EDITORIAL

Delineation of Water Bearing Formations in North Kordofan and West White Nile Area Using Vertical Electrical Sounding (VES) and Borehole Data

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ABSTRACT

The present study was conducted in 2012 to delineate the water bearing formations in North Kordofan and West White Nile areas. Vertical Electrical Soundings (VES) technique data and boreholes information from the study area were used in this study. IPI2Win and Freehand 9.02 software applications were used in this study. The former was used for VES data curves ID interpretation along single profile while the latter was used for drawing purpose. The results of the interpretation indicated that, the study area involves three aquifers: upper, lower and deep aquifers. The upper and lower aquifers locate in Bara Basin and west Kosti Basin whereas the deep aquifer locates in Kosti Basin. The thickness of the upper and lower aquifers together attains 150 m as in Umm Balagi and the thickness of the deep aquifer ranges between 25 to 60 m. The upper and lower aquifers are composed of similar rocks of coarse sand and gravels while the deep aquifer is mainly made up of medium sand. The static water table ranges between 20 m in the northwestern parts to more than 100 m in the southern parts. The mode of occurrence, rocks type, and hydraulic condition of the deep aquifer indicated that the aquifer is not a part of the lower aquifer as believed previously.

INTRODUCTION

The study area lies in Central North Kordofan and West White Nile areas (Fig. 1). It 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). Bara Basin represents the principal basin of the White Nile Rift Basins in the area in addition to Kosti Basin. Hydrogeologically, Bara Basin is divided into three sub basins: El Basheri, Umm Rawaba and Dar Agil whereas Kosti Basin is divided into two sub basins: Hashaba and Umm Agaga (EL Tayeb 2000) (Fig. 2). 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 for human, animals, irrigation, and other uses. This is because the area is highly densely populated. IFAD (1993), EL Tayeb (2000) and Dahab (2007) focused in groundwater assessment and evaluation. Accordingly, the present study aims to delineate the water bearing formations based on the geological and hydrogeological information of the boreholes and geophysical data of vertical Electrical Soundings (VES).

EDITORIAL

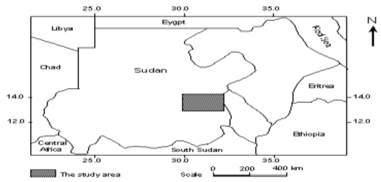

Fig. 1: Location map of the study area

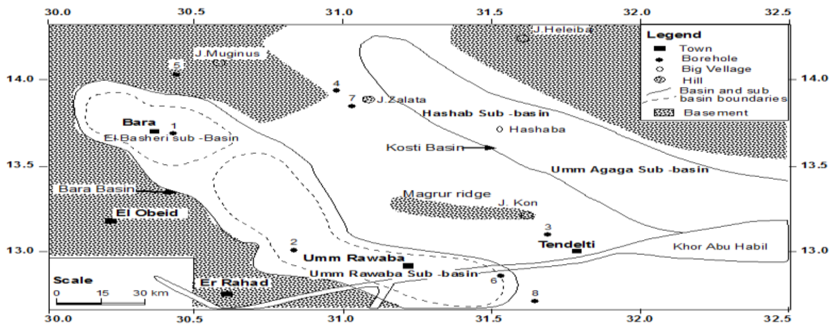

Figure 2: Sedimentary basins and sub- basins in the study area. Modified from El Tayeb (2000)

Regional Geology:

The Basement Complex rocks represent the oldest geological unit which is assumed to be mainly of Pre-Cambrian age (Whiteman 1971). They crop out in the area as form of Jebels (Hills) such as J. Mugunis, J Zalata, J. Heleiba and J. Kon. The Basement rocks are overlain by the Nawa Formation in areas around Er Rahad, or by the Mesozoic sediments of the Nubian Sandston Formation in the base of the basins. The Mesozoic sediments of the Nubian Sandstone Formation are overlain by the Umm Rawaba Formation. The thickness of the Nubian sediments reaches 700 m in Kordofan (Geotehnica 1985). Umm Rawaba Formation represents the main sedimentary unit in the area. It is mainly composed of unconsolidated sediments of sands, granules and clays. The geophysical investigation indicated that the thickness of the formation exceeds 500 m at Bara (El Mansour 2005). It is overlain by the superficial deposits of sand dunes (Qoz sands). The thickness of all unconsolidated sediments in the central part of the Bara Basin attains 1.4 km (Ali 1983).

MATERIALS AND METHODS

Geological and hydrogeological information of 36 boreholes pertaining to the study area in addition to geophysical data of 23 Vertical Electrical Soundings (VES) were used to delineate the water bearing formations in the area under consideration (Tables 1 and 2) and (Fig. 3). The borehole information include: the depths, lithology and water tables. (VES) data include the changes in the apparent resistivity values through different depths from the surface to the bottom. Most of the data was obtained from the field work in 2009.

EDITORIAL

The used method in the data interpretation depended on software applications. IPI2Win is a computer application designed for automated and interactive semi-automated interpretation of VES. In this study it was used for data curves ID interpretation along single profile. This IPI2Win application used as software application in the interpretation of the Vertical Electrical Soundings (VES) data. The results of IPI2Win include the interpreted resistivity of the subsurface layers with their expected thicknesses. The Freehand 9.02 software application is designed for drawing purpose. It was used in the drawing of the maps and sections. The results of the VES interpretation in the light of boreholes lithology are presented in form of geoelectric sections.

RESULTS AND DISCUSSION

Geoelecric sections:

Based on the interpreted resistivity values and thicknesses of the subsurface layers in the light of the boreholes lithology, four geoelectric sections were created (Figs. 4, 5, 6 and 7). These sections show the vertical and lateral changes in the resistivity of the subsurface layers. The resistivity of permeable layers ranges between 10 to 52 Ohm-m (Figs 5 and 7) respectively. These layers are separated by aquiclude layers which have resistivities between 3 and 16 Ohm-m (Figs. 4 and 5). Unsaturated layer represent the cap layer of the sections. The resistivity range of this layer is from 3- 452 Ohm-m (Figs. 5 and 4). The Basement rocks represent the base (bottom) layer of the sections. The resistivity of the fresh Basement reaches 1943 Ohm-m (Fig. 4).

Table – 1: Boreholes locations.

No	Location	Longitude	Latitude	Water depth (m)	Elevation
1	El Shoag	30.05	13.80	40	515
2	El Kalasa	30.37	13.78	26	486
3	Umm Balagei	30.60	13.78	Flow	465
4	Umm Shaiba	30.78	13.70	35	470
5	Umm Dam	31.10	13.77		463
6	At Ticale	31.26	13.77	60	450
7	Hashaba	31.47	13.77	60	431
8	Hamad El Said	31.10	13.65		520
9	Ar Rawda	30.50	13.57	30	505
10	Antatya	30.77	13.58	42	
11	Magrur	30.93	13.54	39	458
12	El Kero	31.43	13.47	65	446
13	Umm Saieda	31.63	13.48	73	410
14	Gellab Hawara	32.00	13.52		410
15	El Sherake	32.25	13.50		
16	At Tayara	30.78	13.22	73	480
17	Umm Nageaha	30.90	13.18	90	
18	Abeya	31.10	13.18	95	480
19	El Gallata Yaseen	31.25	13.17	82	465
20	Shogar	31.30	13.13		
21	Abu lamiss	31.47	13.15	55	448
22	Totah	31.55	13.20		

EDITORIAL

23	Gaghora	31.67	13.24	76	423
24	Abu Gelba	31.83	13.18	75	415
25	Shaa El Deen	31.95	13.20		
26	Rahd El Sheikh	32.11	13.15	56	402
27	Kirg	32.30	13.10	45	
28	Umm Sareiha	30.90	12.87	105	470
29	Gidedeem	31.17	12.86		
30	El Goghan	31.28	12.88		445
31	El Gubsha Badeen	31.46	12.91	81	435
32	El Zurgab	31.57	12.90		432
33	Wad Burr	31.72	12.95	77	
34	Umm Kiterat	31.82	12.95	73	422
35	Tahra	31.92	12.92	71	
36	Wad Abu Rakoba	32.00	12.90	65	411

Table – 2: Vertical Electrical Sounding Sites.

No	Location	Longitude	Latitude
1	El Basheri	30.19	13.77
2	Sheraim Adam	30.43	13.76
3	Tendar	30.71	13.77
4	Umm Dam	30.98	13.75
5	El Kilwat	31.17	13.76
6	El Maksser	31.28	13.83
7	El Shigaila	31.40	13.78
8	Umm Galgi	30.33	13.55
9	Umm Garif	30.57	13.53
10	Umm Sharoaba	30.82	13.52
11	El Shadwanya -1	31.05	13.51
12	El Shadwanya -2	31.19	13.52
13	Shanee	31.31	13.50
14	El Kero	31.44	13.52
15	Gellab Hawara	31.99	13.48
16	Al Lamaima	32.39	13.50
17	Umm Hegleig	30.46	13.29
18	East Bulli	30.64	13.20
19	Abu Gelba	31.82	13.18
20	Kirig	32.26	13.11
21	Nawa Station	30.51	12.86
22	Jebel Hamad Allah	30.65	12.86

EDITORIAL

23	El Ailafoon	12.86	30.90

Four geological sections were created based on the results of the geoelectric sections. These sections indicate that the area includes three aquifers: upper aquifer, lower aquifer and deep aquifer (Figs.8, 9, 10 &11).

Water Bearing Formations (Aquifers):

The geological interpretation depended on the results of the geoelectric sections and boreholes information (depth, lithology and water table). Four geological sections showed the extensions of the geological interpretation depended on the results of the geoelectric sections and boreholes information (depth, lithology and water table). Four geological sections showed the extensions of the three aquifers in the study area.

1- Upper Aquifer:

The upper aquifer depends on the water table. It starts at depth of about 20 m in the northwestern parts to about 100 m in the southern areas (Figs. 8 and 11) respectively.

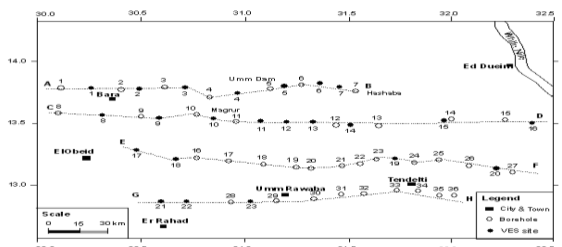

Figure 3 : A map showing geoelectric sections in the area

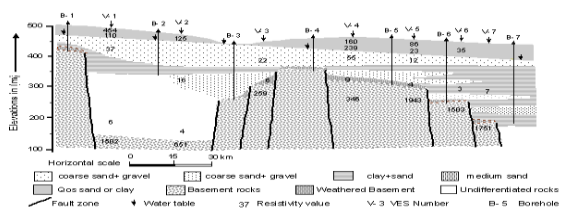

Figure 4: Geoelectric section A - B

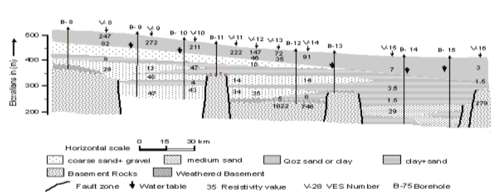

Figure 5 : Geoelectric section C - D

EDITORIAL

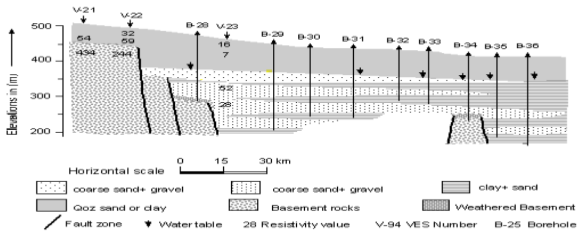

Figure 7: Geoelectric section G - H

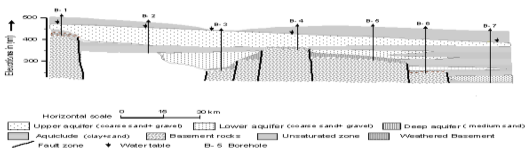

Figure 8: Geological section a - b

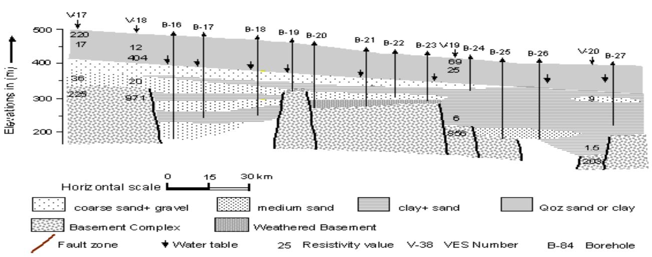

Figure 6: Geoelectric section E - F

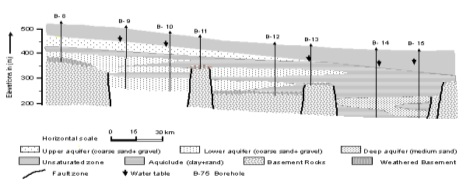

Figure 9: Geological section c - d

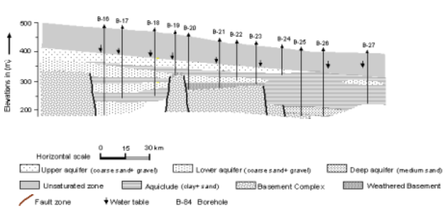

Figure 10: Geological section e - f

EDITORIAL

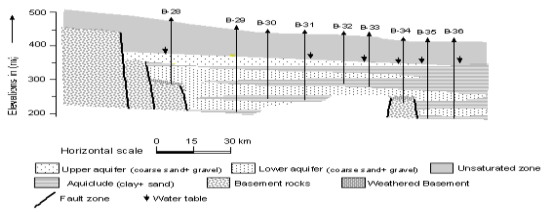

Figure 11: Geological section g -h

The thickness of this aquifer varying from about 80 m as in Umm Balagei borehole (B.H-3 –Fig.8) to less than 10 m as in El Kero borehole (B.H-12 - Fig. 9). The upper aquifer is made up of upper parts of the Umm Rawaba Formation and lower parts of the Qoz sands. It is mainly consists of sand and granule. This aquifer shows a thinning in its thickness south and southeastwards. 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 to the upper aquifer. That means the upper aquifer occurs under free water table condition. The aquifer is separated from the lower aquifer by aquiclude layers. The thickness of these layers varying from about 25 m to 5 m (Figs. 8 and 11).

2- Lower Aquifer:

The upper surface of this aquifer is varying from 80 m as in Umm Balagi borehole (B.H-3 - Fig. 8) to about 140 m in Umm Sareiha borehole (B.H-28 - Fig. 11). The lower aquifer is a multilayered system which is composed of coarse sands and gravels as in the upper aquifer. It is difficult to determine the total thickness of the lower aquifer. This is because no borehole penetrating the total thickness of the aquifer. The lower aquifer lies under confining conditions as in Umm Balagei flow well to semi- confining conditions in other places where it is found to be in direct

contact with the upper aquifer. Umm Balagi well as a second artesian flowing phenomenon in the Sudan penetrating the lower aquifer (El Boushi et al. 1974). The system of the lower aquifer is characterized by a discontinuity due to an existence of Basement rocks in form of horst structures separate the sub basins in the area. Regionally it extends in the most parts of the study area.

EDITORIAL

3- **Deep Aquifer:**

The deep aquifer located in the Kosti Basin in rather deep depths. This aquifer starts at depth of 190 m (B.H-26 - Fig. 10). The thickness of this aquifer ranges from 25 to 60 m (Fig. 9). It is mainly composed of medium sand. The sand is rounded to sub rounded, well sorted and colorless. The depth to the water table of the aquifer decreases eastwards from more than 6o m to less than 45 m (Figs. 9 and 10). It seems that the deep aquifer occurs under confined condition due to an existence of thick clay layer which overlaying the aquifer system. Previous studies e.g. El Tayeb (2000) were believed that, the deep aquifer is a part of the lower aquifer, but the mode of occurrence, rock type and hydraulic condition indicated that the aquifer represents a hydrogeological unit differs from the lower aquifer.

CONCLUSIONS

This study was aided by Vertical Electrical Soundings (VES) data and boreholes information. The integration between the geological and geophysical interpretations showed that, the depths, thicknesses and regional extensions of the aquifers in the study area. The final results of the study indicated, that the area involves three water bearing formations: upper aquifer, lower aquifer and deep aquifer. The upper and lower aquifers locate in Bara Basin and west Kosti Basin whereas the deep aquifer locates in Kosti Basin.

The upper aquifer starts from 20 m in the northwestern parts to about 100 m in the southern parts. The lower aquifer is a multilayered system which is separated by aquiclude layers consist of clay and sand. It is composed of coarse sand and granule as in the upper aquifer.

The deep aquifer is recorded in Kosti Basin only. It starts at depths of about 190 m. This aquifer is made up of medium sand. The thickness of this aquifer ranges from 20 to 60 m. The geological and hydrogeological results of this study indicated that the deep aquifer is not a part of the lower aquifer as believed previously.

EDITORIAL

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EDITORIAL

الملخص

أُجريت هذه الدراسة لتحديد التكوينات الحاملة للمياه الجوفية (خزانات) في منطقه شمال كردفان وغرب النيل الأبيض وذلك بإستخدام طريقه السبر الكهربي الرأسي ومعلومات الآبار في منطقة الدراسة. دلت نتائج الدراسة على تواجد ثلاثة خزانات للمياه تشمل خزان علوي وخزان سفلي وخزان عميق. يقع كل من الخزان السفلي والخزان العلوي ضمن حوض بارا الجوفي بينما يقع الخزان العميق في حوض كوستي الجوفي. يصل سمك كل من الخزانين السفلي والعلوي معاً إلي حوالي 150 متراً كما في منطقه أم بالجي بينما يتراوح سمك الخزان العميق من 20 إلى 60 متراً. يتكون الخزان العلوي والخزان السفلي من أنواع صخريه متشابهة من الحصى والرمل الخشن الحبيبات بينما يتكون الخزان العميق من الرمل المتوسط الحبيبات. يتراوح عمق مستوى المياه الثابت في منطقه الدراسة من حوالي 20 متراً في الأجزاء الشمالية الغربية إلى 100 متراً في الأجزاء الجنوبية. أكدت هذه الدراسة اعتماداً على كل من طبيعة التواجد ونوعيه الصخور والخواص الهيدروليكية أن الخزان العميق لا يمثل امتداداً للخزان الاسفل كما كان يُعتقد سابقاً.