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Recharging of groundwater by the geophysical method based on resistivity meter, a case study of Naya Raipur Chhattisgarh

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Abstract
To maintain the balance in the water table, artificial recharge is being adopted in many regions. For this, numerous studies have been carried out. In the present study, vertical electric soundings have been carried out in the different locations of surrounding Atal Nagar, Naya Raipur at 09 random sites to understand the nature and extent of the aquifer and to find out the groundwater potential zone for rainwater harvesting sites. The main objective of this study is to identify the possibility of an appropriate recharge structure at a suitable location. From the interpretation of the VES curve, the evaluation of layer parameters has been done depicting the actual depth of aquifers and high yielding fracture zones. The VES curve has been made to interpret the subsurface geological layers which indicate the 3 to 4 subsurface layers having different resistivity and thickness. When this VES data is correlated with the lithology data of the area, the actual groundwater bearing zone and potential zone can be identified.

Keywords: Vertical electric soundings, unsaturated zone, lithology, resistivity, groundwater potential zone

1. Introduction

Water is a vital natural source and life originated in water about 3.2 billion years ago. Two-thirds of a living organism consists of water and 90% of cell content is also water. Biochemical reactions in living organisms require an aqueous medium. Therefore, water is important for the survival of living organisms. Groundwater, which makes up about 20% of the world's fresh water supply and is about 0.61% of the entire world's water, so it is the most important source of potable water throughout the world. Hydrogeology is the branch of geology concerned with water occurring underground on the surface of the earth. It is important to have a clear concept about the groundwater condition of a particular region before the construction of an engineering structure, before starting a mining operation, mineral exploration and waste disposal. Groundwater is the most important natural resource. It provides 40% of the nation's public water supply; in addition, 40 million people supply their drinking water from tube wells and domestic wells. It is also the source of much water used for irrigation and represents much of the potential future water supply. But over-extraction of the groundwater may result in different types of problems and hazards. Two prevent this hazard sand for proper utilization of groundwater a hydro-geologist plays a significant role in collecting the data regarding the groundwater condition of the area. Rapid withdrawal of groundwater has seriously imparted the environment in many places. Increased urban populations and industrial developments require larger water supplies. To fill these needs, vast numbers of wells using powerful pumps draw huge volumes of groundwater to the surface, greatly altering nature's balance of groundwater discharge and recharge. For restoring all these problems artificial recharge and rainwater harvesting are the only ways to recharge the groundwater level.

Many researchers (Kumar *et al.*, 2018, Chaudhary & Kumar, 2018; Foundations & Testing, 2010; Indhulekha *et al.*, 2019; Javed & Wani, 2009; Journal *et al.*, 2015; Karanth, 1987; Nandishkumar. L, Karthick. M, Arul Prakash. A, Lokpal Bharani Dharaa. D, Revathy S.S, 2014; Narendra *et al.*, 2013; Ramu & Vinay, 2014; Samuel & Gupta, 2020; Sitender &

Rajeshwari, 2011; Waikar & Nilawar, 2014) [33, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32] have used this technique for groundwater prospect zone mapping.

2. Study Area

Studied the Raipur district is located in the centre of the Chhattisgarh state and is bounded by East longitudes 81°32'05" & 82°59'05" and by North latitudes 19°46'35" & 21°53'00" falling in the Survey of India toposheets no 64G/12, G/16, 64H/9 & 64H/13, It covers an area of 13446 sq. km. Atal Nagar (Naya Raipur) is one of the important townships of Chhattisgarh situated about 17 km SE from the main city of Raipur, occupying an area of about 80 square kilometers or 8000 hectares. However, between 21.161° North latitude and 81.787° East longitudes. (Fig1 Satellite Map) and falls in Toposheet No. 64 G/12 & 64 G/16 Atal Nagar is surrounded by the cities of Raipur, Arang, Rajim and Abhanpur. It includes 41 villages out of which 27 villages form the core of Naya Raipur during the renovation of villages for the Construction of NAYA Raipur, it displaced the population of one village. About half of the total acquired land is being used for forestation, roads, parks, public conveniences, water facilities- canals, green belts etc.; 23% of the land would be reserved for educational institutions.

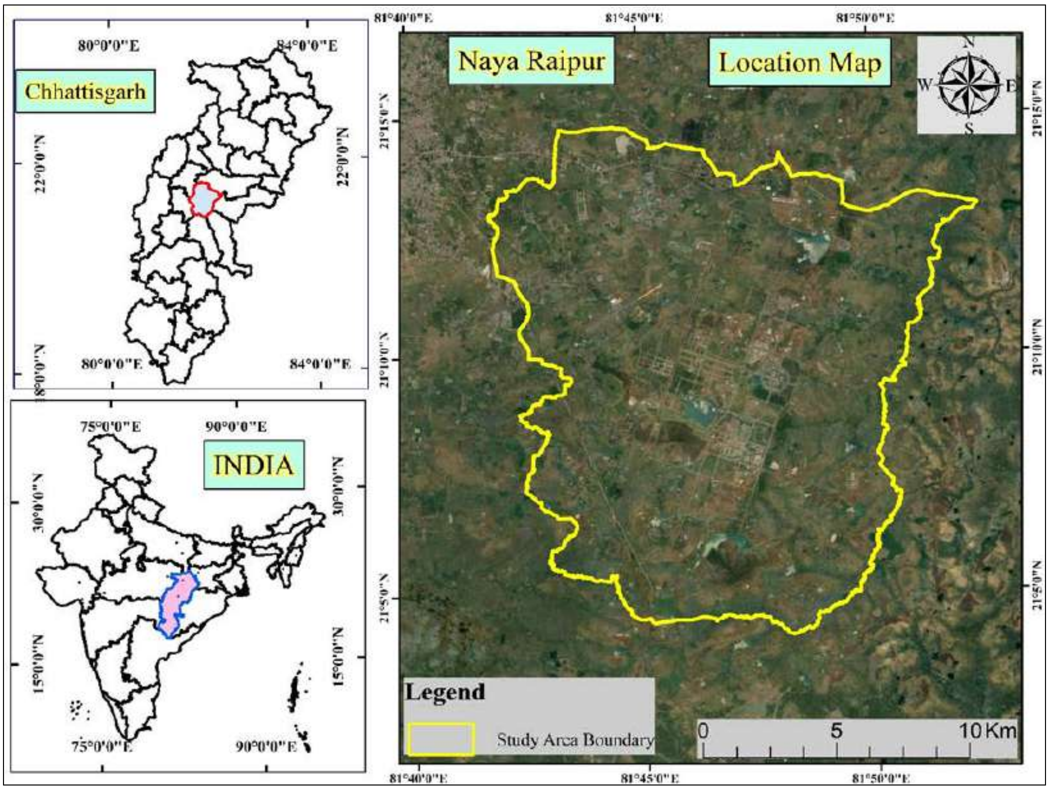


Fig 1: Location map of the study area with yellow color indicates the watershed boundary.

3. Methodology

3.1 Geo-Physical Resistivity sounding through conduct Deep Electrical Resistivity Sounding in Different location we have prepared a Lithology & Fence Diagram of the Area to know the geology of the area.

Run-Off Coefficient Method

Rainwater collected = rainfall (mm) x area of Catchment (m2) x runoff coefficient

3.2 Methods to be adopted for study site

3.2.1 Rationing method (RM)

The Rationing method (RM) distributes store drain water to target the public in such a way that there is a water tank that can service water requirements to the maximum period. This can be done by limiting the amount of use of water demand per person.

3.2.2 Rapid depletion method (RDM)

In the Rapid Depletion method, there is no restriction on the use of harvested rainwater by a consumer. The consumer is allowed to use the preserved rainwater up to their maximum requirement, resulting in a smaller number of days of the utilization of preserved water. The rainwater tank in this method is considered to be the only source of water for the consumer, and an alternate source of water has to be used till the next rain if it runs dries.

3.2.3 Resistivity Survey

Surface electrical resistivity surveying is based on the principle that the distribution of electrical potential in the ground around a current-carrying electrode depends on the electrical resistivities and distribution of the surrounding soils and rocks.

Gradient Resistivity Profiling (GRP- 1 No.s) and Vertical Electrical Sounding (VES – 9 No.s) decode the subsurface condition at the Nava Raipur District Details resistivity survey during the period. Aqua meter CRM-50 resistivity meter was used for the survey. For the present study, both profiling and sounding mode have been carried out. Gradient Method has been done for profiling. Schlumberger configuration and half Schlumberger configuration both have been used for sounding. Maximum spreads were 200m (AB) for profiling and 240m (AB) for sounding.

Using Ohm's law electrical resistivity of sub-surface geologic formation is determined through artificially energizing the subsurface and carrying measurements on the ground surface. The contrast in resistivity value of an individual layer with the surrounding or effective presence (dependent on its relative resistivity and thickness) makes it detectable.
In the electrical resistivity method, a known amount of electrical current (I) is sent into the ground through a pair of electrodes (called current electrodes) and the potential (δV) developed because of the resistance offered by the subsurface due to the passage of this current is measured across another pair of electrodes (potential electrodes) planted into the ground. The ratio between the potential measured and the corresponding current sent into the ground yields the resistance "R" of the ground to a depth depending upon the spacing between the two current electrodes. Through the multiplication of this value of `R' by a geometric factor, a parameter called the apparent resistivity "ρa" is computed. Both the parameters of apparent resistivity "ρa" and the resistance "R" contain information on the geo-electric characteristics of the subsurface. In practice, there exist several configurations but the most commonly used are the Wenner and Schlumberger configurations.

3.2.4 Schlumberger Configuration

In Schlumberger arrangement, all the four electrodes are kept in a line symmetrically over a point `O'. Current is sent through outer electrodes AB and potential across MN is measured. The Separation between the potential electrodes M & N is kept smaller compared to the current electrode distance AB.
The geometric factor 'K' for Schlumberger arrangement is given by

K= π {(AB/2)2 - (MN/2) 2} / MN

Where;
AB is current Electrode spacing MN is potential Electrode spacing.

3.2.5 Wenner Configuration

In Wenner arrangement, all the four electrodes are kept in a line symmetrically over a point `O'. Current is sent through outer electrodes AB and potential across MN is measured. The separation between the successive electrodes is constant. The layout of the Wenner electrode configuration is as shown below.
The geometric factor `K' for Wenner arrangement is given by
K= 2πa
Where 'a' is successive electrode spacing.

3.2.5 Vertical electrical sounding (VES)

VES is a process by which a depth investigation is made. In this, the centre is fixed and the measurements are made by successively increasing the electrode spacing. The apparent resistivity values were obtained with increasing values of electrode separations reused to estimate the thickness and resistivity soft the sub-surface formations. In Schlumberger sounding arrangement, all the four electrodes are kept in a line symmetrically over a point `0; with inner (Potential) electrodes kept closer. For increasing the depth of investigation, the current electrodes, A and B are moved apart symmetrically about the centre point `0' keeping the potential electrodes fixed. This parathion between the Potential Electrodes is changed only when the potential between them drops to allow value during sounding. The apparent resistivity for each electrode separation is calculated by multiplying the resistance `R' with the Schlumberger configuration factor (which is called as Geometrical factor 'K').

4. Data analysis and interpretation

The observed resistance values from the instrument have been multiplied with geometric factor (K) to get the apparent resistivity values for each electrode spacing. The apparent resistivity values for different potential dipoles were brought to a single common potential dipole. The field apparent resistivity data were plotted on log-log graph paper against the half current electrode separation to get the VES curves (x-axis AB/2 value and y-axis apparent resistivity value).
These data of AB/2 and apparent resistivity were interpreted with the help of software IPI2WIN through the curve matching technique. The final results were corroborated with the known hydrogeological conditions existing in the area. The geoelectric layer Parameters (layer resistivity and layer thickness) were obtained for each VES. The field curves of VES are given and the field data of VES is shown in Annexure I & IX.

4.1 Factor Analysis

Identification of fracture at depth in hard rock area by conducting VES, factor analysis method is being used. In this method, first of all, the value of apparent resistivity should be taken for the same potential dipole (MN/2) value. The factor for any AB/2 value is the ratio of apparent resistivity value of that AB/2 and the sum of all the apparent resistivity values of all the earlier AB/2. If the total number of apparent resistivity values of a sounding is then the total factor will be- 1, as there will be a factor for the first AB/2. From the obtained factor values we can identify the same factor value for two consecutive readings of AB/2 will indicate the fracture zone at respective depth. The calculated Factor values for the VES have been shown in the table given below.

5. Result and Discussion

Interpretation of the Total number of Nine VES was carried out at 9 different points of the same location at Village-Tuta Aqua meter CRM500 Resistivity meter has been used for conducting the VES. Schlumberger and half Schlumberger configurations have been used for conducting the VES survey. The maximum current electrode spread for conducting VES was 240m (AB).
The data is plotted on double logarithmic graph paper and matched with standard curves to know the true resistivity and thickness of various layers. The data is also interpreted by Computer using IPI2WIN software to verify the results of partial curve matching. From interpreted results of VES the resistivity and thickness of different layers.

5.1 VES

At this point, Schlumberger and half Schlumberger configurations have been used for VES1. The topmost layers having a resistivity value of 9.3 **Ω**-m whereas the second layer may be weathered limestone with a resistivity of 18 Ω-m. The third layer may be fractured limestone with a resistivity of 30 Ω-m while, the last layer may be massive limestone having a resistivity of 65 Ω-m. The thickness of the topmost layer was1.7 m and the second layer & third layer thickness were 4.3 and 17.4 m respectively.

5.2 VES

At this point, half the Schlumberger configuration has been used for VES. The topmost layer having a resistivity value of 8.6 Ω-m whereas the second layer may be weathered limestone with a resistivity of 16.5 Ω-m. The third layer may be fractured limestone with a resistivity of 60 Ω-m while, the last layer may be massive limestone having a resistivity of 140 Ω-m. The thickness of the topmost layer was 1.8 m and the second layer & third layer thickness were 7.5 and 30 m respectively.

5.3 VES

At this point, the Schlumberger configuration has been used for VES. The topmost layer having a resistivity value of 10.8 Ω-m whereas the second layer may be weathered limestone with a resistivity of 8.3 Ω-m. The third layer may be fractured limestone with a resistivity of 60 Ω-m while, the last layer may be massive limestone having a resistivity of 90 Ω-m. The thickness of the topmost layer was 1.6m and the second layer& third layer thickness were 4.6 and 22.6 m. respectively.

5.4 VES

At this point, the Schlumberger configuration has been used for VES. The topmost layer having a resistivity value of 9 Ω - m whereas the second layer may be weathered limestone with a resistivity of 16 Ω - m. The third layer may be fractured limestone with a resistivity of 38Ω-m while, the last layer may be massive limestone having a resistivity of 95 Ω-m. The thickness of the topmost layer was 3m and the second layer& third layer thickness were 7.6 and 22 m. respectively.

5.5 VES

At this point, the Schlumberger configuration has been used for VES. The topmost layer having a resistivity value of 12.9Ω-m whereas the second layer may be weathered limestone with a resistivity of 18.2Ω-m. The third layer may be fractured limestone with the resistivity of 47.8 Ω-m while, the last layer may be massive limestone having a resistivity of 110 Ω - m. The thickness of the topmost layer was 1.8m and the second layer& third layer thickness were 8 and 24.5 m. respectively.

5.6 VES

At this point, the Schlumberger configuration has been used for VES. The topmost layer having a resistivity value of 340 Ω - m whereas the second layer may be weathered limestone with a resistivity of 46 Ω - m. The third layer may be fractured limestone with a resistivity of 17Ω-m while, the last layer may be massive limestone having a resistivity of 450 Ω - m. The thickness of the topmost layer was 2.8 m and the second layer & third layer thickness were 10.1 and 25.1 m. respectively.

5.7 VES

At this point, the Schlumberger configuration has been used for VES. The topmost layer having a resistivity value of 31.6Ω-m whereas the second layer may be weathered limestone with a resistivity of 101Ω-m. The third layer may be fractured limestone with a resistivity of 16.7Ω-m and the last layer may be massive limestone having a resistivity of 60 Ω - m. The thickness of the topmost layer was1.5 and second- & third-layer thickness was and 3.0 m. & 14.6 respectively.

5.8 VES

At this point, the Schlumberger configuration has been used for VES. The topmost layer having a resistivity value of8.5Ω- m whereas the second layer may be weathered limestone with a resistivity of 15.5Ω- m. The third layer may be fractured limestone with a resistivity of 55Ω-m while, the last layer may be massive limestone having a resistivity of 115 Ω-m. The thickness of the topmost layer was 3.2m and the second layer& third layer thickness were 8.5 and 21.5 m respectively.

5.9 Design of Rain Water Recharge Structure

The three most important components, which need to be evaluated for designing a rainwater harvesting structure, are

- Hydrogeology of the area including nature and extent of aquifer, soil cover, topography, depth to the water table and quality of groundwater.
- Area contributing to runoff i.e., total area and land use pattern, whether industrial, residential or green belts and general built-up pattern.
- Hydrometeorological characters viz. rainfall duration, the general pattern of the intensity of rainfall.

Peak Rainfall=100mm in15mins

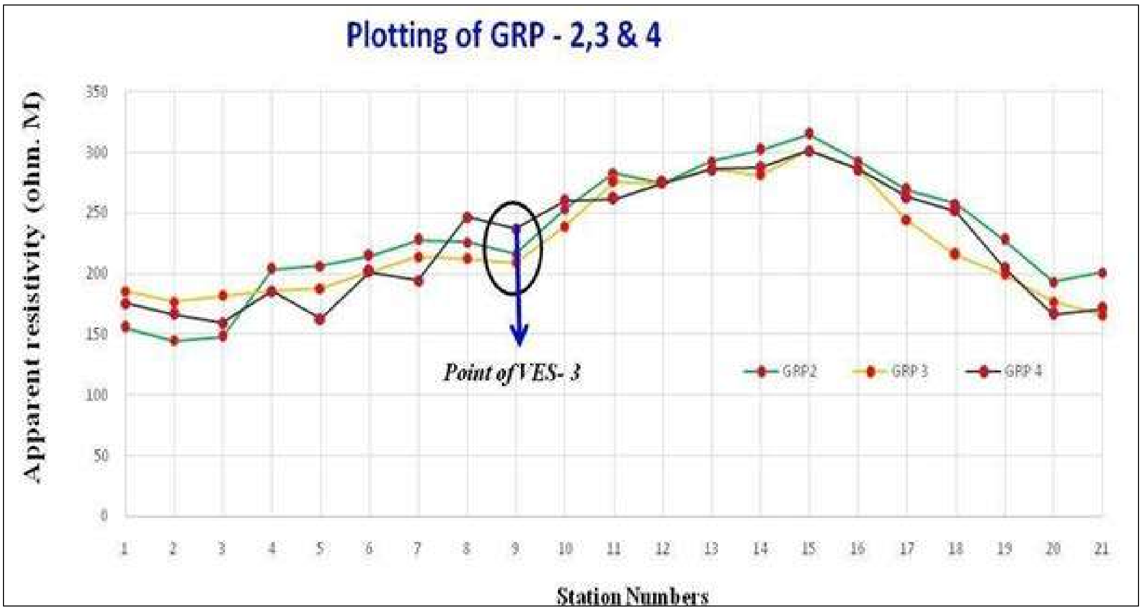
Hourly Intensity rainfall=Peak Rainfall/4

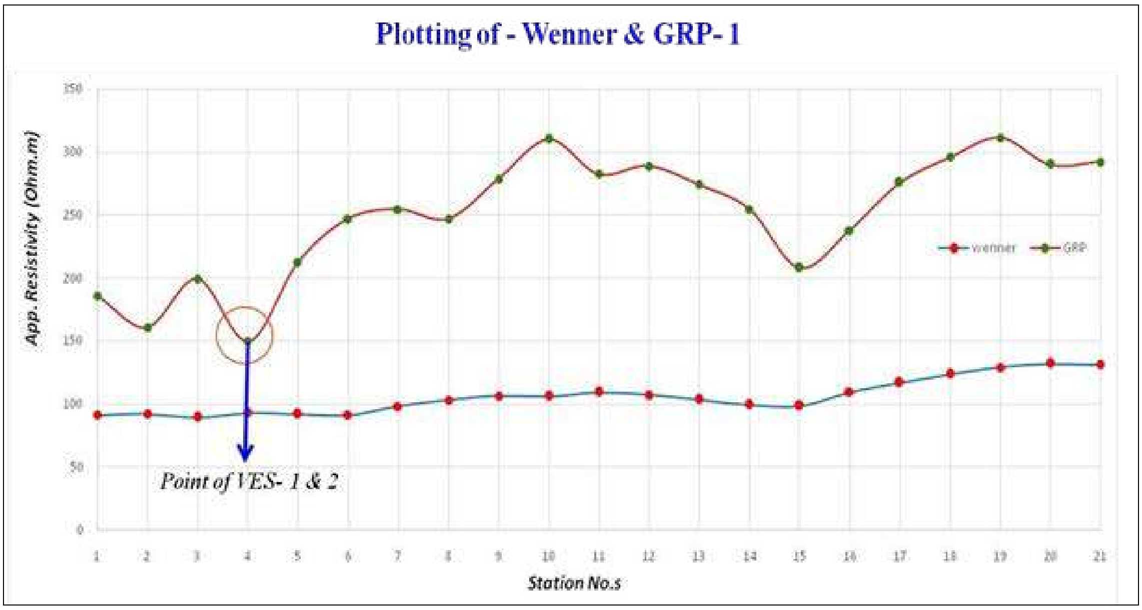
To design the recharge structure, the hourly intensity of rainfall is considered to be 25 mm/hr has been taken into account and the details are tabulated below.

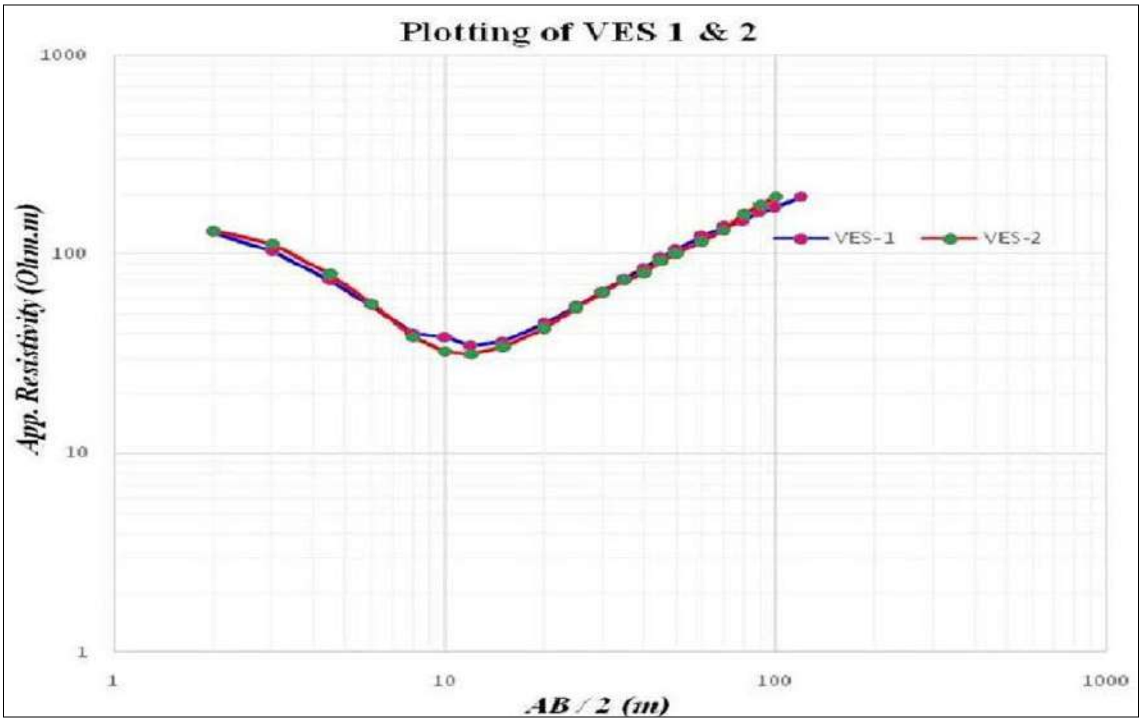
The main interest in rainwater harvesting is methods of collecting and conserving rainwater at an early stage in the water cycle to ensure the best use of rainfall before it runs away into rivers or disappears as evaporation. During monsoon season, whatever rainwater is collected in the premises of the project area, i.e., though, Building/roof area, Road/Paved area, green belt area and Open land will be utilized to recharge the groundwater.

Table 1: Interpreted parameters of VES 1, 2 & 3.

Sounding No.	ρ1 (Ω-m)	ρ2 (Ω-m)	ρ3 (Ω-m)	ρ4 (Ω-m)	h1 mts.	h2 mts.	h3 mts.	Probable Fracture Zone (m)
VES-1 &2	9.3	18	30	65	1.7	4.3	17.4	25-30 & 60-65
VES-3	8.6	16.5	60	140	1.8	7.5	30.0	35-40, 80-85 & 110-120
VES-4	10.8	8.3	60	90	1.6	4.6	22.6	20-30,40-45 & 95-110
VES-5	9	16	38	95	3.0	7.6	22.0	25-30,45-50 & 90-100
VES-6	12.9	18.2	47.8	110	1.8	8.0	24.5	30-35, 70-75 & 95-100
VES-7	340	46	17	450	2.8	10.1	25.1	-
VES-8	31.6	101	16.7	60	1.5	3.03	14.6	-
VES-9	8.5	15.5	55	115	3.2	8.5	21.5	-







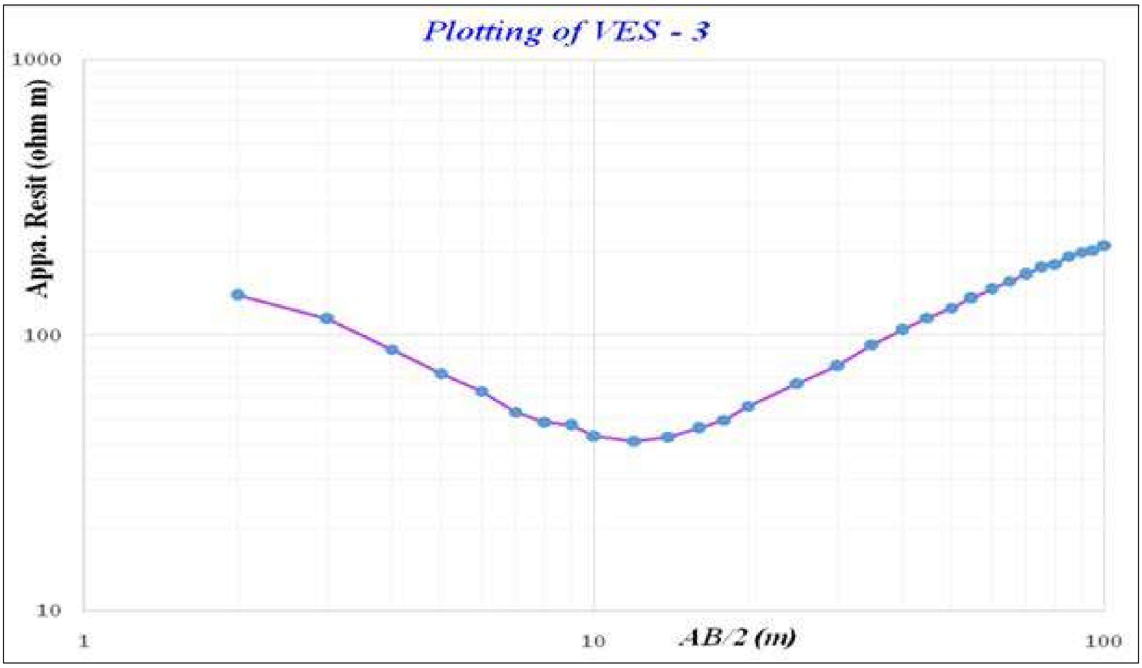


Fig 2: Plotting of GRP (2, 3, & 4), plotting of - WENNER & GRP-1, Plotting of VES 1 & 2, Plotting of VES- 3.

Table 2: The plotting method has shown the WENNER (GRP-1, GRP-2, GRP-3, and GRP-4), and AB/2, VES-1, VES-2.

Station No.	Wenner	GRP-1	GRP - 2	GRP - 3	GRP -4
1	91.27	185.99	155.83	185.99	175.94
2	92.21	161.11	145.00	177.23	166.49
3	89.38	199.30	148.06	182.22	159.45
4	92.77	149.84	203.79	185.81	185.81
5	91.83	212.98	206.72	187.93	162.87
6	91.27	247.04	214.54	201.54	201.54
7	98.24	254.63	227.83	214.43	194.32
8	103.15	246.95	226.37	212.65	246.95
9	106.73	279.01	216.24	209.51	237.16
10	106.16	310.00	253.64	239.55	260.68
11	109.37	282.76	282.76	275.69	261.55
12	107.48	288.98	274.78	274.78	274.78
13	103.71	274.39	292.96	285.99	285.99
14	99.56	254.63	301.83	281.25	288.11

15	98.62	208.04	314.94	301.54	301.54
16	109.74	238.04	292.55	286.05	286.05
17	116.91	275.72	269.36	244.31	263.10
18	123.70	296.11	257.74	215.78	251.75
19	129.36	311.49	227.78	199.31	205.00
20	132.00	290.00	193.34	177.23	166.49
21	131.45	292.02	201.08	165.89	170.91

S. No	AB/2	VES-1	VES-2
1	2	129.17	131.88
2	3	103.84	112.52
3	4.5	73.63	79.23
4	6	55.48	56.32
5	8	39.88	38.12
6	10	38.01	32.16
7	12	34.63	31.43
8	15	36.13	34.21
9	20	44.70	42.43
10	25	54.63	53.86
11	30	63.96	64.01
12	35	74.82	73.70
13	40	84.92	80.43
14	45	95.71	92.46
15	50	105.09	100.76
16	60	122.89	115.95
17	70	137.26	131.20
18	80	147.13	159.53
19	90	161.42	176.85
20	100	171.45	194.98
21	120	193.11	

Table 3: The plotting method has shown the AB/2 m and MN/2 m, K and R (ohm).

S. No.	AB/2 On)	MN/2 On)	K	R (Ohm)	App. Rest (Ohm-m)
1	2	0.4	15.08	9.27	139.79
2	3	0.4	34.71	3.30	114.54
3	4	0.4	62.20	1.43	88.95
4	5	0.4	97.55	0.75	72.87
5	6	0.4	140.74	0.45	62.77
6	7	0.4	191.79	0.27	52.55
7	8	0.4	250.70	0.19	48.39
8	9	0.4	317.46	0.15	46.98
9	10	2	75.40	0.60	43.13
10	12	2	109.96	0.40	41.44
11	14	2	150.80	0.30	42.84
12	16	2	197.92	0.25	45.92
13	18	2	251.33	0.21	49.27
14	20	2	311.02	0.19	55.37
15	25	2	487.73	0.15	66.97
16	30	2	703.72	0.12	77.97
17	35	5	376.99	0.24	92.52
18	40	5	494.80	0.21	104.51
19	45	5	628.32	0.18	115.65
20	50	5	777.54	0.16	125.91
21	55	5	942.48	0.14	136.51
22	60	5	1123.12	0.13	146.86
23	65	5	1319.47	0.12	157.93
24	70	5	1531.53	0.11	166.37
25	75	10	867.86	0.21	176.11
26	80	10	989.60	0.19	181.32
27	85	10	1119.19	0.18	194.04
28	90	10	1256.64	0.16	200.54
29	95	10	1401.94	0.15	204.39
30	100	10	1555.09	0.14	212.93

6. Conclusion

Interpretation of resistivity survey we got the following outcome. The thickness of topsoil varies from 1.5 meters to 3.0 meters with resistivity range from140 Ω-m to 158Ω-m. The thickness of the weathered formation varies from 9.21 meters to 11 meters and the resistivity range is 21.7 Ω - m to 33.4 Ω - m. The third layer mostly indicates fracture zones and the thickness of this layer varies from 5 meters to 9.13

meters and the resistivity range is 128 Ω - m to 350 Ω - m. The last layer is the massive formation which shows high electrical resistivity with the range of 883 Ω - m to 973 Ω - m. From factor analysis, it is observed that there are shallow and deep fractures. Shallow fracture depth varies from 12 m to 15 m and deep fracture depth varies from 80 m to 85 m.
Moreover, Groundwater potential zone and groundwater quality should be integrated as a criterion for decision making to better understand prospect drinking water, in the future, with the help of these technologies, we can find out the availability of water, to achieve this goal, to prepare the different thematic map which is a controlling groundwater parameter like as soil, geology, geomorphology, land use/land cover (LULC), lineament density, drainage density, and slope. To conclude the mapping of groundwater prospect by integrating various indicative areas in a GIS environment, therefore, this research suggests that we can get out of water problem because water problem is the biggest problem of human life. Therefore, more and more research needs to be done on groundwater.

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8. The objective of this study
This chapter aims to demonstrate the use of the GRP (1 to 9) and VES method for the Recharging of Groundwater by the geophysical method based on resistivity meter, a case study of Naya Raipur Chhattisgarh. The study used well locations and different publicly available environmental data.

9. Declaration of interests
We declare that we have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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