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Restoring the Garden of Eden, Iraq

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Abstract

The Iraqi marsh lands, which are known as the Garden of Eden, cover an area about 15-20 10^3 km^2 in the lower part of the Mesopotamian basin. The area had played a prominent part in the history of mankind and was inhabited since the dawn of civilization. The Iraqi government started to drain the marshes for political and military reasons and at 2000 less than 10% of the marshes remained. After 2003, the process of restoration and rehabilitation of Iraqi marshes started. There are number of difficulties encountered in the process. In this research we would like to explore the possibilities of restoring the Iraqi marshes. It is believed that 70- 75% of the original areas of the marshes can be restored. This implies that $13km^3$ water should be available to achieve this goal keeping the water quality as it is. To evaluate the water quality in the marshes, 154 samples were collected at 48 stations during summer, spring and winter. All the results indicate that the water quality was bad. To improve the water quality, then 18.86 km^3 of water is required. This requires plenty of efforts and international cooperation to overcome the existing obstacles.

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1 Introduction

The Iraqi marshlands, which are referred to as the Garden of Eden, are created by the Tigris and Euphrates Rivers system in the lower part of the Mesopotamian basin where the longitudinal slope is very weak (Euphrates about 4 cm/km and the Tigris 8 cm/km) causing the two rivers to meander and split into many branches. This has formed a series of lakes and marshes. During seasonal flood the water overflows the plain and creates complexes of marshes. They cover an area about 15-20 10^3 km^2 (Figures 1 and 2). The Arabs (Islamic Age) called the lakes and marshes Al-Bataih, "the lands covered with torrents". When they came to Iraq, they dug canals and drainage systems in large areas and cultivated lands and changed them into fields. The areas between Kufah, Wasit and Basrah were well-populated. The marshes shrank and increased according to the intensity of the floods of the two rivers throughout the centuries and according to the ability of the rulers of Iraq to control the water of the rivers.

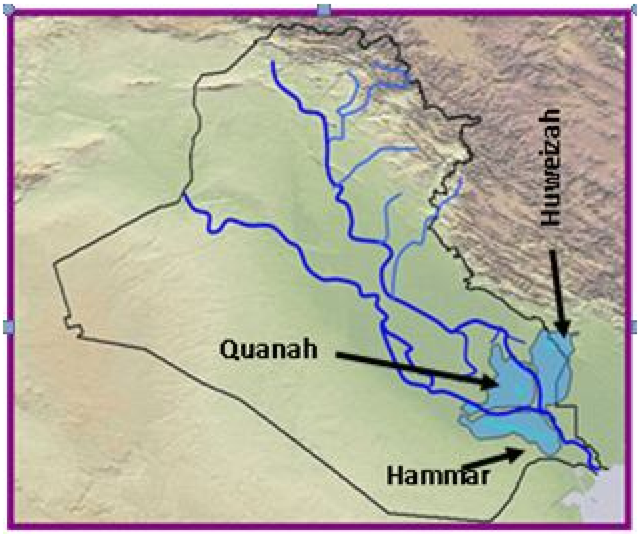


Figure1: Major Iraqi Marshlands

The marshlands stretch between double deltas. An inner one produced by Hillah-Hindiyah on the Euphrates and Sghatt al-Gharaf on the Tigris and a marine delta created by the Karun and Marunjerrahi river system [1]. Near the confluence of the two rivers in Qurnah, the Mesopotamian plain is very narrow due to the formation of conglomeritic alluvial fan of wadi Batin drawing the deposits from Saudi Arabia in the west and the Karun-Karkheh river systems descending from the Zagros mountains in Iran from the east [1]. These marshes are divided into three major units: i/Hammar marshes, ii/Central (Qurnah) marshes and iii/Hawizeh marshes (Figure 1). The water in the marshes lie over clayey soils and water depths are 0.5–2.0 m in dry and wet seasons respectively, while it reaches 6.0 m depth in permanent lakes.

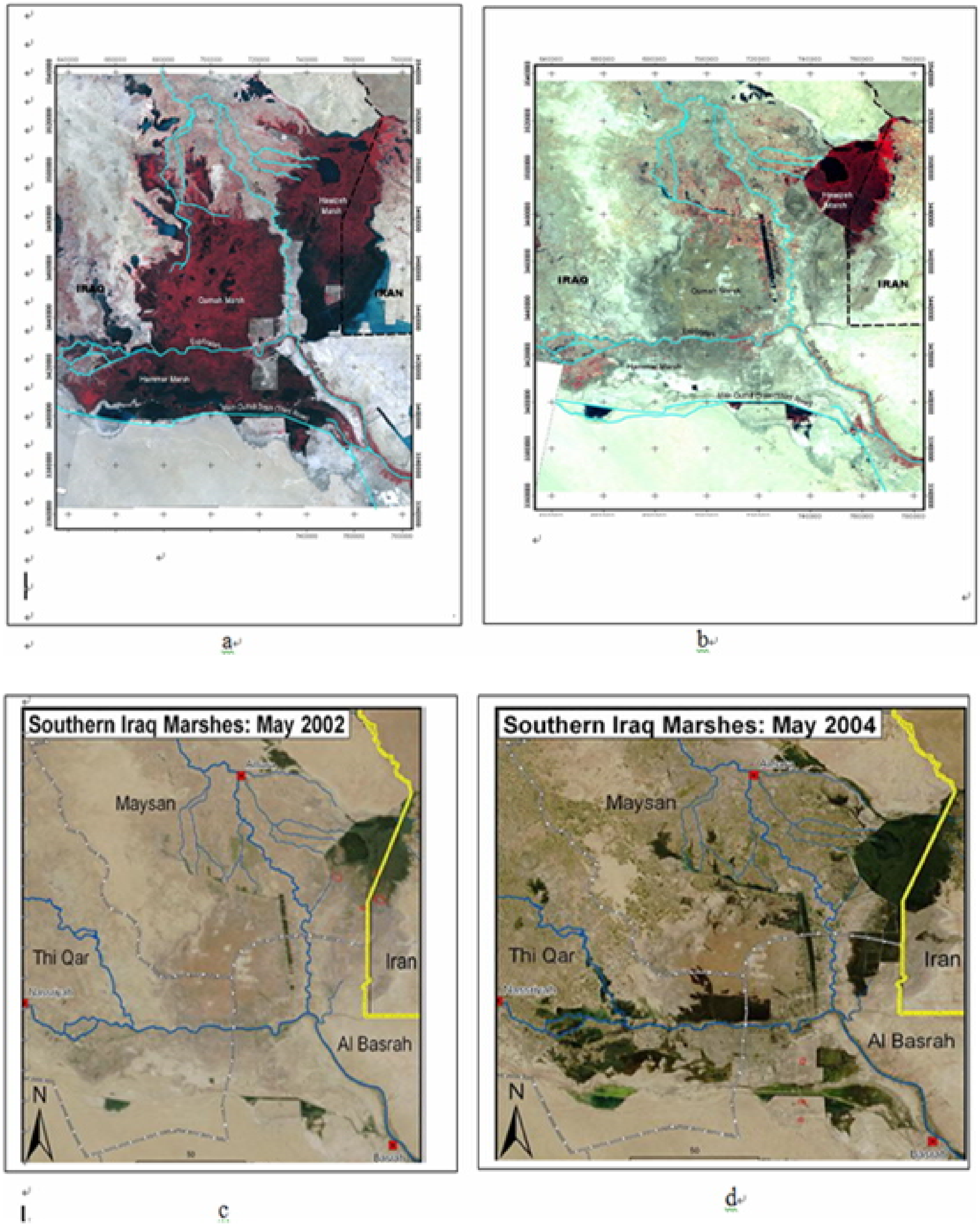


Figure 2: The Mesopotamian Marshes a. 1985 b. 2000 c.2002 d. 2004 [40].

The area was considered among the largest wetlands in the world and the greatest in west Asia. It is considered one of the eleven non marine wetland areas in the world with Endemic Bird Area status [2; 3]. It supports a diverse range of flora and fauna and human population of more than 500 000 persons and is a major stopping point for migratory birds.

The area was inhabited since the dawn of civilization by the Sumerians about 6000 years BP [4 and 5]. Huge number of sculptures and Figures are documented since the Sumerians and Babylonian ages (Figure 3) [6]. Large number of the present inhabitants, referred to as ‘Ma`dan’, are claimed to be descendants of Sumerians. They have their own style of life which is linked with their aquatic environment. Most of them are semi-nomadic and their settlements are located at the edges of the marshes or on artificial islands and their houses are usually built of reed and mud (Figure 4). Water–buffalos are very important for the Marsh Arabs existence. For them water buffalos are like the importance of a camel for the Bedouin [7]. The buffalos are fed on young reed shoots and they provide them with milk, butter, yoghurt, as well as energy and crop fertilizer in the form of fuel and manure. Fishing, hunting and growing rice is the other complimentary things in the life of the marsh Arabs. The marsh dwellers were isolated till the 1970s.

Figure 3: Sumerian clay tablet 5,000 year old depicts an ancient reed house. [9].b- ‘He (Merodach-Baladan, King of Babylon) fled like a bird to the swampland’ and ‘I (Sennacherib, King of Assyria) sent my warriors into the midst of the swamps … and they searched for five days’. But the King of Babylon could not be found. (703 B.C.) [6]. c- Relief showing life in the marshlands in ancient times. [9].

Figure.4: A typical marsh landscape. Villages are built on artificial floating islands by enclosing a piece of swamp, and filling it in with reeds and mud. For flood protection, more layers are added each year to strengthen it.

Reed (Pharagmites communis, Typha augustata) covers large areas of the marshes. The vegetation in the mud flats is usually Carex and Juncus spp., Scripus brachyceras. In the fresh water lakes the aquatic vegetation dominates like hornwort (Ceratophyllum demersum), eel grass (Vallisneria sp.) and pondweed (Potamogeton lucens spp.), as well as bottom vegetation such as stonewart (Chara spp.). In the smaller lakes and back swamps, floating vegetation of waterlilies (Nymphaea and Nuphar spp.), water soldier (Pistia stratiotes) and duckweed (Le mna gibba) are common [3; 8].

The marshlands are very important for migrating birds where several millions of birds reside in these marshes when they migrate [9]. More than 80 bird species were used to be in the marshlands. Due to draining process several species of animals and plants are extinct now while other species are threatened including for example Grey Wolf, Mesopotamian Gerbil [1].

It had been estimated that 60% of the fish consumed in Iraq comes from the marshes [10]. In addition oil reserves had been discovered in and near the marshlands [11; 10].

The draining of the marshlands by Saddam regime in the 1990s brought catastrophic effect on the marsh dwellers, animals and plants. Several initiatives had been taken by the Iraqi Government and others [e.g. 10; 12; 13; 1] to restore this area (Figure 5). It is believed that there are several factors effecting the restoration of the marshlands which are to be discussed in this paper.

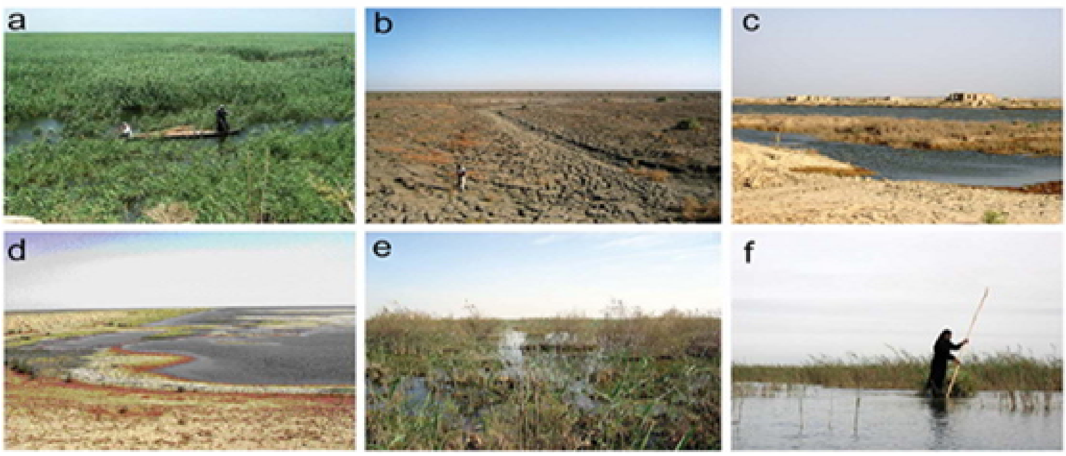


Figure 5: (a) Marsh Arab fishermen Al-Hawizeh marsh in 2003. (b) The totally drained Central marsh 2003. Marsh soil (c) The remains of Al-Hammar marsh 2003 (d) Al-Sanaf, a seasonal marsh area. s (e) Abu Zarag in February 2004). Reflooded in April 2003. (f) Suq Al-Shuyukh in February 2004. (44).

2 Evolution of the lower Mesopotamia

During the last glacial period about 18000 years BC the sea level was about120-130 m below its present level. The Gulf at that period was dry and Shatt al-Arab was flowing directly into the Gulf of Oman [14] (Figure 6). The Tigris and Euphrates Rivers were cutting down to -26 m into the Mesopotamian plain between Qurmat Ali and Qurna and lower than -30 meters at Fao. Probably there were no marshes at that period when the ground water level was low. This period was followed by the rise of sea level at 14000 years BP onwards. Evidence of fresh water peat at Bubiyan island were reported by Gunatilaka [15] and Al-Zamel [16] at -20m deposits which are 2800 years old and at that time the surface of Shatt al Arab delta was 20 m below its present level. Sanlaville [14] suggests that the sea level was raising relatively fast at the period 900 – 6000 BP and it was at its maximum about 4000 years BC. At that period the sea level was 1 to 2 m above its present level [17]. Marine faunas were discovered in various parts of Mesopotamia. In Basrah and Amarah it was found at -2.7 and -8.5 m below soil surface within the sediments of Hammar Formation [18; 19]. From carbon dating it is clear that the Hammar Formation is of Holocene age [15] suggesting that the postglacial transgression reached Amarah area (Figure 6). The area was aquatic where the river bed was raised and the water table while the inner Gulf region was brackish due to its shallow nature and fresh water contribution from the rivers. Summarian cities like Ur and Eridu during the third millennium were located at the coast of the Gulf [20; 21].

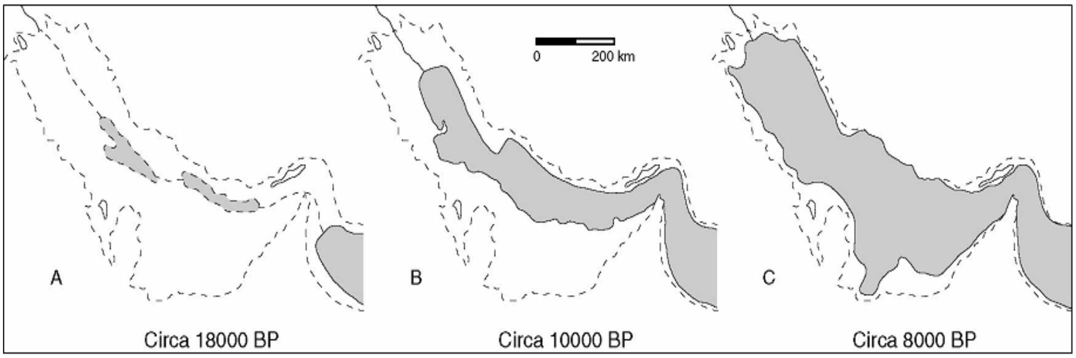


Figure 6: Postglacial transgression of the Gulf area (14).

Over the marine Hammar Formation, abundant river sediments were deposited in the shallow northern region of the Gulf leading to the progression of the delta toward the southeast (Figure 7). This prevented the sea water from entering too far inland and for changing the nature of water from brackish lagoon to fresh water type and resending the coast line toward the south [22]. Archeological sites were discovered at the south of Haur al Hammar and east of Qurna-Basra during the second and first millennium indicating the Gulf shoreline was further south. After this period the rivers were running on the surface of the plain and the marshes took their present configuration and zoning. The southern limit of the Mesopotamian delta was very near its present limit during Hellenistic period and the three rivers had their own estuaries while the sea level is believed to be about one meter lower [14; 23 and 24].

Onward miner events took place where at the seventh century the Tigris River followed the Gharaf bed into the Euphrates forming a very big marsh 370 km long and 90 km wide. At that time the marshes were much bigger than today due to the shift of the Tigris River toward the west (14). Old investigations cited the existence of such big marsh which includes Haur al-Hammar [25]. Due to the large quantity of sediments carried by the Tigris and Euphrates Rivers, Lees and Falcon [26] believed that the area was under subsidence. In view of the excavations and bore holes through Hammar Formation [e.g 27], it is believed that the weight of accumulating sediments compressed the silt and clay. A similar conclusion was cited by Sanlaville [14]. After the second half of the twentieth century the constructions of dams in Turkey and Iraq controlled the floods of the Tigris and Euphrates Rivers. Consequently the marshes are no longer fed by their floods. Furthermore salinity started to increase due to high evaporation rates.

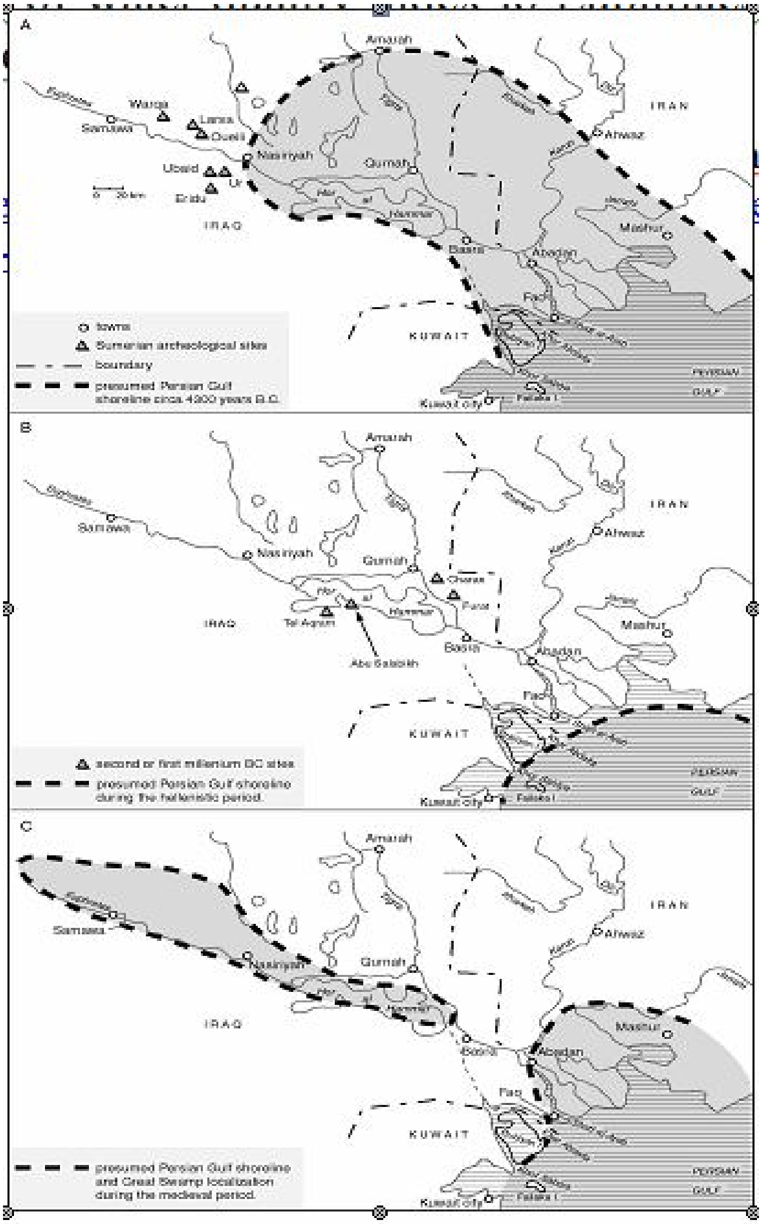


Figure 7: Evolution of the Gulf level and of the Lower Mesopotamian shoreline

since the postglacial transgression (14).

3 Climate of the area

The climate of Iraq is continental and subtropical with hot dry summer and mild wet winter.

The rainy season usually extends from October to May followed by dry season from June to September. The annual rainfall map indicates that the average annual precipitation increases slowly from south-west to north-east. October to May, have a relatively low precipitation where the maximum precipitation takes place during December, to March. The rainy days during the year are between 40 to 60 days and the probability of intensive rainfall (1-10 mm) is only 25-27% [13]. The average annual rainfall ranges from 42 to 185 mm. Within the marshland area, Al Amarah, Al Basrah and Al Nasiriyah stations show an average annual precipitation of 185.42, 152.4 and 109.22 mm respectively [28].

The air temperature within the area reaches more than 50^{o}C during summer and drops rarely below zero during winter. It can be noticed that the mean annual temperature is ranging between 22.2 and 27.2^{o}C. The absolute maximum and minimum are 50 and -2.2^{o}C respectively. June, July and August are the warmest months (monthly average 34^{o}C) while January, February and December are the coldest months (monthly average 8.8^{o}C). It should be mentioned however that about 10 days a year the temperature is equal or below 0^{o}C.

The area is considered as humid area where it reaches its maximum relative humidity in winter (75%) and the minimum in summer (22%) with a mean value of 42%.

The total annual radiation reaches 525 mW/hour where it reaches its maximum in June and July and its minimum in December and January. Eight to nine hours is the sunshine duration as an average during the day, this is equivalent to 72%. In summer sunshine duration reaches 85% while in winter it does not exceed 70%.

The prevailing wind direction is northwesterly and westerly. During spring, a south-westerly wind exists which is referred to as 'khansin'. This wind comes from Saudi Arabia and usually brings sand storms. Mean annual wind velocities are ranging from 3.6 to 5.7 m/sec with the highest mean monthly wind velocities taking place in the period June to August.

Potential evapotranspiration (ETo) map shows that the rate is higher in the south relative to the north. The average annual ETo is higher than 2000 mm. ETo reaches its maximum values during May to September and its minimum during January. During summer, 50% of ETo annual amount occurs while it is 22% during spring and autumn and it reaches its minimum (6%) during winter.

The average annual days with fog is 27 days and the maximum number of fog days occurs in December and January. As far as thunderstorms are concerned, its mean annual number of days is 7 usually occurring during the period October to May.

The average annual dust days are of the range 36-53 days and they usually occur from April to August with the peak in June and July. The western parts suffer more than other parts from the dust storms.

4 Hydrology

Iraq consists essentially of a flat, low-lying plain which rises gently to the southwestern plateau reaching elevations of 940 m, and the northeast to the Zagros Mountains, which rise to elevations up to 3000 m. Elevations most of the Mesopotamian Plain (featureless plain) are vary from few meters below sea level to about 400 meters above sea level. The widest portion of the plain is 200 km, but it narrows towards Basrah to less than 45 km.

The lower reaches of the Tigris and Euphrates Rivers join at Qurnah to form the Shatt Al-Arab, which flows into the Gulf below the town of Fao. In southern

Mesopotamia, both rivers separate in many sub-branches which disappear in a large marshland formation once occupying more than 15 10^3 km^2 (during the early 1970's). Typical water depths within the marshes fluctuate between 0.5-3.5 meters annually. The largest marshes are the Hammar, Huweizah and Qurnah (or Central) Marshes (Figure 2).

Most of the data in this section are obtained from Iraqi Ministries, 2006a, b and c; CRIM, 2008, 2009 a and b.

4.1 Al-Hammar Marsh

The Al-Hammar Marsh is situated south of the Euphrates, extending from near Nasiriyah in the west to the outskirts of Basrah on Shatt Al-Arab in the east. To the south it is bordered by saline lakes and sand dune belt of the Southern Desert.

During the 1970's the marsh area covered approximately 2,8 10^3 km^2 of permanent marsh and lake, expanding to over 4,5 10^3 km^2 during periods of seasonal and temporary inundation. It was approximately 120 km long and 25 km wide. Maximum water depth in the marsh ranged from 1.8 to 3 meters.

During the summer, large parts of the shoreline normally dried out, and banks and islands emerged.

Al Hammar Marsh was fed primarily by flooding and tributaries of the Euphrates River. A considerable amount of water from the Tigris River, overflowing from the Qurnah Marsh, also nourished the Al Hammar Marsh. Groundwater recharge was another source of replenishment.

4.2 Qurnah Marshes

The Qurnah marshes are bounded by the Tigris River to the east and the Euphrates

River to the south, the area is roughly delimited by a triangle between Nasiriyah, Qalat Saleh and Qurnah. During seventies of last century, the Qurnah Marshes covered an area of about 3 10^3 km^2. They receive water mainly from Tigris distributaries branching southward from Amarah.

The marsh complex was densely covered with tall reed beds, interspersed with several large depressions. Along the marsh's northern fringes, dense networks of distributaries deltas were the sites of extensive rice cultivation.

4.3 Huweizah (Central) Marsh

The Huweizah Marsh lies to the east of the Tigris River, straddling the Iran-Iraq border. The Iranian section of the marshes is fed primarily by the Kharkeh River. In Iraq, this marsh was largely fed by two main distributaries departing from the Tigris River near Amarah, known as Al-Musharah and Al-Kahla. During spring flooding, the Tigris would directly overflow into the marshes. It extends for about 80 km from north to south, and 30 km from east to west, the marshes covered an approximate area of 2,35 10^3 km^2. The northern and central parts of the marshes were permanent, but towards the southern sections they became increasingly seasonal in nature. The permanent marshes had moderately dense vegetation, alternating with open stretches of water. Large permanent lakes up to six meters deep were found in the northern parts of the marshes.

4.4 Hydrological conditions at 1990s

The primary source of water to the marshlands is flow from the Tigris and Euphrates Rivers, with the Kharkeh River supplying some water to the Huweizah Marsh, and some supply from groundwater. The wetlands of Lower Mesopotamia comprise shallow lakes and marshes covering a large area (Figure 2) which is formed on two large, flat and active fan deltas which are fed by the floods and water of the Tigris and Euphrates Rivers and their distributaries. The floods of these two major rivers are caused by the winter rain and spring snow melt in Turkey and Iran. The area is poorly drained and have very low gradient of Quaternary alluvial plain [29; 30].

During floods, the dry areas (or highlands) within the marshes are subjected to inundation by the Tigris and Euphrates water and, if it was not for the presence of rivers and levees, the entire region would be completely inundated by surface water. Water from the Tigris feeds the Huweizah and Central marshes due to the inadequate carrying capacity of its channel. The main Tigris channel reduces its cross-sectional area as it approaches the marshes. At Kut, the carrying capacity of the channel is as large as 6.000 m^3/sec, while at Kalat Salih-Kassarah it decreases to 65-70 m^3/sec. Downstream of Kassarah the river is again augmented by lateral inflow from the Huweizah marshes.

Before the 1970's, there was a complex system of natural channels where the Tigris and Euphrates formed interior deltas prior to reaching the marshes. This natural system of distributaries has been altered over thousands of years into agricultural canals. These include the Gharraf (design capacity of 500 m^3/sec) flowing into the marsh Abu Zirig, Butairah (600 m^3/sec), Aridh (700 m^3/sec), Mujar Al-Kabir (210 m^3/sec), flowing into the Qurna Marshes, and Mujarrah, Chahala flowing into the marsh of Huweizah. The Tigris River waters, after flowing through the Qurnah/central marshes, used to be occasionally overtopping the low levees on the right side of the Euphrates during high floods and feed the Hammar marshes. Now this is not possible as the upper reach of the Euphrates River is constrained into higher embankments all the way from Nasiriyah to Mdaineh. Still, eight secondary branches exist and are able to connect the Qurnah marshes to the Euphrates under the Nassiryia-Chebaish-Qurnah road via a number of bridges and culverts and breaches along the north embankment of the Euphrates River. The estimated 100-year event discharge capacity of these openings is 420 m^3/sec.

The Euphrates is divided into several arms downstream of Nasiriyah and flows into the Hammar Marsh along several secondary channels, the largest of which are Aglawin, Akaika (Qeqe), and Haffar. The total discharge capacity of these secondary channels is 1.820 m^3/sec.

The most important development which affected the marshes was the establishment of modern controls of the water of the Tigris and the Euphrates. This led to a decrease in the great floods that affected Iraq and consequently the area of the marshes. In addition, the irrigation projects played an active role in determining the courses of the Tigris and Euphrates and their branches, making future changes improbable.

The discharge of the Euphrates measured downstream of Hindiya before 1990 averaged 597 m^3/sec, and then afterward the discharge averaged 338 m^3/sec. The Tigris downstream of Kut had a mean discharge of 945 m^3/sec before 1990; after 1990 the mean discharge was 368 m^3/sec.

The Kharkeh River supplied approximately 5 10^6 $m^3$to the Huweizah marsh prior to 1990; at the present time, it supplies approximately 2 10^6 m^3. This reduction is due to the usage of water from the Kharkeh Dam built in 2002 [31].

The area of the marshes were highly influenced by the hydraulic structure build during the 20th century, construction of major hydraulic works played an essential role in controlling the floods. Al-Hindiya Barrage was inaugurated in 1913 on the Euphrates River while Al-Kut Barrage was constructed in 1938, which directed more water flow towards the Gharraf River to supply irrigation for field agriculture, thereby decreasing the amount of water flowing from the Tigris into the Qurnah (Central) and Huweizah marshes. In the 1970s the Syrian built dams on the Euphrates River followed by Turkey in the 1990s when they started the GAP project [32]. The post-1990 flow through the Euphrates is approximately half of what had been, while in the Tigris flows have decreased to almost a third of the discharge before 1990. This entire project reduced the quantity of water flowing to the marshes. In addition many oil fields have been discovered within and near the marshes. The exploration of oil leads to drying parts of the marshes. More than 1000 km^2 of area represents the major oilfields in southern of Iraq, and this number will most likely increase in future. The largest oilfields in the marshlands area are:

1. South Rumayllah in the Al Hammar Marsh. This is a super-giant oilfield in production since 1953. The northern portion of the oilfield extends into the marshlands. Approximately 300 km^2 of marshlands have been drained to accommodate its production footprint.

2. North Rumayllah in the Hammar Marsh. North Rumayllah was discovered shortly after the main Rumayllah field in 1954, but did not go online until 1972. Approximately 200 km^2 of marshlands were drained to accommodate its production footprint.

3. Zubayr field within the southeastern most Hammar Marsh. This oilfield has been producing since 1949; approximately 100 km^2 of marshland was drained to allow for production facilities.

4. West Qurnah in the Hammar and Qurnah Marshes. This is essentially the northern extension of the Rumayllah oilfields and represents a separate super-giant oilfield. The field was initially developed in the late 1980s. Only the portion within Hammar Marsh is under production, for which an area of about 150 km^2 of marshlands was drained.

5. Majnoon Field within the Huweizah Marsh. This is a super-giant oilfield discovered in 1977. Approximately 300 km^2 of marshlands were drained to accommodate the footprint of its production facilities.

5 Draining the marshlands

During the last two decades, hydrological programs such as previous Iraqi government drying program and Turkish dam's construction in the headwaters of the Tigris and Euphrates Rivers have nearly destroyed these once-rich freshwater wetlands.

Remotely sensed image analysis of the area indicates that 63% of the marshes diminished in 1992 when it is compared to the year 1985 (33). Tables 1, 2, 3 shows that the al-Hammar and Qurnah marshes almost completely desiccated as well as the presence of evaporate deposits on their major water bodies (33).

Table 1: Land cover classification and change in the Hammar Marsh area 1977-2000 [33].

Land cover Category	1977(km^2)	1985(km^2)	2000(km^2)
Permanent Marsh	1,632	2,347	60
Seasonal Marsh/Agriculture	286	339	210
Open Water	1,933	694	112
Total Wetland	3,565	3,041	172

Table 2: Land cover classification and change in the Qurnah Marsh area 1977-2000 [33].

Land cover Category	1977(km^2)	1985(km^2)	2000(km^2)
Permanent Marsh	2,765	3,244	82
Seasonal Marsh/Agriculture	380	190	689

Open Water	646	203	66
Total Permanent Wetland	3,411	3,447	148

Table 3: Land cover classification and change in the Hawizeh Marsh area 1977-2000 (33).

Land cover Category	1977(km^2)	1985(km^2)	2000(km^2)
Permanent Marsh	2,408	2,496	973
Seasonal Marsh/Agriculture	286	224	507
Open Water	785	766	173
Total Permanent Wetland	3,193	3,262	1,146

Serious attempts to dry the marshes started at the outbreak of Iraq-Iran war in 1980s when Iranian troops advanced inside Iraq [34]. Saddam regime began to drain the marsh lands so that troops can be moved into that area and use the water to block the advances of the Iranian troops [35; 12; 11] and perhaps to get rid of the marsh dwellers [36]. Local dwellers were also taken to the war front. Details of the engineering structures that were constructed to drain the marshes are discussed in details by CRIM [37].

It should be mentioned however that the area was highly contaminated by army munitions and poison gas [34; 38; 39]. Some people think that this was deliberate so that the area will not be possible to live in again [40].

USA encouraged the Kurds in the northern part of Iraq and the marsh dwellers to rebel against Saddam regime in 1991 during second Gulf war [40] and the result was that the Iraqi army crushed the marsh dwellers. During the first Gulf war some army deserters used to hide in the marsh areas and after the 1991 rebellion, some of the rebels took refuge in the marshes. Due to these factors the Iraqi regime sieges the area and movements in and out of the area were forbidden. To enable the army to move inside the marshes, the central government started to execute five major drainage projects to prevent water from the Tigris and Euphrates Rivers from reaching the marches. Later, the army launched a major attack against marsh dwellers using artillery, mortar and ground attacks [41; 42]. This led to a mass exodus of marsh dwellers. Burning and bulldozing villages, confiscating land, forcibly removing inhabitants, taking hostages was a daily practice of the army in the marsh area. Water supplies were poisoned [43].Two third of the marshes were not receiving water inputs in 1993 and at 2000 less than 10% remained [44]. The marsh lands were destroyed and some local dwellers turned to farming in order to survive.

Coast [45] stated that 500 000 marsh dwellers remained in the marsh lands at the end of the first Gulf war. A migration to Iran started in 1990 and 120 000 marsh dwellers left. In 1997, 192 000 marsh dwellers were still living in southern Iraq and 200 000 remained in all Iraq [45]. After the fall of Saddam regime in 2003, people living near the marshes started to break down the diversions structures to let water entering the marsh lands again [44]. After that the Iraqi Government and the International community are trying to restore the marsh lands.

Since 2003, there was an increase in wetland area and vegetation by about 58% [46] and in 2008 the marsh land covered 4.950 km^2 and it was then reduced to 3 420 km^2 in April 2009 and to 2 313 km^2 in July 2009 [40;44]. The reduction was due to water shortages.

UNOHCI [47] estimate that only 10% of the marsh dwellers are living in the marsh lands today and it is believed that others living inside Iraq might return back to the marshes also [48; 49; 50].

The marshlands are well known for their biodiversity and cultural richness. Millions of birds migrating to Africa from Siberia and vice versa were using the marshlands in their journey [2,51]. Rare species such as marbled teal (Marmaronetta angustirostris; 40% to 60% of the world population) and the

Basrah reed warbler (Acrocephalus griseldis; more than 90% of the world population), were assumed to be close to extinction [51], but have recently been seen in a winter bird survey [52]. Furthermore, costal fish in the Gulf area used the marshlands for spawning migrations and the area was used also as nursery grounds for penaeid shrimp (Metapenaeus affinis) and numerous marine species [44].

The pollutants of the Tigris and Euphrates Rivers were used to be filtered in the area before reaching the Gulf while the Gulf area near Kuwait has now been degraded [2, 53, 35].

6 Present conditions of the marshes and its restoration and rehabilitation

After the fall of Saddam regime in 2003 the local people removed some of the embankments on the Tigris and Euphrates Rivers to allow the water to inundate the marsh area. After that the Iraqi government, with the help of US, Japan, Canada, Italy, Denmark and some UN organizations (e.g. UNEP and UNDP) are trying to restore the marsh land. It should be mentioned that these enforced land use changes, climatic variations and changes as well as ecological fragmentation were all caused by draining the marshes. Accordingly, many species were affected as well as the marsh dwellers again. The rate of restoration reached 800 km^2/year [44; 54] while UNEP [1] stated that the expansion rate is 900 km^2/year.

UNEP [1] stated that the wetland and marshes expanded 10% of its 1970s size in January 2003 and to 41% in December 2005 and both Al Hammar and Al Haweiza cover 50% of their original size. The marsh surface area reached 3000 km^2 in 2005 and the variation of the surface water body between summer and winter-spring was 700 to 2000 km^2 [1]. The drought in 2009 and the reduced flow from Iran caused the size of the marshes to shrink to the same area as it occupied in 2003. It should be emphasized that the water quality of large part of the marshes is of low quality [55]. CIMI [54] reported that the percentage of healthy marshes in Basrah, Maysan and Thi Qar Governorates are 42%, 47% and 21% respectively. From the data collected after 2003, it seems that it is impossible to restore the marsh lands as they were before the 1980s. This is due to the saline soil, poor water quality and pollution from military leftover. Parts of the marshlands are still in use as agricultural areas and the owners or the local authorities are reluctant to leave them due to the high agricultural production from these areas. In addition, oil activities took about 30% of the marsh land. Using the data provided from the Ministry of Water Resources (especially CRIM), it is evident that if 75% of the original areas of the marshes are restored i.e. 1800, 1800 and 2425 km^2 for Al Hammar, Al Hawiza and Central marshes respectively. This implies that the quantity of water required is 3263, 5495 and 4128 10^6 m^3 for the three marshes (Table 4).

To evaluate the water quality within the three main marshes, 11(Huweizah marsh), 17 (Al-Hammar Marsh) and 20 (Central marsh) locations were selected (Figure 8). As far as Huweizah marsh, seven locations were from the feeders of the marsh while two were inside the marsh and the last two from the outlets for the marsh. Samples were collected during three seasons from these locations (spring, summer and winter) in 2008 and analyzed at the Iraqi Ministry of Water Resource [56]. It should be mentioned however, that in some locations no samples were collected during summer and winter because the area was dry. The following equation was used to find out the water quality index (WQI):

$$WQI = \left[\prod_{1}^{n} \sqrt[n]{f(c_i)} \right] * 100 \qquad (1)$$

Where:
n: is the number of considered water quality parameters.
c: is the concentration or value of the water quality parameter number i.
f (ci): is the weight factor which is function of the concentration or value of the water quality parameter.
The water quality index for the fish and aquatic life consideration consists of the following water quality parameters; pH, temperature, dissolved oxygen, specific conductivity, total dissolved solid, chloride, Khalid [57].

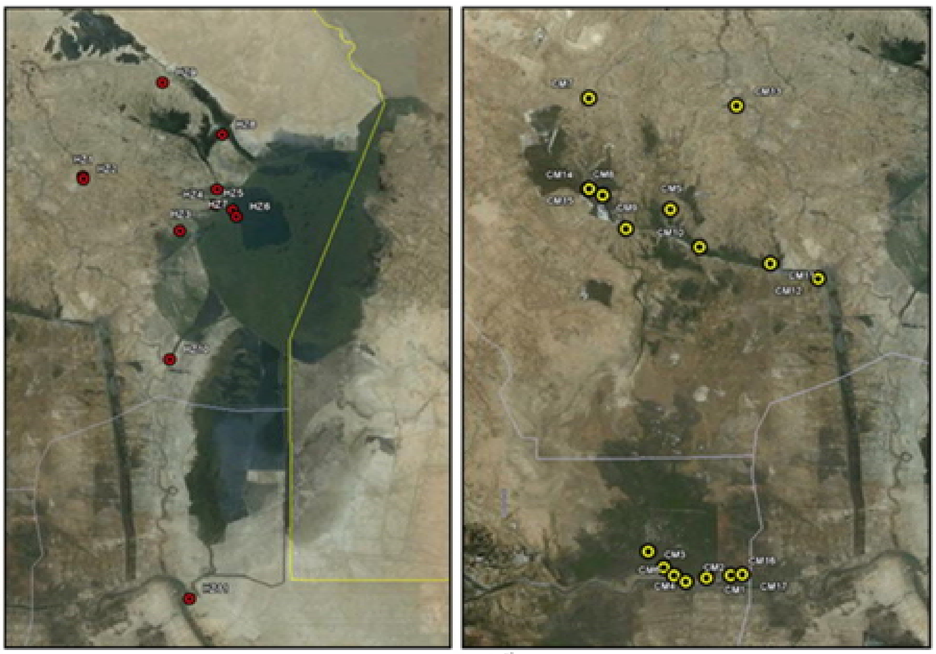
According to the equation the ranking values are given in table 5. The results (Figures 9, 10 and 11) showed that the overall WQI of the marshes water were fluctuating at each marsh during the three seasons, and the best season relatively was spring then winter while summer was the worst.

Table 4: The volume of water required to restore the Iraqi marshes.

Marsh Name	Total available area km^2	Percentage of restorated area (2008) %	Percentage of goal area %	Water Required MCM
Huweizah	1800	44	75	5495
Hammar	1800	23	75	3263
Qurnah	2425	25	75	4128

Huweizah Marsh was relatively the best in its WQI relative to the other two marshes (Figure 9). For the same season, the water quality inside the Huweizah marsh was worse than the quality of most of the feeders. This is believed to be due to high evaporation and evapotranspiration rates.

The WQI of Al-Hammar Marsh was very bad according to the WOI scale for the whole seasons and was bad for its feeders of the marsh are ranged from bad (in three stations on the feeders in spring season) to very bad for most of the locations as shown in (Figure 10). The exceptional station was MH22 where it supplied water from River Tigris directly. The other locations and the marsh itself are highly influenced by the Gulf water entering the marsh and its feeders during tides.



(a) (b)

(c)

Figure (8): Locations of measuring stations for water quality parameters for (a) Huweizah marsh, (b) Qurnah marshes and (c) Hammar marsh

The WQI of Qurnah marshes was very bad for the whole seasons while most of its feeders (especially from the north) had better water quality and are ranged from medium during spring and winter for the most feeders (except one good value in spring for one of them) to very bad during summer as shown in (Figure 11).

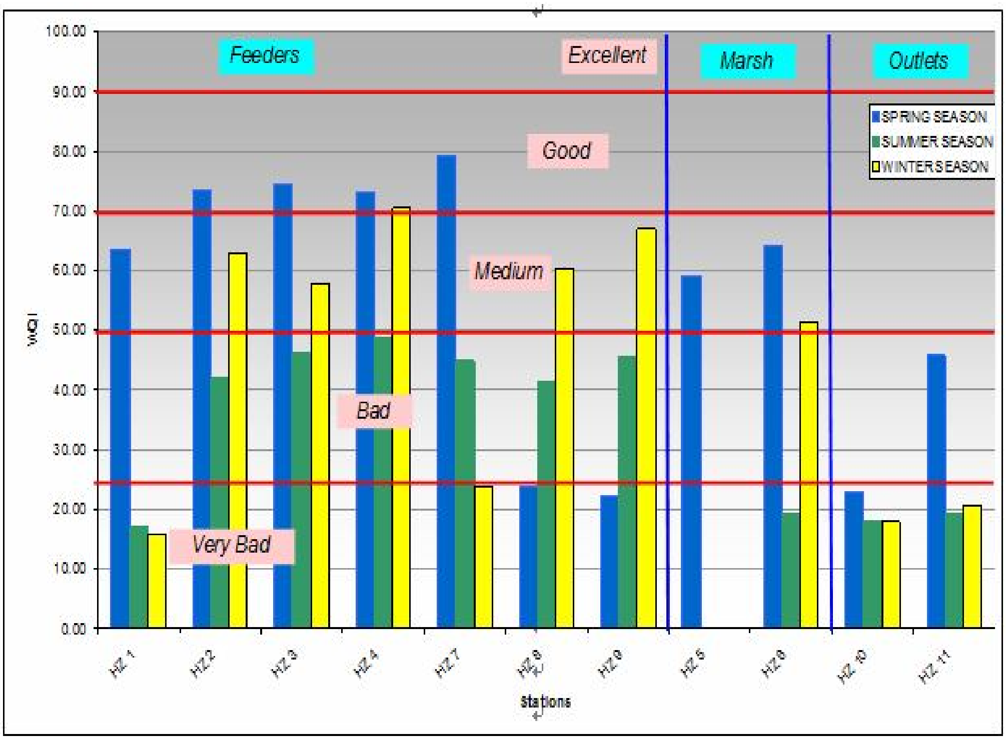


Figure 9: Water quality index values for Huweizah marsh during three seasons in 2008.

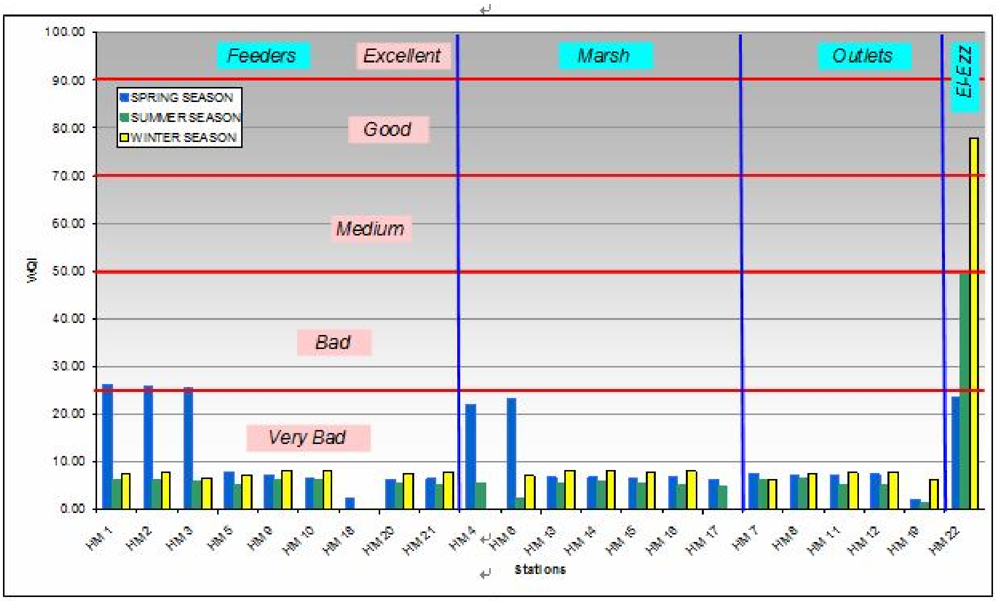


Figure 10: Water quality index values for Hammar marsh during three seasons in 2008.

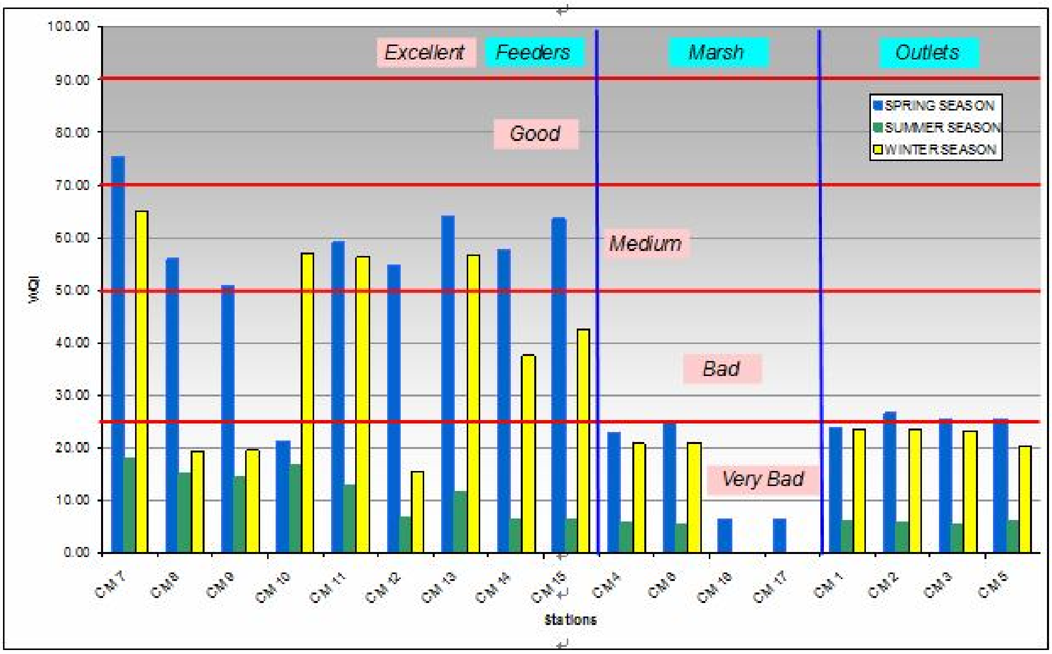


Figure 11: Water quality index values for Qurnah marshes during three seasons in 2008.

In case the water quality in the marshes is to be improved then the water requirements are much more (Table 5).

Table 5: Ranking values of Water Quality Index

WQI value	Quality Rank
0 – 25	Very bad
25.1 – 50	Bad
50.1 – 70	Medium
70.1 – 90	Good
90.1 – 100	Excellent

The Restoration and rehabilitation of the remainder part of the marshes requires multi- disciplinary work and actions. From our point of view the most important steps are the following:

- Open up a dialogue with riparian countries (Turkey, Syria and Iran). This is due to that fact that these countries are controlling the flow of the Euphrates and Tigris Rivers and their tributaries. The flow in the rivers inside Iraq has been tremendously reduced due to the hydraulic structure like dams, and dykes built in the rivers. The effect of the Turkish project GAP and the Syrian dams are discussed by several authors [e.g. 11, 32]. Recently however, the Iranians had dammed many of the rivers contributing to Al Huwiza marsh. It should be mentioned however that 7,68 106 m^3/year is required to overcome evaporation in the area.

- The marshes should be considered as national protected areas similar to Al Haiza which has been designated as a Ramsar site [58].
- Provide essential services to the marsh dwellers and introduce public awareness programs for them and the public about water resources conservation.
- Drainage water must be prevented from entering the marshes. This affects the water quality tremendously.
- Maintenance of the water distribution systems in order to reduce the high loses.
- Irrigation practices should be modernized and suitable techniques should be used. Iraq consumes 85% of its water resources for agriculture [59] and use of suitable irrigation techniques will spare huge amount of water. Water harvesting techniques and non-conventional irrigation techniques can serve as an extra water resource.

6 Conclusions

The Iraqi marshlands, which are referred to as the Garden of Eden, are created by the Tigris and Euphrates Rivers system in the lower part of the Mesopotamian basin where the longitudinal slope is very gentle causing the two rivers to meander and split into many branches. This has formed a series of lakes and marshes. During seasonal flood the water overflows the plain and creates complexes of marshes. They cover an area about 15-20 10^3 km^2. The main marshes are Huweizah, Al-Hammar and Qurnah Marshes Serious measures were taken to drain the marshes in early 1990s and then restoration of the marshes started in 2003.

It is believed that 75% of the area covered by the marshes can be restored. This can be achieved if 3263, 5495 and 4128 106 m^3 of water is supplied for the three marshes.

The present water quality of the marshes is bad. To improve the quality more water had to be supplied for the three marshes.

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