



2D Electrical Resistivity Imaging to delineate the exact boundary and true thickness of granular aquifers

Bakhtiar Q. Aziz, Zana M. Rughzai

Department of geology, College of Science, University of Sulaimani, Iraq

<https://doi.org/10.25130/tjps.v28i2.1337>

ARTICLE INFO.

Article history:

-Received: 22 / 9 / 2022

-Accepted: 11 / 10 / 2022

-Available online: 26 / 4 / 2023

Keywords: Resistivity, aquifer, Inverse section, Wenner – Schlumberger, Sulaymaniyah.

Corresponding Author:

Name: Bakhtiar Q. Aziz

E-mail: zana.faraj@univsul.edu.iq

Tel:

©2022 COLLEGE OF SCIENCE, TIKRIT UNIVERSITY. THIS IS AN OPEN ACCESS ARTICLE UNDER THE CC BY LICENSE
<http://creativecommons.org/licenses/by/4.0/>



ABSTRACT

Electrical resistivity imaging (ERI) is one of the best geophysical techniques for studying subsurface and groundwater aquifer investigations. In clastic sediments, determining the exact boundary between different layers on the inverse section of ERI is not an easy task due to gradual changes in resistivity between surrounding layers and the granular aquifers. Therefore, the main aim of the study is to indicate a more precise boundary of the granular aquifers (true thickness of aquifers) on the inverse section. Two different models were used: the field model and the laboratory model, in the field model, four different locations were selected. They are located in (Kalar, Chamchamal, Bazyan, and Piramagroon), within the Sulaymaniyah Governorate, NE Iraq. Two-dimensional (2D) electrical resistivity imaging was carried out along four profiles of 355 m length with a five-meter electrode spacing. The Wenner-Schlumberger array was used for recording the data. For the lab model, a laboratory geological model was constructed has length, height, and width equal to 192, 65, and 45 cm, respectively. Two synthetic profiles were carried out on this model, they have lengths of 190 cm with electrode spacing of 10 cm. The field results indicated that aquifers in clastic sediments on inverse sections always showed anomalies with apparent thicknesses larger than their true thicknesses, which were obtained from the geological column of the wells. In the four studied locations, aquifers' average true thickness is approximately 68.2% of the apparent thicknesses on the inverse sections. The result of the laboratory geological model also showed that the true thickness of the unsaturated gravel is approximately equal to 59.7% of the apparent thickness of the anomaly, which is formed by the dry gravel layer. Also, the true thickness of the saturated gravel is about 57.1% of the apparent thickness of the anomaly, which is formed by the saturated gravel layer. Moreover, the geological model showed that the higher resistivity layer (dry gravel) creates a narrower transitional resistivity zone between clay and gravel than saturated gravel of lower resistivity.

1. Introduction

The electrical resistivity method (ERM) for the subsurface study was used for the first time for practical purposes in France in 1912, and it has since proved to be one of the most successful means for

shallow subsurface exploration. It is widely used in the investigation of suitable groundwater sources and in monitoring various types of groundwater pollution [1]. A major improvement in the early 1990s was the

development of 2D electrical resistivity imaging methods [2] that provide a more realistic model of the subsurface in geologically complex areas. Currently, 2D surveys are the best economic compromise between achieving extremely precise results and keeping survey expenses low [3].

Electrical resistivity is the oldest method used for groundwater exploration. Several researchers locally used 2D electrical resistivity imaging for groundwater determination in the study area such as, [4, 5, 6]. Furthermore, many studies around the world have used 2D electrical resistivity to delineate groundwater aquifers, such as [7, 8, 9, 10, 11].

The water demand has increased especially groundwater because surface water is not enough for domestic and agricultural uses. In recent years, increasing interest in groundwater has led to more detailed studies on the properties and geometry of aquifers [12]. One of the main problems in the inverse section is a broad transitional resistivity zone between the aquifers and the surrounding layers, so it is not an easy task for the interpreters to indicate an exact boundary between these layers. In most subsurface situations, especially for aquifers in clastic sediments, the robust inversion of apparent resistivity is disabled to minimize a transition zone between aquifer and above or underlain impermeable layers, while it works very good to minimize this broad zone to a narrow one when there is a boundary between clastic and non-clastic sediments. So this study is an attempt to indicate a more accurate and precise

boundary between granular aquifers and surrounding impermeable clastic sediments, by carrying out several 2D ERI in different locations with different lithology, where the water well was drilled previously and the thickness of the aquifer is known from the geologic column of the well. Then, calibration of the aquifer thickness in the geologic column of the well with the inverse section is carried out to investigate the accuracy of this method. To confirm that the field situation is correct a geological model was constructed in the lab and filled with three layers, 25 cm clay at the bottom, 20 cm gravel in the middle, and 15 cm clay at the top.

The four typical sites were selected for the current study, they are located in the Kalar district, Chamchamal district, Bazyan Sub-district, and Pirmagroon Sub-district, within Sulaymaniyah Governorate, NE Iraq. The coordinates of these locations are as follow: latitude ($34^{\circ} 51' 57.05''$ N) and longitude ($45^{\circ} 15' 56.03''$ E), latitude ($35^{\circ} 29' 36.33''$ N) and longitude ($44^{\circ} 51' 04.22''$ E), latitude ($35^{\circ} 38' 17.89''$ N) and longitude ($45^{\circ} 01' 21.02''$ E), and latitude ($35^{\circ} 42' 58.34''$ N) and longitude ($45^{\circ} 09' 10.72''$ E) respectively, as shown in (figure 1). The main reasons for selecting these localities are good productivity and the good thickness of the aquifers, in which gravel and sand form aquifers. In addition, the locations were selected based on the suitability of the aquifer depth and the extent of the area suitable for a 2D electrical resistivity survey.

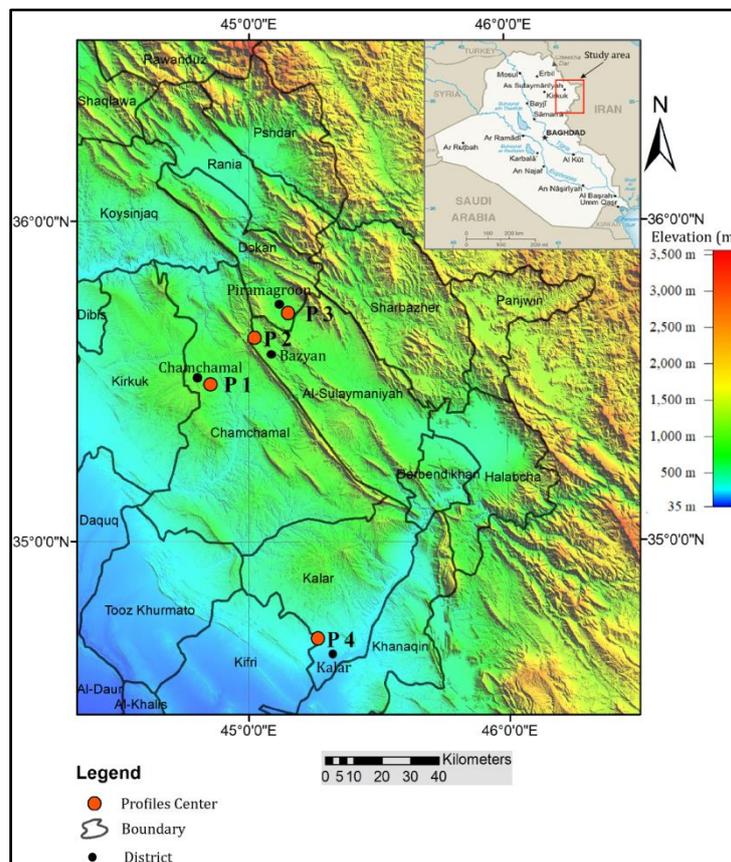


Fig. 1: Location map of the study area.

2. Methodology

The SYSCAL R1 PLUS instrument was used to collect field resistivity data, it is a multi-electrode resistivity meter system. Four locations were selected as optimal locations in different areas surrounding the Sulaymaniyah governorate. In each location, one 2D

profile was carried out, and the centers of the profiles were plotted near the well locations as close as possible as shown in (Figure 2). The orientation of the profiles are selected depending on the accessibility of the area and taking into consideration the small amount of dip of the outcrop layers.

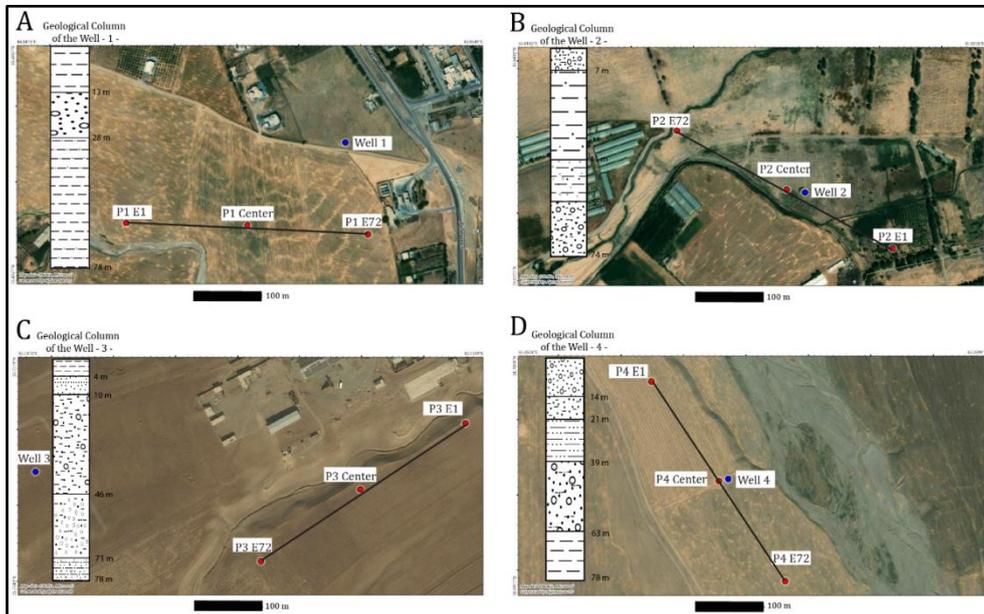


Fig. 2: Well locations and profile lines (A: Profile No.1 Chamchamal District. B: Profile No.2 Bazyan sub District. C: Profile No.3 Piramagroon Sub District. D: Profile No.4 Kalar District).

The Wenner-Schlumberger array type was used in this survey, and the length of each profile is equal to 355 meters with 5 meter electrode spacing to cover the exact depth. The resistivity meter is set up to record 684 data points and with 19 depth levels. In the field, after spreading the entire system, the resistivity meter starts reading data automatically at

each specified point on the subsurface as shown in (Figure 3). A direct current was injected into the ground through two current electrodes, and the variation of the current within the subsurface can be determined through the potential difference between the two other electrodes [13].

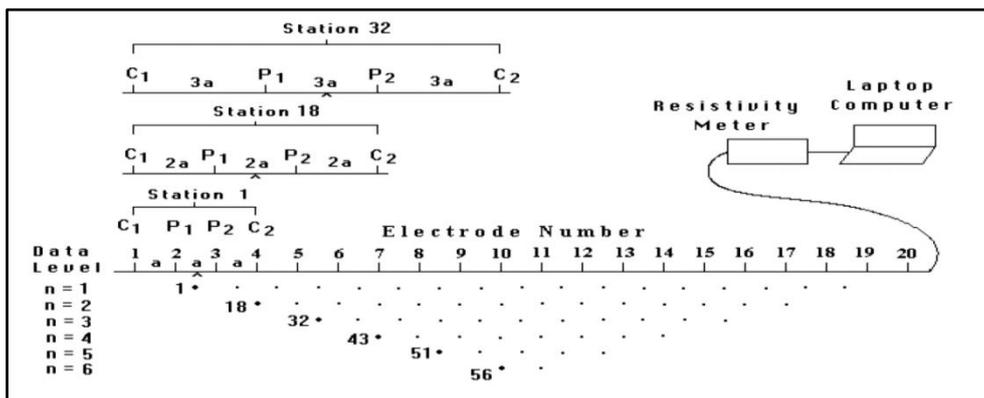


Fig. 3: The arrangement of electrodes for a 2-D electrical survey and the sequence of measurements used to build up a pseudo section [14].

The apparent resistivity data were processed and interpreted by RES2DINV software. The inversion process was conducted to obtain a subsurface image with true resistivity and true depth. The inversion process is carried out to obtain three types of resistivity sections, which consist of the calculated apparent resistivity, measured apparent resistivity, and inverse model resistivity. The misfit between

measured and calculated apparent resistivity produces root mean square (RMS) values [10]. The RMS value of less than 10% indicates high data quality. While, the high RMS value confirms that there is a large inhomogeneity in the subsurface [15]. Before the inversion process, the field data was filtered to exterminate bad data and obtain a better result. The

inversion process parameters were also changed based on the geology of the study area.

Also, in the laboratory, a special model was constructed with dimensions of 192*65*45 cm and filled with three layers, a clay layer with a thickness equal to 25 cm placed at the bottom of the model, 20 cm of gravel at the middle, and 15 cm of clay as a top layer (Figure 4). The construction of this model is most important for displaying a spectrum of contour lines pattern between these components and

comparing them to the actual field data. The array type used for obtaining the data was Wenner-Schlumberger, and the resistivity instrument was set up to record 217 data points for 25 depth levels. The total length of the profile was 190 cm, and 20 electrodes were used, with the electrode spacing equal to 10 cm. The electrode type used is a nail, which has a length of 12 cm and about 6 cm inserted into the clay layer.



Fig. 4 A: Side view of the laboratory geological model. B: Top view of the model.

3. Result and Discussion

This research studied four different areas, with a 355 m length of each profile. All profiles are processed and interpreted as follow:

3.1 Field Model:

3.1.1 Profile One (P1):

It is located at Shorsh quarter, about 4 km SE of Chamchamal District, trending E-W, the total investigation depth is equal to 78 m. The RMS error = 3.6% which means the quality of the data is very good due to an almost perfect match between measured and calculated apparent resistivity pseudo sections (figure 5 a and b). The inverse model is generally composed of two zones depending on the resistivity value distribution. The first zone has a resistivity value ranging from 6 – 17 Ω m. This zone is located at two level zones; the first part is located at a shallow depth 0 – 13 m composed of clay of recent deposit, and the second part, from 28 m to the maximum depth of investigation, is composed of claystone and little sandstone of the Lower Bakhtiari formation. The second zone has a resistivity value

ranging from 17 – 35 Ω m, which represents the coarse cycle of sedimentation of the Lower Bakhtiari composed of gravel, and little sand, with the thickness ranging from 13 – 28 m.

The geological column of well No.1 as shown in (figure 5c) shows that the aquifer is composed mainly of gravel and has a thickness equal to 15 m. The red dashed line represents the whole anomalous body caused by the gravel aquifer and has an apparent thickness equal to 26 m at the location of the well. The black dash line is the boundary of the aquifer drawn on the inverse section on the basis of matching the geological column of the well with the inverse section. Also, the black dash line represents the true aquifer, with a thickness equal to 15m. The inverse section displayed that the anomalous body formed due to the gravel aquifer shows larger thickness, (26 m), than the true thickness (15 m), directly obtained from the column of the well. In this location, the true thickness of the anomaly which represents the gravel aquifer is equal to 57.7% of the total thickness of the anomaly.

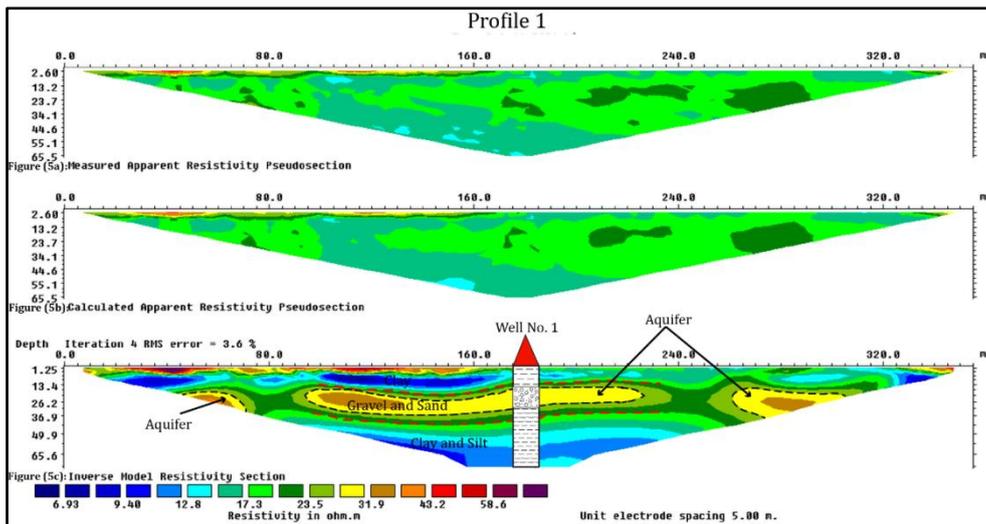


Fig. 5: Resistivity inversion model for the profile 1.

3.1.2 Profile Two (P2):

It is located at Dargazen village, about 10 km NW of Bazyan sub-district, trending NW-SE, the investigation depth equal to approximately 74 m. The quality of the data is very good due to low ratio of RMS error = 2.6%. The inverse model is generally composed of three layers depending on resistivity value distribution, (as shown in figure 6c). The first layer (top soil layer), the green one has thickness of about 6 m. Clay layer Blue one has thickness 6 – 40 m. The third layer is the anomalous body aquifer that

appears at depths ranging from 40 m to the maximum depth of the investigation.

The geological column of well No.2 (as shown in figure 6c) displays that the red line is the upper limit of the aquifer anomaly and the black dash line represents the upper contact of the true aquifer. In this location, it is not possible to calculate the percentage of the true thickness of the anomaly that represents the gravel aquifer to the whole thickness of the anomaly due to the absence of the lower boundary of the anomalous body.

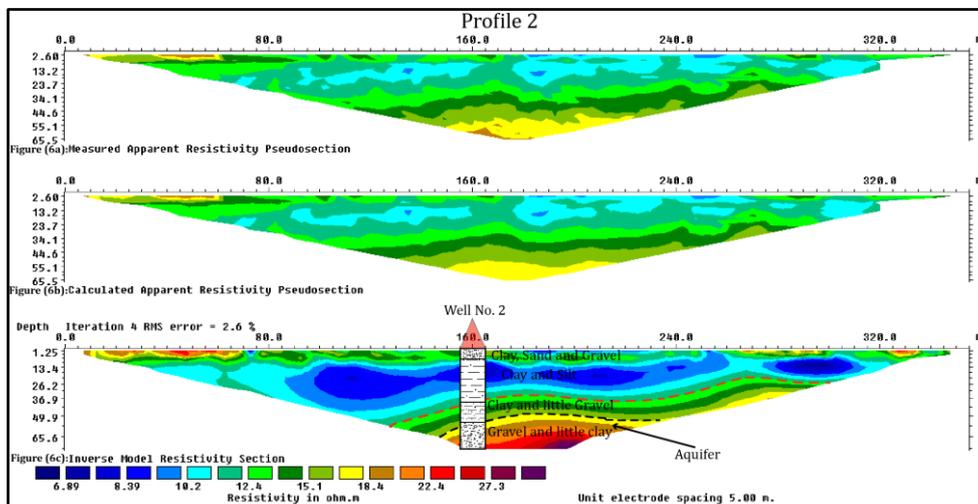


Fig. 6: Resistivity inversion model for profile 2.

3.1.3 Profile Three (P3):

It is located 1 km SE of Piramagroon sub-district, trending NE – SW direction, and the investigation depth is equal to 78 m. The data quality was very good due to the very low ratio of RMS = 2.3%. Depending on the resistivity value, the inverse model can be divided into three zones. The first zone has a resistivity ranges between 10 – 50 Ωm which represents the clay and silt of recent deposits (top layer), blue color has thickness 0 – 8 m. The second zone resistivity ranging between 50 – 90 Ωm which

indicates a groundwater bearing zone composed of gravel, little sand, and clay of recent deposit, with the thickness ranging from 8 – 69 m. The third zone (green at the bottom) appears at depth of about 69 m, has low resistivity ranging from 23 – 42 Ωm, representing a layer of siltstone with little sandstone. The geological column of well No.3 (as shown in figure 7c). The red dash line representing the apparent aquifer thickness anomaly, which is equal to 69 m while, the black dash line represents the true thickness of the gravel aquifer, which is equal to 61

m. Also in this location, the inverse section demonstrated that the anomalous body formed due to the gravel aquifer shows a slightly larger thickness (69 m), compared to the true thickness (61 m), which is directly obtained from column of the well. Furthermore, the percentage of the true thickness of

the anomaly which represents the gravel aquifer is equal to 88.4% of the total thickness of the anomaly. The higher percentage obtained at this location compared to the first location is a result of the aquifer's greater resistivity and thickness.

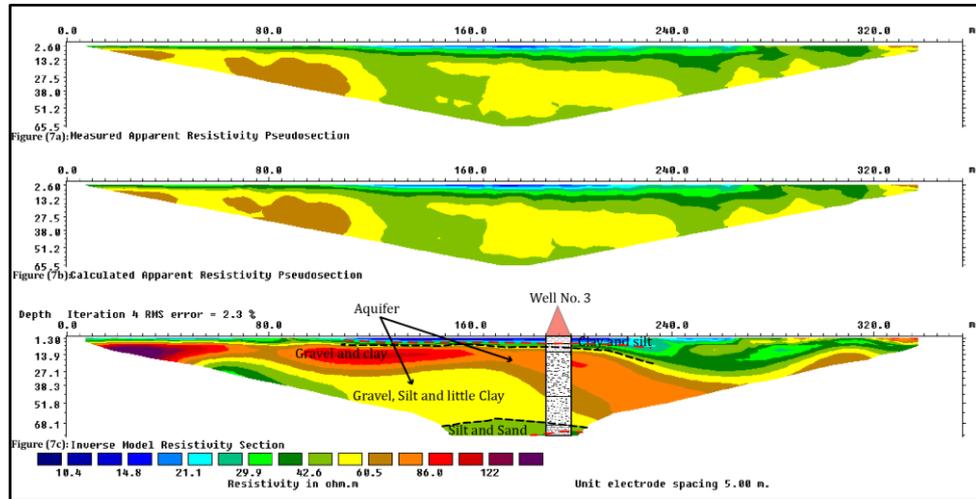


Fig. 7: Resistivity inversion model for profile 3.

3.1.4 Profile Four (P4):

It is located 8 km NW of the Kalar district, trending NW – SE, and the investigation depth equal to 78 m. The data quality was good due to the low ratio of RMS = 6.5%. Depending on the true resistivity distribution, the inverse section is divided into three zones, as shown in (figure 8c). The first zone is indicated at shallow depth with a resistivity value of more than 40 Ωm, which is composed of gravel, sand, and a little clay of recent deposit. In contrast, the second zone, which is located at the middle of the section, is mainly composed of clay and silt with a low resistivity value ranging from 6 – 15 Ωm. The third zone is probably indicated as the saturated zone with a resistivity value ranging from 15 – 40 Ωm, and is composed of gravel, sand, and silt.

The geological column of well No.4 (as shown in figure 8c) illustrates that the aquifer is mainly composed of gravel, which has a thickness of 24 m. The red dashed line represents the whole anomalous body which has an apparent thickness of 41 m at the location of the well. The black dash line is the boundary of the aquifer drawn on the inverse section on the basis of matching geological column of the well with the inverse section. Moreover, the black dash line represents the true aquifer, with a thickness equal to 24m. The inverse section demonstrated that the anomalous body formed due to the gravel aquifer has a larger thickness of (41 m) compared to the directly obtained true thickness of (24 m) from the column of the well. In this location, the true thickness of the anomaly represents the gravel aquifer is equal to 58.5% of the total thickness of the anomaly.

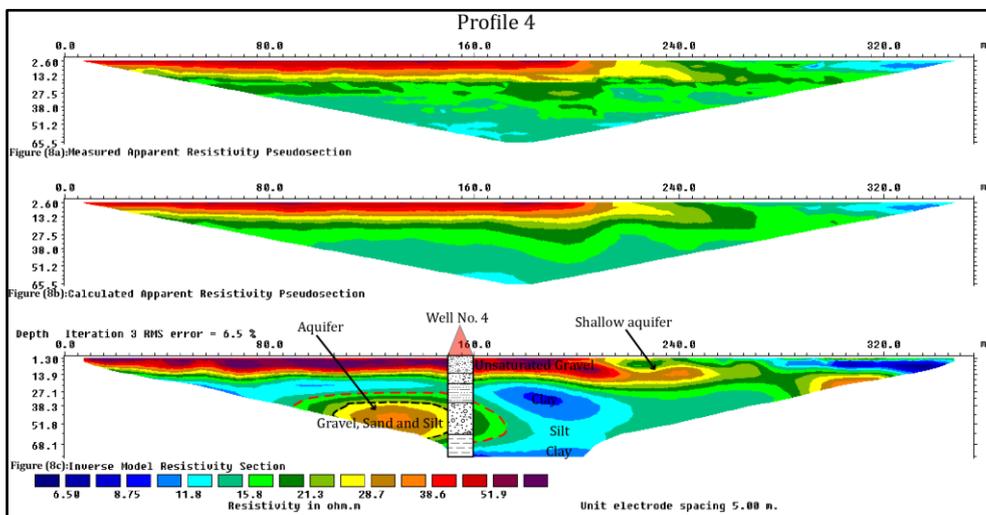


Fig. 8: Resistivity inversion model for profile 4.

3.2 Laboratory Geological Model:

3.2.1 Lab Profile 1 (Dry Condition):

The data for this profile was obtained while the gravel layer is unsaturated and had no water content. The total depth of investigation is equal to 32 cm. Figure 9 shows the inverse section of Lab Profile 1, two layers have showed in the inverse section. The first layer is represented by blue color and shows resistivity values ranging from 30 to 100 Ωm. The actual thickness of the clay layer set at the model is 15 cm while the detected apparent thickness is equal to 9.25 cm. Due to the high resistivity of the unsaturated gravel a transitional zone (spectrum of contour lines) is formed between these two layers with a thickness equal to 6.75 cm and resistivity value ranging from 100 to 460 Ωm. In fact, this transitional zone is a part of the clay layer formed by the effect of high resistive gravel layer.

Theoretically, the maximum depth of investigation of the inverse resistivity model is about 42 cm, which

implies that the lower bottom of the gravel layer (or the upper contact of the third layer) has to be detected by the survey. This is not achieved due to the high resistive gravel layer which minimizes the depth of investigation to 32 cm; the loss of investigation depth is about 24% of the supposed obtained depth. Also, the unsaturated gravel showed a pseudo anomaly (started from the red dash line) larger than the actual anomaly (started from the black dash line). Hence, most of the research failed to misinterpret by selecting the red dash line as a contact between these two layers while the actual one is the black dash line. The synthetic inverse section displays that the percentage of true thickness of the anomaly created by unsaturated gravel is equal to 59.7% of the pseudo anomaly, and the thickness of the transitional zone formed as a result of the high resistive layer has to be added to the thickness of the low resistive layer.

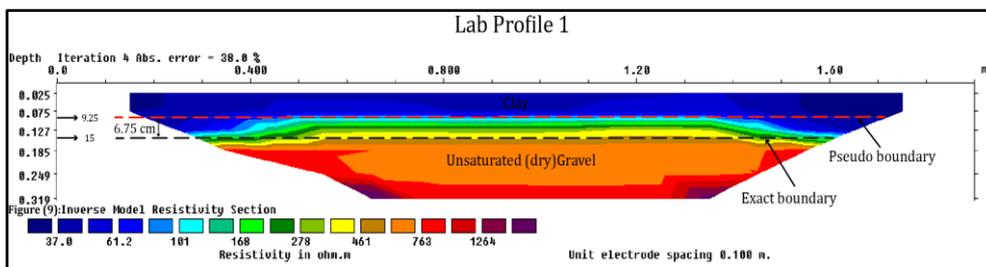


Fig. 9: Resistivity inversion model for Lab Profile 1.

3.2.2 Lab Profile 2 (Saturated Condition):

The data for this profile was obtained while the gravel layer was saturated and filled with natural drinking water. The total depth of investigation is equal to 39.6 cm. Figure 10 illustrates the inverse section of Lab profile 2, and two layers have showed in the inverse section. The first layer represents by blue color and shows resistivity values ranging from 15 to 65 Ωm. The actual thickness of the clay layer set at the model is 15 cm while the detected apparent thickness is equal to 7.5 cm. Due to the high resistivity of the saturated gravel, a transitional zone (spectrum of contour lines) is formed between these two layers has thickness equal to 7.5 cm with a resistivity value ranging from 65 to 280 Ωm. As a matter of fact, this transitional zone is a part of the clay layer, which is formed by the effect of high resistive gravel layer.

Theoretically, the maximum depth of investigation of the inverse resistivity model is about 42 cm, which

means the lower bottom of the gravel layer (or the upper contact of the third layer) has to be detected by the survey. However, depending on the investigation depth, which is about 39.6 cm, the upper contact of the third layer (bottom clay layer) has to be detected by the survey. This is not achieved due to the transitional zone formed by the high resistive gravel layer. The loss of investigation depth is about 6% of the supposed obtained depth. Also, the saturated gravel showed a pseudo anomaly (started from the red dash line) larger than the actual anomaly (started from the black dash line). The synthetic inverse section clearly displays that the percentage of true thickness of the anomaly created by saturated gravel is equal to 57.1% of the pseudo anomaly, and the thickness of the transitional zone formed as a result of the high resistive layer has to be added to the thickness of the low resistive layer.

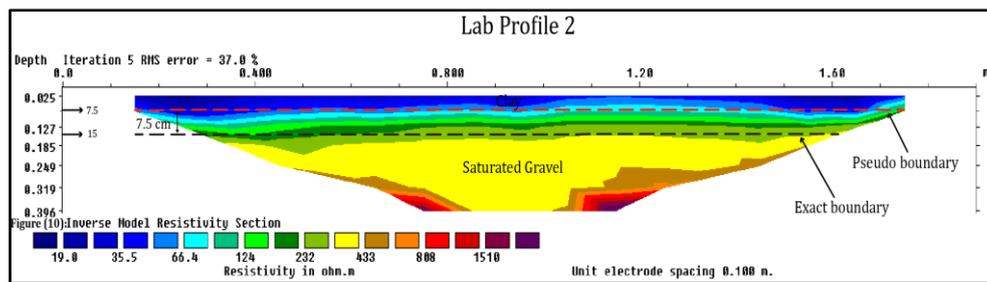


Fig. 10: Resistivity inversion model for Lab Profile 2.

4. Conclusion

In conclusion, electrical resistivity imaging was successfully used to delineate the true thickness of granular aquifers and determine the exact boundary between the granular aquifer zone and the surrounding impermeable layers. From field survey results, the apparent thicknesses of the gravel aquifers in the inverse sections of profiles 1, 3, and 4 are equal to 26 m, 69 m, and 41 m, while true thicknesses of the aquifers in wells No. 1, 3, and 4 are equal to 15 m, 61 m, and 24 m, respectively. The inverse sections of the field survey clarified that the thickness of anomalies always formed by granular aquifers appears larger than their true thickness. The percentages of the true thickness of the aquifers to the pseudo thickness of the anomalies caused by them are calculated for profiles No. 1, 3, and 4, and they are equal to 57.7%, 88.4%, and 58.5%. The different obtained percentages of the true thickness depend on the resistivity contrast between the aquifers and the surrounding layers; a high resistivity contrast gives a high percentage and vice versa. While the synthetic laboratory model showed that the supposed set up depths are not achieved due to the high resistive gravel layer, which reduces the depth of investigation to 32 cm in unsaturated gravel and 39.6 cm in

saturated gravel. The loss of investigation depth is about 24% in the unsaturated gravel and 6% in the saturated gravel of the supposed obtained depth. This confirms that the large resistivity contrast gives a smaller depth of investigation than the smaller resistivity contrast. The unsaturated gravel showed a pseudo anomaly larger than the actual anomaly. The percentage of true thickness of the anomaly created by unsaturated gravel is equal to 59.7% of the pseudo anomaly, and the thickness of the transitional zone formed as a result of the high resistive layer (equal to 6.75 cm) has to be added to the thickness of the low resistive layer. The saturated gravel showed a pseudo anomaly larger than the actual anomaly. The percentage of true thickness of the anomaly created by saturated gravel is equal to 57.1% of the pseudo anomaly, and the thickness of the transitional zone formed as a result of the high resistive layer (equal to 7.5 cm) has to be added to the thickness of the low resistive layer. The transitional zone between the low resistive layer and the high resistive layer becomes narrower when the resistivity contrast is increased and vice versa. For unsaturated conditions, the thickness of this zone is equal to 6.75 cm, and for saturated conditions it is equal to 7.5 cm.

5. References

- [1] B. K. Aziz, "Groundwater Prospects in Parki-Azadi Area, Sulaimani City, NE-Iraq," *J Kurdistan Acad JA*, vol. 1, pp. 15–25, 2001.
- [2] D. H. Griffiths and R. D. Barker, "Two-dimensional resistivity imaging and modelling in areas of complex geology," *J. Appl. Geophys.*, vol. 29, no. 3–4, pp. 211–226, 1993.
- [3] M. H. Loke and J. W. Lane, "Inversion of data from electrical imaging surveys in water-covered areas," *ASEG Ext. Abstr.*, vol. 2004, no. 1, pp. 1–4, 2004.
- [4] B. Q. Aziz, "Two dimension resistivity imaging tomography for hydrogeological study in Bazian basin, west Sulaimani city, NE-Iraq," *Unpubl. Ph. D. thesis, Univ. Sulaimani, Sulaymaniyah, Iraq*, 2005.
- [5] B. K. Aziz and E. N. Baban, "Assessing reliability of 2D resistivity imaging to map a deep graben in Bazian basin, west Sulaimani City, NE-IRAQ," 2006.
- [6] E. N. Baban and B. K. Aziz, "Two dimension resistivity imaging/tomography for hydrogeological study in Bazian basin-west Sulaimani City, Kurdistan region-Iraq," in *Near-Surface Asia Pacific Conference, Waikoloa, Hawaii, 7-10 July 2015*, 2015, pp. 215–218.
- [7] J. M. Thabit and M. M. AL-Hameedawie, "Delineation of groundwater aquifers using VES and 2D imaging techniques in north Badra area, Eastern Iraq," *Iraqi J. Sci.*, vol. 55, no. 1, pp. 174–183, 2014.
- [8] J. M. Thabit and K. A. AL-Tamimi, "Delineation of Quaternary Aquifers by Using Long 2D Imaging in Southern Al-Shihaby Area (Wasit Governorate), Eastern Iraq," *Iraqi J. Sci.*, vol. 56, no. 1C, pp. 785–797, 2015.
- [9] K. O. Aluko, W. O. Raji, and E. A. Ayolabi, "Application of 2-D resistivity survey to groundwater aquifer delineation in a sedimentary terrain: A case study of south-western Nigeria," *Water Util. J.*, vol. 17, no. 7, pp. 71–79, 2017.
- [10] A. Madun, S. A. A. Tajudin, M. Z. Sahdan, M. F. M. Dan, and M. K. A. Talib, "Electrical resistivity and induced polarization techniques for groundwater

exploration,” *Int. J. Integr. Eng.*, vol. 10, no. 8, 2018.
 [11] A. A. AL-Juboury, J. M. Thabit, and F. H. AL-Menshed, “Determine the Groundwater Aquifers in Southwest of Samawah City,(Al MuthannÄ Governorate), Southern Iraq, by using 2-D Resistivity imaging survey,” *Iraqi J. Sci.*, vol. 60, no. 4, pp. 792–802, 2019.
 [12] Z. Asry, A. R. Samsudin, W. Z. Yaacob, and J. Yaakub, “Groundwater investigation using electrical resistivity imaging technique at Sg. Udang, Melaka, Malaysia,” 2012.
 [13] I. Abubakar, N. S. Aliyu, A. L. Ahmed, and C.

Collins, “Application Of Electrical Resistivity Method In Delineating Geological Boundary In Kakara Village, Kano State, Nigeria,” *Int. J. Eng. Sci.*, vol. 2, no. 12, pp. 36–39, 2013.
 [14] M. H. Loke, “Electrical imaging surveys for environmental and engineering studies,” *A Pract. Guid. to*, vol. 2, p. 70, 1999.
 [15] A. M. Abed, K. K. Ali, and A. H. Al-Hadithy, “Resistivity surveys application for detection of shallow caves in a case example from Western Iraq,” *Iran. J. Earth Sci.*, vol. 14, no. 3, pp. 178–185, 2022.

تصوير المقاومة الكهربائية ثنائي الأبعاد لرسم الحدود الدقيقة والسماك الحقيقي لخزانات المياه الجوفية الحبيبية

بختيار قادر عزيز ، زانا محمود محمد فرج روغزاي

قسم علوم الارض ، كلية العلوم ، جامعة السليمانية ، العراق

المخلص

يعد تصوير المقاومة الكهربائية (ERI) أحد أفضل التقنيات الجيوفيزيائية لدراسات التحت السطحية و تحريات المياه الجوفية في ترسبات الفتاتية. تحديد الحدود الفاصلة بين الطبقات المختلفة ضمن ترسبات فتاتية على المقطع العكسي من تصوير المقاومة الكهربائية لم يكن مهمة سهلة بسبب التغيرات التدريجية في المقاومة بين الطبقات المحيطة وخزانات المياه الجوفية الحبيبية. لذلك ، فإن الهدف الرئيسي من الدراسة هو تحديد حدود أكثر دقة لخزانات المياه الجوفية الحبيبية (السماكة الحقيقي لخزانات المياه الجوفية) في المقطع العكسي. تم استخدام نموذجين مختلفين: النموذج الميداني والنموذج المختبري ، في النموذج الميداني ، تم اختيار أربعة مواقع مختلفة. تقع في (كلار ، جمجمال ، بازيان ، بيرامكرون) ، داخل محافظة السليمانية ، شمال شرق العراق. جرى مسح تصوير المقاومة الكهربائية ثنائي الأبعاد على أربعة مقاطع بطول 355 مترًا مع تباعد بين الأقطاب الكهربائية يبلغ خمسة أمتار. تم استخدام مصفوفة Wenner-Schlumberger لتسجيل البيانات. بالنسبة للنموذج المعلمي ، تم إنشاء نموذج جيولوجي المخبري بطول ، وارتفاع ، وعرض يساوي 192 و 65 و 45 سم على التوالي. تم تنفيذ مسارين في هذا النموذج، يبلغ أطولهما 190 سم مع تباعد قطب كهربائي يبلغ 10 سم. أشارت النتائج الميدانية إلى أن طبقات المياه الجوفية في الرواسب الفتاتية على المقاطع العكسية أظهرت دائمًا شذوذًا بسماك ظاهر أكبر من سماكتها الحقيقية ، والتي تم الحصول عليها من العمود الجيولوجي للآبار. في المواقع الأربعة التي تمت دراستها ، بلغ معدل السماكة الحقيقية للخزانات الجوفية و في المواقع الأربعة التي تمت دراستها 68.2% من السماكة الظاهرة على المقاطع العكسية. كما أظهرت نتيجة النموذج الجيولوجي المختبري أن السماكة الحقيقية للحصى غير المشبع تساوي تقريبًا 59.7% من السماكة الظاهرة للشذوذ الذي يتكون من طبقة الحصى الجافة. كما أن السماكة الحقيقية للحصى المشبع تبلغ حوالي 57.1% من السماكة الظاهرة للشذوذ الذي يتكون من طبقة الحصى المشبعة. إضافة على ذلك ، أظهر النموذج الجيولوجي أن طبقات ذات المقاومة العالية (الحصى الجاف) تخلق منطقة المقاومة انتقالية ضيقة جدا مقارنة بطبقات المقاومة المنخفضة (الحصى المشبع) حيث تتكون منطقة انتقالية واسعة نسبيا .