Geoelectric Soundings and Hydrochemical Investigations for Groundwater Potential West of the Nile River, Assiut, Egypt*

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Abstract

Surface geophysical investigations, in addition to hydrochemical measurements were made on some locations at the western part of the River Nile, Assiut. All the geoelectrical sounding measurements were made using the D.C. resistivity method. The geophysical results were integrated with all available geological and hydrogeological information in order to recognize the probability of presence of water-bearing formations, either fresh (low resistivity) or polluted (extremely low resistivity). Two conductive wet zones (shallow and/or deep) were detected. Also, two extremely high resistive zones can be recognized; the first represents the surface dry zone (consisting of dry sands and gravels), whereas the second is deeper in the entire surveyed area and may represent the bed rock (e.g. limestone). Only one extremely conductive zone (< 20 Ohm-m) especially near and at the cultivated land in El-Madabigh and Beni-Adi is present, which may correspond to clayey sediments or a polluted zone. The hydrochemical data show that the salinity decreases along the regional direction of the groundwater flow and also along the sewage water movement in the irrigation canals.

Introduction

Groundwater in Assiut Governorate has a particular importance where it is the second source for fresh water used for drinking, agricultural, domestic, and industrial purposes. The surveyed area is located at the western bank of the River Nile of Assiut Governorate. The whole area is bordered from the west by the Eocene limestone plateau and from the east by the River Nile (Figure 1). The area as a part of southern Egypt is characterized by predominance of dry and hot climatic conditions (low precipitation, high temperature and high evaporation rates). This hot climate leads to a scarcity of natural water supplies, a very necessary natural resource for planning and environmental control in such dry regions.

Geophysical methods represent a significant and important role in the search for water-bearing layers, fresh or polluted. In this study geoelectrical data were collected and reexamined from published studies carried out by the present authors and others (e.g. Ibrahim, 1990; Ebraheem, 1998; Ibrahim et al., 1998; Shaker, 1999; El-Hussaini et al., 2003; El.Tahlawi, 2014) on different parts west of Assiut Governorate.

The main problem in the study area is the presence of multiple sources of pollution, particularly that arise from the sewage station west of Assiut City, in addition to agricultural and industrial activities. The present study aims at obtaining more valuable information about the distribution of water-bearing zones, either fresh or polluted.

Geology and Hydrogeology

The surveyed area is simply a plain covered by Recent Nile deposits (e.g. gravels, sands, silts and clays). These Quaternary deposits, about 90-150 m thick, lay over the eroded Eocene formation (bed rock). Structurally, the faulting and folding are the major deformational features affecting the studied area as a whole. More details about the geology and structure of the area were given by many authors (e.g. Said, 1962 and 1990; Omara et al., 1970; Osman, 1980; Mansour and Philobos, 1983). Different hydrogeological, environmental and social studies were made by many authors (e.g. Wahaab and Badawy, 2004; Dawoud and Ewea, 2009; Aldar, 2011; El.Tahlawi, 2014) in many parts west of the Nile River, including the Assiut Nile Basin. The groundwater conditions in the area as a part of the Nile Basin west of Assiut Governorate is directly controlled by the Nile River, as well as by irrigation and drainage systems of the cultivated lands, especially in the low-laying areas.

Methodology

Geoelectric Data

In the present work geoelectrical data (71 VES-es) were collected and reexamined from the published studies made by the present authors and others (e.g. Ibrahim, 1990; Ebraheem, 1998; Ibrahim et al., 1998; Shaker, 1999; El-Hussaini et al., 2003; El.Tahlawi, 2014) on three areas west of Assiut (Figure 2, Figure 3, and Figure 4). The Vertical Electric Soundings (VES-es) were made by the ABEM-Terrameter SAS 300C and applying Schlumberger configuration. The maximum current electrode spacing (AB/2) reached 900 m, depending on the topographic accessibility in each surveyed area. Some of these VES data (17) were used to construct three subsurface geoelectric cross-sections covering the three studied areas. Valuable data from all interpreted VES-curves (71) about the distribution of resistivity values below the ground surface were used to construct a map of pollution for the entire investigated area.

Hydrochemical Data

In developing countries, fresh groundwater resources have become increasingly scarce, especially in dry and densely populated regions, partly due to the growing population and in part due to the effect of pollution of the near surface aquifers by municipal wastes, industry and intense farming. Therefore, hydrochemical studies and geoelectric resistivity investigations were carried out at different parts in the area west of Assiut. Some studies were made on parts representing cultivated lands, such as west of Assiut City and others representing desert areas such as Beni-Adi and El-Qussiya.

Groundwater samples (14) were collected from different drilled wells and digs in all studied areas lying west of Assiut. These samples were hydrochemically analyzed for major cations and ions (Table 1).

Results and Discussion

Geoelectric Data

All VES-curves were interpreted by the available software programs (Zohdy and Bischorf, 1989b, and IPI2win Software, 2001). The VES-stations 3 and 4 were measured near well No. 4 (west of Assiut City) to determine as closely as possible the true resistivity range of different subsurface geoelectric layers. Comparing results, the authors noticed more conformation between drilling data (from well 4) and geophysical data (VES 3 and 4) obtained only from Zohdy and Bischorf, 1989b (Figure 5 and Table 2).

Table 2 and Figure 5 identify the differences between the vertical distribution of the measured resistivities at the VES-stations 3 and 4. At VES station 4, the observed resistivity values are generally low, even in deep layers, which may indicate low-resistivity formations saturated with polluted water of high salinity, while at VES-station 3, the resistivity values are generally high, particularly, at deeper horizons which may indicate non-polluted formation (possibly a freshwater-bearing zone).

The results of interpreted sounding curves provided useful information about the possibilities of fresh water occurrences and the distribution of polluted zones below the ground surface, especially in cultivated lands (Figure 6, Figure 7, and Figure 8). Low resistivity values in certain locations may be interpreted as water-bearing zones, but in certain cases it is possibly due to shaly or clayey sediments which is very common west of Assiut Governorate. Extremely low resistivity material in certain locations, such as west of Assiut City, may be due to the presence of polluted zones which result from the sewage station.

Hydrochemical Data

The hydrochemical analyses for some collected water samples in the area (Table 1), showed the presence of many dissolved salts of high concentrations, especially in cultivated lands (e.g. west of Assiut City). The determined TDS values indicated that the area is polluted at different sites and depths in different degrees. Generally, the salinity decreases along the regional direction of the groundwater flow and also along the sewage water movement in the irrigation canals. The effect of pollution is arising from the sewage station west of Assiut City, but decreases to the north.

The obtained results identified presence of a shallow surface major polluted body in the entire area. The deep polluted zones are extending vertically down in certain locations (Figure 9).

Conclusions and Recommendations

The results obtained from the critical discussion of both geoelectrical and hydrochemical data on the area west of Assiut Governorate were integrated to determine the possibility of groundwater occurrences and its type (fresh and/or polluted). The main conclusions reached from this study can be summarized briefly as:

1) The area around west of Assiut City represents an enormous and intensely polluted area, particularly the shallow zones. The principal source of the pollution throughout this area is the sewage station there which is draining into canals used by villagers for different irrigation purposes. Other polluted sources are by human activities and fertilizers used by villagers.

2) Another polluted (deep) zone is detected; the possible source of its pollution is the effect of the overlying one. This zone is nearly absent, or present as lamina toward the northern parts (El-Qussiya).

3) Generally, the degree of pollution increases toward the south, (towards the area of the sewage station), also towards the east where population is dense.

4) The area in the northwestern part is the least polluted area detected throughout this study.

5) It is recommended that when new wells are being drilled, it is very important to reach depths more than 100 m to avoid the effect of pollution.

6) Tertiary treatment is highly recommended to remove impurities from sewage water, and fresh water for drinking must be available for people in the area west of Assiut Governorate.

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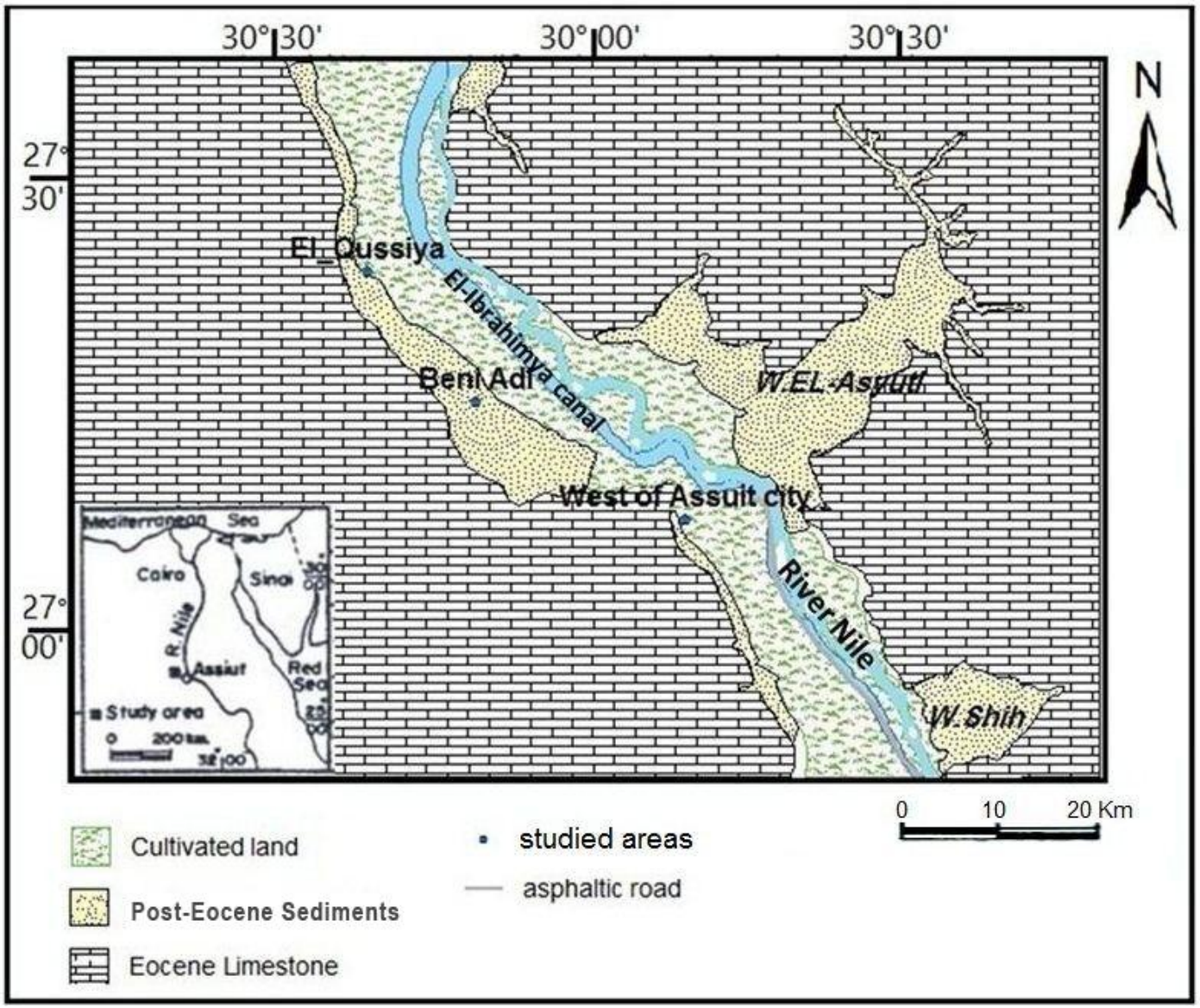

Figure 1. Simplified geological map and locations of the studied areas West of Assiut governorate (modified after Mansour and Philobbos, 1983).

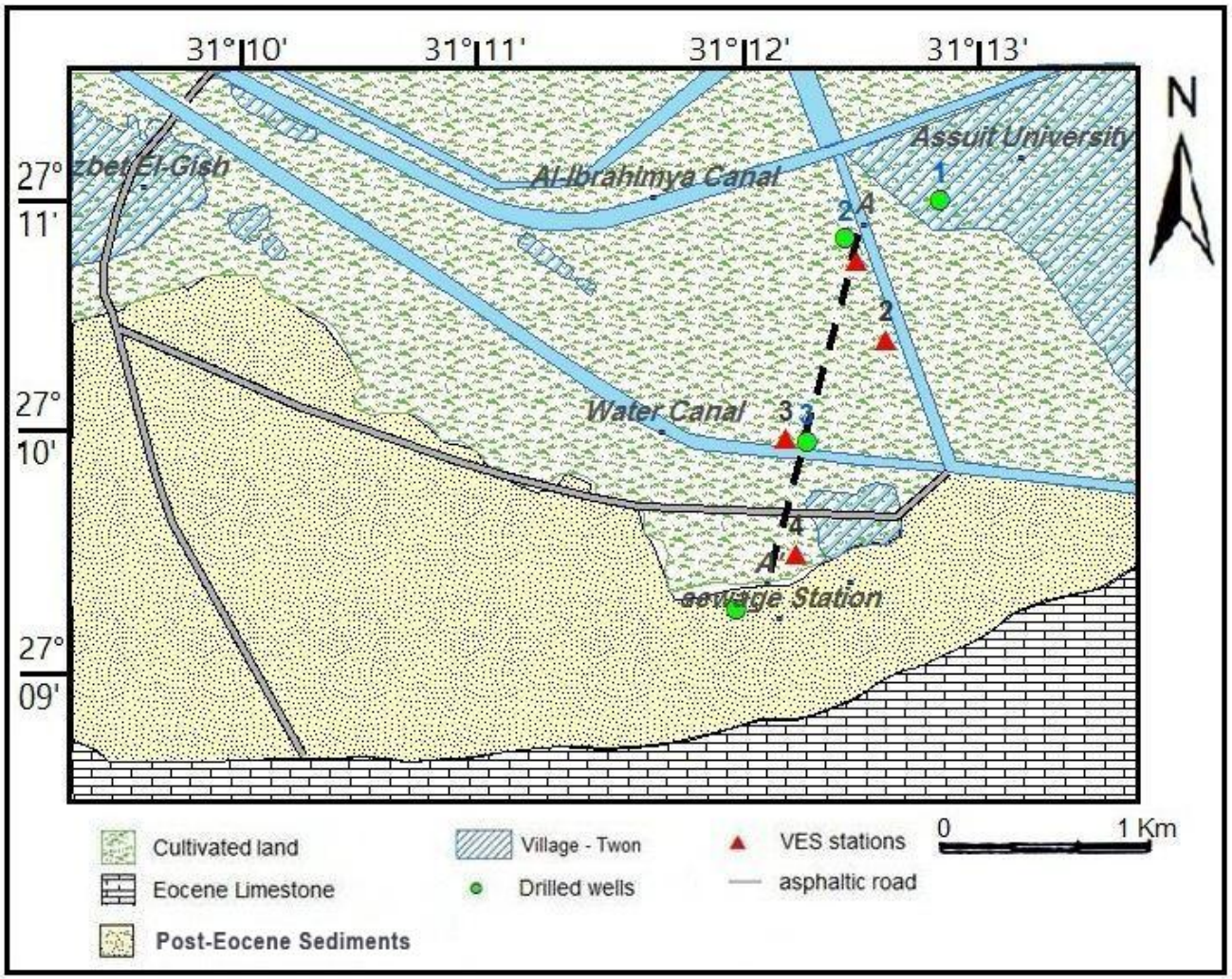

Figure 2. Location map showing the measured VES-stations, drilled wells and the studied profile west of Assiut City.

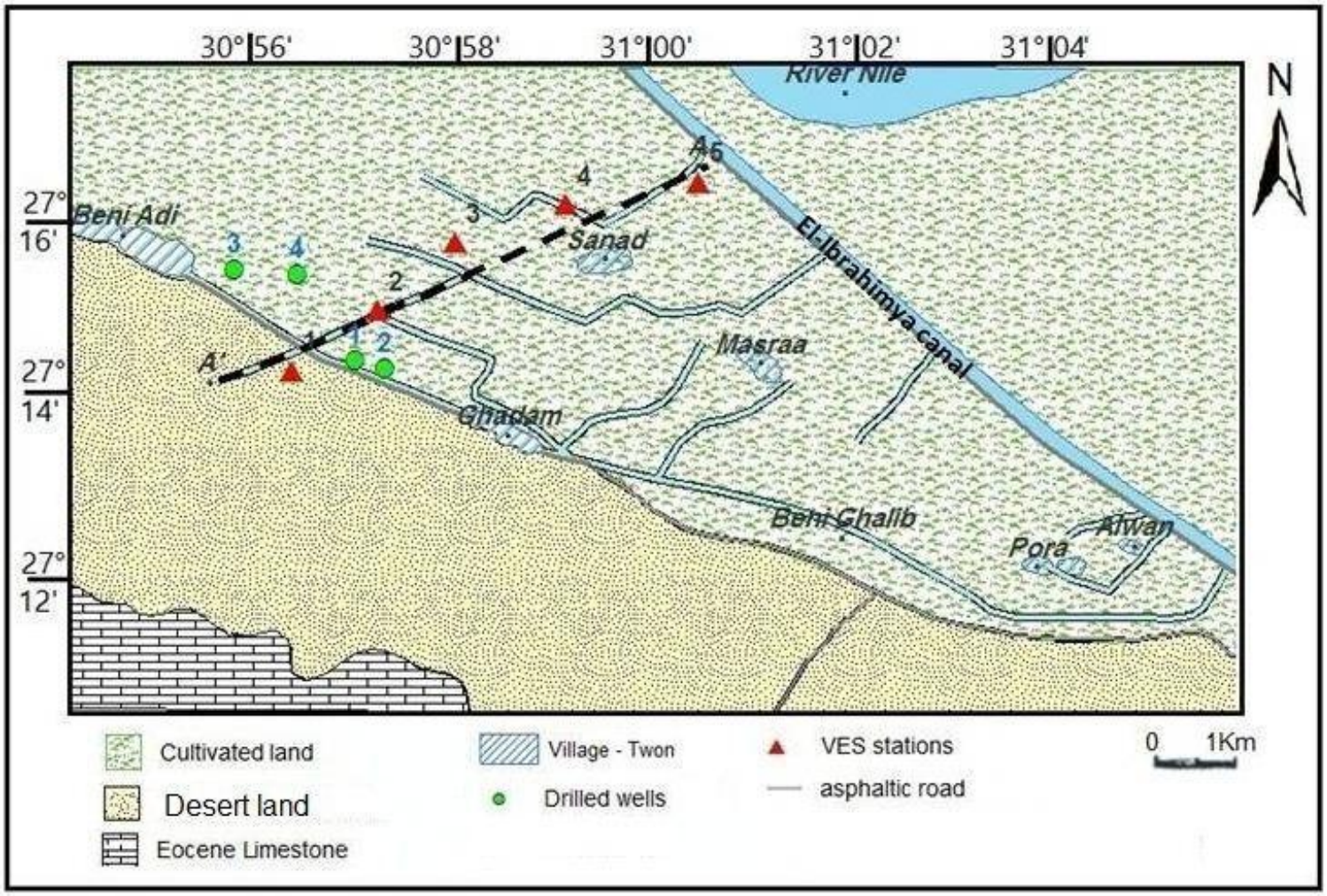

Figure 3. Location map showing the measured VES-stations, drilled wells and the studied profile in Beni Adi.

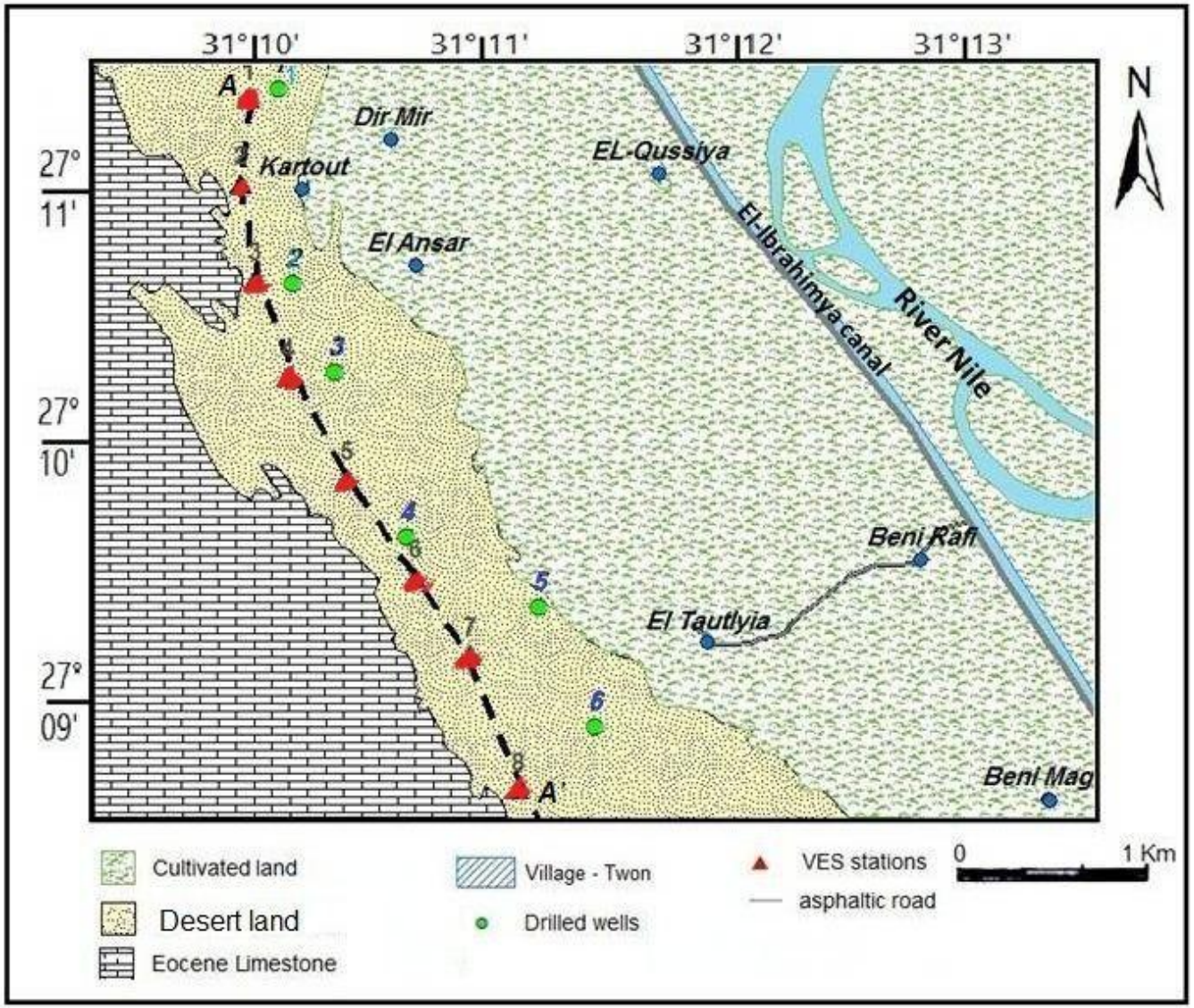

Figure 4. Location map showing the measured VES-stations, drilled wells and the studied profile in El-Qussiya.

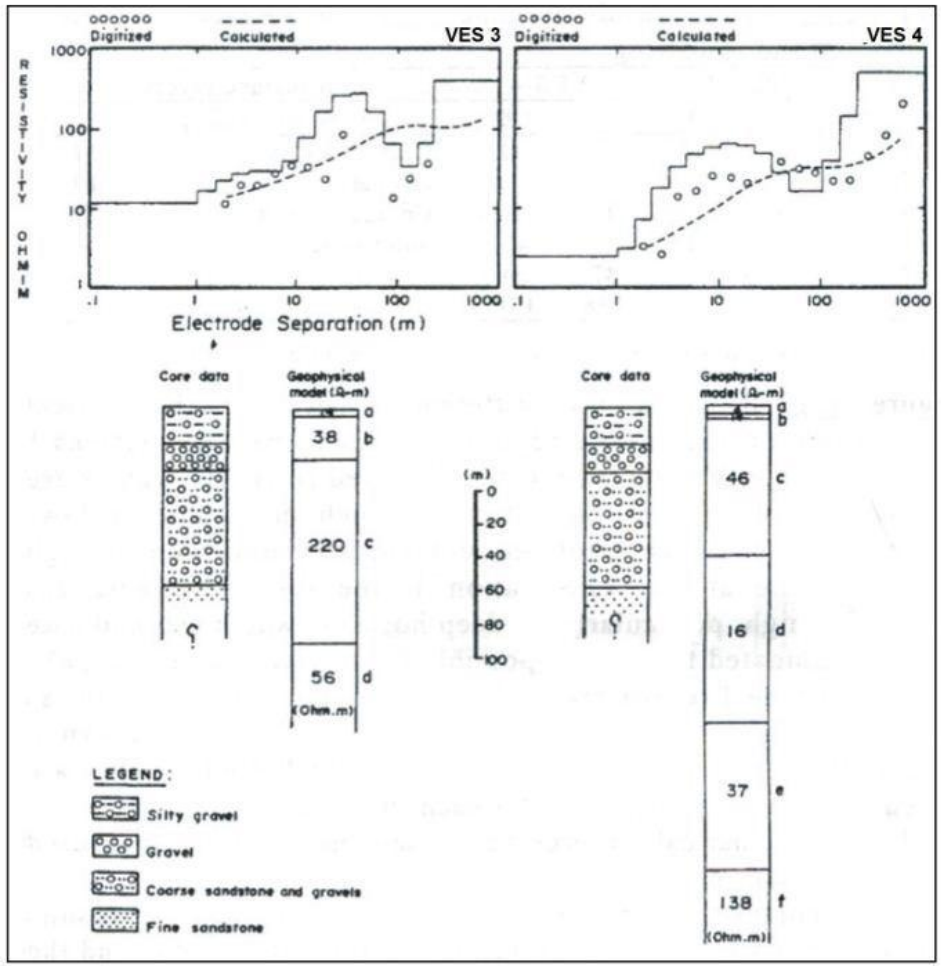

Figure 5. Correlation between results of VES-curves (3 and 4) and the drilling data in Well No. 4 west of Assiut City.

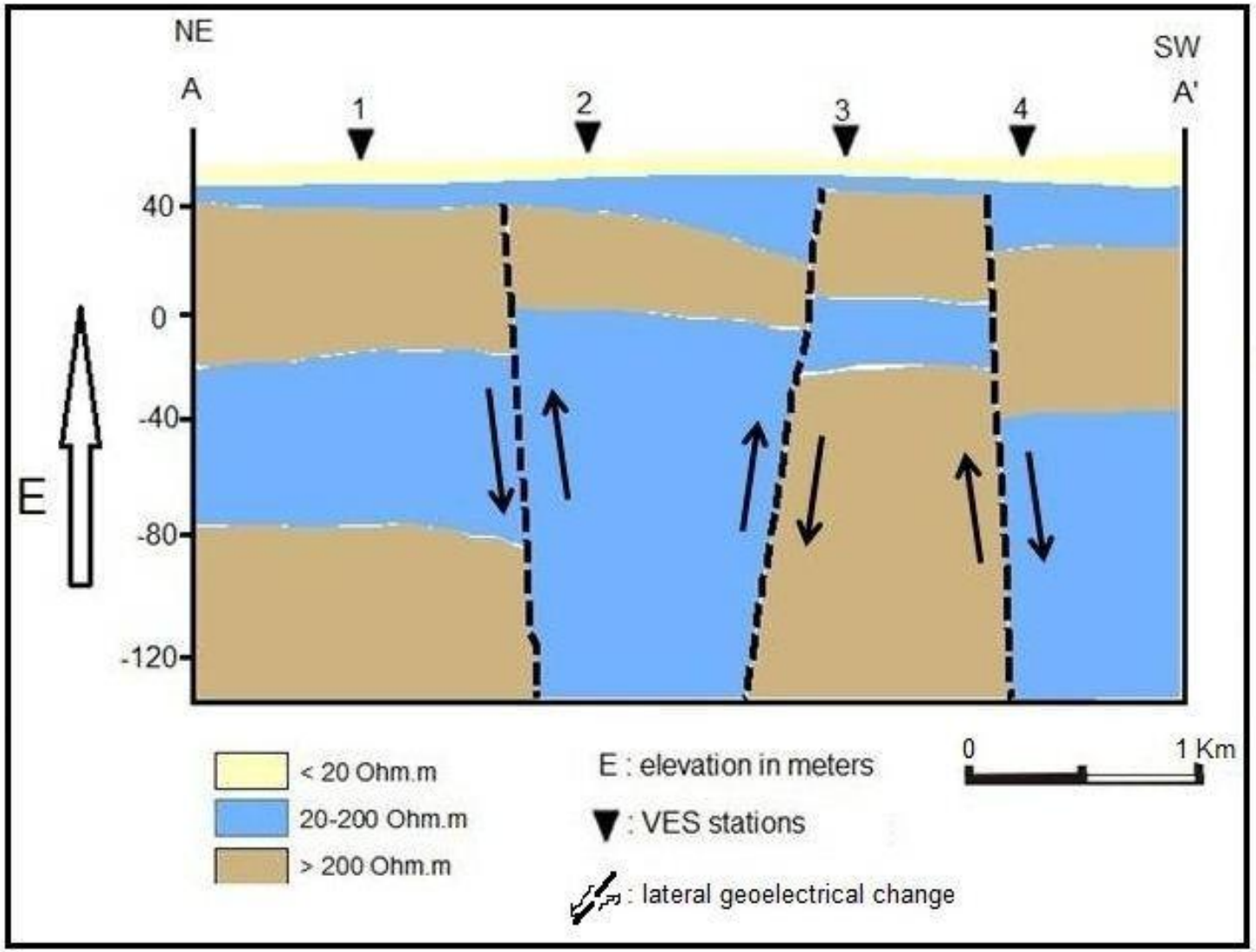

Figure 6. Subsurface geoelectric cross section west of Assiut City.

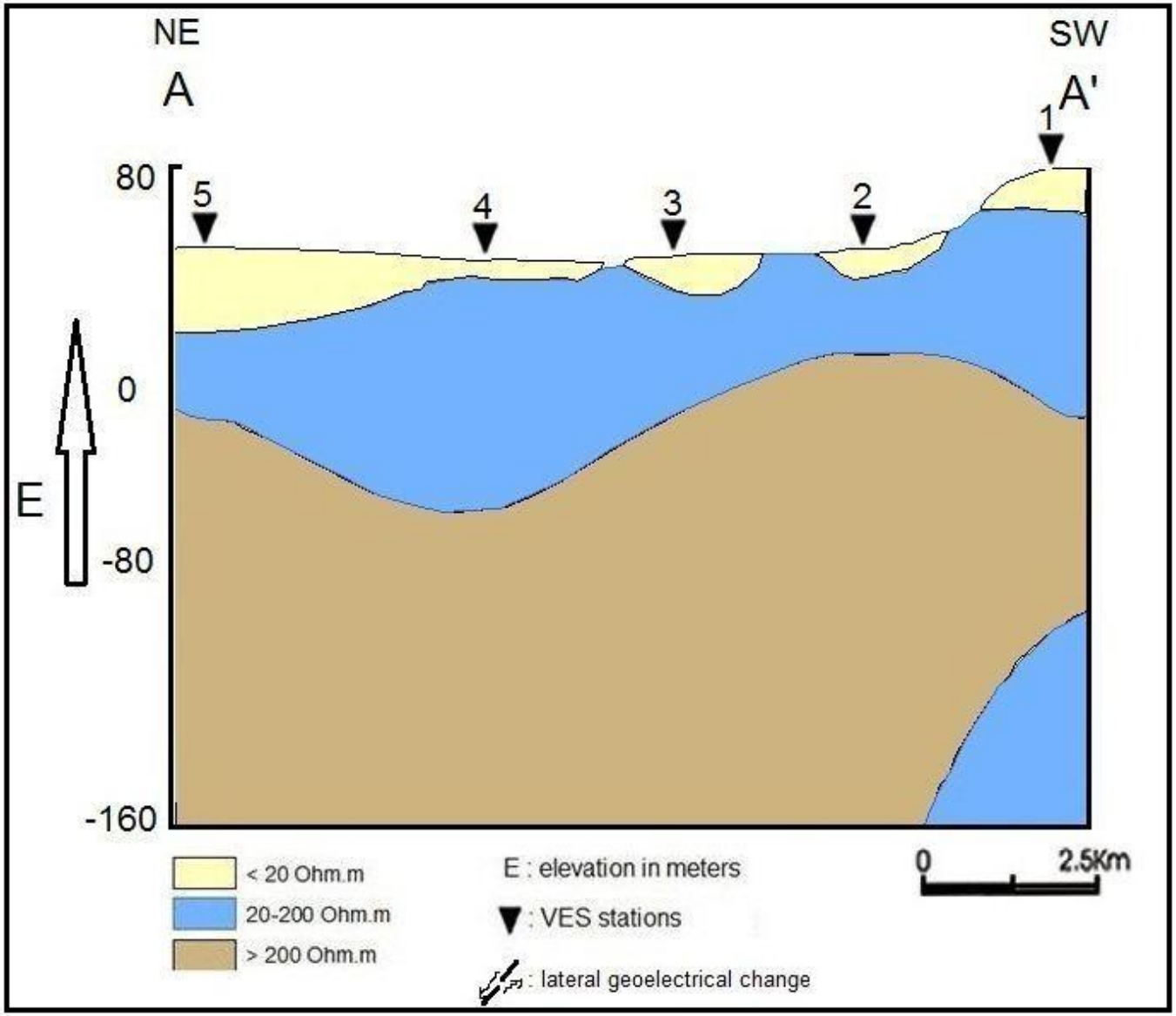

Figure 7. Subsurface geoelectric cross section in Beni Adi.

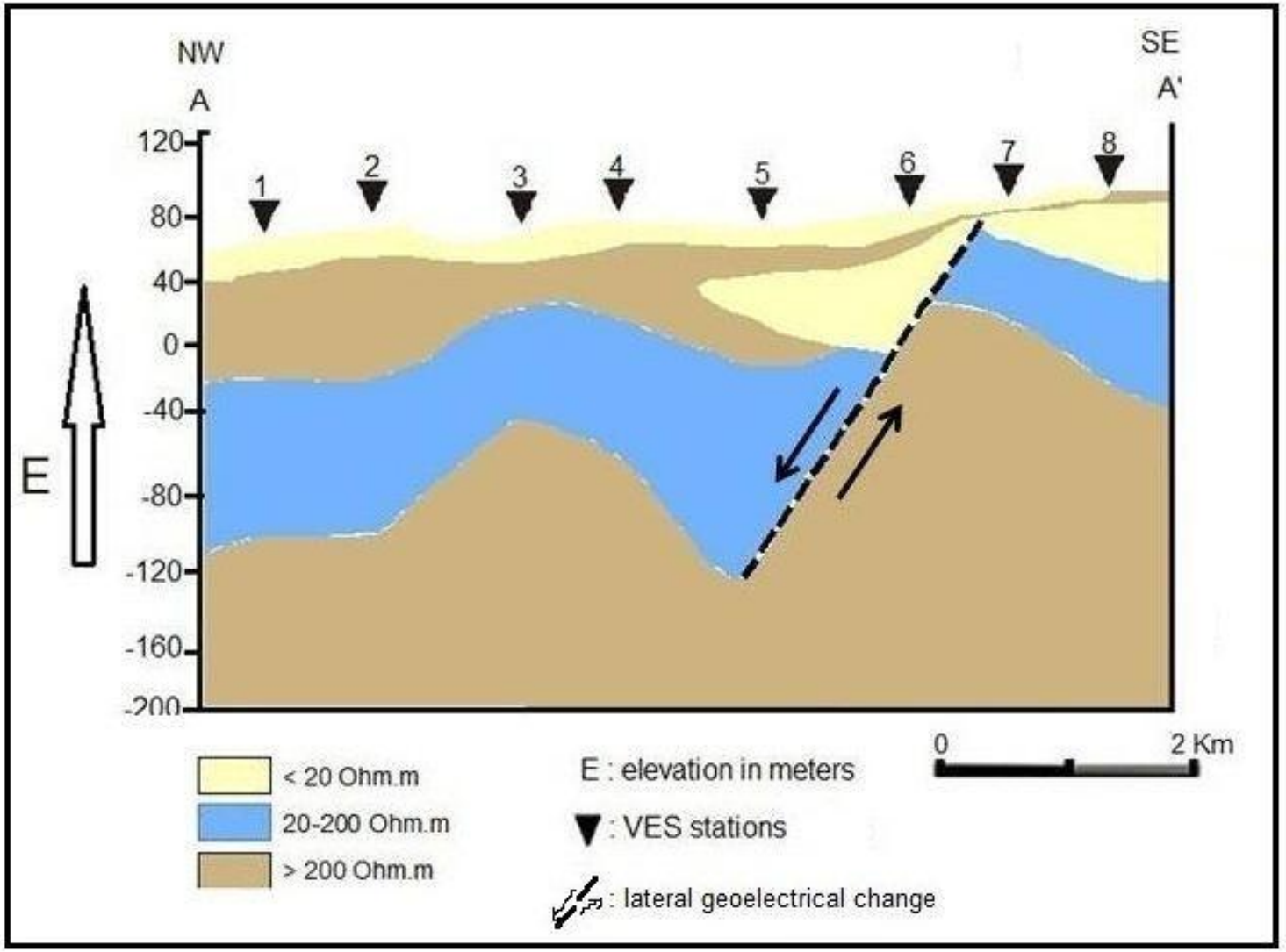

Figure 8. Subsurface geoelectric cross section in El-Qussiya.

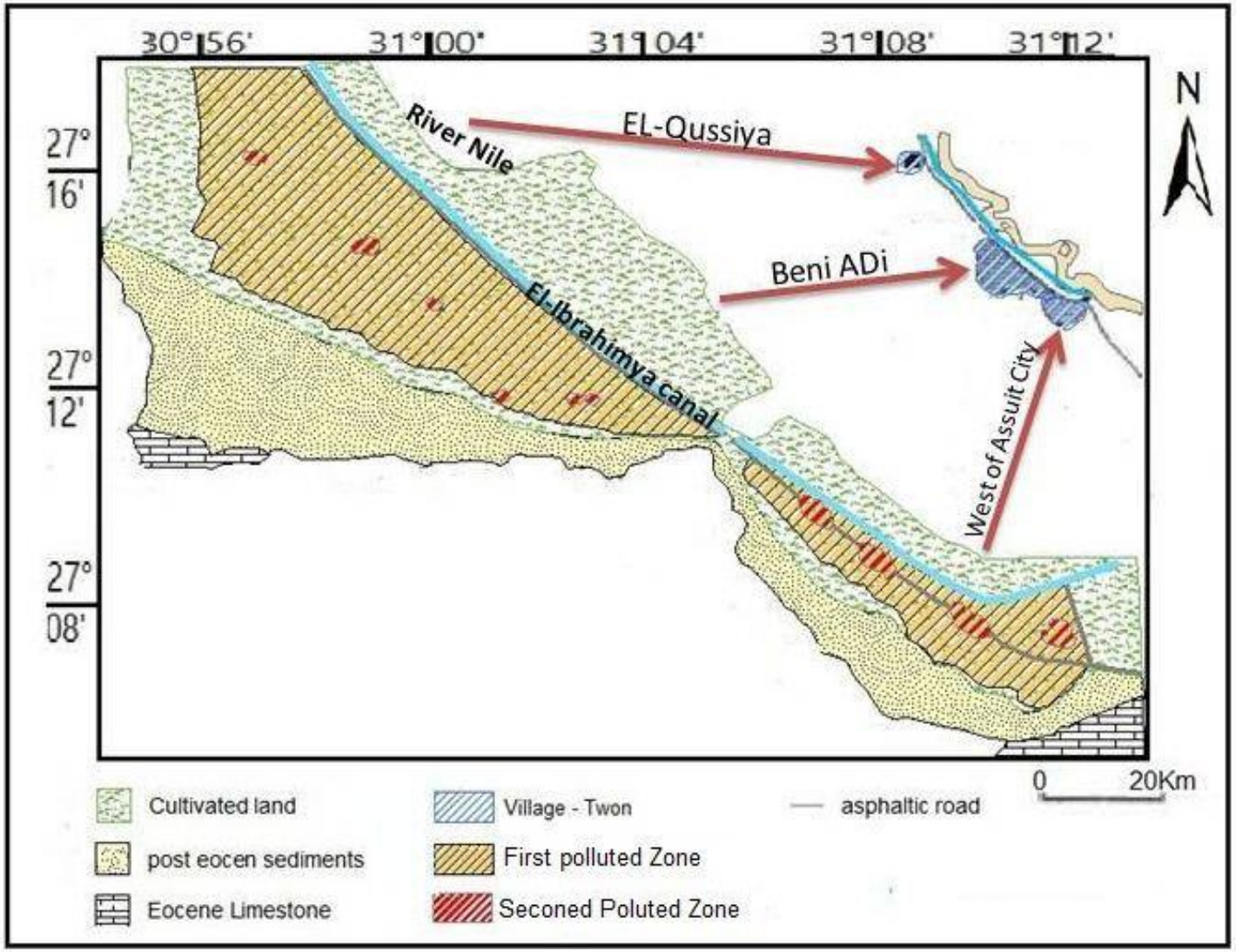

Figure 9. Map showing the distribution of polluted zones (shallow and deep) in the western bank of El-Abrahmia canal, Assiut.

Area	Well No.	pH	E.C $\mu S/cm$	TDS (ppm)	Cations (epm)				Anions (epm)		
					Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}
West of Assiut	1	7.8	219	1401	2.82	13.23	4.34	0.54	2.42	8.55	9.96
	2	8.3	147	940	1.21	6.83	4.78	0.28	6.94	3.32	1.46
	3	7.9	178	1139	2.01	10.45	3.91	0.38	3.82	3.32	9.61
	4	6.9	82	524	2.21	3.68	2.39	0.6	3.12	2.09	3.67
Beni-Adi	1	7.8	443	281	3.22	8.83	30.34	0.51	1.74	0.9	6.02
	2	7.6	450	2880	3.83	9.57	30.81	0.51	3.12	19.4	22.18
	3	8.4	240	1536	0.61	3.66	16.5	0.23	0.94	3.32	10.76
	4	7.9	59	348	2.4	1.6	1.26	0.18	4.51	0.38	0.56
El-Qusaiy	1	7.6	710	4540	0.35	0.24	1.73	0.15	3.82	1.33	1.95
	2	7.5	1470	941	0.5	0.5	9.56	0.12	4.17	3.35	7.18
	3	7.04	570	339	2.2	3.6	3.0	0.1	4.1	3.1	0.6
	4	7.28	1810	1158	0.57	0.57	12.17	0.07	4.17	3.67	10.26
	5	7.28	564	290	2.96	1.98	0.74	0.05	4.41	0.75	0.77
	6	7.44	2285	1462	3.6	7.4	23.9	0.1	3.4	19.0	9

E.C: Electrical conductivity **TDS : Total dissolved salt**

Table 1. Results of hydrochemical analyses of collected water samples.

Zone	VES-3		VES-4		Sedimentary layer	D
	ρ	D	ρ	D		
a	14	G.S	4	G.S	Clay or silts	11
b	33	1.5	14	2	Gravels	19
c	220	16	46	2.9	Coarse S.S and Gravels	55
d	56	72	16	43.9	Sandstone	60
e	-	-	37	94.6	-	-
f	-	-	138	138.9	-	-

ρ (Resistivity in Ohm.m); D (depth in m.); GS (ground surface)

Table 2. Expected subsurface layers in the area west of Assiut City.