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# STUDY ABOUT THE IMPACT OF GROUNDWATER DISCHARGE ON THE BRACKISH-SALINE INTERFACE USING TWO–DIMENSIONAL RESISTIVITY IMAGING IN THE DELTA OF WADI SUDR, WESTERN SINAI, EGYPT

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In the coastal aquifers, the intrusion of saline water occurs due to the intensive pumping which in turn leads to the upconing of the brackish -saline interface towards the wells.

The area of study is the Sudr Research Station of Desert Research Center which is located to the north of Ras Sudr city, about 5 km from the eastern coastal zone of the Gulf of Suez.

The alluvial deposits of the Quaternary aquifer represent the main source of groundwater in the Delta of Wadi Sudr. The depth to the groundwater varies from 4.6 m to 17.1 m from the ground surface. The salinity of the groundwater increases progressively from 2000 ppm in the east to 8000 ppm in the west of the delta, this increase in salinity is due to the intensive discharge which in turn leads to the intrusion of sea water.

The aim of the present study, is the monitoring of the discharge rate effect on the upconing of the brackish-saline water interface in the coastal area of Wadi Sudr Delta and determining the safe yield from water wells in the Sudr Research Station. To achieve the aim of this study, two-dimensional electrical imaging was carried out along 4 profiles in the station passing through two wells. These profiles have N-S (parallel to the Gulf of Suez) and W-E (Perpendicular to the Gulf of Suez) directions. Each profile has 450 m length. The Wenner electrode array was used for acquiring the imaging resistivity data. Each profile is measured before pumping and at different discharge rates and different times from the beginning of pumping.

The results of the data interpretation for the two-dimensional imaging profiles measured during the discharge process revealed the following:-

- The brackish-saline water interface moves slowly at a low discharge rate (8.6 $m^3/h$) of well ($w_2$). The upward movement increases with the increase in the rate of discharge.

- At an intermediate discharge rate ($17m^3/h$) of well ($w_1$) the upward transition of the interface is noticeable but still far away from the well.
- At a higher discharge rate (24 $m^3/h$) of well ($w_1$) the interface upconed rapidly towards the well, this was confirmed by measuring the salinity of pumped water at different discharge rates. The resistivity of the groundwater aquifer decreases in the imaging profiles due to the increase of its salinity by pumping.
- The upconing is more obvious in the profiles measured along the W-E direction (flow direction) than in the N-S direction (perpendicular to direction on the flow) for the same discharge rate, this indicates that the alluvial deposits of the Quaternary aquifer have a higher permeability in the direction of water flow than in the perpendicular direction.

Based on the results of this study, the safe yield of well ($w_1$) in the area of study is less than 24 $m^3/h$. The discharge rate of 17 $m^3/h$ can represent the safe yield in the study area. The value of the safe yield was used in calculating the hydraulic conductivity of the quaternary aquifer in the coastal area of the delta of Wadi Sudr attaining a value of 5.1 m/day.

**Keywords:** aquifers, upconing, brackish-saline interface, Quaternary, Delta Wadi Sudr, Two-Dimensional electrical imaging profiles, discharge rate, resistivity, safe yield, hydraulic conductivity.

The area of study (Desert Research Center station) lies between latitudes 29°37'28" and 29° 37' 43.4" N and longitudes 32° 42' 48.3" and 32° 42' 53" E. It is located to the north of Ras Sudr city and far about 5 km from the eastern coastal area of the Gulf of Suez (Fig.1).

In the coastal areas, intrusion of salt water under brackish or fresh groundwater is expected. This situation commonly occurs in coastal aquifers in hydraulic continuity with the sea, when pumping from wells disturbs the natural hydrodynamic balance. The deltaic part of Wadi Sudr suffers from sea water intrusion as indicated by previous studies (Abdel Hafez, 2001 and El-Sayed, 2003).

Due to the upconing of the brackish-saline interface during the pumping process (Fig.2), the amount of the upconing at the well can be determined according to the Ghyben-Herzberg relationship (Todd, 1980):

$Z = Q/2\Pi \text{ kd } (\rho_s - \rho_f / \rho_f)$ where:

Z = The rise in meter of the interface,

Q = The amount of discharged water ($m^3$ /h),
K= Hydraulic conductivity,
D = the distance between the end of the well and the initial brackish - saline water interface,
$\rho_s$ =density of saline water,
$\rho_f$ = density of fresh water.

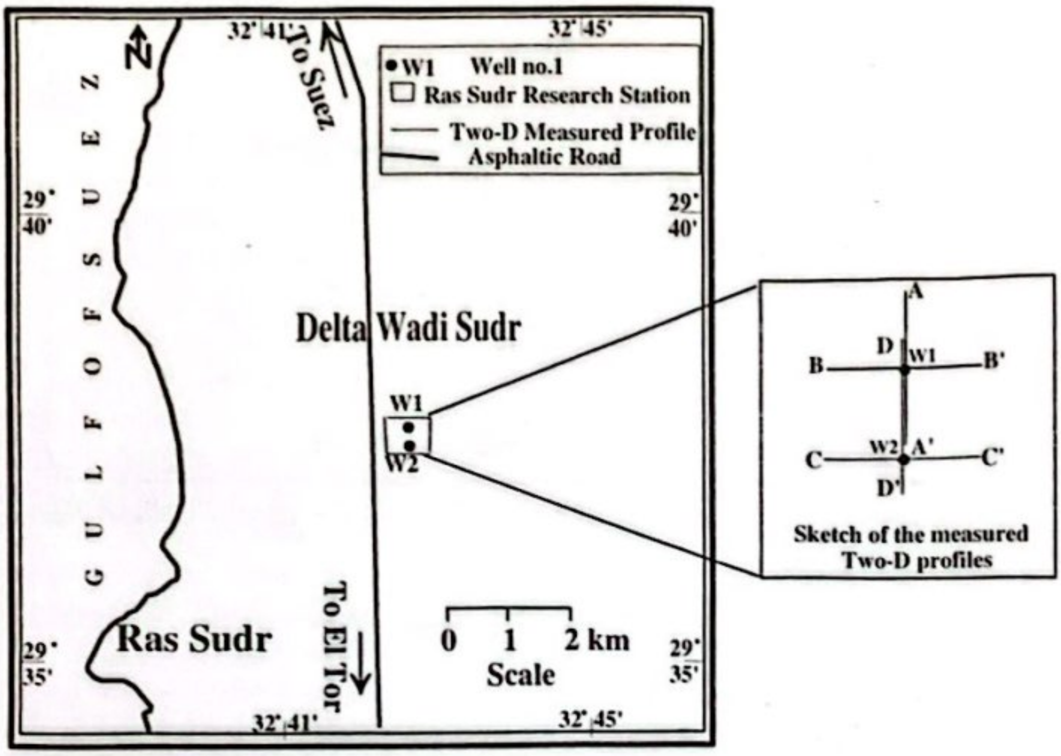


**Fig. (1). Location map of the study area and the measured two-dimension imaging profiles along two wells.**

The critical rise Z/d has been estimated to be approximated from 0.3 to 0.5. Thus adopting an upper limit of Z/d =0.5 represents the maximum permissible pumping rate (Q maximum) without saline water entering the well.

The safe yield (Qmax) of the well can be calculated according to Ghyben-Herzberg relation:

$$Q(max) = \Pi\, d^2\, k(\rho_s - \rho_f / \rho_f) \quad m^3/h$$

Therefore, the aim of the present study is to monitor the effect of the rate of discharge on the upconing of the brackish-saline water interface in the Sudr Research Station of the Desert Research Center and determine the safe yields of wells in the station.

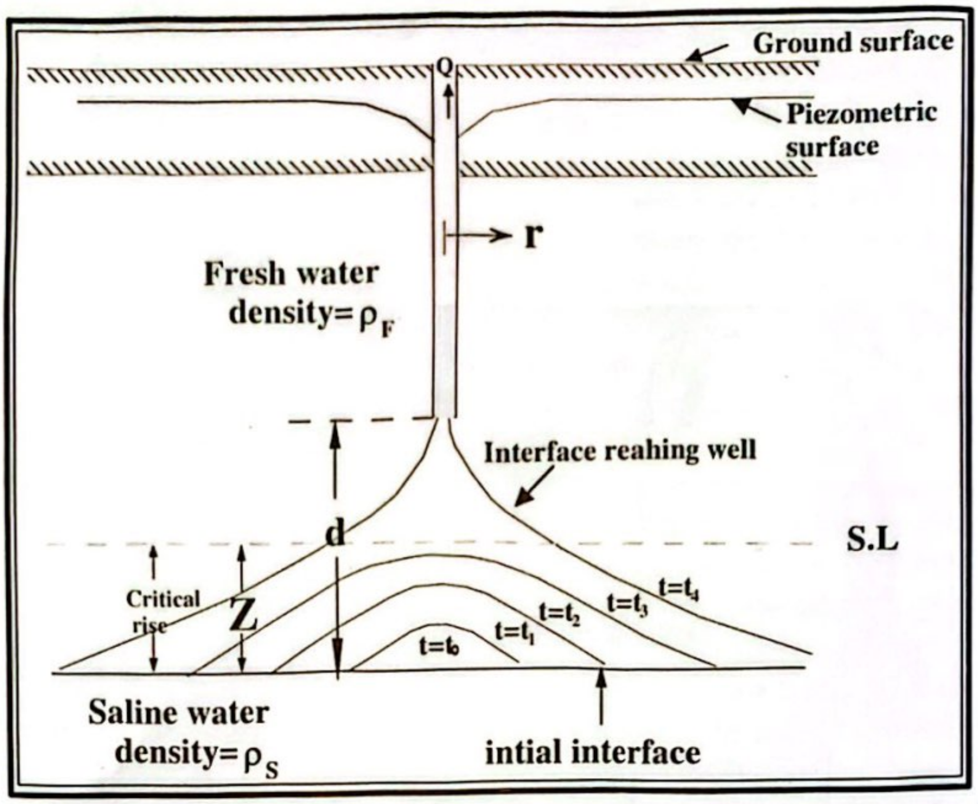


**Fig. (2). Diagram of upconing of brackish- saline water interface during pumping.**

## PHYSICAL SETTING

### (a) Climatic Condition

The Gulf of Suez area is characterized by extreme aridity with low erratic rainfall, high evaporation rates, high summer temperature and vigorous winds.

### (b) General Geomorphology

The general geomorphology of the area was studied by many authors such as, Shata (1955), Hammad (1980) and Hasanein (1989) and others. Hasanein (1989) divided the area between Wadi Sudr and Wadi Gharandal into four geomorphological units. These units are, the dissected table land, the hilly area, the tectonic depressions and the Gulf of Suez coastal plain. The delta of Wadi Sudr lies in the Gulf of Suez coastal plain. This plain is covered with gravels, sands and clay forming remnants of old terraces.

### (c) Geology

Stratigraphically, Wadi Sudr cuts exposed rock units varying from Upper Cretaceous to Quaternary (Said, 1962; Hasanein, 1989 and Gad, 1994). On the other hand, the subsurface lithology penetrated by the wells in the delta of Wadi Surd is restricted to Quaternary alluvium deposits (Fig. 3).

According to Shata (1956), Said (1962 and 1990), Youssef (1969), Abdel Gawad (1970), and Garfunkel and Bartov (1977), the major structures of the investigated area are represented by normal and step faults. The downthrown side of these faults ranges from a few centimeters to several hundred meters. The synthetic types comprise all faults which are parallel to the Red Sea graben and the antithetic type is represented by the faults which are parallel to the Gulf of Suez and Gulf of Aqaba.

**(d) Geophysical Study**

El-Sayed (2003) studied the Wadi Sudr area geoelectrically and detected three water-bearing layers. Two of them are related to Quaternary alluvial deposits and the last one is related to fractured limestone. The Resistivity of the water-bearing formations decrease westward due to the effect of seawater intrusion

**(e) Hydrogeological Setting**

The hydrogeology of the investigated area has been studied by many authors such as Garamoon (1987), Hasanein (1989) and El Sayed *et.al* (1999). Based on the data deduced from El Sayed *et.al* (1999), the groundwater in the Delta of Wadi Sudr is tapped from the alluvial aquifer either from hand dug wells or drilled wells. The alluvial deposits constitute an extremely thick series of fluviatile sand, gravels (flint limestone) and clay. The depth to water in the delta varies from 4.6 m (towards the Gulf of Suez) to 17.1 m from the ground surface, while the water level varies from +2m (towards the Gulf) to +11m above sea level in the east. The flow direction of the groundwater is towards the Gulf. The salinity of the groundwater increases progressively from the east (2000 ppm) towards the west (8000 ppm) i.e. towards the Gulf of Suez. The increase in salinity may be related back to the intensive pumping which in turn leads to the sea water intrusion. The same concept was verified chemically by Abdel Hafez (2001) who concluded that, the groundwater in the Surd area is laterally affected by sea water intrusion due to excessive pumping.

## FIELD DATA

**(a) Two-Dimensional Resistivity Imaging**

Electrical imaging or electrical tomography is a survey technique developed for solving many problems particularly in groundwater and engineering investigations, where the use of resistivity sounding and other techniques are unsuitable (Griffiths and Barker, 1993).

The tomographic surveys normally employ arrays of electrodes on the ground surface for data collection. The survey technique involves measuring a series of constant separation traverses with the electrode separation being increased with each successive traverse. In the Wenner electrode array the measurements starts at the first traverse with unit electrode separation "a" and is increased for each traverse by one unit i.e. 2a, 3a, 4a, ….,na; where n is a multiplier. The length of the profile, depth of penetration and the required resolution determine the applied unit electrode separation.

**(b) Two-Dimensional Electrical Profiles**

The two-dimensional electrical imaging survey was carried out along four profiles (A-A', B-B', C-C' and D-D') at the Sudr Research Station of the Desert Research Center (DRC) in the Delta of Wadi Sudr (Fig.1). The Wenner electrode array was used for acquiring the imaging resistivity data for the all measured profiles. Each profile has 450 m in length and the unit electrode separation "a" is 10m. The measurement process starts from the bottom of the pseudo-section plots with electrode separation "a" equal to 150m to detect the rapid variation near the interface, and decreases by one unit at each traverse until it reached 10 m (i.e. 150, 140, 130,………,10m)

The direct current resistivity meter (Terrameter SAS 1000) was used to carry out the geoelectrical measurements. This instrument measures the resistance (R) at each electrode separation with high accuracy.

- The 2-D profile, image A-A', extends along the N-S direction where well "$w_1$" lies at the center of the profile. Along profile A-A' the measurements were carried out for three cases; the first was carried out before pumping, the second was carried out after 45 minutes of pumping from well "$w_1$" at the rate of discharge of 17 $m^3$/h and the third after 45 minutes of pumping from well " $w_1$" at the rate of discharge of 24$m^3$/h. The salinity of groundwater was measured during each test.
- The perpendicular 2-D, B-B', extends along the W-E direction where well "$w_1$" again lies at the center of the profile. Three measurements along this profile were carried out for three cases; the first was carried out before pumping, the second was carried out after 45 minutes of pumping from well "$w_1$" at a discharge of 24$m^3$/h and the third case was carried out after one hour of pumping from both wells "$w_1$" and "$w_2$" with the rate of discharge of 24$m^3$/h for well " $w_1$" and 8.6$m^3$/h for well "$w_2$". This case was carried out to show the effect of discharge during simultaneous pumping from two adjacent wells on the brackish-saline interface where, the distance between the two wells ($w_1$ and $w_2$) is 225 m. The salinity of groundwater from each well was also measured during these tests.
- The 2-D profile, imaging C-C', extends along the W-E direction where well "$w_2$" lies near the center of the profile. Three measurements along this profile were carried out for three cases; the first was carried out before pumping, the second was carried out after one hour of pumping from well "$w_2$" at the discharge rate of 8.6 $m^3$/h and the third case was carried out after one hour of pumping from both wells "$w_1$" and "$w_2$" with discharge rates of 24$m^3$/h for well "$w_1$" and 8.6$m^3$/h for well "$w_2$". The salinity of the groundwater was measured for each case.

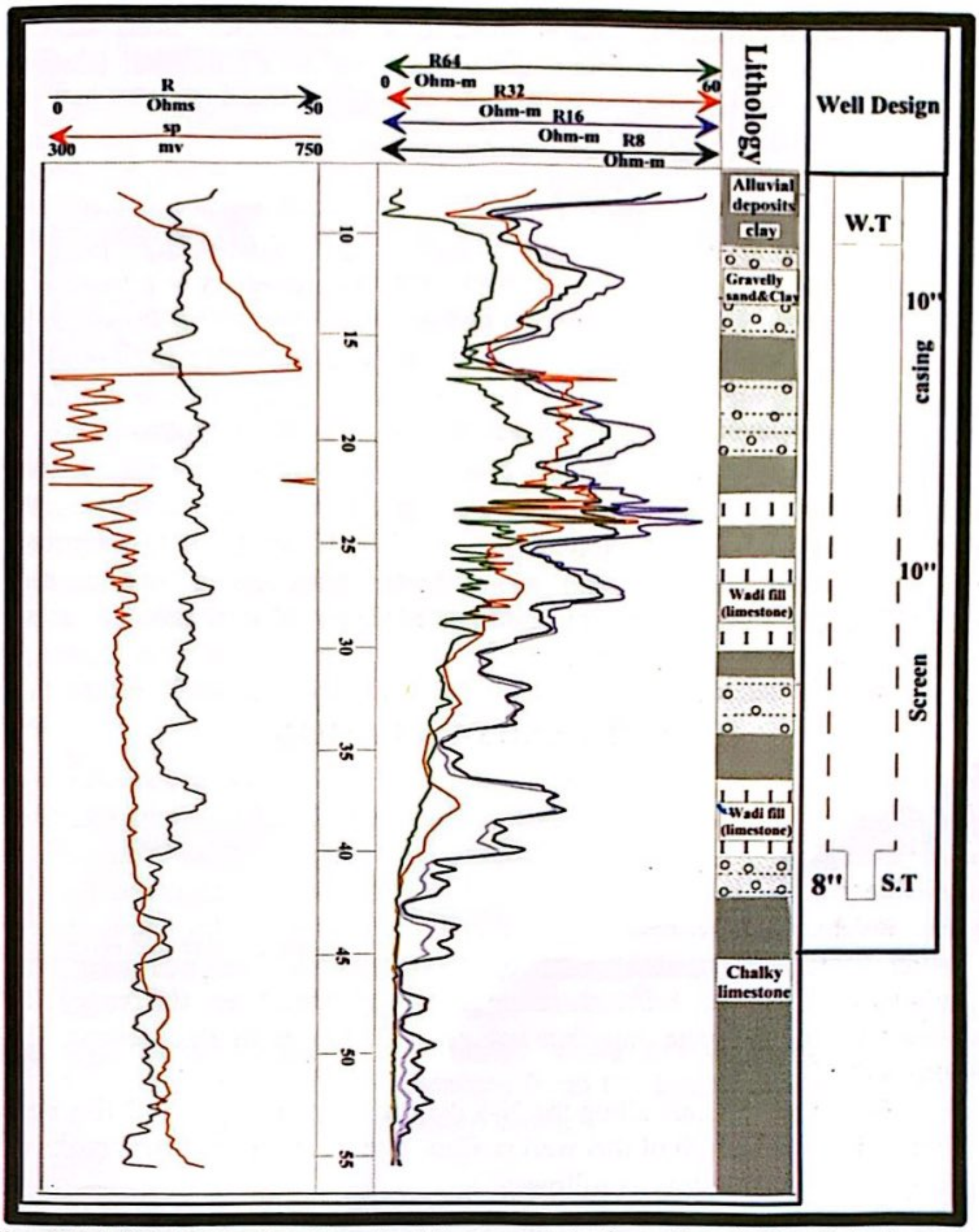


**Fig. (3). Lithological, electrical logs and design of well No. 2 ($w_2$) at the Sudr Research Station.**

- The perpendicular 2-D profile, D-D', extends along the N-S direction where well "$w_1$" lies between electrodes Nos.11 and 12 and well "$w_2$" lies at electrode No. 35 along this profile. The measurements were carried out for two cases; the first was carried out before pumping and the second was carried out after 45 minutes of pumping from well "$w_1$" and well "$w_2$" with a rate of discharge of $24m^3/h$ and $8.6m^3/h$, respectively. The salinity of groundwater was measured for each case.

The measurement transition from case to another along the all measured cases requires returning the water table to its original position (recovery of the well) as one of the essential requirements to start the measurement process.

**(c) Quantitative Interpretation Technique**

For the interpretation of the imaging data, a computer program RES2DINV, ver 3.4, written by Loke (1998) was used. It is a windows-based computer program that automatically determines a two-dimensional (2-D) subsurface resistivity model for data obtained from electrical imaging surveys (Griffiths and Barker 1993). This program is designed to invert large data sets (up to 6324 datum points) measured with a large number of electrodes (up to 1000 electrodes). This program enables to remove bad datum points before inverting the data so that they do not influence the resulting model. A forward modeling subroutine is used to calculate the apparent resistivity values, and a non-linear least-square optimization technique is used for the inversion routine (De Groot- Hedlin and Constable, 1990 and Loke and Barker, 1996a).

## RESULTS AND DISCUSSION

To ease the monitoring process of the brackish-saline water interface and to better define its movement with different discharge rates from wells, a reasonable fixed resistivity value below the interface is assumed for the various inversions. This resistivity value surely is affected by displacement of saline water to the brackish water or mixing of both. This will reduce the resistivity value at the brackish-saline interface. However, the suggested resistivity value below the interface was set to 2 Ohm-m in all cases.

**Profile A-A'**

This profile extends along the N-S direction where well "$w_1$" lies near its center. The total depth of this well is 42m. The discussion of the results of the measured three cases is as follows:

The interpretation results of the first Two-Dimensional imaging profile, representing the case before pumping (Fig. 4), revealed that the resistivity of the groundwater aquifer under the water table (h) at depth of 11.16m from the ground surface has a value of 63.9 Ohm-m. The brackish-saline interface is at a depth (D) of 72 m. The critical rise in the interface "Z" in this case is equal to zero where the discharge value "Q" has zero value. The distance from the end of the well to the interface "d" is equal to 30m. Therefore, Z/d has a zero value. The measured salinity in this case has a value of 6035 ppm.

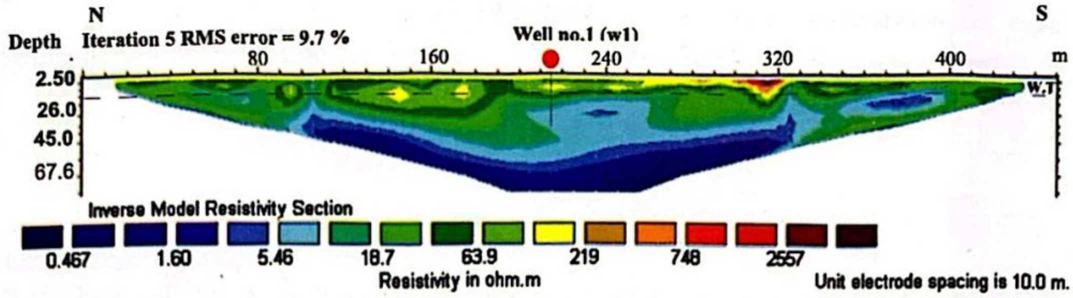


**Fig. (4). True resistivity 2-D image along profile A-A' in N-S direction before pumping (first case).**

The interpretation results of the second Two-Dimensional imaging profile after pumping for 45 minutes at a discharge rate "Q" of 17m$^3$/h (Fig.5) revealed that the resistivity of the groundwater aquifer under the water table at a depth (h) of 12.8m from the ground surface has a value of 56 Ohm-m. The brackish-saline interface has a depth (D) of 60 m. The critical rise in the interface "Z" in this case has a value of 12m. The distance from the end of the well to the interface "d" attains a value of 30m. Therefore, Z/d has a value of 0.4 and the recorded salinity in this case has a value of 6172 ppm

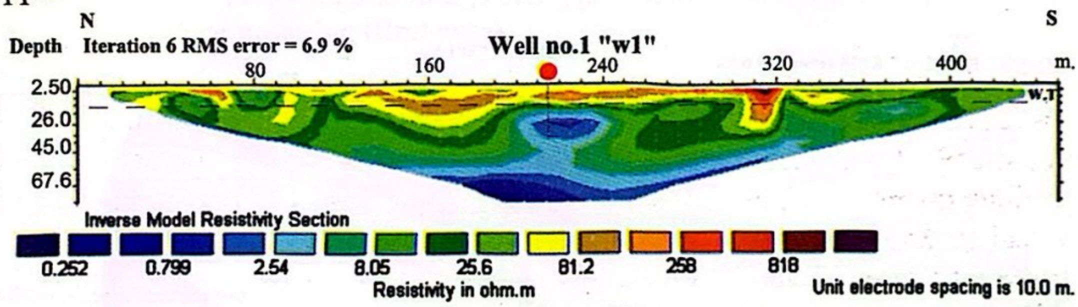


**Fig. (5). True resistivity 2-D image along profile A-A' in the N-S direction after 45 minutes from the beginning of pumping at a rate of 17 m$^3$/h (second case).**

The interpretation results of the third Two- Dimensional imaging profile after pumping for 45 minutes at a discharge rate "Q" of 24 m$^3$/h (Fig.6) revealed that the resistivity of the groundwater aquifer under the table at depth (h) of 12.9m from the ground surface has a value of 47.5 Ohm-m. The brackish-saline interface has a depth (D) of 55m. The critical rise in the interface "Z" in this case has a value of 17m. The distance from the end of the well to the interface "d" attains a value of 30m. Therefore, the Z/d ratio attains a value of 0.56. The measured salinity of pumped water in this case has a value of 6547 ppm.

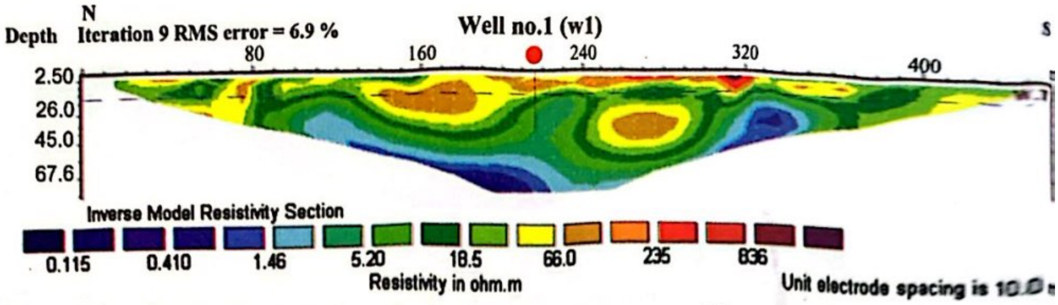


**Fig. (6). True resistivity 2-D image along profile A-A' in the N-S direction after 45 minutes from the beginning of pumping at a rate of 24 $m^3$ /h (third case).**

The determined Z/d values for the different cases of pumping (Table.1) along profile A-A' revealed that, all the cases have Z/d values less than 0.5 except for the third case which has a value of 0.56. This exceeds the limit of the critical rise of the interface by a small amount. Therefore, the salt water begins to enter the well and mixes with the brackish water and hence the salinity increases with a detected value comparable to the other cases.

Similarly the interpretation results of the different cases of profiles B-B', C-C' and D-D' (Figures 7 to 14) are given in Table.1.

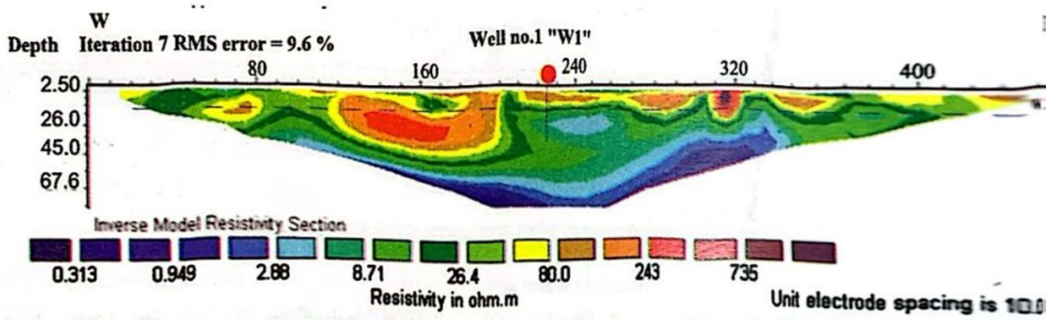


**Fig. (7). True resistivity 2-D image along profile B-B' in the W-E direction before pumping (first case).**

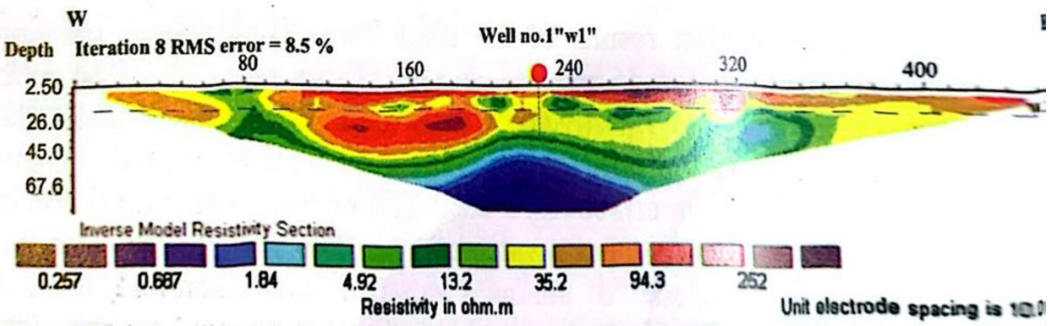


**Fig. (8). True resistivity 2-D image along profile B-B'' in the W-E direction after 45 minutes from the beginning of pumping at a rate of 24 $m^3$ /h (second case).**

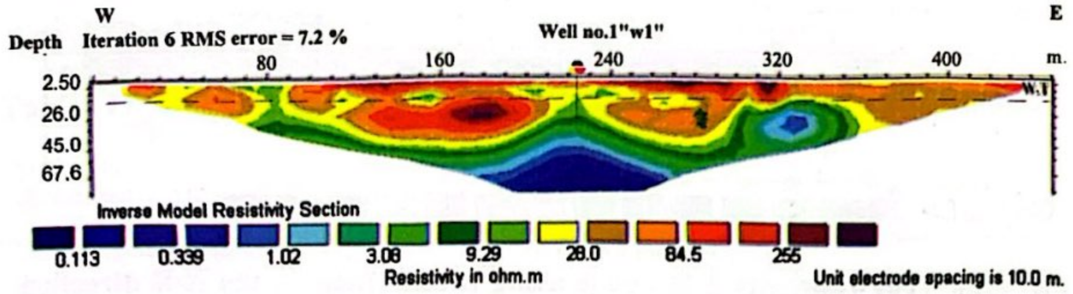


**Fig. (9). True resistivity 2-D image along profile B-B" in the W-E direction, an hour after the beginning of pumping (third case).**

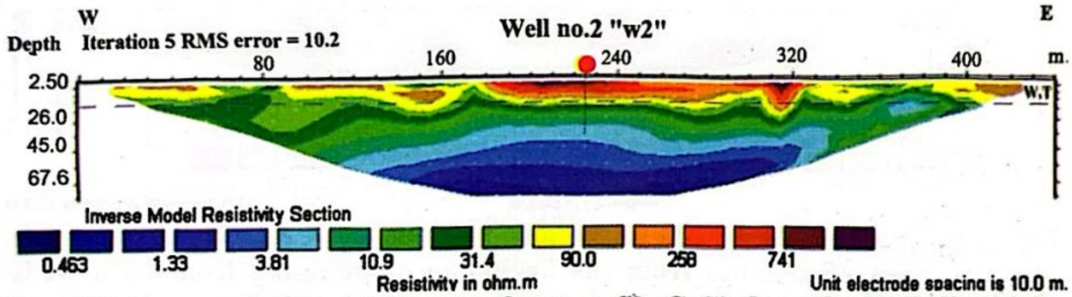


**Fig. (10). True resistivity 2-D image along profile C-C' along the W-E direction before pumping (first case).**

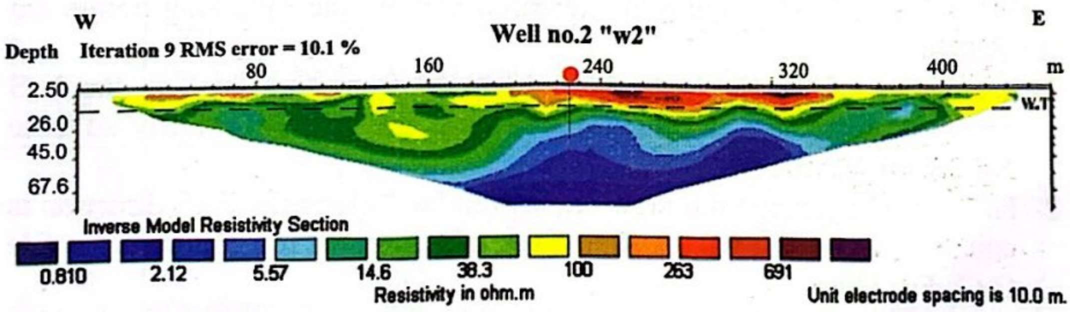


**Fig. (11). True resistivity 2-D image along profile C-C' along the W-E direction, one hour after the beginning of pumping at a rate of 8.6 m$^3$ /h (second case).**

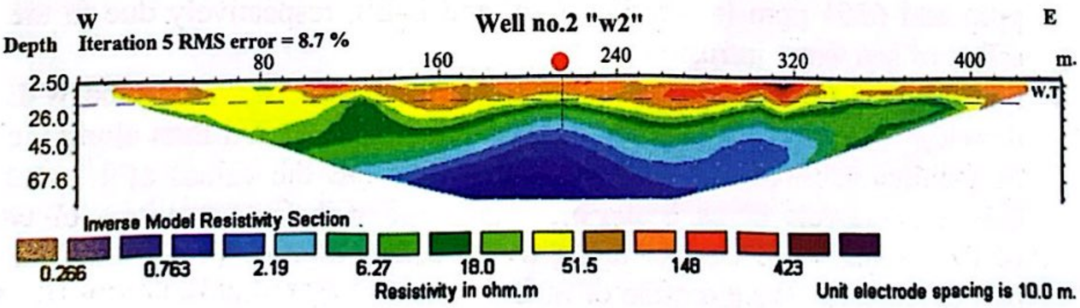


**Fig. (12). True resistivity 2-D image along profile C-C' in the W-E direction, one hour after the beginning of pumping from both wells "w$_1$" and "w$_2$" (third case).**

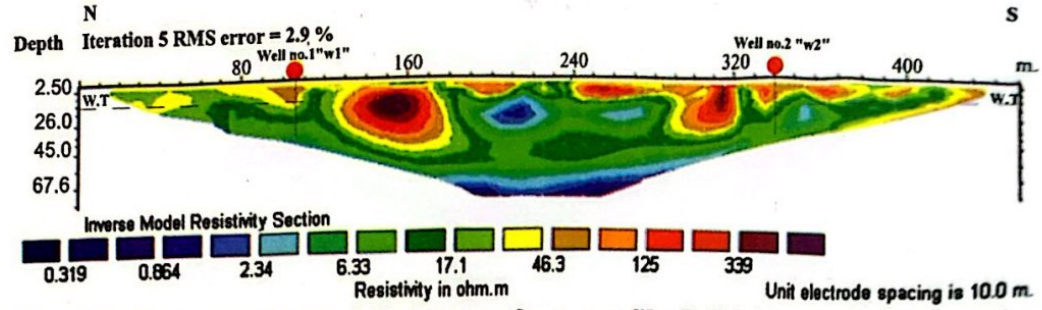


**Fig. (13). True resistivity 2-D image along profile D-D' in the N-S direction before pumping (first case).**

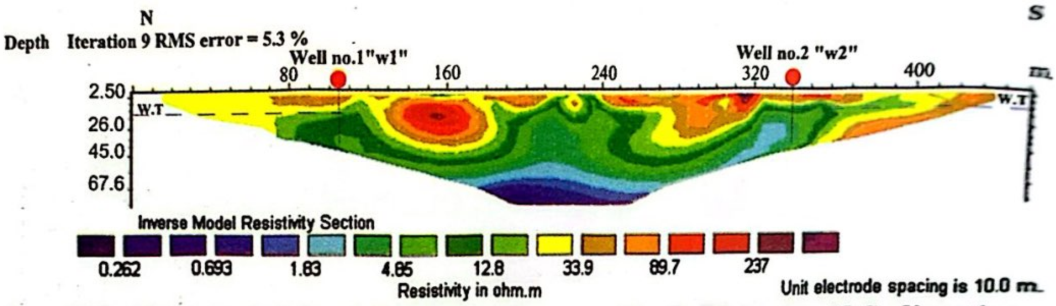


**Fig. (14). True resistivity 2-D image along profile D-D' in the N-S direction after 45 minutes from the beginning of pumping from both wells "$w_1$" and "$w_2$" (second case).**

From the results of interpretation of the four imaging profiles along wells "$w_1$" and "$w_2$" in the Sudr Research Station, the following points are the conclusion:-

1- The effect of the discharge rate (17 $m^3/h$) from well "$w_1$" in the N-S direction is suitable, where Z/d = 0.4 and the salinity is fairly suitable 6172 ppm (profile A-A', Fig. 5).

2- The rate of discharge 8.6 $m^3/h$ from well "$w_2$" along the W-E direction is suitable, where Z/d = 0.33. This gives salinity equal to 3752 ppm (profile C-C', Fig.11).

3- The effect of the discharge rate (24 $m^3/h$) from well "$w_1$" along the N-S and W-E directions are not suitable where, Z/d = 0.56 (profile A-A', Fig.6) and 1.1 (profile B-B', Fig. 8). The reported salinities were 6547 ppm and 6551 ppm (at profiles A-A' and B-B'), respectively due to the effect of sea water intrusion.

4- The effect of the discharge rate (24 $m^3/h$) from well "$w_1$" along the W-E direction (profile B-B') has more favorable values of Z/d than along the N-S direction (profile A-A'), where Z/d ratio has the values of 1.1 and 0.56, respectively (Figs. 8 and 6). This is due to the higher permeability of the groundwater aquifer along the direction of flow (W-E) than the perpendicular to the direction of flow (N-S).

5- The effect of the rate of discharge from the two wells "$w_1$ and $w_2$" at the same time along the W-E direction (profile B-B', Fig. 9 and C-C', Fig. 12) has greater Z/d values than those from pumping from each well at different times, where Z/d has the values 1.23 and 1.1 (Table. 1).

**Table (1). Measured and calculated data for the different profiles cases.**

| Profile .No & (Direction) | Time of Measurements | Salinity (ppm) | Rate of Discharge (Q) $m^3/h$ | Depth of interface (D) m | Z (m) | Total depth of well | d (m) | (Z/d) value |
|---|---|---|---|---|---|---|---|---|
| A-A' (N-S) | Before pumping | 6035 | 0 | 72 | 0 | 42m | 30m | 0 |
| | After 45 min. from pumping | 6172 | 17 | 60 | 12 | | | 0.4 |
| | After 45 min. from pumping | 6547 | 24 | 55 | 17 | | | 0.56 |
| B-B' (W-E) | Before pumping | (well 1) 6041 (well 2) 3705 | 0 | 72 | 0 | 42m | 30m | 0 |
| | After 45 min. from pumping | (well 1) 6551 | 24 | 40 | 32 | | | 1.1 |
| | After 60 min. from pumping | (well 1) 7647 (well 2) 4415 | (well 1) 24 (well 2) 8.6 | 35 | 37 | | | 1.23 |
| C-C' (W-E) | Before pumping | (well 1) 6053 (well 2) 3699 | 0 | 70 | 0 | 40m | 30m | 0 |
| | After 60 min. from pumping | (well 2) 3752 | (well 2) 8.6 | 60 | 10 | | | 0.33 |
| | After 60 min. from pumping | (well 1) 7688 (well 2) 4453 | (well 1) 24 (well 2) 8.6 | 37 | 33 | | | 1.1 |
| D-D' (N-S) | Before pumping | (well 1) 6105 (well 2) 3691 | (well 1) 0 (well 2) 0 | 72 | 0 | well "$w_1$" 42m well "$w_2$" 40m | 30m | — |
| | After 45 min. from pumping | (well 1) 7680 (well 2) 4420 | (well 1) 24 (well 2) 8.6 | 55 (at the middle) | 17 | | | 0.56 |

* This parameters are true for profile D-D' in case of the presence of well at the middle of this profile

## THE SAFE YIELD

The deduced data from the interpretation results of the 2-D imaging profiles at different discharge rates along the measured profiles in the area of study revealed the following:-

- At low discharge rate (8.6 $m^3/h$) of well "$w_2$", the brackish-saline water interface moves slowly upward and Z/d ratio has a low value (0.33) and the salinity increases by a small ratio comparable with the condition before the pumping process (from 3699 to 3752 ppm).

- At high discharge rate (24 $m^3/h$) of well "$w_1$" the brackish-saline interface upcones rapidly upward to the well and Z/d ratios have a high value (more than 0.5). This leads to an enormous increase of the salinity compared with the condition before pumping process (from 6035 to 6547 ppm and reached to 7600 ppm). Therefore, the high discharge rate represents unsafe yield for the quality of groundwater discharged from wells in the area of study.
- At an intermediate discharge rate (17 $m^3/h$) for well "$w_1$", the brackish-saline interface moves upward but still far away from entering the well, and the salinity slightly increases by an acceptable ratio comparable with the case before pumping (from 6035 to 6172 ppm). The relative increase in salinity in this case is related to the movement of the transition zone between the brackish and saline water. Therefore, the safe yield of well "$w_1$" in the area of study is less than 24 $m^3/h$. So, the discharge rate value of 17 $m^3/h$ can represent the safe yield in the area of study.

The safe yield in the area of study aides in the determination of the hydraulic conductivity of the Quaternary aquifer in the coastal area of Delta Wadi Sudr using the Ghyben Herzberg relation:

$Q(max) = \Pi\, d^2\, k(\rho_s - \rho_f / \rho_f)$ $m^3/h$

Where,

$Q(max) = 17\ m^3/h$ , $d = 32$ m , $\rho_s = 1.025$ and $\rho_f = 1$ for well "$w_1$".

Applying this equation in the area of study using the value of safe yield and the other parameters gives the value of hydraulic conductivity of the Quaternary aquifer (k) results in a value of 5.1 m /day.

## CONCLUSION

At low discharge rates (8.6 $m^3/h$) for well "$w_2$" the interpreted true resistivity Two-Dimensional images show little upward movement of the brackish-saline interface. At the intermediate discharge rate (17 $m^3/h$) for well "$w_1$" the interpreted true resistivity Two-Dimensional images indicates a noticeable movement of the brackish-saline interface, but at the same time the interface is still far away from entering the well. This is confirmed by Z/d ratio which is less than 0.5. The resistivity of the groundwater aquifer decreases compared with that recorded at the steady state condition.

The increase in salinity during these two cases is related to the upward movement of the transition zone between the brackish and saline water caused by the pumping process.

On the other hand, at a higher discharge rate of 24 $m^3/h$ for well "$w_1$" or discharging two wells at the same time (24 $m^3/h$ for well "$w_1$" and 8.6 $m^3/h$ for well "$w_2$") the interpreted true resistivity Two-Dimensional images show an increase in the upconing of the brackish-saline interface. The upconing is confirmed by decreasing the recorded resistivity of the groundwater aquifer under the water table compared with the other cases. This is confirmed by the abrupt increase of the measured salinity of the pumped water. The upconing is more obvious in the profiles measured in the W-E direction than in the N-S direction for the same discharge rate; this indicates that the alluvial deposits of the Quaternary aquifer have a higher permeability in the water flow direction than the perpendicular direction

## RECOMMENDATION

To get the best quality for groundwater at the Sudr Research Station it is recommended to decrease the rate of discharge in well "$w_1$" to less than 20 $m^3/h$. The low discharge gives a low rise of the brackish-saline interface and decreases the salinity of pumped groundwater.

It is recommended not to operate two adjacent wells (as $w_1$ and $w_2$) located near each other, at the same time, where the cone of depression of the two wells intersects due to over pumping and this in turn leads to upconing of the brackish-saline interface. Therefore, the resistivity of the water bearing formation will decrease due to the increase in the salinity of the pumped water from the two wells as a result of the intrusion of the saline water.

It is recommended to decrease the total depth of wells and correct the design of the future drilled wells to 20 m of casing over 15 m of screen and put the pumps between 17 to 19 meters in depth and the rate of discharge of the pumps not to exceed 17 $m^3/h$.

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# دراسة تأثير سحب المياه الجوفيه على الحد الفاصل بين المياه متوسطة الملوحة والمالحة باستخدام الجيوكهربية المقطعية ثنائية الأبعاد بدلتا وادى سدر- غرب سيناء-مصر

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فى الخزانات الساحلية يحدث تداخل للمياه المالحة نتيجة للسحب الجائر من الآبار والذي بدوره يؤدى الى ارتفاع الحد الفاصل بين المياه متوسطة الملوحة والمالحة فى اتجاه البئر.

منطقة الدراسة عبارة عن المحطة البحثية لمركز بحوث الصحراء برأس سدر والتى تقع شمال مدينة رأس سدر وتبعد حوالى ٥ كم من المنطقة الساحلية الشرقية لخليج السويس.

الرواسب الوديانية للعصر الرباعى تمثل الخزان الرئيسى للمياه الجوفية بدلت وادى سدر حيث يتراوح عمق المياة الجوفية من ٤,٦ الى ١٧,١ متر من سطح الأرض. ملوحة هذا الخزان تزداد تدريجيا من ٢٠٠٠ جزء فى المليون فى الشرق الى ٨٠٠٠ جزء فى المليون ناحية الغرب والزيادة فى الملوحة ترجع الى السحب الزائد الذى يؤدى الى تداخل مياه البحر.

يهدف هذا البحث الى مراقبة تأثير معدل السحب على ارتفاع الحد الفاصل بين المياه متوسطة الملوحة والمالحة بالمنطقة الساحلية برأس وحساب السحب الأمن لآبار المياه بالمحطة البحثية للمركز بمنطقة الدراسة.

لتحقيق الهدف من الدراسة تم قياس أربعة قطاعات جيوكهربية مقطعية ثنائية الأبعاد تمر ببئرين من آبار المحطة البحثية. هذه القطاعات تأخذ اتجاهات شمال-جنوب و غرب-شرق. طول كل قطاع ٤٥٠ متر وتم استخدام نظام فنر لتوصيل الأقطاب الكهربية و المسافة بين أقطاب التوصيل الكهربى ١٠ متر. تمت عملية القياس على كل قطاع قبل عملية السحب وبعد عملية السحب بمعدلات وأوقات مختلفة من بداية السحب.

نتائج تحليل البيانات للقطاعات الجيوكهربية المقطعية ثنائية الأبعاد بينت الآتى:-

- عند معدل سحب قليل (٨,٦ م$^{٣}$/ساعة من البئر رقم ٢) يتحرك الحد الفاصل بين المياه متوسطة وشديدة الملوحة ببطء.
- عند معدل سحب متوسط (١٧ م$^{٣}$/ساعة من البئر رقم ١) تزداد حركة الحد الفاصل حيث تكون حركة الحد الفاصل ملموسة و لكنها مازالت بعيدة عن الدخول الى البئر.
- عند معدل سحب على (٢٤ م$^{٣}$/ساعة من البئر رقم ١) يتحرك الحد الفاصل بسرعة ناحية البئر وهذا تم تأكيده بقياس الملوحة أثناء عملية السحب للمعدلات المختلفة.
- ارتفاع الحد الفاصل بين المياه متوسطة وشديدة الملوحة يكون أكثر وضوحا فى القطاعات المقاسة فى اتجاه غرب-شرق عن القطاعات المقاسة فى اتجاه شمال-جنوب لنفس معدلات السحب وهذا يدل على أن الرواسب الوديانية لخزان الرباعى لها نفاذية عالية فى اتجاه غرب-شرق (اتجاه سريان المياه الجوفية) عن اتجاه اتجاه شمال-جنوب (الاتجاه العمودى).

طبقا لنتائج هذه الدراسة فان السحب الأمن فى منطقة الدراسة يكون أقل من ٢٤ م$^{٣}$/ساعة وعلى هذا الأساس فان السحب بمعدل ١٧ م$^{٣}$/ساعة يمثل السحب الأمن بمنطقة الدراسة. تم استخدام قيمة السحب الأمن لحساب قيمة معامل التوصيل الهيدروليكى لخزان العصر الرباعى فى المنطقة الساحلية بدلتا وادى سدر والتى تكافىء ٥,١م / يوم.