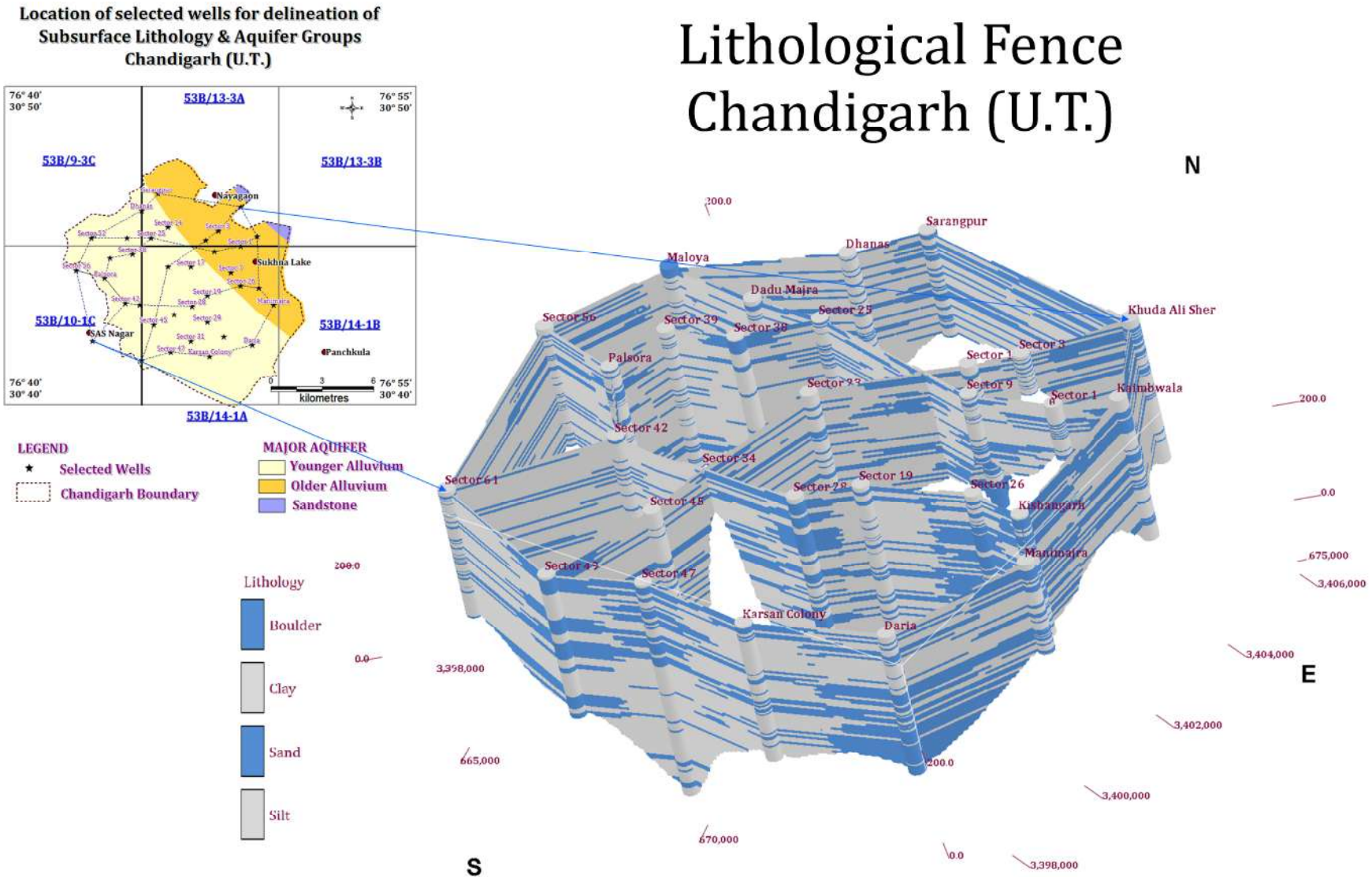
To understand the sub surface lithology and its disposition, the lithological data of the optimized wells drilled by CGWB, MCC and Private Agencies is plotted using the RockWorks15 software and a lithological model has been prepared and is shown in fig. The 2D lithology map and 3D lithological fence diagram has been prepared using the lithology model and are shown in fig 10 & 11 respectively.

Fig 10: 3-Dimension Lithological Model of Chandigarh



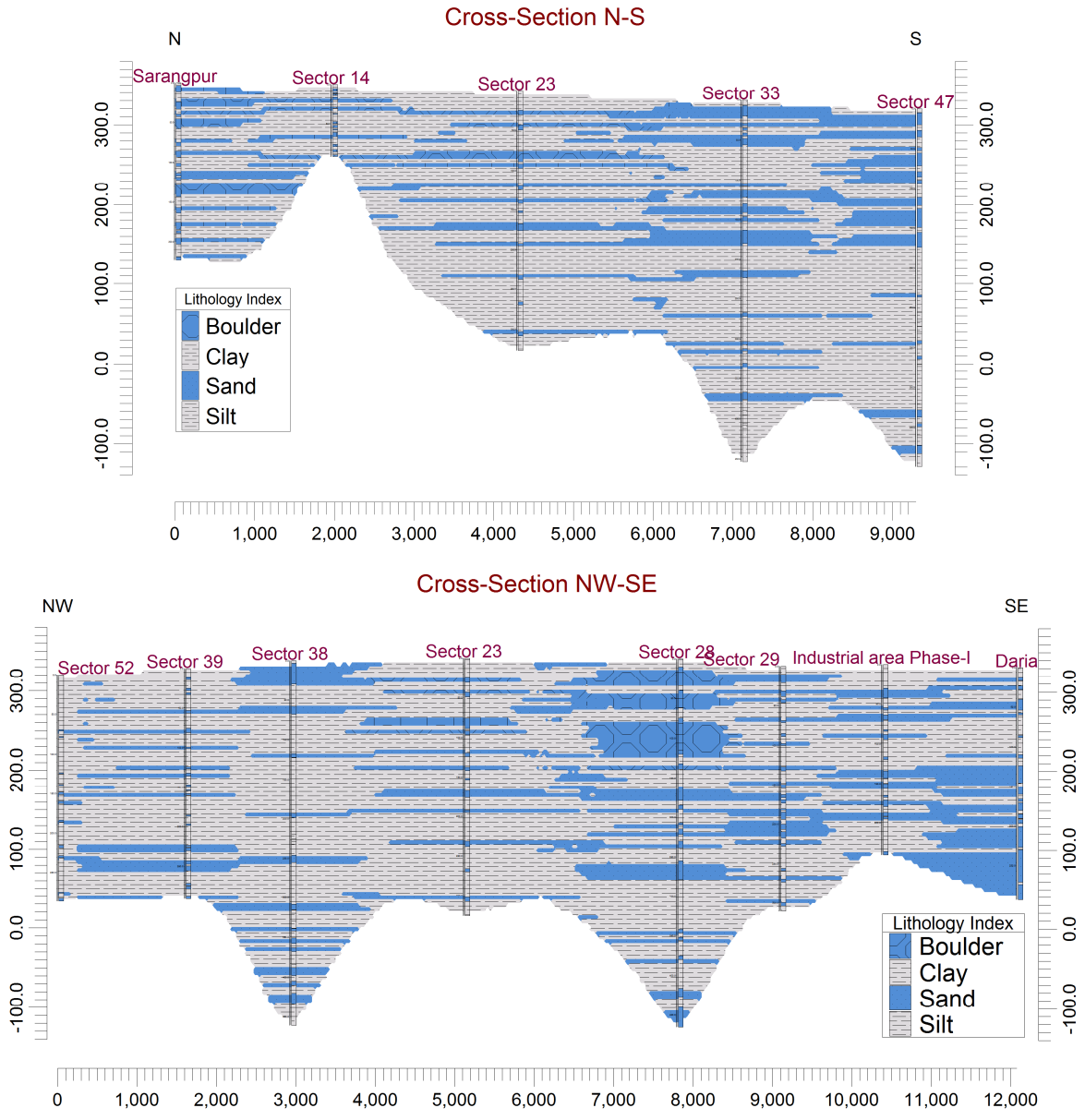
The major aquifer system of Chandigarh is alluvial fan deposit having older and younger alluvium which mainly comprised of boulder, sand, silt and clay. The major lithological formations are sand & clay and silt is found admixed with sand and clay. The coarser sediments and boulders are found in the northern and north eastern part of the area. The top surface layer and soil is mainly silty clay. There is large variation in the occurrence of geological formation in different parts of the Chandigarh. The inter-layering of sand and clay is more frequent in the northern and north-eastern part as compared to southern portion as well as the thickness of the potential aquifer zones is also high in the northern and north-eastern part. There is a thick clay occurrence at shallower depth in western and southern part of Chandigarh and the existence of aquifer zones is also less in this part whereas its frequency is high in north and north-eastern part. The deepest data available is up to 465m bgl at site Sector 28. The 3D lithological fence will represent the much more clear representation of sub-surface lithology in space.

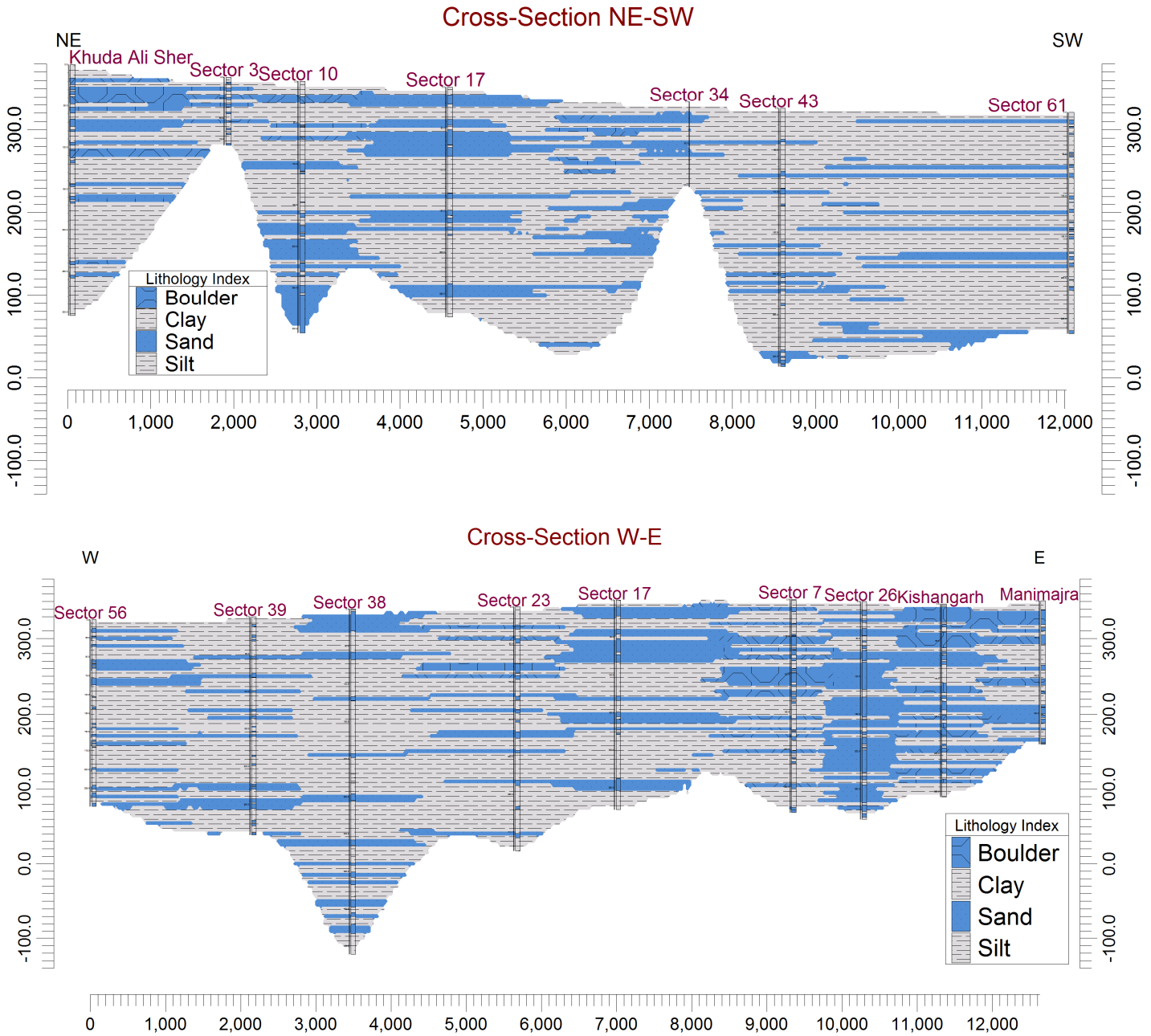
Fig 11: 3 Dimension Lithological Fence of Chandigarh (U.T.)



The cross-sections of lithology along different directions is shown in fig 12. The lithology along NE-SW direction shows that the there is thick clay layers exists in SW part i.e. Sector 61 & 43 and thin and more no. of clay layers exists in NE part i.e. Khuda Ali Sher, Sector 3 & 10. The coarser sediments also found at shallow depth of site Khuda Ali Sher. The N-S section shows the thickness of clay layer increases with depth in southern part. The NW-SE and W-E section also shows that in western part of Chandigarh, the clay layers are thick and sand layer are less in number whereas the occurrence of aquifer layers is more frequent and thick in north and north-eastern part. In southern part of Chandigarh, a less number of shallow sand zones occur followed by thick clay layers making it more susceptible to extract ground water from deeper zones.

Fig 12: Cross-sections of lithological formation along different directions




Cross-Section NE-SW
NE
SW
Khuda Ali Sher
Sector 3
Sector 10
Sector 17
Sector 34
Sector 43
Sector 61
Lithology Index
Boulder
Clay
Sand
Silt
300.0
200.0
100.0
0.0
-100.0
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
Cross-Section W-E
W
E
Sector 56
Sector 39
Sector 38
Sector 23
Sector 17
Sector 7
Sector 26
Kishangarh
Manimajra
Lithology Index
Boulder
Clay
Sand
Silt
300.0
200.0
100.0
0.0
-100.0
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000

3.1.2 Aquifer Geometry

To know the broad picture of the aquifer disposition, inter-relationship of granular zones, nature, geometry and extension of aquifers in Chandigarh, the aquifer grouping has been done using the sub-surface lithology and a three-dimensional aquifer model has been prepared (Fig 13). The aquifer system of Chandigarh belongs to alluvial fan deposit having older and younger alluvium. Due to large variability in the geological formations, the underground aquifer system is also very complex. There are four aquifer groups have been identified up to a depth of 400m. The depth range and their thickness are also highly variable and are given in table 3. The first aquifer is water table aquifer and extends all over the area. The aquifer is mainly composed of fine to coarse grained sand. The thickness of aquifer is high towards north-east and northern part of Chandigarh. The number of aquifer zones is also high in north-east and northern part where as it is less in west and south-western part of Chandigarh. The 2D aquifer cross-sections were also prepared using the aquifer model and are shown in Fig 14.

Fig 13: 3-Dimension Aquifer model - Chandigarh (U.T.)

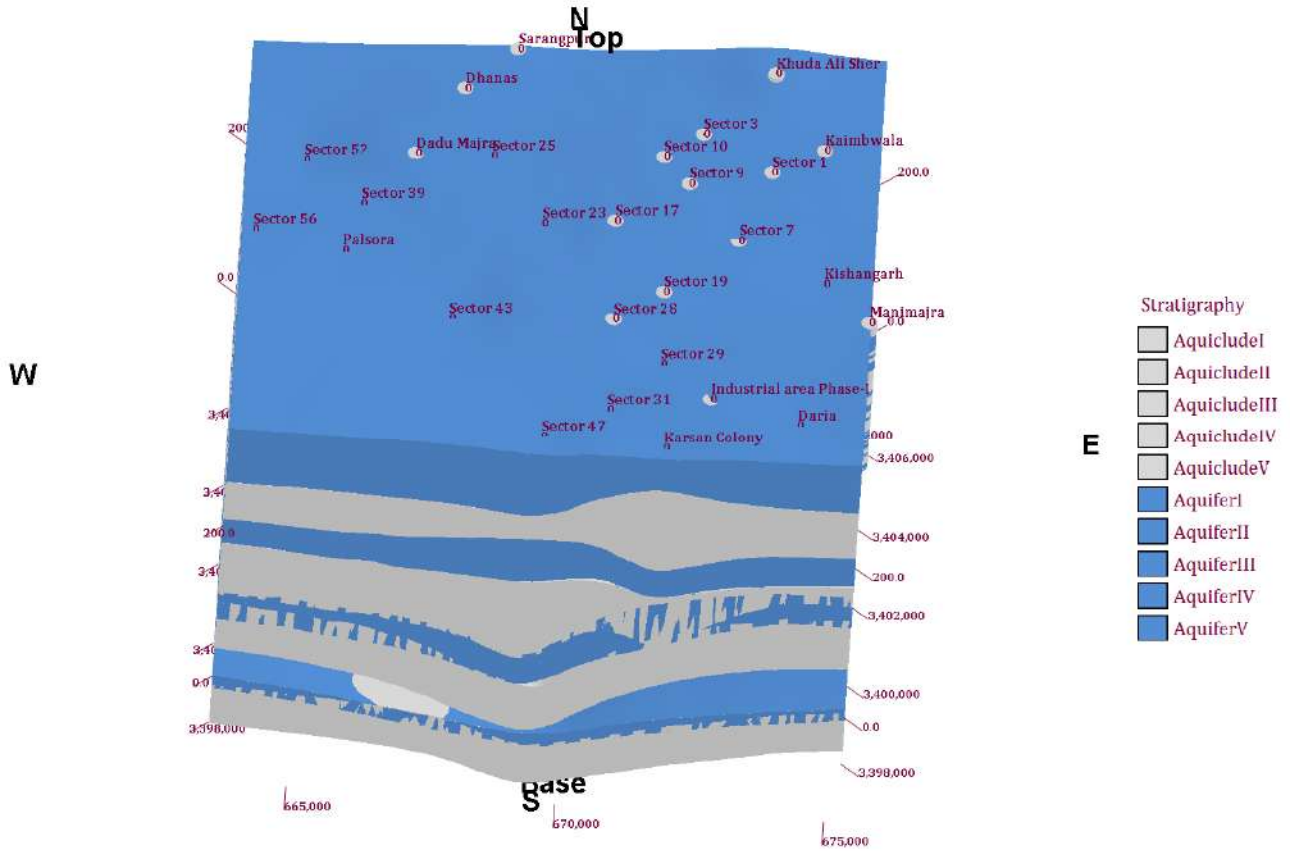
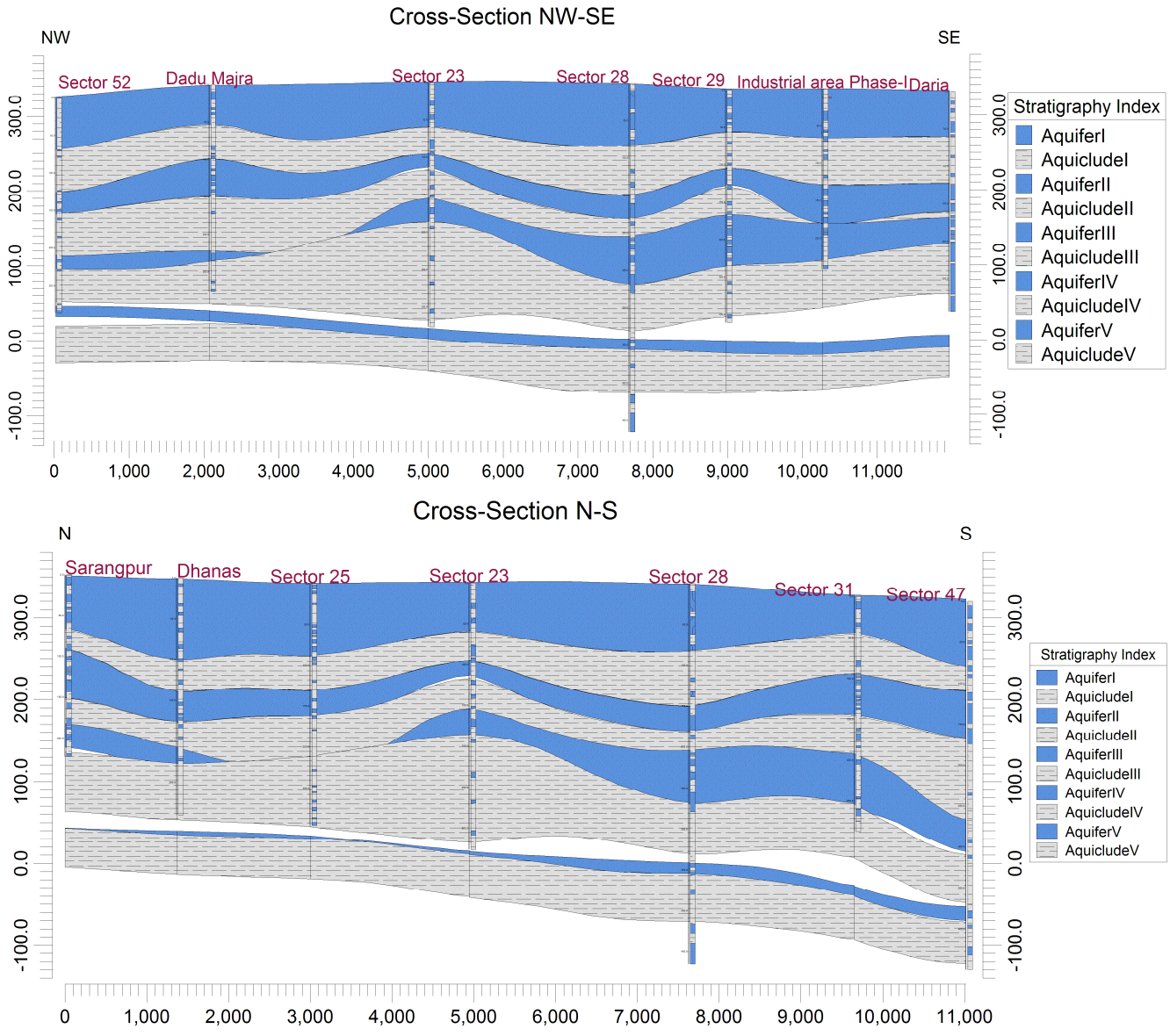
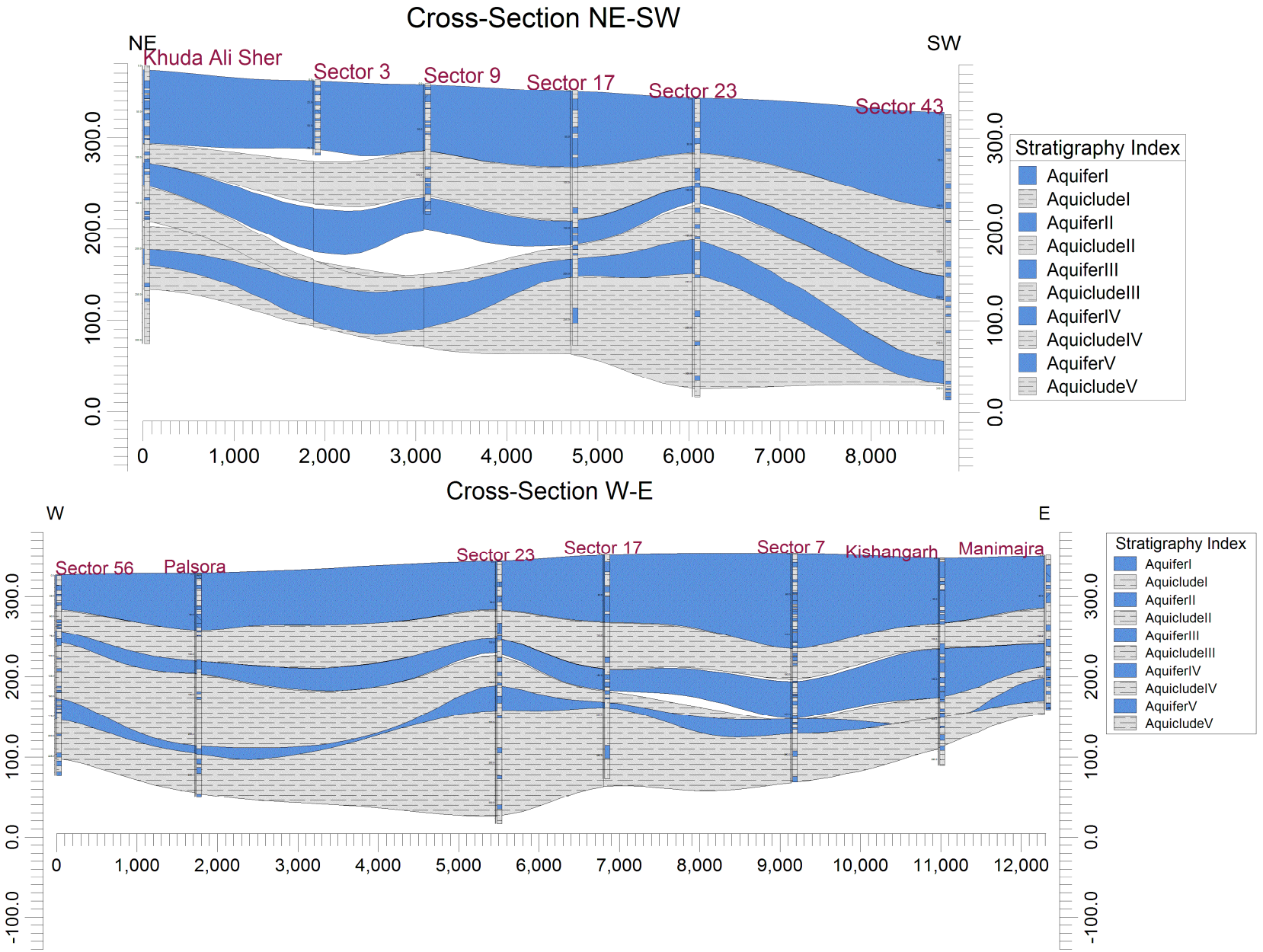


Table 3: Aquifer Grouping in in Chandigarh (U.T.)

Aquifer Group	Depth Range (mbgl)		Thickness (m)	
	From	To	Min	Max
Aquifer I	0	33-139	33	139
Aquifer II	48-261	66-271	10	72
Aquifer III	100-292	121-323	10	78
Aquifer IV (based on only 6 data points)	132-378	153-399	12	21

Fig 14: Cross sections of Aquifer Map of Chandigarh (U.T.)




Cross-Section NE-SW
NE
SW
Khuda Ali Sher
Sector 3
Sector 9
Sector 17
Sector 23
Sector 43
300.0
200.0
100.0
0.0
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Stratigraphy Index
AquiferI
AquicludeI
AquiferII
AquicludeII
AquiferIII
AquicludeIII
AquiferIV
AquicludeIV
AquiferV
AquicludeV
Cross-Section W-E
W
E
Sector 56
Palsora
Sector 23
Sector 17
Sector 7
Kishangarh
Manimajra
300.0
200.0
100.0
0.0
-100.0
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
Stratigraphy Index
AquiferI
AquicludeI
AquiferII
AquicludeII
AquiferIII
AquicludeIII
AquiferIV
AquicludeIV
AquiferV
AquicludeV

4. GROUND WATER RESOURCES

Ground water resource estimation of the area have been carried out by taking Dynamic and Static/In-storage resources of unconfined aquifer and confined aquifers present up to 400m depth. The assessment of dynamic ground water resources of the study area have been carried out jointly by CGWB and Engineering Department, Chandigarh, U T Administration on the basis of Ground Water Estimation Committee (1997) methodology.

The occurrence of potential aquifers (productive granular zones) up to 400 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 study. This assessment of total groundwater resources has been computed based on the available data with CGWB & Engineering Department, Chandigarh, U. T. Administration.

4.1 Ground Water Resources of Multiple Aquifer up to 400m Depth

4.1.1 Unconfined aquifers-

a. Dynamic Resources

The ground water development in Chandigarh has been categorized as Semi-Critical and the stage of ground water development is 89% (Table 4).

b. In-storage Ground Water Resources

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

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

Table 4: Dynamic Ground Water Resources of Chandigarh as on 31.03.2017(in ham)

Assessment unit	Net annual Ground Water Availability	Existing Gross Ground Water Draft for Irrigation	Existing Gross Ground Water Domestic and Industrial Water Supply	Existing Gross Ground Water Draft for all uses [3+4]	Provision for domestic, and industrial requirement supply to 2025 year Natural Discharges	Net annual Ground Water Availability for future use [2-3-6]	Stage of Ground Water Development [5/2*100](%)
1	2	3	4	5	6	7	8
Chandigarh UT	3794	58	3320	3378	3320	416	89

4.1.2 Confined Aquifer

The availability of ground water resources in confined aquifer have two components: Storage under pressure (using Storativity concept) and Storage under desaturated (gravity drainage) condition (using Specific Yield concept) (source: Assessment of Ground Water Resources; A Review of International Practices, 2014) and is shown in Fig 15. However, since ground water withdrawals from confined aquifer are known to have serious environmental degradation effects, the preliminary assessment of ground water resources in confined aquifer is restricted to the estimation of ground water storage under pressure conditions only but here the storage under de-saturation is also computed.

Storativity Concept:

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

Specific Yield Concept:

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

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

The calculation of in-storage resources has been done in two parts due to high variability in geological formation/aquifer system in the northern and southern parts of Chandigarh as mentioned in the aquifer geometry section of the report. In the northern part, the thickness of clay formation is less as compared to southern part therefore the thickness of the granular zone in unconfined/confined aquifer is divided in to two parts with an area covering ratio of 50:50. The average thickness of granular zone in a 50:50 ratio for each aquifer is calculated by dividing the thickness of granular zones falling into the category of more than or less than of a particular thickness i.e. the average thickness of granular zone more/less than 25,30 & 20 m for Aquifer I, II & III is considered respectively.

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

Dynamic and In-storage ground water resources of Aquifer-I, II, III & IV are given in table 5. Total block wise ground water resources are given in table 6.

Fig 15: Concept for Resource Estimation in Unconfined and Confined Aquifer System

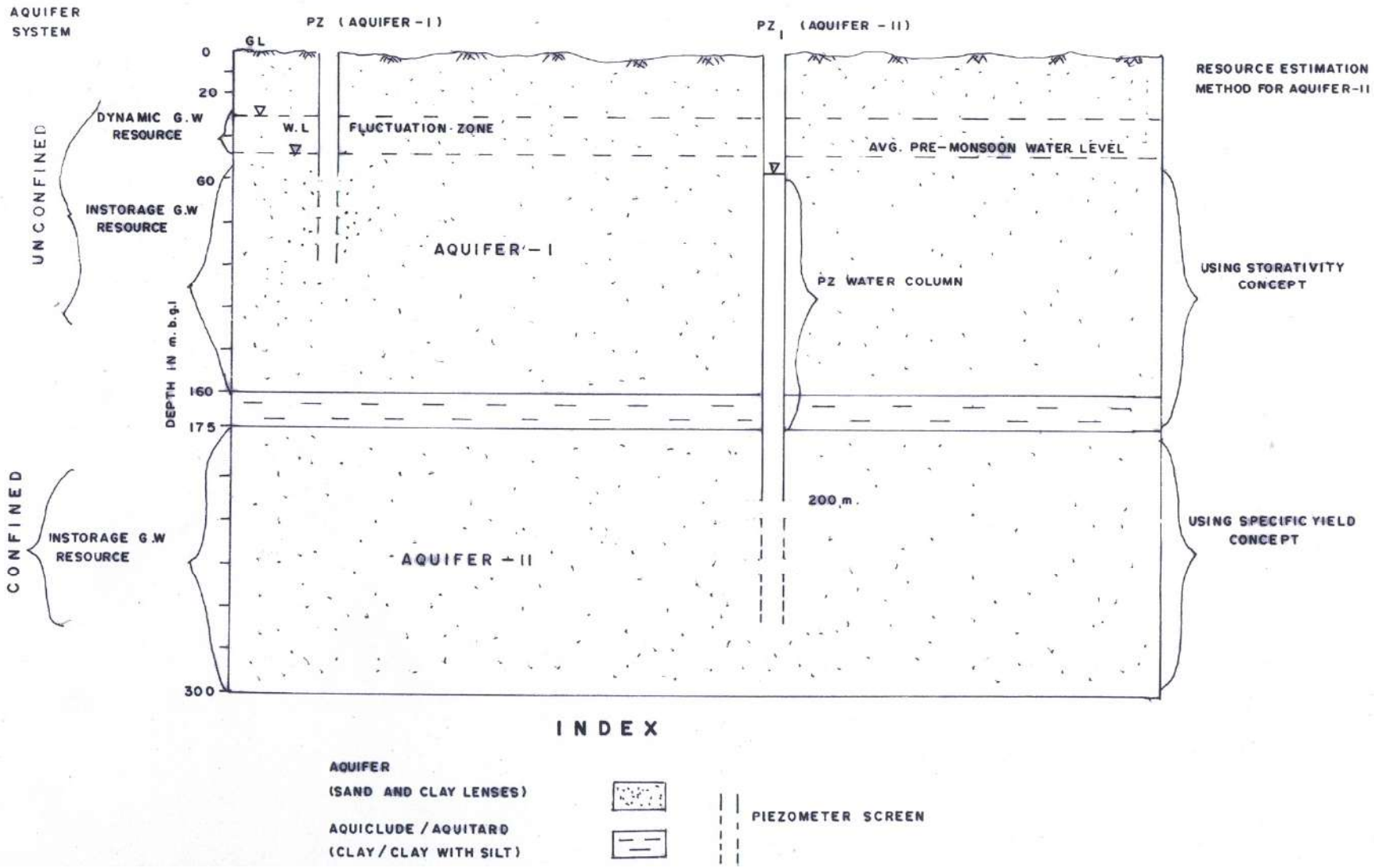


Table 5: Aquifer-wise In-storage Ground Water Resources

Aquifer Group	Name of Assessment Unit	Type of rock formation	Total Geographical Area (Ha)	Top of Unconfined/Confined Aquifer (mbgl)	Depth to bottom of Unconfined/Confined Aquifer (mbgl)	Thickness of the Granular Zone in unconfined/confined aquifer or water column in peizometer of confined aquifer (in m)		Average Specific Yield/ Storativity	In-Storage Ground Water Resources [(4)*(7/8)*(9)] (ham)		Total In-Storage Ground Water Resources [(10)+(11)]
1	2	3	4	5	6	7	8	9	10	11	12
AQ I	Chandigarh	Alluvium	11400	0	33-139	<25m	>25m	0.072	<25m	>25m	19145.16
						13.4	33.25		5499.36	13645.8	
AQ II				22(water level)	26-239	106		0.0005	604.2		604.2
				48-261	66-271	<30m	>30m		<30m	>30m	
						17.92	35.85	0.072	7354.37	14712.84	22067.21
AQ III				100(water level)	38-192	96		0.0005	547.2		547.20
				100-292	121-323	<20m	>20m		<20m	>20m	
						12.91	29.06	0.072	5298.26	11926.22	17224.49
AQ IV				132-378	153-399	based on only 6 data points					
						9.83		0.072	8068.464		8068.46
Total (ham)											67656.72
Total (mcm)											676.57

*The average peizometer head of aquifer II & III is 22 & 100m bgl respectively.

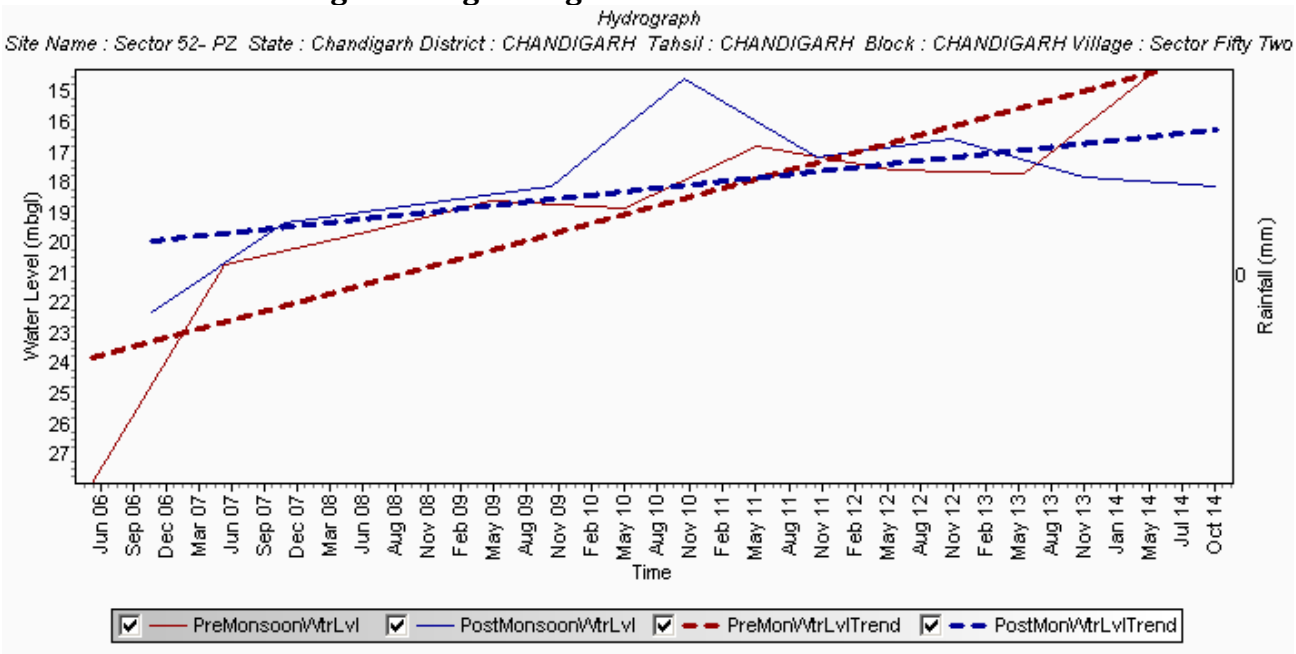
Table 6: Availability of Total Fresh Groundwater Resources in Chandigarh up to 400m depth (in mcm)

Assessment Unit	Groundwater Resources AQUIFER-I		Groundwater Resources AQUIFER-II		Groundwater Resources AQUIFER-III		Groundwater Resources AQUIFER-IV	Total Availabilty of Groundwater Resources
	Dynamic	In-storage	Dynamic	In-storage	Dynamic	In-storage	In-storage	
Chandigarh	4.16	191.45	6.04	220.67	5.47	172.24	80.68	680.73

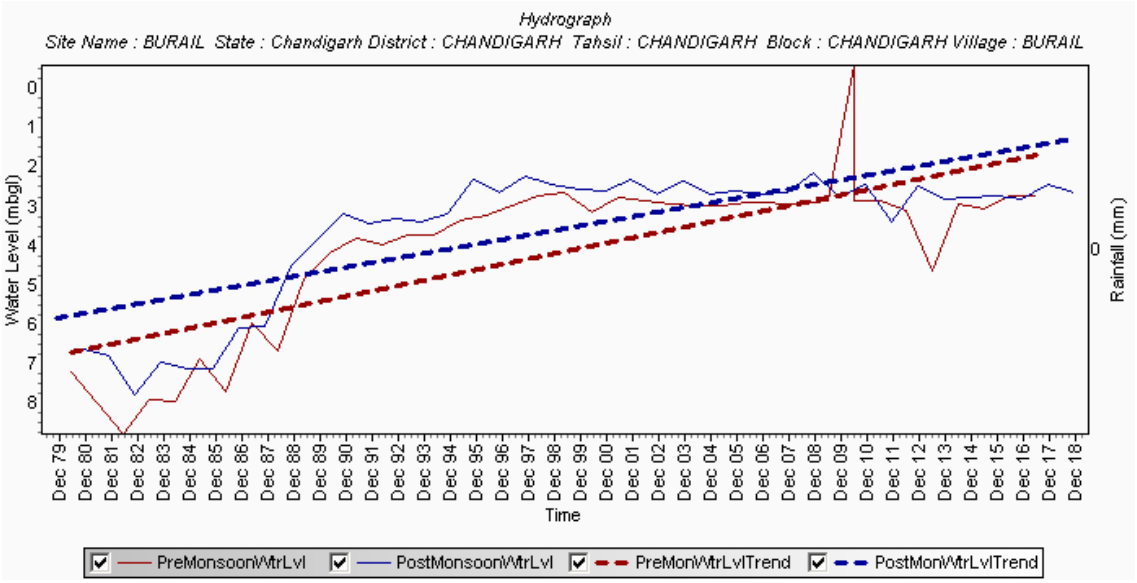
5. GROUND WATER RELATED ISSUES

There are some issues related to ground water in the city like decline in the piezometric head of the deeper aquifers due to sustained pumping more towards the north and north-eastern part. In Chandigarh, the Water Supply Bye Laws of Chandigarh ensure all the water supply is to be met from government tubewells and no private tubewells are allowed to be constructed. Also only the deeper aquifers, below 100 m, are being exploited and thus at present there is none or negligible withdrawal of ground water from shallow aquifers in Chandigarh city. This is also evident from the fact that whereas there is a heavy decline in the water levels of the deeper aquifers due to sustained pumping, there is hardly any decline in water levels of the shallow aquifers and there is the problem of water logging in somr parts (except in the central parts where the decline in the last five years can be attributed to leaky confined conditions) and can be seen in fig 16. The depth to water level pattern for both the shallow and deeper aquifers are almost same only the depth to water level for deeper aquifer is deeper than the water level of shallow aquifer in the same area and reaches up to 100m bgl. The water levels are especially quite shallow in the western and south-western sectors (and Mohali - where in certain areas water logged conditions exist and dewatering had to be resorted to while constructing multi-storeyed buildings). It is worth mentioning that the chemical quality of ground water of all the aquifer systems in Chandigarh is good and within the permissible limits prescribed by BIS (1991) for drinking water.

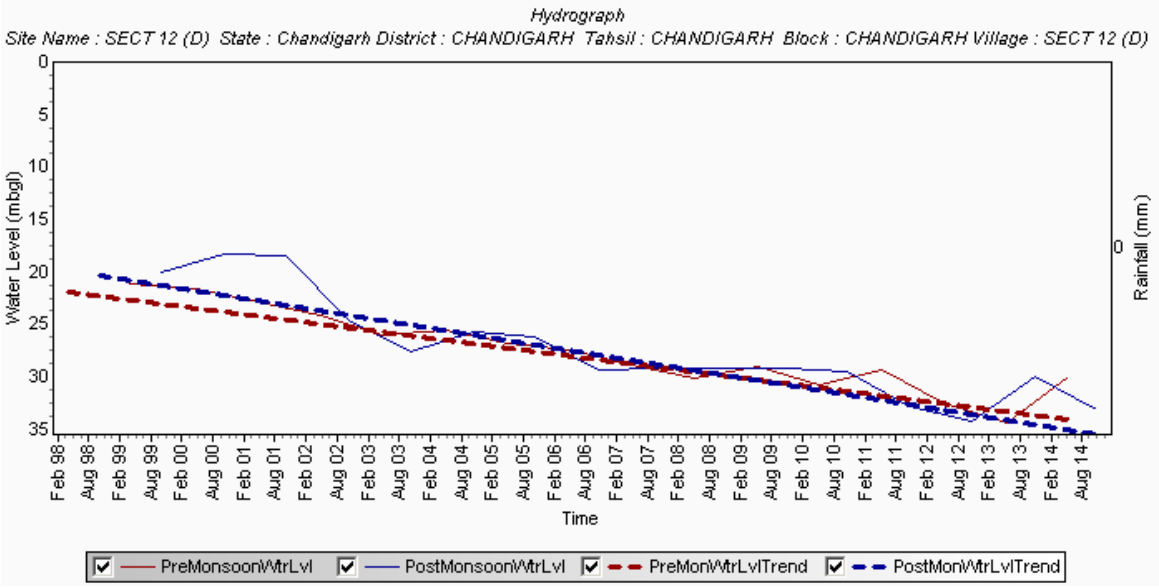
Fig 16: Long term ground water table variation.



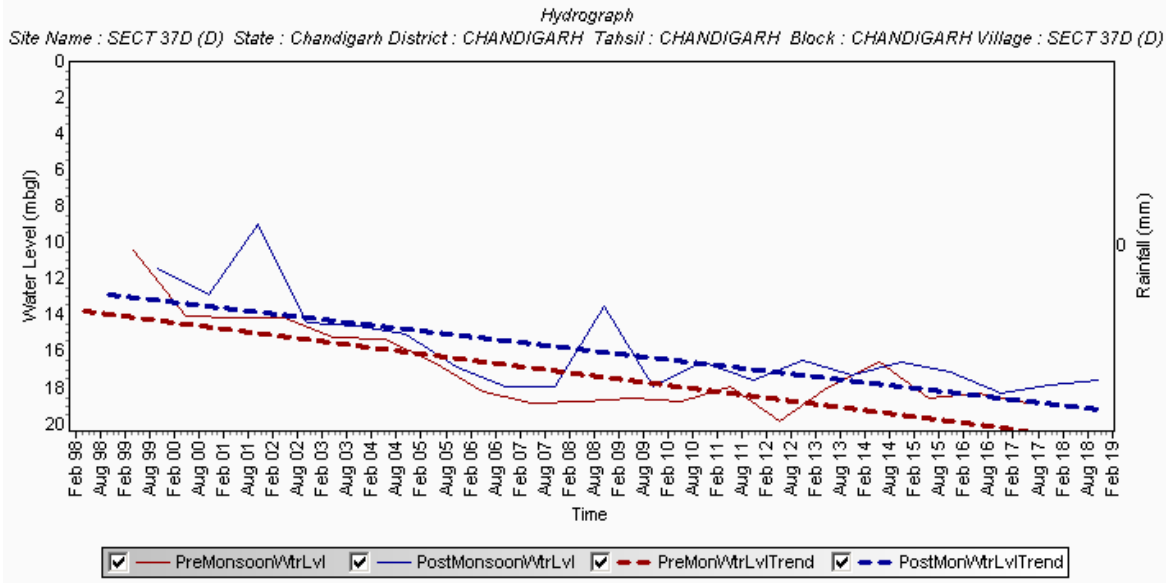
Site at Sector 52 showing long term rise in water level



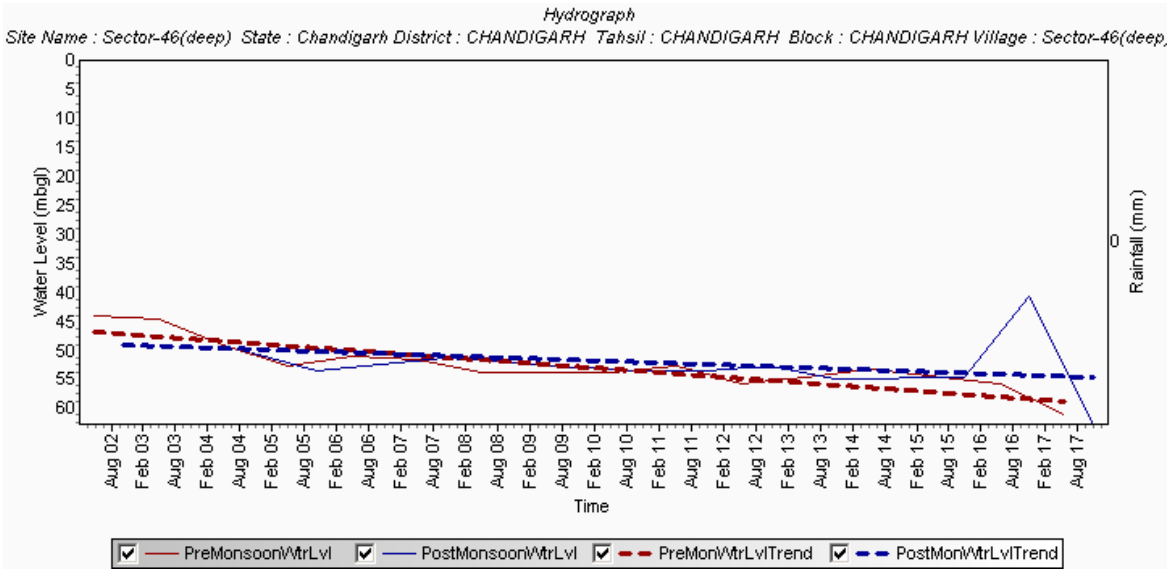
Site at Burail Village showing long term rise in water level



Site at Sector 12 (Deep Piezometer) showing long term decline in water level



Site at Sector 37D (Deep Piezometer) showing long term decline in water level



Site at Sector 46D (Deep Piezometer) showing more or less static trend of water level

6. AQUIFER MANAGEMENT PLAN

As mentioned in ground water related issues section, the major problem is ground water decline in major part and water logging in some parts of Chandigarh.

Declining water level:

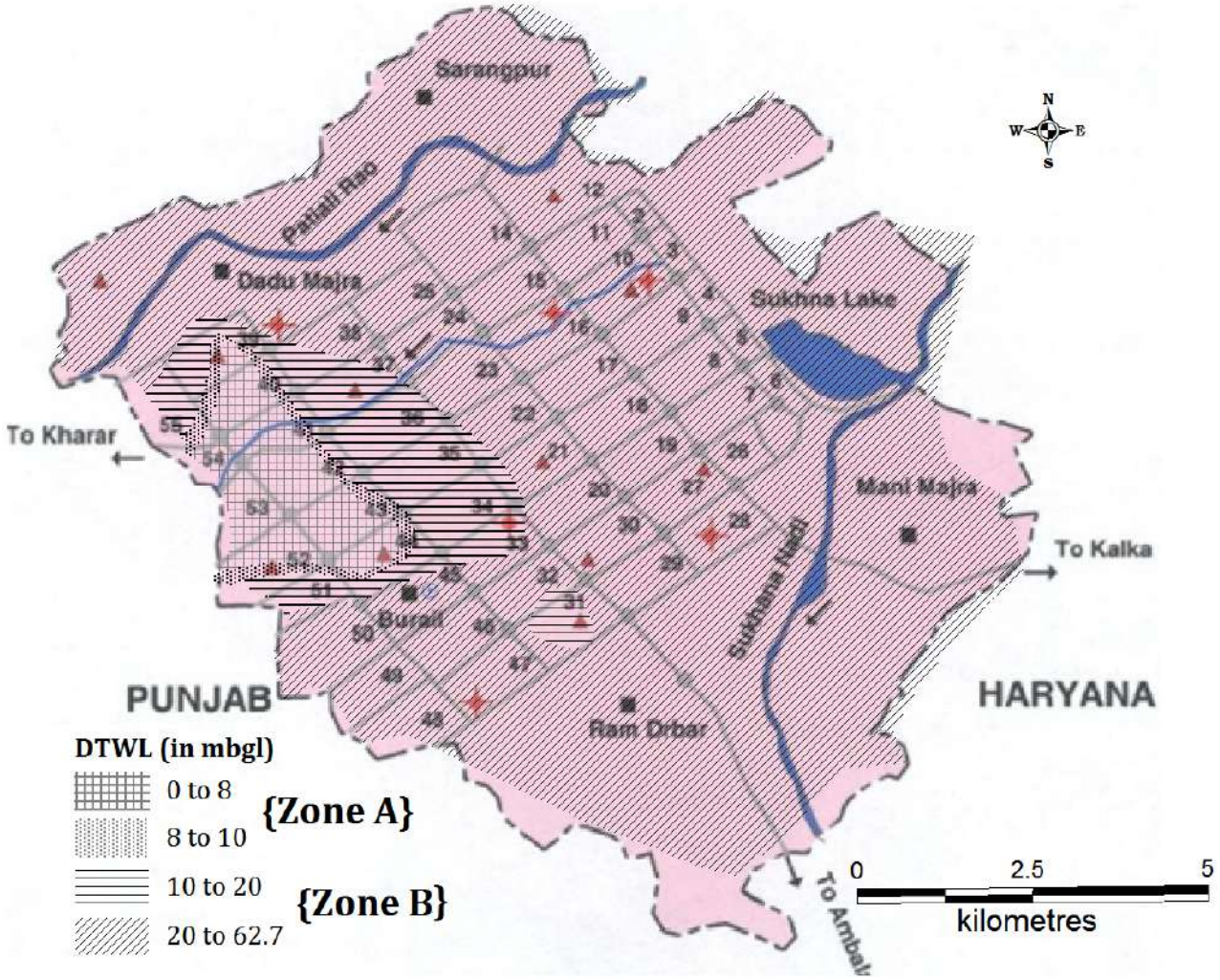
This is observed in both shallow and deeper aquifers of Chandigarh covering northern, eastern, central and southern parts of Chandigarh. To overcome this problem, rainwater harvesting and artificial recharge may be suggested to arrest the decline in the piezometric head and should be made compulsory for all the buildings having a roof area of 250m^2 or more.

Water logging:

This is observed in south-western parts of Chandigarh. To overcome this problem an extraction of water from shallow aquifers is suggested. This shallow aquifer water if cannot be used for primary purposes then it can be used for secondary purposes like for gardening, flushing, cleaning i.e. other than drinking and cooking.

Based on above observation, Chandigarh area can be divided into two zones (Fig 17) i.e. Zone A covering sectors 39, 55, 54, 53, 52, 43, 44, 42 & 40 where water logging is observed therefore, it is suggested to extract shallow aquifer water for secondary uses mentioned earlier above; further these are also not suitable for Artificial Recharge as water level is very shallow and Zone B covering rest of Chandigarh where recharge of deeper aquifer with depth slot of between 70-90mbgl should be done. The design of recharge structure for Chandigarh is given in Annexure I.

Fig 17: Aquifer Management Plan Zonation Map for Chandigarh (U.T.)



7. CONCLUSION

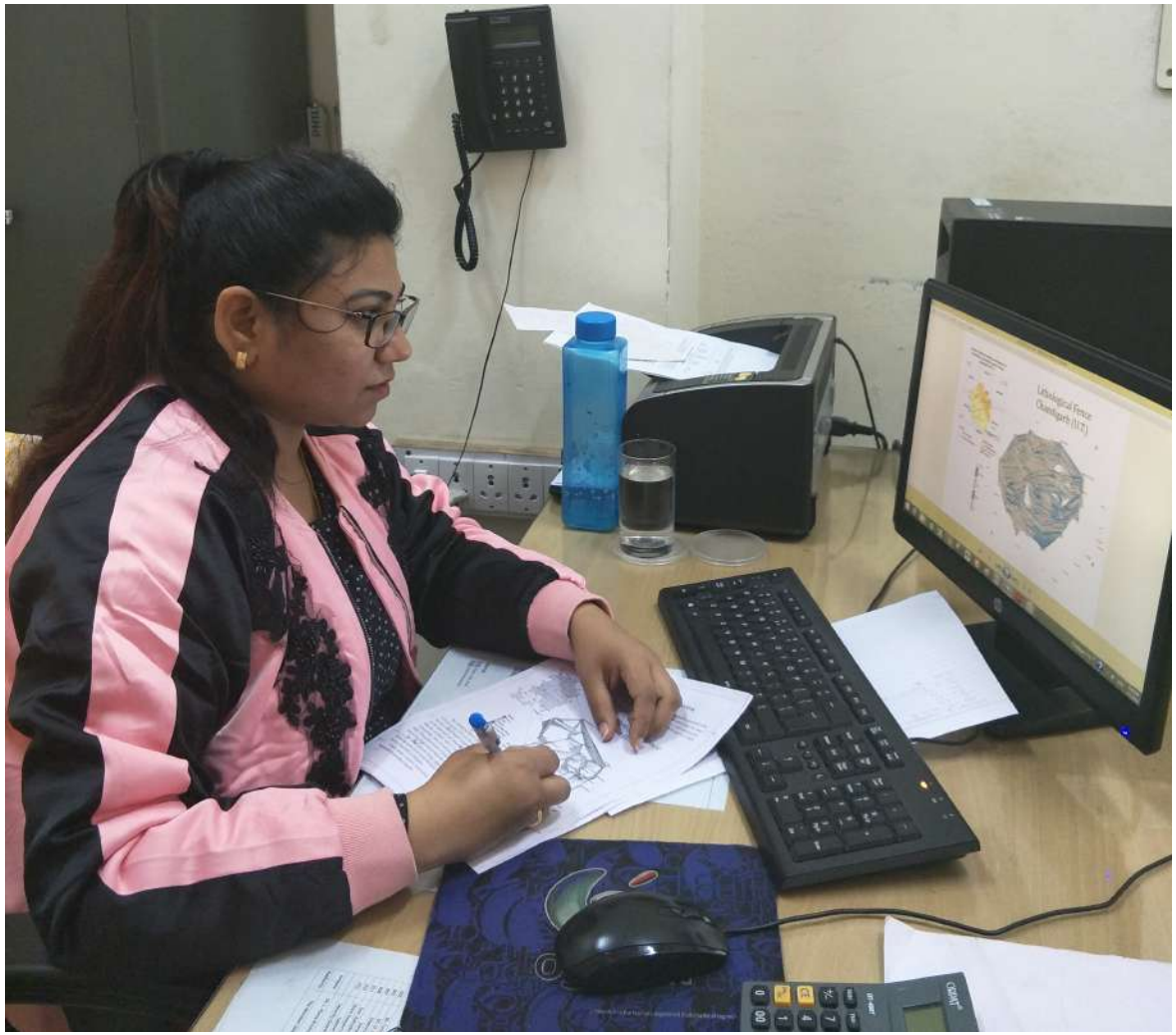
- Chandigarh known, as "THE CITY BEAUTIFUL" is a Union Territory (U.T.) located at the foothills of the Siwaliks about 250 kms north of Delhi. It is the joint capital of Punjab and Haryana states even though it does not form part of any of the two States and has an area of 114 km^2.
- There is an artificially created lake called Sukhna Lake in eastern part and some small ponds exists in the rural areas of Chandigarh.
- The climate of Chandigarh can be classified as subtropical with hot summer and cold winter except during monsoon season when moist air of oceanic origin reaches the area. The normal annual rainfall of the UT is 1061 mm, which is unevenly distributed over the area in 49 days
- The major 70% area of Chandigarh is covered by urbanization and rest 30% is occupied by village habitation, agriculture, forests and other plantations and water bodies.

- Four physiographic units are encountered in Chandigarh; ***The Siwalik range*** trending NW-SE, ***Kandi formation*** piedmont running parallel to the hill ranges. The Kandi formations merge into ***Sirowal formations*** in south and southwest which further merges with the main ***alluvial deposits*** towards south and southwest comprise layers of fine sand and clay.
- The Union Territory of Chandigarh is occupied by semi consolidated formations of upper Siwalik system of middle Miocene age that are exposed in north eastern fringe whereas the rest of the Territory is occupied by Indo-Gangetic plain comprising alluvium of Pleistocene age.
- Lithological sequence encountered during drilling does not show any conformity in aquifer geometry in the area. In the southern part of the area compact/cemented, poorly permeable silt beds exist below 250 mbgl
- Ground water in the area occurs under water table, confined as well as semi- confined conditions.
- During the pre-monsoon, the depth to water level in the shallow aquifer system varies between 2.75mbgl to 53.64 mbgl whereas during the post-monsoon, it varies from 2.57 to 53.55mbgl. In the deep aquifer system the water level ranges from 3.69 to even more than 100m bgl.
- The long term water level fluctuation data of the shallow aquifer system reveals that there is a decline in water levels in northern and central parts of the city whereas in rest of the area it is showing a near static trend while the southern sectors shows rising trend.
- Geophysical investigation in terms of electrical logging/resistivity survey shows that entire area of the Union Territory Chandigarh falls under sedimentary rock formation comprising of sand coarse to fine grained, pebbles, cobbles and gravel, clay horizons and finer sediments alternately. The younger alluvium is restricted to the flood plains of choes and river and older alluvium consists of fine sand, silt and clay. It is located in the foot hills of the Siwalik hill range occupied by kandi in the North-East and Sirowal and alluvium plains in the remaining part
- The ground water is alkaline in nature and fresh to moderately saline. It is low to medium saline with low sodium hazard because of low SAR and is suitable for both drinking and irrigation purposes.
- According to the present NAQUIM study, it has been found that the major aquifer system of Chandigarh is alluvial fan deposit having older and younger alluvium which mainly comprised of boulder, sand, silt and clay.

- There is large variation in the occurrence of geological formation in different parts of the Chandigarh. The inter-layering of sand and clay is more frequent in the northern and north-eastern part as compared to southern portion as well as the thickness of the potential aquifer zones is also high in the northern and north-eastern part
- There are four aquifer groups have been identified up to a depth of 400m. The thickness of aquifer is high towards north-east and northern part of Chandigarh. The number of granular zones is also more in north-east and northern part where as it is less in west and south-western part of Chandigarh
- As per Ground water resource estimation as on March 2017, the stage of ground water development is 89%. The net ground water availability is 3794 mcm, and existing gross ground water draft for all uses is 3378 mcm and net ground water availability for future irrigation development is 416mcm.
- The total fresh ground water resources up to 400m of Chandigarh is 680.73mcm out of which 15.67mcm belongs to dynamic resources and rest 665.06mcm belongs to In-storage ground water resources.
- There are some issues related to ground water in the city like decline in the piezometric head of the deeper aquifers due to sustained pumping which is more towards the north and north-eastern part and there is hardly any decline in water levels of the shallow aquifers or it has started the problem of water logging in these parts.
- Chandigarh area can be divided into two zones for aquifer management plan i.e. Zone A covering sectors 39, 55, 54, 53, 52, 43, 44, 42 & 40 where water logging is observed therefore, it is suggested to extract shallow aquifer water for secondary uses and artificial recharge should not be attempted in this zone. Zone B covering rest of Chandigarh where water level is declining, there recharge of deeper aquifer with depth slot of between 70-90mbgl should be done.

11. PHOTOGRAPHS

Preparation of the report



Key-in & Validation of data

Water Level Monitoring

ANNEXURE I: Results of chemical analysis of water samples from NHS in Haryana (2017)

S. No	Location	pH*	EC* in µS/cm at 25⁰ C	CO_3	HCO_3	Cl*	SO_4	NO_3*	F*	PO_4	Ca*	Mg*	Na	K	SiO_2	TH *as $CaCO_3$
				mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	New Karsan Colony	**7.66**	925	0.0	513	71	0	8.6	0.25	<0.1	112	19	63	**8.30**	12	360
2	Sector 31	7.89	498	0	**282**	28	0	0	0.57	<0.1	72	17	**6.9**	6.60	20	250
3	Sector 44	7.98	878	0.0	577	21	0	8	0.39	<0.1	68	36	88	5.90	19	320
4	Sector 52	8.08	800	0	513	43	0	**0**	0.53	<0.1	72	**46**	40	6.30	21	**370**
5	Maloya	7.96	1146	0	615	71	0	9	0.53	<0.1	**124**	7	128	1.50	16	340
6	Sector 37	7.87	**503**	0	346	**21**	0	1.8	**0.11**	<0.1	56	**7**	60	3.40	23	170
7	Sec.27A	8.34	774	58	359	35	0	13	0.81	<0.1	68	24	78	4.80	20	270
8	Sec.10	7.70	881	0.0	423	71	0	**28**	0.48	<0.1	88	17	77	**1.10**	19	290
9	Sec.12	8.47	973	63.0	500	35	0	1.7	0.47	<0.1	48	29	145	2.40	19	240
10	Burail	**8.51**	**1295**	76.0	**666**	**35**	0	9.3	**0.85**	<0.1	**28**	19	**273**	2	17.00	**150**

ANNEXURE II: Design of proposed recharge structure

Type of structure : Trench cum recharge well
Dimension of Trench : 4 x 3 x 3
(Trench will be filled with one meter filter medium and one and half meter will be free board. It has been kept unlined at the bottom so that water may percolate down.)
Storage capacity of trench with filter medium : 3.6 m^3
Storage capacity of free board in the trench : 18 m^3
Intake capacity of one recharge well : 25.2 m^3/hr
Storage cum Recharge capacity of one recharge structure: 46.8 m^3/hr
(Trench with one recharge well)
Total no. of Recharge Structures Required : 03 Nos. of Recharge Structures
Depth of Injection/Recharge well : 90 m
Dia of pipe : 6 inch
Slotted pipe length : 10 - 15 m

Design of the Recharge Well

The borehole for the construction of recharge well may be drilled down to 70-90 m bgl depth. It may be got electrically logged for clear demarcation of granular and non granular zones. Diameter of recharge borehole may be kept as 300 mm (12"). Assembly of 150 mm (6") may be lowered. The material of well assembly may be PVC of BIS IS 12818:2010 which is less prone to corrosion and incrustation. Slotted pipe of 1.5 mm slot size may be provided against granular zones. Pea size gravel of 2-5 mm may be shrouded in annular space around recharge well assembly. The recharge well needs to be developed with air compressor to remove the drilling mud and finer sediments in the surrounding of borewell screens.

Design of the Trench

The trench may be filled with inverted filter of one meter in thickness. At the bottom boulder of 20-50 mm of 0.3 m be placed, followed by gravel of 5-10 mm of 0.3 m in thickness with top layer of very coarse sand of 2-4 mm. Freeboard of 1.5 m to be kept in the trench. The recharge well assembly to be fitted with two horizontal slotted pipe of one meter in length in the lower filter medium from the bottom of the trench and one meter vertical slotted pipe to facilitate the movement of water to the recharge well.

Recommendation:

1. The drilling may be carried out with the Rotary drilling method (Direct/Reverse) to the depth of 70-90m. The bore hole should be electrically logged for precise delineation of aquifers (coarse granular and fine grained sediments) to be tapped for recharging purpose. The actual design of recharge well will depend on the results on strata chart and electrical log. The PVC pipe and screen of 150mm (6") dia having 1.5 mm slot width may be used against granular zones, as it has more open area for the entrance of water.
2. Roofs of the buildings need to be cleaned prior to rainy season to avoid contamination of decayed leaves & birds waste. Runoff conveyance pipes from roof of the buildings to be attached to the recharge trench.

3. Gravel of appropriate size (2 mm to 4 mm) should be shrouded in the annular space around the well assembly should be filled between upto ground level.
4. The recharge wells should be developed with Air Compressor, so as to remove the finer sediments from vicinity of surrounding of well screens.
5. Three layers of filter media 0.3 m thick each are to be placed at bottom. Size of boulders to be used as filter media at the bottom, should be 20-50 mm followed by 5-10 mm with top layer of very coarse sand of 2-4 mm.
6. The quality of recharge water needs to be ensured. No polluted /sewerage/ muddy water should enter the rain water harvesting structures.
7. Proper & Safe distance of the recharge structure is to be maintained from the sewerage line/ any type of treatment plant etc. to avoid any risk of contamination of the water to be recharged. The catchments should be neat and clean.
8. The structures may be kept at 0.5 m above ground level to prevent surface inflow directly into recharge well.
9. Regular inspection of filter material is essential in recharge structure. Silt deposited on the filter media should be cleaned regularly, preferably prior to rainy season. Filter media (Sand/pea gravel layers) should also be scrapped and refilled annually to maintain a constant recharge rate through filter material.
10. Proper and timely maintenance is the key factor for the success of Artificial Recharge Structure.
11. The details of the structure constructed along with photographs and with Hydro-geological data generated at the site such as strata chart, assembly details, aquifer zones tapped, static water level, discharge on specific draw down, water sample analysis data etc. may be forwarded to the Regional Director, Central Ground Water Board, North Western Region, Bhujal Bhawan, Plot No. 3-B, Sector 27-A, Chandigarh for future use and office record.
12. Permission to install various Artificial Recharge structure and Recharge wells is governed by the prevailing rules and laws in the area.

The plan & section of the trench cum recharge well is given below: