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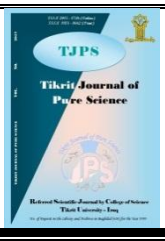

Evaluation of Hydrogeological Conditions, in the three Al-Mishraq Sulphur fields, northern Iraq

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ABSTRACT

This study included an assessment of the hydrogeological conditions of the Mishraq sulphur fields before production, by measuring groundwater levels in (11) wells in Mishraq-2 in 2021, as well as the information of wells obtained, which are (12) wells in Mishraq-3, (68) wells in Mishraq-1. Groundwater levels ranged between (187.71-205.80) m in Mishraq-1, while in Mishraq-2 it ranged between (189.19-196.26) m, as for Mishraq-3 the levels were between (186.4-194.98) m.

The contour maps were drawn for the movement and levels of groundwater, showing that the direction of groundwater movement in Mishraq field-1 is from the west and northwest to the east, with a slight slope towards the southeast, towards the Tigris River, while in the Mishraq field-2, we notice that the direction of groundwater movement is From the east to the west, that is, toward the Tigris River, as for Mishraq field-3, it was found that the direction of movement is from the southeast toward the northwest, that is, toward the Tigris and Great Zab rivers. So it can be said that the Tigris and Great Zab rivers are the two drainage areas in these three fields. The hydraulic properties were analyzed in (44) wells in the three Al-Mishraq fields. Where the values of Transmissivity (T) in Mishraq field-1 ranged between (24.4-1557.5) m^2/day, as for Mishraq-2 it ranged between (23-96.91) m^2/day, while in Mishraq-3 it ranged between (10.5-4002)) m^2//day, and the hydraulic conductivity (K) ranged between (0.26 -14.68) m/day in Mishraq field-1, as for Mishraq-2 it ranged between (0.7-4.2) m/day, while in Mishraq-3 It ranged between (0.37-119.09) m/day.

تقييم الظروف الهيدروجيولوجية في حقول كبريت المشراق الثلاثة، شمالي العراق

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الملخص

تضمنت هذه الدراسة تقييم الظروف الهيدروجيولوجية لحقول كبريت المشراق قبل الانتاج، وذلك من خلال قياس مناسيب المياه الجوفية في(11) بئر في مشراق–2 عام 2021، فضلا عن معلومات الابار التي تم الحصول عليها وهي (12) بئرا في مشراق–3، و(68) بئر في مشراق–1، تراوحت مناسيب المياه الجوفية بين (187.71–205.80) م في مشراق–1، اما في مشراق–2 فتراوحت بين (189.19–196.26) م، وفي مشراق–3 كانت المناسيب بين (186.4–194.98)م. تم رسم الخرائط الكنتورية لحركة ومستويات المياه الجوفية، وتبين أن اتجاه حركة المياه الجوفية في مشراق–1

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يكون من الغرب والشمال الغربي باتجاه الشرق مع الانحدار قليلا باتجاه الجنوب الشرقي اي باتجاه نهر دجلة، اما في حقل مشراق-2 فنلاحظ ان اتجاه حركة المياه الجوفية يكون من الشرق باتجاه الغرب أي باتجاه نهر دجلة، وفي مشراق-3 تبين ان اتجاه الحركة يكون من الجنوب الشرقي باتجاه الشمال الغربي اي باتجاه نهري دجلة والزاب الكبير، لذلك يمكن القول ان نهري دجلة والزاب الكبير هما منطقتي التصريف في هذه الحقول الثلاث.

تم تحليل الخواص الهيدروليكية في (44) بئراً في حقول المشراق الثلاثة، حيث تراوحت قيم الناقلية المائية (T) في حقل مشراق-1 بين (24.4-1557.5) م^2/يوم، وفي مشراق-2 تراوحت بين (23-96.91) م^2/يوم، بينما في مشراق-3 فقد تراوحت بين (10.5-4002) م^2//يوم، اما التوصيلية الهيدروليكية (K) فقد تراوحت بين (0.26- 14.68) م/يوم في حقل مشراق-1، وفي مشراق-2 فقد تراوحت بين (0.7- 4.2) م/يوم، بينما في مشراق-3 تراوحت بين (0.37- 119.09) م/يوم.

1- Introduction

The study area is located in the northern part of Iraq, about 45 km southeast of the city of Mosul, and consists of three fields (M-1, M-2, M-3), where the Al-Mishraq field-1 is located on the opposite western side. The confluence of the Tigris River with the Great Zab River. Between longitudes 17′ 42″) (43˚and (43˚ 20′ 24″) east, and two latitudes 58′ 04″) (35˚ and (36˚ 01′ 40″) north, as for the fields M-2, M- 3 They are located at the eastern part of the river and are separated by the Great Zab river, where Mishraq-2 lies north of the Great Zab river between longitudes (43˚ 20′ 02″) and (43˚ 23′ 11″) east, and two latitudes (35˚ 59′ 22″) and (36˚ 01′ 30″) north, while Mishraq-3 lies south of the Great Zab river between longitudes (43˚ 20′ 30″) and (43˚ 23′ 51″) east, and two latitudes (35˚ 57′ 35″) and(36˚ 00′ 13″) north, as shown in Figure (1).

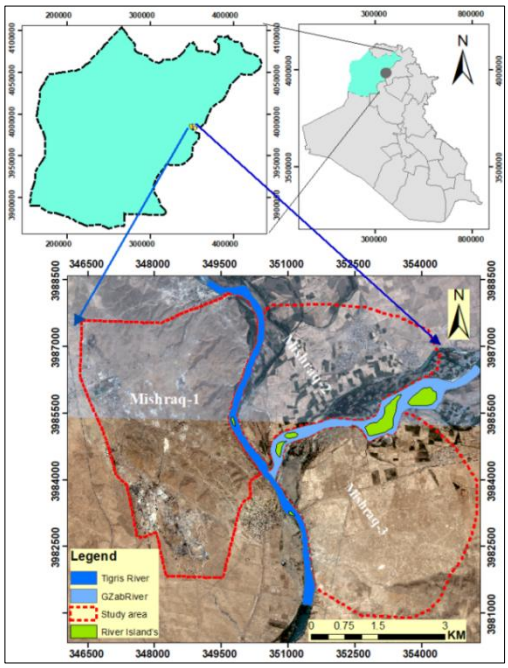

Fig. 1: Location map of the study area

The study area contains sulphur deposits in an economical way according to the study carried out by the Polish company Centrozab in 1971, as well as the studies conducted by Iraq Geological Survey, so studying it from a hydrogeological point of view is considered one of the important matters in the case of re-production from the Mishraq field-1. Or investing the two fields (2,3) to produce sulfur in the future. For the purpose of developing the best ways and solutions to the problems that may appear during investment, such as the high and low levels of groundwater, as well as the amount of water that will be injected to melt sulfur and the resulting leaks into the Tigris river and neighboring areas, which may lead to pollution of the region on the one hand and the Tigris and Great Zab rivers on the other hand.

The current study aims to make a hydrogeological comparison of the groundwater Aquifers, by determining the depths of the groundwater, the direction of its movement and natural discharge, and the hydraulic characteristics of those Aquifers in the three Mishraq Sulphur fields before Sulphur production.

2- Geological setting

The study area covers rock discoveries dating back to the Middle Miocene - Quaternary period, and the exposed rocks in that area are all sedimentary rocks, as they are represented in the AL-Fatha, Injana formations and Quaternary deposits [1] and [2], as shown on the map (2).

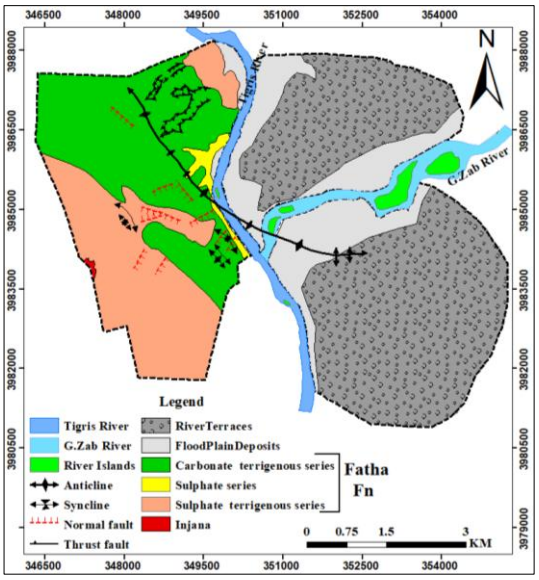

Fig. 2: Geological map of the study area [1]

AL-Fatha formation in the study consists of (10-16) sedimentary cycles, with the thickness of each cycle ranging from less than one meter to more than 20 m [3]. One cycle includes a homogeneous arrangement

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of clay, marl, gypsum and limestone [1]. Since some of these sedimentary cycles are integrated or lack one of the four aforementioned components, the most important characteristic of the Al-Mishraq region is the mineralization of gypsum and anhydrite rocks into Recrystallized sulphureous limestone and secondary limestone [2], [4]. The components of AL-Fatha formation of the aperture are different, they are limestone and siltic, when the sea is open, and when the sea is blocked, this leads to the formation of deposits of evaporites of the type of gypsum, anhydrite and salty substances, but the facies of the evaporites are dominant in the AL-Fatha formation [5], [1].

3- Methodology

1. The stratigraphic columns were drawn for the wells available in the study area excavated by the Polish company Centrozab, whose information was obtained from the the Mishraq Sulphur State Company.
2. The depths of the groundwater were measured in 11 wells in the Mishraq field-2 by a groundwater depth detector. The depths of the groundwater were also obtained in 12 wells in Mishraq field-3, which were measured by the Mishraq Sulphur State Company in 2013. In addition to the measurements made by the Polish company Centrozab in 1971 in 68 wells, the elevation above sea level was also measured using a GPS device, the depth was subtracted to the groundwater from elevation, to obtain groundwater levels in these wells.
3. The Groundwater level map was drawn, which represents a contour map of lines equal to the height of the groundwater level above sea level, meaning the Equipotential Lines, for these three fields before production. Thus, the direction of water movement at any point is the direction perpendicular to the equipotential lines. Taking into account that the areas between the Equipotential Lines and the flow lines the form of squares as much as possible.
4. The results of the pumping test were used for the productive layers of (44) wells before Sulphur production, distributed by (29) wells in the Mishraq field-1, (3) wells in the Mishraq field-2, (12) wells in the Mishraq field-3. based on data obtained from the Mishraq Sulphur State Company. In order to obtain the Hydraulic Properties of Aquifers, given the importance of the productive layers Aquifer in the production process and its impact on the drainage and consumption of industrial water in the production of Sulphur , which requires the study of hydraulic properties.

4- Results and discussion

aquifers in the study area The main 1-

Through the study of the lithological columns of the wells available in the study area, excavated by the Polish company Centrozab and Iraq Geological Survey, whose information was obtained from the Mishraq Sulphur State Company, and through previous studies, the groundwater Aquifers have been identified are:

1-1 Quaternary aquifer

The groundwater aquifers in these deposits are few in terms of quantity, considering that these deposits have limited extensions in the study area, and the depth of the groundwater in them depends on the topography of the region as well as its distance from the Tigris and Great Zab rivers.

2-1 Fatha aquifer

It is the main aquifer located in the study area, as the groundwater in this formation is characterized by the emission of the smell of hydrogen sulfide gas H_2S [6], in addition to being salty water due to the extensive dissolution of the gypsum rocks that make up this formation [7]. Secondary [3] are:

2-1-1 Overburden layers aquifer

The thickness of this Aquifer in (M2, M3) ranges between approximately (17-200) from the surface of the earth to the Aquifer of the productive layers, and the importance of water for the Aquifer of these layers did not appear due to the lack of storativity in this Aquifer.

In (M1), this Aquifer consists of five secondary Aquifers bearing groundwater representing the sediments of the Quaternary period, in a narrow strip adjacent to the Tigris River, the Sulphate terrigenous series, upper part Carbonate terrigenous series, lower part carbonate terrigenous series and middle part sulphate series [1]. Most of these Aquifers are characterized by being non-continuous and poor flowing, as the water supply for these Aquifers takes place from the northwestern side of the Al-Mishraq area and along the direction of the main attic [8], and because the depths of the groundwater measured in the wells range between (47.37-81 m). In Mishraq-1, this tank is considered a dry tank, or it may contain hanging tanks with limited side extension.

2-1-2 Productive layers aquifer

This Aquifer is the largest groundwater aquifers in the Al-Mishraq area, as it extends on both sides of the Tigris River, which includes the three Sulphur layers of the lower part of the Fatah formation. The productive layers aquifer is of the confined aquifer, due to the presence of the marley stratum at the top of the Euphrates formation, and the thick layers of gypsum and mudstone at the bottom of the Overburden layers, which aquitard for the aquifer from the bottom and top [9].

This formation was divided into three secondary aquifers according to [1], [10], separating the three productive layers of dolomite and limestone rocks with little porosity, as well as layers of compressed mudstone with a thickness ranging from (0.5-32) m, which are:

aquifer *2-1-2* -1 The first productive layer
aquifer The second productive layer *2-1-2* -2
aquifer *2-1-2* -3 The third productive layer

These three Aquifers are well isolated from the overlying Aquifers with two layers of gypsum and

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mudstone, with a thickness ranging between (0.5-34) m. And it is found in layers of cavernous limestone rocks, especially the first layer containing Sulphur , in addition to the marly limestone and recrystallized limestone, with an average thickness of approximately (100 m), It has been classified by the Polish company Centrozab, which made a detailed study of the (M1, M2) fields, as well as the study carried out by the General Company for Geological Survey of the Mishraq field-3. As shown in the lithological columns of the wells shown in Figures (3) and (4), which shows that the depth of groundwater in them depends on the topographic slope.

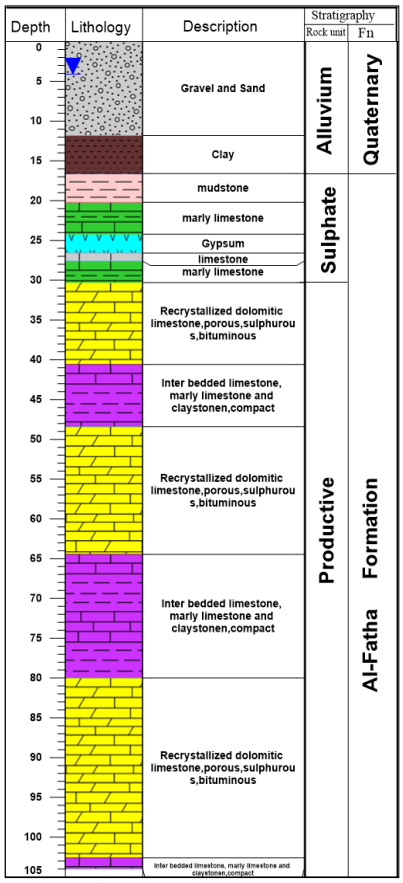

Fig. 3: shows the level of the groundwater relative to the productive layers, borehole (T -1) in Mishraq-2[1]

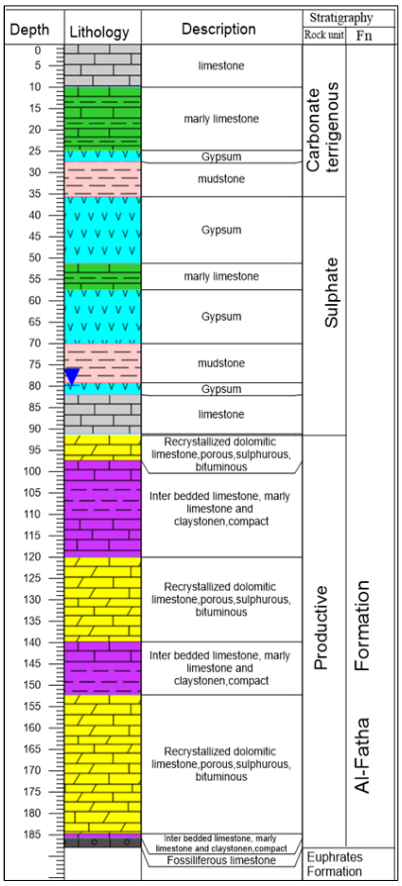

Fig. 4: shows the level of the groundwater relative to the productive layers, borehole (XVIII -8) in Mishraq-1[1]

2- Depth and Water table of Ground Water

A map of the variation of groundwater depths was drawn as shown in Figure (5), through the information of wells shown in Tables (1), (2), (3), before production from the Mishraq Sulphur fields. Where we notice that the depths in Mishraq-1 are increasing In the fold axis (northwest of the field), and lower on both sides of the fold axis, meaning (north and south of the field), As for Mishraq-2, the depths increase towards the east and decrease towards the west, meaning towards the Tigris River. As for Mishraq-3, the depths of the groundwater increase towards the southeast, and these depths decrease towards the Tigris and Great Zab rivers, and this is in line with the topographic inclination of the surface of the earth. Where the depths of the groundwater in Al-Mishraq field-1 ranged between (35.60-83.25) m. In Al-Mishraq field-2 between (4.12-9.18) m, and in Al-Mishraq field-3 it ranged between (2.98-15.12) m, the reason for the great discrepancy in the depths of the groundwater between the Mishraq field-1 on the one hand and the Mishraq fields (2,3) on the other hand are due to topographical reasons, not hydraulic ones.

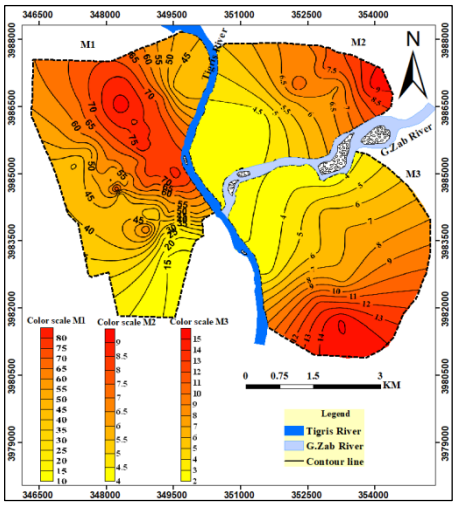

Fig. 5: shows a map of the depths of the groundwater in the three fields before starting the Sulphur production process.

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Table 1: shows the depths and water table of groundwater for the wells of Mishraq field-1 before production in 1971[1].

NO	no-BH	East	North	Elev.(m)	Dep.(m)	W.T
1	P-1	348288	3985210	251.18	59.60	191.58
2	P-2	348427	3985064	256.30	62.40	193.9
3	P_3	348495	3985244	252.97	61.90	191.07
4	P-4	348594	3985435	256.81	66.51	190.3
5	P-5	348706	3985284	256.60	64.60	192
6	viii-8	350015	3984096	249.24	50.10	199.14
7	x-6	349385	3984112	249.29	49.74	199.55
8	x-8	349733	3984364	253.75	56.90	196.85
9	xi-4	348938	3984040	239.00	35.60	203.4
10	xi-5	349103	3984155	238.49	36.00	202.49
11	xi-7	349434	3984404	255.10	56.40	198.7
12	xi-8	349615	3984525	256.07	59.80	196.27
13	xi-9	349790	3984648	263.11	67.95	195.16
14	xii-4	348803	3984185	242.88	40.20	202.68
15	xii-5	348954	3984300	244.57	44.60	199.97
16	xii-7	349330	3984556	255.18	58.45	196.73
17	xii-8	349502	3984682	263.91	69.05	194.86
18	xiii-4	348772	3984312	246.38	44.00	202.38
19	xiii-6	349023	3984644	260.24	60.34	199.9
20	xiii-9	349557	3984960	269.24	76.20	193.04
21	xiv-5	348729	3984633	262.17	59.80	202.37
22	xiv-6	348913	3984734	263.03	67.00	196.03
23	xiv-7	349101	3984878	261.51	67.10	194.41
24	x-3	348909	3983760	261.20	61.20	200
25	xiv-8	349264	3984983	260.92	71.50	189.42
26	xiv-9	349425	3985095	267.82	75.25	192.57
27	xv-4	348462	3984654	255.44	57.20	198.24
28	xv-3	348315	3984545	244.68	40.60	204.08
29	xv-5	348628	3984787	256.62	61.30	195.32
30	xv-6	348809	3984898	260.99	66.50	194.49
31	xv-7	348985	3985024	264.42	72.30	192.12
32	xv-8	349151	3985141	266.12	74.20	191.92
33	xv-9	349308	3985254	264.14	72.60	191.54
34	xvi-4	348392	3984786	249.55	51.80	197.75
35	xvi-6	348706	3985032	261.50	67.55	193.95
36	xvii-3	348116	3984805	249.08	49.40	199.68
37	xvii4	348260	3984932	248.17	51.19	196.98
38	xvi-5	348549	3984910	251.76	57.00	194.76
39	xvii-9	349108	3985501	260.72	72.50	188.22
40	xvii-8	348943	3985410	263.72	71.45	192.27
41	xvii-11	349378	3985764	262.87	71.30	191.57
42	xviii-3	347997	3984973	254.18	53.50	200.68
43	xviii-4	348141	3985080	250.48	51.00	199.48
44	xviii-8	348782	3985614	267.51	79.80	187.71
45	xviii-9	348910	3985768	265.93	75.00	190.93
46	xix-3	347880	3985135	259.17	59.80	199.37
47	xix-4	348025	3985254	255.70	59.45	196.25
48	xix-11	349155	3986039	265.97	74.00	191.97
49	xix-15	349739	3986629	247.57	46.90	200.67
50	xxi-1	347291	3985197	244.47	39.19	205.28
51	xxi-3	347590	3985477	249.93	46.45	203.48
52	xxi-7	348236	3985948	266.12	73.40	192.72
53	xxi-9	348588	3986204	271.73	74.60	197.13
54	xxi-13	349232	3986688	263.83	67.30	196.53
55	xxi-15	349555	3986957	243.92	42.20	201.72
56	xxiii-1	347049	3985497	253.87	48.80	205.07
57	xxiii-3	347356	3985772	261.75	57.85	203.9
58	xxiii-5	347678	3986015	266.18	64.80	201.38
59	xxiii-9	348327	3986515	280.66	83.25	197.41
60	xxiii-11	348652	3986767	273.52	75.80	197.72

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61	xxiii-13	348915	3987027	263.66	66.10	197.56
62	xxv-3	347167	3986133	263.43	58.30	205.13
63	xxv-7	347752	3986572	273.80	71.85	201.95
64	xxv-11	348376	3987042	282.16	77.20	204.96
65	xxvii-5	347355	3986552	268.94	63.79	205.15
66	xxvii-11	348094	3987465	276.80	71.00	205.8
67	xvi-3	348239	3984657	272.40	72.60	199.8
68	xvii-6	348578	3985171	254.77	62.80	191.97

Table 2: shows the depths and water table of groundwater for the wells of Mishraq field-2 before production in 2021.

NO	BH-No	East	North	Elev.(m)	Dep.(m)	W.T
1	Well-1	351398	3986238	193.31	4.12	189.19
2	Well-2	351539	3986260	193.74	4.42	189.32
3	Well-3	352263	3986639	195.63	6.1	189.53
4	Well-4	352263	3986962	196.96	6.14	190.82
5	Well-5	352526	3987246	197.33	6.33	191
6	Well-6	352634	3987565	197.43	6.84	190.59
7	Well-7	353171	3986937	196.96	6.44	190.52
8	Well-8	353968	3987014	205.44	9.18	196.26
9	Well-9	353827	3986607	202.21	8.12	194.09
10	Well-10	353802	3986887	204.77	8.71	196.06
11	Well-11	352884	3987402	198.02	7.65	190.37

Table 3: shows the depths and water table of groundwater for the wells of Mishraq field-3 before production in 2013 (Mishraq Sulphur State Company).

NO	BH-No.	East	North	Elev.(m)	Dep.(m)	W.T
1	W-16	351525	3984282	192.8	6.4	186.4
2	W-17	352150	3984772	193.85	6.63	187.22
3	W-18	353015	3984939	193.18	6.24	186.94
4	W19(H11)	351155	3983513	192.51	5.68	186.83
5	W-20	351995	3983649	194.92	4.22	190.7
6	W-21	352885	3984131	197.72	6.32	191.4
7	W-22	351609	3982837	195.34	8.27	187.07
8	W23	352790	3983254	198.98	6.06	192.92
9	W-24	353425	3983728	201.79	7.13	194.66
10	W25	352731	3982163	206.67	11.87	194.8
11	W-26	353277	3982639	202.3	7.48	194.82
12	W-38	353242	3981712	208.1	13.12	194.98

The flow lines were drawn perpendicular to the equipotential Lines, taking into account that the areas between the equipotential Lines and the flow lines are in the form of squares as much as possible.

From the observation of Figure (6), it was found that the direction of groundwater movement in Mishraq-1 is from the west and northwest to the east, with a slight slope toward the southeast, meaning that it is toward the Tigris River. As for the Mishraq field-2, we note that the direction of the groundwater movement is from east to west, which towards the Tigris River, and in Mishraq-3 it was found that the direction of movement is from the southeast to the northwest, which towards the Tigris and Great Zab rivers. Therefore, it can be said that the Tigris and Great Zab rivers are the two drainage areas in these three fields, and this direction corresponds to the direction of the surface drainage network (valleys) and the topographical slope of the land, It is also in line with geomorphological concepts. As a number of researchers considered the high lands to be recharge areas in general, and most of the lowlands were discharge areas when there is no complex terrain. It was also noted that there are some local changes in the directions of flow, and this may be due to several reasons, including the heterogeneity of the porous medium and thus the variation in hydraulic properties of permeability and porosity, or due to the variation in pumping from the aquifer from one region to another [11], or due to the presence of abnormal recharge of the aquifer in Some areas near cities and villages.

The convergence of groundwater levels above sea level in the recharge and drainage areas gives clear evidence of the presence of hydraulic communication between the three aquifers of the fields, and thus they act as a single body of water.

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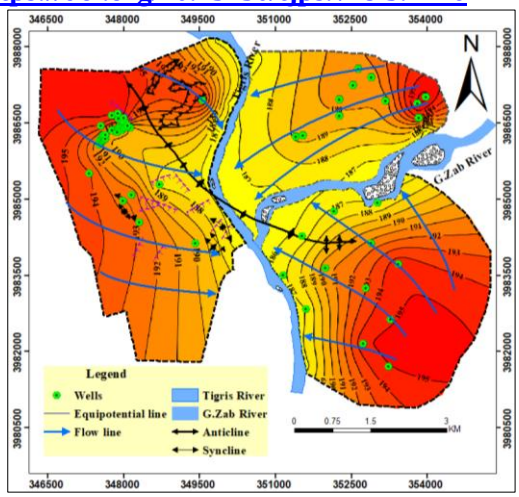

Fig. 6: shows the levels and flow net in the three Al-Mishraq Sulphur fields before starting the Sulphur production process.

3- Hydraulic Properties

The values of transmissivity (T) in Mishraq field-1 ranged between (24.4-1557.5) m^2/ day, and hydraulic conductivity (K) ranged between (0.26 -14.68) m/ day, before production.

As for the Mishraq field-2, the values of transmissivity (T) ranged between (23-96.91)m^2/ day, while the values of hydraulic conductivity (K) ranged between (0.7 - 4.2) m/ day. while in Mishraq field -3, the values of transmissivity (T) ranged between (10.5-4002) m^2/ day, while the values of hydraulic conductivity (K) ranged between (0.37 - 119.09) m / day, as shown in tables (4), (5) and (6).

Table 4: parameters of hydraulic properties of wells in Mishraq field-1 before production[9].

BH.No.	East (UTM)	North (UTM)	K (m/day)	T (m^2/day)
B.H.-34	348875	3985545	0.9	93.1
B.H.-35	349212	3984340	2.66	272.7
p-1	348309	3985223	1.23	127.31
p-2	348448	3985079	1.41	128.1
p-3	348515	3985259	1.47	159.6
p-4	348612	3985451	3.9	422.3
VIII-4	349279	3983595	6	660
VIII-8	350045	3984125	0.26	24.4
XII-8	349526	3984706	10.52	1082.5
XIII-1	348225	3984042	3.69	415.1
XIII-6	349048	3984664	2.89	303.5
XIX-11	349167	3986059	0.33	29.8
XIX-15	349746	3986654	2.28	212.3
XIX-3	347901	3985145	0.71	72
XV-3	348342	3984559	1.12	116.9
XV-5	348652	3984803	0.58	62.4
XV-7	349006	3985043	3.01	316.7
XV-9	349327	3985276	14.68	1557.5
XVII-3	348140	3984817	1.51	154
XVII-8	348961	3985429	9.9	1026.1
XVII-9	349126	3985521	7.72	223.5
XVIII-3	348025	3984984	1.51	154
XVIII-8	348798	3985631	7.72	173.5
XVIII-9	348925	3985787	7.47	251
XXI-3	347608	3985484	1.29	135.6
XXI-7	348250	3985960	0.593	58.4
XXIII-13	348919	3987045	1.15	116
XXIII-5	347691	3986023	0.96	103
XXIII-9	348335	3986528	1.83	172.3

Table 5: parameters of hydraulic properties of wells in Mishraq field-2

BH.No.	East	North	K (m/day)	T (m^2/day)
W4	352170	3985489	1.57	40.45
W8	350106	3985612	0.7	23
W32	352137	3987264	4.2	96.91

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Table 6: parameters of hydraulic properties of wells in Mishraq field-3[12]

BH.No.	East (UTM)	North (UTM)	K (m/day)	T (m^2/day)
W-16	351525	3984282	37.8	1142
W-17	352150	3984772	37.04	1037
W-18	353015	3984939	2.275	68
W19(H11)	351155	3983513	0.365	10.5
W-20	351995	3983649	31.41	1134
W-21	352885	3984131	119.09	2119
W-22	351609	3982837	57.4	1711
W23	352790	3983254	75.495	2604
W-24	353425	3983728	16.27	512
W25	352731	3982163	8.255	260
W-26	353277	3982639	98.77	3101
W-38	353242	3981712	112.4	4002

The hydraulic properties of these three fields were mapped before production, which are represented by the transmissivity as in Figure (7), and the hydraulic conductivity as in Figure (8), It is noted that the values of the transmissivity and hydraulic conductivity in Mishraq-1, increase in the east of the study area near the Tigris River and decrease towards the north and northwest, Because it is affected by the tectonic activity caused by the effect of the Hadhra-Bakhme fault, which causes the of faults and the joints parallel to this main fault, which intersect with the joints resulting from the formation of folds and parallel to the axis of the main Mashraq fold. As the point of intersection of both systems is considered the main point of leakage, but in the Mishraq field-2, the values of the hydraulic properties values increase in the east of the field and decrease towards the west, towards the Tigris River, The reason for the homogeneity of these properties in the Mishraq field-2 may be due to the lack of data for the hydraulic properties obtained from this field. While in Mishraq-3, the values of the hydraulic properties increase in the middle of the study area and decrease towards the north and east in the area, that is, towards the Tigris and Great Zab rivers. This indicates heterogeneity in hydraulic properties in Mishraq-3, and this may be normal for sulphureous limestone because of the presence of voids in some areas, which can extend to tens of meters.

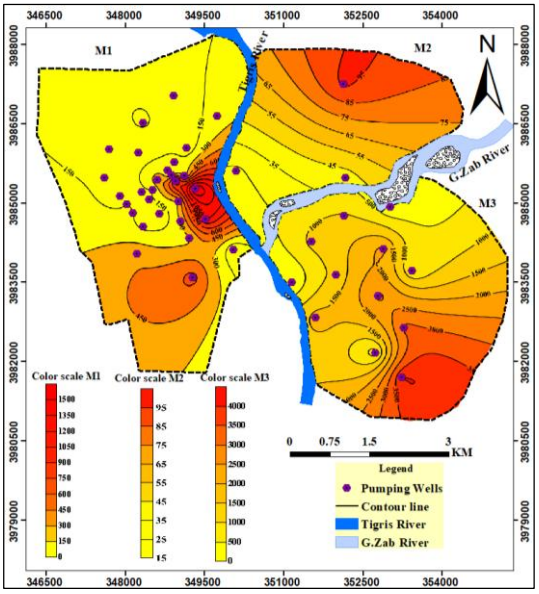

Fig. 7: The distribution map of the transmissivity (T) for the Productive layers in the three fields before production.

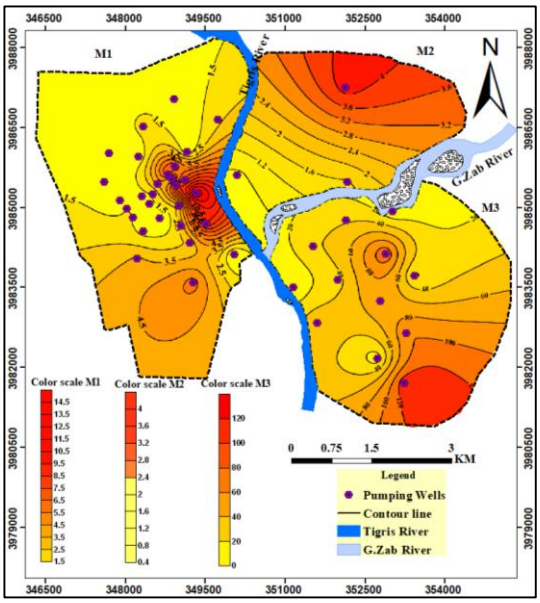

Fig. 8: distribution map of the hydraulic conductivity (K) of the production layers in the three fields before production.

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5- Conclusions

1- Through the study of the lithological columns of some wells in the study area that were drilled by the Polish company Centrozab and the Iraq Geological Survey, two main aquifers have been identified, which are from the bottom, the Euphrates formation aquifer and the productive layers aquifer within the Fatah formation. As for the quaternary aquifers and the covering layers, they are considered dry aquifer or they may contain Perched aquifers.

2- The general direction of groundwater movement in Mishraq-1 is from the west and northwest to the east, with a slight slope toward the southeast, That is, towards the Tigris River. As for the Mishraq field-2, the direction of the groundwater movement is from east to west, meaning that it is toward the Tigris River. As for Mishraq-3, it was found that the direction of movement is from the southeast to the northwest, that is, towards the Tigris and Great Zab rivers, so it can be said that the Tigris and Great Zab rivers are the two drainage areas in these three fields.

3- By analyzing the hydraulic properties of (44) wells in the three Al-Mishraq fields, and studying the maps of the transmissivity (T) and hydraulic conductivity (K) in these fields, It was found that these characteristics increase in the east of the study area near the Tigris River and decrease towards the north and northwest in Mishraq-1. The reason for the increase in these characteristics may be due to their being affected by the tectonic activity caused by the effect of the Hadhra-Bakhme fault, which causes the formation of faults and the joints parallel to this main fault, which intersect with the joints resulting from the formation of folds parallel to the axis of the main Mashraq fold. The point of intersection of both systems is the main leakage point. As for the Mishraq field-2, the values of the hydraulic properties values increase in the east of the field and decrease in the west, that is, towards the Tigris River. The reason for the homogeneity in these properties in the Mishraq field-2 may be due to the lack of data for the hydraulic properties obtained from this field. While in Mishraq-3, the values of the hydraulic properties values increase in the middle of the study area and decrease towards the north and east in the area, that is, towards the Tigris and Great Zab rivers. This indicates heterogeneity in hydraulic properties in Mishraq-3, and this may be normal for sulphureous limestone because of the presence of gaps in some areas, which can extend to tens of meters.

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