

Determination of Lateral Changes in the Physical Properties of Upper Layers of the Soil and Groundwater Depth Using Specific Electrical Resistivity Method for Engineering Purposes

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Abstract

This study represents a small scale electrical resistivity survey at a selected location within the MoST (Ministry of Science and Technology) establishment residence / Jadriyah / Baghdad, in order to detect the physical properties of the top surface layers at the location and predicting the depth of the ground water table which is considered important factor for the foundations of any engineering construction work in the future.

The Horizontal Electrical Profiling (HEP) used to cover up the small area and to give good indicators for the lateral variations of the top soil layer physical properties, where the results show that the site is characterized by deposition is dry to a depth of 1.5 meters in the southern part of the west of it, while the Vertical Electrical Sounding (VES) at the center of the area determined the thicknesses and resistivity at the top layers and the depth of ground water table. Showed where the presence of three geoelectric layers thickness of 1.57 and 2.43 and 5.20 meters respectively.

Key words: Electrical Resistivity; Groundwater; Electrical Sounding and Engineering Purposes.

تحديد التغيرات الجانبية في الخواص الفيزيائية للطبقات العليا للتربة وعمق المياه الجوفية باستخدام

طريقة المقاومة النوعية الكهربائية للأغراض الهندسية

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الخلاصة

تمثل الدراسة إجراء مسح بتقنية المقاومة النوعية الكهربائية بمقياس صغير في موقع مختار داخل مجمع وزارة العلوم والتكنولوجيا في منطقة الجادرية ببغداد، وذلك للكشف عن الخصائص الفيزيائية لطبقات السطح العليا وتحديد عمق منسوب المياه الجوفية الذي يعتبر عاملاً مؤثراً في أساسات أي منشأ هندسي يمكن ان يقام في المستقبل. استخدم المسح الجانبي الافقي لتغطية الموقع وقد أعطى مؤشرات جيدة عن التغيرات الجانبية في الصفات الفيزيائية للطبقات العليا من التربة حيث بينت النتائج ان الموقع يمتاز بترسبات جافة الى عمق 1,5 متر في جزءه الجنوبي الغربي منه ، في حين استخدم الجس العمودي في تحديد سمك ومقاومية الطبقات العليا وعمق منسوب المياه الجوفية. حيث بينت وجود ثلاثة طبقات جيوكهربائية بسمك 1,57 و 2,43 و 5,20 متر على التوالي.

الكلمات المفتاحية: المقاومة الكهربائية، المياه الجوفية، الجس الكهربائي و الأغراض الهندسية.

Introduction

The electrical resistivity method was used to explore sand and gravel sediments prior to the late 1930s (Patterson, 1937). During the period (1912-1914) Conrad Schlumberger began his pioneering studies which lead to understanding of the merits of utilizing electrical resistivity method (Dobrin, 1960). Apparent resistivity (ρ_a) is the electrical resistivity of homogeneous ground that will produce the same response as it was measured in the field using a single set of measuring parameters. Apparent resistivity and apparent conductivity are the reciprocal of each others. Apparent resistivity allows the comparison of measurements from one area to another and provides approximation to the actual earth resistivity (Dobrin, 1976; Sharma, 1976). Modeling is required to determine the representative electrical resistivity structure of the earth (Lucius, *et al.*, 2007).

The principle of this method could be achieved when four metal-stake electrodes are driven into the ground (Telford, *et al.*, 1976). Electric current is introduced into the ground using two of the electrodes, and the electric potential is measured between the other two electrodes. With the help of manual and computer resistivity data processing, a representative resistivity structure of the earth is determined. The method is proven and reliable in identifying areas that are relatively conductive (for example, water-saturated sediments or fine-grained/clay-rich regions) compared to areas that are relatively resistive (such as relatively dry sediments or coarse-grained regions) (Sharma, 1976).

Presently, resistivity surveys are used in a wide variety of minerals, engineering, geologic, and environmental site investigations. With regard to sand and gravel deposits, the resistivity method can detect depth and lateral extent of coarse-grained (sand or gravel) compared to fine-grained (clay) layers, wet or dry sediments, depth to water table, and depth to bedrock (Griffiths and King, 1981).

In the current study the vertical electrical resistivity sounding (VES) point was done in the middle of small area in order to obtain more information on the shallow depth, this depth is sufficient to detect the shallow electrical zones that represent the foundation of a relatively small scale building and how this foundation might be affected by the considered depth of ground water table which obtained by the (VES) interpretation.

Area location and Geology

The location of the studied area represents a small area of about (600 m²) located within the Iraqi Ministry of Science and Technology (MoST) establishment Jadriya - Baghdad Figure (1).

Soil in the area shows high variations along the vertical and horizontal directions. The upper part is named Fill zone sediments (Jassim and Goff, 2006) consists of a mixture of clay minerals and disposing materials like gravel, bricks and other building debris materials and disposals. The thickness of this layer varies between 1 m to 15 meters.

This layer is characterized by its ability to collapse and suffer subsidence so it has low durability for building foundations.

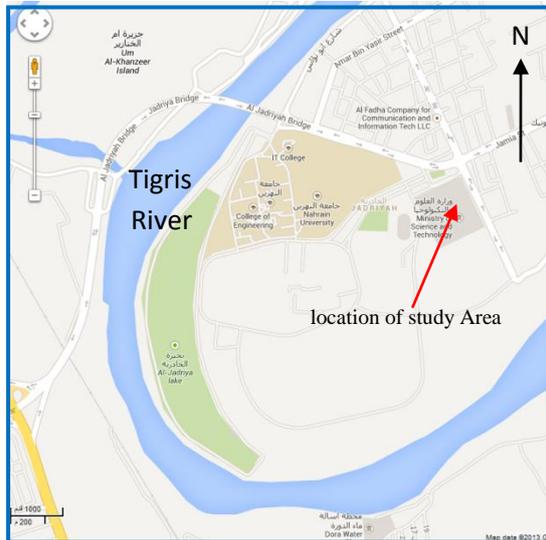


Figure (1) Location of Studied Area As it Appears in a Google Earth map.

Material and Methods

Linear Schlumberger configuration was used for both Vertical Electrical Sounding (VES) and Horizontal Electrical Profiling (HEP). Both were measured using Automatic Resistivity System (ARS-200E) GF Instrument figure (2). Pairs of insulated wire cables are towed along the ground surface. DC current was produced in the earth by the transmitter poles A-B, and voltage was measured simultaneously by the other two poles M-N. With supportive geologic information, the resistivity method can detect the presence of clay layers, and the water table (Sharma, 1976).



Figure (2) Automatic Resistivity System (RAS -200E)

The complete system of the instrument was made by (GF Instruments, Czech Republic), consist of sixteen-electrode cable section with stainless electrodes (30cm. length and 1.0 cm. diameter), 12 V battery pack, PC laptop and RES2DINV interpretation software.

The instrument is high power fully automatic resistivity meter for DC electrical survey applied to ground water exploration, environmental studies, civil engineering, and structural geology investigation; for mineral exploration its induced polarization parameter (IP Chargeability) completes the information given by the classical DC electrical parameter (Resistivity).

For (HEP) survey of the studied location, Schlumberger configuration used to cover the measurement points for the 12 profiles in the studied location in each point AB distance was 6 m and MN distance was 1.2 m which equals to (1/5 AB distance) in each point measurement of (ρ_a) recorded and calculated according to schlumberger equation below (Batte *et al.*,2008):

$$\rho = \pi \left\{ \frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right\} \Delta \frac{V}{I} \dots\dots\dots (1)$$

V= potential, I= Current

Figure (3) shows a sketch for Schlumberger array where potential distance (MN) always kept less or equal to (1/5) the current electrodes distance (AB).

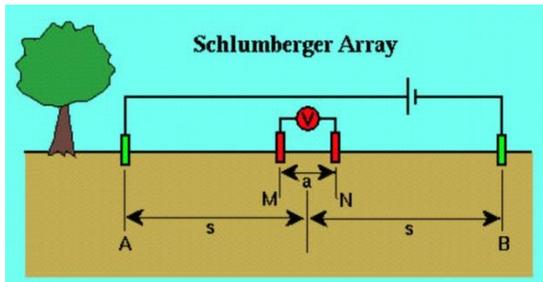


Figure (3) Sketch Diagram of Schlumberger Array Used in Resistivity Data Acquisition.

The (HEP) survey design appears in Figure (4) for the 12 (HEP) traverses that covered the studied location. The distance between one (HEP) point and another is 6 m .

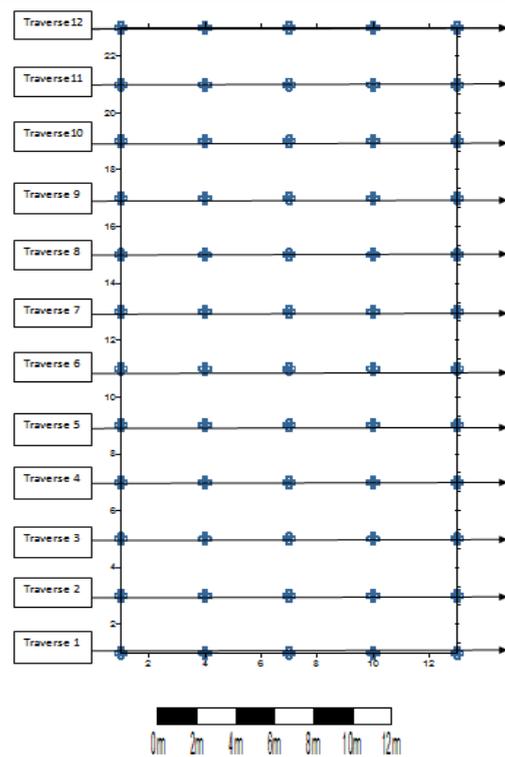


Figure (4) The Resistivity Profiling Survey Design

Results and Discussions

The interpretation technique was studied by many authors such as (Koefoed 1965), (Ghosh,1971), (Flathe,1974), (Zohdy,1974), (Koefoed,1979), (Zohdy,1989), and (Basokur,1999) . The layering parameters (resistivity ρ_i and thickness h_i) can be obtained from the apparent resistivity data. (Zohdy ,1974) and (Van Der Valpen,1988) .

The bulk or total resistivity for a certain bed could be represented by the following equation of multiple variables: $\rho_s = f(c, n, S_w, T_p, Q, \rho_m, \rho_w) \dots\dots\dots (2)$

Where: c= soil clay content , n= soil porosity , S_w =degree of rock saturation with water , T_p = temperature , Q= ionic exchange , ρ_m =rock or sediment solid particles resistance , ρ_w = rock water resistance (Frohlich,1973) .

Figure (5) displays a sample from the results of (HEP) for the traverses (1 and 2) . Similar procedure of interpretation have been achieved for the rest 10 traverses that covers the studied location.

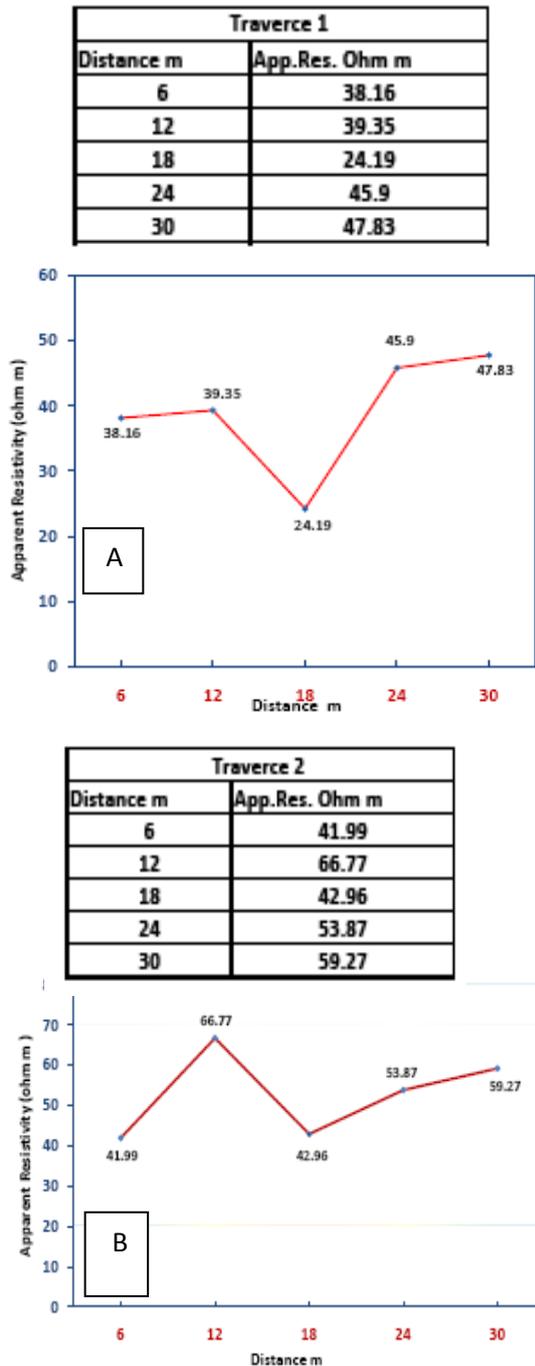


Figure (5) A Sample from the 12 Profiles in the Location (traverses A and B) Showing ρ_a Variation With Distance AB= 6m and MN= 1.2m

A kriging interpolation technique using surfer program used to draw the equi- ρ_a contour map which appears in the figure (6) , the light shades refers to the highly resistive parts of dry top soil , the dark shades refers to the low resistive parts that belongs to the wet soil.

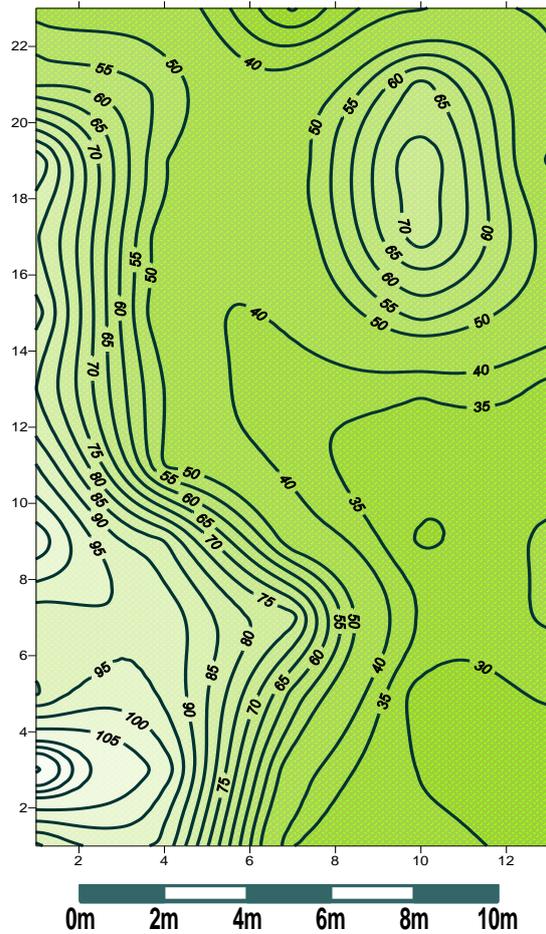


Figure (6) The Equi-apparent Resistivity Map for the Studied Location Showing ρ_a Value Variation with depth of 1.5 Meter , C.I. = 5(Ω .m)

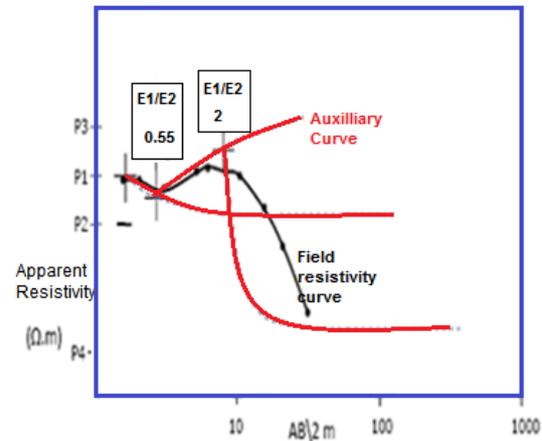
Only the (VES) point which located in the middle of the studied location achieved by using the Schlumberger configuration where AB/2 spacing increased gradually from 1.5m to 30 m and the MN/2 spacing increased gradually from 0.5m to 5m . The (ρ_a) readings obtained using the resistivity

meter (ARS-200E) instrument were listed in the table (1).

resistivity curve and the interpretation with table of results.

Table (1) The (ρ_a) in ($\Omega.m$) Readings for the (VES) Point Located in the Middle of the Studied Location

ρ_2 / ρ_1	App.Res. ($\Omega.m$)	Layer thick.(m)	Curve type
0.65	1=60 ρ	H1=1.57	HK
2	2=40 ρ	H2=0.86	
0.15	3=100 ρ	H3=5.2	
----	4=118 ρ	----	



Figure(7) Vertical Electrical Sounding, Resistivity Curve After Smoothing and Interpretation Using the Auxiliary Point Method of Two Layers Standard Curves (Orellana and Mooney , 1966) .

Meas. No.	AB/2 (m)	MN/2 (m)	App.res. (Ohm m)	St.dev. (%)
1	1.5	0.5	59.38	0.1
2	2.0	0.5	58.73	0.0
3	3.0	0.5	54.45	0.0
4	4.0	0.5	57.96	0.0
5	5.0	1.0	63.11	0.1
6	3.0	1.0	57.56	0.1
7	4.0	1.0	61.01	0.0
8	6.0	1.0	66.01	0.0
9	8.0	1.0	65.59	0.1
10	10.0	1.0	63.91	0.0
11	6.0	2.0	64.43	0.0
12	8.0	2.0	64.25	0.1
13	10.0	2.0	63.09	0.2
14	15.0	2.0	53.26	0.1
15	20.0	2.0	34.97	0.1
16	15.0	5.0	45.11	0.3
17	20.0	5.0	29.89	0.2
18	30.0	5.0	17.20	0.4

Conclusions

The results of (HEP) survey in the studied location referred to a depth of about 1.5 m from ground surface a dry soil at the western parts that gave high resistivity range of (75 - 115 $\Omega.m$) and wet soil at the southern east parts gave low resistivity ranges of (25 - 74 $\Omega.m$).

From the interpretation of the only (VES) point that located in the middle of the small area provided information until the depth of (7.63) meters, this depth is sufficient to detect the shallow electrical zones that represents the foundation for a relatively small building and taking in consideration the depth of water table(the low resistivity zone). The depth from ground surface to the depth of 2.43 meters which represents the electrical layers (h_1, ρ_1 and h_2, ρ_2) have resistivity values of (60 and 40 $\Omega.m$) consequently therefore it represents the top soil layer that soaked with fresh groundwater came from irrigating the area . The third layer which has resistivity value of ($\rho_3=100$

A resistivity curve drawn using a log-log scale by making (ρ_a) as a y-axis and AB/2 as x-axis then manually interpreted by applying the auxiliary point method of partial matching with Orellana and Mooney ,1966 , two layer standard curves in order to obtain the thickness (h) and resistivity(ρ) for the subsurface electrical layers. Figure (7) shows the

$\Omega.m$) represented sand with less porosity and less groundwater content (semi dry) and continue to the depth of (7.63) meters. After this depth low resistivity measured ($\rho_4 = 11.8\Omega.m$).

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