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FULL LENGTH ARTICLE

Delineating groundwater aquifer and subsurface structures by using geoelectrical data: Case study (Dakhla Oasis, Egypt)

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Abstract Geoelectric technique has been used to detect the subsurface stratigraphy and structures around Dakhla Oasis, Egypt. 1D inversion approach has been applied to interpret the geoelectrical data obtained along 10 vertical electrical soundings (VES) using the well known Schlumberger array of AB/2 with electrode spacing varying from 3 to 400 m in successive steps.

A preliminary quantitative interpretation of the vertical electrical sounding curves was achieved firstly by using two-layer standard curves and generalized Cagniard graphs. The final models were obtained in 1D using IPI2 WIN program. The modeling results were used to construct a geoelectrical section.

Three geoelectric units were identified: The superficial geoelectrical layer is composed mainly of sand and gravel with relatively high resistivity values (7.61–346 Ω m) and thin thicknesses (0.252–9.19 m), of late Pleistocene to Holocene (Quaternary deposits).

The second geoelectrical layer is composed of shale (Dakhla Shale). It is characterized by relatively very low electrical resistivity values (0.3–8.68 Ω m). The maximum depth of this layer ranges from 4.18 to 56.4 m.

The Nubian sandstone (upper aquifer) third layer with moderate electrical resistivity values (68.5–1585 Ω m) can be detected at the maximum depth of penetration.

1. Introduction

Dakhla Oasis (Fig. 1) is one of the Oases in the New Valley Government that economically, depends mainly on agricultural activities which yields a large amount of the agricultural drainage and wastewater. Such water is collected through drainage canals in the vacant and uncultivated lands, forming wastewater pond. The occurrence of most of that pond in the highlands is a risk of collapse of the wall and flooding

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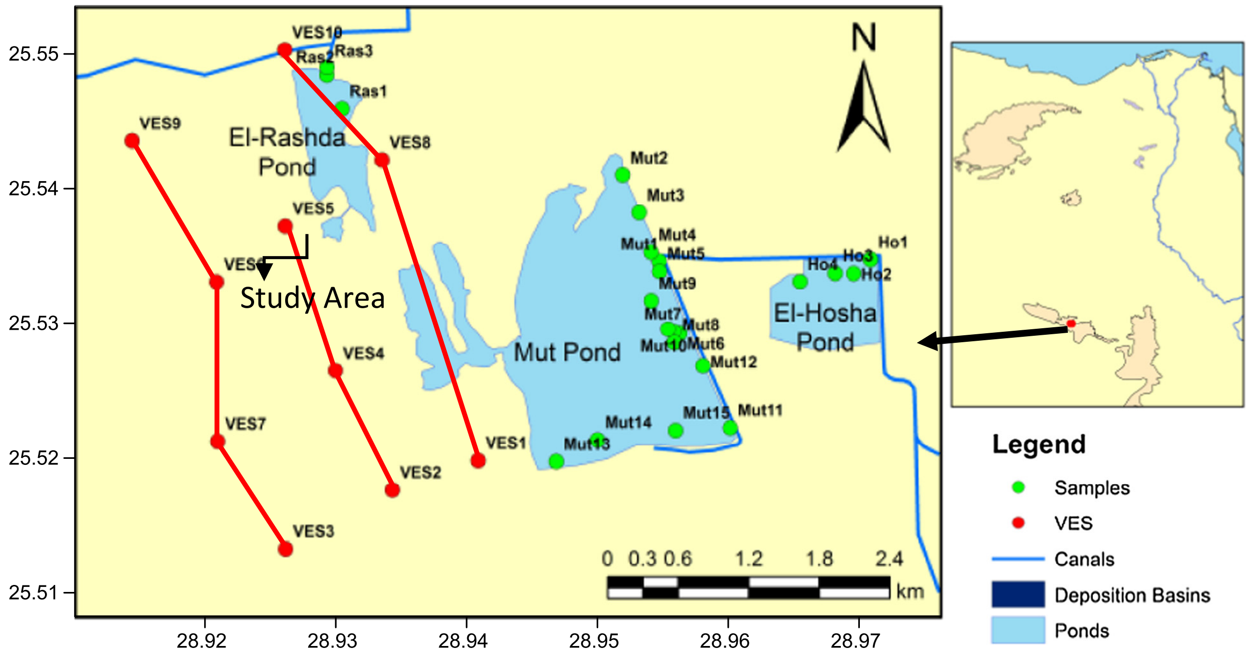

Figure 1 Location map showing Dakhla Oasis.

the neighboring cultivated lands. So, that pond represents serious threats to the population of that Oasis.

The target of the present study is to conduct geophysical investigation of the surrounding lands and to determine the shallow subsurface layers in these areas. Then, we can use the wastewater from that pond to cultivate the surrounding area without affecting the groundwater in the area under investigation.

The leakage of water into the underground aquifer represents a serious threat to the population in this region, especially because they are totally dependent on groundwater or flow of wastewater to the oasis. The presence of an impermeable layer such as shale and clays prevents the leakage of the wastewater into the underground freshwater aquifer. Therefore, the shallow subsurface layers were studied to determine the shale distribution and the possibility of leakage through the different areas around the ponds and to determine the suitable areas for further activities using the wastewater.

Geology of the study area and the successive sedimentary formations within the Dakhla depression dip steadily northward at a very small inclination. Consequently, every formation has a wide outcrop. In general, these formations crop out at the cliff to the north of the depression and they do not appear in the oasis depression itself (Ezzat, 1976). The late Mesozoic-Early Cenozoic rocks, which build the primary sedimentary cover in the area under discussion, are subdivided into a number of mappable lithostratigraphic units. The units are classified generally into two categories: (a) a Jurassic-Campanian sequence, predominantly continental but with marine intercalations, and (b) a Campanian-Lower Eocene tr ansgressive–regressive open marine sequence.

Geophysical investigation is a powerful tool for exploring the subsurface geology and collecting more information about the subsurface layers and structures (Mohamaden et al., in press; El-Sayed, 2010). In this study, geoelectrical resistivity method was used for shallow subsurface investigation to determine the distribution and thickness of the shale layer.

Many authors such as Koefoed (1965a,b,c), Gosh (1971), Zohdy (1975, 1989), Santos et al. (2006), El-Galladi et al. (2007), Sultan et al. (2004, 2009a,b,c,d, 2009), Sultan (2009), Sultan and Santos (2008a,b), Mohamaden (2001, 2005, in press), Mohamaden and Abu Shagar (in press), Abbas and Sultan, 2008, Mohamaden et al. (in press), Abu El-Ata (2012). Hemeker (1984) studied the quantitative interpretation of the geoelectric resistivity measurements.

2. Geoelectric study

The electrical resistivity survey consists of a transmitter, receiver, power supply, stainless steel electrodes, and shielded cables. In the present study, IRIS SYSCAL-PRO instrument is used which computes and displays apparent resistivity for many electrode configurations.

The geoelectrical configuration used in the study is Schlumberger collinear four symmetrical electrodes configuration. The current electrode separation is about 400 m.

The result of the geoelectrical survey was processed and quantitatively interpreted using available geological information and presented as geoelectrical sections along the various profiles.

The obtained data are plotted using ready-made software in order to be processed and interpreted. After data processing and interpretation, layer parameters (true resistivities and thicknesses or depths) of the various current penetrated layers can be obtained (El-Sayed, 2010).

At this study, the area under investigation was covered by 10 vertical electrical soundings at three profiles named profiles 1, 2 and 3 (Fig. 1). These profiles run from north to south. The interpretation of the apparent electrical resistivity data was achieved using two methods, the first is based on curve matching technique using Generalized Cagniard Graph method constructed by Koefoed (1965a,b,c), and the output results are treated according to the inverse problem method using computer program (IPI2win). Then results were represented as geoelectrical section (see Fig. 2).

The geoelectrical resistivity sections obtained from the quantitative interpretation of vertical electrical soundings deduced that.

The Pseudo-Sections and Geoelectrical resistivity sections obtained from the qualitative and quantitative interpretation of vertical electrical soundings deduced that.

2.1. Profile 1

This profile covered by 3 vertical electrical soundings named 10, 8 and 1 (Fig. 1). **The Pseudo-Section** for apparent electrical resistivity shows the following (Fig. 3):

The areas northwest of VES 1 are affected by highly gradient of contour lines which referred that this area is affected by geological and geophysical fault. Also, the area northwest of VES 8 is affected by another fault. Also, the northwestern part of VES 8 and southeastern part of VES 1 are characterized by low electrical resistivity values as a result of shallowing of groundwater for these areas, while the central part of this section is characterized by more deep to groundwater for the upper part of the Nubian Sandstone.

The geoelectrical section for this profile formed from three geoelectrical layers is shown as follows (Fig. 4):

The superficial geoelectrical layer is characterized by moderate electrical resistivity values (292–346 Ω m) and thin thicknesses only around of VES 10 and 1 (0.252–0.502 m). It consists of sand of the Quaternary deposits.

The second geoelectrical layer is characterized by low electrical resistivity values (1–1.13 Ω m) and depth ranges from 13.5 to 56.4 m. It consists of shale.

At the maximum depth of penetration, we can detect the third geoelectrical layer with moderate electrical resistivity (39.4–82.9 Ω m). It is the upper most aquifer at the area under investigation. It is formed from consisting of Nubian Sandstone (upper part of the main aquifer).

This profile is affected by two faults northwest and southeast of vertical electrical sounding no. 8 with downthrown side toward the central part to form a graben structure.

The most promising area for reclaimed by wastewater is the central part of this profile where there are maximum thicknesses of shale layer.

2.2. Profile 2

This profile covered by three vertical electrical soundings named 5, 4 and 2 (Fig. 1).

The Pseudo-Section for apparent electrical resistivity shows that: The area southeast of VES 4 is affected by deep sited fault with highly gradient of contour lines. The southeastern part of this profile is characterized by high resistivity values as a result of deep to the groundwater (Fig. 5).

The geoelectrical section can be deduced that (Fig. 6).

The superficial geoelectrical layer is characterized by moderate electrical resistivity (10–47 Ω m) and thin thicknesses (0.701–1.77 m). It consists of sand (Quaternary deposits).

The second geoelectrical layer. It is characterized by low electrical resistivity values (1–3 Ω m) and depth ranges from 28.8 to 44.7 m. It consists of shale.

At the maximum depth of penetration, we can detect the third geoelectrical layer. It is characterized by moderate electrical resistivity (151–159 Ω m). It consists of Nubian Sandstone. It is the upper most aquifer at the area under investigation.

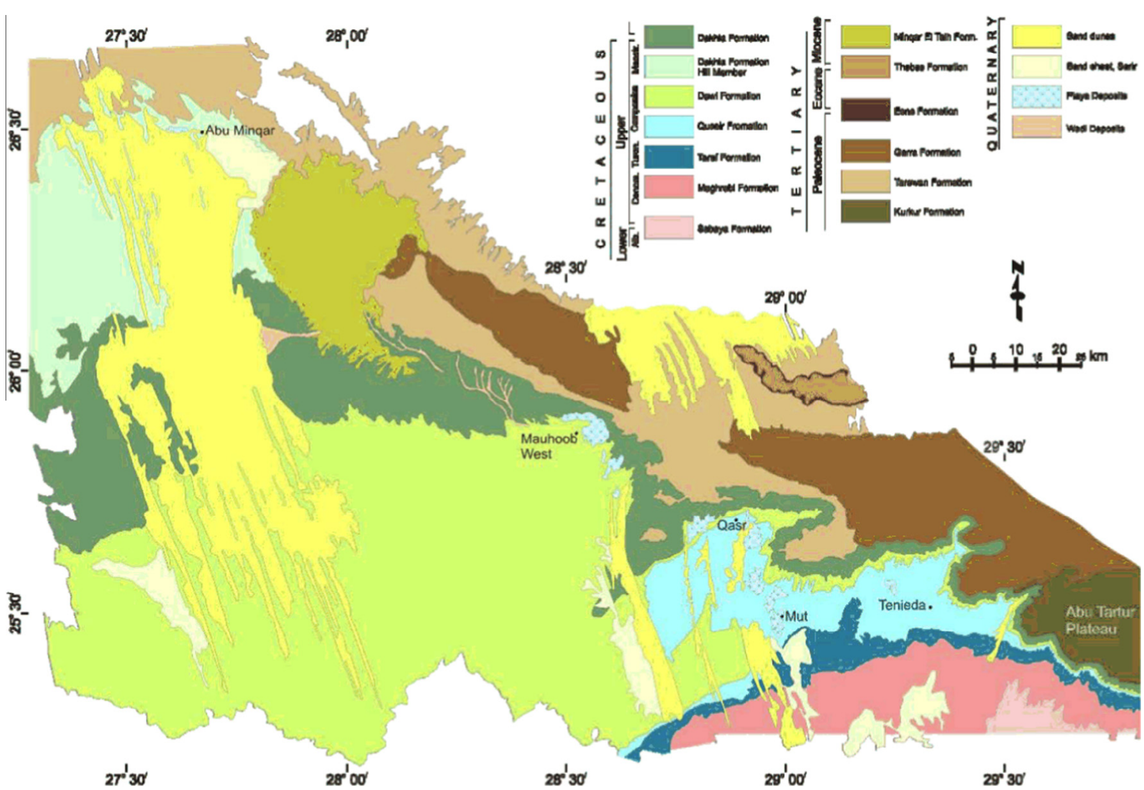

Figure 2 Geological Map of Dakhla Oasis (after Conoco, 1989).

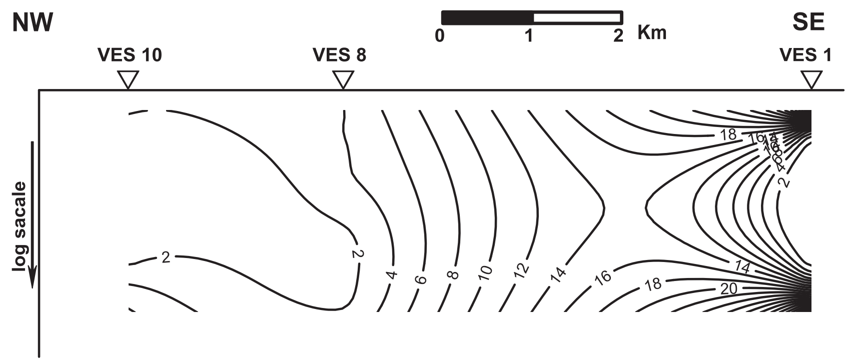

Figure 3 Pseudo-section for apparent electrical resistivity for profile 1.

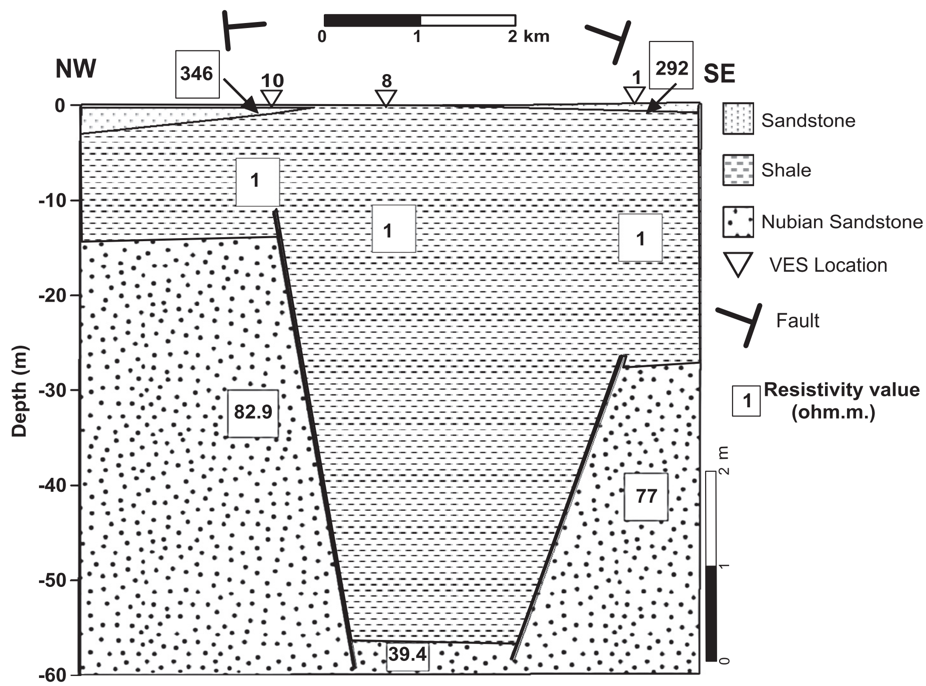

Figure 4 Geoelectrical section for profile 1.

This profile is affected by a fault southeast of vertical electrical sounding no. 4 with downthrown side toward the southeastern part of this profile.

The most promising area for reclaimed with wastewater is the southeastern part of this profile which represented the maximum thickness of shale which prevents affecting the main aquifer (Nubian Sandstone).

2.3. Profile 3

This profile covered by 4 vertical electrical soundings named 9, 6, 7 and 3 (Fig. 1). The geoelectrical section for this profile formed from three geoelectrical layers is shown as follows:

The Pseudo-Section (Fig. 7) for apparent electrical resistivity is one of the qualitative interpretations of the geoelectrical method deduced that the areas around of VES's 6 and 7 are affected by two faults as the result of the highly gradient of the contour lines. The area at the northwestern part of this profile is characterized by low electrical resistivity values at deep zone which reflects this zone with groundwater.

The geoelectrical section can be deduced that (Fig. 8).

The superficial geoelectrical layer is characterized by moderate electrical resistivity values (13.7–47.3 Ω m) and thin thicknesses all over this profile with exception around VES no. 6 (1.38–9.19 m). It is formed from sand frpm the Quaternary deposits.

Under this layer we can detect the second geoelectrical layer characterized by low electrical resistivity values (1–9 Ω m) and depth ranges from 4.18 to 49.1 m. It consists of shale.

At the maximum depth of penetration, we can detect the third geoelectrical layer. It is characterized by moderate electrical resistivity (28.1–69 Ω m). It is the upper most aquifer at the area under investigation. It is formed from Nubian Sandstone.

This profile is affected by two faults southeast and northwest of vertical electrical sounding nos. 9 and 3 respectively with upthrown side toward the central part to form a horst structure.

The most promising area for reclaimed is at the extremely two parts of this profile without affecting the main aquifer

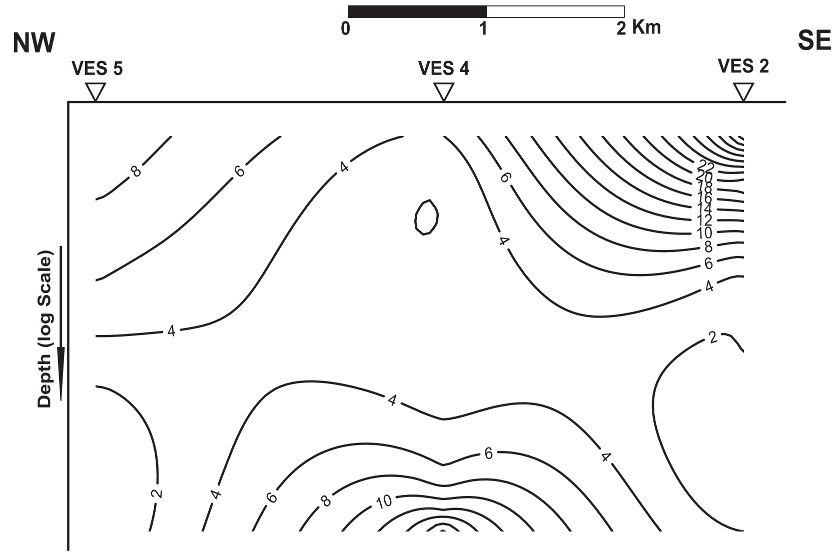

Figure 5 Pseudo-section for apparent electrical resistivity for profile 2.

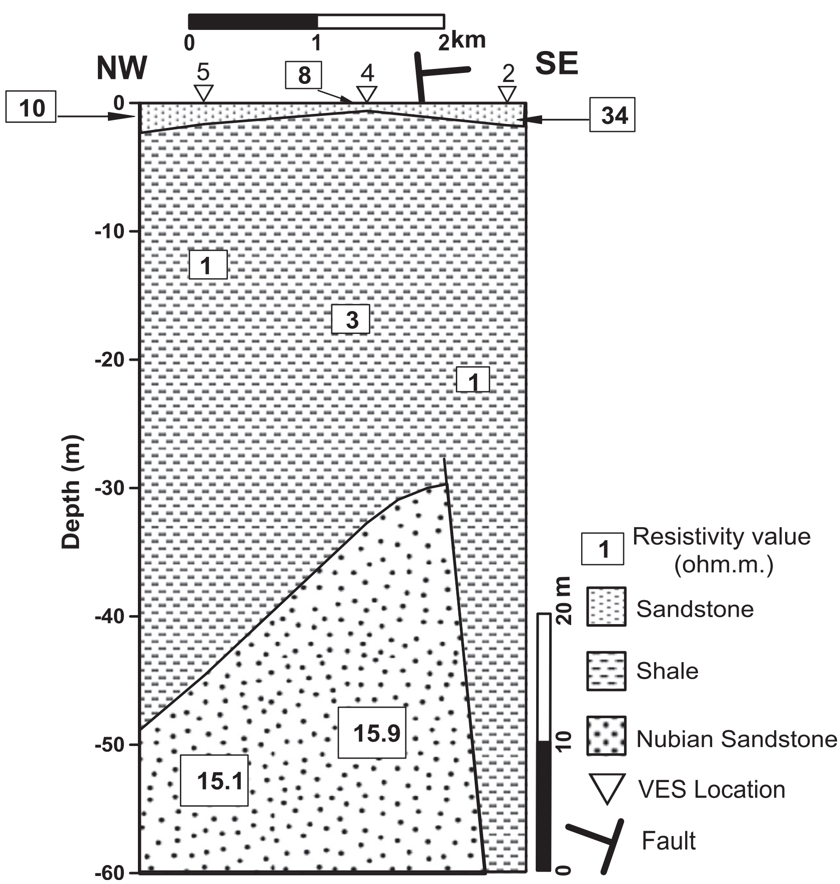

Figure 6 Geoelectrical section for profile 2.

(Nubian Sandstone) at the study area as a result of maximum thickness of shale (Dakhla Shale Formation).

3. Results and conclusions

The superficial geoelectrical layer is mainly composed of sand and gravel with relatively high resistivity values (10–346 Ω m) and thin thicknesses (0.252–9.19 m). The age of this layer is from late Pleistocene to Holocene (Quaternary deposits).

The second geoelectrical layer is from shale (Dakhla Shale). It is characterized by relatively very low electrical resistivity values (1–9 Ω m). The maximum depth of this layer ranges from 4.18 to 56.4 m.

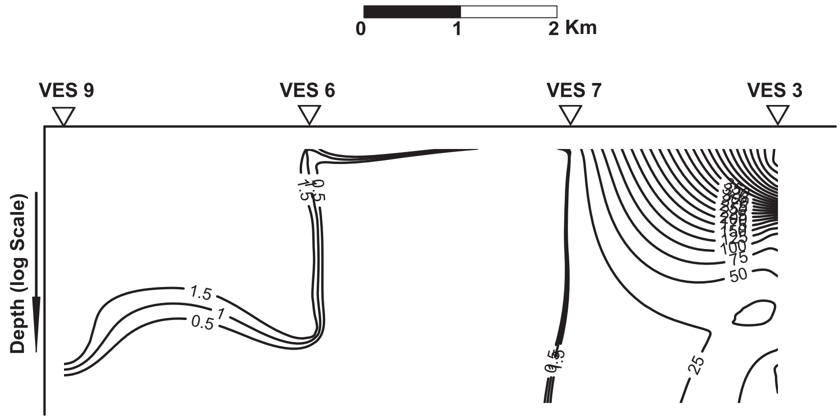

Figure 7 Pseudo-section for apparent electrical resistivity for profile 3.

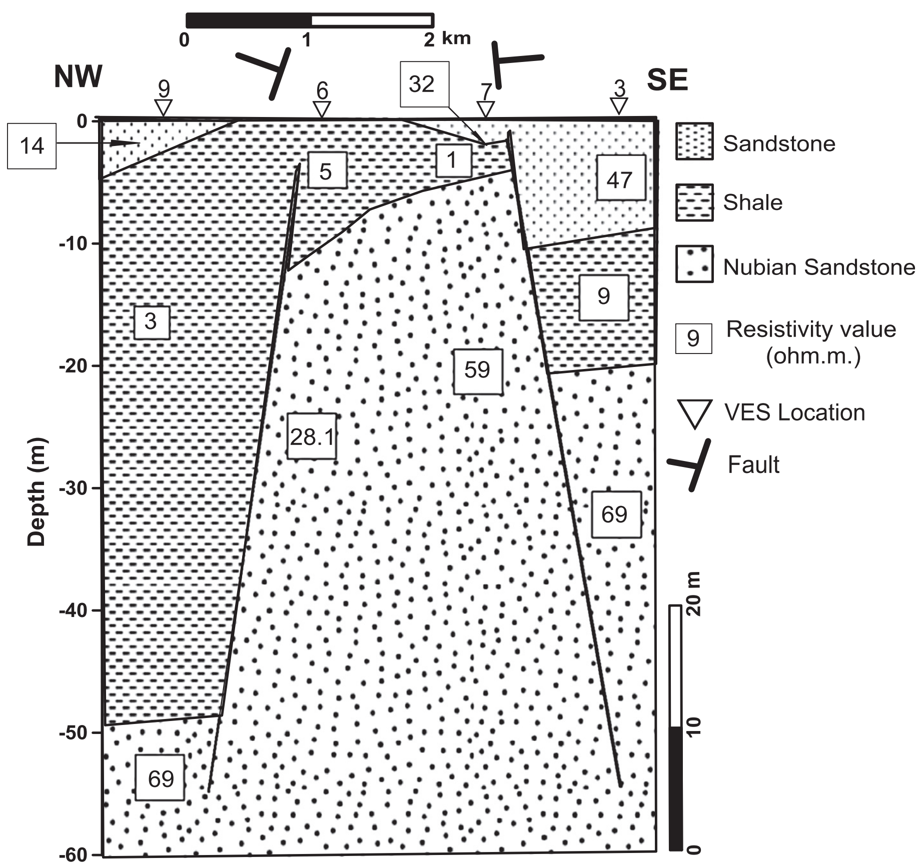

Figure 8 Geoelectrical section for profile 3.

The Nubian sandstone (upper aquifer) third layer with moderate electrical resistivity values (28.1–159 Ω m) could be detected at the maximum depth of penetration.

Structurally, the area under investigation is affected by two geological and geoelectrical faults at the central part of the area with downthrown side toward the central part to form a graben structure.

The most promising area for reclaimed is at the extremely two parts of this profile without affecting the main aquifer (Nubian Sandstone) at the study area as a result of maximum thickness of shale (Dakhla Shale Formation).

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