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Research Article

Regional Extensions of the Water Bearing Formations in Central North Kordofan and West White Nile Area

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I N F O

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A B S T R A C T

This study was done to delineate the regional extensions of the water bearing formations in the area lies between Central North Kordofan and West White Nile States. Interpretation of 23 vertical electrical soundings (VES) correlated with 66 borehole's data to construct geological sections; IPI2Win software was used for VES data ID interpretation. The study indicates that, the area involves three water bearing formations; those are upper, lower and deep aquifer. The upper and lower aquifers extend in Bara Basin and the western part of Kosti Basin, while the deep aquifer is confined only to Kosti Basin. The upper and lower aquifers are composed of similar rocks of coarse sands and gravels whereas the deep aquifer is mainly made up of medium sands. Contrary to the popular belief that the upper aquifer is southerly limited by latitude 13° 00'N, the lithological and hydro geological evidences from the borehole's reports indicate that, the upper aquifer extends in the southern parts of the area, south Khor Abu Habil. Also the mode of occurrence, rock type, and hydraulic condition of the deep aquifer indicated that the aquifer is not a part of the lower aquifer.

Keywords: Aquifers, Bara Basin, Abu Habil, Kordofan, Kosti Basin, White Nile

Introduction

The area under the consideration lies in Central North Kordofan and West White Nile areas (Figure 1). Many studies were conducted including the study area which can be summarized as: Rodis et al. (1965), Hunting Technical Services Ltd. (1970), Mitwali (1969), Ali and Whitely (1981), Ali (1983), Geotehnika (1985), Mohamed, Farwa and El Nazeer (1986), Geotehnika (1988), IFAD (1993), El Tayeb (2000), El Mansour (2005), Abbashar (2005), Dahab (2007) and En Nair (2011).The study area is a part of the Sudanese Rift Basins which are developed as a part of Central Africa Rift System (CARS). These basins extend from the western boundaries of the Sudan to the eastern boarders with Ethiopia (Salama 1985a).

In the study area, the extensive groundwater exploration activities in the recent decades were carried out as a response to the increasing demands of groundwater, whereas ground water is the only source of water for domestic, irrigation and other uses in most of the area and so significant deviations from normal water supplies occur. It is known that during the last three decades, Sudan and other sub-Saharan countries had been hit by drought,

desertification and devastated by famine (El Tayeb, 2000); that means the development, management and protection of the groundwater resources in these arid and semi-arid regions become of a high priority to allow population settlement and to reduce the migration out of these regions.

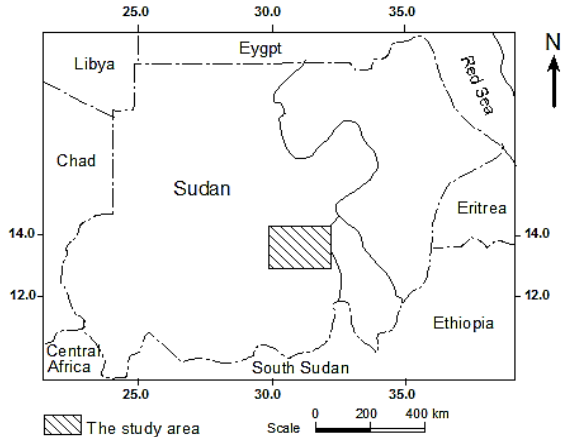

Figure 1.Location map of the study area

Based on the forgoing reasons, the present study aims to delineate the regional extension of the water bearing formations depending on the analysis of the geological, hydrogeological, and geophysical data.

Geology

Two basins occur in the study area, as a part of the White Nile Basins system; Bara Basin and Kosti Basin (Figure 2). The former represents the principal basin of the White Nile Basins in North Kordofan area, whereas the latter is located west of the White Nile. Hydrogeologically, Bara Basin is divided into three sub-basins: El Basheri, Umm Rawaba and Dar Agil whereas Kosti Basin is divided into Hashaba and Umm Agaga sub-basins (EL Tayeb, 2000).

The rock units in the area are represented by six groups: The Basement Complex (Pre-Cambrian) that crop out as a form of Jebels (Hills) such as J. Mugunis, J Zalata, J. Heleiba and J. Kon (Whiteman, 1971). Nawa Formation (Paleozoic) overlay The Basement in the area around Er Rahad and extends beneath the Umm Rawaba Formation or the Superficial Deposits in many localities along Khor Abu Habil. The Mesozoic sediments of the Nubian Sandstone Formation usually overlay the Basement Complex rocks with thickness reaches 700 m in Kordofan (Geotehnica, 1985). Tertiary Sediments overly the Mesozoic sediments and underlying the Umm Rawaba Formation with thickness reaches 2500 min the eastern part; similar sedimentary sequences are also recorded in the Central Sudan Rift Basins (El Tayeb, 2000). Umm Rawaba Formation (Tertiary-Pleistocene) represents the main sedimentary unit in the area; it is mainly composed of unconsolidated sediments (El Tayeb, 2000); kankers and anhydrite are present in some parts (Salama, 1988). The thickness of all unconsolidated sediments in the central part of the Bara Basin attains 1.4 km (Ali, 1983). Superficial Deposits (Pleistocene and Recent) overlie the Umm Rawaba Formation, and mainly consist of dunes (Qoz sands) and Wadi fills of variable thickness (Whiteman, 1971).

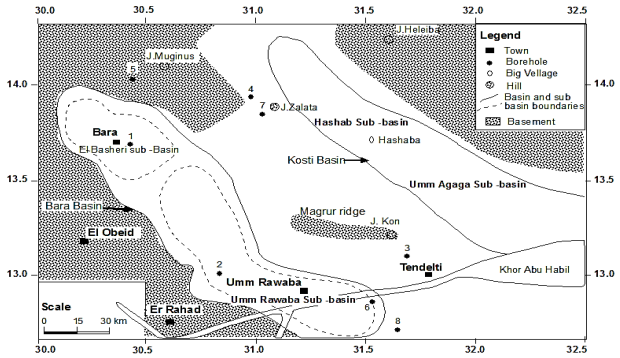

Figure 2.Sedimentary basins and sub-basins in the area (modified after El Tayeb 2000)

Materials and Methods

In this study, geological and hydrogeological data of 66 boreholes (B.H) pertaining to the study area, in addition to 23 Vertical Electrical Soundings (VES) (Figure 3) were used to delineate the water bearing formation systems in the area. The geological and hydrogeological data include lithology, depths, static water levels and elevations of the borehole sites; a summary for these data is shown in Table 1.

Table 1.Summary of 124 boreholes data in the study area

G.S. Elev. (m)	Well Depth (m)	D. to B.C. (m)	S.W.L (m)	EC µ mohs	T.D.S mg/l
401–520	76–426	76–198	*25–105	600–7286	118–5100

* One location having flowing conditions (Um Balagei site)

G.S. Elev.: Ground Surface Elevation, D. to B.C: Depth to Basement Complex,

W D: Water Depth, EC: Electrical Conductivity, TDS: Total Dissolved Solids

Geophysical resistivity measurements were used for determination of groundwater aquifers andtheir thickness, depth to Basement rocks, and detection of structural features. Calibration VESs at some borehole sites were used to correct the interpreted resistivity data. The VES measurements were quantitatively interpreted by using IPI2Win computer software; software designed for automated and interactive interpretation of DC electrical sounding data. Resistivity and thickness of the lithological units were obtained and integrated with borehole data to construct geological sections (Figure 3). Freehand 9.02 software applicationswere used for drawing purposes of the sections and maps in this study.

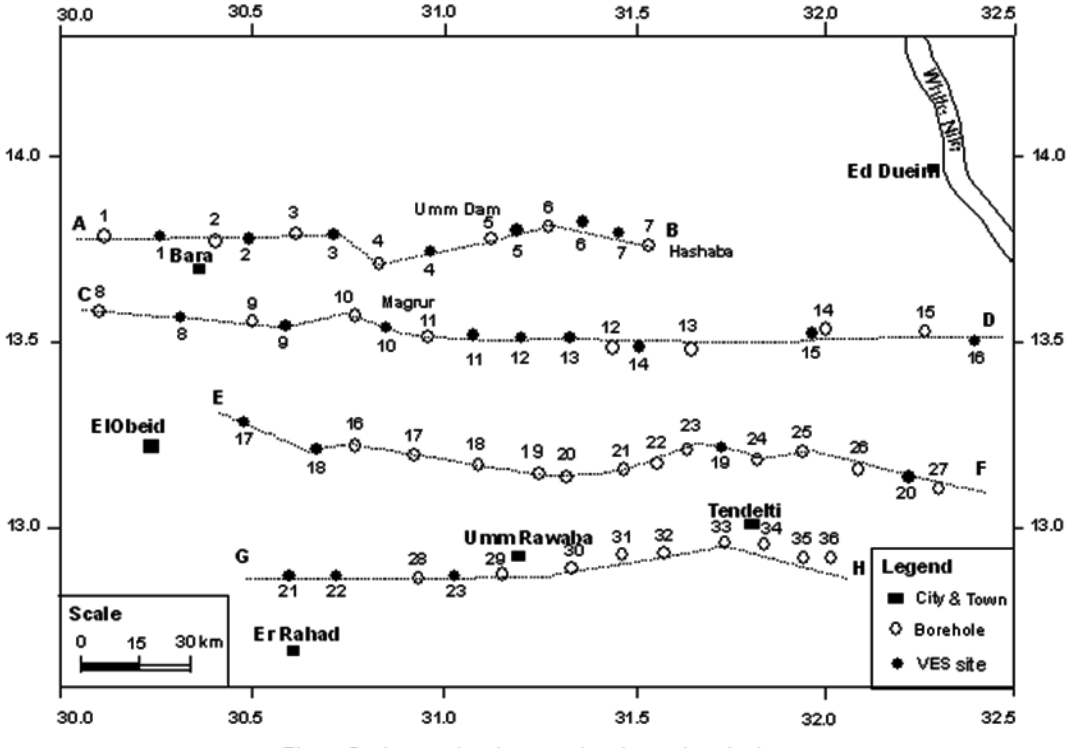

Figure 3.Layout of the geo-electric sections in the area

Result and Discussion

The geological sections constructed based on resistivity results and borehole data manifest the subsurface geologic structure and the hydrogeological conditions of the water bearing formations (Figures 4, 5, 6 and 7).

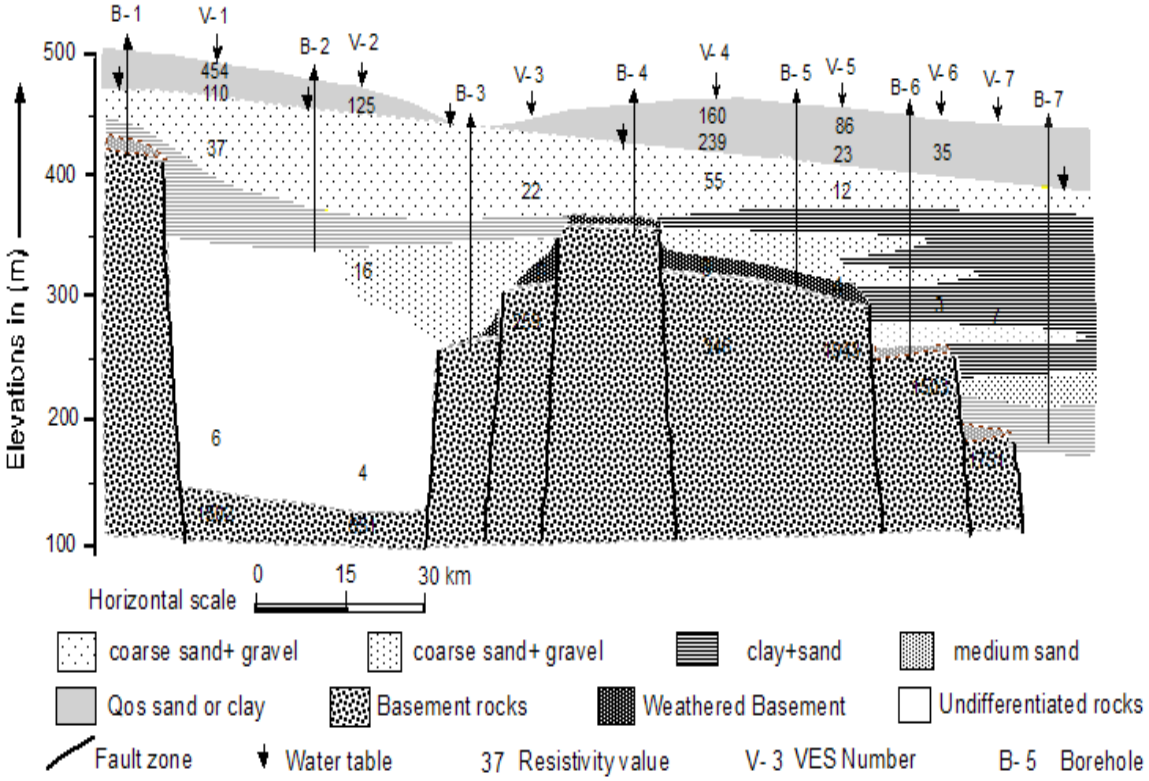

Figure 4.Geo-electric section A-B

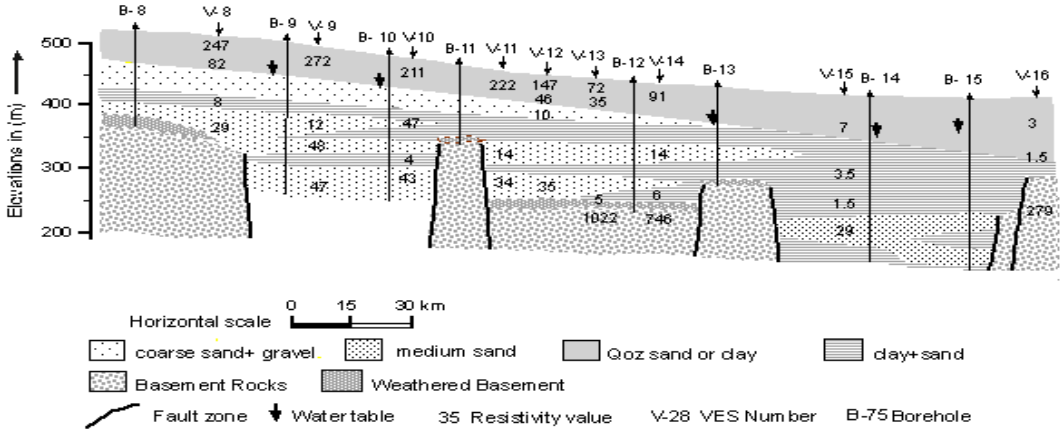

Figure 5.Geo-electric section C-D

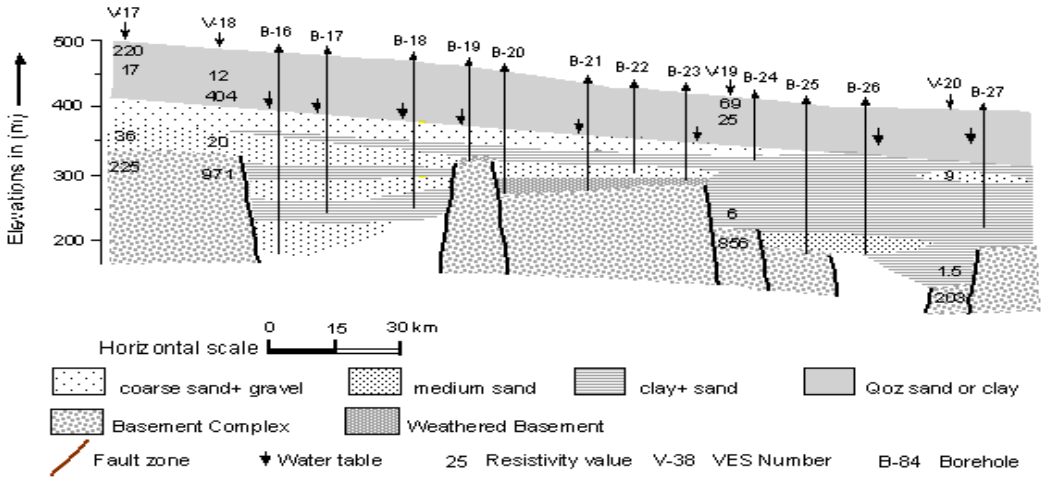

Figure 6.Geo-electric section E-F

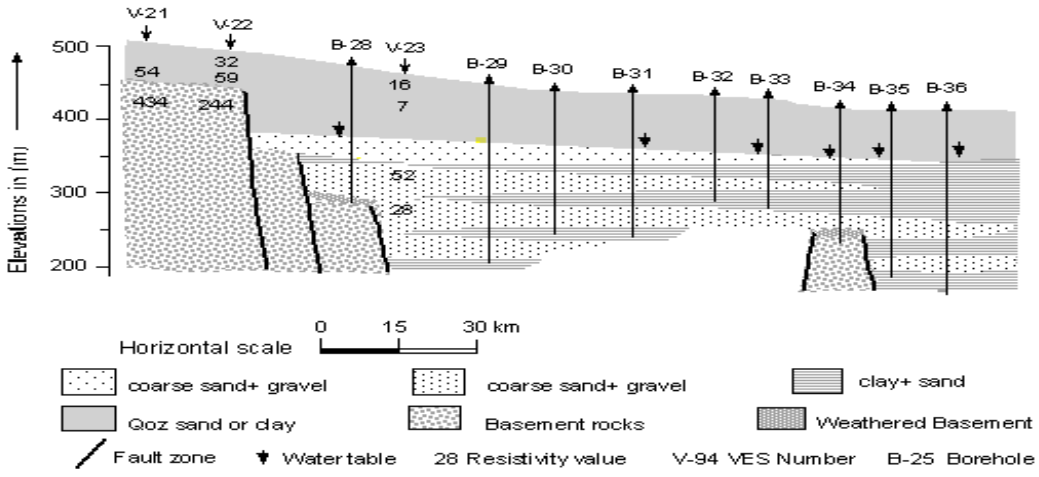

Figure 7.Geo-electric section G-H

The study area comprises four geological units from the oldest to the youngest as follow:

Basement Complex which crops out in many localities as gneisses, schists, granites and syenites with resistivity values range from 279–1751 Ohm.m. The relatively low values of the resistivity may be corresponding to the weathered and fractured portions in the Basement rocks. The Basement Complex reflects high relief surface due to

rifting processes that result in many troughs. The complex structural characteristics of the Basement surface clearly affect the mode of groundwater occurrence throughout the region; the vertical and horizontal extensions of the water bearing horizons, groundwater dynamics, etc. (Figures 4, 5, 6 and 7). Sedimentary sub-basins are frequently separated by shallow seated Basement. The Basement rocks form a dome (ridge) extending from the east to the west passing through the central part of the area, the shallower part of this dome is referred to as Magrur buried ridge (Figure 2). Also an elevated Basement block extending northwest-south east separates Kosti and Bara basins.

Mesozoic sediments or Nubian Sandstone Formation rests on the Basement rocks over most of the area but it is recorded in the northern part of Hashaba at shallow depths. It consists of sandstones, mudstones and conglomerates. Umm Rawaba Formation consists mainly of unconsolidated sands, sometimes gravelly or clayey sand, and clays. The thickness of the Umm Rawaba Formation is certainly highly variable as the formation rests un-conformably on the Basement Complex and other former geological units. Generally Nubian Sandstone and Umm Rawaba Formation show a narrow resistivity values as 1.5–28 Ohm.m, and a mean value of about 24 Ohm.m, which manifest domination of clays and sands in this portion; clay seems to dominate the eastern parts of the area (Figures 4, 5, 6 and 7).

Superficial Deposits overlie the Umm Rawaba Formation with variable thickness. Resistivity in this zone extends from 3–454 Ohm.m, with a mean value of about 108 Ohm.m; these values reflect the dominancy of relatively dry sandy sediments.

The geological sections indicate that the area includes three water bearing formations with resistivity ranges between 9 and 55 Ohm.m (Figures 4 and 6). The resistivity values conforms the sandy nature of these formations. The total thickness of these formations attains to 150 m, and can be categorized into three horizons as upper, lower and deep aquifers (Figures 4, 5, 6 and 7).

The water table in the upper aquifer varies from a depth of about 20 m in the northwestern parts to about 100m in the southern parts of the area (Figures 4, 5, 6 and 7). The thickness of this aquifer varies from less than 10m as in El Kero borehole (B.H-12 in Figure 5) to 80 m as in Umm Balagei borehole (B.H-3 in Figure 4). Umm Balagei borehole represents the only case for a flowing well (artesian) in the area. The upper aquifer is made of the upper parts of the Umm Rawaba Formation and the lower parts of the Qoz sands, under free water table condition; it is mainly consists of sands and granules. Direct infiltration of the rainfall and surface water through the sandy cover in the northwestern part of the area represents the main source of recharge for the upper aquifer; the depth to water table in this aquifer decreases during the rainy seasons. VES results, lithological and hydrogeological evidences from the borehole's reports indicate an existence of the upper aquifer in the southern parts (Figure 8). The upper aquifer is separated from the lower aquifer by aquiclude layers. The thickness of these layers varies from about 5–25 m (Figures 4 and 7).

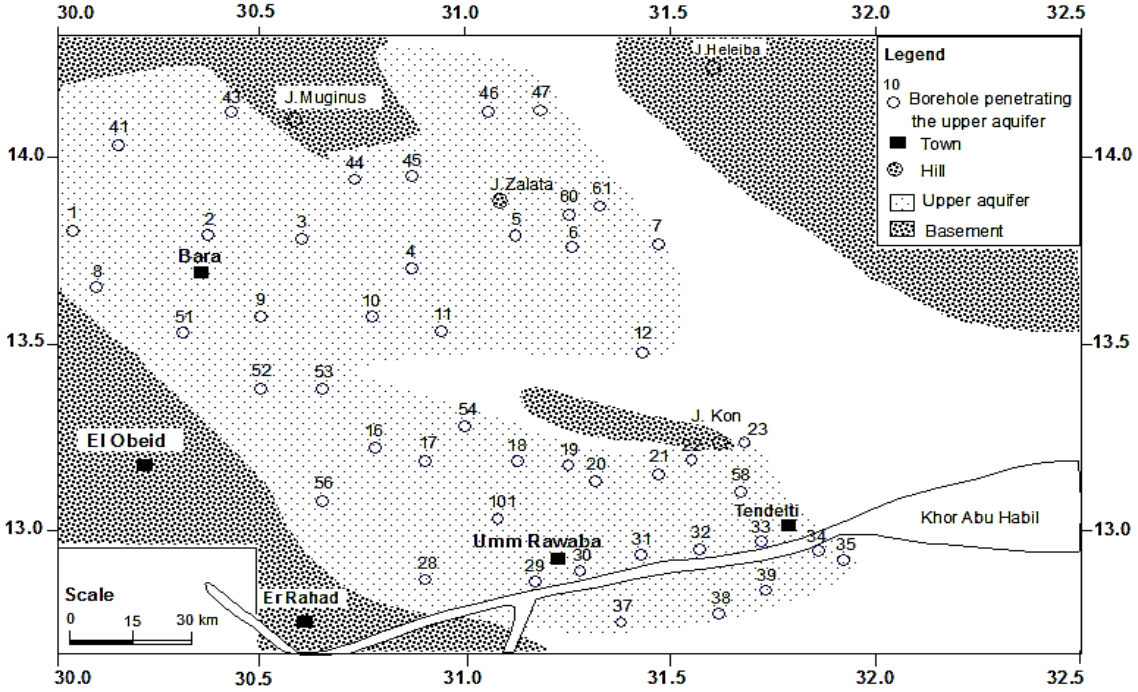

Figure 8.Regional extensions of the upper aquifer

The lower aquifer is a multilayered system; it is composed of coarse sands and gravels as in the upper aquifer. The depth to this aquifer varies from 85 m as in Umm Balagei borehole (B.H-3 in Figure 4) to about 140 m in Umm Sareiha borehole (B.H-28 in Figure 7). The lower aquifer lies under confining conditions as in Umm Balagei flowing well to semi-confining conditions in other places where it is found to be in direct contact with the upper aquifer. The system of the lower aquifer is characterized by a discontinuity due to an existence of Basement rocks in form of horsts at the sides of the sub-basins in the area. No borehole fully-penetrated the lower aquifer, hence it is difficult to precisely determine itstotal thickness. Regionally it extends in the most parts of the study area. The boundaries of the aquifer were delineated from the VES results and boreholes data (Figure 9).

The deep aquifer is located in the Kosti Basin in rather deep depths. This aquifer starts at depth of about 190 m (B.H-26 in Figure 6). The thickness of this aquifer ranges from 25–60 m (Figure 5). It is mainly composed of medium sand; the sand is rounded to sub rounded, well sorted and colorless. The depth to the static water table in the aquifer decreases eastwards from more than 60 m to less than 45 m (Figures 5 and 6). It seems that the deep aquifer occurs under confined conditions due to the existence of a thick clay layer that overlaying the aquifer system. Previously it was believed that the deep aquifer is a part of the lower aquifer. The mode of occurrence, rock type and hydraulic condition indicate that the aquifer represents a hydrogeological unit differs from the lower aquifer. The regional boundaries of the deep aquifer were delineated from the boreholes data and VES results (Figure 10).

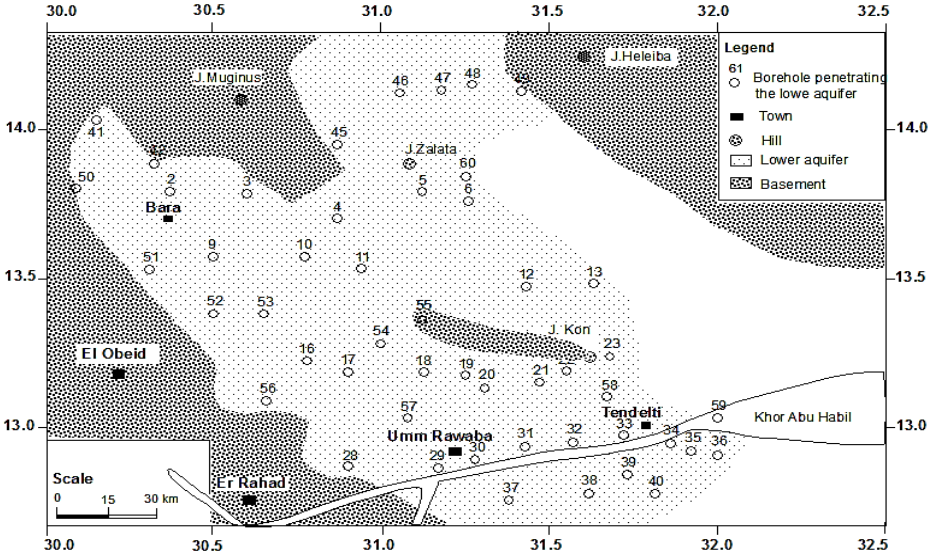

Figure 9.Regional extensions of the lower aquifer

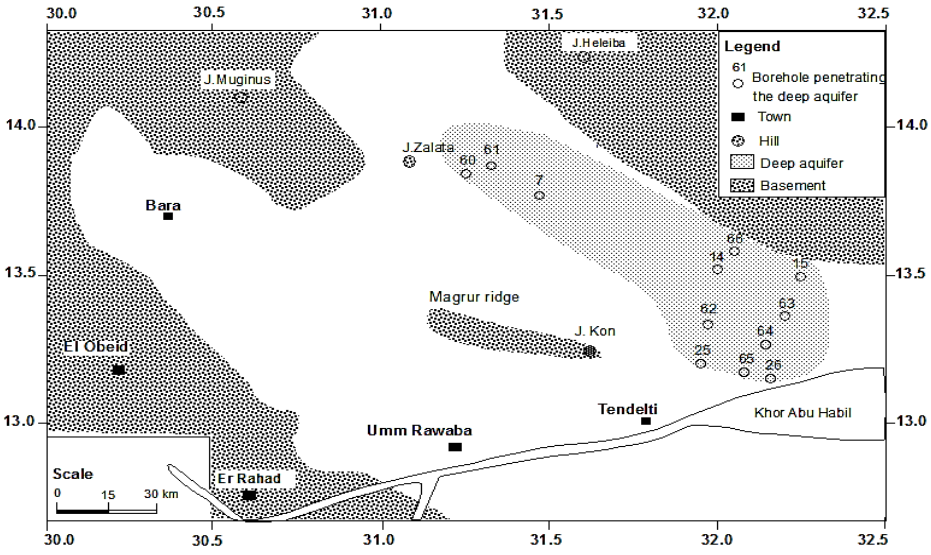

Figure 10.Regional extensions of the deep aquifer

Conclusion

This study based on the integration of the pre-existed borehole's reports and the geophysical resistivity measurements. The depths and thicknesses of the aquifer horizons, water table and rocks resistivity were used to delineate the regional extensions of the water bearing formations in the area. The final results of the study indicate that the area involves three aquifers: upper, lower and deep. The upper and lower aquifers are located in Bara Basin and west Kosti Basin whereas the deep aquifer is located in Kosti Basin.

The thickness of the upper aquifer varies from less than 10–80 m, with free water table ranges from 20–100 m. The lower aquifer extends in the most parts of the study area. Its not fully penetrated and hence its total thickness is difficult to specify; thickness from 80–140 m is recorded in the existing wells, Umm Balagei flowing well is the most prominent mark in this aquifer. The deep aquifer is recorded in Kosti Basin onlyat a depth of about 190 m. Its thickness ranges from 25–60 m, and have depths to water table range from 45–60 m.

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