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Using Geographic Information System (GIS) to estimate the volume of water for Al Dammam unconfined Aquifer within Al Salman basin, Al-Muthana Governorate, South West Iraq

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Abstract

The groundwater represents the main source of water in the study area due to lack of surface water. The Dammam unconfined aquifer represents the main aquifer in the study area and Southern desert because of the regional extent, the quantity and quality of water. Many groundwater wells have been drilled in the study area to coverage the huge demand of water for agricultural purposes. The Geographic Information System (GIS) was used to estimate the volume of water which calculated (25.6964×10^9 m^3) within the study area , automate calculation of the area of Al Salman basin using digital elevation models, derive the thickness maps of Al Dammam unconfined aquifer from Key holes (KH) and Bore holes (BH), draw the groundwater head and flow map in the study area. Such data derived from GIS can help authorities and researchers for groundwater management and further development within the study area.

Keywords: Al Dammam Formation, GIS**,** volume of water**,** Al Salman basin.

أستخدام برنامج نظم المعلومات الجغرافية لتقدير حجم المياه في خزان الدمام غير المحصور ضمن حوض السلمان في محافظة المثنى جنوب غرب العراق

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الخلاصة

تمثل المياه الجوفية المصدر الرئيسي للمياه في منطقة الدراسة وذلك لانعدام مصادر المياه السطحية في حوض السلمان ضمن منطقة الدراسة. يمثل خزان الدمام غير المحصور الخزان الرئيسي في منطقة الدراسة والصحراء الجنوبية وذلك لأمتداده الاقليمي وكمية المياه الجوفية ونوعيتها الملائمة للزراعة. العديد من ابار المياه الجوفية قد تم حفرها في منطقة الدراسة لتغطية الطلب الكبير من قبل القطاع الزراعي. استخدم برنامج نظم المعلومات الجغرافية لتقدير حجم المياه في خزان الدمام غير المحصور في منطقة الدراسة اذ تم حسابه (25.6964×10^9 متر مكعب) اضافة الى حساب مساحة منطقة الدراسة، رسم خرائط السمك لخزان الدمام المفتوح باستخدام ابار اللباب (ابار المرجعية)، رسم خرائط مستوى المياه الجوفية بالنسبة لسطح البحر وحركة المياه الجوفية.

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1- Introduction

Hydrogeological maps in the broad sense deal with the complex system (water and rocks), their properties and interrelations. It changes in time (particularly the water component). They may show mere parameters of a component of the system, a combination of parameters or comprehensive interpretations of hydrogeological data [1]. Such maps help environmental authorities, water resource managers, drilling operators and other practitioners to identify the suitability of groundwater for different purposes [2]. The Geographic Information System (GIS) create an environment for the hydrogeologist's data that is a simulation of the real world in three dimensions: longitude, latitude, and elevation. All data in the field of hydrogeology possess these three defining dimensional features, which can be accurately represented in GIS [3]. During the field work in April 2018 the twenty one groundwater wells were used to draw the head and derive the groundwater flow within the study area.

2- Location of the study area:

The study area (9484) km^2 located southwest Al-Samawa city and Southwest of the Euphrates River, in the stable zone of Iraq. It extends from E 45º 15' 25" to E 44º 1' 20" longitude and N 31° 15' 51" to N 30° 1' 50" latitude (Figure-1).

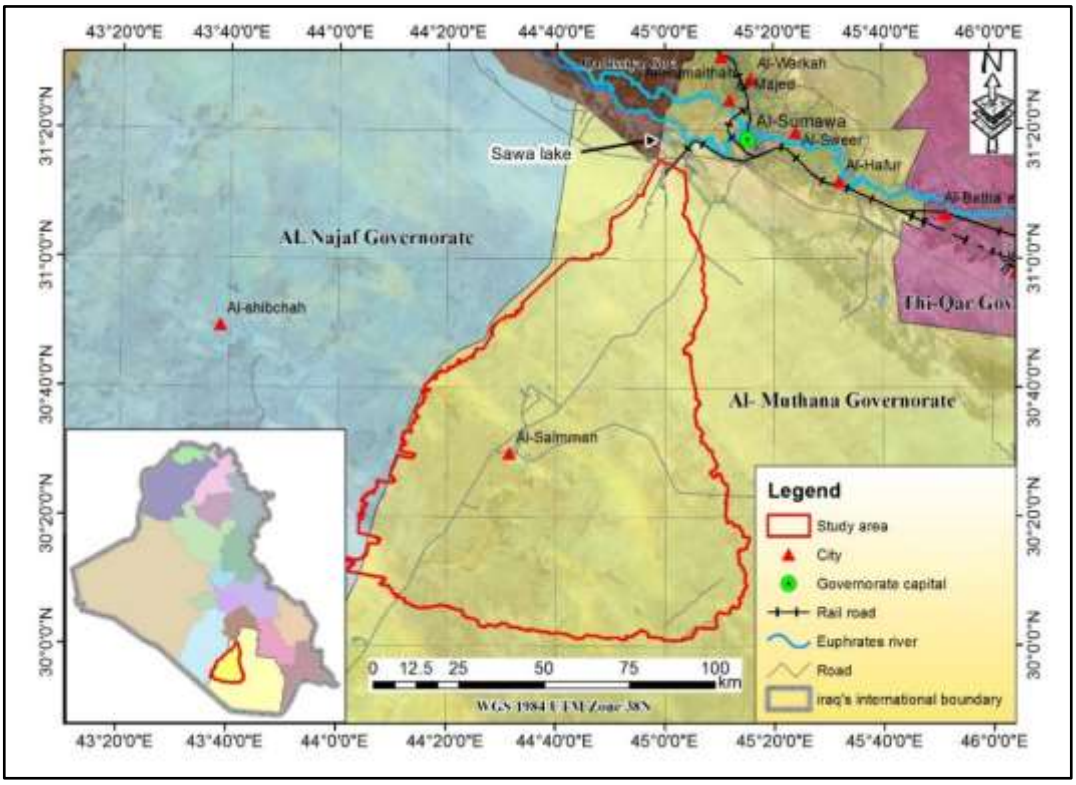

Figure 1-Location map of the study area.

3- Basin Delineation

Water surface runoff is typically discharged through the lowest point at the outlet of a specific area called drainage basin, watershed, or catchment. The basin constitutes a unit of hydrologic system where all the input precipitation is discharged through the outlet as stream flow unless it is lost by abstraction processes such as infiltration [4].The Geographic Information Systems (GIS ver.10) spatial analyst tools was used to automate calculation of the area of Al Salman basin which delineated polygon of the watershed boundaries and derive the topography by using 27 meters resolution digital elevation models (DEM) which downloaded from (www.earthexplorer.usgs.gov) (Figure 2).

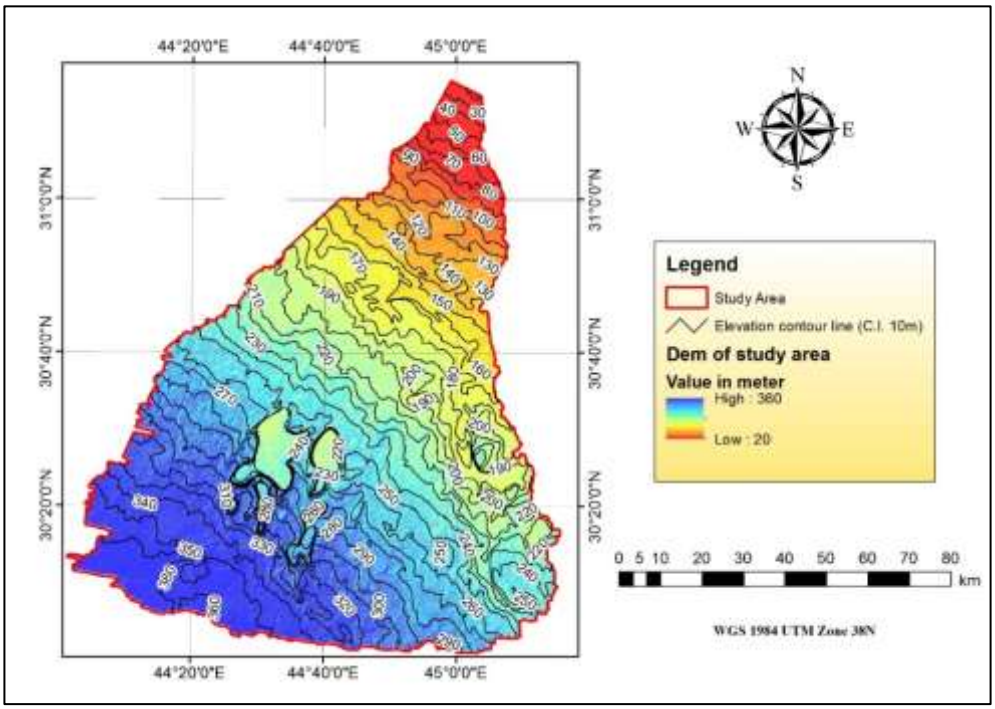

Figure 2- Elevation of the study area derived from 27m Digital elevation model DEM (www.earthexplorer.usgs.gov).

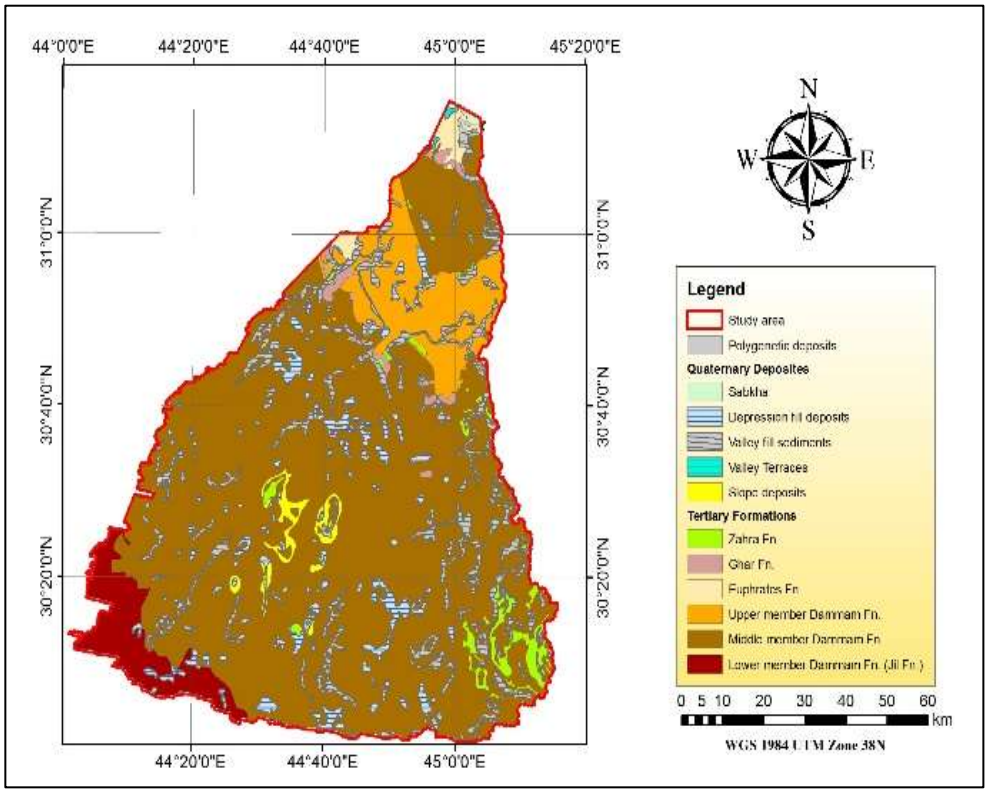

Figure 3-Geological map of the study area digitized from GEOSURV. 1996 (NH-38-6) (NH-38-7), GEOSURV. 1995 (NH-35-10).

4- The thickness of Al-Dammam unconfined aquifer in the study area

The outcrop of Dammam formation is occupying the most of study area (Figure-3). The Dammam carbonate aquifer is separated from Umm Er Radhuma aquifer by aquicludes of marl and marly limestone represent the lower member of Al Dammam formation (Jil formation) and anhydrites belong to Rus formation which has thickness in the range of (20 to 50)m rarely more (Figure-4) [5]. The thickness of lower member of Al Dammam formation (Jil formation) range between (10 to 80)m (Figure-5) and the thickness of middle Dammam formation range between (10 to 90)m (Figure-6). The total thickness of Al Dammam formation range between (40 to 100), the GIS Spatial Analyst Tools/ Kriging was used to derive the thickness maps from Key Hole (KH) No.1,2,3,4,5,7,8 [6],[7]and Borehole (BH) No.8,22[8] and Abu Al Loom Borehole.

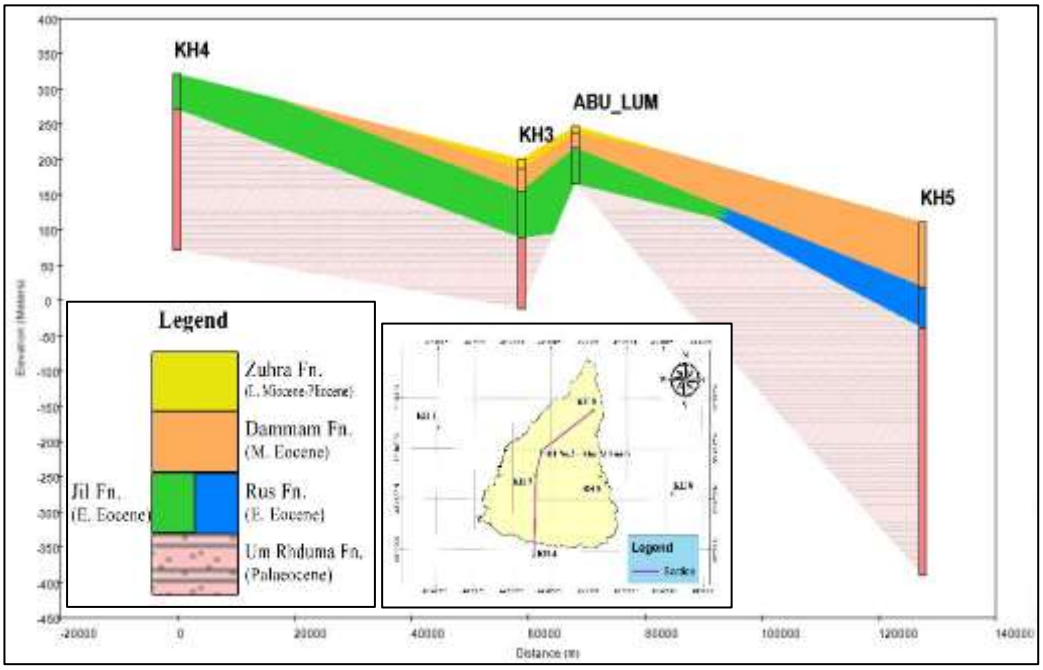

Figure 4-Cross section in the study area between KH4, KH3, BH Abu lum and KH5.

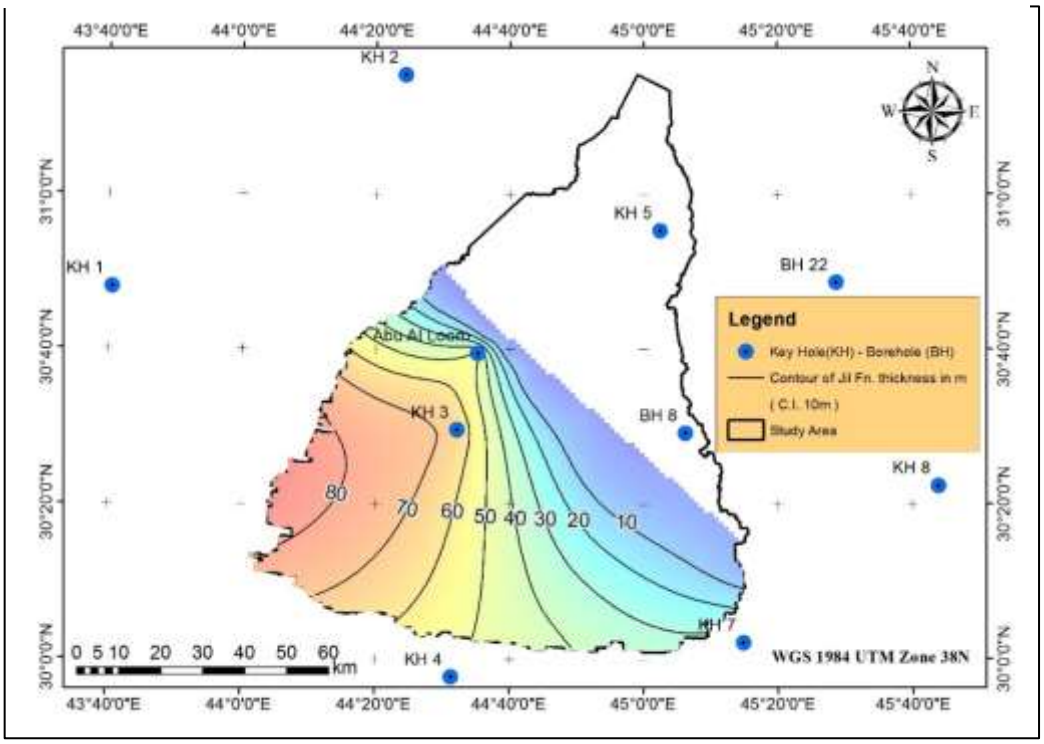

Figure 5-Isopach map of lower member of Al-Dammam Fn. (Jil Fn.) in the study area.

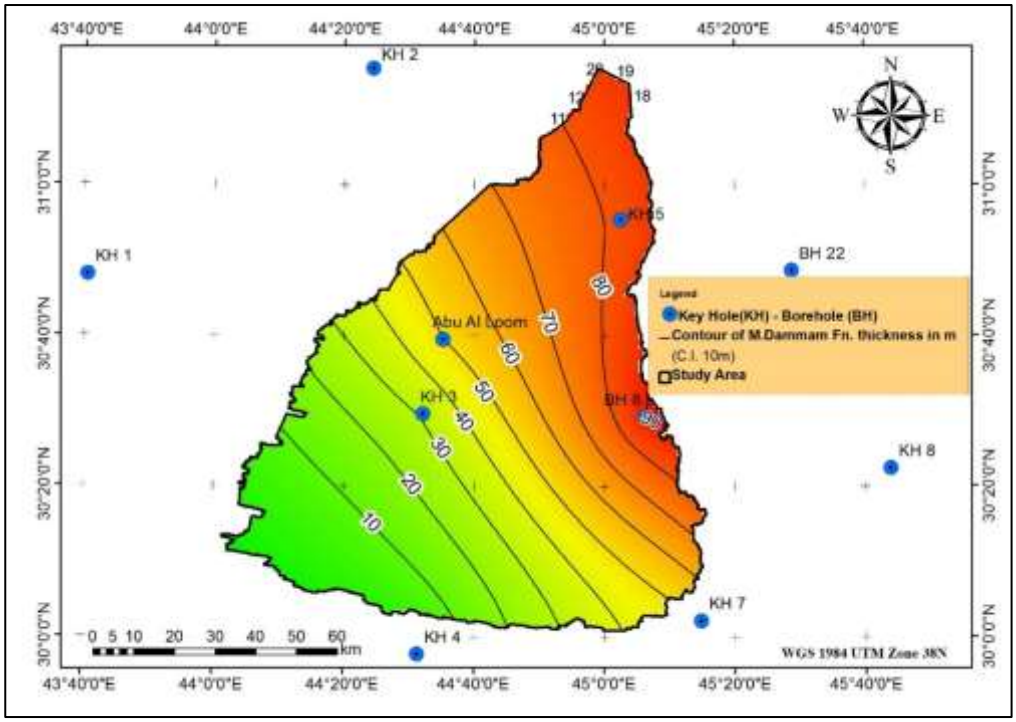

Figure 6-Isopach map of middle member of Al-Dammam Fn. in the study area.

5- Groundwater flow of Al-Dammam aquifer in the study area

Flow net consists of two sets of lines. One set, referred to as equipotential lines, connects points of the equal head and thus represents the height of the water table the second set, referred to as flow lines, and depicts the idealized paths followed by particles of water as they move through the aquifer [9]. During the field work in April 2018 the GPS device (Garman 78s) used to determine the location of groundwater well, the depth to groundwater was measured by water meters level (sounder), and the 21 groundwater wells were chosen having depth not more than 100m to match the thickness of the Al Dammam formation in the study area. The informations regarding the groundwater wells in the study area are listed in (Table-1). The groundwater movement in the study area is from southwest to northeast (Figure-7).

Table 1-The informations of the groundwater wells in the study area for Al-Dammam aquifer collected during field work in April 2018.

S. No.	Longitude	Latitude	Well depth (m)	Elevation a.s.l. (m)	Depth to water (m)	Head a.s.l. (m)
1	E44° 26'22.40"	N30°20' 20.50"	95	259	39	220
2	E44° 28'31.19"	N30°25' 29.9"	90	238	36	202
3	E44° 31' 56.8"	N30°27' 17.23"	80	204	11	193
4	E44° 45' 9.9"	N30°24' 33.9"	85	247	51.4	195.6
5	E44° 40' 3.15"	N30°28' 4.36"	45	200	19.6	180.4
6	E44° 37' 0.51"	N30°46' 7.5"	95	198	70	128
7	E44° 54' 50.7"	N30°48' 58.6"	94	150	70	80
8	E44° 57' 51.8"	N30°48' 35.9"	90	136	58	78
9	E45° 02'57.44"	N30°49' 9.54"	92	129	63	66
10	E44° 55' 12.7"	N31°09' 7.7"	80	61	45	16
11	E44° 56'46.21"	N31°10' 5.8"	94	50	37	13
12	E44° 58'49.49"	N31°09' 55.7"	80	50	35	15
13	E45° 0' 52.7"	N31°08' 52"	80	50	31.7	18.3
14	E45° 6' 13.50"	N31°0' 35"	88	81	56	25
15	E45° 5' 21.6"	N30°58' 3.29"	90	91	59	32

16	E45° 4' 3.9"	N30°55' 23"	100	109	64	45
17	E45° 3' 57.27"	N31°12' 50.54"	80	22	8	14
18	E45° 2' 36.7"	N31°13' 18.7"	35	20	6	14
19	E45° 01' 6.0"	N31°13' 56.55"	40	20	5.2	14.8
20	E45° 01' 36.7"	N31°13' 4.2"	50	25	10.5	14.5
21	E44° 27' 10"	N30°23' 29.4"	90	245	35.8	209.2

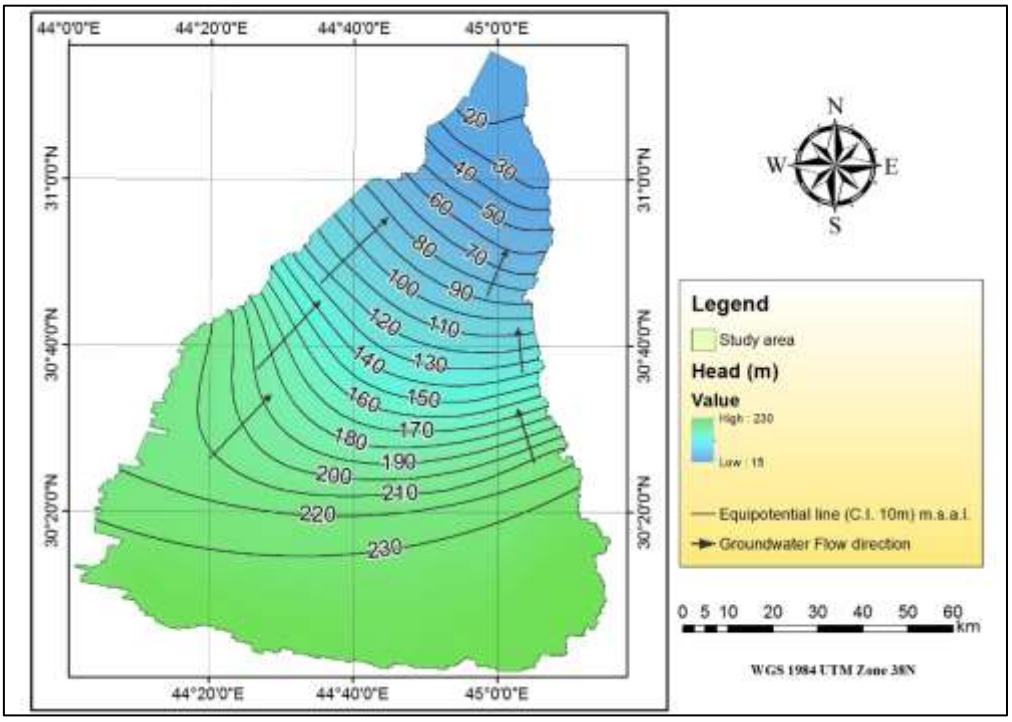

Figure 7-Hydraulic Head, Groundwater movement, and flow direction in the study area.

6- Volume of groundwater calculation

The volume of water (Vw) can be calculated to the aquifer in the study area using the following equation [10]:

$Vw = Sy * A * b$

Where:

Sy: specific yield = 0.037 [11].

A: the area of aquifer within the study area.

b: saturated thickness of the aquifer.

To having saturated thickness value closed to real world, the GIS has been used to create raster represent the bottom of the aquifer (Figure-8) and raster represent the head (which represent groundwater without pumping) then process those rasters using 3D analyst tools to calculate the Total Volume, the calculated Total Volume is $694496.819838 \times 10^6$ m^3 = (A * b) (Figure-9).

So, the volume of groundwater, represent the steady state, in Al-Dammam unconfined aquifer within the study area is

$Vw = 0.037 * 694496.819838 \times 10^6$ m^3

$Vw = 25.6964 \times 10^9$ m^3.

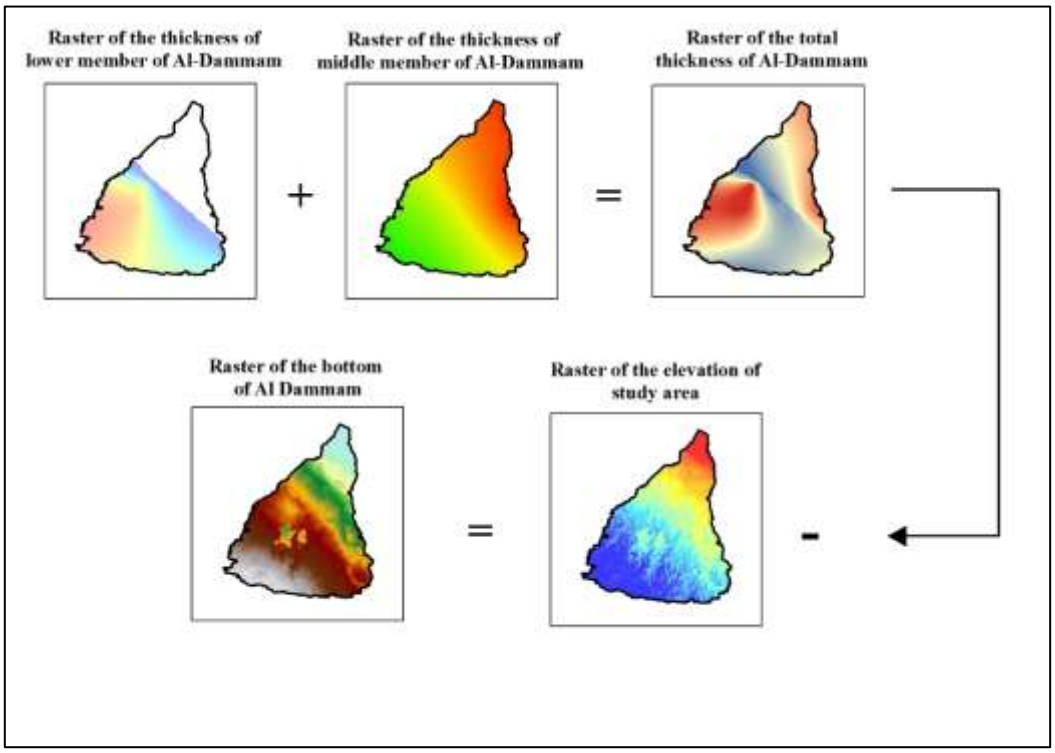

Figure 8-The bottom of Al Dammam Fn. calculation by GIS.

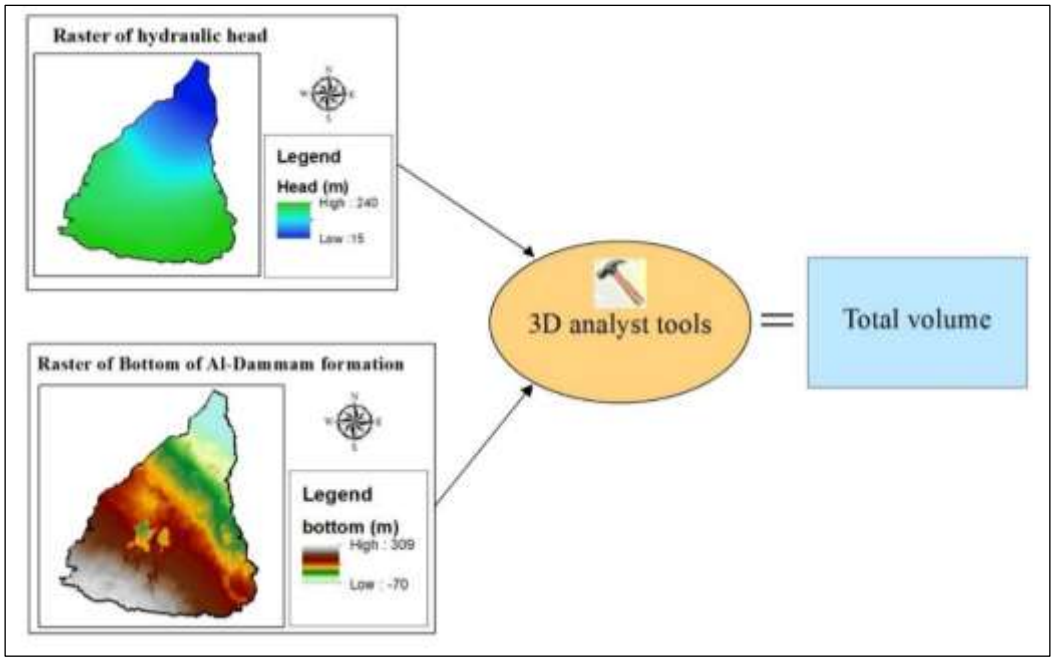

Figure 9-Total volume calculation processing by GIS.

7- Conclusions

Al Dammam unconfined aquifer in the southern desert represents one of the main source of water that vast use for agricultural purposes. The Geographic Information Systems (GIS ver.10), satellite image (DEM), and informations collected from field work were used to the calculated volume of groundwater in the study area which is 25.6964×10^9 m^3 by using the features derived using GIS as following:

1- Elevation range between (20 to 360) m.
2- The thickness of lower member of Al Dammam formation range between (10 to 80) m, the thickness of middle member of Al Dammam formation range between(10 to 90)m, and the total thickness of Al Dammam formation range between (40 to 100)m.
3- The head range between (15 to 230) m
4- The groundwater movement from southwest to northeast.

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