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Geoelectrical Study on the Groundwater Occurrence in Delta Wadi El-Maehashi El Aala, Taba, Southern Sinai, Egypt.

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The area under study lies at km25. south Taba along Taba-Nuweiba road covering Wadi El-Maehashi El Aala ($2km^{2}$). Geomorphologically, the area is represented by a minor basin of the Gulf of Aqaba drainage system. It runs nearly in NW-SE direction. It drains from the water divide of Wadi Watir. Stratigraphically, the study area is occupied by wadi deposits belonging to Quaternary over the basement rocks of Pre-Cambrian.

This study aims to construct a desalinization plant depending on groundwater of rather low salinity than the sea water to cover the demands of the new tourist village. Beside the determination of the upper surface of the basement rocks in the subsurface to find out the large thickness that to suitable sites for drilling wells.

For this study, a grid pattern of 18-Vertical Electrical Soundings (VES) of Schlumberger configuration was carried out in the study area. The maximum distance between the current electrodes is ranging between 500 and 2000m. The location and the ground elevation of these stations are estimated. These soundings have been interpreted both qualitatively and quantitatively to make geoelectrical profiles, panel diagram and maps to evaluate the groundwater conditions and to locate the suitable site or sites of drilling wells. The geoelectical succession consists of 4-geoelectrical zones ("A", "B", "C", and "D"). Surface zone "A" consists of loose sand and composed the top cover of wadi deposits, zone "B" is represented by dry wadi deposits of sand, gravels, boulders, silt and clay. Zone "C" is the waterbearing formation divided into three units (C1, C2 & C3), where, unit "C1" is saturated with brackish water and consists of wadi deposits, unit "C2" consists of the same deposits of unit "C1", but is saturated with high saline water due to the sea water intrusion, unit "C3" consists of saturated fractured basement rocks and zone "D" is represented by the crystalline basement rocks.

Generally, the resistivity values of these zones increase towards the NW direction of the area which is attributed to decrease of clay percent and effect of coarser grains. The decrease of resistivity in zone "C" is due to increase the water salinity and clay intercalation. The thickness of the waterbearing zone "C" increases gradually towards the Gulf.

According to this study, three sites were recommended for drilling of production and injection wells.

Key words:
Quaternary, Stratigraphy, Schlumberger Configuration, Desalinization, Production wells, Geoelectrical Succession, Development, Injection wells, Homogeneity, Tourist Village, Pre-Cambrian.

Development in Sinai is considered as a kind of economic development, where tourist villages are setup on their beaches. In the last decade, the coast of the Gulf of Aqaba attracted the attention of the Government and the investors due to its strategic touristic situation. Accordingly, tens of tourist villages were build up along this coast. One of the big problems faced the investors is the transportation of the necessary water for drinking, domestic uses and construction. The groundwater exploration is the only solving of this problem, where the desalinization of it is cheaper than that of the sea water. Deltas of wadis are representing water resources. One of these water resources is delta Wadi El-Maehashi. This study aims to find out suitable sites for drilling some water wells for supplying the desalinization plant with groundwater and other wells for injection and disposal of the salt water resulting from the desalinization process. Geoelectrical resistivity sounding is a tool uniquely suited to such objective.

The area selected for the present study comprises Wadi El-Maehashi lies at km 25, south Taba, Southern Sinai. The present work is an attempt for delineation the following:

1. The sedimentary succession and its vertical and lateral facies changes.
2. The water bearing formation and its extension.
3. The determination of the upper surface of the basement rocks in the study area.
4. Recommendations to locate productions and injections wells.

To achieve the objectives of this study, the following aspects have been considered:

1- The previous information about geomorphology, geology and hydrogeology of the study area and its surroundings.

2- The Vertical Electrical Soundings distributed in the study area.

3-The land topographic survey to locate the position and ground elevation of the Vertical Electrical Soundings (VES) stations on the topographic map.

4- Qualitative and quantitative interpretation of the field data.

5- Representation of interpreted data on forms of profiles, maps and panel diagram.

Geomorphologic and Geologic Background

The study area, delta of Wadi El-Maehashi, occupies an area of about 2 km^2 south of Taba town on the western side of the Gulf of Aqaba (Fig.1).

The desert area lying to the west of the Gulf of Aqaba , south Sinai, including the investigated area, is characterized by arid to semi-arid climate with hot summer and mild rainy winter. The study area is characterized by a slightly undulated land surface that generally slopes eastward and southeastward towards the Gulf of Aqaba. The ground elevation ranges from 0.5 to 50m above sea level.

Wadi El Maehashi El Aala represents a minor basin of the Gulf of Aqaba drainage system. It runs nearly in NW-SE direction. It drains from the water divide of Wadi Watir of the west of the Gulf of Aqaba. The Pre- Cambrian rocks are the oldest exposed rocks in Wadi El Maehashi, followed upwards by Quaternary deposits.

According to El-Kelany and Said (1989), Orabi (1993), and Takla *et.al.*, (1991), the area lying to southeastern part of Sinai is occupied by deposits ranging in age from the Pre-Cambrian to Quaternary. Stratigraphically, the study area is occupied by wadi deposits belonging to Quaternary deposits overlies unconformable the basement rocks of Pre- Cambrian.

The Quaternary deposits cover the floor of Wadi El Maehashi and extend eastward to the Gulf of Aqaba coastal plain. They are composed mainly of alluvial deposits.

The alluvial fan of Wadi El Maehashi is built up mainly of very coarse sand, gravels and boulders of igneous and sedimentary origin embedded in a fine loamy and silty matrix. This is mainly due to the steep slope of the alluvial fan (41.6 m/km) (El-Kelany and Said, 1989 and Orabi, 1993).

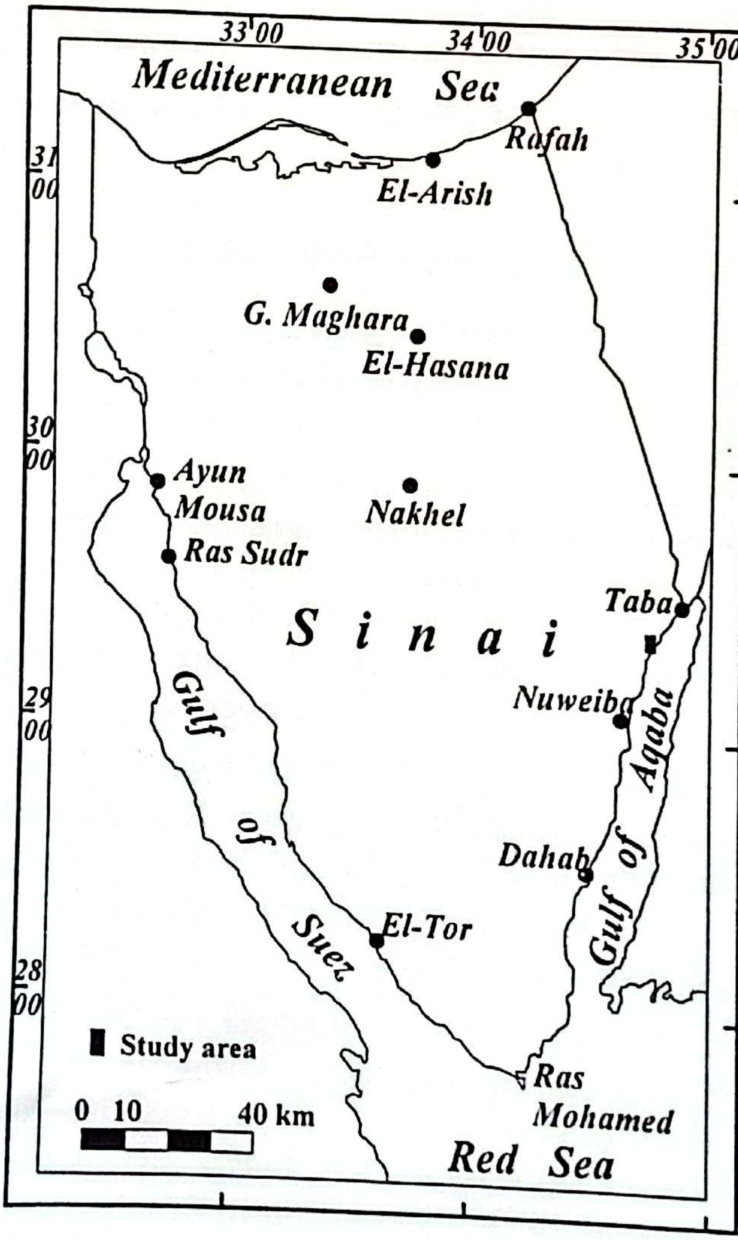


Fig. 1. Location map of the study area.

Field works:

Groundwater investigations in the coastal areas require recording the subsurface changes along traverses perpendicular to the coast in order to detect any probable influence in thickness of the sedimentary successions and the sea water invasion on the groundwater aquifer. The locations of 18 resistivity sounding stations were, therefore, distributed in the form of a grid pattern in Wadi El-Maehashi El-Aala (Fig.2). Some of the sounding stations (as parametric) were measured near to clay outcrop and shoreline for which some data are available for verifying the geophysical interpretations.

The Schlumberger electrode array was used in carrying out the field measurements, where the spreading of the current electrodes (AB) are ranging from 2 to 2000 m. This proved to be sufficient for the aim of the study. The "Terrameter SAS 300" resistivity meter was used for measuring the resistance ($\Delta V/I$). This instrument measures the apparent resistance with high accuracy at different electrodes spacing. The apparent resistivity 'ρ_a' was calculated for each value of AB/2 which is a depth function.

A land survey was carried out in order to determine accurate locations and ground elevations of the sounding stations on the topographic map. The following table shows the altitude of each station.

Altitude of the VES stations above mean sea level in meter.

VES No.	Altitude (m)	VES No.	Altitude (m)	VES No.	Altitude (m)	VES No.	Altitude (m)
1	49.94	6	0.55	11	33.11	16	12.22
2	36.59	7	21.13	12	22.81	17	14.67
3	33.42	8	32.67	13	16.50	18	35.21
4	21.01	9	36.41	14	2.11		
5	2.37	10	46.52	15	1.82		

Interpretation of the Field Data:

The field data of the vertical electrical sounding curves has been interpreted qualitatively and quantitatively to delineate the subsurface sequence of the geoelectrical layers in the area:

Qualitative interpretation: It includes comparison of the relative changes in the apparent resistivity and thickness of the different layers. It gives information about the number of layers, their continuity throughout the area or in a certain direction and reflects the degree of homogeneity or heterogeneity of the individual layer. Qualitative interpretation (Fig.3) of the field curves indicates the following:

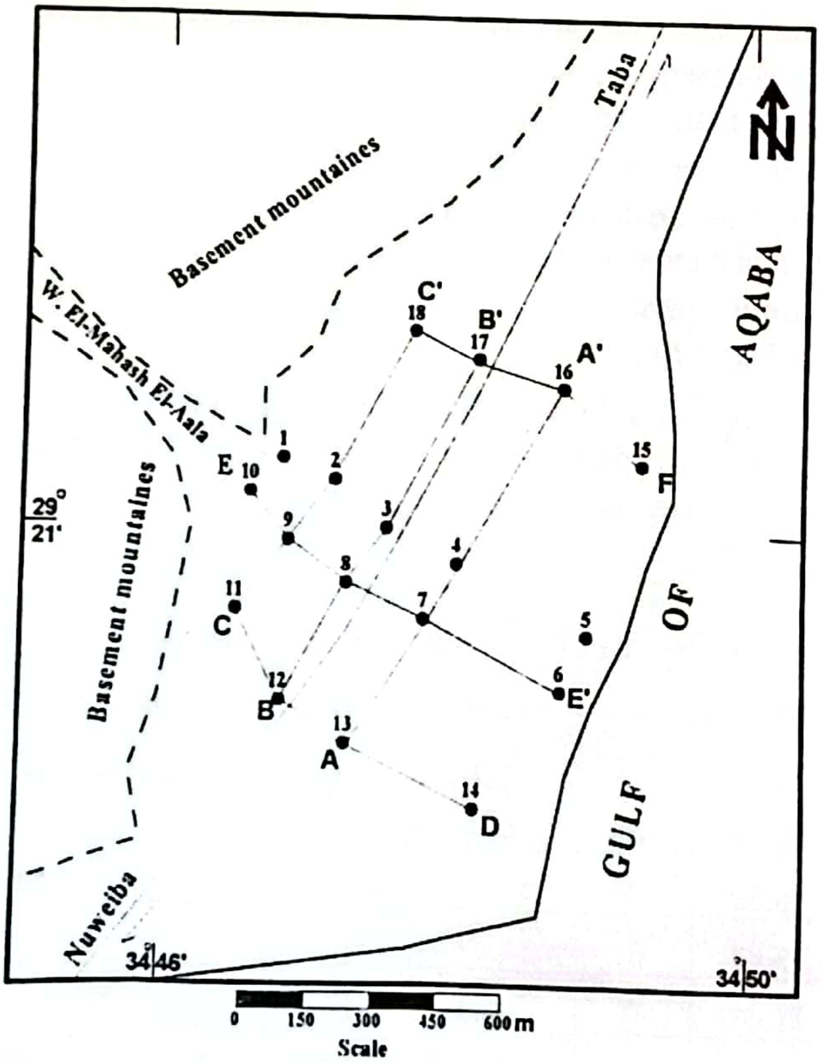


Fig. 2. Location map of the Vertical Electrical Sounding stations and geoelectrical cross sections.

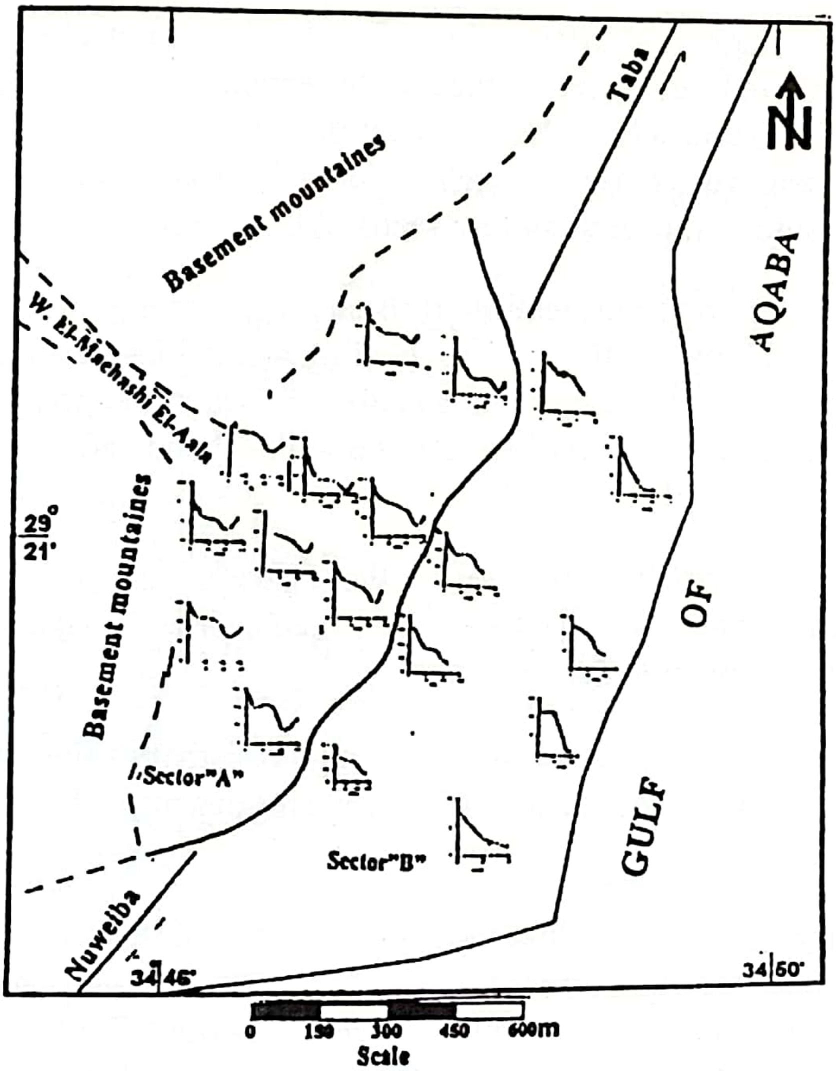


Fig. 3. Aerial distribution map of sounding curves.

1. The general types of the vertical electrical sounding curves can be divided into two main sectors **(Sector "A" and Sector "B").** Each sector has certain type curves. Generally, the resistivity values on the first and second cycles of the resistivity curves are represented the surface and near surface variations. However, they reflect heterogeneity characterizing of the first layers. In going downwards on the field curves (third cycle), the field curves show nearly the same type, which reflects homogeneity and continuous aerial extension of the deep layers in each sector. *i.e.* Sector "A" has field curves terminate with

H-type ($\rho1>\rho2<\rho3$), while sector "B" has field curves terminate with **K-type** ($\rho1<\rho2>\rho3$) or **Q-type** ($\rho1>\rho2>\rho3$).

2. The high resistivity values for the last geoelectrical zone are represented the upper surface of basement rocks or the base of the aquifer, especially in the upstream of Wadi El-Maehashi, where the basement rocks are at shallow depth. This is marked on the right-hand side of the field curves (sector A).

3. From a visual inspection of these types curves, it is noticed that the resistivity of the water bearing formations decreases with depth due to increase in salinity of water and presence of clay intercalation as it marked on the right- hand side of the field curves (sector B).

4. From a visual inspection of these curves in the study area, it is noticed that the thickness of geoelectricals layers increases gradually towards the Gulf.

5. The basement rocks with its high resistivity values appears at shallow depth in sector "A", while it goes more deeper in sector "B".

6. Most of sounding curves were found to start with high resistivity values, followed by a general drop in the apparent resistivity with increasing electrode separation. The high resistivity indicates dry gravely and sandy sediments and boulders in wadi filling. The resistivity drop is, most probably, attributed to a water saturated section.

Quantitative interpretation: Based on a model constructed for each sounding, the interpretation was proceeded using computer program by Zohdy (ATO, 1989) and Van Der Velpen (1988).

Geoelectrical succession:

A detailed subdivision for the sedimentary section was reached through the quantitative interpretation of the sounding data. The quantitative interpretation of the field curves revealed that the geoelectrical succession is formed of a number of layers which are grouped together in four main zones. The first zone "A" and the second zone "B" are dry, the third zone "C" is the water bearing formation and the fourth and the last zone "D" is the basement rock. A detailed description for each zone is discussed as follows:

Geoelectrical surface zone, "A":

The Surface zone represents the surface layer and composed the top cover of wadi deposits. It has a wide range of resistivities varying from 13- 100000 Ohm.m. This variation in resistivity is mainly due to the lithologic variation of dry gravel, some boulders, sand, sandy clay and silt in this zone, while its thickness varies from 0.85m to 3m.

Geoelectrical zone "B":

Zone "B" is represented by dry zone of wadi deposits and composes of sand, gravels, boulders, silt and clay. The resistivity of this zone varies from 100- 5672 Ohm.m reflecting the heterogeneity of its lithology, while its thickness ranges from 6.5-37.1m with general decreases towards the Gulf.

Geoelectrical zone "C":

According to the resistivity values and lithology, zone "C" is represented the water bearing formation in the investigated area and it can be differentiated into three units (C1, C2 and C3) as follows:

Unit"C1":

This is the upper layer of water bearing formation saturated with brackish water and consists of wadi deposits. Its resistivity ranges from 9.7-81.45Ohm.m as observed in the isoresistivity contour map (Fig.4). From this map, we can deduce that the resistivity variation reflects lithologic changes. The higher resistivity values which reflect coarse grains are concentrated in the front of the wadis {upstream} and decreases towards the Gulf reflecting finer deposits {downstream}. The thickness of this unit ranges from 4.5-55.3m with a general increase towards the middle part of the study area as observed from an isopach contour map (Fig 5). Also, the thickness of this unit decreases towards the upstream, where the basement rocks are at shallow depth and decreases towards the Gulf due to the sea water intrusion.

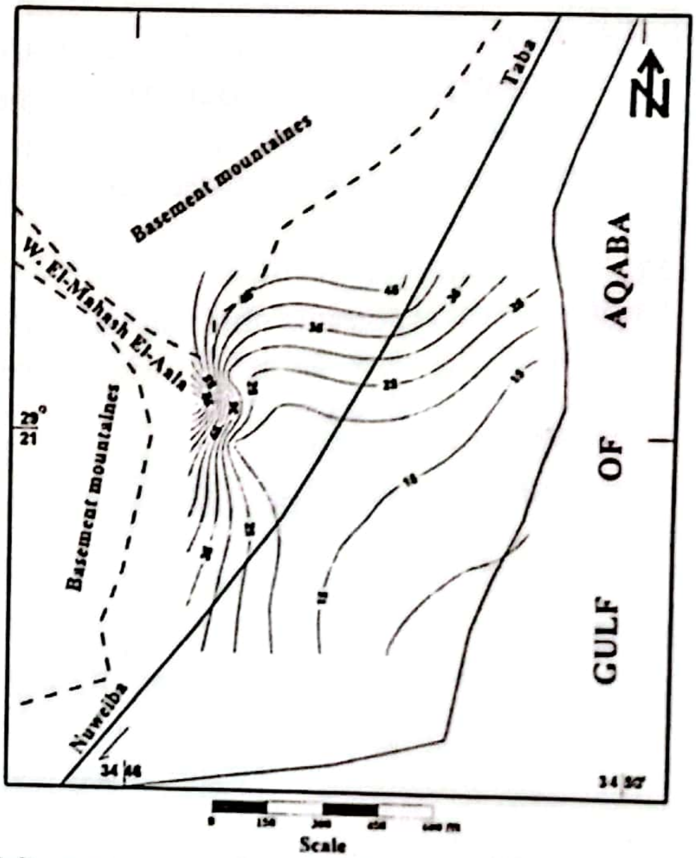


Fig. 4. Isoresistivity contour map for brackish water (Unit C1).

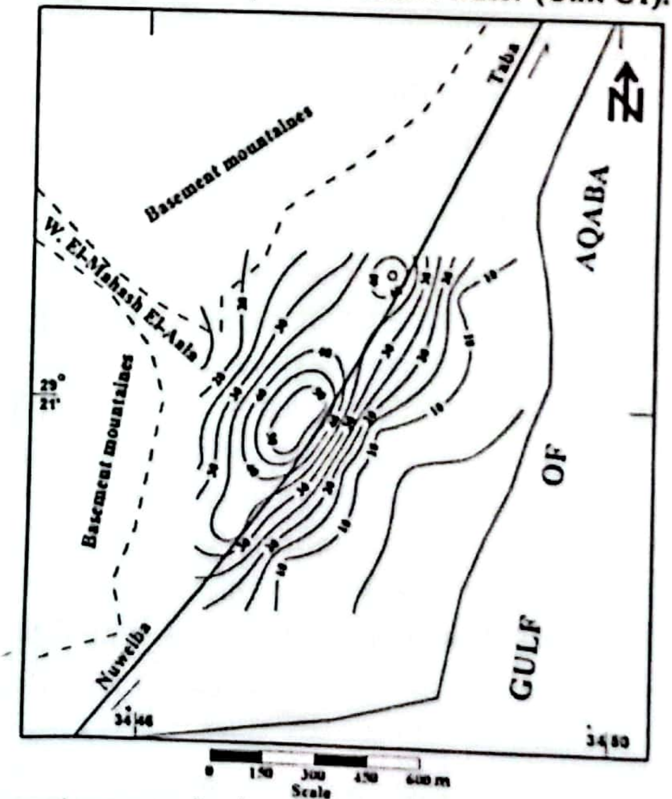


Fig. 5. Isopach contour map for brackish water (Unit C1).

Unit"C2":

This is the second unit of the water bearing formation and is affected by the sea water intrusion. It has low resistivity values ranging from 1.5 to 8.3 Ohm.m. It consists of the same deposits of unit "C1"

Unit"C3":

This is the last unit of water bearing formation and represents the water saturated fractured basement rocks. It exhibits relatively high resistivity values ranging from 105-274 Ohm.m and having 9.2-16.5m thick.

Geoelectrical zone "D":

This zone mainly consists of the crystalline basement rocks. It exhibits the highest resistivity values in the study area, ranging from 899-4026 Ohm.m. Also it represents the base of the aquifer in the study area. The depth to the basement rocks ranges from 65m-103m as observed from Figure (6). It is noticed that the basement rocks regionally slopes towards the Gulf of Aqaba. So, the largest thickness of the aquifer is in the same direction.

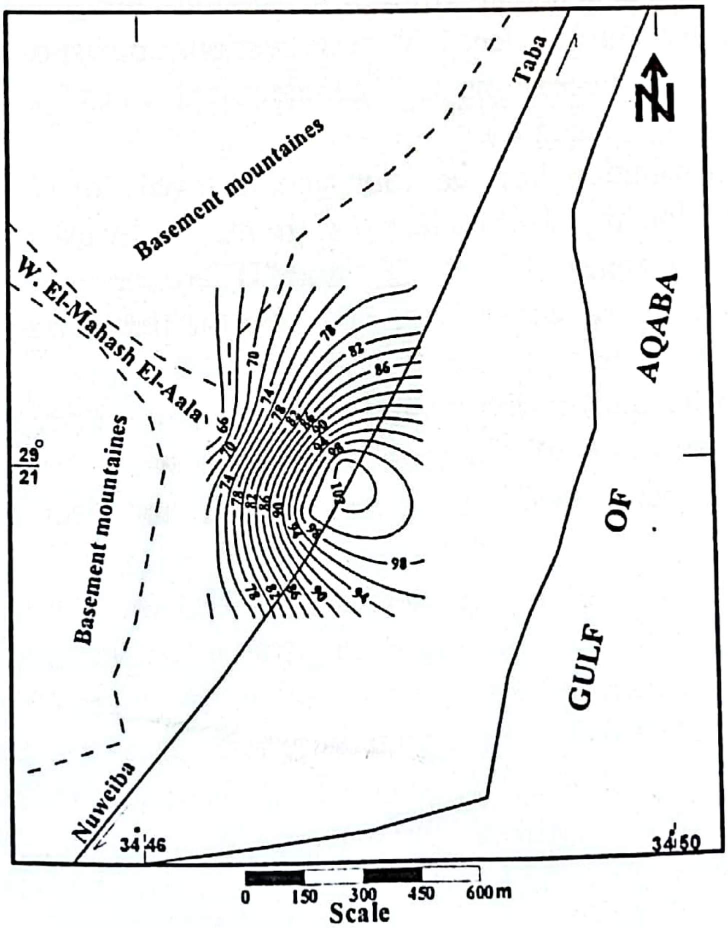


Fig. 6. Depth to basement rocks contour map.

Geoelectrical cross sections:

These sections illustrate the geoelectrical sequence, lateral and vertical variation of the different zones in the profile direction. Six geoelectrical cross sections have been constructed from the interpreted data of the soundings and available geologic information as well as the parametric measurements. Geoelectrical cross sections {(A-A'), (B-B') and (C-C')} cross the area in NE-SW direction (Fig.7) and three other {(C-D), (E-E') and (C'-F')}were constructed in NW-SE direction (Fig.8). The data of the geoelectrical cross sections such as thickness and resistivities of every zone along these cross sections are summarized in Table (1).

To avoid unnecessary repetition, this would facilitate comparisons among these sections. Such geoelectrical cross sections would complete the hydro-geophysical picture and determine the thickness and extension of the water bearing formation to find out suitable sites for drilling of production and injection wells. The main observations and conclusions from these sections are:

1. Generally, the geoelectrical cross sections consist of a complete geoelectrical successions of 4- geoelectrical zones "A", "B", "C" and "D" (Figs. 7 and 8).
2. The distribution of the four geoelectrical zones is different from one locality to another, *i.e.* in the northwestern part of the study area , zones "A", "B", "C" and "D" are represented, while in southeastern part, zones "A", "B" and the first two units of zone "C" are represented (Figs.7, 8 & 9).
3. Generally, the resistivity values of these zones increase towards the NW direction of the area (upstream) which is attributed to increasing percentage of coarse grains and decrease of clay percent.
4. The thickness of dry zone (zone B) decreases toward the Gulf of Aqaba, while the thickness of the water bearing formation (zone C) increases towards the Gulf of Aqaba (Figs. 7 and 8).
5. It is noticed that the basement rocks shows a general dip towards the east (Gulf). The depth to basement rocks increases from 65m at the northwestern part (upstream) to more than 103m at the southeastern part of the study area (downstream) (Figs. 7 and 8).

TABLE 1. *Geoelectrical data from geoelectrical sections in the study area.*

Section	Trend and length	VES'es No. Included	Geoelectrical Zones and Units, Resistivity and thicknes range						General remark
			Surface zone Zone "A"	Dry zone Zone "B"	Zone "C" Unit "C1"	Zone "C" Unit "C2"	Unit "C3"	Zone "D"	
A-A'	NE-SW 910m	13.7.4 & 16	280-79901Ω.m 1.3-2.3m	196-5672 Ω.m 8.1-16.3m	16.1-28.3 Ω.m 21.2-27.1m	6.5-8.3 Ω.m ------	----- -----	----- -----	-Basement is deeper -Brackish water overlies sea water
B-B'	NE-SW 825m	12,8,3& 17	313-100,000Ω.m 1.3-2.5m	178-3442Ω.m 9.2-25.2m	17.1-45.2Ω.m 39.2-55.3m	----- -----	105-168 Ω.m 10.3-13.5 m	899-3930 Ω.m -----	-Brackish water overlies basement
C-C'	NE-SW 745m	11.9.2 & 18	365-100,000Ω.m 1.0-2.7m	100-2667Ω.m 28.1-30.4m	19.3-48.5 Ω.m 23.3-37.6m	----- -----	116-219 Ω.m 11-14.5m	1852-2980 Ω.m -----	-Brackish water overlies busement
C-D	NW-SE 640m	11.12.13 & 14	13.0-16191Ω.m 0.85-1.95m	196-3236Ω.m 13.96-28.1m	9.72-48.5 Ω.m 4.6-39.2m	2.3-8.3 Ω.m -----	117-153 Ω.m 12.1-13.3m	1498-1852 Ω.m -----	-Basment is dipping toward the Gulf. -Sea water intrusion
E-E'	NW-SE 816m	10.9.8.7&6	49.2-79901Ω.m 0.91-3.0m	100-1913Ω.m 16.2-37.1m	10.1-81.5 Ω.m 4.5-55.3m	1.5-6.5 Ω.m -----	113-274 Ω.m 9.2-12.2m	2517-4026 Ω.m -----	-Basment is dipping toward the Gulf. -Sea water intrusion
C'-F	NW-SE 588m	18.17.16&15	43.1-21387Ω.m 0.95-2.0m	229-5672Ω.m 6.5-29.9m	11.6-47.3 Ω.m 6.3-47.1m	1.8-6.2 Ω.m -----	195-214 Ω.m 12.1-16.5m	899-1997 Ω.m -----	-Basment is dipping toward the Gulf. -Sea water intrusion

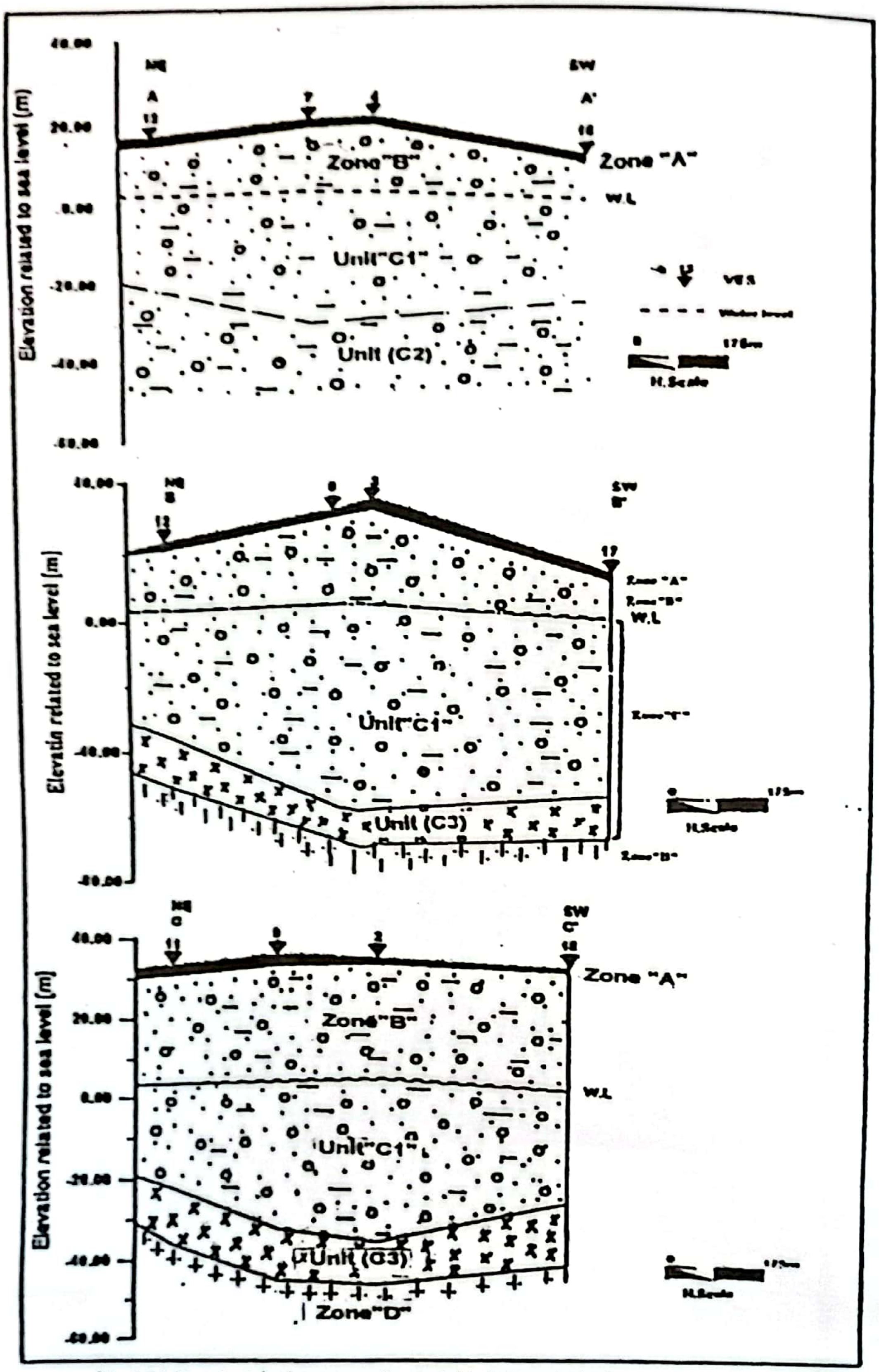


Fig.(7) Geoelectrical cross sections, AA', BB' and C-C'.

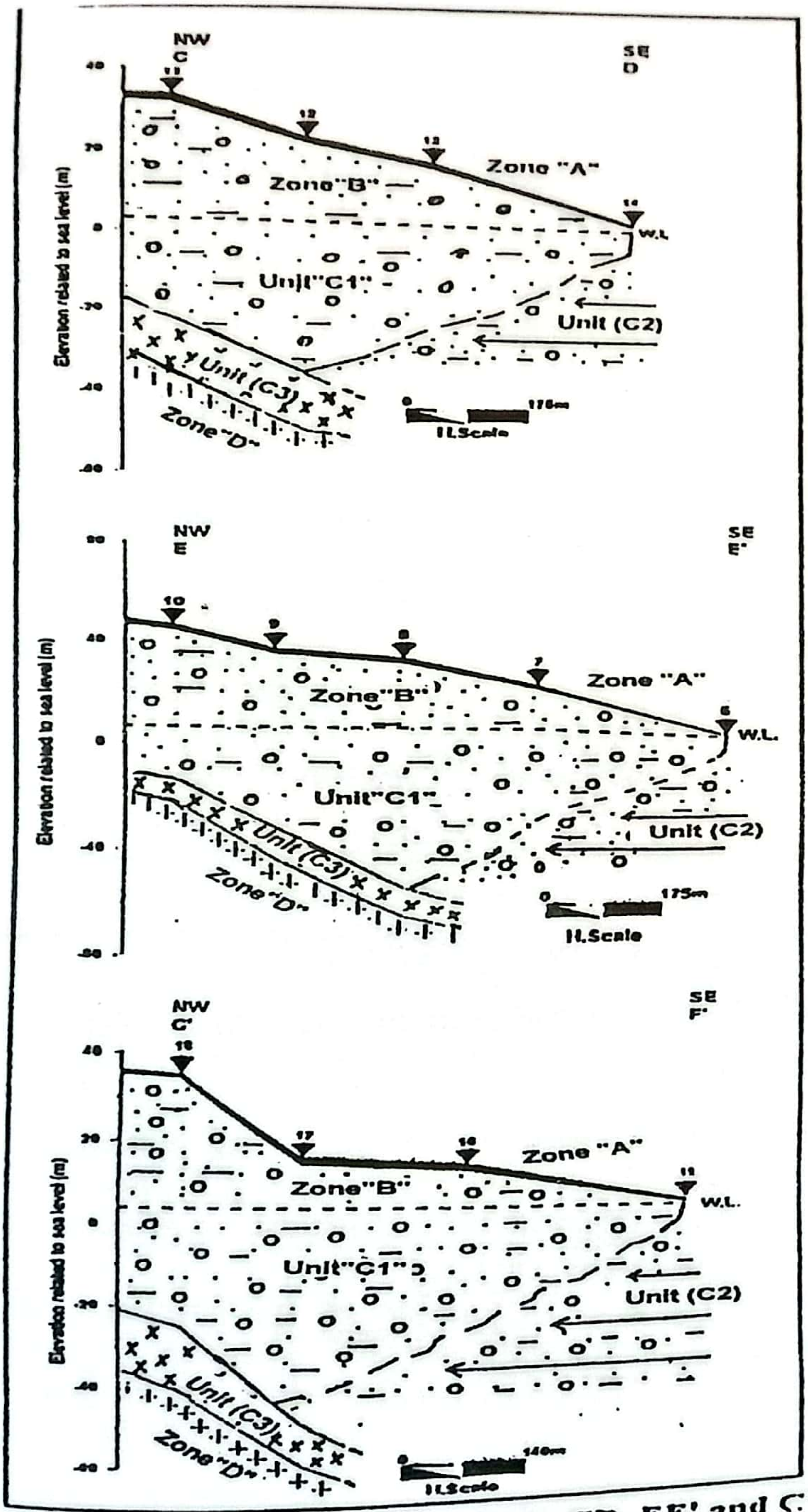


Fig.-(8) Geoelectrical cross sections, CD, EE' and C'F'

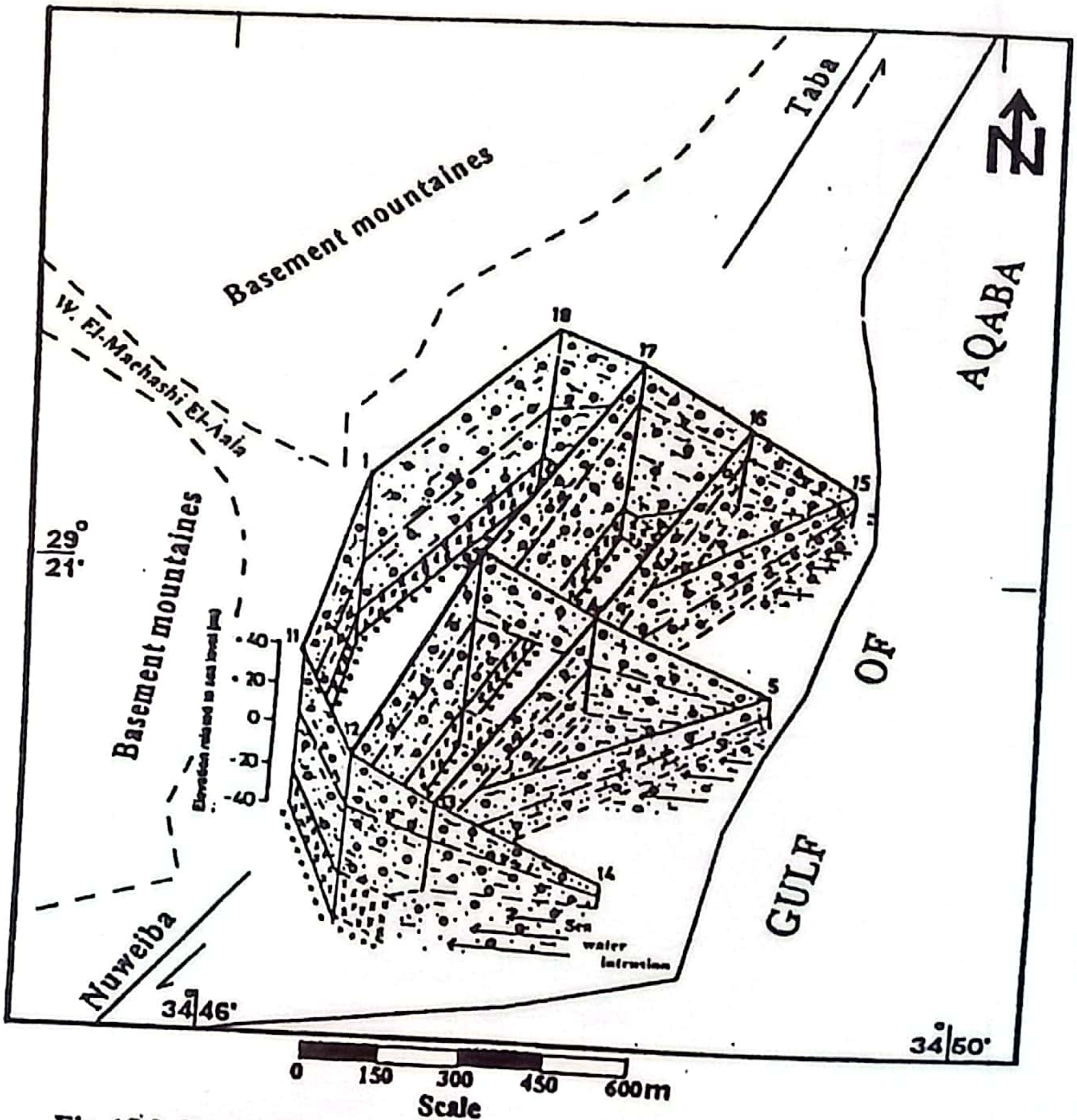
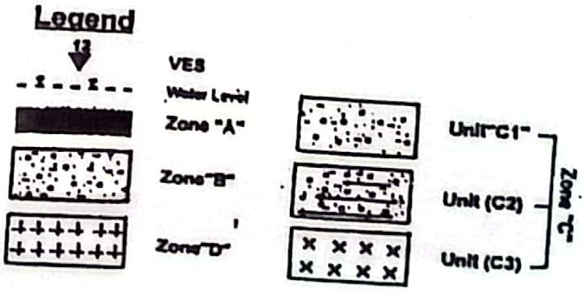


Fig.(9) Panel diagram of geoelectrical zones in the study area.



6. Generally, the depth to water as interpreted from the geoelectrical study ranges between 2m and 35m, which is confirmed with the results of the recommended drilled wells in the area.

7. Generally, it is noticed that the resistivity decreases downwards in the wadi fills water bearing units (units C1 and C2), which can be attributed to the increase in clay content as well as the increase in water salinity. On the other hand, the resistiviy values of the fractured basement water bearing unit (unit C3) are high with respect to the upper ones, while the lower crystalline basement rocks (Zone D) exhibits the highest resistivity values.

8. Hydrogeologicaly, zone "C" represents the water bearing formation in the study area. The invasion of the sea water affects on the thickness of the brackish water as shown in (Figs 5, 8 & 9).

Conclusion and Recommendations

1. The interpretation of the geoelectrical survey carried out in the study area, revealed that the geoelectrical succession in the area consists of four main geoelectrical zones "A" , "B", "C" and "D".

2. Zones "A" and "B" are dry zones, whereas zone "C" is the water bearing zone and consists of three units (C1 , C2 and C3).

3. Vertically, the salinity of water bearing formation increases downward due to the effect of the sea water invasion, and this is evidenced by the decrease in resistivity values downwards.

4. It was found that the present delta of Wadi El-Maehashi is originally a simple delta where the deposits of this delta are coarser at the outlets of the wadi and graded to finer deposits towards the Gulf.

5. It is recommended to exploit the brackish water layer which is considered as the strategic water supply to the area and has a suitable saturated thickness reaching to about 45m. Economically,

desalinization of the brackish water is much cheaper than desalinization of sea water. In Exploiting the brackish water zone, wells should not penetrate the saline water.

6. The sites of VES Nos. 8 and 17 are suitable for drilling production water wells under the previous conditions, due to large thickness of coarser sediment, higher permeability and relatively better water quality, while the site of VES No.6 is suitable for drilling injection well due to its distance from the production wells and it lies down water flow near to the shore line to prevent the groundwater pollution .

7. According to the recommendations of this study, two productive water wells were drilled at VES Nos. 8 and 17, and an injection well was drilled at VES No.6. The results of the drilling are confirmed very well with the present geoelectrical study, reflecting the importance and reliability of the geoelectrical study in such case for any future similar conditions.

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دراسه جيوكهربيه على المياه الجوفيه فـــى دلتــا وادى المحاشى الأعلى ، جنوب طابا ، جنوب سيناء ، مصر .

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تقع منطقة الدراسة فى دلتا وادى محاشى الأعلى جنـــوب طابـا بحوالـــى ٢٥ كـم ويشـغل مسـاحة (٢كـم٢). مـــن الناحيـــة الجيومورفولوجية تعتبر المنطقة دلتا صغيرة من دلتـــاوات خليـــج العقبة وله إتجاه شمال غرب - جنوب شرق وهو ينبع مـــن وادى وتير والمنطقة بها رواسب وديان تنتمى للعصر الحديـــث تعلـو صخور القاعدة التى تنتمى للعصر ما قبل الكمبرى.

هدف الدراسة هو بناء محطة تحلية معتمدة على الميـــاه الجوفية ذات ملوحة أقل من ملوحة البحر لتغذية قرية سياحية على خليج العقبة ولتحقيق الهدف تستخدم طرق المقاومة الجيوكهربيـــة لتحديد السطح العلوى لصخور القاعدة لمعرفة أكبر سمك للطبقـــة الحاملة للمياة وذلك لأختيار أنسب الأماكن لحفر أبار إنتاجية وبـئر صرف (حقن) المياه الخارجة من عملية التحليـــة ذات الملوحـــة العالية

تم عمل ١٨ جسة جيوكهربية لهذه الدراسة موزعة علـــى هيئة شبكة فى الوادى بطريقة شلامبرجير وأقصى مســـافة بيـــن الأقطاب الكهربية (أ ب) تتراوح بين ٥٠٠ الى ٢٠٠٠ م وأماكن وارتفاعات الجسات الجيوكهربية تـــم تعيينـــها بواســـطة أجـــهزة المساحة وتم عمل تحليل للجسات الجيوكهربية كما وكيفا ومنها تـم عمل قطاعات جيوكهربية وخرائط ورسم مجسم فى ثلاثة اتجاهات لمعرفة وتقييم ظروف تواجد المياة الجوفية لأختيار أكـــبر ســـمك للطبقة الحاملة للمياة لتحديد الأبار الإنتاجية وبئر الصرف .

التتابع الجيوكهربى يتكون من أربعة نطاقات جيوكهربيـــة هى { نطاق (أ) ونطاق (ب) ونطاق (ج) ونطاق (د) } :

نطاق (أ) يتكون من رمال مفككة ورواسب الطبقة السطحية للوادى .

نطاق (ب) وهو جاف يتكون من رواسب وديان من رمال وحصى وطين وسلت وجلاميد (بولدرز).

نطاق (ج) هو النطاق الحامل للمياة الجوفية وينقسم الى ثلاث وحدات (ج١،ج٢،ج٣)

- وحدة (ج١) تتكون من رواسب وديان من حصى ورمل ورمال حصوية وطين ومشبعة بالماء الأسن
- وحدة (ج٢) تتكون من نفس رواسب الوحدة (ج١) وممثلة لتداخلات مياه البحر
- وحدة (ج٣) تتكون من صخور القاعدة ذات شقوق

نطاق (د) هوأخر نطاق فى التتابع الجيوكهربى ويتكون من صخور القاعدة الصلبة .

عموما تزيد قيم المقاومة الكهربية لهذه النطاقات ناحية الشمال الغربى للمنطقة وذلك لقلة رواسب الطين وزيادة حجم الحبيبات فى أعلى الوادى وتقل المقاومة الكهربية رأسيا الى أسفل لزيادة رواسب الطين وزيادة الملوحة وتزيد سمك الطبقة الحاملة للمياة تدريجيا ناحية الخليج .

وتبعا لنتائج هذه الدراسة أمكن التوصل لحفر ثلاثة أبار (بئرين إنتاجيين لاستغلال نطاق الماء الأسن لتغذية محطة التحلية وبئر لصرف المياه الناتجة من التحلية) وجاءت نتائج الحفر مطابقة تماما لنتائج الجسات الكهربية .