Hydro-chemical inter-relationship between surface and shallow groundwater within the eastern side of shatt Al-Hilla, Iraq

العلاقه الهيدروكيميائيه المتداخله بين المياه السطحيه والمياه الجوفيه الضحله في الجانب الشرقي من شط الحله / العراق

Dr. Mukdad H. A. Al-Jabbari
Dept. of Geology
College of Science
University of Baghdad

Arshad Wahab Abdul Rheem Al-Enezy
Babylon Water Resources Department

Abstract

The investigated area suffers from the shallow groundwater conditions which causes serious damage to the soil and consequantley to the agricultural and civil construction activities. To examine this problem, five different tracks perpendicular on the Shatt Al-Hilla channel were selected hand dug wells within the area to collect and analysis water samples over low and high of water level conditions. Water levels of both water bodies and their inter-relationships totally controlled by the nature of operation of the Dora regulator which located at kilometer 51 from source of Shatt Al-Hilla. Water samples collected during April, both high and low water levels. The nature of these inter-relationship were varying along the selected tracks due to many local conditions such as, elevations of lands, operation of irrigational regulators, depth of water within the channel cross section, seasons of the water year, high and low water level conditions, climatic changes, soil conditions and the present status of the sewage system within the City of Hilla.

According to the adopted international standards to evaluate the suitability of the surface and shallow groundwater for different uses (drinking, industrial, building and irrigation) indicate that all surface water samples are suitable as drinking water, in state of high water level, while in state of low water level some of hang dug wells are not suitable for drinking water. All water samples are not suitable for industrial purposes. All surface water samples can be used for building and most of the sallow groundwater samples cannot be used for building except some of hand dug wells. All water samples are good for livestock. Surface water is good for agricultural purposes, while the hand dug water samples are suitable for growing most types of crops.

ألمستخلص

تعاني مدينة الحلة من ارتفاع مناسيب المياه الجوفية الضحلة والتي تسبب العديد من المشاكل البيئيه ضمن قطاعات التنميه وخاصة الزراعيه. ولتحديد طبيعة هذا المشكلة وابعادها وتقديم بعض المقترحات بصددها تم اختيار خمسة مسارات متعامدة على مجرى قناة شط الحلة تنتشر قبل وبعد مدينة الحله حيث يتضمن كل مسار عددا من ألابار والتي تم جمع نماذج المياه الجوفية الضحلة لاجراء التحاليل الهيدروكيميائية الشامله ومقارنتها مع نماذج المياه السطحية المتمثلة بشط الحلة في كلا الحالتين المستوى الواطئ والعالي لمستوى المياه في قناة شط الحله . مستويات المياه لكلا الجسمين المائيين وعلاقتهما المتداخله مسيطر عليهما كليا بواسطة تشغيل ناظم دوره والذي يقع في الكيلومتر 51 من نقطة المصدر لشط الحله. تم اخذ عينات الماء السطحي مقابل كل مسار متعامد على الابار المائية الضحلة وفي نفس الوقت التي جمعت فيه عينات المياه الجوفية الضحلة وعند فترة ارتفاع منسوب الماء في شط الحلة واخرى في فترة انخفاضه خلال شهر نيسان . حصول تباين في عملية التغذيه السطحيه للمياه الجوفيه الضحله مابين المسارت الخمسه والتي تعتمد على مجموعه من العوامل مثل ارتفاع منسوب الماء السطحي في قناة شط الحله , عمق الماء ضمن المقطع العرضي للقناة مقابل كل مسار, طول الفتره الزمنيه للمنسوب العالي او الواطيْ , تواجد مصادر مياه المجاري , الفصل من السنه , طبيعة استخدام الاراضي (زراعه , مباني) , الامطار.
تم مقارنه الطيف الواسع من نتائج التحاليل الهايدروكيميائية مع المعاييرِ الدوليه المعتمده لقييمِ نوعياتِ المياه وصلاحيتها للاستخدامات المختلفة (شرب، صناعة، بناء، استخدام حيواني، زراعة ورَيّ) , وقد بينت النتائج ان جميع النماذج السطحيه ونماذج المياه الجوفيه الضحلة تلك التي تكون بالقرب من قناة شط الحله ممكن ان تستخدم للاستهلاك البشري اثناء المنسوب

العالي (بعد اجراء عمليات المعالجه المحدوده) على عكس النماذج المائيه خلال فترة المنسوب الواطئ . كل نماذج المياه السطحيه ممكن ان تستخدم لأغراض البناء على عكس نماذج المياه الجوفيه الضحله التي تكون غير صالحه للبناء بسبب زيادة تراكيز $HCO3^-$ و Mg^{2+} فيها ماعدا بعض النماذج القليله. كل النماذج المائيه بينت انها غير صالحه للأستخدام الصناعي بسبب العسره العاليه , وان كل النماذج المائيه هي صالحه للأستخدام الحيواني ماعدا بعض نماذج المياه الجوفيه الضحلة بسب ازياد تراكيز Mg^{2+}& TDS. اضافة الى ان جميع نماذج المياه السطحيه هي جيده للأرواء الزراعي بينما المياه الجوفيه الضحله تكون ملائمه لأرواء اغلب انواع المحاصيل الزراعيه.

Introduction

City of Hilla (Babylon Governorate), 100 km south of Baghdad City, located between Longitude ($44^0 26^- 65$" & $44^0 31$-00") E and Latitude ($32^0 25^- 30$" & $32^0 31^- 30$") N (Figure.1). Hilla city depends solely on Shatt AL-Hilla (with a designed discharge of 220 m^3/sec.) for maintaining all its water needs. The examined areas characterized by shallow groundwater systems which leads to many negative impacts on the socio-economic, agricultural and civil construction activities beside other problems such as, soil salinaization. However, Shatt Al-Hilla is recharging the shallow groundwater system within the studied area by different rates and different means (Lafta and Nayef, 1999). The main objectives of this investigation to examine the inter-relation between surface water (Shatt AL-Hilla) and shallow groundwater systems in the studied areas spatially and with time, determine the hydrochemical characteristics of both water systems in the studied area to confirm the main finding of this study, and examining the inter-relationship between the surface and groundwater systems in the area is vital issues to understand the proposed inter-relationships quantitatively and qualitatively.

During this study the hydrochemical parameters are examined over two periods, high and low water level condition in channel of Shatt Al-Hilla for surface and groundwater in order to understand the inter-relation between the both water systems by depending on hydrochemical concentrations for both water bodies. To achieve these goals, the study area was divided into five tracks each one is perpendicular on the Shatt Al-Hilla channel course (tracks A, B, C, D and E). Along each track three shallow groundwater hand dug wells except track D includes six of hand dug wells, depths of these wells were ranges from 7 m to 12 m, the nearest well to the Shatt Al-Hilla is 100 m, and farest was about 1150 m. The water samples are collecting from 23 water points (five samples from surface water and 18 samples from shallow groundwater system), each one sample was collected from surface water is be interview a track to compared between the main hydrochemical concentrations of the collected water samples from the both water bodies (Figure .2). The major cations and anions are analyzed in the laboratories of the Ministry of Environment / Babylon Governorate, Temperature (^{0}C), Acidity (pH), (in field), Electrical conductivity (EC), total dissolved solids (TDS), concentrations of major cations (Ca^{2+}, Mg^{2+}, Na^+, K^+), concentrations of major anion (SO_4^{2-}, Cl^- ,HCO^{3-}), Nitrate (NO_3^-) and phosphate (PO_4^{3-}). The concentrations of the examined parameters over the both periods are presented (Table. 1).

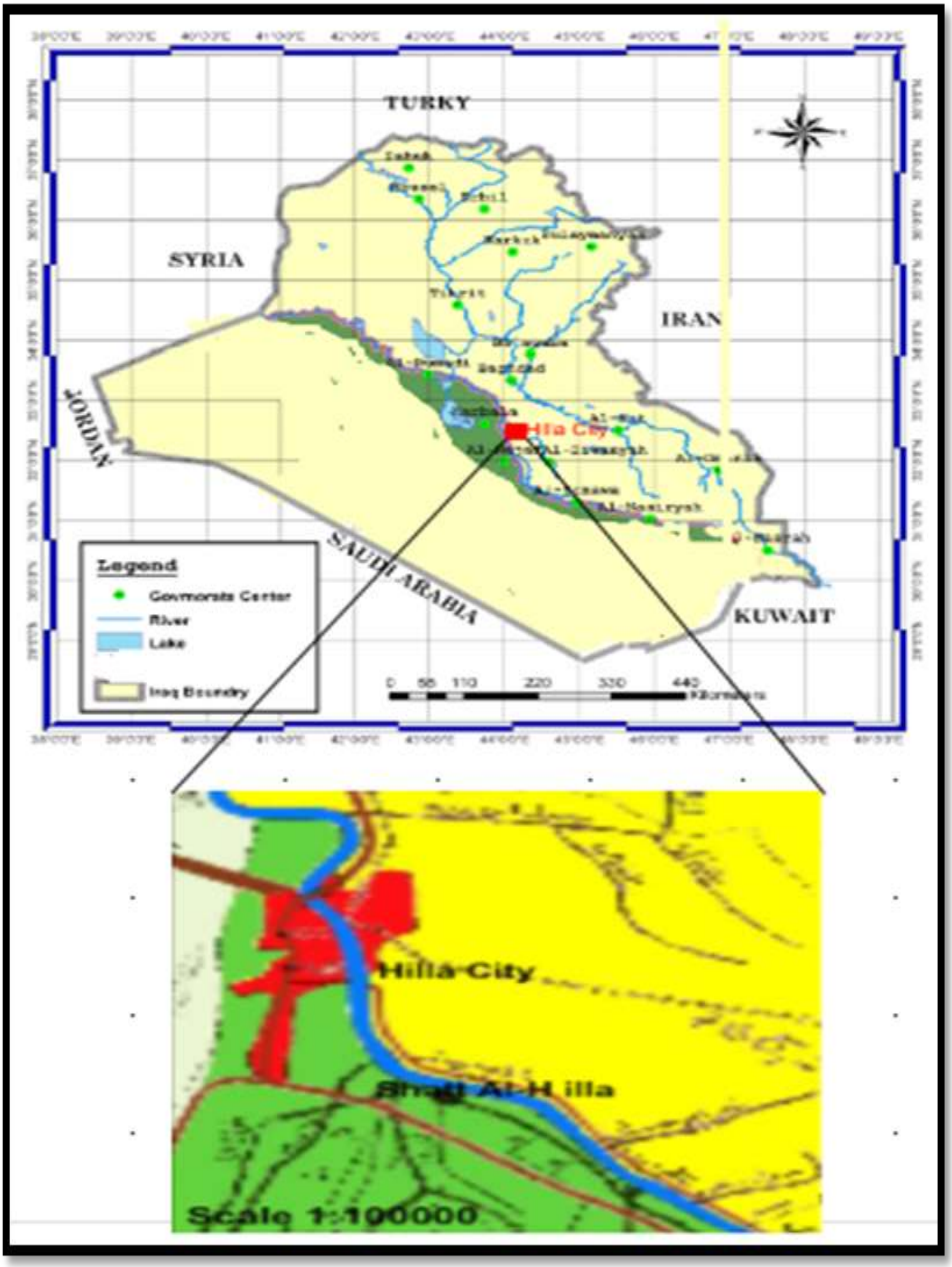


Figure 1: Location of the studied area (BWRD, 2009).

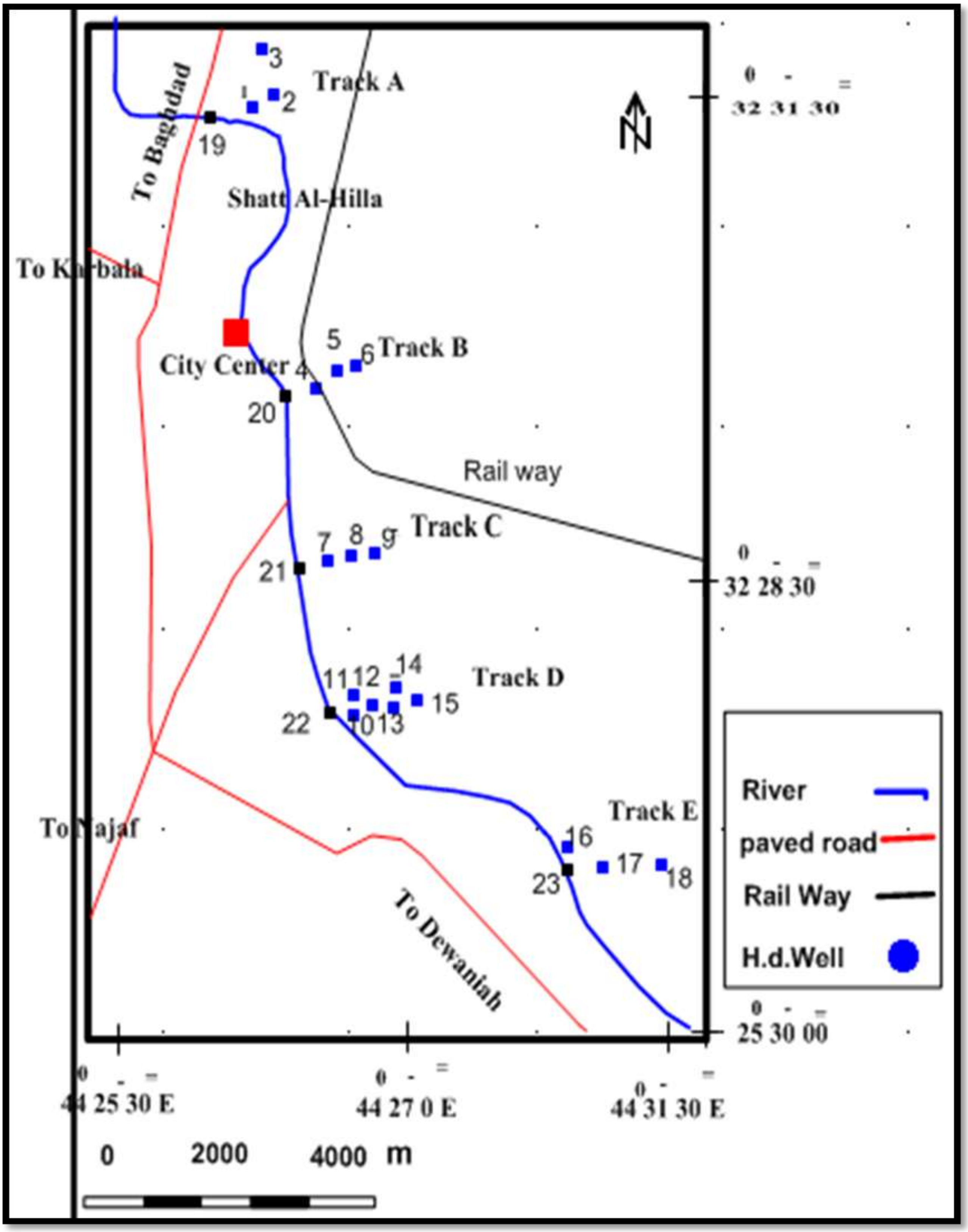


Figure 2. Location of water sampling points in the study area.

Table 1: Averages and ranges of the examined hydrochemical parameters of Surface and groundwater during low and high water level conditions, (Al –Enezy,2012).

Parameters	Samples	Low water level in channel of shatt Al-Hilla			High water level in channel of shatt Al-Hilla		
		Min.	Max.	Avg.	Min	Max	Avg.
^{0}C	Surface water	23	25	24	22	24	23
	Hand dug wells	23	25.5	24.25	23	25.6	24.3
pH	Surface water	7.9	8.1	8.00	7.9	8.08	8.015
	Hand dug wells	6.7	7.45	7.07	6.8	7.36	7.08
T.D.S	Surface water	784	1028	906	721	763	742
	Hand dug wells	1386	6356	3871	1394	5514	3454
EC	Surface water	1190	1561	1375.5	1034	1096	1065
	Hand dug wells	1976	6837	4406.5	1873	6091	3982
$Ca^{2}+$	Surface water	78	110	94	78	101.4	89.7
	Hand dug wells	140.4	402	271.2	124	624	374
$Mg^{2}+$	Surface water	55.2	102.3	78.75	25.7	31.2	28.45
	Hand dug wells	92	549.1	320.5	87	511	299
Na^{+}	Surface water	99.1	102.7	100.9	88.1	98.7	93.4
	Hand dug wells	177.5	716	446.75	171.1	570.6	370.85
K^{+}	Surface water	4.3	4.5	4.4	4.2	4.4	4.3
	Hand dug wells	3	42.4	22.7	3.2	40.3	21.7
HCO_3^{-}	Surface water	92	111	101.5	130	210	170
	Hand dug wells	143	1785	964	325	1503	914
SO_4^{2-}	Surface water	330.5	439.4	384.95	198	290.9	244.4
	Hand dug wells	362	1393.9	877.9	275	1298	786.5
Cl^{-}	Surface water	145	165	155	118.3	125.8	122.05
	Hand dug wells	197.2	2086.4	1141.8	165	1906	1035.5
T.H	Surface water	429	760.5	594.75	319.8	343.2	331.5
	Hand dug wells	760.5	3217.5	1989	752	3198	1975
PO_4^{3-}	Surface water	0.12	0.14	0.13	0.11	0.13	0.12
	Hand dug wells	0.12	0.19	0.15.5	0.11	0.18	0.145
NO_3^{-}	Surface water	0.646	1.121	0.883	0.57	1.1	1.67
	Hand dug wells	0.19	2.36	1.275	0.13	2.23	1.18

hydrochemical analysis

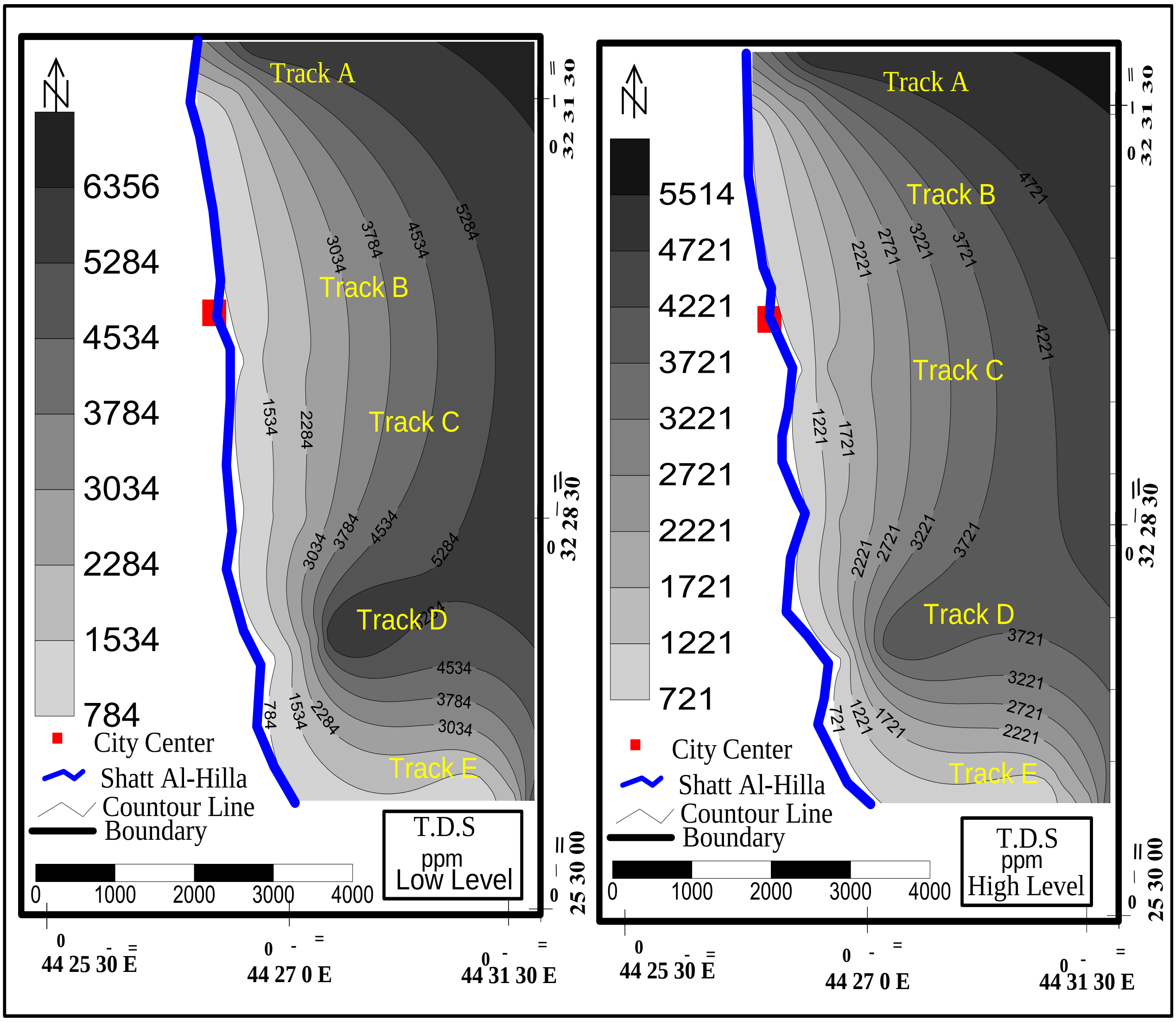
Surface and groundwater samples analyses show the existence of different salt concentrations depending on the sources of water and the amount of soluble constituents present in the soil column through which the water passes. Waste water from industrial, agricultural, sewage and drainage water considered as other important artificial source which degrades the quality of water, thus, it was important to examine the physical, chemical and biological characteristics of water samples for the both water bodies under both conditions in order to get good understanding of the interrelationship between both water bodies as well as to examine the suitability of water from both systems for different uses. The hydrochemical analysis includes Physical and chemical characteristics for both water bodies.

Physical characteristics

Color and Odor generally originated from organic matter, human compounds and dissolved components, which is enhanced at high water temperature (WHO, 2004). In general, water temperatures are relatively higher during the low water conditions than higher water level conditions (Table.1). The pH values were higher in surface water samples than shallow groundwater samples and higher under high water level conditions within the surface water samples while it was higher during high water level conditions within groundwater due to the dissolution of organic material from agricultural lands (Table.1). TDS values were higher under low water level conditions (Figure 3a). Decreasing in TDS values under high water level conditions related to the dilution processes that lead to general decreases in total salts concentrations. Exceptional high dissolved salt concentration within the shallow groundwater samples i.e. sample no. 3 and 15 were TDS values increased up to 6285 and 6356 respectively because the sampling site is far away from Shatt Al-Hilla channel. Along track B, TDS values were low relatively (Figure 3a and 3b) due to the water coming from residential neighborhood. Along track D, TDS values were higher even if it is nearer to Shatt Al-Hilla channel because of limited exchange between the two water bodies, especially in low water level conditions (Figure 3a). Depending on TDS values, water samples can be classified into different water type using (Freeze and Cherry approach, 1979) (Table 2). Shallow groundwater samples (1, 2, 3, 4, 5, 6, 7, 8, 11, 12, 13, 14, 15, 16, 17 and 18) were brackish type during under both water level conditions, while Shatt Al-Hilla water samples was fresh water type under high and low water level conditions except sample no. 23 was brackish water type under low period level conditions (Figure 3 a and b). EC of collected water samples from Shatt Al-Hilla and shallow groundwater with average values of 1065 and 3982 µmohs/cm under high water level conditions and with average values of 1375.5 and 4406.5 µmohs/cm respectively, under low water level conditions. TH of both surface and sallow groundwater samples under low water level with average values of 594.75 ppm and 1989 ppm respectively. Under high water level conditions TH were with average values of 331.5ppm and 1975 ppm respectively. TH values for all collected water samples within the studied area were very hard according to (Todd, 2007) and (Boyd, 2000).

Table 2: Classification of water depending on TDS.

Category	TDS (mg/L)	High water level	Low water level
Fresh Water	0 - 1000	19,20.21,22,23	19,20.21,22
Brackish Water	1000 - 10000	Hand dug wells(1,2,3,4,5,6,7,8,9,10,1112,13,14.15.16.17.18)	Hand dug wells(1,2,3,4,5,6,7,8,9,10,1112,13,14,15,16,17,18,23)
Saline Water	10000 - 100000	-	-
Brine Water	> 100000	-	-



(a) (b)

Figure 3: (a) Contour map presenting TDS distributions under state of low water level conditions. (b) Contour map presenting TDS distributions under state of high water level conditions.

Chemical characteristics

Calcium Ca^{2+} concentrations within the collected water samples under low water level conditions with an average values of 94 ppm and 271.2 ppm within both surface and shallow groundwater respectively while under high water level conditions it was with an average values of 89.7 ppm and 374 ppm within both surface and shallow groundwater respectively. Calcium ion concentrations within shallow groundwater are higher than surface water especially within samples located far away from Shatt Al- Hilla i.e. samples no. 3, 6, 9, 15 and 18.

Concentrations of Mg^{2+} under low water level conditions within surface and shallow groundwater samples with average values of 78.75 ppm and 320.5 ppm respectively and it was with average values of 28.45 ppm and 299 ppm respectively under high water level conditions (Table 1). It is evident that the spatial variations of Mg^{2+} concentrations under low water level conditions were higher than those samples under high water level conditions due to the dilution processes.

Concentration of Na^+ within surface and shallow groundwater samples with average values of 100.9 ppm and 446.75 ppm respectively under low water level conditions and it was with average values of 93.4 ppm and 370.85 ppm respectively under high water levels (Table 1). The concentrations of Na+ under low water conditions are relatively higher than the concentrations under high water level conditions.

The concentration of K^+ within the collected water samples from surface and shallow groundwater with average values of 4.4 ppm and 22.7 ppm respectively under low water level and with average values of 4.3 ppm and 21.75 ppm respectively under high water level conditions (Table 1). The relative higher concentration of K^+ in the area is due to the dissolution of potassium salts from the soil and fertilizer from agricultural lands.

The concentration of chloride in the collected water samples from surface and shallow groundwater with average values of 155 ppm and 1141.8 ppm respectively under low water level conditions and it was with average values of 122.05 ppm and 1035.5 ppm respectively under high water level conditions (Table 1). It is clear that the concentration of chloride along track D were higher due in the direction of shallow groundwater toward the main channel of Shatt Al-Hilla due to the limited exchange between both water bodies in this track (Figure3a). Generally, concentration of chloride under low water level was higher than under high water level due to the dilution operation. Bicarbonate concentration within the collected the surface and shallow groundwater samples respectively with average 101.5 ppm and 964 ppm under low water level conditions and it was within the surface and shallow groundwater samples respectively with an averages of 170 ppm and 914 ppm under high water level conditions (Table 1). The bicarbonate concentration in the collected water samples was highly affected by sewage water within the studied area. The shallow groundwater samples far away from the channel of Shatt Al-Hilla have higher bicarbonates concentration. Concentration of sulfate ions in the collected water samples from the surface shallow groundwater with average values 384.95 and 877.95 ppm respectively under low water level conditions and with average values 244.45 and 786.5 ppm respectively under high water level conditions (Table 1). The sulfate concentrations under low water levels is higher than that under high water level conditions which can be attributed to the diluting processes by Shatt Al-Hilla water under high water level conditions. The sulphate concentrations in surface water could be originated from shallow groundwater and sewages under low water level conditions.

The concentrations of nitrate in the collected water samples in the studied area from both surface water and groundwater samples with average values of 0.883 ppm and 1.275 ppm respectively under low water level conditions and with average values of 1.67 ppm and 1.18 ppm respectively under high water level conditions (Table 1). The concentrations of nitrate under low water level conditions were higher than its concentrations under high water level conditions which can be attributed to the movement of water front toward Shatt Al-Hilla channel under low water level conditions.The concentration of phosphate in the water samples within the studied area from surface water and shallow groundwater with average values of 0.13 and 0.155 ppm respectively under low water level conditions and with average values of 0.12 and 0.145 ppm respectively under high water level conditions (Table 1).

Hydrochemical formula and water type

The types of water are connected with their chemical and physical properties which change relatively with respect to time and place. These changes are slow in groundwater comparing with surface water (Hem, 1989). Water type is very important in determining the best way for water use whether if these uses are human, agricultural, or industrial. There are many methods and manners to classify groundwater from the hydrochemical one of these methods is:

Ivanov equation to determine water type.

$$TDS_{mg/L} = \frac{Anions\,epm\%\,decreaing\,order}{Cations\,epm\%\,decreasng\,order}\;pH \qquad \text{(Ivanov equation)}$$

According the type of water points, it is generally the sequence of anions begins with predominant of SO42-, Cl- and HCO3- in order, while for cations the situation is different depending on the type of water. In general Surface water is predominant with Ca2+, Na+, and Mg2+ under high water conditions while it is predominant with Mg2+, Ca2+ Na+ under low water level conditions:

-Under high water conditions.

$$TDS\ (763)\frac{SO4(51.67)\ Cl(28.46)\ HCO3(19.85)}{Ca(47.57)Na(36.48)Mg(14.93)K(1.01}pH\ (8.08)\ (Mg\text{-Na- Ca-}HCO_3\text{ -Cl-}SO_4)$$

-Under low water conditions.

$$TDS\ (1028)\frac{SO4(58.56)Cl(29.79)\ HCO3(11.64)}{Mg(46.20)Ca(30.12)Na(23.03)K(0.63)}pH\ (7.9)\ (\text{Na-Ca- Mg-}HCO_3\text{ -Cl-}SO_4)$$

Mg^{2+} ion in water samples are higher in shallow groundwater due to the high solubility of (MgCl2, $MgSO_4$ & $MgCO_3$) components. In shallow groundwater the predominant ion is Mg^{2+} under both water level conditions and Na^{+} ion are more than Ca^{2+} ion:

$$TDS\ (1923)\frac{cl\ (42.43)\ SO4(34.80)\ HCO3(22.75)}{Mg(44.21)Na(27.91)Ca(26.96)K(0.90)}pH(7.1)\ \ (\text{Ca-Na-Mg-}HCO_3\text{-}SO_4\text{-Cl})$$

Classification of water

There are many methods and manners to classify groundwater from the hydrochemical aspect such as (Piper, 1944; Sulin, 1946; Johns, 1968;Schoeller, 1972; Collins, 1975; Schoeller and Sulin, 1981; and Chadha,1999). All these classifications depend on the main cations and anions concentrations, by unit equivalent weigh of ion (epm) or mile equivalent per liter (meq/L).
The goal is to determine the most important properties of groundwater and for this purpose, Chadha (1999) was applied.
Chadha diagram is constructed by plotting the difference in mill equivalent percentage between alkaline and alkali metals, [(Ca^{+2}+mg^{+2}) - (Na^{+} + K^{+})](epm %) expressed as percentage of reacting values on the X axis and the difference in mill equivalent percentage between weak acidic anions and strong acidic anions. [(HCO_3^{-} + CO_3^{-}) – (Cl^{-} + $SO_4^{=}$)] (epm %) is also expressed as percentage of reacting values on the Y axis (Chadha, 1999):
According to this classification all water samples in the studied area under both water level conditions located within (zone 6) where Alkaline earth's exceed alkaline metallic and strong acids exceed weak acids. This zone is characterized by:
Ca^{2+}-Mg^{2+}-Cl^{-} type
Ca^{2+}-Mg^{2+} -dominant Cl^{-} type
Cl^{-} dominant Ca^{2+} Mg^{2+} type

Water for drinking purposes

Iraqi standard (2009) and WHO (2006) standards have been used as guides for the water quality evaluation for drinking purpose (Table 3). Accordingly, all surface water samples are suitable for drinking water under high water conditions unlike many water samples under low water conditions.

Table 3: Comparison of the water samples within the studied area with the Iraqi and WHO standards.

Parameters	Iraqi Standard 2010	WHO Standard 2006	Low water level	High water level
pH	6.5 - 8.5	6.5 - 8.5	all samples	all samples
TDS	1000	1000	19,20,21,22	19,20,21,22
EC	-	1530	19,20,21,22	19,20,21,22
Ca^{2+}	150	100 - 300	all except No.3 and 15	all except No.3,13,14 and 15
Mg^{2+}	100	-	16,19,20,21,22	16,19,20,21,22
Na^{+}	200	200	16,19,20,21,22	7,16,19,20,21,22
SO_4^{2-}	400	250	7,19,20,22	7,19,20,21,22
Cl^{-}	350	250	7,9,10,11,16,19,20	all except
TH	500	500	19,20	19,20,21.22
NO_3^{-}	50	50	all samples	all samples
PO_4^{3-}	-	-	-	-

Industrial purposes

The use of water for industrial purposes requires many specifications in terms of qualities and specifications for each industrial activity (AL-Janabi, 2008). The standards given in (Table. 4) represent the maximum permitted values of water constituents which indicate that all water samples are not suitable for industrial purposes.

Table 4: Water-quality requirements for selected industries (Hem, 1985).

Industries		Constituents									
		Ca^{2+}	Mg^{2+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	NO_3^{-}	Po4	TH	pH	TDS
Textiles		-	-	-	-	-	-	0	25	-	100
Chemical pulp and paper	Unbleached	20	12	-	-	200	-	-	100	6-10	-
	Bleached	20	12	-	-	200	-	-	100	6-10	-
Wood chemicals		100	50	250	100	500	5	-	900	6.5-8.0	1000
synthetic rubber		80	36	-	-	-	-	-	350	6.2-8.3	-
Petroleum products		75	30	-	-	300		-	350	6.0-9.0	1000
Canned, dried, and frozen fruits and vegetables		-	-	-	250	250	10	-	250	6.5-8.5	500
Soft-drinks bottling		100	-	-	500	500	-	-	-	-	-
Leather tanning		-	-	-	250	250	-	-	soft	6.0-8.0	-
Hydraulic cement manufacture		-	-	-	250	250	-	-	-	6.5-8.5	600

Livestock purposes

The water of the studied area had been evaluated for livestock uses depending on the classification proposed by Altoviski (1962). This classification is based on some of the major cations and anions (Table. 5). On the basis on these classifications all water samples are good for livestock except for few groundwater samples.

Table .5: Classification of livestock water (Altoviski, 1962).

parameters	Very good	Good	permissible	Can be used	Threshold	Low water Level	High water Level
Na^{+}	800	1500	2000	2500	4000	177.5-716	171.1-570.6
Ca^{2+}	350	700	800	900	1000	140.4-402	124-624
Mg^{2+}	150	350	500	600	700	92-549.1	87-511
Cl^{-}	900	2000	3000	4000	6000	197.2-2086.4	165-1906
$SO4^{2-}$	1000	25000	3000	4000	6000	362-1393.9	275-1298
TDS	3000	5000	7000	10000	15000	1386-6356	1394-5514
TH	1500	3200	4000	4700	64000	760.5-3217.5	752-3198

Surface and shallow groundwater for Agricultural purposes

Use the water for agricultural purposes depends on how much plants could bear the concentration of some ion concentrations which depend on many conditions i.e. the properties of the soil, structure, ability to retain water and the content of organic materials, method of irrigation, crop type, climate and health management. Based on (Todd, 1980) classification all water samples are suitable for growing most types of crops (Table 6).

Table 6: Relative tolerances of crops to salt concentrations (Todd, 980).

Crop Division	Low Salt Tolerance	Medium Salt Tolerance	High Salt Tolerance
Fruit Crops	0-3000 µmohs/cm Lemon, Strawbrry, Peach Spricot, Almond, Plum Orange,	3000-4000 µmohs/cm Cantaloupe, Olive, Fig Pomegranate	4000-10,000 µmohs/cm Date palm
Sample No.	1,4,5,6,7,8,9,10, 11,1216,17,19,20,21,22,2,3	2, 13, 14	3,15,18
Vegetable Crops	µmohs/cm 4000-3000 , Celery,,Green beans Radish	4000-10,000 µmohs/cm Cucumber, Peas, Onion Carrot, Potatoes, Sweet Corn, Lettuce, Cauliflower, Bell pepper, Cabbage,Broccoli, Tomato	10000- 120,000 µmohs/cm Spinach, Garden beets
Sample No.	2, 13, 14	3, 15, 18	-
Field Crops	4000-6000 µmohs/cm Field beans	6000-10,000 µmohs/cm Sunflower, Corn (field) Rice, Wheat, (grain)	10,000- 16,000 µmohs/cm Cotton, Sugar beet
Sample No.	18	3,15	-

Conclusions

1- All water samples (surface water and shallow groundwater) were colorless and odorless accepted water samples from hand dug wells along track B due to their near position from the residential areas.
2- There are unlikeness in the water interchange process between surface and shallow groundwater along the five tracks which be effect on hydro-chemical concentrations and amount of this water interchange depended on many factors such as, elevations of surface water levels within Shatt Al-Hilla channels, depth of cross section in Shatt Al-Hilla canal, high and low water level periods, local topography of the sites, existing of sewages water sources, season from the year, nature of land use and the nature and patterns of rain fall in the area.
3- The total dissolved solid salt TDS within shallow groundwater system near Shatt Al-Hilla channel is less than that within groundwater system far away from Shatt Al-Hilla channel due to the dilution process by fresh Shatt Al-Hilla surface water.
4- The concentrations of the examined chemical ions (Mg2+, Na+, K+, $SO42^{-}$, Cl^{-} ,$HCO3^{-}$, $No3^{-}$,$PO4^{-}$) for all examined samples within the studied area are higher within samples representing low water level conditions in channel of shatt Al-Hilla except Ca2+ unlike those representing high water level conditions due to process of dilution.
5- The concentration of phosphate ($PO4^{-}$) is high within samples near the residential areas (Track A and B) due to the sewage waste inputs to the shallow groundwater system.
6- The hydrochemical formulae and water type shows that the predominant ion within shallow groundwater is $Mg2^{+}$ ion and Na^{+} is more than Ca2+ under both water level conditions.
7- The inter-relationship along track D between groundwater and surface water systems is limited, which causes rising of salts along track D.
8- Comparison of the obtained hydrochemical results for both surface and groundwater samples with the WHO(2006) and IQS(2009) standards indicate that all surface water samples and groundwater samples (near the channel) are suitable for drinking purposes' under high water level conditions (after limited treatment) unlike water samples under low water level conditions.
9- All water surface and groundwater samples are not suitable for industrial purposes because of its general high hardness.
10- All surface water samples can be used for building unlike shallow groundwater samples due to the increase in the concentrations of $HCO3^{-}$ and $Mg2^{+}$, except for few samples.
11- All water samples are good for livestock except in some hand dug wells due to the increasing in $Mg2^{+}$& TDS concentrations.
12- Surface water, as excepted, is good for all type of agricultural activities while the shallow ground water are suitable for some types of crops.

Recommendations

1. To control one of the main sources of pollution within the area we recommend construction of a sewage network and proper water treatment plan for recycling of sewage followed by reusing these treated water again in the agricultural activities.
2. Concrete lining of the main perfusions creek to control water losses through infiltration of water to the shallow groundwater at a first stage then using piping systems of the creeks to control the infiltration as well as the evaporation loss of the already limited available water in the area.
3. Redistribution of the water by passing good shear of water of Shatt Al-Hilla through Babylon creek which can pass the water at the end of its courses behind Al- Dora regulator. Such idea will help in controlling the recharging of groundwater within the studied area as well as controlling the deterioration of surface water by sewage systems from the city of Hilla. Implementing such idea will need a new look from the engineers to maintain the present channels of Shatt Al-Hilla.

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