AQUIFERS DELINEATION USING VERTICAL ELECTRICAL SOUNDING IN SOUTH AND SOUTHWEST OF SAMAWA CITY, SOUTHERN IRAQ

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ABSTRACT

This study includes application of (VES) Vertical Electrical Sounding for delineation of aquifers in the area located south and southwest of Samawa City, southern Iraq. The VES was carried out by using Schlumberger array in the 16 sounding points distributed along three profiles trending NW – SE, except one point that is not located within any profile. The field curves of apparent resistivity are interpreted by the application of forward calculation and inverse modeling. The results of the inverse modeling are used to construct three geo-electrical sections along electrical profiles, and then converted to geological sections by including the lithological well sections and all available geological and hydro-geological information. The results indicate the presence of three aquifers. The first is the Euphrates aquifer which is located at depths ranging between 1 and 7 m. This aquifer overlaps with the Ghar aquifer in the southeast area, and thus forming one hydro-geological unit. The thickness of this aquifer varies from 8 to 30 m. The second is the Ghar aquifer which appears at depths (1 – 3) m. The thickness of this aquifer ranges between 12 and 40 m. The third is Dammam aquifer, which occurs below the Euphrates aquifer in the north and southeast of the Al-Emaed spring. It also occurs below the Euphrates and the Ghar aquifers in the southeast end of the studied area; its depths ranges between 13 and 43 m, in most locations, but to the south and southwest of Al-Emaed spring, near the ground surface. Its thickness ranges between 100 and 120 m, and it splits into two parts in the area located north and southeast of Al-Emaed spring. The lower part is characterized by increased fractures in comparison with the upper part. The presence of hydraulic connection between these aquifers is observed and this agrees with previous studies.

تحديد الخزانات الجوفية باستعمال الجس الكهربائي العمودي في جنوب وجنوب غرب مدينة السماوه، جنوب العراق

جاسم محمد ثابت و احمد سرداح الزبيدي

المستخلص

تضمنت هذه الدراسة تطبيق الجس الكهربائي العمودي (VES) لتحديد الخزانات الجوفية في المنطقة الواقعة جنوب وجنوب غرب مدينة السماوه، جنوب العراق. أنجز الجس الكهربائي العمودي باستعمال ترتيب شلمبرجر للأقطاب في 16 نقطه جس توزعت على ثلاثة مسارات ماعدا نقطه جس واحدة لم تقع ضمن أي مسار، وقد فسرت المنحنيات الحقلية للمقاومة النوعية الكهربائية بتطبيق كل من طريقة الحساب الأمامي (Forward Calculation) وطريقة الموديل المعكوس (Inverse Modeling). وقد تم الاعتماد على نتائج طريقة الموديل المعكوس لرسم ثلاث مقاطع جيوكهربائيه على طول مسارات المسح، حولت هذه المقاطع الى مقاطع جيولوجية بالاعتماد على المقاطع

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الصخرية للآبار المحفورة والتي تمر بها تلك المسارات بالإضافة إلى كل المعلومات الجيولوجية والهيدروجيولوجية المتوفرة. بينت نتائج الجس الكهربائي العمودي من خلال المقاطع الجيولوجية وجود ثلاثة خزانات للمياه الجوفية في المنطقة، الخزان الأول هو خزان الفرات الذي يقع على عمق يتراوح (1 – 7) م، يتداخل هذا الجزء من الخزان مع خزان تكوين الغار ليشكلان وحده هيدروجيولوجية واحده في المنطقة الجنوبية الشرقية من منطقه الدراسة بسمك يتراوح بين (8 – 30) م. الخزان الثاني هو خزان تكوين الغار ويقع على عمق يتراوح (1 – 3) م وله سمك يتراوح بين (12 – 40) م. أما الخزان الثالث فهو خزان تكوين الدمام الذي يقع تحت خزان تكوين الفرات شمال وجنوب شرق عين العميد وتحت خزان تكوين الغار في نهاية المنطقة الجنوبية الشرقية لمنطقة الدراسة ويقع هذا الجزء من الخزان على عمق يتراوح بين (13 – 43) م تقريبا في معظم المناطق ماعدا المنطقة الواقعة جنوب وجنوب غرب عين العميد، حيث يكون قريبا من سطح الأرض، أما سمك الخزان فيتراوح بين (100 – 120) م، ينقسم هذا الجزء من الخزان الى جزئيين في المنطقة الواقعة شمال وشرق عين العميد، الجزء الأسفل يتميز بكثرة وجود الكسور مقارنه بالجزء الأعلى. كما لوحظ وجود اتصال هيدروليكي بين هذه الخزانات وهذا ما يتفق مع الدراسات السابقة.

INTRODUCTION

The groundwater is considered as the main source of water in the southern desert areas of Iraq, for lack of the sources of surface water, and with the increase demand on the water during the last years for the paucity of rainfalls, and the random drillings which endangers groundwater exploitation. Therefore, we need to increase the studies and researches about locations and thicknesses of the aquifers, and this study is one of them.

Most electrical resistivity surveys for groundwater exploration were carried out by traditional Vertical Electrical Sounding (VES) technique. There are several studies on the use of VES surveys in groundwater such as Bose and Ramkrishna (1978), Van Overmeeren (1989), Medeiros and Lima (1990), Dutta *et al*. (2006), Umar *et al*. (2007), Amin (2008) and Kumar *et al*. (2010).

The study area is located within Al-Rehab area at south and southwest Samawa city, between (45° 01' – 45° 20') East and (31° 00' – 31° 13') North, as shown in (Fig.1), and it forms a part of the eastern edge of the Southern Desert. The area includes some villages which depend on the water of Al-Ghadhari and Al-Emaed spring, as well as the water wells for the agriculture and other uses. Figure (2) shows the geological map of this area. The aim of this study is to apply vertical electrical sounding (VES) for delineating the groundwater aquifers.

FIELD WORK

The VES field work was carried out using the Schlumberger arrangements. The total numbers of VES points are 16, as shown in (Fig.1). The maximum distance between the current electrodes is (600) m, while the maximum distance between potential electrodes is 80 m. The measurements were taken according to modified table from Bhattacharya and Patra (1968); and Al-Ane (1998). This table was used for the purpose of avoiding the ratio (MN/AB) equal to (1/3) and (1/4), as much as possible to reduce the theoretical displacements in the field curve branches.

The VES points were distributed along three profiles (A – A'), (B – B'), (C – C'), which are trend parallel to the strike of layers. The length of profile (A – A') is (10.5) Km, and the distance between one VES point and another is (2.1) Km, and the total number of sounding points on this profile is (6) VES. The length of profile (B – B') is (12) Km, and the distance between one VES point and another is (3) Km, the total number of sounding points is (5) VES on this profile. On the other hand the length of (C – C') is (9) Km, and the distance between VES point and another is (3) Km, the total number of sounding points in this profile is (4). Only VES-7 is not located along any of the profiles; it is located near the well (3).

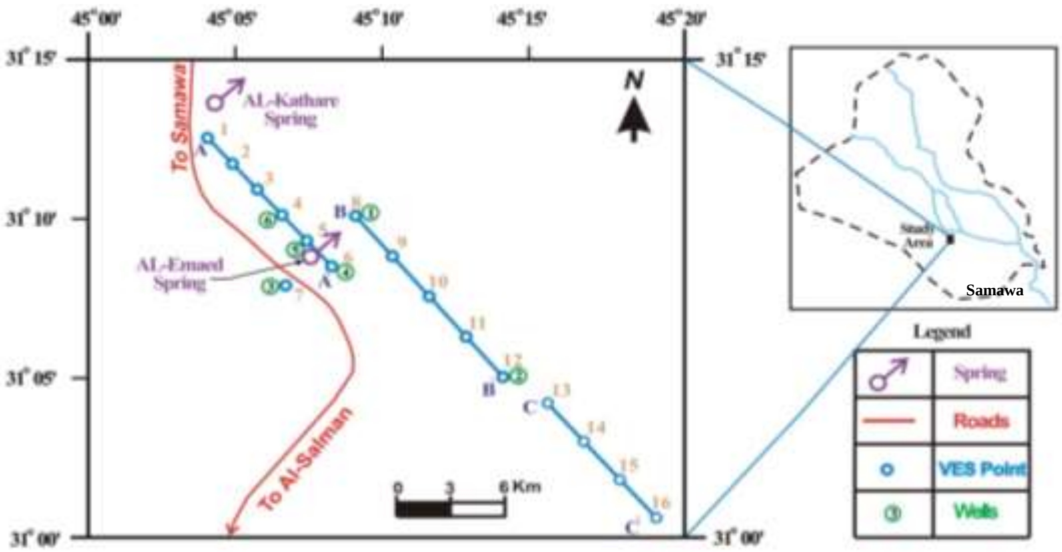

Fig.1: Locations of profiles with VES points (Modified from Al-Zubedi and Thabit, 2012)

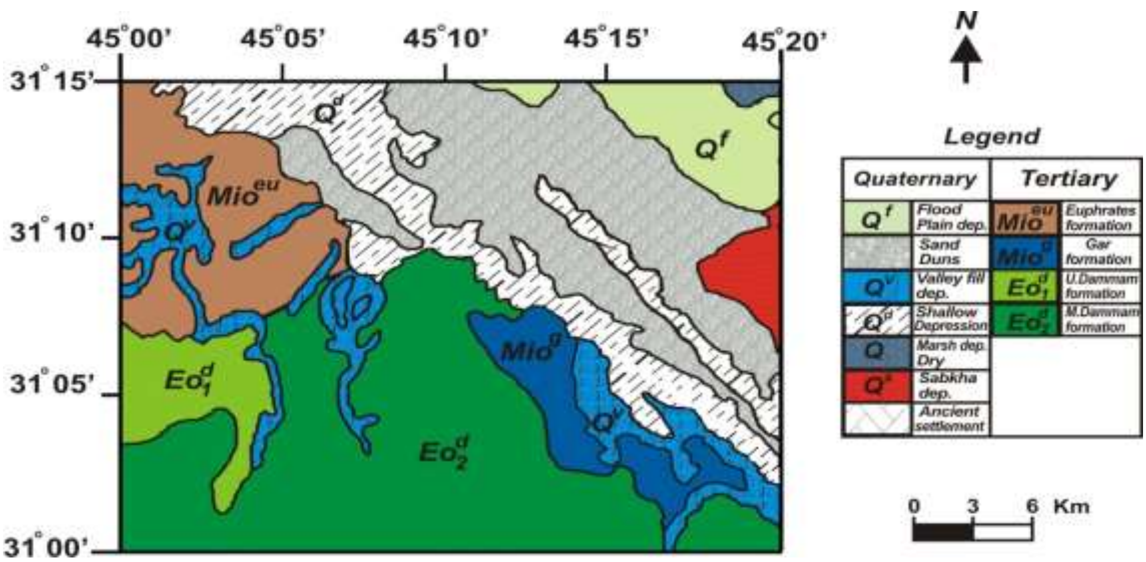

Fig.2: Geological map of studied area (after Sissakian, 2000)

- **Quality of Field Data**

After completing the measurements of VES points, the results of the apparent resistivity values are plotted on log-log paper to form apparent field curves. These curves show many distortions in the shapes as shown in (Fig.3).These distortions are generally caused by the lateral inhomogeneity in the lithology of the ground, errors in measurements, or by equipment failure (Zohdy, 1974).

Since the resistivity meter used in the field was a new and modern instrument (SYSCAL R2) the distortions resulting by errors in measurements or by equipment failure are automatically suppressed. Additionally, the standard deviation of the resistivity (noise indicator), can be observed through monitor during measurements. Therefore, most distortions in the field curves in the studied area are caused by lateral inhomogeneity in the ground.

The interpretation of VES points depend on (ρa) measurements. Therefore, we must remove the distortions from the apparent resistivity field curves by smoothing, which represents the first step in interpretation. However, this distortion phenomena that appear on the field curves are cusps, scattering (ρa) values, discontinuity and sharp maximum (Zohdy, 1974).

In the present study, the quality of field curves was very good, and only two phenomena appeared on these curves, which are, formation of Cusps andScattering (ρa) values, as shown in (Fig.3).

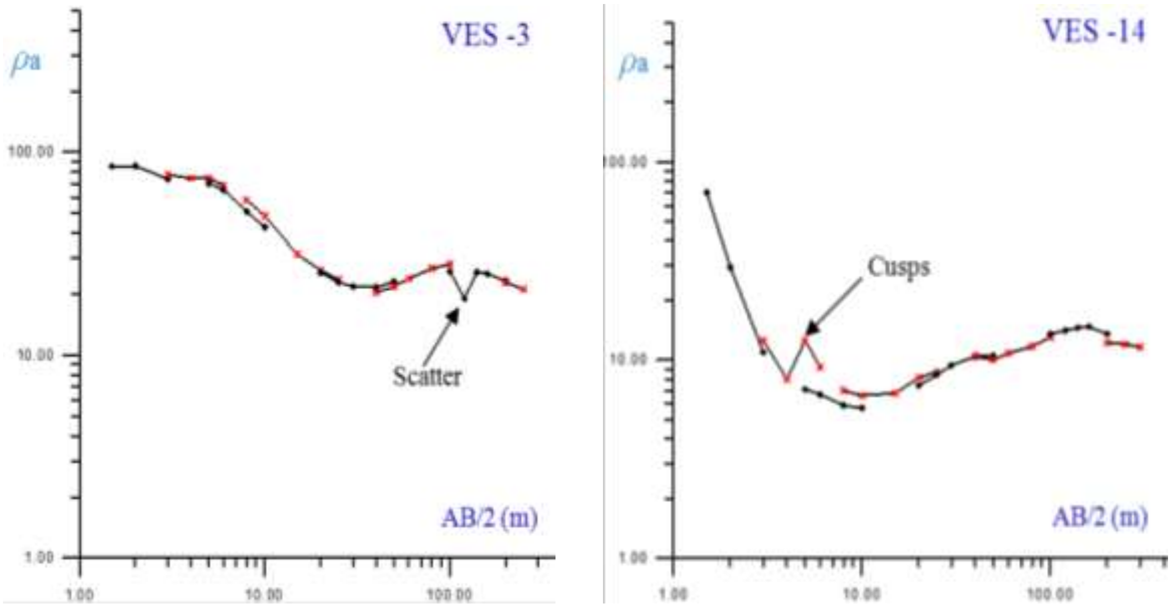

Fig.3: Appearance of Scatter and Cusps in the field curves of VES 3 and 14

GEOELECTRIC AND GEOLOGICAL SECTIONS

There are three geo-electrical sections drawn along the profiles (A – A'), (B – B') and (C – C'). All these sections are supported by lithological sections of five wells and the hydrogeological section of Al-Shemari (2006), except the section (C – C') which is only supported by the hydrogeological section. The lithological sections of wells and other geological and hydro-geological information have been used to convert the geo-electrical sections to geological sections in order to determine the aquifers in this area accurately.

- **Geoelectrical and Geological Section Along Profile A – A'**

This geoelectrical section passes through the Vertical Electrical Sounding points (1, 2, 3, 4, 5 and 6). It is supported by three lithological sections of wells (4, 5 and 6), which are located near VES points (4, 5 and 6) respectively. (Fig.4) and (Fig.5) show the geological section. The length of this section is (10.5) Km and it includes five geoelectrical horizons.

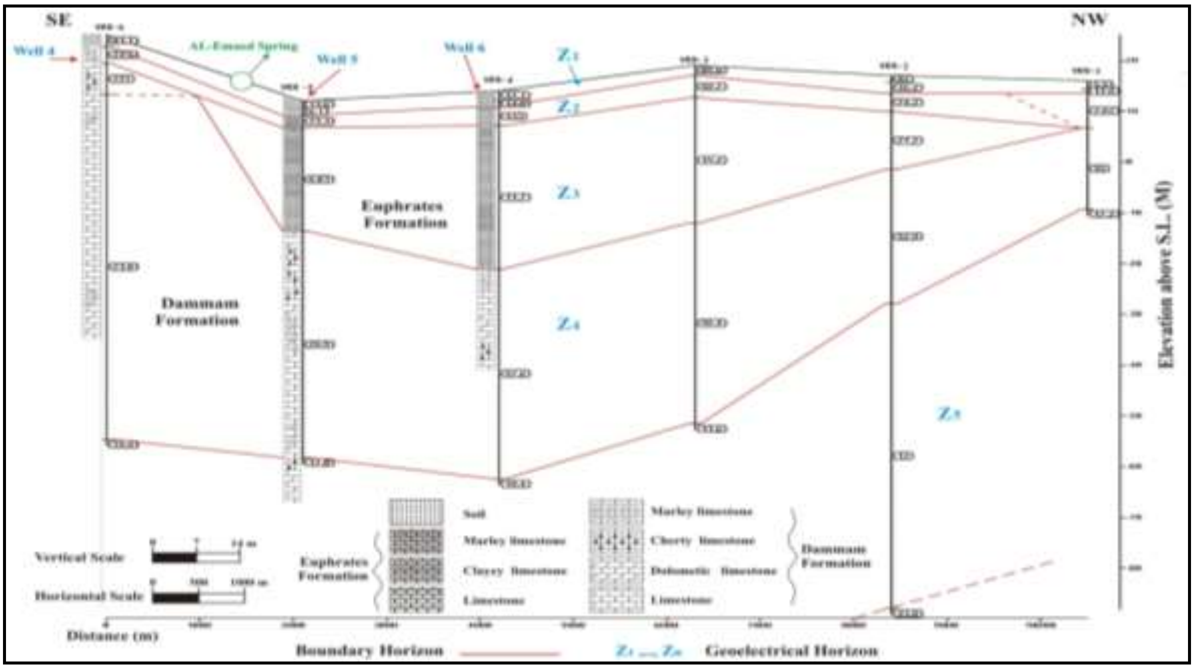

Fig.4: The geo-electrical section along profile (A – A')

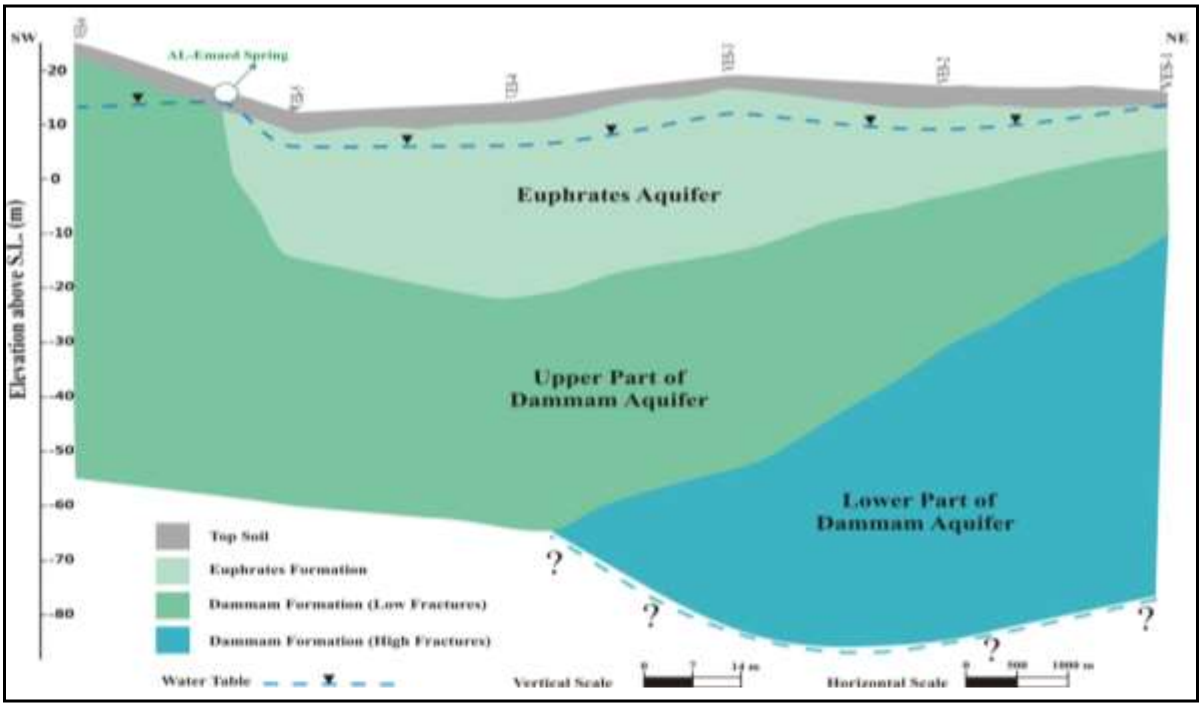

Fig.5: The geological section along profile (A – A'),
(Modified from Al-Zubedi and Thabit, 2012)

- **Geoelectrical and Geological Section Along Profile B – B'**

This geo-electrical section passes through VES points (8, 9, 10, 11 and 12), as shown in (Fig.6). It is supported by lithological sections of the wells (1 and 2) which are located near VES-8 and VES-12, to plot the geological section (Fig.7). The length of this section is (12.0) Km.

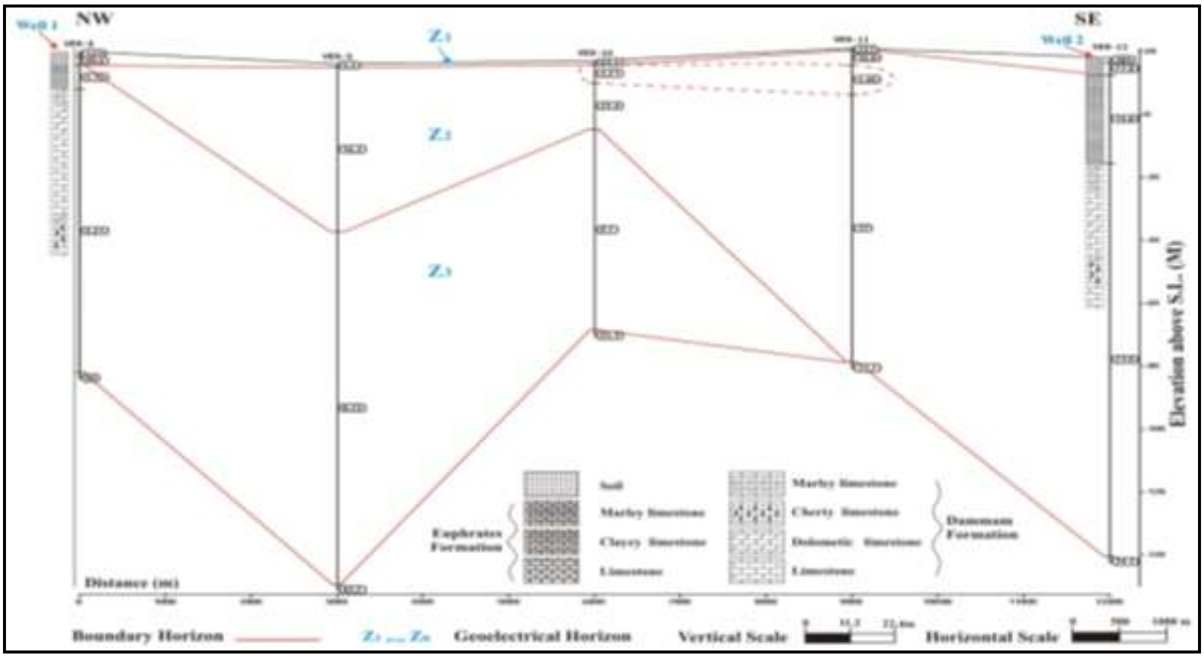

Fig.6: The geo-electrical section along profile (B – B')

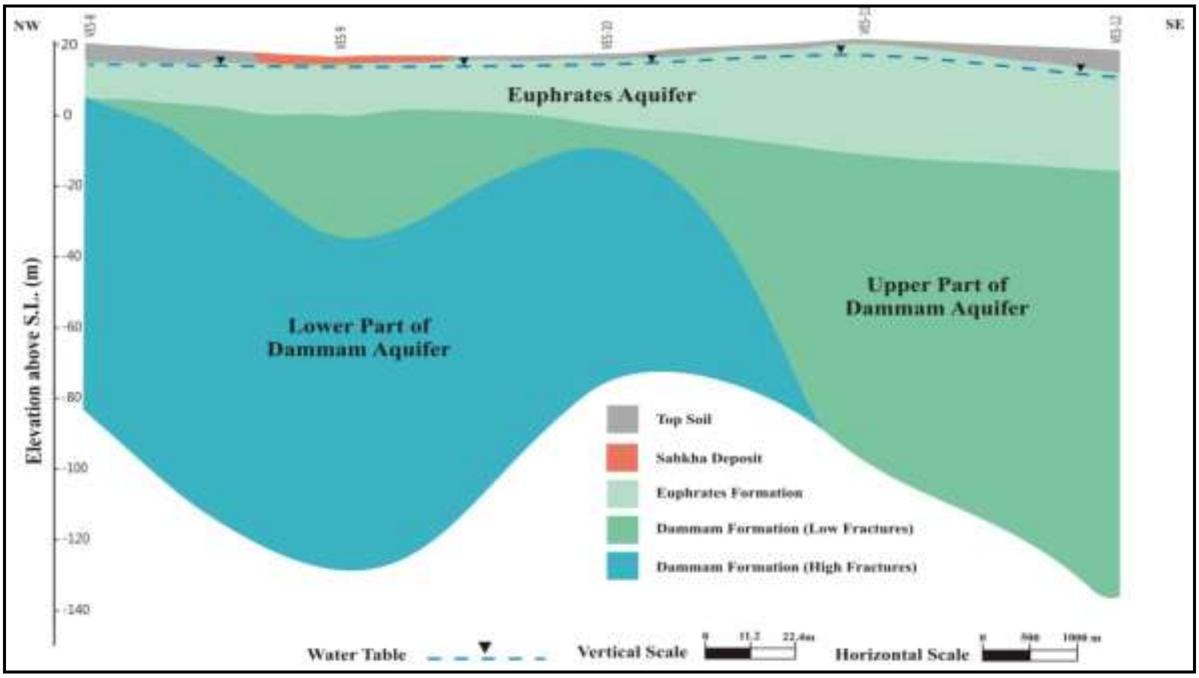

Fig.7: The geological section along profile (B – B'),
(Modified from Al-Zubedi and Thabit, 2012)

- **Geo-electrical and Geological Section Along Profile C – C'**

The geo-electrical section passes through VES points (13, 14, 15 and 16), as shown in (Fig.8), and it is supported by the hydrogeological section of Al-Shemari (2006), to plot geological section (Fig.9). The length of the section is (9000 m), and it includes three horizons. The Dammam aquifer does not appear in the VES-15 and VES-16, due to the presence of layers with low resistivity that may prevents the current penetrating to a greater depth.

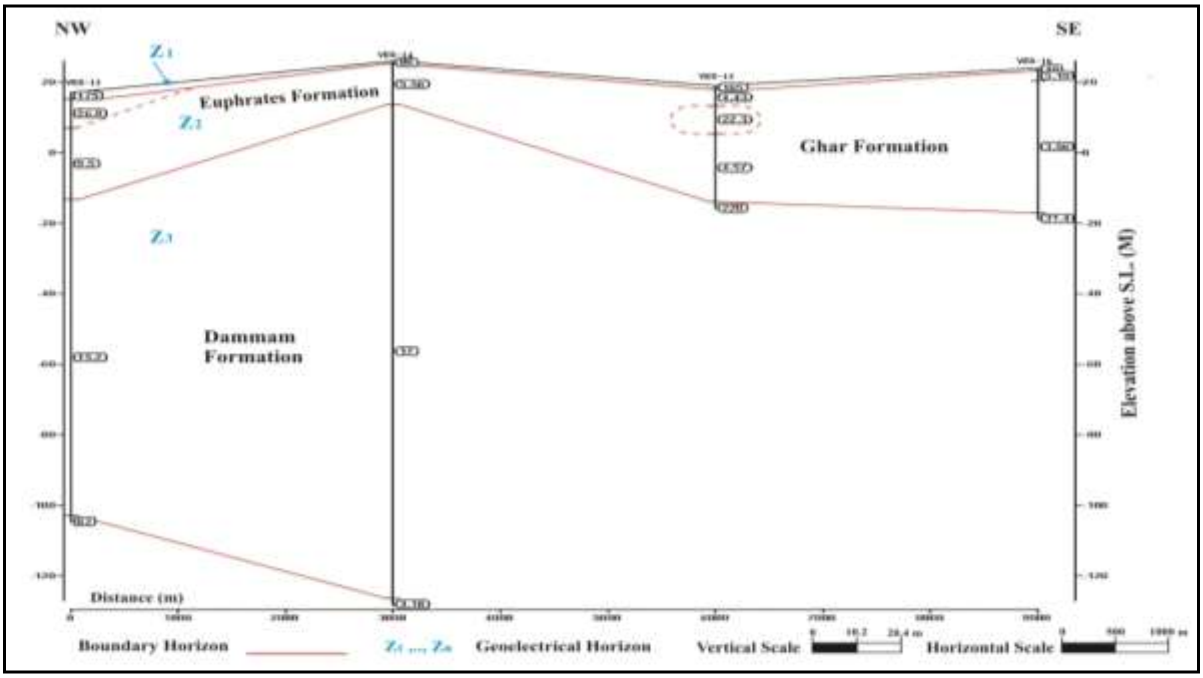

Fig.8: The geo-electrical section along profile (C – C')

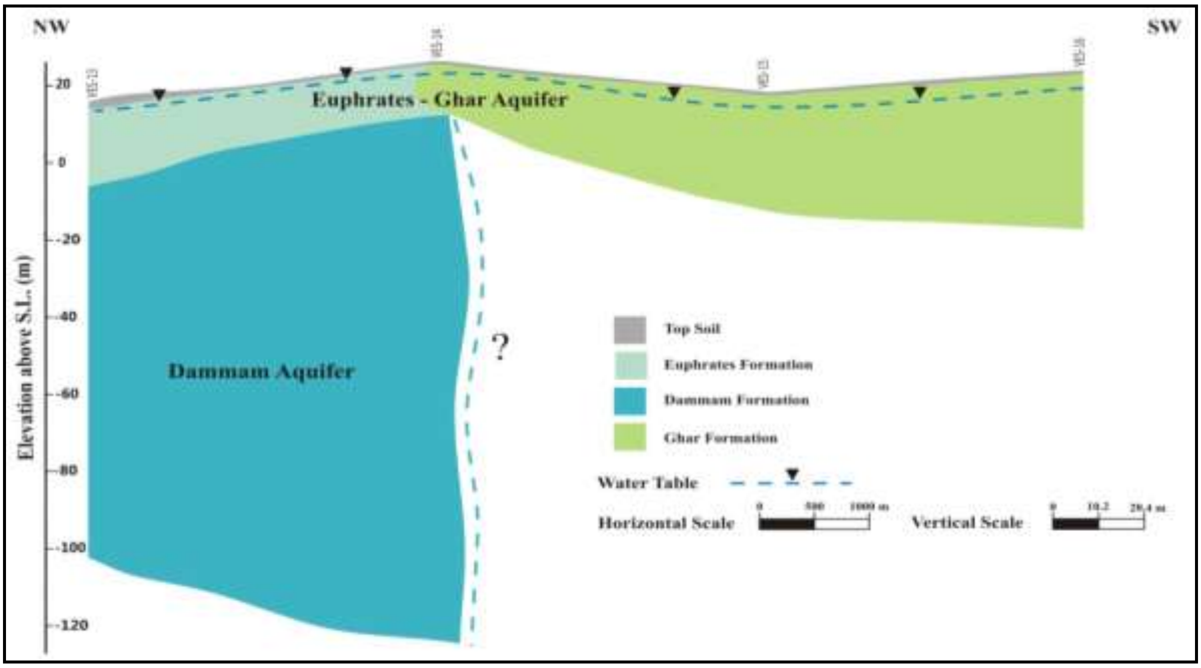

Fig.9: The geological section along profile (C – C')

AQUIFER DELINATION

The geo-electrical and geological sections show the existence of three aquifers in the studied area, these are:

- **Dammam Aquifer**

This aquifer appears in the whole of the study area, and it is located under Euphrates aquifer in the north and southeast of the Al-Emaed spring, and also located under Euphrates and Ghar aquifer in the southeast end of the studied area. However it is located at depths ranging between 13 and 43 m, in most locations, except the area south and southwest of Al-Emaed spring, where it comes near the earth's surface, as appeared in geological section (A – A'). The thickness of this aquifer ranges between 100 and 120 m, according to the result of the electrical surveys, and hydrogeological section of Al-Shemari (2006).

This aquifer is one of the important aquifers in this area, (Al-Jiburi and Al-Basrawi, 2008), and it is divided into two parts in the north and southeast of Al-Emaed spring. The lower part is characterized by increasing of the fractures in comparison with the upper part, and with the lower yield of water, according to the information obtained from the well (6). Therefore, it is believed that the lower part is the best in the whole area.

- **Euphrates Aquifer**

This aquifer appears in the north and southeast of the study area at depths ranging between (1 – 7) m, under the soil layers and it is overlapping with the Ghar aquifer in the southeast end of the studied area. In the south and southwest Al-Emaed spring, this aquifer is not observed. The thickness of this aquifer varies from (8) m near VES-8 to (30) m near VES-3. However, it does not represent the important hydrological unit in this area, in comparison with Dammam aquifer. It has bad water quality in most cases, and has limited extension, according to Al-Jiburi and Al-Basrawi (2008).

- **Ghar Aquifer**

This aquifer appears only in the area between VES-14 and VES-16, at depths ranging between 1 and 3 m, above the Dammam aquifer. Its thickness varies form (12) m at the VES-14 to (40) m at the VES-16. This aquifer together with the Euphrates aquifer represent one hydrological unit, and it is of no importance in the studied area, due to the high salinity and its local extent, according to Al-Shemari (2006); Al-Jiburi and Al-Basrawi (2008).

In general, we observe the presence of hydraulic connection between these aquifers, especially in the north and southeast of Al-Emaed spring. This may be caused by the increasing fractures in this area.

CONCLUSION

The electrical resistivity surveys for the studied area have shown some important results, which are given as conclusions follows:

- The vertical electrical survey proved the existence of five geo-electrical horizons within profile (A – A') and three within both (B – B') and (C – C').
- Three aquifers are found through the results of vertical electrical survey. The first is the Euphrates aquifer, and it is located at a depths ranging between 1 and 7 m. This aquifer overlaps with the Ghar aquifer in the southeast of the studied area, and is forming one hydro-geological unit. The second is Ghar aquifer and it appears at depths varying approximately from 1 to 3 m above the Dammam aquifer.
- The third is the Dammam aquifer and is located under the Euphrates aquifer in the north and southeast of the Al-Emaed spring, and also located under Euphrates and Ghar aquifer at the southeast end of the studied area. However, it is located at depths ranging between 13 and 43 m, in most of the area, except the area south and southwest Al-Emaed spring, where it is located near the ground surface. The lower part is characterized by increase of the fractures in comparison with upper part. Therefore, it is believed that the lower part is the best, and if new wells to be drilled in this area, we recommend to drill to this aquifer.

- In general, the results of vertical electrical survey show the presence of hydraulic connection between these aquifers, in the north and southeast of Al-Emaed spring and may be caused by the increase in the fractures in southeast Al-Emaed spring, and by the presence fault in the north of this spring.

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