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A TRIAL FOR MITIGATION OF WATERLOGGING PROBLEM IN NEW RECLAIMED AREAS IN THE DESERT FRINGES OF BENI SUEF AND EL-MINYA GOVERNORATES, EGYPT.

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"محاوله للتخفيف من حدة مشكلة غدق المياه بمناطق الإستصلاح الجديدة في الأطراف الصحراوية لمحافظتي بني سويف والمنيا ـــ مصر"

خلاصة:

من أهم المشاكل التي تهدد مستقبل مشاريع التنمية الزراعية بمناطق الإستصلاح بمصر مشكلة غدق الأراضي. وفي هذا البحث تم مناقشة حلين للتخفيف من حدة هذه المشكلة بمناطق الإستصلاح الجديدة بالأطراف الصحراوية لمحافظتي بني سويف والمنيا. يعتمد الحل الأول على خفض منسوب المياه الجوفية بضخها من المناطق الغدقة وإعادة إستخدامها في زراعة مناطق إستصلاح جديدة ، ولكن تتوقف جدواه على إمكانية إنشاء شبكة جيده للصرف. بينما التخلص من المياه الزائده بالصرف البيولوجي يعتبر الحل الثاني المقترح والأمثل حيث يتناسب مع ظروف الصرف الحالية، ولما له من آثار بيئية إيجابية.

ABSTRACT

Expanding the reclamation of new lands within the unlimited desert area of Egypt has started to face the continuous growth of population and the urgent need for food security. The reclamation of the Nile valley's desert fringes affects its traditional cultivated areas as a result of the difference in the topographic level, inadequate drainage system and the existence of shallow-depth clay lenses beneath these sites which creates a perched condition that helps greatly in fasting the rising rate of water table.

The present paper threw light on a trial to mitigate the waterlogging problem due to the reclamation activities in the high-land desert fringes of Beni Suef and El-Minya governorates. The reclamation area was increased by 250% through the interval 1984-2001 as detected from the processed satellite images. The topographic feature of the reclaimed area reached 6 cm/km as detected from Digital Elevation Model (DEM).

Two proposed scenarios for mitigation of waterlogging problem were checked by using groundwater flow model in two spatial dimensions (ASM). Draining the water excess using suitable dewatering design is proposed as a first scenario to mitigate the problem. The proposed design has been tested and calibrated using mathematical modeling techniques under the present pumping conditions (583 m^3/h in summer and 375 m^3/h in winter) with

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increase in magnitude 0.08 m^3/sec through ten proposed dewatering-wells well distributed in the low-land logged area. The results showed that the losses from the logged area reached 0.048 m^3/sec after 100 days which approaches 36% of the average annual supplemented groundwater. So, the third of the supplemented groundwater abstractions can be saved when reusing the dewatering quantity in irrigation. The second scenario proposed the construction of four experimental biological-drainage farms in the most deteriorated areas with evapotranspiration consumption process of 0.118 m^3/sec. The second short-term proposed scenario is considered more adequate since the drainage of the pumped water during dewatering process is still a problem.

Improvement of drainage techniques, minimizing irrigation rate and replacing the present flooding irrigation method used in the surrounding cultivated lands by another suitable dripping techniques are recommended for mitigation of waterlogging problem. The reuse of drainage water will decrease the groundwater demand. The decrease of irrigation openings' diameter and the increase of lifting stations' efficiency will contribute in mitigation process.

1-INTRODUCTION

The climate in the studied area is hot and dry in the summer, and mild with rare rainfall in the winter. The maximum temperature ranges between 21 °C in January and 37 °C in July. The average evaporation intensity reaches 17 mm/day through summer season (Apr.-Sep.) while reaches 8 mm/day through winter season (Oct.-Mar.). The precipitation is scarce and does not exceed 6 mm/year. The mean monthly relative humidity during day time varies from 36% in May to 62% in December. The average monthly ETo, calculated with the modified Penman formula (FAO, 1979), ranges from 3mm/day in December to 9 mm/day in May.

Geographically, the studied reclaimed area is located in the desert fringes of Beni Suef and El-MinyaGovernorates. The reclaimed area lies between the geographical coordinates 30° 42′ - 30° 51′ E and 28° 30′ - 28° 55′ N. It is bounded from the east by Bahr Yussef, from the west by Western desert, and from the north by Fayum depression (Fig.1).

The rapid increase in the reclamation area was estimated from the processed Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) images covering the whole area. The two images were taken at 1984 and 2001 (Fig.2) which enabled good correlation in this interval. The high resolution of ETM+ image (28.5m) gives a good chance for accurate estimation of the new logged areas. Combined use of image processing and GIS techniques (Arcview 3.2, ERDASE IMAGINE 8.4 and SURFER8 software) proves to be a rapid and accurate method for land use characterization of the desert fringes area under reclamation.

The processed images show that the area of the reclaimed desert fringes, including the logged areas, increased from 20000 Feddan to 51000 Feddan through the interval of the satellite-images dates. This is confirmed with the field investigation during March 2003 (Table 2). Furthermore, the estimated double increase in reclamation area reflects the critical deterioration of both soil and groundwater resources.

Similarly, Digital Elevation Model (DEM) was used to automatically extract the topographic features of the reclaimed area. Two basic products derived from DEM are slope and aspect maps (Fig.3). The grey shades in the slope map in Fig.3-C represent ranges of slope with dark grey being very steep and light grey almost flat areas. The slope map shows the distribution of the maximal slope at each elevation point, whereas Fig. 3-B shows the distribution of slope direction or aspect for each cell. The DEM shows that the topographic feature of the reclaimed area is different widely which reflects an expected drainage problem. As a general its average slope reaches 6 cm/km from east to west direction. Their average ground surface elevation is about 40m above mean sea level (amsl) and higher than the adjacent traditionally cultivated area by 10m.Geomorphologically, the Nile River passes through high eastern and western calcareous plateaux with general slope from south to north. The cultivated lands in the west of River Nile are generally much wider than those in the east. The geomorphology of the study area is simple. The Young alluvial plains, Fanglomerates, Old alluvial plains, Calcareous plateaux, Sand dunes and Hydromorphologic pattern or drainage lines are the main geomorphologic units in the study area (Said, 1981).

Geologically,the sedimentary rocks belonging to Tertiary - Quaternary deposits occupy the surface of the study area (Fig.4). The Holocene silt and clay and Pleistocene sands and gravels cover the flood plain. They include Wadi deposits, Nile Fanglomerates, Nile Silts and Sand dunes. The Pleistocene sediments are represented by the Early Pleistocene deposits (Prenile deposits with fluviatile sediments), Middle Pleistocene deposits (Euonile deposits with coarse, massive and thick graded sands and gravel) and Late Pleistocene deposits (Neonile deposits with fluviatile sand, silt and clay, Said 1991). The high sand/shale ratio content of the soil cover of these deposits, especially in the southern area (≈ 3, Saad 1999), decreases the drainage efficiency and consequently causes water logging problem.

The subsurface Tertiary deposits in the study area are divided into Eocene and Pliocene deposits according to Tamer et al, 1974 (Table1). The Eocene deposits (385m) divide into Middle and Upper Eocene deposits. Middle Eocene deposits (300m) include Wadi Rayan Formation (shallow marine limestone intercalated with shale and sandy shale) and Beni Suef Formation (marine shale, marl and limestone). Upper Eocene deposits (85m) include Maadi Formation (shallow marine shale and limestone) and Qasr El-Sagha Formation (littoral marine to continental clastic sequence with Oyster beds). The Pliocene deposits include Kom El Shelul Formation (sandstone beds and coquinal limestone at top) and undifferentiated clay, sand and conglomerates.

The subsurface Quaternary succession (≈214m, Tamer et al 1974, Table1) is subdivided into Plio-Pleistocene of Old Nilotic deposits with total thickness 150m, Pleistocene of Old lacustrine deposits and Young Nilotic sediments (5m and 44m respectively) and Holocene section with 15m. The Quaternary deposits are underlying by the impermeable Pliocene clays and/or the Eocene carbonate.

Hydrogeologically,the groundwater system that underlies the study area consists of two productive aquifers; the Quaternary sand and clay water bearing formation and the Eocene Carbonate aquifer (Fig.5). The Quaternary aquifer represents the main aquifer in the study area and consists of thick unit of relatively coarse graded sands and gravels. The maximum thickness reaches 200m in the Valley flood plain reducing to about 50m in the studied reclaimed desert fringes. This aquifer is covered by the Holocene silt and clay layer which reflects the semi-confining condition while the unconfined condition is predominant in the desert fringes. The Eocene aquifer in the west of the Nile Valley is composed mainly of clay, marl with streaks of limestone. The hydraulic connection between the two aquifers is pronounced through the present fault planes.

Sub-soil water flow and irrigation water requirements

The Quaternary aquifer is recharged generally from the seepage of River Nile and irrigation canals and locally, in the study area, from the seepage of excess irrigation water. The average depth to water in the study area in the year 1975 was 11 m below the surface (Attia,1991) and reached 2.14 m below the surface at March 2003 (Table2).

The sub-soil peizometric surface map constructed from the field data of 2003 (Fig.6) shows that the general local trend of sub-soil water movement in the Quaternary aquifer is from west to east with hydraulic gradient varies from 2.5×10^{-3} in the western areas with high relief to 2×10^{-4} to the eastern low relief areas. As a general, the sub-soil water flow direction in the study area did not affect by the water logging problem since there is no sharp change between peizometric surface maps of 1990 and 2003 (Fig.6).The only exception is the local mound in map of 2003 which may be related to seepage water allocated locally in low-land areas. Moreover, there is no obvious difference between the seasonal fluctuations of the peizometric sub-soil water surface in winter or summer seasons (Table 2) or in the annual fluctuations from 1990 to 2003 as reflected from the resultant map (Fig.7). This means that the waterlogging problem may be related to inadequate drainage conditions more than flood irrigation system. Also, it is noticed that there is no significant trend in the cultivated and logged area fluctuations during the summer and winter of 2002/03 (Table 3, and Fig.8) which assures that the bad drainage conditions are more effective than flood irrigation system in waterlogging problem. Crop evapotranspiration ETc was estimated according to Kc factor (0.86 and 0.76 for summer and winter season respectively, FAO1977), potential evapotranspiration ETo (167.12 and 79.447 cm for summer and winter season respectively, according to Penman modified 1984) and the cultivated area (32974 and 40309 Feddan for the two mentioned seasons respectively, Table3). ETc for the studied area reached 143.72 and 60.379 cm/season for summer and winter respectively (Table 3). Applying addition of 47 % for leaching requirements (Percentage of irrigation salinity to drainage salinity =(700/1500)x100=47%) and 20% for conveyance losses, the irrigation water requirements reached 330405m^3 for summer season and 169686m^3 for winter season.

Actually, the irrigation water is applied once every 3-12 days for new reclaimed desert fringes soil. The average amount of water applied is about 10cm/irrigation giving an average surface water demand of about 14849 m^3/irrigation/summer and 16930 m^3/irrigation/winter. The surface water supply (maximum lifting rate of 4 and 3.4 cm/day/irrigation in summer and winter respectively) is supplemented by groundwater abstractions of about 583 m^3/h in summer and 375 m^3/h in winter.

2-DESCRIPTION OF THE PROBLEM

The main source of irrigation in the reclaimed desert fringes area (51000 Fed) is surface water diverted from Bahr Yussef Canal into two main unlined channels (Fig.1). Eight lifting stations, with maximum discharge of 32 L/sec, lift the irrigation water from these two unlined channels to the reclaimed area (up to 30m) then diverts to the fields through unlined lateral and farm ditches. Flood irrigation is the predominant method of irrigation. Both the lifting and irrigation efficiency does not exceed 60%. There is no man-made drainage system in the reclaimed area. The subsurface soil in the reclaimed area is fine sand which allows about 20% of the total seepage to be discharged (Awad 2002). All of these factors beside the presence of the underlying impermeable bed caused waterlogging problem.

3- MITIGATION OF WATERLOGGING PROBLEM

The two spatial dimensional groundwater flow model (ASM, Kinzelbach & Rausch, 1989 version 3.1) was applied along with available climatologic, geologic and hydrologic data to check two proposed scenarios for mitigation of waterlogging problem.

The equation describing the transient two-dimensional areal flow of groundwater in the heterogeneous anisotropic aquifer is expressed as (Bear, 1979):

$$\frac{\partial}{\partial x}[T_{xx}\frac{\partial H}{\partial x}]+\frac{\partial}{\partial y}[T_{yy}\frac{\partial H}{\partial y}]=S\frac{\partial H}{\partial t}+W+\sum_{k=1}^{m}[\delta(x-x_k).\delta(y-y_k).Q_k]$$

Where;

T_{xx}= Transmissivity in the x direction (L^2/ T).

T_{yy}= Transmissivity in the y direction (L^2/ T).

H = Potentiometric head (L).

S = Storage coefficient (dimensionless).

W = Distributed volumetric water flux per unit area, positive sign for discharge and negative sign for recharge (L/ T).

Q_k = Volumetric water flux at point (source/sink) located at (x_k,y_k), positive sign for withdrawal and negative sign for injection (L^3/T).

$\delta (x - \xi)$ = Dirac delta function.

t = Time (T).

x, y = Cartesian coordinates in the principal direction of transmissivity (L).

m = Number of nodal points.

This equation was solved using the Galerkine method and the finite difference technique (Warner, 1987). The properties of the aquifer are assumed to be uniform within each cell. Representative values of parameters within each cell are assigned to each node, creating matrices for initial heads, transmissivities,saturated thickness, and withdrawal or recharge rates. The matrix-solution technique is performed by Conjugated Gradients method for steady state and transient state.

Application of the model on the study area

The modeled area reaches 635 km^2. The computational grid for the aquifer in the modeled area is divided into 29 columns and 20 rows (580 nodes, Fig.9). The aquifer is semi-confined to unconfined. The assumed vertical homogeneity adequate to allow treatment as a single layer.

Boundary conditions

It includes the hydraulic conditions at the boundaries of the aquifer. The eastern boundary (Bahr Yussef

Canal) is assumed to be prescribed piezometric head boundary (equipotential boundary, Bear & Verruijt 1987). The western aquifer boundary allows no flow due to the presence of Eocene plateau (no-flow boundary).The northern and the southern boundaries, chosen far enough from the well field effect, are assumed to be constant heads.

Aquifer properties

The initial conditions of the aquifer include

=Aquifer parameters; transmissivity ranges from 1222 m^2/day (Abdel Magid 1998) to 6293 m^2/day (Gommah 1992), the storage coefficient of the semi-confined parts ranges from 0.0001 (El-Arabi 1998) and 0.04 (Abdallah et al. 1999) while it reaches 0.20 in the unconfined aquifer part (Awad 2002). The average vertical hydraulic conductivity is varying from 0.0017 to 0.030 m/day (Awad 1999).

= Aquifer geometry; includes vertical and areal extent of the aquifer.

= Aquifer stresses; the aquifer is recharged due to leakage from irrigation canals, and deep percolation of excess irrigation water with an average recharge amounts to 0.055 m/day and $3.31x10^{-10}$ m^3/sec/m^2 from rainfall. The average percolation through the clay layer is varying from 0.004 to 0.014 m/day. The discharge from wells reaches 583 m^3/h in summer and 375 m^3/h in winter. Due to the absence of deep percolation component in the model, the rate of deep percolation was subtracted from well discharge rate for every grid cell.

Calibration of the groundwater flow model

Before the model can perform its tasks in predicting the optimum solution of the water logging problem, it must be calibrated. The model is calibrated against the available average annual groundwater heads (Table2 and Fig.6). The calibration of the model is based on steady state conditions, under which, the sum of all in/outputs has to be zero. Under time-varying conditions (transient state), the sum represents the change in water storage. Results are found to be comparable with maximum error $7.6x10^{-6}$ m/node and the difference between the in-/outflows (Q_{total}) is in the order of $0.73x10^{-4}$ m^3/sec for the modeled area and $0.73x10^{-5}$ m^3/sec for the logged area. This result obtained may give a good reliability in both measured and calculated parameters, which extend to the response of the developed model. Accordingly, the water balance for the modeled aquifer was obtained (Fig. 10).

Mitigation scenarios

The mitigation of water logging problem depends on the social and economical conditions of the farmers. The lining of the canals and improvement of the irrigation practices are both long-term solutions. While the dewatering of the seepage water that allocated locally in low-land areas and reuse it for irrigation or the construction of experimental biological-drainage farms especially in the most deteriorated areas may be the short-term solution for both irrigation and drainage. These two proposed scenarios were assumed to mitigate the waterlogging problem.

4- RESULTS AND DISCUSSION

The first proposed scenario keeps the actual discharging rates (583 m^3/h in summer and 375 m^3/h in winter with annual mean of 479 m^3/h) with increase in magnitude 0.08 m^3/sec through ten proposed dewatering-wells well distributed in low-land areas, thereby evaluating the predicted practices after one hundred days. The water balance resulting from this assumption and the predicted change in peizometric head are presented in (Fig.11 and Fig.12A, B).

Figure 11 shows that under the proposed outflow rate conditions, the discharge from the sub-soil water by the proposed dewatering wells (value of Q-w for selected area in the Fig.11) reaches 0.048 m^3/sec which approaches 36% of the average annual groundwater discharge.This means that one third of the supplemented groundwater abstractions can be saved when reusing the dewatering quantity in irrigation. This is applied locally in some farms (Alaa Sharaby farm in West El-Fashn). The present inadequate drainage conditions may cause difficulties for applying this solution. Also, the modeled area is responded to change in positive direction as a result of change in magnitude and sign of subsurface flow component Q HOR. (from 0.59E-7 to -0.26E-6 m^3/sec). On the other hand, the unchanged peizometric contour curvature under different numbers of dewatering wells (Fig. 12A, B) points to the presence of more than one source of charge (may be upward leakage).

The second proposed scenario depends on maximizing the evapotranspiration component for balancing the sub-soil water regime. It keeps the present conditions and proposed the construction of four experimental biological-drainage farms in the most deteriorated areas normal to the seepage direction. These farms will consume 0.118 m^3/sec via 124 ACASIA trees assuming that the evapotranspiration of this tree equals 0.00095 m^3/sec. The simulation of this proposed solution was carried out by increasing the evaporation in the proposed sites by 0.118 m^3/sec for the all. The output of this scenario showed that Q-w component was increased after 1000 days from 0.27 to 1.8 m^3/sec for the modeled area, while it changed from 0.22 to 1.4 m^3/sec for the logged area (Fig.13).

Also, the predicted peizometric contour lines were positively changed after 1000 day (Fig.14A, B). The comparison between the water balance components of the two proposed solutions, especially the difference between in-/outflows

(Q TOTAL), gives a priority for the second proposed solution. Also, the expected drainage problem with the first proposed solution and the positive environmental effect of the second makes the latter is more acceptable.

5- CONCLUSION AND RECOMMENDATIONS

The study area suffers from some problems especially waterlogging as a result of absence of integrated water management. Both topography and bad drainage conditions of the study area are the main causes of this problem. A trial to mitigate waterlogging problem was carried out in this paper. The area under reclamation was increased by 250% through the interval 1984-2001 as estimated from the processed Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) images. The topographic slope of the reclaimed area reaches 6 cm/km as shown from the slope map derived from the DEM. The estimated irrigation water requirements reached 330405 m^3 for summer season and 169686 m^3 for winter season while the estimated maximum surface water yield by the present lifting stations does not exceed 301916 m3/season which reflects a shortage of irrigation water requirements due to the lack of efficiency and the need of supplemented groundwater.

To study the mitigation options of waterlogging problem the aquifer was simulated and discretized in 580 rectangular node-centered cells by applying the mathematical model ASM. The model was calibrated in steady-state condition. The difference between in/output items was in the order of 0.73×10^{-4} m^3/sec. Two scenarios were proposed for simulation and prediction. The first scenario keeps the present discharge from the present wells (583 m^3/h in summer and 375 m^3/h in winter) with increase in magnitude 0.08 m^3/sec through ten proposed dewatering-wells well distributed in the logged areas. The losses from the logged area, applying this scenario, reach 0.048 m^3/sec which approaches 36% of the average annual groundwater discharge. This means that one third of the supplemented groundwater abstractions can be saved when reusing the dewatering quantity in irrigation. The constraint of this short-term solution is the drainage problem of the pumped water. The second scenario keeps the initial conditions and proposed the construction of four experimental biological-drainage farms in the most deteriorated areas which consume 0.118 m^3/sec via the evapotranspiration component. The second proposed scenario is considered more suitable than the first due to the positive environmental effect, while the drainage of the pumped water during dewatering process is still questionable, especially in low topographic areas.

Recommendations concerning mitigation of waterlogging problem through improvement of irrigation and drainage techniques are focused in this paper. Also, the increase of lifting stations efficiency will decrease the groundwater demand. The decrease of irrigation openings' diameter to equalize the actual irrigation requirements and decreasing the interceptor drain's level will contribute in mitigation process. The reuse of drainage water in the new reclamation projects will also mitigate the groundwater level increase.

6- REFERENCES

Abdallah, A. M., Korany, E., A., and Abdel Magid, G., M., (1999) "Hydrogeologic Investigation on Beni Suef area, Nile Valley, Egypt". Sedimentology of Egypt: Vol. 7, pp 55-69.

Abdel Magid, G. M., (1998) "Hydrogeological and hydrogeochemical studies of the Nile Valley area, Beni Suef Governorate, Egypt": M. Sc. Thesis, Fac. Sci., Cairo Univ., 224 p.

Agricultural Administration of El-Fashn (2003) "Census of cultivated lands during 2002-2003 in West El-Fashn project." Dep. Stat. Internal Rep. 4 p. (in Arabic).

Attia, A.R. F. (1991) " Economic Evaluation of Groundwater Development Plans In Upper Egypt." RIGW/IWACO, RTM-91 Cairo-Egypt Oct., 5-9, 1991 pp153-165.

Awad S.R., (1999) "Environmental Studies on Groundwater Pollution in Some Localities in Egypt". Ph.D. Thesis, Faculty of Science, Cairo University.

Awad S.R., (2002)" Groundwater logging and salinization along the western fringes of the Nile valley, Egypt". Proceeding of the 3rd Inter. Con. For Groundwater Level Control in Urbanized areas, Mansoura Univ., 19-21 Dec. 2002(electronic CD).

Bear, J. (1979) "Hydraulics of Groundwater." McGraw-Hill, New York.

Bear, J. & Verruijt, A. (1987) "Modeling Groundwater Flow and Pollution." D. Reidel Publishing Company, Dordrecht, Holland. 414 pp.

El-Arabi N.E., (1998) "Environmental Monitoring of Groundwater in Egypt". Conference on Coping with Water Scarcity, Hurghada, Egypt, August 1998, pp. 4.8-1 to 4.8-7.

Food and Agricultural Organization FAO, (1977) "Crop water requirements". Irrigation and Drainage paper No.33. FAO, Rome.14 P.

---- **FAO, (1979)** "Yield response to water". Irrigation and Drainage paper No.24. 14 P.

Gommah, A. A. A. (1992) "Hydrogeological and sedimentological investigations in the area between Beni-Suef and Beni-Mazar, Egypt" M. Sc. Thesis, Fac., of Sci., Al-Azhar Univ. 237p.

Kinzelbach, W. and Rausch, R. (1989) "Groundwater Flow and Transport Model (ASM). " Gesmathochshule Kassel- Universitat, D-3500 Kassel, FRG. (Software & manual).

Penman, H. L. (1984) 'Natural evaporation from open water, bare soil and grass' Roy. Soc. London, Proc. Ser. A., 193. pp 120-146.

Research Institute for Groundwater RIGW, (1991) "Groundwater Investigations, Quiman El-Arous". Inter. Report, 42 p.

Research Institute for Groundwater, RIGW, (1997) "Information Book, Ver.1: Inter. Report.

Saad, S.M.M. (1999) 'Hydrogeological Assessment Of The Fluctuation Of Groundwater Levels In The Quaternary Aquifer In The Area Between Beni Suef And Giza, Nile Valley, Egypt" M. Sc. Thesis, Fac., of Sci., Ain Shams Univ. 148p.

Said, R., (1981) "Geological Evaluation of the Nile" Springer Verlag, New York.

Tamer, M. A., El Shazly, M. and Shata, A., (1974) 'Geology of El-Fayum, Beni Suef Regions": Bull. Desert Inst. Egypt, Vol. 25, No. 1, 2, pp. 27-47.

Warner, J. (1987)"Mathematical Development of the Colorado State University Finite Element 2-Dimensional Groundwater Flow Model." Groundwater Technical Report 2, Colorado, USA.

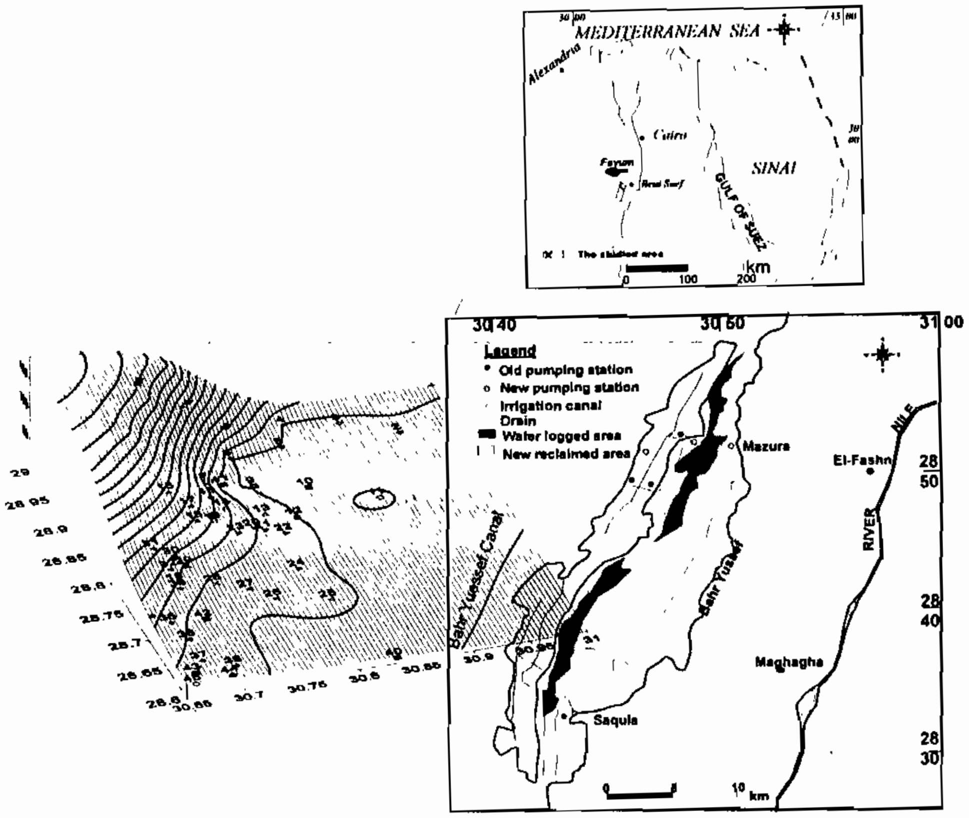


Fig. 1: Location map of the drilled wells, irrigation canals and drainage system in the new reclaimed area in the desert fringes of Beni-Suef and El-Minya governorates.

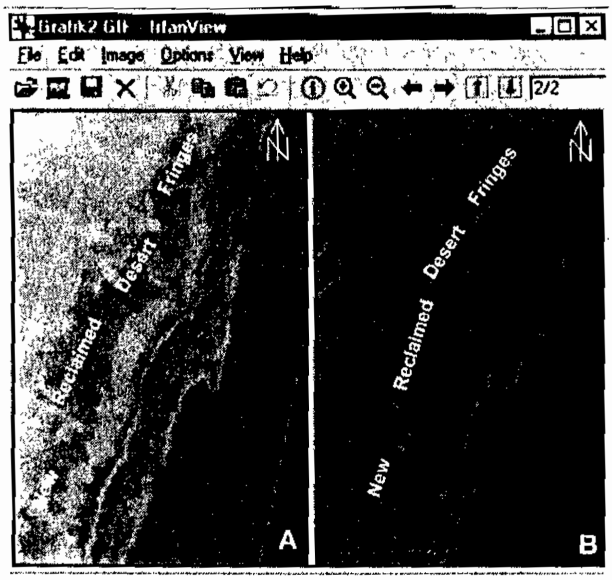


Fig. 2: The processed satellite images of the study area, (A) Landsat Thematic Mapper (TM) and (B) Enhanced Thematic Mapper Plus (ETM+).

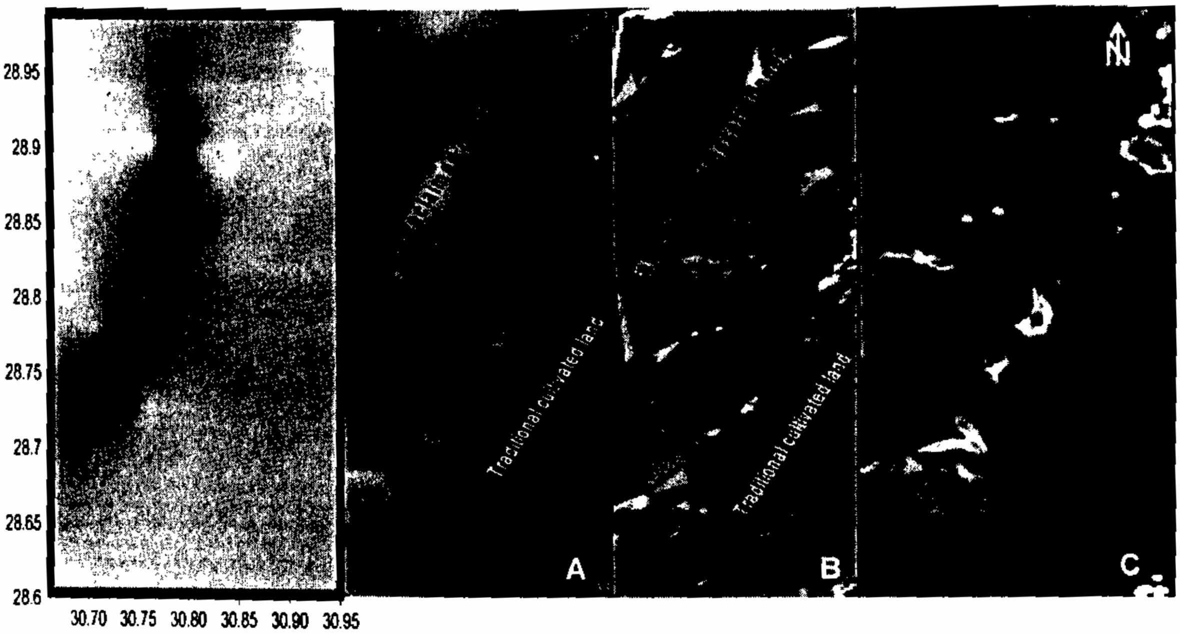


Fig.3: The relief map (left map, from SURFER), the Digital Elevation Map DEM (A), Aspect map (B) and Slope map (C) of the study area.

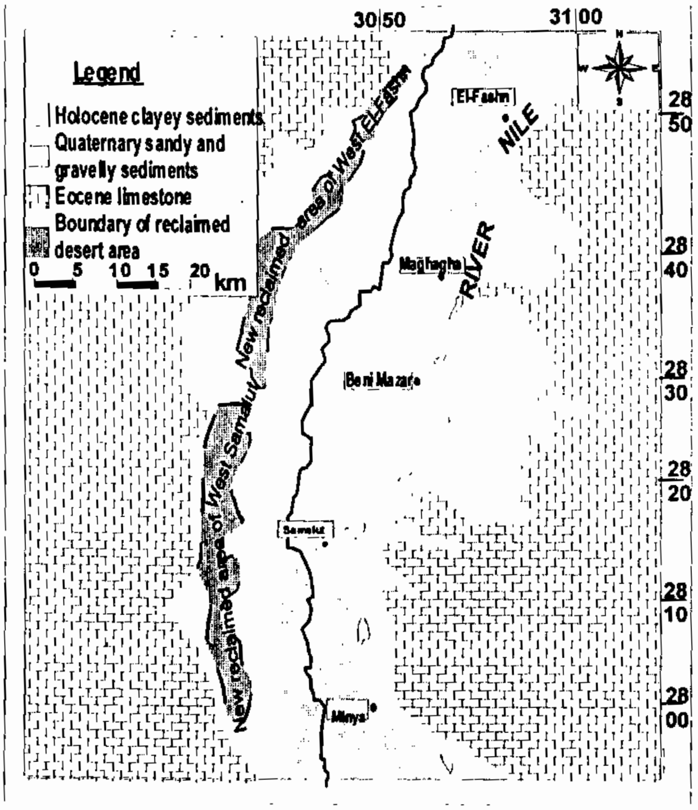


Fig.4: Geologic map of the study area

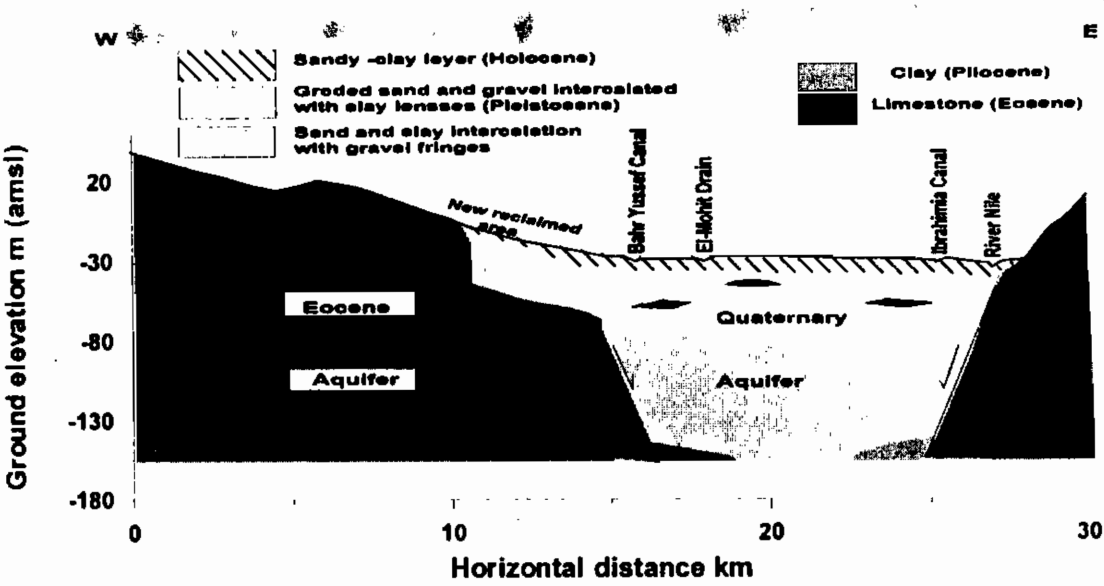


Fig.5: Hydrogeological cross-section of the study area (Modified after RIGW, 1991)

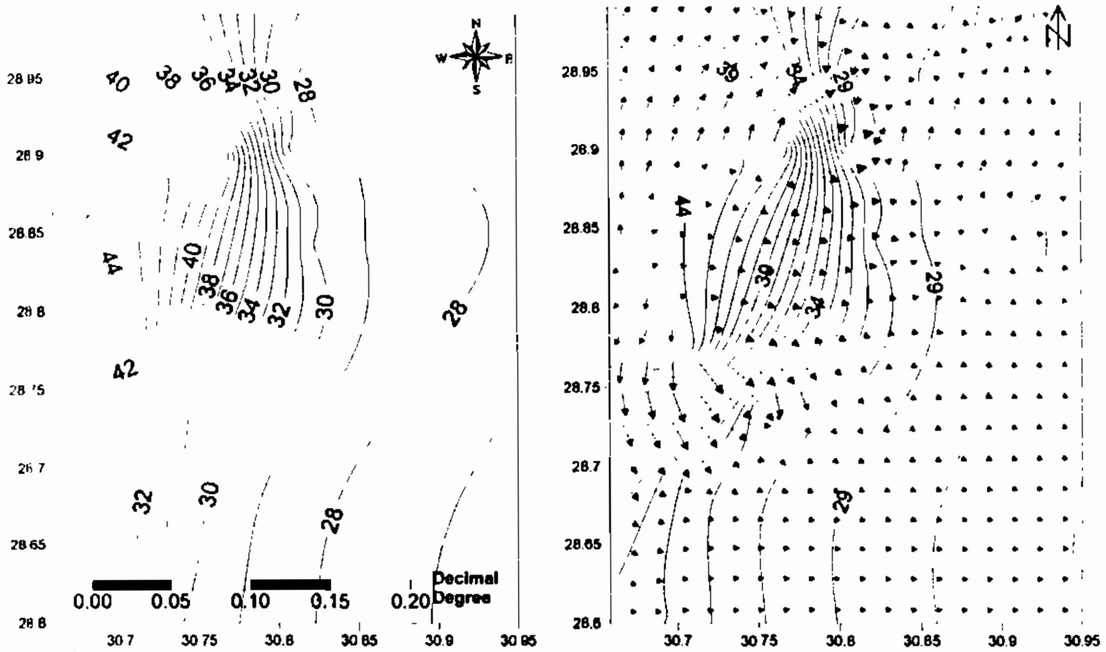


Fig. 6: Peizometric surface contour map of the sub-soil water in the study area during 1990 (left map) and the flow lines in March 2003 (right map).

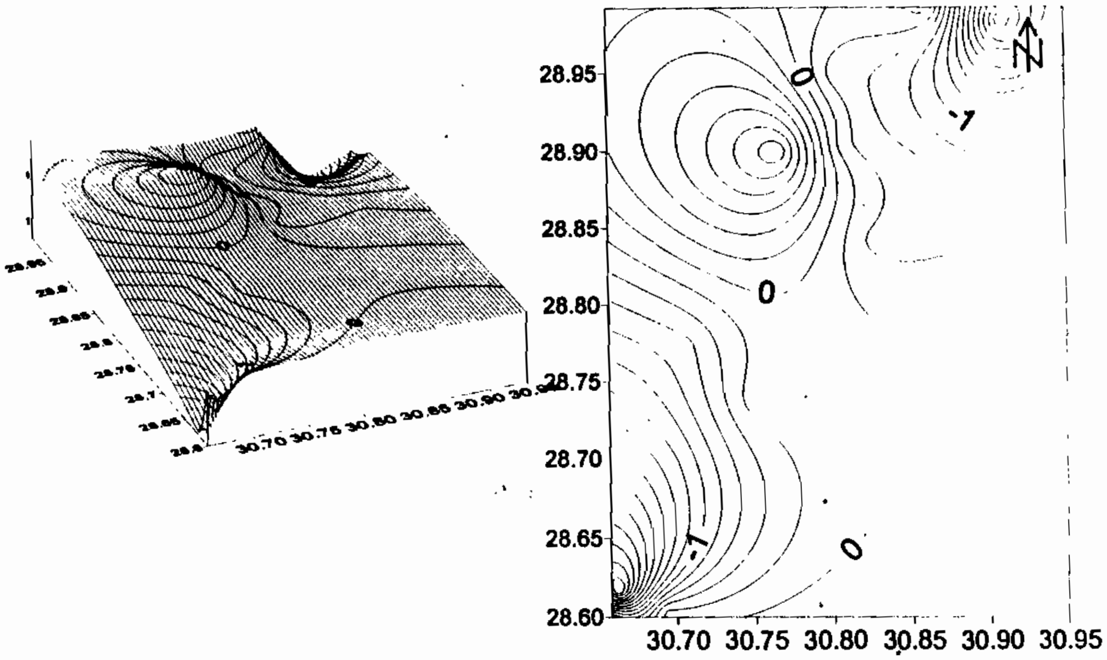


Fig. 7: Contour map and block diagram represent annual mean fluctuations of sub-soil water peizometric surface of the study area during 1990-2003.

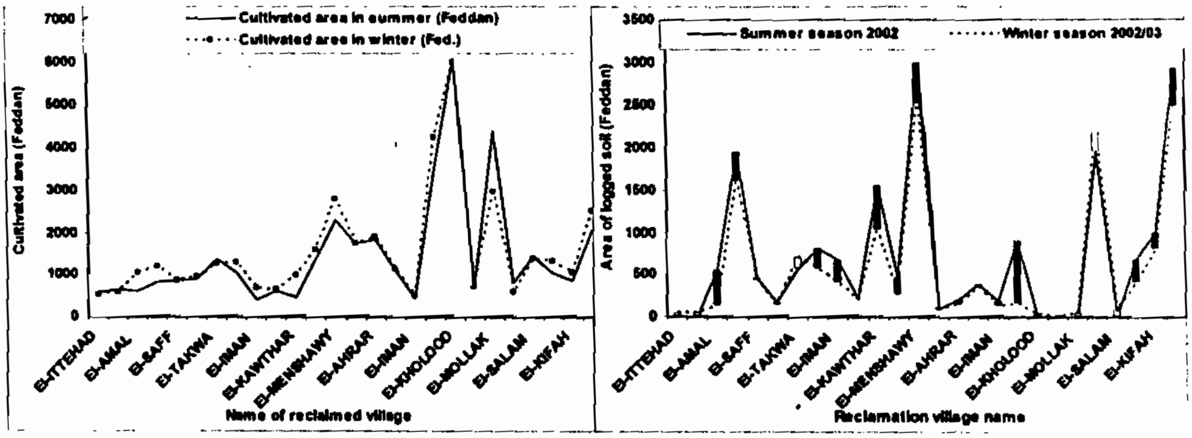


Fig. 8: Map showing the fluctuation of the cultivated area (left map) and the logged area (right map) of the study area during 2002/2003.

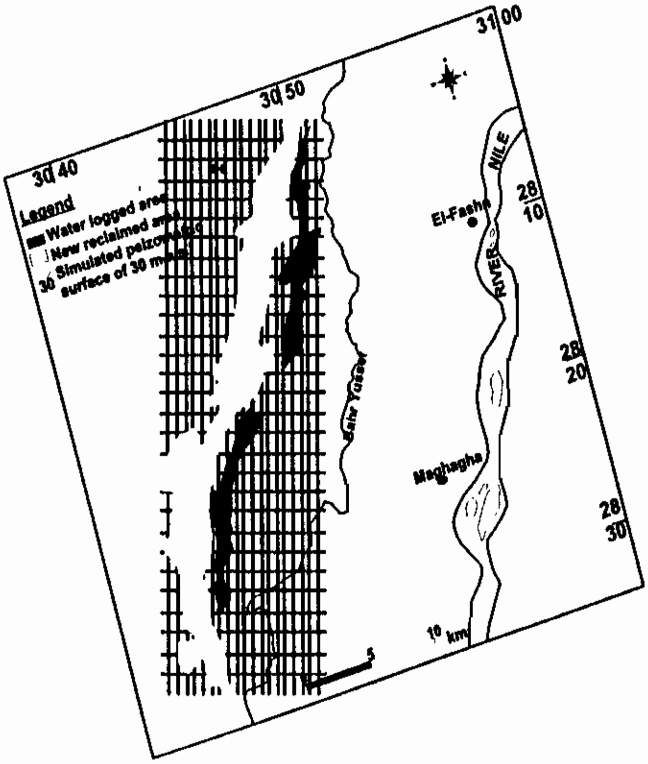
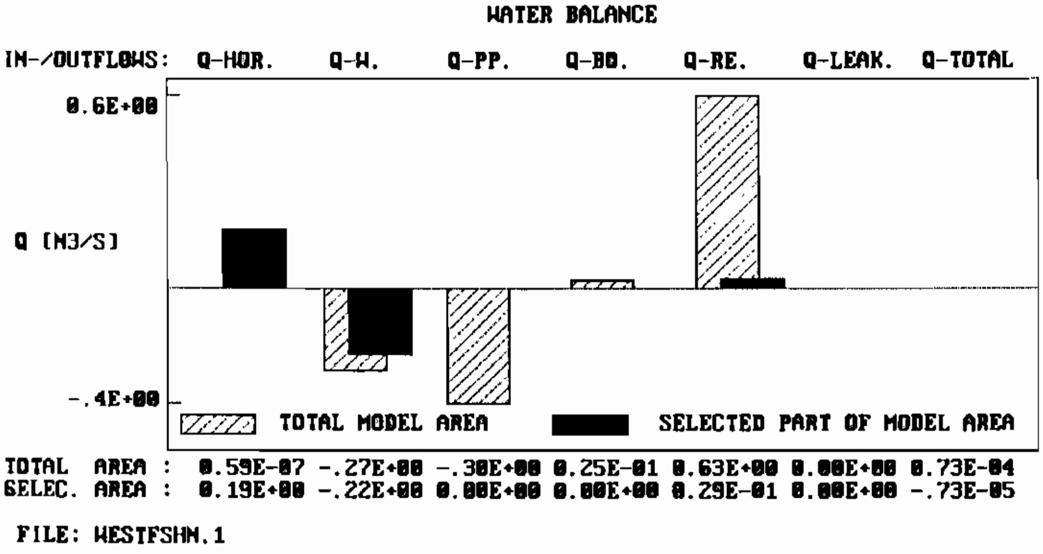


Fig. 9: The finite difference grid of the modeled area.



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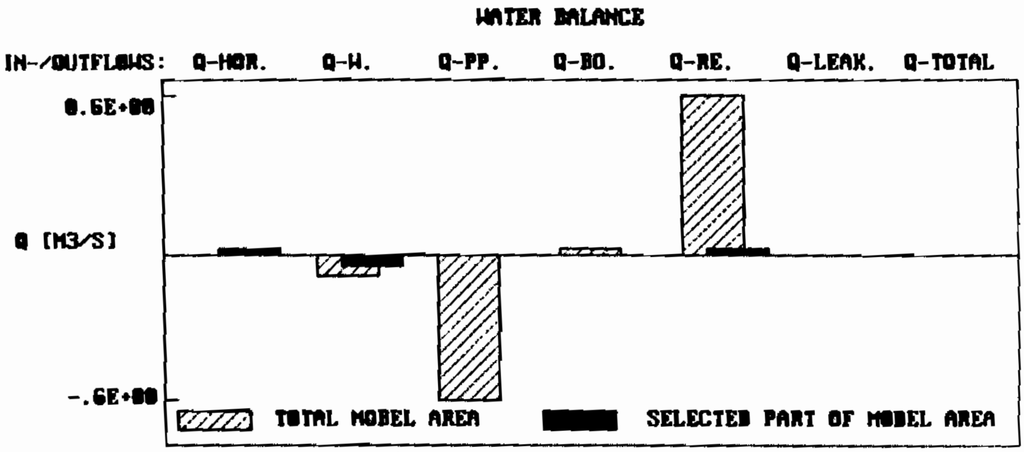
TOTAL  AREA :  0.59E-07 -.27E+00 -.30E+00 0.25E-01 0.63E+00 0.00E+00 0.73E-04
SELEC. AREA :  0.19E+00 -.22E+00 0.00E+00 0.00E+00 0.29E-01 0.00E+00 -.73E-05

FILE: WESTFSHN.1
```

Fig. 10: Water balance of the modeled area (Steady state condition).



```
TOTAL  AREA :  -.20E-06 -.80E-01 -.57E+00 0.25E-01 0.63E+00 0.00E+00 0.77E-04
SELEC. AREA :  0.22E-01 -.40E-01 0.00E+00 0.00E+00 0.26E-01 0.00E+00 0.33E-05

 FILE: WESTFSHN.1  TIME = 100 D
```

Fig. 11: The predicted water balance due to the first proposed scenario.

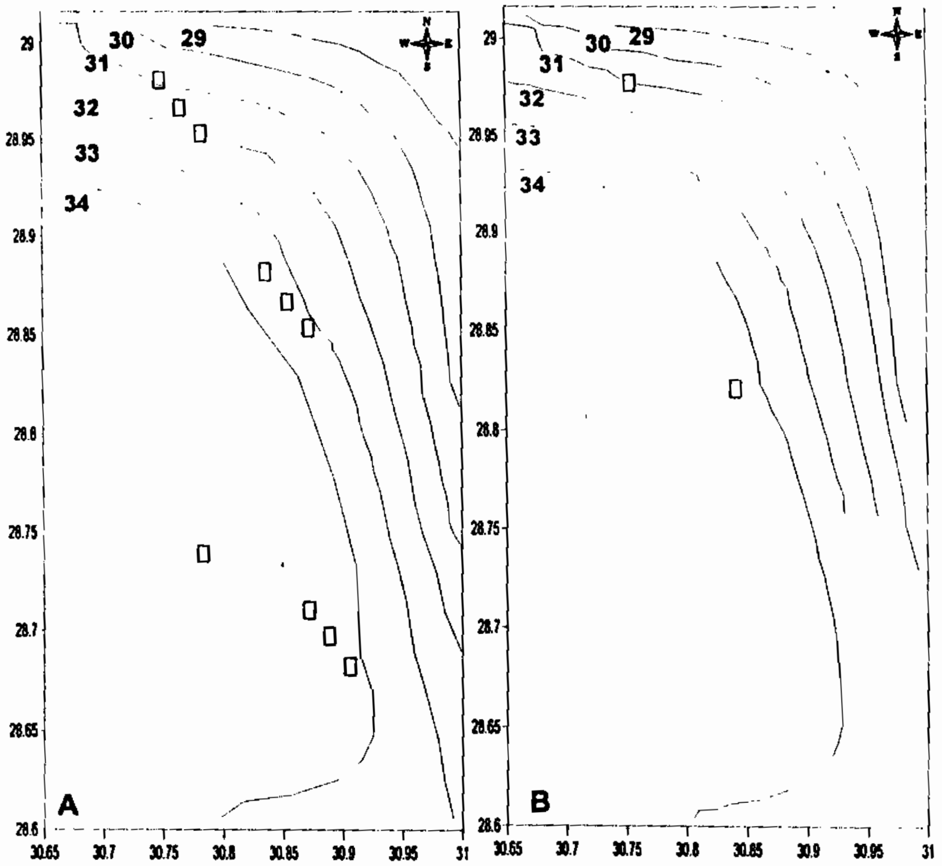


Fig.12A, B: The predicted peizometric head of the modeled area according to the first proposed scenario.

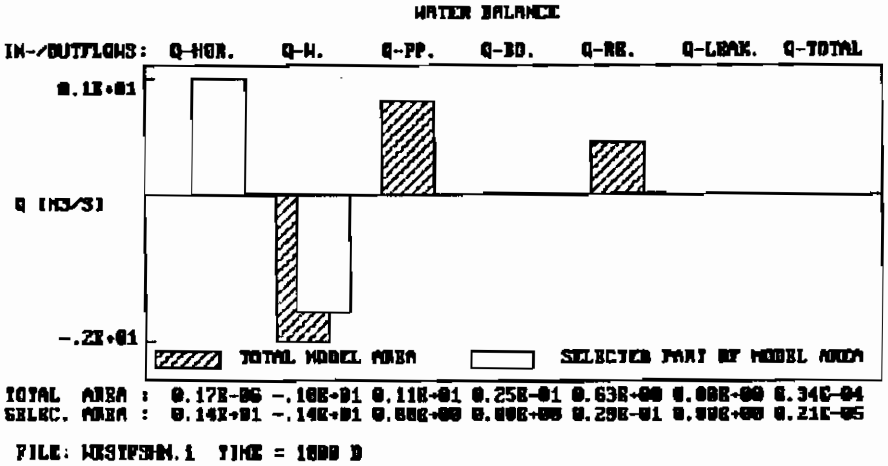


Fig. 13: The predicted water balance due to the second proposed scenario.

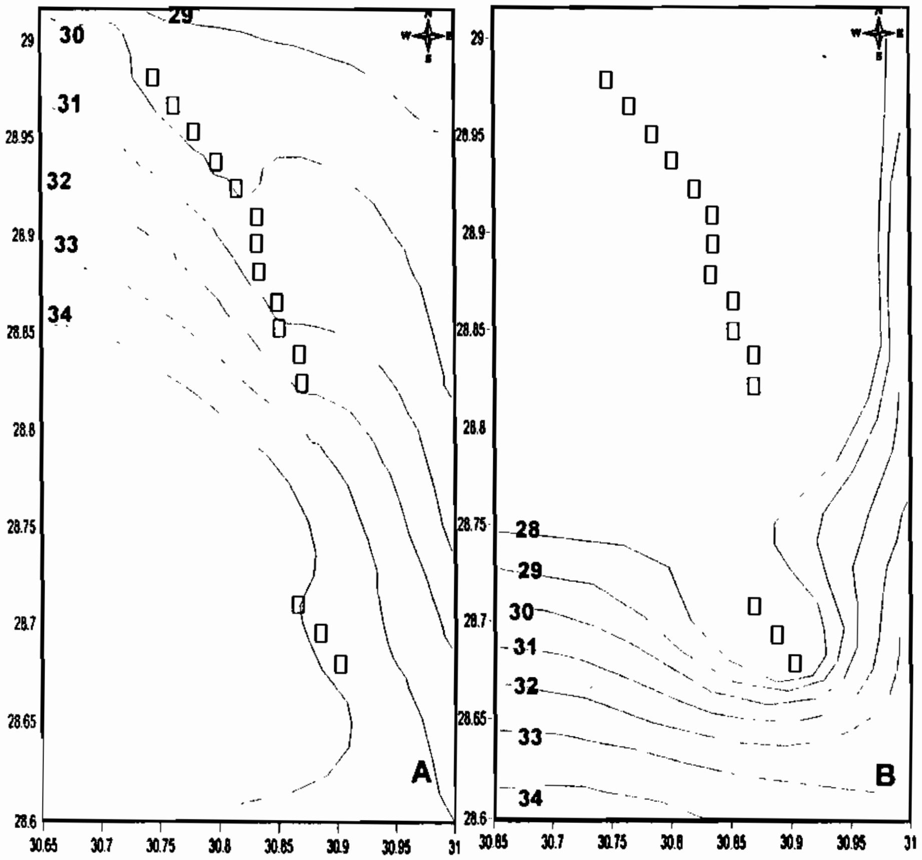


Fig. 14 a,b : Predicted hydraulic head distribution of the modeled area (Second proposed scenario)

Table1: Lithostratigraphic succession of the study area (Tamer et al., 1974)

Era	Age	Thickness (m)	Lithology
Quaternary	Holocene	12	Nile silt
		3	Wadi fillings
	Pleistocene	44	Young Nilotic deposits
		5	Old Lacustrine deposits
	Plio-Pleistocene	150	Old Nilotic deposits
Tertiary	Pliocene	50	Old Deltaic gravels
		30	Shallow Marine sandstone
		100	Deep Marine clay, sandstone lenses
	Upper Eocene	85	Calcareous sandstone, Marl
	Middle Eocene	300	Limestone, Marl

Table2: Seasonal and annual fluctuations of sub-soil peizometric surface in some selected wells during the interval 1990-2003 in the study area

Serial N	Location		Ground Level m.a.m.s.l	Seasonal fluctuation (m) (1990**-2003)		Mean depth to water (m)		Resultant (m)
	Long.	Lat.		Winter	Summer	1990**	2003	
1	30.658	28.6	34.48	-0.25	2.48	32.96	32.84	-0.12
2	30.692	28.605	33.89	0.24	-0.03	31.87	32.05	0.18
3	30.663	28.616	35.68	-2.84	-2.33	35.4	32.74	-2.66
4	30.7	28.7	33.52	--	--	33.16	32.35	-0.81
5	30.766	28.717	31.12	--	0.12	30.17	30.41	0.24
6	30.75	28.738	32.38	0.29	0.15	29.99	30.31	0.32
7	30.708	28.775	47.19	-0.23	-0.65	44.7	44.45	-0.25
8	30.825	28.842	30	-0.02	--	29.74	29.69	-0.05
9	30.9	28.85	31.61	-0.05	-0.23	28.81	28.78	-0.03
10	30.85	28.887	29.26	-0.11	-0.22	29.03	28.94	-0.09
11	30.808	28.903	30	-0.12	-0.16	28.79	28.86	0.07
12	30.767	28.9	49.78	0.63	2.28	40.84	42.62	1.78
13	30.95	28.95	29.59	-0.81	-0.48	27.36	26.69	-0.67
14	30.803	28.95	30.1	-0.1	-0.22	28.46	28.32	-0.14
15	30.85	28.958	29.52	-0.03	-0.71	27.39	27.07	-0.32
16	30.908	28.983	27.8	--	-2.46	27.21	24.6	-2.61
17	30.863	28.992	28.76	0.4	-0.03	27.25	27.54	0.29

**The records of 1990 from RIGW 1997 (internal report)

Table 3: Records of the cultivated and logged areas during 2002/2003 (Agricultural Administration of El-Fashn Census 2003).

Village name	Location	Summer season 2002 (Apr. – Sep.)		Winter season 2002/2003 (Oct.-March)	
		Cultivated area (Feddan)	Logged area (Feddan)	Cultivated area (Feddan)	Logged area (Feddan)
El-ITEHAD	WEST-El-FASHN	575	1	526	50
El-FATH		630	2	588	44
El-AMAL		610	551	1035	126
El-WAFAA		840	1953	1195	1598
El-SAFF		850	451	870	431
El-FEDAA	WEST-SAMALUT	900	171	939	132
El-TAKWA		1380	560	1238	702
El-HODA		1045	813	1295	563
El-IMAN		410	665	664	393
El-EKHLAS		625	214	638	201
El-KAWTHAR		460	1560	989	1031
REFAAH		1385	455	1585	255
El-MENSHAWY		2305	2995	2780	2520
WEST-FASHN	BENI-SUEF	1750	90	1755	85
El-AHRAR		1837	193	1900	130
El-FOSTAT		1100	380	1130	350
El-IMAN		420	180	485	115
El-THEWAR	El-MENIA	3500	900	4250	150
El-KHOLOOD		6061	NIL	5986	29
El-INTESAR		705	NIL	705	NIL
El-MOLLAK		4390	NIL	2950	50
25JANIUARY		800	1953	575	2178
El-SALAM		1436	NIL	1366	70
AMARNAH		1050	665	1315	400
El-KIFAH		850	1000	1050	800
El-NEEL		2060	2930	2500	2490
TOTAL		32974	18682	40309	14893
ETo (cm/season/Fed)		167.12	--	79.447	--
ETc (cm/season/Fed)		143.72	--	60.38	--
Total I.W.R (m3/season)		330405	--	169686	--