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Comparison between Conventional Arrays in 2D Electrical Resistivity Imaging Technique for Shallow Subsurface Structure Detection of the University of Technology

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ABSTRACT

The most common conventional arrays which are used in 2D electrical resistivity imaging techniques are Wenner array, dipole-dipole array and Wenner-Schlumberger array. These arrays have been tested in the University of Technology Camp / Iraq - Bagdad to find out the suitable array for type of subsurface structure of the study area. Borehole data near the study area have been used to qualify (confirm) the results. Six 2D images have been created (two images for each array) in this study. The length of each image is 60 m with depth between 8 to 12 m. The results show that Wenner-Schlumberger array is the most suitable array for the target area. Moreover, the subsurface of the study area is consisting of three types of soil (Silty clay, clay and sand).

Keywords: Electrical Resistivity Image, Arrays.

مقارنة بين المصفوفات التقليدية لتقنيات المقاومة النوعية الكهربائية ثنائية الابعاد لكشف المنشاءات التحت الارض الضحلة في الجامعة التكنولوجية

الخلاصة

ان المصفوفات (الترتيبات) الأكثر شيوعا المستخدمة في طريقة المقاومة النوعية الكهربائية ذات البعدين هي ترتيب دايبول - دايبول و ترتيب فنر شلمبرجير وترتيب فنر. هذه الترتيبات تم تجربتها في موقع الجامعة التكنلوجية/ العراق – بغداد ، من اجل إيجاد الترتيب الأكثر ملائمتا لنوع تركيب ما تحت سطح الأرض لمنطقة الدراسة. نتائج الحفر الاختبارية القريبة من منطقة الدراسة تم استخدامها لتأكيد نتائج هذا البحث. تم انشاء ستة صور ثنائة الابعاد (صورتين لكل مصفوفة). ان طول كل صورة هو ٦٠ متر وبعمق يتراوح بين ٨ الى ١٢ متر. النتائج أوضحت بان ترتيب فنر شلمبرجير هو الأكثر ملائمة لمنطقة الدراسة، بالإضافة الى ان طبقات الأرض لمنطقة الدراسة تتكون من ثلاثة أصناف من التربة (طين غريني ، طين و رمل).

INTRODUCTION

There are many reasons lead human to explore the subsurface structure such as it is needed for buildings, environmental, agriculture, archeology…etc. The most common method for explore subsurface is boreholing. Although,

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the borehole is the most accurate method but not always suitable for all wanted target because this method has some disadvantages such expensive, limited data, damage the study area and relatively need long time. Therefore, geophysics technique used to avoid the disadvantages of the boreholes [Hussein, 2010]. There are many geophysical methods and each method has its disadvantages and advantages depend on the target and the type of the study area. On the geophysical techniques is 2D electrical resistivity imaging. The advantages of 2D electrical resistivity methods are it is very good method to study complex subsurface structure, it has good ability to detect ground water, cavities and pipes, it is relativity economical methods, easy and portable equipment and can cover long distance. The disadvantages of 2D electrical resistivity method are is not so accurate compare to borehole results and choosing unright array will reduce the accuracy of the results. It is needed to test the many arrays on the study area to find out the suitable array to the study area. Therefore, the target of this study is to find out the suitable array to structure of university of technology [Reynolds, 1997].

Borehole data Table (1) shows that the surface layer consist of sandy silty clay with thickness about (1 to 3) m with a little amount of gravel . silty clay layer comes after the surface layer till the depth 12 m where the sand in this layer almost equal to the amount of the clay. the third layer deeper than 12 m consist of sand only.

2D ELECTRICAL RESISTIVITY IMAGING METHOD

Resistivity measurements are based on the difference of resistivity values between different sub-surface materials. The 2D electrical resistivity imaging survey is employed in the proposed site with ABEM SAS4000 multi electrodes system as shown in Figure (1).

Figure (1) Tools and equipment used in electrical resistivity imaging.

The arrangement of the electrodes is called the electrodes array. Table (3) shows typical configurations with four electrodes. The apparent resistivity value depends on the geometry of electrode [geometric factor K] [Reynolds, 1997]. Geometric factor depends on the position of the electrodes in the array. Resistivity imaging (RI) has different types of electrode arrays. The most common arrays in resistivity imaging are Wenner, the dipole-dipole and Wenner-Schlumberger [Samouelian et al., 2005; Loke, 2010].

In order to compare between different arrays, the survey was repeated two times using three different arrays, which are the dipole-dipole, Wenner-Schlumberger, and Wenner array.

The data collected in the survey was interpreted by using RES2DINV 2-D inversion software which this software uses the rapid least squares inversion method to model the final resistivity section [Loke and Barker, 1996]. The depth of the resistivity image depends on the distance between the electrodes, the used array, and the used equipment [Hack, 2000].

The Wenner array has the strongest signal strength. This can be an important factor if the survey is carried in areas with high background noise. One possible disadvantage of the dipole-dipole array is the very small signal strength for large values of the “n” factor. In Wenner-Schlumberger array the signal strength is weaker than that for the Wenner array, but it is higher than the dipole-dipole array [Loke, 2010].

The Wenner array has a moderate depth of investigation. In general, the dipole-dipole array has a shallower depth of investigation compared to the Wenner array. The median depth of investigation for the Wenner-Schlumberger array is about 10% larger than that for the Wenner array for the same distance between the outer (C1 and C2) electrodes for "n" values greater than three.

The Wenner array is good in resolving vertical changes (i.e. horizontal structures), but relatively poor in detecting horizontal changes (i.e. narrow vertical structures). The dipole-dipole array is good in mapping horizontal changes (vertical structures), such as dykes and cavities, but relatively poor in mapping vertical changes (horizontal structures) such as sills or sedimentary layers. Wenner-Schlumberger array is moderately sensitive to both horizontal (for low "n" values) and vertical structures (for high "n" values).

One disadvantage of the Wenner array for 2-D surveys is the relatively poor horizontal coverage as the electrode spacing is increased. This could be a problem if you use a system with a relatively small number of electrodes. Dipole-dipole array has better horizontal data coverage than the Wenner array. In Wenner-Schlumberger array the horizontal data coverage is slightly wider than the Wenner array, but narrower than that obtained with the dipole-dipole array.

Wenner array has having a good vertical resolution, thus it gives clear image for groundwater boundaries as a horizontal structure. The dipole- dipole array is good in mapping vertical structures, such as dyke and cavities, but relatively poor in mapping horizontal structures such as sills or sedimentary layer [Loke, 2010].Wenner-Schlumberger array might be a good compromise between the Wenner array and the dipole-dipole array.

RESULTS

The results in Figure (2) and Figure (3) show three resistivity pseudo-sections of Line 1 and Line 2 for three conventional different arrays. The arrays are the dipole-dipole, Wenner-Schlumberger and Wenner. Each pseudo-section is 2D resistivity image where the coordinate is length (x-axis) and depth (z-axis). The color of each 2D image present the resistivity values of the structure of the subsurface.

The resistivity values ranges of Line 1 are between (1-1000, 1-100 and 5-30 Ω.m) for the dipole-dipole, Wenner-Schlumberger and Wenner array respectively. Besides, the resistivity values ranges of Line 2 are between (1-300, 1-30 and 5-20 Ω.m) for the dipole-dipole, Wenner-Schlumberger and Wenner array respectively. The depths of the investigation for the thee arrays are 8.27, 12.1 and 10.2 m for the dipole-dipole, Wenner-Schlumberger and Wenner array respectively.

The above results have been interpreted according to nearby borehole data Table (1) and material resistivity values Table (2) where the dark gray colour which has resistivity value about 5 Ω.m can be interpreted as silty sand. While light gray colour which has resistivity value about 10 Ω.m have been interpreted as soil (sandy silty gravelly) clay. In addition, blue colour in the image with 20-40 Ω.m interpret as sand.

Furthermore the high resistivity values (50 and above Ω.m) is interpreted to drainage pipe. The drainage pipe has been discovered in at the depth two meters on the left side of the image. The pipe location have been confirmed from the site.

It is so clear from the results that the dipole-dipole image is complicated comparing to other images where this result is expected because the dipole-dipole array is so sensitive. However, Wenner-Schlumberger and Wenner array image are clear images.

The depth of penetration of Wenner-Schlumberger array is deeper than other arrays. Otherwise, the accuracy and identify of the arrays with nearby boreholes as well the reality of the Wenner-Schlumberger array is the most identity with borehole results.

Table (1)Boreholes data near to the study area [S. & Engineering Consulting Bureau2008].

	Borehole 1				**Borehole 2**				**Borehole 3**			
Depth (m)	**Clay (%)**	**Silt (%)**	**Sand (%)**	**Gravel (%)**	**Clay (%)**	**Silt (%)**	**Sand (%)**	**Gravel (%)**	**Clay (%)**	**Silt (%)**	**Sand (%)**	**Gravel (%)**
1.5	47	28	15	10	43	32	14	11	41	31	18	10
3.0	41	29	12	8	40	33	17	10	52	46	2	0
4.5	-	-	-	-	-	-	-	-	48	47	5	0
6.0	51	46	3	0	57	41	2	0	57	40	3	0
7.5	52	42	6	0	56	41	3	0	55	41	4	0
9.0	52	46	2	0	-	-	-	-	56	40	4	0
10.5	59	36	5	0	55	41	4	0	63	35	2	0
12.0	-	-	-	-	0	4	94	2	-	-	-	-
15.0	-	-	-	-	0	3	95	2	-	-	-	-

Table (2) Resistivity values of the common materials of the study area [Loke, 2010].

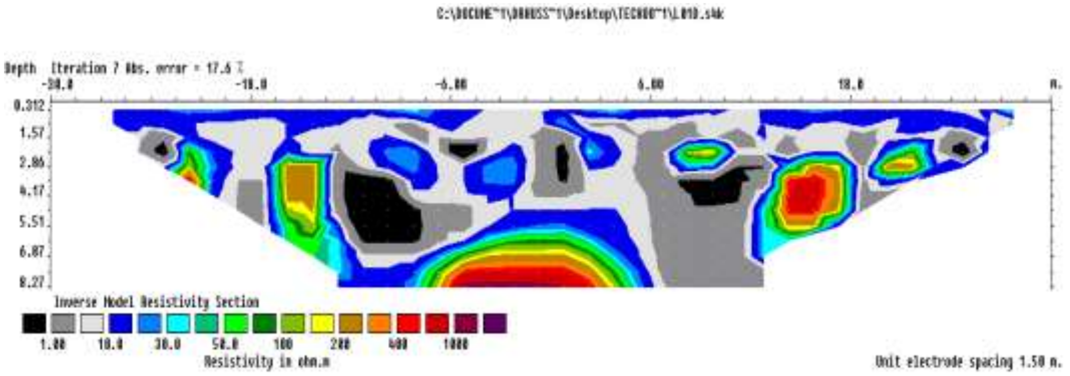
Material	**Resistivity (Ω.m) from Reyoland**	**Resistivity (Ω.m) of the subsurface from 3D resistivity image**	**Color in 3D image**
Silty Clay	1-100	5	Dark gray
Soil(40% clay)	8	10	Light gray
Sand	10-800	20-40	Blue
Pipe	High	50-above	Green

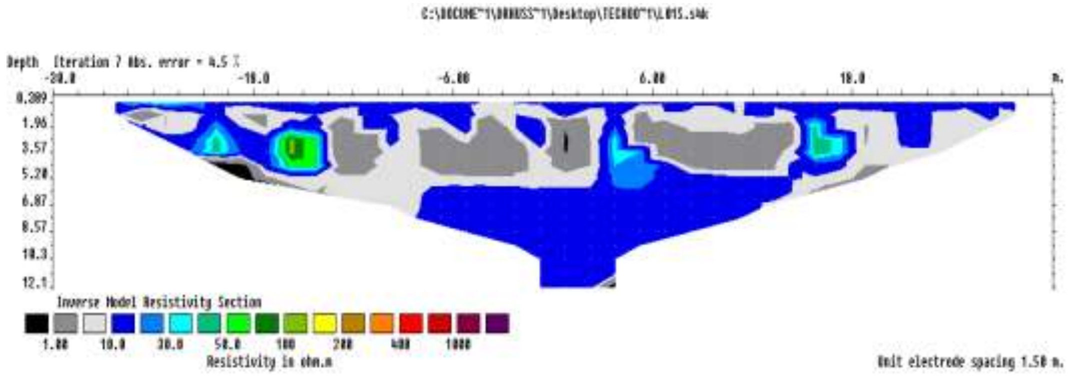
As a result of Wenner-Schlumberger array is the most expedience for this study area due to identify with reality, clearance and depth of penetration.

Table (3) Geometric factor and arrangement of common resistivity imaging arrays [Loke, 2010].

Array	**Geometric factor (K)**	**Arrangement**
Wenner	2πa	
Dipole-dipole	πn(n+1)(n+2)a	

Wenner-Schlumberger	πn(n+1)a	C1 P1 P2 C2 •←na→•←a→•←na→•





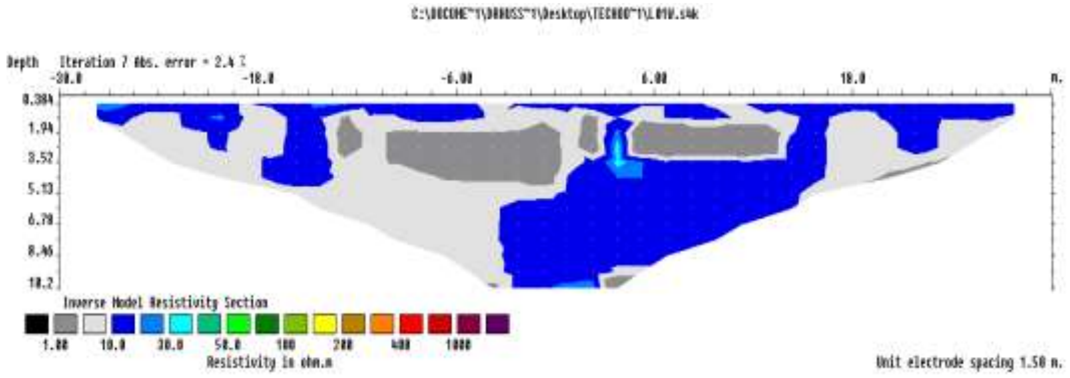


Figure (2) 2D electrical resistivity image for Line 1 by using the dipole-dipole, Wenner-Schlumberger and Wenner.

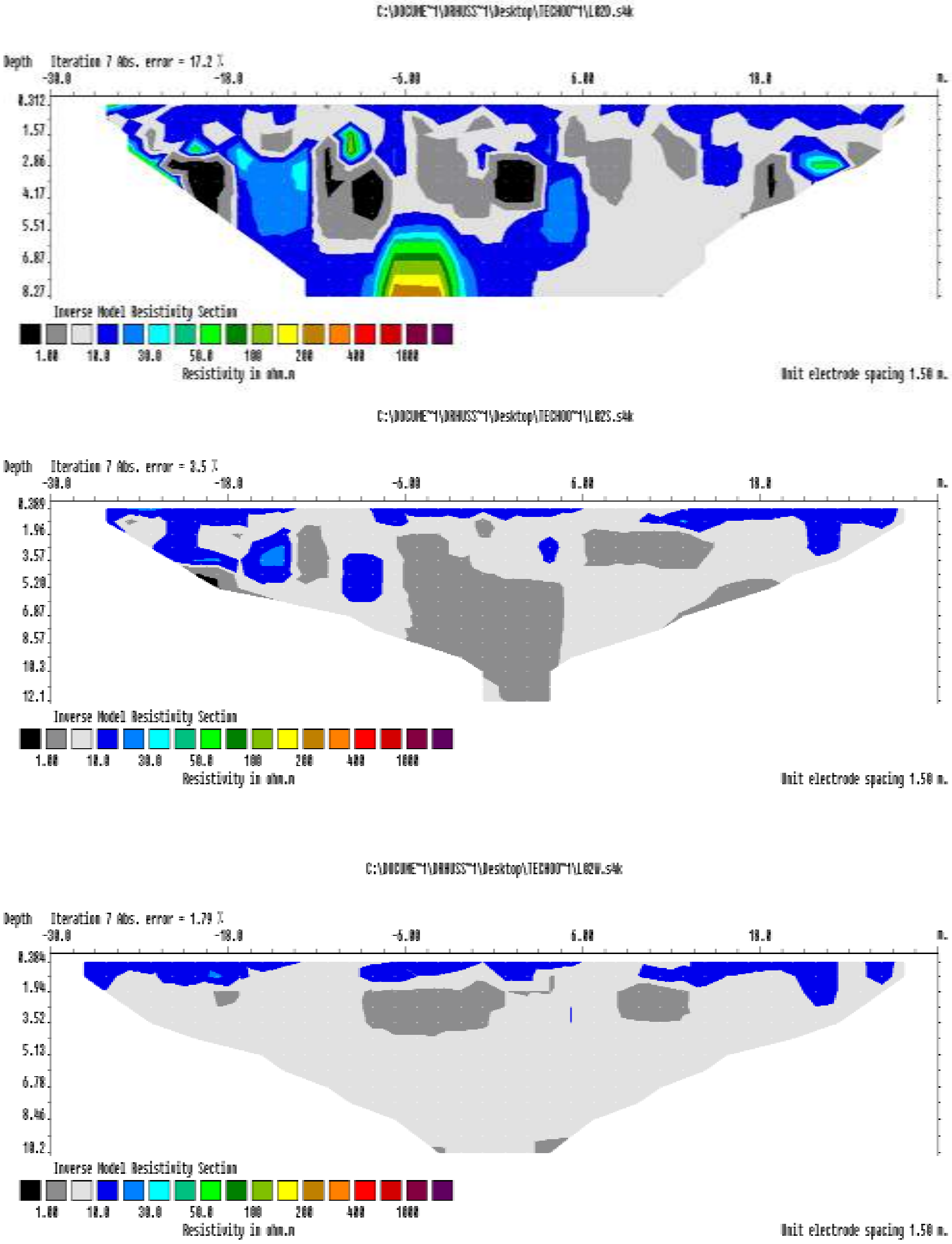


Figure (3) 2D electrical resistivity image for Line 2 by using the dipole-dipole, Wenner-Schlumberger and Wenner array.

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