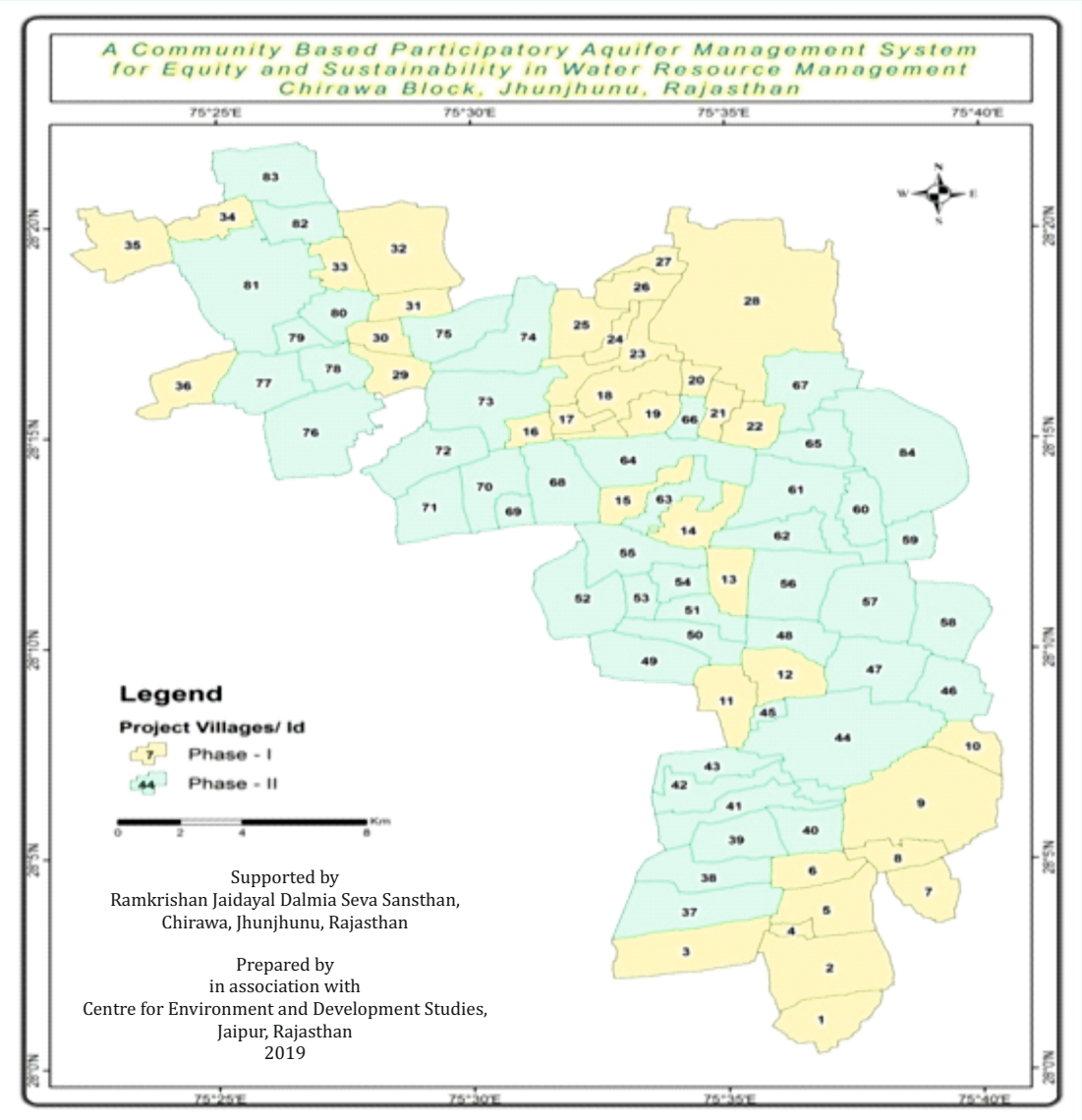
GEOPHYSICAL MAPPING AND IDENTIFICATION OF POTENTIAL GROUNDWATER RECHARGE LOCATIONS IN CHIRAWA BLOCK



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March 2019

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Acronyms

RJDSS	:	Ramkrishan Jaidayal Dalmiya Sewa Sansthan
CEDSJ	:	Centre for Environment and Development Studies Jaipur
VES	:	Vertical Electrical Sounding
GPS	:	Geographycal Positioning System
amsl	:	Above mean sea level
m	:	Meter
bgl	:	Below ground level

GEOPHYSICAL MAPPING AND IDENTIFICATION OF POTENTIAL GROUNDWATER RECHARGE LOCATIONS IN CHIRAWA BLOCK

1.0 Introduction

As the Rajasthan population continues to grow much faster than the rest of India, the need and demand for water escalates. The multiple uses of any water source in any given area can be incompatible, both in terms of the amount of water people require and the effect on the resources they have. Conflicts are brewing over the use and preservation of the Rajasthan's increasingly scarce supplies of water, while it is increasingly being recognized that improved management of water is imperative to sustainable development, poverty alleviation and biodiversity preservation. To resolve these issues in humane ways, we have to take a hard and critical look at the way we have managed freshwater resources in the past, and find new solutions that will be sustainable in the long-term. Current approaches to water management are highly segregated, focusing on technical improvements and engineering solutions without sufficient attention to their basic social and sustainability goals. More technology is not always better. A reorientation of the technological approach may be more effective in delivering water services where they are needed, when they are needed, at a cost that is realistic and acceptable. Generally, holistic, environment-based and community-led developmental approach is especially useful in times when climate change, economic growth and rising aspirations are severely stressing the ecological, biological and hydrological systems.

'Community participation' has become a catchphrase. But there are black holes in the practice of community participation. A community is not a collection of equal people living in a particular geographic region. It is usually made up of individuals and groups who command different levels of power, wealth, influence and ability to express their needs, concerns and rights. Communities contain competing interest groups, such as, the rich and the poor, Farmers with fields and livestock to water, Landless farmhands with children to care for, Marginalized groups and members of minority religions, tribes or castes, Businessmen who own industries which require water, Housewives who need water for drinking and

washing, Women and men, above all Conservationists committed to protecting freshwater ecosystems, etc. Where water is a scarce and vulnerable commodity, there will be competition for supplies and those at the lowest end of the power spectrum will go without. That means the poor will always have less access and control over water resources. Blanket 'community participation' is therefore insufficient to mediate between the various needs of water users in any given situation. The power hierarchy within communities will ensure that water distribution follows its patterns. Disadvantaged groups will always lose out. Instead, strenuous efforts have to be made to ensure that community participation is based on democratic principles that increase social stability and create conditions whereby all stakeholders within communities are ensured fair rights, access to information and an adequate share in decision-making processes.

It is widely accepted that Jhunjhunu will run out of water by 2030 as there is hardly any surface water source in the district and ground water development is above 300 percent. Hence, focus on village-level demand-side management of water is the need of the hour. RJDSS is working in the Chirawa Block of the Jhunjhunu district for last 10 years addressing the water problem in the 80 villages by adopting Community Management of Water Resources Approach.

RJDSS in their attempt of Community Management of Groundwater in 35 villages of Chirawa Block of Jhunjhunu District of Rajasthan requires consideration of all the above listed social, environmental and other aspects with an extra effort to institutionalize community governance system to address the equity and sustainability aspects. However, information on most of these aspects were covered in the socio-economic, water resource management(including Water Balance Study) and technical studies (Geophysical study) conducted by Centre for Environment and Development Studies, Jaipur(CEDSJ) from time to time to support RJDSS intervention, still comprehensive understanding have to be developed for expected outputs and outcome.

RJDSS believes that unless people decide to help themselves, as a community and as individuals, no meaningful, sustainable and replicable impacts

can be realized. Therefore, RJDSS sees its role as motivating people and accompanying them in their efforts at realizing their own potential leading to improving the quality of their lives. In order to achieve this goal RJDSS focuses on building up the local institutional and organizational capabilities of the people through continuous capacity building activities.

Work in the field of water management takes into account this central tenet while focusing on demand side issues of planning, budgeting, allocation and improving efficiency of use. Supply side issues, such as improving the water table, surface storage and aquifer recharge, rain water harvesting across landscapes and drainage channels, are addressed by mapping of water resources, present utilization pattern, future needs, likely State/public interventions, present water laws and regulations, governance system, etc. In this effort the present study is limited to geophysical survey of 45 left out villages of Chirawa Block, providing village wise detailed information on ground water parameters.

1.1 Physical features of Jhunjhunu District

Jhunjhunu district is located in north eastern part of Rajasthan, covers a geographical area of 5911 sq km and bordering Haryana state in east and north east, district Sikar in south west and district Churu in north-west. It lies between latitudes N27°38′26.49″ & N28°31′05.15″ and longitudes E75°01′31.21″ & 76°05′47.99″. It includes eight blocks namely Chirawa, Surajgarh, Buhana, Khetri, Udaipurwati, Navalgarh, Jhunjhunu and Alsisar. The area is drained mainly by kantli River. South eastern part is drained by Singhana River and south western corner of district is drained by Budhi nala. Khetri area is drained by Kantli River. All the rivers and nalas are ephemeral in nature and flows in response to heavy rains during monsoon season. Chirawa block lies in almost central part of district Jhunjhunu, covers a geographical area of 522 sq km and bounded by Khetri block in south & south east, Udaipurwati in south west, Buhana and Surajgarh in east and north east, Churu district in north, Alsisar in north west and Jhunjhunu in West. Chirawa block is notified by Central Ground Water Authority in year 2005. The stage of ground water development in the block is 284.41 as on dated 31.03.2013. It lies between latitudes N28°00′22.04″ & N28°22′2.63″ and longitudes E75°22′07.42″ & 75°40′23.36″.

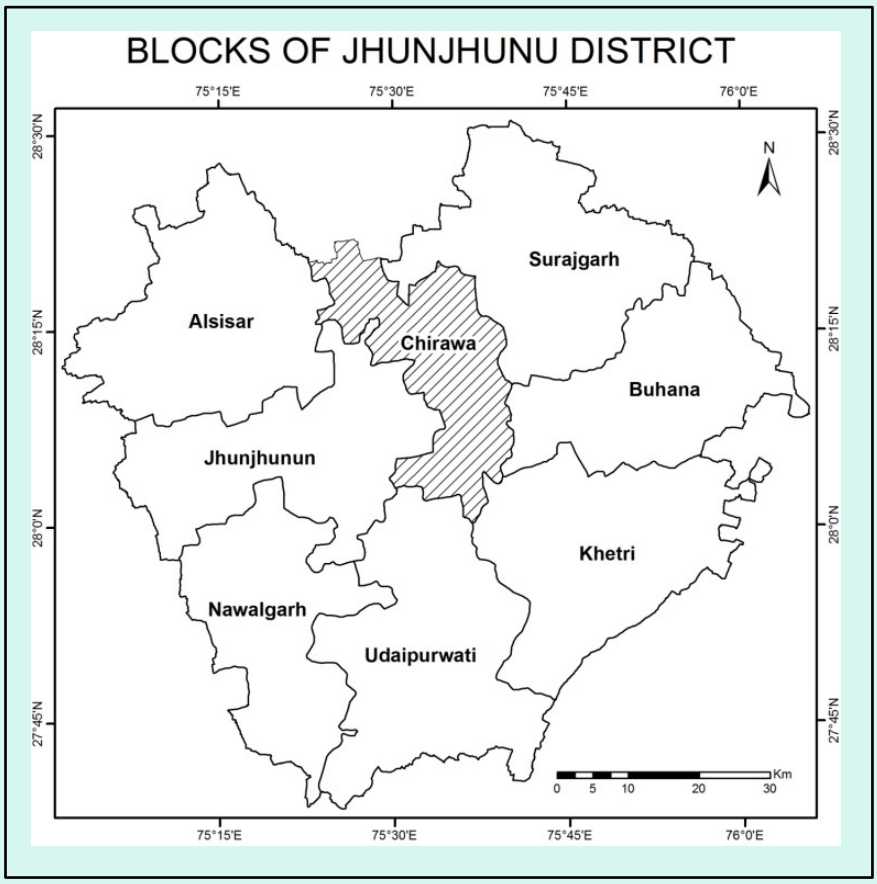

Figure 1: Blocks of Jhunjhunu District.

Less than normal rainfall and erratic distribution of rain leads to water shortages. Weather and climate changes over the world have resulted in recurring droughts. The ever increasing population pressure in our country, coupled with urbanization, has resulted in immense pressure on water resources. Surface water bodies have been continuously contaminated. The increasing dependency on ground water has resulted in immense pressure on ground water has resulted in the lowering of ground water table.

During last few years there has been growing awareness of crucial importance of water for development and development processes. All societies, past present and future depend upon sufficient clean freshwater for their survival and development. To study how the variability and character of freshwater resources create different constraints and opportunity for development is to study a field that lies at the heart of development studies for the region.

1.1.1 Location

Chirawa block is one of eight blocks of district Jhunjhunu and covers 522 sq. km of geographical area. It is bounded by khetri block in south & south east, Udaipurwati in south west, Buhana and Surajgarh in east and north east, Churu district in north, Alsisar in north-west and Jhunjhunu in West. Hills of Aravali series are founded in the south and south eastern part. The area is mainly drained by River Kantli, extended between latitudes N28°00′22.04″ & N28°22′2.63″ and longitudes E75°22′07.42″ & 75°40′23.36″.

1.1.2 Topography

Hills of Aravali range covers eastern and south eastern part of district Jhunjhunu, runs in north east to south west direction. Rest part of district is covered by undulating plains. The general topographic elevation of Chirawa block vary between minimum 283m above mean sea level and maximum 411m above mean sea level.

1.1.3 Climate and Rainfall

The climate of the area is classified as semi arid. It is very hot in summer and very cold in winter. In summer, the temperature goes up to 48°C in May- June months and drop down to 3°C in winter. The average rainfall in monsoon season (1901 – 2015) is 361.38mm and the average rainfall in non monsoon season (1901 – 2015) is 64.46mm.

1.1.4 Geology

Geology of the region has a dominant role in geomorphic evolution of any area and also plays an important role in controlling groundwater conditions with cumulative factors as lithology, structural geometry, mineral composition, soil texture etc. Therefore, study of geology (including physiographic or geomorphic assessment) of the region forms one of the essential aspects of groundwater investigation. The district is mainly covered by blown sand. Rocks of Delhi Super Group and Malani Igneous Suite are found in Khetri, Udaipurwati, Buhana and jhunjhunu blocks. Rocks of Alwar Group are exposed around Udaipurwati, mainly comprised of quartzite, schist, grit, arkose etc intruded by Post Delhi intrusive such as amphibolites, granite, pegmatite quartz veins etc. Rocks of Ajabgarh Group are exposed around khetri, mainly comprised of phyllites, biotite schist, calcareous gneisses etc intruded by Post Delhi intrusive.

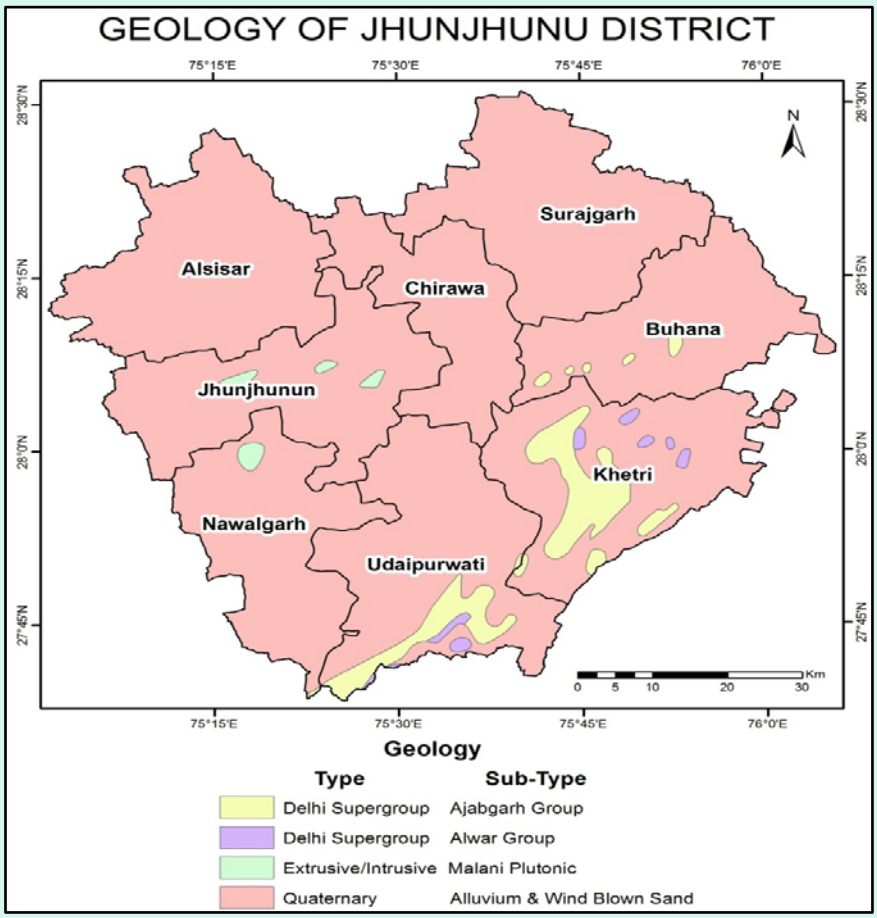

Figure 2: Geology of Jhunjhunu District.

Table 1: Geological formation, their lithology and chronological age.

Age	Formation	Lithology
Quaternary	Unconsolidated	Recent & old alluvial and Aeolian(clay, silt, sand, pebble, gravel), Calcareous older alluvium(clay, silt, sand, pebble, gravel), laterite, lithomargic clay, ferruginous concretions
Cainozoic, Mesozoic	Consolidated Effusive	Basalt with/ without intertrapeans
Cainozoic, Mesozoic, Upper Palaeozoic	Semi-Consolidated	Sandstone, Shale, Limestone & Conglomerates
Cainozoic, Proterozoic	Consolidated Intrusive	Granite, Ultramafics & Dolerite
Cainozoic, Proterozoic	Sedimentary and Meta Sedimentary	Shale, Quartzite, Slate, Sandstone, Phyllite, Schist

Age	Formation	Lithology
Proterozoic	Sedimentary and Meta Sedimentary	Limestone & Dolomite
Proterozoic,Azoic	Meta Sedimentary	Schist, Phyllite, Slate, Gneiss, Marble
Proterozoic,Azoic	Meta Sedimentary	Charnockite, khondalite
Azoic	Basal Crystalline	Granite- Gneiss- complex

1.1.5 Geomorphology and Soil Type

Geomorphology can be described in terms of several components, such as landforms, hills, their nature, characteristics and stability, which constitute some of the basic parameters essential for hydrogeological investigation. Geomorphic history of the area helps in proper evaluation of surfacial material and the configuration of the bedrock profile. Relevant geomorphic and hydrogeological parameters have been integrated to evaluate the groundwater regime and the changes during last few years. Hilly area of south eastern part of district Jhunjhunu is characterized by hills of Aravalli range, running in north easterly direction. The undulating area with small hills, lies in south western part of district. The major portion of hills is found in Khetri and Udaipurwati tehsils. Desertic plains occupy the northern part of district and covered with sand dunes. The general slope of the area is from south east to north-west. Desert soil and sand dunes cover most of the area. These are non calcareous soils, sandy to loamy sand, loose and structure less.

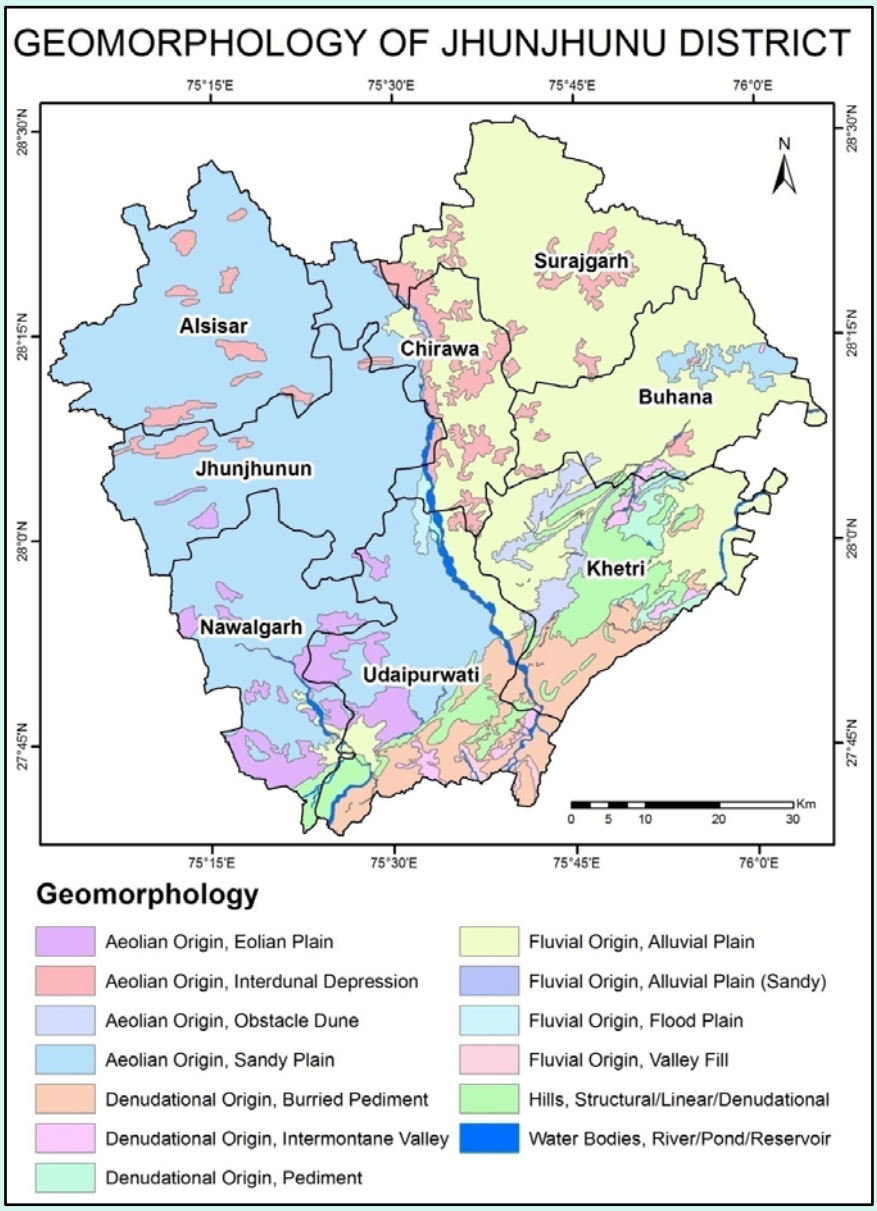

Figure 3: Geomorphology of Jhunjhunu District.

1.1.6 Physiography of the Study Area

The Physiography of Rajasthan is the result of complex erosional and deposition processes operative during the geological history, mainly during the Late Tertiary and Quaternary periods. viz. the western sandy plains, Aravali range and the hilly region, the eastern plains and the south-eastern Rajasthan Pathar. These divisions are based on the existing relief features and provide a basis for the study of geomorphic evolution of the terrain, which has been sculptured through a number of erosional cycles, represented by various peneplained surfaces. Lithology and

structure have essentially played a dominant role in carving out the present configuration of the landforms as is evident from their spectacular correlation.

The area consists of fairly open undulating plains, with hillocks in the southern and south eastern parts. A wide spectrum of geomorphic features is seen in the area due to dominant fluvial and aeoalian activities. Different geomorphological units of alluvial terrain comprise of Older and Younger alluvial plains, blown sand, abandoned channel courses etc. Kantli River is ephemeral in nature, mainly drain the area.

1.1.7 Hydrogeology

Ground water in the area generally occurs under water table in Quaternary alluvium and weathered/ fissures, fractures of hard rocks of Delhi Super Group. The alluvium is the main water bearing formation of the area. Topographic/ physiographic features and lithology significantly control the occurrence and movement of ground water.

Alluvium composed of sand, clay, kankar and gravel forms the main potential aquifer in the area. Thickness of alluvial sediments may vary from 60m to 110m. Ground water occurs under unconfined to semi confined conditions in the primary porosity ie pore spaces and interstitial openings of Quaternary alluvium while its occurrence and movement in quartzite, schist, phyllite, and gneisses of Delhi Super Group is mainly controlled by secondary porosity ie fissures and fractures planes. Five hydrogeological formations viz; Younger Alluvium, Older Alluvium, Phyllite & Schist, Quartzite and gneisses are the main water bearing formation (aquifer) in this region. Quaternary sediments as older alluvium and Aeolian, sand, gravel mixed with varying amount of clay and kankar covering most of the area. Phyllite, Schist, Quartzite and Gneisses of Delhi Super Group occupy as deep seated secondary porosity under unconfined to semi confined conditions.

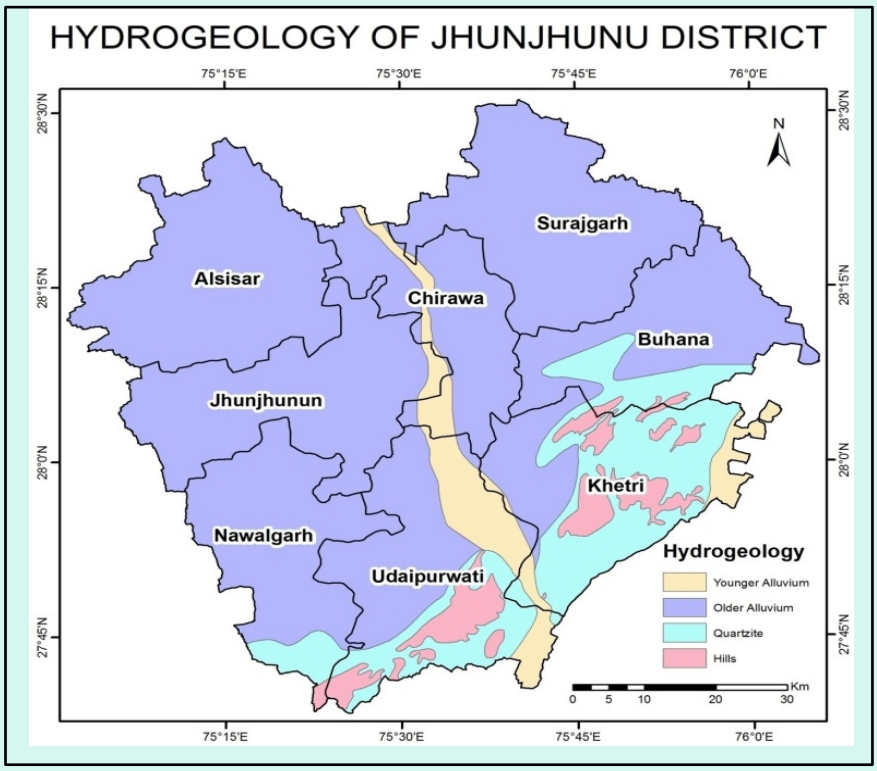

Figure 4: Hydrogeology of Jhunjhunu District

1.2 Methodology of the Study

Ramkrishan Jaidayal Dalmia Sewa Sansthan (RJDSS) is working on the water resource management aspects in Chirawa block, of Jhunjhunu district. The RJDSS is planning for water resource augmentation by recharging the aquifers through rainwater harvesting. Centre for Environment and Development Studies Jaipur (CEDSJ) is providing technical guidance and support to RJDSS for ground water augmentation and management using participatory approach of management.

Geophysical Electrical Resistivity survey has been conducted in 80 villages of block- Chirawa, District- Jhunjhunu to infer the extension of aquifers their thickness, permeable and impermeable layers, clay lenses, depth to rock and quality of ground water.

The whole area has been divided into four Clusters namely, Cluster-1, Cluster-2, Cluster-3 and Cluster-4. RJDSS has under taken 36 villages from all the four clusters of Chirawa block during Phase- I of the study to improve the water management and agriculture practices and to ensure drinking water security under

the project “A community Based Participatory Aquifer management System for Providing Equity and Sustainability in Water Resource Management” from Department of Science and Technology, Government of India.

In continuation to the earlier intervention RJDSS planned to extend the services in remaining 46 villages of Chirawa block. The selected 46 villages(List given below) from the different clusters of Chirawa block in Phase- II, the new study area, are shown in Figure 5.

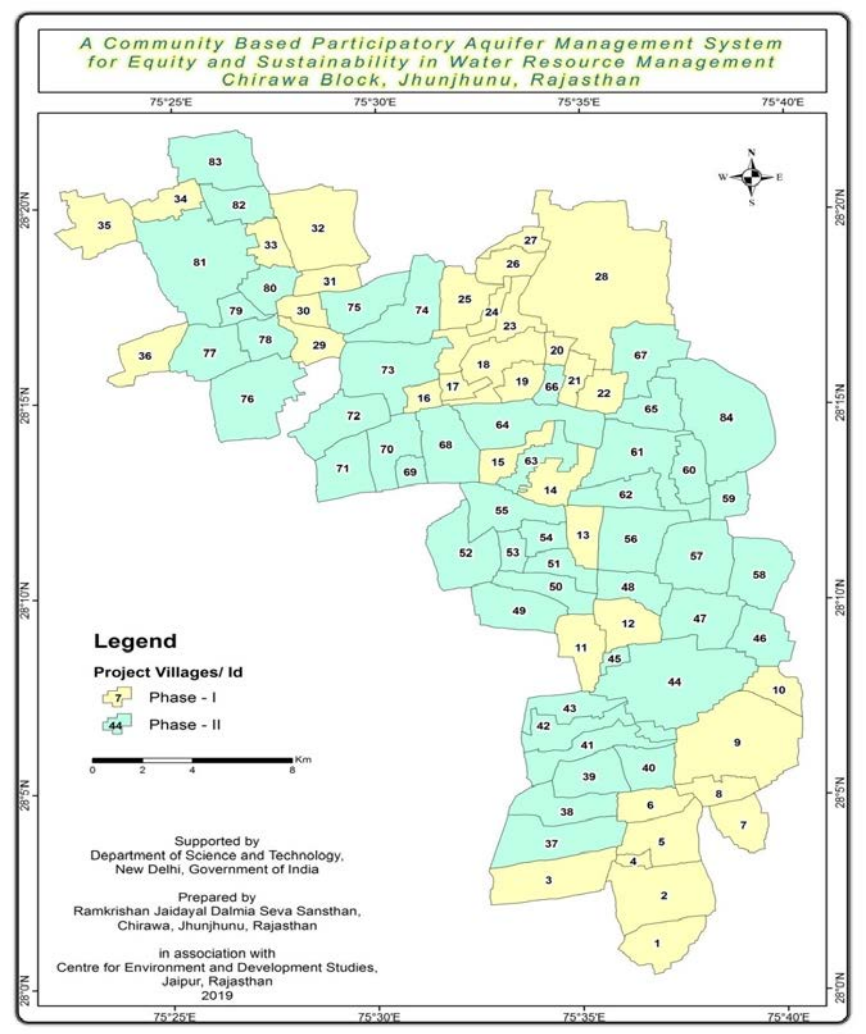

Figure 5: Phase I and II Survey Villages of Chirawa Block.

List of Phase I and II villages of Chirawa Block

Phase–I		
Id	Name	Area(Ha)
1	Nizampura	559.88
2	Chanana	1079.38
3	Gowla	890.44
4	Thakron Ki Dhani	82.35
5	Bhukana	662.13
6	Lodipura	377.91
7	Chirasan	432.69
8	Shri Amarpura	315.75
9	Kithana	1709.67
10	Joriya	320.92
11	Malupura	494.28
12	Sari	502.65
13	Brajlalpura	365.69
14	Gotra Nooniya	454.71
15	Gothri	332.08
16	Dhani Meghsagar	176.56
17	Haripura	175.22
18	Khuriya	646.89
19	Patel Nagar	279.82
20	Ismailpur	140.36
21	Shekhpura	230.09
22	Bhompura	324.88
23	Badangarh	550.83
24	Alampur	171.27
25	Kuthabpura	491.04
26	Gowli	334.66
27	Chainpura	185.64
28	Narhar	3259.00
29	Jakhra	341.14
30	Bhairugarh	245.22
31	Manpura	294.69
32	Bajawa	1152.40
33	Sainipura	294.50
34	Mahti Ki Dhani	333.08
35	Raghuveerpura	676.75
36	Dilawarpura	474.36
Phase – II		
37	Solana	892.12
38	Mehrampur	554.61
39	Kayamsar	517.93
40	Padampura	411.79
41	Kishorepura	545.90
42	Shyampura Matana	578.21
43	Keharpura Kalan	396.60
44	Sultana	1784.76
45	Kishanpura	89.89
46	Khudot	514.79
47	Jhanjhot	727.21
48	Bari	415.26
49	Keharpura Khurd	637.74
50	Bhamarwasi	415.56
51	Akhtarpura	314.07
52	Khudana	811.08
53	Vijaypura	195.07
54	Kanwarpura	251.40
55	Bhaktawarpura	631.22
56	Nari	809.66
57	Ardawata	907.56
58	Gidaniya	674.61
59	Khemu Ki Dhani	285.43
60	Nizampura (Shyopura)	383.87
61	Ojtu	1007.16
62	Dhatarwalon Ka Bas	451.52
63	Ajeetpura	373.96
64	Lamba Gothra	951.63
65	Shyopura	467.08
66	Prithvirajpura	163.70
67	Sultana Ka Bas	713.62
68	Alipur	717.75
69	Dheerawali Dhani	159.90
70	Narnod	528.06
71	Maligaon	566.49
72	Ghumansar Khurd	680.37
73	Budania	999.18
74	Dhatarwala	800.41
75	Jakhora	602.38
76	Lamba	1096.55
77	Nalwa	612.02
78	Govindpura	364.84
79	Bagpura	190.46
80	Bola Ki Dhani	369.91
81	Mandrela	1741.91
82	Nandrampura	421.76
83	Tigiyas	795.80
84	Chirawa	1638.96

1.2.1 Geophysical Techniques used for Sub- Surface Studies

Geophysical techniques are non–invasive and cost effective best approaches to provide subsurface hydrogeological information beneath the earth surface to delineate the aquifer system. Geophysics is the science applying principles of physics to investigate the subsurface lithological system. Efficacy of a geophysical technique lies in its ability to sense and resolve hidden subsurface conditions accurately.

Different surface geophysical techniques are available for aquifer determination depending on measuring the earth's physical properties. Electrical resistivity method is most commonly used method, because of its relatively simple response to the quantity and chemical quality of ground water, for aquifer delineation.

1.2.2 Electrical Resistivity Method

Electrical resistivity method is used in aquifer delineation for its efficacy in detecting water bearing zones, presence of interstitial water in the pores and its chemical quality. It can differentiate between unsaturated and saturated aquifer system and between fresh, brackish and saline formation water. It has ability to identify lithology, determine depth and thickness of a geoelectric layers which may form the aquifer system. The main purpose of electrical resistivity method in aquifer system is to identify ground water- yielding zones (whether granular or fractured), zone geometry and variations in the quality of ground water.

In resistivity method, a known amount of electric current is sent into the ground through a pair of electrodes and potentials developed due to current within the ground are measured across another pair of electrodes on the ground. To study the variation with depth, i.e. acquiring information deeper and deeper, the separation between the current electrodes is increased successively. The set of successive measurements (keeping the central point of electrode configuration fixed) with increasing current electrodes spacing in steps, is popularly known as Vertical Electrical Sounding (VES). Graphical plot of apparent resistivity with increasing current electrodes separation is field curve at the point of observation. Matching of

field curve with a theoretical curve for a known vertical distribution of the resistivity and thickness gives geoelectrical layer sequence at the point of measurement.

Figure 6: ABEM Terrameter instrument for Geophysical Electrical Resistivity Survey.

1.2.3 Objectives

- Delineation of lithological formations, their thickness and depth.
- Identification of saturated and unsaturated zones.
- Delineation of permeable and impermeable layers and clay lenses
- Depth to rock formation weathered/fractured rock.
- Variation in chemical quality of ground water with depth.

1.2.4 Investigation Methodology

The current and potential electrodes are placed in various configurations, but the most extensively used electrode configuration for subsurface investigation is the ***Schlumberger Configuration***. In this configuration the four electrodes are placed symmetrically along a straight line, the current electrodes are on the outside and the potential electrodes on the inside along the array. To change the depth range of the measurements, the current electrodes are displaced outward, when the ratio of the distance between the current electrodes to that between the potential electrodes becomes too large i.e. more than 5 times, the potential electrodes must also be

displaced outward, otherwise the potential difference becomes too small to be measured with sufficient accuracy.

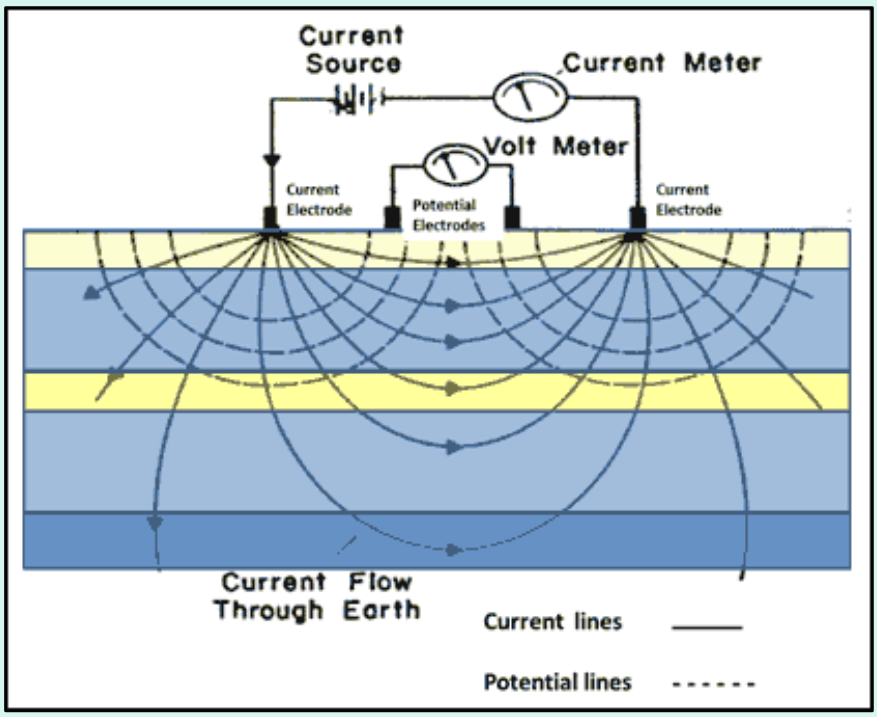

Figure 7: Schlumberger Electrode Configuration for Electrical Resistivity Survey

In the Schlumberger Configuration, the apparent resistivity (Pa) is calculated by the formula.

$$\rho_a = \frac{\pi}{2}\left(\frac{L^2 - l^2}{l}\right)\frac{\Delta V}{I}$$

$$= K\left(\frac{\Delta V}{I}\right)$$

Where ρ = Apparent resistivity

L = half of the distance between current electrodes

I = half of the distance between the potential electrode.

π = constant

ΔV = Potential difference

I = amount of current

K = constant, known as geometric factor and based on the type of electrodes configuration.

Geophysical measurement is based on the assumption that the subsurface consist of a sequence of distinct layers of finite thickness, each of these layers is assumed to be electrically homogenous and isotropic and the boundary planes between subsequent layers are assumed to be horizontal.

For ascertaining subsurface occurrence of ground water, the resistivity response depends primarily on the amount of impregnating water, the conductivity and quality of water and manner in which water is distributed. The first two factors have a nearly linear relation with the resistivity while the influence of the third factor is more complicated and depends on the nature of aquifer material.

Resistivity method of ground water is based on resistivity contrast rather than on absolute values. Summarizing, it can be stated dry formation, whether porous or non porous are practically poor conductors and hence the resistivity will vary with amount of pore water and quality of water.

1.3 Ground water and hydrologic Cycle

Hydrologic cycle is the fundamental principle of ground water hydrology. Water evaporates and moves upward to form cloud and after condensation falls down to the earth as precipitation. It evaporates again by radiant energy of sun. This process repeated in a never ending cycle. This is known as hydrologic cycle, which never stops. Precipitation creates runoff and travels over the ground surface fills the lakes, rivers and percolates downward through pores and openings in the soil and fissures/ fractures in rocks to replenish aquifers under the ground. Some places receive more precipitation and others less. Water keeps changing from solid to liquid to gas repeatedly. As clouds move over mountains, water vapor condenses to form precipitation and freezes to form snow on the peaks of mountains.

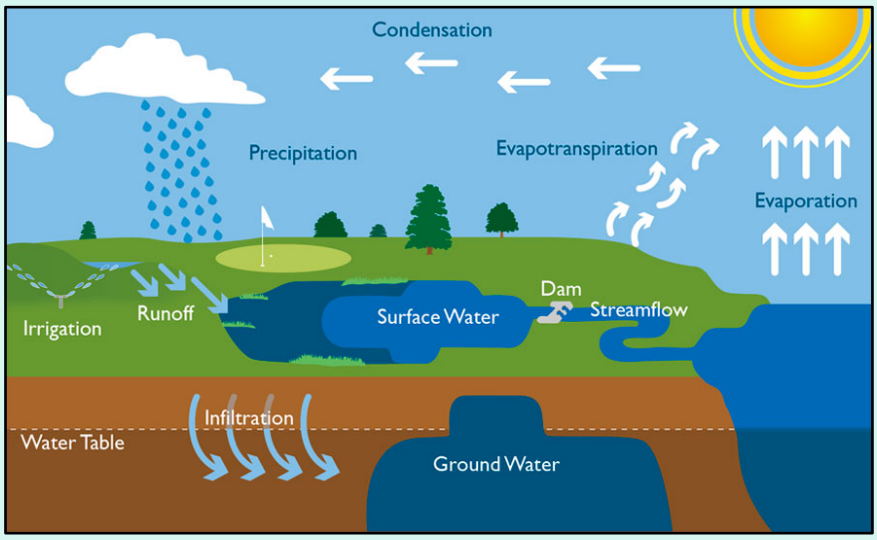

Figure 8: Schematic representation of hydrologic cycle

1.4 Artificial Recharge to Ground Water

The reasons for decline in water table in major parts of the area can be attributed to ever increasing exploitation of ground water to meet the growing demand for agriculture, drinking, domestic and industrial purposes. Increasing urbanization and industrialization have caused not only surface water pollution but have also caused ground water pollution in the area resulting in adverse effect on the health, environment and imbalance in the eco-system.

The artificial recharge to ground water aims at augmentation of ground water reservoir by modifying the natural movement of surface water, utilizing suitable civil construction techniques.

1.5 Advantages of Artificial Recharge

Artificial recharge techniques normally address the following issues:

- Enhancement of the sustainable yield in areas where over-development has depleted the aquifer, conservation and storage of excess surface water for future requirements as these requirements often change within a season or a period.
- Improvement in the quality of existing ground water through dilution.
- Avoiding water impoundment and flooding on roads during storm showers.

- The basic purpose of artificial recharge of groundwater is to restore supplies from aquifers depleted due to excessive ground water development.
- It helps in reducing the soil erosion and flood hazard.
- It is a simple, economical and eco-friendly method of water resource augmentation.

1.6 Implementation of Artificial Recharge Schemes

Following components are essentially involved for successful implementation of artificial recharge schemes:

- Assessment of resource water.
- Planning of recharge structures.
- Finalization of specific techniques and designs.
- Monitoring and impact assessment.
- Financial and economic evaluation.
- Operation and maintenance.

The following design may be used for artificial recharge of surface water to ground water in project area of Chirawa block, district- Jhunjhunu.

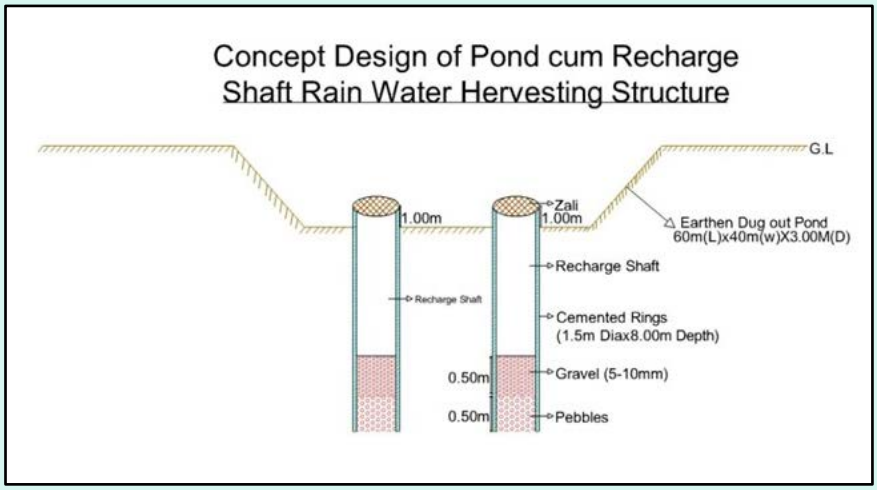

Figure 9: Concept design of Pond cum Recharge Shaft rain Water harvesting Structure

CHAPTER II

GEOPHYSICAL ELECTRICAL RESISTIVITY SURVEY, INTERPRETED RESULT & LITHOLOGICAL INFERENCES

2.0 Geophysical Electrical Resistivity Survey

To delineate the subsurface geology, depth and thickness of geoelectric layers and quality of ground water, Geophysical Electrical Resistivity Survey was conducted at 121 VES locations, in the study area, i.e., villages of Chirawa Block, Jhunjhunu District. The survey work was conducted in different phases during the month of October and November using ABEM Terra meter instrument and VES data were collected on grid pattern. The whole surveyed area was categorized in four clusters namely, Cluster - 1, Cluster - 2, Cluster - 3 and Cluster - 4. Vertical electrical soundings were conducted at 121 locations. The field data were collected and interpreted and the following inferences are drawn on the basis of resistivity values of different layers and the nature of curves obtained from field data and its interpretation. Latitude, longitude and elevation of each location were recorded using GPS (Geographical Positioning system). The vertical distance is measured in meter amsl (above mean sea level) and lateral distance is measured in meter. In the surveyed area, 13 types of lithological formations were identified. Those are shown in the following legend.

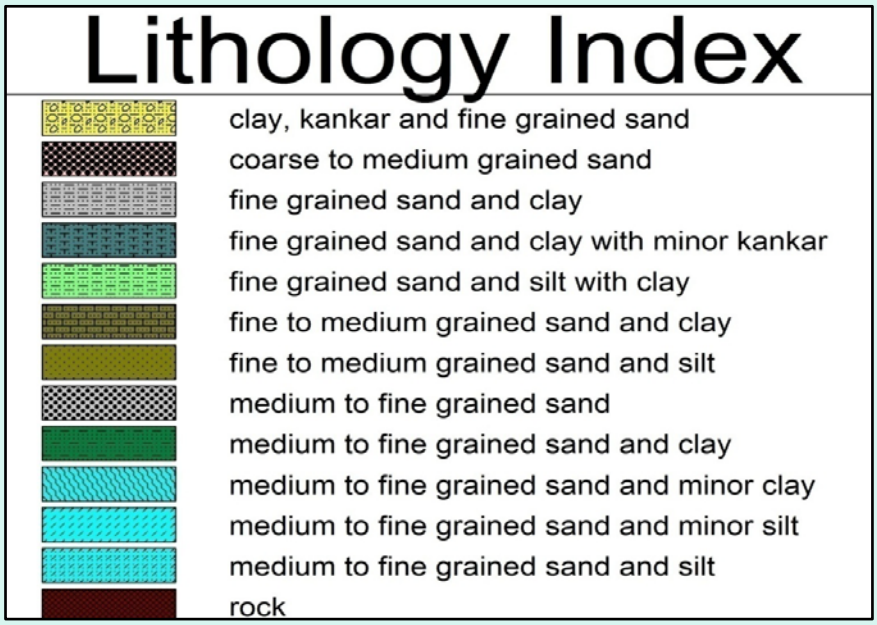

Figure 10: Lithological index.

2.1 Cluster - 1

Phase II of Cluster-1 includes villages Solana, Meharampura, Kyamsar, Padampura, Kishorepura, Shyampura Matana, Keharpura Kalan, Kishanpura and Sultana. Vertical Electrical Sounding (VES) was conducted in the villages of Cluster- 1 at 24 locations (VES111 – VES134). Rest of 8 villages of cluster- 1 (Gowla, Chanana, Nizampura, Shri Amarpura, Bhukana, Chirasan, Lodhipura, Kithana and Jodiya) were covered during phase I of study, in the year 2016 - 17. VES locations of Cluster- 1 are shown in following map.

2.1.1 Interpreted Results

Phase II of Cluster-1 includes villages Solana, Meharampura, Kyamsar, Padampura, Kishorepura, Shyampura Matana, Keharpura Kalan, Kishanpura and Sultana. Vertical electrical soundings were conducted at 24 locations. The field data were collected and interpreted by using a computer software programme. As per the interpretation of field data, the resistivity of different layers and their corresponding thickness of the formations are summarized in the following tables:

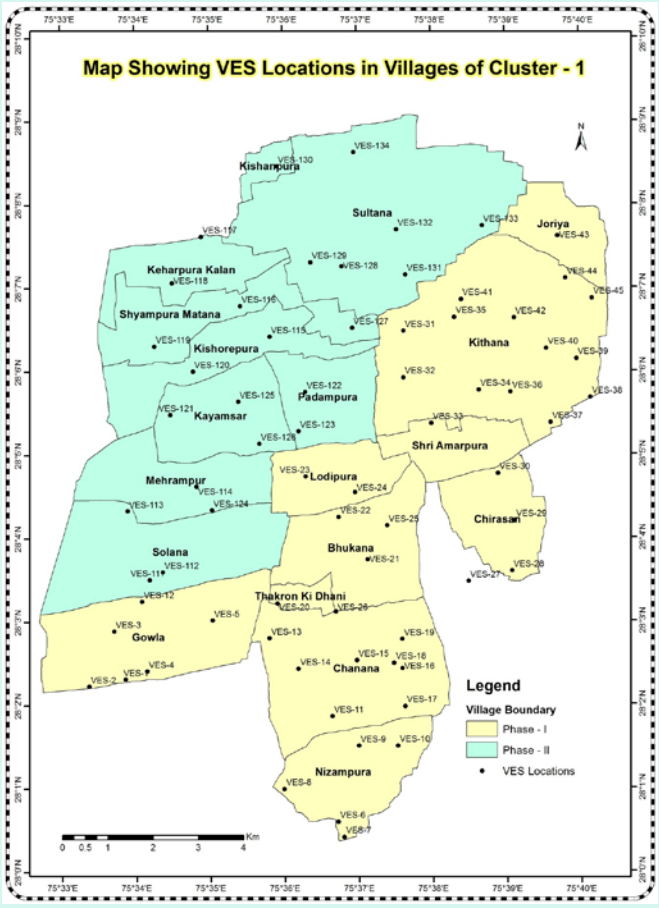

Figure 11: VES locations in villages of Cluster (1).

Table 2: Interpreted Result of VES data in Villages of Cluster-1

S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm- meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
1	111	Solana	South west of village Solana, towards river and HT	N28° 03′ 30.15″ E75° 34′ 11.35″	340	221	134	56.8	298		1.62	6.81	23.1	66.2		97.73
2	112	Solana	In the field of shri Ram Niwas s/o shri Jairam	N28° 03′ 35.82″ E75° 34′ 22.13″	160	96.9	49.8	24.8	28.9	224	1.77	4.17	12.1	41.9	32.6	92.54
3	113	Solana	Solana	N28° 04′ 19.72″ E75° 33′ 53.62″	217	187	49.8	24.8	33	335	1.64	4.31	18.4	26.9	44.9	96.15
4	114	Meharampura	In front of govt school near Jode	N28° 04′ 37.39″ E75° 34′ 49.65″	52.1	31.8	75.7	38.2	28.9	282	1.25	3.44	14.1	51.5	30.7	100.99
5	115	Kishorepura	Near play ground	N28° 06′ 24.98″ E75° 35′ 49.18″	95.9	65	33.2	36.6	24.3	155	1.5	8.09	39.1	29	19.7	97.39
6	116	Shyampura Matana	In the field of shri Mahavir Singh s/o shri Govind Singh	N28° 06′ 47.02″ E75° 35′ 25.51″	78.9	28.3	60.1	12.4	19.5	95.9	1.35	8.29	22.5	42	20.3	94.44
7	117	Keharpura Kalan	Near Jode and school	N28° 07′ 37.09″ E75° 34′ 54.03″	54.3	35.5	117	29.8	342		1.23	3.93	24.5	68.2		97.86
8	118	Keharpura kalan	On Kachcha rasta towards Matana, near water tank	N28° 07′ 03.73″ E75° 34′ 30.22″	158	136.4	94.72	36.78	215.4		1.78	4.22	28.05	62.2		96.21

S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm- meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
9	119	Shyampura Matana	Matana Shyampura near HT	N28° 06′ 18.19″ E75° 34′ 15.80″	266	159	33.8	81.1	140		1.77	3.9	24.4	63.2		93.27
10	120	Kishorepura	Kishorepura	N28° 06′ 00.04″ E75° 34′ 46.95″	69.58	52.38	36.25	26.87	98.44		2.37	3.21	24.49	60.9		90.98
11	121	Kyamsar	In the field of shri Anil Omprakash	N28° 05′ 29.03″ E75° 34′ 28.34″	152	93.3	73.9	19.5	24	195	1.26	5.9	12.5	56	20.6	96.26
12	122	Padampura	Padampura	N28° 05′ 45.02″ E75° 36′ 17.93″	87	125	43.6	23.6	167		1.67	10	10.5	71		93.17
13	123	Padampura	Padampura, near Galgati Jode	N28° 05′ 16.91″ E75° 36′ 12.37″	98.5	137	80.5	27.8	104		1.51	3.35	29.4	64.2		98.46
14	124	Meharampura	Towards Solana Boundary	N28° 04′ 20.24″ E75° 35′ 01.87″	74.5	143	73.3	43.6	143		1.46	2.7	29.1	63.7		96.96
15	125	Kyamsar	Kyamsar	N28° 05′ 38.28″ E75° 35′ 23.59″	162	71.1	138	38.8	140		1.99	7.7	6.86	81.2		97.75
16	126	Kyamsar	Kyamsar	N28° 05′ 08.01″ E75° 35′ 40.64″	102	144	28.7	34.8	121		1.67	7.51	41.8	46		96.98
17	127	Shyampura Matana	Chak Keharpura,In Jode area	N28° 06′ 31.08″ E75° 36′ 56.02″	97.4	85	38.2	42.4	151		2.08	1.91	16.1	77.3		97.39
18	128	Sultana	Sultana	N28° 07′ 15.41″ E75° 36′ 47.68″	132	343	63.3	25.2	214		1.95	3.39	18.7	76		100.04

S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm- meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
19	129	Sultana	On Kishorepura road	N28° 07′ 18.48″ E75° 36′ 22.42″	83.6	69.6	32.3	18	21.7	187	2.51	1.74	28.1	23.5	35.7	91.55
20	130	Kishanpura	Maliyo ki Dhani	N28° 08′ 27.44″ E75° 35′ 55.41″	86.3	60.1	99	68.9	23.4	215	1.2	2.56	6.19	28.7	58.8	97.45
21	131	Sultana	In the field of shri Bhawar Singh s/o shri Indra Singh Shekhawat	N28° 07′ 09.37″ E75° 37′ 39.31″	41.1	55.8	20.2	101	21.5	209	1.43	2.43	5.19	20.2	67.2	96.45
22	132	Sultana	On Jodiya road	N28° 07′ 41.92″ E75° 37′ 31.96″	145	92.5	187	33.3	137		1.43	2.43	10.5	83.3		97.66
23	133	Sultana	In Jodiya road	N28° 07′ 44.60″ E75° 38′ 41.53″	95.9	76.1	103	22.8	242		1.43	3.86	23.2	69.5		97.99
24	134	Sultana	On Sari road near HT	N28° 08′ 37.47″ E75° 36′ 57.71″	84.5	115	48.2	22.9	26	264	1.65	6.37	28.8	38.9	19.2	94.92

2.1.2 Inferences of Geophysical Electrical Resistivity Survey, Cluster - 1

Phase II of Cluster - 1 includes villages Solana, Meharampura, Kyamsar, Padampura, Kishorepura, Shyampura Matana, Keharpura Kalan, Kishanpura and Sultana. Vertical electrical soundings were conducted at 24 locations (VES111 – VES134). The field data were collected and interpreted and the following inferences are drawn on the basis of resistivity values of different layers and the nature of curves obtained from field data and its interpretation. In the surveyed area, different lithological formations are identified. Point wise details of lithological formations corresponding to different layers are described as below:

VES point wise details of lithological formations corresponding to different layers:

VES (111):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand
h_3	The formation consist of medium to fine grained sand and minor clay
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (112):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of medium to fine grained sand and minor clay
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (113):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand
h_3	The formation consist of medium to fine grained sand and minor silt
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (114):

Layers	Lithological Formation
h_1	The formation consist of fine to medium grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation consist of medium to fine grained sand with minor clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (115):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of medium to fine grained sand with minor clay
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation consist of fine to medium grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (116):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine grained sand and clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

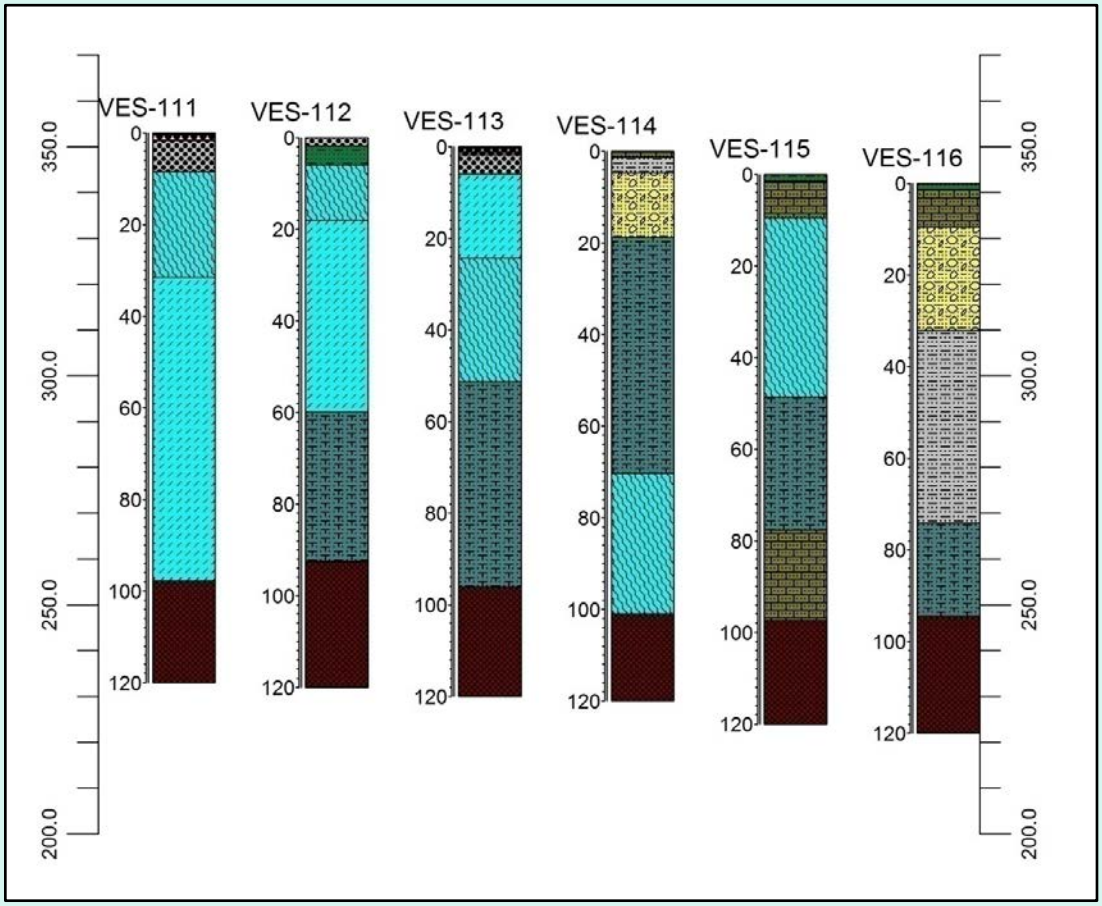

Figure 12: Lithological formation from VES(111) to VES(116).

VES (117):

Layers	Lithological Formation
h_1	The formation consist of fine to medium grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand with minor clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (118):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine grained sand and clay with minor kankar
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (119):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand
h_3	The formation consist of medium to fine grained sand and minor silt
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (120):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of fine grained sand and clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (121):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (122):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of medium to fine grained sand and minor clay
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

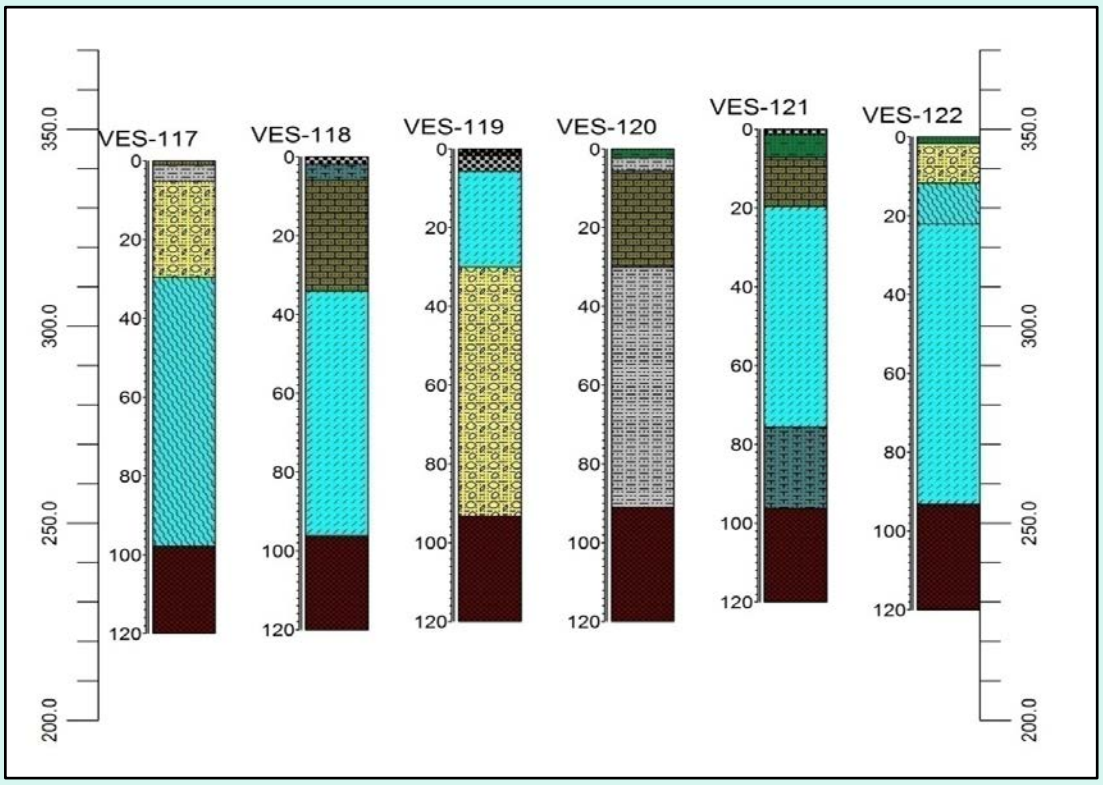

Figure 13: lithological formation from VES (117) to VES (122).

VES (123):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of fine to medium grained sand and silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (124):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of fine to medium grained sand and silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (125):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine to medium grained sand and silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (126):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of medium to fine grained sand and minor silt
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (127):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of medium to fine grained sand and silt
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (128):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of medium to fine grained sand and silt
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

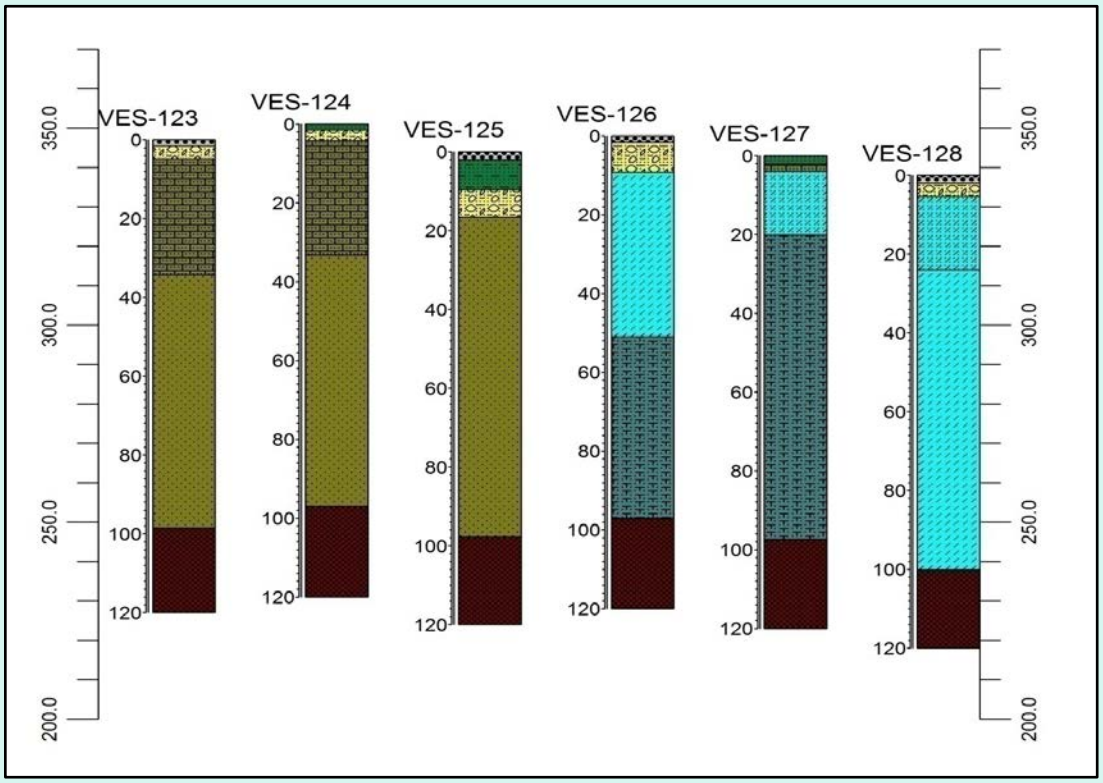

Figure 14: Shows lithological formation from VES(123) to VES(128)

VES (129):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of medium to fine grained sand and silt
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (130):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine grained sand and silt with clay
h_5	The formation consist of medium to fine grained sand and minor silt
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (131):

Layers	Lithological Formation
h_1	The formation consist of fine grained sand and clay
h_2	The formation consist of fine grained sand and clay with minor kankar
h_3	The formation consist of fine grained sand and silt with clay
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of fine to medium grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (132):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (133):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (134):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of medium to fine grained sand and minor clay
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

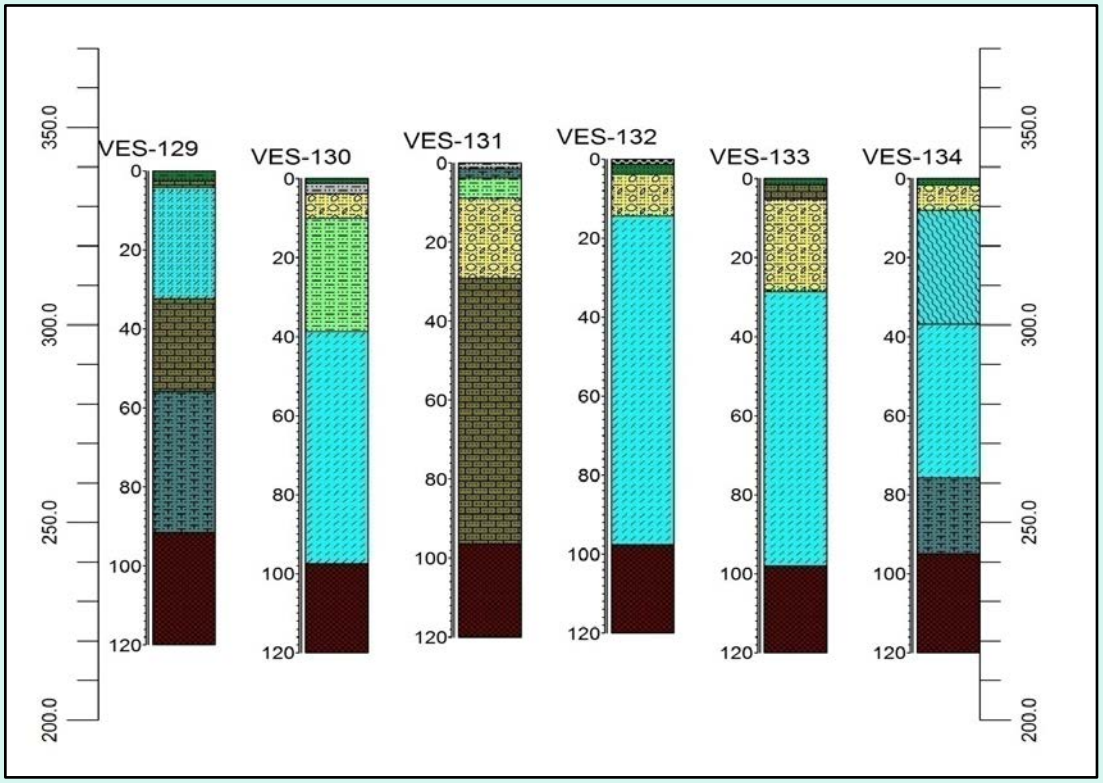

Figure 15: Shows lithological formation from VES(129) to VES(134).

2.1.3 Representation of Lithological Formations along Cross Sections

To represent subsurface lithological formations or different layers, depth to bedrock, permeable and impermeable layers, saturated and unsaturated zones & their thickness, 10 cross sections (AA′, BB′, CC′, DD′, EE′, FF′, GG′, HH′, II′ and JJ′) have been selected. Each cross section passes through different VES locations. A blue line in section profile represent water table along the section. The portion of

aquifer thickness lies below water table is known as saturated aquifer thickness. The saturated aquifer thickness for every section is shown in another figure. The following map shows the different cross sections.

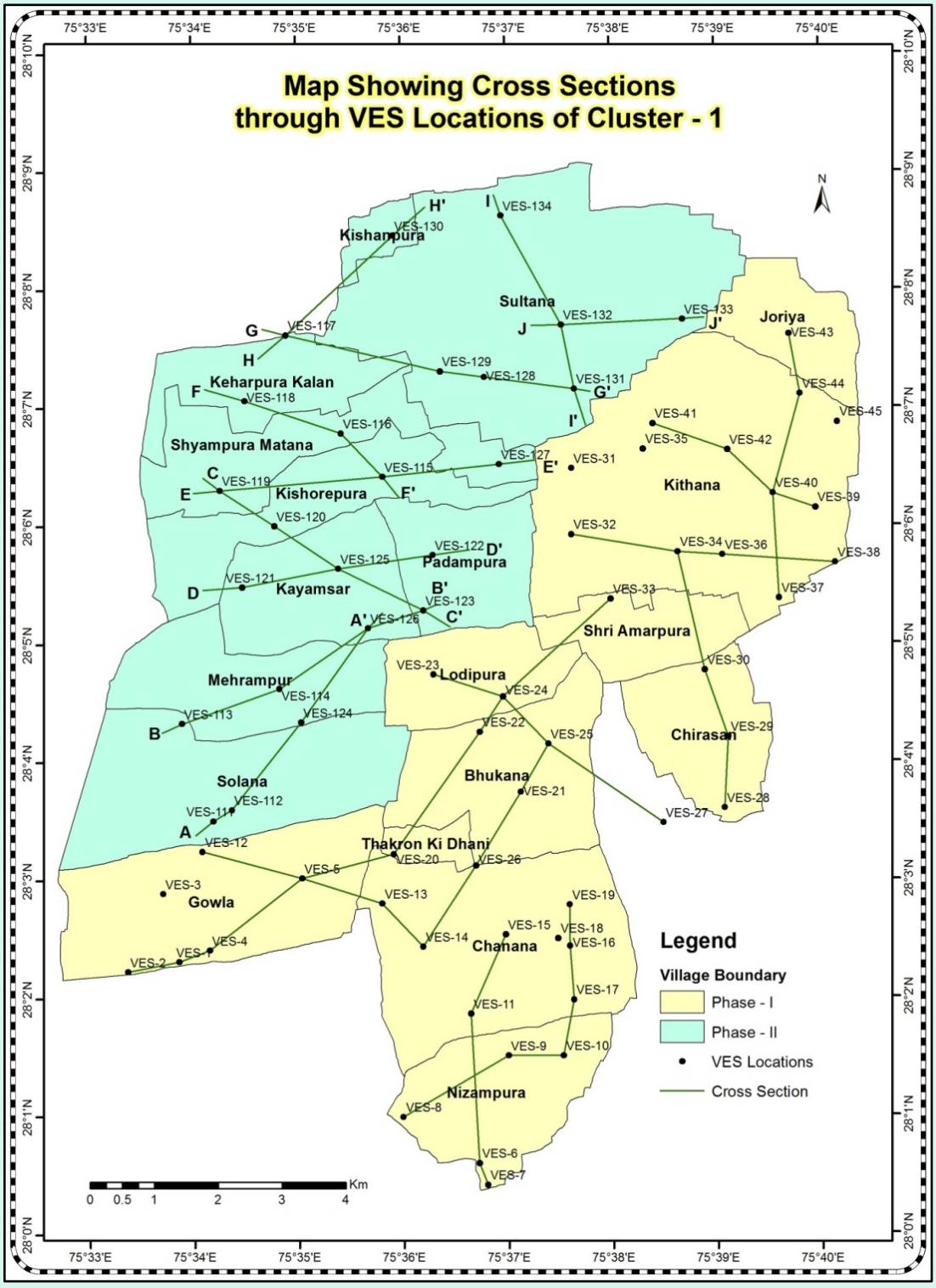

Figure 16: Different cross sections through VES locations of Cluster – 1.

The following figures show different cross sections and saturated aquifer thickness:

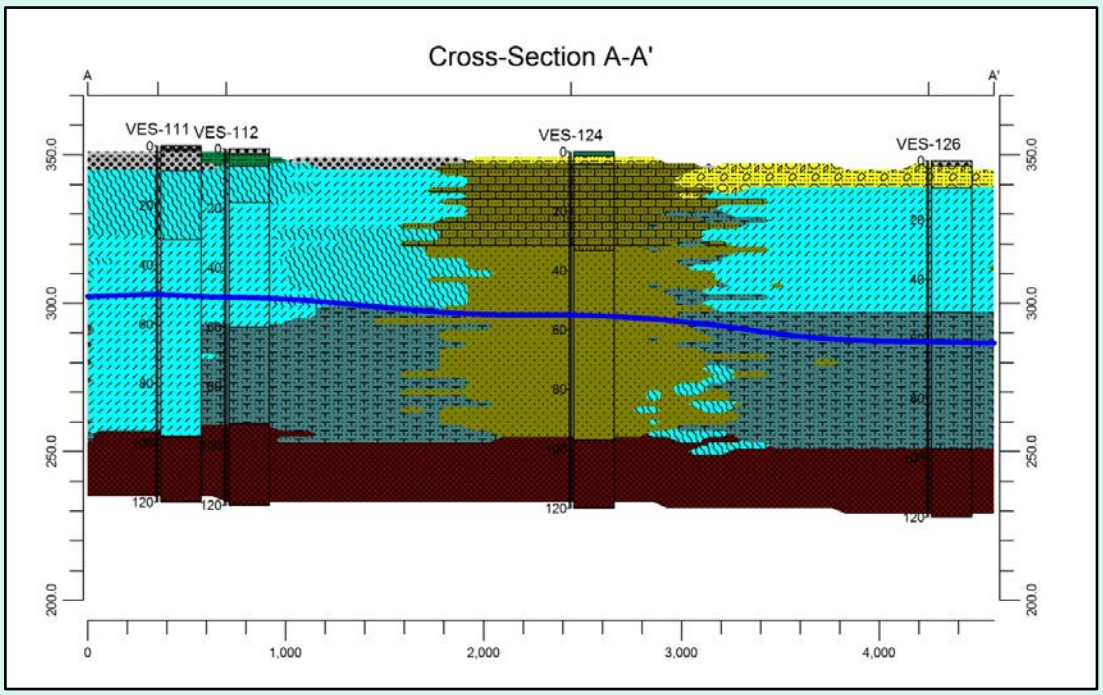

Figure 17: Cross Section A-A′ passes through VES (111), VES(112), VES (124) and VES (126).

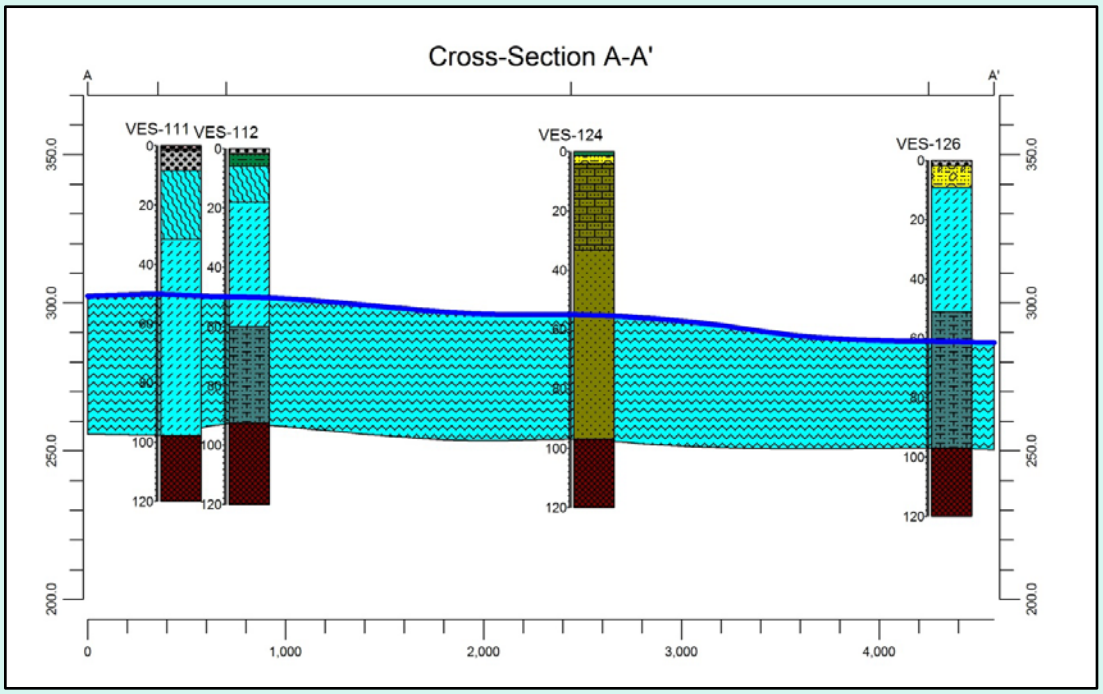

Figure 18: Saturated aquifer thickness along cross section A-A′.

Cross Section B-B′:

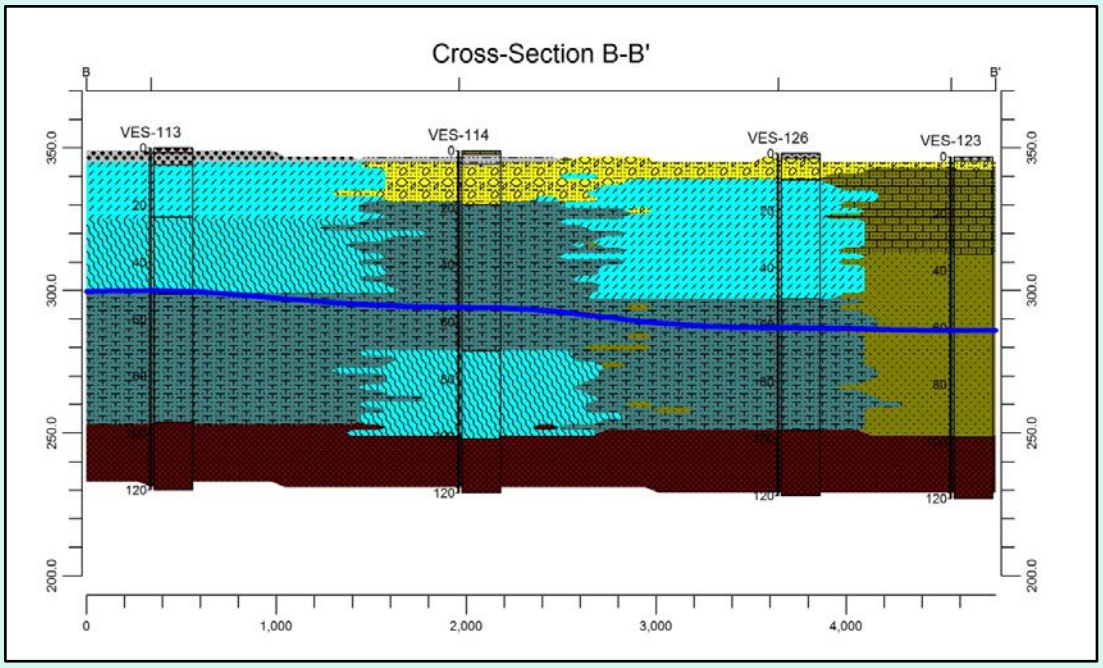

Figure 19: Cross Section B-B′ passes through VES (113), VES (114), VES (126) and VES (123).

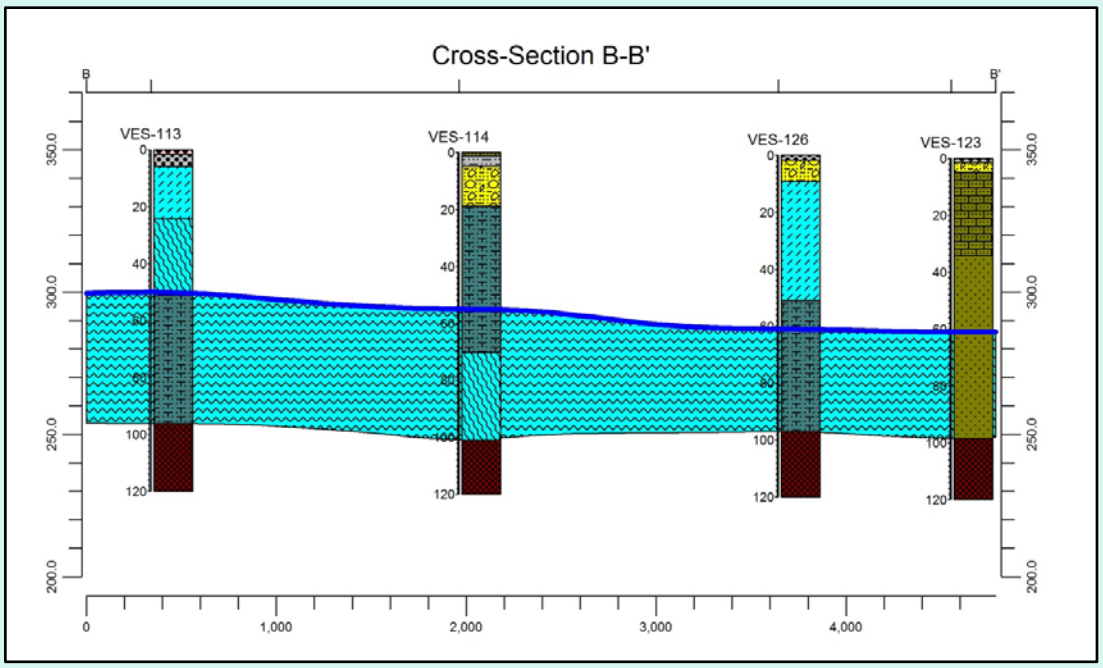

Figure 20: Saturated aquifer thickness along cross section B-B′.

Cross Section C-C′:

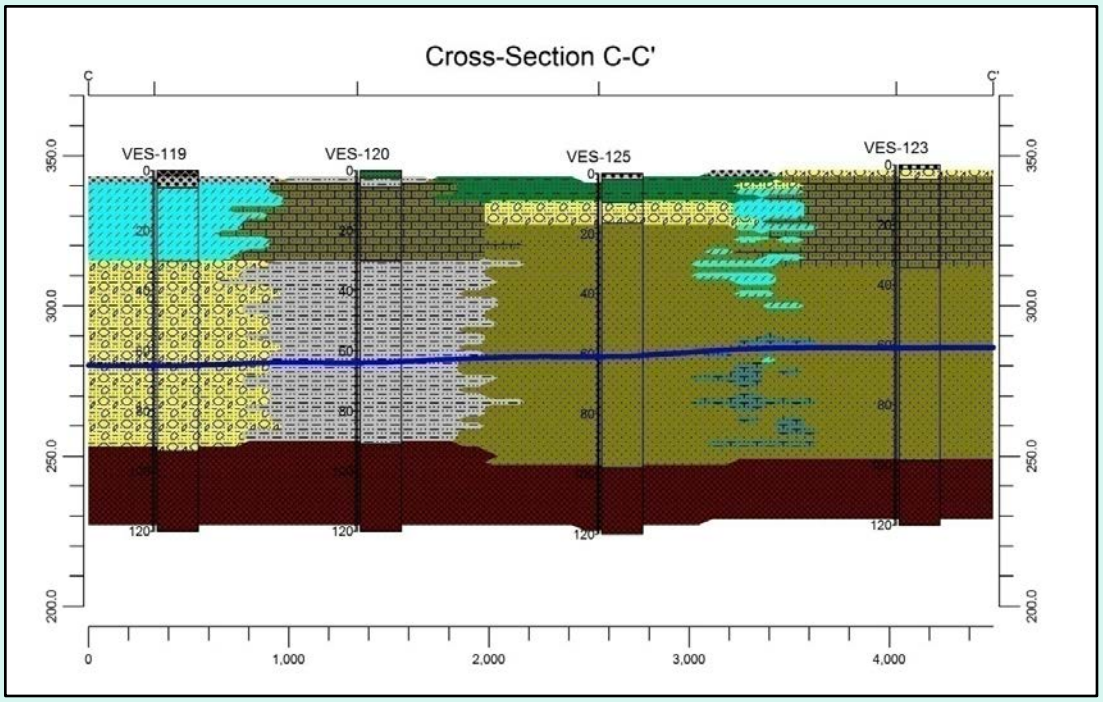

Figure 21: Cross Section C-C′ passes through VES (119), VES (120), VES (125) and VES (123).

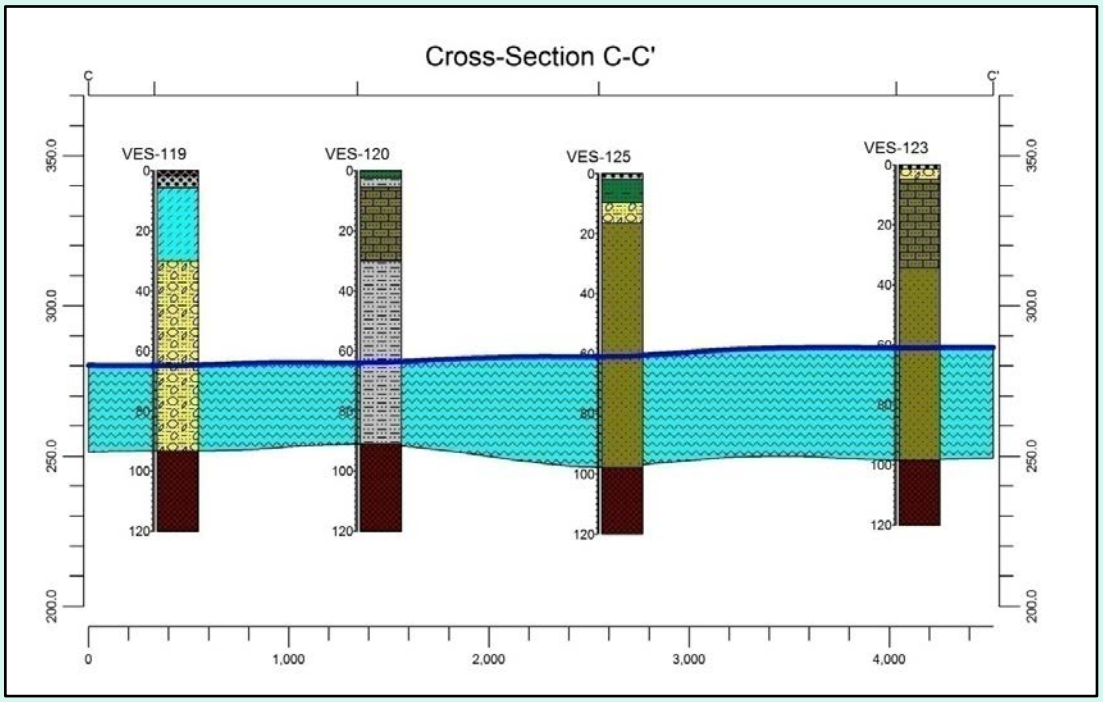

Figure 22: Saturated aquifer thickness along cross section C-C′.

Cross Section D-D′ :

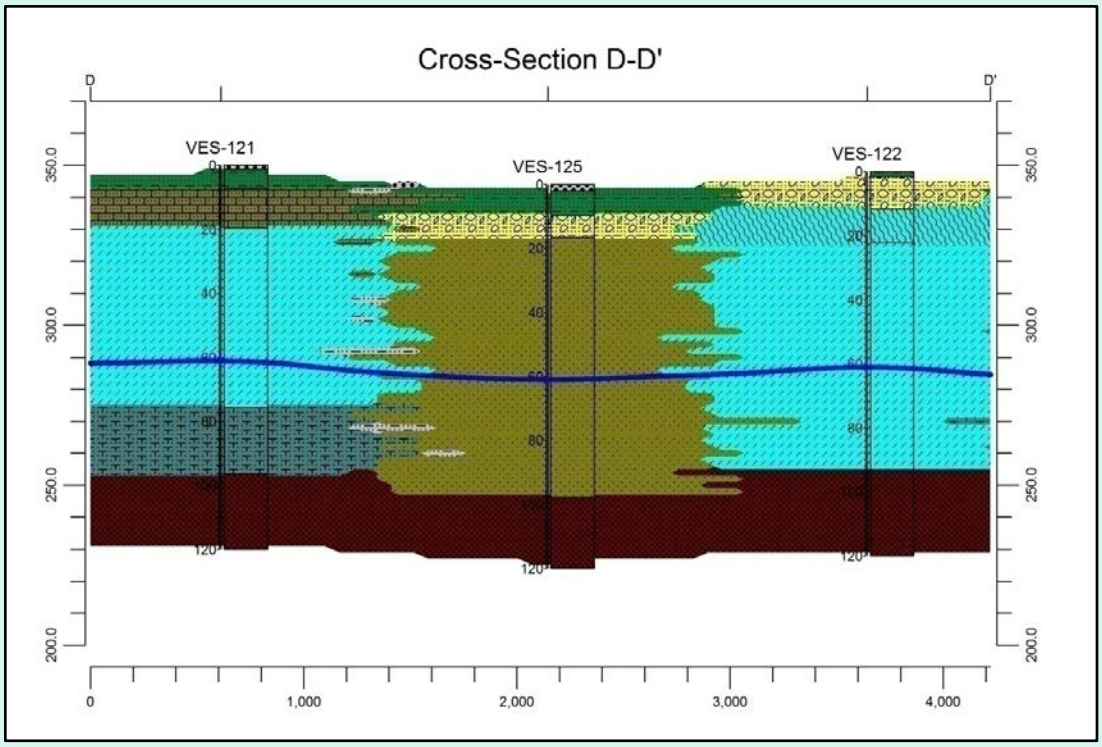

Figure 23: Cross Section D-D′ passes through VES (121), VES (125) and VES (122).

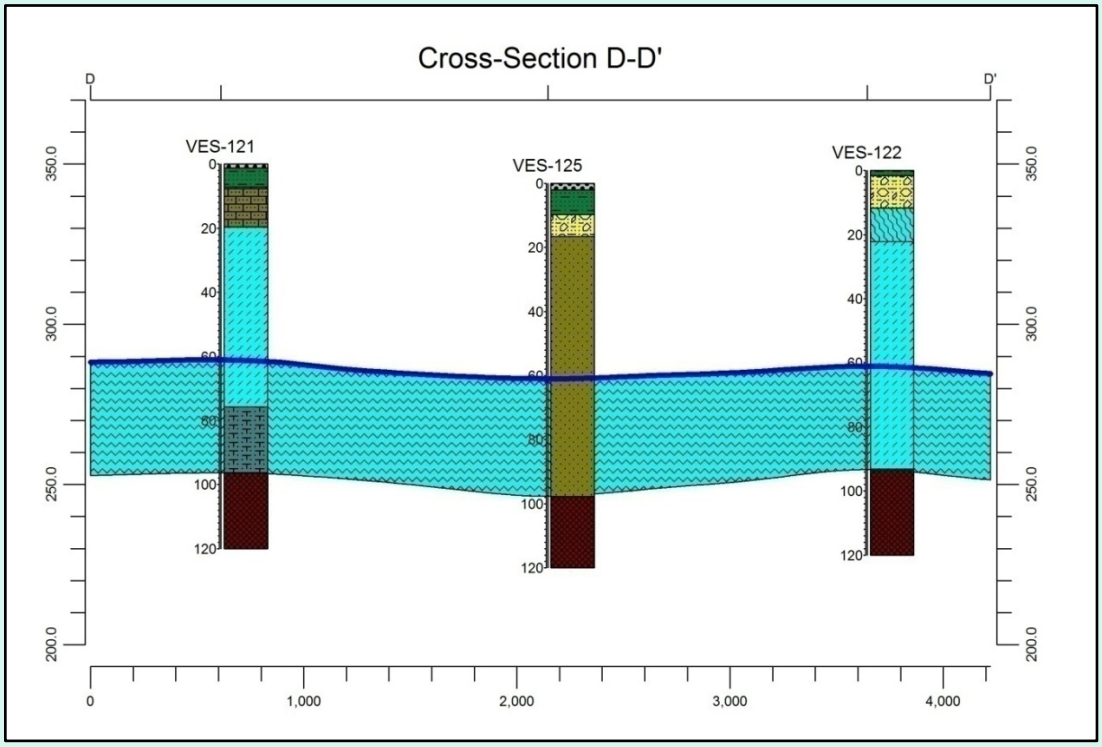

Figure 24: Saturated aquifer thickness along cross section D-D′.

Cross Section E-E′:

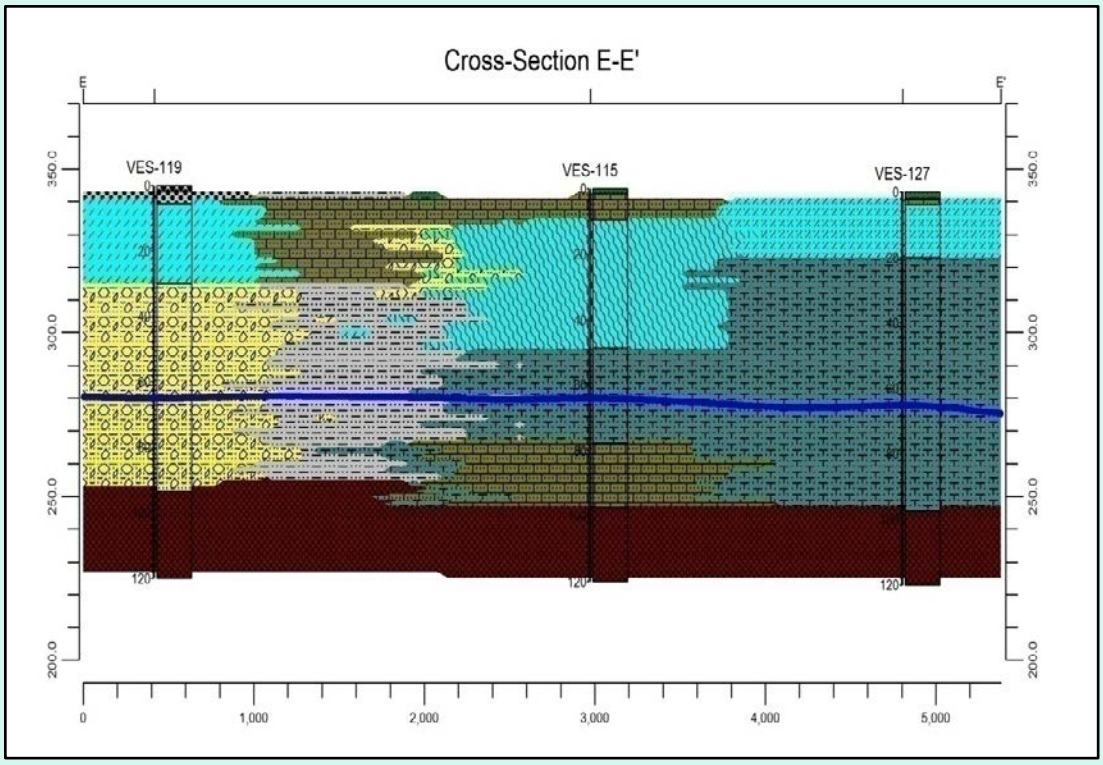

Figure 25: Cross Section E-E′ passes through VES (119), VES (115) and VES (127).

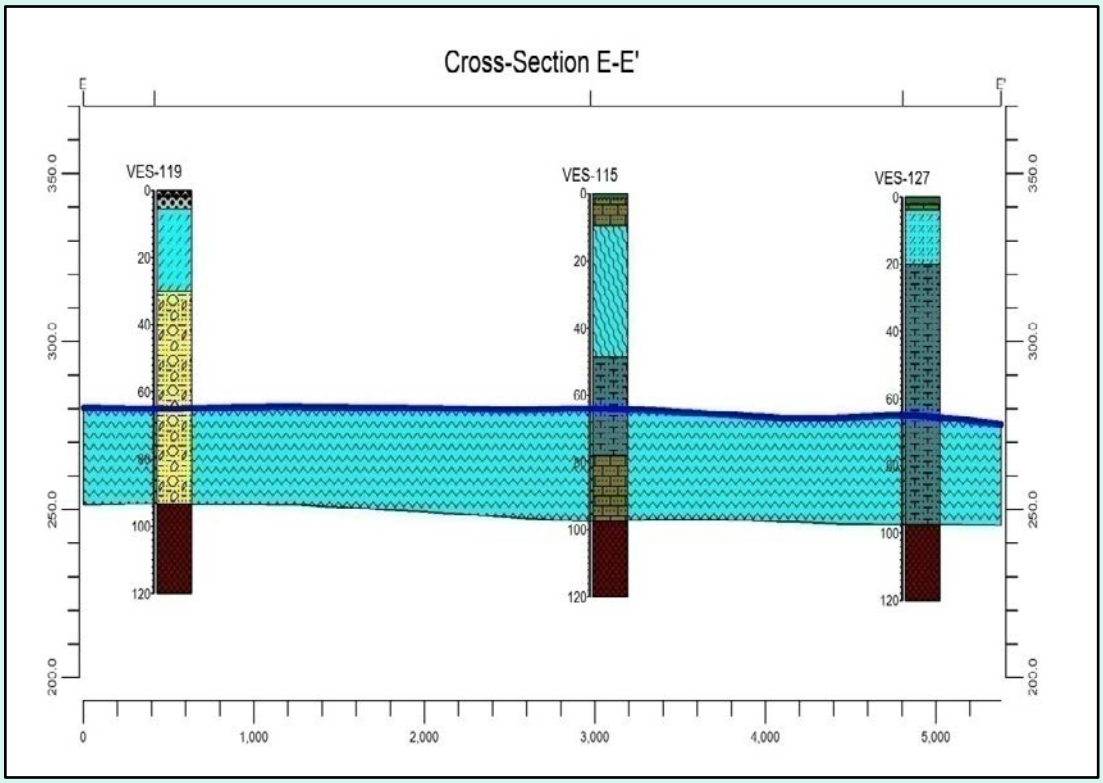

Figure 26: Saturated aquifer thickness along cross section E-E′.

Cross Section F-F′:

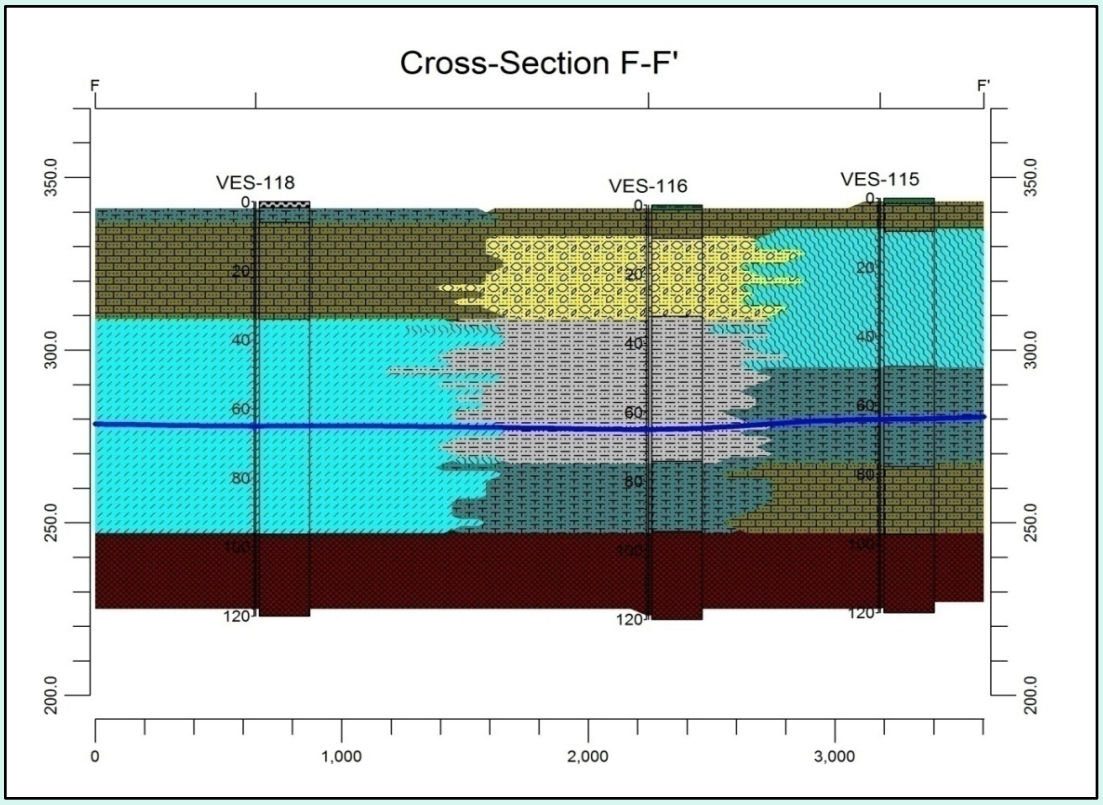

Figure 27: Cross Section F-F′ passes through VES (118), VES (116) and VES (115).

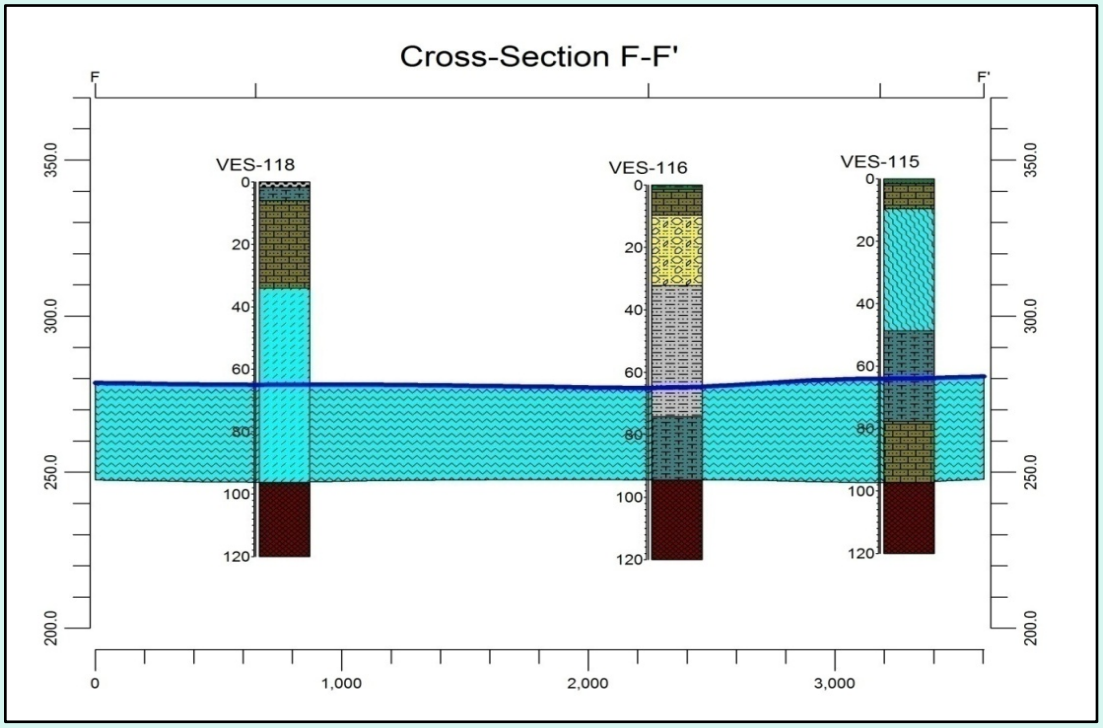

Figure 28: Saturated aquifer thickness along cross section F-F′.

Cross Section G-G′:

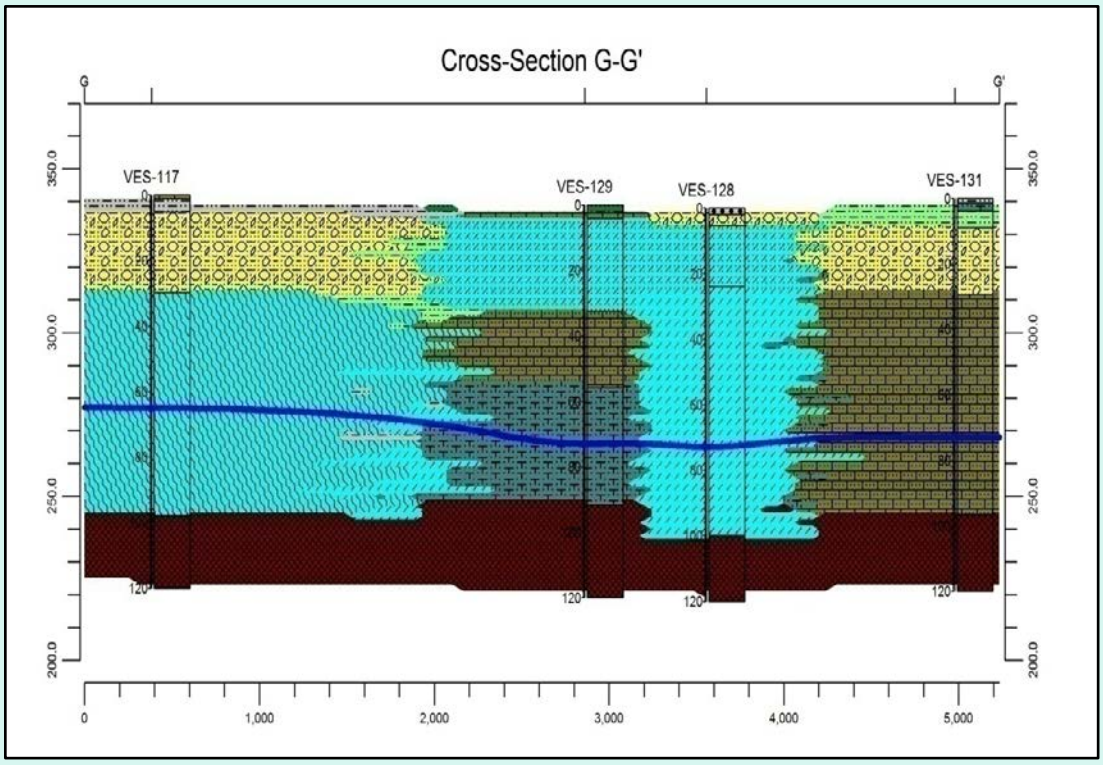

Figure 29: Cross Section G-G′ passes through VES (117), VES (129), VES (128) and VES (131).

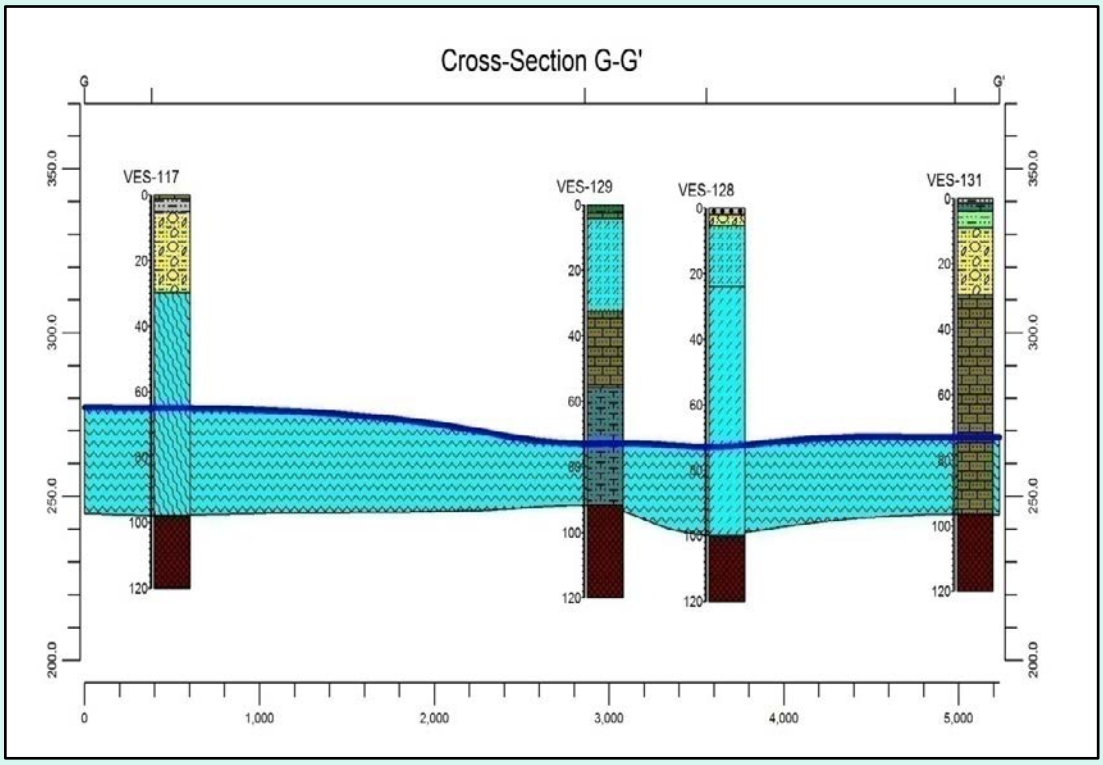

Figure 30: Saturated aquifer thickness along cross section G-G′.

Cross Section H-H′:

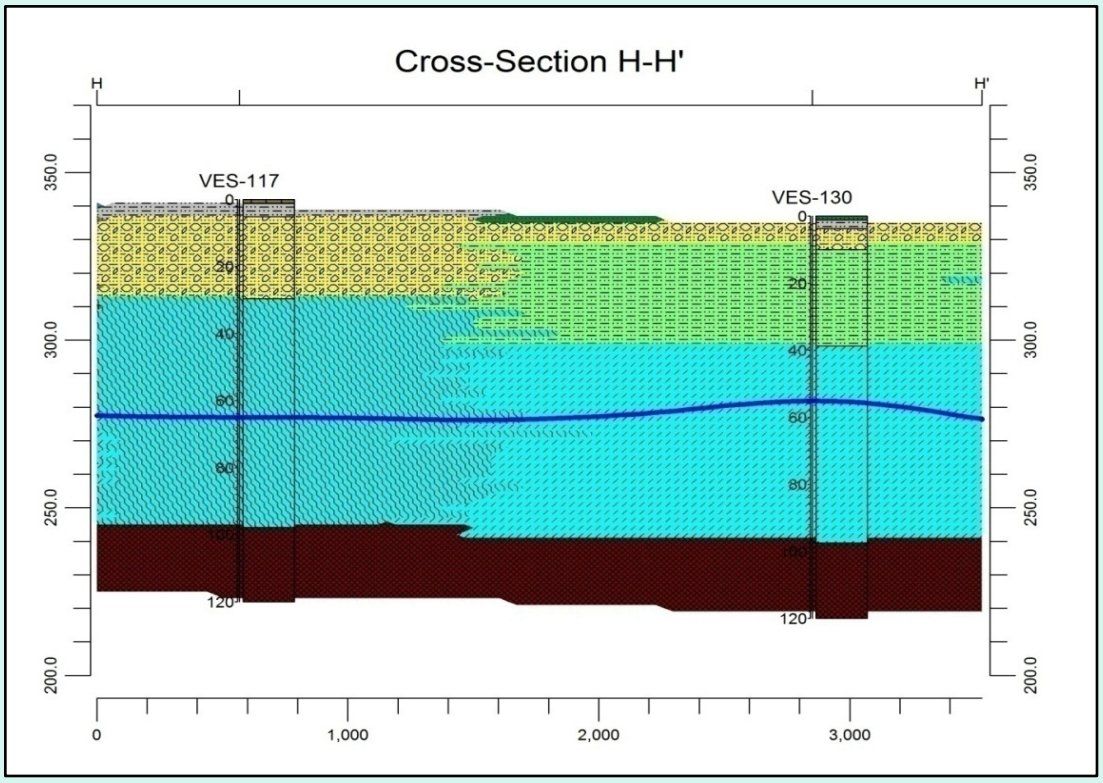

Figure 31: Cross Section H-H′ passes through VES (117) and VES (130).

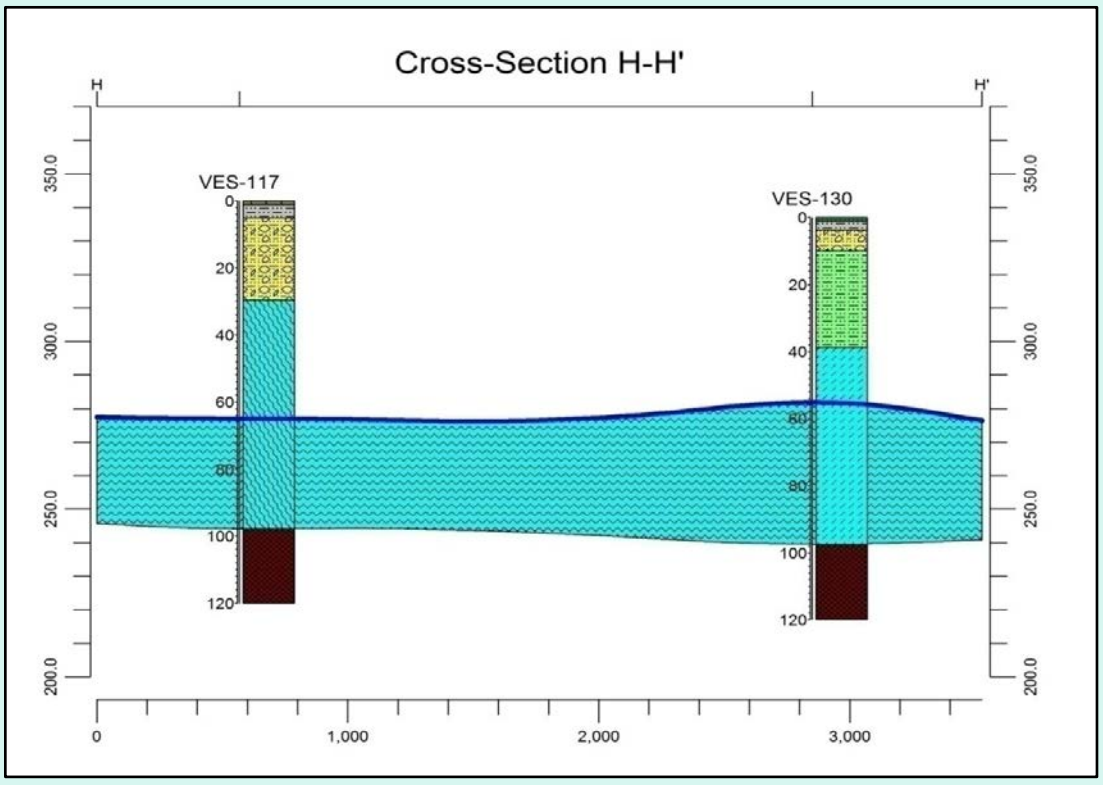

Figure 32: Saturated aquifer thickness along cross section H-H′.

Cross Section I-I′:

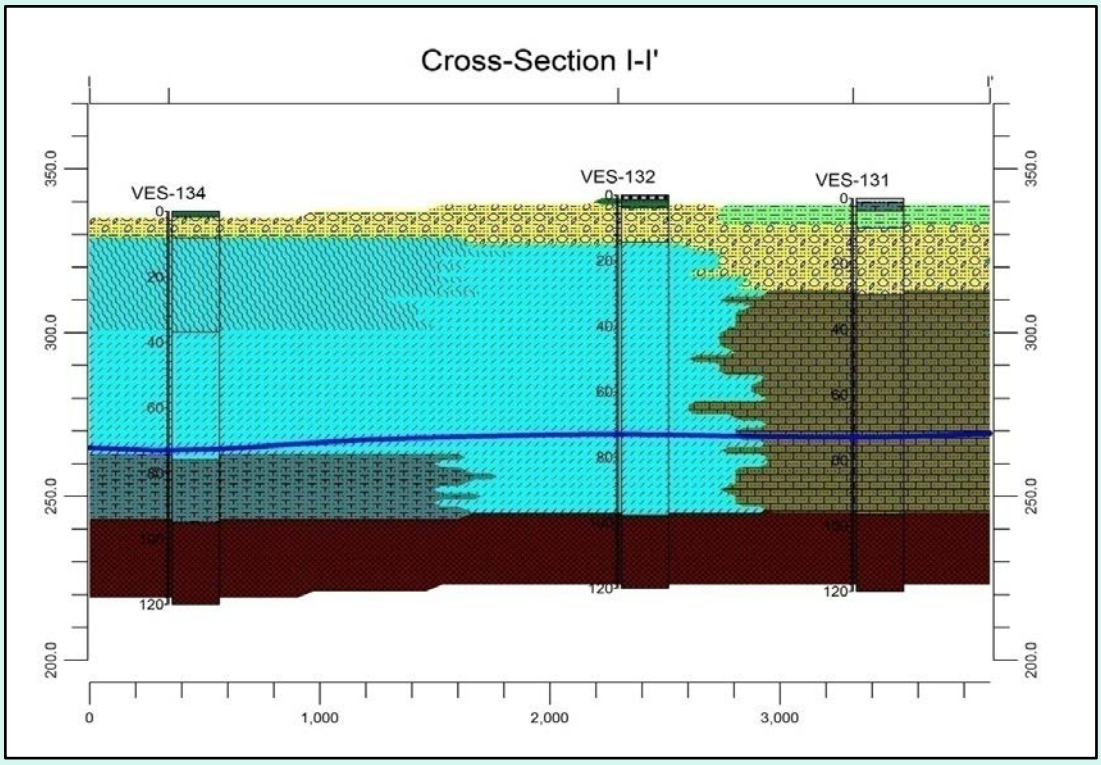

Figure 33: Cross Section I-I′ passes through VES (134), VES (132) and VES(131).

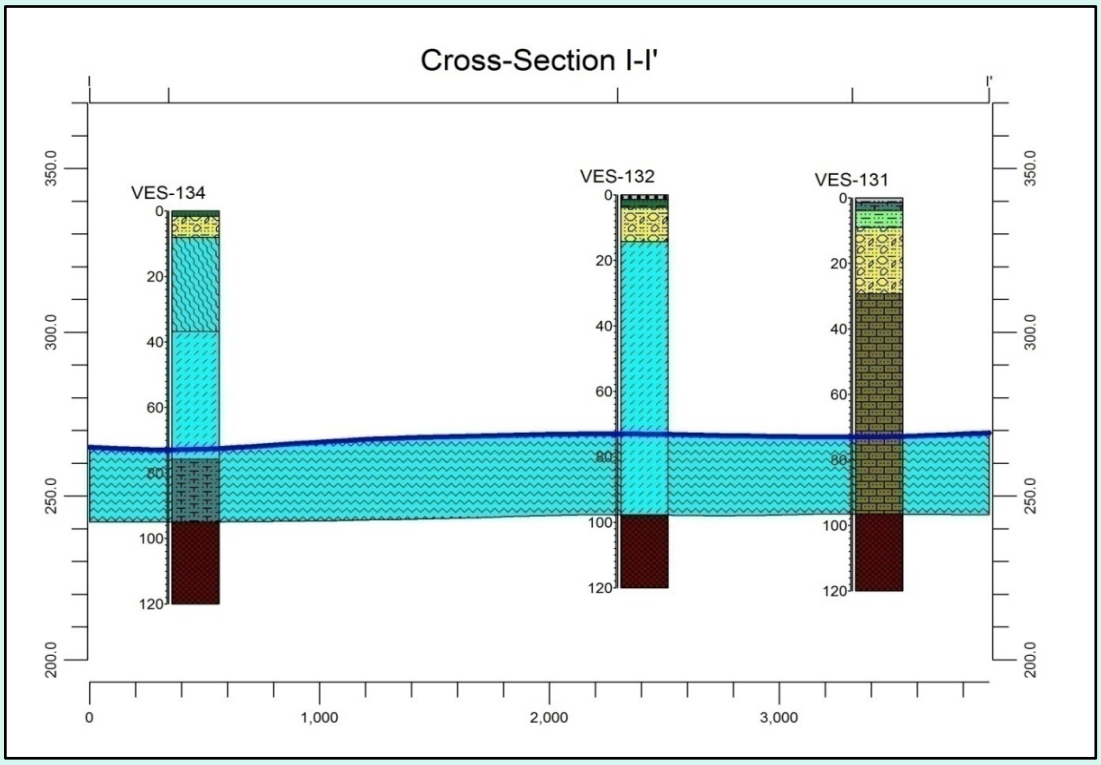

Figure 34: Saturated aquifer thickness along cross section I-I′.

Cross Section J-J′:

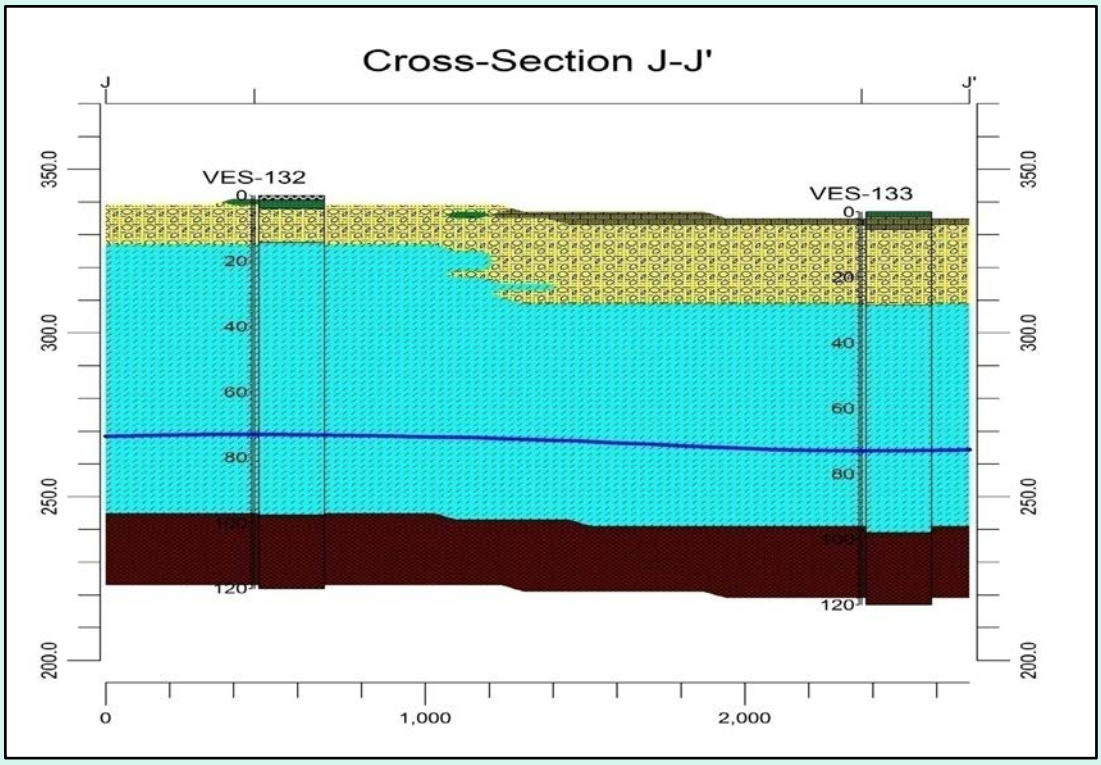

Figure 35: Cross Section J-J′ passes through VES (132) and VES (133).

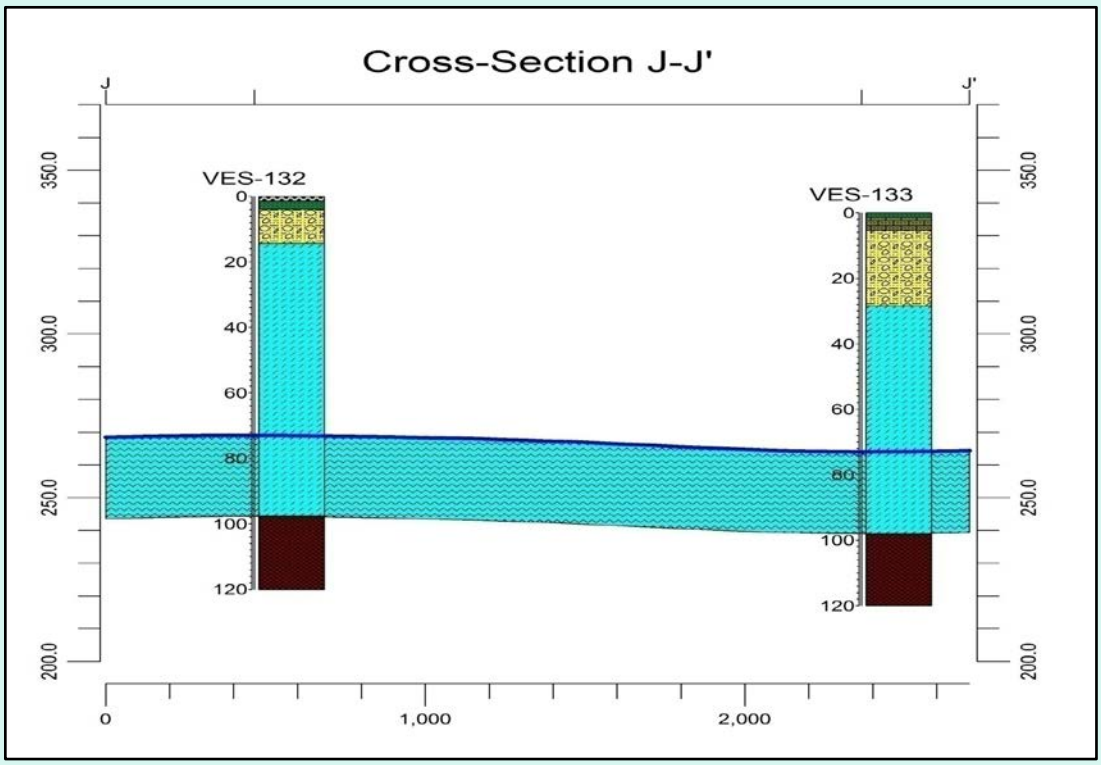

Figure 36: Saturated aquifer thickness along cross section J-J′.

2.1.4 Findings and Suggestions- Cluster - 1

- Alluvial thickness may vary from 90m to 100m bgl(below ground level) in most of the area.
- A minor fissures and fractures may appear in rock formation having low to moderate quantum of ground water.
- By studying the inferences of vertical electrical soundings and their lithological representation along cross sections, thickness of permeable unsaturated aquifer, it seems that VES No. 111, 112, 113, 117, 118, 121, 122, 126, 128, 132, 133 and 134 are comparatively better sites for artificial recharge. But VES No. (111) is located towards river side, therefore, recharged ground water may underflow towards river. Proposed sites for artificial recharge are shown in following map.

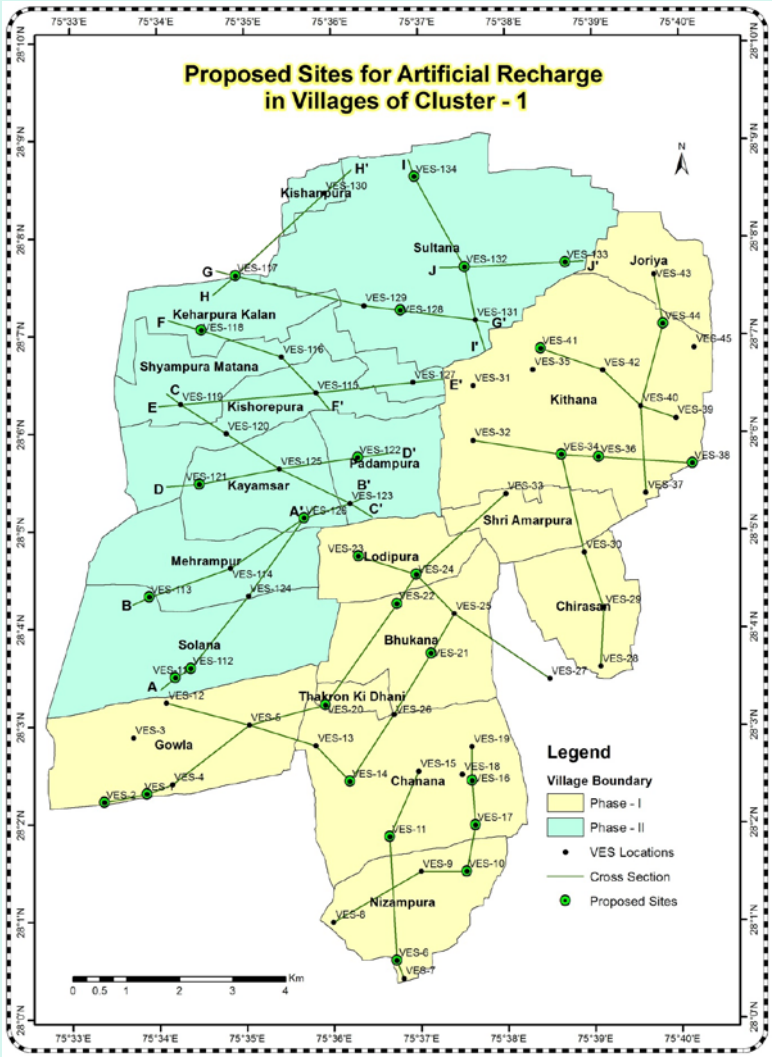

Figure 37: Proposed sites for artificial recharge in villages of Cluster - 1.

- The VES (111) located towards river Kantli, have a good aquifer zones, indicate that younger alluvium along river Kantli are comparatively good aquifer, having better yielding capacity.
- A thin hard layer of clay, kankar with fine grained sand (impermeable layer) is presented in lithological formation of most of the villages of studied area which hinder the percolation of rain water to ground water level, therefore, the design of recharge structure in such a manner that the quantum of surface water may be injected below this impermeable layer, and only 5 to 10m before water level for fast and efficient augmentation of ground water.
- The details of proposed VES sites, their locations and thickness of impermeable layers are given in following table.

Table 3: Thickness of impermeable/ less permeable layer at proposed sites of cluster- 1

S. No.	VES No.	Village	Location	Coordinates	Thickness of impermeable/ less permeable layer in m bgl
1	111	Solana	South west of village Solana, towards river and HT	N28°03′30.15″ E75°34′11.35″	1.5m – 10m
2	112	Solana	In the field of Ram Niwas s/o Jairam	N28°03′35.82″ E75°34′22.13″	2m - 6m
3	113	Solana	Solana	N28°04′19.72″ E75°33′53.62″	1.5m - 6m
4	117	Keharpura Kalan	Near Jode and School	N28°07′37.09″ E75°34′54.03″	5m - 30m
5	118	Keharpura Kalan	On kachcha rasta towards Matana, near water tank	N28°07′03.73″ E75°34′30.22″	2m - 35m
6	121	Kyamsar	In the field of Anil Om Prakash	N28°05′29.03″ E75°34′28.34″	1m - 20m
7	122	Padampura	Padampura	N28°05′45.02″ E75°36′17.93″	2m - 15m
8	126	Kyamsar	Kyamsar	N28°05′08.01″ E75°35′40.64″	1.5m - 10m
9	128	Sultana	Sultana	N28°07′15.41″ E75°36′47.68″	2m - 10m
10	132	Sultana	On Jodiya road	N28°07′41.92″ E75°37′31.96″	4m - 15m
11	133	Sultana	On Jodiya road	N28°07′44.60″ E75°38′41.53″	5m - 30m
12	134	Sultana	On Sari road near HT	N28°08′37.47″ E75°36′57.71″	1.5m - 10m

2.2 Cluster - 2

Phase II of Cluster-2 includes villages Khudot, Jhanjhot, Gidania, Ardawata, Bari, Nari, Khemu ki Dhani, Nizampura, Dhatarwal ka Bas, Oztu, Shyopura, Ajeetpura, Bakhtawapura, Kawarpura, Vijaypura, Ekhtawarpura, Bhamarwasi, Keharpura Khurd, Khudana and Lamba Gothra. Vertical Electrical Sounding (VES) were conducted in 20 villages of cluster- 2, at 61 locations (VES135 – VES195). Rest of 5 villages of cluster- 2 (Malupura, Sori, Brijlalpura, Noonia Gothra and Gothri) had been covered during phase I of study in the year 2016 - 17. VES locations of cluster- 2 are shown in following map.

Figure 38: Map showing VES locations in villages of cluster- 2

2.2.1 Interpreted Result

Phase II of Cluster - 2 includes villages Khudot, Jhanjhot, Gidania, Ardawata, Bari, Nari, Khemu ki Dhani, Nizampura, Dhatarwal ka Bas, Oztu, Shyopura, Ajeetpura, Bakhtawapura, Kawarpura, Vijaypura, Ekhtawarpura, Bhamarwasi, Keharpura Khurd, Khudana and Lamba Gothra. Vertical electrical soundings were conducted at 61 locations. The field data were collected and interpreted by using a computer software programme. As per the interpretation of field data, the resistivity of different layers and their corresponding thickness of the formations are summarised in the following tables:

Table 4: Interpreted Result of Villages of Cluster-2

S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm- meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
1	135	Khudot	On Sultana road	N28° 09′ 09.18″ E75° 39′ 03.41″	78.9	64.3	34.9	43.6	109		1.67	6.35	13.4	69.5		90.92
2	136	Khudot	In Jode area	N28° 08′ 53.19″ E75° 39′ 50.92″	72.2	157	32	89.7	24.8	129	1.21	2.24	15.1	20.8	55.3	94.65
3	137	Khudot	Towards Hirwa	N28° 09′ 33.96″ E75° 39′ 24.66″	119	87.7	33.5	27.8	145		1.92	5.47	31.7	53.4		92.49
4	138	Gidania	Towards Khudot boundary	N28° 10′ 04.73″ E75° 39′ 03.18″	70.7	116	45.2	24.3	282		1.45	3.54	22.3	62.3		89.59
5	139	Gidania	In Play Ground	N28° 10′ 39.39″ E75° 39′ 08.55″	92.1	64	31.5	42.4	16.9	254	3.46	7.89	17.4	10.5	45.7	84.95
6	140	Gidania	On Dangar road	N28° 11′ 21.66″ E75° 39′ 20.12″	88.6	70.3	31.5	65	15.9	120	1.72	9.63	8.36	10.3	60.5	90.51
7	141	Gidania	On Khemu ki Dhani road	N28° 11′ 27.75″ E75° 39′ 00.65″	39.8	59.7	20.9	50	17.8	188	1.18	1.86	8.49	13.7	63.4	88.63
8	142	Jhanjhot	Jhanjhot on Gadania road	N28° 10′ 02.54″ E75° 38′ 27.75″	113	54.3	86.3	22.7	161		1.29	23.4	14.1	58.1		96.89
9	143	Jhanjhot	Jhanjhot on Sari road	N28° 09′ 53.77″ E75° 37′ 15.59″	70.3	49.4	36.8	68.9	18.6	128	1.63	4.19	14.8	18.8	58	97.42
10	144	Jhanjhot	Jhanjhot on Sultana road	N28° 09′ 13.60″ E75° 37′ 22.68″	245.8	213.8	38.24	46.42	108		1.95	5.22	22.67	64.88		94.72

S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm- meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
11	145	Khemu Ki Dhani	Khemu ki Dhani on Chirawa road	N28° 12′ 48.77″ E75° 38′ 44.45″	63	32	66.7	15.2	20.8	224	1.49	5.15	13	40.8	34	94.44
12	146	Khemu Ki Dhani	Towards Dangar boundary	N28° 12′ 14.28″ E75° 39′ 00.62″	30.8	16.3	18.4	24.6	81		1.1	5.86	7.95	74.6		89.51
13	147	Ardawata	Towards Dangar boundary	N28° 11′ 04.61″ E75° 38′ 37.72″	67.8	38	29.1	34.8	20	112	1.39	7.43	16.1	14.3	49.9	89.12
14	148	Ardawata	Towards Gidania, in the field of shri Bahadur Singh s/o shri Kal Singh	N28° 10′ 47.75″ E75° 38′ 24.47″	76.1	53.5	25.2	17.9	215		1.89	11.1	20.3	52.1		85.39
15	149	Ardawata	On Nari road	N28° 11′ 17.32″ E75° 37′ 15.89″	88.15	58.8	20.44	44.04	21.89	195	1.45	5.93	20.21	12.06	53.26	92.91
16	150	Ardawata	Towards Khatia ki Dhani boundary	N28° 10′ 59.45″ E75° 37′ 28.56″	41.3	24.2	38	17.4	13.9	242	2.07	12	15.5	21.2	35.6	86.37
17	151	Ardawata	Towards Jhanjhot boundary	N28° 10′ 25.70″ E75° 37′ 37.32″	43.6	19.1	51.3	22.4	19.7	248	1.09	3.38	5.85	19.5	57.4	87.22
18	152	Nari	Towards Ardawata near Railway crossing	N28° 11′ 24.31″ E75° 36′ 49.53″	120	53	42.3	23.1	226		1.69	3.31	25.5	65.7		96.2
19	153	Nari	Towards Oztu near open scrub	N28° 11′ 51.66″ E75° 36′ 14.45″	36.6	32.1	72.6	23.4	35.9	264	1.93	4.47	22.7	40.9	18.7	88.7

S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm- meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
20	154	Nari	Near Railway Line (Railway Station)	N28° 11′ 10.44″ E75° 36′ 02.69″	95.9	70.3	63	33.2	252		1.7	7.49	17.1	34.1		60.39
21	155	Nari	Towards Bari boundary	N28° 10′ 50.65″ E75° 36′ 08.01″	95.9	41.8	24.1	29.8	116		1.56	2.87	20.5	46.5		71.43
22	156	Khudana	Khudana	N28° 11′ 26.23″ E75° 31′ 15.98″	348	48.3	24.2	18.3	374		3.48	16	31.9	52.6		103.98
23	157	Khudana	In the field of shri Maduram s/o shri Jaduram	N28° 11′ 08.01″ E75° 31′ 22.55″	338	114	56.3	61.8	22.9	354	1.65	4.77	18.5	5.1	69.2	99.22
24	158	Khudana	towards Kantli River	N28° 10′ 49.97″ E75° 31′ 48.79″	338	85	73.3	20.9	27.6	325	2.7	7.54	18.2	52	12.8	93.24
25	159	Khudana	Towards river bank	N28° 11′ 18.00″ E75° 32′ 07.86″	374	103	86.3	30.3	546		2.48	8.41	20.4	71.9		103.19
26	160	Khudana	Towards river bank, in the field of shri Chandagiram	N28° 10′ 51.45″ E75° 32′ 10.53″	121	37	110	22.7	456		1.03	3.91	24.9	73.9		103.74
27	161	Bari	Bari ka bas, in the field of shri Meharchand s/o shri Birbalram	N28° 09′ 57.23″ E75° 36′ 38.16″	69.9	46.9	57	17.6	22	342	1.4	12.2	15.7	51.7	15.4	96.4

S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm- meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
28	162	Bari	On Ekhtawarpura road	N28° 10′ 08.85″ E75° 35′ 55.72″	133	89	55	37.1	168		1.07	14	11.5	71.1		97.67
29	163	Bari	On Ekhtawarpura road on Kachcha rasta to Brijlalpura	N28° 10′ 32.36″ E75° 35′ 31.29″	150	37.9	48.6	15.3	404		4.16	21	26.6	46		97.76
30	164	Ekhtawarpura	In Jodi area	N28° 10′ 39.53″ E75° 34′ 33.95″	262	132	229	54.6	362		5.46	14.6	11.7	67.5		99.26
31	165	Ekhtawarpura	In the field of shri Gulab Singh s/o shri Mool Singh	N28° 11′ 07.72″ E75° 34′ 04.39″	171	53.4	148	51.3	67.9	292	3.43	10.6	15.5	11.1	54	94.63
32	166	Bhamarwasi	Bhamarwasi	N28° 10′ 14.24″ E75° 34′ 04.90″	119	85	179	63.8	45.7	877	1.87	8.52	19.7	49.2	19.2	98.49
33	167	Bhamarwasi	In Ladna Jodi	N28° 09′ 53.75″ E75° 34′ 33.35″	201	298	125	89.7	48.6	479	1.3	3.95	33.9	20.8	38.5	98.45
34	168	Bhamarwasi	Towards Railway Line	N28° 10′ 34.16″ E75° 34′ 10.86″	124	65.3	85.6	36.8	285		5.25	19.3	37.7	33.9		96.15
35	169	Keharpura Khurd	In the field of shri Sunil s/o shri Mathuram	N28° 09′ 55.43″ E75° 33′ 44.81″	108	44.7	109	36.8	179		2.06	9.09	76.5	10.8		98.45
36	170	Keharpura Khurd	In Jodi area on Salempura road	N28° 09′ 28.85″ E75° 33′ 18.56″	171	61.4	123	35.1	450		1.26	8.51	49.7	39.7		99.17

S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm- meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
37	171	Keharpura Khurd	Towards river	N28° 9′ 47.60″ E75° 33′ 10.33″	158	51.3	130	43.3	262		2.66	7.66	56.5	37.9		104.72
38	172	Keharpura Khurd	Keharpura Khurd	N28° 9′ 50.63″ E75° 34′ 06.57″	63.3	87.7	123	36.5	278		1.92	12.1	45	44.9		103.92
39	173	Bakhtawarpura	On Alipura road kachcha rasta	N28° 12′ 26.27″ E75° 33′ 05.90″	113	65.8	76.2	108	56.3	292	1.92	7.78	47.1	25	19	100.8
40	174	Bakhtawarpura	On Alipura road kachcha rasta near HT	N28° 12′ 41.15″ E75° 32′ 50.89″	95.4	25.9	99	66	35.1	242	1.2	3.21	6.3	35.5	52.3	98.51
41	175	Bakhtawarpura	Towards khudana boundary in river area	N28° 11′ 59.63″ E75° 32′ 14.40″	182	70.1	41.3	96.9	32.5	856	1.76	1.67	6.88	14.6	72.7	97.61
42	176	Vijaypura	In the field of shri Hanuman Singh s/o shri Nani Singh	N28° 11′ 19.39″ E75° 33′ 31.58″	179	83.7	52.5	115	52.1	207	1.54	7.93	27	47.8	13.4	97.67
43	177	Vijaypura	In river area	N28° 11′ 08.19″ E75° 33′ 06.44″	162	83.7	210	78	111	604	1.72	8.05	10.3	5.26	71.6	96.93
44	178	Kawarpura	Kawarpura	N28° 11′ 29.49″ E75° 34′ 23.51″	54.2	33.3	109	45	70	379	1.72	4.41	19	4.22	67.6	96.95
45	179	Kawarpura	Near the village	N28° 11′ 58.74″ E75° 33′ 52.76″	75.6	50.2	121	49.4	609		1.64	3.69	15.1	77.3		97.73

S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm- meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
46	180	Bakhtawarpura	Towards Nunia Gothra	N28° 12′ 28.21″ E75° 33′ 35.02″	32.6	120	58.8	72.2	199		1.64	8.62	49.5	31.7		91.46
47	181	Oztu	Oztu	N28° 13′ 17.13″ E75° 36′ 54.55″	180	86.3	81.1	19	440		1.6	8.47	15.3	72.3		97.67
48	182	Dhatarwal Ka Bas	Dhatarwad Ka bas	N28° 12′ 46.53″ E75° 36′ 32.30″	26.4	82.8	43.8	35.3	38.6	274	2.82	7.29	26.5	14.1	46.1	96.81
49	183	Shyopura	Towards bricks factory	N28° 14′ 52.01″ E75° 37′ 04.56″	87.2	73.7	81.5	16.3	242		2.13	7.97	9.49	72.3		91.89
50	184	Shyopura	Towards Oztu border near bricks factory	N28° 14′ 28.43″ E75° 37′ 08.58″	40.9	21.4	85.9	54.3	19.1	342	1.09	2.22	16.4	18.9	59.8	98.41
51	185	Lamba Gothra	Towards river	N28° 14′ 27.01″ E75° 33′ 05.47″	222	41.6	70	26.6	717		1.12	8.8	15.2	72.5		97.62
52	186	Lamba Gothra	In Jode area on Ismailpura road	N28° 14′ 47.32″ E75° 33′ 30.74″	77.3	47.9	24.6	54.3	112		3.59	2.32	23.9	67.9		97.71
53	187	Lamba Gothra	Lamba Gothra	N28° 14′ 33.36″ E75° 34′ 06.35″	114	41.6	61	24.6	252		0.94	4.03	24.7	63.2		92.87
54	188	Lamba Gothra	In Tolana Jode area	N28° 14′ 34.03″ E75° 35′ 12.56″	57.2	50.9	171	43.6	313		1.56	2.18	36.3	58.4		98.44
55	189	Ajeetpura	Ajeetpura	N28° 13′ 34.47″ E75° 34′ 04.65″	31	52.9	31.5	35.7	28	210	2.07	18.4	9.88	21	47.1	98.45

S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm- meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
56	190	Ajeetpura	Ajeetpura, in Jode area	N28° 13′ 10.03″ E75° 33′ 37.96″	158	212	96.2	168	49	244	1.09	2.11	6.88	8.81	75.1	93.99
57	191	Oztu	Oztu, in Jode area	N28° 14′ 04.60″ E75° 37′ 11.05″	122	177	103	22.9	471		1.09	4.21	18.7	72.9		96.9
58	192	Nizampura	Nizampura	N28° 13′ 59.53″ E75° 37′ 46.85″	63.3	33.7	42.2	15.6	145		1.43	18.9	18.5	57.1		95.93
59	193	Oztu	Oztu	N28° 13′ 28.25″ E75° 35′ 38.19″	56.1	16.4	76.5	15.1	354		1.07	2.7	24.9	66.3		94.97
60	194	Nizampura	Nizampura	N28° 13′ 13.05″ E75° 37′ 19.65″	99	33.9	49.7	21.8	264		1.05	4.22	35	50.7		90.97
61	195	Shyopura	In Play Ground	N28° 14′ 39.82″ E75° 37′ 33.28″	63.3	45.5	61.7	14.1	282		2.09	7.11	20.5	61.8		91.5

2.2.2 Inferences of Geophysical Electrical Resistivity Survey, Cluster - 2

Phase II of Cluster- 2 includes villages Khudot, Jhanjhot, Gidania, Ardawata, Bari, Nari, Khemu ki Dhani, Nizampura, Dhatarwal ka Bas, Oztu, Shyopura, Ajeetpura, Bakhtawapura, Kawarpura, Vijaypura, Ekhtawarpura, Bhamarwasi, Keharpura Khurd, Khudana and Lamba Gothra. Vertical electrical soundings were conducted at 61 locations (VES135 – VES195). The field data were collected and interpreted and the following inferences are drawn on the basis of resistivity values of different layers and the nature of curves obtained from field data and its interpretation. In the surveyed area, different lithological formations are identified. Point wise details of lithological formations corresponding to different layers are described as below:

VES point wise details of lithological formations corresponding to different layers:

VES (135):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of medium to fine grained sand and minor clay
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (136):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of medium to fine grained sand and silt
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of medium to fine grained sand and minor silt
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (137):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of medium to fine grained sand and silt
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (138):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of medium to fine grained sand and minor clay
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (139):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of medium to fine grained sand and silt
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation consist of medium to fine grained sand and minor silt
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (140):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of medium to fine grained sand and silt
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of medium to fine grained sand and minor silt
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

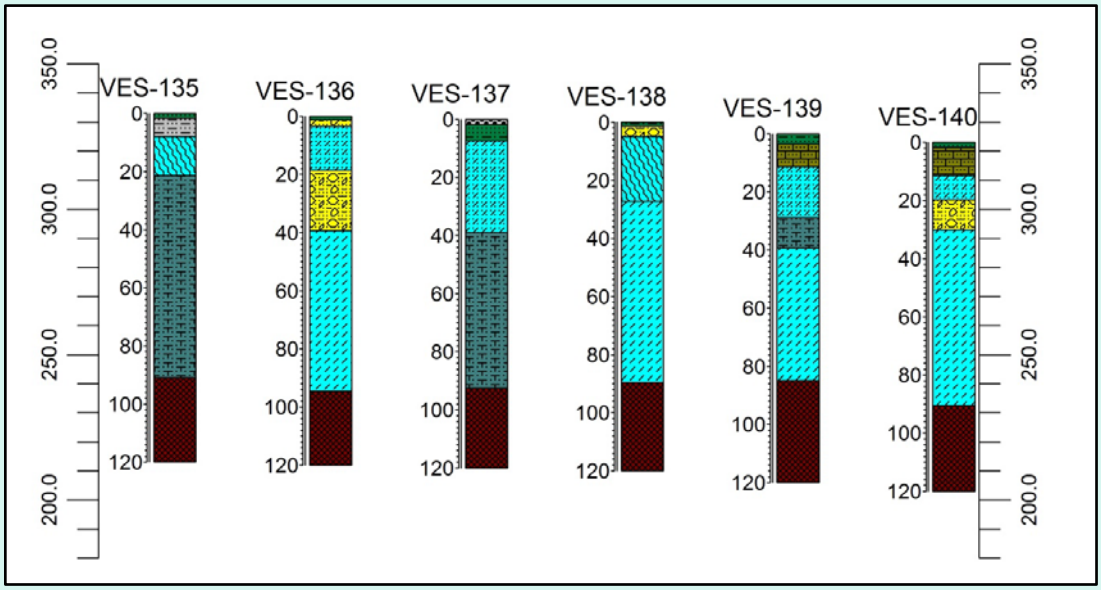

Figure 39: Lithological formation from VES(135) to VES(140).

VES (141):

Layers	Lithological Formation
h_1	The formation consist of fine grained sand and clay
h_2	The formation consist of fine grained sand and clay with minor kankar
h_3	The formation consist of medium to fine grained sand and clay
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of fine grained sand and silt with clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (142):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine grained sand and silt with clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES 143:

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of fine grained sand and silt with clay
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of fine grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (144):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand
h_3	The formation consist of medium to fine grained sand and minor clay
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (145):

Layers	Lithological Formation
h_1	The formation consist of fine to medium grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (146):

Layers	Lithological Formation
h_1	The formation consist of fine grained sand and clay
h_2	The formation consist of fine grained sand and silt with clay
h_3	The formation consist of fine grained sand and clay with minor kankar
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

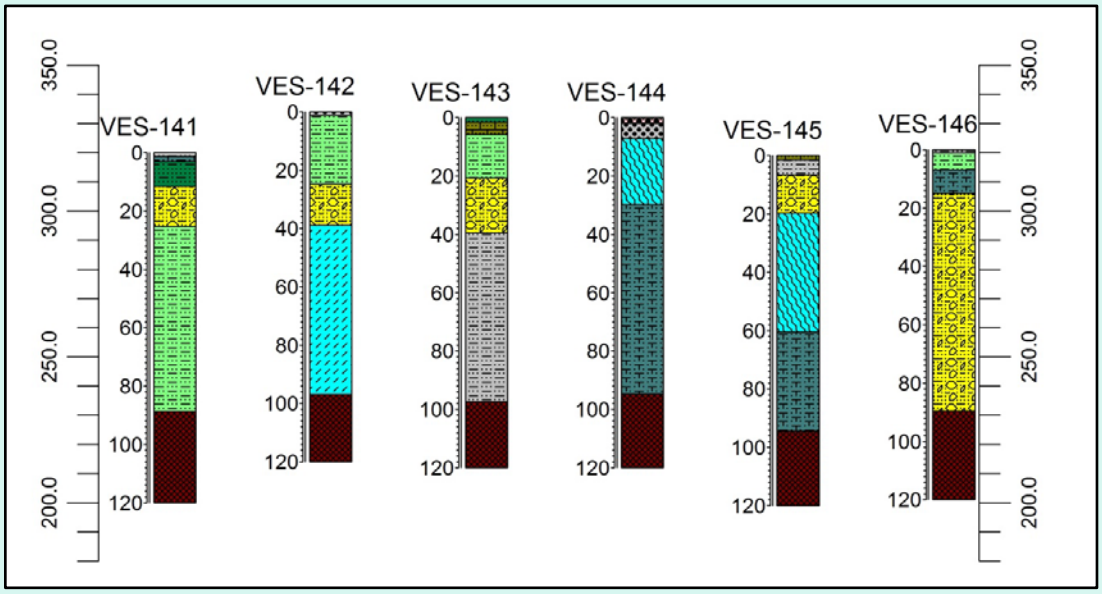

Figure 40: Lithological formation from VES(141) to VES(146).

VES (147):

Layers	Lithological Formation
h_1	The formation consist of fine to medium grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of fine grained sand and silt with clay
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation consist of medium to fine grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (148):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of medium to fine grained sand and minor silt
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (149):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of fine grained sand and silt with clay
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of fine to medium grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (150):

Layers	Lithological Formation
h_1	The formation consist of fine grained sand and clay
h_2	The formation consist of fine grained sand and silt with clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine grained sand and clay
h_5	The formation consist of fine grained sand and silt with clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (151):

Layers	Lithological Formation
h_1	The formation consist of fine grained sand and clay
h_2	The formation consist of fine grained sand and silt with clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine grained sand and clay
h_5	The formation consist of fine grained sand and silt with clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (152):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of fine grained sand and silt with clay
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

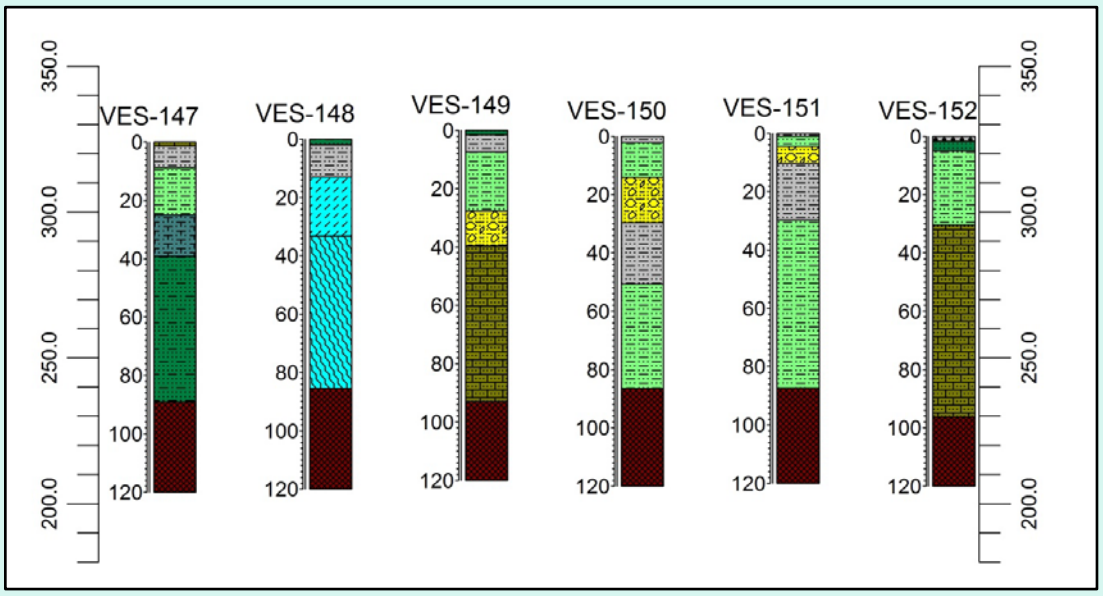

Figure 41: Lithological formation from VES(147) to VES(152).

VES (153):

Layers	Lithological Formation
h_1	The formation consist of fine grained sand and clay
h_2	The formation consist of fine grained sand and silt with clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (154):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of fine grained sand and silt with clay
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (155):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine to medium grained sand with silt
h_3	The formation consist of medium to fine grained sand and minor silt
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (156):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of fine to medium grained sand with silt
h_4	The formation consist of fine grained sand and clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (157):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand
h_3	The formation consist of medium to fine grained sand and silt
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation consist of medium to fine grained sand and minor silt
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (158):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand
h_3	The formation consist of fine grained sand and clay
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

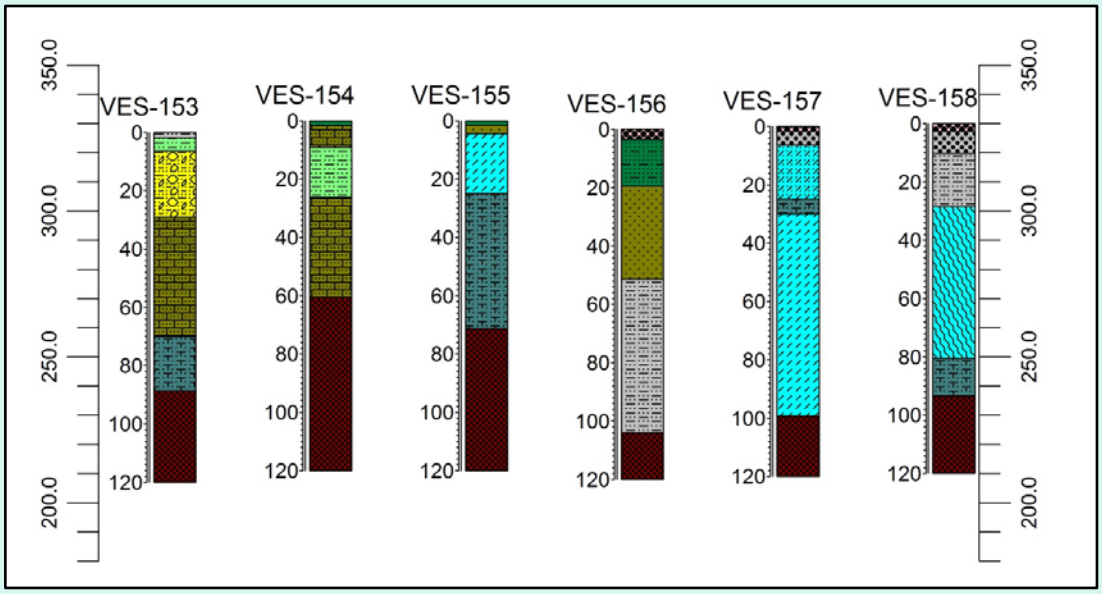

Figure 42: Lithological formation from VES(153) to VES(158).

VES (159):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand
h_3	The formation consist of fine grained sand and clay
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (160):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (161):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (162):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (163):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (164):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

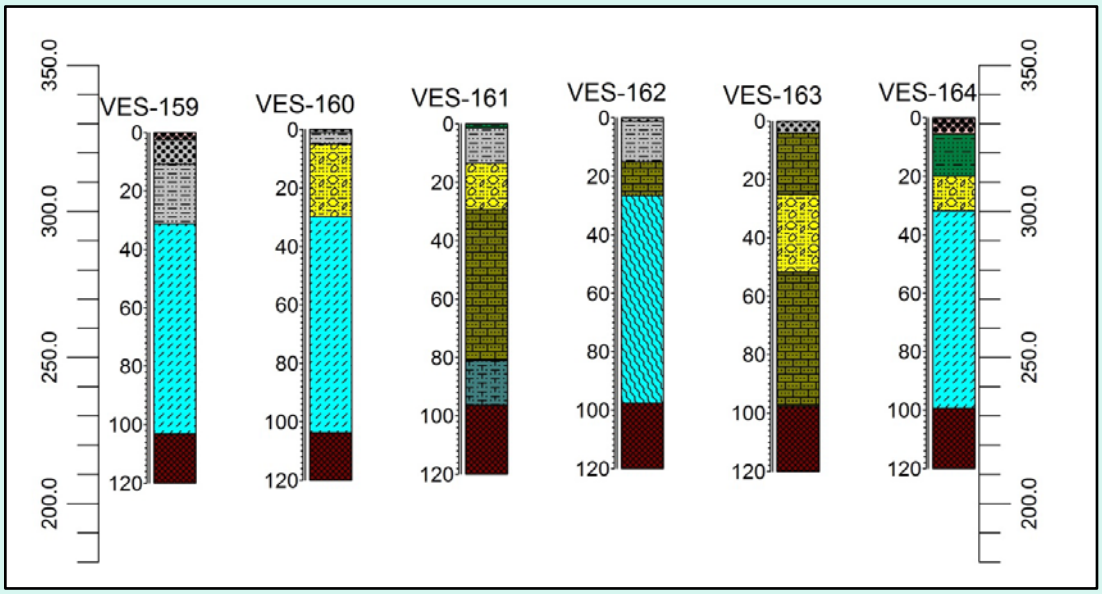

Figure 43: Lithological formation from VES(159) to VES(164).

VES (165):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine grained sand and clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (166):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine grained sand and clay
h_5	The formation consist of fine to medium grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (167):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of fine grained sand and clay
h_5	The formation consist of fine to medium grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (168):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (169):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (170):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

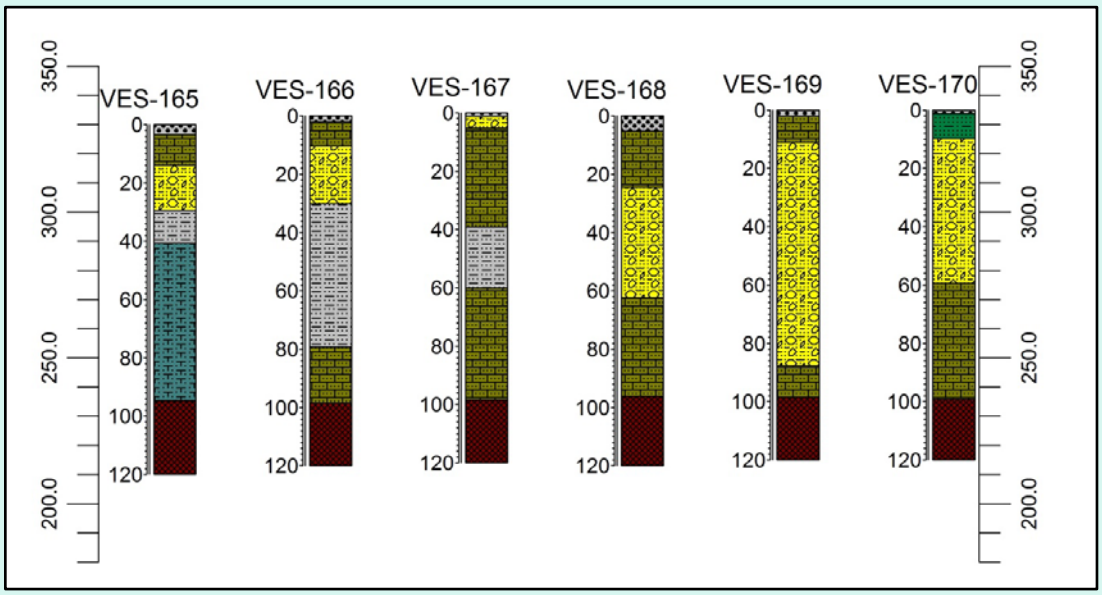

Figure 44: Lithological formation from VES(165) to VES(170).

VES (171):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (172):

Layers	Lithological Formation
h_1	The formation consist of fine to medium grained sand and clay
h_2	The formation consist of fine grained sand and clay with minor kankar
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (173):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of fine grained sand and clay with minor kankar
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of medium to fine grained sand and minor clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (174):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine grained sand and clay
h_5	The formation consist of fine to medium grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (175):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of fine grained sand and clay
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of fine to medium grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (176):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of fine grained sand and clay
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of fine to medium grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

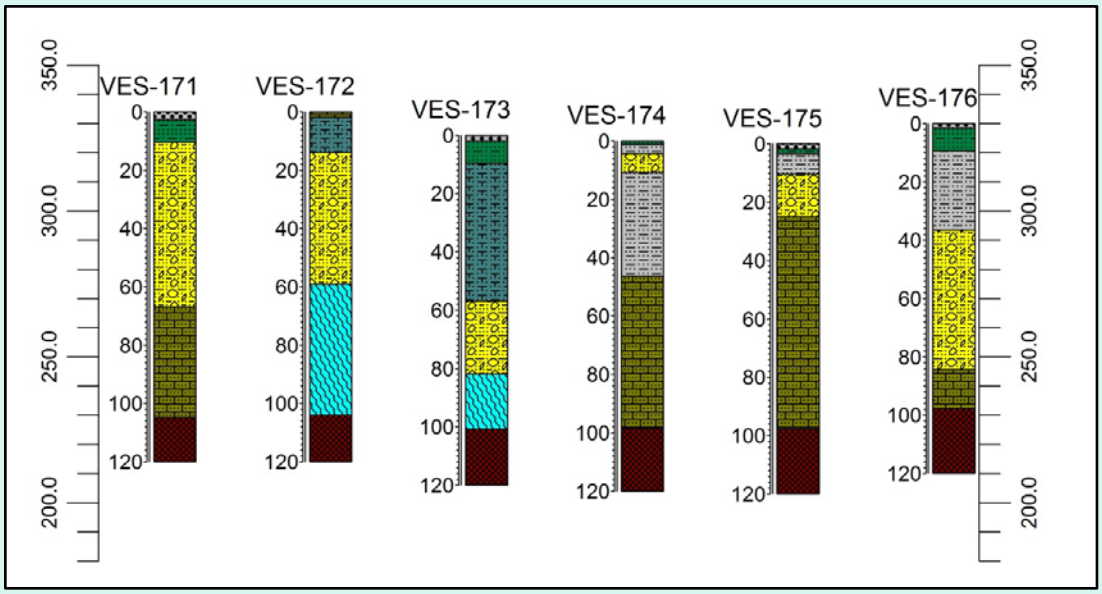

Figure 45: Lithological formation from VES(171) to VES(176).

VES (177):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine grained sand and clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (178):

Layers	Lithological Formation
h_1	The formation consist of fine to medium grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine grained sand and clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (179):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (180):

Layers	Lithological Formation
h_1	The formation consist of fine grained sand and clay
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (181):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of fine grained sand and clay with minor kankar
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (182):

Layers	Lithological Formation
h_1	The formation consist of fine grained sand and clay
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of fine grained sand and clay
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

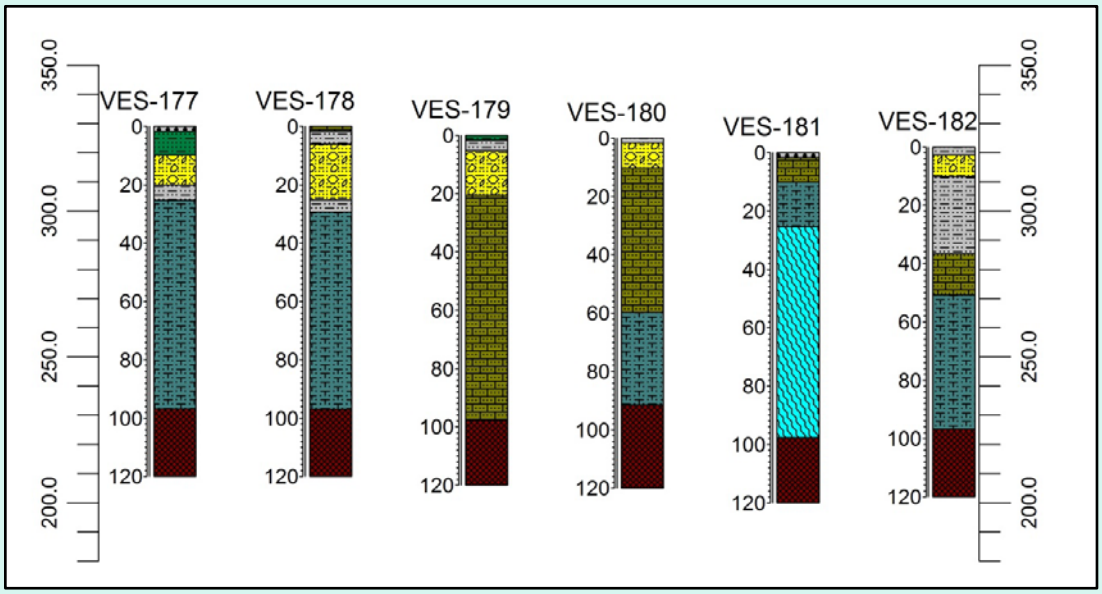

Figure 46: Lithological formation from VES(177) to VES(182).

VES (183):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (184):

Layers	Lithological Formation
h_1	The formation consist of fine grained sand and clay
h_2	The formation consist of fine grained sand and silt with clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation consist of fine to medium grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (185):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine grained sand and clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (186):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of fine grained sand and clay
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (187):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (188):

Layers	Lithological Formation
h_1	The formation consist of fine to medium grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

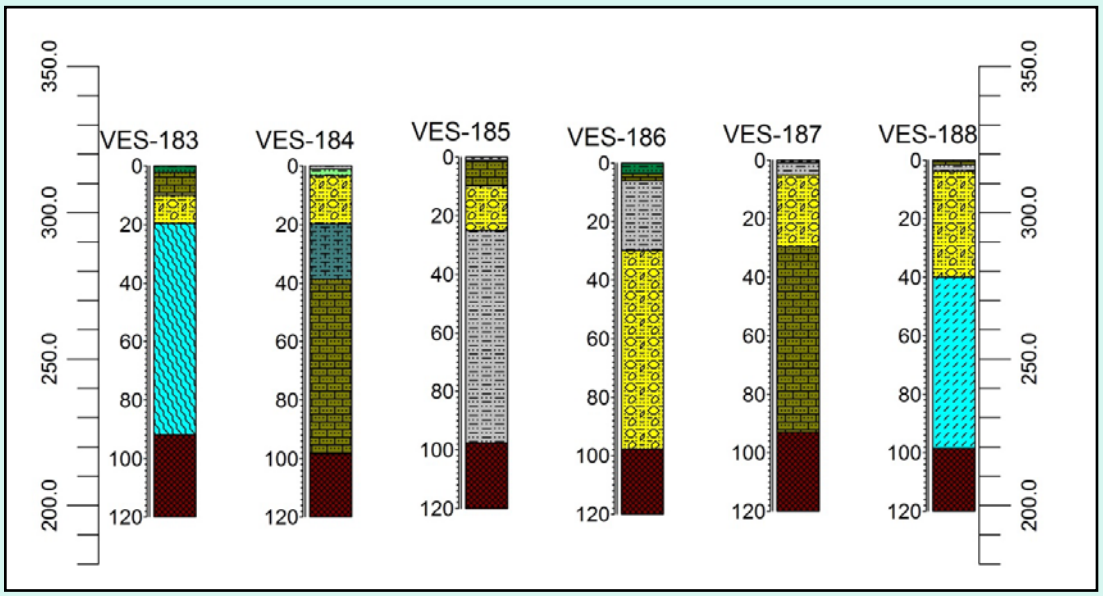

Figure 47: Lithological formation from VES(183) to VES(188).

VES (189):

Layers	Lithological Formation
h_1	The formation consist of fine grained sand and clay
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of medium to fine grained sand and clay
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation consist of fine to medium grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (190):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation consist of medium to fine grained sand and minor clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (191):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (192):

Layers	Lithological Formation
h_1	The formation consist of fine to medium grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (193):

Layers	Lithological Formation
h_1	The formation consist of fine to medium grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (194):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (195):

Layers	Lithological Formation
h_1	The formation consist of fine to medium grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

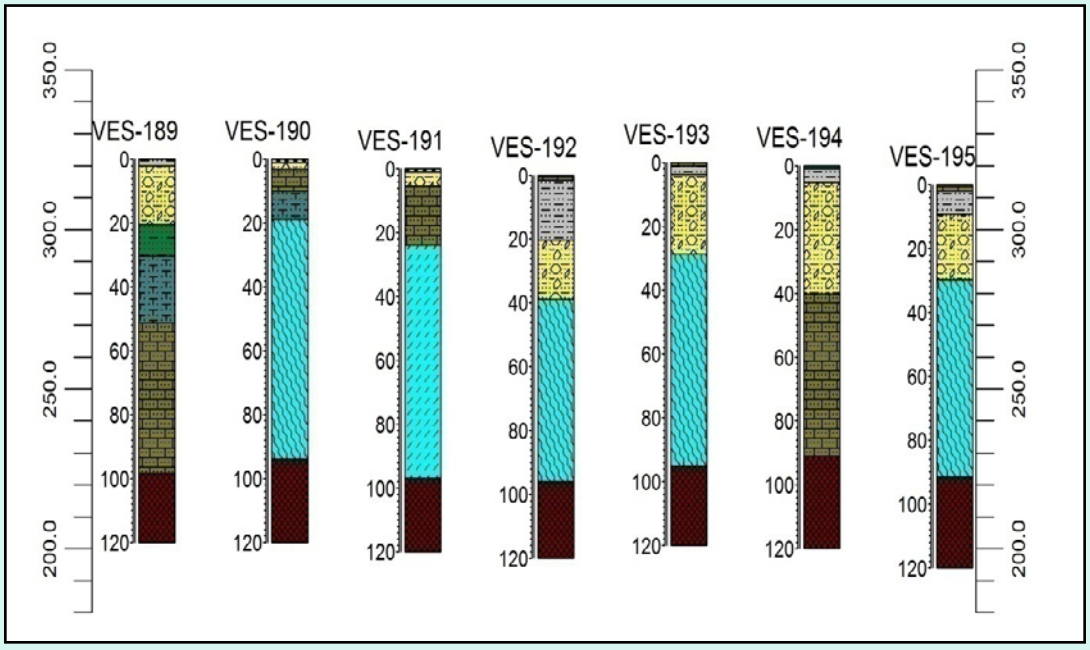

Figure 48: Lithological formation from VES(189) to VES(195).

2.2.3 Representation of lithological formations along Cross Sections

To represent subsurface lithological formations or different layers, depth to bedrock, permeable and impermeable layers, saturated and unsaturated zones & their thickness, 23 cross sections (AA′, BB′, CC′, DD′, EE′, FF′, GG′, HH′, II′, JJ′, KK′, LL′, MM′, NN′, OO′, PP′, QQ′, RR′, SS′, TT′, UU′, VV′ and WW′) have been selected. Each cross section passes through different VES locations. A blue line in section profile represent water table along the section. The portion aquifer thickness lies below water table is known as saturated aquifer thickness. The saturated aquifer thickness for every section is shown in another figure. The following map shows the different cross sections.

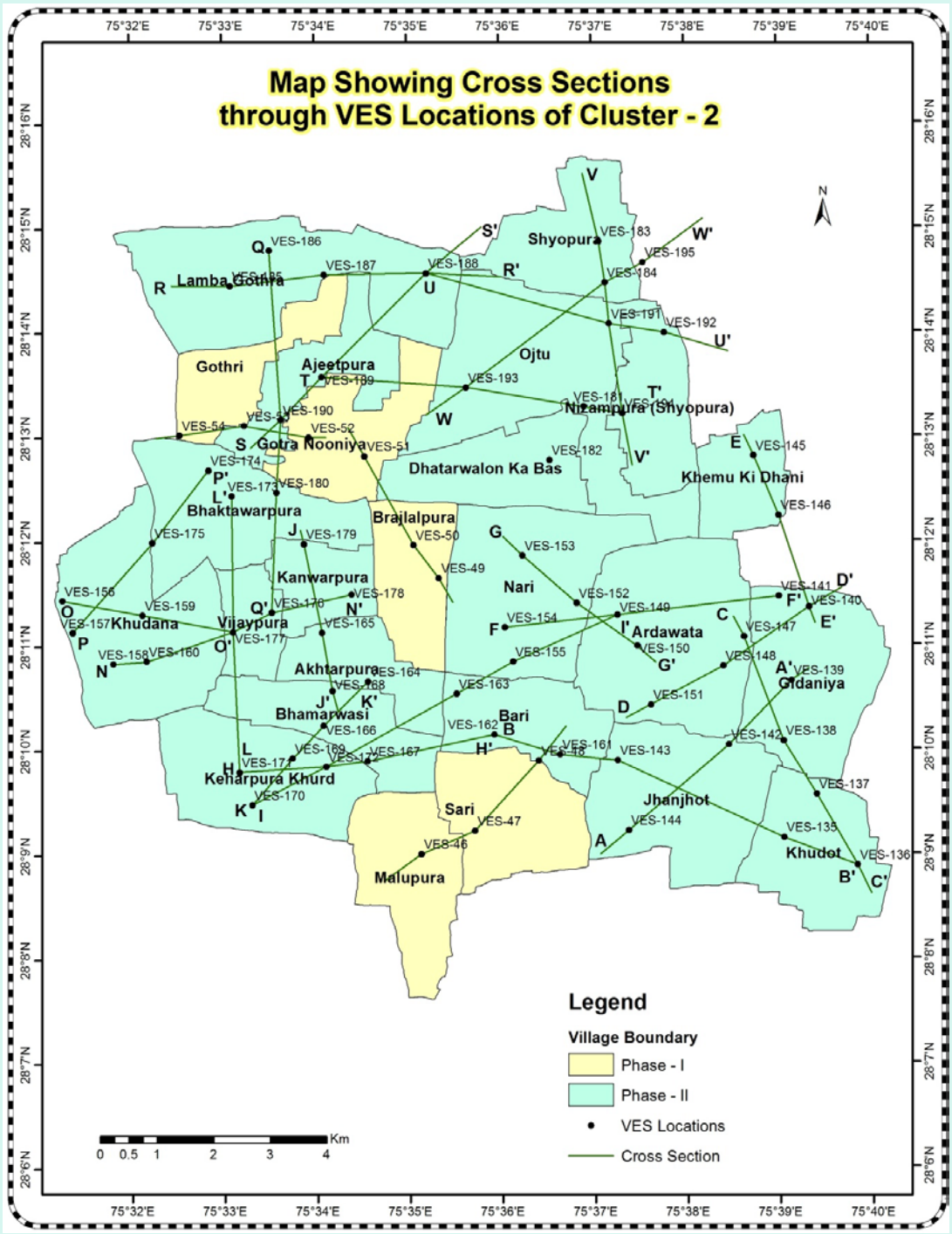

Figure 49: Map showing different cross sections through VES locations of Cluster - 2

The following figures show different cross sections and saturated aquifer thickness.

Cross Section A-A′ :

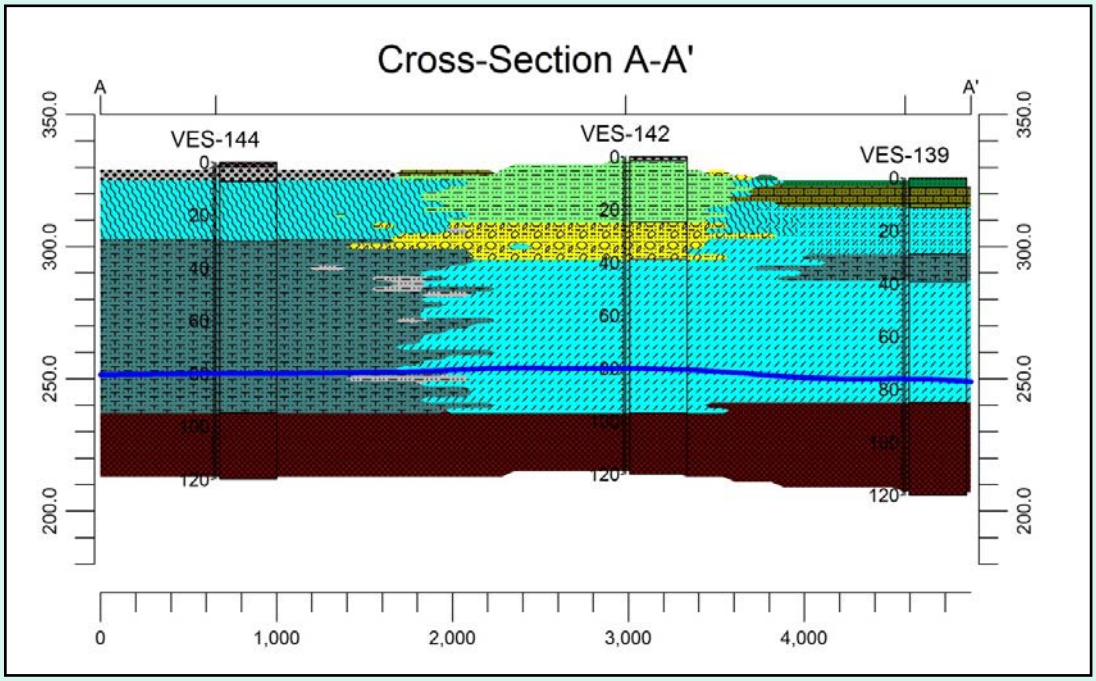

Figure 50: Cross Section A-A′ passes through VES (144), VES (142) and VES(139).

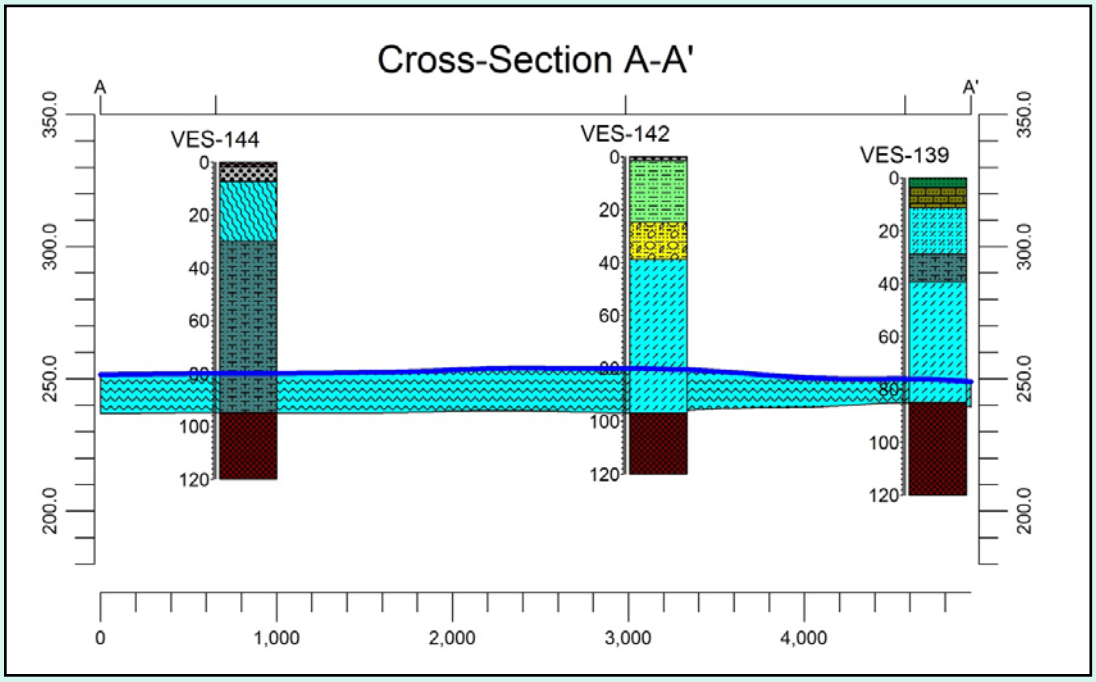

Figure 51: Saturated aquifer thickness along cross section A-A′.

Cross Section B-B′ :

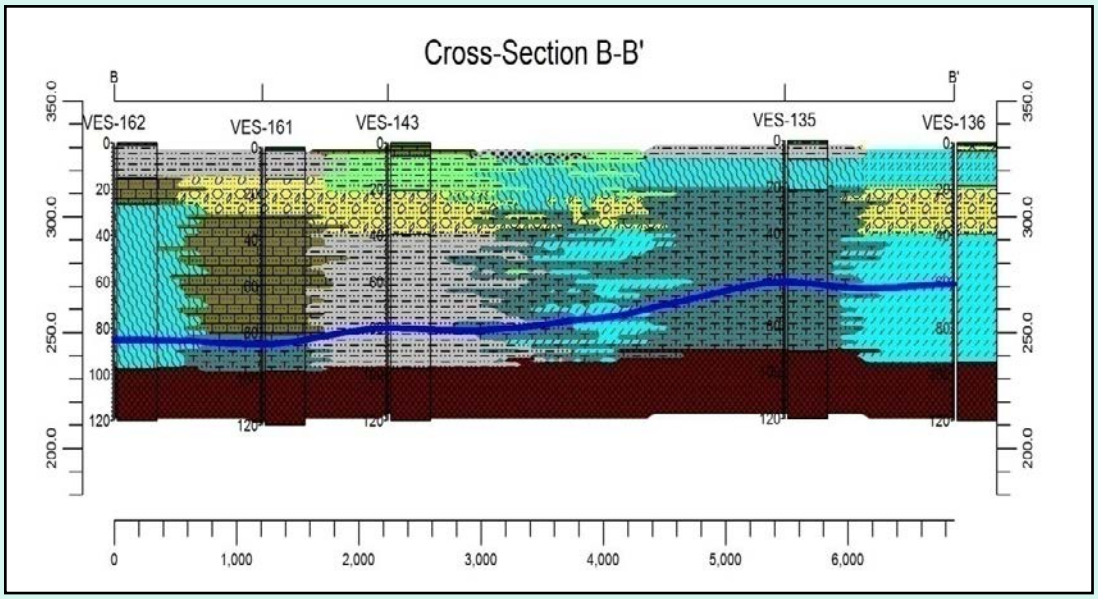

Figure 52: Cross Section B-B′ passes through VES(162), VES(161),VES(143), VES(135) and VES(136).

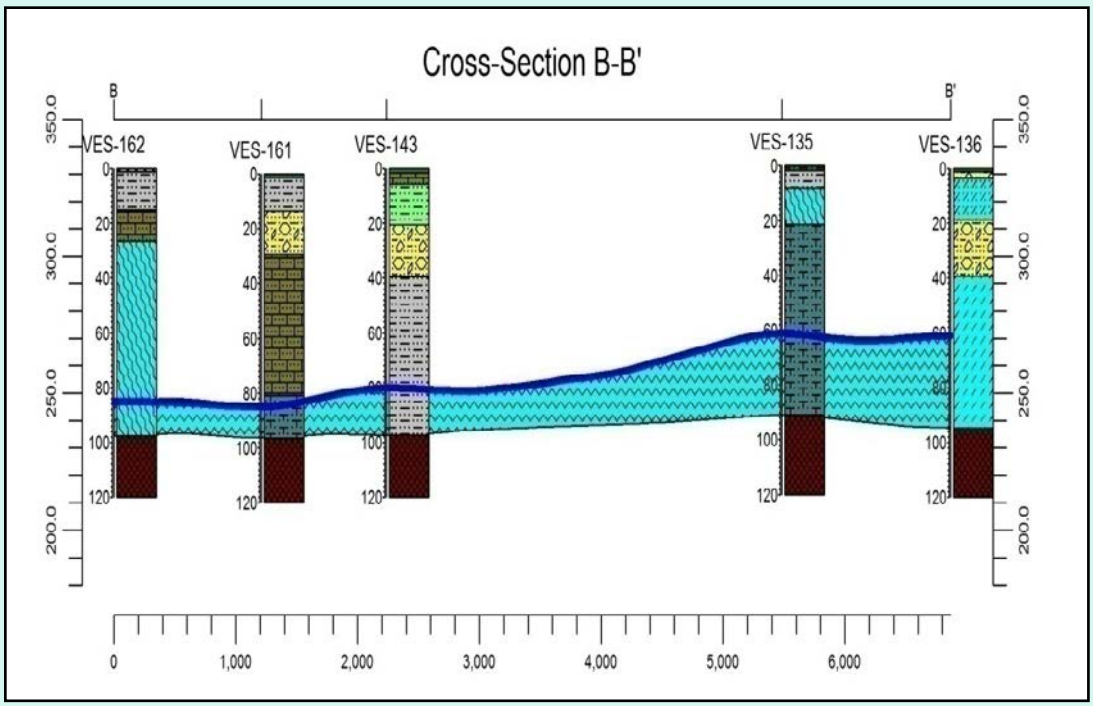

Figure 53: Saturated aquifer thickness along cross section B-B′.

Cross Section C-C′ :

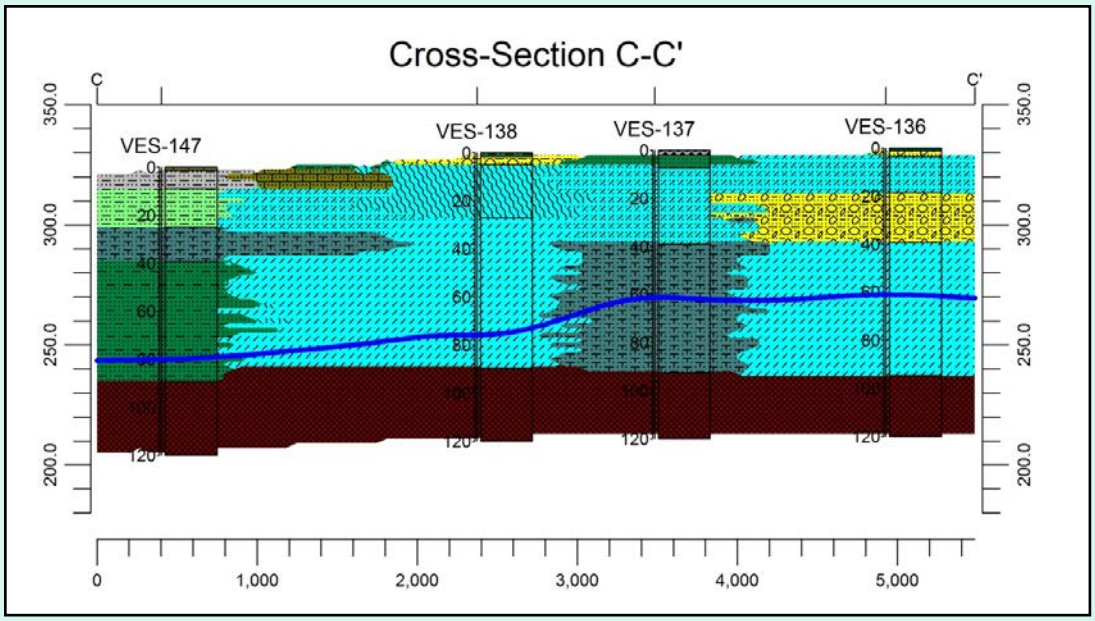

Figure 54: Cross Section C-C′ passes through VES(147), VES(138), VES(137) and VES(136).

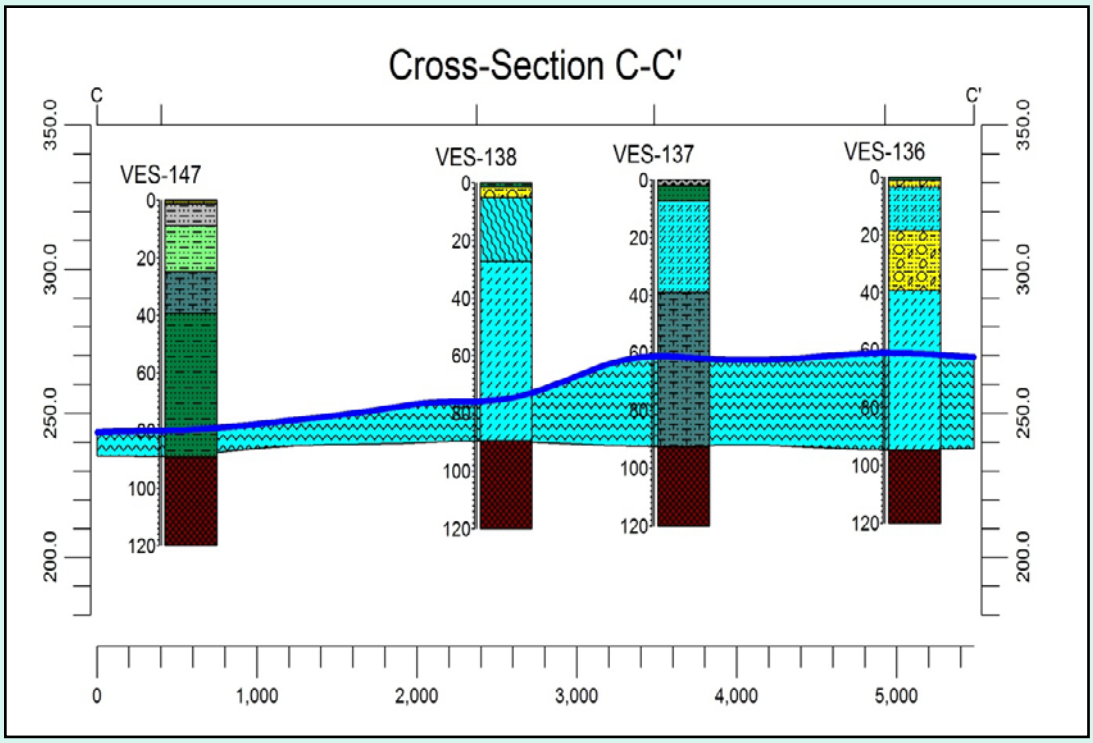

Figure 55: Saturated aquifer thickness along cross section C-C′.

Cross Section D-D′ :

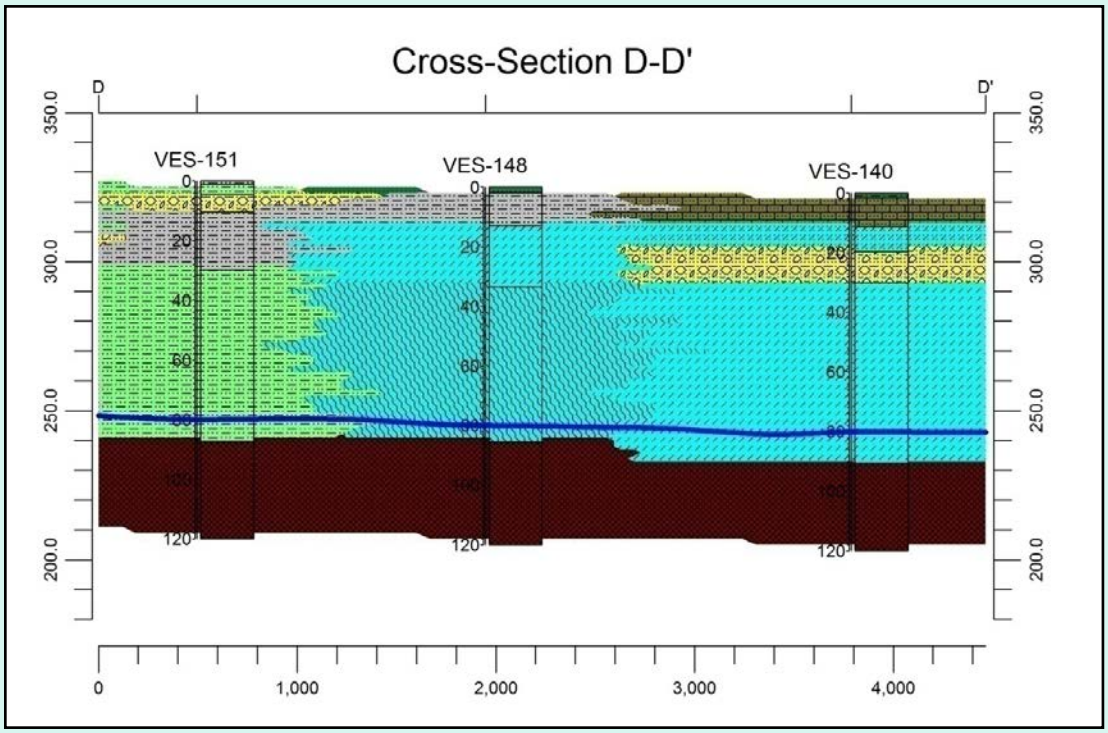

Figure 56: Cross Section D-D′ passes through VES (151), VES (148) and VES (140).

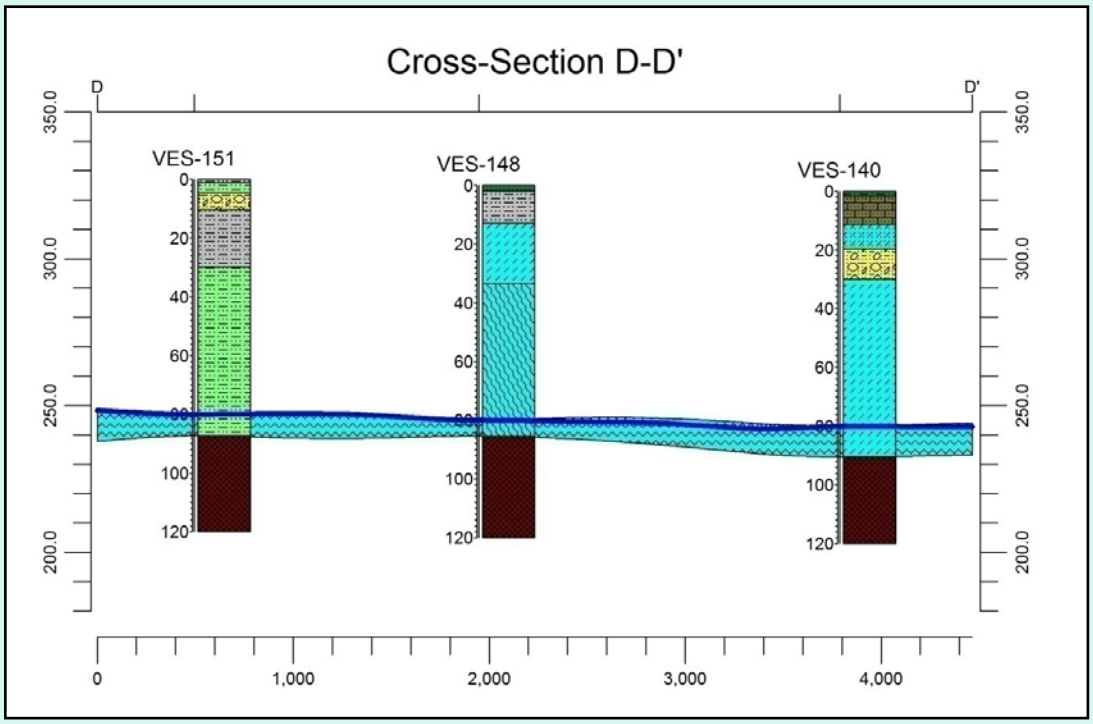

Figure 57: Saturated aquifer thickness along cross section D-D′.

Cross Section E-E′ :

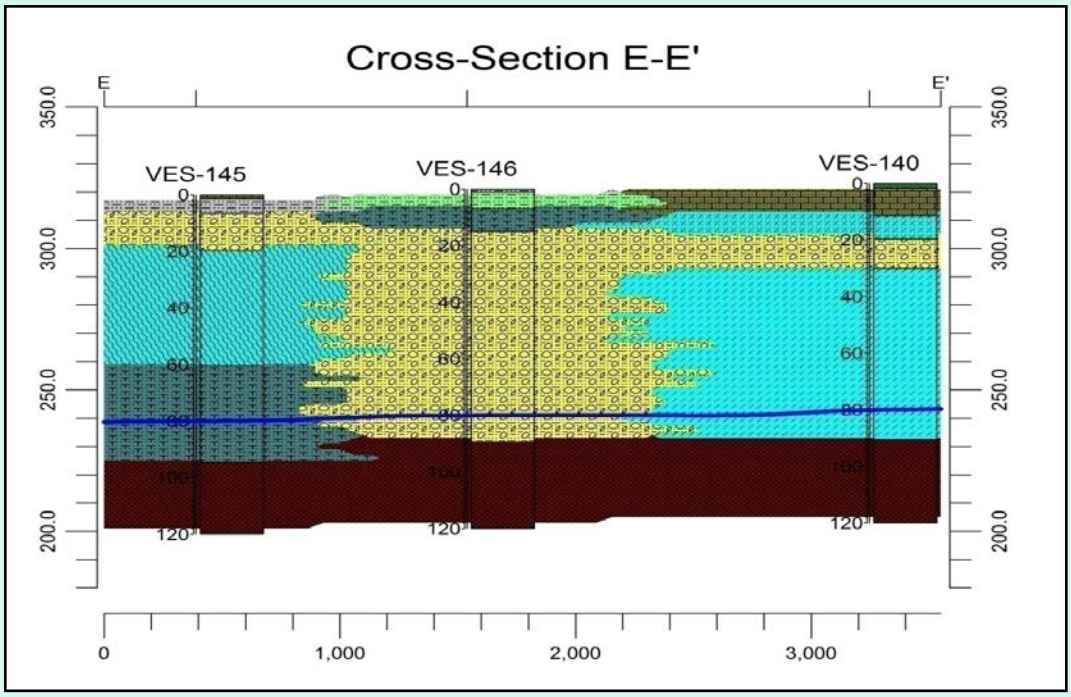

Figure 58: Cross Section E-E′ passes through VES (145), VES (146) and VES (140).

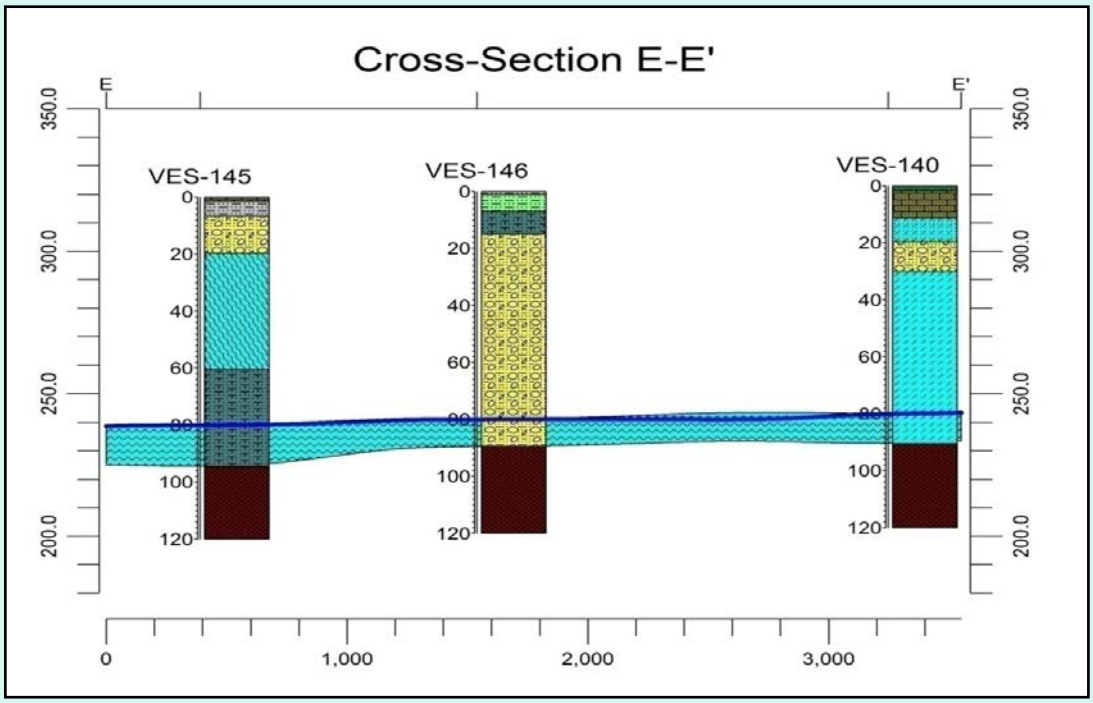

Figure 59: Saturated aquifer thickness along cross section E-E′.

Cross Section F-F′ :

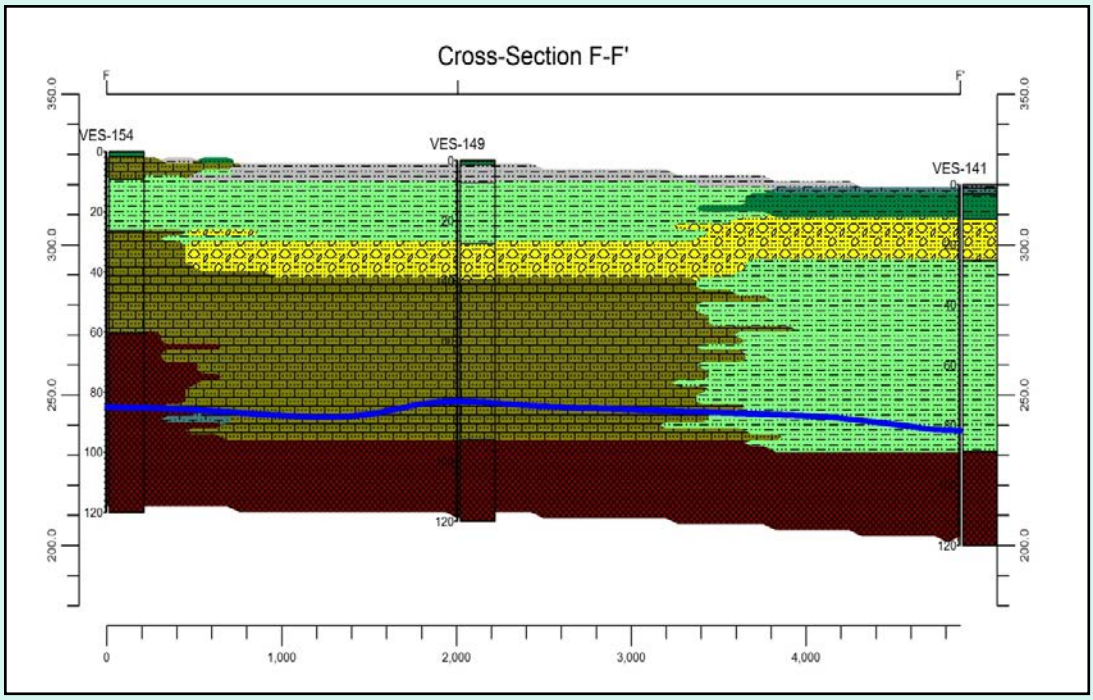

Figure 60: Cross Section F-F′ passes through VES (154), VES (149) and VES (141).

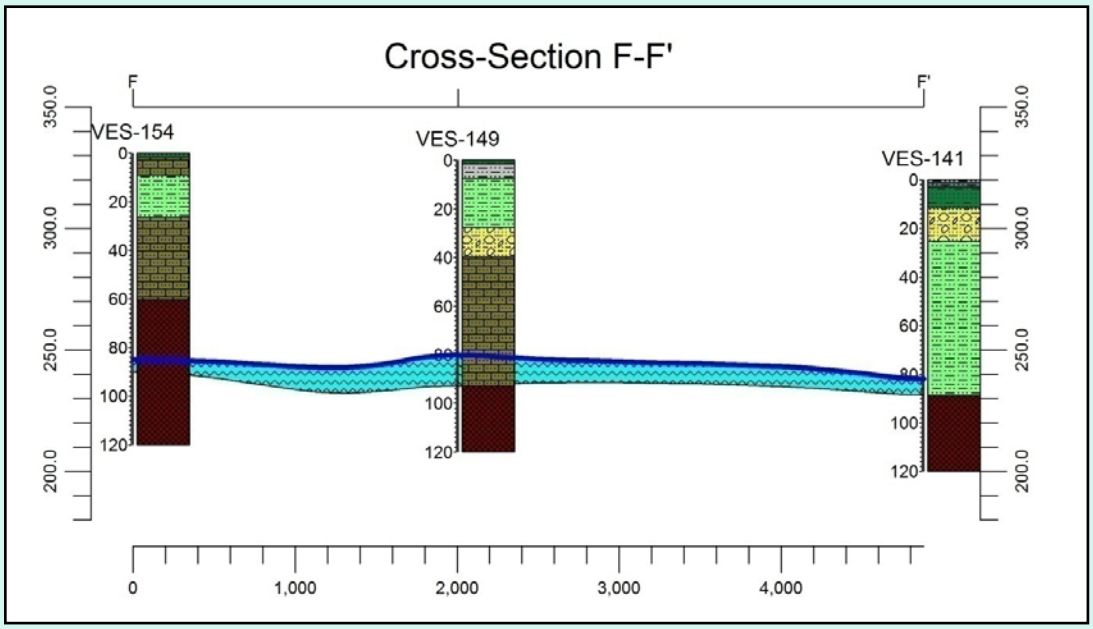

Figure 61: Saturated aquifer thickness along cross section F-F′.

Cross Section G-G′ :

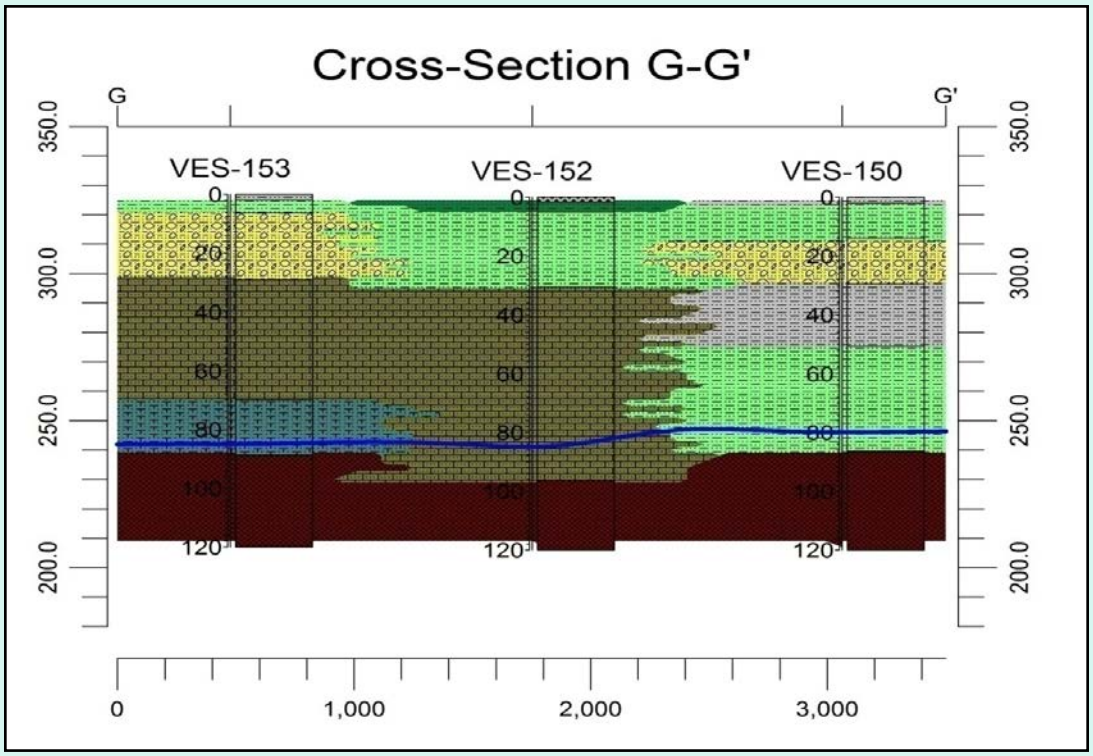

Figure 62: Cross Section G-G′ passes through VES (153), VES (152) and VES (150)

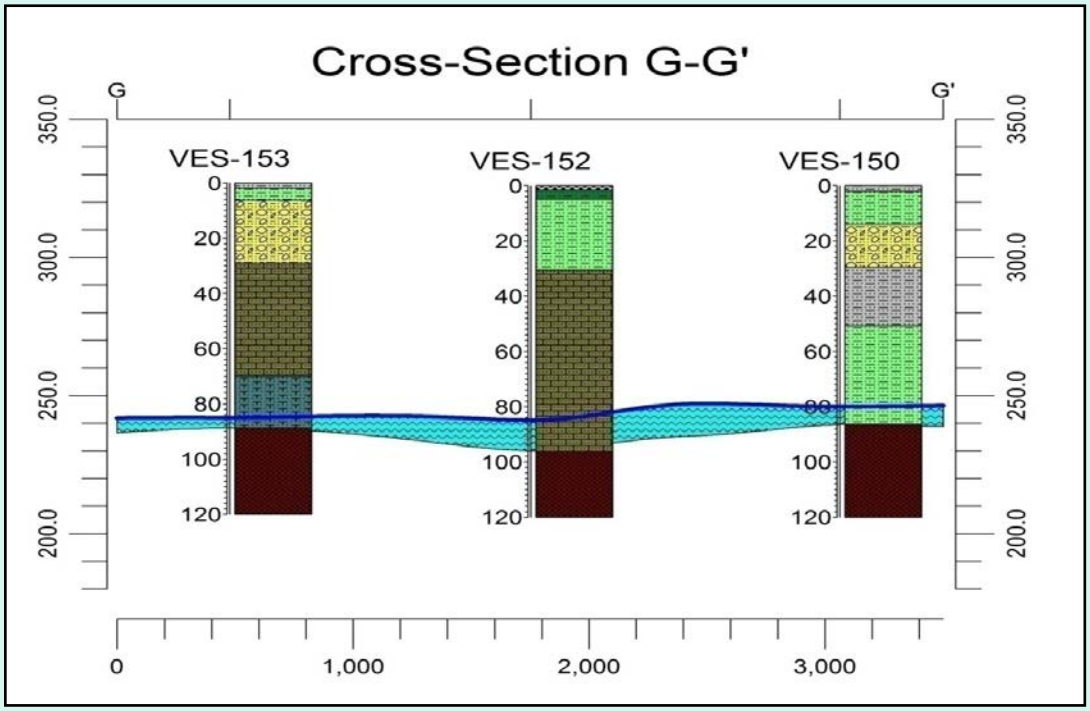

Figure 63: Saturated aquifer thickness along cross section G-G′.

Cross Section H-H′ :

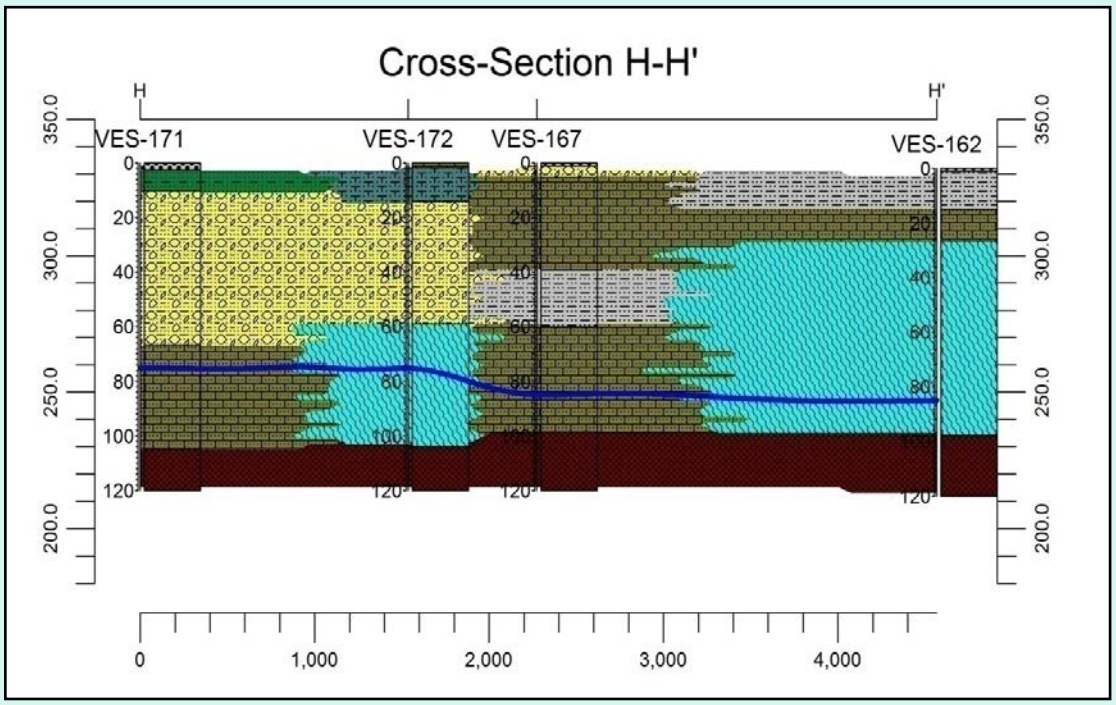

Figure 64: Cross Section H-H′ passes through VES (171), VES (172), VES (167) and VES (162).

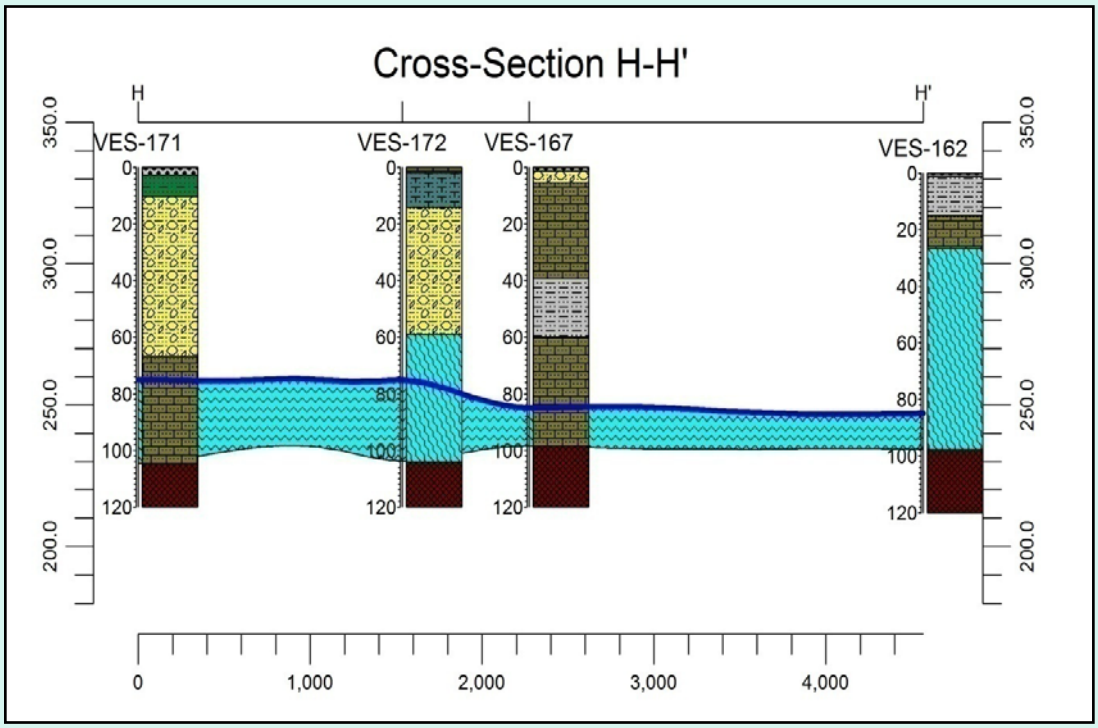

Figure 65: Saturated aquifer thickness along cross section H-H′.

Cross Section I-I′:

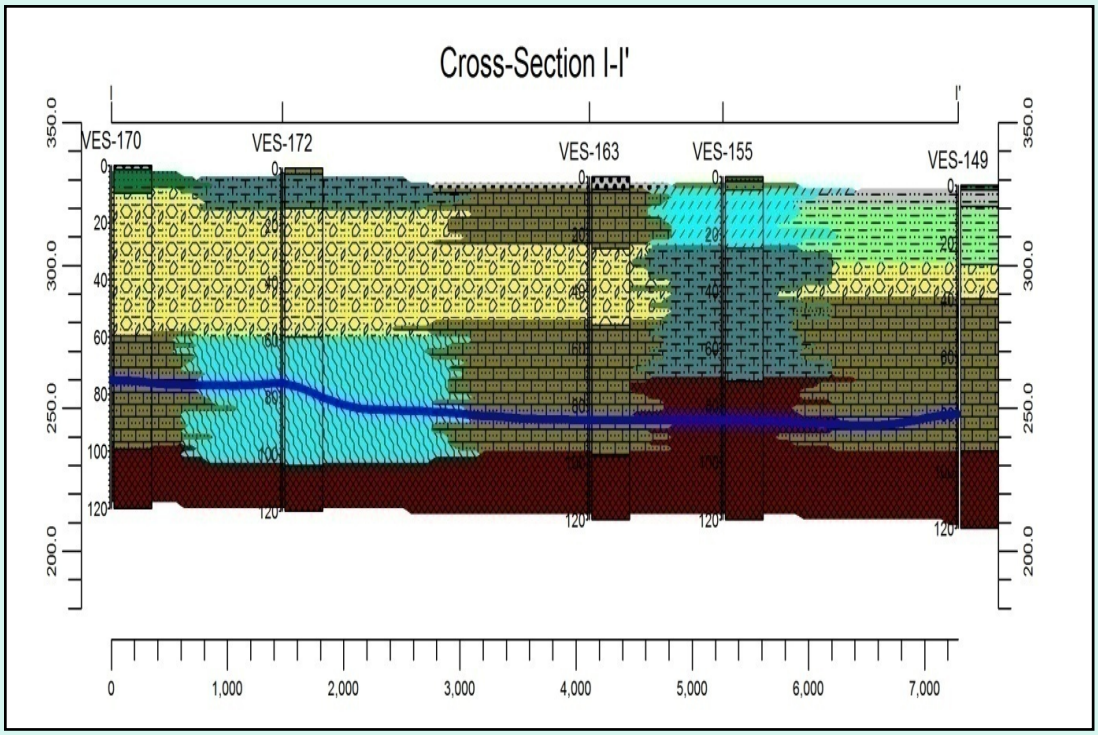

Figure 66: Cross Section I-I′ passes through VES (170), VES (172), VES (163), VES (155) and VES (149).

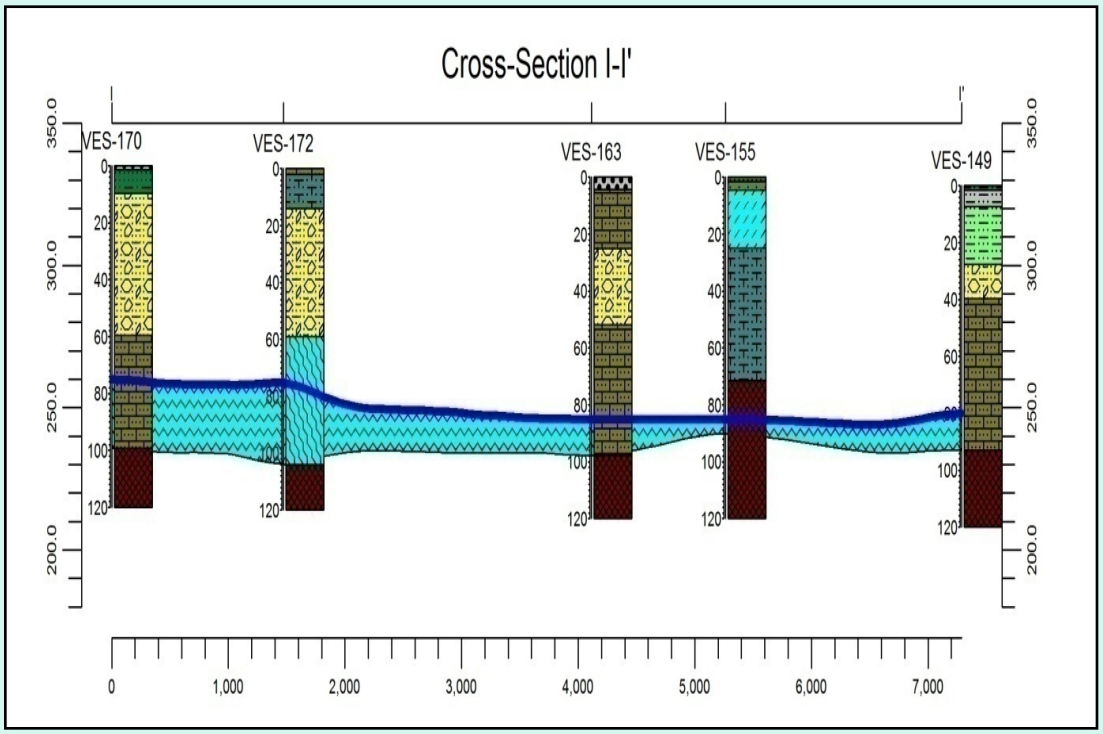

Figure 67: Saturated aquifer thickness along cross section I-I′.

Cross Section J-J′ :

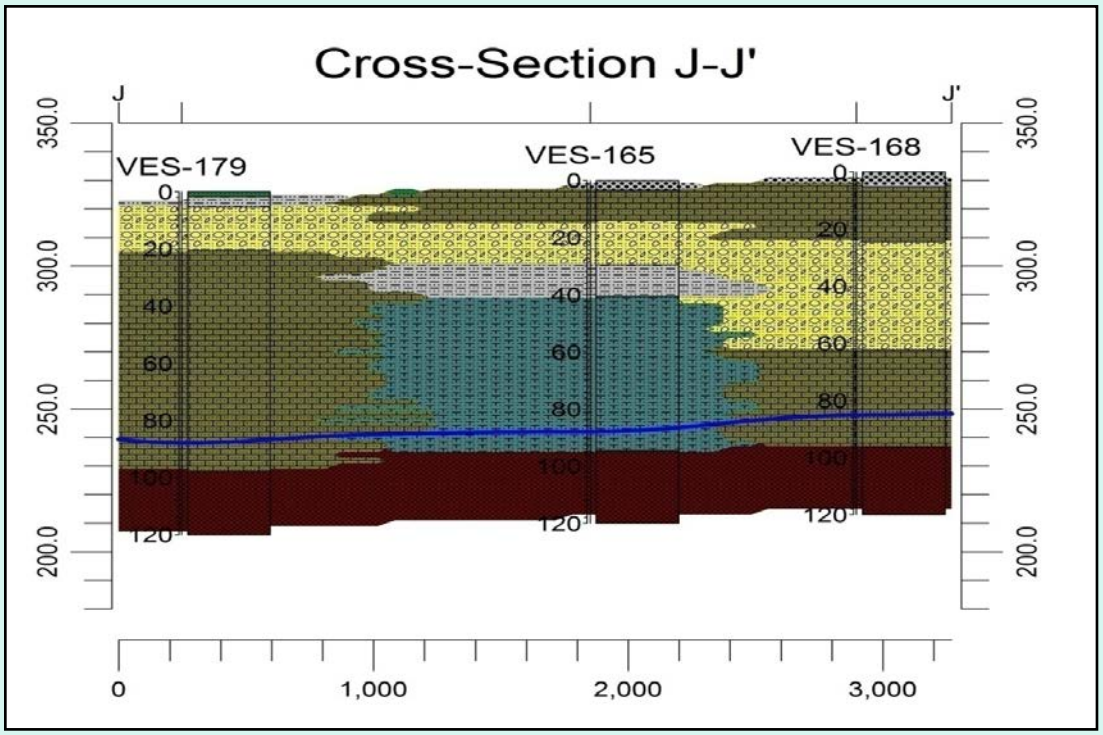

Figure 68: Cross Section J-J′ passes through VES (179), VES (165) and VES (168).

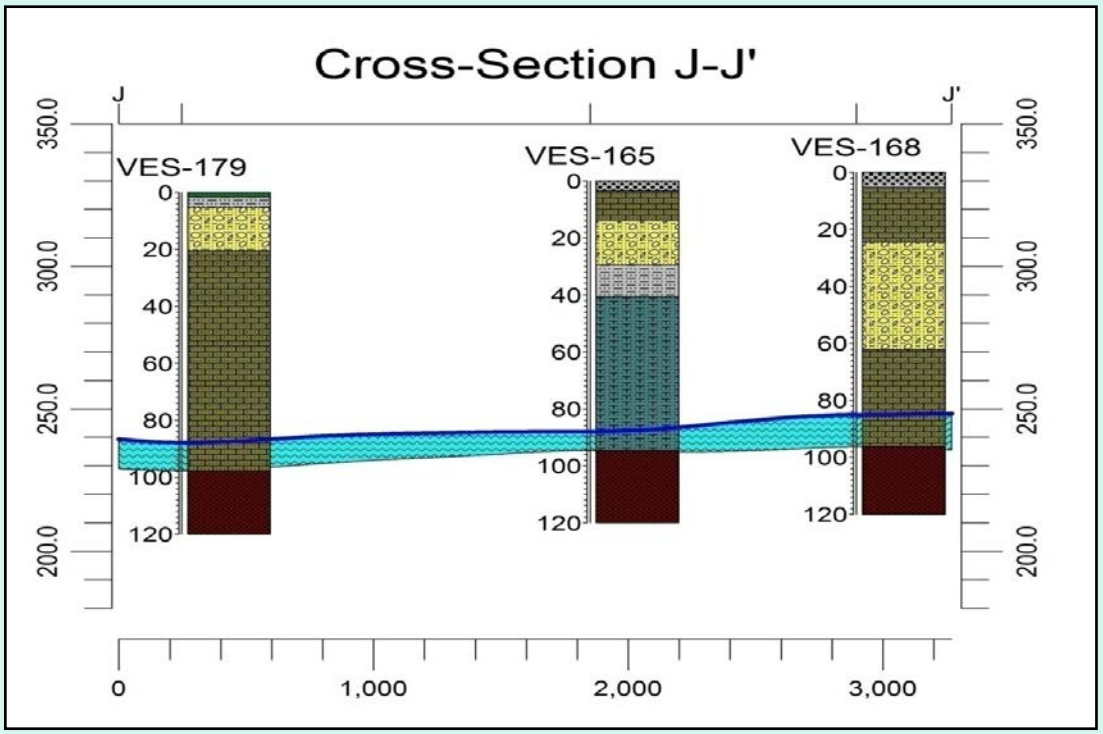

Figure 69: Saturated aquifer thickness along cross section J-J′.

Cross Section K-K′:

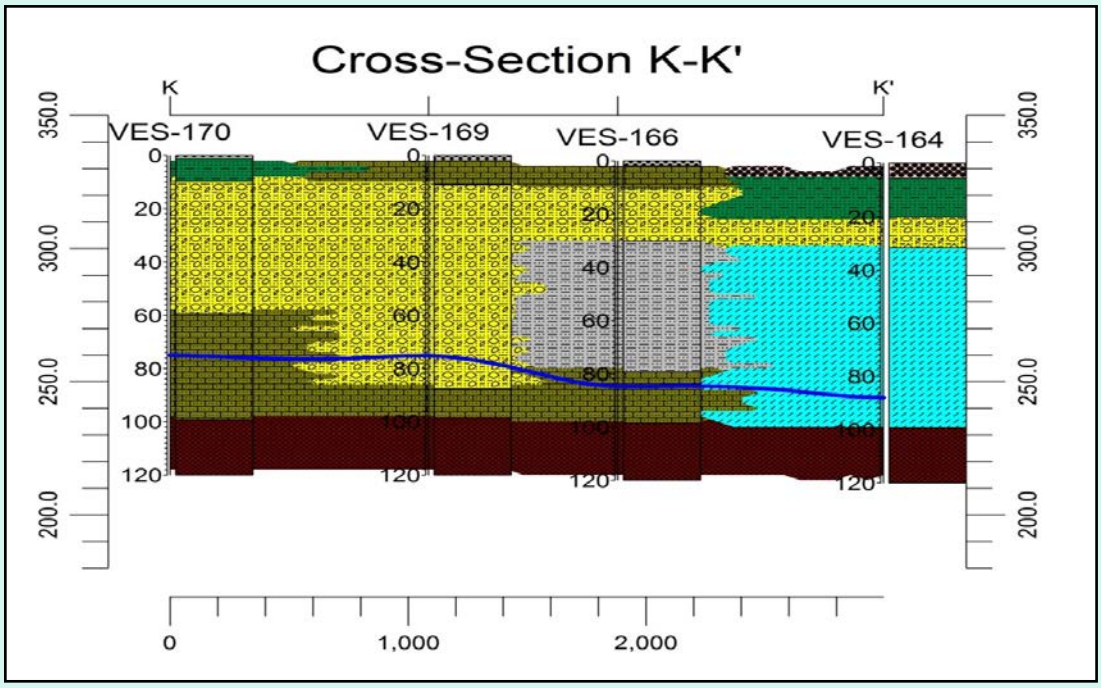

Figure 70: Cross Section K-K′ passes through VES (170), VES (169), VES (166) and VES (164).

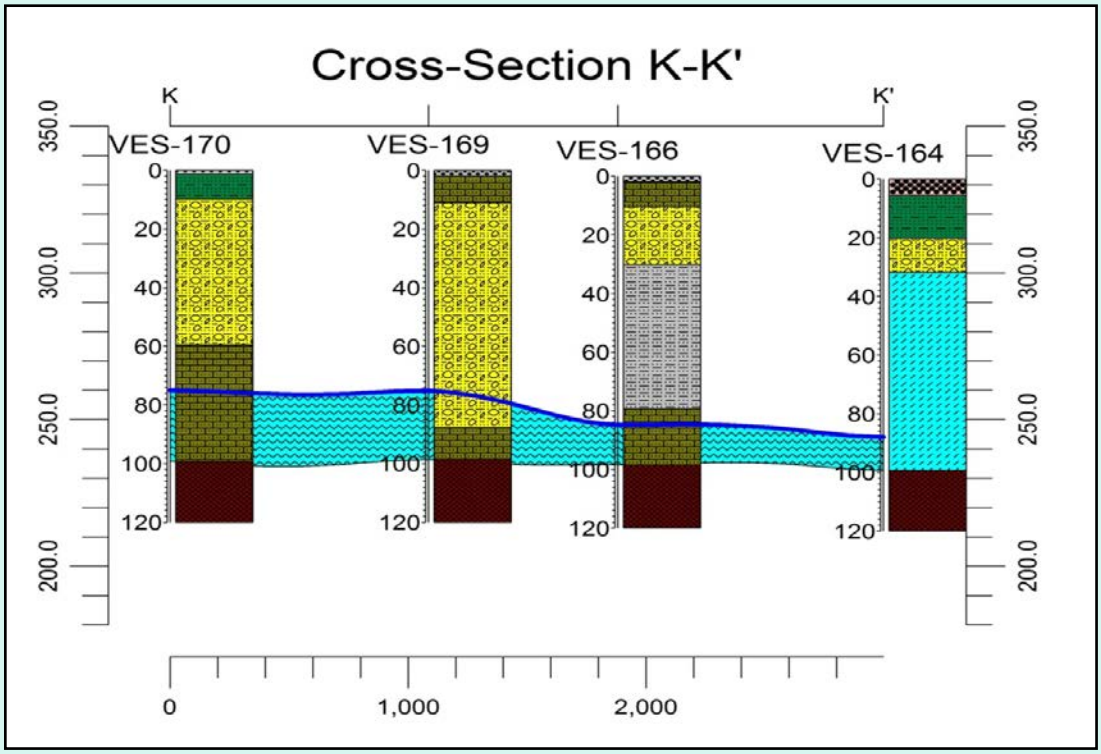

Figure 71: Saturated aquifer thickness along cross section K-K′.

Cross Section L-L′ :

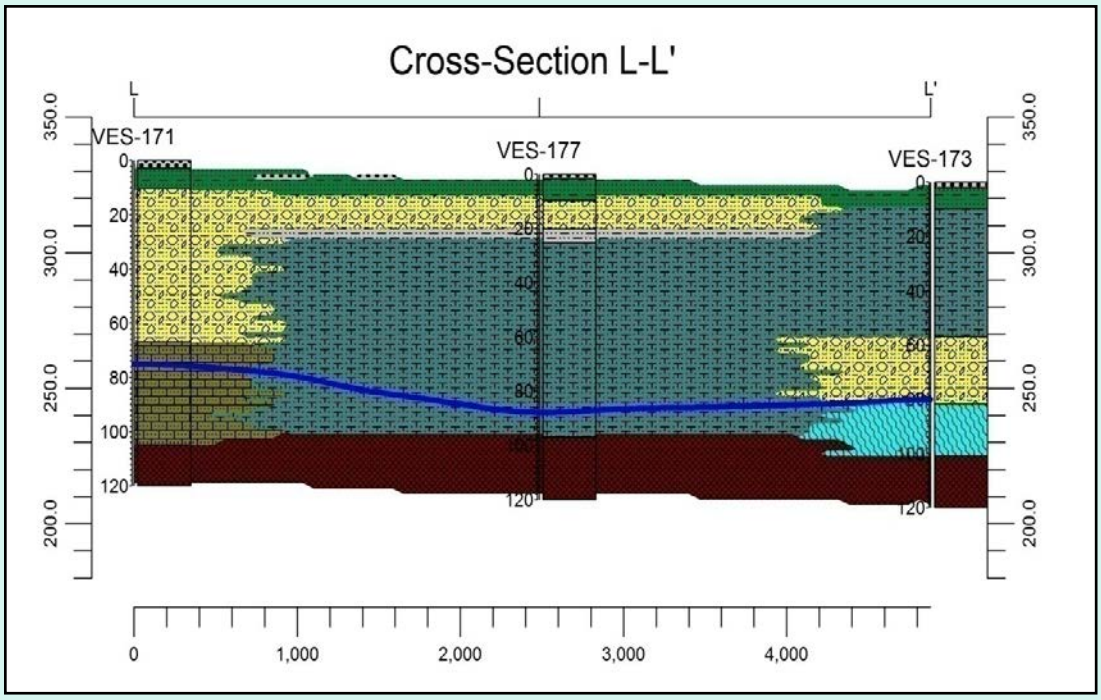

Figure 72: Cross Section L-L′ passes through VES (171), VES (177) and VES (173).

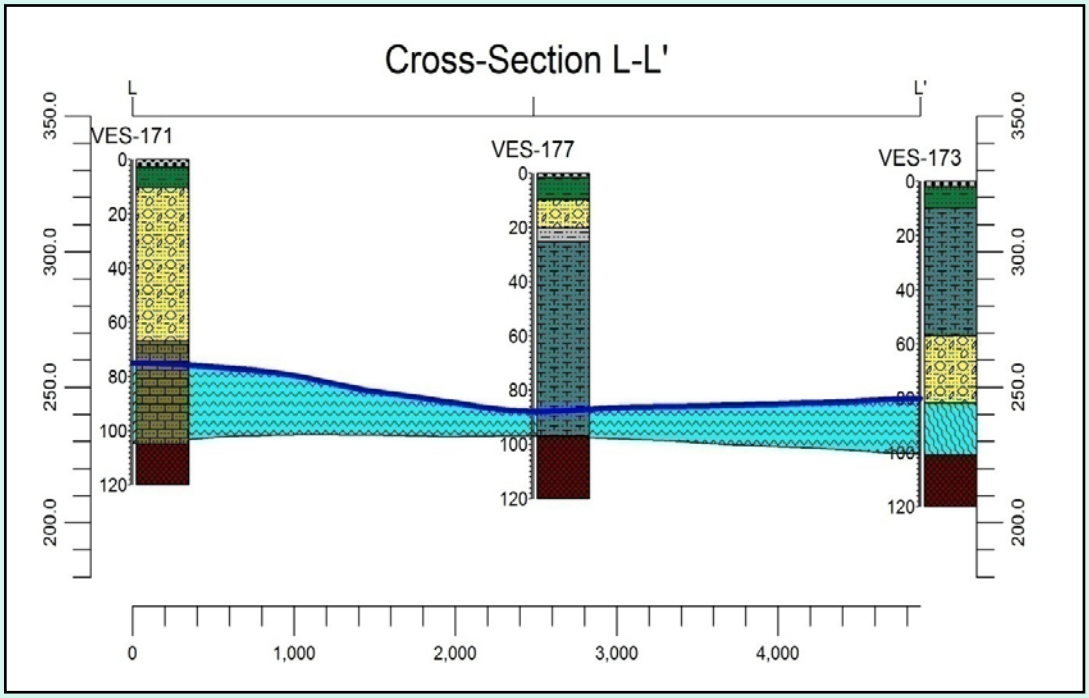

Figure 73: Saturated aquifer thickness along cross section L-L′.

Cross Section M-M′:

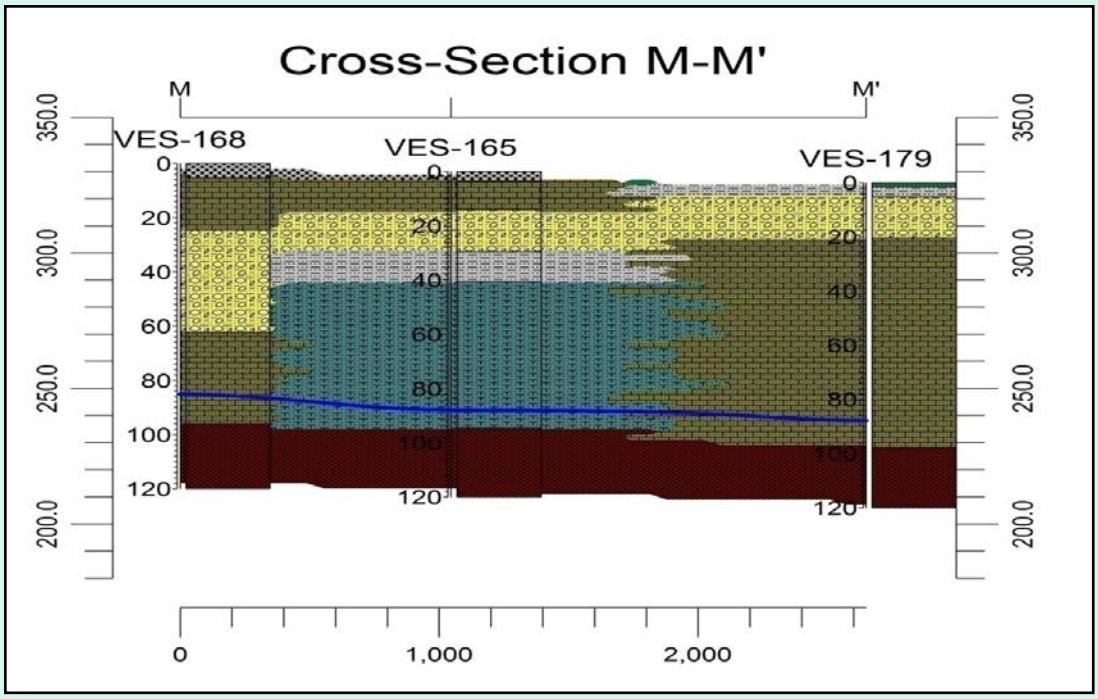

Figure 74: Cross Section M-M′ passes through VES (168), VES (165) and VES (179).

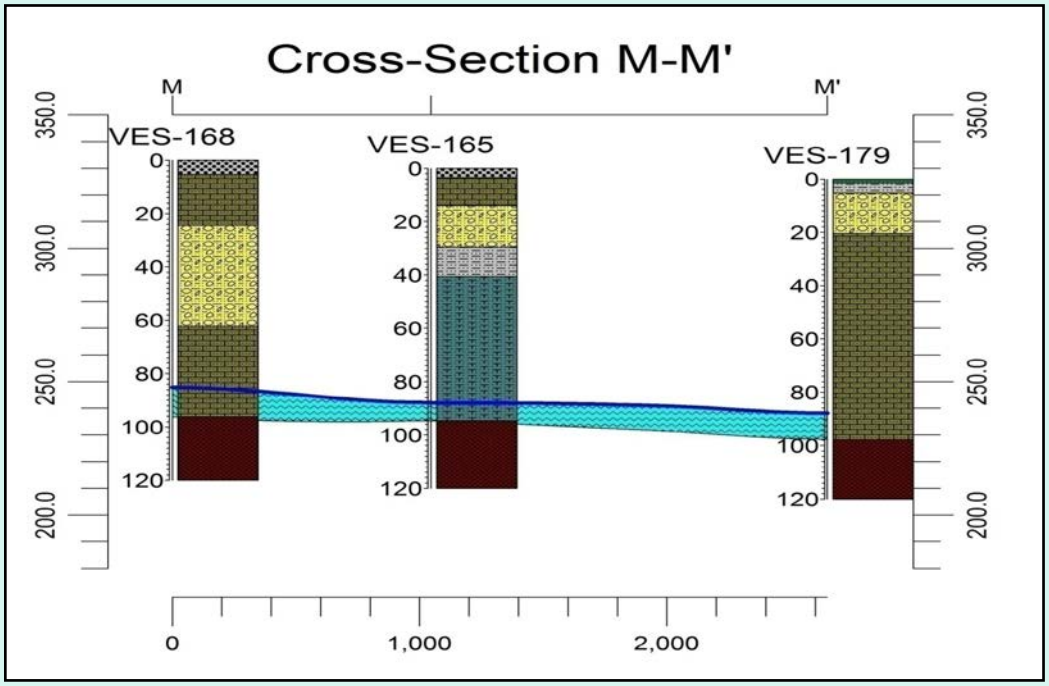

Figure 75: Saturated aquifer thickness along cross section M-M′.

Cross Section N-N′:

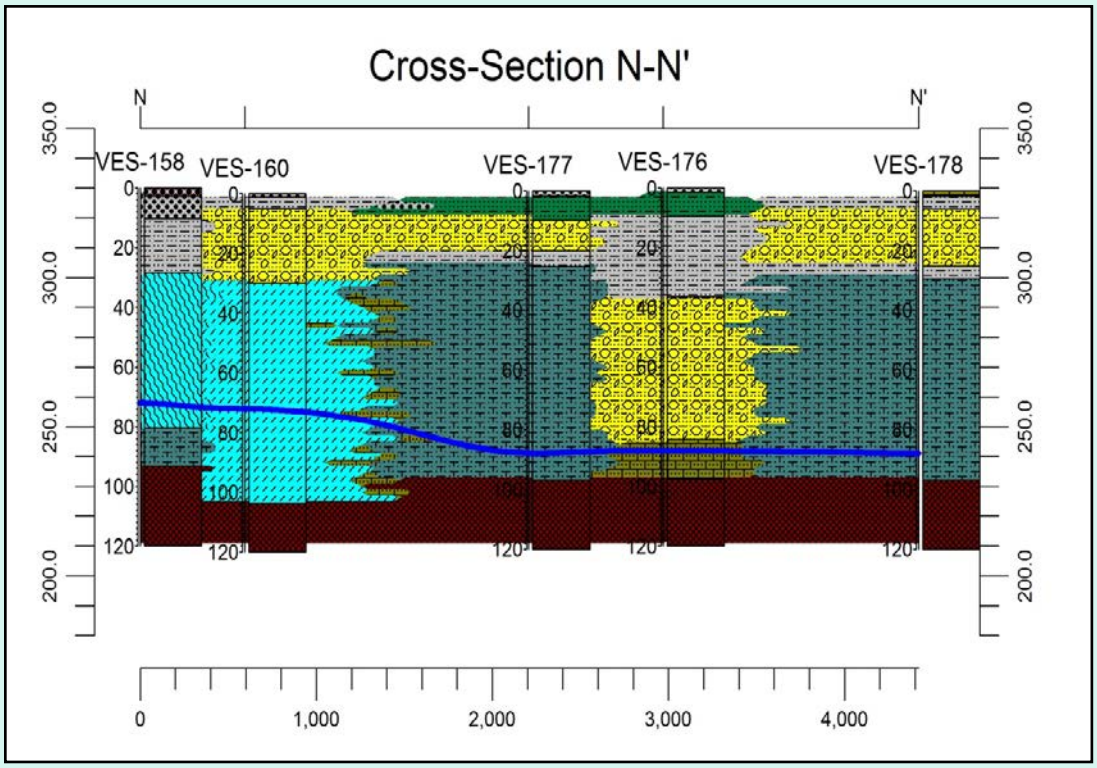

Figure 76: Cross Section N-N′ passes through VES (158), VES (160), VES (177), VES (176) and VES (178).

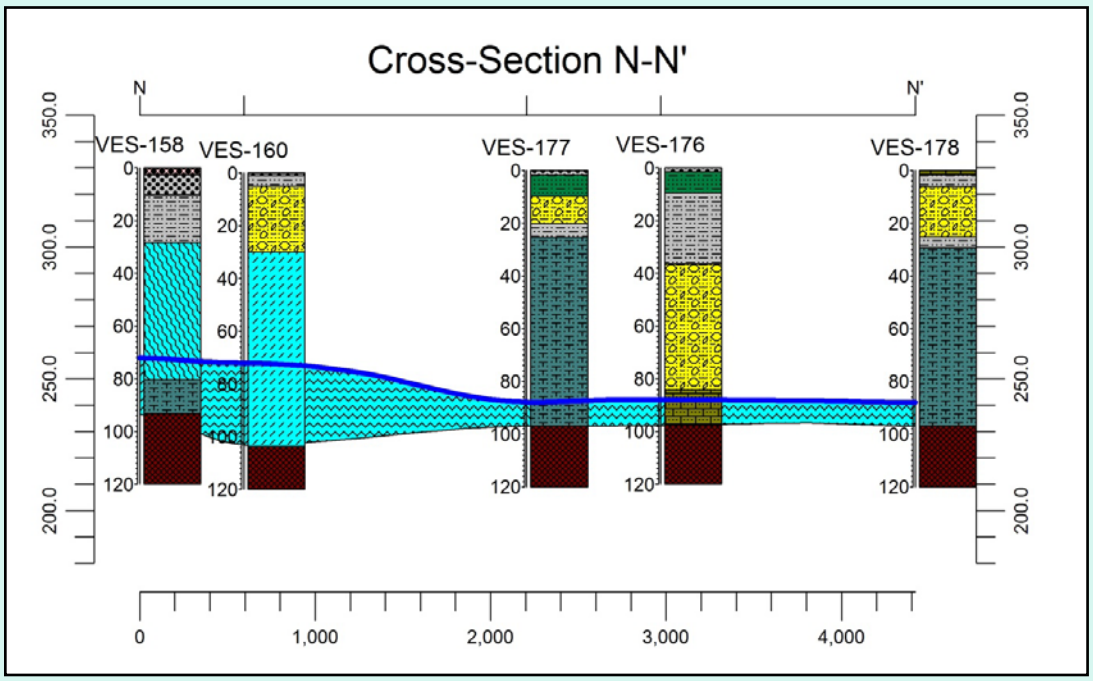

Figure 77: Saturated aquifer thickness along cross section N-N′.

Cross Section O-O′ :

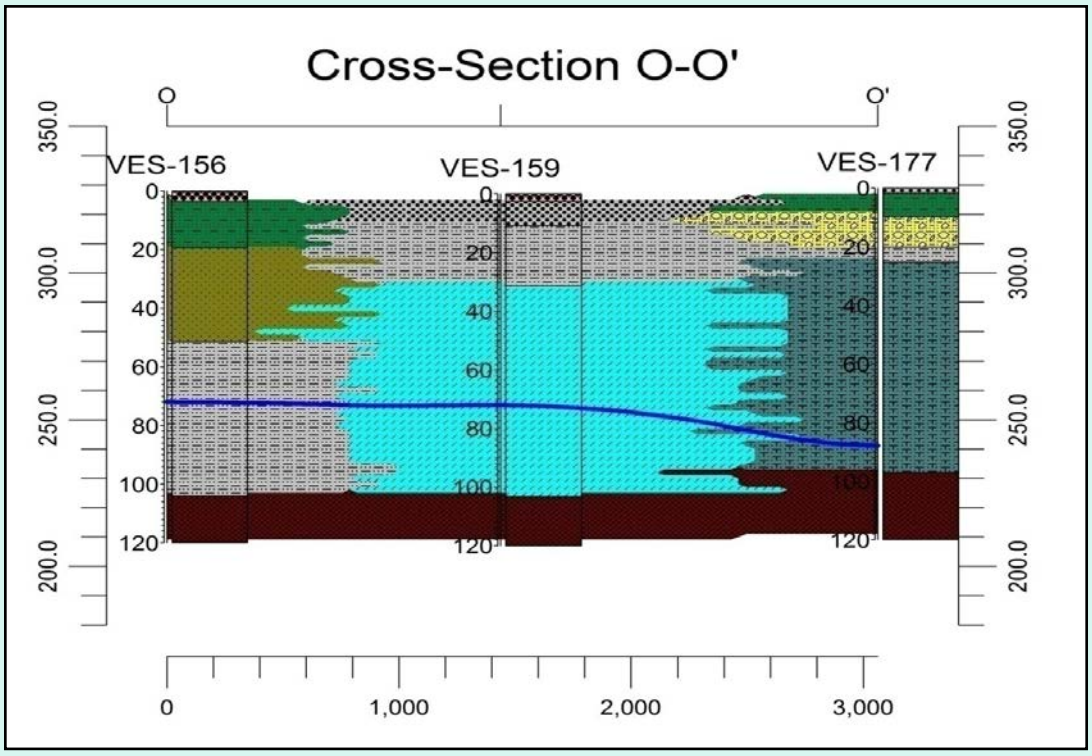

Figure 78: Cross Section O-O′ passes through VES (156), VES (159) and VES (177).

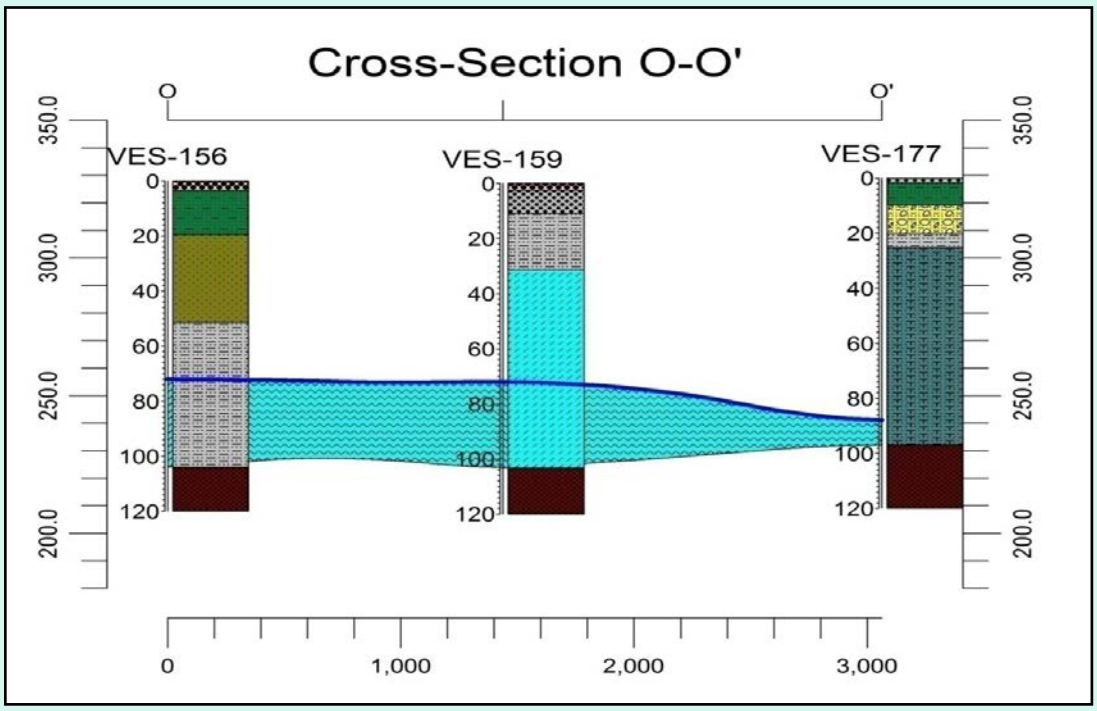

Figure 79: Saturated aquifer thickness along cross section O-O′.

Cross Section P-P′ :

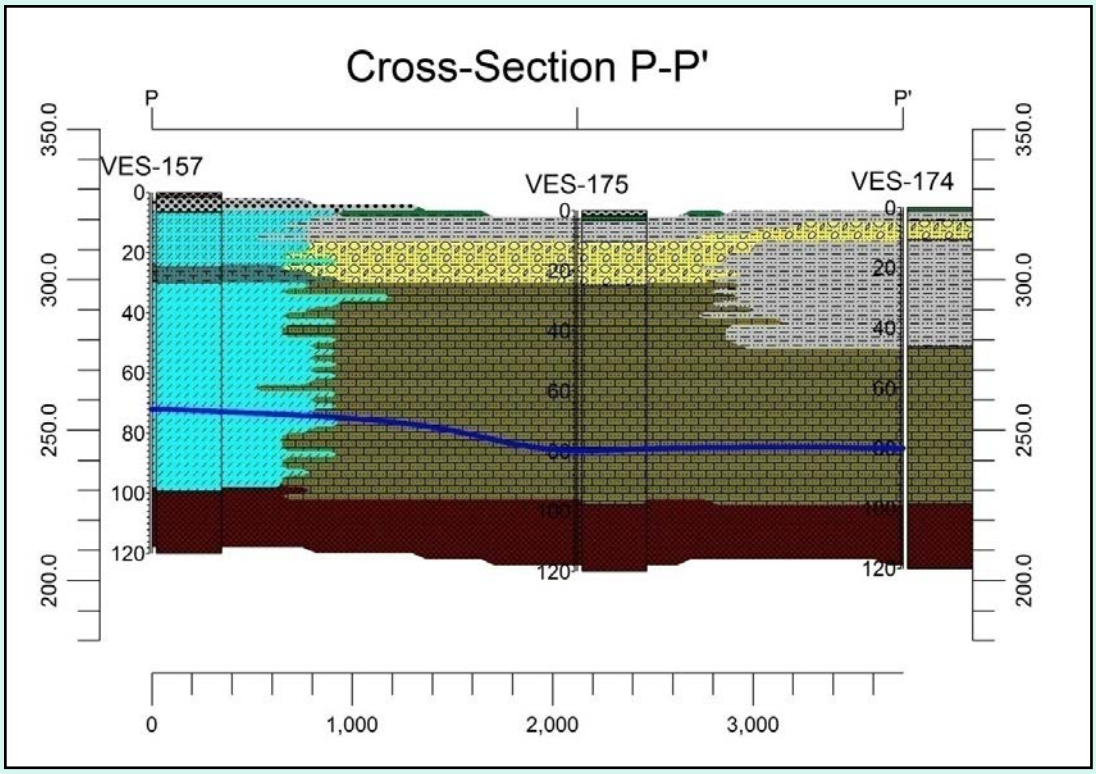

Figure 80: Cross Section P-P′ passes through VES (157), VES (175) and VES (174).

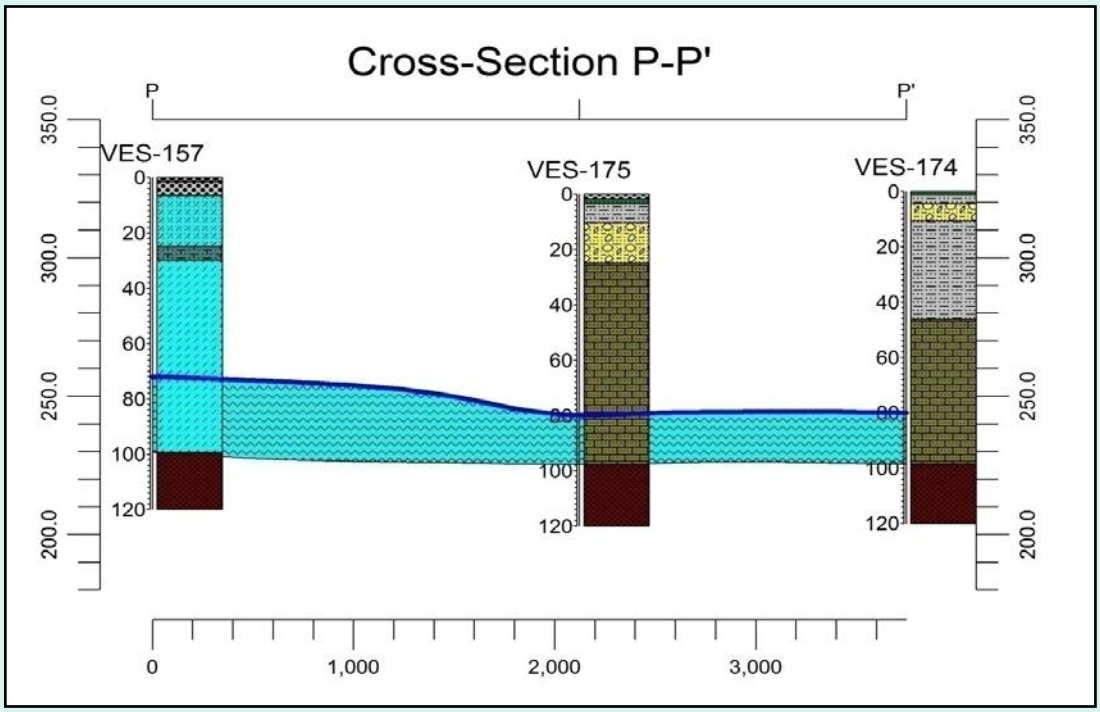

Figure 81: Saturated aquifer thickness along cross section P-P′.

Cross Section Q-Q′ :

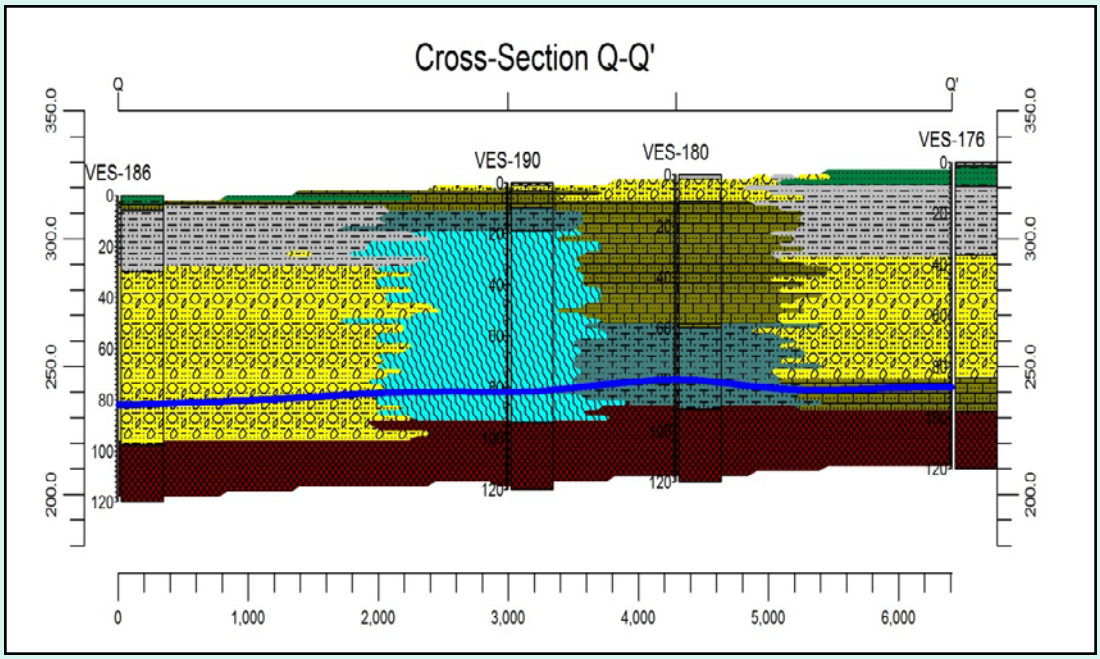

Figure 82: Cross Section Q-Q′ passes through VES (186), VES (190), VES (180) and VES (176).

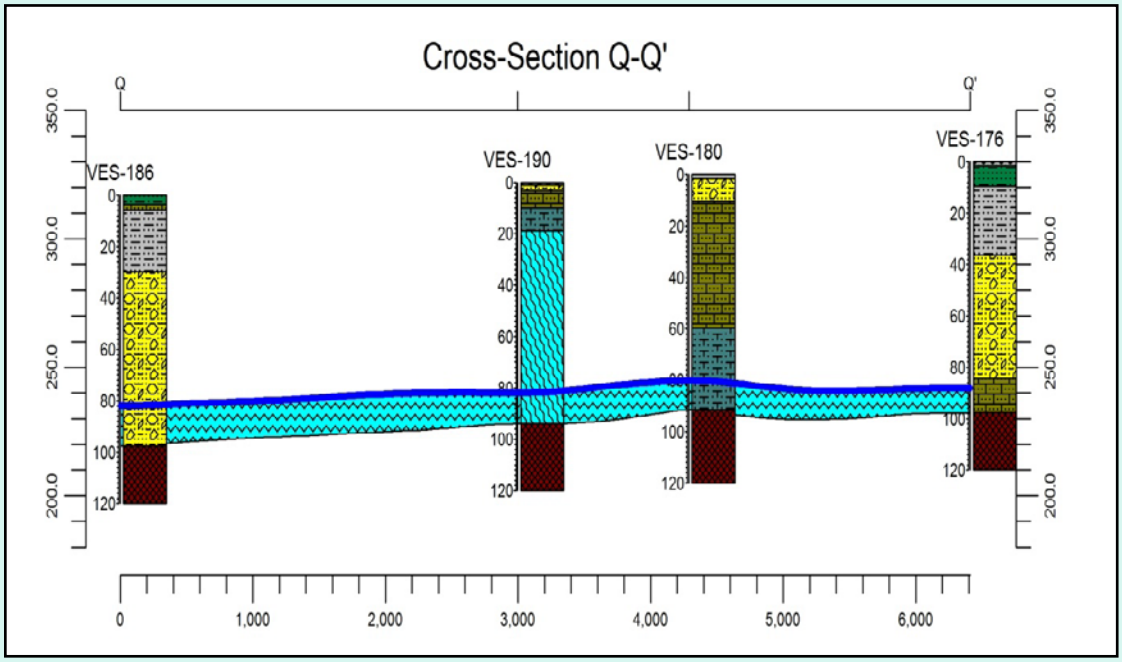

Figure 83: Saturated aquifer thickness along cross section Q-Q′.

Cross Section R-R′:

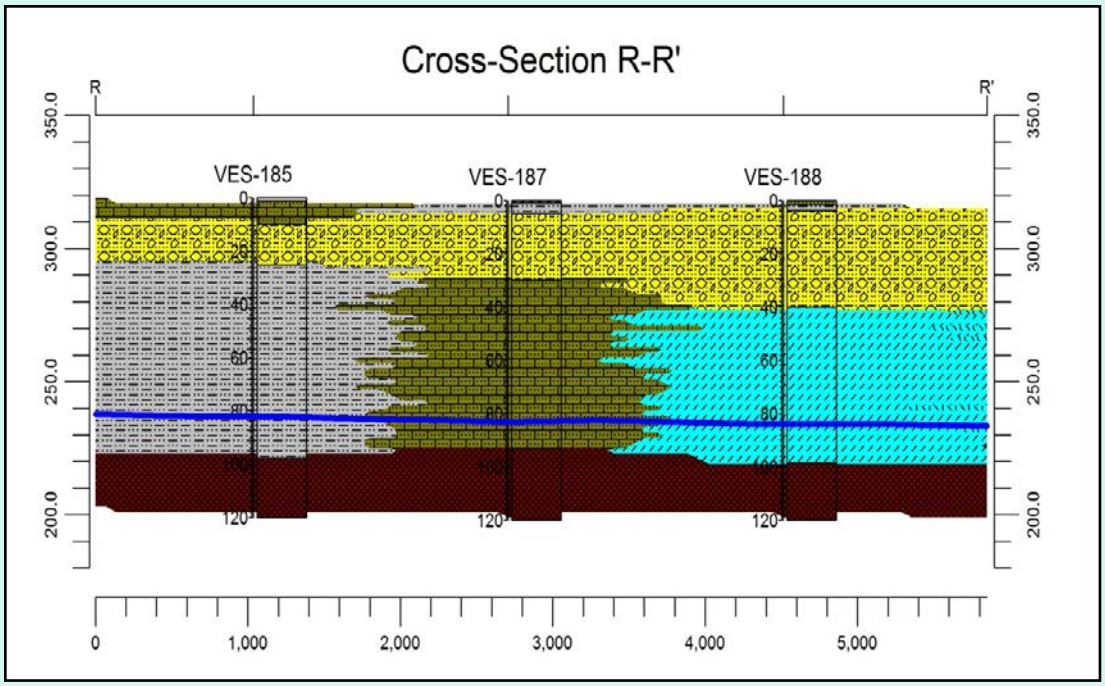

Figure 84: Cross Section R-R′ passes through VES (185), VES (187) and VES (188).

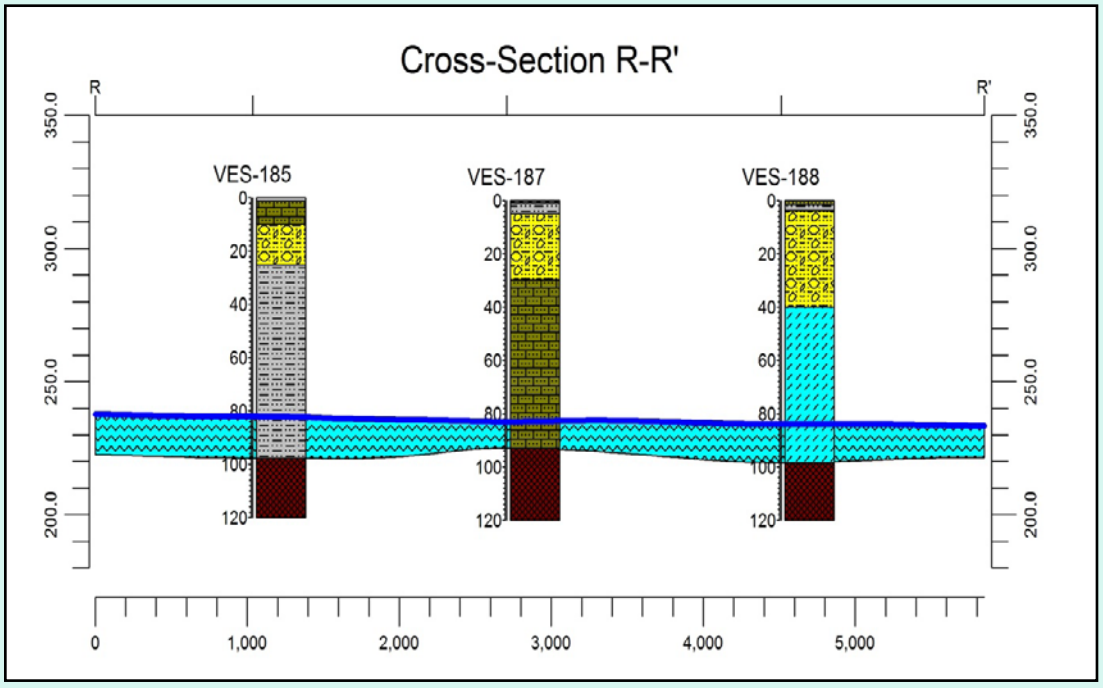

Figure 85: Saturated aquifer thickness along cross section R-R′.

Cross Section S-S′:

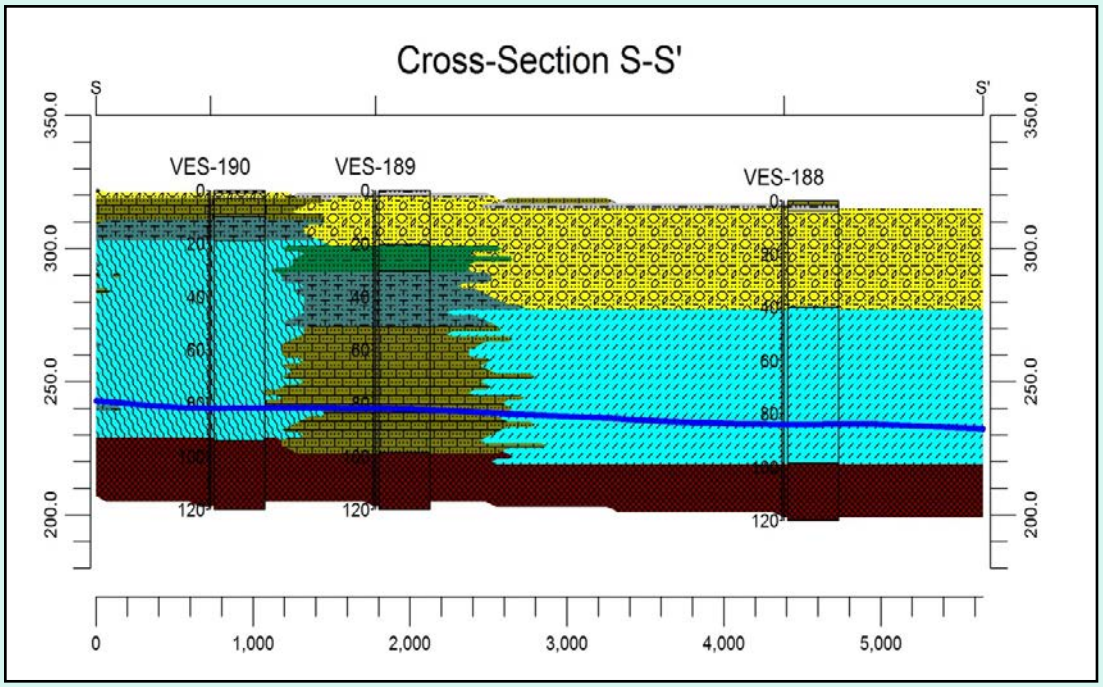

Figure 86: Cross Section S-S′ passes through VES (190), VES (189) and VES (188).

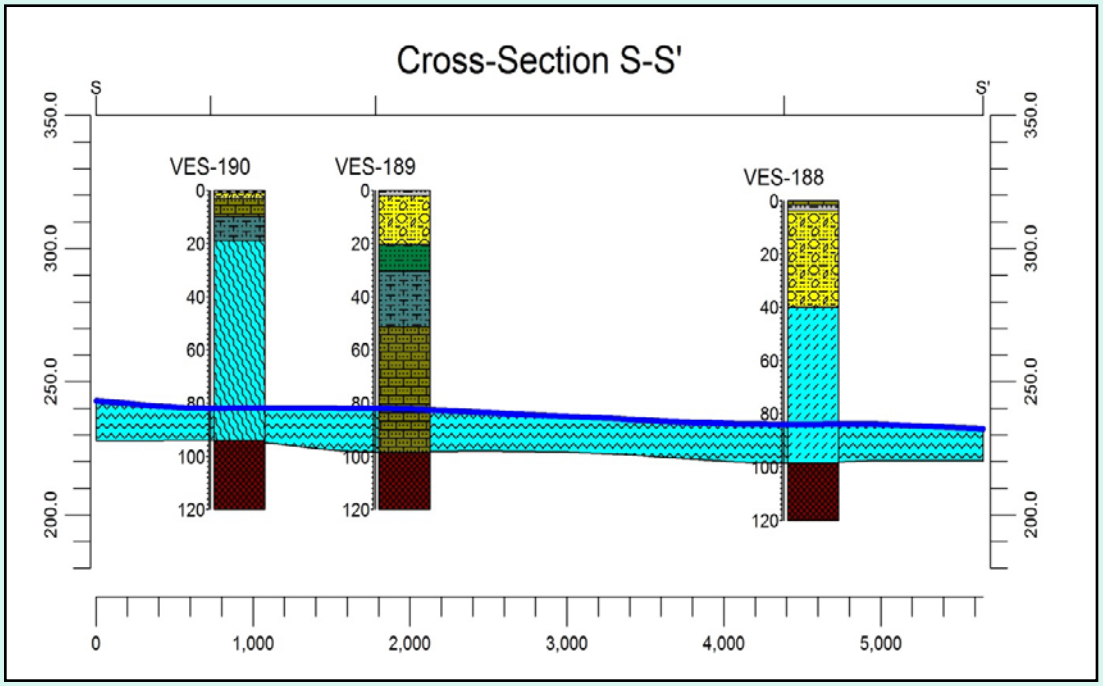

Figure 87: Saturated aquifer thickness along cross section S-S′.

Cross Section T-T′:

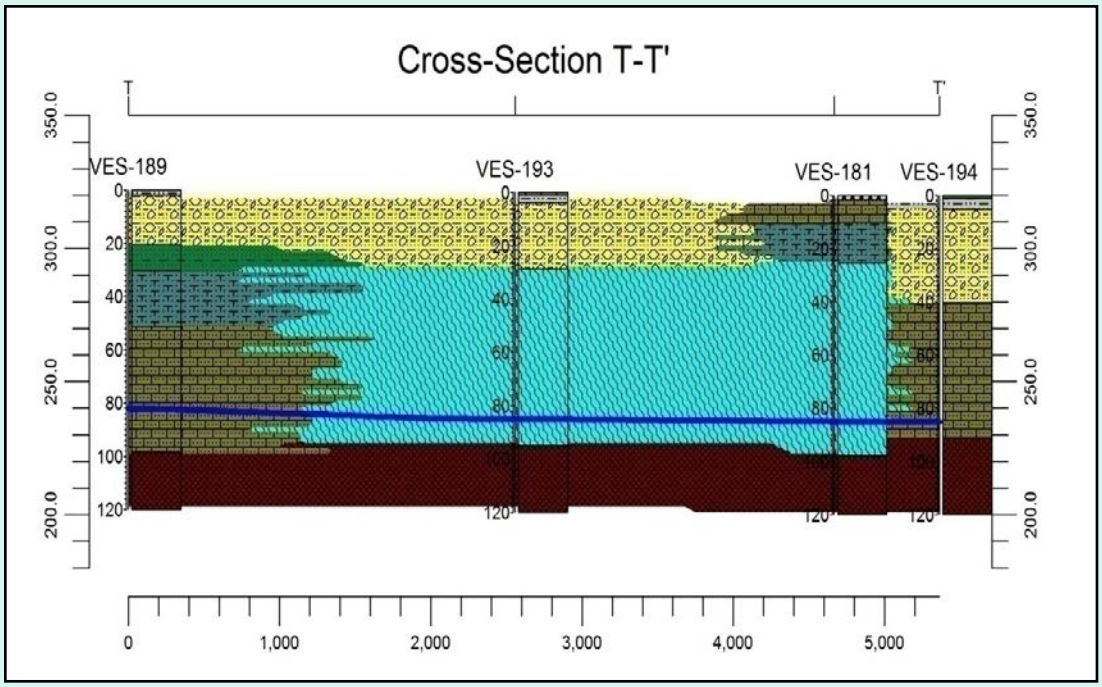

Figure 88: Cross Section T-T′ passes through VES (189), VES (193), VES (181) and VES (194).

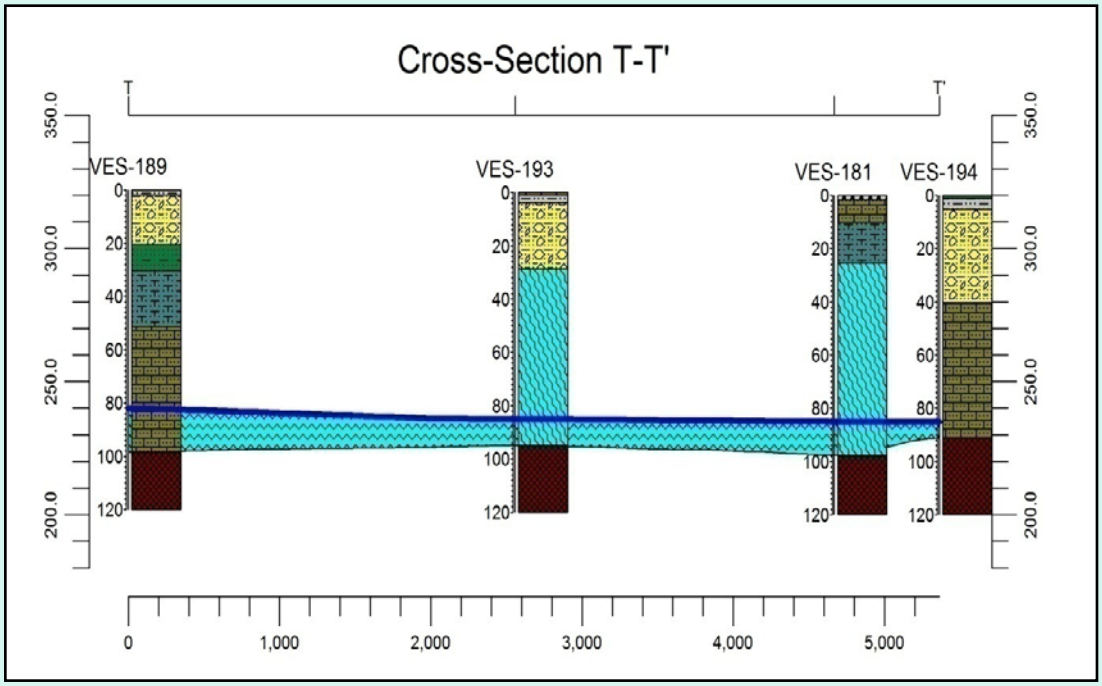

Figure 89: Saturated aquifer thickness along cross section T-T′.

Cross Section U-U′:

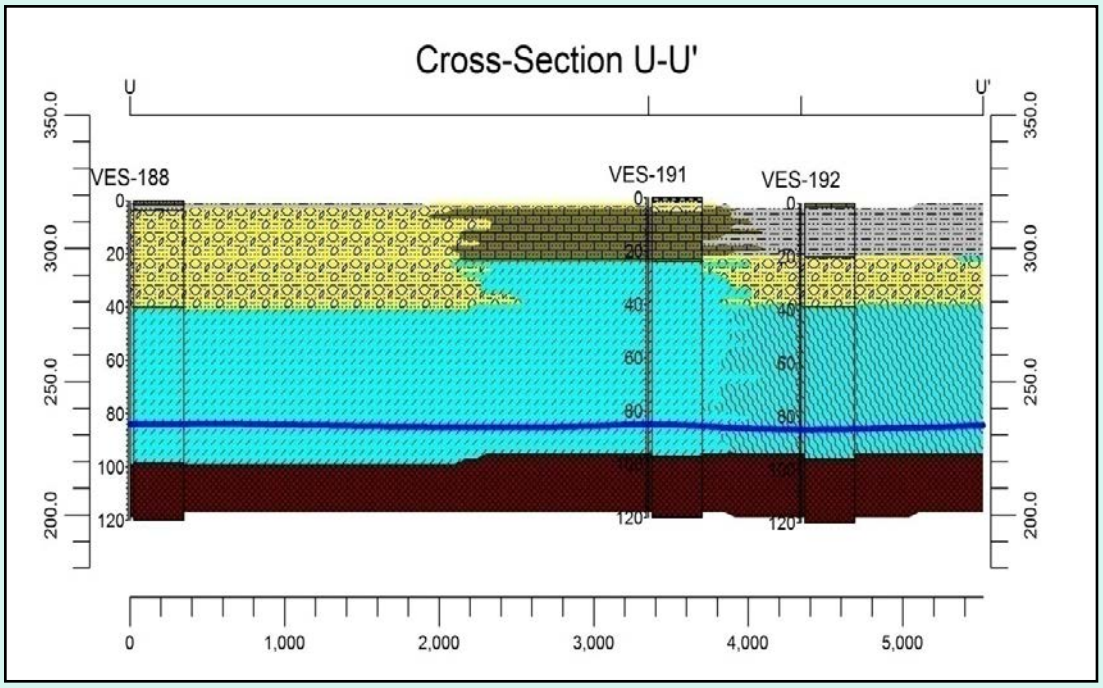

Figure 90: Cross Section U-U′ passes through VES (188), VES (191) and VES (192).

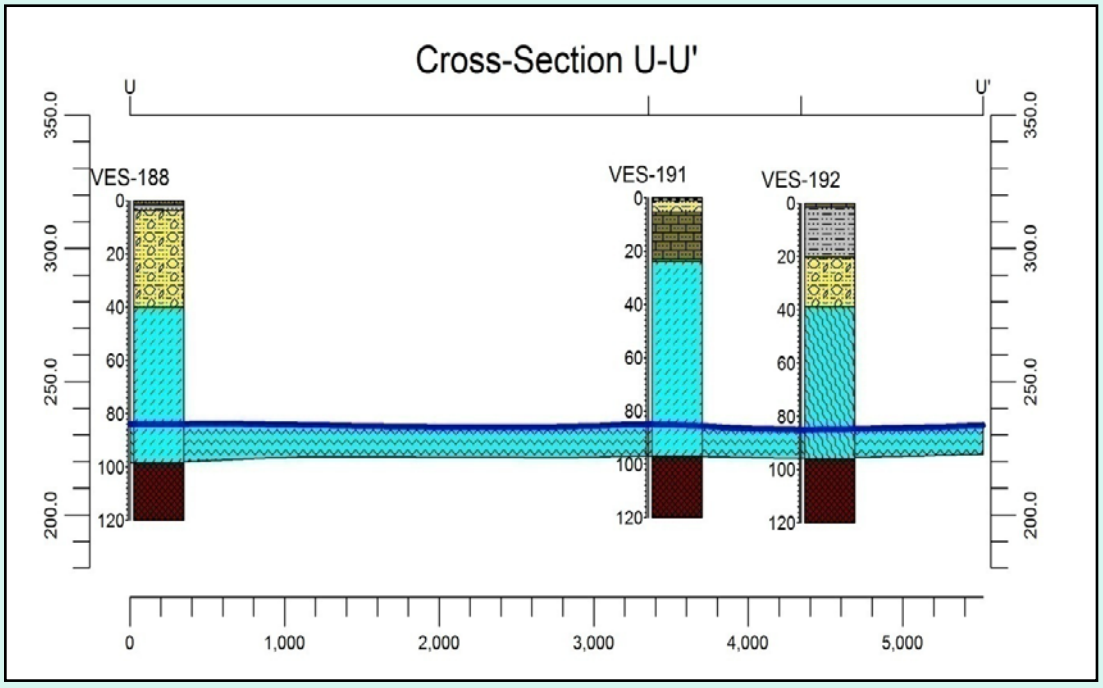

Figure 91: Saturated aquifer thickness along cross section U-U′.

Cross Section V-V′ :

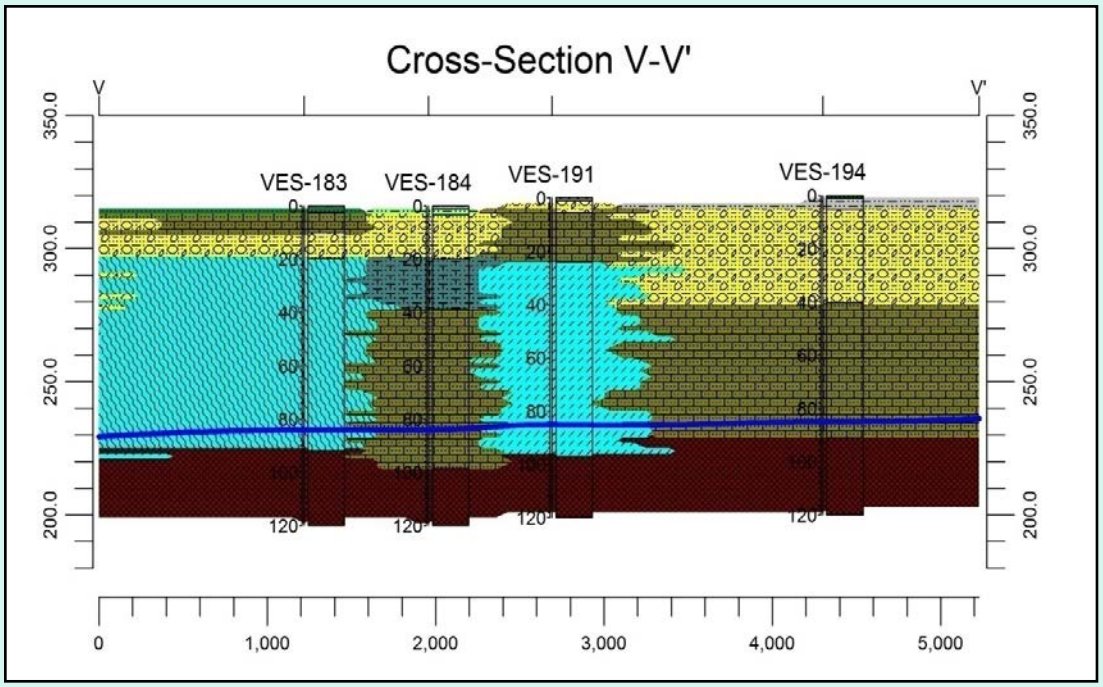

Figure 92: Cross Section V-V′ passes through VES (183), VES (184), VES (191) and VES (194).

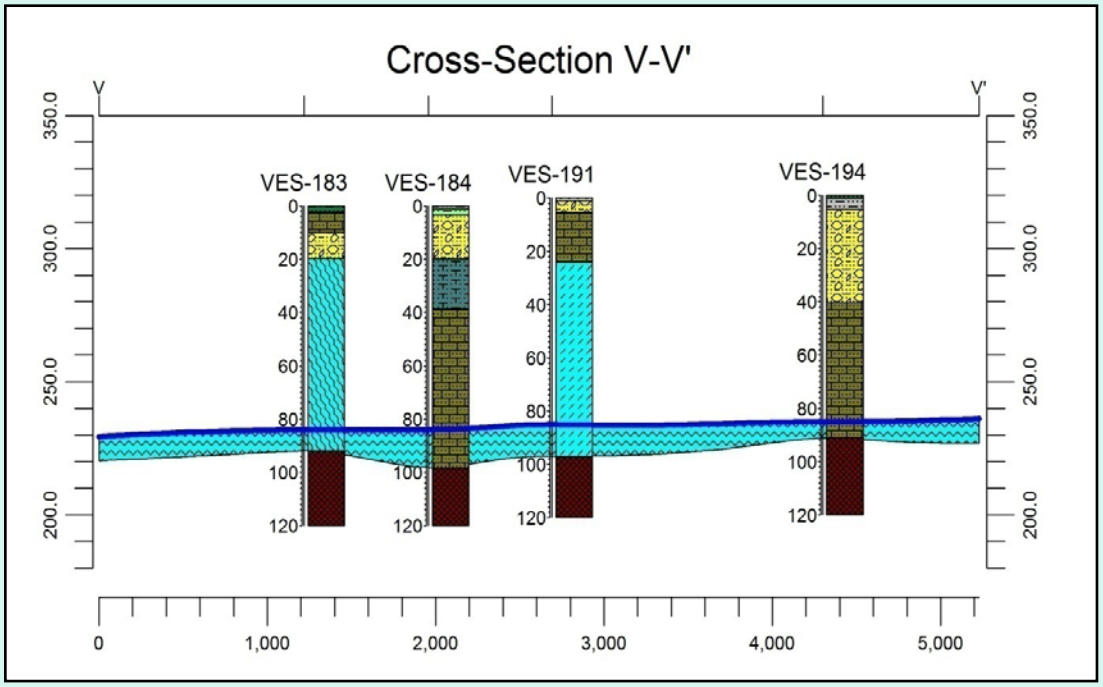

Figure 93: Saturated aquifer thickness along cross section V-V′.

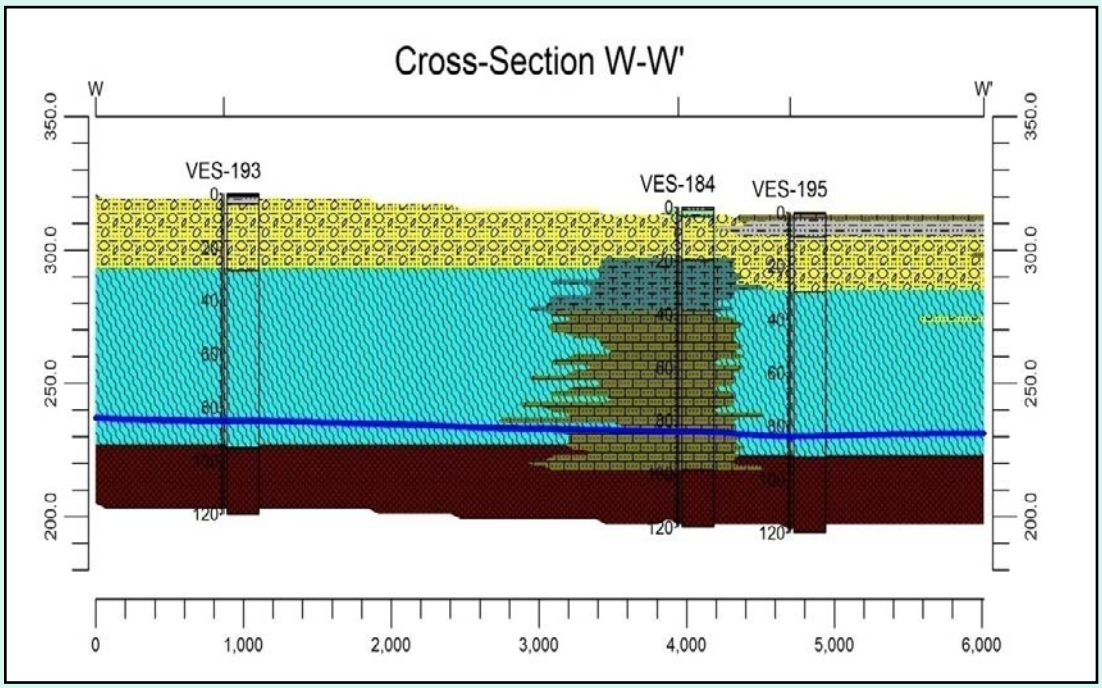

Figure 94: Cross Section W-W′ passes through VES (193), VES (184) and VES (195).

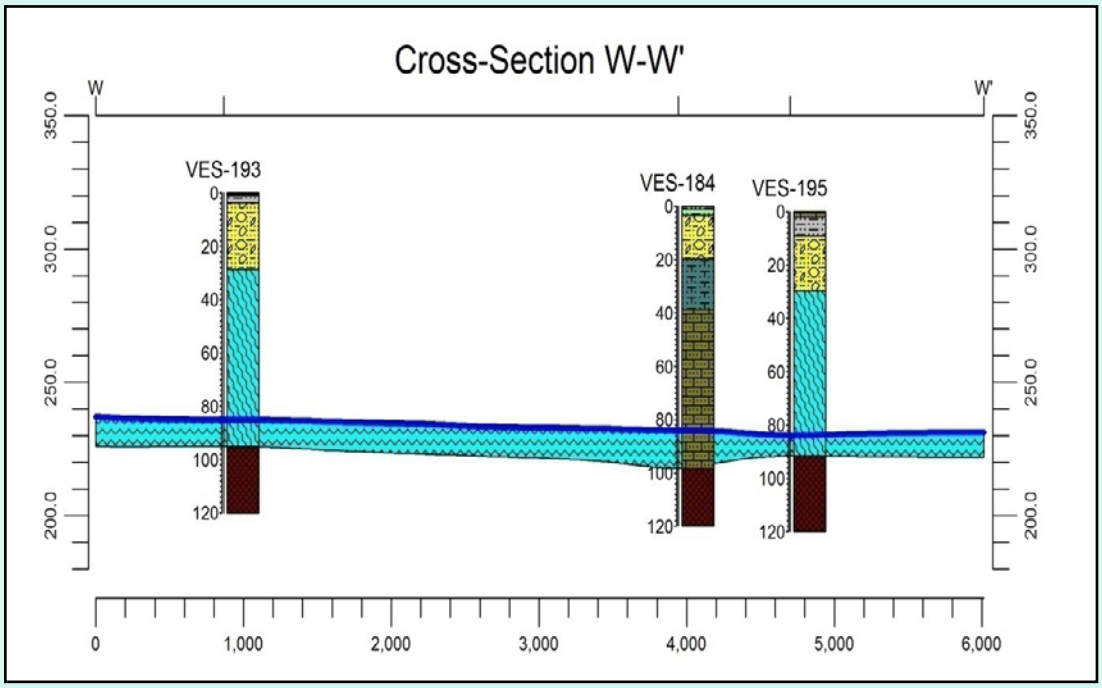

Figure 95: Saturated aquifer thickness along cross section W-W′.

2.2.4 Findings and Suggestions = Cluster- 2

- Alluvial thickness may vary from 80m to 104m bgl(below ground level) in most of the area.
- Alluvial thickness of village Nari may vary from 60m(near Railway Station) to 96m(Towards Ardawata) bgl, due to hills.
- A minor fissures and fractures may appear in rock formation having low to moderate quantum of ground water.
- By studying the inferences of vertical electrical soundings and their lithological representation along cross sections, thickness of permeable unsaturated aquifer, it seems that VES No. 136, 138, 139, 140, 142, 148, 157, 158, 159, 160, 162, 164, 181, 183, 188, 190, 191, 192, 193 and 195 are comparatively better sites for artificial recharge. But VES No. 158, 159, 160 are located towards river side, therefore, recharged ground water may underflow towards river. Proposed sites for artificial recharge are shown in following map.

- The VES158, 159, 160 located towards river Kantli, have a good aquifer zones, indicate that younger alluvium along river Kantli are comparatively good aquifer, having better yielding capacity.
- A thin hard layer of clay, kankar with fine grained sand (impermeable layer) is presented in lithological formation of most of the villages of studied area which hinder the percolation of rain water to ground water level, therefore, the design of recharge structure in such a manner that the quantum of surface water may be injected below this impermeable layer, and only 5 to 10m before water level for fast and efficient augmentation of ground water.

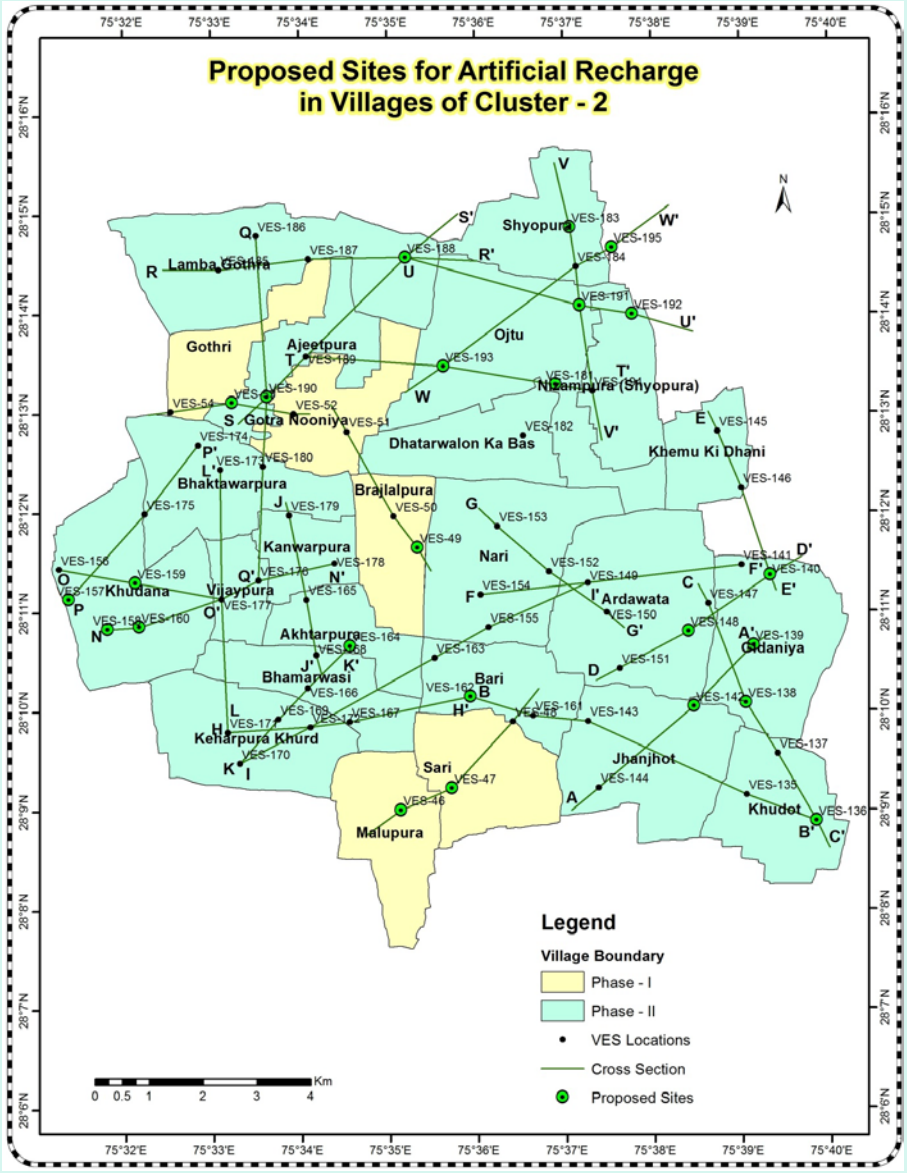

Figure 96: Map shows proposed sites for artificial recharge in villages of Cluster - 2.

The details of proposed VES sites, their locations and thickness of impermeable layer are given in following table.

Table 5: Thickness of impermeable/ less permeable layer at proposed sites of cluster - 2.

S. No.	VES No.	Village	Location	Coordinates	Thickness of impermeable/ less permeable layer in m bgl
1	136	Khudot	In Jode area	N28°08′53.19″ E75°39′50.92″	18 – 40m
2	138	Gidania	Towards Khudot boundary	N28°10′04.73″ E75°39′03.18″	1.5 – 5m
3	139	Gidania	In Play Ground	N28°10′39.39″ E75°39′08.55″	28 – 40m
4	140	Gidania	On Dangar road	N28°11′21.66″ E75°39′20.12″	20 – 30m
5	142	Jhanjhot	On Gidania road	N28°10′02.54″ E75°38′27.75″	25 – 40m
6	148	Ardawata	Towards Gidania, in the field of shri Bahadur Singh s/o shri kal Singh	N28°10′47.75″ E75°38′24.47″	2 – 13m
7	157	Khudana	In the field of shri Maduram s/o shri Jaduram	N28°11′08.01″ E75°31′22.55″	25 – 30m
8	158	Khudana	Towards Kantli river	N28°10′49.97″ E75°31′48.79″	10 – 28m
9	159	Khudana	Towards river bank	N28°11′18.00″ E75°32′07.86″	10 – 31m
10	160	Khudana	Towards river bank, in the field of shri Chandagiram	N28°10′51.45″ E75°32′10.53″	5 – 30m
11	162	Bari	On Ekhtawarpura road	N28°10′08.85″ E75°35′55.72″	15 – 27m
12	164	Ekhtawarpura	In Jodi area	N28°10′39.53″ E75°34′33.95″	20 – 32m

S. No.	VES No.	Village	Location	Coordinates	Thickness of impermeable/ less permeable layer in m bgl
13	181	Oztu	Oztu	N28°13′17.13″ E75°36′54.55″	10 – 30m
14	183	Shyopura	Towards bricks factory	N28°14′52.01″ E75°37′04.56″	10 – 20m
15	188	Lamba Gothra	In Tolana Jode area	N28°14′34.03″ E75°35′12.56″	3 – 40m
16	190	Ajeetpura	In Jode area	N28°13′10.03″ E75°33′37.96″	10 – 20m
17	191	Oztu	In Jode area	N28°14′04.60″ E75°37′11.05″	5 – 24m
18	192	Nizampura	Nizampura	N28°13′59.53″ E75°37′46.85″	20 – 40m
19	193	Oztu	Oztu	N28°13′28.25″ E75°35′38.39″	3 – 30m
20	195	Shyopura	In the play ground	N28°14′39.82″ E75°37′33.28″	9 – 30m

2.3 Cluster - 3

Phase II of Cluster-3 includes village Sultana ka Bas. Vertical Electrical Sounding (VES) was conducted in Sultana ka Bas of Cluster- 3, at 2 locations (VES196 – VES197). Rest of 13 villages of cluster- 3 (Bhompura, Shekhpura, Ismailpura, Patel Nagar, Khudia, Badangarh, Alampura, Qutubpura, Gowli, Chainpura, Narhar, Haripura and Dhani Meghsar) had been covered during Phase I of the study in the year 2016 - 17. VES locations of cluster- 3 are shown in following map.

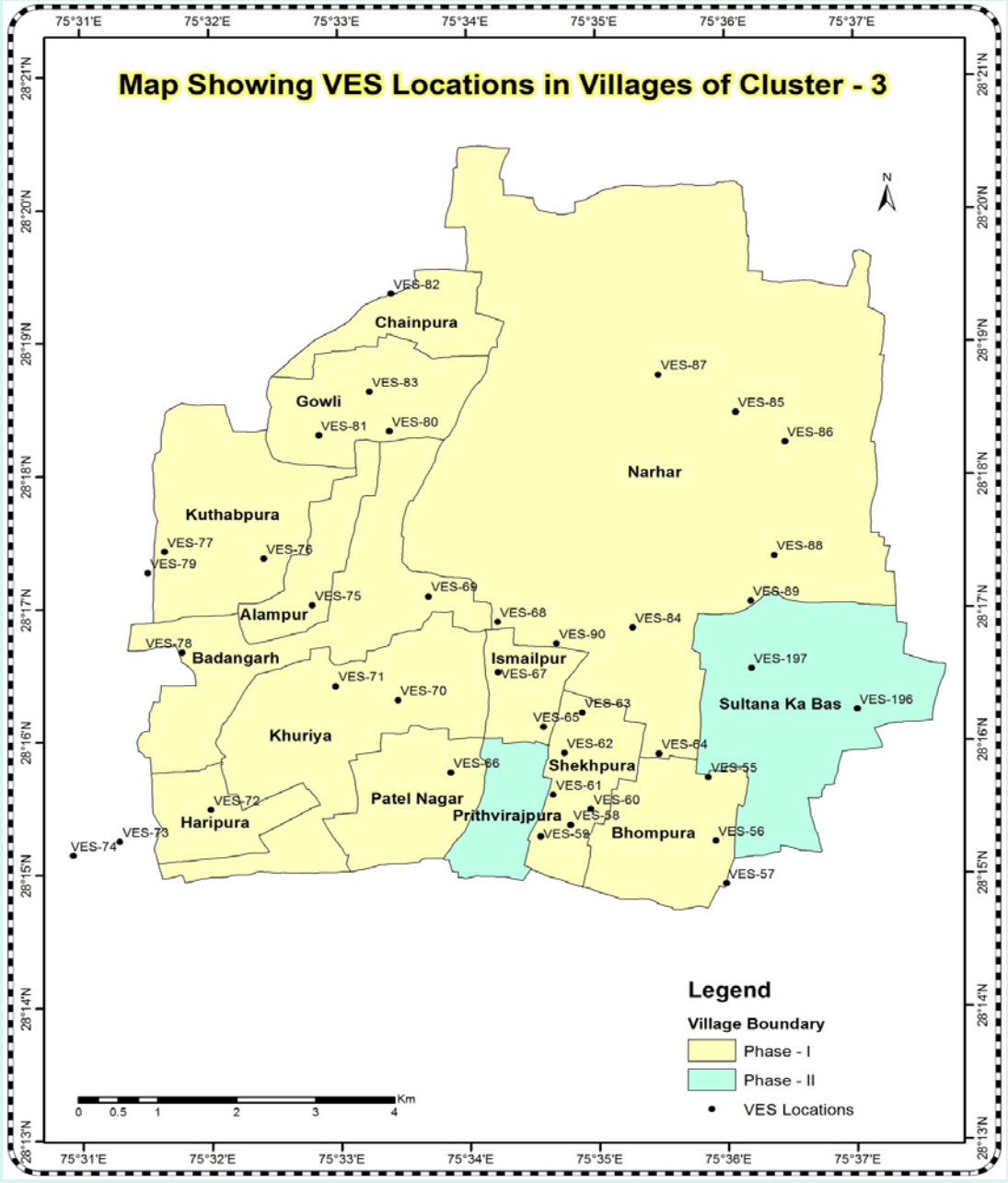

Figure 97: Map shows VES locations in villages of Cluster - 3

2.3.1 Interpreted Result

Phase II of Cluster-3 includes village Sultana ka Bas. Vertical electrical soundings have been conducted at 2 locations. The field data are collected and interpreted by using a computer software programme. As per the interpretation of field data, the resistivity of different layers and their corresponding thickness of the formations are summarised in the following tables:

Table 6: Interpreted Result of Villages of Cluster (3)

S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm-meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
1	196	Sultana Ka Bas	Sultana Ka Bas	N28° 16′ 13.96″ E75° 37′ 00.77″	135	95.5	49.4	85.6	39.7	109	1.09	3.48	15.1	39.8	33.8	93.27
2	197	Sultana Ka Bas	Sultana Ka Bas	N28° 16′ 32.53″ E75° 36′ 11.58″	54.3	66.7	113	27.2	342		1.78	2.76	25	73.1		102.64

3.2 Inferences of Geophysical Electrical Resistivity Survey, Cluster - 3

Phase II of Cluster- 3 includes village Sultana ka Bas. Vertical electrical soundings were conducted at 2 locations (VES196 – VES197). The field data were collected and interpreted and the following inferences are drawn on the basis of resistivity values of different layers and the nature of curves obtained from field data and its interpretation. In the surveyed area, different lithological formations are identified. Point wise details of lithological formations corresponding to different layers are described as below:

VES point wise details of lithological formations corresponding to different layers:

VES (196):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of medium to fine grained sand and minor clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (197):

Layers	Lithological Formation
h_1	The formation consist of fine to medium grained sand and clay
h_2	The formation consist of fine grained sand and clay with minor kankar
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

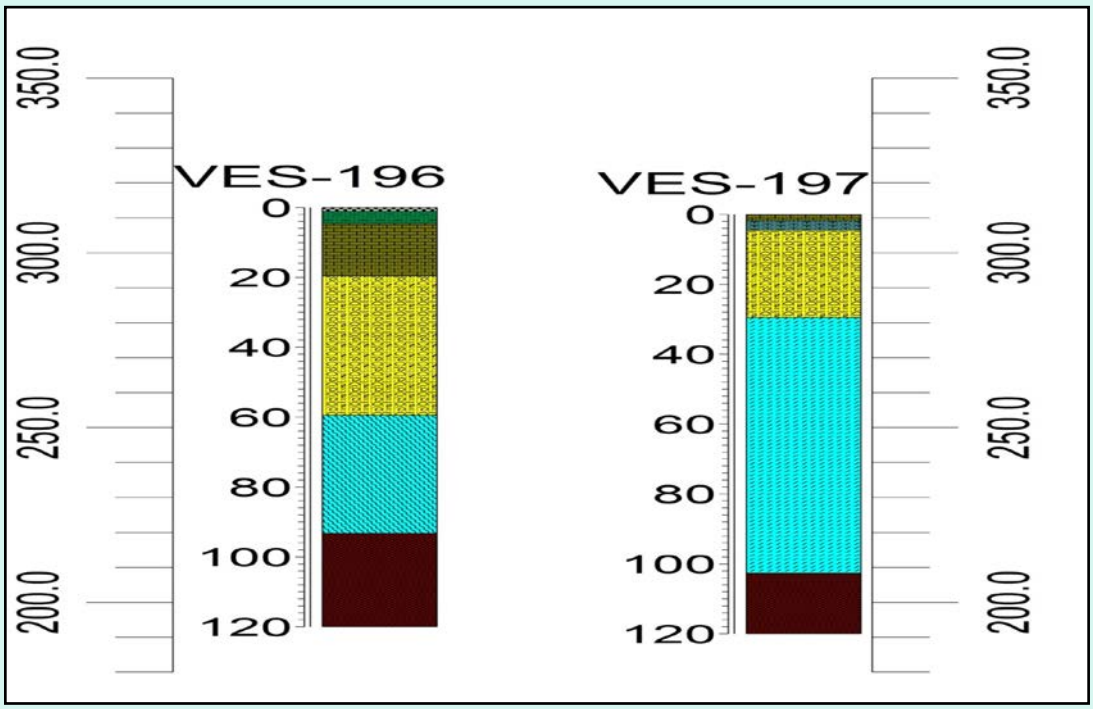

Figure 98: Lithological formation from VES(196) to VES(197).

2.3.3 Representation of Lithological Formations along Cross Sections

To represent subsurface lithological formations or different layers, depth to bedrock, permeable and impermeable layers, saturated and unsaturated zones & their thickness, 1 cross section (AA′) has been selected. Cross section passes through different VES locations. A blue line in section profile represent water table along the section. The portion aquifer thickness lies below water table is known as saturated aquifer thickness. The saturated aquifer thickness for section is shown in another figure. The following map shows the cross sections.

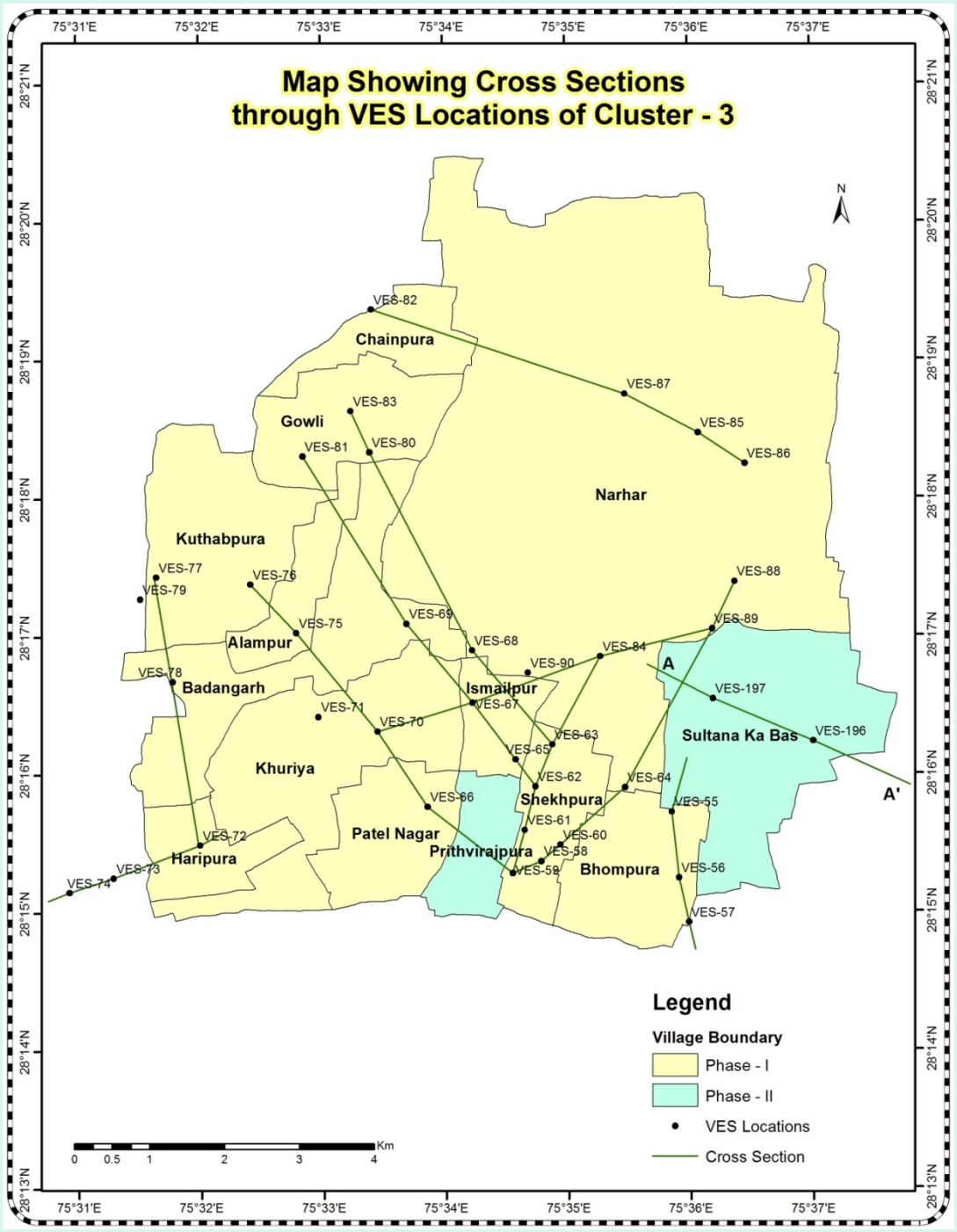

Figure 99: Map shows different cross sections through VES locations of Cluster – 3

The following figures show different cross sections and saturated aquifer thickness:

Cross Section A-A′:

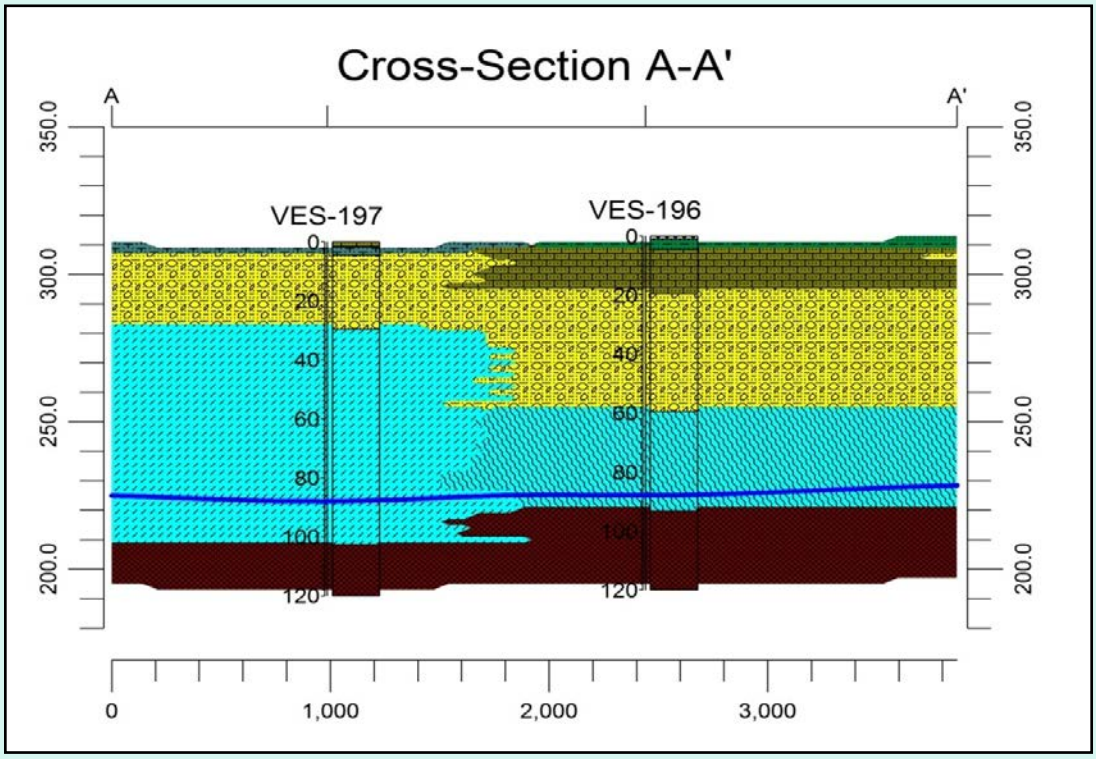

Figure 100: Cross Section A-A′ passes through VES (197) and VES (196).

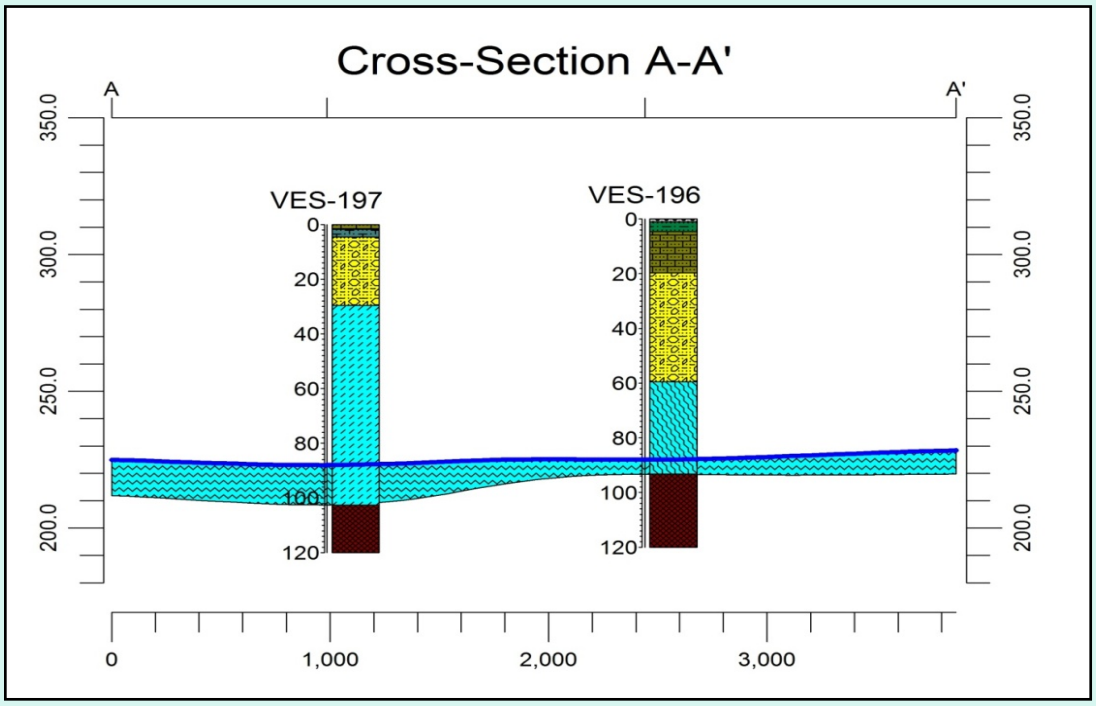

Figure 101: Saturated aquifer thickness along cross section A-A′.

2.3.4 Findings and Suggestions, Cluster – 3

- Alluvial thickness may vary from 93m to 103m bgl(below ground level) in most of the area.
- A minor fissures and fractures may appear in rock formation having low to moderate quantum of ground water.
- By studying the inferences of vertical electrical soundings and their lithological representation along cross sections, thickness of permeable unsaturated aquifer, it seems that VES No. 197 is comparatively better site for artificial recharge. Proposed sites for artificial recharge are shown in following map.
- A thin hard layer of clay, kankar with fine grained sand (impermeable layer) is presented in lithological formations of the village Sultana ka Bas, of studied area which hinder the percolation of rain water to ground water level, therefore, the design of recharge structure in such a manner that the quantum of surface water may be injected below this impermeable layer, and only 5 to 10m before water level for fast and efficient augmentation of ground water.

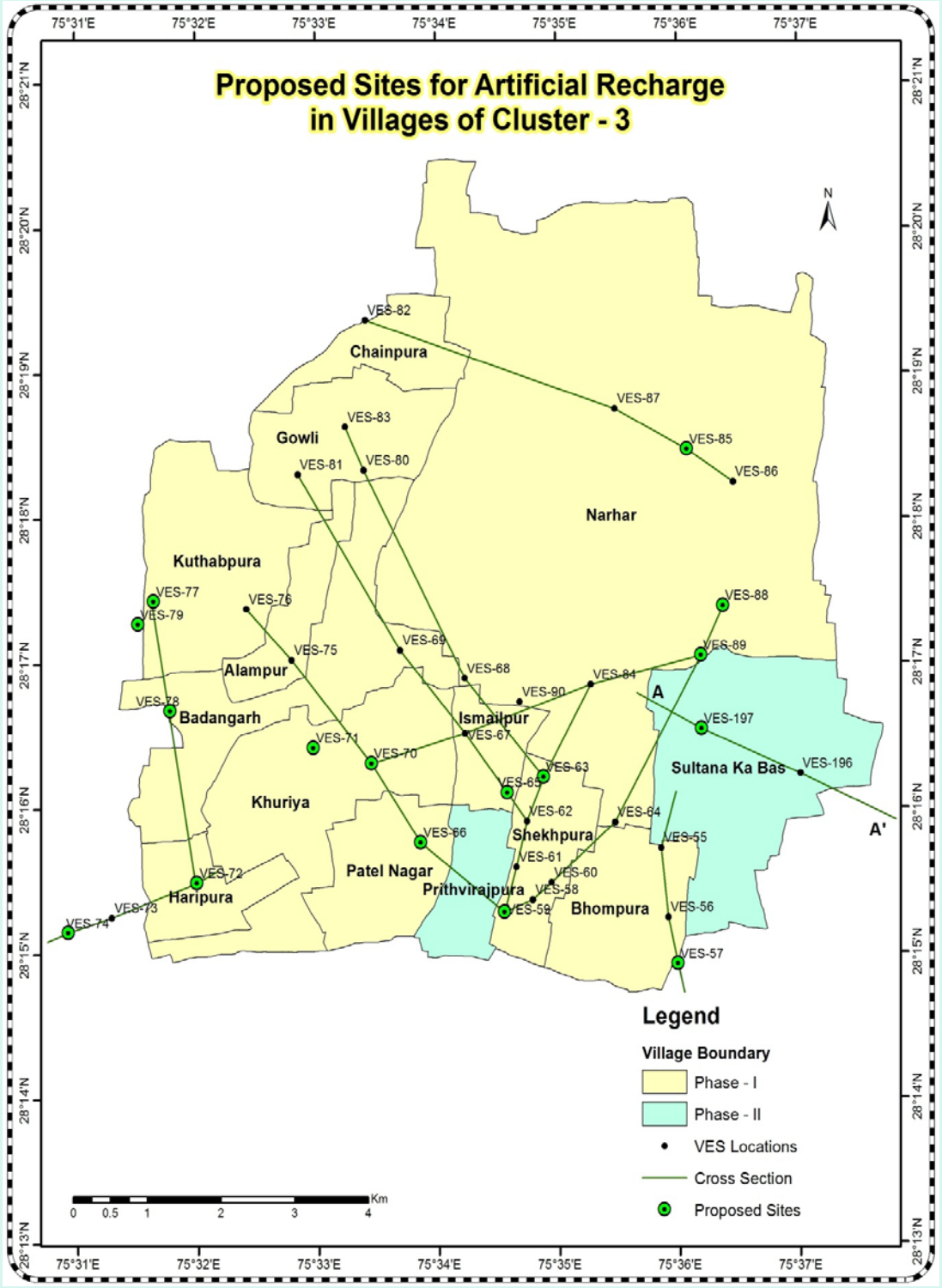

Figure 102: Map shows the proposed sites for artificial recharge in villages of Cluster - 3.

The details of proposed VES sites, their locations and thickness of impermeable layers are given in following table.

Table 7: Thickness of impermeable/ less permeable layer at proposed sites of cluster - 3.

S. No.	VES No.	Village	Location	Coordinates	Thickness of impermeable layer in m bgl
1	197	Sultana ka Bas	Sultana ka Bas	N28°16′32.53″ E75°36′11.58″	4 - 30m

2.4 Cluster - 4

Phase II of Cluster-4 includes villages Alipura, Dheer wali Dhani, Narnod, Maligaon, Ghumansar, Budania, Dhatarwal, Jakhoda, Lamba, Nalwa, Govindpura, Bhola ki Dhani, Mandrela, Nandrampura and Tigias. Vertical Electrical Sounding (VES) was conducted in 15 villages of Cluster- 4, at 34 locations (VES198 – VES231). Rest of 8 villages of Cluster- 4 (Jakhara, Bhairugarh, Manphara, Bajawa Suron Ka, Sainipura, Mahti Ki Dhani, Raghuveerpura and Dilawarpura) were covered during phase I of study in the year 2016 - 17. VES locations of Cluster- 4 are shown in following map.

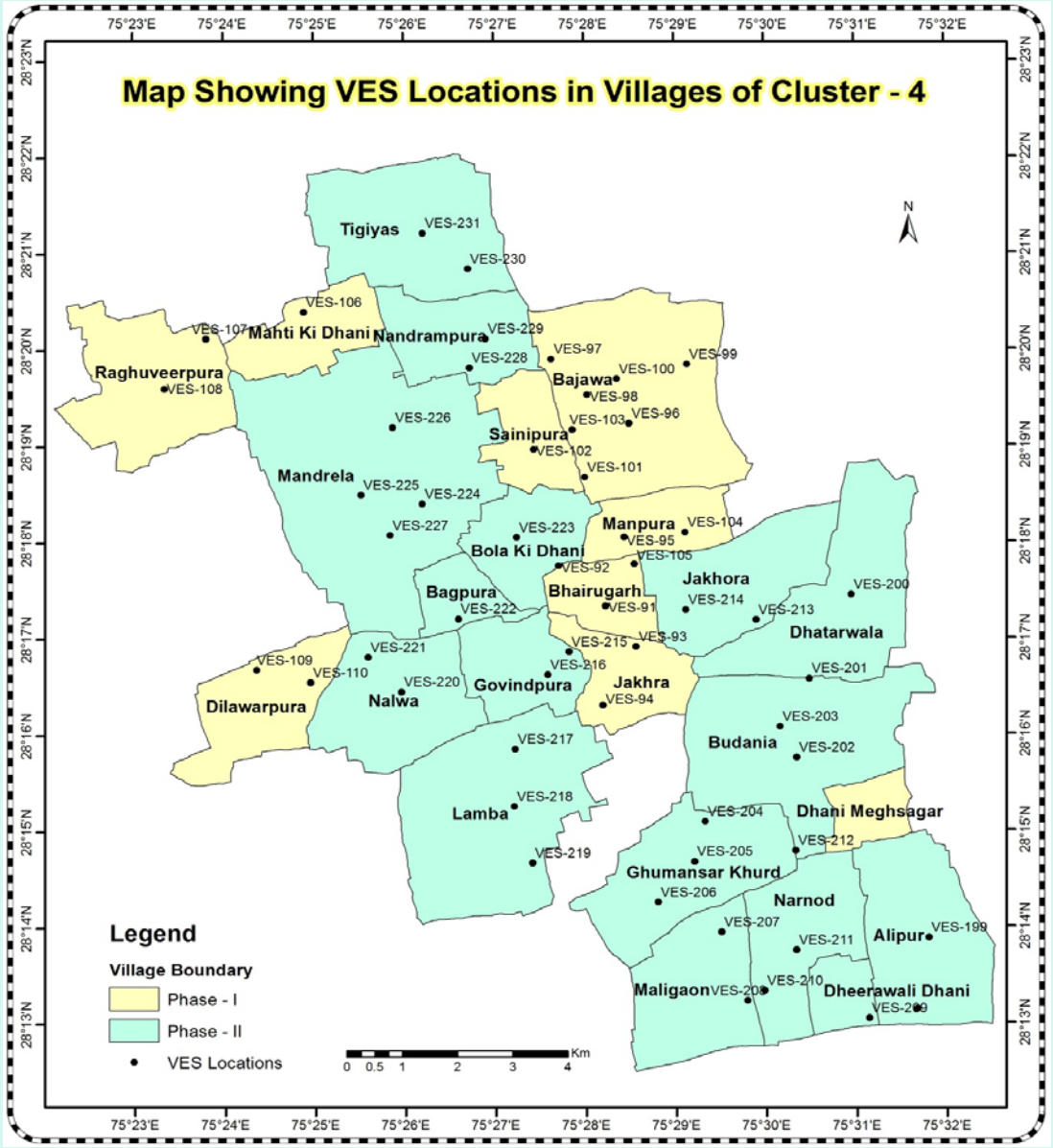

Figure 103: Map shows VES locations in villages of Cluster – 4.

2.4.1 Interpreted Result

Phase II of Cluster- 4 includes villages Alipura, Dheer wali Dhani, Narnod, Maligaon, Ghumansar, Budania, Dhatarwal, Jakhoda, Lamba, Nalwa, Govindpura, Bhola ki Dhani, Mandrela, Nandrampura and Tigias. Vertical electrical soundings were conducted at 34 locations. The field data were collected and interpreted by using a computer software programme. As per the interpretation of field data, the resistivity of different layers and their corresponding thickness of the formations are summarised in the following tables:

Table 8: Interpreted Result of Villages of Cluster 4

S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm-meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
1	198	Alipura	In the field of shri Raghuvir ji s/o shri Ratan ji	N28° 13′ 08.38″ E75° 31′ 40.35″	327	73.9	145	33.8	37.6	256	1.07	3.22	6.1	59.1	29	98.49
2	199	Alipura	In Jode area	N28° 13′ 53.00″ E75° 31′ 48.29″	193	88.3	58.6	68.9	53	236	1.12	4.01	14.2	50.1	29	98.43
3	200	Dhatarwal	In river area	N28° 17′ 27.06″ E75° 30′ 57.48″	365	90.4	125	47.1	227		2.68	11.6	37.1	53.4		104.78
4	201	Dhatarwal	Towards Budania boundary	N28° 16′ 34.65″ E75° 30′ 29.37″	113	11.7	30.6	17.5	21.4	190	1.13	5.68	44.5	9.03	41.8	102.14
5	202	Budania	Budania	N28° 15′ 45.51″ E75° 30′ 20.76″	140	106	54.2	21.9	33.5	401	1.13	6.04	23.9	41.8	31.2	104.07
6	203	Budania	On Ghumansar road	N28° 16′ 04.66″ E75° 30′ 09.80″	176	95.5	54.2	78.6	27.2	739	1.4	1.8	12	14.2	62.5	91.9

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S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm-meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
7	204	Ghumansar	Towards Budania	N28° 15′ 05.57″ E75° 29′ 19.81″	250	71.7	80.5	24.6	28.9	586	2.01	13	14.2	50.1	11.2	90.51
8	205	Ghumansar	Ghumansar	N28° 14′ 40.82″ E75° 29′ 12.58″	105	50.2	63.3	27.9	36.8	256	1.08	3.84	22.4	52.9	11.7	91.92
9	206	Ghumansar	On Kasimpura road	N28° 14′ 15.32″ E75° 28′ 48.09″	348	222	79.9	94.7	23.3	287	1.38	5.04	8.42	4.78	75.1	94.72
10	207	Maligaon	Maligaon	N28° 13′ 56.81″ E75° 29′ 30.23″	210	50.5	96.2	18	26.4	614	3.57	11.1	10.9	54.3	17.8	97.67
11	208	Maligaon	Maligaon	N28° 13′ 13.79″ E75° 29′ 47.58″	172	68.9	36.8	57.2	19.9	705	1.24	6.68	11.9	10.8	63.4	94.02
12	209	Dheer wali Dhani	Near Adarsh Education Institute	N28° 13′ 02.74″ E75° 31′ 08.45″	301	177	54.6	94	23.5	643	1.24	2.73	11.6	15	67.2	97.77
13	210	Narnod	Towards Maligaon	N28° 13′ 20.10″ E75° 29′ 58.79″	101	38.2	52.7	13.6	16.4	643	2.86	7.68	9.58	60.5	16.8	97.42

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S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm-meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
14	211	Narnod	Towards Budania	N28° 13′ 45.40″ E75° 30′ 20.09″	166	109	51.7	56.3	19	638	1.66	4.77	18.5	5.11	62.5	92.54
15	212	Budania	Towards Narnod	N28° 14′ 47.38″ E75° 30′ 19.82″	112	76.2	29.2	31.7	50.5	577	1.28	8.56	21.2	28	32.8	91.84
16	213	Jakhoda	In Jode area	N28° 17′ 11.22″ E75° 29′ 54.04″	110	42	53	19.9	27	530	2.94	16.7	5.72	54.5	15.6	95.46
17	214	Jakhoda	Jakhoda	N28° 17′ 17.67″ E75° 29′ 07.46″	85.9	56.4	84.5	26.7	28.8	182	1.44	3.53	6.92	58.4	25.1	95.39
18	215	Govindpura	Govindpura	N28° 16′ 51.65″ E75° 27′ 49.53″	236	79.9	123	23.1	401		1.32	5.21	12.8	74.7		94.03
19	216	Govindpura	Govindpura	N28° 16′ 37.36″ E75° 27′ 35.48″	32.5	37.6	17.4	22.2	14.1	276	14.4	10.3	25.3	11	40	101
20	217	Lamba	Near Electric Sub Station	N28° 15′ 50.97″ E75° 27′ 13.56″	204	58.6	66.8	15.8	426		3.13	17	5.46	77.6		103.19

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S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm-meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
21	218	Lamba	Near Maniram's field	N28° 15′ 15.32″ E75° 27′ 12.67″	105	136	49.8	66.3	25	581	3.68	6.4	14.9	5.34	73.7	104.02
22	219	Lamba	Lamba	N28° 14′ 40.14″ E75° 27′ 24.66″	53.5	21.9	43.1	14.8	19.1	252	1.21	6.16	17.6	44.6	27.8	97.37
23	220	Nalwa	Nalwa	N28° 16′ 26.90″ E75° 25′ 57.82″	51	26.2	16.7	13	15	172	2.58	11.6	36.3	9.56	35.8	95.84
24	221	Nalwa	In Khadar Jode	N28° 16′ 48.50″ E75° 25′ 35.70″	102	68.1	101	18.7	342		1.91	7.73	20.2	71.7		101.54
25	222	Bagpura	Near school	N28° 17′ 12.35″ E75° 26′ 35.98″	108	65.8	102	18.4	684		1.56	7.42	15.8	72.9		97.68
26	223	Bhola Ki Dhani	In the field of shri Ram Singh	N28° 18′ 03.04″ E75° 27′ 14.79″	131	59	81.7	13	21.2	252	1.33	4	14.3	59.6	15.5	94.73
27	224	Mandrela	Near bypass	N28° 18′ 24.11″ E75° 26′ 12.20″	374	130	63.8	16.6	214		1.56	12.8	17.6	64.2		96.16

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S. No.	VES No.	Village	Location	Coordinates	Resistivity of different layers (ohm-meter)						Thickness of corresponding layers (m)					Depth to bedrock (m)
					ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	h1	h2	h3	h4	h5	H
28	225	Mandrela	Mandrela	N28° 18′ 29.62″ E75° 25′ 31.52″	160	48.6	146	20.1	83		1.16	3.48	5.75	85.8		96.19
29	226	Mandrela	Towards Electric Power Station	N28° 19′ 11.83″ E75° 25′ 52.77″	121	60.9	68.9	14.3	301		1.76	8.4	19.2	68.3		97.66
30	227	Mandrela	In the field of shri Mumtaj Ali	N28° 18′ 04.40″ E75° 25′ 50.59″	94.7	104	21.4	25.7	112		1.76	12.6	64.9	17		96.26
31	228	Nandrampura	Nandrampura	N28° 19′ 48.86″ E75° 26′ 43.88″	119	37.1	40.7	17.3	22.2	91.1	1.86	8.14	10.6	29.2	44.9	94.7
32	229	Nandrampura	Towards Tigias	N28° 20′ 07.05″ E75° 26′ 54.46″	56.4	47.2	61.7	19.7	84.1		6.78	8.29	5.16	72.2		92.43
33	230	Tigias	In the field of shri Mahavir ji s/o shri Salag Ram	N28° 20′ 50.51″ E75° 26′ 43.07″	34.9	40.9	18.6	14.9	17.2	148	1.86	11.8	12.1	44.6	27.6	97.96
34	231	Tigias	Tigias	N28° 21′ 12.95″ E75° 26′ 12.99″	56.4	92.9	51.8	20.7	24.7	55.8	1.86	6.98	11	59.5	14.5	93.84

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2.4.2 Inferences of Geophysical Electrical Resistivity Survey, Cluster - 4

Cluster- 4 includes villages Alipura, Dheer wali Dhani, Narnod, Maligaon, Ghumansar, Budania, Dhatarwal, Jakhoda, Lamba, Nalwa, Govindpura, Bhola ki Dhani, Mandrela, Nandrampura and Tigias. Vertical electrical soundings have been conducted at 34 locations. The field data were collected and interpreted and the following inferences are drawn on the basis of resistivity values of different layers and the nature of curves obtained from field data and its interpretation. In the surveyed area, different lithological formations are identified. Point wise details of lithological formations corresponding to different layers are described as below:

VES point wise details of lithological formations corresponding to different layers:

VES (198):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (199):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of fine to medium grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (200):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (201):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (202):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of fine to medium grained sand and silt
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (203):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of medium to fine grained sand and minor clay
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of medium to fine grained sand and minor silt
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

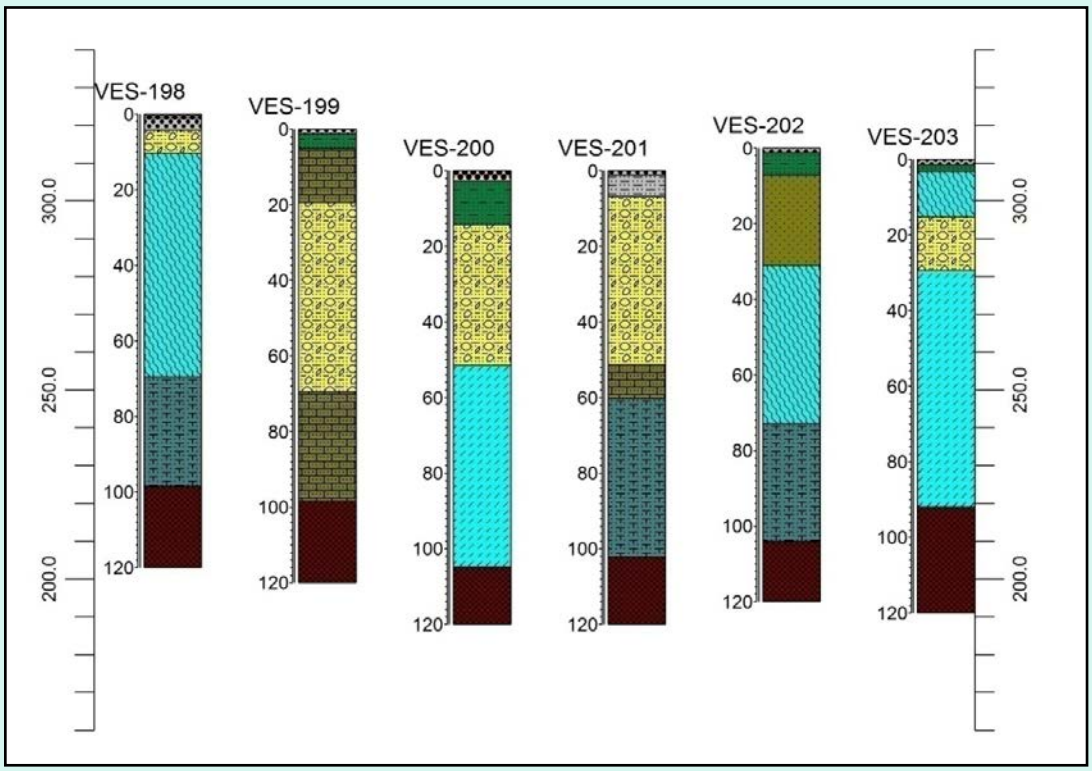

Figure 104: Lithological formation from VES(198) to VES(203).

VES (204):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (205):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (206):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand
h_3	The formation consist of fine to medium grained sand and silt
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation consist of medium to fine grained sand and minor silt
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (207):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (208):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of fine grained sand and silt with clay
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of fine to medium grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (209):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand
h_3	The formation consist of medium to fine grained sand and clay
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of medium to fine grained sand and minor silt
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

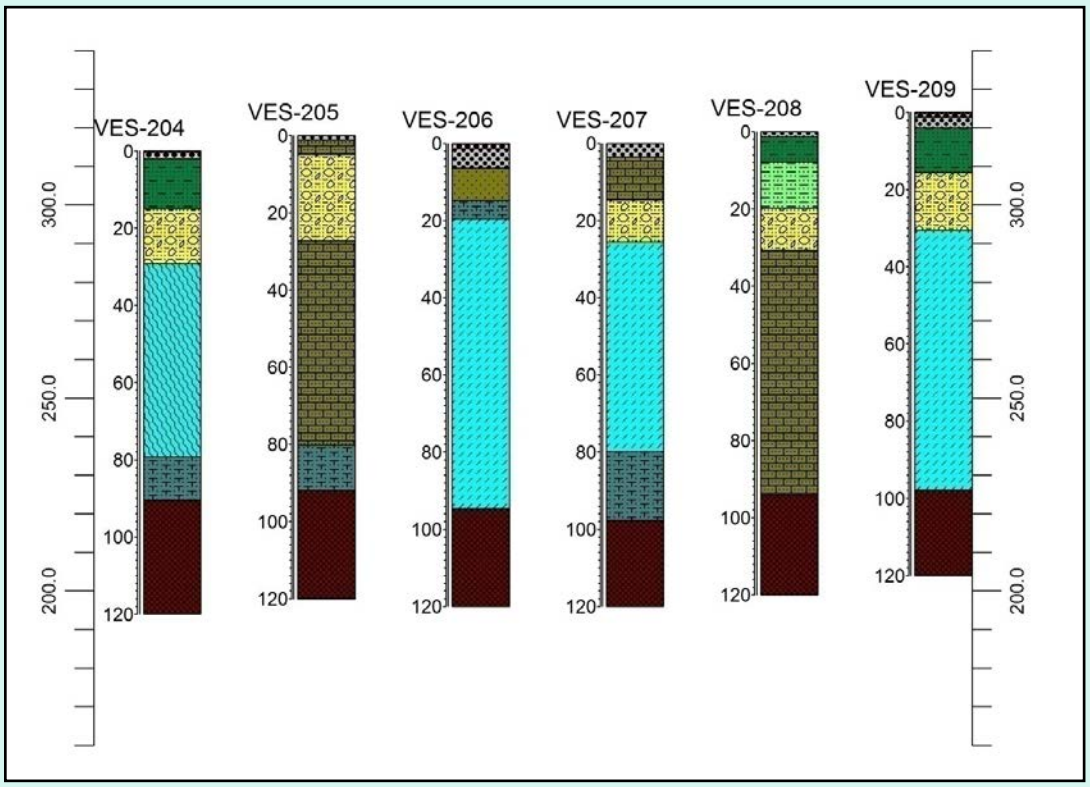

Figure 105: Lithological formation from VES(204) to VES(209).

VES (210):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (211):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of fine to medium grained sand and clay

h_4	The formation consist of fine grained sand and clay with minor kankar
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (212):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of fine grained sand and clay
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation consist of clay, kankar and fine grained sand
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (213):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (214):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of fine grained sand and silt with clay
h_3	The formation consist of clay, kankar and fine grained sand

h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (215):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

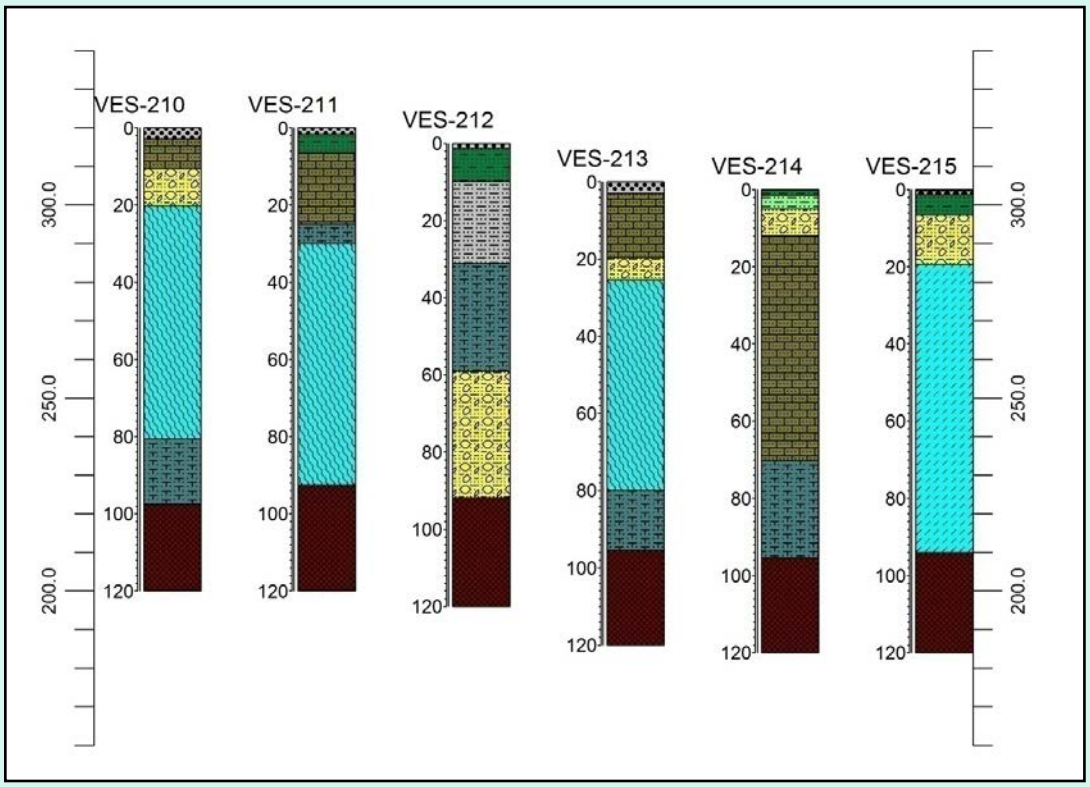

Figure 106: Lithological formation from VES(210) to VES(215).

VES (216):

Layers	Lithological Formation
h_1	The formation consist of fine grained sand and clay
h_2	The formation consist of fine grained sand and clay with minor kankar
h_3	The formation consist of fine grained sand and silt with clay
h_4	The formation consist of clay, kankar and fine grained sand
h_5	The formation consist of fine to medium grained sand and clay
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (217):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (218):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation consist of medium to fine grained sand and minor silt
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (219):

Layers	Lithological Formation
h_1	The formation consist of fine to medium grained sand and clay
h_2	The formation consist of fine grained sand and silt with clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (220):

Layers	Lithological Formation
h_1	The formation consist of fine to medium grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of fine grained sand and silt with clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (221):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

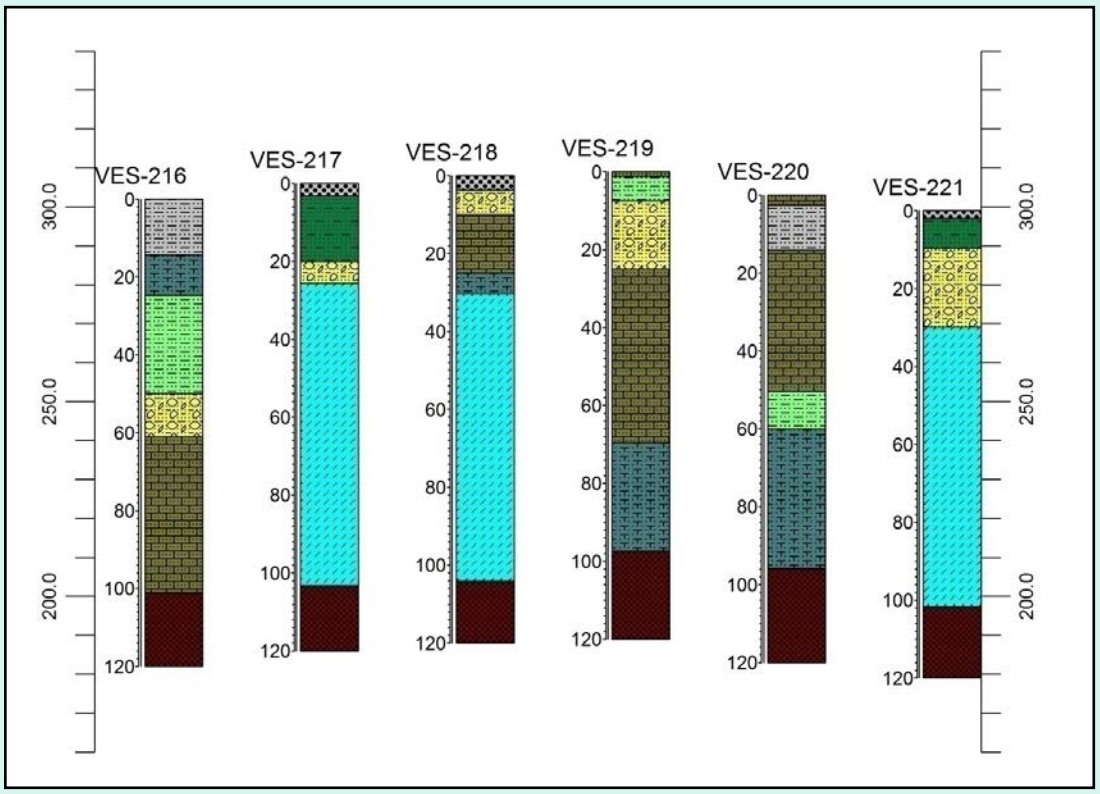

Figure 107: Lithological formation from VES(216) to VES(221).

VES (222):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (223):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (224):

Layers	Lithological Formation
h_1	The formation consist of coarse to medium grained sand
h_2	The formation consist of medium to fine grained sand
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (225):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor silt
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (226):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of medium to fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (227):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand and clay
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of medium to fine grained sand and minor clay
h_4	The formation consist of fine grained sand and clay with minor kankar
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

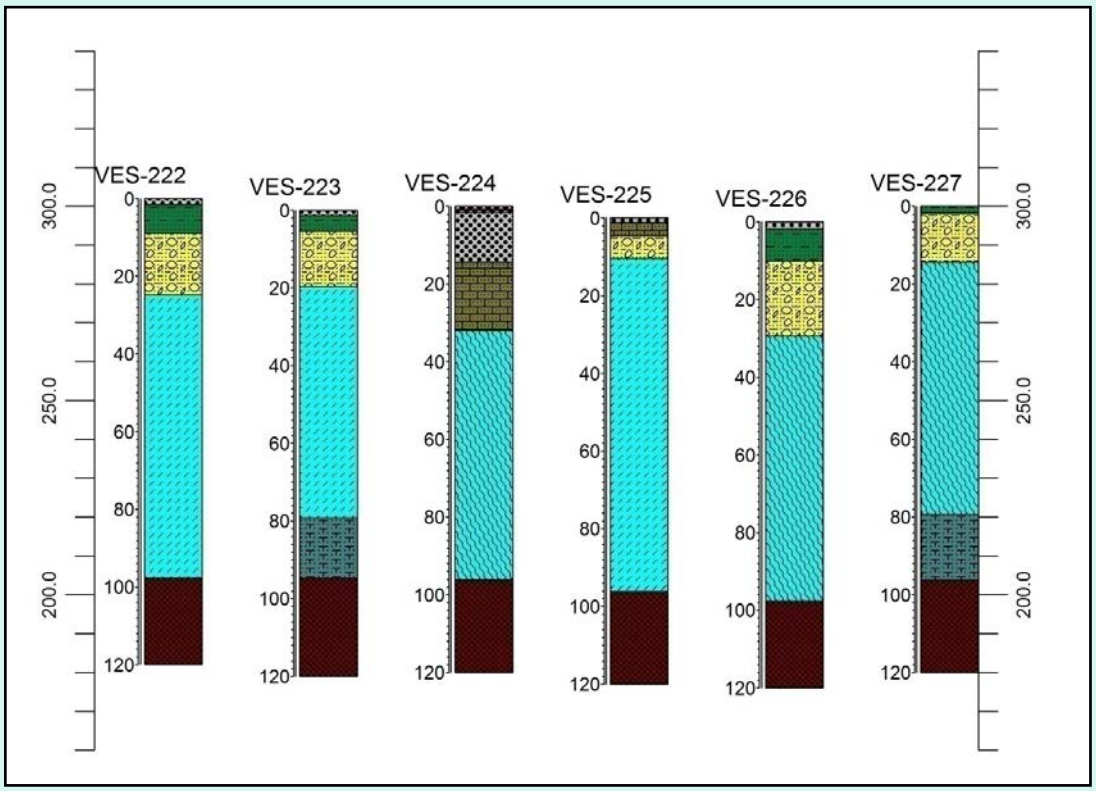

Figure 108: Lithological formation from VES(222) to VES(227).

VES (228):

Layers	Lithological Formation
h_1	The formation consist of medium to fine grained sand
h_2	The formation consist of fine to medium grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of fine grained sand and clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (229):

Layers	Lithological Formation
h_1	The formation consist of fine to medium grained sand and clay
h_2	The formation consist of fine grained sand and clay
h_3	The formation consist of clay, kankar and fine grained sand
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (230):

Layers	Lithological Formation
h_1	The formation consist of fine grained sand and clay
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of fine grained sand and clay
h_4	The formation consist of fine to medium grained sand and clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

VES (231):

Layers	Lithological Formation
h_1	The formation consist of fine grained sand and clay
h_2	The formation consist of clay, kankar and fine grained sand
h_3	The formation consist of fine to medium grained sand and clay
h_4	The formation consist of medium to fine grained sand and minor clay
h_5	The formation consist of fine grained sand and clay with minor kankar
h_6	The formation encountered is rock which has few fissures & fractures containing little quantity of ground water.

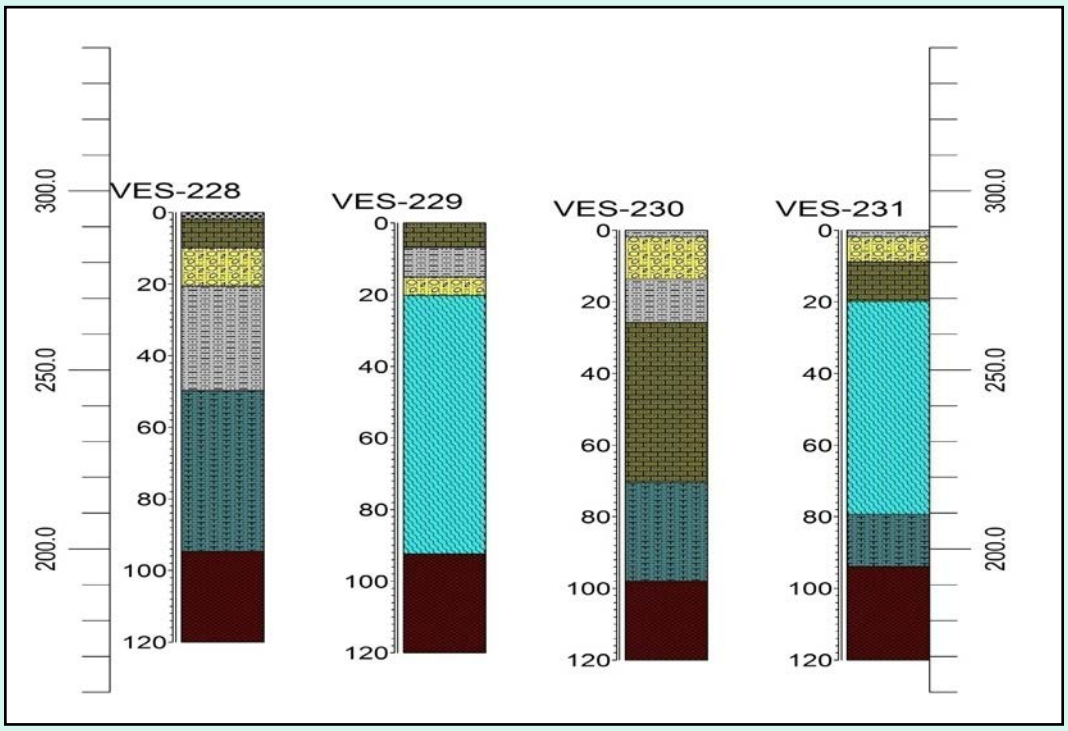

Figure 109: Lithological formation from VES(228) to VES(231).

2.4.3 Representation of lithological formations along Cross Sections

To represent subsurface lithological formations or different layers, depth to bedrock, permeable and impermeable layers, saturated and unsaturated zones & their thickness, 18 cross sections (AA′, BB′, CC′, DD′, EE′, FF′, GG′, HH′, II′, JJ′, KK′, LL′, MM′, NN′, OO′, PP′, QQ′ and RR′) have been selected. Each cross section passes through different VES locations. A blue line in section profile represent water table along the section. The portion aquifer thickness lies below water table is known as saturated aquifer thickness. The saturated aquifer thickness for every section is shown in another figure. The following map shows the different cross sections.

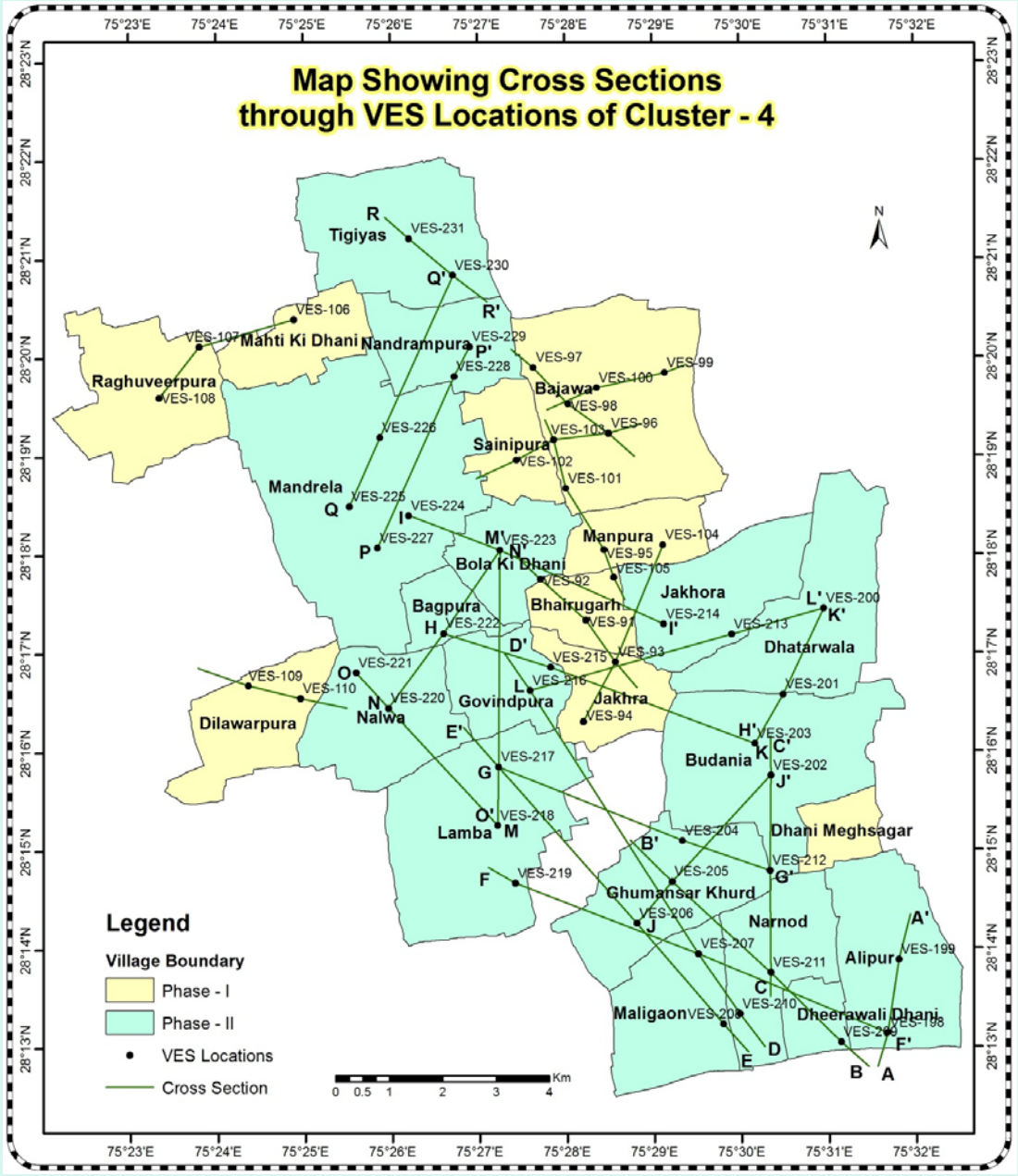

Figure 110: Map shows different cross sections through VES locations of cluster – 4

The following figures show different cross sections and saturated aquifer thickness:

Cross Section A-A′ :

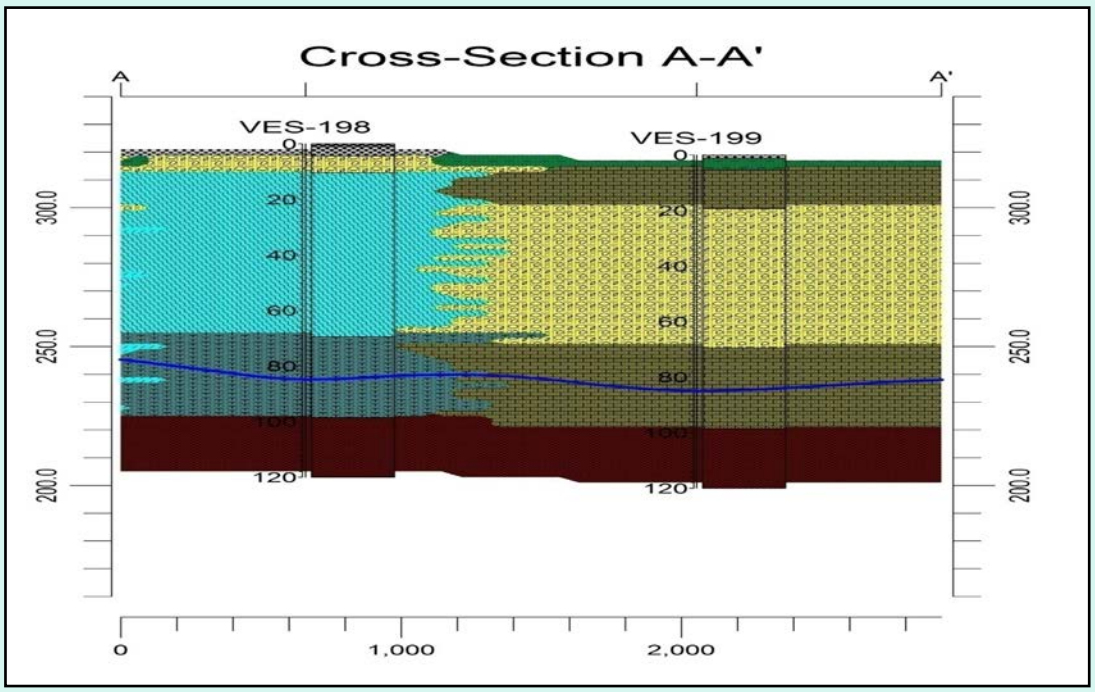

Figure 111: Cross Section A-A′ passes through VES (198) and VES (199).

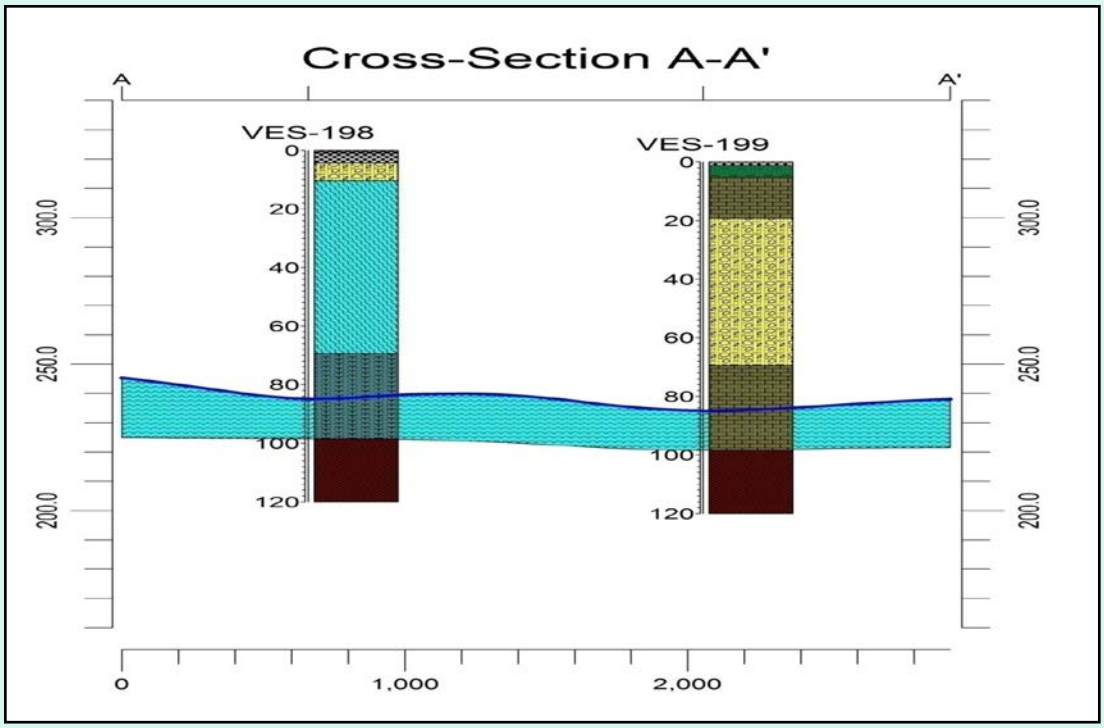

Figure 112: Saturated aquifer thickness along cross section A-A′.

Cross Section B-B′:

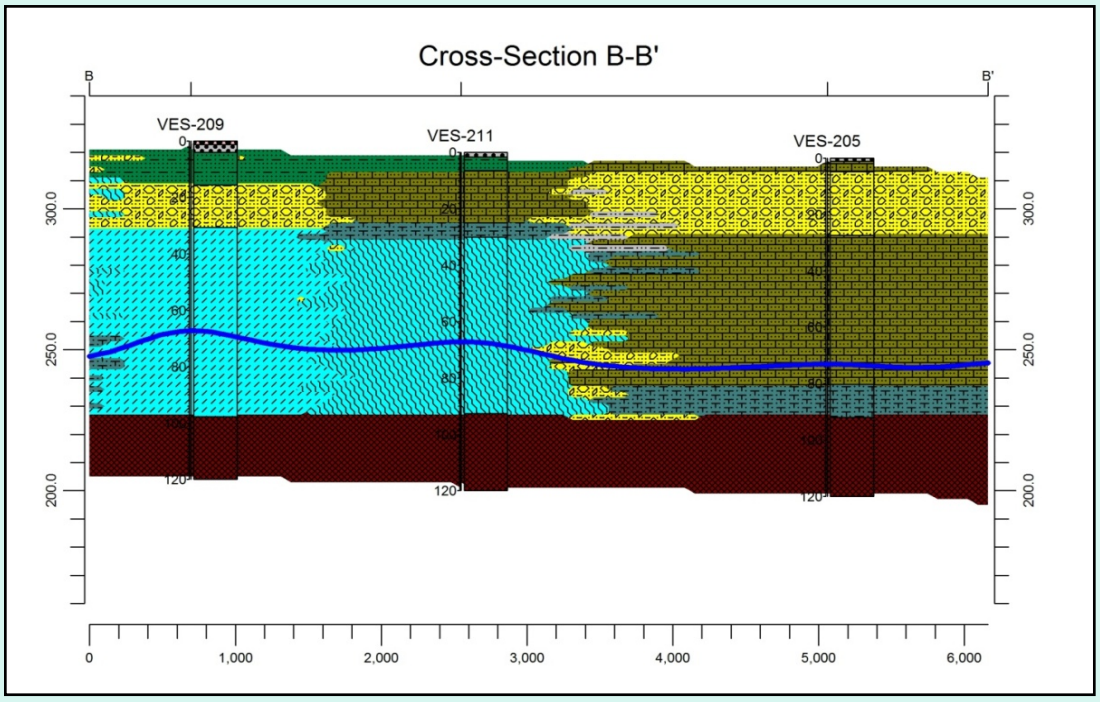

Figure 113: Cross Section B-B′ passes through VES (209), VES (211) and VES (205).

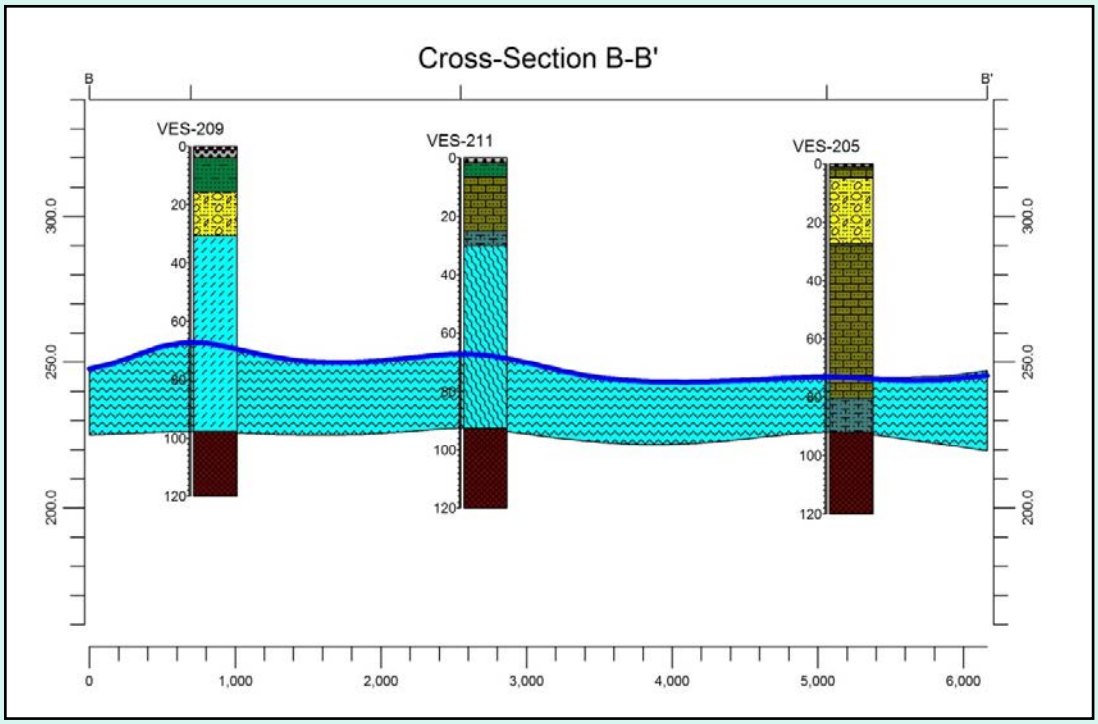

Figure 114: Saturated aquifer thickness along cross section B-B′.

Cross Section C-C′:

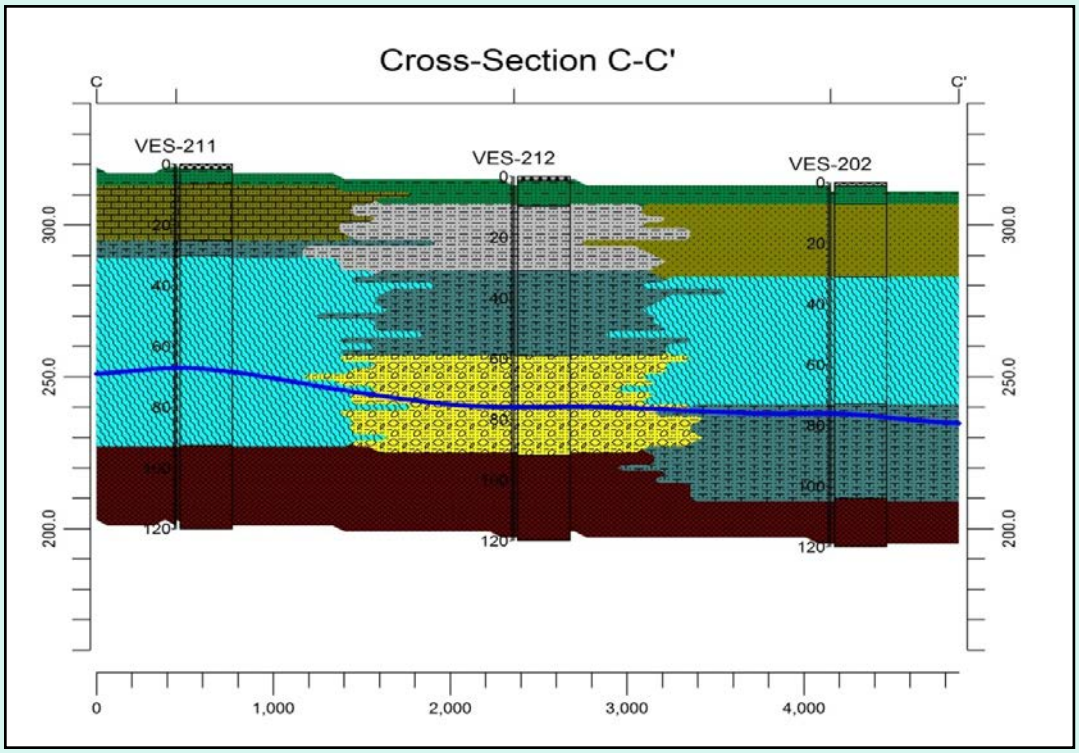

Figure 115: Cross Section C-C′ passes through VES (211), VES (212) and VES (202).

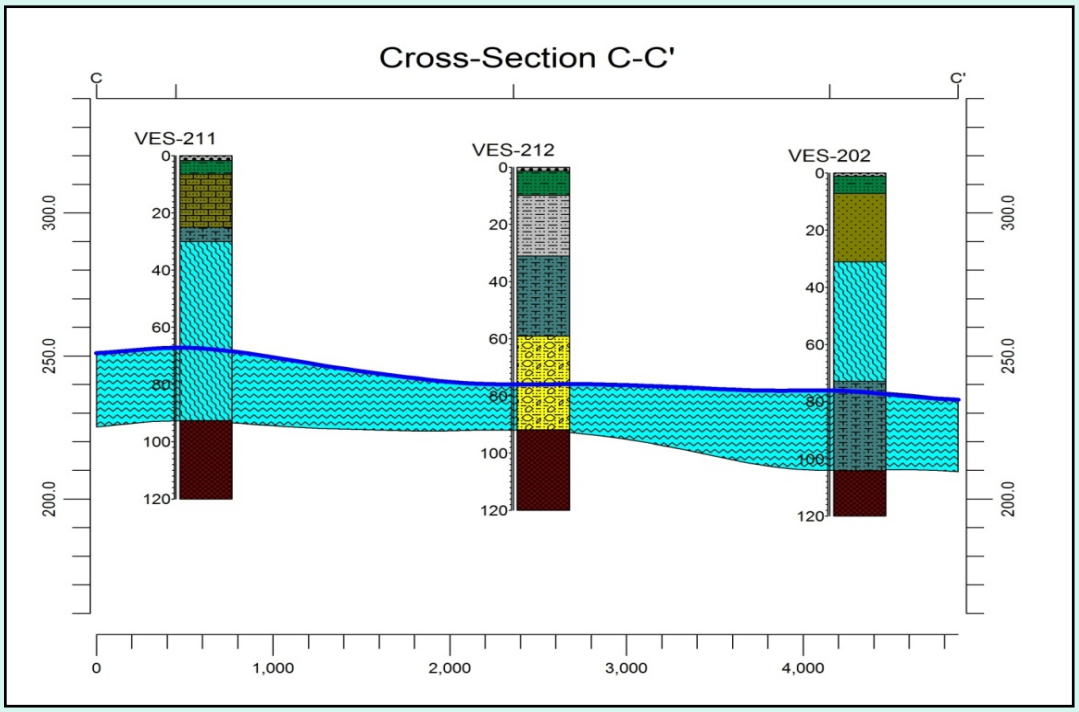

Figure 116: Saturated aquifer thickness along cross section C-C′.

Cross Section D-D′:

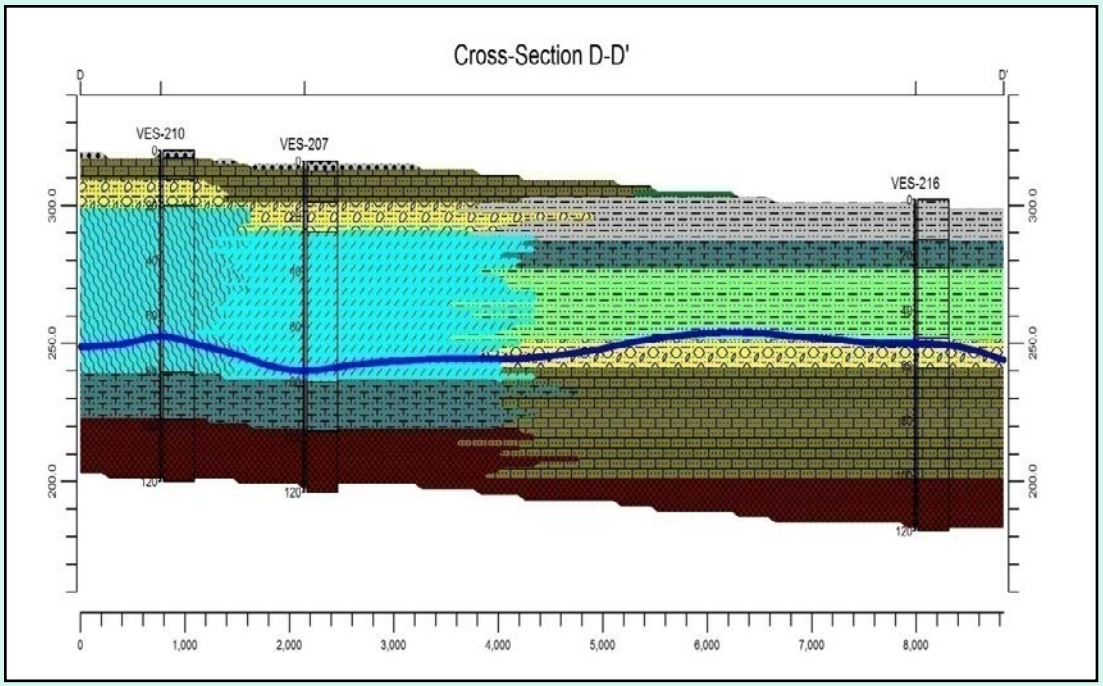

Figure 117: Cross Section D-D′ passes through VES (210), VES (207) and VES (216).

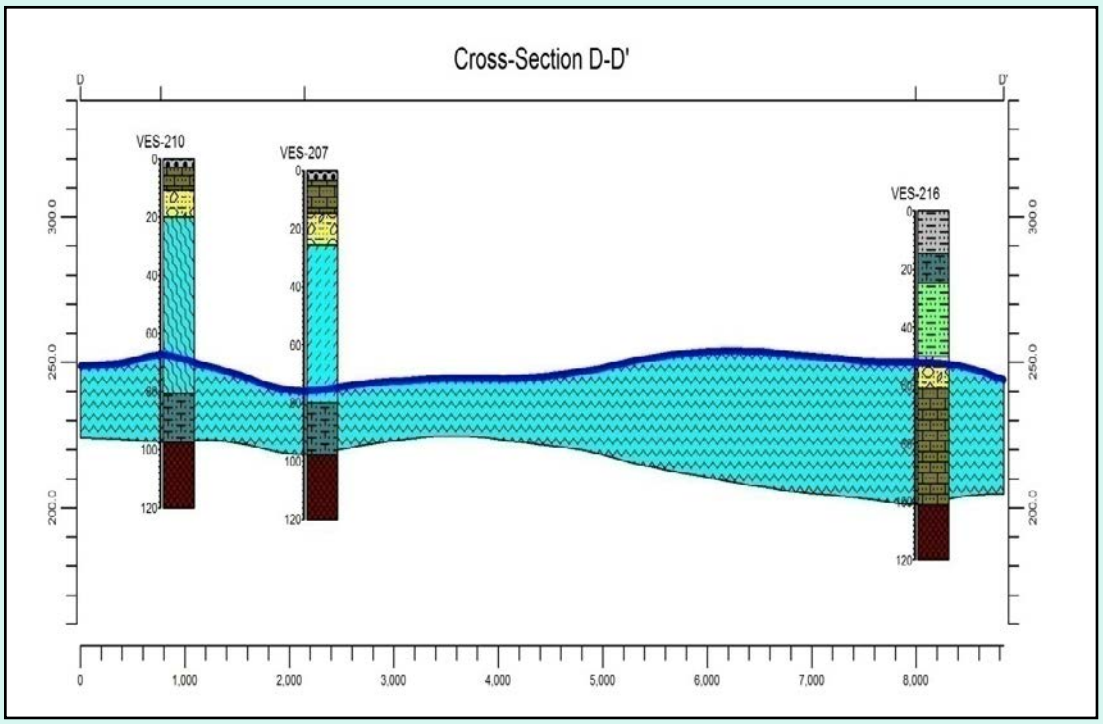

Figure 118: Saturated aquifer thickness along cross section D-D′.

Cross Section E-E′:

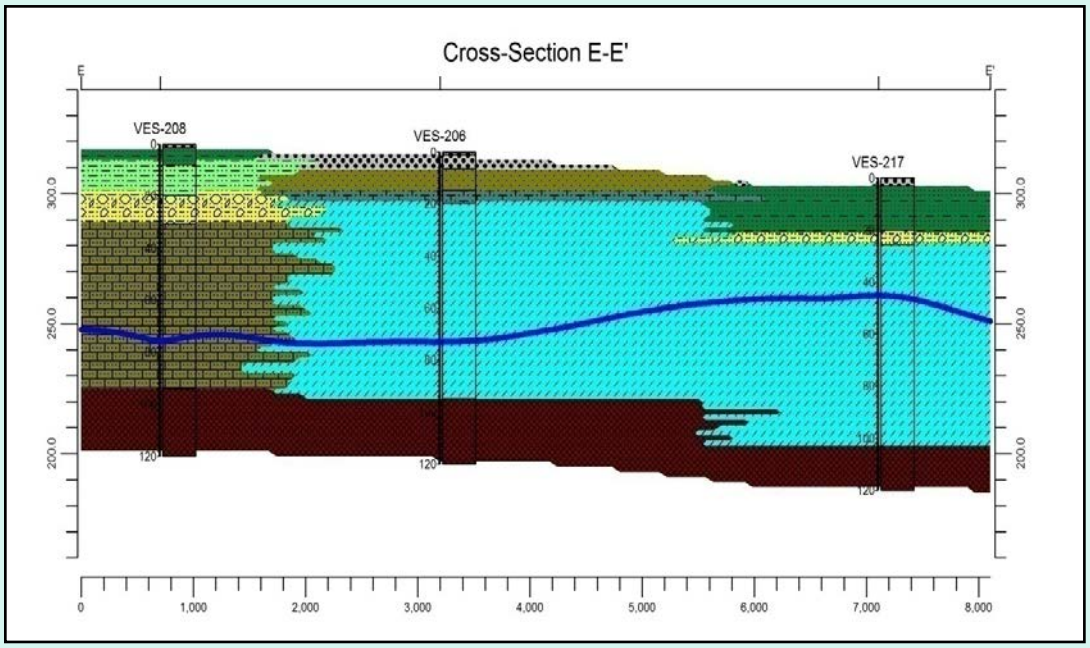

Figure 119: Cross Section E-E′ passes through VES (208), VES (206) and VES (217).

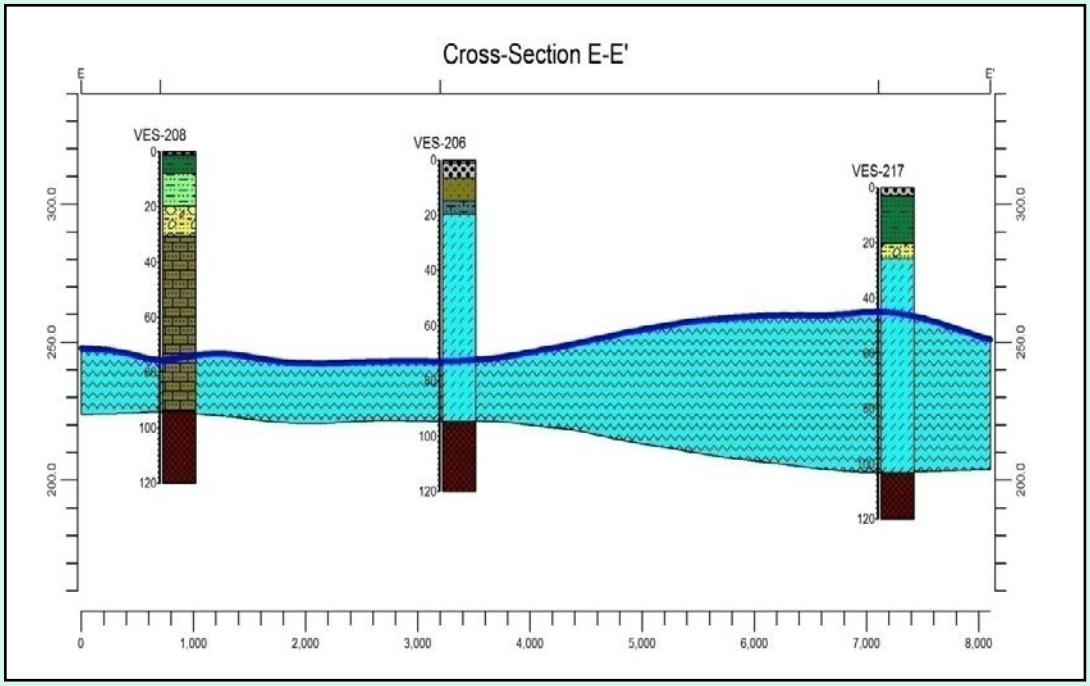

Figure 120: Saturated aquifer thickness along cross section E-E′.

Cross Section F-F′:

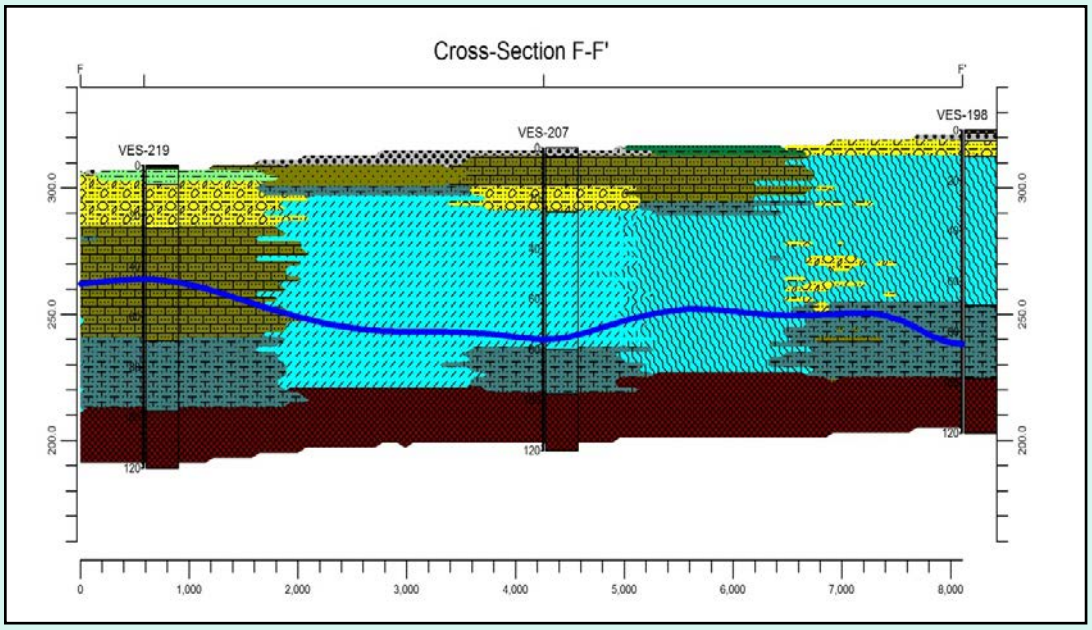

Figure 121: Cross Section F-F′ passes through VES (219), VES (207) and VES (198).

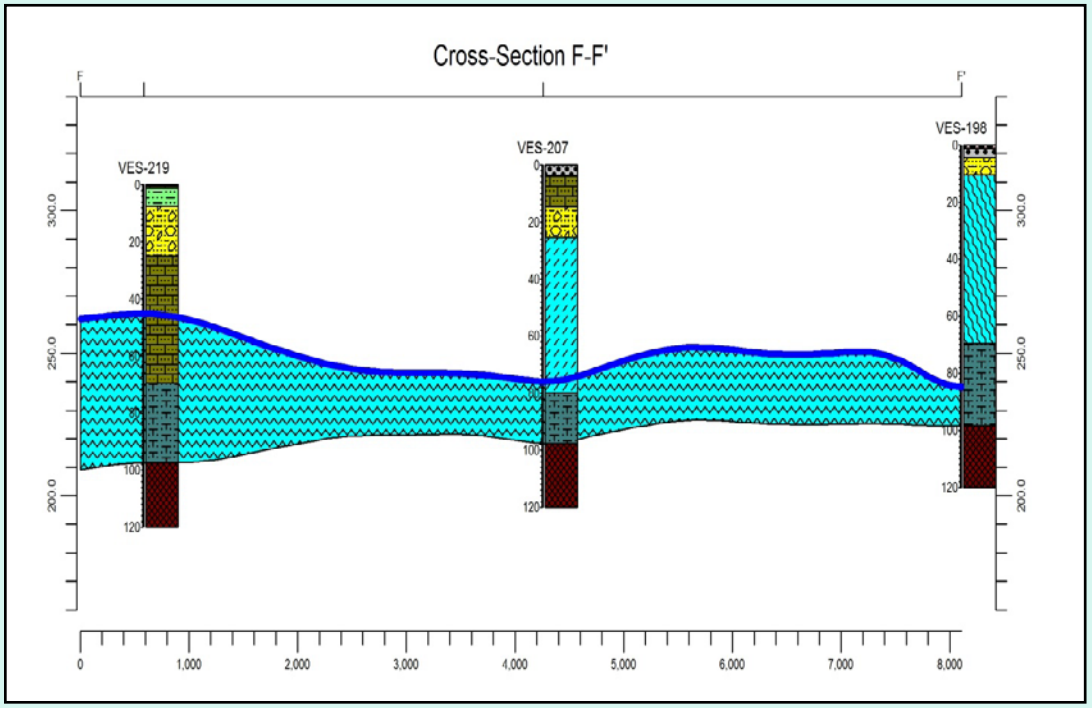

Figure 122: Saturated aquifer thickness along cross section F-F′.

Cross Section G-G′:

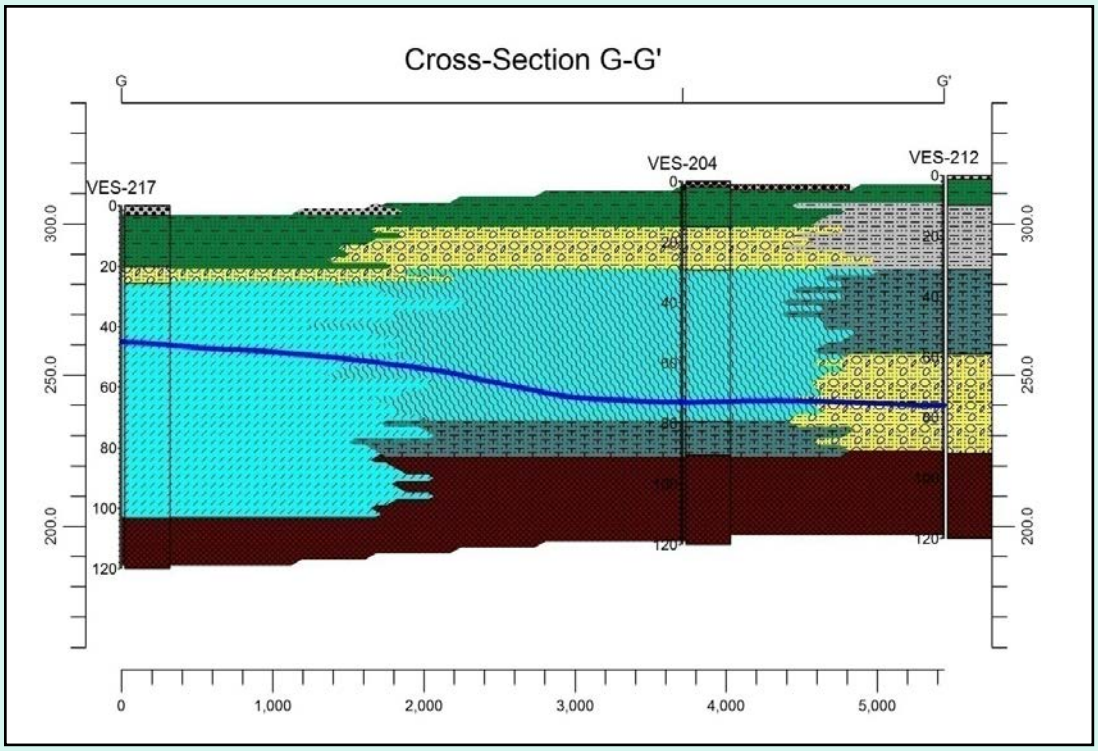

Figure 123: Cross Section G-G′ passes through VES (217), VES (204) and VES (212).

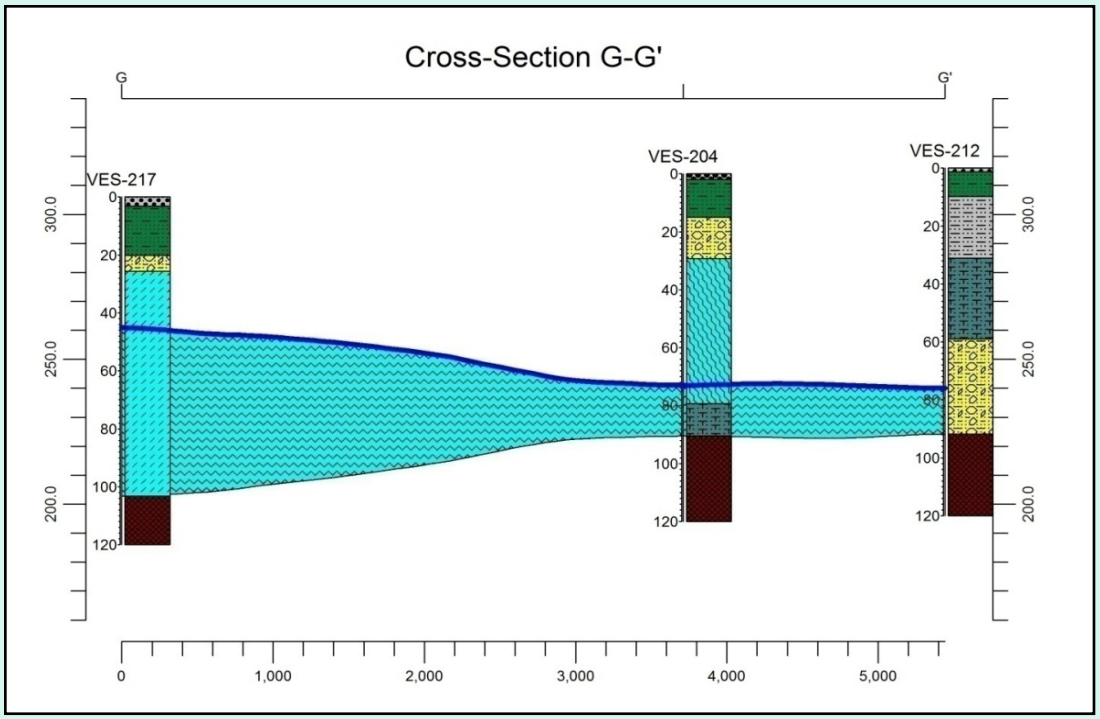

Figure 124: Saturated aquifer thickness along cross section G-G′.

Cross Section H-H′:

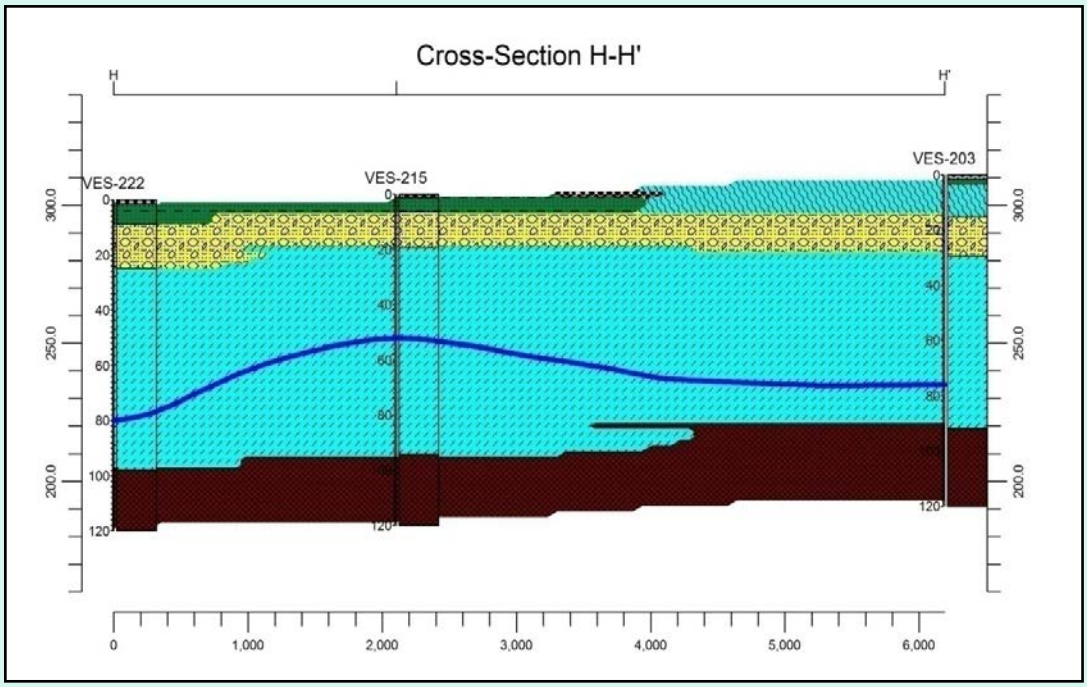

Figure 125: Cross Section H-H′ passes through VES (222), VES (215), and VES (203).

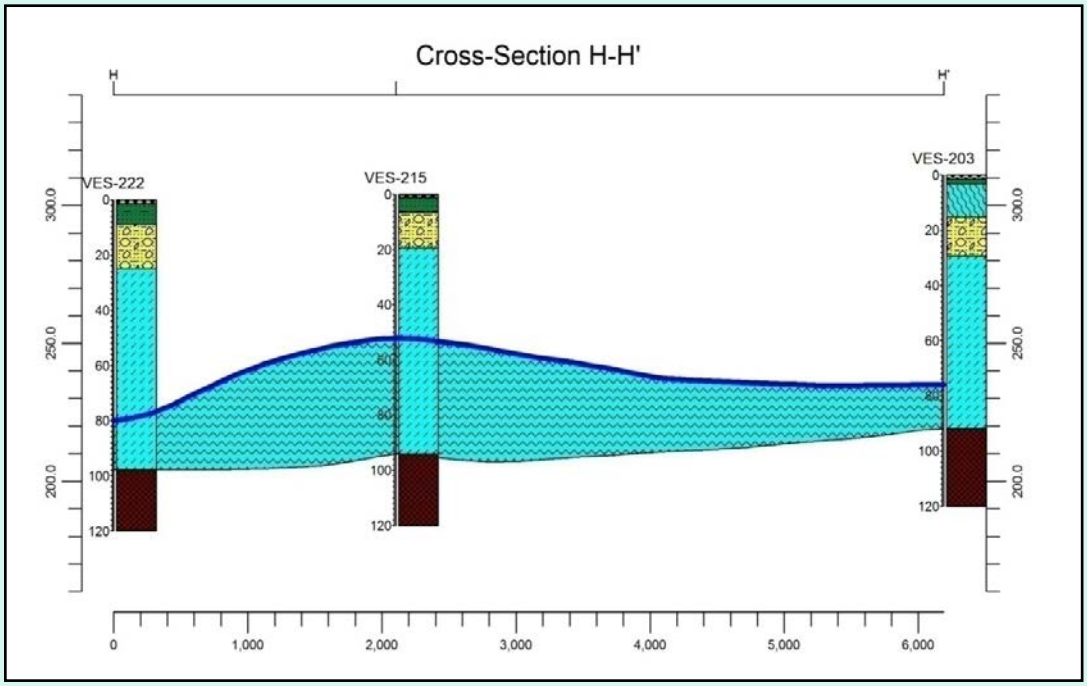

Figure 126: Saturated aquifer thickness along cross section H-H′.

Cross Section I-I′:

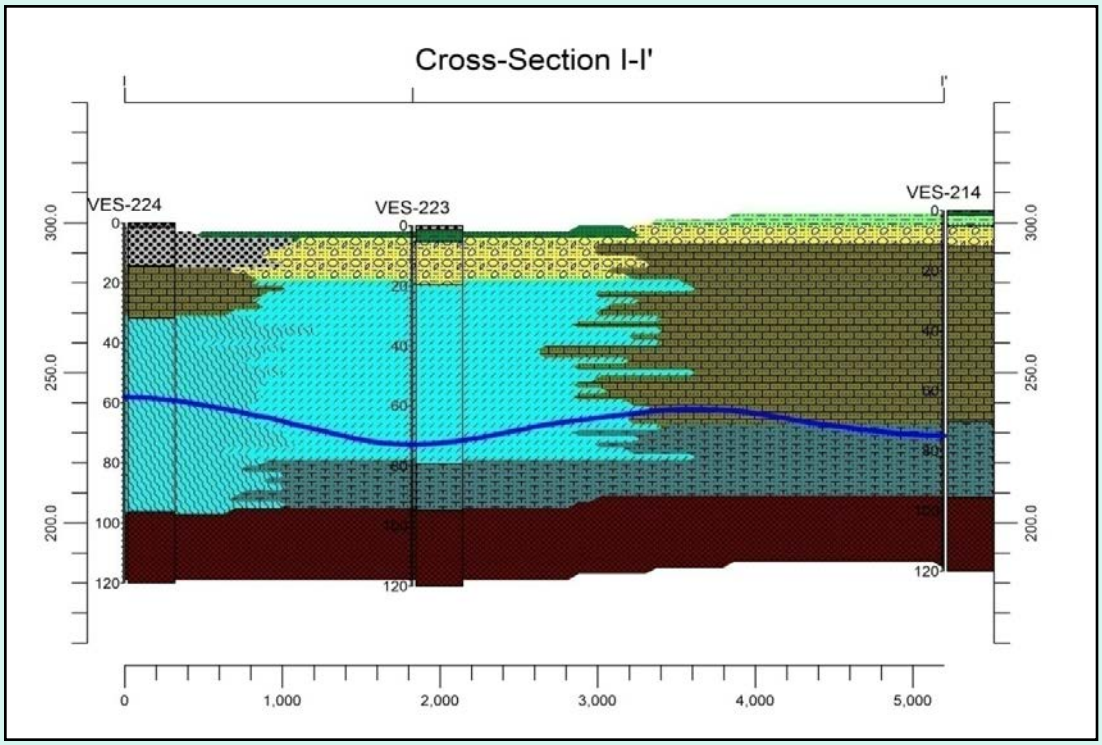

Figure 127: Cross Section I-I′ passes through VES (224), VES (223), and VES (214).

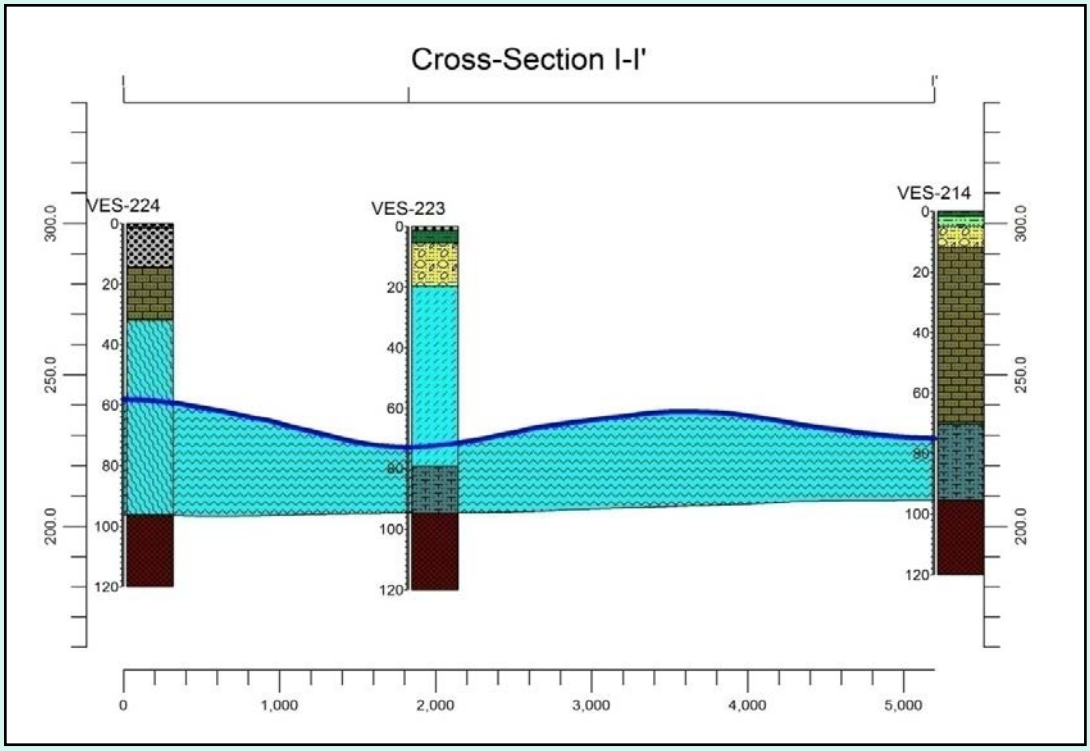

Figure 128: Saturated aquifer thickness along cross section I-I′.

Cross Section J-J′:

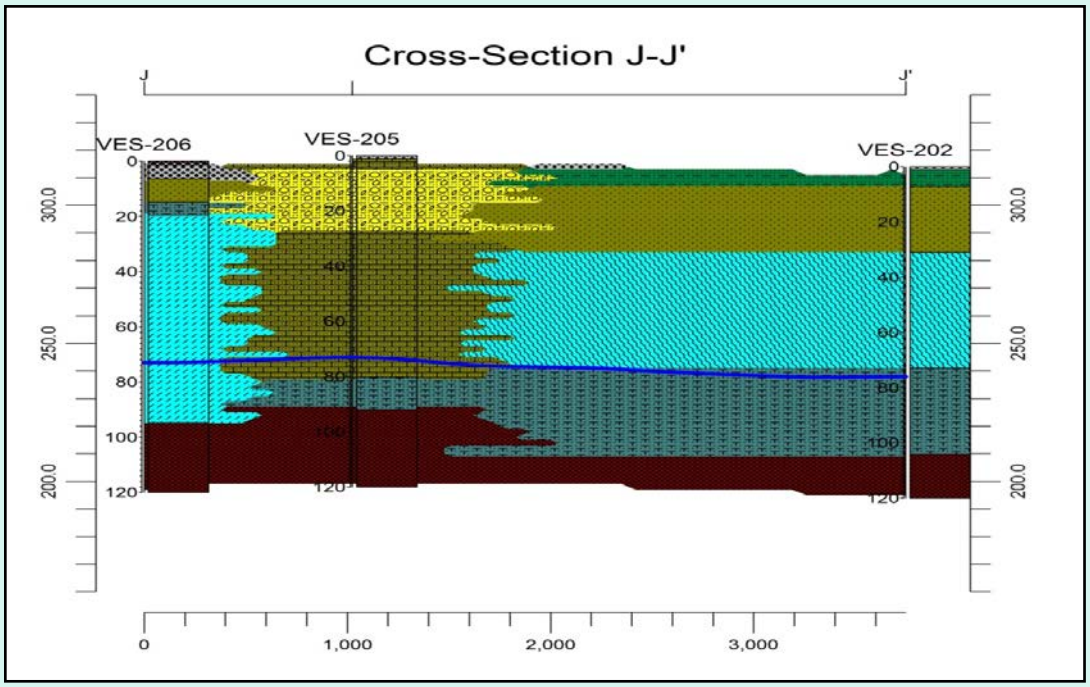

Figure 129: Cross Section J-J′ passes through VES (206), VES (205), and VES (202).

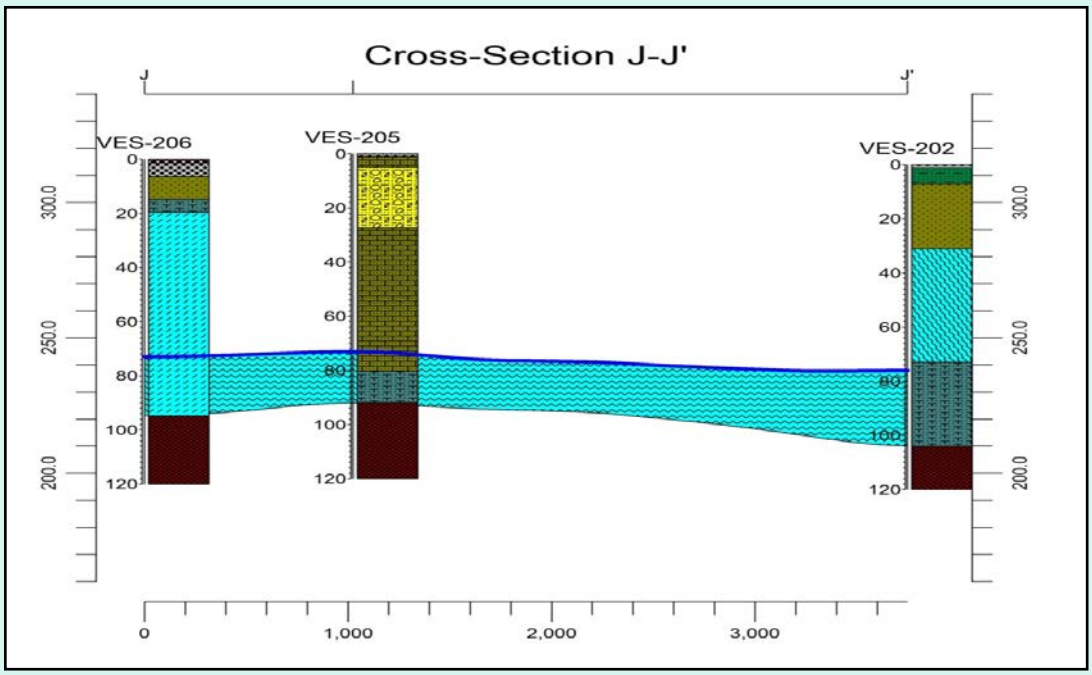

Figure 130: Saturated aquifer thickness along cross section J-J′.

Cross Section K-K′:

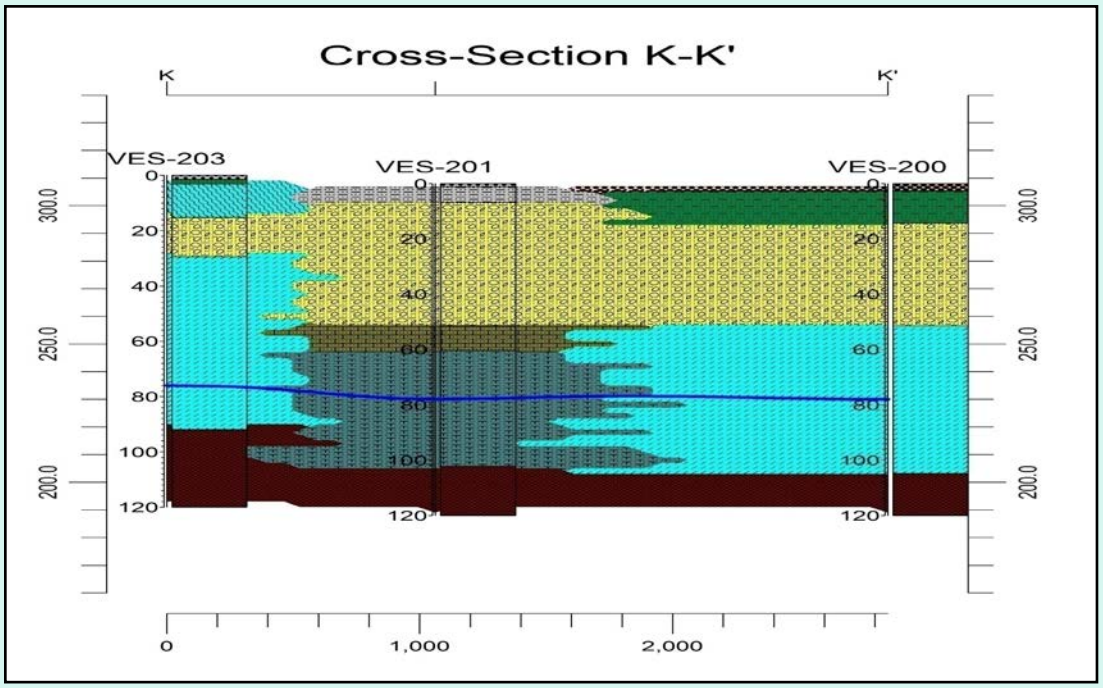

Figure 131: Cross Section K-K′ passes through VES (203), VES (201), and VES (200).

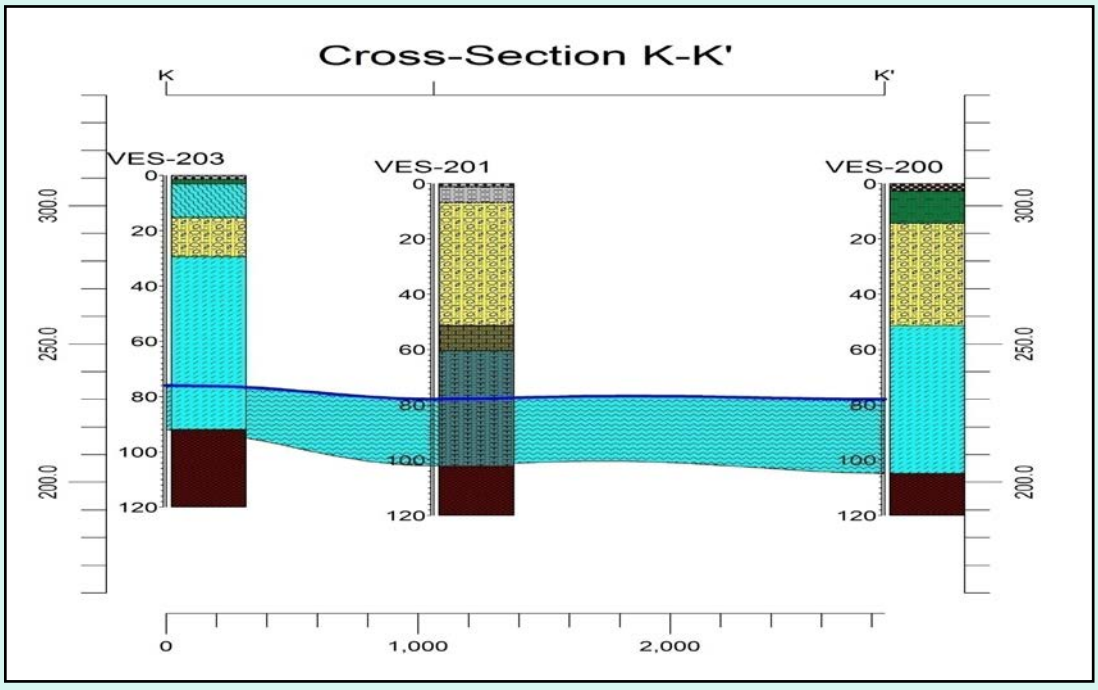

Figure 132: Saturated aquifer thickness along cross section K-K′.

Cross Section L-L′:

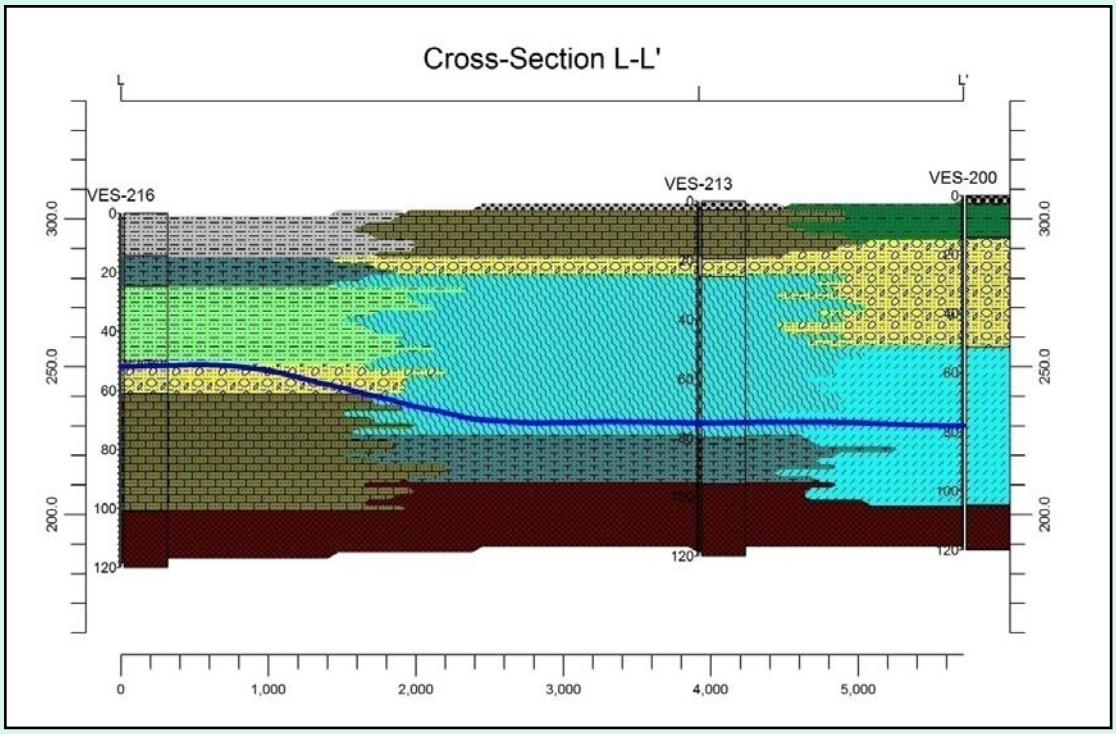

Figure 133: Cross Section L-L′ passes through VES (216), VES (213), and VES (200).

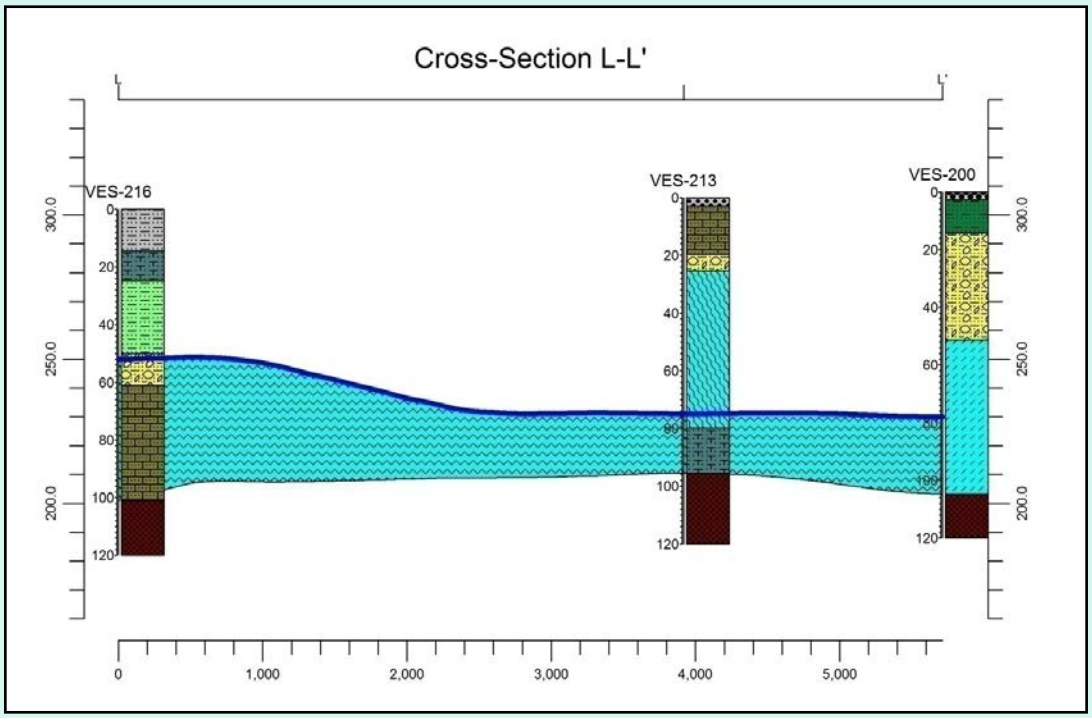

Figure 134: Saturated aquifer thickness along cross section L-L′.

Cross Section M-M′:

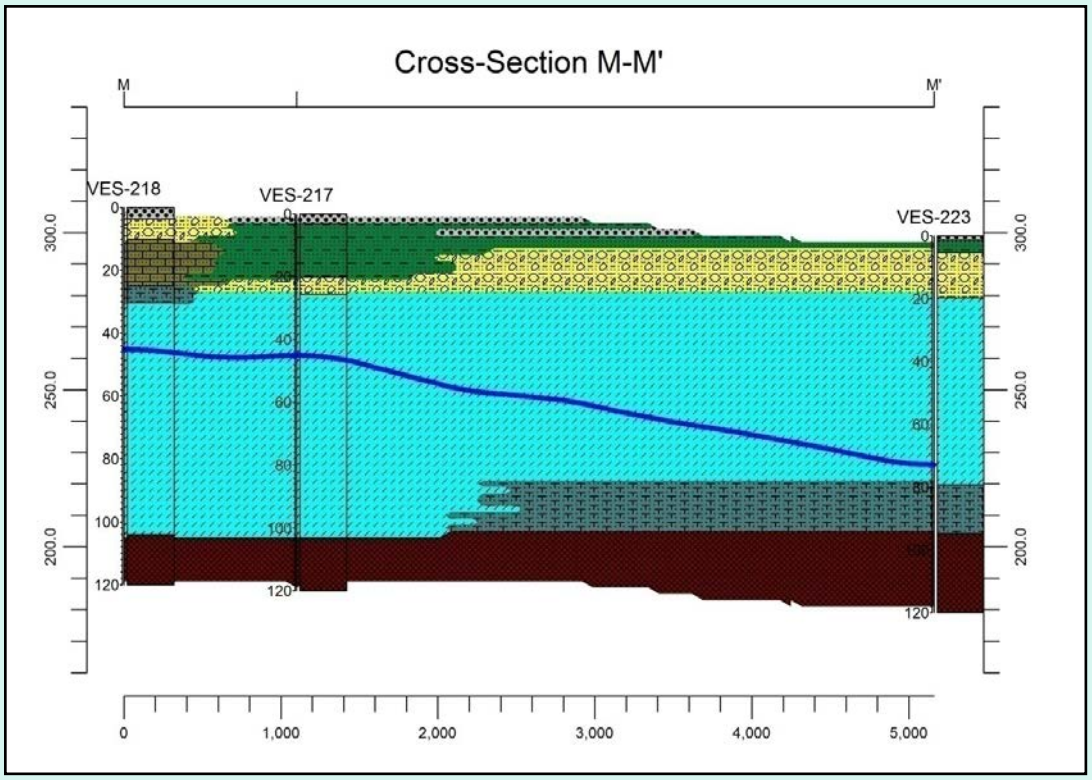

Figure 135: Cross Section M-M′ passes through VES (218), VES (217), and VES (223).

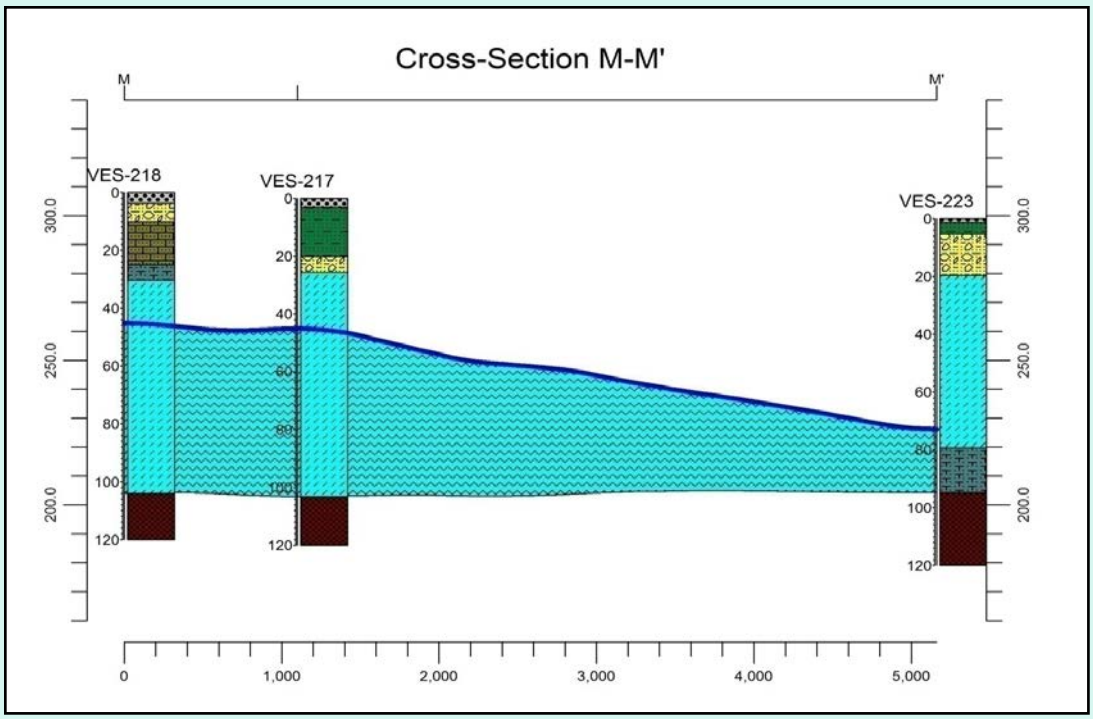

Figure 136: Saturated aquifer thickness along cross section M-M′.

Cross Section N-N′:

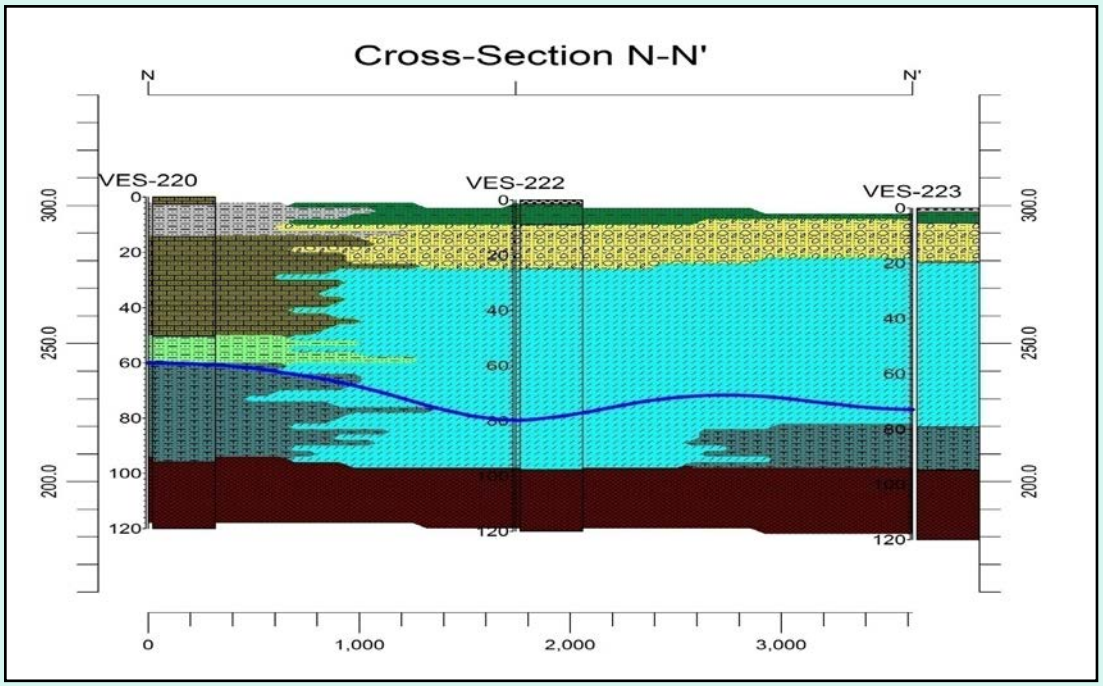

Figure 137: Cross Section N-N′ passes through VES (220), VES (222), and VES (223).

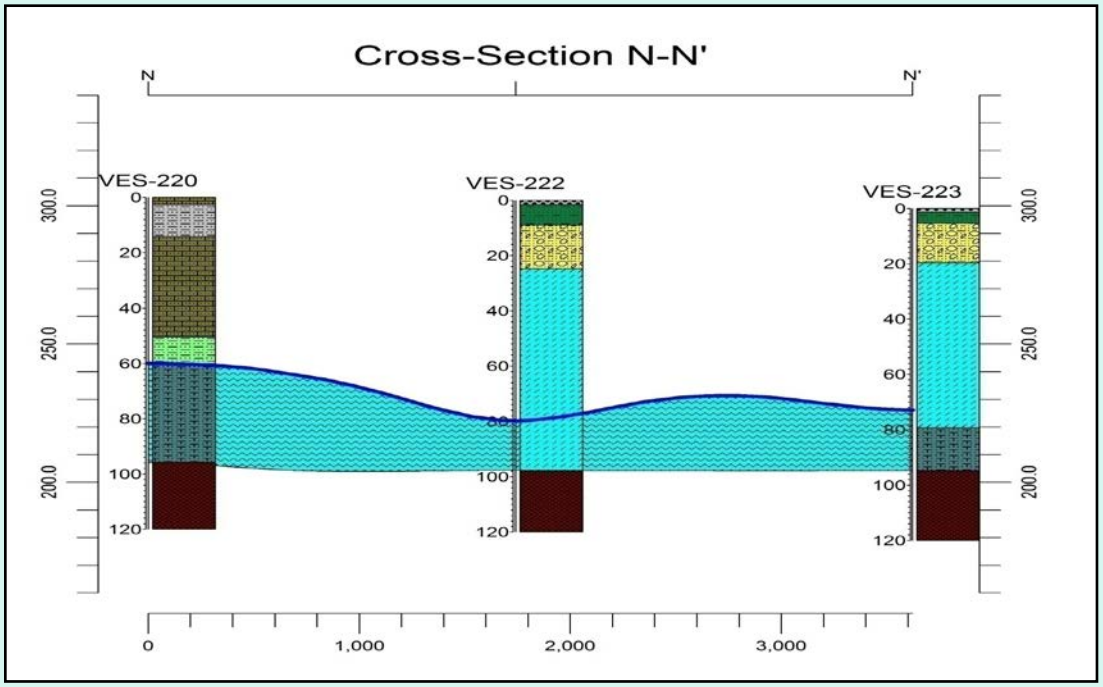

Figure 138: Saturated aquifer thickness along cross section N-N′.

Cross Section O-O′:

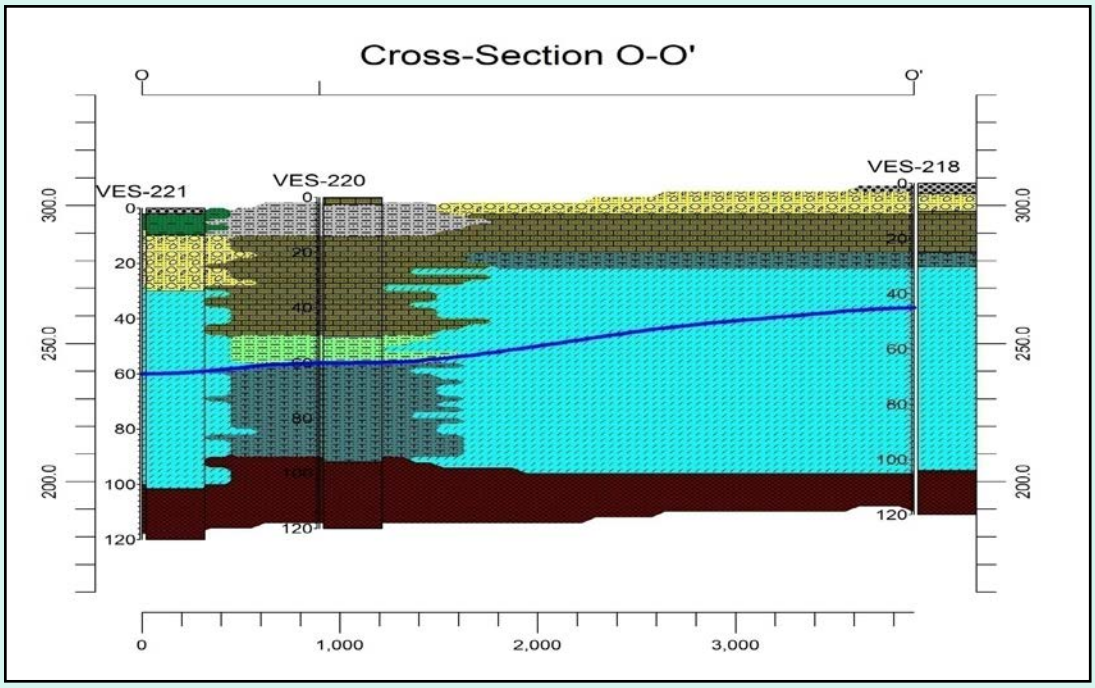

Figure 139: Cross Section O-O′ passes through VES (221), VES (220), and VES (218).

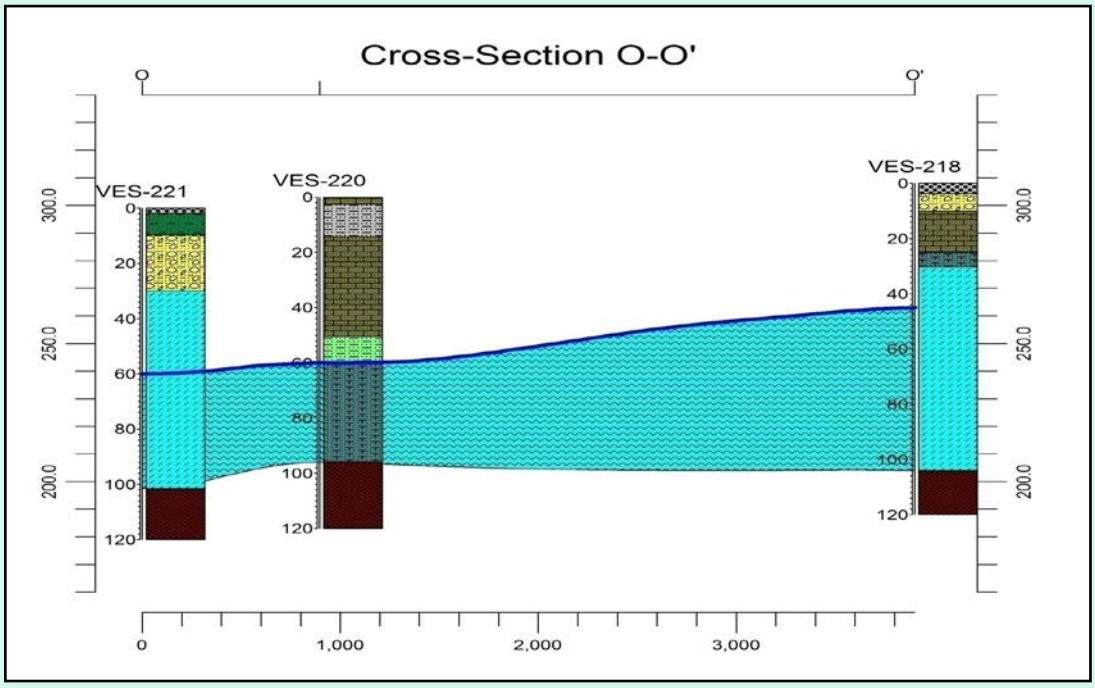

Figure 140: Saturated aquifer thickness along cross section O-O′.

Cross Section P-P′:

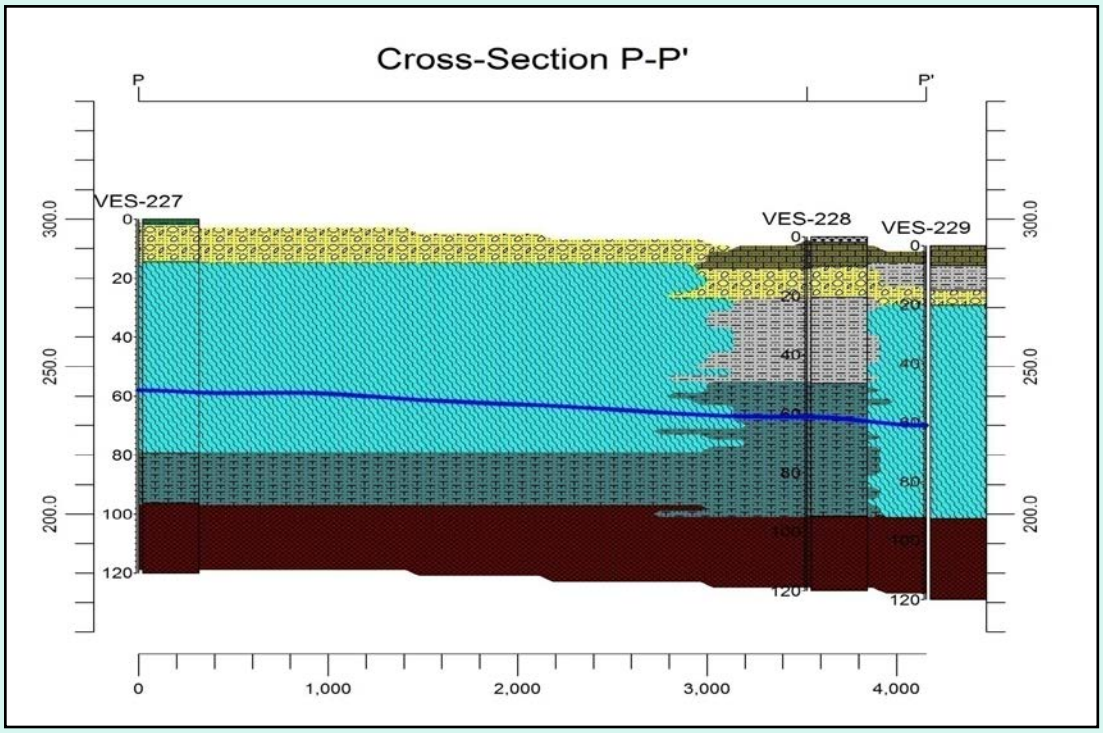

Figure 141: Cross Section P-P′ passes through VES (227), VES (228), and VES (229).

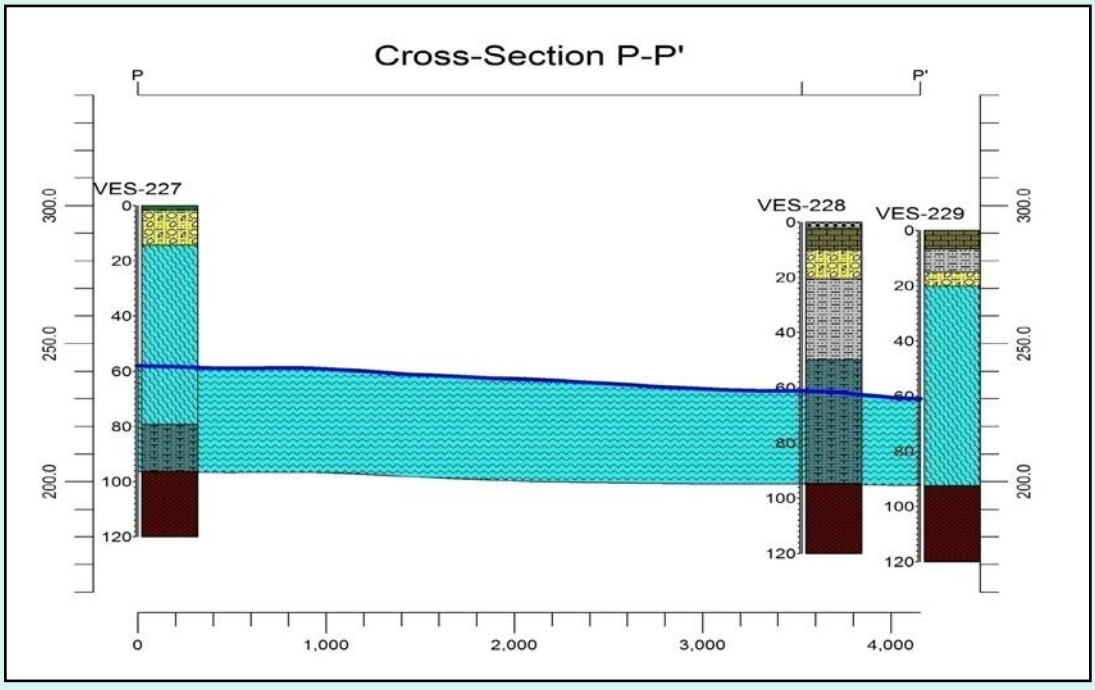

Figure 142: Saturated aquifer thickness along cross section P-P′.

Cross Section Q-Q′:

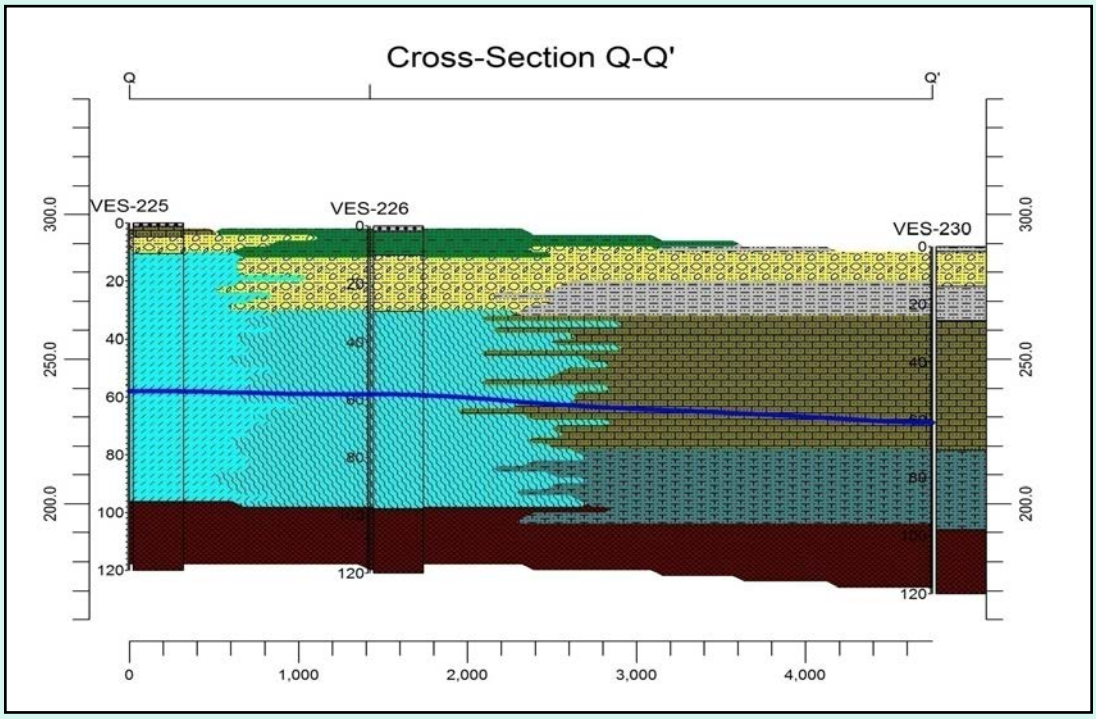

Figure 143: Cross Section Q-Q′ passes through VES (225), VES (226), and VES (230).

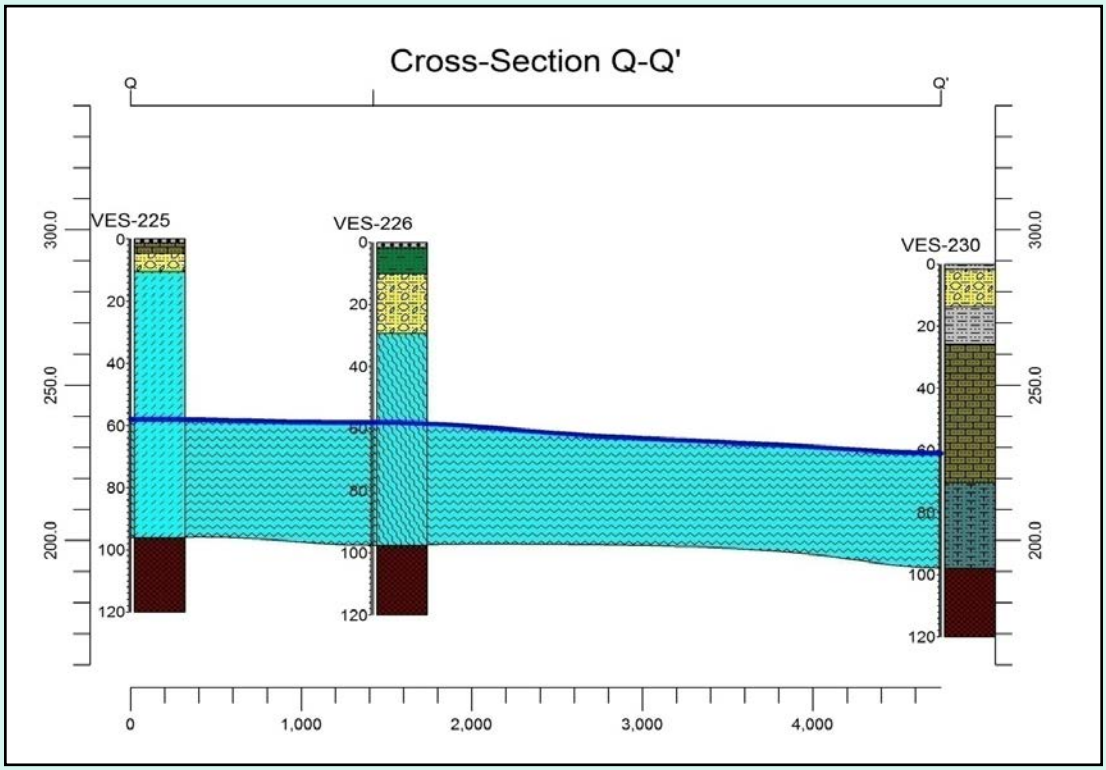

Figure 144: Saturated aquifer thickness along cross section Q-Q′.

Cross Section R-R′:

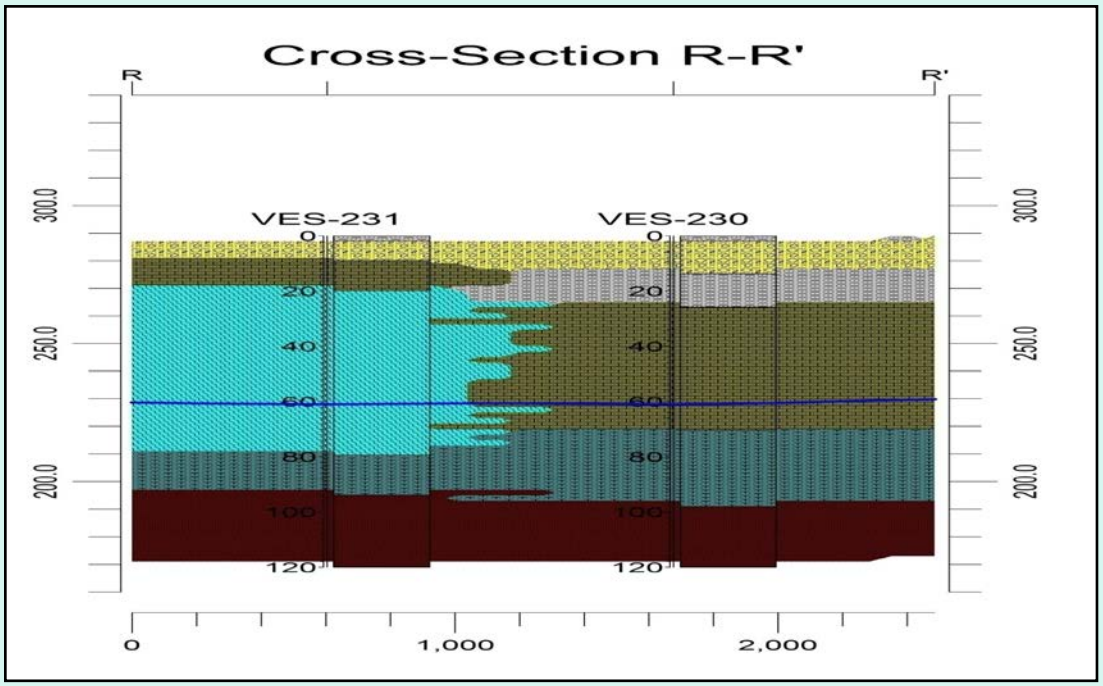

Figure 145: Cross Section R-R′ passes through VES (231) and VES (230).

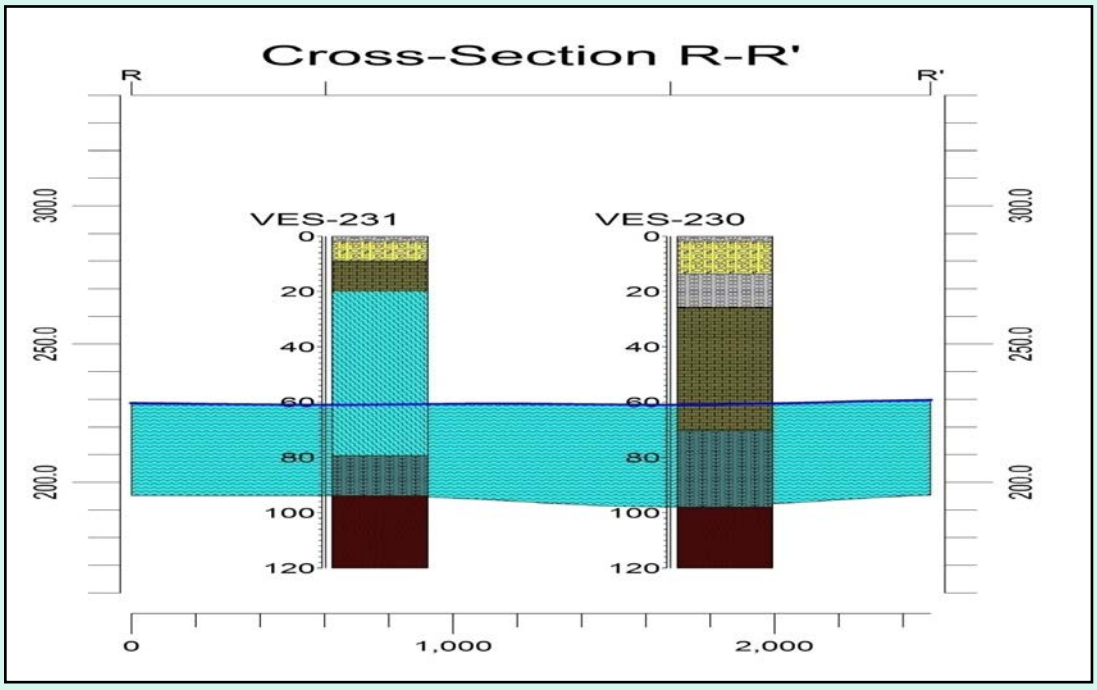

Figure 146: Saturated aquifer thickness along cross section R-R′.

2.4.4 Findings of Geophysical Electrical resistivity Survey and Suggestions, Cluster – 4

- Alluvial thickness may vary from 90m to 104m bgl(below ground level) in most of the area.
- A minor fissures and fractures may appear in rock formation having low to moderate quantum of ground water.
- By studying the inferences of vertical electrical soundings and their lithological representation along cross sections, thickness of permeable unsaturated aquifer, it seems that VES No. 198, 200, 203, 204, 206, 207, 209, 210, 211, 213, 215, 217, 218, 221, 222, 223, 225, 226, 227, 229 and 231 are comparatively better sites for artificial recharge. But VES No. (200) is located towards river side, therefore, recharged ground water may underflow towards river. Proposed sites for artificial recharge are shown in following map.
- The VES(200) located towards river Kantli, have a good aquifer zones, indicate that younger alluvium along river Kantli are comparatively good aquifer, having better yielding capacity.
- A thin hard layer of clay, kankar with fine grained sand (impermeable layer) is presented in lithological formation of most of the villages of studied area which hinder the percolation of rain water to ground water level, therefore, the design of recharge structure in such a manner that the quantum of surface water may be injected below this impermeable layer, and only 5 to 10m before water level for fast and efficient augmentation of ground water.

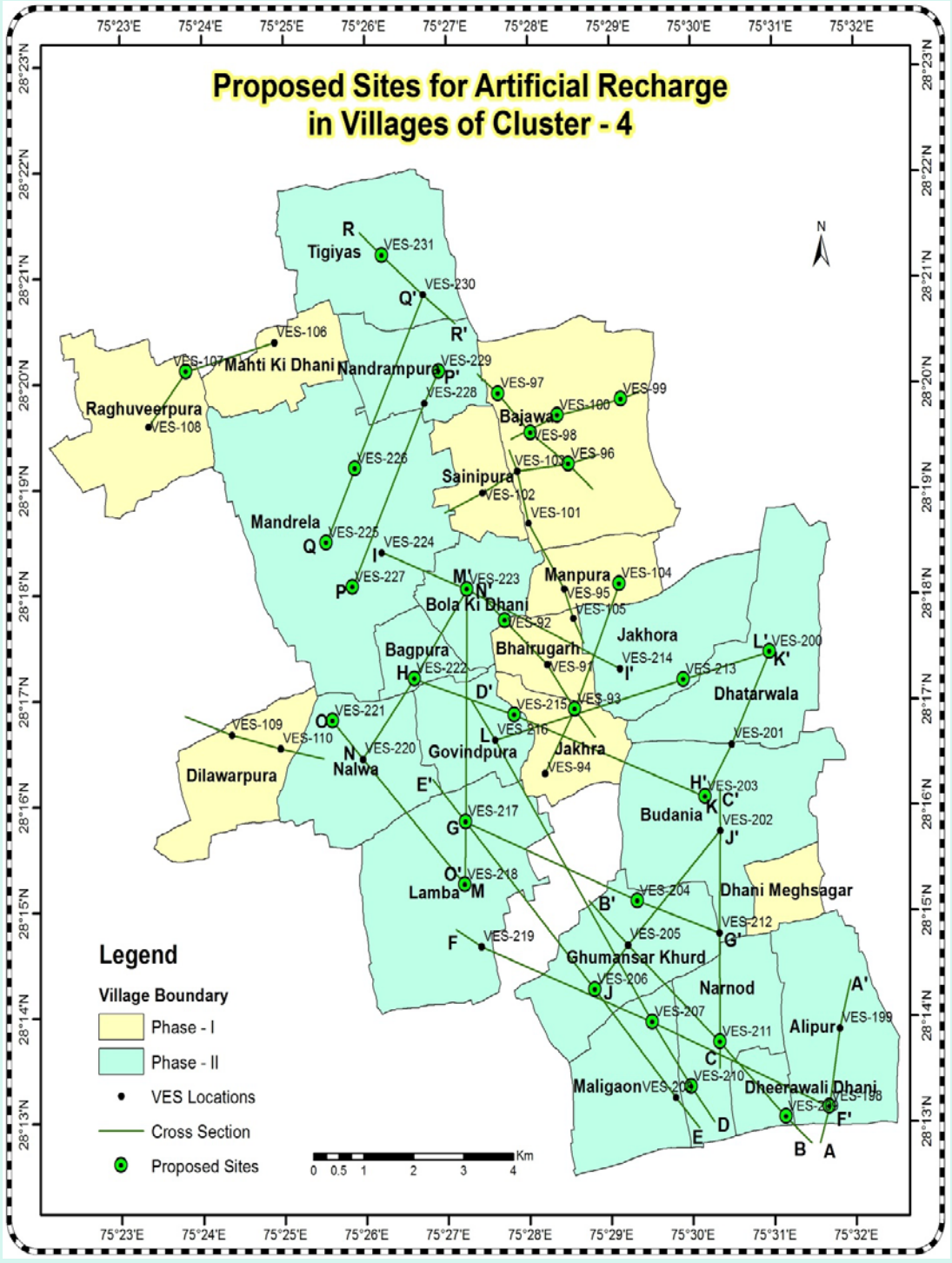

Figure 147: Map shows the proposed sites for artificial recharge.

The details of proposed VES sites, their locations and thickness of impermeable layers are given in following table.

Table 9: Thickness of impermeable/ less permeable layer at proposed sites of cluster - 4.

S. No.	VES No.	Village	Location	Coordinates	Thickness of impermeable/ less permeable layer in m bgl
1	198	Alipura	In the field of shri raghuvir ji s/o shri Ratan ji	N28°13′08.38″ E75°31′40.35″	4 - 10m
2	200	Dhatarwal	In the river area	N28°17′27.06″ E75°30′57.48″	14 - 51m
3	203	Budania	On Ghumansar road	N28°16′04.66″ E75°30′09.80″	15 – 30m
4	204	Ghumansar	Towards Budania	N28°15′05.57″ E75°29′19.81″	15 - 30m
5	206	Ghumansar	On Kasimpura road	N28°14′15.32″ E75°28′48.09″	15 - 20m
6	207	Maligaon	Maligaon	N28°13′56.81″ E75°29′30.23″	15 – 26m
7	209	Dheer wali Dhani	Near Adarsh Education Institute	N28°13′02.74″ E75°31′08.45″	15 – 31m
8	210	Narnod	Towards Maligaon	N28°13′20.10″ E75°29′58.79″	10 – 20m
9	211	Narnod	Towards Budania	N28°13′45.40″ E75°30′20.09″	25 – 30m
10	213	Jakhoda	In Jode area	N28°17′11.22″ E75°29′54.04″	20 – 25m
11	215	Govindpura	Govindpura	N28°16′51.65″ E75°27′49.53″	7 – 20m
12	217	Lamba	Near Electric Sub Station	N28°15′50.97″ E75°27′13.56″	20 – 26m
13	218	Lamba	Near shri Maniram's field	N28°15′15.32″ E75°27′12.67″	25 – 30m
14	221	Nalwa	In Khadar Jode	N28°16′48.50″ E75°25′35.70″	10 – 30m
15	222	Bagpura	Near School	N28°17′12.35″ E75°26′35.98″	9 – 25m
16	223	Bhola Ki Dhani	In the field of shri Ram singh	N28°18′03.04″ E75°27′14.79″	5 – 20m
17	225	Mandrela	Mandrela	N28°18′29.62″ E75°25′31.52″	5 – 10m
18	226	Mandrela	Towards Electric Power Station	N28°19′11.83″ E75°25′52.77″	10 – 30m
19	227	Mandrela	In the field of shri Mumtaj Ali	N28°18′04.40″ E75°25′50.59″	2 – 15m
20	229	Nandrampura	Towards Tigias	N28°20′07.05″ E75°26′54.46″	15 – 20m
21	231	Tigias	Tigias	N28°21′12.95″ E75°26′12.99″	2 – 20m

2.4.5 Depth to Water Level

The Cluster wise depth to water level is reported below:

Table 10: Depth to water level in villages of Cluster - 1.

S No.	Village	Depth to water level (m) bgl
1	Solana	48 - 52
2	Mehrampura	55 - 60
3	Kyamsar	60 - 64
4	Padampura	60 - 64
5	Kishorepura	60 - 64
6	Shyampura Matana	64 - 67
7	Keharpura Kalan	64 - 67
8	Kishanpura	52 - 55
9	Sultana	70 - 73

Table 11: Depth to water level in villages of Cluster - 2.

S No.	Village	Depth to water level (m) bgl
1	Khudot	61 - 65
2	Jhanjhot	80 - 82
3	Gidania	76 - 82
4	Ardawata	80 - 82
5	Bari	85 – 90
6	Nari	85 - 90
7	Khemu ki Dhani	80 - 82
8	Nizampura	85 - 90
9	Dhatarwal ka Bas	85 - 90
10	Oztu	85 - 90
11	Shyopura	85 - 90
12	Ajeetpura	80 - 82
13	Bakhtawarpura	80 - 82
14	Kawarpura	85 - 90
15	Vijaypura	85 - 90
16	Ekhtawarpura	85 - 90
17	Bhamarwasi	80 - 85
18	Keharpura Khurd	73 - 78
19	Khudana	70 - 75
20	Lamba Gothra	80 - 85

Table 12: Depth to water level in villages of Cluster - 3.

S No.	Village	Depth to water level (m) bgl
1	Sultana ka Bas	85 - 90

Table 13: Depth to water level in villages of Cluster - 4.

S No.	Village	Depth to water level (m) bgl
1	Alipura	80 - 85
2	Dheer Wali Dhani	65 - 70
3	Narnod	65 - 70
4	Maligaon	72 - 76
5	Ghumansar	70 - 75
6	Budania	72 - 76
7	Dhatarwal	75 - 80
8	Jakhoda	72 - 76
9	Lamba	42 - 47
10	Nalwa	58 - 63
11	Govindpura	50 - 55
12	Bhola ki Dhani	72 - 75
13	Mandrela	56 - 60
14	Nandrampura	58 - 63
15	Tigias	58 - 63

2.4.6 Quality of Ground Water

Rain water after infiltration through soil add water to ground water reservoir(aquifer) and hence the ground water quality dependent on the type of soil, type of rock below the soil and the residence time in which the water infiltrates from the surface to the saturated zones. The details on groundwater quality in different clusters is discussed below.

The quality of ground water in villages of Cluster - 1, seems to be potable but the problem of fluoride may occur towards some part of village Sultana and Kishanpura

The quality of ground water in villages of Cluster - 2, seems to be potable but the problem of fluoride may occur more or less everywhere.

The quality of ground water seems to be potable in village- Sultana Ka Bas of cluster - 3

The quality of ground water seems to be potable in villages of Cluster - 4 but the problem of high fluoride may occur in most of the villages of cluster - 4, especially in some part of villages Mandrela, Tigias, Nandrampura, Bhola ki Dhani, Govindpura, Nalwa and Lamba. The quality of ground water seems to be slightly saline with fluoride content in villages Ghumansar, Maligaon, Dheer wali Dhani, Govindpura and Bhola ki Dhani.

2.4.7 Ground Water Management

The following are the suggestions regarding groundwater management in the study area;

- Stage of ground water development of Chirawa block is 284% which reflects excessive withdrawal of ground water in comparison to recharge, resulting in depletion of water level and reduction in yield of wells and tube wells. In connection to this, Central Ground Water Authority, New Delhi has already been notified Chirawa block for regulation and control of ground water development.
- A modern agricultural management should be practiced for effective water management in the area by cultivating crops requiring less watering and also encourage use of micro irrigation, i.e. sprinkler and drip system and more of drip irrigation should be encouraged.
- De-fluorosis plants may be installed in villages facing high fluoride contamination in ground water.
- Mass awareness programmes should be arranged at local level to make common people aware of importance of ground water resources, its better practices of usage in domestic and agriculture.
- Awareness building training programmes should be arranged at local level to make farmers and people aware of various techniques of artificial recharge to ground water augmentation.

Technical Terms

- Climate: Sum of meteorological influences as temperature, moisture, wind, pressure and evaporation.
- Aquifer: A saturated geological formation having good permeability to supply sufficient quantity of ground water to a tube well or well.
- Unconfined Aquifer: An aquifer which upper boundary is water table and rests on an impervious formation.
- Ground Water: Water exists in pore spaces and fractures in rocks and sediments beneath the earth's surface.
- Semi Arid: Regions having moderate precipitation.
- Topography: Details of physical features of land surface on a map.
- Geomorphology: Description of land forms and hills.
- Physiography: Study of surface features of the earth.
- Geology: Study of earth's science.
- Hydrogeology: Science dealing with the occurrence and distribution of ground water.
- Water Table: Upper surface of saturated zone at atmospheric pressure.
- Permeability: Property of soil or rocks for flow of water.
- Artificial Recharge: Addition of surface water to ground water by manmade arrangements.
- Saturated Zone: Pores and fractures below land surface are completely filled with water.
- Unsaturated Zone: Pores and fractures below land surface are partially filled with water and air.
- Impermeable Layer: A layer of solid material, which does not allow water to pass through it.
- Electrical Resistivity: Property that measure, how strongly of a given material opposes the flow of electric current.
- Vertical Electrical Sounding: A geophysical method for investigation of geological formations.