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The effect of Al-Wand lake on the shallow groundwater aquifer in Khanaqin area, Diyala Governorate, Iraq

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Abstract
The relationship between Al-Wand lake and groundwater was studied in Khanaqin cityby identifying water levels for Al-Wand lake and the shallow groundwater aquifer for 2019 and 2020. The hydrochemical analyses of Al-Wand river water, Al-Wand lake water and shallow groundwater, and identifying the grain size analysis and mineralogy of the surface sediments have been done. This relationship was adopted on climate data of the study area by knowing which seasons contained water surplus or water deficit, and porosity and permeability define of soil that affects groundwater movement, and identify the salinity that effect on water quality.

Keywords: The sediment, the water resource, grain size and hydrochemical analysis, the relationship between Al-Wand lake and groundwater and water suitability.

تأثير بحيرة الوند على خزان المياه الجوفية الضحلة في منطقة خانقين، محافظة ديالى، العراق

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الخلاصة:
تمت دراسة العلاقة بين بحيرة الوند والمياه الجوفية في مدينة خانقين، من خلال تحديد مستويات المياه لبحيرة الوند وخزان المياه الجوفية الضحلة لعامي 2019 و2020. وقد أجريت التحليلات الهيدروكيميائية لمياه نهر الوند ومياه بحيرة الوند والمياه الجوفية الضحلة، فضلا عن تحديد تحليل الحجم الحبيبي والمعدني للرواسب السطحية. وقد اعتمدت هذه العلاقة على البيانات المناخية لمنطقة الدراسة من خلال معرفة المواسم التي تحتوي على فائض المياه أو العجز في المياه، فضلا عن تحديد المسامية والنفاذية للتربة التي تؤثر على حركة المياه الجوفية، وكذلك تحديد الملوحة التي تؤثر على جودة المياه.

INTRODUCTION

Water is vital for all life forms and is used in different ways. Al-Wand river is considered the main source of surface water in the Khanaqin area which is a tributary of the Diyala river. Khanaqin City depends on the Al-Wand river to maintain all of its water needs but its supply is

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not enough to support these needs, accordingly, the local consumers compensate their needs from groundwater resources through drilling wells mainly by the farmers to sustain their agronomic activities within the area. Climate change and its consequences, such as reduction of precipitation and temperature increasing had a vital role in the declining freshwater resources. Groundwater is considered the second resource after the surface water, runoff and rainfall in all over the world [1]. Water quality is one of the most important aspects of hydrological studies. Hydrochemical studies reveal the quality of water as physical and chemical parameters, to obtain its suitability for human, animal drinking, agriculture and industrial purposes. The decrease of flow is accompanied by deterioration of the water quality due to the increase in salinity and other pollutants. This high salinity concentration is believed to be due to the chemical weathering of the sediment as well as by the evaporation of irrigation water and the moisture left in the soil from the previous irrigation by groundwater [2].

Khanaqin area is located in Diyala governorate in the east of Iraq and bordered by Iraqi-Iranian frontiers from the east and Diyala river from the west (Figure 1). The study area is situated between longitudes (45^o 21' 10" - 45^o 30' 30") E and latitudes (34^o 15' 11" - 34^o 22' 00") N.

Geologically, the Khanaqin area is a part of the unstable shelf within the low folded zone, Hemrin belt which is represented by the foothill zone (Figure 2). The formations age is from Middle Miocene to Holocene represented by Fatha, Injana, Mukdadiya and Bai Hassan formations and the quaternary deposits consecutively [3].

The farmers of the Khanaqin area used the groundwater and surface water for irrigation purposes; despite the presence of salinity, so it is essential to assess the relationship between water and the sediment and their relationship with Al-Wand lake. Iraq climate in this period testified notable change, rainfall after drought periods lead to groundwater recharge decrease result sediment erosion thus stockage water spill decrease. To investigate the assessment of groundwater recharge either from the rainfall or from the infiltration of storage water for Al-Wand reservoir, it is important taking into consideration the sediment texture and groundwater utilization [4].

The aims of the study are to investigate the effect of Al-Wand lake on the shallow groundwater aquifer in the Khanaqin area, Diyala Governorate, Iraq. The research deals with the water salinity of Al-Wand lake water and shallow groundwater as well as identifying the grain size analysis and mineralogy of the surface sediments. The relationship of Al-Wand lake surface water level with the groundwater static water level was taken into consideration in this study for two years 2019 and 2020 on monthly basis.

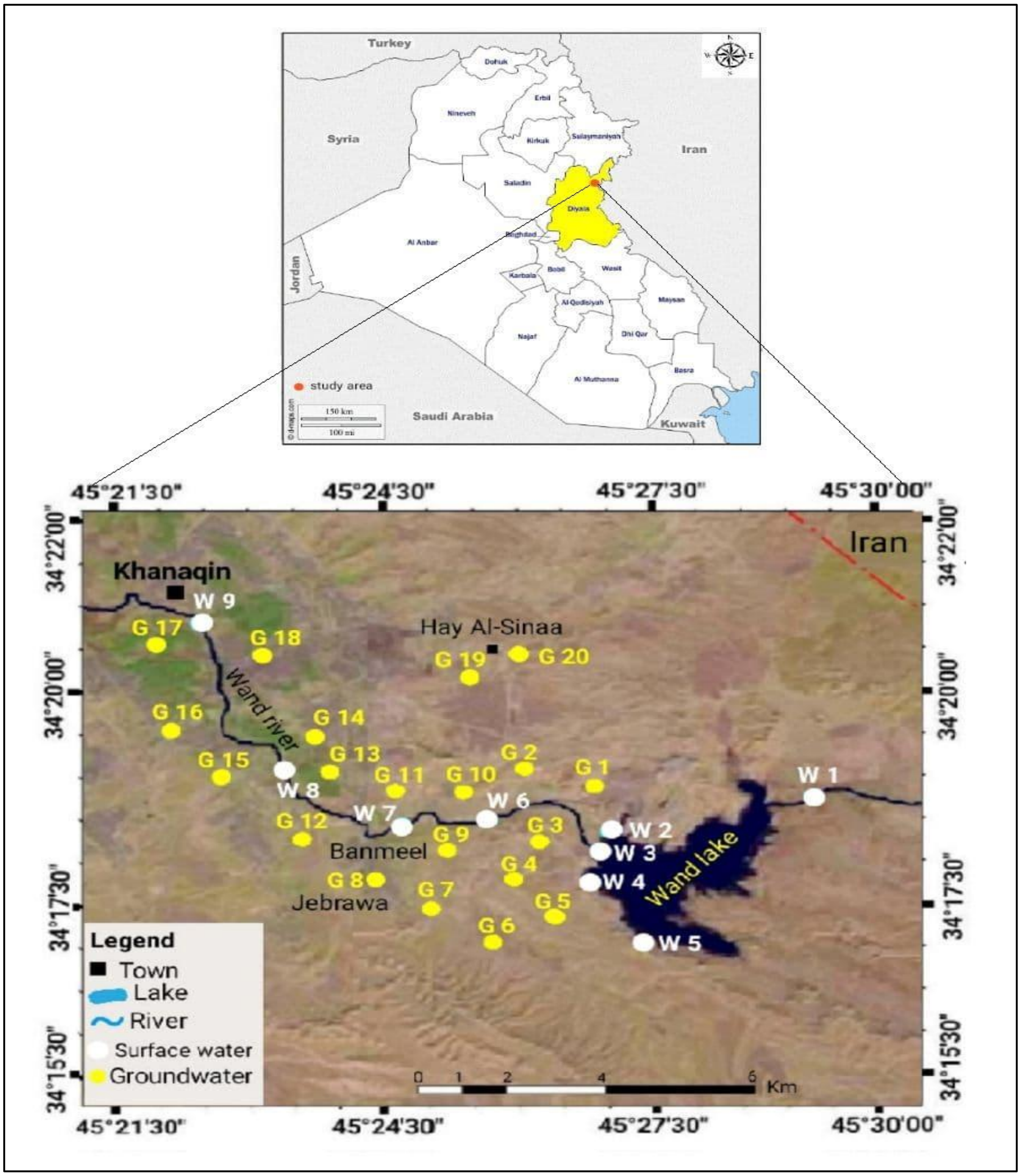

Figure 1- Study area in Khanaqin city

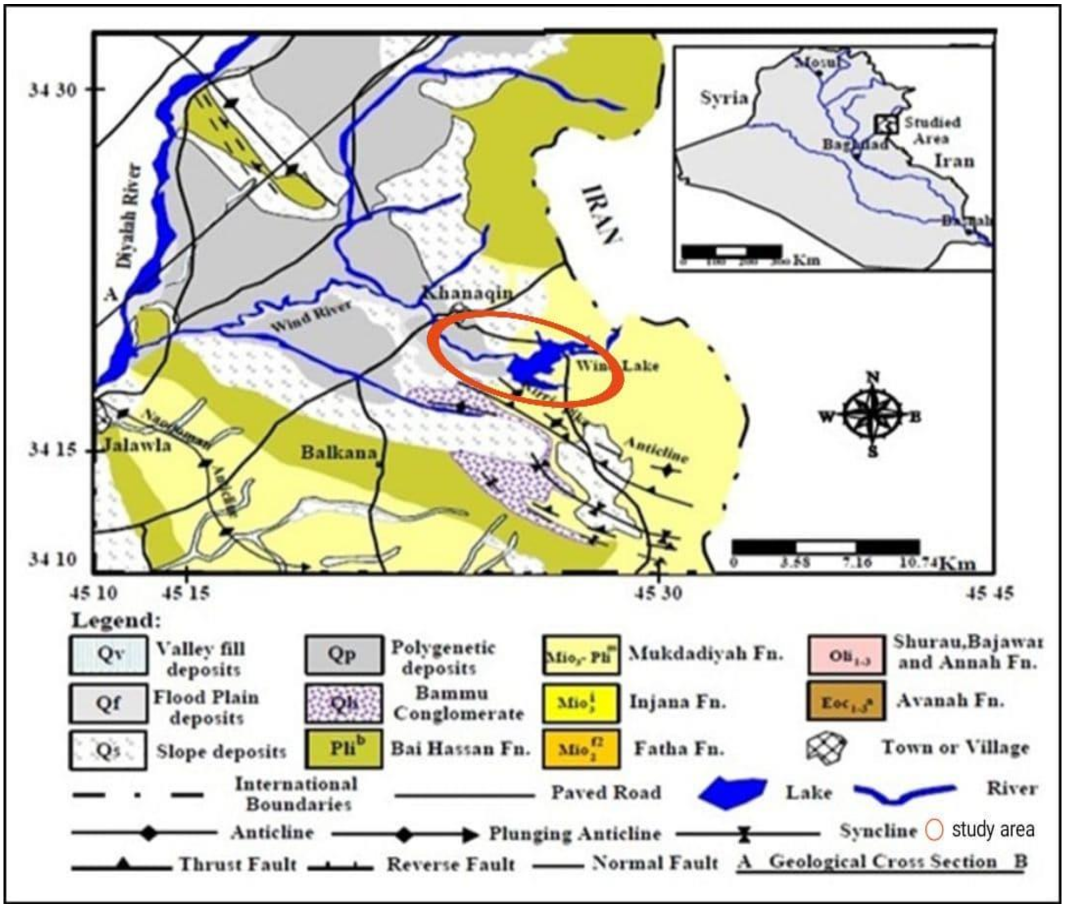

Figure 2- Geological Map of Khanaqin area.

MATERIALS AND METHODS

A. The sediment:

Collecting samples from surface sediment represented by sand, silt and clay were analyzed and put the samples in plastic bags. Grain size analysis of (15) samples distributed in the study area were done by sieving method [5][6]. The results tabulated in Table -1 based on Folk (1974) method use (Figure 3).

B. The water resource:

The salinity as TDS and EC of 39 water samples were investigated, surface water 9 samples from Al-Wand lake and Al-Wand river, and groundwater 20 samples for two periods (October 2019), and (April 2020) (Table 2A and B). The relationship of Al-Wand lake surface water level with the groundwater static water level was taken into consideration in this study for two years 2019 and 2020 on monthly basis (Table 3).

Table 1- The percentages (%) of sand, silt and clay in the study area.

Soil No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
Sand %	13. 7	13.3	12. 9	15. 5	9.8	12.8	16. 7	14. 1	7.5	11. 8	15. 0	13. 8	17. 5	16. 5	16. 4	13.8
Silt %	50. 7	50.1	49. 5	52. 8	54. 3	48.4	44. 4	45. 4	47. 8	43. 1	36. 7	32. 8	30. 8	29. 9	34. 2	43.4
Clay %	35. 6	36.6	37. 6	31. 7	35. 9	38. 8	38. 9	40. 5	44. 7	45. 1	48. 3	53. 4	51. 8	53. 6	49. 4	42.8

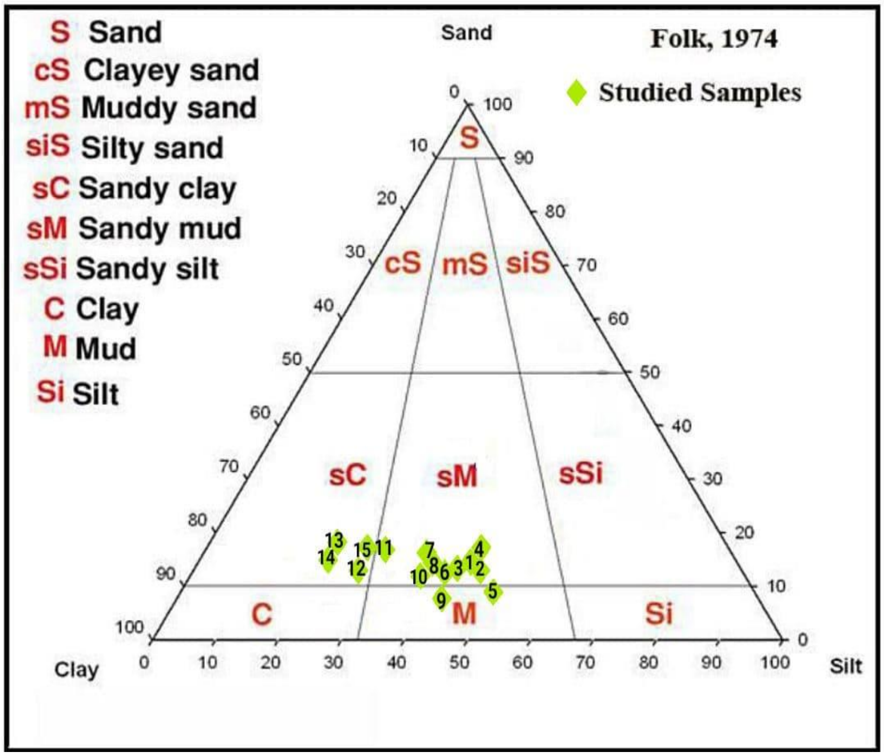

Figure 3- Classification of soil texture of studied area (Folk, 1974).

Table 2 A- TDS and EC values of surface water samples in the study area (October-2019 and April-2020).

No.	Octer-2019		April-2020	
	TDS (ppm)	EC (µs/cm)	TDS (ppm)	EC (µs/cm)
W1	597	999	552	930
W2	613	1035	572	1030
W3	628	1100	573	1031
W4	634	1115	575	1036
W5	705	1350	578	1061
W6	782	1660	586	1100
W7	865	1920	582	1120
W8	878	1960	592	1030
W9	985	2367	607	1185
Average	743.0	1500.7	579.7	1058.1

Table 2 B- TDS and EC values of groundwater samples in the study area (October-2019 and April-2020).

No.	Octer-2019		April-2020	
	TDS (ppm)	EC (µs/cm)	TDS (ppm)	EC (µs/cm)
G1	1382	2485	758	1027
G2	1174	2210	812	1094
G3	1050	2098	845	1167
G4	1310	2316	789	1295
G5	1435	2010	973	1357
G6	1754	2700	1007	1483
G7	1914	2891	1084	1507
G8	2225	3215	1129	1620
G9	2310	3389	1178	1687
G10	2422	3500	1242	1810
G11	2977	3981	1273	1895
G12	2717	3756	1387	2007
G13	2975	4018	1420	2104
G14	3078	4189	1486	2237
G15	3332	4371	1550	2314
G16	3601	4597	1612	2370
G17	3447	4318	1765	2622
G18	3592	4507	1800	2691
G19	4207	4980	2437	3642
G20	4189	5180	2524	3780
Average	2554.6	3535.6	1353.6	1985.5

Table 3- The average water level of Al-Wand lake and shallow groundwater aquifer based on monthly measurements for two years 2019 and 2020.

Month	Average Al-Wand lake Water Level (m.a.s.l.) for years 2019 and 2020	Average piezometers groundwater static Level (m.a.s.l.) for years 2019 and 2020	The level Difference (m)
January	213.55	205.82	7.73
February	215.16	205.95	9.21
March	215.20	206.13	9.07
April	215.90	206.26	10.64
May	215.10	206.40	8.7
June	215.10	206.51	8.59
July	214.66	206.50	8.16
August	213.03	206.48	6.55
September	211.12	206.45	4.67
October	207.15	206.28	0.87
November	209.16	205.99	3.17
December	213.90	205.68	8.22
Minimum	207.15	205.68	0.87
Maximum	215.90	206.51	10.64
Average(m)	207.15	206.19	6.94

RESULTS AND DISCUSSION

A. Grain size analysis:

The analysis results of fifteen sediment samples distributed in the study area show that the silt percentage is a major part of the sediment with an average of 43.4 %, followed by the clay with an average of 42.8 %, while the sand is of the lowest average 13.8 %, (Table-1). The sediment texture in the eastern part of the study area near Al-Wand lake is indicating higher percentages of sand and silt (more than 60%) with fewer amounts of clay (less than 40%). Sand and silt ratio indicates on presence of sufficient porosity and permeability of good flow of water from Al-Wand lake and Al-Wand river to groundwater, while in the western part near the city of

Khanaqin which reflect lower percentages of sand and silt (less than 60%) with higher amounts of clay (more than 40%) that is believed of relatively lower permeability (Figure 4).

B. Hydrochemical analysis:

Total dissolved solids (TDS) and electrical conductivity (EC) are good parameters in the evaluation of water quality to measure the total dissolved minerals in water [7] [8]. The TDS values of Al-Wand lake and Al-Wand river water samples in October 2019 have an average value of 743 ppm, while the groundwater has an average value of 2554.5 ppm. Whereas, in April 2020, the TDS value of surface water samples have an average value of 579.7 ppm, and the groundwater samples have an average value of 1358.1 ppm (Figure 5) (Tables 2A and B). The electrical conductivity (EC µs/cm) of surface water samples in October 2019, has an average value of 1500.7 µs/cm, while the groundwater samples have an average EC value of 3535.5 µs/cm. Whereas, in April 2020, the EC value of surface water samples are with an average value is 1069 µs/cm, and the groundwater with an average value of 1985.5µs/cm (Figure 6) (Tables 2A and B).

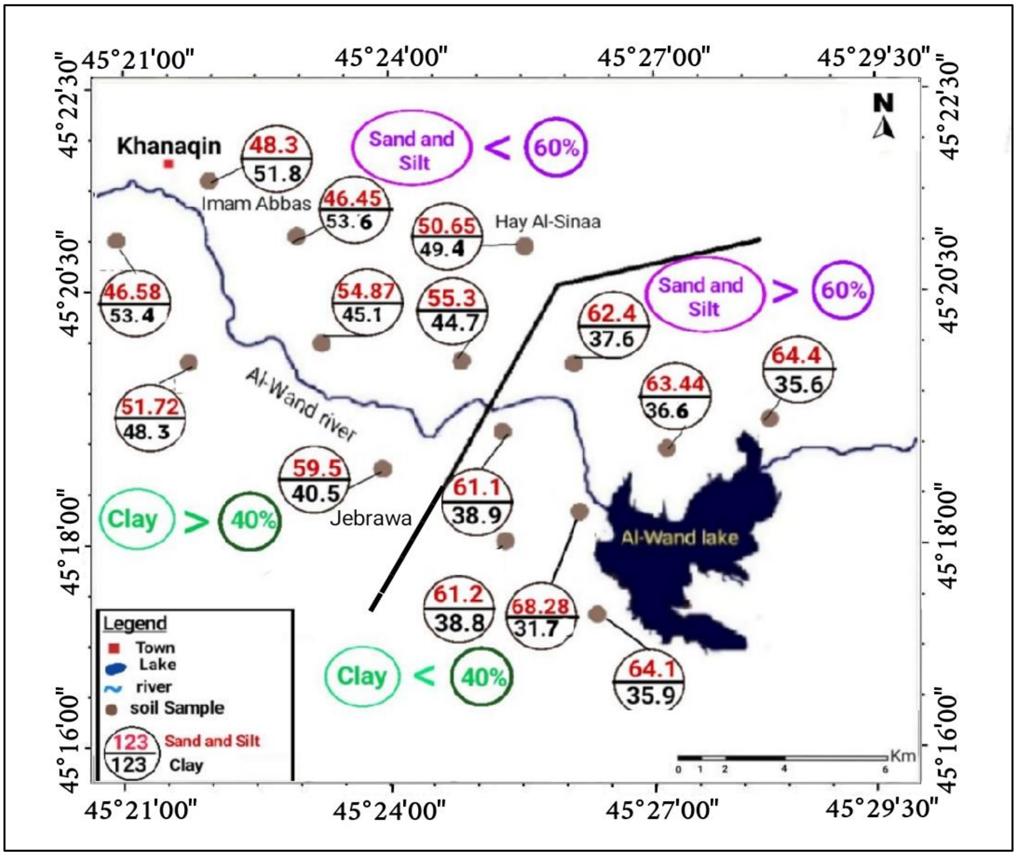

Figure 4- Distribution of the sediment texture in the study area**.**

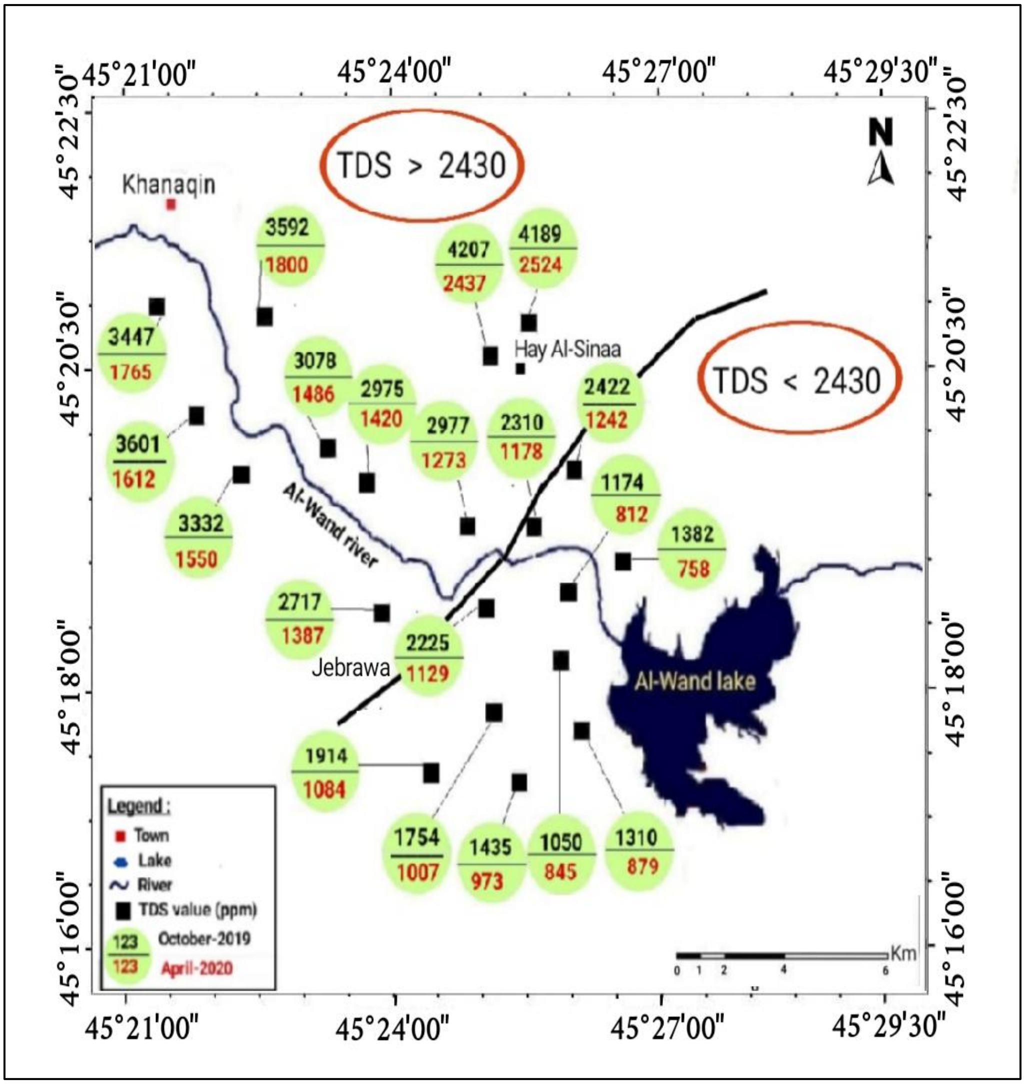

Figure 5- Distribution of the TDS value for two seasons (October-2019 and April-2020) for groundwater in the study area**.**

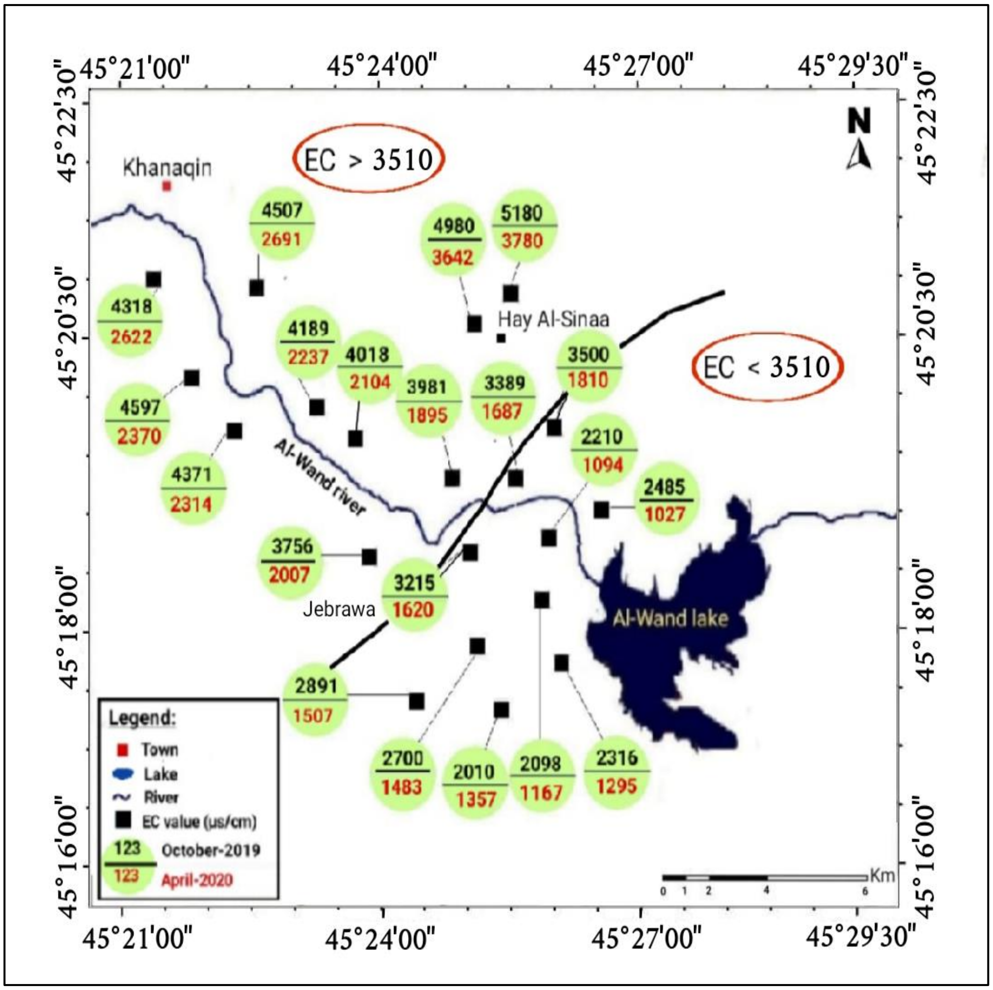

Figure 6- Distribution of the EC value for two seasons (October-2019 and April-2020) for groundwater in the study area.

The relationship between Al-Wand lake and groundwater:

The measurements of the static water level of the groundwater wells as well as Al-Wand reservoir surface water level for two years on monthly basis were taken into consideration. It was found that the average Al-Wand lake water level (m.a.s.l.) for Years 2019 and 2020 are ranging from 207.15 m.a.s.l., during October to 215.90m.a.s.l. during April, while the average piezometers groundwater static Level for years 2019 and 2020 are ranging between 205.68m.a.s.l. during December and 206.51m.a.s.l. during June, (Table 3). Consequently, that may divide into two periods, the first period is from August to November (i.e.4 months) where the difference is less than 7m reaching the minimum variation during October 0.87m, the second period is from December to July (i.e.8months) were the difference is more than 7m reaching the maximum variation during April (10.64m) (Table 3). These periods were compared with the measured average monthly water deficit period that is from April to October (7months) and the measured average monthly water surplus which is from November to March (5 months) for Khanaqin Station for the period (1980-2019) (Table 4) [9]. It is so clear that during the winter and spring months that represent low utilization of groundwater, and with water surplus period, during the high water level of Al-Wand lake (during 8months from December to July, with more than 213.5m.a.s.l.) the lake recharge the groundwater until the period of water deficit especially from August to November (4months) the lake level was lowering to less than 213m.a.s.l., due to high utilization. The differences between the groundwater and Al-Wand lake levels reflect minimum variation ranging from 6.55m during August to 0.87m during October(Table 3), indicating that the groundwater recharge of the water surplus and Al-Wand lake water storage period has reached the groundwater during these months August to November so that it took four months from April to August for recharging groundwater within the area near Al-Wand lake and consequently took more time to reach the wells far away from the lake.

Table 4 -Water deficit and water surplus in the study area for the period1980-2019 (Ibrahim and Al-Dabbas, 2021)

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Total
WS (mm)	0	24.00	34.18	40.30	28.83	19.92	0	0	0	0	0	0	147.24
WD (mm)	42.25	0	0	0	0	0	15.56	97.85	149.1	215.05	199.27	102.13	821.21

Water suitability for different purposes:

The average surface water and groundwater salinity (as TDS and as EC) for two periods (October 2019 and April 2020) are compared with the Iraqi quality standard IQS (2009), and World Health Organization Standard WHO (2007) to determine its suitability for drinking, irrigation and different uses. It is found that Al-Wand river and Al-Wand lake water are within Iraqi quality standard IQS (2009), and World Health Organization Standard WHO (2007) for the two seasons the dry season October 2019 and the wet season April 2020. They are suitable for drinking**,** while the groundwater is unsuitable for drinking. According to Sodium adsorption ratio (SAR), Sodium-ion percentage (Na%) and Residual Sodium Carbonate (RSC) the surface and groundwater quality in the study area are suitable for irrigation purposes, while the Salinity (TDS) in the surface water is slightly saline and in groundwater is moderately saline in two periods, When comparing the quality of surface and groundwater with the standards of different uses in both periods shows that it is suitable for livestock and building uses, while the industrial uses the surface water is suitable and groundwater is unsuitable.

CONCLUSION

- The total water surplus is for five months from November to March noticed as 147.24mm, while the total water deficit seven months from April to October is 821.21mm, which obviously expects higher groundwater utilization.
- The groundwater hydrochemical investigations show variations in salinity between the dry season (October-2019) with minimum (1050 ppm) and maximum (4207 ppm), and wet season (April-2020) with minimum (758 ppm) and maximum (2524 ppm.), as well as relative differences in salinity were noticed between the wells near Al-Wand lake and near Khanaqin city which is far from Al-Wand lake.
- The relationship between Al-Wand lake and groundwater depends on their water level. It was found that the average Al-Wand lake water level (m.a.s.l.) for years 2019 and 2020 are ranging between 207.15 m.a.s.l. during October to 215.90 m.a.s.l. during April, while the average groundwater static level (m.a.s.l.) for years 2019 and 2020 are ranging between 205.68 m.a.s.l. during December and 206.51 m.a.s.l. during June. Actually, the effect varies between those wells near the reservoir and the other well far away from the lake near Khanaqin city. Such finding is obvious due to the relatively higher porosity and permeability of the sediment near the reservoir in general that is composed of more than 60% silt and sand-size particles compared with less than 60% near the city of Khanaqin.

- Actually the effect varies between those wells near the reservoir and the other well far away from the lake which is near Khanaqin city. It is believed that during the period of high Groundwater utilization the recharge water is not reached the aquifer due to the low flow speed of the groundwater and the sediment facies changes that reflect the inhomogeneity of the aquifer transmissivity and hydraulic conductivity, so that the salinity increase. The water surplus of the year before during months of the recharge water just reached the shallow aquifer whether from Al-Wand lake or from the rainfall over the Khanaqin secondary basin.
- It is found that surface water is within IQS, 2009, and WHO, 2007, standards i.e. suitable for drinking, while the groundwater is unsuitable for drinking. The surface water of Al-Wand lake and Al-Wand river are of class (Slightly Saline type) which is used for irrigation according to Rhoades, 1982 Classification of irrigation water. While, the ground water samples according to Todd, 1980 and Rhoades, 1982, Classification of irrigation water, are of class (Moderately Saline type) and range from doubtful water that suitable for certain crops to unsuitable water for irrigation as indicated in the wells (G.W14, G.W15, G.W16, G.W17, G.W18, G.W19 and G.W20), which are located relatively far from Al-Wand lake and near Khanaqin area.
- Therefore, it is recommended to utilize the groundwater well located near Al-Wand lake rather than the wells near Khanaqin for irrigation purposes.

REFERENCES

[1] Al-Dabbas, M. A. and Saad M. Abdul Razzaq, "Climatic analysis and climatic water balance determination for Al-Yusufiyah area, southern Baghdad, Iraq", *Iraqi Journal of Science, 2017,* vol. 58, no.3A, pp.1246-1255, 2017. DOI: 10.24996/ijs.2017.58.3A.8

[2] Al-Dabbas, Al-Kubaisi, Q., Hussein T. and Al-Kafaji, "Ground Water Assessment and Management at Khanaqin area, Diyala Governorate, Iraq". Second International Conference on Building, Construction and Environmental Engineering-BCEE2 which is going to be held in Beirut, Lebanon in October 17-18, 2015.

[3] Oleiwi, A. S., "Hydrogeological and Environmental study of Khanaqin area, Northeastern of Iraq". College of Science, University of Baghdad, 2015.

[4] Ahmed A.M., Mummad, A.A., and Dawood, K.S., "Hydrogeological study of upper part of Diyala Basin, Ministry of Water Recourse", *General Commission of Groundwater*, 2005,150p.

[5] Goossens, D., "Techniques to measure grain-size distribution of loamy sediments: a comparative study of ten instruments for wet analysis" *Journal of Sedimentology,* vol. *55,* pp. 65-96, 2008.

[6] Al-Dabbas, M. A. and Marwa A. A., "Assessment of soil pollution in the Ishaqi project area- Salah Al-Dean Governorate, Iraq", *Iraqi Journal of Science*, vol. 61, no. 2, pp. 382-388, 2020. DOI: 10.24996/ijs.2020.61.2.16

[7] Mathers, G., *The properties of groundwater, Department of Environmental science England, John Wiley and sons Inc., New York, U S A* , 1982, 406 p.

[8] Heath, R. C., *Basic Groundwater Hydrology*, U. S. *Geological Survey, Water Supply Paper, 220,* 1983, *86p.*

[9] Ibrahim I. A. and Al-Dabbas, M., "Climate parameters analysis as indication of Climate Changes for Central and eastern Iraq: Khanaqin climate condition as case study", *Iraqi Journal of Science, in press,* vol. 62, no.12, 2021.