THE IMPACTS OF ENVIRONMENTAL-GEOMORPHOLOGY OF THE KUT BARRAGE ON THE TIGRIS WATERWAY AND THE NEIGHBORING REGIONS

[1]Asst.Prof.Dr. Ayad A. Ali Salman Al- Shammary
Department of Geography/College of Basic Education/University of Wasit
ayads@uowasit.edu.iq

***lecturer. Dr. Nagham Mansour Obaid*[2]**
Department of Geography/College of Education-Ibn Rushd/University of Baghdad
nagham.mansoor@ircoedu.uobaghdad.edu.iq

Abstract:

The research dealt with the effect of Kut Barrage on the geomorphological processes and the natural environment system in the course of the Tigris between the cities of Al-Ahrar and Kut in central Iraq. It was clear from the research the contribution of Kut Barrage in changing the surface runoff system between the front and back of the barrage, as well as changing the type of processes and the prevailing geomorphic forms, as the sedimentation activates the front of the barrage and erosion at its back, which affected the change in the morphology of the river, sediment retention at the front of the barrage, the burial of the bottom and reducing the validity of the stream. This also affects the efficiency of the barrage's work and coastal erosion in the downstream environment and prevents the formation of the delta in the Arab Gulf, and the high levels and the accumulation of water mass in front of the barrage increases the possibility of activating earthquakes in the presence of tectonically active structures.

Environmentally, the barrage affects the rise in the level of groundwater at the front of the barrage and its decrease at the back, and the qualitative characteristics of groundwater and surface water are negatively affected, which is reflected in natural habitats and aquatic life, in addition to the flooding and collapse of banks and soil salinization, which affects the infrastructure of the city and the neighboring agricultural lands, and the research predicts the possibility of the collapse of the barrage and the resulting effects.

Keywords: *Kut Barrage, River Morphology, Geomorphological-Environmental Effects, Sediment Dynamics, Barrage Collapse.*

1- Introduction:

Man has tried to control the flow of rivers according to his different needs, and it has become rare for rivers to exist in their natural form. Great changes have occurred in them through the barrages that are built on them, for the purpose of reducing the risks of flooding, generating electricity and storing, or regulating the flow in the lower part of the river behind the barrage. And the benefit of these engineering facilities is to human activities, especially in arid and semi-arid areas, but at the same time they cause harm to the environment and to humans alike. They affect the nature of the prevailing geomorphic processes, and they also have various environmental effects resulting from the river's attempt to adapt to that strange entrance to its hydrological system. So, this research attempts to determine those effects of Kut barrage and predict the potential risks in the research area, and then put forward appropriate recommendations to support decision-makers.

Journal of New Zealand Studies NS34 (2022), https://doi.org/ 10.5281/zenodo.7367998

Previous scientific efforts for similar studies in the field of geomorphology and the natural environment such as Al-Timimi's study[1] dealt with the variation in the level of the Euphrates river with the effect of Al- Hindiya barrage, as well as the study of Al-Dulaimi[2], which dealt with the impact of Haditha barrage on the Euphrates river, as for Kut barrage, there is no study that addressed the geomorphic-environmental effects of it on its region in detail, and this scientific gap this research attempts to cover by addressing the research problem that revolves around: What is the impact of Kut barrage on the geomorphology of the Tigris river and its ecosystem in the research area, and what is the scope of that impact, and what are the geomorphological and hydrological risks associated with the introduction of this engineering origin to the natural system of the river?

The research aims to build a database using modern technologies and fieldwork in order to monitor and observe future changes and risks resulting from the construction of the barrage in this site, the direction of which may be difficult to predict, as it is human intervention in the natural system of the river, working to change its natural behavior and the system of surface and underground flow, in a way that suits human temporary needs, which requires employing the applied geomorphological approach to elicit and analyze the information about the reality of affecting natural and human factors and processes, compare the pros and cons, terrestrial manifestations and the resulting environmental phenomena, and try to invest this engineering facility in an optimal way and reduce its immediate and future effects to prevent its aggravation and propose solutions and alternatives.

1.1 The Research Area:

The research area is located in the center of Iraq in Wasit governorate, and in line with the research objective and based on the limits of the effect of Kut barrage between the front and the back of Kut barrage, the research area identified in the width range the natural river brims, and in the length range the area between Hiwar project near the city of Al-Ahrar north of Kut barrage (50 km) and the village of Al-Migasis/Al-gardiya south of Kut Barrage (23 km). Accordingly, the research area was determined within the astronomical range extending between two latitudes (27`32º-36`32º) north and longitudes (30`45º-55`45º) east, occupied an area of (666.75)km^2, and the length of the Tigris river within this area is (73 km). As for the time limits of the research, they were determined by the period (1933) before the establishment of the barrage until the year (2021). Note Figure (1).

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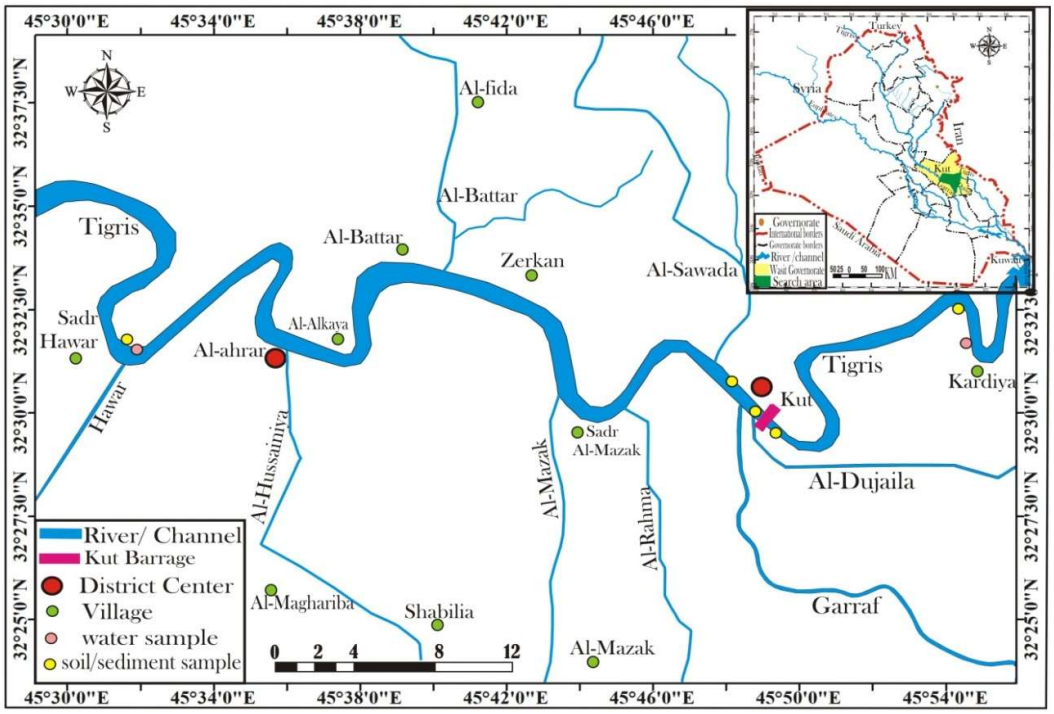

Figure (1) The location of the research area from Wasit governorate, Iraq and the locations of soil and water samples

Source: 1- Satellite Visualization of the Research Area, Landsat 8, 2018, Using ARC MAP GIS V. 10.6.

2- General Directorate of Survey, Map Production Section/Digital Unit, Administrative Map of Iraq for the Year 2017, Scale 1/100000.

1.2 General Specifications of Kut Barrage:

It is an engineering facility that regulates the flow of the river, and distributes its water on the main Tigris River (between Wasit and Maysan governorates), Shatt Al-Gharraf (between Wasit and Thi Qar governorates) and Dujaila stream in Wasit, which both branch off from the right side of the Tigris at the front of the barrage at a distance of 2 km and 330 m, respectively, and this is done by raising the river levels and directing them towards those branches[(3)], note figure (2), in addition to the role of Kut barrage in securing continuous surface irrigation for other projects in Wasit, the most important of which is on the left side; (Al-Sawwada, Al-Battar), and on the right side; Al-Rahma and Al-Dalmaj in its three parts (Al-Hiwar, Al-Hussainiya, Al-Mazzak), see figure (1).

The barrage was opened in 1939, in terms of geometry, its length is (550)m, consisting of (56) openings capable of draining each opening (6000)m^3/s, separated by supports with a width of (2.25)m for one support, the barrage on the right includes a navigational passage for ships with a length of (80)m, a width of (16.5)m, and a design level of (18.50) m above sea level, the barrage with all its branches was able to secure water for nearly 2 million acres[(4)].

Journal of New Zealand Studies NS34 (2022), https://doi.org/ 10.5281/zenodo.7367998

Figure (2) Kut barrage system and Tigris branches, Al-Gharraf, Al-Dujaila
Source: a UAV on 4/17/2022.

The water levels of the Tigris are decreasing towards the south with the increase in uses and waste. However, Kut barrage is trying to create a permanent artificial flood to achieve the goal for which it was established, by raising the levels by (8.6)m for a distance of (47)km in the front of the barrage (north of Kut city).[(5)] This matter made the water level of the Tigris higher than the neighboring lands, so it began to suffer from waterlogging and salinity, which required the establishment of an artificial drainage system that ends at the (public estuary) to alleviate this side problem[(6)], as well as the establishment of embankments on both sides of the river, with the aim of blocking the movement of water within the course and avoiding its overwhelming over the city and the neighboring lands, as well as restricting the geomorphic activity of the river to avoid the processes of carving and eroding the sides of the stream towards the lands of the flood plain and trying to change its course during the floods.

Kut barrage is trying to maintain a level of (18)m to secure continuous surface irrigation for irrigation projects. However, the climatic changes that were reflected in the decline of rains and the decrease in the water supply from Turkey, required adapting to that by reducing the level of the front of Kut barrage to 16.5 m for the current year 2022 to 50%.[(7)] In general, in the dry years, the effect of Kut barrage reaches only to Al-Gharraf and Dujaila projects and sometimes Al-Mazzak, and in the middle years the effect reaches Al-Hussainiya project, as for the moist years, the effect reaches Al-Hiwar project at the end of the research area, see figure (3).

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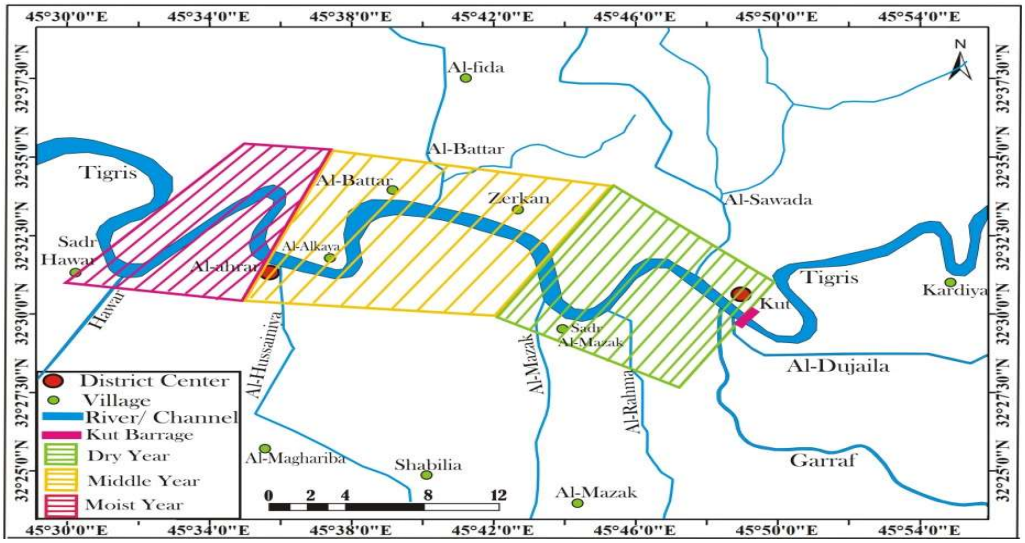

Figure (3) The variation in the influence area of the height of water levels in the front of Kut barrage during the moist, meddle and dry years

Source: Satellite visualization of the research area, Landsat 8, 2018, using ARC MAP GIS V. 10.6.

1-3 Natural Characteristics:

The structural geology of the research area is located in the secondary sedimentary plain within the range of the unstable pavement of the sub-belt (Tigris belt), which is an area affected by alpine movements. So, the collision of the Arab plate with the Iranian one resulted in a number of faults and folds, the most important of which is Al-Salman Fault, which crosses the Tigris in a transverse manner near the city of Kut.[8] The area also contains subsurface structures (Tal Al-Hawa) adjacent to the Tigris and Dujaila, (Al-Ahdab) adjacent to the Tigris and Gharraf rivers, see figure (4), which are tectonically active structures that affected the change of the Tigris course in successive stages.[9]

As for stratigraphy, the research area is completely covered by the sediments of the Quaternary Age, and is divided into two types, the first is the ancient sediments dating back to the Pleistocene Age, and its upper limit is (15m) below ground level with a thickness of 174m. These sediments consist of fragments of sand, silt and mud, and desertified layers appear overlapping with each other. The second type is the modern surface sediments dating back to the Holocene Age, which are the most prevalent deposits in the research area, consisting of flood sediments with a thickness of 15m. They are fragile sediments affected by geomorphic processes[10]. In general, all geological formations do not represent an engineering problem when the levels vary in the front and back of the barrage. There are no soluble rock detectors or unstable sediments that require filling and stabilization.

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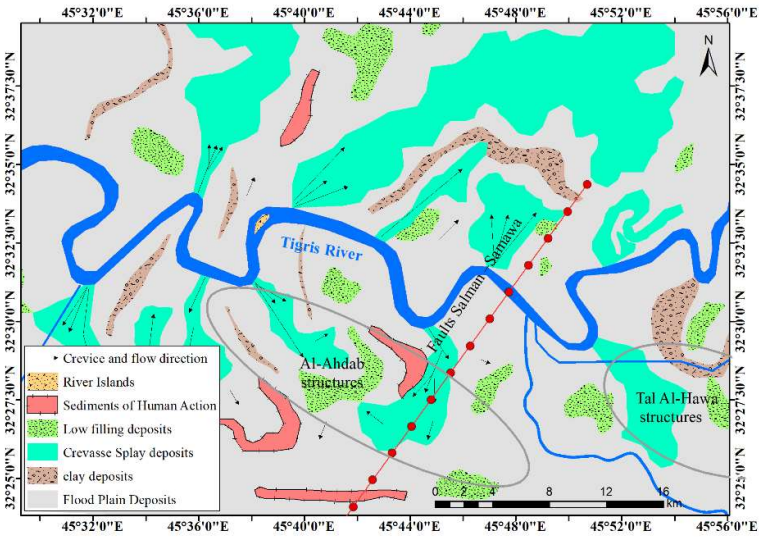


Figure(4) Geological formations and structural features in the research area

1- Anwar M.Barwary & and others. Geological Map Of AL-Kut Quadrangle Sheet NI-38-15. (GM-27). State Establishment Of Geological Survey And Mining . Scale 1:250 000.Edtton 1994. -2-Tipor Buday & Saad .Z, Jassim, Tectonic map of Iraq, Scale, 1:1000.000, 1984. -3- Jaafar al-Sakni, A New Window on the History of the Euphrates in the Light of Geological Evidence and Archaeological Discoveries, Ministry of Culture and Information, House of General Cultural Affairs, Baghdad, 1993, pg. 46.

Topographically, the surface of the research area is characterized by its simplicity in view of its extension within the sedimentary plain range. It is devoid of topographical variation except for the landforms of the river course. The height of the surface is longitudinal at the beginning of the search area (20m) and ends at a height of (16m), note figure (5), Therefore, the surface gradually descends from the northwest to the southeast by (5.5)cm/km,[(11)] and with this direction is the flow of the river and the movement of materials.

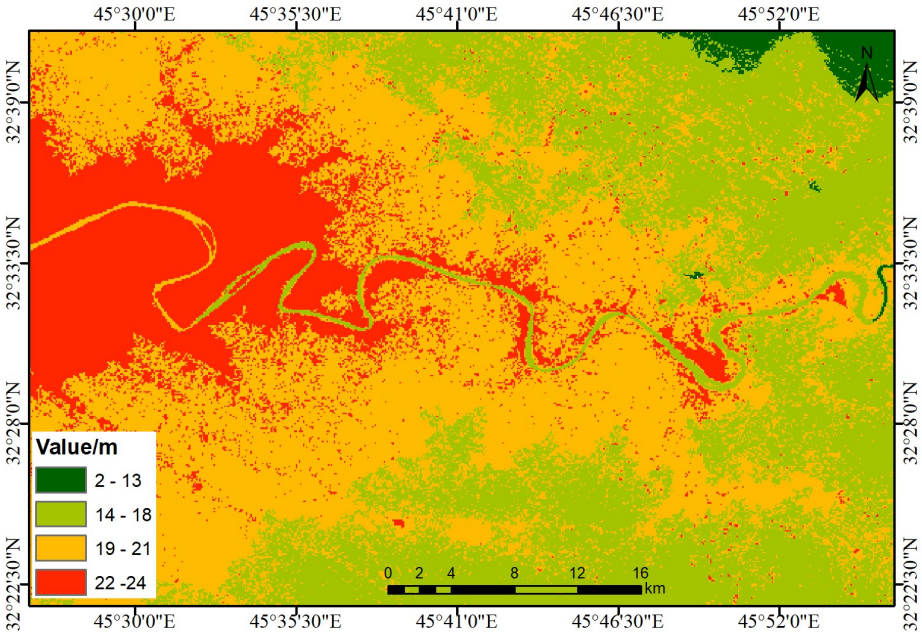


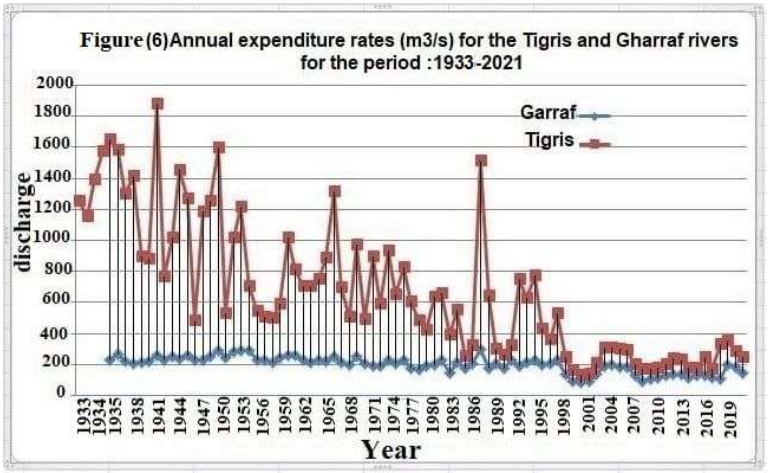
Figure (5) Categories of surface height in the research area

Source: Digital Elevation Model (DEM) data using Arc Map.V10.6.

Pedologically, the soil is characterized as silt, moved and newly formed, which was deposited by rivers within the sedimentary plain. Its composition includes a mixture of clay, sandy and limestone materials, and in some of its salts rise, and they are very deep and free of stones and gravels.(12) The area includes a group of soil types, but the affected one in the research topic is the soil of the river brims that occupy the high ranges on both sides of river courses, as they rise by 2 m above the soil range of the neighboring river basins, which are formed by coarse to medium fragments deposited by the high floods. The soil is of weak to medium physical structure, yet it is considered one of the most fertile types of soils due to its low salt, depth and good permeability under natural conditions, facilitating the process of draining the excess water naturally towards the riverbed that is close to it constantly.(13)

Hydrologicly for surface water during the period (1933-2021), the highest levels of the Tigris were recorded in the front of Kut barrage at 19.50 M.S.L on 23/3/1954. It passed a water discharge of 5890m^3/s(14), and the lowest levels were recorded at 16.05 M.S.L on 7/9/2002 with a discharge of 145m^3/s, the Gharraf recorded a similar variation to the Tigris between 17.52 M.S.L on 2/2/1940, corresponding to a discharge of 515m^3/s(15), and the lowest levels were recorded in cases of complete drought during summer seasons for several years.(16) Note figure (6).

As for the groundwater, the laying of layers and the distribution of alternating sediments of river origin lead to a complex and hydraulically interconnected aquifer. The general gradient of the piezometric surface of groundwater is from the feeding areas at the slopes of Himreen hills, east and north-east of Wasit governorate, to the south and southwest. The ridge follows the barriers of the Tigris and Al-Gharraf, which indicates that the main source of nutrition for the water group is derived from the effective seepage from the rivers. The depth of the groundwater level ranges between (1.8-3m) and does not generally exceed (5m) from the surface of the earth.(17) It is clear from figure (6) that it rises by 15 M.S.L at the front of Kut barrage, and decreases to 10 M.S.L at its back.



The predominant groundwater quality consists of chloride, and some of it is bicarbonate water near river basins and irrigation canals. The groundwater is saline at a rate of (5000-10000mg/L) in the area of the river basin adjacent to the natural river brims, and its salinity

decreases to (3000-5000mg/L), so it becomes medium salinity near the Tigris at the city of Kut, and decreases more along the east course of Al-Garraf, see figure (7). The groundwater supply of the Tigris is estimated at about 29% of the total surface supply and rainfall.[18]

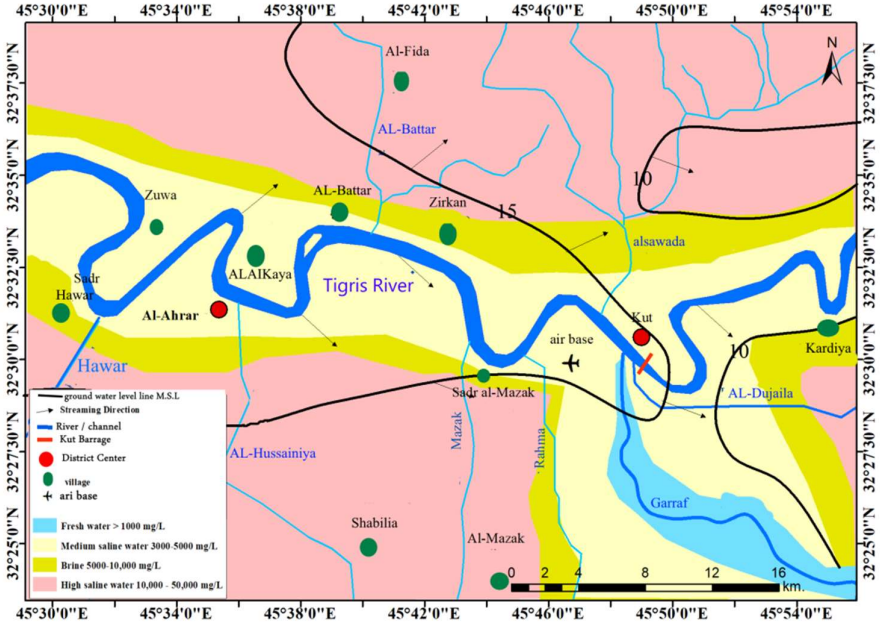


Figure (7) The level and direction of groundwater in the research area

Source: State Company of Geological Survey & Mining, Hydrogeological map of Al-Kut (Sheet NI-38-15) Scale 1: 250000, Baghdad, 2009.

Climatically, according to Köppen's classification, the climate of the research area is continental, semi-tropical, dating back to the hot semi-arid desert region (Bwh). It is characterized by high temperatures, thermal range and high evaporation, as the average temperature reached 25ºC, maximum 32ºC, minimum 17ºC, thermal range 15ºC, evaporation 3702mm, and low humidity rate 48%, with a total rainfall 149mm in the spring and fall seasons, the peak is in the short winter with its absence in the long summer, and the prevailing northwest winds[19], making the climatic water balance suffers from water deficit throughout the seasons of the year.

Biologically on the human side, urban centers extend along the Tigris and its branches in the research area, the most important of which are the city of Kut and the city of Al-Ahrar. Rural settlements also spread and represent an important backbone for these urban centers, and humans form in these gatherings human terrain and practice various activities and uses to serve their requirements, but they often negatively affect the behavior of the stream and its natural environment, in terms of excessive consumption of water, dumping of sewers and sewage waste, and the establishment of facilities such as irrigation canals, works of cladding banks and bridges (12 bridges), the Nile flower embankments (7 embankments), and the construction of Kut barrage, which changed its geomorphic, hydrological and environmental characteristics. On the botanical aspect, a group of wild plants spreads across the river brims, weeds such as halfa, sorrel, and sap…, trees such as gharb and willows, and shrubs such as tarfa and weevils…. AS for near the banks of the stream, reeds, sedges, and silhouette grow as well as water plants such as shambalan, Nile flower, snesla, and others. As for the animal aspect: there are a group of wild animals and birds in the research area, in addition to aquatic animals such as fish, turtles and

others.

2- Research Methodology and Work Method:

The research was based on the regional methodology, as the research determined the scope of its interest in the region affected by the operation of the origin of Kut barrage. The research also adopted the systems lands methodology, which deals with the course of the river as an open and independent system with clear boundaries and consists of elements related to balanced relations, and also used the historical, descriptive, analytical and quantitative method in processing the data and information, understanding and explaining the change of phenomena over time.

Data and information were collected based on previous studies, relevant government departments and personal interviews, as well as downloading (Landsat) and (DEM) visuals with a resolution of 30 meters from the site of the geological area (USGS) and carrying out the necessary data derivation, analysis and processing using (Arc Map GIs V10.6) techniques in order to extract geomorphic and environmental information. The research relied mainly on field visits and personal interviews with residents and employees in government institutions to determine the extent of the impact of Kut barrage on the Tigris, to diagnose problems, land manifestations and environmental phenomena, and to watch the natural relations closely and repetitively, and document them with photographs using the regular camera and the drone camera LSRC S7S.

The fieldwork included during the period from March to May 2022 digging (9) experimental wells for the purpose of following up the variation in the height of the groundwater level according to the depth and distance from the banks during the time. Two samples of the Tigris water were collected in Al-Ahrar and Al-Gardhiya villages, and two sediment samples were collected at the front and back of the barrage, and three soil samples, the first at Al-Ahrar district, the second at Al-Gharraf river, and the third at the village of Al-Gardhiya. Field equipment and tools were used, the most important of which are a (GPS- MAP.78S) device, a mercury thermometer to measure water temperature, a box for storing samples, plastic containers (1 liter) for collecting water samples, a measuring tape, a small manual pick, a large pick, and nylon bags. Several measurements were made, some of which were directly in the field, and other measurements were transferred to the laboratories of the Ministry of Science and Technology in Baghdad for the purpose of analysis according to internationally approved methods.

3- Results and Discussion:

The natural-geomorphic characteristics in the research area, especially the active subsurface structures and the lack of slope, have contributed to stimulating the transformation of the course of the Tigris in four phases throughout history, so the Tigris fluctuates in its flow direction between its current flow and the adjacent flow of Al-Gharraf river.[20]

Through establishing Kut barrage, the old streams of the river were resupplied with water and delivered to agricultural lands and population centers on Al-Gharraf and Tigris rivers extending to the south along the current Tigris river, so the research area was ideal for establishing an organizational barrage as it is the most sensitive and affected area by natural changes.

However, it was not a successful step to raise the doors of Kut barrage in 1969 and to develop its old design level of 16.75 M.S.L, which guarantees continuous surface irrigation only for the Dujaila and Al-Gharraf projects, to the new level of 18.50 M.S.L,[21] in order to deliver sustainable continuous surface irrigation in a direction opposite to the land slope to the North of

the barrage projects a long distance away, in conjunction with the low ground level and the rise in the groundwater level. In light of this new situation, Kut barrage contributes to a group of effects, the most important of which are:

3-1 Geomorphic effects:

3-1-1 Earthquakes:

The induced earthquakes are generated by the accumulation of water mass and sediments in the front of the barrage body, which leads to shedding great weight and stress on certain layers without others in a way that is reflected on the static balance,[22] and changing the stability of faults and subsurface structures close to the search area, especially since the research area is often affected by Seismic activities of the adjacent Zagros mountain belt[23], making fault, fissures and joints in the rock layers to become a path that seeps water through, resulting in the disruption of the foundations of the infrastructures, especially Kut barrage.

3-1-2 The Process of Deposition in the Front of the Barrage:

In the research area, the Tigris enters a transitional phase between the stages of late maturity and the beginning of aging, coinciding with the decrease in its slope and the speed of its waters,[24] so the river tends to lengthen its course by forming torsions, through the process of horizontal corrosion and the retreat of the fragile banks to the back and increasing the width of the stream,[25] as the research area includes 7 turns, 4 of which are at the front of the barrage and 3 at its back, and three meanders, 2 of which are at the front of the barrage and one at its back, and consequently increasing the severity of the river meanders and turns, as well as stimulating the manifestations of sedimentation on the bottom, the formation of river tongues, the growth of barriers and river islands, as the research area includes 11 river islands, 8 of which are at the front of the barrage, 3 at the back of Kut barrage, and 9 of river tongues, 7 of which are at the front of the barrage and 2 at its back, in addition to reducing the manifestations of torsion cutting, the formation of crescent lakes or the erosion of banks, and the formation of extrusion indications due to the barrage control of the volume of flow and reducing the chances of flooding.

During the period (1964-1995), the rate of the suspended sediment load at Kut barrage station fluctuated between (2-62) million tons/year[26] according to the variation in the amount of water discharge, and the river consumes a large amount of its energy when its load rubs against the bottom and banks,[27] and it decreases the energy of the river and the speed of the water currents slows down when it reaches the body of Kut barrage to 0.3m/s. These artificial conditions force the river to dump its load and activate the sedimentation process, so the sediments accumulated in the front of the barrage in quantities of more than 3 million m^3, which is a cumulative outcome for many years since its establishment until the time Present.[28]

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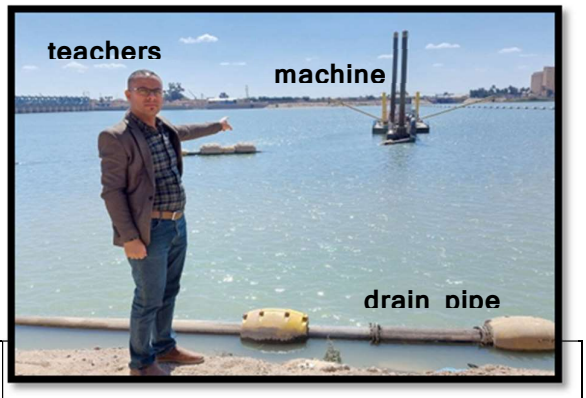
3-1-3 Changing the Level of the Bottom in the Front of the Barrage:

The sediment gathering in front of Kut barrage will lead to a change in the level of the riverbed, as the sediment usually begins with the slow water current, hundreds of meters in the front of the barrage body. On the other hand, the continuation of the sedimentation process and the immersion of the bottom of the stream leads to a decrease in the suitable water and thus its unsuitability for river navigation, which stopped decades ago, in addition to the decrease in the capacity of the stream and the absorptive capacity in passing flood waves to 50% compared to its capacity in 1988[29]. In the front of Kut barrage, by giant pumps periodically to maintain its work, as they raise the water and sediments and direct them towards the sedimentation basins, to isolate the water from the sediment in the river tongue on the left bank of the Tigris near Hay Al-Mu'alimeen, which has repercussions in raising the moisture of the neighboring soil. Note figures (8) and (9).

front of the barrage near Hay Al-Mu'alimeen



Source: field study 27/3/2022.

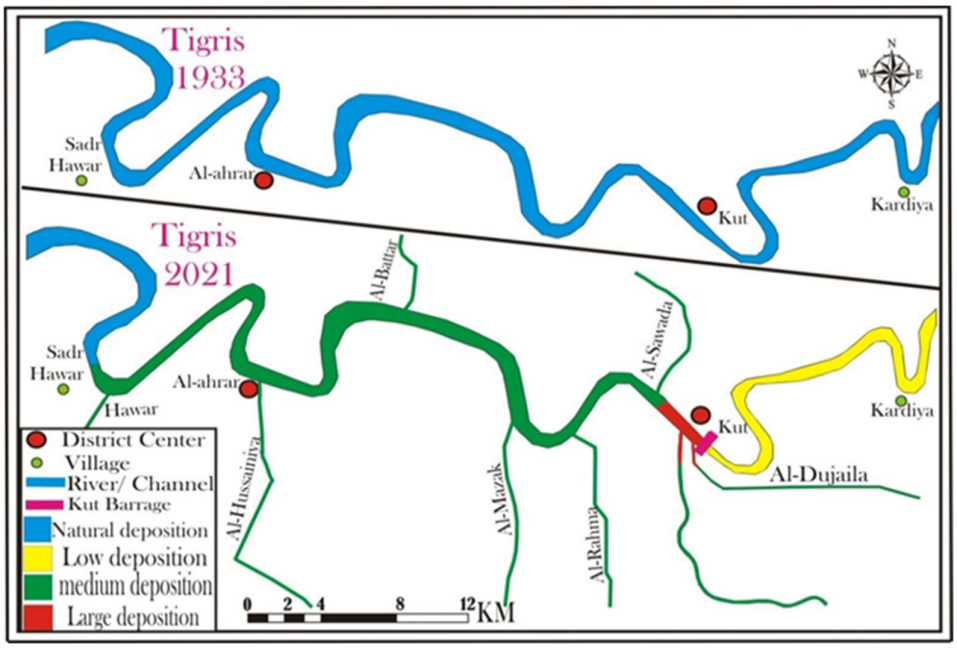


Figure (10) The development of the sediment movement before and after the construction of Kut barrage between 1933 and 2021

Source: The researchers.

3.1.3.1 Analysis of Soil and Sediment Properties:

The rate of concentration of suspended sediments in cross-sections 500m in front of Kut barrage ranges between 670-762 mg/L[30], and in general, the sedimentation accompanies a regular sorting of sediment grains along the river course, according to the direct relationship between the volume and weight of the transported sediments on the one hand, the amount of discharge and the speed of the current on the other hand, it is noted from Table (1) that the bottom sediments in the front of Kut barrage have a sandy alluvial texture that is coarser than the sediments at the bottom with alluvial texture, because Kut barrage forced the coarse fragments to sediment, and the released water behind Kut barrage was of little sediments, as well as in the case of bank sediments which were sandy mixture at the beginning of the research area, while their softness increased near the embankment with a silty mix, then it became behind the embankment clay alluvial at the village of Al-Gardhiya, and the proportion of sand in those models was (42, 34, 19) %, respectively, from north to south of the region. The average porosity is 42.6%,[31] and the permeability rate is 6 mm/hour,[32] and these ratios facilitate the processes of drainage and water supply between the watercourse and the bank soil and the brims of rivers, and the soil content of salts and minerals and the slow movement of groundwater stimulates the evaporation process from the soil. and salt it.

Table (1) Physical properties of soil and sediment samples in the research area

No.	Model Site	Depth	Bulk Density mg/cm^3	True Density mg/cm^3	Porosity %	Sand %	Silt %	Mud %	Texture
1	Front of Kut barrage	Bottom	-	-	-	48	30	22	Sandy silty
2	Back of Kut barrage	Bottom	-	-	-	20	39	41	Muddy silty
3	River tongue at Al-Ahrar	30cm	1.46	2.40	39.2	42	23	35	Loam sandy
4	River tongue at Al-Garraf	30cm	1.47	2.54	42.2	34	35	31	Loam sandy
5	River tongue	30cm	1.41	2.64	46.59	19	40	41	Muddy silty

	at Al-Gardhiya								

Source: fieldwork and laboratory work, laboratories of the Ministry of Science and Technology - Baghdad, 2022.

3-1-4 The Erosion Process behind the Barrage:

In its natural course, the river tries to balance the processes of corrosion and sedimentation, which is governed by the energy of the river according to the amount of water, slope, and the nature of the rock formation of the bottom and banks, and other factors[33]. If its energy is less than its load, it is disposed of by sediment, and if its energy exceeds its load, its bottom and sides are carved.

Despite the decrease in the amount of water releases behind Kut barrage, after the river throws most of its load in the front of the barrage, its energy is released in the form of water currents flowing at great speed, through which the river practices the process of erosion of the bottom and banks behind the barrage to restore balance and stability to the river.[34] Undoubtedly, Kut barrage represented an artificial renewal point for the river's energy rejuvenation after it entered the aging stage. Those rapid currents of 0.703m/s flow behind the barrage[35] have a great erosion action, working to erode the foundations of Kut barrage and the side earth embankment, and corroded soil and mud in the bottom at the foundations of iron and concrete bridges behind Kut barrage, such as (Al-Anwar, Al-Izza Al-Jadida, Al-Hadid Al-Askari,Al-Hadid Al-Karama wal Jihad) bridges, so in order to avoid that, concrete water weirs were installed to dissipate the water power of water currents flowing through the gates of the barrage, note figure (11), and this method in addition to the reduction of water quantities decreased the erosion work of the hydro-accelerators behind the barrage, and helped in the formation of some sedimentary features such as tongues, barriers, river islands, secondary waterways and shallow pools between the bank and the island in which reed and papyrus plants grow, which speeds up the process of sedimentation and its coalescence to the bank, as on the island of Kut, which is confluent at the back of the barrage directly.

Figure (11) wasted water at the end of the Kut Barrage. Field study on 3/5/2022

3.1.5 Coastal Erosion:

Kut barrage works to reduce the volume of sediment supplies reaching the estuary, whether by holding it in front of the barrage or distributing it to its subsidiary projects. It retreats

backwards instead of advancing and protecting the coast of the country,[36] and the decrease in the water supply to the estuary is reflected in the progress of sea water and the saline tongue towards Shatt al-Arab, the rise in the level of salty sea water compared to the level of groundwater and the salinization of agricultural lands located near it.

3-1-6 Changing the Shape of the Longitudinal and Transverse Sectors:

The morphology of the stream is subject to change in terms of dimensions and slope between the front and back of the barrage, as the width of the stream in the northern section/at Al-Ahrar district reached 375m and a depth of 5m, and the cross-section of the stream became shallow in the northern part/the front of the barrage with a width (612)m and little depth 3.5-4m, in contrast to its cross-section in the southern part/the back of the narrow barrage (300m) near Al-Gardhiya and at a depth of 6m in view of the vertical carving[37], which is an inevitable geomorphic result to adapt to the new hydrological conditions created by Kut barrage system, after the river had its own natural system, which extends back thousands of years.[38]

3-2 Hydrological Effects:

3-2-1 Changing the Flow System:

The Tigris flow system is characterized by the concentration of the flood period and the high discharges in spring and less rate in winter, during this limited period, the river supplies the surrounding areas with groundwater due to the high level of water. As for the periods of declining discharges, they are concentrated in autumn and summer seasons, during which the groundwater supplies the river at different rates depending on the level of low water level, but the water fluctuation does not suit the various and continuous human requirements, especially for agricultural uses, so Kut barrage worked to change this system and created a state of fullness of the stream and a permanent flood that affects the direction of groundwater movement.

3-2-2 Changing the Groundwater Level:

The water retention in the front of Kut barrage and the rise in its level formed hydraulic pressure on the cross-section of the stream, which stimulates the leaching of water towards the neighboring banks and the rise in the level of groundwater in the lands at the front of Kut barrage. This is one of the geological risks that have several repercussions, the most important of which are construction problems and the impact of the infrastructure of residential neighborhoods near Kut barrage, especially the neighborhoods of Al-Mu'alimeen, Al-Haidariya, Al-Hora and Al-Kafaat because its surface level (17-17.5) M.S.L is lower than the level of the rise in the water level, provided by the stable front of Kut barrage at 18 M.S.L in normal conditions. Naturally, water seeps into it due to the height difference, which activates the chemical and physical weathering action, the foundations of buildings are eroded, and the walls are affected by the rise of groundwater and exposed to moisture that activates salt weathering, see figure (12), as well as the swelling of the mud and cracking of the floors of houses, in addition to the overflow of light and heavy sewage channels, while it is offset by a permanent decrease in the level of the river water behind the barrage below 11.40 M.S.L; therefore, it drains the groundwater of adjacent areas towards the river.

Figure (12) The salinity of agricultural soil and its extension towards the walls of the houses in the Al-Dahira region. Field study on 12/4/2022.

3-3 Environmental Impacts:

3-3-1 Changing Ecosystems:

The change in the hydrological and geomorphological system is reflected in the change of ecosystems, affecting the distribution of the population and their concentration along the branches of the Tigris, and the difference in the volume and quantity of water between the front and back of Kut barrage, leads to a variation of the appropriate physical and chemical properties of aquatic organisms and plants, and thus disrupts the ecosystem, as the areas in the front of the barrage are richer in habitats and biodiversity than the areas behind the barrage, as the volume of sediments and stones in the river behind the barrage is less, where fish lay their eggs, and the migration of fish from water disturbance sites near the barrage origin, and the natural nutrients that reach the fisheries in the sea coast of southern Iraq are decreasing. The gathering of water in the front of the barrage helps in stimulating the growth of some types of plants in a high density, especially water-hungry plants such as the Nile flower, which causes the loss of huge amounts of water, while the speed of the current at the back of the barrage contributed to reducing the growth of these aquatic plants.

3-3-2 Changing the Qualitative Characteristics of Water:

The deviation of the Tigris in the research area towards the expansion of its course and the slow flow and the accumulation of water spread over a wide cross section in the front of the barrage, and the distribution of water to the projects located in the front of Kut barrage increases the surface area exposed to evaporation, infiltration and dissolution, as the quality of the collected water in the front of Kut barrage is affected by friction with materials and chemical solutions that water dissolves as it passes over the rock layers.[39]

The acceleration of population growth by 3% is accompanied by an increase in water consumption for individuals and a decrease in levels, and an increase in organic and inorganic waste resulting from the activities of agriculture, industry and services, and there are 5 high concentrations of domestic sewage stations behind the barrage that are dumped into the river without any treatment, and most of the measured elements are higher permissible limits according to the determinants of river conservation systems from pollution No. (25) for the year 1967.[40]

These wastes contribute to changing the chemical, physical and biological properties of water, which pose a threat to human health and living things, in addition to their impact on the severity of the geomorphic work of running water and the resulting terrestrial manifestations about her.

Table (2) Chemical and physical properties of water samples of the Tigris river, the front and back of Kut barrage

Site	Chemical Properties								Physical Properties		
	PH	EC µs/cm	TDS mg\L	Positive ions mg\L			Negative ions mg\L		Temp	Turb NTU	T.S.S mg\L
				Ca	Mg	Na	Cl	So4			
Al-Ahrar	6 %	1097	798	92	67	97	99	249	27	526	103
Al-Gardhiya	8.2	1251	895	114	79	121	120	303	28	64	61

Source: Field work and laboratory work, laboratories of the Ministry of Science and Technology, Baghdad, 2022.

It is clear from table (2) that the values of the total dissolved salts at the beginning of the research area at Al-Ahrar district are 798mg/liter, while they rose to 895mg/L at the end of the research area at Al-Gardhiya village. As for the electrical conductivity at Al-Ahrar, it reached 1097 microsiemens/cm and increased to 1251 microsiemens/cm at Al-Gardhiya. As for the pH at Al-Ahrar, it was 7.6 and at Al-Gadhiya 8.2, both are within the basal direction, and this is due to the high evaporation and salt concentrations and the decomposition of organic materials, while the negative and positive ion elements (calcium, magnesium, sodium, chlorides, sulfates) were recorded (92, 67, 97, 99, 249) mg/L at Al-Ahrar, and increased to (114, 79, 121, 120, 303) mg/L at Al-Gardhiya, as a result of decreasing levels and increasing water withdrawn for various uses and pollutants dumped in the river.

The water temperature varied with a difference of one degree Celsius between the beginning and end of the research area. The values of turbidity amounted to 526 NTU, while the suspended solids amounted to 103mg/L at Al-Ahrar, the turbidity decreased to a quarter of its value of 64 NTU, and the suspended solids to almost half of its value to 61 mg/L at the turbidity and this is consistent with the study. These results clearly indicate three important facts, first; most of the measured element values are high and affected by pollution, but they are within the internationally permissible limits (except: Turb, T.S.S, EC), second; deterioration of water quality in general by advancing southward, third; the effective contribution of Kut barrage in increasing the intensity of the variance of the values of these characteristics between the front and back of the barrage through increasing concentration, dilution or blocking sediments.

3-3-3 Impact on Agricultural Lands:

Kut barrage worked to reduce the possibility of flooding, and thus deprived agricultural lands of the opportunity to renew their fertility with the silt reserved in its front. The barrage contribution to increasing the salinity of the irrigation water is also reflected in the salinity of the agricultural soil.

3-3-4 The Flooding of Banks and Their Collapse:

With the impact of Kut barrage, the Tigris appears as a suspended river that rises above the brim and the neighboring lands, which are theoretically submerged by the river water, were it not for the earthen barrages that work to confine the water, lengthen the infiltration line and reduce its slope, but it does not prevent infiltration that reaches the low areas below the permanent level of the front of the barrage. Among the factors that contribute to the continuation of the leaching process, in addition to the factor of surface and the roughness and permeability of the soil texture, is the decrease of salts in the soil, as the salts when hydrated do not allow water to penetrate into the soil, in addition to the high temperatures that increase the rates of soil moisture evaporation, increasing its ability to absorb additional quantities of water leaked.(41)

The area located between the highest and the lowest suitable in the brims of the river and the banks is subjected to weathering due to the succession of wetting and drying processes, and its imbalance through the variation of its weight between heavy and light, and the variation of its size between swelling and contraction because it contains clays that have less cohesion, and the internal pressure of the soil increases, which leads to cracking, disintegration and collapse, as well. The sudden drop in levels affects the loss of the body of the water column, which represents a bond and a compressive force that prevent the natural brims from collapsing and increasing the sediments that reach the stream.(42) From a pedological and agricultural point of view, the high groundwater level causes soil flooding and imposes anaerobic conditions, which prevent the growth of plants, trees and palms, which are subject to death or stunting, note figure (13).

As for the depth levels of the groundwater in the banks and the brims of the rivers, in the longitudinal dimension, the water levels are high in the wells that are 0.8km away in the front of Kut barrage, and the wells that are 7km away are lower in height. As we head north of the research area towards Al-Ahrar district, the levels decrease due to the decrease in the impact of the barrage in raising the levels of the river. As for the transverse dimension, as we move away from the river course with the height of the surface, the levels decrease and vice versa. In the high brims of the rivers in the concave meanders, the groundwater level is away from the surface, while the levels rise and are close to the surface in the low brims, especially the convex curves.

Table (3) The depth level of groundwater at the front and back of Kut barrage and the speed of its infiltration

Well No.	Site & length distance from the barrage/km	Width distance from the bank/m	Bank direction	Water depth from ground surface/cm	Infiltration velocity/time min
1	0.8 front	1	Left	7	1.5
2	0.8 front	3	Left	20	4
3	0.8 front	6	Left	35	10
4	7 front	1	Left	13	6
5	7 front	3	Left	33	10
6	7 front	6	Left	51	35
7	1 back	1	Right	>150	-
8	1 back	3	Right	>150	-
9	1 back	6	Right	>150	-

Journal of New Zealand Studies NS34 (2022), https://doi.org/ 10.5281/zenodo.7367998

Source: Field study for the period March to May 2022.

The wells located at the back of Kut barrage, up to 150 cm, did not show groundwater, and no clear signs of waterlogging or salinization were observed in the research area.

The fluctuation of the groundwater depth level is affected by water consumption and water releases from the Samarra and Kut barrages, and this is reflected in the renewal of the soil water in the brims and banks and the increase in water salinity drained towards the river, while the flow of groundwater coming from the river upstream of the barrage continues to the low areas without interruption, as evidenced by its continued leaching at the foundations of neighboring buildings and obstruction of construction works unless continuous intake pumps are provided as in the building of Al-Kut Tourist Hotel (formerly), note figure (14).

Figure (13) Palm death due to waterlogging and salinization of soil

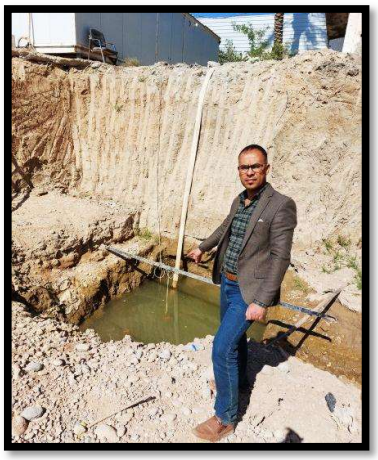


Figure (14) Foundations of Al-Kut Tourist Hotel

Source: Field study 27/3/2022.

3-3-5 The Soils on the River Brims are Salty:

The continuation of the bank flooding and the rise of groundwater levels, is reflected in the melting of soil salts with the activity of the capillary property as a result of high temperatures and evaporation, which makes the salts concentrate in the upper layer of the soil, turning the fertile flooded soils on the brims of the Tigris into saline-desert lands that cause health and environmental problems for neighborhoods and human activity.

3-4 Possibilities for the Barrage to Collapse:

Every engineering facility has a time life that determines its operational efficiency, and the average useful life for barrage design is estimated at about (50) years,[43] 83 years have passed since the construction of Kut barrage, and as its age progresses, it requires follow-up of its validity and periodic maintenance to prolong its work, especially since there are several factors that affect the efficiency of its work and threatening it with collapse, the most important of which is the change in flow and temperature regimes, as well as the accumulated sediment in the front of the barrage body and the reduction in its operational capacity,[44] the weight of the water mass imposed on the barrage due to the high level in its front and low level behind it, the weight of the cars passing on it, the exposure of the barrage body to damage as a result of the American bombing during the second Gulf War in 1991, which caused the demolition of parts of the barrage

bridge, the loss of the electrical system for the gates (17, 18, 19), and other damages that the Ministry of Water Resources and the local government deliberately repaired them.(45) In the event that the barrage reaches stages that cannot be maintained, its removal will have many geomorphological effects.

The possibility of the barrage suddenly collapsing will have a great impact on several levels, the most important of which is the potential human losses as a result of the flood waves resulting from the flow of the retained water mass at once through a stream filled with sediment, as well as expensive losses due to the damage of facilities, infrastructure and human uses close to the stream, and the cost of the evacuation of the population and the payment of material compensation for those affected, as well as the dangers of thirst and drought for the population on the two Gharraf and Dujaila projects, which require periodic maintenance and the establishment of an early warning system for such dangers.

4- Conclusions:

Kut barrage constituted an anthropogenic transformation of the Tigris river that contributed to changing its natural properties, especially after recent updates that raised its level and expanded its service area. The quality of the water, the ecological system of the river course, control of the drainage amount, levels of surface and ground water, and thus the control of the water current strength, the activity of geomorphic processes, the stream morphology and the resulting shapes between the front and back of the barrage, as the sedimentation process was activated on the bottom and the formation of tongues, barriers and river islands at the front of the barrage and the reduction of the course absorptive capacity of the flood and the operational efficiency of the barrage, while the process of bottom and side erosion is active behind the barrage, and the raising of water levels has caused several problems for the areas adjacent to the stream north of the barrage. So, the banks were affected by the resulting infiltration, rising groundwater levels, waterlogging, salinization, collapse, damage to agricultural lands, the impact of urban infrastructure, and vice versa behind Kut barrage.

These effects can be dealt with in several ways, the most important of which is to return to work at the old barrage level of 16.75 M.S.L, and to feed remote irrigation projects with pumps to reduce the area of negative impact of Kut barrage, while continuing to sweep sediments automatically, or to practice auto-purification through almost complete closure of the barrage gates with opening one of the gates completely, as well as the navigation lock, which contributes to dredging the sediments in the front of Kut barrage and diverting them behind the barrage, in anticipation of any sudden flood peak, which may cause catastrophic losses because it cannot be absorbed by the sediment-buried stream, or it may be suggested to dig a side channel with a watershed deeper than the riverbed, with entrance and exit sealed gates, through which it passes.

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