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Evaluation of the Ground Water in Baghdad Governorate / Iraq

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Abstract

The coverage area of Baghdad Governorate area is considered as a part of the Mesopotamia plain, which belongs to the unstable shelf. This area is totally covered by quaternary sediments. The sediments are composed mainly by cyclic alteration of clay, silt, sand and very fine gravels. Quaternary sediments represent the main aquifer for all parts of Baghdad governorate.

Arc GIS 9.3 and GMS 6.5 programs were used in drawing high accurate estimating maps, to define salinity, type of the ground waters, the general direction of their movement, the distribution values of transmissivity of upper aquifer, with distribution and the amount of draw down for these wells, also drawing map for the ground waters depth zones.

It can be concluded that the salinity of the ground water in Baghdad Governorate ranges between (fresh water – Brine water) in general, with the predominance of chloridic water type and the presence of sulphatic water type in other places. The direction of the ground water movement is mainly from the west towards the east and north and southeast, with the presence of local movements other directions. The transmissivity coefficient ranges between (50 – 350) m^2 / day in general, but these values decrease toward the east, especially east of the Tigris River as indicated by the level of draw down in the wells, which ranges between (2 – 10) m. The results reflect that the ground water depth in Baghdad Governorate ranges between (2 – 50) m depending on the distance from the river and irrigation channels, which are considered as sources of water recharge to the ground water.

Keywords: Baghdad Governorate; Iraq; Upper Aquifer; GIS; GMS

تقييم المياه الجوفية في مدينة بغداد/ العراق

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الخلاصة

تغطى مدينة بغداد والتي تعتبر جزء من السهل الرسوبي والتي تقع ضمن الرصيف غير المستقر برواسب العصر الرباعي، وهذه الرواسب تتكون من التغيرات الدورية بين الطين والطمى والرمل والحصى الدقيق جدا. تعتبر رواسب العصر الرباعي الخزان الجوفي الرئيسي في مدينة بغداد.

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استخدمت برامج (Arc GIS 9.3) و (GMS 6.5) في رسم الخرائط عالية الدقة لتحديد الملوحة ونوع المياه الجوفية والاتجاه العام لحركتها وقيم الناقلية للخزان الجوفي العلوي مع توزيع وكمية الانخفاض التي تحدث في تلك الآبار. كذلك تم رسم خريطة لعمق المياه الجوفية.

تبين من خلال الدراسة إن ملوحة المياه الجوفية في مدينة بغداد بصورة عامة تتراوح بين (الماء العذب– الماء المالح) والمياه الغالبة هي من نوع (Chloride) مع وجود المياه من نوع (Sulphate) في بعض المناطق.

حركة المياه الجوفية بصورة عامة تكون من الغرب باتجاه الشرق والشمال والجنوب الشرقي. معامل الناقلية بصورة عامة يتراوح بين (50-350 m^2/day) وهذه القيم تنخفض باتجاه الشرق وخاصة شرق نهر دجلة والذي يظهر ذلك من خلال الانخفاض في تلك الآبار والذي يتراوح بين (2-10 m) وتعكس هذه النتائج إن عمق المياه الجوفية في مدينة بغداد يتراوح بين (2-50 m) اعتمادا على البعد عن الأنهار وقنوات الري والتي تعتبر مصادر تغذية للمياه الجوفية.

Introduction

Baghdad Governorate is a part of sedimentary plain in Mesopotamia Plain. It belongs to Unstable Shelf and represents unsymmetrical syncline, filled by quaternary alluvial sediments, which belongs generally to Pleistocene and Holocene sediments. Those sediments composed mainly from clay, mud, silt and little bit fine gravel, heterogeneously distributed, which cause unordered extent for ground water aquifers.

Clay and mud represent a confining bed at the upper part of quaternary sediments, its thickness almost between (10 – 20) m, while ground water available in the lower beds among fine sand and pebbles.

Quaternary sediments in Tigris basin represent a hydraulic connecting aquifer; its thickness exceeded 70m. In some locations, this connection with Injana Formation (U. Miocene) particularly at west and south of the governorate while this connection at east direction is far away from Tigris basin [1].

Horizontal permeability percent (Kx) to perpendicular one (Ky) for upper sediments (5 – 7) m, reflect un homogeneity. The percent range between (5 – 8) times, that is mean beds permeability reduce in respect with extension, accordingly will not represent ground water aquifer in the area [2].

This study aim recognizing hydrogeological and hydrochemical situation of the governorate, particularly the upper part of main ground water aquifer by studying the hydraulic properties, levels, flow direction, and indicate its quality, water depth and salinity.

Many hydrogeological studies were carried out on different parts of the Baghdad Governorate by different researchers:[2-7], in addition to number of researches and unpublished thesis. In general, these studies took in consideration the governorate hydrogeologic situation and executing chemical evaluation for these aquifers.

The climate of the Baghdad is mainly arid to semi arid, with clear effect of the Mediterranean climate on the area. It is characterized by dry and hot summer, and cold with moderate rain winter. According to the meteorological information supplied by[8] for the years (1981 – 2000), the annual mean rainfall its about 140 mm, the annual relative humidity is within the range of (45 – 46) %, the annual evaporation is about 3300 mm, the annual mean temperature its about 23° C and the annual mean wind speed ranges from (3 – 3.5) m/sec.

Materials and Methodology

Depending on available information of 435 wells in Baghdad Governorate (Figure -1) which have been drilled by the State of the Ground Water Drilling Wells, and Iraqi Geological Survey, especially on last decade.

Water well informations have been tabulated as a data base at the Iraq geological survey, and carried out a lot of laboratory chemical analysis. Those wells data including major anions and cations in addition to total dissolved solids (TDS), electrical conductivity (EC) and water acidity (pH). Modern programs and scientific data analysis was used such as geographic information system (arc GIS 9.3) and ground water Modeling system (GMS 6.5), which request a variable estimating programs which provide high accurate values for the missing data for the regions, which basically depends on data accuracy. Programs deeded by (hydraulic, hydro chemical, hydrological, and weather data).

First program has been used throughout a Geostatistical Analyst Extension by using (Kriging Method) and (Spherical Model). This program provides high accurate estimating amounts and very close to measured one. Also, the program was used for specify and figure out (1) Zones of water salinity distribution and quality of water aquifer. (2) Contours map for ground water table and flow directions. (3) Contours map for upper part of aquifer transmissivity. (4) Contours map for ground water cone of depression in governorate productive wells. (5) Map for ground water static level plus indicating zones by colors.

The second program used for obtaining maps and two-dimensional sections (2d grid data), or three-dimensional (3d grid data) which specify and indicate (1) Ground water movement direction and relationship with surface water, there is relatively direct proportion between ground water movement raw length and water speed. (2) Three dimensional model (solid model) show succession of beds in the governorate as well as locations and depths of beds represent the ground water beds. (3) Ground water movement direction for some of selective wells in the study area.

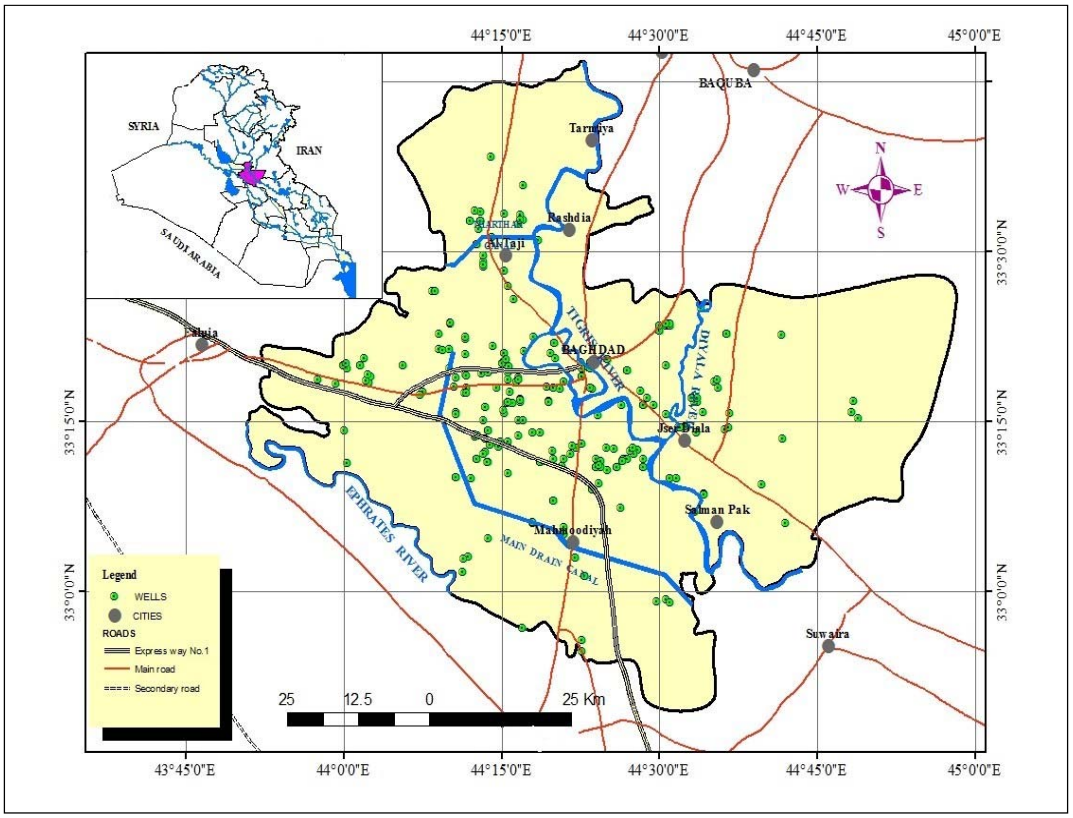

Figure 1- Location map of the wells in Baghdad Governorate

Results and Discussion

Throughout studying outcome data analysis of the wells in the governorate, the following can concluded:

Type and Salinity of the Ground Water

According to the groundwater analysis that done in the laboratories of the Iraqi Geological survey, Generally, the groundwater types differ in the Baghdad area, it is sulphatic in the most western part of the map area with chloridic water in between, while it is chloridic near the irrigation channels with sulphatic type water or/and bicarbonatic water in between, which depends on the water quantity that percolate from river courses and irrigation channels, especially during flood period.

The groundwater is classified according to the total dissolved salts into six classes these are (Figure -2):

***Fresh water** (less than 1000 mg/l), this quality available near the rivers and irrigation canals, these wells characterized by its shallow depth, recharge from surface water and rainfall. The type of aquifers

almost unconfined or perched, and its water quality almost bicarbonates, this water quality can't be notice easily on the map because of its minority and its small area relative to map scale.

*** Slightly brackish water** range between (1000 – 3000) mg/l**,** located western Tigris River in small areas, and its aquifer almost as unconfined, and it is almost sulphatic quality.

***Brackish water** range between (3000 – 5000) mg/l, this water quality extends over wide area specially western and southwest places of the governorate, and aquifers are unconfined to semi confined, while its quality is sulphatic with chloridic water.

***Highly brackish water,** it's salinity range between (5000-10000) mg/l, it represent the dominant salt type, and form the dominant mixed water, at hydraulic connection with Injana aquifer (Upper Miocene). The type of water in this group is almost sulphatic, interfering with chloridic one, especially at eastern parts of the governorate, because it was influenced by the nature of clay sediments in the area.

***Saline water**, its salinity range between (10000-50000) mg/l, including separate areas within the governorate, specially northern and eastern parts, and this water represent generally the deep water wells, and those which replenished far away from surface water. Its dominant aquifers are confined; it's almost sulphatic quality north and south of governorate, and chloridic quality east of the governorate.

*** Brine water,** its salinity more than (50000) mg/l, including areas within the southern parts of the governorate, it's almost sulphatic quality.

Ground Water Level and Movement

Ground water movement system in the study area represents part of the general movement system of Tigris Basin, considering Tigris and Diyala rivers as the discharge zone in general, this is why the area is considered of great importance to possible to draw a contour map of equi potential line with the flow directions (Figure- 3).

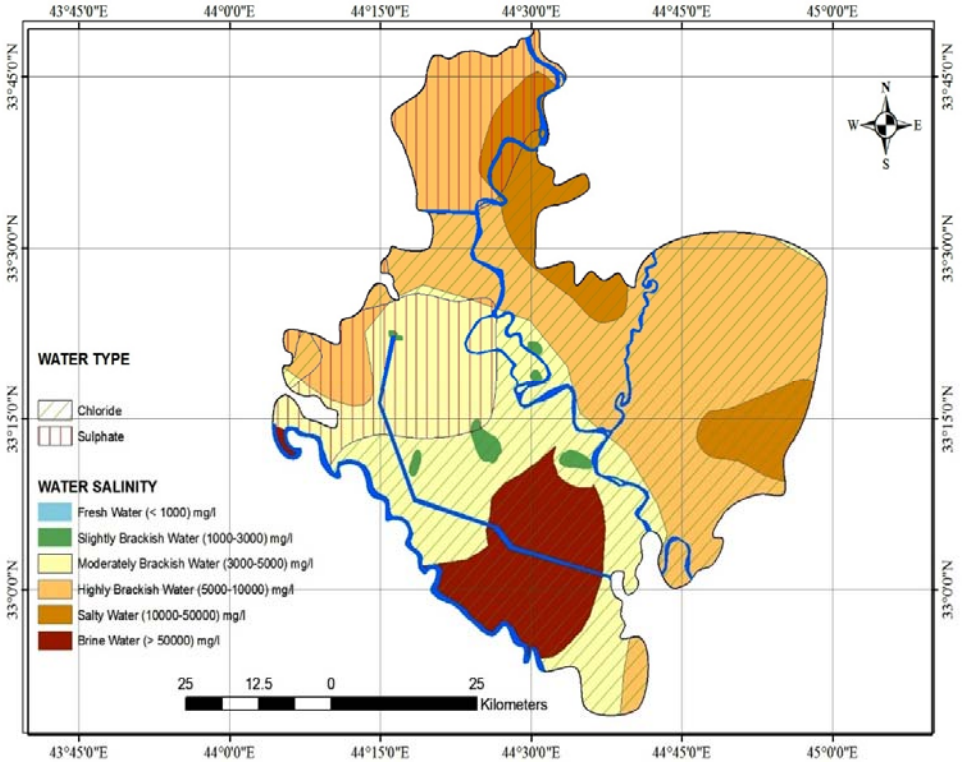

Figure 2- Distribution of the salinity and water types zones in Baghdad Governorate

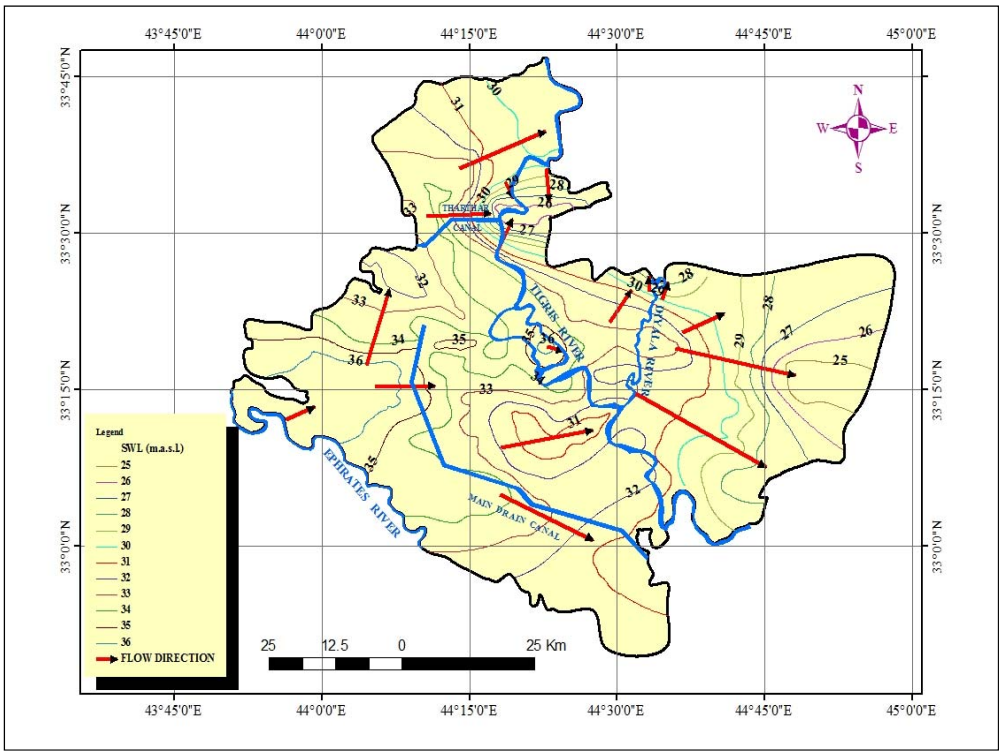

Figure 3- Hydrogeological map of the Baghdad Governorate, shows static water level and direction of ground water flow

The governorate ground water levels range between (> 25 – < 36) m above sea level and it is noticed that there is an increase in the value of the hydraulic slope, clearly north of the governorate, probably as a result of little permeability of the area rocks. This was also concluded by [6] who figured out a mud bed over silt layer appeared in the cross sections of the well drilled in the area.

The eastern areas of the governorate are recognized by the dropping of their ground water levels compared to those of the western areas, this is why it is out of sure that the flow is going to be from west to east and southeast, but the presence of the rivers (Tigris, Diyala and Euphrates), which represent important hydrogeological borders for aquifer systems specially in Quaternary sediments, led to appearance of local movements due to the hydraulic connection between those rivers and ground water (recharge and discharge). Upper part of Tigris River, especially at north governorate borders is recognized as a recharge area to the ground water on both banks (Figure -4), then Tigris converts to a discharge area for ground water, at its west bank before meeting Diyala River, and a recharge area at its (Tigers River converts to a recharge area at both banks especially on flood periods). While the upper part of Diyala River as it is shown in figure, is considered as a recharge area to the ground water within governorate borders, convert to a discharge area at its' lower part, and the flow converted towards the east and southeast whenever we moved away from the river, where the discharge areas are in the low topography areas outside governorate borders. As to Euphrates River, which is located at governorate south west border, its' eastern bank is regarded as a ground water recharge area and the flow direction is from the river towards northeast. The local flow directions, of some selective wells west of Tigris River, have been specified (Figure -5) by using (GMS 6.5 Program), where two flow directions could be noticed; the first towards the river and the second towards the south.

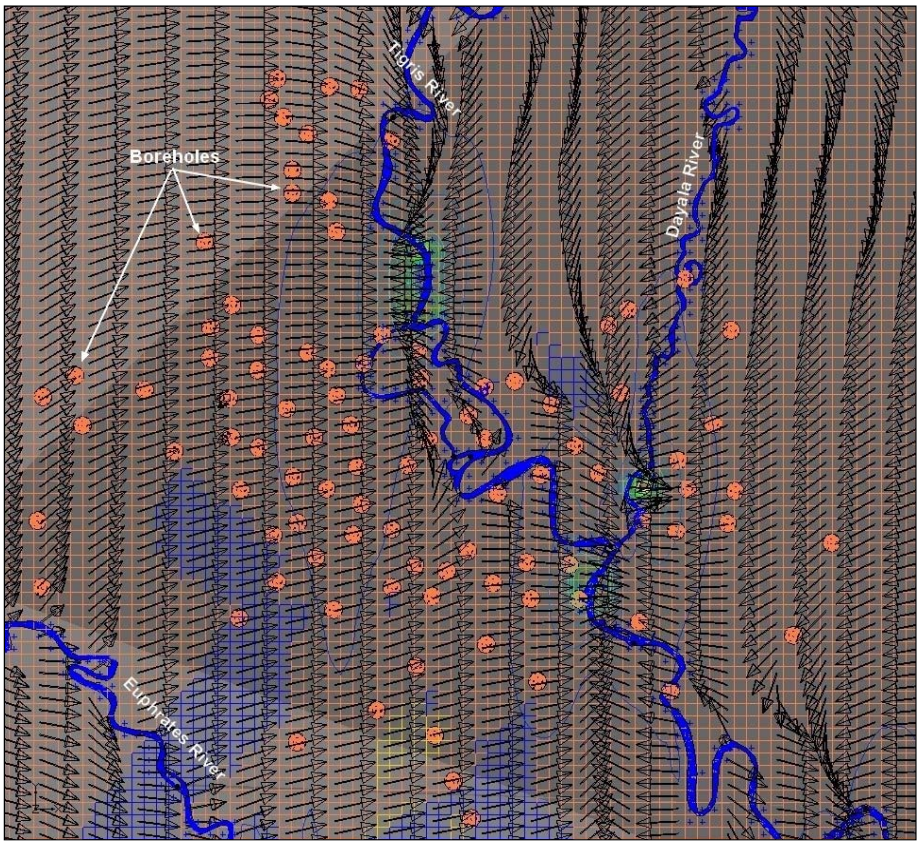

Figure 4- Direction of the ground water movement and it's relation with surface water in the area

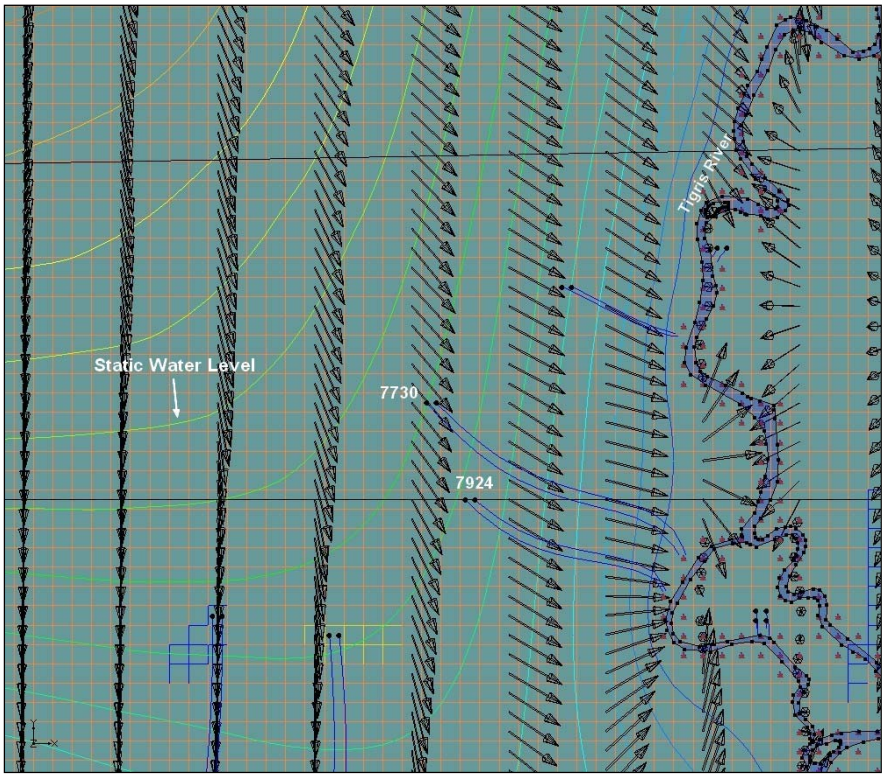

Figure. 5- Map shows the direction of the ground water in some selected wells in Baghdad area

Generally, the water table fluctuation depends on many natural and industrial factors, especially the amount and distribution of rainfall in the area, flood periods and high evaporation, which affect the shallow unconfined aquifers, in addition to digging of irrigation canals and the unwise draw from the wells.

Transmissivity Coefficient and Cone of Depression

According to the pumping test analysis that done in some location of studied area, the hydraulic parameters shows that Heterogeneous sediments of the aquifer in the governorate, which is a general property of Quaternary aquifers, led to variation in transmissivity coefficient (T) of those aquifers. A contour map of transmissivity was drawn as shown in (Figure- 6), where its' amount ranges between (> 50 – < 350) m^2/day. The presence of impermeability layers, like mud and clay within aquifer sediments has a clear effect on the littleness of this coefficient, especially in the east area of Baghdad Center, where the geological cross sections of the wells drilled there indicated, the presence of thick clay bed overlay a silt bed, and their thicknesses increase by moving eastward, while its' values increase by the rivers area and the middle and southwest areas of the governorate. The variation in the transmissivity coefficient distribution in the area, led to variation in depths distribution of cone depression resulted from well pumping, where (Figure- 7) shows that its' value ranges between (> 2 – < 10) m, and inversely proportional with water transmissivity coefficient, this is why their values increase in the eastern areas and decrease at rivers regions, middle and southwest areas of the governorate.

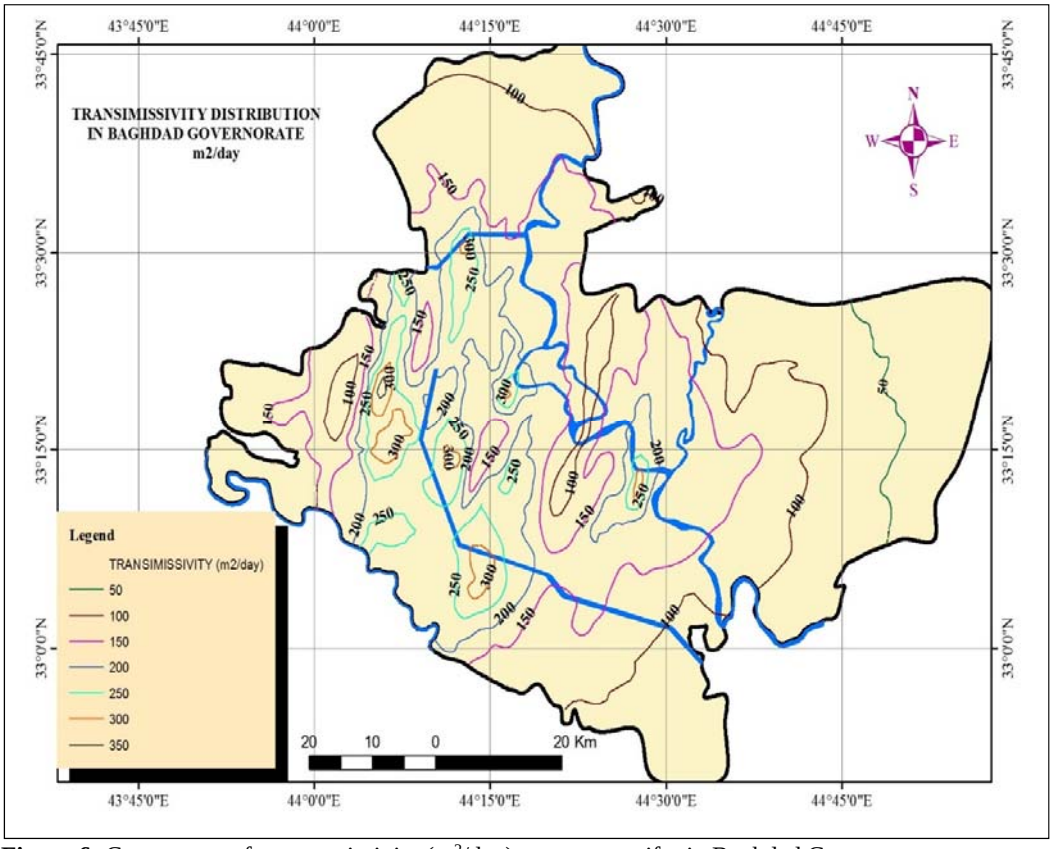

Figure 6- Contour map for transmissivity (m^2/day) to upper aquifer in Baghdad Governorate

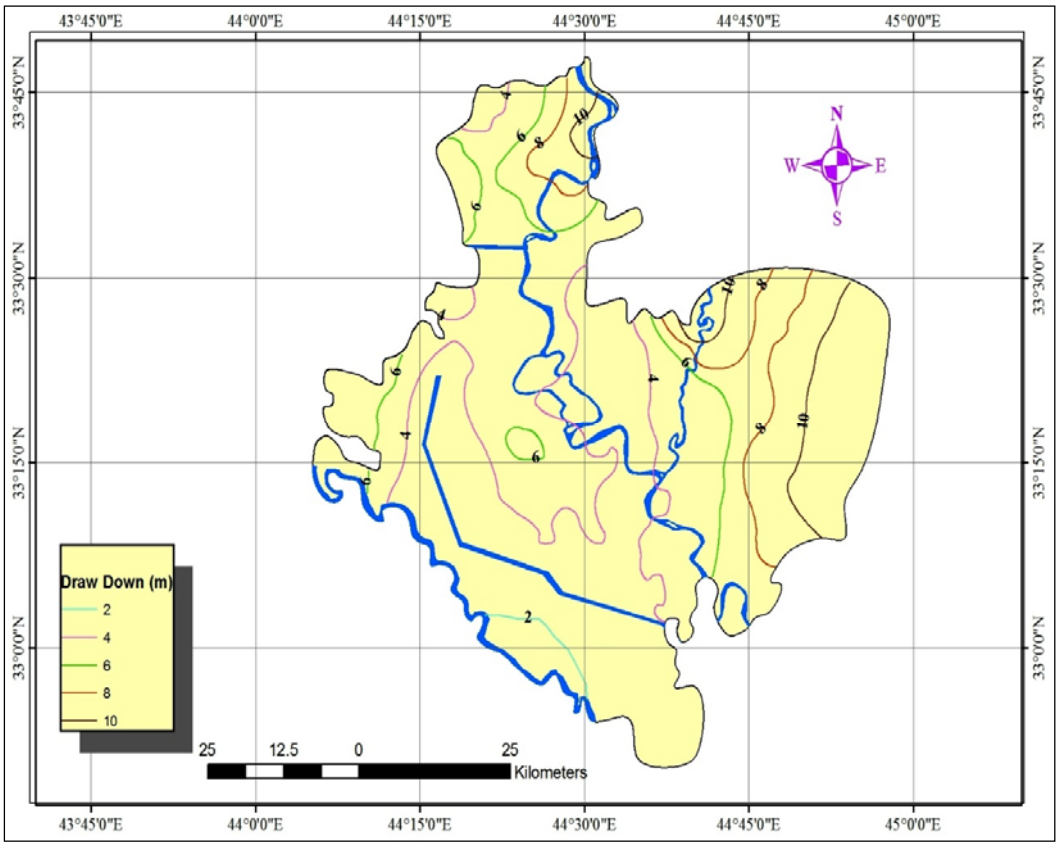

Figure 7-Contour map for cone depression values in upper aquifer of Baghdad Governorate

Ground Water Depth

Ground water depth represents an important factor in specifying the depths and a location of the wells requested to drill and depends basically on the amount of the recharge replenishment and lithological nature of these aquifers. According to the water level measurement between the period (2009-2010) measured amount of ground waters from drilled wells were adopted to draw a map to the governorate main upper aquifer zone (Figure -8), where the ground water depths range between (>2 – <50) m. Generally, ground water is shallow in the regions close to the rivers in middle part of the governorate, while it becomes deeper towards east and west.

Throughout studying the geological sections of the wells drilled in the governorate, the characteristics of their lithological beds and their relationship with the ground water noticed during drilling operations, two main aqueous beds were indicated to 50 meter depth. In some deep wells aqueous beds number may approach six beds, figures (-9 and -10) show a three dimensional model (solid model), which figure out the shape and extension of both types of beds, the shallow one and the deep one of the shallow wells where the aqueous in general are thick and shallow by the areas of rivers and irrigation canals, while they are deeper far away.

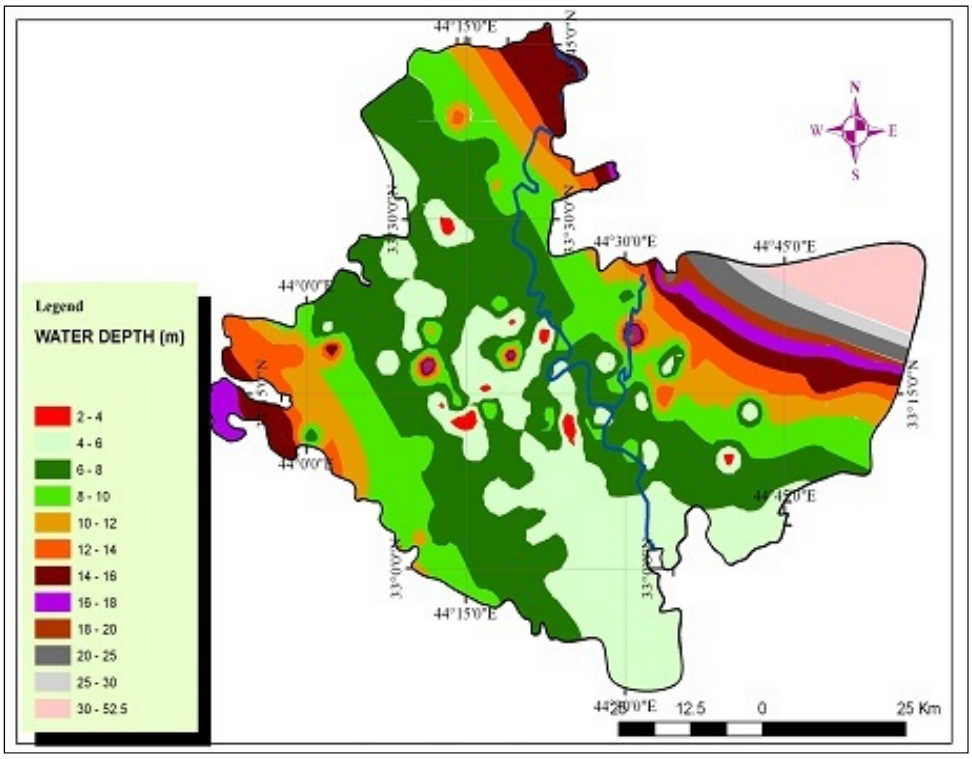

Figure 8- Zoning map shows the depth of the first water layer in Baghdad Governorate

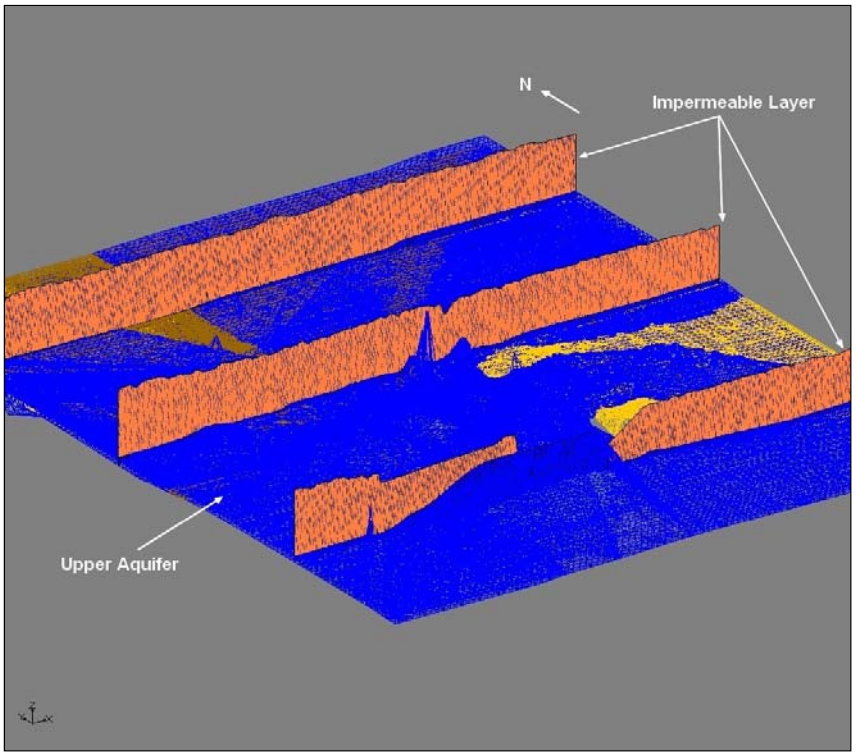

Figure 9-Three-dimensional model, show the extension of the first aquifer in Baghdad area

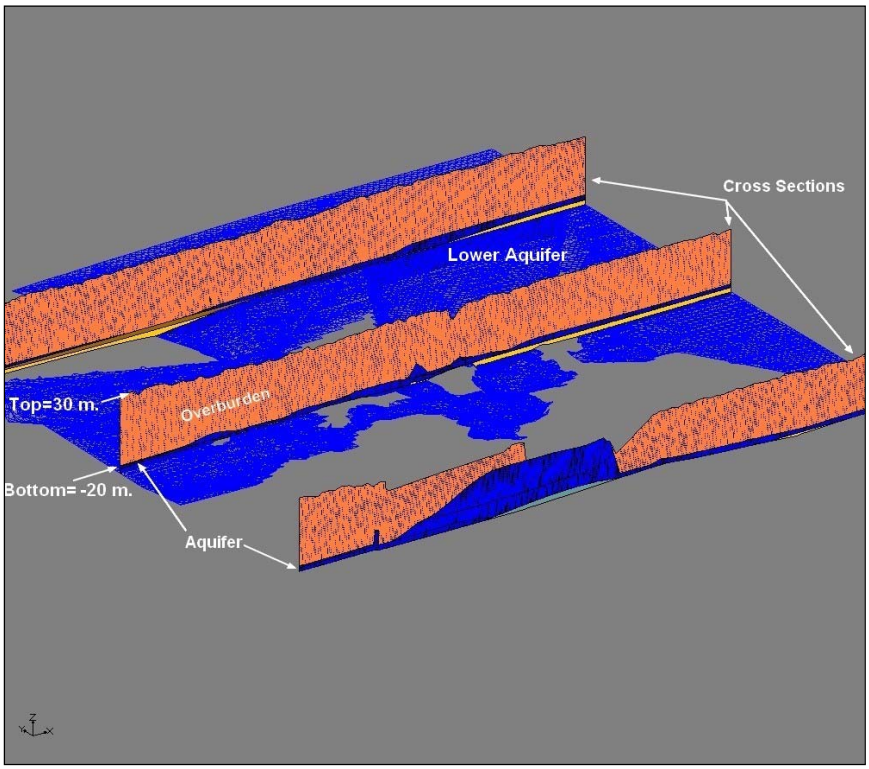

Figure 10-Three dimensional model, show the extension of the second aquifer in Baghdad area

Conclusions and Discussions

1- Quaternary sediments represent the main aquifer in Baghdad Governorate, especially within the flood plain areas. These sediments are composed of alternation of clay, silty clay, clayey silt, silt, sand and gravel. Fine sediments represent the aquitards, while sand and gravel form the aquifers. These sediments have abrupt lithologic changes both laterally and vertically, therefore, are considered regionally as a lithologically complex aquifer system.

2- By using developed estimation programs, the following maps were drowning

*Map of salinity and quality distribution zones, figure out six salinity type zones, ranges between fresh water to brine water quality. The groundwater types differ in the area, it is sulphatic in the most western part of the area with chloridic water in between, while it is chloridic near the irrigation canals with sulphatic type water or/and bicarbonatic water in between, which depends on the water quantity that percolate from river courses and irrigation canals, especially during flood period.

*Contour map of ground water static level and flow direction. The direction of ground water movements within the western part of the study area is from west and northwest towards east and southeast. Euphrates River is considered as a recharge area within the eastern bank of the river, where the movement is towards Tigris River. In the eastern part, the groundwater movement is toward south and southwest. Tigris and Diyala rivers are considered as discharge areas for the groundwater, north of their merging area, south of Baghdad city. Tigris River is considered as the recharge area south of the area, especially during flood period or increasing of water level in the river, especially in the left bank of the river. The right bank of Tigris River it considered as discharge region; during decreasing of water level in the river and as recharge region during flood period.

* Distribution transmissivity coefficient values contour map of upper aquifer in Baghdad Governorate, ranges between (> 50 – < 350) m^2/day, which increase at river areas, water canals, middle and southern west areas of the governorate, and reduce toward eastern part of the governorate center, which the sediments are impermeable beds including mud and silt. There is relationship between transmissivity coefficient and amounts of cone of depression as well as the influence of transmissivity coefficient on governorate productive wells level draw down.

*Zoning map of the ground water depth in governorate, with three dimensional models indicate the extension of both shallow and deep aqueous beds.

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