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The impact of the connection of Tharthar Channel to the Euphrates River at Habbaniyah–Fallujah area

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ABSTRACT

Rivers, like any other natural phenomenon, strive to maintain a stable state that is suitable for their environment or region. Any changes in the conditions surrounding the river will make the river out of its stable state. This makes the river change its characteristics to adapt to these changes and return to a state of stability again. This research aims to determine the impact of the Tharthar-Euphrates channel on the main Euphrates River in the Fallujah area. Measurements for current velocity, width, and depth were taken for two cross-section profiles of the river in two different locations before and after the Tharthar - Euphrates Channel connection point with the main Euphrates River. Measurements were done on two dates: November (the end of the dry season) and April (the end of the rainy season). To detect changes happening in the Euphrates course, this work was supported by using a series of satellite images (1972 to 2024) to detect the movements that occurred in the river. Also, the calculations of the sinuosity factor (1972, before the construction of the Thartha Channel, to recent time) show that some new banks appear as a new fertile area. Sinuosity showed the Tharthar channel has a strong effect on the Euphrates after the connection point, also the Euphrates, even in its recent low discharge and many drought seasons, still has some effect on its course. The results showed an increase in the sinuosity factor of about 0.8 after connection due to the effect of the channel.

Keywords: *Euphrates, Fallujah, Landsat, Meandering, Shifting*

1 INTRODUCTION

The River Euphrates is one of the most historically important rivers and the longest in Western Asia. It is one of the defining rivers of Mesopotamia. It originates in Turkey and flows through Syria and Iraq to meet with the Tigris River in the Shatt al-Arab, which empties into the Arabian Sea [1]. This major river can change the direction of its streams in some areas in natural and sudden ways. Rivers are considered one of the most significant geomorphological and hydrological influences that affect the Earth's surface and alter its characteristics directly or indirectly. During the flow of rivers, which carry suspended sediments or mineral solutions, they alter the areas adjacent to the riverbanks and the bottom as well. There are erosion processes in some areas and sedimentation in other areas, with the dissolution of some rocks through which the river flows. Over time, all of this might change the shape and characteristics of the course and the surrounding areas. Water level measurement is a crucial element of hydrological monitoring and water resources management. Data from water levels are typically used to calculate runoff, water supply volumes, and flood discharge. Additionally, water level data help validate and calibrate hydrological and hydrodynamic models, improving the accuracy of hydrological forecasts, particularly for predicting extreme events such as floods [2].

Major rivers around the world have undergone significant changes in flow, diminishing their natural capacity to adapt to and absorb disturbances. With anticipated shifts in global climate and water demands, this could lead to

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serious issues, including the loss of native biodiversity and increased risks to ecosystems and human populations from flooding or water shortages. In this study, we project river discharge under various climate and water withdrawal scenarios and integrate this with data on the effects of dams on large river basins. This approach allows us to create global maps that illustrate potential discharge and water stress changes for dam-impacted and free-flowing basins. Our project suggests that every populated basin worldwide could experience changes in river discharge, and many face water stress [3]. Therefore, studying the changes that may occur to the river and the changes that occurred previously, with a possibility of their continued occurrence in the future, and developing solutions for them. It is considered one of the priorities that must be studied because of a possible change in the river. Al-Tharthar - Euphrates channel is considered one of the important parts of the Al-Tharthar lake project. It was established in 1976 to connect the lake to the Euphrates River [4]. The length of the Tharthar-Euphrates Channel downstream of the division regulator is 9.5 km, and the water was first diverted through the channel to the Euphrates River in 1976 [5]. This study aims to clarify the effects on the Euphrates River due to the connection of the Tharthar Channel in the Habbaniyah - Fallujah area.

2 STUDY AREA

The located area between Habbaniyah and Fallujah region in Anbar governorate, within the administrative boundaries of the Fallujah city, is located between latitudes 33° 21’ 0" N - 33° 24’ 0" N and longitudes 43° 33’ 0" E - 43° 39’ 0" E, Figure 1.

3 MATERIALS AND METHODS

3.1 Recent measurements for euphrates river

There have been many recent changes (flow velocity, depth, and width) occurring in the river course, which can serve as indicators of past changes and may also affect the future. Two cross-sections, P1 and P2, of the river were selected for areas before and after the connection point between the Euphrates and the Tharthar channel (Figure 1). For each profile, the flow speed and depth of the river were measured in order to draw the river section using an Intelligent electromagnetic velocimeter (MGG/KL DCB). Measurements were made from one bank to another and along a previously specified path using a boat. The distance between two points was 10 meters, and the current speed was measured at three depths for each point (0.2, 0.6, and 0.8) of the total depth. After that, contour maps were drawn showing the current speed and the topographic section of the river course (Figure 2). Inside the confluence, the tributaries flow in a mutually deflecting manner, and this deflection is the outcome of pressure gradients created by the spatial pattern of water-surface elevations that steer the confluent flows into the receiving area [6]. The river’s water flow velocity significantly affects the residence time of water, which in turn influences both high and low water levels, as well as water quality, in global-scale hydrological modeling [7].

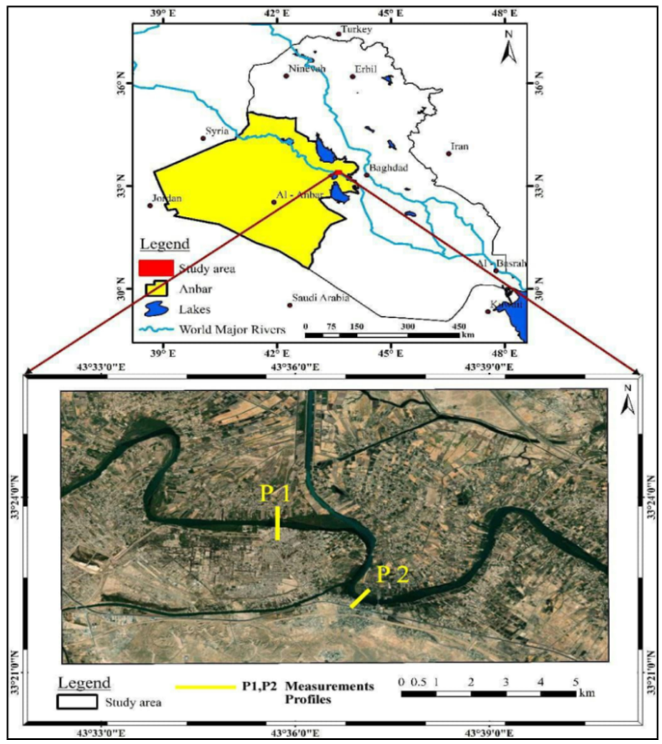

Fig. 1 Structural holes through two-dimensional shapes, where each one is enclosed by different surface boundariesStudy area and measuring profiles

4 RESULTS AND DISCUSSION

Two sets of measurements were made in different seasons: the first set on 1/11/2023 (end of summer season, dry season, and minimum river discharge), and the second set on 24/4/2024 (peak of rainy season, humidity, and maximum spring discharge). Measurements were taken for both profiles on the same day to ensure the same conditions for the area. Studying the differences that may be observed in the same profiles between the two measurement periods provides a clear understanding of the activities carried out by the river under the influence of the surrounding conditions, including the climate, as well as the primary factor, which is the connection of the Tharthar Channel to the Euphrates.

Fig. 2 Current velocity measurements from a boat

Profile 1: This profile is located before the connection point, at the first set of measurements taken on January 11, 2023. The width was 192 m, and the depth was about 3.5 m. At the deepest point, with shallow water less than 0.5 m. At the left bank, current velocity ranged between less than 0.2 m/s measured at the bottom and the areas of friction with the river channel section. Because of that, the speed of the current was increased in a consistent manner until we reached 0.8 m/s in a circular closure located approximately in the middle of the river and above the maximum depth of the channel. The shape of the bottom was winding with the presence of slight rises and falls in proportion to the speed of the currents above it (Figure 3). Stream flow measurements are frequently constrained to low flow conditions, which introduces significant uncertainty when extending rating curves to higher water levels [8].

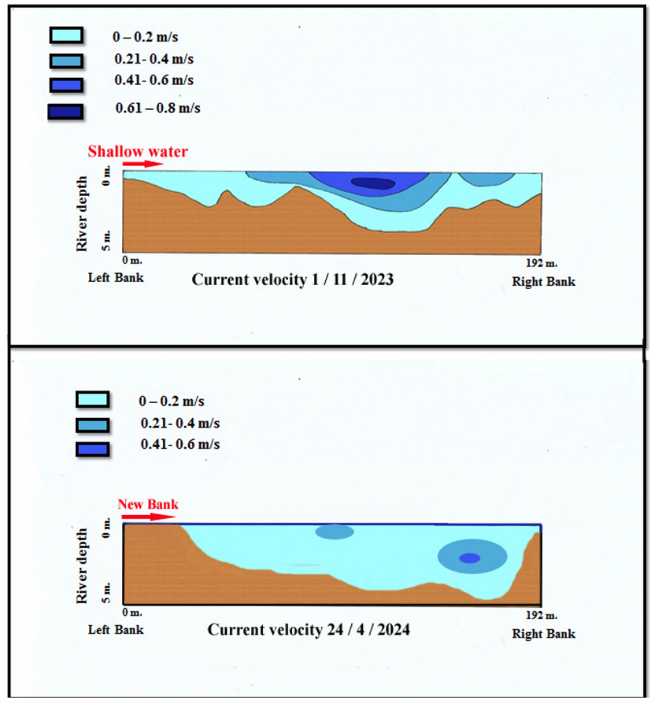

Fig. 3 Current velocity at P1 and river profile at two sets of measurements

The second set of measurements, taken on 4/24/2024, at the same location, revealed many changes that had occurred to the river and current, most notably a decrease in the river's width by 30 meters. This is because the water level on the left bank has decreased and appeared as a natural extension of the old bank. This narrowing of river width made the river expend its energy by deepening the bed and reaching a depth of 5 meters, and it is clear that the speed of the current decreased due to the expansion of the cross-sectional area of the river. Velocity ranged between less than 0.2 m/s to 0.6 m/s as a fast flow near the right bank, just above the deepest point in the river, which, over time, can cause side erosion in the bank as the first step in river shifting.

Profile 2 This is located after the point of connection. The same sets of measurements, dates, and methods were conducted for this profile. In the first set of measurements, width of the river was about 100 meter, depth was 6.3 meter, shape of the river bottom was smooth and homogeneous, except for one depression located on the side of the water current due to the speed of this current, which appeared on the contour maps as a contour closure at a speed of 0.6 m/s (Figure 4). The morphology of an alluvial river channel affects the movement of water and sediment along it, but in the long run, it is shaped by those processes. In rivers, it has created an emphasis on equilibrium configurations with simple morphology and uniform steady flow, whether between equilibrium states or indefinitely, is to be expected in a world in which hydrology, sediment supply, and base level are not fixed [9].

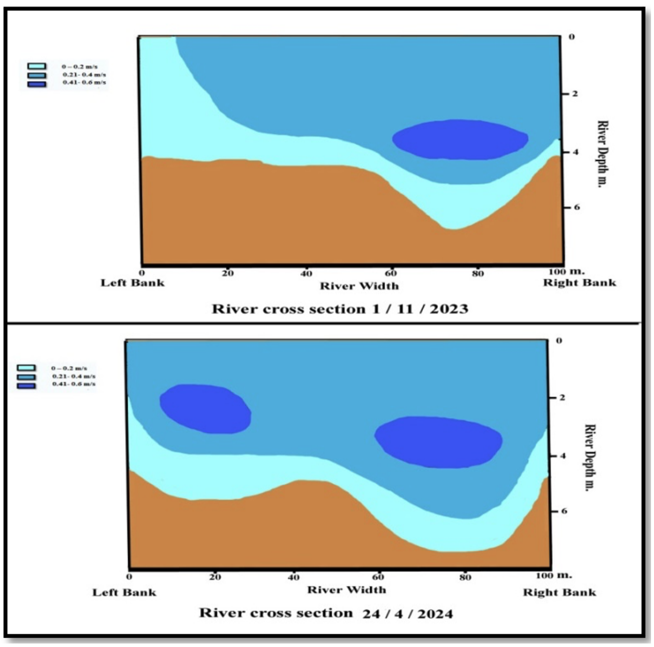

Fig. 4 Current velocity at P2 and river profile at two sets of measurements

In the second measurement, conducted on April 24, 2024, some changes were observed in the shape of the river section and in the speed of the water currents. The fast current near the right bank remains present, with the same speed. A new current was also recorded near the left bank, with the same speed as the first one. This is believed to mean that both of these currents originate from the original currents of the Euphrates River and the Tharthar Channel. Therefore, the contour map of currents revealed two contour closures with higher speeds than the rest of the profile speeds. This was likely due to the measurement being taken during the spring season, with high rainfall rates and higher discharges. Therefore, we expect that this second profile will be exposed to more active river operations than the first profile, which is located before the connection point between the Euphrates and the channel. Regarding the bed profile, we observed the appearance of a depression under the second new current, attributed to the speed of this current. As for the total depth of the river, it increased to 6.8 m; the width remained almost the same as in the first measurement, reflecting its morphologically dynamic nature.

4.1 Sinuosity factor

The ratio of the actual length of the course of any river or valley to the ideal length is the actual length, which is the real distance that the course travels on land with all its meanders and shifting, while the ideal length represents the shortest distance that the course takes in its past area.

$$\text{Sinuosity facto} = \text{Actual length} \,/\, \text{Ideal lengt} \qquad (1)$$

An increase in the coefficient indicates that the river is in an active state, characterized by continuous growth of river meanders. This may be due to an increase in water entering the river, resulting from weather conditions or the connection of water channels to the main course of the river. The Sinuosity Index (SI) is a measurement used to assess the shape distortions of rivers and streams by evaluating the effect of a river's path over a given region and vice versa. Rivers meander due to natural phenomena such as floods and changes in channel slope. Additionally, human activities like dam construction, agricultural projects, and settlement development can also cause rivers to meander [10].

To calculate the river's sinuosity factor, two areas were chosen before and after the connection point, and on two different dates: 1972, before the construction of the Tharathar Channel (calculations were based on satellite images Landsat MSS 2), noting that the channel was built in 1978. Calculations were repeated for the same area in 2024 (based on satellite images Sentinel – 2 L2A) (Table 1).

Table 1 Calculation of Euphrates River

Sinuosity Factor		
Year	Calculation before connection point	Calculation after connection point
1972	1.36	1.43
2024	2.05	2.23
Increasing in factor	0.69	0.8

The results showed that Sinuosity Factor calculations for the year 1972 for the areas before and after the connecting point are very close. It indicates the relative stability of the river during that period (before the construction of the Thartha Channel), despite the high discharge rates preceding the subsequent dry seasons. As for 2024, the rates have clearly increased, indicating the relative activity and effectiveness of the river course despite the long dry seasons that occurred in the area. This is explained by the effect of the additional water entering the Euphrates River coming from the Tharthar Channel. This is more evident by observing the difference in the coefficient of sinuosity for the area after the connecting point, which is greater than the Sinuosity Factor for the area before the confluence. The effects of this channel, "Meander" and "sinuous," are synonymous and describe a river or stream that rarely follows a straight path, as most streams tend to meander, especially when not confined to a narrow valley or gully.

The curved channel introduces additional flow energy dissipation that is absent in a straight channel. This energy loss results from the alteration of the flow path [11]. Excavations of riverbank alluvium also significantly contribute to river erosion and channel migration, which are among the factors influencing changes in the sinuosity index of the river course [12].

4.2 Detecting river changes using satellite images

Satellites can provide a series of recordings and images from different dates for the study area. The Landsat satellite series, launched in 1972, is considered one of the first scientific satellites to begin recording reflections and imaging the Earth's surface. Accuracy at the time was 79 meters with many wavelength bands. This type of image was used in this study for Sinuosity Factor calculations and to detect the movements and changes that occurred in the river before and after the connection of the Tharthar Channel. These images were compared with the latest available recordings for the area, which were from 2024, and had an accuracy of 15 meters for the Sentinel satellite (Figures 5-7). To detect changes, the scale of the two images was unified using ArcGIS software. The two images were matched using the geographical coordinates of the area as a fixed reference that does not change. Then, the reflectivity pixels between the two images were subtracted to obtain a new map showing the areas that changed during the period from 1972 to 2024. If there are no changes in the area, the reflectivity values will stay the same, causing the pixels to appear dark or black. In contrast, areas that have changed may appear as new islands beneath the water, such as the growth of a riverbank due to a decrease in water level, which transforms a water area into dry land, or the growth of plants, among other changes. All of these give different reflections to the pixels, and thus, when subtracted, they will appear as bright or light areas (Figure 8). The river and morphological variables used in the study were obtained from available satellite imagery, digital elevation models, and relevant maps. River morphology describes the shapes of river channels and their changes in shape and direction over time. It serves as an indicator of various environmental processes and conditions. River channels result from numerous geographical and geomorphological factors, including geology, climate, and human activities. These factors influence landscape-dependent variables such as sediment supply, stream discharge, and vegetation, which in turn shape the river channel [13].

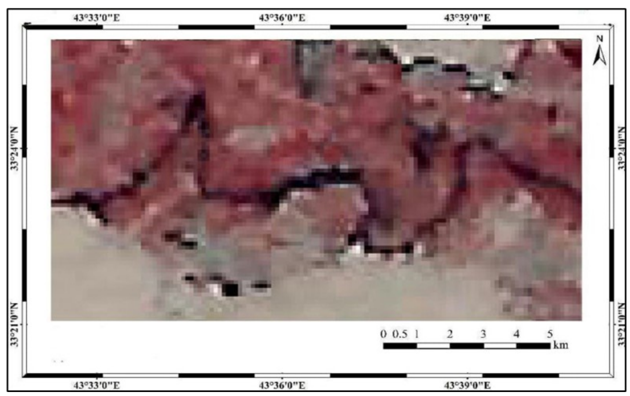

Fig. 5 Area at 21/11/1972 Landsat 1

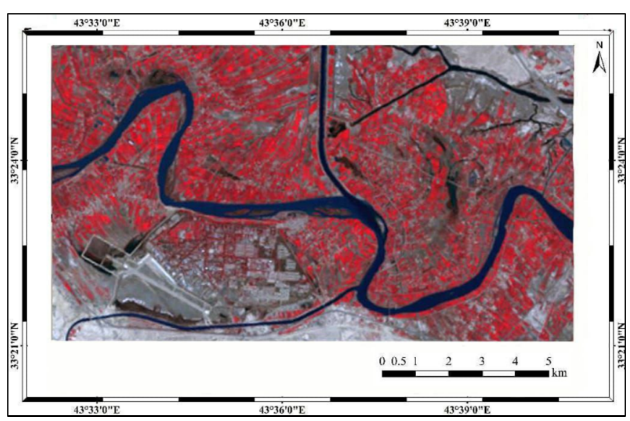

Fig. 6 Area at 23/3/1994 Landsat 5

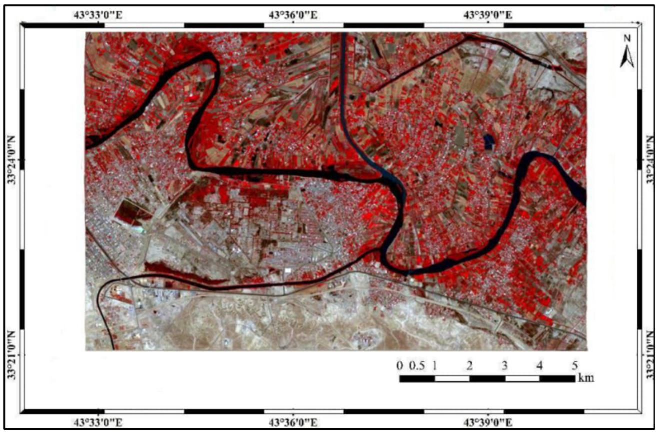

Fig. 7 Area at 19/6/2024 Sentinel -2

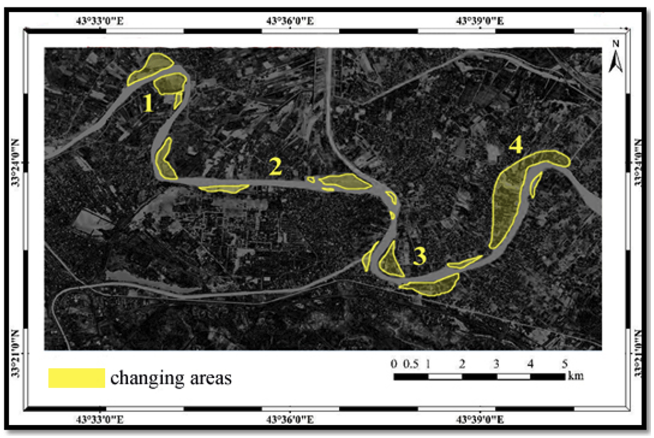

Fig. 8 Changing at study area

The figure above shows that several areas have changed due to the river's activity. For easier analysis, the study area was divided into four regions, two before the connection point and two after it:

Region 1: It is located within the peak of the river's meander. It shows a large shifting of the river towards the south, where the left bank was changed from part of the river's course to an extension of the bank (dry soil), and the exact opposite happened on the right bank of the river, where it entered the river's course.

Region 2: It is located within a nearly straight course, so it was not greatly affected by the river's shifting, and the changes observed were only the appearance of new islands resulting from the low water level due to successive dry seasons. The previous measurement, Profile 1, was part of this area.

Region 3: It is located after the connection point and is one of the most active of the four regions due to its proximity to the connection point and its receipt of large quantities of added water and sediments transported from the Tharthar Channel. This region, located on the top of a river meander, showed both banks and the convex and concave curves of the river have been clearly affected and changed during the period between the two satellite images. The river is flowing south.

Region 4: It is located at the end of the study area, just on a large meander of the Euphrates. It is clear that the river in that area has lost much of its energy and has shifted to lateral erosion, moving towards the right bank and in a southeast direction. This is why a wide area of extension of the left bank has appeared, which has caused the river to be narrower and erode on the right bank.

5 CONCLUSION

- The Euphrates River continues to alter the topography of its banks and the shape of its course, thereby determining the areas of change, despite the general drought and low discharges.

- The canal has significantly impacted the Euphrates River, altering its stability in both areas before and after the point of contact.

- The impact of the canal was more pronounced in areas located downstream, as it was directly responsible for containing additional water and sediments. New river islands appeared in the middle of the course or near the banks, which later merged with the existing islands, leading to a narrowing of the course.

- The lateral shift of the river and the erosion of the banks of the areas located in the direction of the river movement pose a threat to agricultural and residential areas and livestock

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DECLARATIONS

Conflict of interest

The authors declare they have no competing of interests.

Consent to publish

N/A

Ethical approval

N/A

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