MANAGEMENT OF GROUNDWATER RESEOURCE OF DIBDIBBA SANDY AQUIFER IN SAFWAN- ZUBAIR AREA, SOUTH OF IRAQ

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ABSTRACT

Safwan- Zubair area is located at south of Iraq. It represents the southern sector of Iraqi Desert which is an arid region with scarce and finite resource. Because no perennial river exists, groundwater is a major natural resource within the area being question. The upper part of Dibdibba Sandy formation, clastic sand unconfined usages with high drainage soil condition. This study investigates the hydrologic budget of the aquifer for the period from (1980 to 2000). The original groundwater reserves in the usable aquifer is estimated to have been approximately (3136×10^6 m^3). Prolonged groundwater extraction (equal to 300.8×10^6 m^3 on the average basis) in excess of the natural rate of replenishment (equal to 92×10^6 m^3 on the average basis) has critically lowered groundwater levels in the exploited aquifer where the net decline of head is of about (0.52 m). Depletion of storage will induced undesirable effects on the aquifer including salinization and upward saline leakage from the deep aquifer due to change in the vertical flow rates (equal to 56 × 10+ m^3/y on the average basis). Four alternative plans are suggested to alleviate the deterioration of aquifer groundwater, quantitively and qualitively. These including: redistribution of operating wells uniformly over the study area, designing shallow ponds with appropriate diameters, redistribute the agricultural area and type of crops with minimum water consumptions like cereal instead of tomato, and artificially recharging the aquifer.

INTRODUCTION

Groundwater is an important resource in many areas of the world for drinking, irrigation, industrial and other usages. It is a vulnerable resource because it may deplete or degrade due to many reasons including overexploitation, reduction of groundwater recharge, contamination etc. Depletion of water bearing layer is a serious problem, especially in the arid and semi-arid regions in which groundwater is the main source of water for irrigation and other supply affairs. Study of the water budget of a hydrogeological system provides a practical means of gaining a better understanding of the system under consideration and throws light on the significant factors which control the response of the system to a given stress.

Safwan-Zubair area is located at the extreme part of south of Iraq (Fig.1). It represents the south part of Western Desert bounded by latitudes (30°05′-30°25′) and longitudes (47°30′-47°55′). It is covered nearly (1200 km^2) from the total area of Dibdibba plain. The area is one of the largest and most important agricultural regions in Iraq, especially during the cold months of the year when the most other area in country is stopped partially because of the hard climate conditions. More than (75%) of land area irrigated water pumped from the same aquifer. Intensive utilization in the area began before fifty years when diesel pumps were introduced.

Morphologically, the area in question is a flat plain that generally slopes towards north east. The important geomorphologic features within this area are: shallow wadies which may carry occasional runoff after rainstorms; tidal flat in addition to the sand dunes that are disposed throughout the area in the south and south west parts. A single significant relief within the area is Jabal Sanam, a rounded hill which rises about (150 m) above sea level (Al-Naqib, 1970).

High evaporation rates, high relative humidity, low rainfall rates and low wind speed characterize climate of the area.

The original groundwater reserves in the usable upper part aquifer is estimated to have been approximately (3136×10^6 m^3), but each year, farmers draw from it more than (92×10^6 m^3) on the average basis. Effect of intensive pumping due to increased random drilling wells and its pumping rates on reserved storage requires a comprehensive and detail investigations. The main objective of this study is to provide basic information on the lumped change in aquifer storage during the last two decades. This information may also be used as a basis to estimate subsequent changes resulting from further developments. Due to the lack of sufficient data and complexity of hydrogeological system under consideration, calculations of water budget components will mainly depend on averages and generalizations.

HYDROGEOLGICAL SETTING :

The upper part of Dibdibba formation, in which the most productive units are sands and gravels, is the main aquifer in Safwan-Zubair area. It is characterized by unconfined to semi-confined conditions (Haddad and Hawa, 1979; Al-Jawad *et al.*, 1988; Al-Kubasi, 1996). The average of its saturated thickness is nearly (14 m). hard clayey lenses are often disposed throughout the body of aquifer in both saturated and unsaturated parts (Fig.2). These clay lenses are formed barriers for percolated water in some places. Hence, a perched aquifer is founded due to this phenomenon. Under the investigated aquifer there is a relatively regional hard clayey bed. It is conceived as the base of the aquifer. The average of its thickness is nearly (2 m) and the hydraulic conductivity reaches (0.38 m/d) (Al-Kubasi, 1999). It acts as a confining bed separating the upper part of Dibdibba formation, which mostly contains brackish water type from confined to semi-confined saline aquifer below. The hydraulic continuity between the two water bodies result in transfer of water from the deeper aquifers across the confining hard clayey bed when the hydraulic head in the upper aquifer is lowered response to pumping operation. Upward leakage often happens where the clayey bed is slightly thin or disappears, so that the brackish water of the unconfined aquifer is directly floating over the saline water of the deeper aquifer.

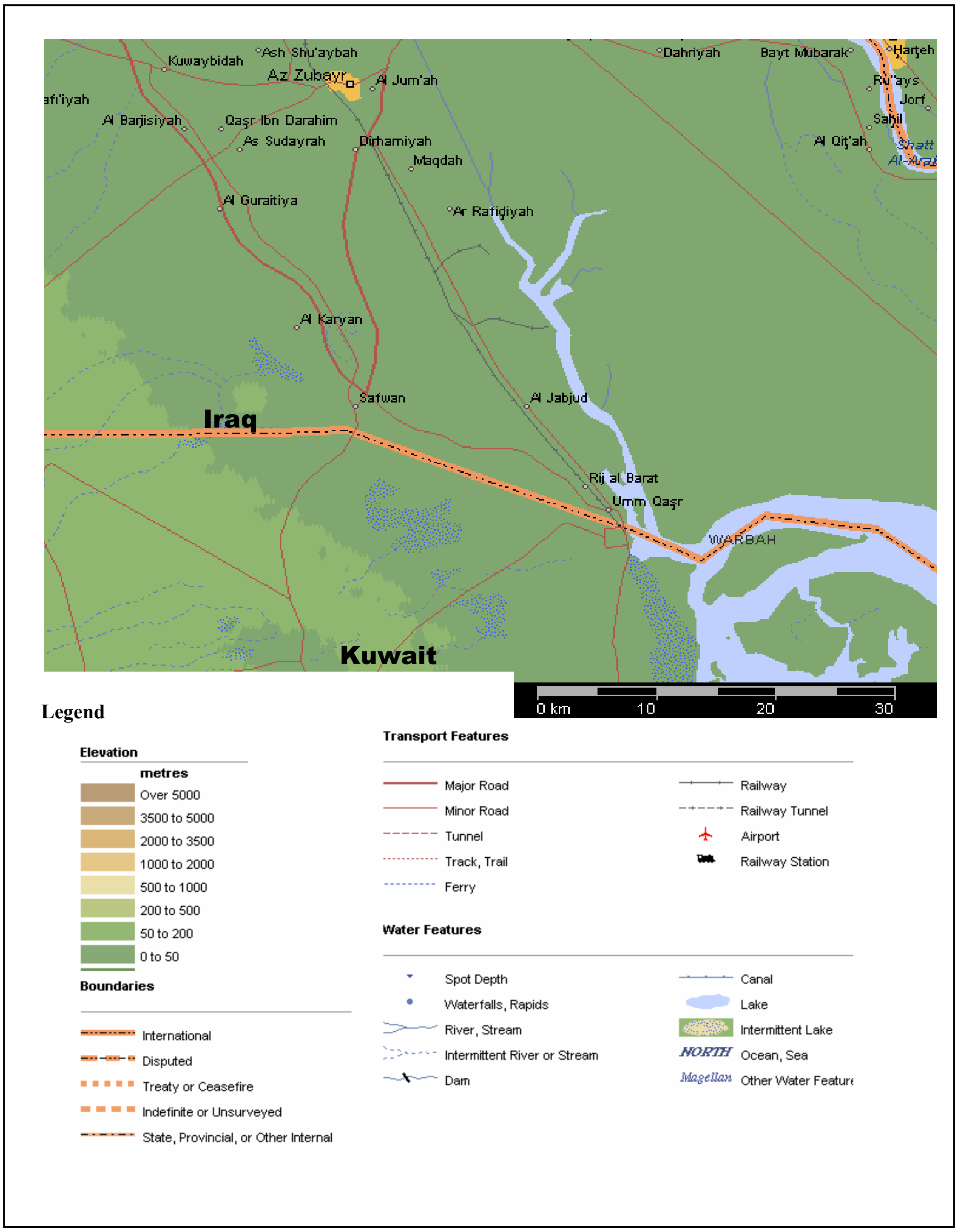

Fig.(1) Map of the study area

According to the many previous studies (Haddad & Hawa, 1979; Al-Rawi *et al.*, 1981; Al-Jawad, 1988; Al-Kubasi, 1996; Atiaa, 2000) the transmissivity of the aquifer is generally greater than (300 m2/d), i.e., the hydraulic conductivity is higher than (20 m/d). The specific yield ranges between (0.035-0.4). The flow direction in the area is from northeast to southeast with average of hydraulic gradient of about 0.0018 (Fig.3).

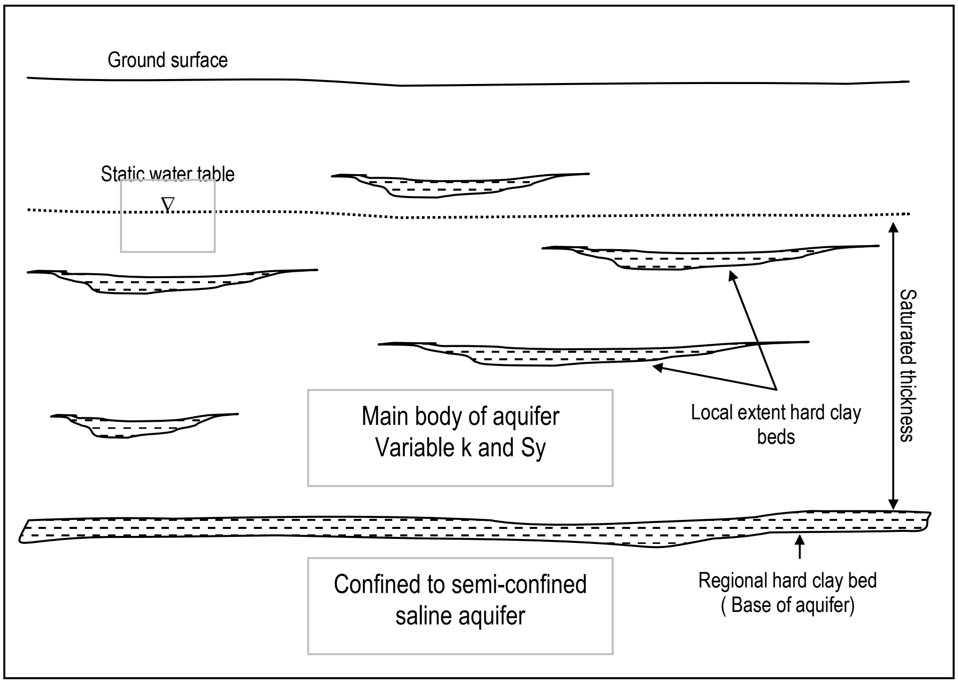

Fig.(2) A prototype of upper unconfined clastic Dibdibba aquifer in Safwan-Zubair area

(Modified after Haddad & Hawa, 1979)

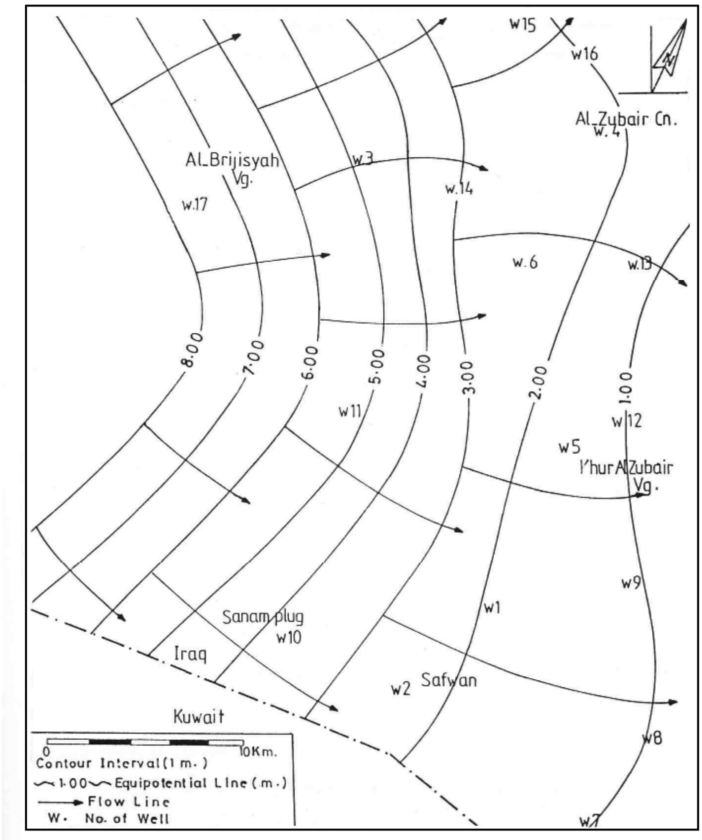

Fig.(3) Groundwater flow in area of question
(After Al-Abadi, 2002)

DEVELOPMENT OF WATER BUDGET EQUATION :

Development of water budget for a hydrologic system begins with formulation of a conceptual model. A conceptual model is a simplified representation of the essential features of the physical hydrogeological system, and its hydrological behavior, to an adequate degree of detail. It is itself based on an initial literature review, data collection and hydrogeological interpretation.

Figure (4) shows the suggested conceptual model for the aquifer in which, the clayey bed which is separating usable aquifer from the underlying more saline deep one is a semi-impervious boundary across which a certain amount of flow take place, i.e., the unconfined aquifer is treated mathematically as a dependent one. A choice of this model to represent the behavior of the aquifer is based on the following two reasons:

- Continuous deterioration of groundwater quality of the upper aquifer because of mixing process between the two water types of the two aquifers, especially at the eastern parts of the study area (Al-Suhail, 1999).
- Lowering of water table of the unconfined aquifer due to presently pumping scheme conveniently causes a relatively certain difference (About 0.20 m) between water levels of the two aquifer, resulting in transfer of water toward the upper unconfined aquifer because the gradient of the potential groundwater field becomes then toward it.

The hydrologic continuity for a hydrologic system can be stated as follows: (Philip & Wang, 1988)

$$I(t) - O(t) = \frac{ds}{dt} \qquad \text{...(1)}$$

Equation (1) may be expanded or abbreviated depending on what part of the hydrologic cycle is interested in and, depending on the available data base over the period of record (Dommenico & Schwarts, 1998). According to the suggested model and assumptions inherent in the hydrologic water budget equation of the upper unconfined aquifer is stated as (Fig.5):

$$\left(R_N + L_{up}\right) - Q_p = \pm \Delta S \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where:

R_N: groundwater recharge due to direct infiltration from rainfall

L_{up}: upward leakage

Q_p: pumped groundwater

ΔS: a lumped change in all subsurface water

All items in the above equation have a unit of discharge, i.e., volume per time.

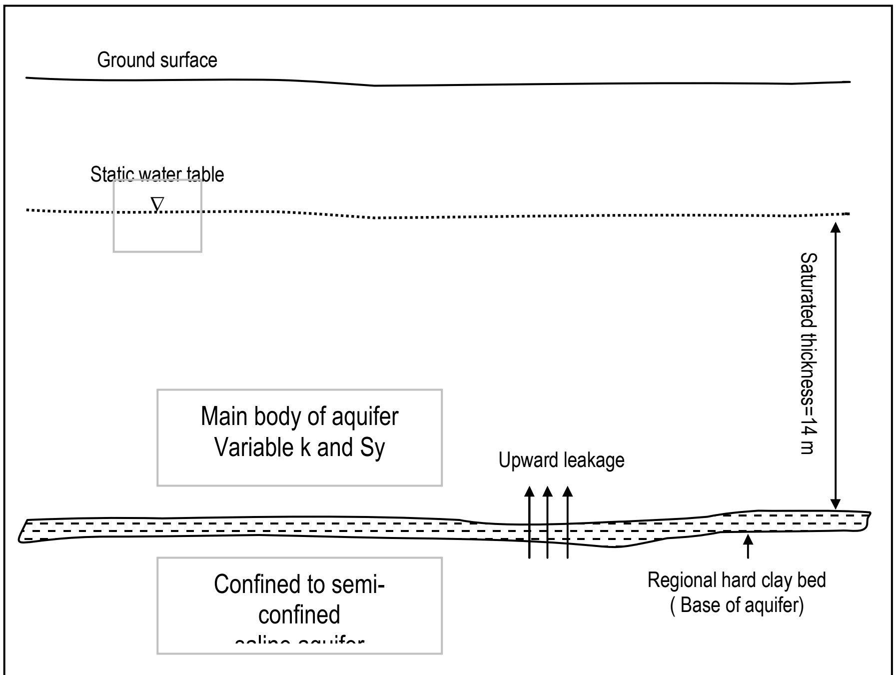

Fig.(4) A suggested conceptual model of the upper part of Dibdibba aquifer

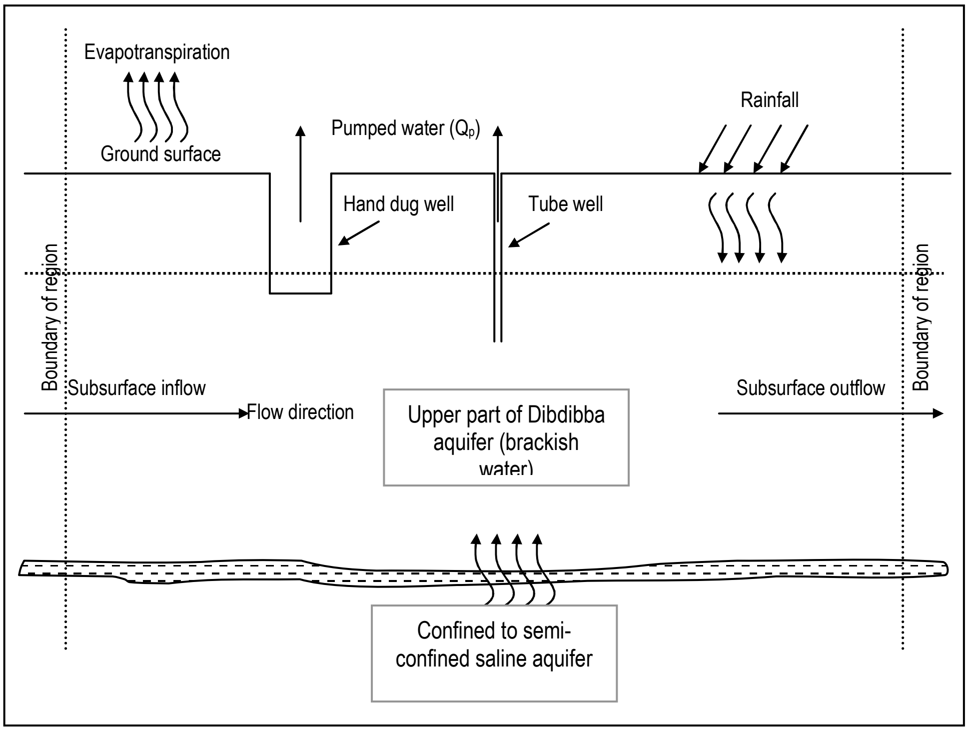

Fig.(5) Components of water budget of the upper part of Dibdibba aquifer in Safwan-Zubair area.

COMPUTATION OF WATER BUDGET EQUATION COMPONENTS

Groundwater recharge (R_N component) was calculated using water surplus concept. Absence of overland flow due to high infiltration capacity of the exposed sandy units demonstrates that a rapid infiltration of rainfall to enough depths occurs before any subsequent evaporation takes place. However, overland flow can be subtracted from water surplus quantity. No sufficient data concerned with soil moisture content is available, but highly impermeable sand leads to ignore this component and regarded it as additional loss during evapotranspiration process. Average of water surplus for study period (from 1980-2000) with assumption that the soil moisture approaches zero was (0.20 mm/year). The average of groundwater recharge was (92×10^6 m^3/year). Table (1) reveals results of the computations for the study period.

Large diameter hand dug wells are commonly used for abstracting groundwater in Safwan-Zubair area compared with tube wells due to many reasons including, shallow depths of water table, high well capacity, and the seepage area they provide. They had been drilled randomly with non-uniform shapes. The number of exploited wells is about (5000) in (1999) (Atiaa, 2000). The annual increase of wells is approximately (200) wells. In the area, there are two irrigation systems, furrow and trickle. The first is applied by (15%) of farms while the second is adopted by (85%) of farms (Al-Abadi, 2002). The percentage of re-infiltrated groundwater is (86%) depending on furrow and (33%) through the trickle irrigation system (Nommas & Al-Asadi, 2001) respectively. Due to the lack of sufficient data about the exact number of the pumping wells and their distribution over the study area, an approximated method was used to calculate this important component employed in the water budget equation. With the assumption of a systematic growth of drilled wells of both types, hand dug and tube wells for well number, total discharge of the Safwan-

Zubair wells (Q_p component) for each water year of the period of interested was estimated by multiplying the total number of the operating wells during the interested water year by the average discharge of one well (about 7ℓ/s) and by the working time of pumping during the entire water year (about 198 d) (Table.1).

Subsurface inflow and outflow components were determined using the flow net technique. Due to the fact that these values were relatively small quantities and equal (3×10^6 and 2.5×10^6 m^3/year, respectively), the effect of one component cancels the other. Hence, they are not introduced in the water budget equation of the area.

Upward leakage (L_{up}) was estimated using the following formula: (Hamil and Bell, 1986)

$$L_{up} = \frac{A k_v \Delta h}{H} \qquad (3)$$

where

L_{up}: upward leakage (m^3/y)

A: area of influence of upward leakage (m^2)

Δh: head difference between the two water levels (m)=0.20 m

H: thickness of the confining clayey bed (m)=2.00 m

k_v: vertical hydraulic conductivity of the confining bed =0.38 m/d

The above values are adopted to represent the hydraulic characteristics of the confining bed according to Al-Kubasi, (1999). Therefore, the computed value of upward leakage is (56×10^6 m^3/y). This value is considered as a constant because of the slight fluctuations of groundwater level in comparison with the saturated thickness of aquifer.

Other flow components such as inflow by urban activity especially at large population's areas and near enormous industrial establishments are ignored due to the lack of available information and because they occupy a small portion of the study area compared with the agricultural areas.

A lumped change of subsurface storage was calculated then, based on the resultant computation above, Table (1) and Figure (6).

Table (1) computations of water budget components

Water year	$R_N \times 10^6$ (m^3/year)	$Q_p \times 10^6$ (m^3/year)	$\Delta S \times 10^6$ (m^3/year)	$h_{decline}$ (m)
1980-1981	63	130	-14	0.0625
1981-1982	53	149	-43	0.1919
1982-1983	51	166	-62	0.2767
1983-1984	56	182	-73	0.3258
1984-1985	67	199	-79	0.3526
1985-1986	136	216	-27	0.1205
1986-1987	104	232	-75	0.3392
1987-1988	72	249	-142	0.5535
1988-1989	24	266	-189	0.8437
1989-1990	47	283	-183	0.8169
1990-1991	135	299	-111	0.4955
1991-1992	99	316	-164	0.7321
1992-1993	126	333	-154	0.6875
1993-1994	4	349	-292	1.3035
1994-1995	24	365	-288	1.2857
1995-1996	183	381	-145	0.6473

1996-1997	151	398	-194	0.8660
1997-1998	90	417	-274	1.2232
1998-1999	150	533	-330	1.4732
1999-2000	207	553	-293	1.3080
	92.10	300.8	156.6	Net decline of head =0.52 m

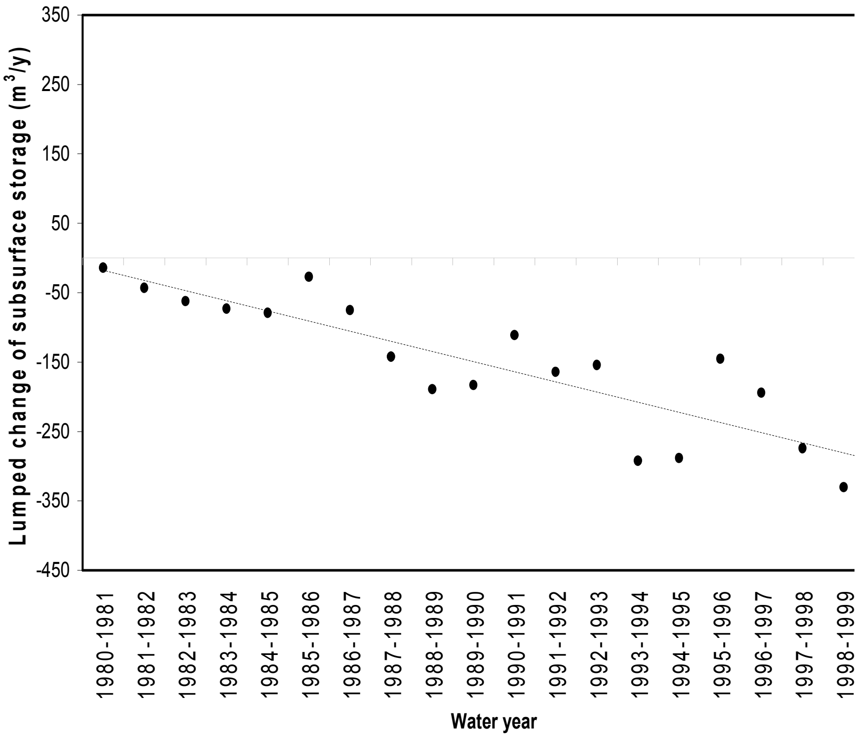

Fig.(6): A Lumped change of subsurface storage during the last decades

RESULTS AND DISCUSSION :

Results of water budget calculations and the trend of a lumped change of subsurface storage shown in Table(1) and Figure (6) demonstrates that the usable unconfined upper part of the Dibdibba aquifer in Safwan-Zubair area follows the direction of mining of resource. Therefore, the aquifer can be classified as depleted one. Since this situation was dominant during the last two decades, this led to depletion of the aquifer and introduced undesirable effects on it, quantitively and qualitatively. Quantitvely because more than (0.52 m) of the saturated thickness of aquifer would be drained, and qualitatively due to chemical mixing process between two water bodies. The average decline of groundwater levels during the last two decades was (0.7 m). Because most of penetrating depths of the hand dug wells, a common way for abstracted shallow groundwater in the area range between (1-3 m) on average basis. Such drop in head is not acceptable because most of the hand dug wells would become dry. Scheme of pumping operation and random drilling of wells are the main reasons caused such affects. The adequate management of the area requires:

- Controlling of pumping rates and duration of the existing operated wells and redistributing them uniformly over the area in order to alleviate interfering.
- Constructing large ponds acting as surface shallow wells in order to alleviate the current overpumping of the aquifer and decrease the difference in head as possible as between the bodies of water in the area under question. The design of such ponds requires a detailed study of the dynamics of flow toward them for accurate prediction of the allowable pumping rate within the constraints of available drawdown and a given pumping time.

- Control of agricultural area and type of crops. Lowers of agricultural area decreases water consumptions and losses. Select a crop (like cereals with lower water consumptions) contribute in decreasing water requirements and volume of pumping (Al-Asadi *et al*., 2005). Al-Asadi *et al* (2005) showed that water equirements for agricultural areas decrease to (27%) if select crops which need low water requirements like cereal.
- The best alternative plan, but a difficult and an expensive one to enhance the water availability for pumping and rebalance the aquifer is by using an artificial recharge scheme. Transport of available water with good quality using an appropriate method from Shatt Al-Arab river, (Table 2), which is located at (30) km to the north east of Barjizia area (Figure 1) during water surplus of the river is a preferable suggestion for replenishing depleted supplies and preventing a continuous deterioration of its quality. The comparison of the sum of present water requirements of Shatt Al-Arab river province (about 570×10^{6} m^{3}/y) with available water (2.2×10^{10} m^{3}/y) on the average basis demonstrates that large quantities of water are losing to the Arabian Gulf. Transfer of about (96×10^{6} m^{3}/year) from unused available water of Shatt Al-Arab river and recharging the aquifer artificially using an appropriate scheme (furrows and ditches are preferable method due to high infiltration capacity of exposed formation) during cold month of the year will rise its water table to the (0.5-1 m) and improve its groundwater quality. The detailed evaluation of using recharge and expected improvement induced in water quality are

only possible if proper numerical and geochemical models of the system are developed.

From the suggested plans to protect of aquifer, the plans 1 and 3 are difficult tasks and expensive. The best one of them under the dominant situation of the country is by conducting shallow ponds. This plan requires a comprehensive analysis from the design of view in addition to consider a dimensional analysis of design problem for generalization of study results.

CONCLUSIONS :

The usable unconfined aquifer in Safwan-Zubair area follows the direction of mining if the resource due to the dominant pumping scheme and random distribution of the operated wells throughout the area. The drop in head and deterioration of groundwater quality of the aquifer were the most serious problem that caused occurred as a result of dominant this situation during the last two decades. Three alternatives plans is outlined in order to alleviate deterioration of the aquifer quantitvely and qualitatively. The best and cheap one is by designing a shallow ponds act as shallow wells with appropriate diameters. The other methods to enhance the availability of the water for pumping is by using an artificial recharge or controlling of pumping rates and duration and/or redistribute the existing wells uniformly over the area.

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Dictionary

الكلمـــــــــــــــة	معناهـــــــــــــــــــــا
Hydrogeological setting	الوضع الهيدروجيولوجي
Transmissivity[1]	ناقلية المكمن المائي
Hydraulic conductivity	التوصيلية الهيدروليكية
Hydraulic gradient[2]	التدرج الهيدروليكية
I(t)	مقدار الجريان الداخل كدالة للزمن
O(t)	مقدار الجريان الخارج كدالة للزمن
ds/dt	مقدار التغير بالخزين كدالة للزمن
R_N	مقدار تغذية المكمن المائي من الامطار
L_{up}	مقدار تغذية المكمن من المكمن الاسفل عبر طبقة الطين الفاصلة بين المكمنيين
Qp	مقدار الضخ من الابار
Evapotranspiration	مقدار التبخر–النتح
Rainfall	الامطار
Boundary of region	حدود المنطقة
Subsurface inflow	الجريان التحت سطحي الداخل
Subsurface outflow	الجريان التحت سطحي الخارج

[1] تحسب نافليية المكمن المائي من حاصل ضرب السمك المشبع b في التوصيلية الهيدروليكية للمكمن K

[2] يجسب التدرج من حاصل قسمة الفرق في المنسوب Δh على الفرق في المسافة ΔL .

Flow direction	اتجاه الجريان
Tube well	بئر انبوبية
Hand dug well	بئر واسع القطر
Confined to semi-confined aquifer	مكمن مائي محصور الى شبه محصور
Upper part of Dibdibba aquifer	الجزء الاعلى من مكمن الدبدبة
Water surplus	الزيادة المائية
A	المساحة المتأثرة بالتصريف الداخل عموديا من الطبقة السفلى
H	سمك الطبقة العازلة
K_v	التوصيلية الهيدروليكية للطبقة العازلة