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Major Irrigation Systems on Tigris River within Mesopotamia

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Abstract

Several irrigation systems have been built at Tigris River basin within Mesopotamia plain. The upper part of Tigris at Mesopotamia is extensively exploited, and several major projects were constructed since the 1970s. These are Ishaqi, Khalis, Diyala Combined Reach, Nahrawan, Dujailya and Dalmaj. Other projects were partially developed, which are Middle-Tigris, Gharraf projects, Great Amarah and KutButaira. The important barrages in this part are Kut Barrage, as well, as the barrages in Amarah area which are of vital importance for irrigation and navigation. Shaat Al-Arab is one of the most important waterways in Iraq. This river has been suffered from water scarcity and riparian countries actions. Solutions for adaptation to adapt the situation were studied and planned carefully, but still there is need for more work to cope with the situation in Basra area.

Keywords: Ishaqi Project, Middle-Tigris Project, Gharraf Canal, Dalmaj Project, Diyala River Projects, Dalmaj Project, Dujailya Project, Great Amarah Project.

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1. Introduction

This paper presents the major irrigation systems along Tigris River and Diyala River within Mesopotamia. Some of these projects are long standing since early history like; Nahrawan, Ishaqi, Gharraf, Dujailya, while others were implemented after 1920. After 1920, there was much interest to exploit the lands of the Tigris river basin in Mesopotamia. One of the early works was the construction of Kut Barrage. This barrage is of vital importance to supply Gharraf area and rise raise water levels for irrigating the lands upstream. Since 1970s, implementation of major projects began, which are Ishaqi, Khalis, Diyala Combined Reach, Nahrawan and Dalmaj projects. Other major projects have been partially developed; these are Middle-Tigris, Dujailya, Gharraf, and Great Amarah.

2. Medium and Small Projects Along Tigris within Mesopotamia

There are many medium and small irrigation projects along the Tigris River downstream of Fatha, which are served either by pumping or gravity flow. These projects are:

2.1 Naifa Project

Naifa projects are several projects on the left and right sides of Tigris River, which are served by pumping. These projects were studied for the first time by the consulting engineers Messrs Ahmed Sousse and Vahi Sevian in 1971 who and when they submitted the planning report of the project to the Higher Agricultural Council-Supreme Agricultural Board. It covered and was aimed study of the irrigation of lands at the left side of the Tigris River in the districts of Samarra and Tikrit. Some of the projects were implemented, which are:

1. Alam Irrigation Project: It's located near Alam town adjacent to Tigris River left bank; bordered to the south by the Tikrit-Kirkuk road. The net area of the project is 18,000 donums, it was implemented by the Turkish company Kaska and commissioned in 1985. Project discharge is $3m^3/s$. The water is lifted to a 16.85km concrete main canal, from which concrete flumes are branching. Drainage is natural through existing wadis, among which is wadi Al-Aly which out flows into Tigris River. The project is also called the Khaleej project or sometimes Al-Aly project.
2. Albu-Ajil Project: This project is located south of Alam project and south of Tikrit-Kirkuk road. The net area of project is 6,000 donums.
3. Oja Project: The project is located in Oja sub-district to at the right side of the Tigris River. The project was implemented in 1983, and the net area is 6,500 donums.
4. Uwaynat Project: project is to the south of the city of Oja, on the right side of the Tigris River, the area of project is 10,000 dunams.

5. Tigris Project: The land of project is located to the east of Tigris district and right to Tigris River. Project area is 11.5 thousand donums, it was implemented in 1984.
6. Dur project: It's in Dur district, to the left of Tigris, net area is 8,000 donums.
7. Al – Rusasi Project: This is one of the important projects in Samarra district to at the left side of the Tigris River. The project is intended to revive the old Al – Rusasi Canal and part of the old Nahrawan Canal. The project is supplied by gravity from Tigris River through head regulator and head reach canal which intersects with Samarra-Tikrit highway. The main canal, which has been renovated, is 34km long and is planned to irrigate an area of 120,000 donums, but the current area is less. The implemented phase of Al – Rusasi project was completed in 2001.
8. Duloiya Project: it is located near the confluence of Adhaim and Tigris Rivers within the Duloiya area. The project is irrigated by pumping and the irrigation network mainly of earth canals covering around 25,000 donums.

2.2 Nai Projects

Nai is a fully reclaimed project, the land of the project is located at the left side of the Tigris River, where water is lifted to project by pumping station on Tigris River located 8km downstream from the confluence of Adhaim and Tigris. And the pumped discharge is $9m^3/s$. The net area of the project is 28,000 donums, and the drainage water is discharged to the Tigris. The project was designed and implemented by the Organization of land Reclamation in 1983, but unfortunately it has been abandoned and deteriorated at the time being for many reasons (Al-Simawi, 2011, Al-Simawi, 2014, Board, 1977, Irrigation, 2001).

2.3 Badra-Jassan project

Badra and Jassan area is well known with its rare species of date palms. Badra fan, extends into Iraq from the Iranian side and its agriculture has suffered from water scarcity since 1930s especially after the construction of dams on the Iranian side. In order to cope with this problem, the Ministry of Agrarian Reform entrusted Messrs Sir M. McDonald in 1961 with the study of alternative solutions for water supply to the areas of Badra Jassan and Mandali, which was the other area suffering from the same problem. The Consultants submitted their report in 1969 which included the presently adopted alternative and the construction of Badra-Jassan project was started in 1974 aiming at irrigating the orchards of Badra, Jassan and Zurbatiya. As well as providing municipal water supply for the population of few thousands. The project consists of the main feeder canal conveying water from Tigris River to the project whereby water is lifted to this concrete lined canal by a pumping station on the river, while four more pumping stations were constructed for lifting along the route. The main canal is 65.5km long and it gives one branch at km 10 to supply one large state farm, which is part of Middle Tigris project. The canal route includes two siphons to pass it under major wadis; the first is a wadi which collets rainwater

discharges from the northeast lands and pass it to Shweicha Lake, and the second is at the intersection with Galal Tarsakh Wadi. One more concrete lined canal bifurcates from the main canal near its end and known as Jassan Canal, it is 13.2km long and has discharge capacity of 13.2m^3/s. which irrigate an area of 25,000 donums. The main canal itself crosses the Glal Badra wadi by high pressure asbestos cement pipeline, whereby water is pumped to Badra town by one of the four pumping stations already mentioned. At Badra some of the water is lifted by one of the pump stations and another pipeline to irrigate Zurbatiya orchards, while the remaining discharge is distributed into a network of concrete lined canals to irrigate the orchards of Badra itself and to supply drinking water for the population (Board, 1977, Macdonald, 1971) .

2.4 Kut-Butaira Project

The project consists of nine sectors located on the right side of the Tigris River where water is supplied by pumping from the river. The studies of the project were prepared by the French Consultant Messrs Gersar in 1983. In 2007, the implementation No. 4 was started near Sheikh Saad sub-district. The area of this sector this sector area is 10.8 thousand donums, and the drainage water is being diverted to the nearby marshes. The development of this sector are complete now works are under way in Sector No.2.

2.5 Abu Beshot Project

Abu Beshot project is located in the sub-district of Kumet on the left side of the Tigris, its net area is 23,000 donums. Water to the project is supplied by pumping station of capacity 8.4m^3/s. The project is fully reclaimed so in addition to the network of lined canals, collector drains of 36.5km total length were excavated, as well as field drains were installed. The drainage system is connected to the nearby marshes.

2.6 Nahar Saad Project

Nahar Saad project is located in Maysan governorate to on the left side of the Tigris. The project depends on pumped water supply from the river. The total discharge of the pumping station is 16m^3/s and the its net irrigated area is 75,000 donums. The project development was started in 1968 and it was divided into four stages. The main canal is 35km long, of which 19km is lined. The first phase of 25,000 donums has been completed. Other stages are still under construction. Drainage is done by network of drains which are collected by main drain from which all the drainage water is pumped to a nearby marsh, the total discharge of the station is 3.6m^3/s (Al-Simawi, 2010, Al-Simawi, 2011, Ministry of Water Resources, 2005).

3. Ishaqi Irrigation Project

Ishaqi project was named after the ancient Ishaqi Canal which had existed during the Sassanid era but then it was abandoned. It had extended at those times from Tikrit to Agarkof depression. Later on, after the building of Samarra by Khalifa AlMu'tasim to become the capital of the Abbasid State, the upper part of this canal was re- excavated again by this Khalifa to irrigate one of his large army camps on the right side of the Tigris River south west of Samara. Historians differ on the origin of the canal's name; while some of them attribute it to Ishaqi bin Ibrahim, Al-Mu'tasim's uncle and his head of police who was commissioned to do the re-excavation works, while others say it was taken from Al-Mu'tasim's first name (Abu Ishaq). The modern Ishaqi canal and its network, however, was one of the priorities of the Development Board since its establishment in 1952. The planned Samarra Barrage on the Tigris River was to be the headwork structure for this network, in addition to divert the Tigris floods into the Tharthar depression and to power generation. While the barrage was completed and went into operation in 1956, the Ishaqi irrigation project was still in the planning stage. The Development Board had started the studies of the project for the first time by awarding the planning and the design works to Messrs Bennie & Partners, who the completed studies and contracts design for the construction contracts from (1) to (8). In 1966 Messrs SPANCO from Spain completed the documents of contracts from (9) to (15). Ishaqi project command area extends from Ishaqi sub-district to Kadhimiyah district. The Ishaqi Canal head regulator is incorporated in the structure of Samarra barrage and it has four openings with dimensions (2.5×3.5)m in the form of four culverts of a length of 391m, discharging into the main Ishaqi project open canal with a discharge of 80m^3/s. The length of the main canal is 30km and it branches at its end to two branches: the east branch serving the eastern sector of the project and the western branch serving the wester sector of the project. The East Branch Canal runs at the left side of the main canal, crossing the Baghdad-Mosul road and runs parallel to Tigris River down for 80km, its maximum discharge is 38m^3/s, and it is lined with concrete. The Est Branch Canal begins at the branching location of the main canal, continued downstream, with maximum discharge of 42m^3/s, for a distance of 61km. This canal was lined with rubber sheeting due to high content of soluble gypsum of the soil; this lining was shortly afterwards damaged and replaced with concrete. The West Branch Canal is passed in its route through one siphons under the Tharthar-Tigris canal in its way to the area north of Kadhimiyah district. The net area of the project is 321,000 donums, which is served also by a network of drains, there are 42 distributary canals with total length of 665km, and 1,642 watercourses, making total length of all canals 3,620 km. The irrigation system is served completely by a network of drains which go parallel to the canals. The network consists of two main drains, the Eastern drain is 60km long with discharge capacity of 6.35m^3/s, and the Western Drain which is 56km long and has a discharge capacity of 6.2m^3/s. The two drains meet together to mark the starting point of the Main Outfall Drain (M.O.D). In addition to the main drains, there are 27 branch

drains, of total length of 971km, and 1,591 collector drains, of total length of 2,524km. The part of the area located at the right side of Tharthar-Tigris Canal drains directly into Sabaa Al-Bour drain, which flows into the M.O.D. Implementation of the whole project was started in the late 1960s and began at an accelerating progress in the mid-1970s. The main canal was inaugurated in the summer of 1979, and the reclamation works of the project continued until 1994 (AlSimawi, 2010, Al-Simawi, 2011, Al-Simawi, 2014, Ministry of Water Resources, 2005, Sousa, 1948.)

4. Diyala Weir

Diyala weir is located on the Diyala River at a distance of 7km downstream of Hamrin Dam. This weir serves all the irrigation projects in Lower Diyala Area. Khalis irrigation project on the left and Combined Head Reach irrigation projects on the right, as well as the orchards on both sides of the Diyala River lower reach. At the early days, a temporary dam was built from timber and stone, and it was rebuilt each time it collapsed due to high floods. In 1928, a semi-temporary weir was built, but soon it was collapsed in 1935. Another weir was constructed between 1936 and 1940 and collapsed once more in 1946. As the interest in the irrigation of the Diyala Basin increased due to the construction of Derbendikhan Dam, the consultants Messrs Sir M. MacDonald were entrusted with the study of the irrigation development of Diyala area, including Diyala weir. The Consultants presented in 1963 a study of new gated weir structure combined with two head regulators for both Khalis Canal and Combined Reach Canal. Implementation of the whole project was completed in 1969. The weir is 400 m long concrete structure with 23 openings controlled by vertical lift gates. Gates dimensions is are (2×12)m. The discharge capacity of the weir is 1200m^3/s at elevation 67.5m a.s.l. Included in the main structure also there are two gated scour sluice, one being at each end which together have maximum discharge capacity of 700m^3/s. The right side scour sluice has three gates and the left side with one has five gates. All of the scour sluices gates have dimensions of (2.5×8)m. Diyala weir acts to ensure water levels for the operation of the two main head regulators, the dimensions of the openings of these regulators are (2.5×8)m. On the right, the Khalis Canal head regulator is provided with three gates and has maximum discharge of 75m^3/s, while on the left, the Combined Reach head regulator is provided with four gates and has maximum discharge of 126m^3/s (Al-Simawi, 2010, Directorate General of Irrigation, 1954, Ministry of Water Resources, 2005). Figure 1, is an aerial view of Diyala Barrage.

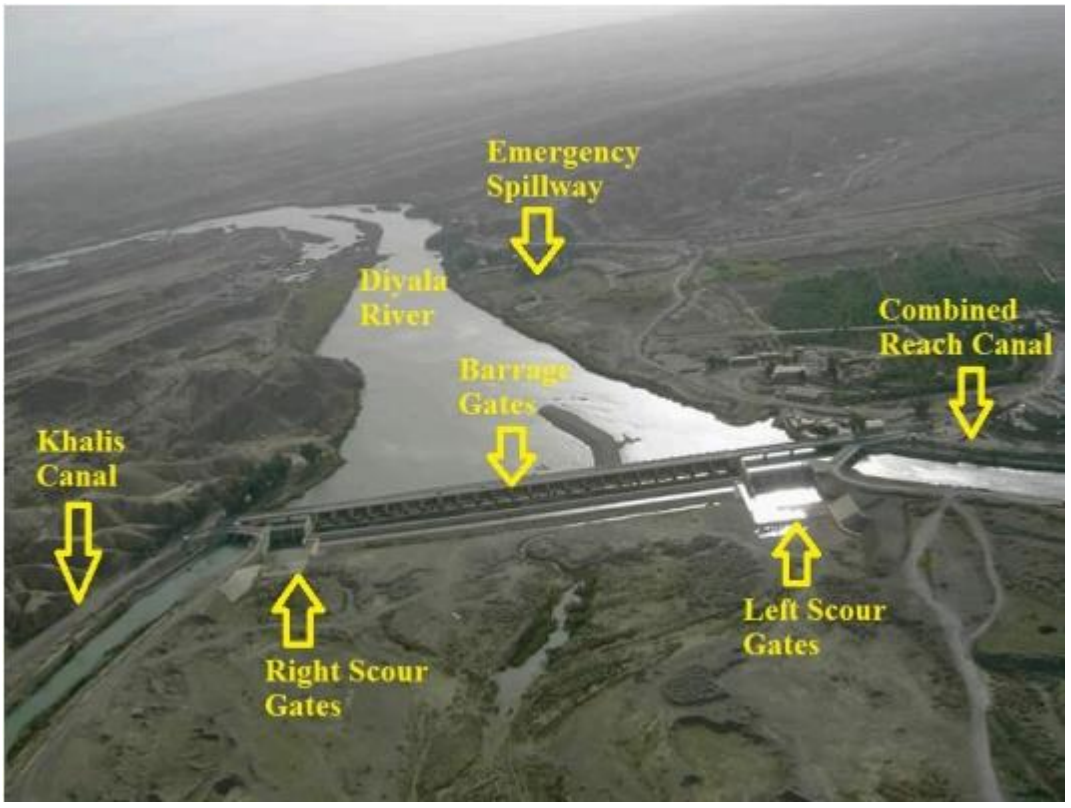

Figure 1: Aerial view of Diyala Barrage.
(Resources, 2020). (Edited by Author).

5. Khalis Irrigation Project

Khalis project is located on the right side of Diyala Rive. The project is irrigated by gravity with its main canal transporting its water supply from Khalis head regulator which is incorporated in the right end of Diyala Weir. Khalis irrigation project is divided into two parts, Upper Khalis and Lower Khalis projects. The consultants Messrs Sir M. MacDonald prepared the studies, planning report of the project in addition to contracts designs and documents in the period from 1957 to 1960. First stage of construction was initiated in 1967 and works continued until 1985.The Khalis main canal is lined with concrete. The maximum canal discharge is 96 m3/s, while the normal discharge is 65m^3/s. The project is also covered by a drainage network and drainage water is either pumped or drained into Diyala River and Tigris River. The net area of the Upper Khalis project is 215,837 donums, of which 13,960 donums are orchards. The net area of Lowe Khalis is 230,000 donums, of which 10,000 donums are orchards (Al-Simawi, 2010, Al-Simawi, 2011, Al-Simawi, 2014, Irrigation, 2001).

6. The Combined Head Reach projects

After the construction of Diyala weir, the area located on the left of the lower reach of Diyala River was organized to be irrigated from a common source which is the combined head reach canal. This canal runs parallel to the left of Diyala River from its beginning in the head regulator incorporated in the Diyala weir onwards.
The projects in this section are the following parts:

6.1 Combined Reach Canal

The discharge of this canal is withdrawn from Diyala weir through its head regulator Downstream Combined Reach head regulator at Diyala weir. The total length of the canal is 14.6km and its discharge capacity is 129m^3/s. The canal was implemented in 1969 feeding the irrigation projects of Mandali, Ruz, Muqdadiyah, Mahrut and Saryah. Several regulators are built along canal, the most important of which is the km 3.5 regulator. This is a cross regulator having six bays of (2.5×4)m openings, its maximum discharge is 117.8m^3/s. Head regulators for main canals, which are branching from the combined head reach canal are the following:

a. Mandali canal head regulator.
b. Ruz canal head regulator.
c. Mahrut canal head regulator.
d. Saryah head regulator, in addition to the Haroniya canal head regulator.

6.2 Mandali Irrigation Project

The orchards of Mandali town on the Iraq-Iran borders were previously irrigated mainly from the Wadi Harran also called Galal Gangir. This stream originates from the Iranian side of the border and it used to feed some irrigation canals in Mandali area, such as Filsht, Al-Suwaiq, Jizani, and Muawalih. But due to the unfair use of water by Iran, the discharge decreased during the 1930s, resulting in a considerable reduction of the irrigated orchards, in addition to the migration of the population and a large decrease in the number of residents in Mandali. Several alternatives were studied to supply the area from Diyala River. The current alternative, an open canal feeding from the Combined Head Reach canal was adopted. This alternative, called for the construction of an open gravity flow canal and the use of two pumping stations together with pipelines in two reaches of the project. Mandali main Canal begins at km 3.5km of the Combined Head Reach canal and continues as an open canal until it reach km 25 where pumping station No. 1 is located at Imam Wais village. The canal discharge is pumped here through 1.0-meter diameter bituminous coated steel pipe for a distance of 2.28km, then it continues as open canal. At the Km 44, the canal gives one branch at the left side to irrigate the Upper Naft Irrigation Project. At km 54, the main canal ends where pump station NO. 2 pumps the water across Wadi Al- Naft and all the way up to Mandali town. In Mandali the discharge is divided into group of canals feeding the agricultural lands and orchards, as well as providing water to be pumped by pumping station No.3 to provide drinking water for the city of population of

Mandali town. Mandali Canal was implemented in the 1970s and subsequently parts of the canal collapsed due to the presence of gypsum in the soil, so rubber butyl sheeting were used to repair these parts.

6.3 Ruz Project

The project is located between Mahrut project and Salah Al-Dien flood way. This flood way protects the project from the floods of the eastern torrents coming down from Hamrin range and it drains to Attariya depression. Ruz Project is irrigated from the by the main Ruz canal. The canal has of discharge of 38.8m^3/s. The branch canals that offtake from this main canal, down to km 21, are all located within the boundaries of Muqdadiyah project and this reach is not lined. After km 21 Then the boundaries of the Ruz irrigation project begin. Reclamation has been under way since 1979, and the net area of the reclaimed land is 170,000 donums. Project total net irrigated area is 230,000 donums.

6.4 Muqdadiyah Irrigation Project

Muqdadiyah Irrigation Project is located between Diyala River and the boundaries of Ruz, Mahrut and Saryah projects. The projects is irrigated by branch canal branched form from the Combined Head Reach Canal and the Main Ruz Canal within the area of Muqdadiyah district. Muqdadiyah project is one of the oldest projects that have been redeveloped. Some of its canals have been lined between 1982 and 1985. The net area of the project is approximately 73,000 donums, including 20,964 donums of orchards and 49,872 donums are reclaimed.

6.5 Mahrut Irrigation Project

It's partially reclaimed project. The project is located between Ruz and Saryah projects. The Irrigation backbone of the project is Mahrut Main Canal, which starts from the end of the Combined Head Reach Canal and extends to Kanaan Canal. The main canal of the project was implemented in 1981. Development works were stopped but were resumed in 2001 and to stop again in 2003. The net area of the project is 167,000 donums. The canal is 77.9km long, of which 26.14km in the first reach are lined.

6.6 Sariyah Irrigation Project

The last project in the combined head reach projects is Sariyah Project. The area of this project is located between Diyala River and Mahrut project area. It is an old project linked now by a new feeder canal to the combined head reach canal for its water supply. No reclamation works have been done in this project and it is considered as one of the most densely populated areas of the Diyala Governorate. The net area of the project is 162,000 donums which include 37,000 donums of land in Tel Asmar sector located in at the tails. Moreover, part of the project amounting to 35,000 is planted with orchards. Some parts of Sariyah main canal within the towns of Baquba and Buhrez (Al-Simawi, 2010, Al-Simawi, 2011, Al-Simawi,

2014, Directorate General of Irrigation, 1954, Irrigation, 2001, Ministry of Water Resources, 2005).

7. Nahrawan Irrigation Project

The lands of this very old project used to cover the extensive area on left side of the Tigris River from Hamrin mountain range down to the northern outskirts of the city of Kut embracing all the region forming the Diyala River basin after the river crosses this mountain. The main Nahrawan Canal extended for 225km from its beginning above Samarra to the southeast of Baghdad at the outskirts of Kut, and it was described by Sir William Willcocks, who had studied the irrigation of Mesopotamia for the Ottomans by saying:

"The Great Al- Nahrawan Canal was the greatest and grandest of all irrigation canals of the ancient times that we know of today. It had extended for 300 kilometres and supplied water to an area of 80,000 square kilometers of irrigated land. Its discharge must have been between 250-300 cubic meters per second. From the remains of the canal, it must have had a width of 120 meters in some parts and a depth of 12 meters".

This great project collapsed and deteriorated after the invasion of Bagdad by the Mongols in 1258. The restoration and revival of part of the project was considered early in the work of the Development Board in the 1950s, within the scope of the Diyala Irrigation systems, already described, and the Left Diyala- Kut projects. The first study for the Left Diyala- Kut projects was commissioned to the consultants Messrs. Bennie and Partners, the consultant who submitted the report in 1956, then this was followed by another study that was completed by Messrs Sir M. McDonald, who submitted their report in 1959. Parts of the project have been underway since the 1970s, which include the following parts:

7.1 Mada'in Irrigation Project

The project area is 51.6 thousand donums which are irrigated from the left side of Diyala River and is fed by the following three pumping stations:

a. Nahrawan pumping station.
b. New Qargholia pumping station.
c. Old Qargholia pumping.

Due to the fact that pumping stations are located on Diyala River in the proximity of the sewerage treatment plant of Baghdad, this has affected the quality of water. The project canals are not lined, and the drainage network is connected to Wehda project.

7.2 Wehda Project

The area of this project is 42,000 donums, and most of the irrigation canals are lined with concrete. The project is irrigated by the main Wehda pumping station that lifts water from Tigris River and the total discharge is 13.5m^3/s. Wehda and Mada'in projects discharge their drainage water into Al-Lej main drain at the south of the

project that ends at Salman Pak pumping station, which pumps it out to Tigris River. There are also stretches of land which are irrigated directly from either the Diyala or the Tigris rivers by privately owned pumps with total discharge of 20.42m^3/s (Al-Simawi, 2010, Al-Simawi, 2011, Al-Simawi, 2014, Ministry of Irrigation, 1984, Ministry of Water Resources, 2005) .

8. Middle-Tigris Project

Middle-Tigris Project is one of largest and most important irrigation development projects located on right and left sides of Tigris River between Baghdad and Kut. It has many important cities within it, most notably Suwaira. The total development project was studied by Messrs Swiss Consultants Consortium who had carried out studies of the whole area project and submitted their report in 1983. This was followed by Iraqi consultants who re-studied it again, the last of the revisions was a study submitted by the National Centre for Studies and Designs in 2008. The total area of the whole development project is 1.66 million donums. Some parts which were medium and small size projects were fully or partially developed inside the command area. These projects are namely, Hafriyah project, the jut farm, state farm, Kusaiba, Shuhaimiyah and Radhwan Farm. The total area of these smaller developments is 440,555 donums not counting cities areas and areas set aside for urban development, Tigris River, transportation routes and current and future infrastructure. The net total of the remaining area to be developed is 792,323 donums. Figure 2 shows a map of Middle-Tigris Project.

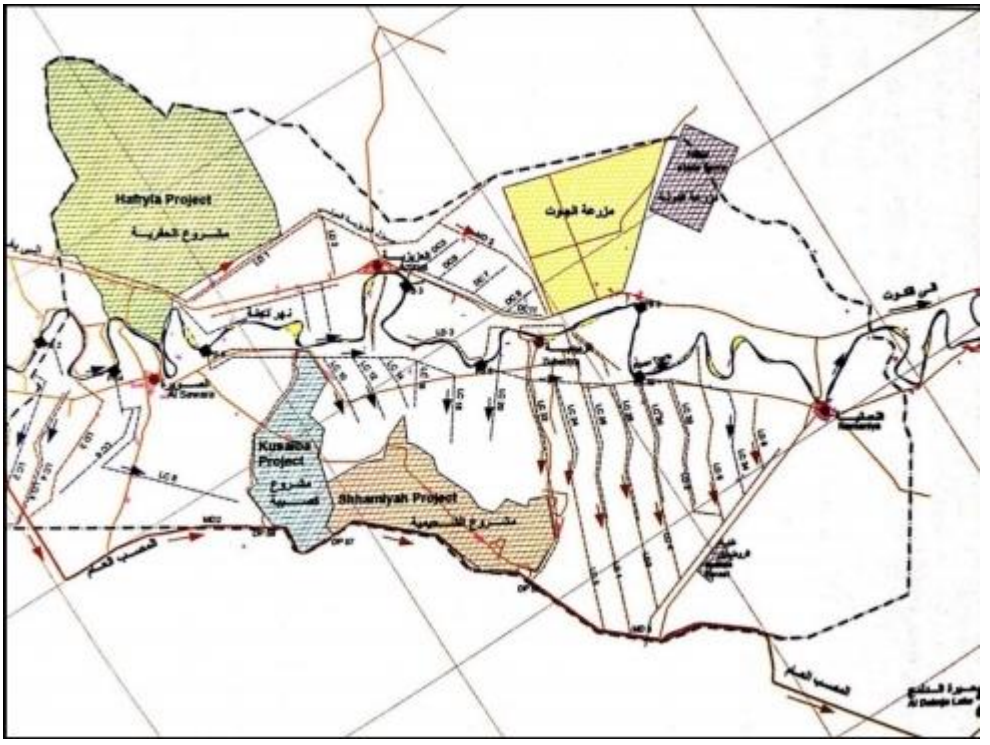

Figure 2: General Irrigation Project map of The Middle Tigris Project. (Al-Simawi, 2010).

The currently exploited parts of from the major scheme, mentioned above are detailed as follows:

8.1 Hafriyah project

Also called Suwaira project, the project is located on the left side of the Tigris River within Suwaira district, its net area is 133.6 thousand donums. The project is irrigated by three pumping stations feed the irrigation system, these pumps are:

a. Khachiah First Station: it is the largest of these stations, the total discharge is 25.7m^3/s. The station lifts water to the 27.35km lined canal. On the canal's route there are two booster pumping stations, the first is Khaciha Second Station at the km13.5km, and the second is Khachia Third station at Km25.8 of the canal route.
b. Zugaitiya Pumping Station: This pumping station pumps the water into both Zugaitiya and Douhan Canals. Zugaitiya Canal is a 16.5km-long earth canal with discharge of 4.75m^3/s. On the route of this canal, at a distance of 12.5km, there is a booster pumping station. Douhan Canal is also an earth canal, 12.5km long, the discharge capacity is 3.45m^3/s, and at the end of this canal there is a booster station also.

c. Rubaidha Pumping Station: This is the last of these pumping stations and it feed a 3.65km long canal of discharge 4.8m^3/s.

The drainage network is connected to Hallata Main Drainage Pumping Station, which pumps this water into Tigris River. The project was implemented between 1974 and 1990.

8.2 Kusaiba Project

Kusaiba project is located south of Suwaira City. The project boundaries of this project extend from the Tigris River to the M.O.D. The net area of the project is 45.8 thousand donums. It is irrigated by one main pumping station installed on Tigris of having a total discharge of 12.6m^3/s. The station lifts the water to a 10km lined main canal that give out branches and distributary canals with totaling lengths of 143km. The drainage network is connected to the M.O.D. The project was implemented during 1973 to 1984.

8.3 Shuhaimiyah Project

The project is located to the south of the Kusaiba project. Its net area is 167,000 donums. The project is irrigated by pumping from Tigris River through a main pumping station of total discharge 13m^3/s. The station lifts water to the main lined canal of 20km lengths. The drainage network discharge into the M.o.D. The project was implemented during 1973 to 1984.

8.4 Dabouni Project

It is also called the Jut Farm. The project net area is 54,000 donums and it is irrigated from Tigris River through a main pumping station of total discharge capacity of 16m^3/s. The station lifts the water to a 22.5km lined main canal. The project is fully reclaimed and served by branch and distributary of total length of 78.8km in addition to flumes of total length of 371.7km. The Drainage network is linked with Shweicha Lake.

8.5 The State Farm Project

It is one of the projects linked to Badra-Jassan project. The project's net area is 25,000 donums, and it is irrigated from Badra-Jassan project main canal at km 10, where the water is supplied by the 3m^3/s state farm main canal. The irrigation network has flumes with total length of 23.85km. The project is drains into Shweicha Lake through one main drainage pumping station.

8.6 Radhwan Farm

It is also called Radhwan Forest This farm is located west of the city of Numaniyah. It is irrigated by pumping station installed on the right side of Tigris River (AlSimawi, 2011, Board, 1977, Designs, 2008) .

9. Dalmaj Irrigation Project

The Dalmaj project is bordered to the north by the Tigris River and to the south by Dalmaj Lake. The project was first studied by the Development Board from 1956 to 1959, the study was carried out by Messrs Sir M. MacDonald and the designs and contract documents were prepared between 1960 and 1963. One of the requirements for the operation of the project was to have the operating water level of Kut Barrage to at 18.1m a.s.l. The project area is 237,000 donums and it has three main canals connected to a network of branch and distributary canals with parallel three drainage networks, one for each main canal. The main canals from the upstream to downstream are Huwar Canal, Hussainiya Canal and Mazak Canal. These canals flow by gravity except for Huwar Canal, which is feed by pumping; Figure 3 shows a map of Dalmaj Irrigation project. The main canals of the project have the following details:

1. Huwar Canal: A 24.9km unlined canal.
2. Hussainiya Canal: A 30km unlined canal, water is drawn from Tigris River through a 3 openings head regulator with maximum discharge of 13.5m^3/s and a normal discharge of 8.34m^3/s.
3. Mazak Canal: A 22km unlined canal, water is drawn from Tigris River through a two-open head regulator with maximum discharge of 9m^3/s, and a normal discharge of 7m^3/s (Figure 3).

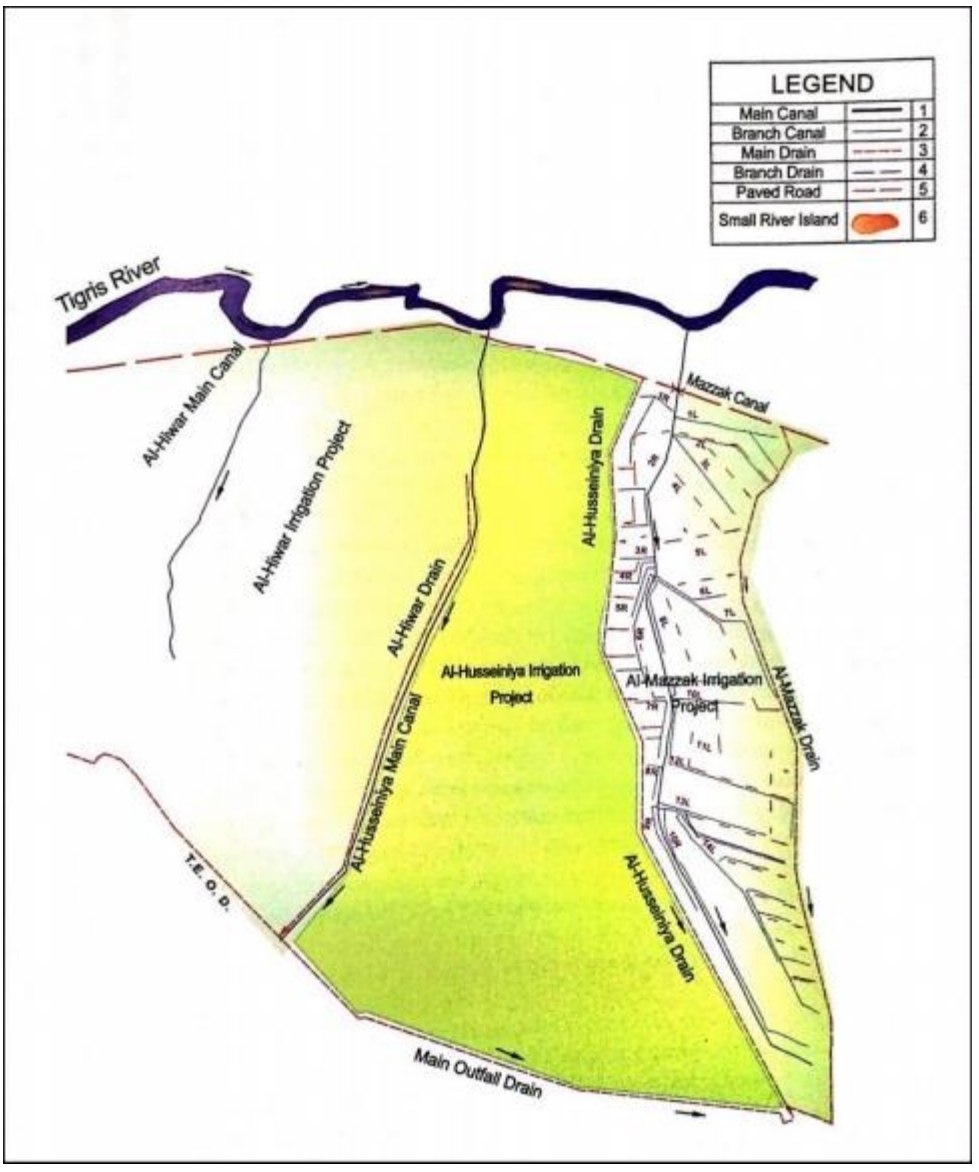

Figure 3: Map of Dalmaj Irrigation Project.
(Ministry of Water Resources, 2005).

The drainage network in the project is draining to Great Gharraf Drain at the south of the project. The project was reclaimed from 1974 to 1984 by a Pakistani company, where the integrated reclamation works included in an area of 153,338 donums (AlSimawi, 2011, Al-Simawi, 2014, Board, 1977) .

10. Kut Barrage

Kut Barrage is one of the old operating barrage on the main rivers in Iraq. it was suggested by Sir William Wilcox in his 1911 report, to control water levels in Gharraf Canal. Messrs Coode Wilson & Partners Consulting Engineers conducted studies and designs in 1930s. Construction works of Kut Barrage had started in 1936 by the British Contractors Balfour Beatty company to carry out the civil works, while Ransom and Rapper manufactured hydro-mechanical works. It was inaugurated in 1939. The maximum operation water level of the barrage was initially 16.7m a.s.l., but later on this was modified to a new water level of 18.5m a.s.l. This was done by Messrs Sir M. McDonald Consulting Engineers when they performed the studies of the Middle Tigris projects and reassessing the role of the barrage. They had concluded, it was necessary to ensure higher operation water levels to supply the whole area proposed for irrigation. As a result, the barrage modifications to the new higher levels were carried out and were completed in 1967. Kut Barrage is supplying now Dujailya irrigation project, two branches of Dalmaj irrigation project, and Gharraf Canal with water. The Barrage is a concrete structure 550m long; it is provided with 56 openings that are controlled by vertical lift gates of dimensions (6×6.5)m with a total discharge capacity of 6,000m^3/s. On the right side of the barrage, there is fish ladder and beside that the navigational lock of dimensions (16.5×80)m is located. Dujailya main head regulator is part of the scheme, and it is placed at a distance of 330m upstream and to the right of Kut Barrage, this regulator was inaugurated together with the project itself. But then it was modified in 1978. It consists of two bays with dimensions of openings of (5×6)m. At a distance of 2km upstream to the right of Kut Barrage, there is also located the Gharraf Canal head regulator. The regulator consists of seven openings of dimensions (3.8×6)m, in addition it has navigational lock with dimensions (8×80)m. The regulator maximum discharge is 500m^3/s, and the normal discharge is 350m^3/s (Al-Simawi, 2010, Al-Simawi, 2014, Ministry of Water Resources, 2005, Sousa, 1966, USACE, 2003). Figure 4 shows an aerial view of Kut Barrage system.

Figure 4: Aerial view of Kut Barrage system (Esri, 2020) (Edited by Authors).

11. Gharraf Canal Projects

Gharraf Canal is the largest and longest branch of Tigris River in Mesopotamia. It's length is 178 km and it has a maximum discharge of 500m^3/s. The development of Gharraf area was one of the interests of Sir William Willcocks, who proposed the construction of Kut Barrage. Later under the Development Board, The American Company Knappen-Tippetts-Abbett-McCarthy (TAMS) Consulting Engineers submitted in 1952 a study on the improvement of navigation. Later on, Messrs CUTHA studied the project and then followed by Messrs Sir M. McDonald who submitted a study of the Gharraf, whereby the projects was divided into two main parts; the lands to the left of Gharraf was denoted as East Gharraf and the lands to the right is denoted as West Gharraf. The planning report submitted in 1968. Messrs Gersar, a French Consultant prepared another study which was in 1983, the study included the drainage works. Finally, Messrs Swiss Consultants Consortium presented studies on land development downstream of Badaa regulator. The net area for West Gharraf the project is 384,000 donums while that for East Gharraf is 475,000 donums.

11.1 Gharraf Canal Regulators

Along the Gharraf Canal, four regulators were constructed by the German Contractor Polensky and Zöllner according to the study submitted by TAMS Company in 1952, Polensky and Zöllner in addition to construction of dykes on both sides for a length of 168km, the details of these works are as follows:

a. Regulator No. 1, near Al-Hay town; it consists of five openings and has normal discharge of 250m^3/s while its maximum discharge is 500m^3/s. The regulator includes a navigational lock.
b. Regulator No. 2, near Fajir town, it consists of four openings and it has normal discharge of 200m^3/s, while the maximum discharge is 300m^3/s. The regulator includes a navigational lock also.
c. Regulator No. 3, near Qal'at Sukkar town, it consists of four openings, and it has normal discharge of 120m^3/s, while the maximum discharge is 300m^3/s. The regulator includes a navigational lock.
d. Regulator No. 4, downstream of Rifai town, it consists of four openings and it has normal discharge of 250m^3/s, while the normal maximum discharge is 300m^3/s. The regulator includes a navigational lock.

11.2 Regulators of Badaa and Al-Shatra

Two regulators existing at the end of Gharraf Canal were built in 1929 using from brick masonry, their details are:

a. Badaa Regulator, which has six openings. Three of these openings 3 are of dimensions (2.5x5.5)m and the three others are of dimensions (3.5x5.5)m. The normal discharge of the regulator is 25m^3/s.

b. Al-Shatra Regulator: This is the head regulator of Al-Shatra Canal; it has three openings of dimensions (2.7×3)m and one opening of dimensions (3×3.5)m. the normal discharge of this regulator is 15m^3/s.

11.3 Magheshi Project

Magheshi is part of the West Gharraf Project. This he project is located in Fajir sub-district, it was implemented in the 1970s and it serves an irrigation network of 17.7 km main canal whose discharge is 15m^3/s.

11.4 Dawaya project

The Dawaya project is located in the downstream of Gharraf, project and it is part of West Gharraf project. This project is partially reclaimed. The net area of the project is 135,000 dunams served mostly by earth canals which are fed mainly by Dawaya main canal. This canal branches out from the upstream of Badaa Regulator. The project was implemented in 1970. Two parts of this project are the Hutaman sector which was carried out with and area of 23,000 donums. The project is served by 112km of collector drains, 85km of branch drains in addition to 19km main drain all of which are discharging into East Gharraf Drain.

11.5 Gharraf Drains

The Gharraf irrigation project is served by two main drains. To the east it is the East Gharraf Drain, and to the west it is the West Gharraf. The 172km East Gharraf Drain starts form Dujailya project and it joins with M.O.D. Its' discharge is 26m^3/s. The study and designs of the drain were completed by the French Consultants Messrs Gersar in 1986 and the work was started in the 1990s, but it was left uncompleted. The project was then resumed in 2008 and all excavations were completed together with one pumping station at km 52.This pumping station has total discharge capacity of 26m^3/s and it pumps the drainage water into the M.O.D.. West Gharraf Drain is 44.75km long, it discharges into the Great Gharraf Drain by pumping station of discharge capacity of 17.7m^3/s. Excavations of this drain began in 2007 and are not complete yet, including the pumping station (Al-Simawi, 2010, Al-Simawi, 2011, Al-Simawi, 2014, Board, 1977, Macdonald, 1967).

12. Dujailya Irrigation Project

Dujailya irrigation project is fed from Kut barrage as indicated previously. Its main canal begins at the head regulator located at the upstream right side of the barrage. The excavation of Dujailya Main Canal was begun in 1937 by the General Irrigation Directorate and was completed in 1945. The development of the project was resumed in 1974 by the Higher Agricultural Council. The project was planned and developed by consultants and contractor from previous Yugoslavia on the model of Beograd Agro-Industrial complex. The area of the first phase is 93,000 donums, which was completed in the period from 1973 to 1987. Partial development work was carried out to exploit the land of the second and third phases. The net area of

the project is 225,000 donums. When the project is fully developed, the main canal is to be 57km long with total discharge of 42m^3/s. Branching from Dujailya Main Canal, there are 13 branch canals called (Shakhat), with total length of 250 km and is they are mostly earth canals (Al-Hakeem, 2015, Al-Simawi, 2010, Al-Simawi, 2011, Al-Simawi, 2014, Board, 1977).

13. Great Amarah Project

The regulation of irrigation in the Amarah area is not only to achieve irrigation objectives, but also provides navigational depths for river navigation. The project was studied by several consultants, the last of which was the Indian Consultants Messrs WAPCOS. The general scheme includes many sectors and details to achieve a net area of 588,000 donums. The irrigation system is divided into the following main areas in addition to several small plots served by canals branching from Tigris River, namely:

a. Butaira and Eraidh Canals which are branching approximately 15km upstream of Amarah Barrage, to the right of Tigris.
b. Mesharah and Kahlaa Canals which are branching upstream of Amarah Barrage, to the left of Tigris.
c. Majar AL-Kabir Canal which are is branching 25km downstream of Amarah Barrage from the right side of the Tigris River.
d. Machriya Canal which is on the left of Tigris River, the canal is irrigating 25 thousand donums.

The development of the project area was carried out except the sugar cane farm in Al-Majar district, which was already existing. The area of this farm is 47 thousand donums, unfortunately its status of the farm now is heading into declination. The barrages and regulators which have been constructed in the Great Amarah project, are the following:

a. Butaira and Eraidh Regulators: The two regulators are located at the beginning of each of Butaira and Eraidh canals. These regulators and other regulators and barrages in Amarah area were designed by the consultant Messrs SEKOUB from Poland in joint venture with Iraqi consultants Messrs and Khair- Allah Wardi, but final and detailed design was carried out by the design section in the General establishment of Irrigation and Drainage projects in 1975. The two structures were completed in 1979, and each consists of six openings of dimensions (8x8)m and, with maximum discharge of 700m^3/s. The normal discharge of Butaira Canal is 80m^3/s while the normal discharge of Eraidh Canal is 20m^3/s. The two regulators are designed with such large capacity to for flood management and the to bypass flood waves downstream Kut Barrage to the central marshes due to the limited capacity of the Tigris River reach in the city of Amarah
b. Kahlaa Regulator: This regulator is located upstream left of Amarah Barrage, at the beginning of Kahlaa Branch and it was completed in 1977. The regulator consists six openings controlled by radial gates of dimensions

(6×8)m. The maximum discharge of the regulator is 477m^3/s, while the operational discharge is 35m^3/s.

c. Mesharah Regulator: This regulator is located at the upstream left, at the head of Mesharah Canal. It was completed in 1978 and it includes two openings controlled by radial gates with dimensions of (2×7)m. The maximum discharge of the regulator is 150m^3/s, while its operational discharge is 50m^3/s.
d. Amarah Barrage: The construction of this barrage was started in 2000 and it was completed in 2004. The barrage consists of six openings controlled by radial gates of dimensions (6×8)m. Its discharge is 373m^3/s and it includes fish ladder and navigational lock with dimensions of (20×217)m.
e. Majar AL- Kabir Regulator: This regulator it is located at the head of Majar AL- Kabir branch, 25km downstream of Amarah Barrage to on the right side of the Tigris River. This regulator was completed in 1978 and it includes three openings with dimensions of (6×9)m. The maximum discharge of this structure is 170m^3/s, and its normal discharge is 100m^3/s.
f. Machriya Head regulator: This regulator is located at the head of Machriya Canal, the maximum discharge is 15m^3/s, and normal discharge is 5m^3/s. The head regulator consists 3 openings of dimensions (3×4)m. The regulator was opened in 1979
g. Qal'at Saleh barrage: This barrage is situated at a distance of 45km downstream Amarah Barrage. Its construction was completed in 1978 and it has three openings of dimensions (6×8)m, which are controlled by radial gates. The barrage includes fish ladder and navigation lock of dimensions (16.5×100)m.
h. Kassara Barrage: This Barrage is located at a distance of 70km downstream from Amarah Barrage. It was implemented in 1978 and has three openings with dimensions of (6×8). The barrage includes fish ladder and navigation lock of dimensions (16.5×100). This Barrage is neglected at the present time and needs rehabilitation (Al-Simawi, 2010, Al-Simawi, 2011, Al-Simawi, 2014, Board, 1977, Directorate General of Irrigation, 1954, Ministry of Irrigation, 2001).

14. Shatt Al-Arab Irrigation Project

Shatt Al-Arab is the last major river in Mesopotamia. The length of Sahtt Al-Arab is 197 km and it is formed at the confluence of the Tigris and the Euphrates Rivers in Qurna. Two more rivers namely, Karkha and Karun rivers, which are riparian rives shared with Iran, join Shatt- Al- Arab downstream of the city of Basra. Iran is extensively, and unfairly, using the resources of these two rivers and discharges the reminder to Shatt Al-Arab. As a consequence of the reduction in the flow this has caused the progression of salt intrusion from Arabian Gulf resulting in grave negative impacts on agricultural lands that are irrigated and drained naturally by the tidal phenomena in the River, as well as affecting the intakes of drinking water

supply treatment plants.
Shatt Al-Arab project includes not only the areas that are irrigated from the Shatt Al-Arab itself, but also those irrigated by Tigris and Euphrates in their lower reaches. The Development Board had entrusted Messrs Knappen-Tippetts-Abbett-McCarthy (TAMS) Consulting Engineers with the study of the area, the Consultants submitted several reports on the development of the project from 1954 to 1958. It was followed by a study prepared by Messrs Nippon Koei Consultants from Japan, which was submitted in 1972. The study was not approved by the Ministry of Irrigation at the time. Another study of the project was subsequently carried out by Messrs Polservice from Poland and its report was submitted in 1981. This report contains the following key details on the project:

1. Development of 28,000 donums from the Tigris River.
2. Development of 35,000 donums the Euphrates River.
3. Development of 240,000 donums on both sides of Shatt Al-Arab.
4. The construction of a Barrage downstream of Garmat Ali.
5. Securing the irrigation of orchards and providing drinking water up to the Fao area.

The project was not implement in its integrated form for many reasons, the most important of which were the war in 1980s and the international economic sanctions on Iraq from 1990 up to 2003.
The existing infrastructures of this projects is are:

14.1 Suwaib Project

The Suwaib Project which is located around the town of Qurna, on the left side of Tigris River. The net area of the project is 19,000 donums, and the project is served by a pumping station. The project's land is also drained a drainage pumping station.

14.2 Shatt Al-Arab Canal

The canal is 130m long, which has a discharge capacity of $30m^3/s$. The initial area served by this canal has been reduced from 240,000 donums to 120,000 donums. The Barrage has not been as recommended by of Polservice, and instead a pumping station of discharge $30m^3/s$ discharge capacity was built at the site of Kutaiban, the station lifts the water to an open canal left of Shatt Al-Arab. The canal then runs for 40km and flows through siphon structure to the other side of Shatt AlArab. The siphon structure has been carried out by jacking under Shatt Al-Arab for a length of 1200m and having discharge of $20m^3/s$. From the siphon on the canal continues for 90km to Fao.

14.3 Basra Water Canal

The function of this canal is to provide raw water of good quality to the treatment plants of the cities of Nasiriya, Souq Al-Shoyokh and Basra from Gharraf Canal. It is an open canal 238.5km long with a discharge of $21m^3/s$, it continues then until it comes to a siphon structure which carries it under the M.O.D at km 49. At km 61.5

it reaches the Euphrates River at the site of Pump station (PS1), where water is pumped through another siphon running beneath the Euphrates River and it is formed of three 1.6m diameter pipes. From there it continuous as an open canal again. When the canal reaches km 165.5 there is pumping station (PS2 which lifts the water through pipes which pass on a bridge over the M.O.D, from here it runs to intersect with the Um Al-Ma'arik Canal at the km 169.35. This later canal crosses Basra Water Canal through box culvert, while Basra Water canal itself, at a distance of km 227.75, where it reaches to the storage basins (R0). This basin is built for water storage to avoid the impact of water shortage during any malfunction in the operation of the canal, and it has a capacity of 750,000 cubic meters. Later on, another basin is built with capacity of 5 million cubic meters as an extension. From these basins, the canal extends to its end at km 238.5 east of Basra International Airport, where Basra water directorate facilities are located. Figure 5 shows a general map of Basra Water Canal. Figure 6 also gives a view of the (R0) reservoir. Basra water canal was lined with concrete for 200km, the rest was lined with good quality soil due to the high gypsum content of the site and nearby borrow areas. The maximum total discharge of the canal is 21m^3/s, including 5m^3/s for the city of Nasiriya, 1m^3/s for the city of Souq Al-Shouyokh and 15m^3/s for the city of Basra. After 2003, the canal suffered much damage due to the incorrect procedure used to maintain the clay lined parts which has caused leaks and collapses in the sections of the canal. Moreover, the canal itself was subjected to abuses by many parties. This led the water treatment stations to rely on withdrawing its water supply from the Shatt Al-Arab again (Al-Simawi, 2010, Al-Simawi, 2011, Al-Simawi, 2014, Board, 1977, Ministry of Irrigation, 2001) .

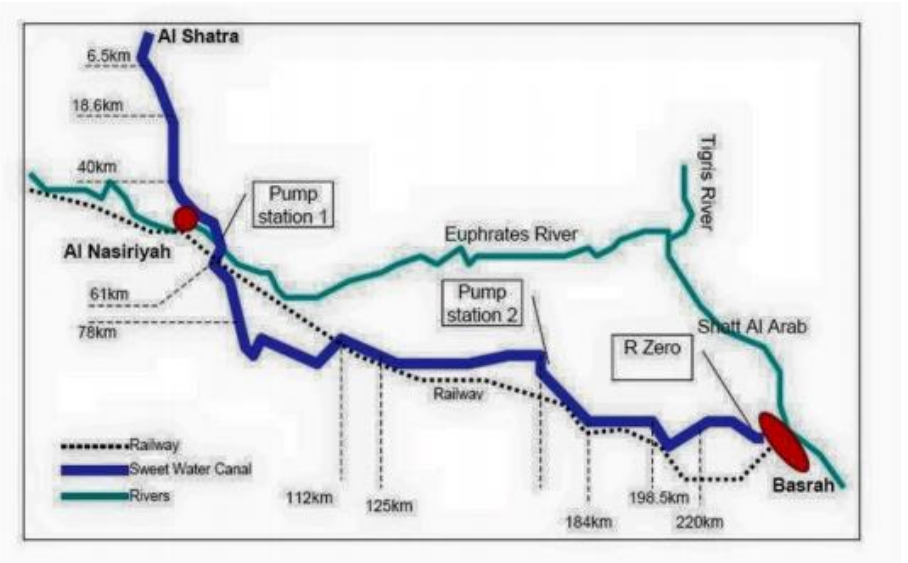

Figure 5: General outline of Basra Water Canal. (Ministry of Water Resources, 2020).

Figure 6: General view of R0 reservoir (Ministry of Water Resources, 2020.)

What about the North Jazira, Eski Kelak, Hawija and Kirkuk Projects? and many other project like Khalil Kan Project? and many other projects which I cannot remember, they are also within Mesopotamia.

15. Conclusion

Tigris River has been the source of irrigation water for the long established agriculture in this part of Mesopotamia, and at the same time it satisfied other needs such as being a navigation route and source of drinking water. Many conclusions can be drawn here, of which:

1. Except the reach of Diyala River, and the upper Zab and the lower Zab Rivers, the large projects almost discharging drainage water to M.O.D.
2. Diyala area, Kut and Gharraf areas are large irrigation areas and they are most important in term of land size and infrastructures.
3. Many small and medium size projects are depending on lift irrigation; however, the successful planning and implementation of barrages have made gravity irrigation possible for large tracts of land forming major projects.
4. The lands downstream from Kut Barrage are mostly not reclaimed in the same extent as manifested in the upper parts of Tigris in Mesopotamia.

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