Evaluation of the Groundwater Potentiality in Tushka area

Eng. Osama M. Sallam , Prof. Dr. Taher M Hassan* and Prof. Dr. A

ABSTRACT

Egypt covers an area of slightly over one million km$^2$ of the arid belt in North Africa and Western Asia. About 3.4% of the area is occupied by a population of 70 millions, of which 98% are concentrated along the Nile Valley and the coastal zones. The major challenge facing Egypt now is the need to better develop and manage the very limited natural resources (Water, Lands and Energy) to meet the needs of population growing.

To achieve best distribution for the population over the whole country and to increase the agricultural area, many reclamation projects were started. One of these projects is Tushka Project in the South Egypt. Tushka project aims at reclaiming about 540,000 feddans west of Lake Nasser, behind the High Dam at Aswan by construction of Sheikh Zayed Canal connected to Lake Nasser. Six millions people are expected to migrate to the area within the next two decades. The first step of government plan's is to provide water that will enable communities to form.. The pumping station installed at the inlet of the canal to pump an average of five billions cubic meters per annum at a rate of 300 cubic meters per second. An integrated management plan for the available water resources must be applied to save water for this project. Groundwater development plan plays an important role to save a part from the water demand for this project. (Tushka area).

The previous studies in Tushka area for the groundwater potentiality and the aquifer characteristics are not enough as a base for development plans. Therefore, this research concentrates on this region to study the aquifer system in Tushka area and to evaluate the groundwater potentiality for future development of the area.
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Introduction

The study area is located in the South eastern part of the Western Desert, between latitudes 22° 00’ - 24° 00’ N and longitudes 29° 30’ - 32° 00’ E, covering an area about 30000 km\(^2\). It is bounded with Tushka depression and Darb El Arbain to the North, Sudanese border to the South, River Nile to the East, and adjacent East Owinate to the West. It is accessible through a network of asphaltic roads, desert tracks and Camel roads. The first class asphaltic road in western part of the area in the southwest direction along the famous old Darb El-Arbain track, to connect the main towns Asyut and Kharga. It continues further South to Egypt –Sudan borders, passing by Gable Abu Bayan in the northwestern side of the area. The main highway in the area runs in a South West direction, connecting Aswan city , Abu-Simbel and southwards to Wade Halfa in Sudan.

The study area is located in the arid and hyperarid region. Meteorological data for some stations around the study area indicate that the area is characterized by a hot dry summer, and
cold winter. The mean monthly maximum temperature ranges between 23°C in January to 40°C in July, while the mean minimum temperature ranges between 7°C in January and 22°C in July. The relative humidity in the area ranges between 27% in July and 51% in January. The area under study is generally flat plain with hills, ridges and scarps that are mostly rugged and rough. The ground surface elevation varies from about 150 to 230 m above mean sea level. The land that lies adjacent Nasser Lake about 200 m above mean sea level and extends Westward.

![Figure 1](image_url)

**Figure 1.** The detailed location map for Tushka area.

**Definition of the aquifer system in the study area**

The results of the drilling of groundwater wells by RIGW, the surface geophysical, geological exploration method and previous studies were used to prepare two cross sections in the study area as shown in figure (2). These cross sections show that the water bearing formation found to be multilayered. The aquifer system is composed of sands and sandstone partly separated by clay intercalations. The Nubia aquifer at this particular area is similar the Nubian sandstone aquifer in the other part of the western desert. Also these cross sections show that the structural condition affects the lateral and vertical extension of the Nubian aquifer system in the study area as shown in figures (3 4 ). The regional picture of the aquifer in the study
area shows that it is formed of successive water bearing layer hydraulically connected at some areas and disconnected at others.

Figure 3. The location of hydrogeological cross sections.

Figure 4. Hydrogeological cross section A-A’
Aquifer extent

The lower boundary of the Nubia aquifer in the study area is generally the surface of the basement rocks. Basement rocks are exposed to the South East of the study area along the Nile and El-Mayet Nusab El Balgum outcrop. Another shallow basement occurrence is around Nekhli-Aswan uplift in the Western North part side of the study area. The depth to the basement regionally increases in Southeast and decreases in Northwest until vanishes at Nekhli Aswan uplift.

The data collected from previous geophysical survey, geological exploration and fully penetrated wells (RIGW, 1998-20001) indicate that the thickness of the Nubian aquifer is variable as shown in figure (5). The aquifer thickness ranges between 400 to 500 m in the area around Lake Nasser. The thickness is completely reduced at the basement rocks exposures.
**Depth to groundwater**

The data collected from all available wells in the study area are used to define the depth to groundwater and saturated thickness of the aquifer system. The shallowest depth to Groundwater (less than 40 m) occurs in the area close to Lake Nasser and Khour Tushka. In addition, the depth to Groundwater increases gradually until reaches about 140 m at the area located at Aswan-Amada road intersection and at the area located between Abu-Simble and Wadi Halfa road. Figure (6) shows the contour map for the depth to groundwater in the study area.

**Regional flow pattern**

The water level in the study area ranges between 200 m (M.S.L) at the southwestern corner, 100 m (M.S.L) at Northeastern corner. In addition, the groundwater level ranges between 160 m (M.S.L) close to Lake Nasser, and 110 m (M.S.L) at the Northwestern corner. Figure (7) shows the contour lines of the potentiometric surface of the Nubia aquifer system in the study area. This map was prepared using the available water level data from the exiting wells in the study area.

![Figure 5. Contour map of the aquifer thickness.](image)
Figure 6. Depth to Groundwater contour map of the study area.

Figure 7 Contour map of the groundwater level in the study area
Numerical Simulation of the Study Area

Conceptual basis of the model

Visual MODFLOW will be used to simulate groundwater flow in the study area. It is the most complete and easy use modeling environment for applications in three dimensional groundwater flow and contaminant transport simulation. Conceptual model is based on number of assumptions that must be verified and Aquifer system hydrogeological setting taking into account the following:

- The unconfined nature of the aquifer system.
- Spatial variations in directional transmissivity (or hydraulic conductivity) were resulting from variation in saturated thickness of the flow section.
- Temporal variation in the transmissivity resulting from potentiometric level changes.
- Realistic outer boundaries, preferably to be natural boundaries of the system, wherever possible. If not the arbitrary chosen boundaries should be remote and to be accurately defined in location and type.

Boundary conditions of the study area

Figure (8) shows the natural boundaries of the Nubia aquifer system and due to the lack of hydrogeological information, the outer boundaries have been chosen.

(a) The northwestern boundary: it approximates the basement outcrop of Nekhlai Aswan uplift and it is considered as no flow boundary. This case can be expressed as:
(b) Southwestern boundary: is defined by the inflow front to the study area and it is considered as specified head boundary (180 m).
(c) Southeastern boundary: is defined by the inflow front to the study area and it is considered as specified head boundary (Lake Nasser level).
(d) Northeastern boundary is approximated to the equipotential line of 110 m and it is considered as specified head boundary.
(e) The South boundary: It is considered as no flow boundary.
(f) The Northwestern boundary: It is considered as no flow boundary.

Aquifer hydraulic parameters

The horizontal hydraulic conductivity is given as equal values in the two principal axes directions (x, y). During steady state calibration, where fault occurrence exhibits possible hydraulic effect on the groundwater flow direction, the hydraulic conductivity across the fault was set to be 5 times lower than the hydraulic conductivity along the fault zone. Specific yield / storativity values for this parameter was determined based on the results of pumping tests, which has been carried out in the study area.

Model Calibration

Before the model can be used in predicting the response of the system to any future activities, it must be calibrated. Calibration of a flow model refers to demonstration that the model is capable of producing field-measured heads and flows, which are the calibrated values. The model is calibrated against the available average annual groundwater levels of the 18 wells. The calibration of the model is based on steady state nonlinear conditions. The calibration
process has been done through several trials by adjusting the hydraulic conductivity and recharge. Results are found comparable within $\pm 3$ m. with the observed heads. Figure (8) shows the calculated and observed groundwater levels in the study area at piezometers. The model was found sensitive to changes in the hydraulic conductivity, the specific head along the boundaries, the groundwater recharge and the extraction from the aquifer system.

Figure 8. The boundaries of the groundwater flow model for the study area.

Figure 9. the calculated and observed groundwater levels in the study area at piezometers.
Aquifer Response to Extraction Scenarios

Extraction pattern and distribution was entered as required quantities to be exploited from the system. The following extraction plans were simulated

**Extraction scenario 1**

In this scenario, extraction rate is 53 million m$^3$/year from the wellfields The simulation period was 45 years. Table (1) gives the results and output of the model for the extraction scenario no. 1. and Figure (10) shows the drawdown contour map at year 2045

<table>
<thead>
<tr>
<th>Area</th>
<th>Drawdown (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 year</td>
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<tr>
<td>Halfé road</td>
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<td>Abu Simble road</td>
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<tr>
<td>Zayed canal</td>
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<tr>
<td>Amada road</td>
<td>6.78</td>
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<tr>
<td>Tushka depression</td>
<td>3.62</td>
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</table>

**Extraction scenario 2**

In this scenario, extraction rate is 95 million m$^3$/year from wellfields Table (2) gives the results and output of the model for the extraction scenario no. 2. and Figure (11) shows The drawdown contour map at year 2045

<table>
<thead>
<tr>
<th>Area</th>
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<td></td>
<td>10 year</td>
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<tr>
<td>Halfé road area</td>
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<td>Abu Simble road</td>
<td>4.68</td>
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<td>Zayed canal area</td>
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<td>8.96</td>
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<td>Tushka depression</td>
<td>3.77</td>
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</table>
Figure 10. The drawdown contour map (m) at year 2045 (scenario no. 1)

Figure 11. The drawdown contour map (m) at year 2045 (scenario no. 2)
Extraction scenario 3

In this scenario, extraction rate is 192 million m$^3$/year from wellfields. Table (3) shows the results and output of the model for the extraction scenario no. 3 and Figure (12) shows the drawdown contour map at year 2045.

Table 3. Drawdown at different locations (scenario no. 3)

<table>
<thead>
<tr>
<th>Area</th>
<th>10 year</th>
<th>20 year</th>
<th>30 year</th>
<th>40 year</th>
<th>45 year</th>
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</thead>
<tbody>
<tr>
<td>Halfe road</td>
<td>2.14</td>
<td>8.88</td>
<td>16.2</td>
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<td>25</td>
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<tr>
<td>Abu Simble road</td>
<td>5.22</td>
<td>14.8</td>
<td>24.2</td>
<td>33.21</td>
<td>35</td>
</tr>
<tr>
<td>Zayed canal</td>
<td>0.65</td>
<td>3.19</td>
<td>7.1</td>
<td>11.92</td>
<td>13</td>
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<tr>
<td>Amada road area</td>
<td>10.4</td>
<td>20.1</td>
<td>28.5</td>
<td>36.24</td>
<td>37.7</td>
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<td>Tushka depression</td>
<td>3.85</td>
<td>7.74</td>
<td>12.1</td>
<td>16.56</td>
<td>17.5</td>
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</tbody>
</table>

Extraction scenario 4

In this scenario, extraction rate is 261 million m$^3$/year from wellfields. Table (4) gives the results and output of the model for the extraction scenario no. 4 and Figure (13) shows the drawdown contour map at year 2045.

Table 4. Drawdown at different locations (scenario 4)

<table>
<thead>
<tr>
<th>Area</th>
<th>10 year</th>
<th>20 year</th>
<th>30 year</th>
<th>40 year</th>
<th>45 year</th>
</tr>
</thead>
<tbody>
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<td>Abu Simble road</td>
<td>7.13</td>
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<td>14.3</td>
<td>20.12</td>
<td>21.3</td>
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Critical extraction rate

In order to determine the critical extraction at which the depth to water must not increase more than about 100 meters at any part of the modeled area. Additional simulating runs were carried out for a simulation period of 45 years after the completion of installing all wellfields. It was found that the extraction of 95 million m$^3$/year by the end of 45 years of pumping, water will be lifted at a depth of about 100 meters from the ground surface in the Halfe road area, Abu Simble road area, and Tushka depression area. Table (5) shows the maximum depth to water at year 2045 for extraction scenarios.
Figure 12. The drawdown contour map at year 2045 (scenario no. 3)

Figure 13. The drawdown contour map at year 2045 (scenario no. 4)
### Table (5) max depth to groundwater (m) at year 2045

<table>
<thead>
<tr>
<th>Area</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
</tr>
</thead>
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<td>Halfa road area</td>
<td>86.22</td>
<td>95.31</td>
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<td>Abu Simble road</td>
<td>92.4</td>
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<td>72.38</td>
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<td>Amada road area</td>
<td>92.92</td>
<td>103.2</td>
<td>115.42</td>
<td>131.52</td>
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<tr>
<td>Tushka depression area</td>
<td>96.2</td>
<td>98.7</td>
<td>102.5</td>
<td>106.3</td>
</tr>
</tbody>
</table>

### Conclusions and Recommendation

- The regional picture of the aquifer on the study area is one from basins (Nubia basin) that formed of successive water bearing layer hydraulically connected at places and disconnected at others places.
- The depth to basement regionally increases in southeast and decrease in northwest directions until equal zero at Nekhl Aswan uplift.
- The shallowest depth to water (less than 40m) occurs on the area closed Lake Nasser and Tushka khour. The depth to water increases gradually until reaches up to 140 at the area, which located at Aswan-Amada road intersection area
- The saturated thickness of Nubian aquifer ranging between (50-200) occurs within the area extending between Owinat road and Tushka depression. The saturated thickness increases progressively to reach 400m to Lake Nasser.
- The water level in the study area ranges between 200m (M.LS.L) at the southwestern corner, 100 m (M.S.L) at the northeastern corner. In addition, ranges between 160m closed Lake Nasser, 110 at the northwestern corner.
- It is recommended to use another tools to estimate the net recharge from Lake Nasser to groundwater aquifers.
- New observation wells must be drilled in the areas, which the geological and hydrogeological data is not sufficient.
- The area must be divided to subareas and for each area, a detailed investigation with more accurate data must be carried out.
- The distance of the abstraction wells must be far enough form the Lake Nasser to avoid any contamination due to the agricultural or any other activities.

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