Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (41) No. (1) January, 2019

Efficiency of Different Dewatering Systems in Long Term Projects

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ملخص البحث

معظم المناطق السكنية بمصر تقع بوادي النيل والدلتا حيث أنه المصدر الرئيسي للمياه بمختلف إستخداماتها الآدمية والزراعية . وحيث تمثل هذه المساحة حوالي 5% من إجمالي مساحة مصر ويعيش عليها تقريبا 97 % من التعداد السكاني المصري. هذه المنطقة في الغالب مغطاه بطبقة من الطين والتي تحتوي شبكات الري حيث يوجد العديد من القناطر والهدارات على هذه الشبكات بما فيها نهر النيل وذلك لتنظيم وحفظ مناسيب المياه عند المناسيب المطلوبة. ومن الأهم الآثار الجانبية لمثل هذه القناطر إرتفاع مناسيب المياه السطحية أمامها والتي بدورها تؤدي إلى إرتفاع مناسيب المياه الجوفية في المناطق السكنية المحيطة بها حيث تؤثر بالسلب على المباني السكنية . وبناء علية أصبح من الضروري تخفيض مناسيب تلك المياه في مثل هذه المناطق لحل المشكلة والحفاظ على المباني السكنية من الأضرار التي قد تؤدي إلي تضررها. وتعتبر مدينة إسنا إحدى المدن التي تعاني من تلك المشكلة حيث أدت عملية إنشاء قناطر إسنا إلى إرتفاع مناسيب المياه الجوفية بالمنطقة السكنية المحيطة . ويهدف هذا البحث إلى تقييم مختلف الطرق التي قد تستخدم لعملية تخفيض مناسيب المياه الأرضية بمدينة إسنا وذلك عن طريق عمل نموذج رياضي بإستخدام برنامج (GMS) حيث يتم عمل نمذجه ومعايرة للنموذج الرياضي حتى يحاكي حركة المياه بمنطقة الدراسة ومن ثم إستخدام هذا النموذج الرياضي في تقييم تأثير عمليات السحب على مناسيب المياه الجوفية بالإضافة إلى تحديد مميزات وعيوب كل طريقة من طرق التخفيض من الناحية الإنشائية.

Abstract

In Egypt, most of residential areas are located around the River Nile as, it is the main water supplier for domestic and agriculture uses. While the delta and Nile valley are only 5 % of Egypt area but it contains 97 % of Egypt's population. it almost covered by clay layer and contains the irrigation network. Many regulators and barrages are located on the Nile River to regulate and sustain the water levels at desired values. One of the side effects of these regulators is the rising of water levels in the upstream that causes the groundwater levels to rise in the surrounding residential areas. This rise of groundwater levels in residential areas negatively impact the safety of existing buildings. The dewatering processes are needed in similar areas to resolve this problem and to save the buildings from deterioration. Esna city is one of deteriorated cities that suffers from this phenomenon. The Constructing of Esna barrage caused the groundwater to rise in the residential area. The main objective of this research is to assess the impact of different dewatering systems that can be used for lowering the water table in the city. Modflow code was used to simulate a groundwater flow model for Esna city. The simulated model was then used to assess the efficiency of proposed dewatering methods. moreover, the research will evaluate the advantages and disadvantages of each dewatering system.

Introduction

Most of residential areas in Egypt are located in Nile valley and delta where surface water is available from the Nile River and its branches. Many regulators are constructed on the River Nile and the main canals cause the water level to rise and consequently rising of water table the residential area; (Dawoud et al., 2006). The rising of groundwater in residential areas threatens the buildings foundations and construction of, sewage network, drinking water networks, light poles and other constructions. Therefore, it was urgent to design a suitable dewatering system to control these water levels. Several of dewatering systems were proposed to decrease the water table in similar areas such as: pumping wells and subsurface drainage. Esna city was the study area in this research. It is located in the south at upper Egypt, 150 km north Aswan city. There are two barrages on the River Nile opposite to Esna city. The old one was constructed in 1908 but, it stopped working. The new barrage was constructed in 1995 and located 1150 meter north the old one (Abu–Zeid, 1995). Esna city is divided into two parts, the old land which is located besides the River Nile and the new reclaimed lands to the west of the old land (M. Abdel Monem et al 2014, 2015). The residential area is surrounded from all directions by surface water sources. The Nile River from the east, Asfon canal in the north, Maksar canal in the south and Ramady canal in the east side

One of the significant issues that threatens the residential areas is the absence of the sewage network while the drinking water network covers most of the residential area. Septic tanks are used to get rid of the sewage water. Moreover, the location of the residential area between different surface water sources, with fluctuating water levels and absence of sewage network led to rise in groundwater level in the city reaching the street levels in some locations. Lowering of groundwater levels in Esna city is essential. Many groundwater lowering techniques were suggested to solve this problem through many studies However, the selected method was the pumping wells. 20 pumping wells were drilled to cover the residential area on five lines. Some of these wells started to pump water out with rates30 and 40 $m^3/hour$. The subsurface drainage system was also proposed to solve the problem of groundwater rising in the study area (RIGW 2010).

In this research a numerical model was developed using the available previous data with a new collected data then, all of these scenarios tested. The objective of this research is to compare between the two different proposed dewatering systems also, the optimal operating system for the current proposed solution. The advantages and disadvantages of the two proposed systems were identified.

Region Under Investigation

2.1 Physical and Hydrogeological Settings

2.1.1 Geomorphic Feature

Esna city lies on the flooded plain for the River Nile which is limited by the limestone plateau and separated by some sandy hills and agricultural land. The geomorphological units for the study area are Young alluvial plains, Old alluvial plains and Calcareous Structural Plateau (Figure 1). The study area was exposed to several geological process that formed the geological and hydrological features in the area.. The lithological sequence in the study area contains sediment formation related to new, immediate and old ages. Some of these formations are located on ground surface or under surface layers while others are found in deep layers. The most important hydrogeological formation is the quaternary formation which are Pliocene sedimentation ages, Pleistocene sedimentation ages and Holocene sedimentation ages.

2.1.2 Hydraulic Feature

The valued aquifer in the study area is the Quaternary (Figure 2) which extended with the River Nile from Aswan to Cairo. And limited in the east and west by the elevated limestone plateau which is located in the eastern and western desert respectively at the both sides of the River Nile. The hydrogeological maps indicate that the component layers for the Quaternary aquifer are; The agriculture surface soil layer with average thickness equals to1.5 meters thickness. Then, the top unit of clay and Silt Aquitard with average thickness equals to 15-meter thickness. Then, Sand and Gravel Aquifer Layer with average thickness equals to 250-meters thickness. Finally, the Base of Aquifer Pliocene Clay. It is recharged through Infiltration from excess irrigation water. infiltration form sewage networks or septic tanks and Groundwater movement from other aquifers like Nubian aquifer. The groundwater movements direction and velocity in the quaternary aquifer varied according to location. Besides the River Nile the movement direction often from south to north but, to the east of the city the movement direction in most cases from east to west due to high topographic levels in the east to the low levels in east and River Nile. Also, there are local movement due to previous mentioned recharge sources and topographic features which causes groundwater movements to the lowest levels locations and causing watering in these locations.

Data Collection

In order to assess the dewatering system efficiency, it was necessary to calculate the Topographic features, groundwater sources and levels, continuity between surface water and groundwater, aquifer features, recharge rates and stratigraphy of the area. The data is used to create the groundwater model that is used in the assessment process for the different dewatering systems.

3.1 Survey Works

The ground levels in the study area were calculated from previous old survey works conducted by RIGW. Afterwards, these data were verified by using the differential global position system (DGPS). All the topographic data were collected from both sources then, a contour map for the study area was generated. The ground surface levels in the study area range from 79.30 to 82 meters AMSL.

3.2 Groundwater Water Levels and Monitoring Network

39 observation wells were constructed by RIGW during studying the groundwater rising phenomenon in Esna city. 33 of these wells are shallow with average depth of 5 meter in the clay layer and 6 wells are deep with average depth of 15 meters in the sand layer. The monitoring process continued for four months. In order to study the interaction between the upper clay layer and lower sand layer, two wells were drilled at the same location one is shallow and the second is deep well. The relation between the two curves from the recorded data is shown in (figure 3). The chart indicates full matching between the two curves. This explain the strong corelating between the water levels in the upper and lower layer. After collecting and analyzing the data from observation network, a contouring map for groundwater levels was generated (Figure 4) in order to use it in the calibration process.

3.3 Surface Water and Canals

Surface water levels monitoring data was collected and used to calibrate the developed model in the steady and transient state. The residential area in Esna city is surrounded by surface water from all sides. The River Nile from east side with water level ranging between 78 & 79 meters (AMSL) in the upstream and 72.3 & 78.4 meters (AMSL) in the downstream. At the north, Asfon Canal is with water level equals to 76.35 meters (AMSL). The east fringe of the residential zone in Esna city is limited by Ramady canal with water level equals to 80.50 meters (AMSL). The south fringe is bounded by Maksar canal with water level equals to 80.3 meters (AMSL). It was observed that the high surface water levels were observed in the east and south boundaries of the residential area (Figure 5).

3.4 Pumping Test

In order to calculate the hydraulic parameters of the aquifer in study the area, 12 pumping tests were conducted by RIGW. (Figure 6) indicates the locations where the tests were conducted. Continuous, step pumping test and recovery were performed and analyzed. (Table 1) summarized the aquifer hydraulic properties for the 12 tested locations. Statistical analysis was applied to remove the outliers of storativity value. The resulted storativity value is $5 * 10^{-5}$. The specific storage value is considered 0.005 for third and fourth layer while, for first and second layer the specific storage is obtained from literature with 0.0025.

3.5 Recharge Rates

The residential area in Esna city is provided by drinking water network but, until this time septic tanks are used to dispose the Wastewater. However, septic tanks act as the main source for recharging the water table and groundwater in the residential area. The estimated recharge rate is 0.002213 m /day. The recharge from the agriculture area at the east fringes of the study area at the old agriculture land is estimated from 0.001 to 0.0005 m/day. All these values were taken in consideration in the developing the model.

3.6 Stratigraphy of Study Area

The stratigraphy of the soil in the study area was investigated by RIGW during the previous study. 30 boreholes were drilled in Esna city covering most of the study area (Figure 7). Rockworks software was used to interpolate the results of boreholes and connect between similar layers in order to develop a conceptual 3D model for the stratigraphy of the study area (Figure 7). The analysis conducted by the software divided the soil profile into 4 different layers. The first layer is about 3 meters thickness and consists of fill with some interbeds of clay. The second layer with 7 meters thickness consists of clay with very low hydraulic conductivity However, this layer is intercalated by some lenses of sand which increases hydraulic conductivity of this layer. The third layer is 3 meters thickness consists mainly from sand mixed with silt or clay. This layer is the top part of the aquifer. The last layer consists of sand and gravel up to the base of aquifer.

Numerical Model

4.1 Numerical Model Characteristics

In order to understand the nature of groundwater movements, levels, and interaction, a numerical model was developed for the study area. The previous collected data was used to build up the groundwater model. The developed model used the Modflow through code of GMS interface version 10.0.8. The modeled area is

3481*4339 meters. The model discretization is 140 columns * 174 rows however, in the vertical direction it was divided in to four layers.

4.2 Numerical Model Calibration

The input data described above represents the best estimate available at the start of calibration. The calibration obtains a close agreement between the observed and the calculated head. The readings from the monitoring wells network were used in steady state flow calibration. (Figure 8) shows the most deteriorated locations in the area.

Assessed Dewatering Systems and Scenarios

The main objective of this research is to evaluate the proposed methods for lowering the groundwater levels in the study area and similar areas. The calibrated model was used to assess the effects of the different lowering methods that can be used for this objective. The aquifer specific yield and storativity that calculated from the pumping test were added to the transient model (Table 2). Most of previous studies suggested two main effective methods for groundwater lowering; pumping wells, and subsurface drainage. Each of these proposed systems has advantages and disadvantages that will be assessed using the developed model.

5.1 Pumping Wells Dewatering System

One of the proposed solutions by previous studies for groundwater rising phenomena in Esna City is pumping wells (RIGW. 2010, Z. El-Fakharany et al 2014 and Ghanem et al. 2011). Moreover, it was the chosen solution to be implemented in the city (figure 9). The pumping wells are arranged in 5 lines to carry the extracted water to Ramady canals. Ttwo proposed scenarios were suggested for the operation scheme of the pumping wells; 30 and 40 $m^3/hour$. In the current study, the proposed extraction rates by the previous were tested using. In addition, another three-scenario for the operation schemes of the wells are proposed and tested within this research. The first, operation scheme is to operate the half wells at 80 $m^3/hour$ alternatively in staggered pattern. The second proposed scheme is operating the wells adjacent to the Ramady and Maksar canal to 60 $m^3/hour$ while operate the other wells at 30 $m^3/hour$. Finally, the third scenario is the one day on and off operating schedule plan was considered. For the first 300 days the extraction rate will be 100 $m^3/hour$ then, the extraction rate will be decreased to 75 $m^3/hour$ for the next 200 days and finally, the extraction rate will sustain at 30 $m^3/hour$ till the end of scenario time steps.

Continuous Extraction at Rate 30 $m^3/hour$(W_A).

The first tested scenario is to operate the wells continuously at extraction rate equals to 30 $m^3/hour$. The resulted drawdown for both layers (1&3) equals to 2.38 below the starting head. However, it reached the steady state condition after 1000 and 2400 days for layer 3 and 1 respectively. The required drawdown level to solve groundwater rising is about 1 meter below the staring head levels which could be obtained after about 100 & 750 days for third and first layer respectively. The total extracted volume of water per day for this scenario is 14400 m^3.

Continuous Extraction at Rate 40 $m^3/hour$(W_B).

The second tested scenario is to operate the wells to pump 40 $m^3/hour$. The maximum resulted drawdown for this scenario is 3.29 m in both first and third layers. The required time to reach steady state condition is 1900 and 1000 days for the first and third layers respectively. Also, the required time for lowering the groundwater levels for 1 is 500 and 70 days for clay and sand layer respectively. The total extracted volume of water per day for this scenario is 19200 m^3.

One day Alternative Extraction rate of 80 $\boldsymbol{m^3/hour}$(W_C).

As, it is not feasible to operate the wells constantly for 3650 days to achieve the well continuous pumping, this scenario is proposed. Wells need to be stopped for maintenances processes and rehabilitation. This scenario proposed to operate the wells with a full day on and off schedule, with extraction rate equals to 80 $\boldsymbol{m^3/hour}$. The on and off in wells operating schedule was designed in a staggered pattern. The maximum drawdown in the two layers is 3.44 meter from the starting head. The required time to reach steady state condition is 1800 and 1250 days for the first and third layers respectively. The required drawdown which is 1 meter is obtained in first layer after 500 days and 67 days for the third layer. The total extracted volume of water per day for this pumping scenario is 19920 m^3.

Continuous Variable Pumping Rate of 30 and 60 $\boldsymbol{m^3/hour}$(W_D).

Another proposed scenario in this research was tested by applying variable extraction rates from pumping wells. It was noted that the main source that cause the water table rising in study area is Ramady and Maksar canal in west and south. Therefore, the proposed scenario was to set extraction rate of 60 $\boldsymbol{m^3/hour}$ for adjacent wells to these two canals. However, the rest of the wells extract with rate equals to 30 $\boldsymbol{m^3/hour}$. The maximum drawdown in both layers is 3.24 meters from the starting head. The steady state condition was obtained after 1800 and 1200 days for the first and third layers respectively. The required drawdown which is 1 meter is obtained in first layer after 540 days and 80 days for the third layer. The total extracted volume of water per day for this scenario is 20160 m^3. By comparing between all the previous scenarios (Figure 10), it is clear that the minimum groundwater lowering obtained from the first scenario with continuous extraction rate equals to 30 $m^3/hour$ with 2.38-meter drawdown from the starting head; and the maximum drawdown is obtained from one day on and off operating schedule with extraction rate equals to 80 $m^3/hour$ with 3.44-meter drawdown from the starting head. It is also noted that the last three scenarios are almost similar in their results.

As mentioned before, the desired drawdown in the study area is 1 meter from starting head. Moreover, the drawdown in last three scenarios reached about 3.40 below starting head in about 500 days. This drawdown is beyond needed and increase the cost of dewatering process. On the other hand, in the first scenario the drawdown reaches its maximum value, 2.38-meter in 750 days, which is 8 months longer than the last three scenarios. up on the previous, a final scenario is proposed in order to reach the required groundwater level in short time and low cost.

The one-day alternative gradual decreasing pumping rates (W_E).

As mentioned before the objective is to find appropriate scenario that achieves the drawdown in short time and decrease the long-term cost. Also, it has to be applicable from rehabilitation and maintenance perspective. The one day on and off operating schedule plan will be considered. For the first 300 days the extraction rate will be increased to 100 $m^3/hour$ then, the extraction rate will be decreased to 75 $m^3/hour$ for the next 200 days and finally, the extraction rate will sustain at 30 $m^3/hour$ till the end of scenario time steps. (Figure 11) presents the resulted water levels according to the last scenario. It shows that, the required groundwater level is achieved after 350 days from starting the extraction. The draw-down increased to 1.46-meters after 867 days then it was raised again to 1.10 meters at the end of the stress period. The groundwater total volume that is extracted during the model stress period in million cubic meters for all scenarios are 52.56, 70.08, 72.71, 73.58 respectively. But, for the last scenario, the total extracted volume of water is 33.48 MCM which is significantly smaller compared to the other scenarios. (Figure 12) indicates the resulted countering map for ground water levels according to (W_E) scenario

A comparison between the five operating pumping scenarios (Table 3) in terms of, the maximum resulted depth, required time to reach this depth as a steady state case, the required time in days the reach the required depth and the daily disposed volume of water for each scenario. The table indicates that the most optimized operating system was (W_E) because, it achieved the required depth in short time with minimum disposed volume of water and finally, the applicability of the operating scheme.

5.2 subsurface dewatering System

The second proposed solution for the groundwater levels rising in Esna city is sub-surface drainage. The previous studies proposed three scenarios for groundwater lowering using subsurface drainage. The first scenario is through excavation the drain with depth of 2 meters. The hydraulic permeability for the filling material in this tested scenario is 50 m/day. The second scenario is similar to first one but the drain depth is increased to 2.5 meters below ground surface. The last tested scenario is also similar to second one but, the permeability increased to 70 m/day. The three scenarios were tested throw the calibrated model. The results for all scenarios show, that the effect of drains was very limited, only at the drain location (Figure 13). It only decreases the groundwater levels in about 30-45-meter width zone in each side of the drain lines. It had no effect on groundwater levels outside this narrow zone. Therefore, an additional scenario was applied in this research using subsurface drainage. The distance between the drains centerlines did not exceeded the range of 45 meters respect the current streets direction. The drain network is designed at 2 meters depth below the ground surface also, the permeability value of filling material around the drains pipe line is estimated to be 50 m/day. The developed model outputs show that the drains network lowered the groundwater levels 1.5 meters locally around the drain path but the effect doesn't exceed 30 to 45 meters away from the drain (Figure 14).

Discussions

In this research the calibrated hydrogeological model was used to assess the proposed dewatering systems in long term project and it its effect on groundwater level. There are two main proposed dewatering systems in similar cases; pumping wells and Subsurface drainage. Nine scenarios were assessed for the two systems; five scenarios for pumping wells system and four scenarios for subsurface drainage.

The four tested scenarios for pumping wells (W_A, W_B, W_C, W_D) achieved the required drawdown in first layer. The maximum drawdown for these scenarios was 2.38, 3.92, 3.44, 3.24 meters respectively. The steady state was achieved after 2400, 1900, 1800, 1800 days respectively. The one-meter drawdown was achieved by these scenarios after 750, 500, 500, 540 days respectively. The daily total volumes which are disposed from these scenarios are 14400, 19200, 19920, 20160 m^3/day respectively. Most of operating schedule for these scenarios were not applicable because of continuity of extraction in these scenarios. The disadvantages of these four scenarios are; more than needed drawdown, workability cost increase, length of required duration, huge volumes of the disposed water and applicability of operating scheme. In order to overcome these disadvantages, the fifth scenario (W_E) was proposed. The obtained drawdown in this scenario was 1.46 meters it takes 350 days to be achieved. The operating system for this scenario was one day on and off alternative that allow the time for maintenance and therefore, lowering the cost workability. Finally, the total disposed water volume was 9173 m^3/day. As the pumping wells in general considered a dynamic system which may have negative effect on building stability in study area, the fifth scenario has the minimum fluctuation rang that decrease the risk that may threaten the building stability.

The second proposed solution for lowering groundwater levels was subsurface drainage. Four scenarios were tested for the system. Three scenarios are in the same location for drains and variation in depth and permeability of filling material. The resulted drawdown was almost the same. The disadvantage of this scenario is the limited efficiency range which does not exceeded the 45 meters from the drain center line. In order to overcome this weak point, the fourth scenario was tested by changing the drains location to be closed to each other. The distance between these center lines did not exceeded the 45 meters. The streets location was respected in this scenario. The proposed scenario lowered the groundwater level in the deteriorated area. However, it increases the initial cost for constructing this solution.

Conclusions and Recommendations

7.1 Conclusions

- This research discussed the problem of groundwater rising in some residential areas in Egypt. Also, the efficiency of the proposed system and operating scenarios for dewatering this water.
- Esna city was chosen to be the case study. All geological and hydrogeological data about the study area were collected. Some of these data were collected from previous studies and others conducted during this study. The survey works were collected from the previous studies then precured by using differential GPS during this study. Groundwater levels were obtained from monitoring wells that constructed by RIGW in the study area. Also, surface water sources and levels were collected for the same period. Recharge to groundwater were estimated. And aquifer properties were calculated from pumping well tests.
- The data from boreholes that conducted in Esna city was interpolated to approximate the lithology of the area. All of previous data were inputted to the developed model that consists of four layers 174*140 matrix of rows and columns. Steady state model was calibrated using the previous data then, the transient model was calibrated by using the pumping test results.
- The developed model was used to check the previous studies scenarios effect on groundwater levels
- There were two main solution were proposed by previous studies, pumping test and sub surface drainage. Number of five scenarios were checked for pumping test solution and four scenarios were solved for sub surface drainage. The groundwater levels and fluctuation with time for all of these scenarios were calculated.
- The pumping well was dynamic system as it increases the fluctuation of groundwater levels but can be controlled by managing the operating scenarios.

- The subsurface drainage is a static system. There is no fluctuation in groundwater levels. Also, it lowers the groundwater levels to the desirable level but, in narrow range to the drains centerline with about 45 meters range. That can be solved by decreasing the distance between these drains locations to not exceed 45 meters but, that will increase the initial cost.

7.2 Recommendations

After fulfilling objectives of the study and analysis the results, the following recommendation are required to be considered.

- Studying other lowering system options for similar areas. And assess its effect on groundwater levels.
- Study the effect of these dewatering scenarios on building stability in similar areas.
- Assess these dewatering scenarios with different types of soil.

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Table 2: Hydraulic Properties for Aquifer from Pumping Tests.

WELL	T (m^2/d)	K (m/d)	S
5	1410	14.1	0.00507
5D	1890	18.9	0.00488
P14	1940	19.4	0.0000245
P15	1810	18.1	0.00489
P16	2690	26.8	0.000502
p17	2460	24.6	0.000000437
P21	2900	29	4.68E-09
P22	2460	24.6	0.000000316
P23	5080	50.8	9.78E-14
P24	2310	23.1	3.41E-09
P25	2740	27.4	3.69E-10
P26	1050	10.5	0.0000111
Average	2395	23.94	0.00128153

Table 3: Layers Properties Considered in Developed Model

Layer	K_h m/day	K_v m/day	s_y	s_s
1	0.001	0.0001	0.02	0.00250
2	1	0.1	0.09	0.00250
3	25	2.5	0.22	0.00500
4	30	3	0.22	0.00838

Table 4: Comparison Between Pumping Wells Operating Scenarios Results

scenario	**Max. Depth (meter)**	**Required Time for steady state (days)**	**Req. Days for 1-meter D.D (days)**	**Daily Disposed water volume (m3)**
W_A	2.38	2400	750	14400
W_B	3.92	1900	500	19200
W_C	3.44	1800	500	19920
W_D	3.24	1800	540	20160
W_E	1.46	870	350	9173

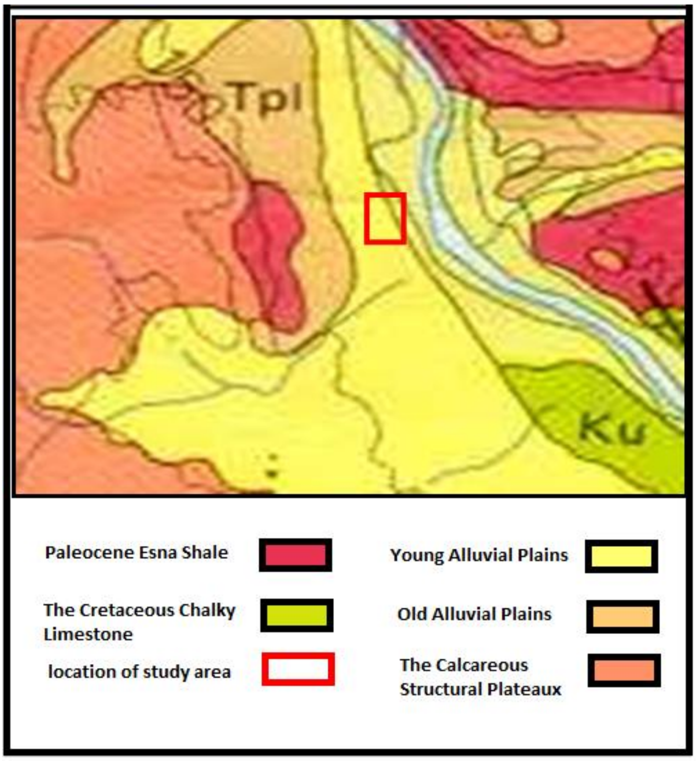

Figure 19: Geomorphological and Geological Features of The Study Area.

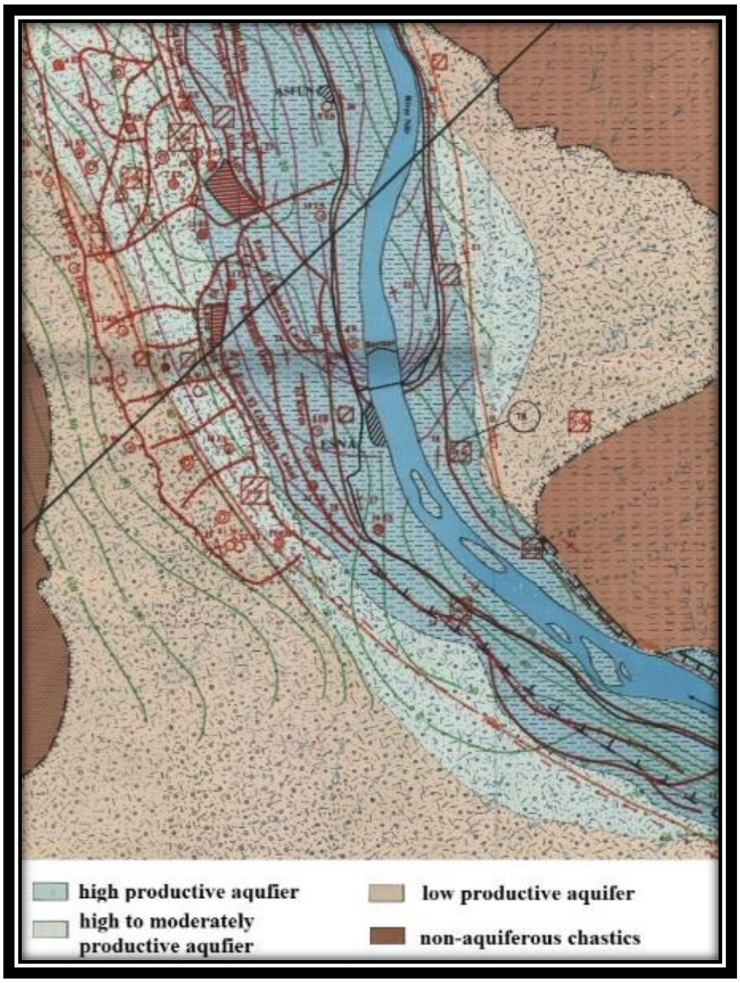

Figure 20: Hydrogeological Map for Study Area.

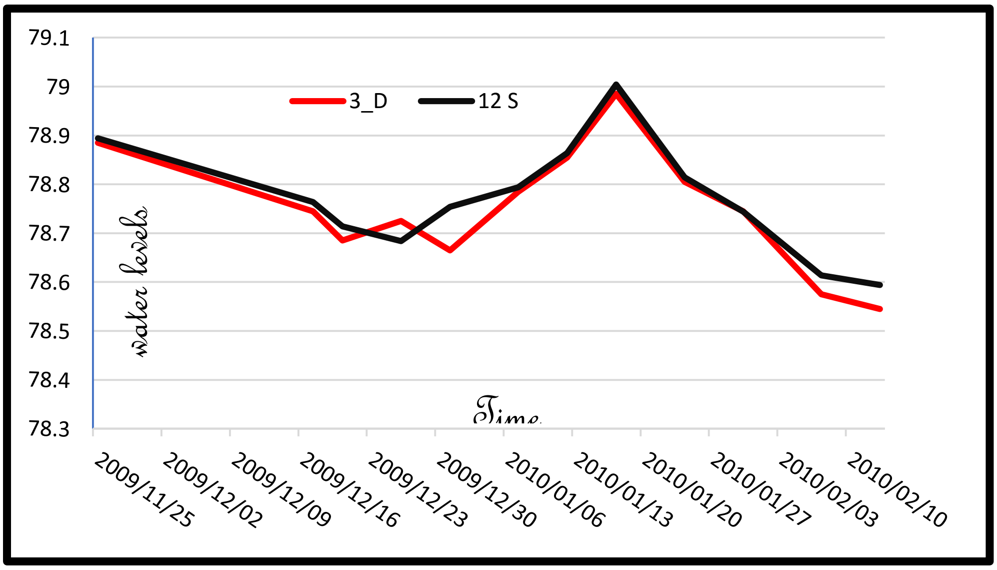

Figure 21: The Correlation Between Groundwater Levels in Shallow and Deep Wells

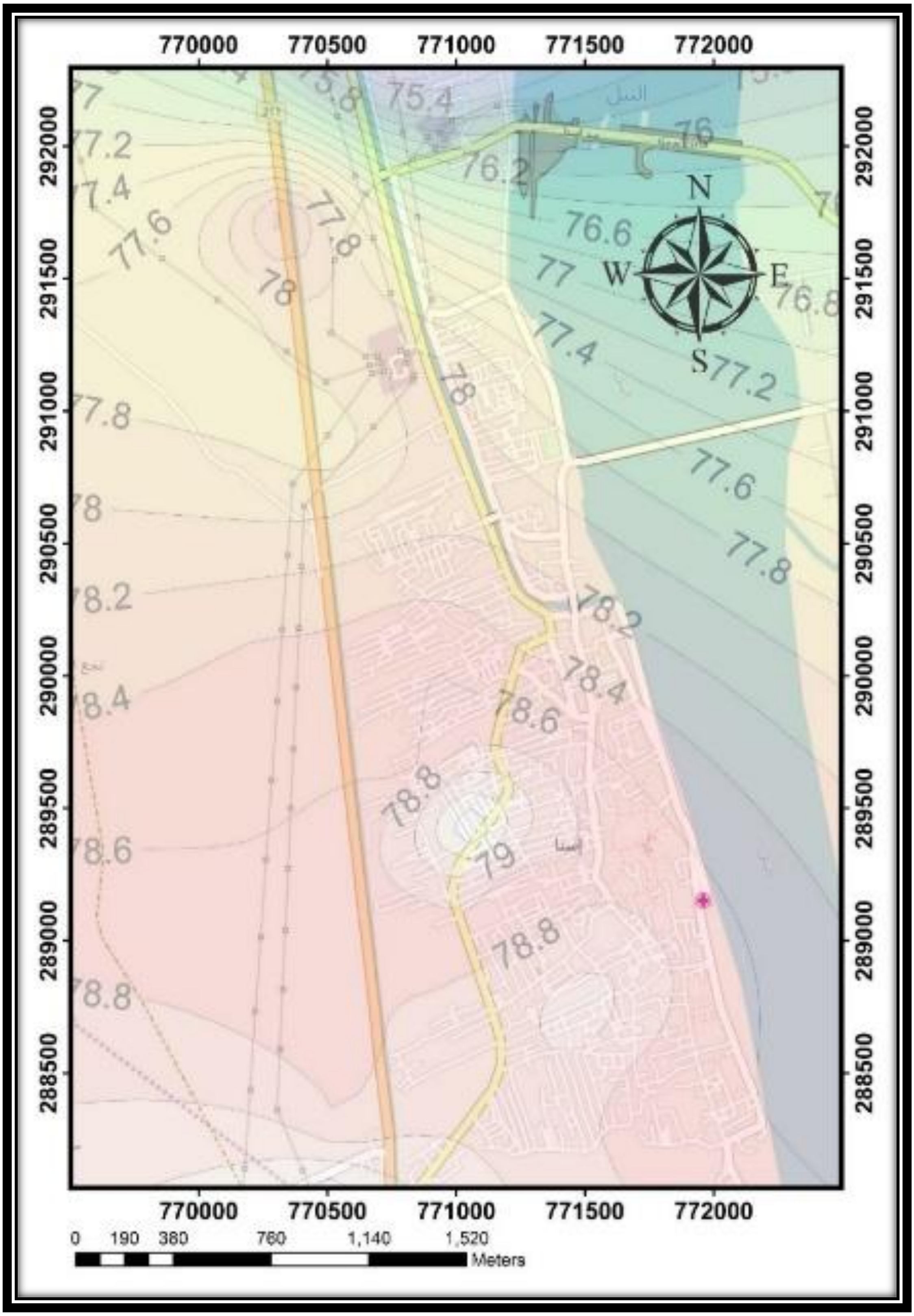

Figure 22: Groundwater Levels in The City

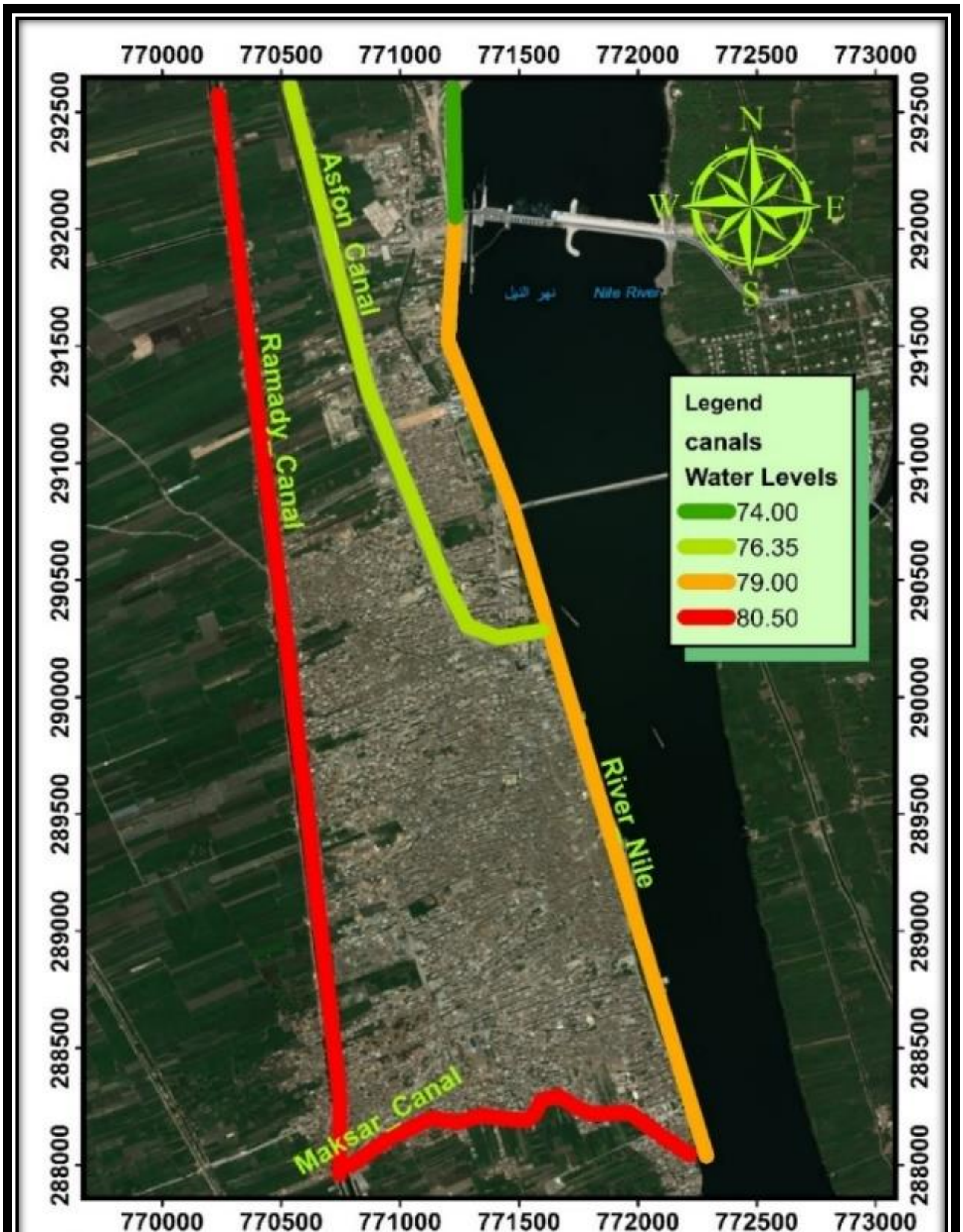

Figure 23:Surface Water Levels in Study Area

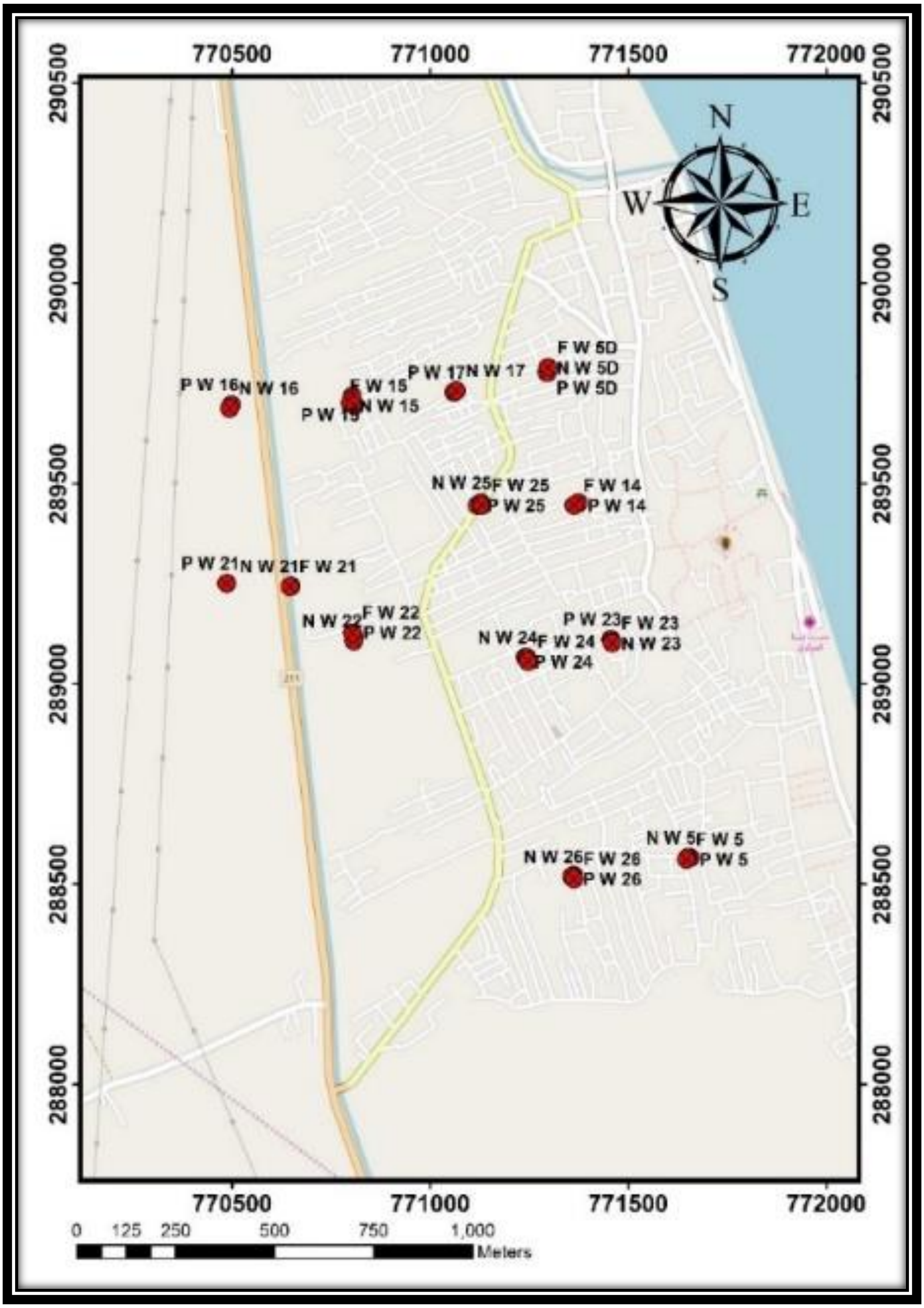

Figure 24: Pumping Test Locations

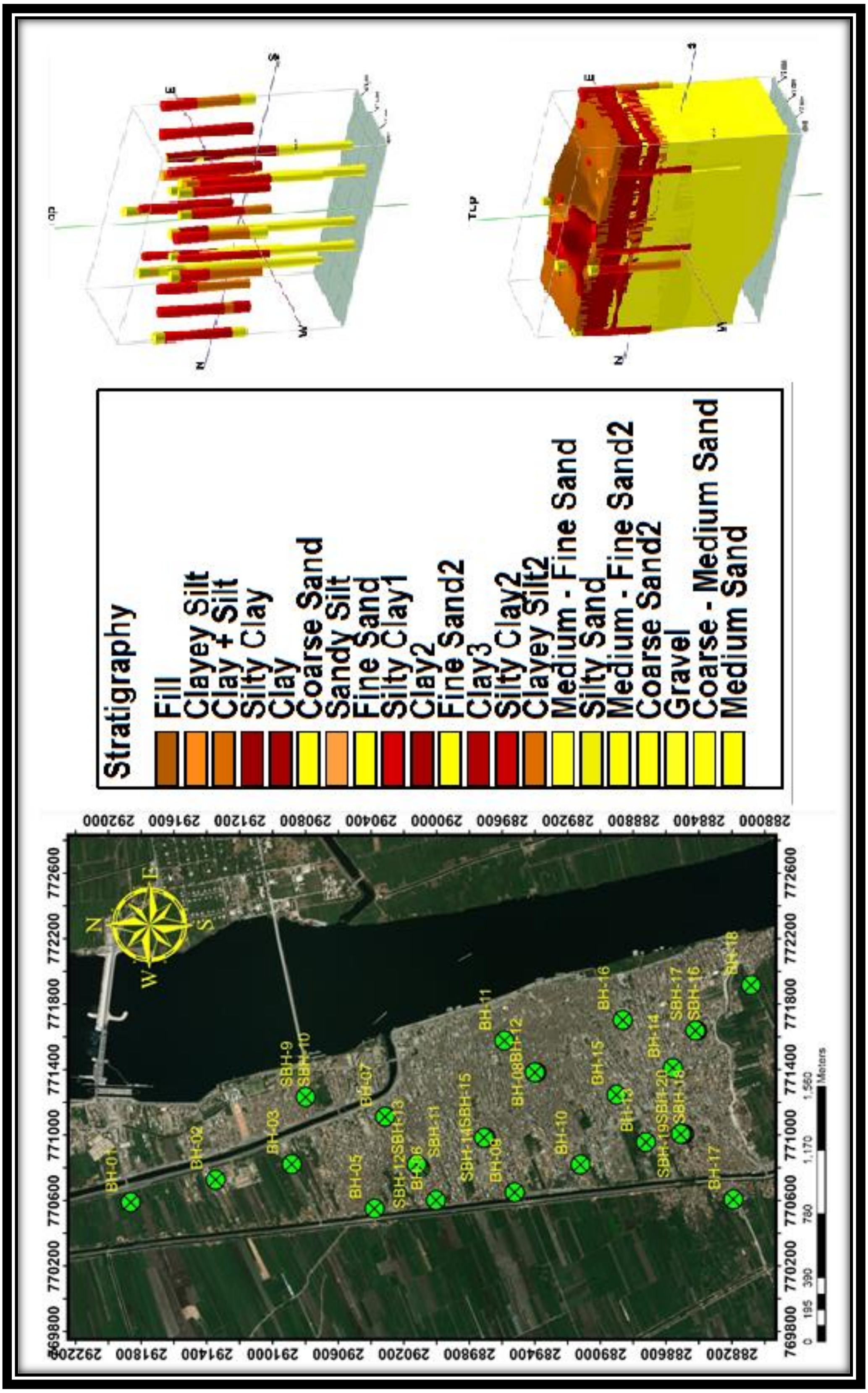

Figure 25: Boreholes Distribution, Locations & 3D Conceptual Model for Stratigraphy in The Study Area

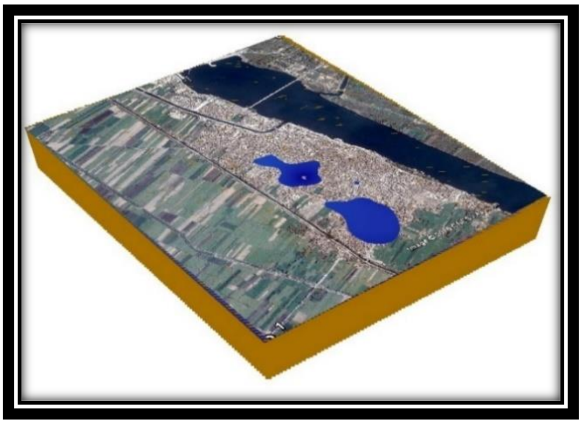

Figure 26: The Most Threated Locations in The Study Area

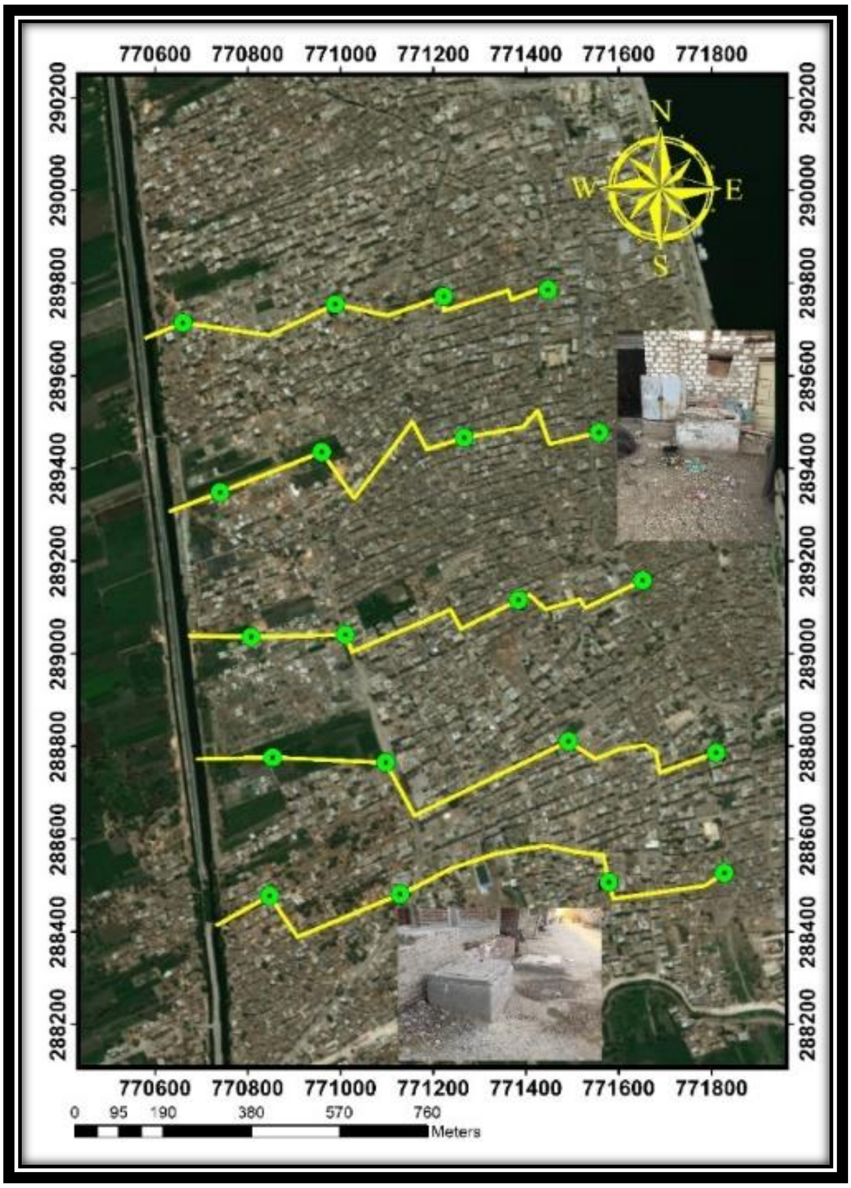

Figure 27: Locations of Pumping Wells and Pipe Line

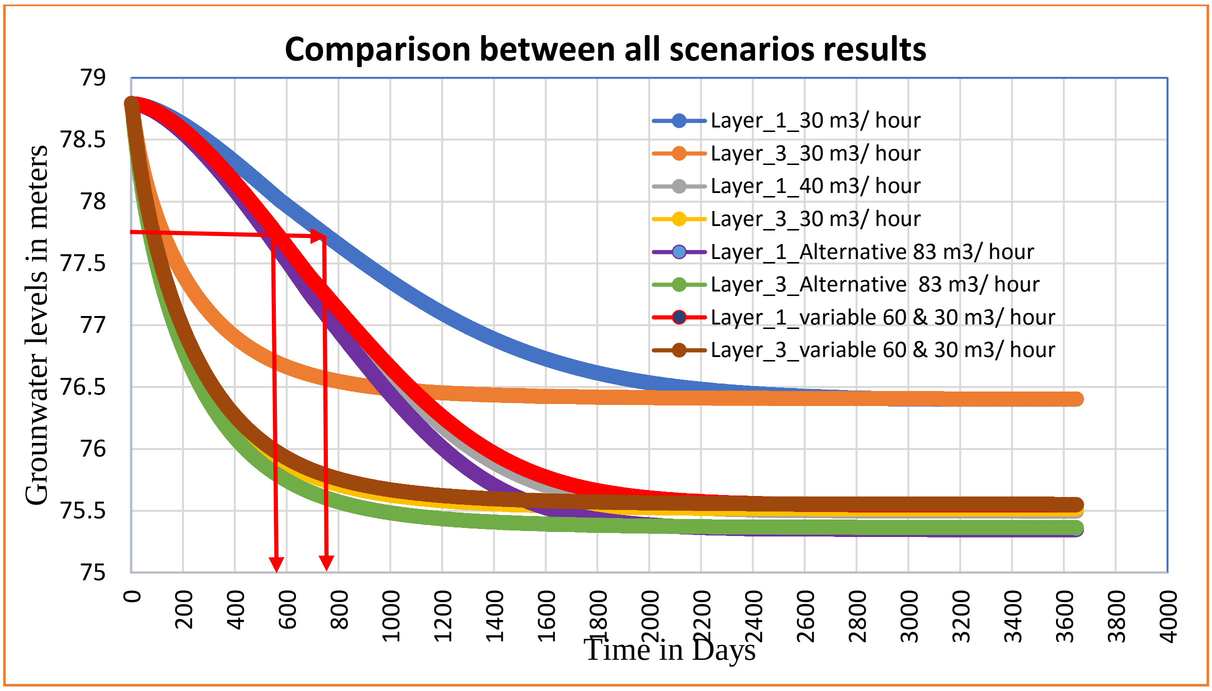

Figure 28: Comparison Between All Scenarios Results

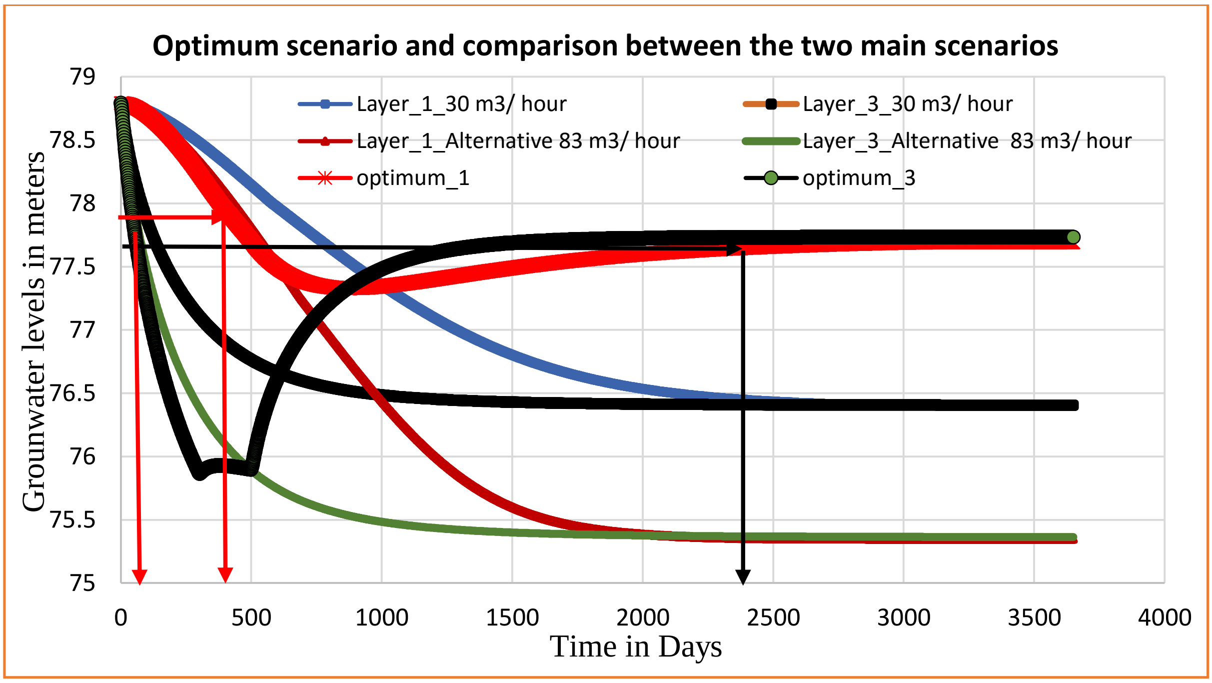

Figure 29: Optimum Scenario and Comparison Between the Two Main Scenarios

Figure 30: Contouring Map for Groundwater Levels Resulted From (W_E) Scenario

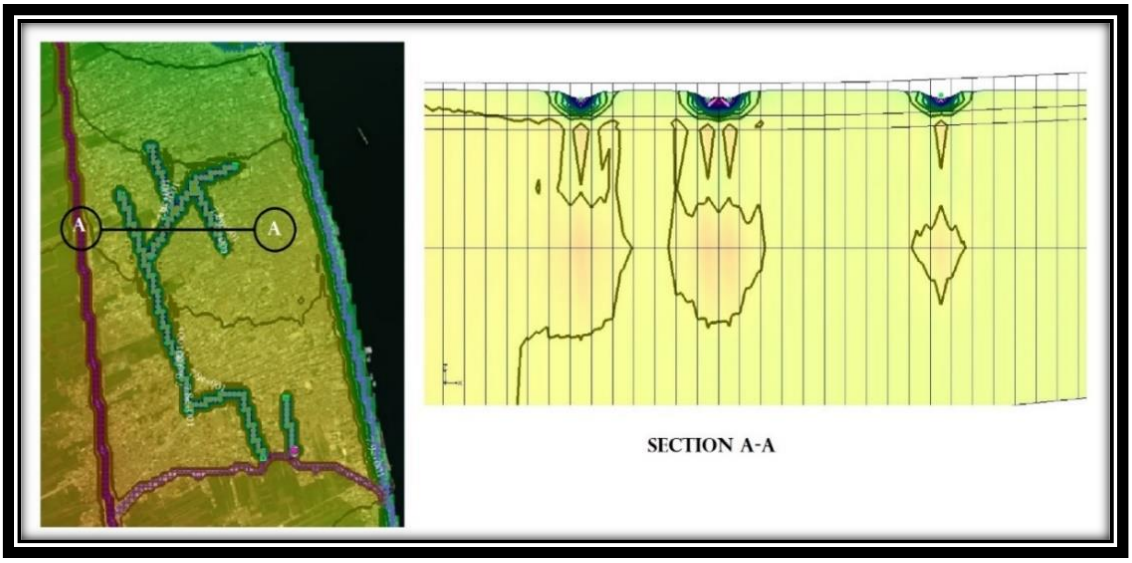

Figure 31: Effect Of 2 Meters Depth Drain with Filling Material Permeability 50 $^{m}/_{day}$ On Groundwater Levels in The First Layer

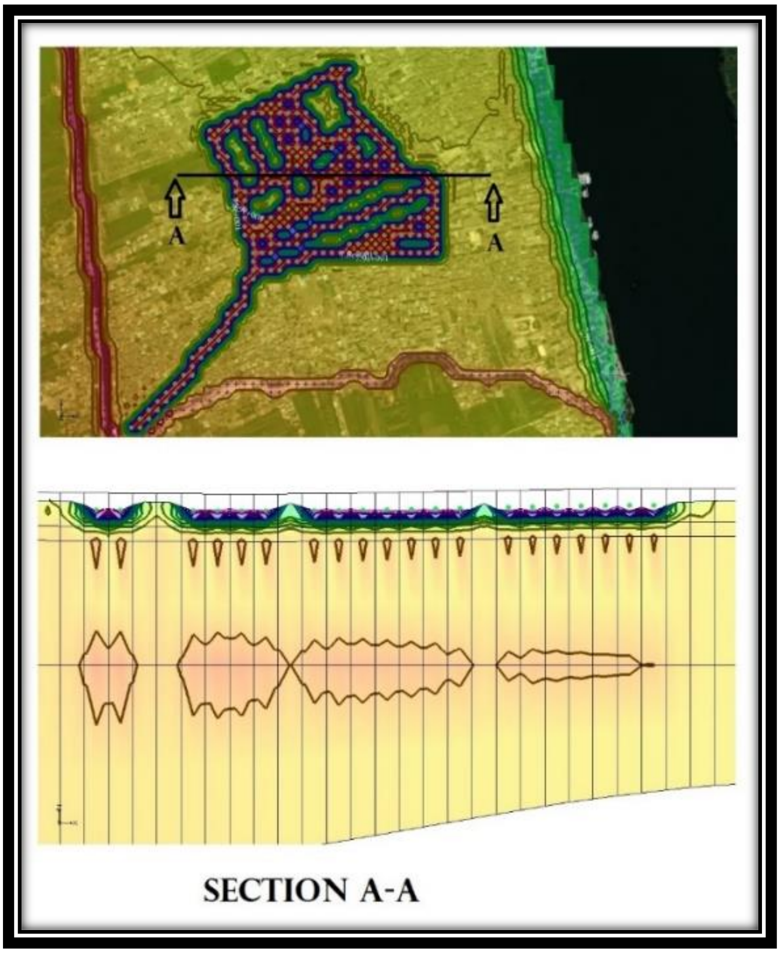

Figure 32: Effect of Drainage Network System on Groundwater Levels.