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Water Resources Projects in Iraq: Barrages

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Abstract

Barrages are the early water resources structures that were built in the modern history in Iraq. The main function of the barrages to rise the water levels to feed the main canals of irrigation projects. Further, some barrages are functioning as a diversion structures during floods. The first built barrage and still in operation is Kut Barrage which opened in 1939, while the last one is Amarah Barrage that were opened in 2004. Some of the barrages are in good conditions, some are suffering from technical issues, and others especially at the lower reaches of Tigris and Euphrates Rivers getting insufficient maintenance. Generally, the upstream approaches need dredging of the sediments and small islands, and there is a need also for bathymetric survey of the rivers sections near barrages.

Keywords: Dibis Dam, Diyala Barrage, Samrra Barrage, Kut Barrage, Amarah Barrage, Ramadi Barrage, Fallujah Barrage, Hindiyah Barrage, Kufa Barrage.

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1. Introduction

Barrages across Iraq are among the earliest built irrigation projects in Iraq. Across the main rivers in Iraq, many barrages had been built and others are under construction. These kinds of structures were constructed since the early time of civilization in Mesopotamia. In the modern history, the shortage of water in Hilla branch obliged Ottoman authorities to build Hindiyah Barrage across Euphrates. Later, William Willcocks recommendations that presented in 1911 had triggered the building of gated Hindiyah Barrage, Kut Barrage, Fallujah Barrage, Ramadi Barrage and Samarra Barrage. Only Hindiyah Barrage was built before World War I. Later in the 1930s Kut Barrage was built. After commencing of Development Board in 1950s, Ramadi and Samarra Barrages were built, and Barrages in Euphrates lower reach. The works continued in 1960s to build other controlling structures, which are Dibis dam and Diyala Barrage. In the 1980s, New Hindiyah and Fallujah Barrages had built as well as Barrages in Kifl-Shinafiyah reach of Euphrates. Also, Amarah Barrage was commissioned in 2004.

2. Dibis Dam

Although Dibis Dam functioning as barrage, but due to the relatively high storage in term of medium capacity, hence it's named Dibis Dam, more precisely Dibis is a regulating dam. Dibis Dam construction coincided with the implementation of the Dokan Dam, where the idea is to maximize land exploitation that irrigated by Lesser Zab River within Kirkuk–Hawija-Adhaim irrigation project. Development Board has entrusted Binnie and Partners Company to conduct the study and design of Dibis Dam, then Polnesky and Zulner German Company was carried out the project and completed in 1965.

The dam lies near Dibis city, where the project includes 112-meter-long earth fill embankment, behind which a small lake with a capacity of 50 million cubic meters at elevation of 253m a.s.l. this is the operational level. Concrete part in the dam is consisting 8 openings with dimensions of 8m×11m which are controlled by radial gates; the gates could pass the maximum flood discharge of 4300m^3/s. It also includes fuse-plug spillway, a saddle dam configuration on the right of the concrete partition. The saddle dam is constructed with crest elevation 25cm lower than concrete part, in order to permit the water overflowing during the exceptional floods. Project includes also fish ladder. The earth fill part has a concrete core of 0.5m width, the core shelled by earth fills, where the tallest height of the body is 22m.

Kirkuk irrigation project main regulator is a part of the project, this regulator was constructed on the left side of dam body. Kirkuk irrigation project main regulator composed 5 openings with dimensions of 4.7m×7m controlled by radial gates, could pass maximum discharge of 300m^3/s, at the maximum operational level. The total length of the project is 650m.

Dibis Dam was exposed to an overflow over the dam body in 1984 due to the occurrence of high flood wave downstream of Dokan Dam and a human error in the operation of the gates, as well as the accumulation of sediments upstream of saddle

dam. A Chinese company between 1985 and 1987 had made the necessary repairs and the dam resume to operation [1, 2, 3, 4]. Figure 1 shows a general view of Dibis Dam.

Figure 1: General view of Dibis Dam. (Source:[5]).

3. Diyala Barrage

Diyala Barrage is located on Diyala River at a distance of 7 km downstream of Hemrin Dam. This Barrage is serving the irrigation projects in Lower Diyala Area. Namely, Khalis irrigation project on the left and Combined Reach irrigation projects on the right, in addition to the orchards on both sides Diyala River and the municipal requirements of the cities and towns in the region. At the early times, a temporary dam was being built from trees and stone from time to time where it was going to collapse during flood seasons. In 1928, a semi-temporary weir was built, but soon it was collapsed in 1935. Another second weir was re-built between 1936 and 1940 and collapsed in 1946. As the interest in Diyala Basin raised and the construction of the Darbandikhan Dam completed, Sir M. MacDonald Company had been entrusted to study Diyala area, including Diyala Barrage. The company presented in 1963 a study of new gated barrage and head regulators for both Khalis Canal and Combined Reach Canal. Then, the implementation of Diyala Barrage by a Finnish company, the works completed in 1969.

The barrage is 400m long concrete structure with 23 openings controlled by vertical gates has dimensions of 2m×12m, the discharge capacity is 1200m^3/s at elevation 67.5m a.s.l. The main structure are including scour gates on both sides, the right

side with three gates and the left side with five gates. All of scour gates have dimensions of 2.5m×8m, the scour gates have maximum discharge of 700m^3/s. The emergency spillway was prepared on the left side upstream the barrage, in the case of exceptional high floods, the spillway have to lead water to Saladin flooding stream, which is connected to Shweicha depression. Diyala Barrage ensures water levels for two main head regulators, the dimensions of the openings of these regulators are 2.5m×8m, on the right, Khalis head regulator with 3 gates and maximum discharge of 75m^3/s, while on the left, there is Combined Reach head regulator with 4 gates and maximum discharge of 126m^3/s [2, 3, 6]. Figure 2 shows an aerial view of Diyala Barrage.

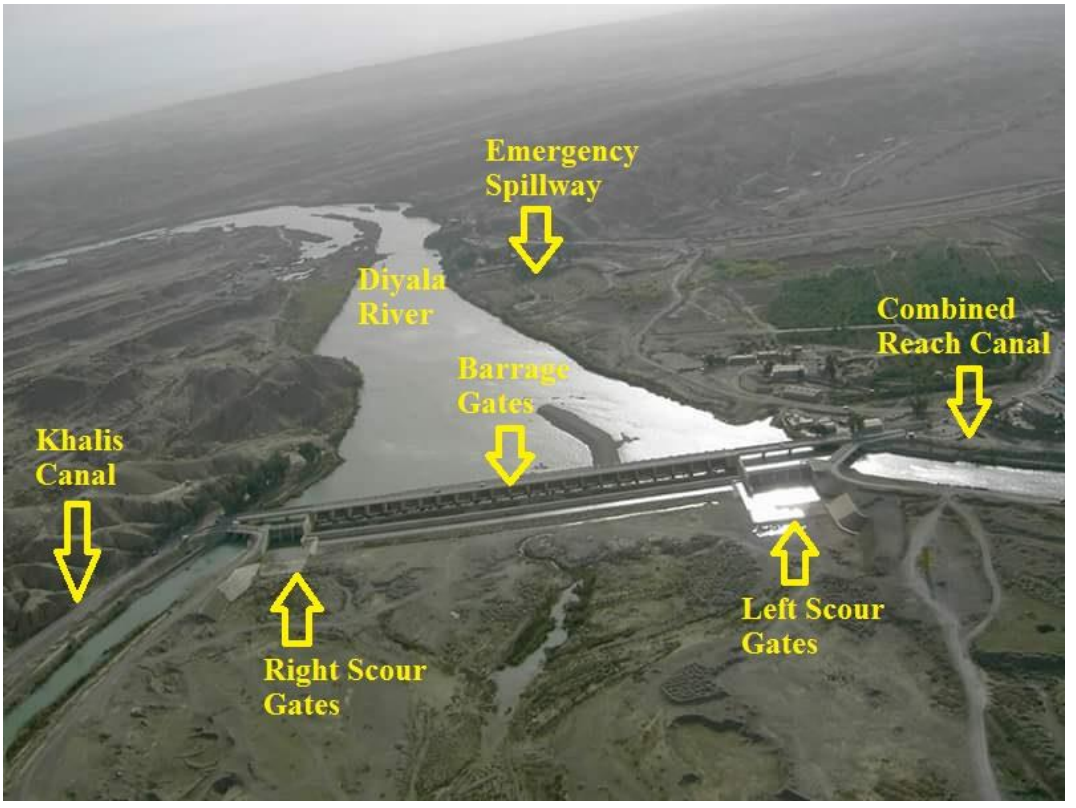

Figure 2: Aerial view of Diyala Barrage. (*Edited by Author*). (Source:[5]).

Among the main existing problems affecting Diyala Barrage is the excavation work in the adjacent quarries downstream the barrage, these excavations caused changes in the original river cross section. Changes in river cross section have hydraulically negative impacts in term of hydraulic jump location, where it had shifted away from the stilling basin. Scouring began to appear near barrage foundations. As a technical measure, concrete sill was constructed in the stilling basin in 2008 to contain the hydraulic jump within the basin. Excavations in the quarries continued up to date, and still resemble an evolving threat [3].

4. Samarra Scheme

Tharthar project is one of the main water resources projects that have been carried out to control floods and secure Baghdad. William Willcocks had proposed the site to be an escape to prevent flooding of Baghdad. Later, the Development Board and after the flood in 1954, which is the last flood that was sank parts of the city of Baghdad, had decided to put in place the cornerstone of Tharthar Project. The German company, Zublin, was entrusted to do the implementation of the structure, Ransom and Rapier British Company carried out hydro-mechanical works. The project was opened on 16/4/1956. Samarra Scheme is the key control structures of Tharthar project. Samarra Scheme includes:

1. Samarra Barrage.
2. Tharthar regulator

Samarra Barrage has a length of 252m consisting of 17 openings (12×12) meters of dimensions. On the right side of the barrage, there is hydro-power plant with 14 units, with a maximum generation of 87MW, The power station was opened in 1971. Maximum discharge of Samarra Barrage is 7000m^3/s. To Irrigate Ishaqi Irrigation Project, there are 4 irrigation openings; with a diameter of 2.5m underground buried pipes feed the Main Canal of the Ishaqi.

Tharthar regulator is located to the right of Samarra Barrage, the regulator is consisting 36 openings with dimensions of 7m×12m. the maximum discharge of Tharthar regulator is 9000m^3/s, during the flood season in 2019m there is approximately 1000m^3/s passed through the regulator [1, 2, 3]. Figure 3 shows a satellite view of Samarra Barrage and Tharthar Regulator.

Figure 3: Satellite view of Samarra Barrage and Tharthar Regulator (*Edited by Author*). (Source:[7]).

5. Kut Barrage

Kut Barrage is the oldest existing barrage on a main river in Iraq, had been suggested by Sir William Wilcox in his 1911 report, where the goal was secure water levels for Gharraf Canal. Sir Coode Wilson & Partners Consultants undertook the necessary studies and designs as a result of its mandate to study the irrigation projects in 1930s. Construction works in Kut Barrage started in 1936 by the British company Balfour Beatty to carry out the civil works, while Ransom and Rapper had implemented the hydro-mechanical works. The Barrage opened in 1939. Kut Barrage was started to work at elevation of 16.75m a.s.l. Later, when Middle Tigris projects had been under consideration, especially Dalmaj project, the barrage function was reassessed by Sir M. McDonald Consultant, where it was found necessary to ensure higher levels to ensure the project water supply. Consequently, the barrage modified to a new operational level of 18.5m a.s.l. modification works was completed in 1967. Hence, Kut Barrage capable of providing water by gravity to Dujailah irrigation project, two branches of Dalmaj irrigation project, and Gharraf Canal.

Kut Barrage is a concrete barrier of 550m long, comprising 56 openings controlled by vertical gates of dimensions 6m×6.5m with a discharge capacity of 6000m^3/s. On the right side of the barrage, there are fish ladder and beside the navigational lock of dimensions 16.5m×80m. It was vandalized by an air raid attack in 1991 and rehabilitated later by the Iraqi staff.

Dujailah main head regulator is a part of the project, the regulator is at distance 330 m upstream to the right of Kut Barrage, this regulator as opened with the project, then modified in 1978. It consists of two openings with dimensions 5m×6m with maximum discharge is 42m^3/s and normal discharge is 35m^3/s.

At a distance of 2km right of the upstream Kut Barrage, there is Gharraf Canal head regulator. Which consists 7 openings of dimensions 3.8m×6m, in addition it has navigational lock with dimensions (8×80) m. Regulator maximum of is 500m^3/s, the normal discharge is 350m^3/s [1, 4, 2, 3, 8]. Figure 4 shows a general view of Kut Barrage.

Figure 4: General view of Kut Barrage. (Source:[5]).

6. Amarah Barrages

One of the major irrigation projects in Iraq is Amarah great project, which a partially developed project. Project command area is within Maysan governorate, and it depends on the water of Tigris River where many old canals branched from the river. Development of the area was mentioned since Willcocks recommendations in 1911; he proposed the construction of barrages to assure the required navigational depths. The exploitation of Amarah land was assessed later by many consultants, the proposed barrages by consultants was to serve the irrigation purposes. There are three existing barrages across Tigris river, which are:

6.1 Amarah Barrage

This Barrage had been studied under Great Amarah project by the consultants Seigub and Khairallah Werdi, and the Indianan consultant WAPCOS was conducted the detailed design and submitted the final study in 1982. Construction of the barrage started in 2000 and completed the work in 2004. It consist 6 openings controlled by radial gates of dimensions 6m×8m to pass discharge of 373m^3/s. The body of the barrage includes fish ladder and navigational lock with dimensions of 20m×217m. Additional measures were subsequently implemented to protect the city of Amarah as well as the groundwater drainage system, but it was not completed, affecting the operational level, which was set to be 9m a.s.l., where the current operational level is 6m a.s.l. [2, 3]. Figure 5 shows a general view of Amarah Barrage.

Figure 5: General view of Amarah Barrage. (Source:[5]).

6.2 Qal'at Saleh Barrage

Qal'at Saleh barrage is located near town of Qal'at Saleh on the Tigris, at a distance of 45km downstream Amarah Barrage. It was implemented in 1978 and consists of 3 openings with dimensions of 6m×8m and controlled by radial gates. The barrage includes fish ladder and navigation lock of dimensions 16.5m×100m. It has no sufficient and maintenance despite its existence on a main river.

6.3 Kassara Barrage

Kassara Barrage is located on the Tigris, at a distance of 70km downstream Amarah Barrage. It was implemented in 1978 and consists of 3 openings with dimensions of 6m×8m and controlled by radial gates. The barrage includes fish ladder and navigation lock of dimensions 16.5m×100m. The barrage is abandoned and needs a rehabilitation to resume to operation.

7. Ramadi Barrage

Ramadi Barrage was built on Euphrates River, upstream the city of Ramadi; the structure function is to raise water levels that required for operation of Warrar Regulator which diverts water through Warrar Canal to Habbaniyah Lake. The Barrage length is 209m, and it consist 24 gates, their dimensions are 6m×8m, and the design discharge is 3600m^3/s at level of 51.5m a.s.l. It includes a navigational look with dimensions of 6m×40m and a fish ladder. Figure 6 shows a general view of Ramadi Barrage from the upstream side.

Figure 6: General view of Ramadi Barrage from the upstream side. [(Source:[5])].

Ramadi Barrage was air attacked in 1991, damage occurred. The rehabilitation was made by the staff of the Ministry of Irrigation. It also suffered damage due to the security circumstances in 2014 in Iraq. The cadres of the Ministry of Water Resources are currently undertaking rehabilitation works for the barrage.
On the upstream left, there Warrar Regulator which is composed 24 gates with dimensions of 6m×8m, maximum discharge of the regulator is 2800m^3/s [2, 3, 9].

8. Fallujah Barrage

Fallujah Barrage considered as a part of Great Abu Ghraib Irrigation Project. The Barrage was first proposed to by William Wilcocks in 1911 along with Euphrates left Canal, for the purpose of securing water levels to the left Euphrates branches from Saqlawiya to Iskandariya. At the beginning of 1970s, the interest raised about Great Abu Ghraib Irrigation Project. Hence, Selkhozpromexport Soviet Company had commenced to designs the barrage and presented the final report in 1978. Then, Barrage was opened in 1985.
Fallujah Barrage located at Euphrates River at a distance of 5 downstream the city of Fallujah. The barrage has 10 openings controlled by radial gates of dimensions 8.5m ×16m; the maximum discharge is 3600m^3/s at the maximum operational level

44.79m a.s.l. There is fish ladder, and the navigational lock is not implemented, supposed to be implemented in the future. The barrage rise the water to the Combined Canal, that feeding Great Abu Ghraib Irrigation project, this canal is branched from the left side of Fallujah Barrage, where the water discharged through the head regulator which consists of 4 openings of dimensions 3.5m×6m and has operational discharge of 104m^3/s.
The Barrage caused the rise of the groundwater level in some areas of Fallujah, which necessitated the establishment of a drainage system. It also suffered damage after the security events in 2014 [2, 3, 8].

9. Hindiyah Barrage

Water shortage in Hilla branch was triggered in the 2nd half of 19th Century; this was due to the closure of Saqlawiya Canal and the resulting increase of Euphrates discharge. Discharge increments of Euphrates caused scouring of the river bed downstream Hilla Canal branching. Hence, discharges increased toward Euphrates with less discharges in Hilla branch, sediments began to accumulate in Hilla branch bed and caused bed rise. Ottoman Authorities was taken measure at the last quarter of 19th Century, where the French engineer Schoenderfer was entrusted to find a solution.
Weir across Euphrates River was built, this weir could not withstand for long. After Willcocks intervention, he presented a design of new barrage with 36 openings of 5m width each, the barrage was completed and opened in 1913. This barrage served for decades and passed several flood waves. Then, appeared that there was a need for a new barrage after the deterioration of the long-standing barrage.
Ministry of Irrigation entrusted the French company Sogreah to prepare the designs and studies, where it was initiated in 1978. Then the Chinese Engineering Company started the implementation of the dam in 1984 and completed in 1989. The new Hindiyah barrage project consists of main barrage, a hydroelectric station, navigational locks, and head regulators for Hilla Canal, Kifl Canal, Hussainiya and Bani Hassan Canal, as well as an administrative complex and a residential complex for the employees. Figure 7 shows the details of Hindiyah Barrage.
The new barrage is located 1.7km upstream of the old barrage. It consists of the following parts:

1. Main Barrage: a concrete with 6 openings of dimensions 6.75m×16m controlled by radial gates, maximum is 2500m^3/s at the maximum level is 32.55m a.s.l. On the right side, there is hydroelectricity station comprises 4 units with a capacity of generating 15 megawatts and discharge 420m^3/s. Beside the station, the navigational lock with dimensions of 20mx150m and also the fish ladder.
2. Hilla Canal main regulator: to the left of the main barrage is Hilla Canal main regulator which consists 6 openings with dimensions of 5.4m×6m controlled by radial gates and passes maximum discharge of 326m^3/s, while the normal discharge is 200m^3/s, to the left of the regulator is an island

within the river had being developed, where the project management building had built. To the left of the island, a 600-meter navigational channel linking Hilla Canal and Euphrates River and includes a navigational lock with dimensions 6m×90m.

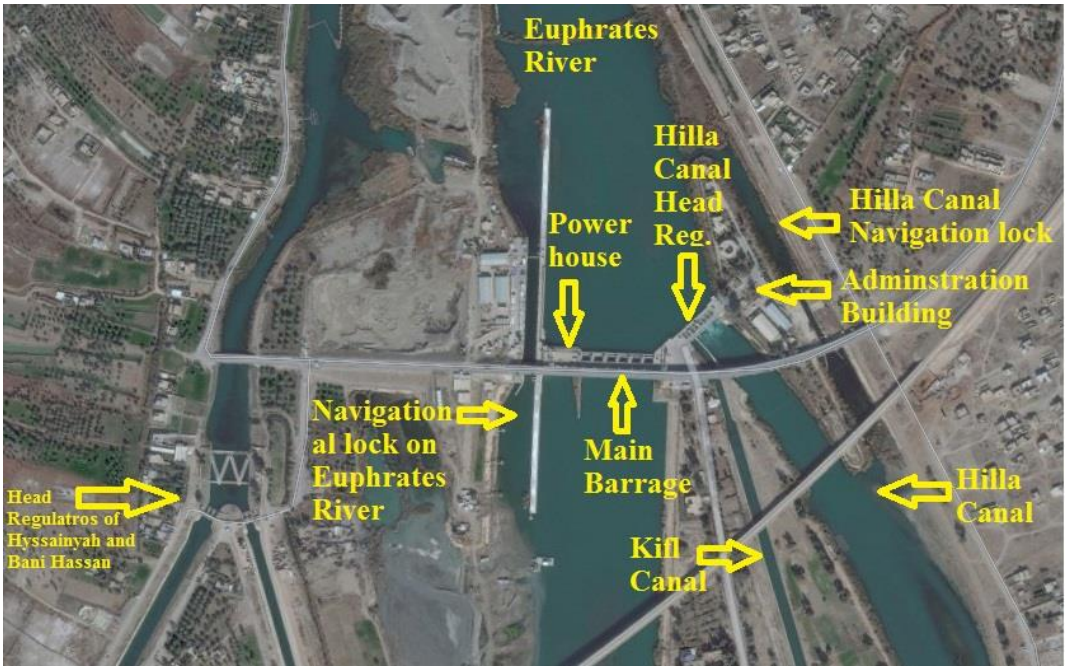

Figure 7: The details of Hindiyah Barrage. (*Edited by Author*). (Source:[7]).

3. Kifl Canal head regulator: this regulator is between the main barrage and Hilla Canal main regulator, it consists two openings with dimensions of 3.4m×4.5m, maximum discharge is 36.12m^3/s, while the normal discharge is 20m^3/s.
4. Bani Hassan head regulator: to the right side of the main barrage, there is the closure dykes of the abandoned river reach, then a joint canal leading to the head regulators of Hussainiya and Bani Hassan Canal. Bani Hassan head regulator consists two openings with dimensions of 3.4m×6m and the maximum discharge is 45m^3/s.
5. Hussainiya head regulator: it lies right of Bani Hassan head regulator. It consists of 3 openings with dimensions of 3.4m×6m. The maximum discharge of the regulator is 55 m^3/s, and the normal discharge is 32m^3/s.
6. Fish protection meshes: in order to prevent passing of fish to the irrigation courses, a 1cmx cm meshes were installed. The first mesh is at Kifl Canal head regulator with dimensions 2.5m×24m, while the second is at upstream of Hussainia and Bani Hassan head regulators, it was installed in configuration as the letter (W), length of 36m and height of 5m. It is connected to a course to return water to Euphrates River.

7. Infrastructures: include a project management building, a residential complex for workers and a railway bridge for Musayab-Karbala railway. [2, 8, 3, 10].

10. Kifil-Shinafiyah Barrages

Kifl-Shinafiyah irrigation project is one of the major projects in Iraq in terms of area and population. Euphrates River passing across the project through two main branches. Namely, Shamia Branch and Kufa Branch. Several Barrages were built in different times. Which are:

10.1 Shamiya Branch regulators

Downstream Kifl city, Euphrates River is branching into two streams, to the left Shamiya Branch, and to the right Kufa Branch, Regulators were built across Shamiy Branch to rise the water for the irrigation canals. In this branch the regulators are without navigation locks as the main stream considered for navigation is Kufa Branch. The regulators on Shamiya Branch are:

1. Abbasiyah Regulator: it is the first regulator on Shamiya Branch, located upstream of Abbasiyah city. Sogreah French Company had designed this regulator with others in the area, while Chinese company for construction engineering was implemented this structure with other regulators in 1980s. Abbasiya regulator was opened in 1988, it consists 6 openings of dimensions 6.3m×12m controlled by radial gates and pass maximum discharge of 1100m^3/s. The regulator also has a fish ladder.
2. Shamiya Regulator: it is located upstream of Shamiya city at the station 39 km of Shamiya Branch, was opened in 1986 consists of 6 openings of dimensions 6.3m×12m which are controlled by radial gates and its' maximum discharge 1100m^3/s. The regulator has a fish ladder.
3. Khawarnaq Regulator: it is located upstream of Ghamas city at the station 69 km of Shamiya Branch, was opened in 1986 consists of 5 openings of dimensions 8m×8m which are controlled by radial gates and its' maximum discharge 1100m^3/s. The regulator has a fish ladder.

10.2 Kufa Branch Barrages

The Barrages and Regulators built on this branch are:

1. Kuafa Barrage: It is the first structure on Kufa Branch, with the same companies that had designed and built the hydraulic structures in 1980s in the area, Kufa Barrage was opened in 1988.Kufa Barrage has 7 openings with dimensions of 6.3m×12m controlled by radial gates passing maximum discharge of 1400m^3/s. The regulator includes a fish ladder and a navigational lock with dimensions of 20m×150m. The barrage includes also a hydroelectric power station with 4 units generating 6 megawatts. Figure 8 shows a general view of Kufa Barrage.

Figure 8: General view of Kufa Barrage. (Source:[5]).

2. Meshkhab Barrage: This structure is located in Meshkhab city, where it was completed in 1959. The barrage consists 7 openings has width of 12.55m controlled by vertical gates and pass maximum discharge of 750m^3/s. It includes a fish ladder and a navigational lock with dimensions of 8m×80m.
3. Abu Ashraa Regulator: is one of the long-standing regulator located near Qadisiyah sub-district. It was completed in 1936, a drop structure had been added also and completed in 1939. The regulator is composed of 4 openings with dimensions of 2.5m×3m controlled by vertical gates; the maximum discharge is 50m^3/s. On the left of the regulator there is navigation lock with dimensions of 6m×105.75m.
4. Al-Ya'aw Regulator: It is also one of the old regulators, which is located on the beginning of Al-Ya'aw River, which branches from the upstream of Abu Ashraa regulator at 5km to the left. This regulator was completed by the governing company Balfour Beatty in 1940 and is composed of 7 openings with dimensions 2.5m×3m, the maximum discharge is 200m^3/s [2, 8, 3, 6].

11. Lower Euphrates Reach Hydraulic Structures

When Euphrates River passing Near Souq Al-Shouyokh city, it's branching to several branches. Many hydraulic structures where built in the late 1950s and 1960s, to control the water distribution in the farmlands. The main control structures in this reach of Euphrates River are:

1. Ghlewen Regulator: Ghlewen Branch is branching from Euphrates River at a distance of 9km upstream of Suq Al Shoyokh city. This branch confluence with Euphrates River again near Al Fuhood sub-district. The discharges of the branch were controlled by Ghlewen Regulator, which consists 5 openings discharged 250m^3/s, the regulator was built in 1968.
2. Ekaikah Barrage: Safha Branch is starting from the left of Euphrates River at approximately 2km upstream Suq Al-Shoyokh city, the length of Safha branch is10km and at the end There is Ekaikah Barrage, which consists of 5 openings of discharge 300m^3/s, the barrage has a fish ladder and navigational lock with dimensions of 8mx60m. Right of Ekaikah Barrage, there is Garmat Hassan Regulator, which has 3 openings have discharge capacity of 100m^3/s. Both Structures were opened in 1957. Downstream, Ekaikah Branch is confluence with Ghlewen branch, while Garmat Hassan Branch is confluence with Euphrates River at Al-Taar city.
3. Haffar Barrage: it is the last Barrage on Euphrates River before confluence with Tigris River in Qurna. The Barrage was built near Bani Se'id city in 1957 and consists of 7 openings have discharge capacity 500m^3/s, in addition to fish ladder and navigational lock has dimensions 8m×60m [8, 3].

12. Conclusion

After more than a century of commissioning the barrages in Iraq, many lessons and conclusions could be identified, of the most important are:

1. Barrages had played an important role in terms of controlling floods and irrigating the farmlands. No failure appeared, but some technical problems that could be solved.
2. There is no intensive utilization of the available capacities of hydropower generation by all possible means.
3. All of barrages need bathymetric survey and updated operation and maintenance manuals.
4. The navigation infrastructures and despite of its' readiness were not used as planned.
5. Pertaining the scouring issue in the foundations of Diyala Barrage, it's a result of illegal quarries excavations. The design is absolutely successful.
6. Barrages in the lower reach of both Tigris and Euphrates Rivers seem to had no sufficient maintenance and some of them are abandoned.

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