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GEOPHYSICAL EXPLORATION OF AQUIFER DEPTH AT GOPALI, KHARAGPUR-I BLOCK, PASCHIM MIDNAPORE DISTRICT, WEST BENGAL, INDIA

Mayank Sharma [*1], Hardik Sharma [*2], Mukesh Kumar Sharma [*3]

[*1]Post Graduation Student, PG Department Of Geology, St. Xavier's College, Ranchi, Jharkhand, India.

[*2]Graduate Student, Department Of Construction Engineering, Jadavpur University, Kolkata, West Bengal, India.

[*3]Geophysicist, Geo Exploration Services, Kharagpur, West Bengal, India.

ABSTRACT

The overuse of water from aquifers has resulted in a decrease in the groundwater table. Gopali, a small village on the outskirts of Kharagpur, has some clean drinking water requirements. Hence, the goal of the study was to determine the depth of aquifer in this location that would generate a large volume of water, so that a tube well could be drilled and provide enough water for the settlement. As a result, we identified seven favorable locations for Vertical Electrical Soundings in order to better understand the area's subsurface geology and assess the probability of an aquifer (VES1 to VES 7 respectively). The study dealt with collection of resistivity data, assessing it, and survey the aquifer layers using this method. In this situation, the electrode spacing was determined using a Schlumberger electrode approach. IGIS DDR3 DC resistivity meter with 600m transverse extension (AB) was used to conduct the exploration at Gopali, block Kharagpur-I, Paschim Midnapore district, West Bengal, India. Because of the significant lateral expansion, over 150m of current penetration data was recorded. Clay-sand intercalations with medium to fine-grained sand were discovered in this sedimentary area, and these alterations were mostly observed between 70 and 150 meters.

Keywords: Aquifers, Schlumberger method, Geophysical investigation, Resistivity, Groundwater, Vertical Electrical soundings.

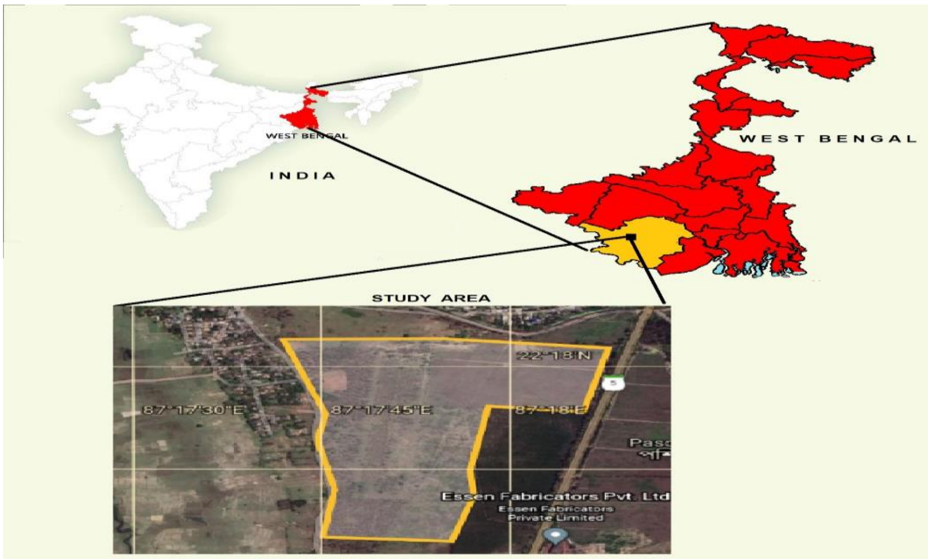
I. INTRODUCTION

Water is the most important natural resource on the earth; without water, life would not be possible. With the advancement of science and technology, dangerous pollutants are now being discharged into water sources, causing pollution. Water contamination has an impact on the life that consumes it. Much of the time, groundwater is regarded as one of the purest sources of water and is safe to drink not considering the case in which arsenic and other contaminations are present. Gopali is a small settlement on the outskirts of Kharagpur town. It has some vast open areas, forest lands and an ashram for children and orphans. It comes under the Kharagpur-I block of Paschim Midnapore of West Bengal. There had been some crises in this area for clean drinking water. Hence, this research work was carried out. The research's goal was to identify aquifer depth in the study area that could be used as a great water source. Aquifers are formations that have the capacity to store water and then release it when needed. Vertical Electrical Sounding with the Schlumberger array was utilized to discover this. Seven VES were conducted in this large region namely VES1 to VES 7, at points S1 to S7 respectively. The investigation was carried out using an IGIS DDR3 DC Resistivity meter.

Geology of the area

Silda-Jamboni-Binpur of Paschim Midnapore as well as Purulia district in West Bengal are underlaid by hard rocks comparable to those of Jharkhand's Singhbhum district, whilst the rest of the state has Quaternary poorly consolidated formations *(CGWB, 2006)*. The province of Paschim Midnapore is underlain by a variety of geological strata, ranging from Pre-Cambrian hard cemented rocks to modern unconsolidated alluvium. Phyllites, mica schists, hornblende schist, dolerites, and quartzites are the most common hard consolidated rocks. The foliation of the schistose and phyllite rocks is NE-SW and heavily distorted *(CGWB, 2006)*. Rivers and flood plain deposits make up the area of Gopali in Kharagpur-1 block, which is part of the Paschim Midnapore district. Laterite covers the major part of the area, followed by quaternary alluvium cover, and finally tertiary deposits. In tertiary sediments, the aquifer is mostly found. The Pleistocene alluvium consists of laterites, brown sandy clays, and brown to reddish brown sand. Pale white silt, sandy clay, sand, and medium dark greyish clay are all present in the recent younger alluvium. In this area, pre-quaternary rocks have faults, foliations, fissures, and limited permeability *(CGWB, 2006)*. This area's tertiary formations originate from the Mid-Pliocene epoch. The primary elements of tertiary formations include fine to medium sand and lithomargic clay, as well as quartz, phyllite, granite pebbles, and gravels *(CGWB, 2006)*. Hard laterite, Morum-clay and clay-sand make up the subsurface layers we encountered up to the current penetration depth. According to hydrological considerations, the area confronts a variety of aquifer types, ranging from confined to semi-confined, with a high yield. As a result, any type of tube-well can be used here, whether it is a low-duty tube-well or a high-duty tube-well.

Location of the study area:



MAP 1: Location of the study area (Gopali)

Gopali is a small settlement lying towards the south of Kharagpur town. Gopali is a village of Kharagpur-I block, district Paschim Midnapore, West Bengal, India (MAP 1). It is well connected with Kharagpur by bitumen roads. Towards the south of the area lies Salua, famous for its EFR air force station. There is an orphanage, opposite to the study field known as Gopali Ashram. The closest raileay station is Hijli station nearly, 7 kms away and Kharagpur Junction approximately 12 kms. Kolkata is the nearest airport about 130kms away. The closest bus stop is Gopali bus top. A road passes from the east of the study area, connecting Kharagpur and Keshiary. The nearest settlements to Gopali are Hijli Co-operative Society (2 KM), Talbagicha (3 KM), IIT Kharagpur (3 KM), D.V.C Power House (4 KM), and Chota Tengra (5 KM). Kharagpur-I Block, Midnapore Block, Medinipur East Block, and Midnapore Block are all towards the north of Gopali. The nearest cities to the study area are, Kharagpur, Jhargram, Minapore and Jaleswar (Odisha). The following Map 2 shows the location of the study area. The study area also has a forest land nearly 20 acres. The study area is basically a field of 100 acres lying in-between the co-ordinates of $22^0$17’34” N – $22^0$18’04” N latitude and $87^0$17’42” E – $87^0$18’07” E. In this vast area, a total of 7 VES points were selected whose locations (MAP 2) are provided in table 1 below:

Table 1: GPS location of the VES points in the study area

POINTS	LATITUDE	LONGITUDE
S1	$22^0$18’00” N	$87^0$17’47” E
S2	$22^0$17’58” N	$87^0$17’54” E
S3	$22^0$17’59” N	$87^0$18’02” E
S4	$22^0$17’47” N	$87^0$17’53” E
S5	$22^0$17’52” N	$87^0$17’47” E
S6	$22^0$17’42” N	$87^0$17’48” E
S7	$22^0$17’36” N	$87^0$17’52” E

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MAP 2: Distribution of VES points in the study area

II. METHODOLOGY

Vertical Electrical Sounding is a fantastic way to identify groundwater aquifers in geophysical investigation. Electrical resistivity approach includes the VES method. The Ohm's law is the basis for the electrical resistivity approach. The soundings have been conducted with the help of an IGIS DDR3 DC Resistivity meter and four electrodes. Two of the four electrodes were used to monitor current and the other two were used to assess potential drop. Two of these were thus current electrodes, whereas the others were potential electrodes (*Sharma M, 2021)*. We acquired the Resistance values directly from the resistivity meter, i.e., V/I. After obtaining the resistance values, it must be multiplied by a factor of "K" to achieve the absorption coefficient *(Zohdy A.A.R et al., 1974).* The geometric layout of electrodes and the distance between them have a big impact on "K." The apparent resistivities along the current electrode spacing AB/2 were utilized as inputs in the Resist v1.7 software to generate the curve *(Sharma M, 2021)*. Here, Schlumberger array method was used to get the data. The data was obtained and the apparent resistivity was measured by the formula:

$$\rho = K \times R \quad \text{....... (1)}$$

(Where geoelectric constant is K and field Resistance is R.)

Because resistivity is measured in ohm-m and resistance in ohms, it is evident that K has a length unit, meter (Sharma M, 2021). The value of K varies according on the electrode spacing, and for the Schlumberger array it is stated as (*Schlumberger M, 1939):*

$$K = \pi . \frac{(\frac{AB}{2})^2 - (\frac{MN}{2})^2}{MN} \quad \text{...... (2)}$$

Electrode Spacing:

The figure 1 below depicts the electrode arrangement employed in the study area.

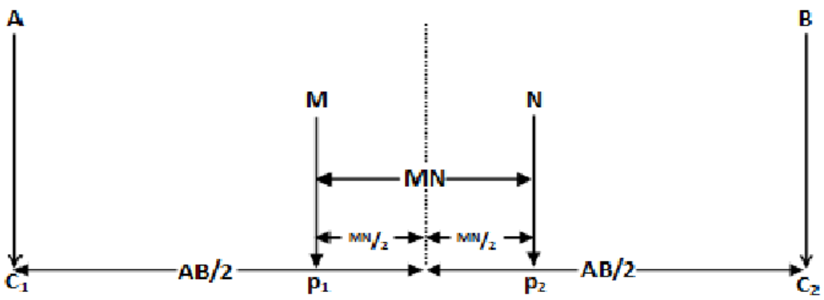

Figure 1: Schlumberger array (After Sharma M, 2021)

n the diagram above, A and B are current-carrying electrodes, while M and N are potential electrodes. MN is the distance between M and N, i.e., potential electrodes, and AB is the distance between current electrodes. Here M and N are placed between A and B (*Sharma M, 2021*). If a larger depth of current transmission is required, the electrodes A and B are symmetrically relocated to a greater distance. The following formula is used to compute apparent resistivity:

$$\rho=\pi.\frac{(\frac{AB}{2})^2-(\frac{MN}{2})^2}{MN}.\frac{V}{I} \quad \text{....... (3)}$$

Also considering, AB>>MN but, for better field data acquisition, AB ≥ 5MN is taken (*Todd D.K, 1980).*

Data acquisition:

Data collection is the most critical aspect of any field study because mistakes and errors can occur. We employed the Schlumberger array method to collect observations at the study site. The data was collected for a lateral AB separation of 600m, resulting in a current penetration depth of roughly 150m, because, the depth of current penetration is believed to be between 0.25AB and 0.5AB (Patra H.P. et al.,1968; Singh K.P. et al., 2005). Seven VES were done at sites S1, S2, S3, S4, S5, S6, and S7 in the Gopali study region, with the names VES 1, VES 2, and VES 3. VES 3, VES 4, VES 5, VES 6, and VES 7 are the respective VES numbers. The readings were now recorded in the data sheets using the AB/2 and MN/2 codes. The data was recorded with AB/2 equal to 1.5m at the beginning and continued until AB/2 became 300m. The measurements began at MN with a distance of 0.5m and subsequently increased in accordance with the AB/2 separation to a maximum distance of 40m. For MN/2 is 0.5m: In this scenario, the M and N were positioned 1 m apart, while the current electrodes were located 3 m apart, i.e., AB/2 equals 1.5m during the first measurement. The resistivity meter provided the R value. The AB/2 separation was then raised to 2m, 3m, and 4m, respectively. Because AB/2 was already 10 times MN/2, it was time to raise the MN/2 value. As a solution, the MN/2 was raised to 1m to improve the outcomes. Now f or MN/2 equals 1m: In the same way as MN/2 =0.5m, MN/2 was fixed at 1m this time, the current electrodes were then shifted with AB/2 extending from 4m to 10m. MN/2 was increased to 2m at 10m, and successive values were recorded.

III. MODELING AND ANALYSIS

The apparent resistivity values collected in the field are entered into the Resist v1.7 application, and the true resistivities are collected as the output (Sharma M, 2021). The thickness of the strata is computed and obtained in addition to the apparent resistivity values. The true resistivity values and stratum thicknesses are listed in table 3 after the analysis of the data. The real resistivities of the strata are ρ_1, ρ_2 and ρ3 whereas the thickness of the relevant layers is T1, T2, and T3. The VES graph, which is displayed with apparent resistivities as the y-axis and AB/2 as the x-axis, is another significant part of the analysis. Table 3's last column contains the results of the curve type analysis. The names of the curves are based on the real electrical resistivity of the layers in relation to one another. The resistivity relation and curves for the three-layer system are defined as follows in table-2:

Table 2: Various curve types (After Sharma M,2021)

TYPE OF CURVES	*RESISTIVITY RELATION*
A	ρ 1<ρ 2 <ρ 3
Q	ρ 1>ρ 2 >ρ 3
H	ρ 1>ρ 2 <ρ 3.
K	ρ 1<ρ 2 >ρ 3

Here, the true resistivities of the layers 1, 2 and 3 are ρ 1,ρ 2 and ρ 3 respectively. The examination of the result table below shows real resistivities for layers 1, 2, and 3 as ρ 1,ρ 2 and ρ 3 correspondingly. The thicknesses of the successive layers are T1, T2, and T3. The third layer continued beyond 150m, which was the current greatest penetration depth, but the thickness is unknown. However, it is certain that it goes beyond 150 meters.

Table 3: Analysis of Data

VES NO.	POINT no.	ρ1 (ohm-m)	ρ2 (ohm-m)	ρ3 (ohm-m)	T1 (m)	T2 (m)	T3 (m)	CURVE TYPE
VES 1	S1	201	86	36	21	46	∞	Q
VES 2	S2	195	95	38	20	48	∞	Q
VES 3	S3	199	91	43	21	45	∞	Q
VES 4	S4	210	104	35	24	49	∞	Q
VES 5	S5	192	89	37	25	51	∞	Q
VES 6	S6	224	101	40	20	48	∞	Q
VES 7	S7	212	98	41	22	50	∞	Q

Resist software was used to plot the graphs, which took apparent resistivities and AB/2 as input. The following are the curve projections for each VES (Figure-2 and Figure 3):

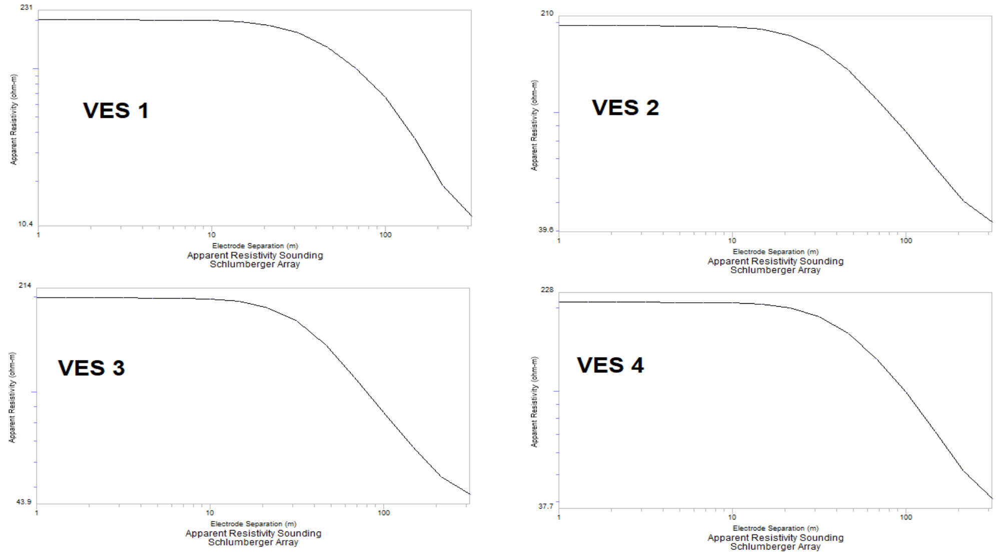

Figure 2: VES curves (VES 1- VES 4)

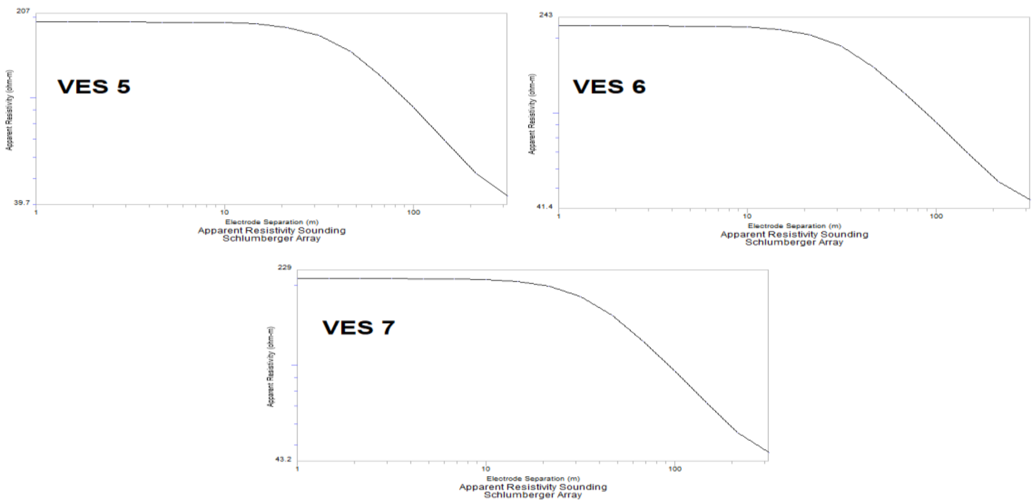

Figure 3: VES curves (VES 5- VES 7).

Co-relating the VES curves with the table 2, it is clear that all the curves obtained are "Q" type curves in which the successive resistivity values go on decreasing. Layer 1 has the highest value and Layer 3 has the lowest value.

IV. RESULTS AND DISCUSSION

From the analysis of data, three layers are discovered upto the current penetration depth and it is very well clear that the curves obtained are "Q" type and the successive layers have decreasing resistivity values. On co-relating the resistivity values with the local geology of the area, it was established that the top most layer is hard laterite having a thickness of 20-25m showing a resistivity range of 190-225 ohm-m. The successive layer is clay-morum layer having resistivity range of 86-104 ohm-m and thickness of 45-51m. Some clay-sand aquifers are present in this layer but would yield lesser amount of water due to the presence of fine-grained sand. The last layer encountered is the aquifer layer of clay-sand having a resistivity of 35-43 ohm-m. This layer is quite thick and extends beyond the current penetration depth i.e., 150m. Hence, all the points investigated in the area are good for sinking the tube well as they would definitely yield high amount of water. In this last layer, clay-sand alterations are present which are a good source of water. The layer starts at the depth of 66-75m depending upon the different point. Please refer the Table 3 for the depth of the third layer. Just add the T1 and T2 to get the depth of layer 3. It extends beyond 150m. As per this calculation, point S3 is best for sinking the tube-well

V. CONCLUSION

The curves formed are "Q" type curves which indicate the decrease in the resistivity values of successive layers. The topmost layer was found to be hard laterite, whose exposures are clearly visible as we move towards the South of the study area towards Salua. Similarly, the second layer, was morum-clay section which is not a good aquifer and hence is omitted. Now, from the analysis table and geology of the area, it is very clear for the result that the last layer shows a resistivity range of 35-43 ohm-m which on co relation with the geology states that the layer is a clay-sand section. The aim of the research was to find the most suitable point for drilling and sinking of tube well and from the analysis it was clear that the whole study area has a good groundwater potential. The last layer extends beyond the depth of penetration i.e., 150m which means the last layer is nearly 60-70m. It mainly comprises of clay-sand alterations and hence is a great aquifer. The point having relatively greater layer 3 thickness is best for sinking of tube-well. Hence, point S3 was selected as the clay-sand section here starts at relatively lesser depth of 66m. In general, all the points have good groundwater potential, but when it comes to selecting one, S3 is the best. It has clay-sand alterations with coarser sand which has higher porosity and water retention property. Therefore, in order to meet the water needs, a tube-well must be sunk at point S3.

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