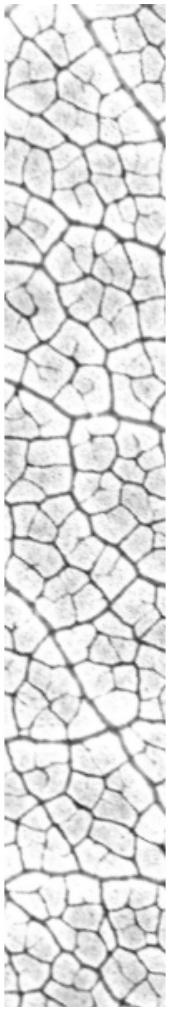

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Confined aquifer field potentiality new classification

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Abstract
This research introduces new classification for confined aquifer field, the previous classification for Aquifer potentiality was done by Geohage, 1979 and depends only on transmissivity which set that more than 500 m^2/day in is classified as high potentiality, meanwhile 50-500 m^2/day is moderate, and the rest between low to negligible. The previous classification; did not take in consideration the other hydraulic properties of the aquifer, the surface area extension of the aquifer and the heterogeneity of the aquifer which all affect directly on water exploitation management. The research was conducted in the three areas of Darb El Arbeain, southern western Desert, Egypt. In this study four suggested scenarios of pumping rates have been explored using the three dimensional finite difference flow model (MODFLOW 2005) to simulate the flow system. The study introduced new classification for confined aquifer classification where set that any confined aquifer exploiting 100 000 m^3/day with less than 20 m steady aquifer drawdown, aquifer response, is classified as high potential, meanwhile under same exploitation rate with 20-40 mt as aquifer response is considered as moderate potentiality, and the rest is low in potentiality.

Keywords: Aquifer potentiality, hydraulic properties, surface area extension, flow model (MODFLOW 2005), moderate potentiality

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INTRODUCTION

Darb El-Arbeain projects aims for reclamation and development of 12, 000 feddans on the Nubian Sandstone aquifer which is the main source of groundwater in the southern western Desert of Egypt. Darb El-Arbeain area lies between long. 29° 00/ and 31° 00/ E and lat. 22° 00/ and 24° 30/ N (**Fig. 1**). It comprises an area from south Baris town and extends along Darb El-Arbeain road towards south direction of the Egyptian Sudanese border. It is divided into three areas: Northern part, middle part and Southern part. The annual rainfall is less than 1.1mm. The Nubian sandstone aquifer in the area of study is capped by a confining bed (Dakhla Formation) and underlain by basement rocks. **The target of this study is to introduce new classification of confined aquifer taking in consideration the quantity of water exploitation possibility versus drawdown and considering the confined aquifer specifications.**

DESCRIPTION OF THE STUDY AREA

Darb El- Arbaein is subdivided into three geomorphologic units, the southern Naklai-Sheb pene-plain; the western Atmur peneplain; and a plateau surface (Issawi 1971). Geologically, the exposed rocks range from Pre-Cambrian to Quaternary sediments (CONOCO 1989). The litho-stratigraphic successions are divided into seven units, from base to top (CONOCO 1989, El-Gammal 2004, Fathy et al. 2001, Ghazal 2002, Korany et al. 2002): 1) PreCambrian basement 2) Paleozoic-Mesozoicsandstone; 3) Lower Cretaceous; 4) Upper Cretaceous; 5)Paleocene; 6) Eocene; and 7) Quaternary. Darb El-Arbaein area is related structurally to the Red Sea and south western regions (EGSMA 1987a, 1987b). Issawi (1971) has identified the faults in E-W, NE-SW and NW-SE and three anticlines (Bir Kiseiba, Rage, and Shirshir) (Fathy et al. 2002).

METHODOLOGY

1. collecting and interpreting the results of different pumping rates simulation in the three areas of Darb El Arbeain.
2. using the simulation under the below pumping rates;
   A- All wells pumping out = 110% of initial recharge
   B- All wells pumping out = 180% of initial recharge
   C- all wells pumping out = 280% of initial recharge

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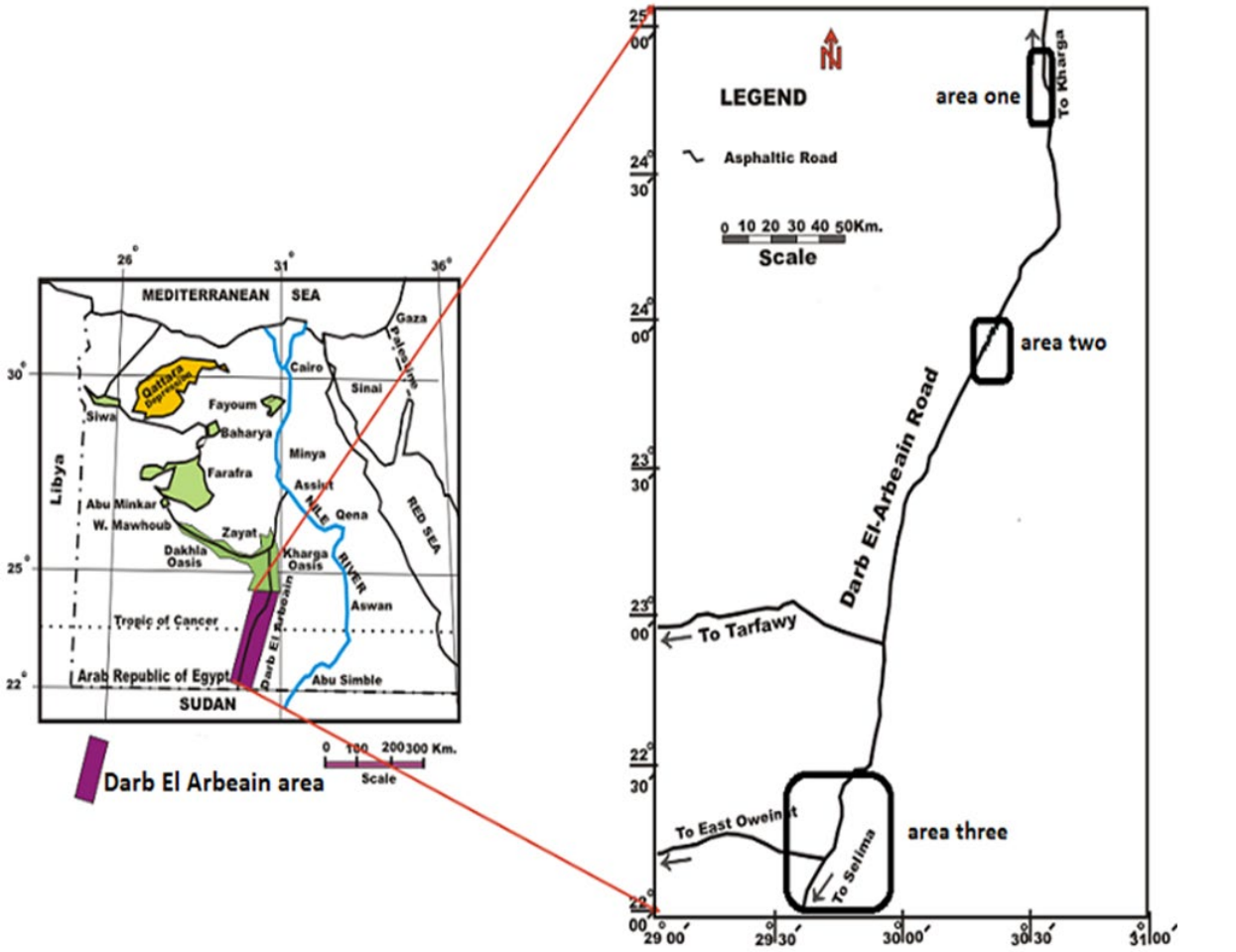

Fig. 1. Darb El Arbeain Map

Table 1. Aquifer potentiality classification (Geohage 1979)

Potentiality of the aquifer	Transmissivity (m^2/day)
High	>500
Moderate	50 – 500
Low	5 – 50
Very Low	0.5 – 5
Negligible	< 0.5

Table 2. Some Hydraulic Characteristics Of The Aquifer (Kamel 2004)

Well name	Transmissivity (m2/day)	Area related	Potentiallity classification
4	982	Area one	High
5	987	Area one	High
8	2034	Area one	High
11	375	Area two	Moderate
19	360	Area two	Moderate
27	325.2	Area two	Moderate
35	393.8	Area two	Moderate
65	886.7	Area three	High
71	1076	Area three	High
86	1997	Area three	High
90	1267	Area three	high

D- all wells pumping out = 370% of initial recharge

GEORHAGE (1979) CLASSIFICATION

Georhage (1979) classification for confined aquifer potentiality is shown in **Table 1**.

The area classification as per Geohage, 1979 is attached in **Table 2**.

The Disadvantages of Geohage, 1979 Classification That Did Not Take in Consideration;

1- The other hydraulic properties of the aquifer like hydraulic gradient, hydraulic conductivity.
2- The surface area extension of the field of the aquifer
3- The heterogeneity of the aquifer formation
4- It depends only on one-day maximum for testing and monitoring.
5- It is not taking in consideration running the wells in the same time which means it is ignoring the effect of affecting of the wells on each other.
6- The aquifer responds to pumping rate or exploitation rate. **The aquifer respond is new concept could be defined as; the average drawdown in the entire confined aquifer under pumping condition when reaching the equilibrium of water level.**

THE THREE CASES STUDIES

The first case study is the northern part which extends 90 km to the south from Paris town and has an

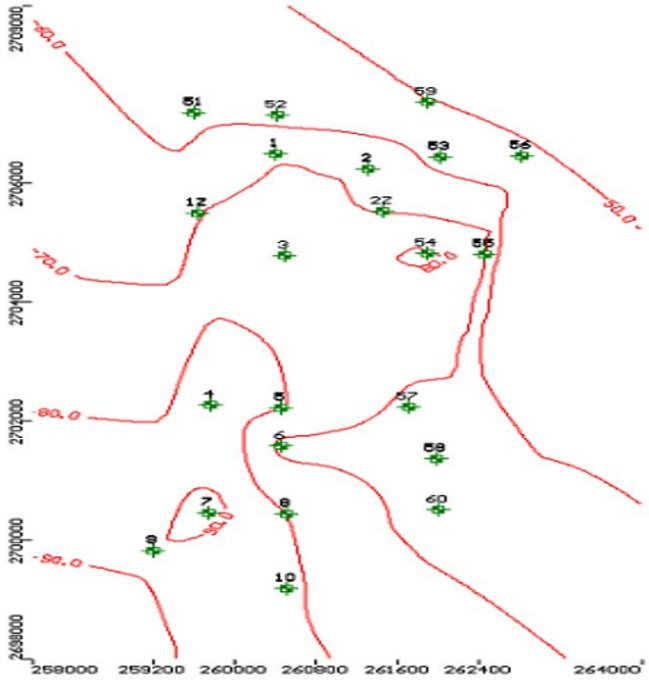

Fig. 2. Piezometric levels in area one, Darb El Arbeain

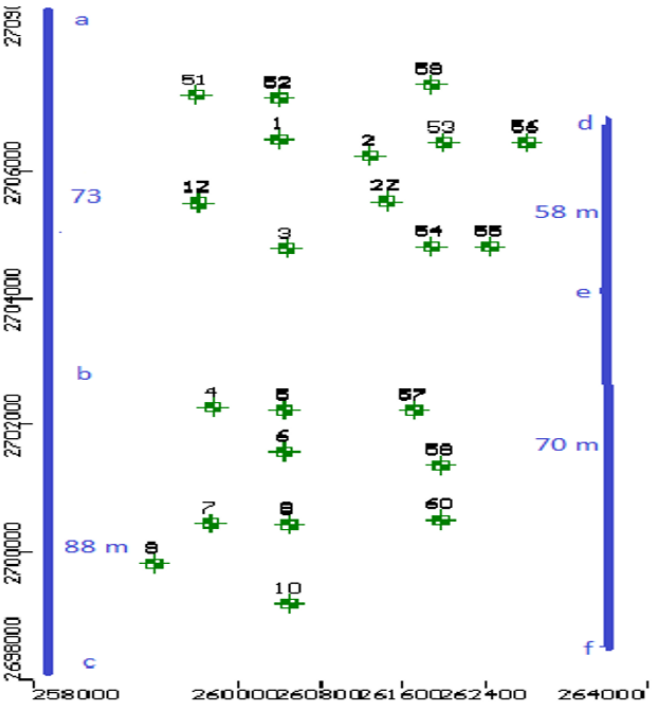

Fig. 3. Boundary condition heads in area one, Darb El Arbeain

area of 90 km^2, the second case study is the central part which extends for 80 km to the south of the northern part and has 120 km^2 in area, and the third case study is the southern part extends for 200 km to the south of the central part and has 170 km^2 in area.

First Case Study (Northern Area of Darb ElArbeain)

Applying modelling and correlate with field data (visual mod flow calibration which is 94 %).

Initial Model Input (First Assumption);

Kx = Ky = 3.07 m/day Kz = 0.307 m/day, no of aquifers; 1 (divided into 4 layers), no of rows = 100, no of columns = 183 (each cell is 60*60 mt), Average Specific storativity = .0001 m^{-1} , Average total porosity = 0.3, average effective porosity = 0.15 (El-Beih 2007), Piezometric level; taken from Kamel et al. 2004 (**Fig. 2**), currently average pumping rates of the wells is 1700 m^3/day, Boundary conditions (**Fig. 3**); the western

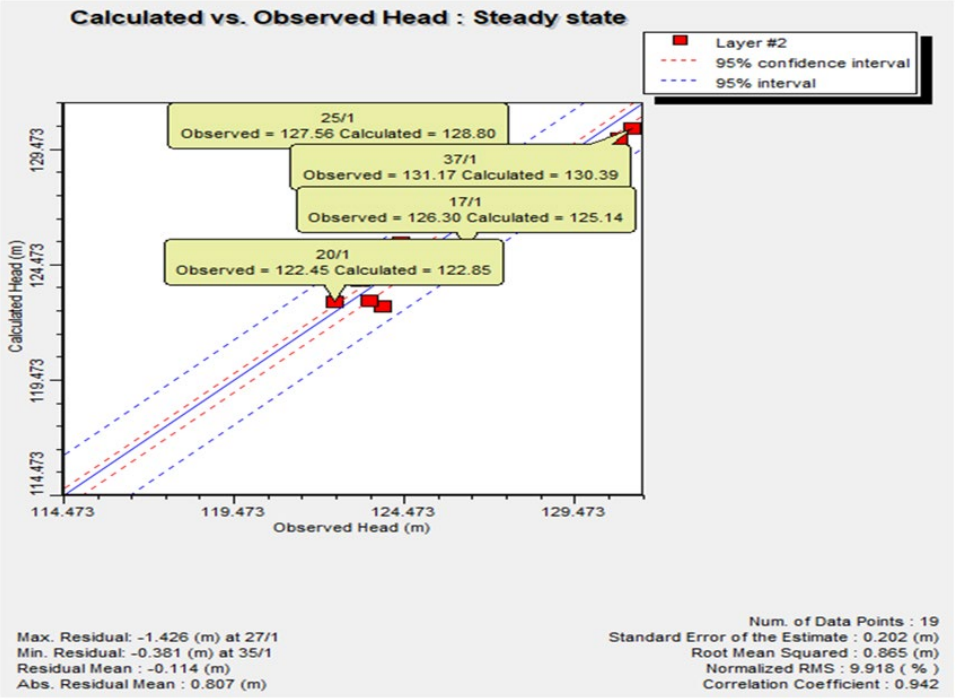

Fig. 4. Calibration results in area three

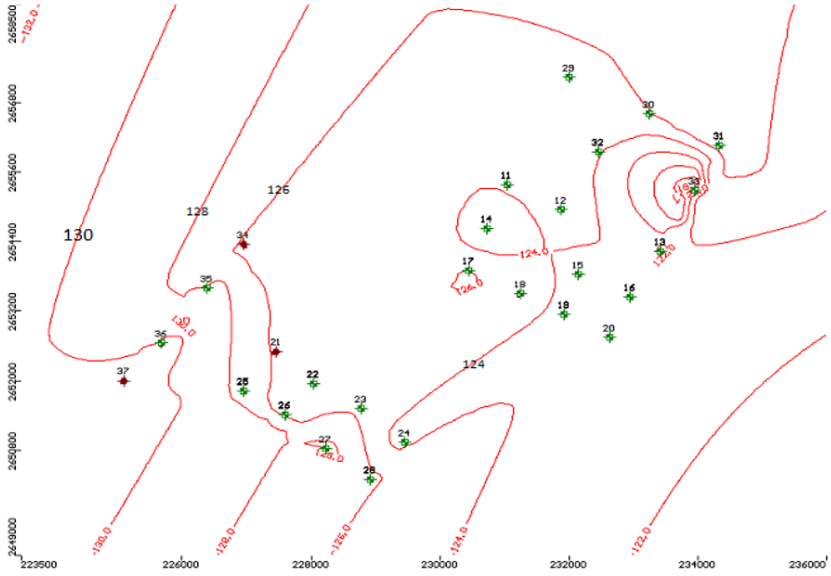

Fig. 5. Calibration results in area three

boundary; consist 2 segments, line a-b represent constant head 73 mt, meanwhile line from b-c represents 88 mt. The eastern boundary; line d-e represent constant head 58 mt, and line e-f represent Constant head 70 mt. The northern and southern parts represent no flow boundary. Area one target is to reclaim around 3 000 feddans. Calibration (**Fig. 4**) involved comparison of the model results and observed heads at 22 observation points (taken from pumping wells) from a piezometric head map to run in a steady state simulation, once the model calibrated, the calculated hydraulic heads were used as initial heads for the transient flow scenarios.

Second Case study (Middle Area of Darb ElArbeain)

Applying modelling and correlate with field data (visual mod flow calibration which is 94 %).

Initial Model Input (First Assumption);

Kx = Ky = 2.1 m/day Kz = 0.21 m/day, no of aquifers; 1 (divided into 4 layers), no of rows = 250, no of columns = 190 (each cell is 50*50 mt), Average Specific storativity = .0001 m^{-1}, Average total porosity = 0.3, average effective porosity = 0.15 (El-Beih 2007), Piezometric level; taken from Korany et al. 2002 (**Fig. 5**),

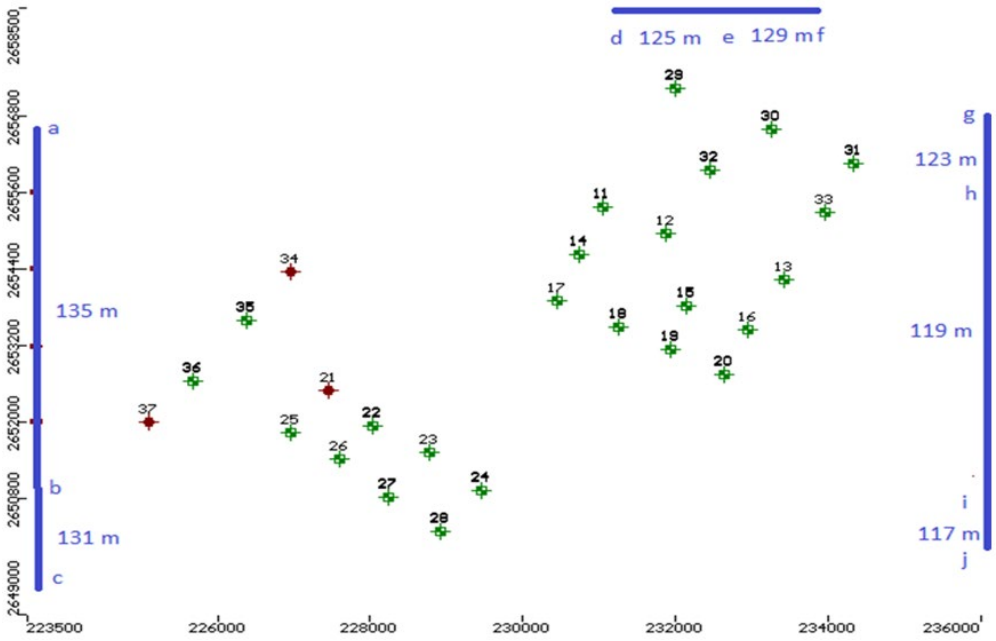

Fig. 6. Boundary conditions in area two in Darb El Arbeain

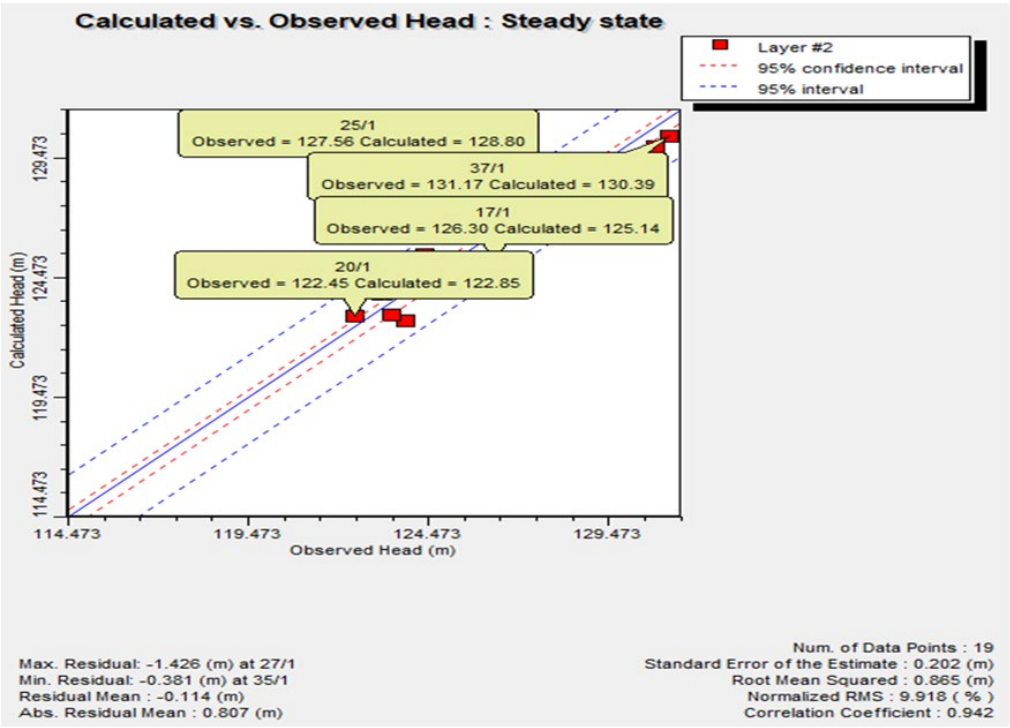

Fig. 7. Boundary conditions in area two in Darb El Arbeain

currently average pumping rate of the 27 wells is around 2000 m3/ day.

Boundary conditions (**Fig. 6**); the western boundary; consist 2 segments, line a-b represent constant head 135 mt, mean while line from b-c represents 131 mt. the eastern boundary; line g-h represent constant head 123 mt, line h-i represent Constant head 119 mt, and line i-j represent Constant head 117 mt. the northern boundary; line d-e represent constant head 125 mt, line e-f represent Constant head 129 mt. the southern parts represent no flow boundary.

Area one target is to reclaim around 4 000 feddans. calibration (**Fig. 7**) involved comparison of the model results and observed heads at 24 observation points (taken from pumping wells) from a piezometric head map to run in a steady state simulation, once the model calibrated, the calculated hydraulic heads were used as initial heads for the transient flow scenarios.

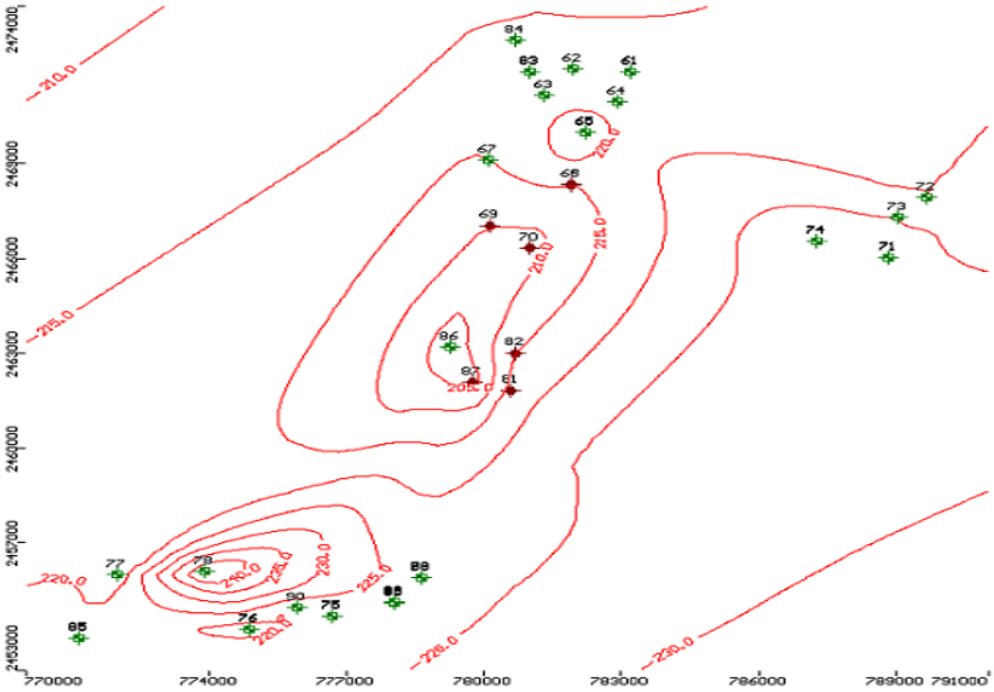

Fig. 8. Boundary conditions in area two in Darb El Arbeain

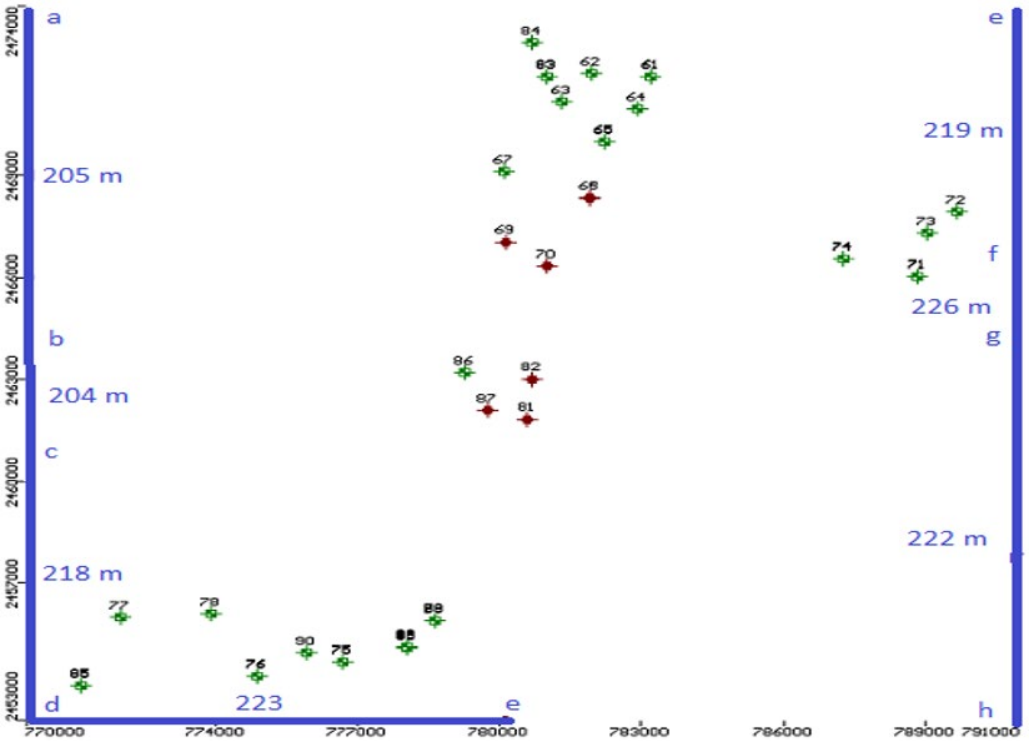

Fig. 9. Boundary condition heads in area three, Darb El Arbeain

Third Case Study Three (Southern Area of Darb ElArbeain)

By applying modelling (visual mod flow, and after calibration which is 92 %).

Initial Model Input (First Assumption);

$K_x = K_y = 6.5$ m/day $K_z = 0.65$ m/day, no of aquifers; 1 (divided into 4 layesr), no of rows = 200, no of columns = 200 (each cell is 50 * 50 mt), Average Specific storativity = .0001 m^{-1}

Average total porosity = 0.3, average effective porosity = 0.15 (El-Beih, 2007), Piezometric level; taken from Korany et al. 2002, (**Fig. 8**), currently the pumping still not yet started from the area. (have 30 wells ready),

Boundary conditions (**Fig. 9**); the western boundary; consist 3 segments, line a-b represent constant head

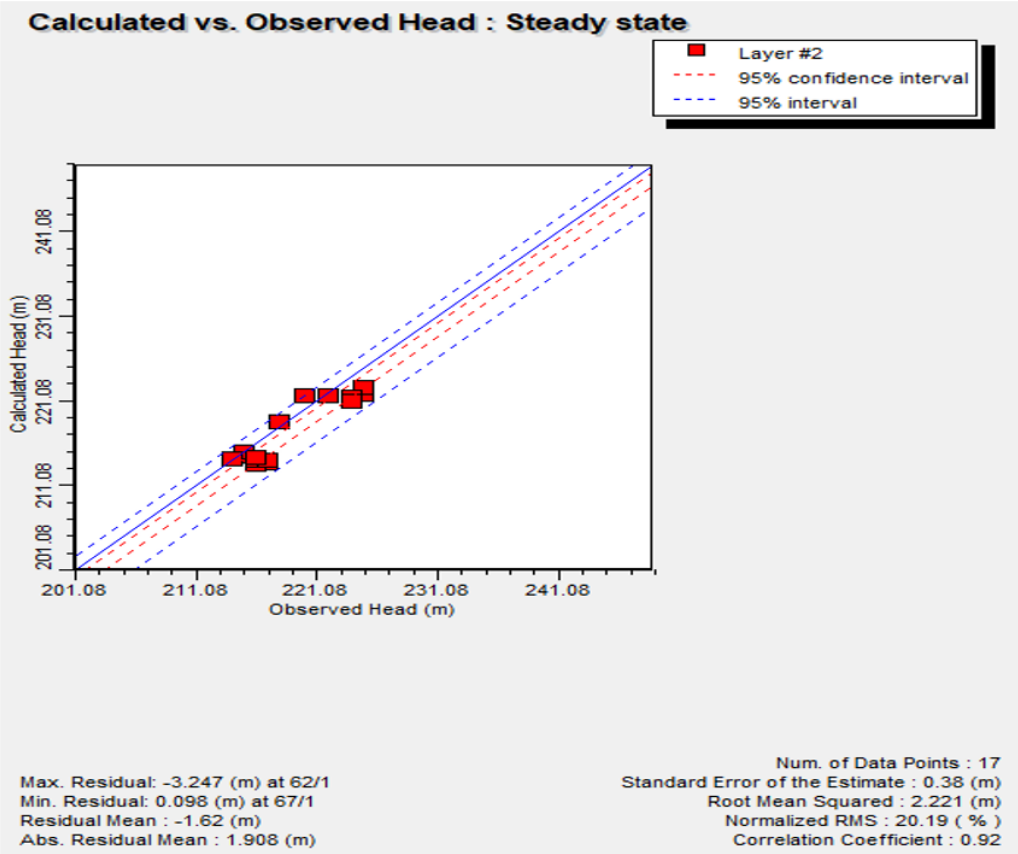

Fig. 10. Boundary condition heads in area three, Darb El Arbeain

Table 3. Area one aquifer responds under different exploitation rates, in surface area 6 000 m* 11 000 m

$Q_{out}/Q_{in(initial)}$	Exploitation rate from entire area, m^3/day	Aquifer respond (average aquifer drawdown), m
1.1	37 400	6
1.8	61 600	10
2.8	94 600	16
3.7	125 400	18

Table 4. Area two aquifer responds under different exploitation rates, in surface area 12 500 m* 9 500 m

$Q_{out}/Q_{in(initial)}$	Exploitation rate from entire area, m^3/day	Aquifer respond (average aquifer drawdown), m
1.1	32 400	**6.5**
1.8	54 000	**13.5**
2.8	81 000	**17**
3.7	108 000	**35**

205 mt, mean while line from b-c represents 204 mt, and line c-d represents 218 m. the eastern boundary; line e-f represent constant head 219 mt, and line f-g represent Constant head 226 mt, and line g-h represent constant head 222 m. the southern parts line d-e represent constant head 223 mt. the northern parts represent no flow boundary.

Area three target is to reclaim around 5 000 feddans. calibration (**Fig. 10**) involved comparison of the model results and observed heads at 23 observation points (from current wells) from a piezometric head map to run in a steady state simulation, once the model calibrated,

Table 5. Area three aquifer responds under different exploitation rates, in surface area 21 000 m* 21 000 m

$Q_{out}/Q_{in(initial)}$	Exploitation rate from entire area, m^3/day	Aquifer respond (average aquifer drawdown), m
1.1	54 000	**14**
1.8	90 000	**18**
2.8	138 000	**23**
3.7	180 000	**28**

Table 6. Confined aquifer potentiality classification

Exploitation rate from entire area, m^3/day	Aquifer respond (average aquifer drawdown), m	Potentiality Classification for using
100 000	Less than 20 m	**High**
100 000	20 - 40	**Moderate**
100 000	More than 40	**poor**

the calculated hydraulic heads were used as initial heads for the transient flow scenarios.

CONFINED AQUIFER RESPOND

The aquifer respond, average drawdown, under different pumping rates for the three areas are tabulated in **Table 3-5**.

INTRODUCING NEW CONFINED AQUIFER POTENTIALITY CLASSIFICATION

Introducing confined aquifer new classification depends on the quantity of water could be exploited in m^3/day versus the aquifer respond and tabulated in **Table 6**.

The main advantage of new classification is;

1- **Making The correlation between all hydraulic parameters of the aquifer field.**
2- **Taking in consideration the aquifer surface area.**
3- **Taking in consideration the hetrogenty degree of the aquifer and the impact on the aquifer respond in the pumping conditions.**
4- **The classification considers the time of running wells which means more accuracy.**

As per the new classification, so we can classify area one and area three as high potential area for exploiting water and land reclamation, meanwhile the second area could be classified as moderate potentiality.

CONCLUSIONS

The study areas located as southern western desert of Egypt. It is characterized by arid climatic conditions. Four different pumping scenarios were applied for 25, 50, and 100 years. Through applying visual modflow and correlation with field data, introducing new confined aquifer potentiality which set that with exploitation rate of 100 000 m^3/day; with aquifer respond, average drawdown, less than 20 m the aquifer is considered high in potentiality, when the drawdown ranging between 20-40 m the aquifer is considered moderate, and when the drawdown of the aquifer increases more than 40 m it classified as low potentiality.

RECOMMENDATIONS

For any management plan to be successful in any confined aquifer the classification must be addressed. This is due to the fact that it has high impacts on the project economics. More studies are required for confined aquifer projects.

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