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SUBSURFACE EXPLORATION OF SOIL

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ABSTRACT

With advancement in technology, geotechnical engineers have well realised the importance of electrical resistivity sounding method for subsurface exploration. The accuracy of subsurface profiles interpreted from resistivity sounding data depends not only on the experience and skill of interpreter but also on subsurface conditions and selections of appropriate interpretation technique.There are number of techniques available for interpreting resistivity data . In the light of this, present studies were planned to interpreting the field data of electrical resistivity sounding at six selected locations. Barnes technique has been used for evaluating the true resistivity and thickness of each the stratum and also estimate the present of ground water table.

INTRODUCTION

Electrical resistivity method is widely used by geophysicists and geologists for studying subsurface profiles of their concern. However, geotechnical engineers have well realised the importance of geophysical methods for subsurface explorations. Electrical resistivity is one such non-destructive technique which is now being increasingly used as a complementary to direct method of exploration due to its simplicity, low cost and quick output.

Resistivity soundings at a field location provide the values of apparent resistivities (ρ_a) at different depths of subsurface strata beneath. The apparent resistivity up to any particular depth is a function of true resistivity (ρ) and thickness (t) of various strata through which the current passes. Unless one interprets (ρ_a) to derive (ρ) it is not possible to identify various strata in subsurface profile. The present studies were planned to interpreting the field data of electrical resistivity sounding at six selected locations. Barnes method is one of this technique used in this study for evaluating the true resistivity and thickness of each of the stratum and estimate the present of ground water table.

GEOPHYSICAL EXPLORATION TECHNIQUES :-

Geophysical exploration techniques determine in situ physical properties of rock masses and locate subsurface physical property. In drilling programme provides detailed subsurface information at specific locations, geophysics provides bulk information over large areas (whiteley, 1983)

Geophysical exploration techniques are now being increasingly used in:

(i) Identifying the ground water - potential zones .
(ii) Identifying the presence of geological structures.
(iii) Estimating the dimensions of the deep - seated ore bodies.
(iv) Getting the information with regard to subsurface lithology.

The subsurface investigation at any engineering work site is most essential to decide its suitability for supporting the foundation , its utility as construction material or to suggest type of foundation .

Often it becomes necessary to explore vast areas in limited period while planning and designing structures such as dams, canals, railway and road embankments. Advancement in technology provides geophysical methods for such types of subsurface exploration. Electrical resistively techniques is one such method employed to investigate large areas in short time (Shamsher and Kate, 1990) .The various geophysical methods classified as follows :

(i) Seismic methodld.
(ii) Gravimetric method.
(iii) Magnetic method.
(iv) Electrical method.

Amongst these, electrical resistively method is very much common in use for subsurface exploration for Geotechnical Engineering purposes. Electrical method is widely used by civil engineers because of its simplicity and rapidity. The electrical method makes use of the fact that various materials of earth crust consolidated or unconsolidated, possess electrical properties of wide variation. The range of variation in resistivity of different soils and rocks is larger than any other physical property.

Electrical resistivity investigation is perhaps the most effective and commonly employed method in ground water prospecting. The increasing acceptance of the method is large , due to the favourable result obtained. The technique is also preferable to other geophysical methods due to the comparatively low cost of investigations, simple field procedure and reasonably dependable result of data interpretation in terms of hydrogeology of the area (Ballukarya , et al, 1981).

ELECTRICAL RESISTIVITY SOUNDINGS

Circuit arrays : Two circuit array arrangements, are commonly used for conducting electrical resistivity soundings in the field . These are Wenner's circuit array and Schlumberger's sircuit array , in Wenner's array the electrodes are spaced at equal spacing (Fig.1); the resistivity ρa is calculated by using the following equation:

$$\rho a = 2\Pi a_1 R \qquad (1)$$

In which a_1 is the electrodes spacing and R is the resistance i.e the ratio between potential difference (E) and current (I) . The depth of current penetration in this case is equal to a_1.

In Shlumberger's array, the seperation between adjacent electrodes are not equal but current electrodes are spaced much farther apart than the potential electrodes (Fig.2). The resistivity ρa is obtained from :

$$\rho a = \Pi R (a_2^2 - b^2) / 2b \qquad (2)$$

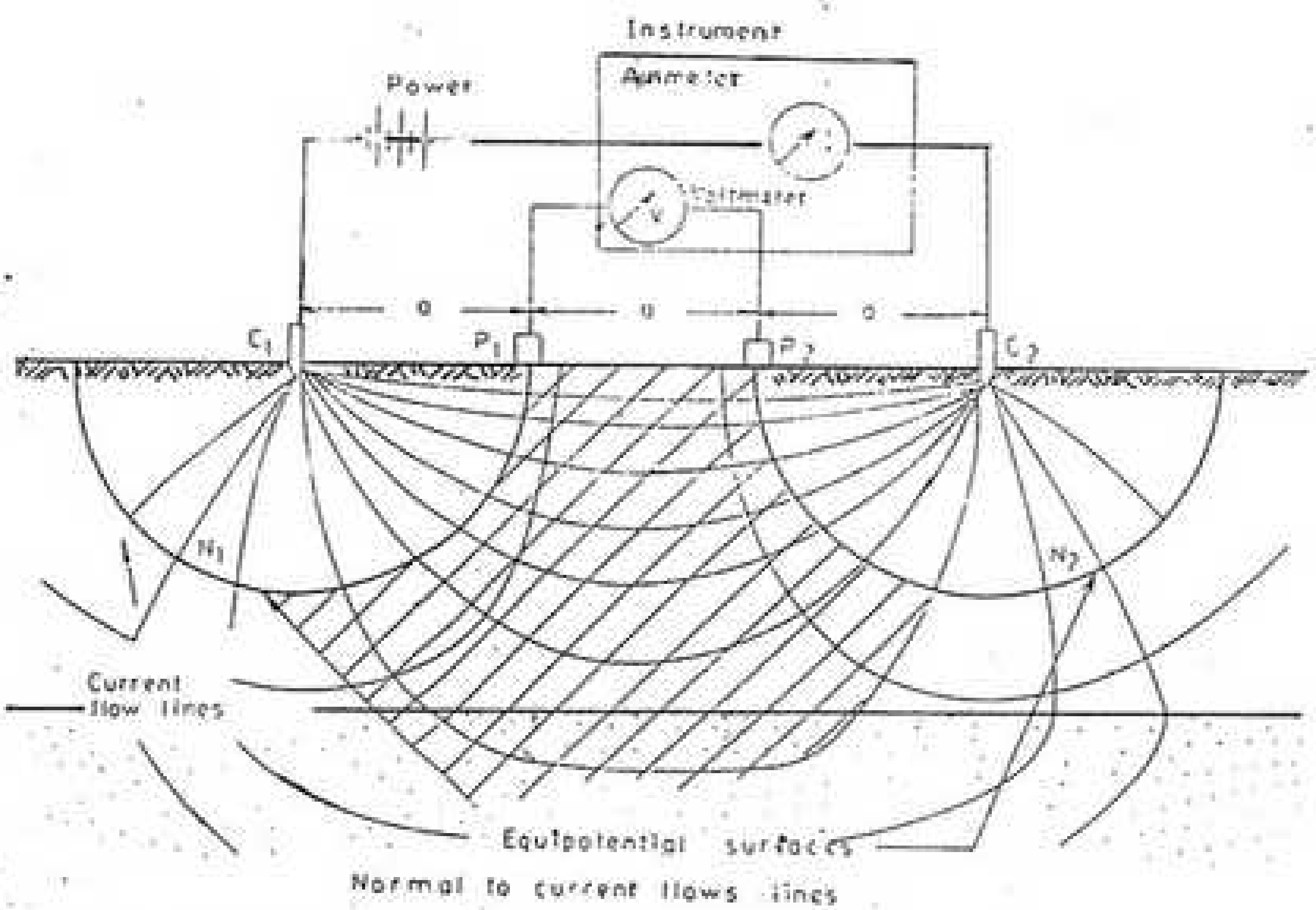

FIG. 1 SCHEMATIC ARRANGEMENT OF WENNER ARRAY

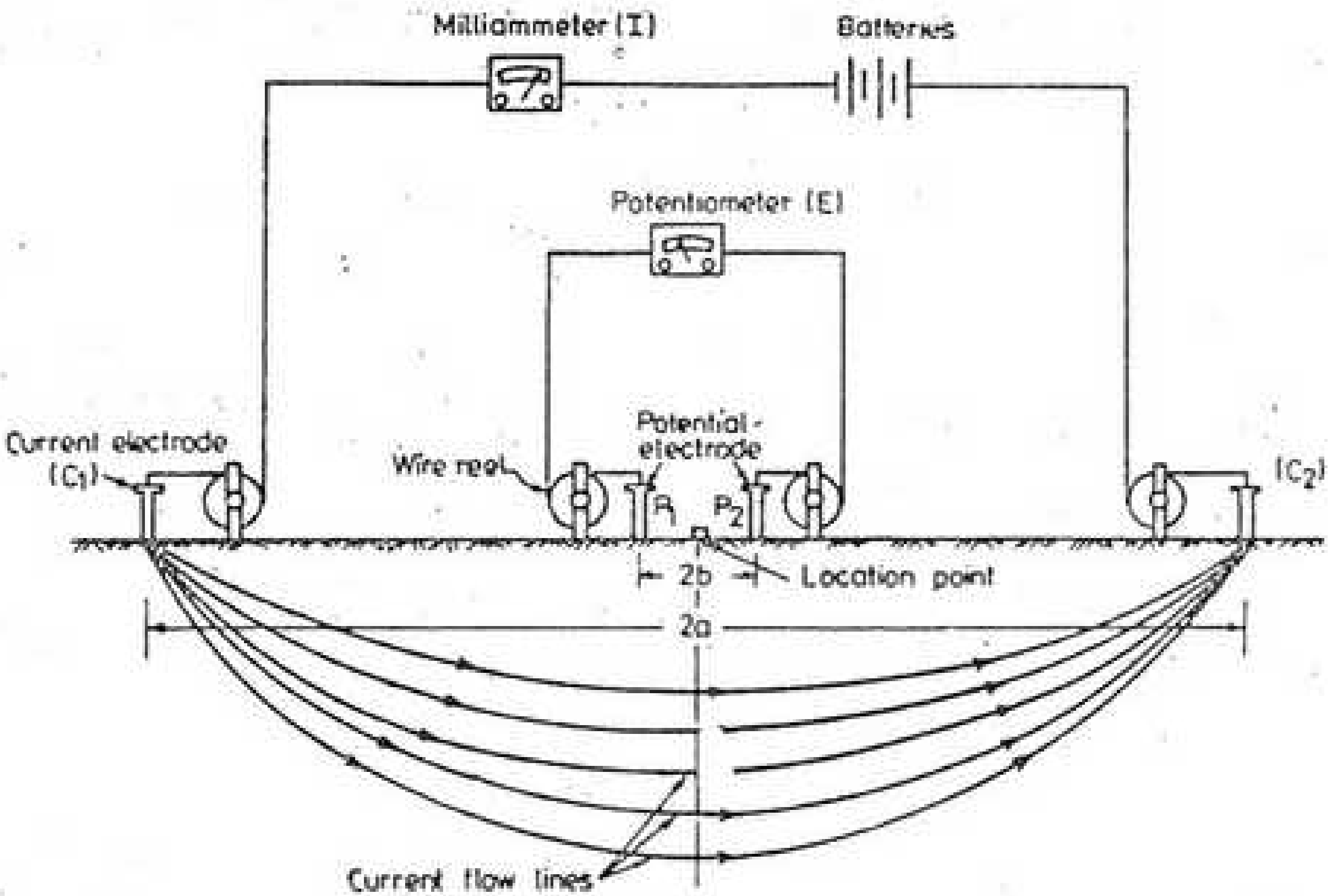

FIG. 2 - SCHEMATIC ARRANGEMENT OF SCHLUMBERGER ARRAY

Where $2a_2$ is spacing between current electrodes and b is the spacing between potential electrodes. The depth of current penetration into the ground for the arrangement is a_2.

INTERPRETATION

The log of subsurface profile can only be prepared when the following information are available. These are (i) each and every stratum comprising the profile in identified (ii) their thicknesses, sequence and depth below ground is known and (iii) the depth of ground water table if exists, within the depth explored is known. The electrical resistively soundings data is capable of furnishing all the above information provided it is interpreted correctly. The commonly used interpretation techniques are Moore's cumulative plot (Moore, 1961), Hummel's extension (Hummel, 1931). Direct slope (Baig, 1980), Inverse slope (Sankar Narayan and Ramanujachary, 1967) Barnes layer method (Barnes, 1954) and Master or Standard curve matching (Compagnie General de Geophsique, 1963).

BARNES LAYER METHOD

There are number of interpretation techniques used as mentioned above for identifying the true resistivity and thickness of each layer of the soil strata. Barnes layer method is one of this technique, which is suitable for geotechnical engineer where the required depth is limited (Shallow depth) compared with ~~depth~~ depth required by geophysics and geologist (great depth).

The Barnes method attempts to distinguish the resistivity of layers. The layer thickness is assumed to be equal to the increment in the electrode spacing. It is probably the best to use equal increments of spacing during the survey. If (R_{n-1}) is the resistance of soil up to the bottom of a certain number of layer (n-1) layers, and R_n is the measured resistance when the next layer (n^{th}) layer is also included by increasing the electrode spacing by one increment, then the resistance R_L of the layer added by the new reading (i.e the n^{th} layer) is given by :

$$\frac{1}{R_L} = \frac{1}{R_n} - \frac{1}{R_{n-1}} \qquad (3)$$

Then the average apparent resistivity (ρ_L) of the n^{th} layer is given by :

$$\rho_L = \frac{2 \Pi a_L}{1/R_L} \qquad (4)$$

Where :

a_L = incremental electrode spacing (layer thickness).

$\frac{1}{R_L}$ or $\frac{1}{R_n}$ = is defined as "conductance" which has the unit of Ohms.

By computing the values of ρL and a_L and draw it in the normal graph paper, the values of the true resistivity and their thikcnesses can be identified as shown in Fig.3.

IDENTIFYING SUBSURFACE PROFILE :

The interpretation of sounding data primarily aims at understanding the subsurface conditions, the number of layers present , their thickness , the resistivity of individual layers and few other geoelectrical parameters from a knowledge of local geology and the resistivities of layers , it is often possible to identify the lithological unit in a given area, which can be made use of hydrogeological studies .

A rogh correlation of resistivity to materials is given in Table 1 and Fig. 4 the resistivity decreases with increase water content and with increasing water salinity .

Table 1 : Resistivity Correlation

Types of Materials .	Resistivity (Ohm - m)
1. Wet to moist clayey soils	1.5 - 3
2. Wet to moist silty clay and silty soils	3 - 15
3. Moist to dry silty and sandy soils	15 - 150
4. Well fractured to slightly fractured bed rock with moist soil filled cracks	150 - 300
5. Sand and gravel with silt	300
6. Slightly fractured bedrock with dry soil filled cracks sand and gravel with leyer of silt.	300 - 2400
7. Massive bedded and hardrock coarse dry sand and gravel deposits.	>2400

FIEID RESISTIVITY SOUNDING DATA :

1-Field data :

Herein an attempt has been made to interpret the given field data of Electrical Resistivity

sounding at 6 selected locations, designated herein by 1, : 2, up to 6 . Approximate area of 3km.

The instrument used was D.C Resistivity meter and the circuit array was Wenner's arrangement. Elctrode spacings (a) were increased by 0.15 m initially to as high as 2.5 m at the end. The observations for resistance (R) were available up to a maximum current penetration depth of 20m .At each location, observations were also taken by changing

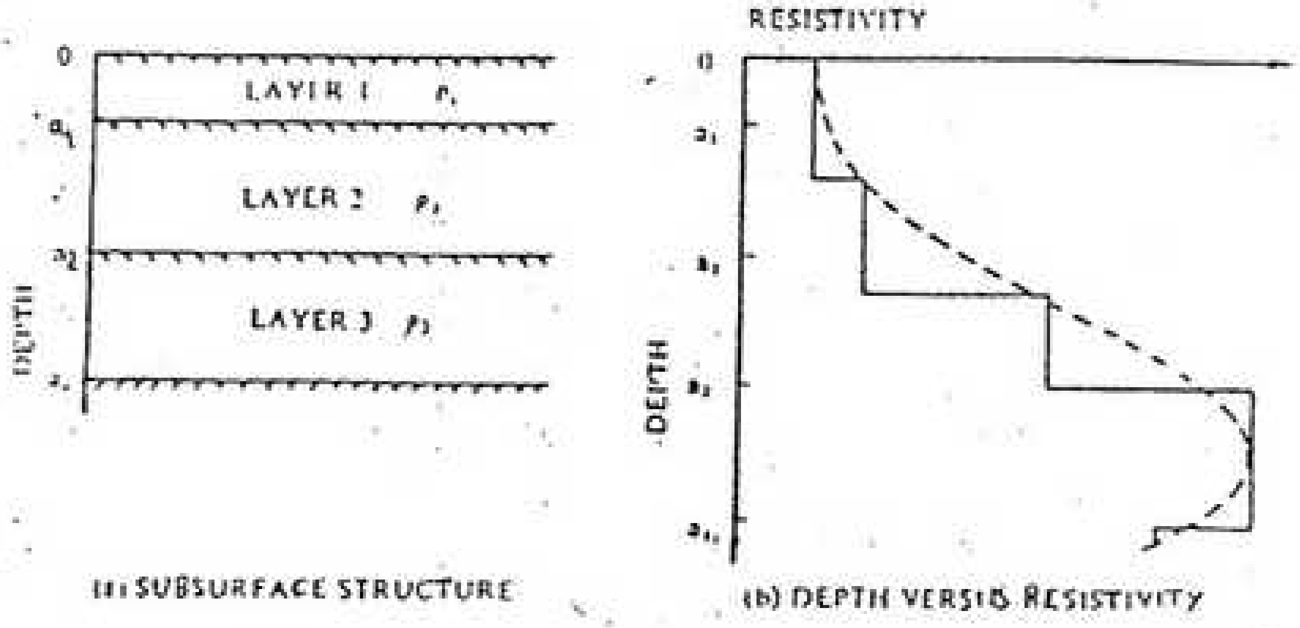

FIG.3 INTERPRETATION BY BARNES METHOD

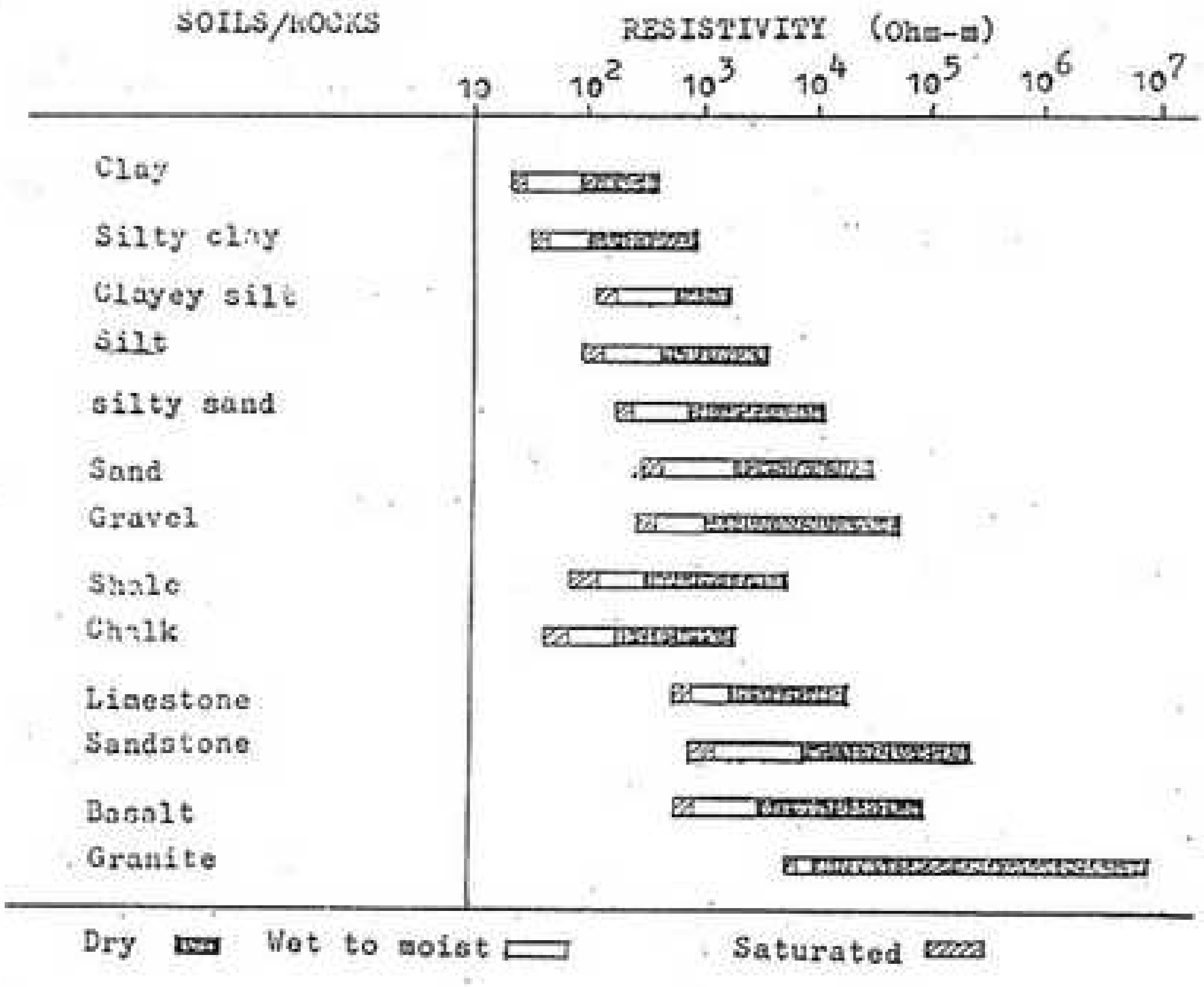

Fig.4 APPROXIMATE RANGES FOR THE ELECTRICAL RESISTIVITY FOR SOILS AND ROCKS

electrode line through 90° and the average values have been reported. The apparent resistivity (ρ_a) values at various depth were calculated by using equation (1).

2-Interpretation :

Barnes technique has been used for evaluating the true resistivity (ρ) and thickness (t) of each of the stratum from the vertical electrical sounding data equation (3) and(4).

RESULTS AND DISCUSSION

The vertical electrical sounding results at all the six locations have been presented in fig(5 and 6) in the form of variation between apparent resistivity (ρ_a) and electrical spacing (a) on semi-log plot. The maximum and minimum values of apparent resistivity (ρ_a) observed at various locations are shown in Table 2. In general, these apparent resistivity values primarily indicate the presence of low resistivity layers in subsurface profiles and possibility of encountering ground water table (GWT) within the depth explored.

Generally the value of 25 Ohm.m resistivity indicate the GWT (Donaldson and Keller, 1974). The GWT are observed at the depth of around 13m, 15m,18m and 10m at locations 1,3,5 and 6 respectively. The interpreted values of thicknesses (t) and resistivities (ρ) of different subsurface strata at the study locations, obtained from Barnes layer interpretation technique, are presented in Table 3.

Table 2 Maximum and Minimum Values of Apparent Resistivity at Various Field Locations.

Location No.	ρ_a max. (Ohm.m)	ρ_a min (Ohm.m)
1	46.2	15.1
2	50.2	24.1
3	81.01	8.98
4	200.20	23.74
5	95.77	16.49
6	92.32	4.08

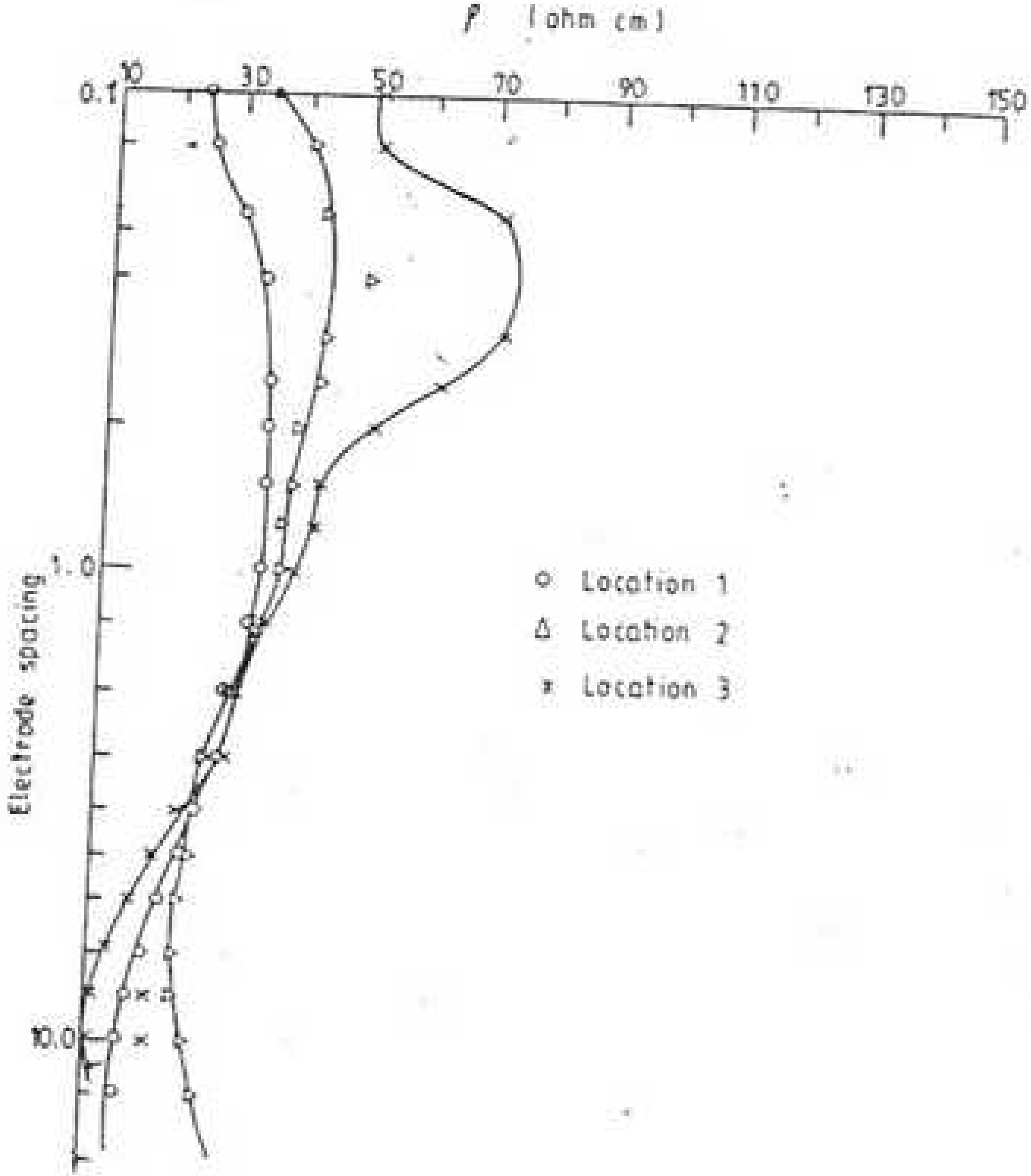

FIG. 5 APPARENT RESISTIVITY VARIATION WITH ELECTRODE SPACING

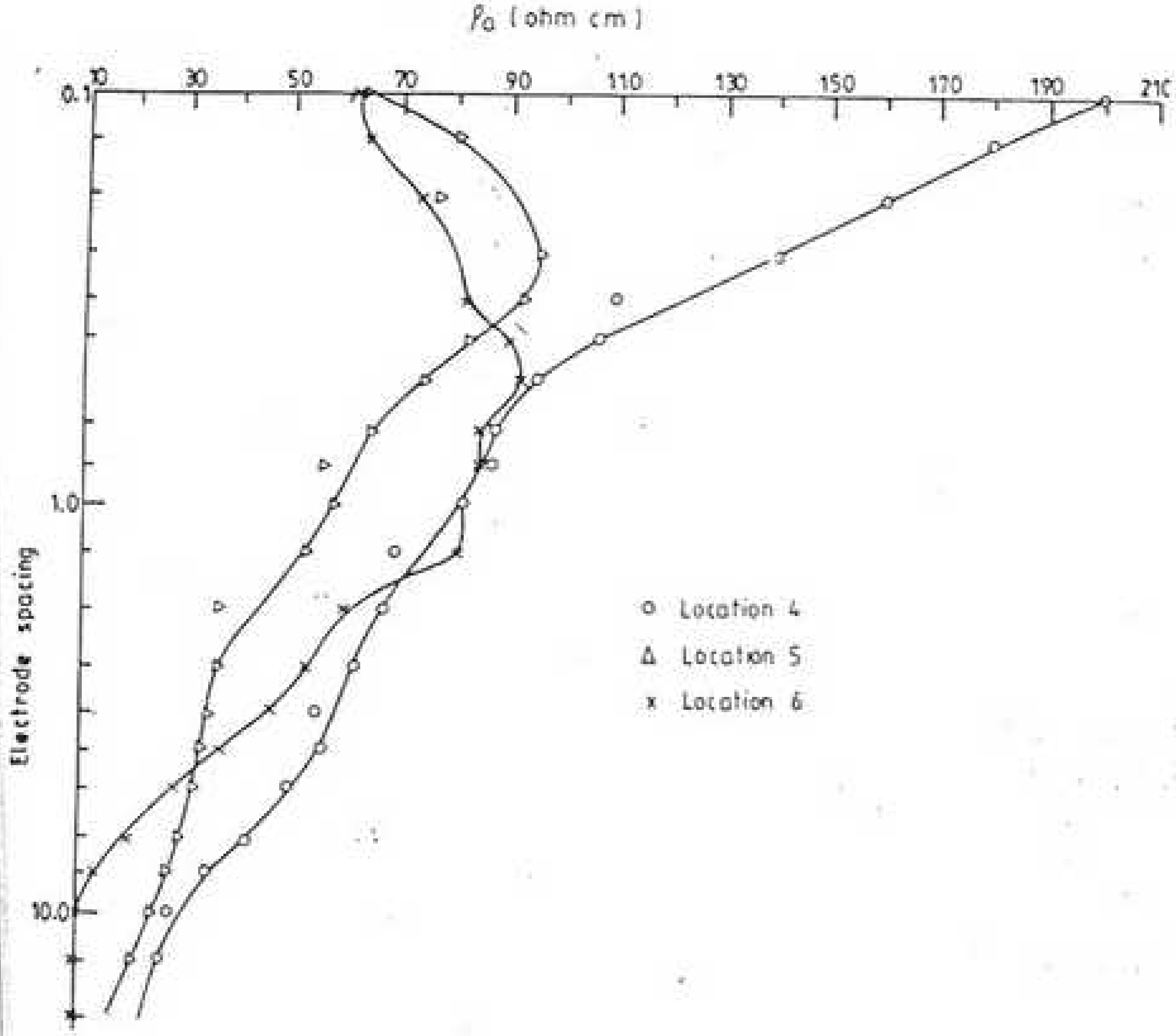

FIG. 6 APPARENT RESISTIVITY VARIATION WITH ELECTRODE SPACING

Table 3 Layer Thickness and True Resistivity by Barnes Interpretation Technique

Location No.											
1		2		3		4		5		6	
t (m)	ρ (Ohm-m)	t (m)	ρ (Ohm-m)	t (m)	ρ (Ohm-m)	t (m)	ρ (Ohm-m)	t (m)	ρ (Ohm-m)	t (m)	ρ (Ohm-m)
0.4	55	0.25	94	0.4	85	0.4	69	0.3	53	0.3	67
1.5	27	1.6	32	1.1	94	2.0	43	3.2	25	2.1	80
8.0	17	8.15	22	16.6	23	7.6	25	6.5	12	4.2	20
-	25	-	48	-	34	-	14	11.5	7	-	2
								-	19		
1.9	55		94		85		69		53		67
		1.85		1.5		2.4		3.5		2.4	
	27		32		94		43		25		80
8.0	17		22	16.6	23		25		12		20
↓	25	↓	48	↓	34	↓	14	↓	7	↓	2
									19		

It is observed from Table 3, that the values of thickness (t) indicate more than one layer of soil below ground level as given in fig. 7. But when these thicknesses compared with true electrical resistivity it is found within the same range of true electrical resistivity having one particular thickness, for example in location 1 it is observed that the thickness of the top layer equal 0.4 m with true electrical resistivity of 55 Ohm.m and the thickness of the next layer is 1.5 m with true resistivity of 27 Ohm.m and so on. When these true electrical resistivities values are compared with Fig.4 it can be found that the true electrical resistivity contain both the values under one type of soil strata, means that the top soil is of one type of soil which is silty clay with actual thickness of 1.9 as shown in Fig.8. Similar modification have been carried out for the other locations. The modifiyed values of true electrical resistivity with its actual thicknesses are given in the bottom of Table 3.

The investigation of the given area in this study have a uniform soil and profiles, which contain a clay layer with some percent of silt with a thickness ranges between 1.9 m in location 1 and 4m thick in location 5 as a top layer. In location, 4,5 and 6 found a clay layer next to the top layer which is cantinues. In locations 1,2 and 3 found a clay layer with some silt continues as a next layer to the top one. Except at location-3 at the lower depth found silt layer as it is shown in Fig.8.

In general the value of true electrical resistivity of 25 Ohm.m indicate the present of ground water table (GWT). In the present study, the GWT found at depth of 4.2 m as minimum at location 6 and 6.5m, 7.6m, 8.0m and 8.15m at locations5,4,1 and 2 respectively. Maximum depth of GWT found at location 3 with depth of 16.6m.

It can be conclude that the electrical resistivity technique can be used to investigate the subsurface soil and estimate the ground water table.

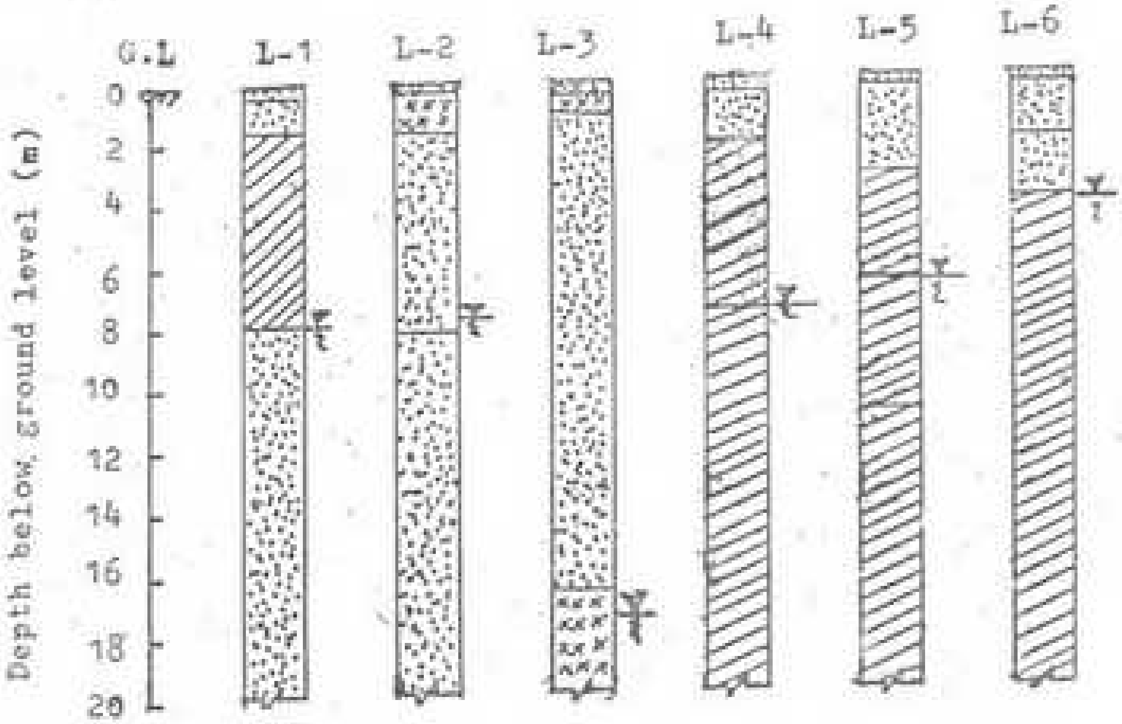

Fig.7 SUBSURFACE PROFILES INTERPRETED BY BARNES TECHNIQUE

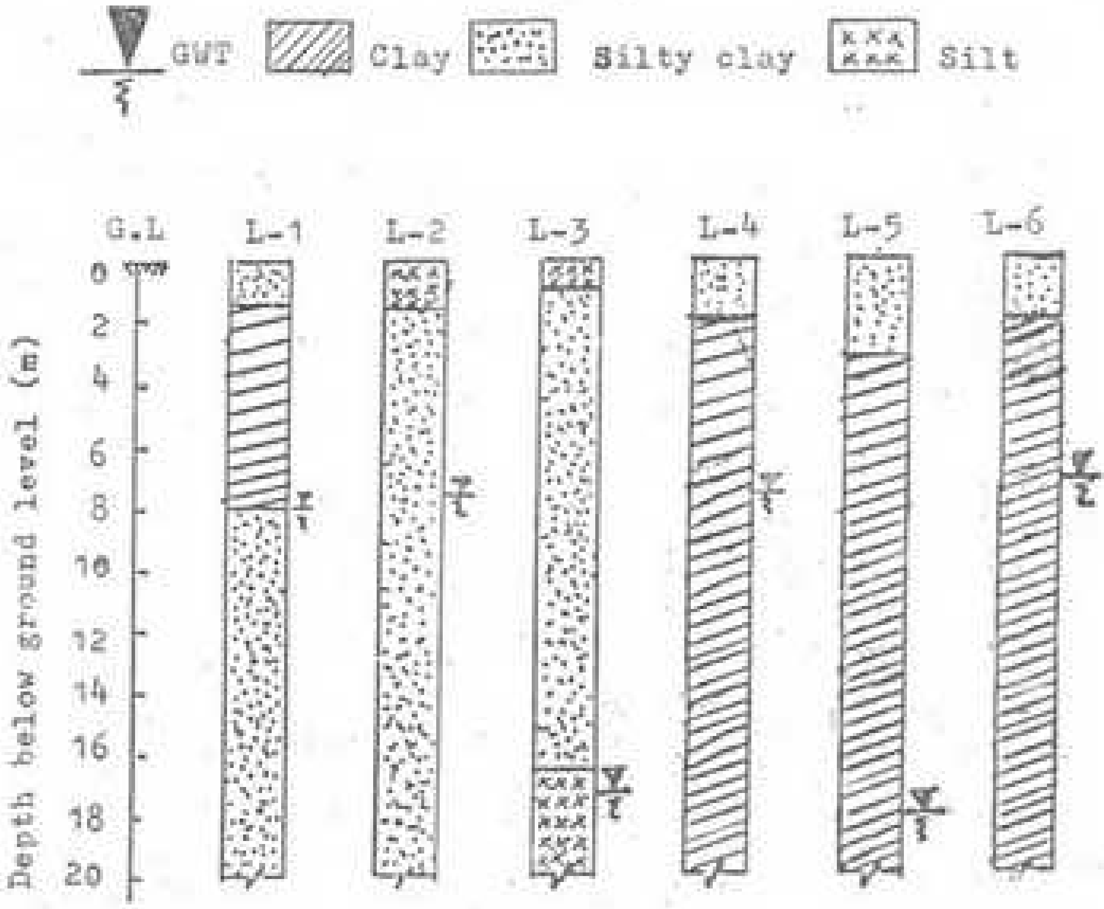

Fig. 8 MODIFYED SUBSURFACE PROFILES

CONCLUSIONS:

1.The used of the electrical resistivity is one such non - destructive technique, used as a complementary to direct method of exploration due to its simplicity , low cost and quick output.

2.This technique provide investigation of the subsurface strata, thicknesses, type of soil and estimate the ground water table.

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