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EVALUATION OF SOIL AND WATER RESOURCES IN WADI WARDAN, SINAI, EGYPT, USING ELECTRICAL RESISTIVITY METHOD

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ABSTRACT

A number of 15 Vertical Electrical Soundings were carried out in the Delta of Wadi Wardan, on the western coastal zone of Sinai, about 55 km south of Suez. The study objectives were to find out the change in thickness of the soil cover in depth to water table across the area where ground is the only usable source of water for any agricultural project. The soil was found to vary in thickness from 0.5 to 2.2 m while the water table was found to lie at a depth of 6.5 to 10.5 m below the surface. Quantitative points out to the possibility that the shallow succession in the area is structurally controlled by a normal NE-SW fault affecting both the soil and the bearing formation in such a way that they become thick in the southern part of the area. The soil thickness map and depth to water table map prepared from this study can be of much help in planning water well drilling and land use programs. More emphasis, however, should be put on the southern part of the area as to its relatively higher soil and water potentials.

INTRODUCTION

Sinai Peninsula has received an increasing importance during the last decade as to the possibility of locating new agricultural lands to meet the ever increasing needs of the population. Soil and water resources have, consequently, become the focus of many research projects in different parts of the peninsula. The present study deals mainly with the soil and ground water resources in the Delta of Wadi Wardan (on Sinai West coast) with two main objectives : The thickness of the soil cover and depth to water table across the area. The method of electrical resistivity was used as it has been successfully applied in similar localities to locate geologic or hydrologic boundaries (e.g. Bayoumi and Sayed 1972 and Sayed 1984).

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Location

The Delta of Wadi Wardan lies directly to the south of Ras Sudr on the eastern coast of the Gulf of Suez at about 55 kilometers south of Suez (Fig. 1). It is bounded from the east by a Table Land, known locally as the Mountaneous Plateau and on the west by the Gulf Water. It covers an area of about 45 square kilometers.

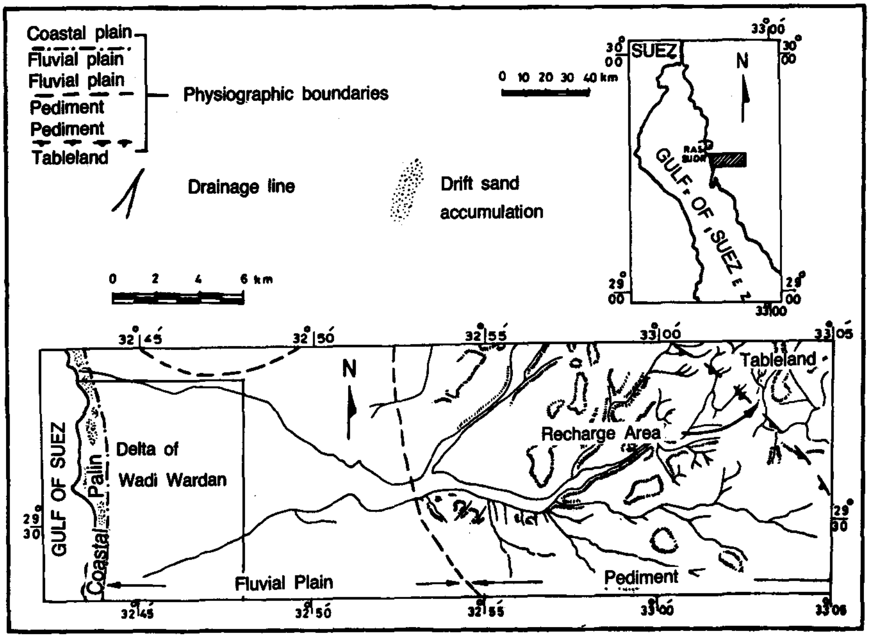

Figure 1. A map showing location and physiography of the area.

Geomophologic and Geologic Features

The area occupies mainly the Flood plain, one of the 4 main geomorphologic units recognized in the region.The surface is almost flat where ground elevation rtanges, on the average, from 20 to 25 meters above sea level. To the east of Wadi Wardan, the Plateau Region rises to about 600 meters and is dissected on its western slopes by several dry vallies that drain winter runoff westward. Between the Flood Plain and the Mountaineous Plateau lies the Piedment Plain. On the extreme west, the coastal plain extends parallel to the Gulf Coast in the form of narrow belt of drift sands and small scattered sand dunes. The plateau is covered mainly with the Neogene calcareous rocks, the Piedment plain is covered with the Miocene marine deposits while both the

Flood Plain and the coastal Plain are covered with Recent deposits in the form of coarse sand and gravel upstream and loam and sand downstream. The shallow subsurface succession consists mainly of Pliocene and Pleistocene gravel, sand and clay.

Hydrolic Features.

Annual rainfall on the area is about 20 mm on the coastal side and goes up to 50 - 70 mm on the eastern side close to the high land. The Table Land is the main recharge area for the shallow aquifer. Few showers in winter time activate the dry steep valleys running across the western slopes of the Table Land. Water drains down to the Flood Plain where it partly evaporates and partly percolates to the water table.

The aquifer is formed mainly of sand and gravel under free condition. The lower confining bed is the Pliocene clay which separates, in most cases, the fresh water aquifer from the underlying sea water-saturated zone.

FIELD MEASUREMENTS

The method used in conducting field measurements is the Direct Current Electrical Resistivity Sounding using Schlumberger electrode configuration. In this method a measured direct current 'I' is applied to the ground surface through two current electrodes separated by a distance "L". The potential difference 'ΔV' is then measured through two inner electrodes separated by a distance 'I' apart where 1 is usually L/4 to L/10. The four electrodes are placed along a straight line parallel to bed strike in the area where the measuring points lies at the middle of that line. Increasing the electrode spacing symmetrically with respect to the measuring point means increasing the depth of investigation at that point. The electrical resistivity for a given electrode spacing is calculated by the formula.

$$\rho a = \frac{\pi}{4} \left(\frac{L^2-1^2}{1}\right) \frac{\Delta V}{1}$$

where ρa is the apparent resistivity in Ohm. m. A plot of the apparent resistivity against half the electrodes spacing (L/2) gives a Vertical Electrical Sounding (VES) curve. By applying any of the known interpretation methods, such curve is tranformed into a vertical geoelectric section indicating the number of layers encountered at the measuring point, their depths thickness and resistivitis.

The method has been applied to 15 locations in the Delta of Wadi Wardan as shown in Fig. 2, forming a grid pattern with a grid spacing of about 2 kilometers. The density of the measuring points is about 1 VES station for each 3 square kilometers which is considered to be fairly reasonable regarding the physiographic nature of the area, the required level of investigation and costs. The resistivity survey is not extended closer to the Gulf shore line due to the presence of scattered sand accumulations and the highly conductive saline surface deposits which renders the field measurements difficult. The minimum current electrode spacing was one meter and the maximum ranged from 200 to 300 m depending on local limiting factors. Measurements of both the current and potential were made by means of the "Electronic compensator SK-1" using dry batteries as a power source.

INTERPRETATION AND DISCUSSION OF RESULTS

The interpretation method used here is a numerical one based on the inversion of Schulmberger electrical sounding curves into layer thickness and resistivities using the interaction method described by Zohdy, 1974. Calculations are carried out using the FORTRAN IV Computer Program desired By Zhody 1973. Use was made of the computer "I.B.M. 4341 CMS operating System". The method has the advantage over the other methods that it saves much time and more accurate results, moreover it cares of the effect of the Principle of Equivalence, which means the presence of more than one possible geo-electric section model for the same VES curve with different combinations of layer thickness and resistivities.

The interpretation output is summarised in Table 1 in the form of depth to bottom, thickness and resistivity of each layer encountered at each of the 15 VES stations. The table shows that the shallow succession in the area is represented by either a three-layer case, as for VES 8, or 4-layer case for the other 14 VES stations. The resistivity inter-relationship for each of the soundings is illustrated in Table 2.

The identify the members of the geo-electric succession, correlation of the geophysical results was carried out with the geologic and hydrologic data making use of the following.

1. Regional geology and hydrology known about the western coast of Sinai.
2. Local water depth measurements in some of the native wells in the area, which showed a depth to water table of 8-10 m.
3. The geo-electric-hydrologic succession concluded by Sayed 1984 (Table 3) for Wadi Sudr which lies directly to the north of Wadi Wardan. Both wadies are physiographically and geologically similar, whereas no lithologic sections were available for Wadi Wardan in particular.

Table 1
Results of quantitative interpretation of the VES curves.

VES No.	Geoelectric layer No.	Depth to Bottom m	THICKNESS m	Electrical resistivity Ohm.m.
1	1	0.5	0.5	1000
	2	3.4	2.9	111
	3	10	6.6	136
	4	∞	∞	7
2	1	0.6	0.6	650
	2	2.8	2.2	72
	3	9.5	6.7	31
	4	∞		3
3	1	0.8	0.8	400
	2	1.8	1.0	100
	3	10	8.2	81
	4	∞	∞	16
4	1	0.8	0.8	170
	2	2.8	2.0	57
	3	8.5	5.7	226
	4	∞	∞	15
5	1	1.0	1.0	95
	2	1.8	0.8	285
	3	8.0	6.2	142
	4	∞	∞	8
6	1	0.85	0.85	170
	2	4.0	3.15	43
	3	7.0	3.0	170
	4	∞	∞	23
7	1	1.0	1.0	650
	2	7.5	6.5	325
	3	22.0	14.5	185
	4	∞	∞	13
8	1	1.2	1.2	570
	2	6.5	5.3	30
	3	∞	∞	8

Table 1 Contd.

VES No.	Geoelectric layer No.	Depth to Bottom m	THICKNESS m	Electrical resistivity Ohm.m.
9	1	1.3	1.3	1500
	2	7.5	6.2	300
	3	24	16.5	129
	4	∞	∞	7
10	1	1.2	1.2	1000
	2	9.0	7.8	530
	3	21.0	12.0	160
	4	∞	∞	14
11	1	2.2	2.2	480
	2	8.5	6.3	69
	3	23.0	14.5	46
	4	∞	∞	2
12	1	1.6	1.6	950
	2	10.0	8.4	317
	3	24.0	14.0	106
	4	∞	∞	6
13	1	1.0	1.0	1500
	2	9.0	8.0	214
	3	21.0	12.0	143
	4	∞	∞	8
14	1	0.8	0.8	300
	2	10.5	9.7	246
	3	23.0	12.5	82
	4	∞	∞	15
15	1	1.2	1.2	350
	2	7.0	5.8	95
	3	20.0	13.0	65
	4	∞	∞	6

Table 2
Electrical resistivity inter-relationship at each of the sounding stations

Sounding Station	Layer resistivities
2,3,7,9,11,12, 13, 14 and 15	$\rho_1 > \rho_2 > \rho_3 > \rho_4$
1,4,6	$\rho_1 > \rho_2 > \rho_3 > \rho_4$
5	$\rho_1 > \rho_2 > \rho_3 > \rho_4$
8	$\rho_1 > \rho_2 > \rho_3$

Table 3
Geoelectric and hydrologic succession in the Delta of Wadi Sudr (after Sayed 1984)

Geoelectric layer	Dept to Top m	Thickness m	Rssistivity Ohm. m	Hydrologic horizon
Surface	0	1 - 2.5	50 - 1400	Soil zone
2	1 - 2.5	3 - 9.5	25 - 340	Aeration zone
3	4 - 10.5	12 - 20	18 - 120	Fresh water zone
4	21 - 27	∞	5 - 16	Saline water zone

The study of these data made it possible reaching to a conclusion about the general succession in the area (Table 4) including the soil thickness and depth to water in the form of the two maps shown in Figures 2 and 3. Explanation and discussion of each of these two maps are given next.

Table 4
Geoelectric succession in the Delta of Wadi Wardan

Geoelectric Layer	Depth to Top m.	Thickness m	Resistivity Ohm m.
Surface	0	.5 - 2.2	95 - 1500
2	0.5 - 2.2	0.8 - 9.7	30 - 530
3	1.8 - 10.5	3 - 16.5	31 - 226
4	7 - 24	∞	2 - 23

(I) Soil Thickness Map.

The soil zone is represented on the VES curves by the first geoelectric layer having a resistivity range of 95 to 1500 Ohm.m. The thickness of this zone as read on the interpretted geoelectric sections are mapped as shown in Fig. 2. The map reflects the following features.

(1) The thickness of the soil cover from 0.5 m to 2.2 m. The area is seen, however, to be divided into two distinct parts; part I in the north with a maximum thickness of 1.0m and part II in the south with a maximum thickness of 2.2 m.

(2) In part I, the change in soil thickness is rather slow, having a southward rate of increase of 0.13 m/km while in part II the thickness increases from both the north and the south towards the middle with rates of 0.5 m/km and 0.62 m/km respectively.

(3) Regarding the almost flat topography of the area, particularly the southern part, the bottom surface of the soil zone is seen to form a shallow elongated basin the deepest part of which lies in the middle of part II. The axis of this basin runs nearly in the east-west direction, i.e. parallel to the surface flow direction.

(4) The wide range of soil resistivity is mainly attributed to the change in its mechanical composition, as it is formed of alluvial deposits. Low resistivity is observed in places where fine soil fractions, and consequently high moisture holding capacity, dominate. Similarly places covered with coarse sand and gravel are observed to have higher resistivity values.

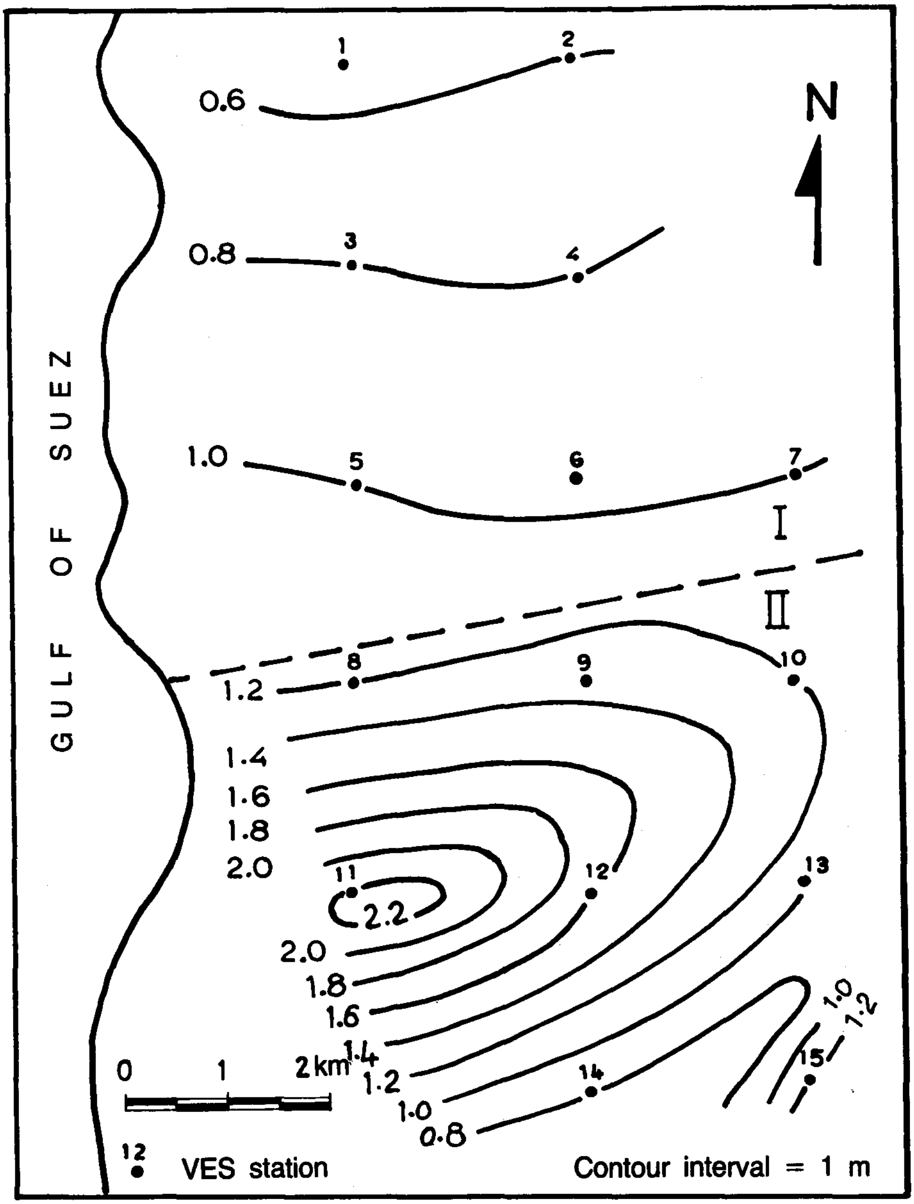

Figure 2. A map showing thickness of the soil.

(II) Depth to water Table Map

From the correlation of the obtained geoelectric sections with the other sorts of data, the water table in the area was found to be at a depth varying between 6.5 and 10.5 m below the ground surface as shown by the water depth map of Fig. 3. The water bearing formation is represented on VES 1,2,3,4,5,6, and 8 by the last geoelectric layer with a resistivity ranging from 3 to 23 Ohm.m which is lower than the expected value for a fresh water bearing formation as it lies close to resistivities of brackish water bearing sands or clay beds. On the other hand, the same formation corresponds to the third geoelectric layer on VES 7, 9, 10, 11, 12, 13, 14 and 15 with a resistivity ranging from 46 to 185 Ohm.m which represents well the resistivity range oif a fresh water bearing formation in the region. This divides te area into two parts, part I including VES 1, 2, 3, 4, 5, 6, and 8 and part II including the other VESes. A possible explanation for this situation is that the aquifer thickness in Part I of the area is so small (i.e. few meters) that the measured resistivity values are more affected by the presence of the underlaying lower confining clay bed and sea water saturated zone, both are higly conductive and can not be differentiated. In the same way the water bearing formation in Part II is regarded to be thick enough to be well identified on the VES curves. In Part II the lower confining bed has a resistivity bed range of 2-15 Ohm.m and lies at a depth of 20 to 24 m which is almost the depth to sea level in the area. This refers to the possibility that the water bearing formation in the area is structurally controlled in such a way that a normal. NE-SW fault exists at the boundary between Part I and Part II of the area with its downthrown side in Part II. This is schematically illustrated Fig. 4. Accurate location of such a fault on the surface, however, requires a more intensive electrical resistivity survey.

This interpretation fits also well with the pattern by which the thickness of the soil cover changes from Part I to Part II as Fig. 2 illustrates.

The two contour maps of Fig. 2 and Fig. 3 are helpfull in locating suitable spots for water and land use within the Delta of Wadi Wardan, while Fig. 3 provides a better understanding of the shallow subsurface succession including the free aquifer, confining clay bed and sea water intrusion in the area.

CONCLUSIONS

Electrical resistivity survey in the Delta of Wadi Wardan has revealed the pattern with which the thickness of the soil cover and the depth to water table vary across the area. The southern part of the area has been indicated to have more agricultural potential as to the thickness of both the soil zone and the fresh bearing formation as well as the quality of groundwater. Future planning for drilling water wells or land use can be directed according to the results reached to in this work.

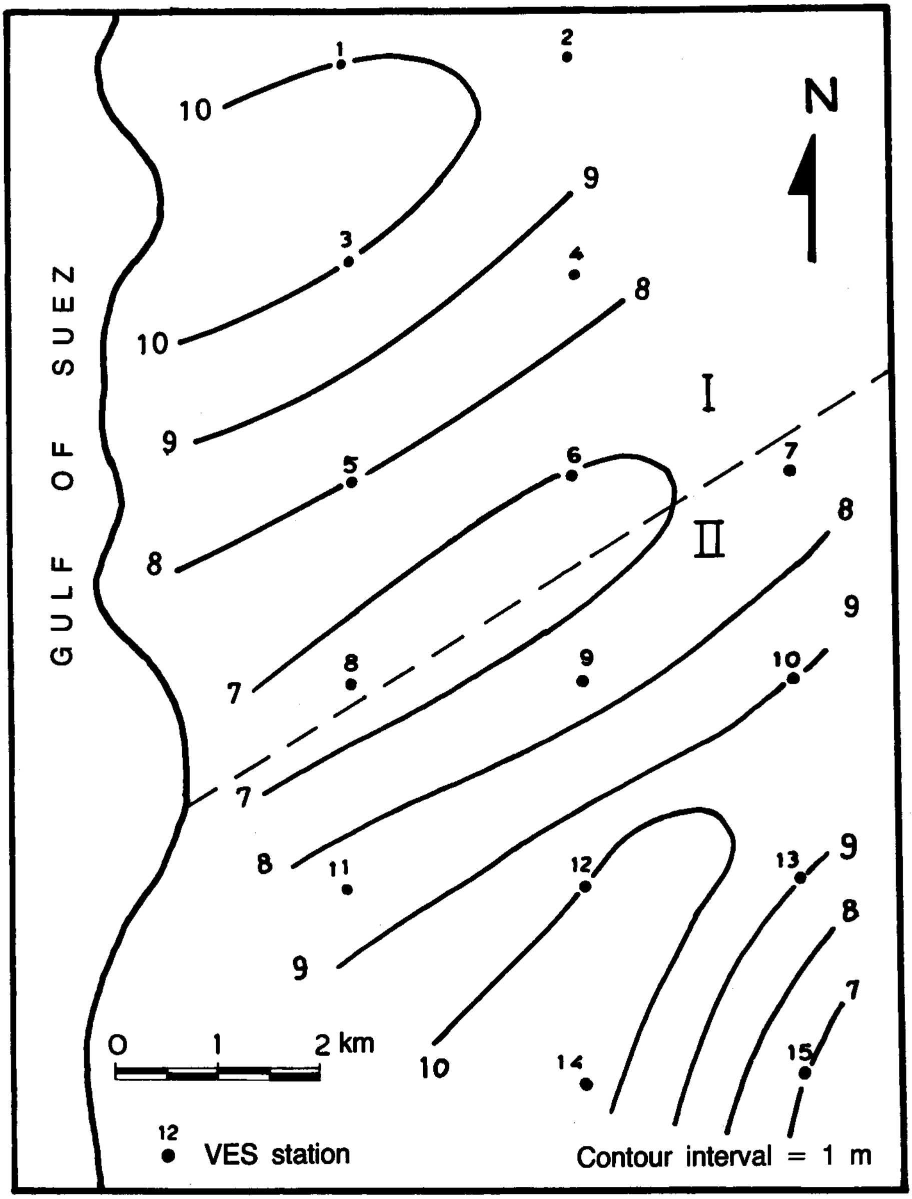

Figure 3. A map showing depth to water table.

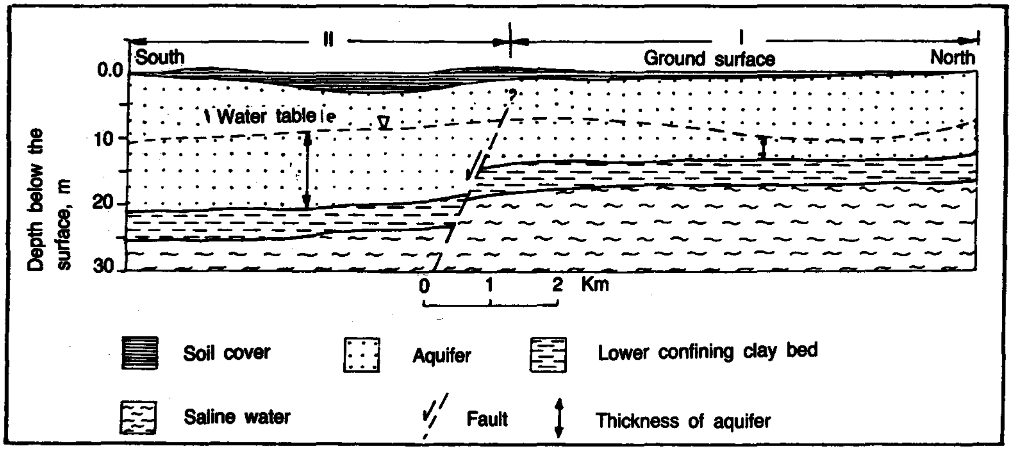

Figure 4. A schematic cross section across the area.

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تقييم مصادر التربه والمياه في منطقة وادى وردان بسيناء ، جمهورية مصر العربية ، باستخدام طريقة المقاومة النوعية الكهربية

مختار عبد العزيز سيد و طلعت علي عبد اللطيف

تم عمل ١٥ جسة كهربية في منطقة دلتا وادى وردان الواقعة على الساحل الغربي لشبه جزيرة سيناء على بعد حوالي ٥٥ كيلو متر جنوبي مدينة السويس ، وذلك بهدف دراسة مدى التغير في سمك غطاء التربة وكذلك التغير في عمق مستوى الماء الجوفي حيث يمثل الماء الجوفي المصدر الوحيد للمياه الذي يمكن استخدامه لأي من المشروعات الزراعية بالمنطقة . وقد دلت هذه الدراسة على أن سمك غطاء التربه يتراوح بين ٥ر٠ متر و٢ر٢ متر بينما يقع مستوى الماء الجوفي على عمق يتراوح بين ٥ر٦ متر و٥ر١٠ متر تحت سطح الأرض .

وقد بين التفسير الكمي للقياسات احتمال تأثر المنطقة بصدع عادي يتجه من الشمال الشرقي إلى الجنوب الغربي مؤثراً على كل من غطاء التربه والتكوين الحامل للمياه بحيث يزداد سمك كل منهما في الجزء الجنوبي من المنطقة . هذا ويمكن الاستفادة من خريطتي تغير سمك التربه وتغير عمق الماء الجوفي اللتين تم عملهما من هذه الدراسة في التخطيط لحفر آبار المياه وباستغلال التربه بها على إنه يجب التركيز في هذا الصدد على الجزء الجنوبي من المنطقة للامكانيات الأكبر نسبياً لكل من مصادر المياه والتربة بها .