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Comprehensive Detection and Evaluation of Groundwater-Bearing Aquifers at West Assiut Power Plant, Egypt

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THE WEST Assiut Power Plant is a cornerstone of the development projects in Upper Egypt. The first stage of this project was opened in May 2016, covering an area of approximately 85 acres, boasting a capacity of 1,500 MW of electricity, and entailing an initial cost of $1.5 billion. However, the realization of its full potential hinges on the availability of sustainable water resources, which is essential for continued growth and prosperity in Upper Egypt. The primary goal of this study is to provide a comprehensive verification and evaluation of groundwater-bearing aquifers in the West Assiut governorate, as well as to understand the interconnection and interactions among these aquifers. Additionally, an exhaustive qualitative assessment of groundwater appropriateness for various goals ranging from drinking and domestic use to livestock husbandry and agricultural irrigation is performed. The study detected the properties of the aquifers including transmissivity, storage coefficient, etc. through a detailed analysis of 46 wells to facilitate the required water resources to sustain the development and prosperity of Upper Egypt. The investigations of hydrochemistry of groundwater samples were detected to determine the hydrochemical properties of the groundwater. The range of the TDS value is 643 mg/l (freshwater) to 5715 mg/l (Moderately saline).

Keywords: Water bearing formation, pumping tests, Hydraulic parameters, Hydrogeochimestry, qualitative evaluation, West Assiut city.

1. Introduction

The Egyptian Government prioritizes new reclamation projects as key strategic objectives due to urbanization and high population density in the Nile Valley area. Given the significance of groundwater for these projects, thorough investigation and evaluation are imperative. Especially in arid regions, such as the study area (Fig. 1), extensive efforts are required to uncover and utilize new groundwater sources (Mahmoud and Kotb, 2017). This is essential, particularly following the construction of the Dayrout-Farafrah new road, which enhances accessibility and potential for development. The research area is located in the region that separates the western plateau from the Nile valley. It is seen in geological formations with a rather complex geological regime that is dated between the Quaternary and Tertiary periods. The entire zone is structurally a component of the ancient Nile Valley zone. The Assiut region has three primary aquifers in terms of hydrogeology. These aquifers are Separated from the top into three distinct aquifers: i) Upper Pleistocene (found in the Nile Valley area) composed of intercalations of fluvial sands and gravels; ii) Plio-Pleistocene (found in Wadi El Assiuty) composed of fine-grained sandstone formations; and iii) Lower Eocene limestone aquifer made up of fractured carbonate rocks (RIGW, 2017).

This study holds special importance as it focuses on evaluating and identifying different groundwater-bearing aquifers within a significant development project in Upper Egypt. The primary aim is to determine the hydraulic characteristics and qualitatively assess the aquifers, thereby fostering sustainable development in the region. This objective is achieved through comprehensive field and office work, encompassing pumping tests, recovery tests, and groundwater assessments. Numerous hydrogeological studies have been conducted in the

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western part of Assiut governorate, underscoring the critical need for informed resource management in this vital region. The hydrochemical investigation in the present study deals with the major ions concentrations, relative abundances, and physical parameters of groundwater. Samples of groundwater were collected from the different aquifers. 46 Samples of groundwater were analyzed by using the modern instrument using inductively coupled plasma mass spectrometry (ICP-MS) in the National Water Research Center laboratory for analysis operations according to the standard methods. Results of hydrochemical analysis were used to classify the different types of groundwater. It was used to evaluate the quality of the aquifers' groundwater for various uses. The following provides a summary of the relatively few previous studies carried out within the study area. According to El Miligy (2003), there are four main hydrogeological provinces in the Assiut Governorate, each with unique geological, hydrographic, and hydrologic features. The eastern province comprises the eastern plateau, the southern province includes Abu Tieg, Assiut, the Northern Province extends widely from Assiut to Dayrout, and the east-Ibrahimia province receives direct groundwater recharge from the Ibrahimia Canal. Furthermore, Mahmod (2015) investigated the assessment of groundwater in the Assiut Governorate, Egypt, for household and drinking purposes. The interaction between surface water (SW) and ground water (GW) and its effect on the groundwater salinity of the quaternary aquifer at the area between Assiut and Dayrout, EGYPT, was studied by Marco A. El-Dakar et al. (2016).

2. Study Area

The research area is situated in west Assiut Governorate in Upper Egypt, Approximately between longitudes 30˚ 59′ 45′′ and 31˚ 00′ 15′′ E and latitudes 27˚ 10′ 30′′ and 27˚ 11′ 10′′ N (Fig.1).

3. Geologic Setting

Geomorphologically, from west to east, the study area is dominated by the following three units (Abdel Moneim et al., 2016): First, the recent alluvial plain which represents the former irrigated farmlands utilizing the Nile's surface water and major waterways like Bahr Yousef, El-Ibrahimiya Canal, and El-Sohagiya. Secondly, the ancient alluvial plain that stretches from the limestone plateau cliff to the more recent alluvial plain. Moreover, groundwater is used for irrigation. Lastly, the limestone plateau forms the eastern and western boundaries of the Nile Valley and it is composed of limestone that has fractures, with sand and gravel at the surface (Figs. 2A, C).

Sedimentary rocks are the representative types of the surface mappable rock units of Tertiary and Quaternary age, as shown on the topographical geology map (Fig. 2B) (Conoco, 1987).

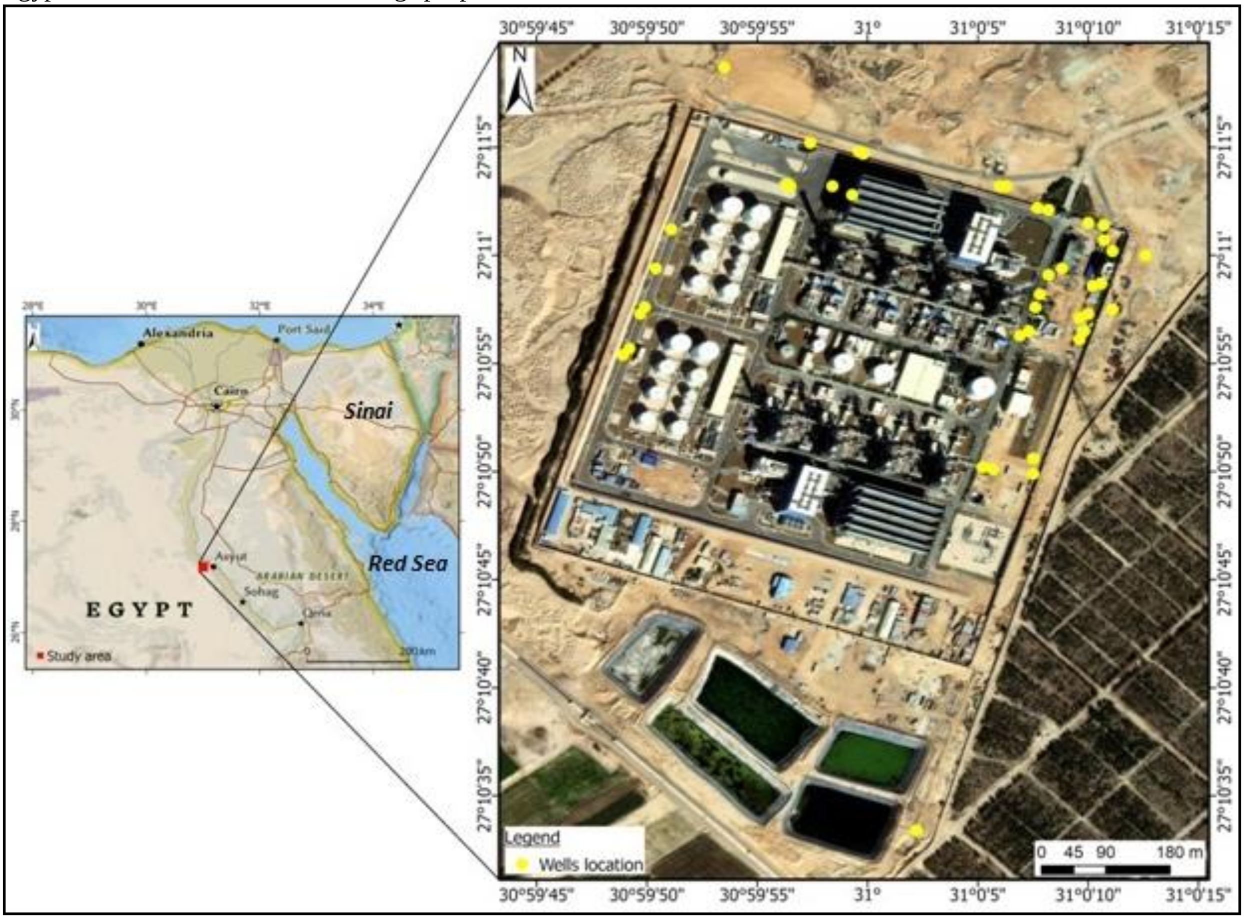

Fig. 1. A map showing the location of the study area overlaid on a high-resolution Google Earth satellite image, indicating the positions of the investigated wells.

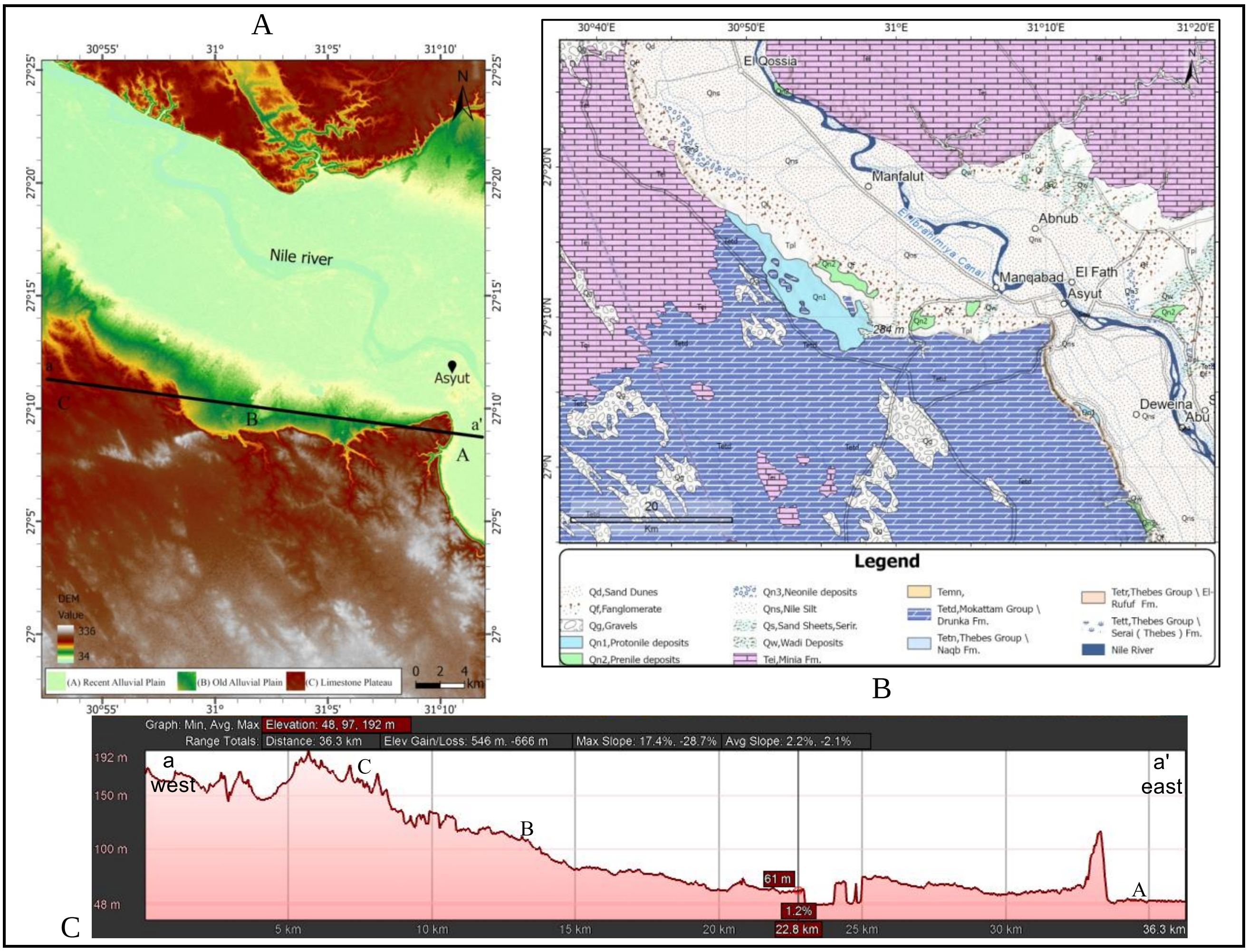

Fig. 2. A- Geomorphology and digital elevation model. B- Geological map (After Conoco 1987). C- Topographic profile a–a' of the research area.

4. Materials and methods

This work covers a series of studies that deal with, geology, hydrogeology, and hydrogeochemistry. The field studies, rock exposures, and hydrographic patterns using topographic maps and geological maps, carrying out pumping tests and recovery tests, injection tests on the representative wells, measuring the depth to water in the representative wells, full description of The study area's aquifers and groundwater availability to evaluate the possibilities for groundwater as an additional resource, getting representative samples to be examined chemically in the Central Laboratory for Environmental Quality Monitoring (CLEQM), representing the chemical data using standard diagrams and make qualitative evaluation for groundwater. Finally, understanding the connection and interaction between the different groundwater-bearing aquifers in West Assiut governorate.

The location of the studied wells is shown in (Fig.1). Forty-six wells were drilled at different depths varying from 172 to 1250 m. The groundwater samples were analyzed for physical properties as specific electric conductivity (EC), and pH measurements; and the chemical properties as major ions (potassium, sodium, magnesium and calcium, chloride, sulfate, bicarbonate, and carbonate) and nutrients (nitrate, ammonia, and phosphate), also (iron, manganese cadmium, zinc, copper lead, nickel, and chromium) as trace elements. The chemical analyses were carried out in the Central Laboratory for Environmental Quality Monitoring (CLEQM) laboratories according to the standard methods.

5. hydrogeological setting

A sedimentary sequence spanning a wide range of geologic time dominates the Assiut region from the Late Cretaceous to the Quaternary (Fig. 3) and Table 1. Generally, this succession's thickness averages roughly 1500 meters. (Ibrahim et al., 1995). The study region is divided into three major aquifers. The Lower Eocene limestone aquifers, the Plio-Pleistocene, and the Pleistocene.

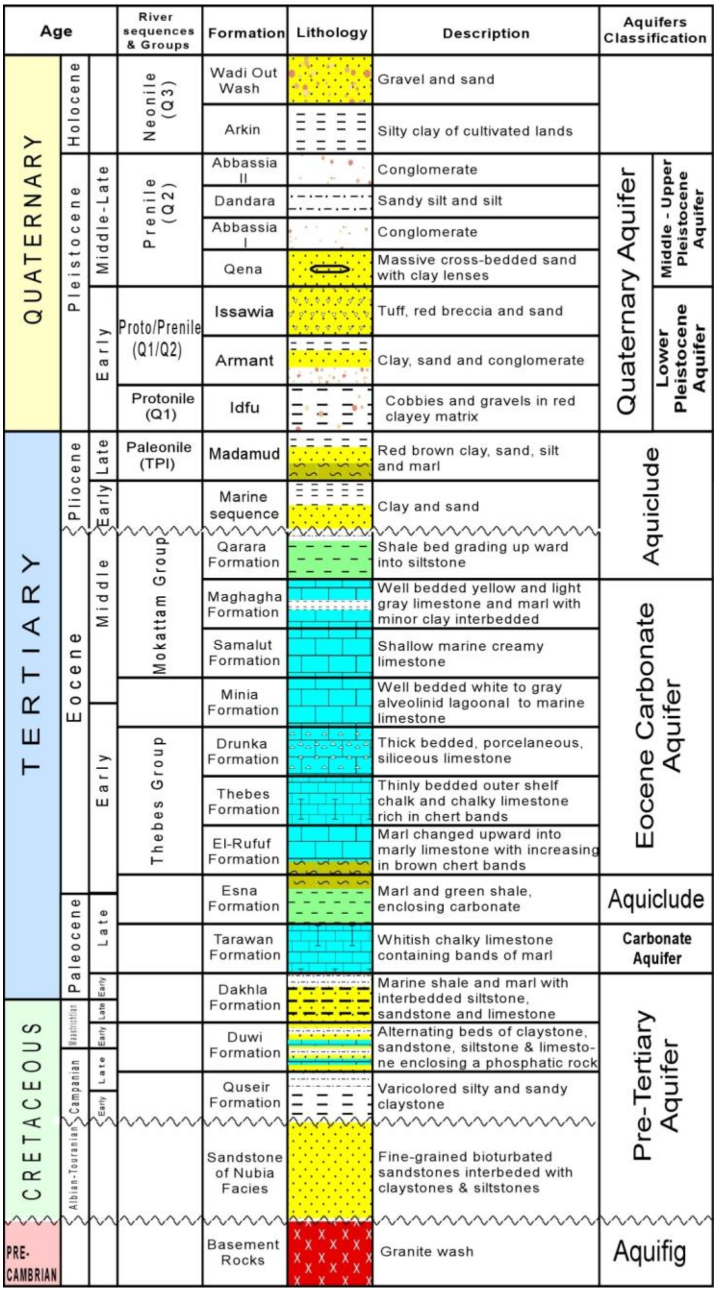

Fig. 3. Lithological Section of the research area Accompanied by Aquifer Classification (After Said,1981 & EGPC).

Table 1. Sources of recharge to the aquifers in Assiut area and their discharge mechanisms (After Present work, Tamer and Rashwan, 1987 and Awad et al., 1997).

Aquifer	Recharge sources	Discharges	Depth to water
Pleistocene (Nile Valley)	Seepage from the surface water system. Infiltration of return flow water after irrigation.	-Discharge to the underlying -PlioPleistocene aquifer -Out flow into the River Nile. -Evapotranspiration - Pumping from wells utilized for food production and agriculture.	3 – 20 m
Pleistocene (Wadi El Assiuti)	- from the aquifer beneath the Nubian sandstone system. -The surface runoff due to the occasional flash floods	-Pumping from wells used mainly for irrigation.	26-80 m
Plio-Pleistocene	-Vertical seepage from the overlying Pleistocene aquifer at the desert fringes. - seepage from the rare flash floods and the surface water system. -Possibly from the older aquifers.	-Pumping from wells used mainly for irrigation. -Lateral seepage to the neighboring. The Nile Valley's Pleistocene aquifer.	13-65 m
Eocene	-From the underlying Nubian sandstone aquifer system. -The surface runoff due to the occasional flash floods.	-Pumping from wells used in irrigation and human consumption.	92-150 m

The Plio-Pleistocene aquifer is symbolized by a thin strip running between the western limestone plateau and the former Nile Valley agricultural fields along the western desert fringes. It is dominated by fluvial fine-grained sand and sandstone of Madamud Formation overlying thinner marine sandstones of Kom El Shelul Formation. Its main constituents are cracked carbonate rocks of the Drunka and El Minia formations. The groundwater surface of the lower Eocene Limestone aquifer is visible at 92 to 150 meters in depth. (Fig. 4).

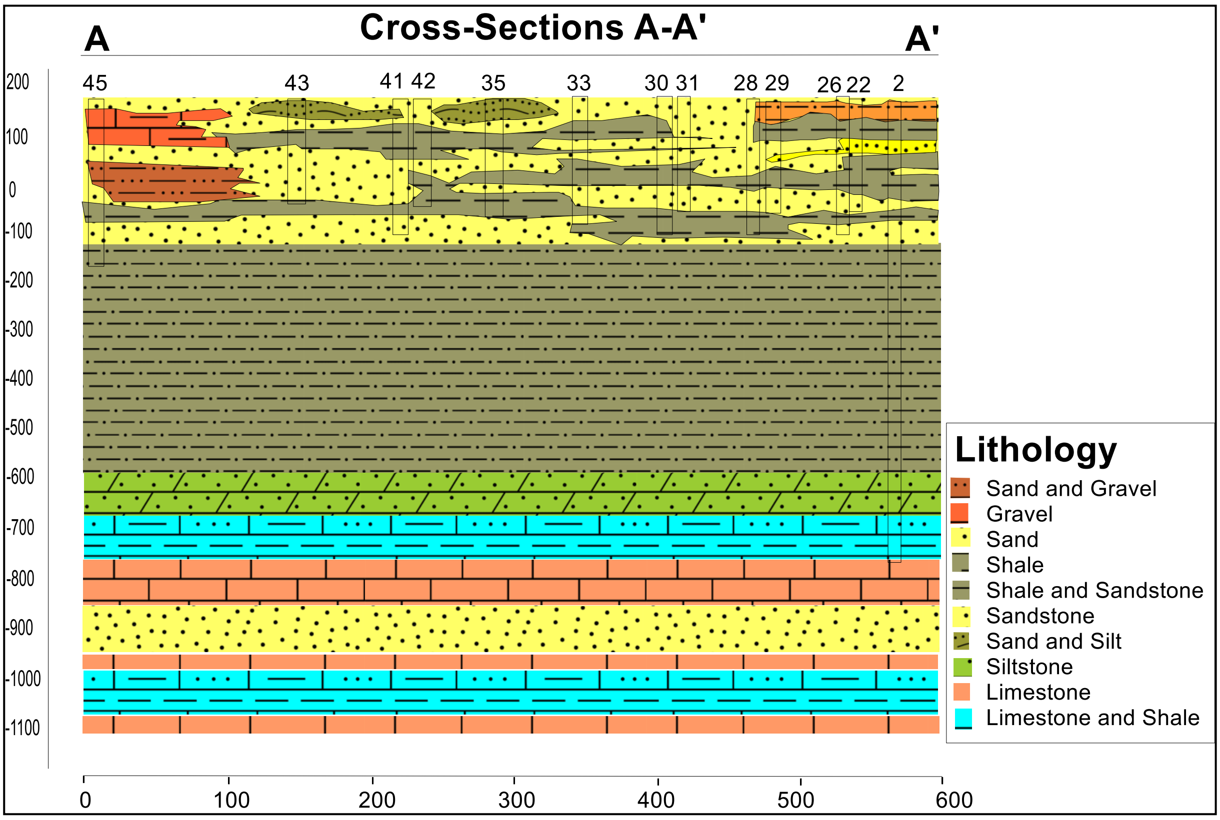

Fig. 4. Hydrogeological cross-section in the west-east area under research (After RIGW, 2017).

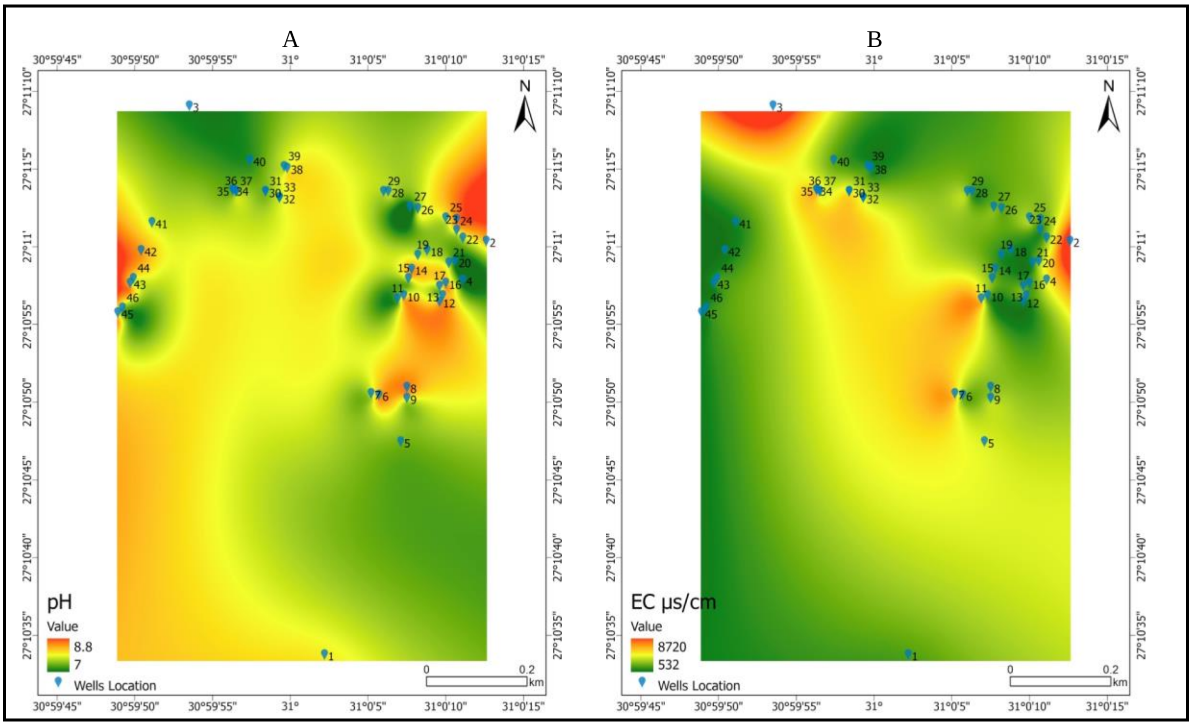

Fig. 5. A- pH zonation Map, B- Electric Conductivity Map.

6. Results and Discussion

The study area's groundwater samples' hydrochemical analysis are shown in table 2.

Content of Hydrogen Ion (pH)

Guidelines for pH in drinking and irrigation water range from 6.5 to 8.5 in pure natural water, according to WHO (2011), EPA, and FAO (1985). Based on the results of the research area's groundwater sample analysis (Fig. 5), The value of pH has a range of 7.34 to 8.46. The results demonstrate that the research area's groundwater is slightly alkaline and acceptable for irrigation as well as drinking.

Conductivity of Electricity (EC)

In the research area, groundwater conductivity varies from (1.004 to 8.53) µs/cm. The conductivity of groundwater is strongly linked to the total amount of dissolved salts (ions) in the research area (Figs. 5A, B).

Table 2. Hydrochemical examination of research area groundwater sample.

Well	pH	EC	Units	TDS	K^+	Na^+	Mg^{2+}	Ca^{2+}	Sum of	CL^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}	Sum of	Water Type
1	8.06	1.875	ppm	1200	13.03	360.7	10.58	26.9	411.21	404.8	17.85	418.9	0	842.55	$Na\text{-}HCO_3$
2	8.09	8.53	ppm	5715	12	1800	11.66	82	1905.66	2618	30.71	732	0	3382.71	Na-Cl
3	7.37	8.25	ppm	5280	80	1080	1192	471.2	2823.2	1660	1125	177	0	2962	$Mg\text{-}Cl_2$
4	7.37	3.75	ppm	2405	8	782	15.13	152	957.13	1092	281	107	0	1480	Na-Cl
5	7.6	3.73	ppm	2391	7	812	15.1	163	997.1	1059	264	117	0	1440	Na-Cl
6	8.32	2.54	ppm	1625	21.54	424.7	25.75	75.84	547.83	581	0.200	268.5	16.03	865.73	$Na\text{-}HCO_3$
7	7.75	4.98	ppm	3187	5.003	885.5	15.01	183.4	1088.91	1321	285.2	180.2	0	1786.4	Na-Cl
8	8.39	2.7	ppm	1720	3.005	500.8	24.23	71.6	599.635	749.7	160.3	150.3	0	1060.3	Na-Cl
9	7.71	3.3	ppm	2112	5.007	620.9	15.02	74.8	715.727	826.1	80.11	278.4	0	1184.61	Na-Cl
10	8.3	1.924	ppm	1231	4.008	370.8	22.68	4.008	401.496	541.1	38.68	217.4	26.05	823.23	Na-Cl
11	7.55	5.13	ppm	3283	8.004	800.4	56.89	172	1037.29	1421	163	241.1	0	1825.1	Na-Cl
12	8.4	1.034	ppm	663	3.007	200.5	13.24	17.04	233.787	192.5	20.35	250.6	28.07	491.52	$Na\text{-}HCO_3$
13	8.34	1.446	ppm	925	4.009	280.6	8.018	20.05	312.677	305.7	25.06	225.5	10.02	566.28	Na-Cl
14	8.37	2.06	ppm	1319	3.086	380.8	16	65.33	465.216	509	116.2	252.5	13.03	890.73	Na-Cl
15	7.59	2.56	ppm	1641	6.01	385.7	15.03	60.1	466.84	505.9	82.14	225.4	0	813.44	Na-Cl
16	8.4	1.736	ppm	1114	5.512	282.5	9.831	33.59	331.433	476	60.73	322.7	26.06	885.49	Na-Cl
17	7.61	2.58	ppm	1651	11.02	435.8	22.04	77.13	545.99	574	165.3	214.4	0	953.7	Na-Cl
18	7.85	1.323	ppm	846	3.007	270.6	9.743	14.47	297.82	279.7	11.83	325.8	0	617.33	$Na\text{-}HCO_3$
19	8.02	1.393	ppm	891	4.009	250.6	14.23	24.61	293.449	260.6	22.05	285.7	0	568.35	$Na\text{-}HCO_3$
20	7.34	3.12	ppm	1997	3.004	450.7	43.75	154.2	651.654	682.6	300.4	229.7	0	1212.7	Na-Cl
21	7.88	1.557	ppm	996	3.007	292.6	8.018	25.73	329.355	325.7	32.07	225.5	0	583.27	Na-Cl
22	7.67	2.85	ppm	1829	5.008	534.8	21.03	66.1	626.938	587.9	130.2	175.3	0	893.4	Na-Cl
23	7.75	1.469	ppm	940	7.016	285.6	10.02	31.07	333.706	288.4	0.200	310.7	0	599.301	$Na\text{-}HCO_3$
24	8.39	1.73	ppm	1104	2.445	327.7	13.82	53.42	397.385	399.9	60.43	320.7	12.03	793.06	Na-Cl
25	7.82	2.98	ppm	1910	5.008	575.9	15.02	80.81	676.738	775.2	110.2	259	0	1144.4	Na-Cl
26	7.89	2.12	ppm	1356	5.01	350.7	16.33	76.5	448.54	511	100.2	250.5	0	861.7	Na-Cl
27	7.05	2.61	ppm	1669	7.012	485.8	17.03	64.27	574.112	662.1	110.2	195.5	0	967.8	Na-Cl
28	7.81	1.69	ppm	1081	2.658	254.3	27.05	62.26	346.268	380.8	93.9	240.5	0	715.2	Na-Cl
29	7.74	2.94	ppm	1881	6.009	500.8	33.77	48.28	588.859	572.9	104.2	243.4	0	920.5	Na-Cl
30	7.5	5.3	ppm	3432	4.502	586.2	57.02	152.1	799.822	1075	219.1	128	0	1422.1	Na-Cl
31	7.8	4.2	ppm	2717	4.604	636.6	66.06	177.2	884.464	1208	250.2	115.1	0	1573.3	Na-Cl
32	8.1	2.7	ppm	1806	5.909	460.7	38.66	103.2	608.469	851.4	147.2	203.3	0	1201.9	Na-Cl
33	7.7	5.1	ppm	3303	5.903	772.4	84.04	203.1	1065.44	1701	226.1	94.05	0	2021.15	Na-Cl
34	7.9	4.8	ppm	3080	4.703	697.5	70.05	185.1	957.353	1449	345.2	92.06	0	1886.26	Na-Cl
35	7.4	5.5	ppm	3532	5.302	740.2	75.02	181.1	1001.62	1450	310.1	89.03	0	1849.13	Na-Cl
36	7.8	4	ppm	2576	5.406	607.6	51.05	129.1	793.156	1123	160.2	152.2	0	1435.4	Na-Cl
37	7.9	3.8	ppm	2470	6.107	626.7	47.25	142.2	822.257	1197	207.2	156.2	0	1560.4	Na-Cl
38	8.1	1.473	ppm	943	4.009	280.6	3.498	29.74	317.847	320.7	59.94	200.5	0	581.14	Na-Cl
39	7.87	1.847	ppm	1182	4.008	280.6	12.27	52.2	349.078	340.7	44.09	326.7	0	711.49	Na-Cl
40	7.45	2.19	ppm	1404	4.008	310.6	40.08	110.2	464.888	535	138.3	235.4	0	908.7	Na-Cl
41	7.94	1.283	ppm	821	2.005	240.6	10.23	20.42	273.255	250.6	34.08	290.7	0	575.38	$Na\text{-}HCO_3$
42	8.38	1.156	ppm	740	2.005	204.7	16.36	29.32	252.385	253.9	31.98	200.5	24.06	510.44	Na-Cl
43	8.46	1.17	ppm	749	1.173	200.5	16.87	27.71	246.253	231.6	32.88	207.5	25.06	497.04	Na-Cl
44	7.89	1.914	ppm	1224	3.006	370.8	14.03	35.07	422.906	425.9	62.47	275.6	0	763.97	Na-Cl
45	8.33	1.004	ppm	643	1.263	174.9	14.74	26.06	216.963	154.4	57.14	260.6	13.03	485.17	$Na\text{-}HCO_3$
46	7.6	1.51	ppm	966	3.007	291.7	9	33.07	617.477	338.8	41.09	231.5	0	611.39	Na-Cl

Groundwater Salinity

TDS is a measurement of the quantity of materials dissolved in water, which gives the degree of water freshness. In the area under study, groundwater salinity ratings vary from 643 mg/l to 5715 mg/l. The salinity distribution map of the studied area (Fig. 6) shows that the low salinity water < 1000 mg/l (freshwater) according to (Hem, 1970). This category is considered the predominant water salinity type in the studied area. Also; there is the class of higher salinity water (1000-2000 mg/l) in the area, a class of salinity ranging from 2000 to 3000 mg/l is extending westward of the studied area.

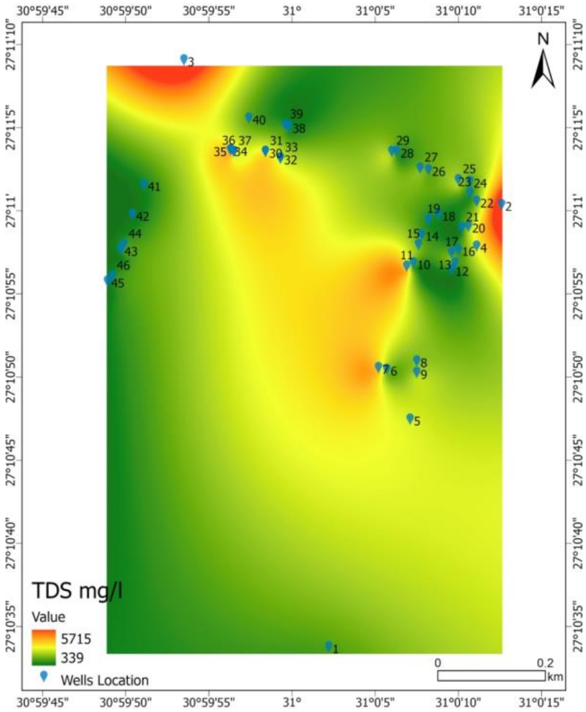

Fig. 6. Total Dissolved Solids Map of the Study Area.

Water with a salt level of less than 600 mg/l is typically regarded as having decent palatability; drinking water loses a substantial deal of its flavor at TDS levels higher than roughly 1000 mg/l. However, According to the WHO International Standards for Drinking Water, total solids concentrations higher than 1500 mg/l would significantly reduce the water's suitability for drinking (WHO, 2011), whereas the Environmental Protection Agency (EPA, 2011) set a TDS guideline of 500 mg/l.

Major Cations

The chemical analysis indicates that the groundwater in the investigated area has a potassium level ranging from 1.173 to 80 mg/l. Sodium concentrations in groundwater vary from 174.9 to 1800 mg/l. Magnesium concentrations range from 3.498 to 84.04 mg/l. The calcium ion concentration in the current study is between 12 and 4.008 mg/l. The World Health Organization recommends 200 mg/l of sodium. (WHO, 2011) so samples no 12 and 45 are found to be accepted while the rest samples are found to be exceeded the recommended guideline. On the other hand, no guideline was suggested for potassium while calcium and magnesium are mainly related to hardness (Figs. 7A, B, C, and D).

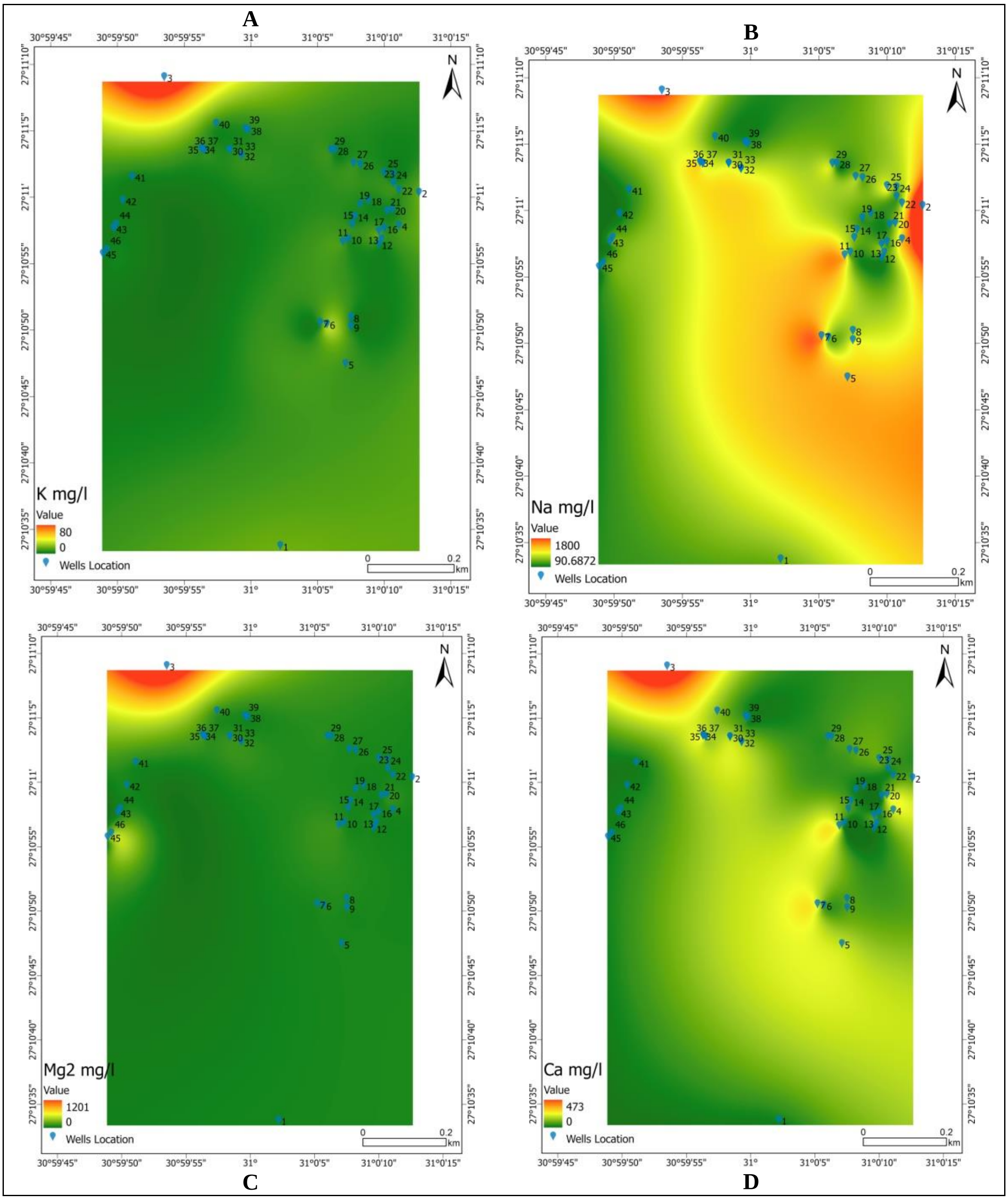

Fig. 7. Major Cations Concentration Maps (A-Potassium, B- Sodium, C- Magnesium, D calcium).

Major Anions

Generally In the examined area, the content of chloride varies from 154.4 to 2618 mg/l. According to WHO (2011), the maximum permissible amount of chloride is 250 mg/l. The area under investigation had sulfate concentrations ranging from 0.2003 to 345.2 mg/l. The data from the chemical analysis indicate that the concentration of bicarbonates in the studied area is varied between 94.05 and 732 mg/l. and the guideline for sulfate content is 500 mg/l (WHO, 2011). The content of carbonates in the area under study varies from 0.2003 to 28.07. According to WHO (2011), there is no evidence of a chloride recommendation value for drinking water. (Figs.8A, B, C and D).

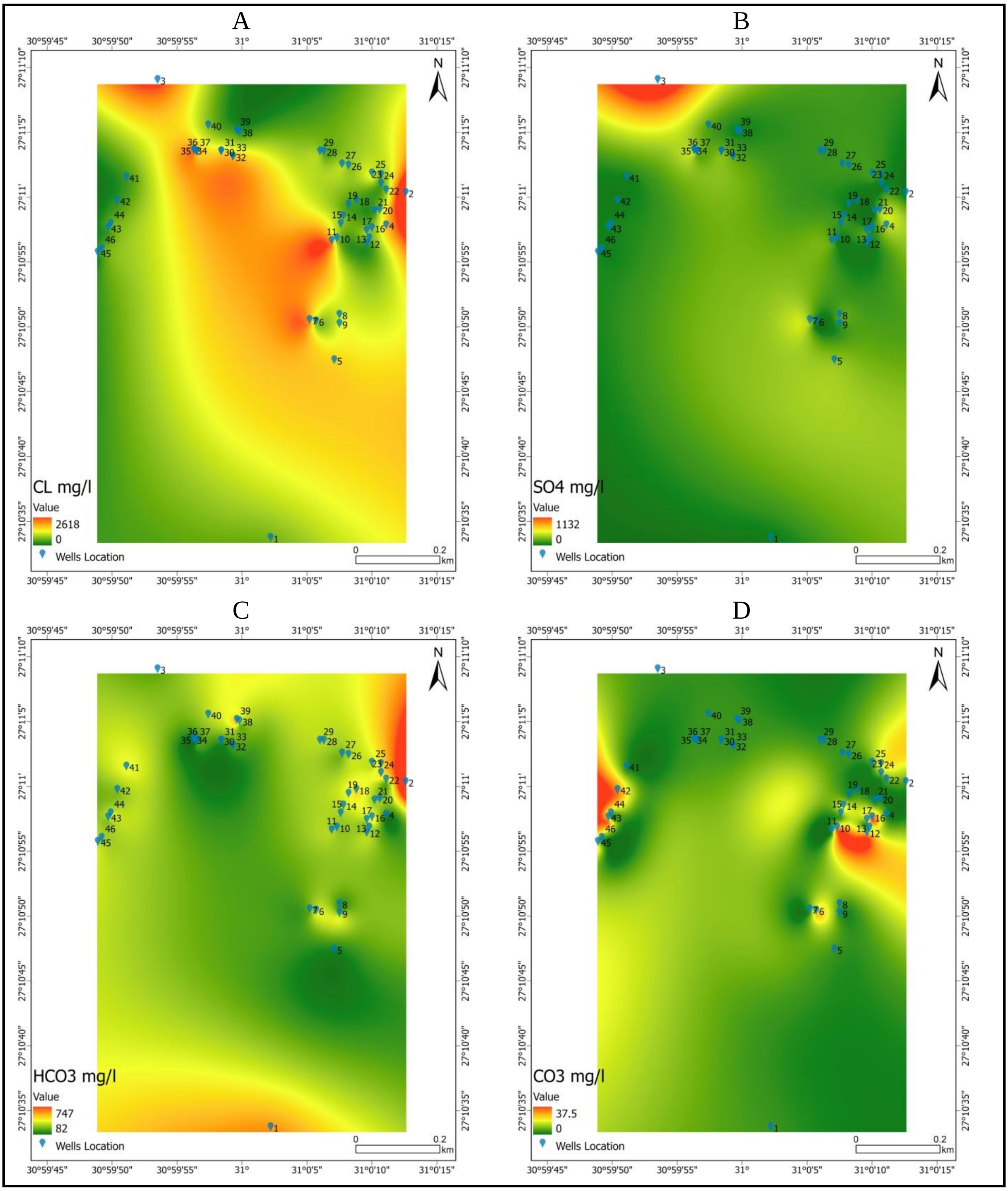

Fig. 8. Major Anions Concentration Maps (A- chloride, B- sulfate, C- bicarbonates, D carbonates).

Water Types and Origin

- **Piper Diagram**

Generally, (Na-Cl) type water represents the general water type in the main wells (Fig.9). In addition to ($Na-HCO_3$) type water which is associated with well no. 1, 6, 12, 18,19,23,41, and 45 in the study area. ($Mg-Cl_2$) type water is represented in well no. 3.

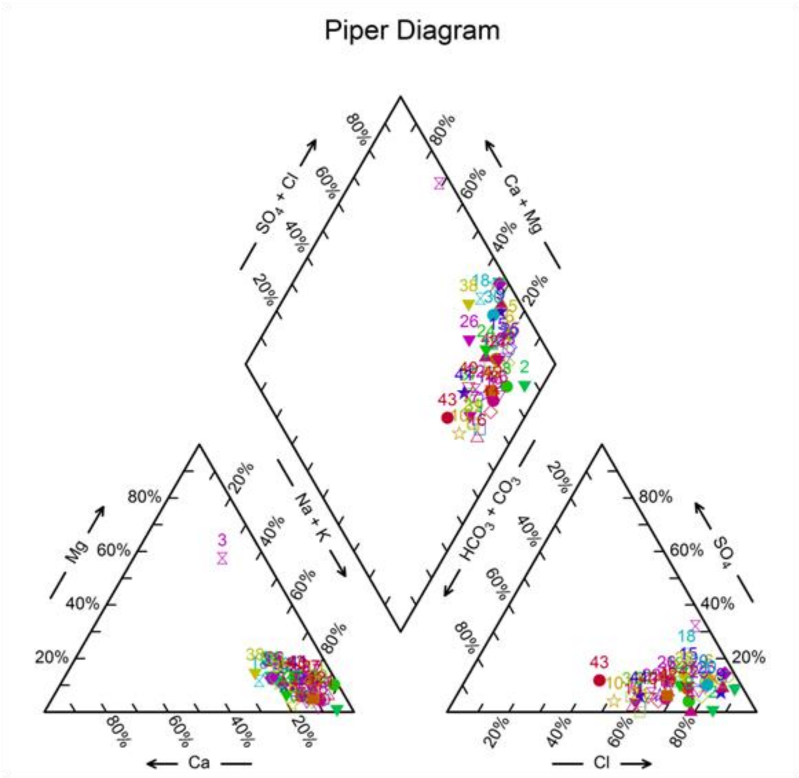

Fig. 9. Piper Classification Diagram.

- **Schoeller's diagram**

The charting of the chemical data on the semilogarithmic paper represents the relationship between various ions. Where the cations and anions are grouped according to how mobile they are. This relationship shows that the water samples in the studied area are mainly characterized by the following pattern (Fig. 10.).

According to Schoeller's graphic, all of the groundwater samples in the research area had high Cl content and high Na content, and they all showed almost the same trend of major ion rise and reduction, or similar "fingerprints" in the water.

The samples revealed a distinct ionic composition with a cationic order of abundance and a Na+ dominance. Cl > SO_4 < HCO_3 > CO_3 < K < Na > Mg < Ca epm, epm,i.e, The Na-Cl type was used to characterize the chemical composition, as demonstrated in Fig. 13.

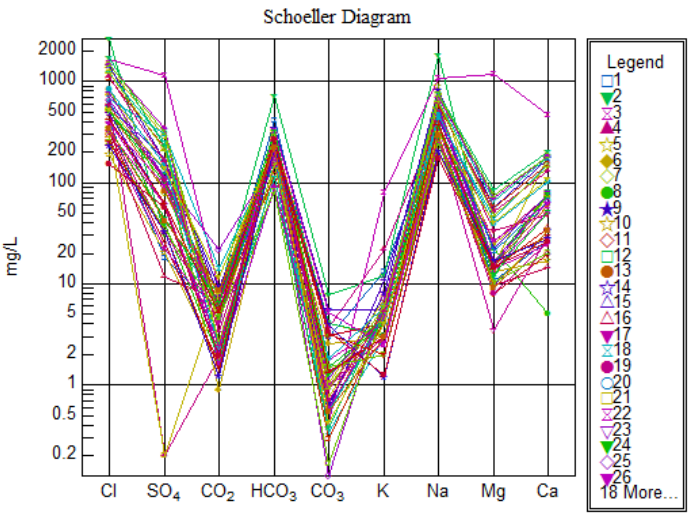

Fig. 10. Schoeller Diagram.

Durov diagram

Two ternary diagrams were used to plot the results in epm (Durov diagram) where; the Plotting the values of the cations against the anions perpendicularly resulted in a center rectangular as shown in Fig. 11.

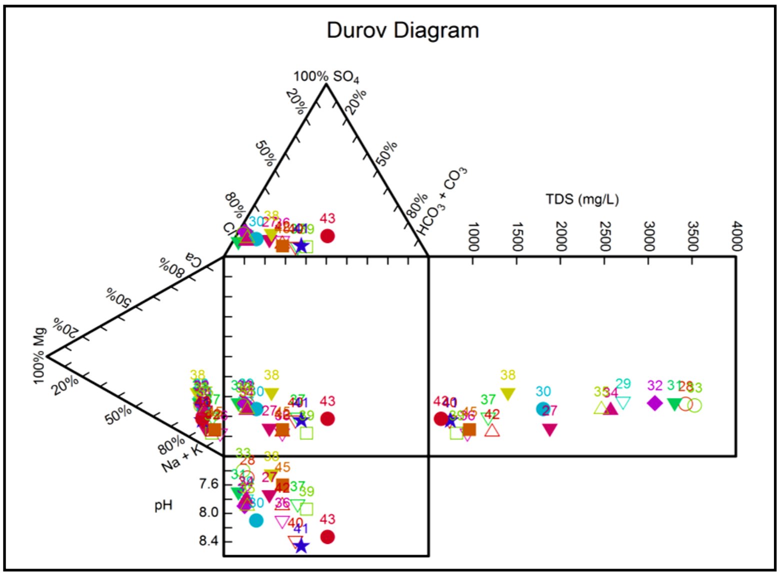

Fig. 11. Durov's Classification Diagram.

Elements in Trace

Groundwater contains minor elements in concentrations of less than 0.1 mg/l, but sometimes much higher. The following ions Iron (Fe^{2+}), Manganese (Mn^{2+}), Zinc (Zn^{2+}), Lead (Pb^{2+}), Cadmium (Cd^{2+}), Chromium (Cr^{3+}), Copper (Cu^{2+}), and Nickel (Ni^{2-}) are the most common minor elements encountered in the area under investigation, they were investigated to assess the water's quality and determine these components' harmful impacts.

Iron (Fe^{2+})

According to the iron concentration in the area under investigation (Fig. 12) it is clear that the minimum concentration of Iron (0.007 mg/l), while the maximum concentration (3.642 mg/l). According to WHO (2011) and EPA (2011), The recommended limit of iron in drinking water is 0.3 mg/l; however, the allowed maximum in groundwater is 1 mg/l. The highest amount of iron that is advised to be present in irrigated water is 5 mg/l, according to FAO (1985).

Manganese (Mn^{2+})

In the investigated area the concentration of Manganese content varies from (0.002 mg/l) to (0.19 mg/l) (Fig.12). According to WHO (2003), The maximum permitted value of 0.5 mg/l is set for manganese in drinking water, with a recommended of 0.1 mg/l. Additionally, the FAO (1985) states that 0.2 mg/l is the maximum acceptable content of manganese in irrigated water.

Zinc (Zn^{2+})

In the area under investigation the concentration of Zinc (Zn^{2+}) content varies between (0.01 mg/l) and (0.11 mg/l) (Fig.15). According to WHO (2011), The recommended daily allowance of zinc in drinking water is 3 mg/l. FAO (1985) states that 2 mg/1 is the recommended maximum for zinc content in irrigation water.

Lead (Pb^{2+})

High concentration of Leads affects in the human health and usually correlated with blood test levels, also, the nerve system is negatively impacted by it. The concentration of Lead in the studied area is very low. It ranges between (0.003 mg/l) and (0.03 mg/l) (Fig 12). The recommended level of lead in drinking water is 0.01 mg/l, per the World Health Organization (2011). Additionally, the highest recommended limit for lead content in irrigation water is 5.0 mg/l, according FAO (1985).

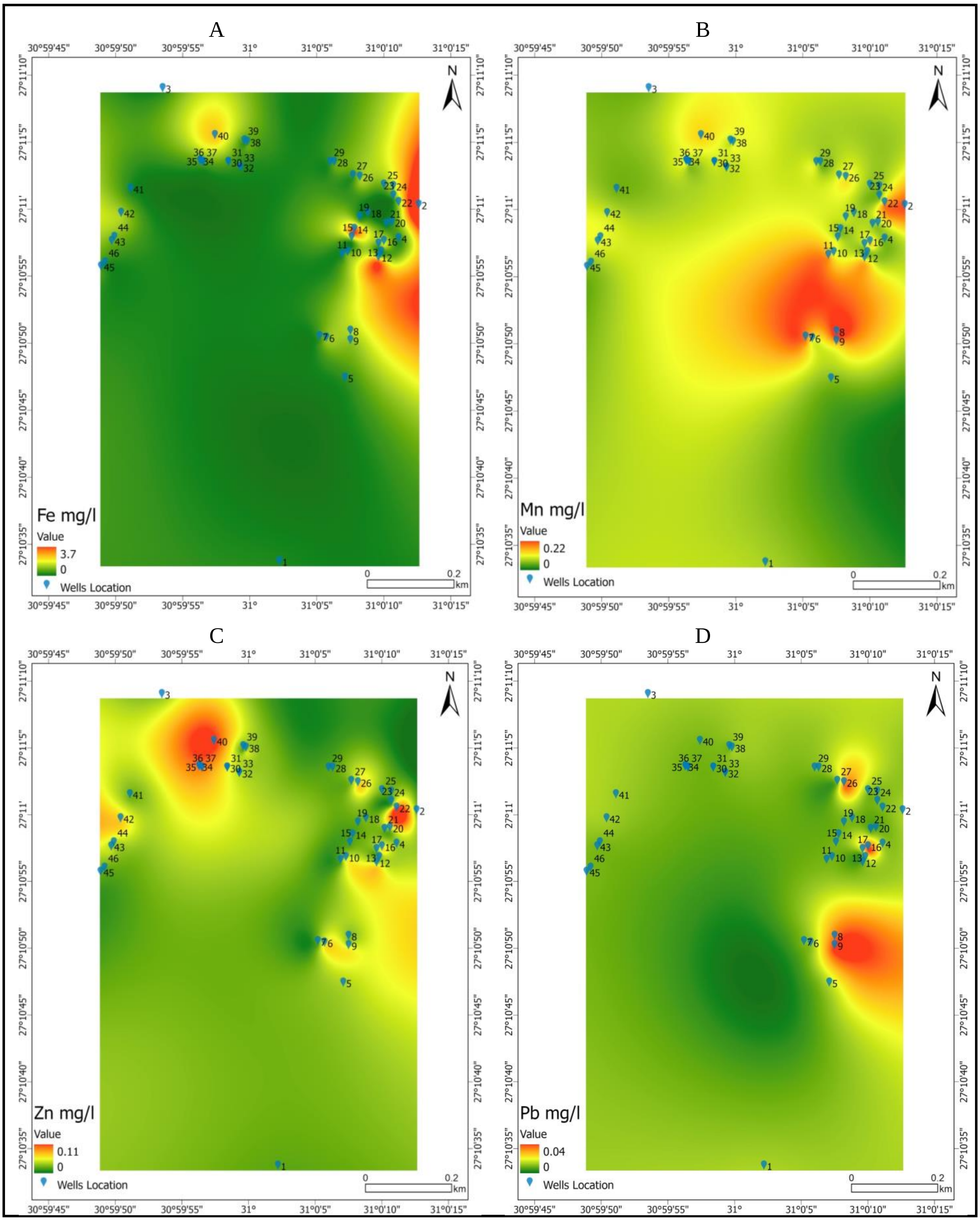

Fig. 12. Trace Elements Concentration Maps (A-Iron, B- Manganese, C- Zinc, D- Lead).

Cadmium (Cd^{2+})

The range of cadmium concentrations in the examined area is 0.001 mg/l to 0.01 mg/l, which is accepted as very low. (Fig. 13). The recommended standard for cadmium in drinking water is (0.003 mg/l), according to WHO (2011).

Chromium (Cr^{3+})

In the area under investigation, the concentration of chromium content varies from 0.001 mg/l to 0.098 mg/l.

The suggested recommendation value for chromium in drinking water is 0.05 mg/l, according WHO (2011) (Fig. 13). Additionally, the maximum permissible content of chromium in irrigation water is 0.1 mg/l, per FAO 1985.

Copper (Cu^{2+})

The copper content in the area under research varies from (0.001 mg/l) to (1.15 mg/l) (Fig. 13). According to WHO (2011) and EPA (2011), It was suggested that the drinking water's copper content should not exceed 1 mg/l. The recommended level of copper in irrigation water is two milligrams per liter, according to FAO (1985).

Nickel (Ni^{2+})

From a health perspective, nickel is significant primarily because of its high propensity for allergies. The concentration of Nickel content in the groundwater in the study area is ranged between (0.001 mg/l) and (0.15 mg/l) (Fig. 13). According to WHO (2011), the guideline value of Nickel in the drinking water was recommended to be (0.02 mg/l). The maximum amount of nickel that is advised for irrigation water is (0.2 mg/1), according to FAO (1985).

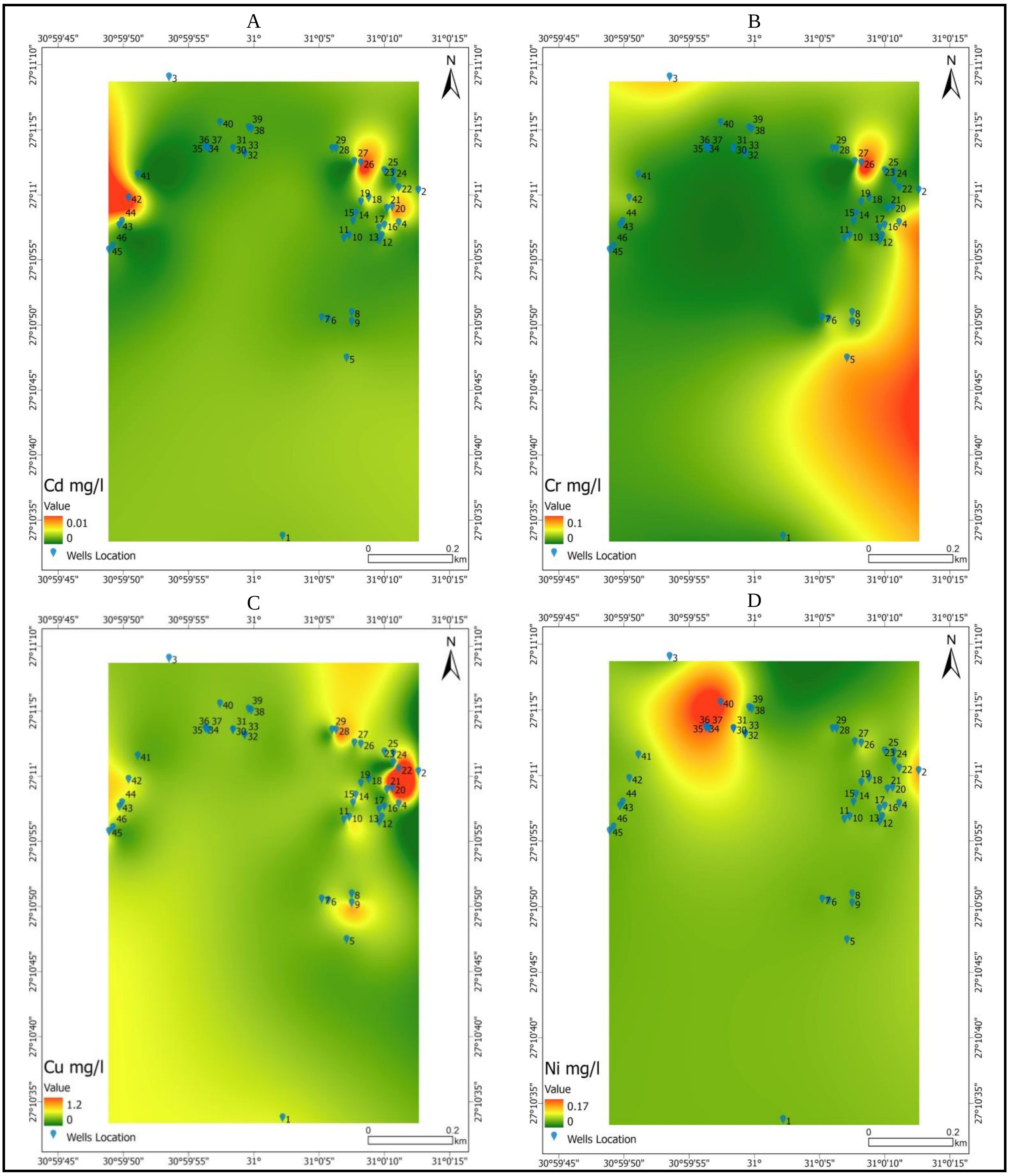

Fig. 13. Trace Elements Concentration Maps (A- Cadmium, B-Chromium, C- Coppered, D- Nickel) Nutrients.

The term "nutrients" refers to those substances which plants or animals need in order to live and grow, and are necessary for life as we know it, particularly for nitrogen and phosphorus. Eating plants or other animals provides animals with the resources they need to develop and procreate. In the context of water quality, "nutrients" refers primarily to those substances that are required for plant development.

Phosphate (PO_4^{2-})

The majority of the wells in the investigated area have phosphate content concentrations ranging from 0.2 mg/l to 1.52 mg/l. which regarded as much concentration (Fig. 14). His water is contaminated with phosphate and should not be used, as advised by the World Health Organization (2011), the National Academy of Sciences, and the National Academy of Engineering (1972);the appropriate phosphate guideline is less than 0.1 mg/1;

Nitrate (NO_3^-)

All sources of combined nitrogen, especially those containing both organic nitrogen and ammonia, should be regarded as possible sources of nitrate since the majority of nitrogenous elements in natural water likely to be transformed to nitrate. (Atta et al., 2008). The region's nitrate content concentrations vary from 0 mg/l to 84.04 mg/l (Fig. 14). According to WHO (2011) where the constructed guideline is (50 mg/l). Also, according to FAO (1985).

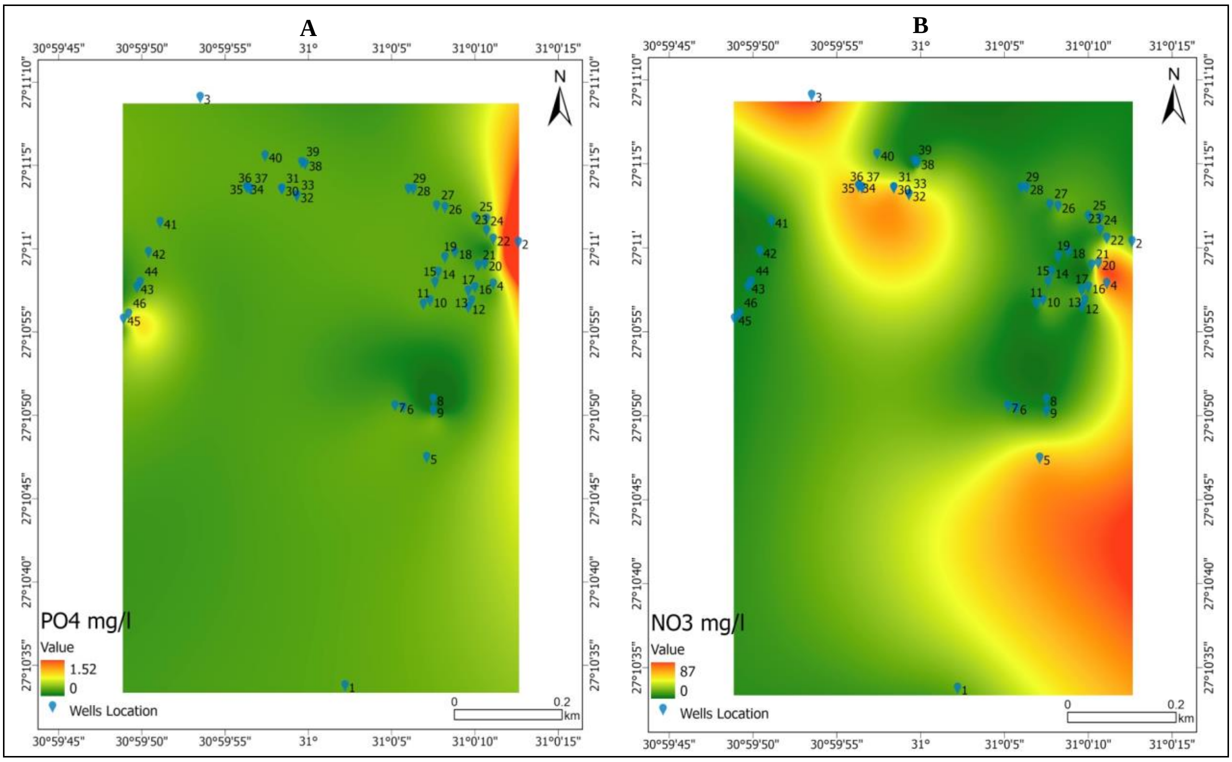

Fig. 14. Nutrients Concentration Maps (A- Phosphate, B- Nitrate).

• Sodium's Relative Proportion to Other Cations

Wilcox 1948 was defining the relative percentage of Na^+ to common cations by the following relation;

$$Na\% = \frac{Na^+}{Ca^{2+} + Mg^{2+} + Na^+} \times 100$$

Referring to Wilcox's diagram (Fig. 15), it's clear that, most of groundwater in the investigated area is mainly permissible to good and doubtful to unsuitable to use for irrigation purposes in the studied area. On the other hand, excellent to good water to use.

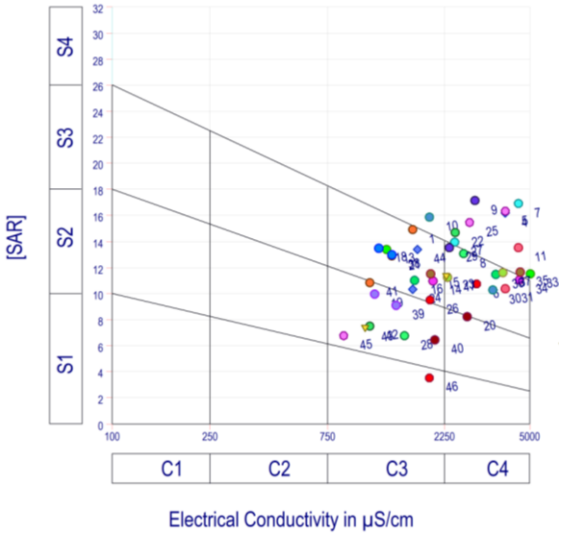

Fig. 15. Suitability of Irrigation Water Diagram (After Wilcox, 1948).

- **The Residual Sodium Carbonate (RSC)**

The term Residual Sodium Carbonate could be defined by the following equation;

RSC = [(CO_3^- + HCO_3^-) - (Ca^{2+}+ Mg^{2+})]

According to (Richard, 1954), It is not appropriate to use water with more than 2.5 epm RSC for irrigation. water containing 1.25-2.5 epm RSC is marginal, while water having less than 1.25 epm RSC is probably save. The determined RSC of several groundwater samples within the examined area (Table 3) between -1486.2 and 305.339 epm for samples taken from groundwater.

Table 3. Residual Sodium Carbonate.

Well No	RSC	Well No	RSC	Well No	RSC	Well No	RSC	Well No	RSC
1	381.42	**11**	12.21	**21**	191.752	**31**	-128.16	**41**	260
2	638.34	**12**	248.39	**22**	88.17	**32**	61.44	**42**	178
3	-1486.2	**13**	207.452	**23**	269.61	**33**	-193.09	**43**	187
4	-60.13	**14**	184.2	**24**	265.49	**34**	-163.09	**44**	226
5	-61.1	**15**	150.27	**25**	163.17	**35**	-167.09	**45**	232
6	182.94	**16**	305.339	**26**	157.67	**36**	-27.95	**46**	-92
7	-18.21	**17**	115.23	**27**	114.2	**37**	-33.25		
8	54.47	**18**	301.587	**28**	151.19	**38**	167.262		
9	188.58	**19**	246.86	**29**	161.35	**39**	262.23		
10	216.762	**20**	31.75	**30**	-81.12	**40**	85.12		

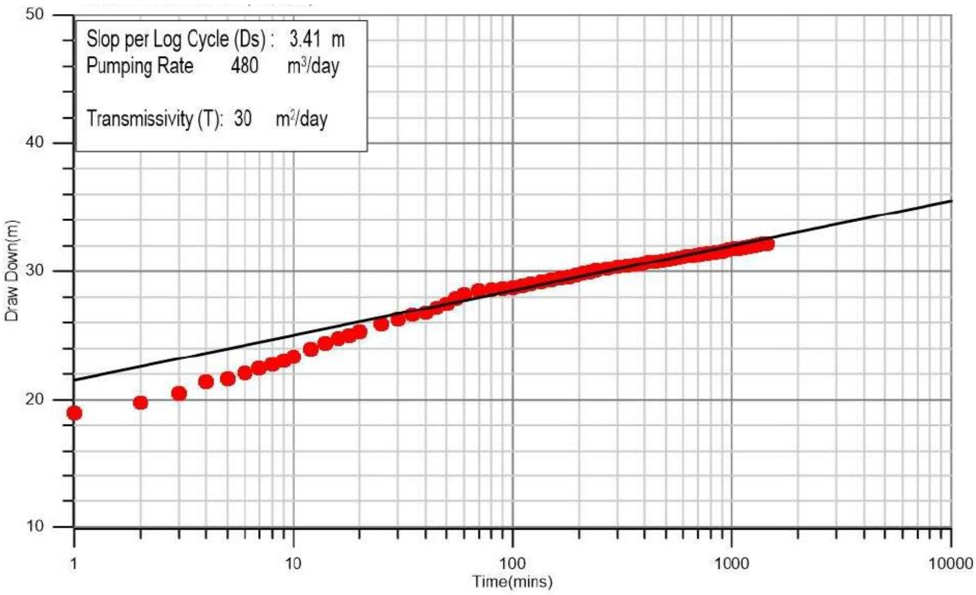

Fig. 16. Examination of the pumping test results.

Hydraulic parameters

hydraulic characteristics, which include the storage coefficient (S), transmissivity (T), and hydraulic conductivity (k) (or specific yields for unconfined aquifers). Under the effect of a unit gradient, the quantity of flow per unit cross section area is known as the hydraulic conductivity (k). The rate of flow through a cross-section of unit width throughout the whole thickness of the aquifer with a hydraulic gradient of unity is known as transmissivity (T). Additionally, it is equivalent to the sum of the hydraulic conductivity (also known as permeability) and the aquifer's thickness. The amount of water released or stored per unit surface area of the aquifer per unit change in the component of head normal to that surface is the definition of both the storage coefficient and the specific yield. The specific yield of an aquifer pertains to its unconfined portions, whereas the storage coefficient solely applies to its confined portions (Todd, 1959). Step tests and long-duration pumping tests (24 hours) were used as a method to assess the hydraulic characteristics of the research wells while in the field. The acquired data are summarized in Tables 4 and 5 and displayed in Fig. 16.

Table 4. The hydraulic parameters' computed values in the research wells.

Well no.	Total depth (m)	Depth to water (m)	Pumping rate(m^3/day)	Pumping duration (hr)	Total Drawdown (m)	Δs (m)	Transmissivity (m^2/day)
1	1250	**flow**	-	-	-	-	-
2	830	47.2	360	24	16.85	66.7	1
3	300	72.04	960	24	35	5.5	35
4	310	58.5	1248	24	7.98	0.59	400
5	310	59.85	480	24	32.18	3.41	30
6	203	60.5	1440	24	18.59	2.53	104
7	230	63.5	1248	24	33.49	1.98	120
8	172	62.89	1200	24	11.64	2.87	75
9	230	61.12	1680	24	32.33	3.4	100
10	191	60.89	1440	24	6.99	0.72	366
11	244	56.5	1680	24	8.56	1.2	260
12	202	60.4	1440	24	8.44	0.82	320
13	227	54.6	1680	24	5.96	0.78	400
14	185	59.9	1680	24	5.98	0.37	831
15	244	56.8	1680	24	6.33	0.81	400
16	191	59.35	1680	24	9.82	0.53	580
17	227	54.11	1680	24	6.33	0.74	420
18	203	58.17	1680	24	4.71	0.92	340
19	350	56.94	1680	24	7.05	81	400
20	197	54	1680	24	5.68	0.69	450
21	221	56.5	1680	24	6.57	0.85	400
22	203	52.41	1680	24	5.2	0.82	400
23	227	54.94	1680	24	7.41	0.58	550
24	215	57.77	1680	24	6.58	1.3	236
25	244	55.21	1680	24	7.41	0.41	750
26	203	57.93	1680	24	5.12	0.75	400
27	244	52.88	1680	24	8.75	0.51	600
28	197	60	1680	24	6.87	0.92	335
29	197	55.56	1680	24	7.68	0.99	310
30	190	58.7	1680	24	6.3	0.288	1067.5
31	190	58.7	1680	24	5.2	0.216	1423
32	242	57.25	1800	24	5.65	0.288	1143
33	242	57.25	1800	24	7.68	0.36	915
34	202	56.15	1632	24	7.71	0.216	1382.66
35	202	56.15	1632	24	7.58	0.245	1220
36	243	57.75	1800	24	5.65	0.32	1039
37	243	57.75	1800	24	5.12	0.31	1089
38	190	60.65	1680	24	10.7	1.6	192
39	256	57.18	1680	24	13.65	0.91	200
40	197	56.6	960	24	5.47	0.76	230
41	173	59.5	1680	24	9.41	1.1	300
42	203	60.82	1440	24	16.74	1.8	147
43	190	60.84	1440	24	14.44	1.79	147
44	244	66.6	1200	24	34.74	5.9	50
45	209	70.65	1320	24	8.44	3.2	76
46	239	58	1440	24	21.9	3.8	100

Table 5. Results of Drawdown Pumping Tests (step).

Well No.	Stage No.	Pumping rate (Q) m^3 / hr	Formation loss Coefficient(B) hr / m^2	Well loss Coefficient(C) hr^2 /m^5	Well Efficiency (%)	Dynamic water level	drawdown	Stage time (hr)
1	-	-	-	-	-	-	-	-
	-	-			-	-	-	-
	-	-			-	-	-	-
2	-	-	-	-	-	-	-	-
	-	-			-	-	-	-
	-	-			-	-	-	-
3	1	20	0.7	0.0035	90.91	87.46	15.42	2
	2	30			86.96	96.21	24.17	2
	3	40			83.33	105.65	33.61	2
4	1	42	0.13	0.00022	93.36	64.55	6.00	2
	2	52			91.91	66.11	7.56	2
	3	62			90.50	67.69	9.14	2
5	1	20	0.5	0.0045	90.91	87.46	15.42	2
	2	30			85.94	93.26	26.15	2
	3	40			83.33	105.65	33.61	2
6	1	30	0.25	0.00028	96.75	68.39	7.89	2
	2	50			94.70	73.79	13.29	2
	3	70			92.73	79.69	19.19	2
7	1	30	0.39	0.00463	73.74	78.73	15.23	2
	2	40			67.80	87.61	24.11	2
	3	52			61.83	95.34	31.84	2
8	1	30	0.0016	0.1	0.05	67.34	4.45	2
	2	50			0.03	72.55	9.66	2
	3	70			0.02	77.83	14.94	2
9	1	30	0.35	0.00106	91.67	72.38	11.26	2
	2	50			86.85	81.59	20.47	2
	3	70			82.51	90.36	29.24	2
10	1	30	0.093	0.0005	86.11	64.57	3.68	2
	2	50			78.81	66.43	5.54	2
	3	70			72.66	68.53	7.64	2
11	1	30	0.057	0.0005	79.17	58.66	2.16	2
	2	50			69.51	60.58	4.08	2
	3	70			61.96	62.93	6.43	2
12	1	30	0.081	0.00079	77.36	63.59	3.19	2
	2	50			67.22	66.08	5.68	2
	3	70			59.43	68.33	7.93	2
13	1	30	0.083	0.00013	95.51	57.18	2.58	2
	2	50			92.74	59.12	4.52	2
	3	70			90.12	60.98	6.38	2
14	1	30	0.077	0.00027	90.48	62.40	2.50	2
	2	50			85.08	64.59	4.69	2
	3	70			80.29	66.48	6.58	2
15	1	30	0.061	0.00026	88.66	60.84	2.04	2
	2	50			82.43	62.65	3.85	2
	3	70			77.02	64.30	5.50	2
16	1	30	0.1	0.00035	90.50	62.68	3.33	2
	2	50			85.11	65.35	6.00	2
	3	70			80.32	68.04	8.69	2
17	1	30	0.082	0.00007	97.50	57.25	3.14	2
	2	50			95.91	59.02	4.91	2
	3	70			94.36	60.80	6.69	2
18	1	30	0.016	0.00053	50.16	59.05	0.88	2
	2	50			37.65	60.51	2.34	2
	3	70			30.13	61.71	3.54	2
19	1	30	0.079	0.00013	95.30	59.40	2.46	2

	2	50			92.40	61.22	4.28	2
	3	70			89.67	63.03	6.09	2
20	1	30	0.071	0.00015	94.04	56.26	2.26	2
	2	50			90.45	57.94	3.94	2
	3	70			87.12	59.68	5.68	2
21	1	30	0.071	0.00015	94.04	56.26	2.26	2
	2	50			90.45	57.94	3.94	2
	3	70			87.12	59.68	5.68	2
22	1	30	0.072	0.00009	96.39	54.65	2.24	2
	2	50			94.12	56.28	3.87	2
	3	70			91.95	57.88	5.47	2
23	1	30	0.071	0.00037	86.48	57.42	2.48	2
	2	50			79.33	59.36	4.42	2
	3	70			73.27	61.77	6.83	2
24	1	30	0.075	0.000045	98.23	59.46	1.69	2
	2	50			97.09	60.66	2.89	2
	3	70			95.97	61.84	4.07	2
25	1	30	0.029	0.00043	69.21	56.43	1.22	2
	2	50			57.43	57.86	2.65	2
	3	70			49.07	59.27	4.06	2
26	1	30	0.057	0.00016	92.23	59.80	1.87	2
	2	50			87.69	61.12	3.19	2
	3	70			83.58	62.75	4.82	2
27	1	30	0.079	0.00051	83.78	55.75	2.87	2
	2	50			75.60	57.99	5.11	2
	3	70			68.88	61.00	8.12	2
28	1	30	0.052	0.00019	90.12	61.72	1.72	2
	2	50			84.55	63.17	3.17	2
	3	70			79.63	64.36	4.36	2
29	1	30	0.068	0.00023	90.79	57.80	2.24	2
	2	50			85.53	59.70	4.14	2
	3	70			80.86	61.44	5.88	2
30	1	40	0.072	0.000168	91.46	61.85	3.15	2
	2	55			88.63	66.53	4.68	2
	3	70			85.96	72.83	6.3	2
31	1	40	0.072	0.000168	91.46	61.85	3.15	2
	2	55			88.63	66.53	4.68	2
	3	70			85.96	72.83	6.3	2
32	1	40	0.072	0.0000345	98.12	59.96	2.96	2
	2	55			97.43	64.11	4.15	2
	3	70			96.75	69.76	5.65	2
33	1	40	0.072	0.0000345	98.12	59.96	2.96	2
	2	55			97.43	64.11	4.15	2
	3	70			96.75	69.76	5.65	2
34	1	40	0.048	0.000576	67.57	62.66	3.66	2
	2	55			60.24	68.56	5.9	2
	3	68			55.07	76.34	7.78	2
35	1	40	0.048	0.000576	67.57	62.66	3.66	2
	2	55			60.24	68.56	5.9	2
	3	68			55.07	76.34	7.78	2
36	1	40	0.096	0.0001152	95.42	59.96	2.96	2
	2	55			93.81	64.11	4.15	2
	3	72			92.05	69.67	5.65	2
37	1	40	0.096	0.0001152	95.42	59.96	2.96	2
	2	55			93.81	64.11	4.15	2
	3	72			92.05	69.67	5.65	2
38	1	30	0.11	0.00066	84.75	64.44	3.79	2
	2	50			76.92	68.12	7.47	2
	3	70			70.42	71.34	10.69	2
39	1	30	0.16	0.00051	91.27	62.42	5.24	2
	2	50			86.25	66.43	9.25	2
	3	70			81.76	70.83	13.65	2

40	1	20	0.052	0.0011	70.27	58.12	1.52	2
	2	36			56.77	59.72	3.12	2
	3	50			48.60	62.07	5.47	2
41	1	30	0.078	0.00086	75.14	62.50	3.00	2
	2	50			64.46	66.00	6.50	2
	3	70			56.44	68.91	9.41	2
42	1	30	0.2	0.00048	93.28	68.57	7.75	2
	2	50			89.29	71.83	11.01	2
	3	70			85.62	77.56	16.74	2
43	1	30	0.18	0.00036	94.34	66.60	5.76	2
	2	50			90.91	70.59	9.75	2
	3	70			87.72	75.28	14.44	2
44	1	25	0.18	0.00036	95.24	79.88	13.28	2
	2	35			93.46	88.64	22.04	2
	3	50			90.91	101.34	34.74	2
45	1	30	0.072	0.0037	39.34	77.79	7.14	2
	2	45			30.19	81.76	11.11	2
	3	55			26.13	85.56	14.91	2
46	1	30	0.25	0.00196	80.96	67.22	9.22	2
	2	50			71.84	75.68	17.68	2
	3	60			68.01	79.87	21.87	2

7. Conclusions

The main ions' hydrochemistry (K^+, Na^+, Mg^{2+}, Ca^{2+}, $SO4^{2-}$, HCO_3^- and CO_3^-) with trace elements (Fe, Mn, Zn, Pb, Cd, Cr, Cu and Ni) were found in order to ascertain the groundwater's hydrochemical characteristics. The TDS measurement ranges for fresh water (643 mg/l) and moderately salinized water (5715 mg/l). According to Hem (1970) classification 26.19 % of samples fall under fresh water category, 54.76 % of samples under slightly saline category and only 19.06 % of samples in moderately saline category. Furthermore, TDS and EC have a comparable connection in terms of places where they increase and decrease. The groundwater in the exploration zone varies from slight to moderate alkaline according to pH values which vary from 7.34 to 8.4. With the exception of phosphate, the amounts of trace elements are below the suggested amounts. The content of phosphate is also higher than that recommended limit all over the area. The application of water treatment process is needed, while nitrate content is very low as well as ammonia. The hydrochemical composition reflects the (Na- Cl) water type which is recorded in most of wells of the study area. Another water type (Na-HCO3) is recorded in the other wells and there is only one sample (No.3) represents Mg- Cl_2 type. According to the relative proportion of sodium to the other cations, some of wells in the investigated area have moderate water class and some of them have intermediate water class and the other are bad water class. Mainly permissible to good and doubtful to unsuitable for irrigation purposes in the studied area. Also, the residual sodium carbonate (RSC) is varying between (-1486.2 and 305.339) epm for groundwater samples. It's recommended to use this groundwater carefully after treatment especially in the highest value.

According to (WHO, 1984) and (EHCW, 1995) 45.6 % of the groundwater samples in the study area is suitable water for drinking. The other groundwater samples in the study area are unsuitable water for drinking due to their high salinity range, i.e. they are suitable for Toilets and flushing. Therefore, the desalination and treatment processes should be recommended. A number of factors were taken into consideration when classifying groundwater for irrigation, including: (EC, TDS, SSP, SAR, RSC, MAR, Cl and hazardous metals). The groundwater can classify according to Wilcox diagram into four classes, one sample is god water class while ten of samples are moderate water class and twenty five of samples are intermediate water class and the other are bad water class. The Cooper-Jacob assessment approach, together with the pumping test concept, has been utilized in this work to assess the aquifer's characteristics in 46 wells. Aquifer characteristics such as transmissivity and storage coefficient are used to assess groundwater potential. It may be seen from the pumping data findings that the aquifer is drawing down at a rapid pace because of structural displacements or the existence of lineaments.

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الكشف والتقييم الشامل لطبقات المياه الجوفية في محطة كهرباء غرب أسيوط، مصر

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تعد محطة كهرباء غرب أسيوط حجر الزاوية في مشروعات التنمية في صعيد مصر. وتم افتتاح المرحلة الأولى من هذا المشروع في مايو 2016، على مساحة 85 فدانًا تقريبًا، بقدرة 1500 ميجاوات من الكهرباء، بتكلفة أولية قدرها 1.5 مليار دولار. ومع ذلك، فإن تحقيق إمكاناتها الكاملة يتوقف على توافر موارد المياه المستدامة، وهو أمر ضروري لاستمرار النمو والازدهار في صعيد مصر. الهدف الرئيسي من هذه الدراسة هو توفير كشف وتقييم شامل لطبقات المياه الجوفية الحاملة للمياه الجوفية في محافظة غرب أسيوط، وكذلك فهم الترابط والتفاعلات بين هذه الطبقات. بالإضافة إلى ذلك، يتم إجراء تقييم نوعي شامل لمدى ملاءمة المياه الجوفية لأغراض مختلفة تتراوح بين الشرب والاستخدام المنزلي وتربية الماشية والري الزراعي. وقد كشفت الدراسة عن خصائص طبقات المياه الجوفية بما في ذلك معامل النقل والتخزين وما إلى ذلك من خلال تحليل تفصيلي لـ 46 بئراً لتسهيل الموارد المائية اللازمة لاستدامة التنمية والازدهار في صعيد مصر. تم الكشف عن التحليل الهيدروكيميائي لعينات المياه الجوفية لتحديد الخواص الهيدروكيميائية للمياه الجوفية. تتراوح قيمة TDS من 643 ملجم/لتر (ماء عذب) إلى 5715 ملجم/لتر (ماء معتدل الملوحة).