CONFINED AQUIFER PIEZOMETRIC HEAD DEPLETION IN THE DYNAMIC STATE

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Abstract: This research introducing the depletion of piezometric head in the confined aquifer. The results were obtained through application of simulation program (visual mudflow) in the three areas of Darb El Arbeain, southern western Desert, Egypt. **Through different pumping scenarios for each case study, by running each case for 110 %, 180%, 280%, and 370% of initial calculated recharge and interpolation till the depletion of the piezometric head in each case study separately then correlate all cases of study and introducing depletion trend and guiding equations, the study revealed that the heterogeneity of the aquifer depends on both The time required for water level equilibrium under dynamic condition and The percentage of difference between max and min value of drawdown.**

1.Introduction

Darb El-Arbeain projects aims for reclamation of 12, 000 feddans in the 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). Geographically It is divided according into three areas: Northern part (case one), middle part (case two) and Southern part (case three). **The target of this study is to introduce the governing equation to the depletion in the confined aquifer. Predicting the performance of the piezometric head is important for managing groundwater exploitation.**

2. Areas of Study

Darb El-Arbaein is subdivided into three geomorphologic units, the southern Naklai-Sheb pene-plain; the western Atmur peneplain; and a plateau surface. The litho-stratigraphic successions are divided into seven units, from base to top: 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. The faults have identified in E-W, NE-SW and NW-SE and three anticlines (Bir Kiseiba, Rage, and Shirshir). The stored water in Nubian sandstone is mainly fossilized water and ranges from20000 to 40000 y.

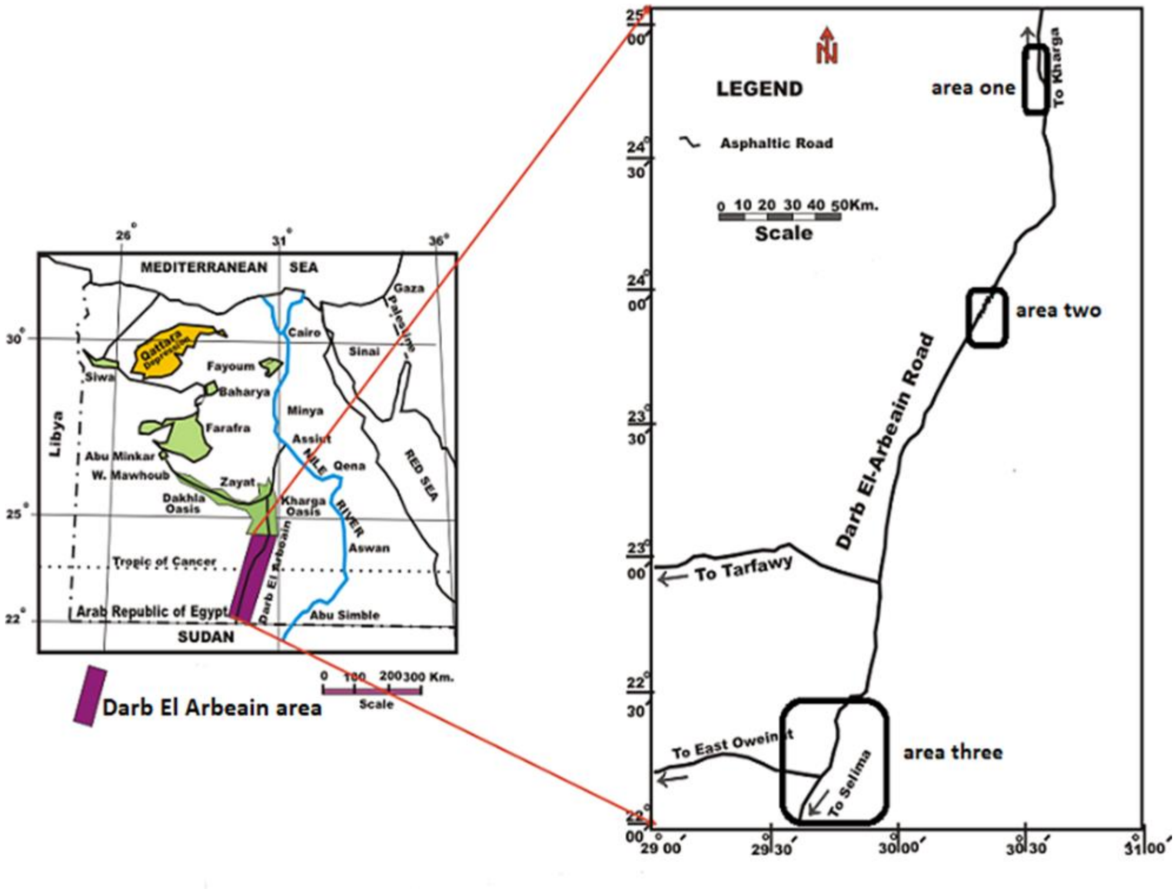

Fig.(1): Darb El Arbeain Map

The case no 1 extends 90 km to the south from Paris town and has an area of 90 km^2. Meanwhile the second case extends for 80 km to the south of the northern part and has 120 km^2 in area. The third case extends for 200 km to the south of the central part and has 170 km^2in area.

2-1 First Case study (northern area of Darb ElArbeain)

Hydraulic conductivity; 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), groundwater level at 2004 taken from Kamel et al. 2004 (Fig.2), currently average pumping rates of the wells is 1700 m^3/ day. Piezometric heads Bounding the area (Fig.3) ;the western boundary; consist 2 segments, line a-b represent constant head 73 m, mean while line from b-c represents 88 m. the eastern boundary; line d-e represent constant head 58 m, and line e-f represent Constant head 70 m. 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 22observation points (taken from pumping wells) from a piezometric head map to run in a steady state simulation, visual mod flow calibration is 94 %. once the model calibrated, the calculated hydraulic heads were used as initial heads for the transient flow scenarios.

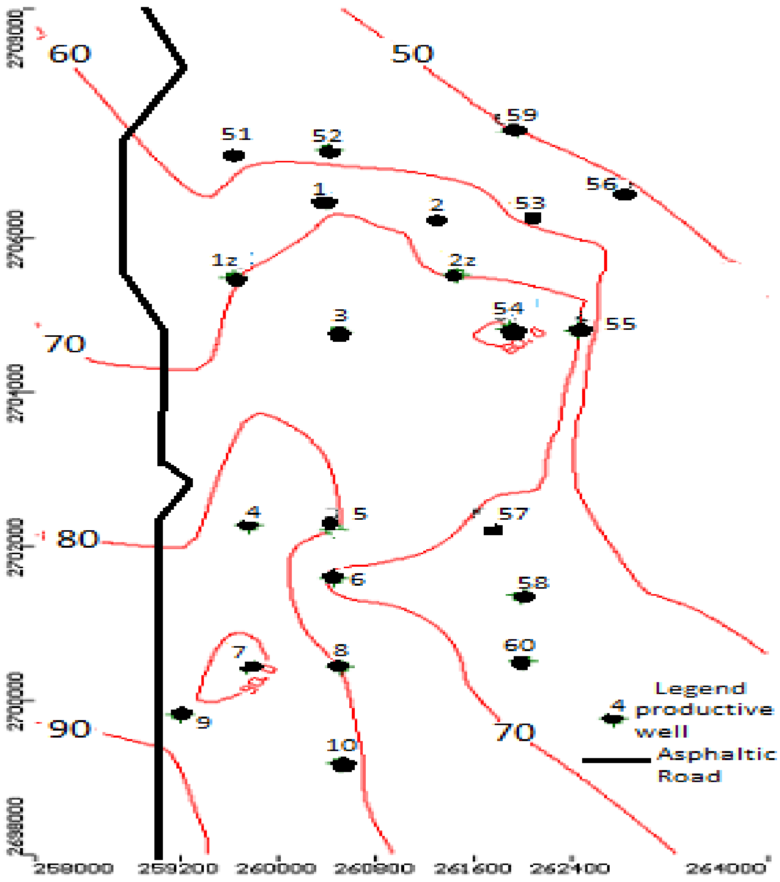

Fig.(2): piezometric levels in area one, Darb El Arbeain

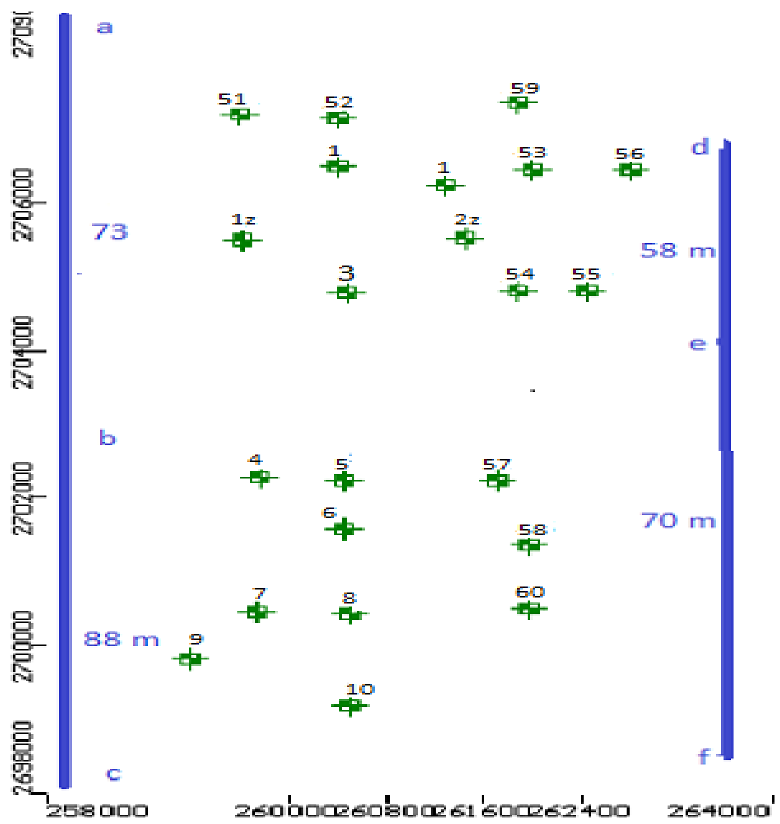

Fig. (3): Piezometric heads bounding area one, Darb El Arbeain, m, used for calibration

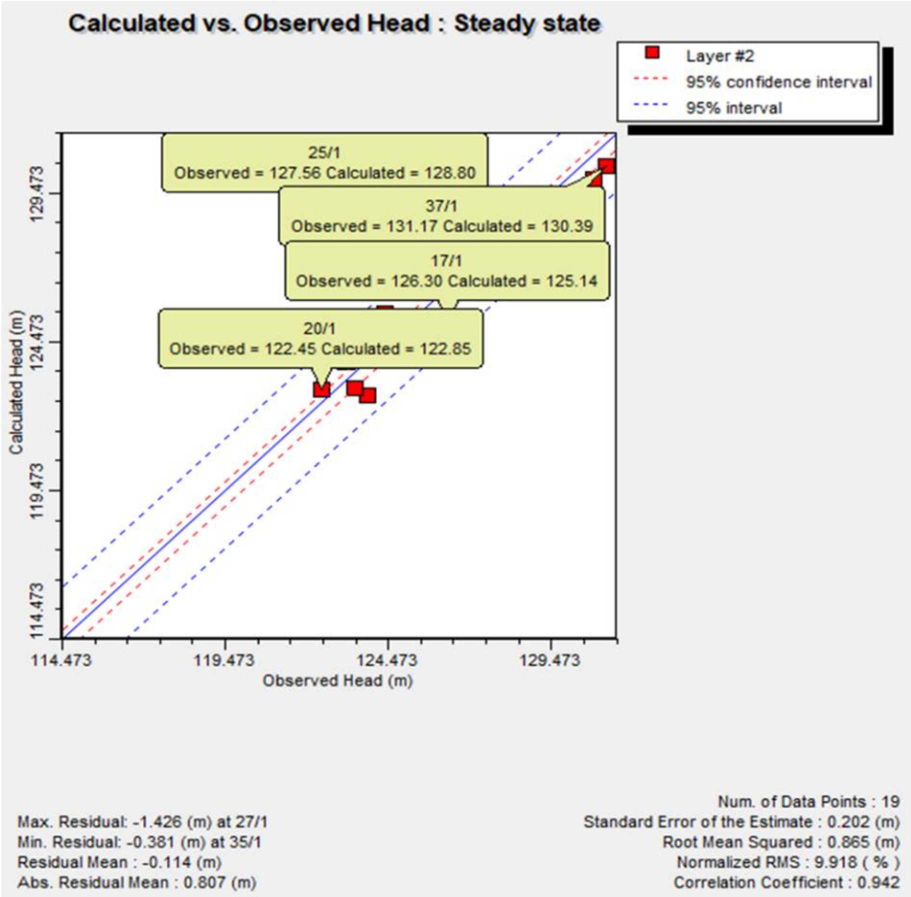

Fig.(4): calibration results in area three

2-2 Second Case study (Middle area of Darb ElArbeain)

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

The hydraulic conductivity; 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), currently average pumping rate of the 27 wells is around 2000 m^3/ day. Piezometric heads Bounding the area used for calibration (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 two 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.

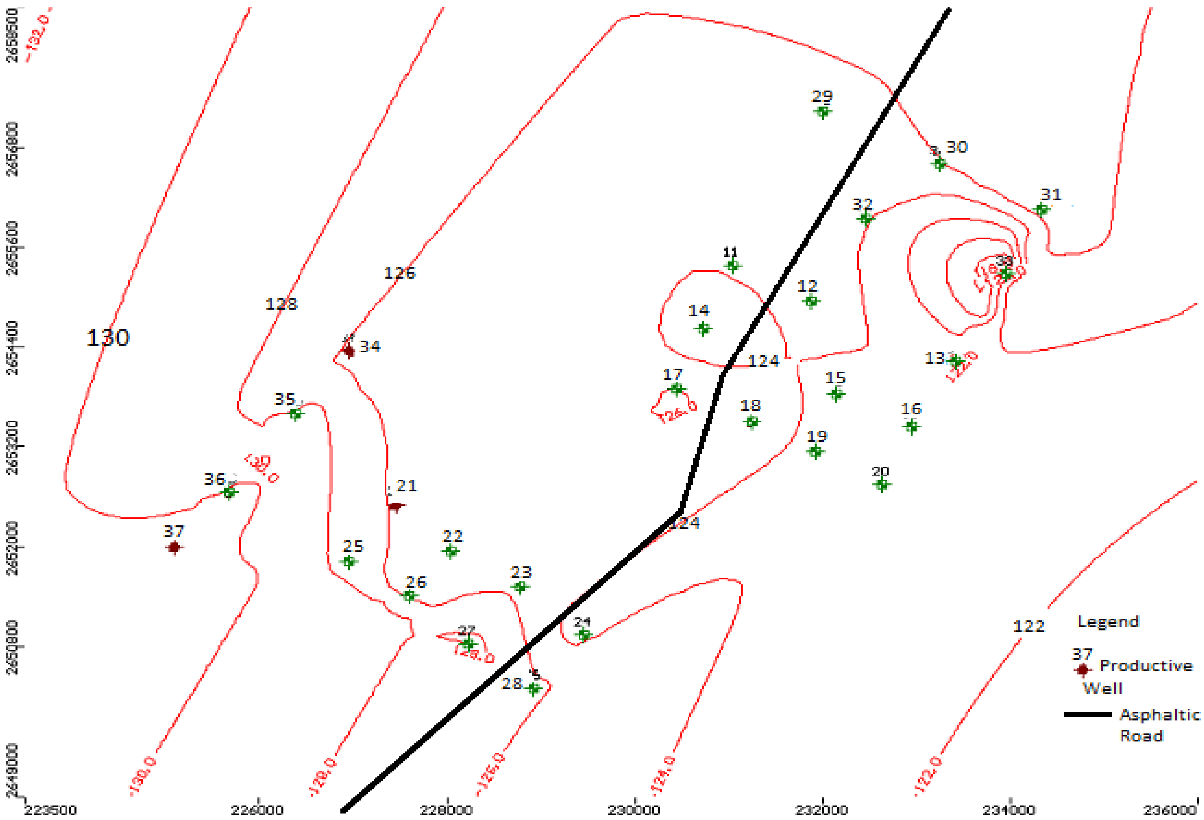

Fig.(5): piezometric levels in area two, Darb El Arbeain

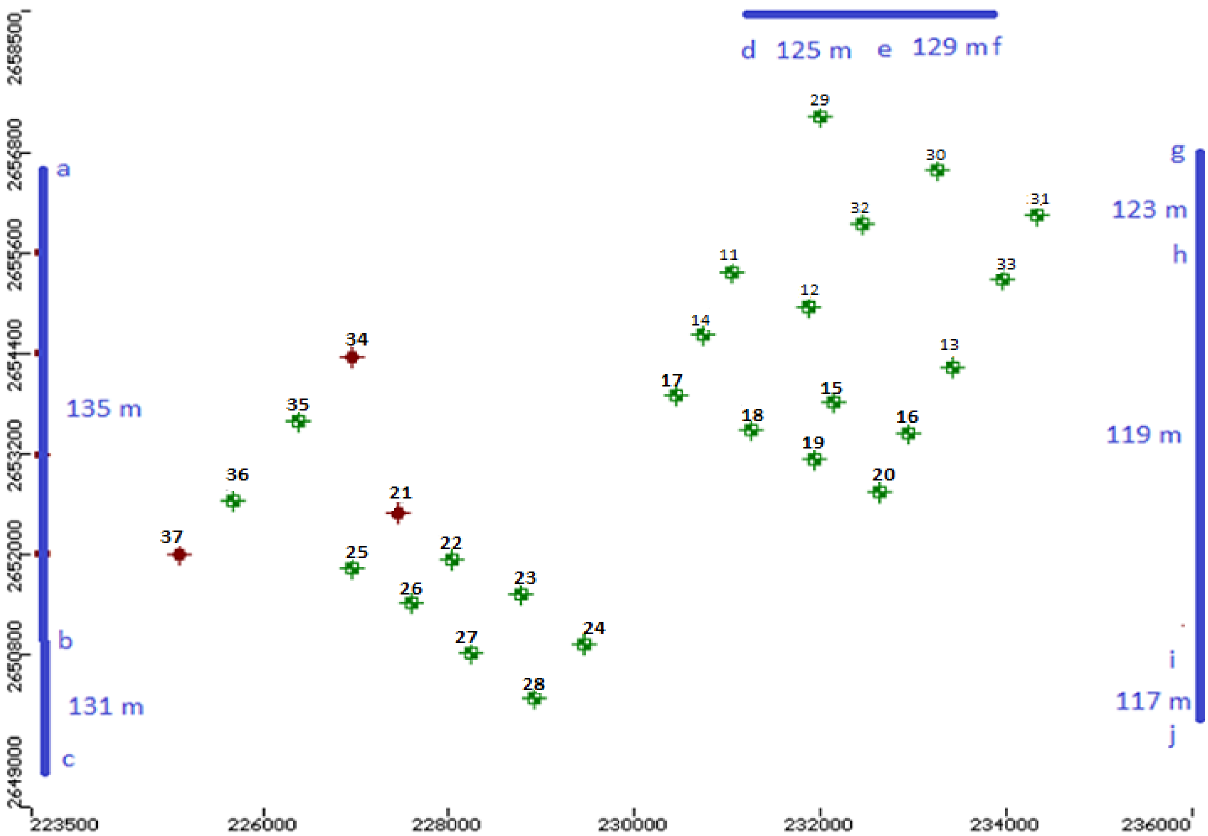

Fig.(6): Piezometric heads Bounding area two in Darb El Arbeain, m, used for calibration

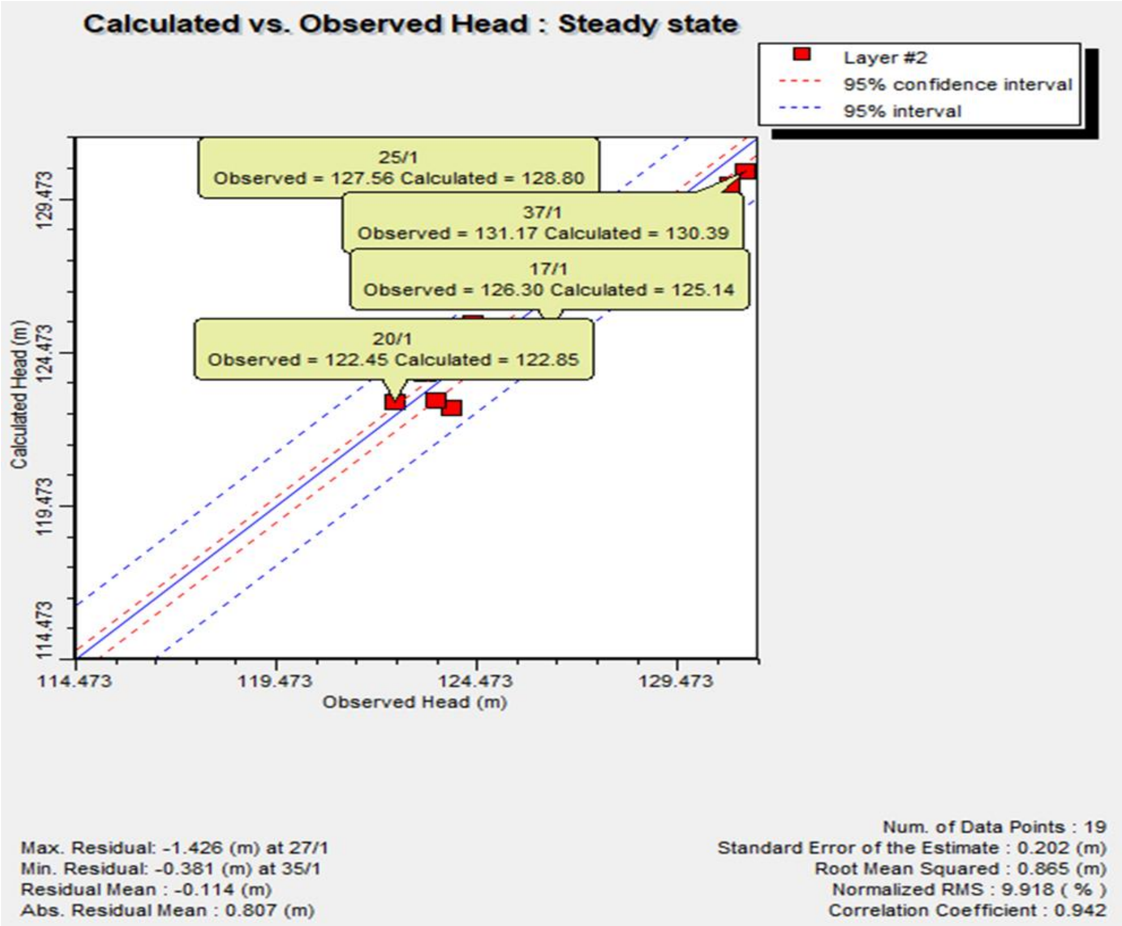

Fig. (7): calibration result to area two, Darb El Arbeain

2-3 Third Case Study Three (Southern Area Of Darb ElArbeain)

The hydraulic conductivity; $K_x = K_y = 6.5$ 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). Piezometric head Bounding the area (Fig.9); the western boundary; consist 3 segments, line a-b represent constant head 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 at23 observation points (from current wells) from a piezometric head map to run in a steady state simulation, calibration is 92 %, once the visual mudflow model calibrated, the calculated hydraulic heads were used as initial heads for the transient flow scenarios.

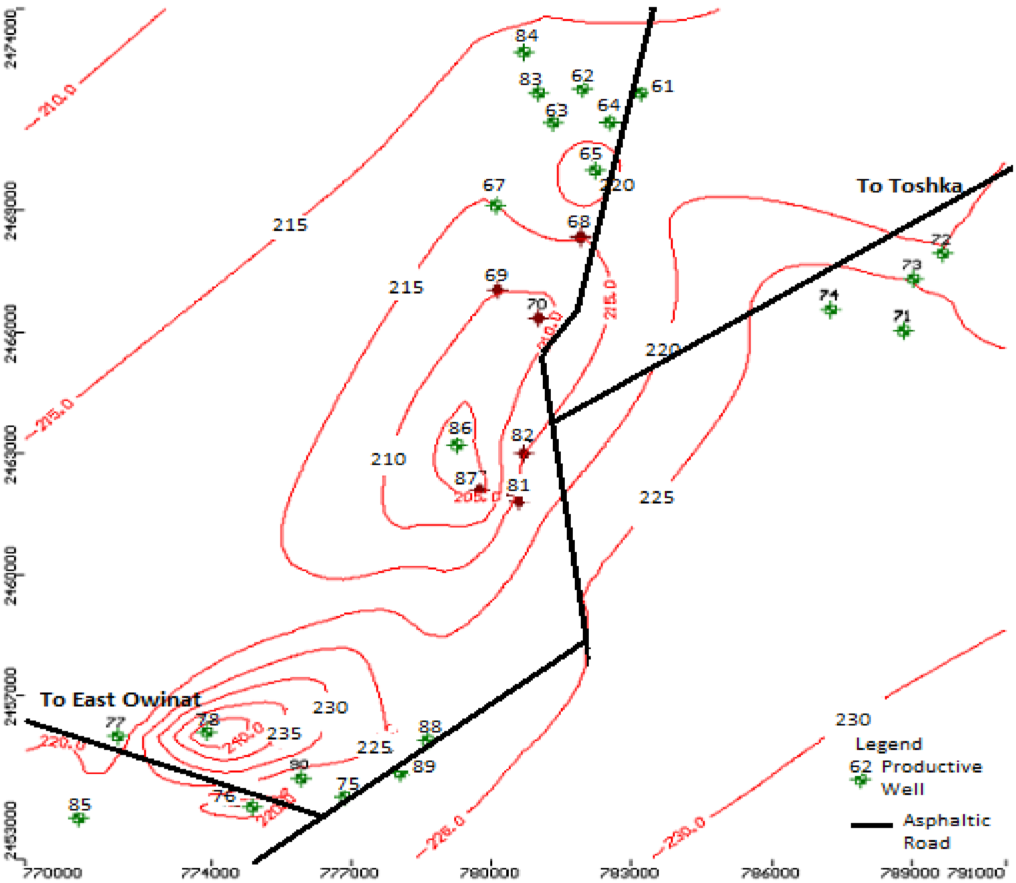

Fig.(8): piezometric levels in area three, Darb El Arbeain

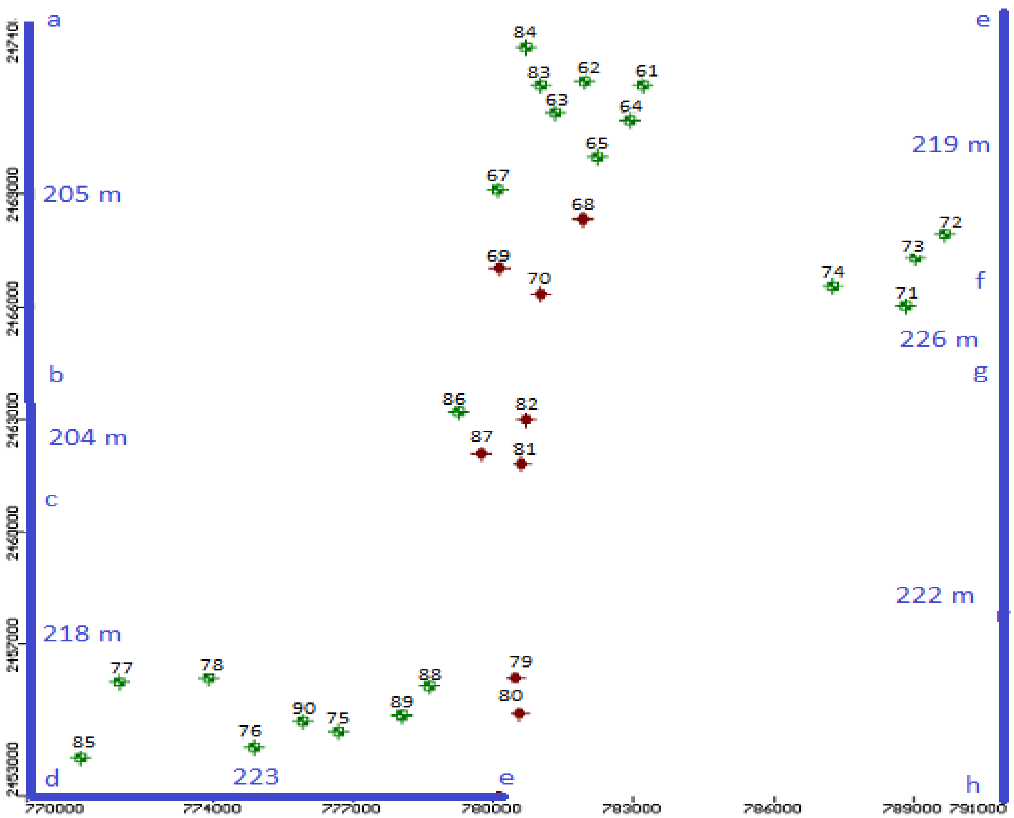

Fig.(9): Piezometric heads bounding area three, Darb El Arbeain, m, used for calibration

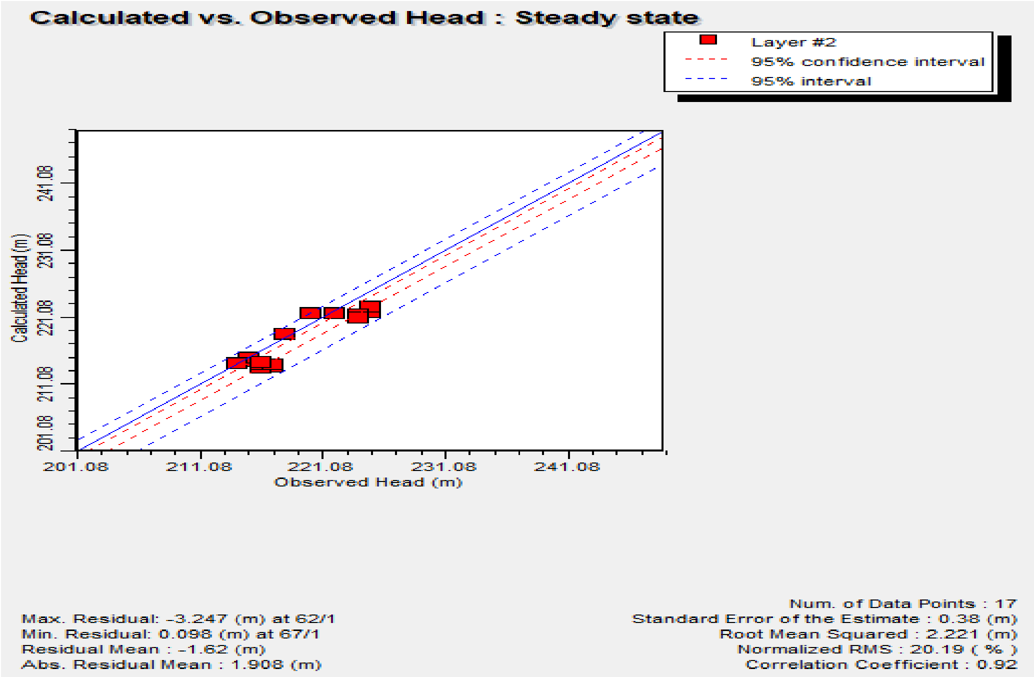

Fig. (10): calibration results in area three

3. Piezometric head performance

3-1 Piezometric head performance in the first case study

3-2 Piezometric head performance in the second case study

3-3 Piezometric head performance in the first case study

4. Equilibrium in Darb El Arbeain Confined Aquifers under Dynamic Conditions

The drawdown response in all areas under different pumping rates are illustrated in Fig. 15, 16, 17, and 18. Area two and area three showing that maximum Drawdown is more than three times the minimum drawdown and more time for stability representing more inhomogeneity. Meanwhile **area one representing more stability of the confined aquifer, more smoothly changing in the aquifer properties and more proper distributing of the wells reducing the individual effect of the wells on each other due to relatively less time**

for equilibrium and the difference between maximum and minimum Drawdown is in the range of twice.

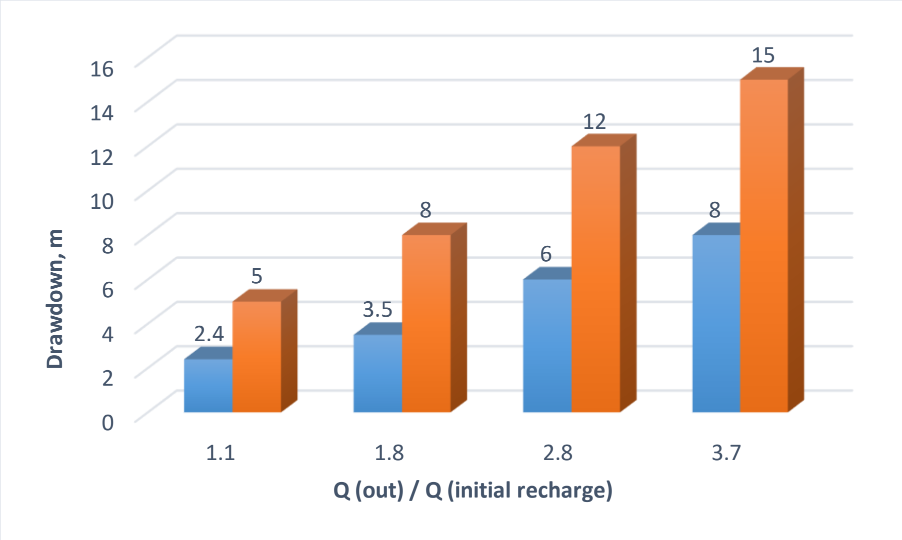

Fig. (15): Min. Vs Max. Drawdown, m, in area one under different pumping rates

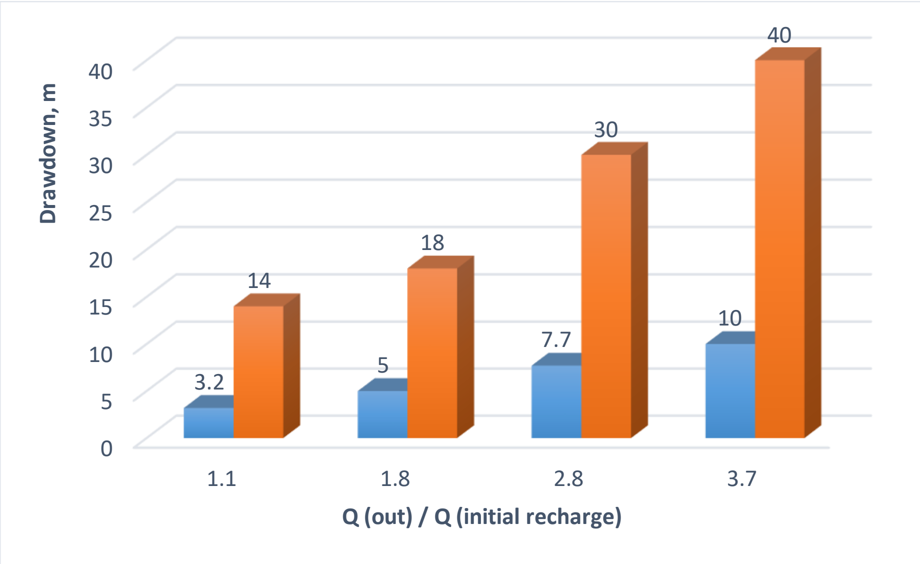

Fig. (16): Min. Vs Max. Drawdown, m, in area two under different pumping rates

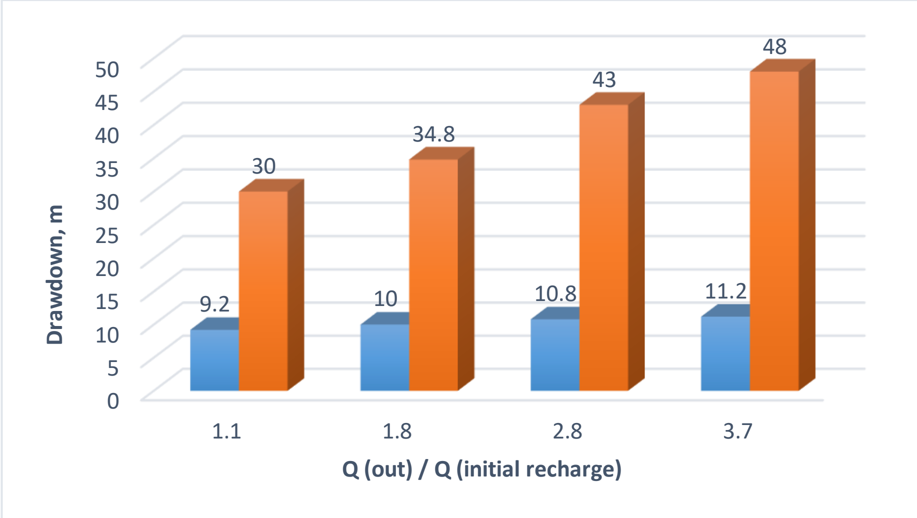

Fig. (17): Min. Vs Max. Drawdown, m, in area Three under different pumping rates

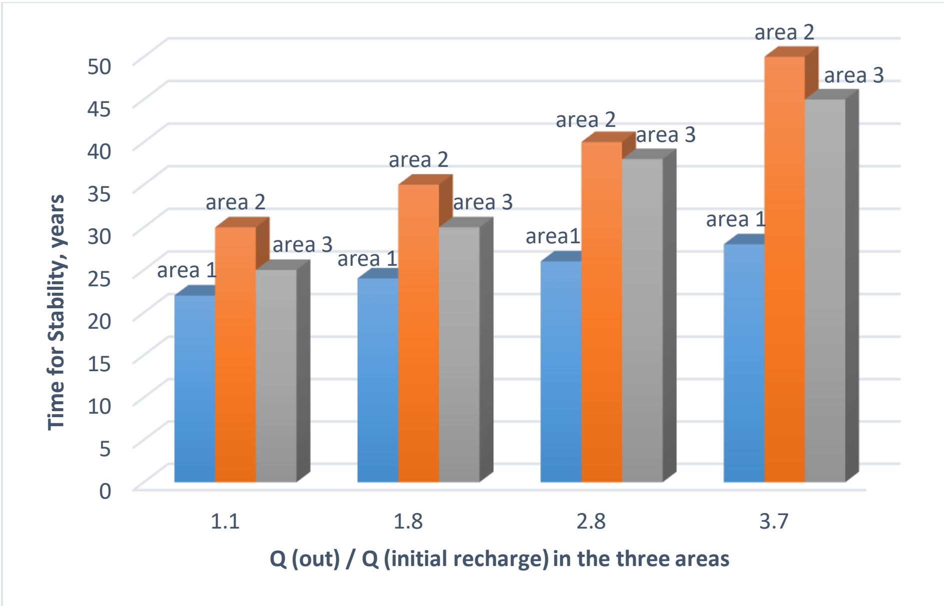

Fig. (18): Time for stability under different pumping rates in the three areas

5.Results and Discussion of the Aquifer Formation Stability Index

The index of aquifer formation stability is indicated through;

a- **The time required for water level equilibrium under dynamic or pumping conditions**, which sometimes may be also used to clear poor hydraulic properties of the aquifer, but here we will use it for confined aquifers with good potentiality. In first case the time required for equilibrium in dynamic condition while pumping out from the aquifer 370 % of the initial recharge is around 28 years, comparing same pumping conditions with area two and area three; the time required for water level equilibrium are 45 years and more. This reflects more stability in northern area compared with second and third areas, but still affected by some aquifer formation instability due to tectonic movements (Fig. 19). **So more aquifer formation stability**

expresses less time than 28 years required to reach water level equilibrium while pumping out from the aquifer 370 % of the initial recharge to the aquifer.

b. **The percentage of difference between max and min value of drawdown in the aquifer.** Which also may be used for expressing low hydraulic properties but here will be dedicated for good confined aquifer potentiality. In the first case the max value of drawdown is around 2 times of minimum drawdown value which confirm more stability comparing with second and third case studies (Fig. 19). Second and third cases shows that max drawdown values are more than 3 times of minimum value of drawdown. **So more aquifer formation stability express that the max value of drawdown is less than 2 times of the min value of Drawdown.**

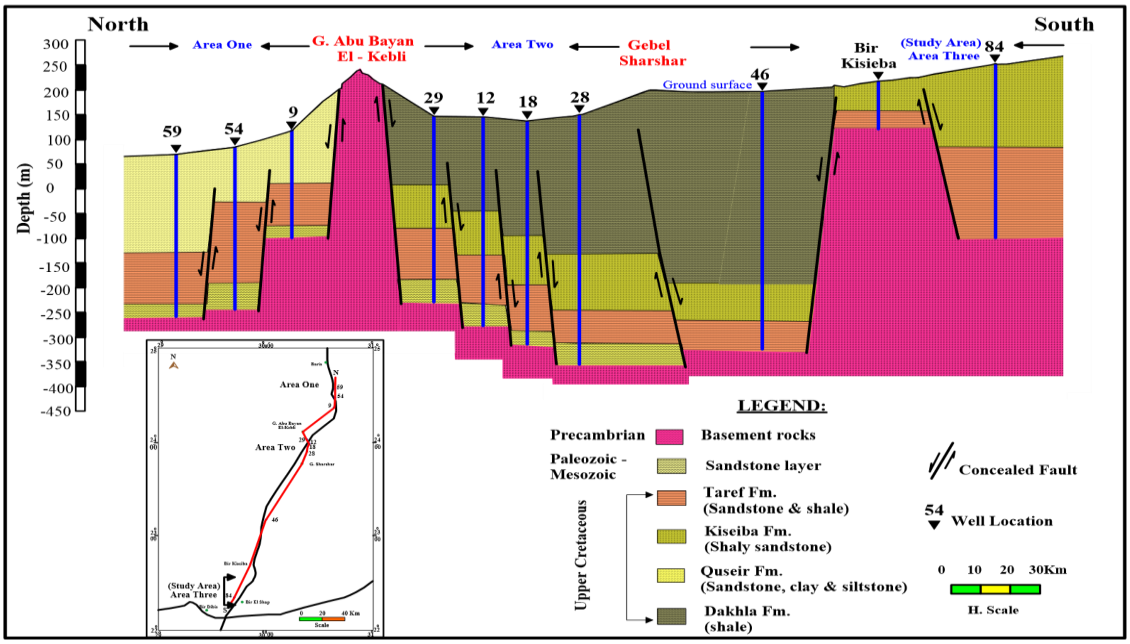

Fig. (19): A very generalized hydrogeological cross section along the three areas of Darb El Arbaein, International Journal of Geosciences, 2012

6. Conclusions

The study areaslocated 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. The results indicated that more aquifer formation stability expresses less time than 28 years required to reach water level equilibrium while pumping out from the aquifer 370 % of the initial calculated recharge to the aquifer, and more aquifer formation stability expresses that the max value of drawdown is less than 2 times of the min value of Drawdown.

7. Recommendations

For any management plans to be successful in any confined aquiferthe heterogeneity index must be addressed. This is due to the fact that it has high impacts on water table drawdown, heads variations and the time for equilibrium. More studies are required for heterogeneity index to be in confined aquifer projects.

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