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Groundwater High Elevations Damaging the Environment at Mosul City

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Abstract: High elevations of groundwater at Mosul city is a very big problem and may cause mass destructions to the environment, health and Building foundations due to the closing of groundwater near ground surface to a depth of water in many places (less than 1 m). From filed investigations for 43 large diameters shallow wells, the water elevations were measured 14 times through 7 months. Utilizing raster based GIS operations with automated parameter estimation (PEST) the conceptual model was build and converted to numerical model. After model calibration the hydraulic conductivity values have been found. The elevations, path lines and flow vectors maps were drawn from model results. Three sectors for groundwater elevations in the city have been defined and introduced to the water management agency for prompt decisions. The distributed finite-difference flow code (MODFLOW) selected in this study has approved to be a useful tool for creating a groundwater flow model for the study area. The results of the model can be used for the sewerage net design in Mosul city also for the planning of the agriculture and industrial projects.

Keywords: Groundwater; Mosul city; Environment; Modeling.

1. INTRODUCTION

Groundwater is considered one of the basic sources in many countries in the world to supply cities and urban places with water for domestic, agricultural and industrial uses, due to unavailable surface water and lack in rainfall quantities. On Other side, groundwater existence near ground surface may cause many engineering environmental problems in many places in the world specially the urban places in the cities such as land flooding which may cause clogging in the storm and waste water network. This may leads to collect the rainfall water in addition to the released water quantities from homes and traditional shops especially during the strong rainfall storms. These surface water sumps may lead to environmental and health problems. Consequently may lead to negative effects on buildings foundations and structures. Recently this problem was appeared in Mosul City especially in the inner districts after the increasing in the construction and building processes. Mosul city is suffering in winter season at some places from the appearance of surface water collection weakly discharge especially after rainfall storms. Some places are suffering also from the land flooding which caused some environmental and health problems. From the observations and field survey in such places it was reached that an increment in the groundwater elevations during winter season was found. In fact the drainage system and the water supply network are old and suffering from number of problems since the last 20 years. These problems represented by the clogging, leaking from both the storm water and water network supply network. These leaked water quantities added to the groundwater in the area and leading to increase water elevations day after day till reach this stage.

Mosul city is located topographically in a depression surrounded by hilly lands from the east and west slopping toward city centre and Tigris River. This characteristic brought this city to deliver big quantities of surface runoff during rainfall, flowing through number of main Wadies to Tigris River. A big quantity of these amounts of flowing water infiltrates and feeds the groundwater which may move in similarity with the surface water movement. This feeding process leads to the increasing in the groundwater levels and cause the land flooding in many places which already suffers from the ancient

waste and storm water networks due to the clogging processes.
The aim of the present research is to study and evaluate the ground water situation in Mosul city using computer simulation, starting with the prediction of conceptual model depending on some assumptions to get the final model. This model describes and simulates the ground water movement in the city using field data such as groundwater elevations measurements in shallow wells existed in many places in the city. This study could be used and depended by many environmental and engineering agencies for the future studies concerning the heavy waste water network design in addition to the possible uses in the planning of future industrial and agricultural projects.

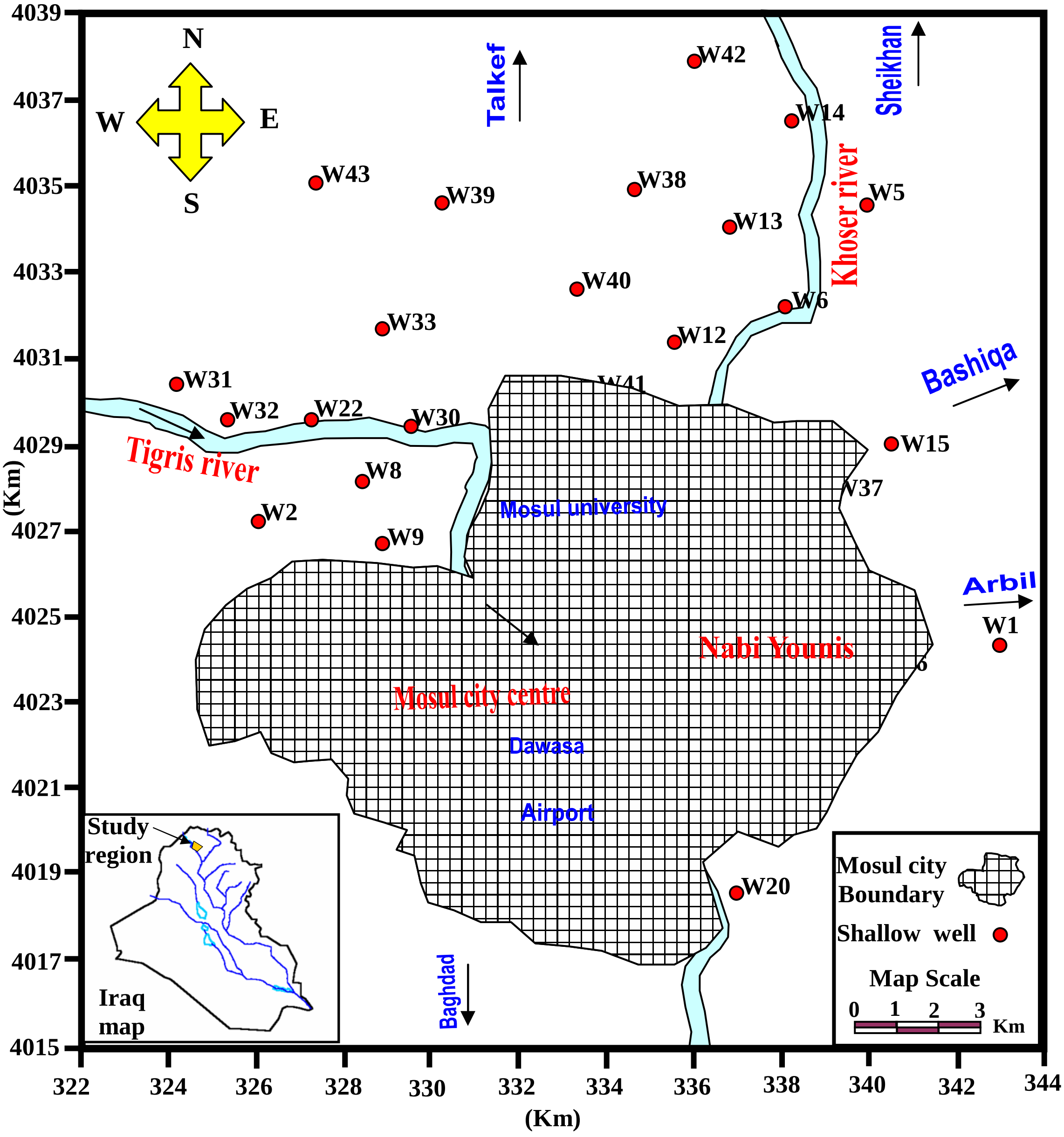

Figure 1. Regional map showing the study region boundary and observation wells locations.

2. FIELD WORK

The field work included studying the topographical maps for Mosul city to calculate the area of the study region which was about 528 Km^2 (22 Km in the x-axis and 24 Km in th y-axis). Surveying for 43 observation wells was conducted, (fig 1). Simi-monthly data for the groundwater elevations in those wells for about 7 months during the year 2001-2002 was collected. The daily water supply to the city network from the pump stations was recorded too. Many geological reports for the research area were studied, this aids in the relevant assumptions for the conceptual model in-addition to suggest number of soil permeability values and the ground water aquifers which can be depended in the numerical model operation for describing the groundwater movements, elevations and flow directions in the city.

3. GEOLOGY OF THE STUDY AREA

The geological formations of Mosul city includes Pilaspi, Fatha and Injanah formations in-addition to alluvial terraces and recent sediments, Al-Dabagh et al [1991]. Pilaspi formation consists of succession layers of dolometic limestone with marly limestone. This formation is characterized by containing fissures and many fractures which brought it good groundwater aquifer. Fatha formation is consists of many sedimentations cycle of marl rocks, limestone and gypsum. Injanah formation forms successions of sand stone rocks graded, silty and clay stone which was deposited as sediment cycles. The graded sand and silt stone forms of good layers storing water. This type of formation is existed in the west and north of Mosul city. Alluvial terraces and the recent sediments was the formation formed from the material leaved by the rivers as a result of changing its direction. This type of formation is existed on the east side along with Tigris River in Mosul City. These terraces cover Fatha and Injanah formations in many places. The Tigris River old terraces are characterized by the dolomite stones consisting gravel with different sizes, silt and sand. All those stones are combined by carbonic materials.
From the study of geological characteristics for those stones, they observe to have a high permeability in compare with other types of rocks and can be consider as a good aquifer for water storage. Large numbers of the observation wells in Mosul city is located within a half kilometer distance from Tigris River. Figure (2) shows the locations of the convex folds surrounded Mosul city. General speaking the convex folds consider feeding places to groundwater, while concave folds consider as the groundwater storages and there axis controls the groundwater direction.

4. GROUNDWATER FEEDING SOURCES AT MOSUL CITY

Many assumptions and variables that may affect the groundwater elevations were studied and evaluated. The amount of leaked water from water supply network as a result of existing cracks in the network pipes was estimated to be 30 % of all the pumped water quantities. This is one of many reasons causes the increasing in the groundwater elevations in Mosul city. Another reason is the amount of released quantities of waste water from the houses, shops in-addition to the seeped water from septic tanks as a result of fissures in their beds. This leads to feed the groundwater which in-turn leads to variation in the soil properties and values of hydraulic conductivity.

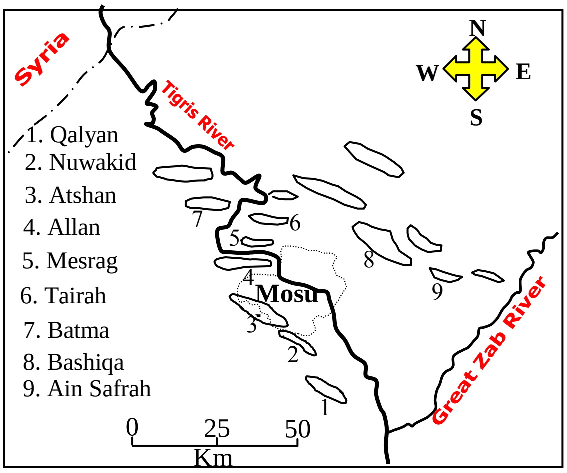

Figure 2. Convex folds locations around Mosul City.

5. NUMERICAL MODEL AND SIMULATION

Numerical model simulation system was used to build numerical model for the study region. The finite-difference flow code (MODFLOW) existed within groundwater modeling system (GMS), ECGL [2003], Harbaugh et al [1996] was used to perform this simulation. Using this system the study area was divided into large number of cells similar in sizes. The water balance equation for each cell was applied. after feeding the data available for some variable and assuming values for the others. The hydraulic head values or values of water elevations for all points in the study area could be estimated as a result from model operation, Faust et al [1980], Mercer et al [1980], Thomas [1973].
The (GIS) tools was used to build up the numerical model to aid in the combination process of topographical, geological and hydrological data using curves, points and polygons which represents deferent features.
The study area (Mosul city) which is about 528 km^2 as shown in fig (1) was depended to apply the model. The region was divided into three dimension cells using 90 horizontal lines in the x-direction and 82 vertical lines in the y-direction and made a network with 7380 cells. The dimension for each cell is (275 * 275) meter. Depending on thickness

of the top soil layer and thickness of the geological formation near the Tigris river a 20 m thickness was depended for the model cells. As known the properties of any cell in the numerical model is homogenous and isotropic but those properties may different from cell to cell. A preliminary value for hydraulic conductivity was assumed to run the model and obtain the elevations for groundwater in the study region. The model was calibrated using the parameter estimation method (PEST), ECGL [2003], as shown in (figure 3a). The calibration process continues to minimize the values of changes between the actual measured data with data results from the model operation (fig 3b). After large numbers of trials, a best coincidence between the measured and the predicted values was obtained and the most differences for water depth is within ±0.5 m in the most area of the study region as shown in figure (3a) and table (1).

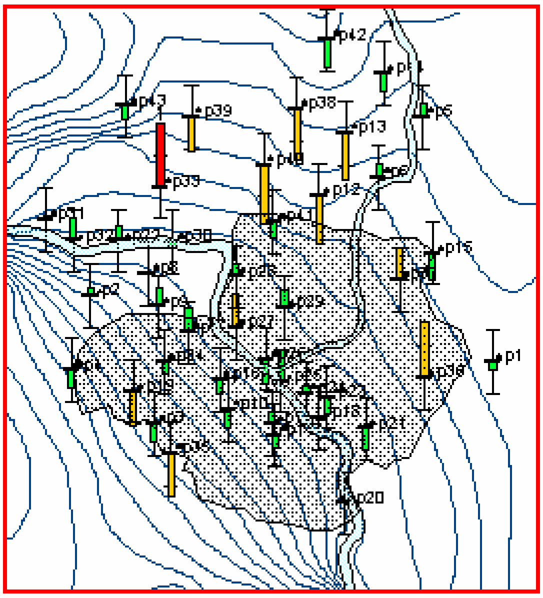

Figure 3a. Differences between computed and measured elevations by automated calibrations using PEST method (Feb. 2002)

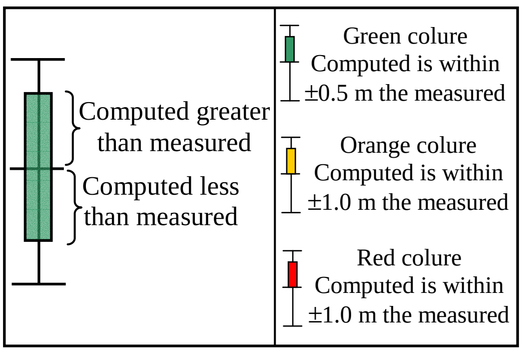

Figure 3b. Relationship between computed and measured water elevation value

There are many reasons may cause the Differences to be more than 0.5 m in some wells like pumping water from those wells at the same day of measuring the water level, Another reason is the leakage from water supply network.

Table 1. Comparison between measured water elevations in shallow wells with the computed elevations resulting from numerical model.

Well No.	G.Elv. (m.a.c.l)	Observed (m)	Computed (m)	Residuals (m)	water depth (m)
p1	251.33	243.2	242.98	-0.22	8.13
p2	245.08	234.1	234.35	0.25	10.98
p3	249.12	245.3	244.75	-0.55	3.82
p4	272.78	262.4	261.83	-0.57	10.38
p5	264.45	253.5	253.98	0.48	10.95
p6	253.32	242.32	242.76	0.44	11
p7	218.32	212.03	212.81	0.78	6.29
p8	222.31	214.1	214.16	0.06	8.21
p9	223.12	217.72	218.33	0.61	5.4
p10	226.31	223.26	222.69	-0.57	3.05
p11	220.45	215.4	215.02	-0.38	5.05
p12	252.53	242.13	240.58	-1.55	10.4
p13	261.62	254.5	253.01	-1.49	7.12
p14	268.73	257.6	256.99	-0.61	11.13
p15	255.14	245.2	244.39	-0.81	9.94
p16	221.33	217.25	216.78	-0.47	4.08
p17	217.36	212.8	213.15	0.35	4.56
p18	213.3	209.15	209.11	-0.04	4.15
p19	251.86	244.6	243.54	-1.06	7.26
p20	213.13	207.18	207.3	0.12	5.95
p21	222.78	214.2	213.53	-0.67	8.58
p22	218.57	211.5	211.99	0.49	7.07
P23	219.69	212.3	211.73	-0.57	7.39
p24	213.5	210.05	210.29	0.24	3.45
p25	211.8	208.16	209.14	0.98	3.64
p26	213.5	210.22	209.44	-0.78	3.28
p27	215.72	208.33	209.38	1.05	7.39
p28	218.33	210.15	210.52	0.37	8.18
p29	219.03	215.2	215.8	0.6	3.83
p30	219.5	211.4	211.32	-0.08	8.1
p31	225.37	218.08	218.23	0.15	7.29
p32	217.9	212.21	212.882	0.672	5.69
p33	228.87	222.12	226.64	4.52	6.75
p34	230.04	227.32	226.98	-0.34	2.72
p35	252.12	248.16	246.84	-1.32	3.96
p36	236.62	229.6	231.4	1.8	7.02
p37	244.74	236.24	237.25	1.01	8.5
p38	269.22	260.1	258.55	-1.55	9.12
p39	255.88	248.35	247.25	-1.1	7.53
p40	255.14	246.07	244.25	-1.82	9.07
p41	240.05	234.11	233.58	-0.53	5.94
P42	278.1	270.21	269.27	-0.94	7.89
P43	265.17	257.34	256.89	-0.45	7.83

As a result from the numerical model operation the groundwater movement vectors within Mosul city were calculated and drawn as shown in figure (4).

Through the identification of the vectors of the groundwater movements the feeding source of water for any point inside the study area was obtained. Figure (5) shows the shaded critical zones within Mosul city concerning the elevations of groundwater to be near ground surface. The lands in critical zones are flooded with water during rainfall season due to a very weak discharge through waste and storm water network. Figure (5) is drawn using interpolation tools in GMS and depending on wells data.

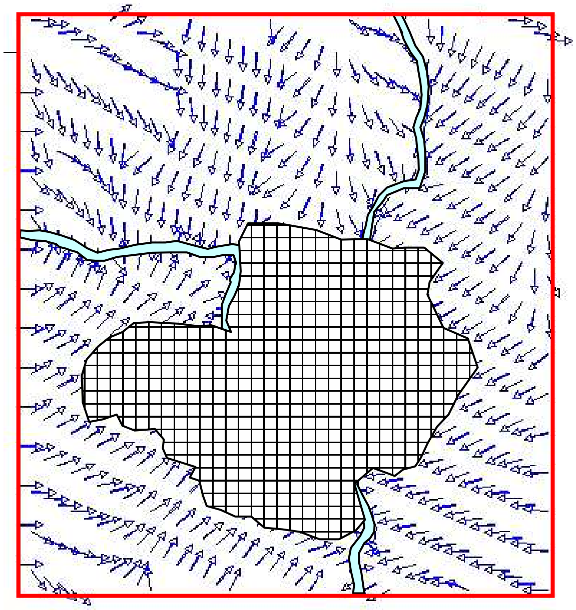

Figure 4. Flow vectors showing the groundwater flow directions (Feb. 2002).

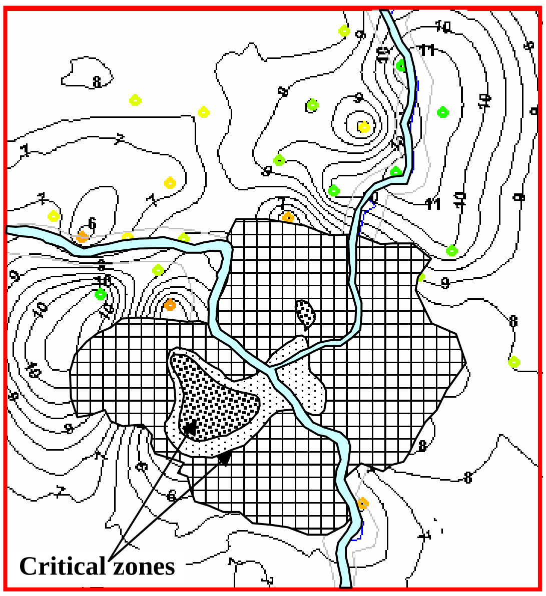

Figure 5. Contour lines for groundwater depths measured from ground surface. (Feb. 2002).

Knowing sources of water feeding any region is very useful and could be used to stop and cut the source of water in case of increasing the groundwater elevations above undesired level. The ground water path lines of the study area were predicted from the model operation as shown in figure (6). This figure shows the paths of groundwater movements from the external area around Mosul city toward city centre especially toward Tigris River. Generally speaking the operation of the present numerical model is used to obtain the sites having undesired groundwater elevations, consequently shallow groundwater depths have a negative influence on environment and health, in addition to its negative effects on the engineering constructions represented by their foundations. Another side of effect as a result of having groundwater high elevations is the filling of storm water network and prevents the discharging of rainfall quantities which in turn leads to settlements and constructions subsidence.

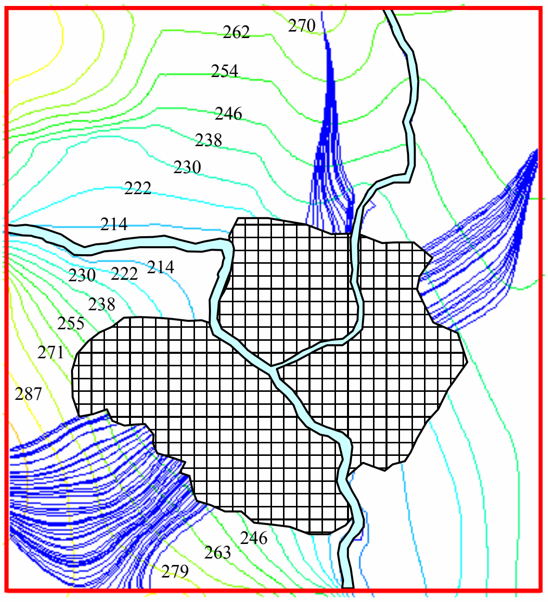

Figure 6. Groundwater flow lines feeding the critical regions in Mosul city.(Feb. 2002).

Another result from model prediction is the values of hydraulic conductivity for the aquifers in study area as shown in figure (7). The hydraulic conductivity values ranged between (4 to 28) meter/day.

The benefits from applying the numerical model on Mosul city are to manage the future plans, studies and activities in this area concerning the design and construction of the main sewerage network in the city. Also from specifying the places and zones where the hydraulic conductivity values are too low and by predicting the more critical places in the city subjected to flooding and any ground water increment touching the foundations of the existed constructions.

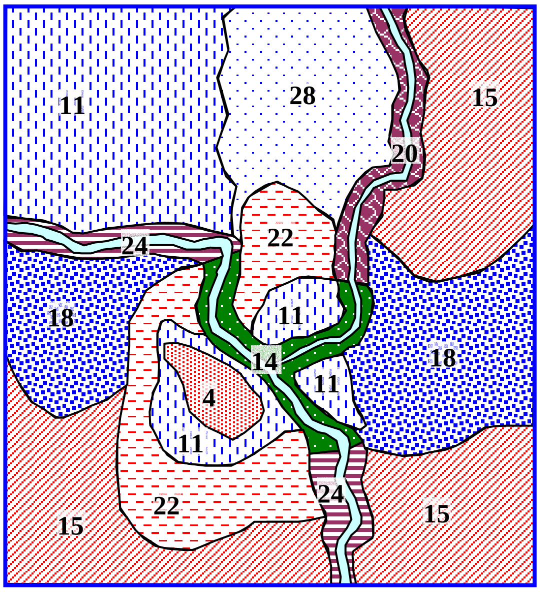

Figure 7. Hydraulic conductivity values in m/day for different zones in the study region, results from numerical model after final calibration.

6. CONCLUSIONS

From the collected data groundwater elevations in the observation wells and the geological formations at Mosul city and through the numerical model operation to predict and simulate the movement of groundwater; many ground water properties were found such as:

- Predicting the zones having undesired values of groundwater elevations due to its shallow depth.
- Predicting flow vectors which represents flow directions in each point.
- Predicting the groundwater paths leading to critical zones using flow lines.

The simulation process indicates that the real reason behind the increasing in the groundwater elevations in Mosul city belong to the unbalance occurs in the study area through the increasing in the feeding sources for groundwater (Water supply and sanitary drainage and rainfall) with the decrement in the hydraulic conductivity values (k) as a result of the variation in the soil properties. Consequently this will cause to reduce the capability of the aquifers to store or transmit the additional water quantities to the river and cause the high groundwater elevations year after year.

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