

# DEVELOPING A HYDRAULIC SIMULATION MODEL TO DETECT THE AGRICULTURAL LAND-USE SERVED BY IRRIGATION CHANNELS: A CASE STUDY AL-KHORA RIVERS, SOUTH OF IRAQ

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**Abstract:** This research aims to determine the areas and locations of agricultural lands served by irrigation water in the Al-Khora region, northwest of Basra city. As the irrigation water flows to the agricultural lands in Al-khora area through the irrigation channels branching from the Al-Saraji and Al-Khora rivers, which branch from the Shatt Al-Arab, and are designed to irrigate the surrounding agricultural lands depending on the tide's phenomenon. Since the tidal water level in the Shatt al-Arab is variable throughout the day, which leads to an irregular distribution of water between one region and another throughout the days of the year, and it is difficult to determine the areas served by irrigation water whenever we move away from the Shatt al-Arab. Therefore, this study focused on building a hydraulic simulation model in the HEC-RAS program to simulate the flow in the rivers of the study area and to know the extent of its spread in the surrounding areas. The areas of agricultural uses reached by the tidal water were determined in the periods of the lowest tide in November, the volumes of water used in the irrigation process and the ranges of their impact on the neighboring areas were also calculated. The study concluded that the agricultural areas confined between the Sarraji and Al-Khora rivers can increase from 1298 to 1698 acres (equivalent to 31% of its original area), if the areas of land that can be irrigated by the side canals branching from the two rivers are taken into consideration.

**Keywords:** *Hydraulic simulation, tide channel, hydraulic models, Basra rivers, irrigation canals.*

## 1. Introduction

Most of the studies in the city of Basra focused on land uses (residential, commercial, and industrial) neglecting the rest of the land uses and methods of controlling and exploiting them in a way that serves the process of economic development, especially agricultural use. The agricultural use can have a major contribution to improving the country's economy because of the strategic location of the Basra which makes it a focal point for interaction between the different uses of the land. These uses can be used to control the available resources if they are controlled by proper planning methods [1].

The city of Basra, and in particular the central district, is characterized by the abundance of irrigation channels that penetrate the city branching from the Shatt al-Arab. The most important of Basra city channels are the six rivers system (Al-Saraj, Al-Khora, Al-Ashar, Al-Khandak, Al-Rabat, Al-Jabila). These channels contribute to irrigating the surrounding areas by relying on the tidal phenomena that occur on a

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daily basis, as the water level rises by the tide at morning to its maximum, causing the flow of water from the Shatt al-Arab to these rivers and then back to the natural level at evening [2]. In this study, this phenomenon was used and exploited to determine the extent of the extension of the tide and the agricultural areas that can be irrigated. Thus, achieving a balance between using agricultural land and water bodies and controlling them.

### **1.1. Research Problem**

The lack of a clear vision for the master plan designers of how to exploit the water resources of the Shatt al-Arab in determining the boundaries of agricultural areas and how the system of agricultural land use interacts with the surrounding water bodies. In addition, the lack of a specific methodology in diagnosing and measuring these interactions, which negatively affects the identification of agricultural sites that are serviced and suitable for agricultural production whose features have been lost as a result of their mixing with other land uses.

### **1.2. research aims**

- 1- Defining the irrigation channels that the tidal water reaches in the study area.
- 2- Determining the ranges of the spread of irrigation canals water inside the agricultural lands.
- 3- Determining the locations and areas of agricultural land uses served by the channels above, which can be used in the future in controlling, developing and rehabilitating these lands for the cultivation of crops that are commensurate with the amount of water reaching them.

### **1.3. Research Hypothesis**

The hypothesis that this study wants to prove states:

Irrigation canals branching from the Shatt al-Arab are capable of delivering water to the lands designated for agriculture, and they can irrigate wider ranges and areas if taking into account the difference in level between the two tidal phenomena.

### **1.4. Research Methodology**

The research relied on the analytical approach through the use of spatial analysis programs and simulation software (Geographic Information System- GIS 10.4.1, Autocad Civil 3D 2020, HEC-RAS) to analyze and interpret spatial data for the study area (agricultural land uses and irrigation channels) to give results on the positive effects of irrigation channels on agricultural use.

## **2. Land Uses and Their Role in Urban Development**

The study of land uses requires defining concepts and terms that help in understanding the natural, economic and social factors of the region and the city, which can be used to reach the planning goals [3]. The most important concepts can be identified as follows:

### **2.1. Land Use**

Land uses take several concepts, but they are related in that they show the direct human interest and activity, and the extent of his interaction with the surrounding environment [4]. It is defined as: "The actions that a person carries out on a specific area of land, by exploiting his natural potentials, by exploiting the best human potential" [5].

It is also defined as: "The requirements of a person from the land to live on and use it for other life purposes in addition to housing" [6].

Or it is "the methods used by a group of the population aiming to obtain the fulfillment of their necessary requirements" [7].

And it is "the activity of human in the land to which he is associated, and his use of it is limited to a specific area of land, whether urban or rural" [8].

## **2.2. Rural land**

Rural land is the land used in agricultural production, in both types of plants and animals. It can be classified into two types:

- Arable land: which is constantly subject to agricultural operations.
- Non-arable lands: which are not regularly subject to various agricultural operations, and include lands that are not used for agricultural use, such as residential lands or warehouses, irrigation facilities, drainage canals, and desert soils [6].

## **2.3. Agricultural Land Use**

It is the area occupied by agricultural investment [9], and the continuous human intervention to change the surrounding environment to satisfy the human needs, and to know the extent of the viability of these uses to provide them [10].

## **2.4. Change in Land Use**

It is the transformation that takes place in a certain phenomenon due to the combination of subjective and objective variables. In other words, it is a noticeable shift that takes place in the type of land use in the temporal and spatial dimensions and its size. This shift is commensurate with human intervention to achieve better results as well as changes in other factors (social, economic, and urban). This leads to the imposition of new patterns, whether in the growth of stable volume or the emergence of new settlements or change in the rank of the existing stable [11]. Changes often result in the emergence of problems in the region, which are caused by the failure to enter the element of estimation or prediction at all, which leads to the

necessity of preparing stages for remedying them temporarily (phasing) by determining what is required for the development of the region, and solving these problems accommodates socio-economic trends [11].

The spontaneous change is the prevalent characteristic in the regions, and it occurs at the level of fragmented, non-comprehensive sectors that leads to the occurrence of problems, including social, economic, health and urban, accompanied by a poor distribution of investments, an imbalance in land uses, a disparity in the levels of civilization, and a lack of services, which makes a difference in The urban emergence between the countryside and the city, which causes the population to change the uses of agricultural land to other uses.

This does not mean a rejection of change, but rather a holistic view that controls the work of the regional and stable entity in a manner that is in line with social and economic trends in a rational direction, making the process of change a continuous process and an extension of a plan based on assessment, forecasting and organizing the elements of the region and the interaction of current and future uses of the land.

The development of agricultural use, which is necessary to cover the region with agricultural production and the provision of green spaces that helps to improve the healthy environment, makes the change synchronized with the development of services that increase competition on land and prevent overlapping uses, and it gives a formula of integration that supports the planning factors aimed at developing the region with accreditation on the region's own resources [12].

## **2.5. Irrigation and Agricultural Drainage**

It is the technique concerned with supplying agricultural areas with the water needed for agricultural uses in a precisely calculated manner based on climate, topography and the nature of the soil (pH, gradient of grains, ... etc). Supplying

agricultural areas with water that maintains the moisture content necessary for the growth of agricultural crops, and washes the soil from excess salts, to maintain an acceptable salt concentration. There are two types of irrigation, the first is natural, in which the water reaches agricultural areas in a natural way, and the second is the industrial irrigation that is done through the distribution of water using pumping stations and different ways to drain it. Irrigation systems depend on irrigation channels that are established with a specific width to deliver water from the source to the regions with Agricultural use, and some types of large canals are used as links for transporting ships and boats purposes [13].

### **3. The Role of Agricultural Use in Improving the Urban Environment and Economic Activity**

The most important elements that are reflected on the city's economy and the urban environment can be summarized in the following aspects.

- A. The element of benefit: the basic needs of members of society are satisfied with a high percentage of the agricultural sector's production.
- B. The aesthetics element: as the aesthetics of the environment has a relationship with life, relaxation and moistening the air to carry out comfortable respiratory operations for humans, by ridding the environment of huge quantities of carbon dioxide. The shade of trees and plants also protects people from the scorching heat of the sun, meaning that they soften the atmosphere and affect heat, wind [14].
- C. Environmental impacts: Plants provide the soil with organic matter necessary for its fertility, as well as protect the soil from erosion. It stabilizes sand and thus

reduces the phenomenon of desertification. Forests and weeds also act as a water reservoir, as they regulate the runoff of water and help to absorb water and make it seep into the soil [15].

As for the vitality of the agricultural sector in the process of economic development, it is reflected in the following matters and reasons: [16]

- Achieving any surplus in agricultural production reduces imports of agricultural products. This surplus contributes to increasing exports, obtaining foreign exchange [17].
- works to provide sufficient supply to meet the inevitable increases associated with the increase in income and the increase in the population, which reduces the inflationary pressures resulting from the increase in demand.
- Generating savings and providing financial capabilities to finance the activity of the agricultural sector, and other economic sectors, especially the financing of industrial activity.
- The development of the agricultural sector works to expand the local market for manufactured products, which leads to full employment of productive capacities.

### **4. The Study Area (Basra City)**

The city of Basra is located in the northwest of Basra Governorate in the south of the West Bank of the Euphrates River. The city is bordered on the north by Maysan governorate, on the south by Zubair district, on the east by Qurna district, and on the west by Dhi Qar governorate. It occupies a geographical location (27.77 ° north - 18.94 ° east) [18], as illustrated in Figure 1.



Figure 1. The location of the city of Basra [19].

The population distribution in Basra varies from one region to another, but the primary sources indicate that the Basra and Zubayr areas represent the greater relative importance of the population [11]. Fao ranks last for the destruction of the city in the war. As for the rural population, they are concentrated in the regions of Qurna and Medaina, then Zubayr and Shatt al-Arab only. As for Abu al-Khasib, which is a previously known rural area, the civil encroachment in it has begun to dominate the rural character, and the population has shifted to civil works due to the devastation of most agricultural lands due to wars, water salinity, or uselessness. Work in it due to the deterioration of productivity, the lack of financial returns or income obtained from agricultural activity, the lack of support for agricultural work and the high costs of production. The decline in the contribution of the agricultural sector to the Gross Domestic Product (GDP) and the migration of many peasant families to the profession of agriculture, leaving the countryside and going to the city after the agricultural sector became expelled for employment for the reasons that have passed has led to a decline in the contribution of the

agricultural sector in the economic process and its decline to a large extent [17].

Despite the deterioration of the agricultural sector in the city of Basra, the city is distinguished by the fact that its land is flat, and its levels range from (-2 to 5) meters above sea level, and there are many water bodies and irrigation channels. Irrigation of agricultural lands in the city of Basra depends entirely on irrigation canals, due to the hot desert climate and the relative high humidity with an increase in the hours of solar brightness, which made the dependence on irrigation channels for irrigation. The Shatt al-Arab is the main source of water, and the main irrigation channels are branched from it, as the city of Basra is distinguished by the branching of six main rivers from the Shatt Al-Arab inside the city to form an irrigation system used to irrigate agricultural lands that were previously in the region before they were transformed into residential uses, except for some areas that have preserved on its agricultural nature, it is the area confined between Al-Sarraj and Al-Khora rivers and called Al-Khora sector [1,2], Figure (2).

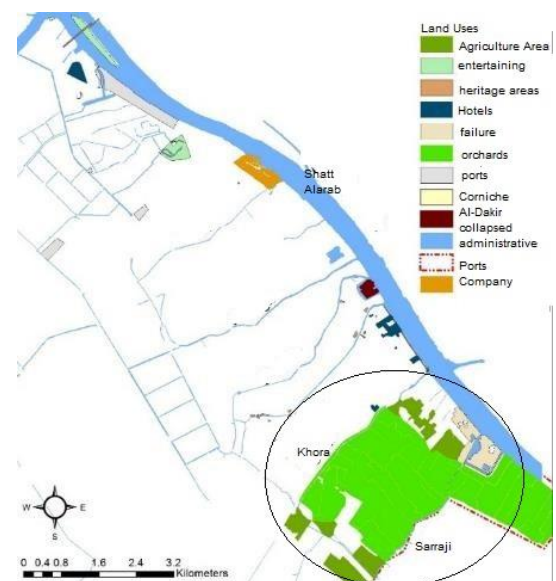


Figure 2. Map of the study area shows the agricultural lands between Al-Sarraj and Al-Khora rivers

The agricultural areas confined between the Al-Saraji and Al-Khora rivers use natural irrigation based on irrigation channels that branch from the Al-Saraji and Al-Khora rivers, and extend along the study area, forming an integrated irrigation network with side branches to the right and left of each channel to irrigate the largest possible area of agricultural areas. In the recent period and as a result of the great transformation and change that occurred in the land use, which led to the disappearance of agricultural use and its mixing with other uses in a way that is difficult to determine the suitable lands for agriculture and their areas and borders in addition to the difficulty of knowing the lands served by irrigation in order to develop and rehabilitate them completely. This study will try to reach a strategy through which economic development can be achieved for this sector by controlling this use and knowing the agricultural areas that can be exploited in the future. If these lands are identified, it can improve the environmental and economic situation of the city and the region [19].

## **6. Research Methodological and Results**

### **6.1. Hydraulic simulation models**

The concept of simulating rivers is to build a model to simplify the complex real system of water flow, and the associated physical processes of different scales, to give forms of water flows and their velocity within the hydrological system [20]. Each simulation model has parameters obtained from accurate surveys of river sections and from specific tables of riverbed type. These parameters are then defined as inputs to the simulation program [21], in order to give an output that mimics the real system of water flow. The United States Army Corps of Engineers produced and developed the HEC-RAS (Hydraulic Engineering Center - River Analysis System) as a system for analyzing rivers and

channels. This program is considered one of the most prominent programs for building hydrodynamic models that simulate stable and unstable flow within two and three dimensions of rivers, as well as to simulate the transport of pollutants and sediments in watersheds [22]. HEC-RAS relies on the continuity and momentum equations to simulate a one-dimensional unstable flow (as in the case of rivers in the study area), and to build the hydraulic simulation model, the program needs to define some inputs which can be summarized as follows: [1,2, 23]

- (1) Geometric data: represent accurate topographic survey of river shape and Manning coefficient (roughness coefficient) values. Accurate topographical surveys of the cross-sections of Al-Sarraji and Al-Khora rivers were obtained from Basra Municipality to represent the geometric data of the rivers of the study area.
- (2) Initial Conditions: Water levels of upstream of the river when time is zero. Tide levels were obtained at the upstream of the Al-Sarraji and Al-Khora rivers from the Marine Sciences Center in Basra.
- (3) Boundary Condition: continuous changes in water levels of upstream or downstream.

As for the outputs of the simulation model, they are values, longitudinal and cross sections, static and moving maps, tables of levels, flows, velocities of water, and pollutants that change over time.

### **6.2. Building a Hydraulic Simulator Model**

- A. The ArcGIS 10.4.1 program was used to produce a map representing the land uses of the study area, based on a corrected satellite image of the Landsat for the City

of Basra for the year 2019. Figure (3) shows the productive land use map, and shows Al Saraji and Al-Khora rivers system branching from the Shatt al-Arab, which represents the study area. Land use data has been exported from ArcGIS 10.0.1 to Autocad Civil3D 2020 for the purpose of constructing longitudinal and cross sections of rivers.

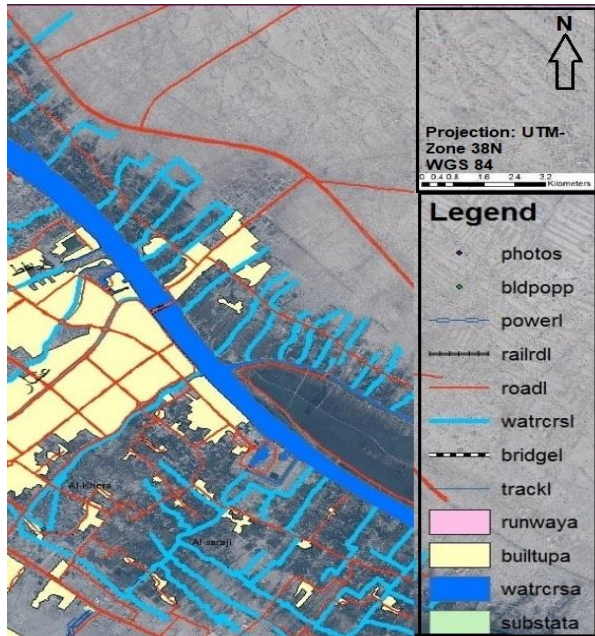


Figure 3. Land uses for Basra city and the main irrigation channels.

B. Cross sections and profiles of the rivers system (Al-Sarraji - Khoura) were produced by using AutoCAD Civil 3D 2020 after data was imported from ArcMap 10.4.1 (GIS). As the survey points of 2020 for river sections were used to build a Digital Elevation Model (DEM) for the river bed, and then relied on the DEM in deriving the longitudinal and cross sections of the river. As for the ground survey points that have been used, the coordinates were observed by the Differential GPS device after the river has been divided into equal sections of not more than 100 meters between one

cross section and another, with 10 points per cross section to show the real change in the shape of the river with high accuracy. As shown in Figure (4-A), Figure (4-B), Figure (5-A) and Figure (5-B). Longitudinal and cross-sectional data were exported to HEC-RAS as Geometric Data.

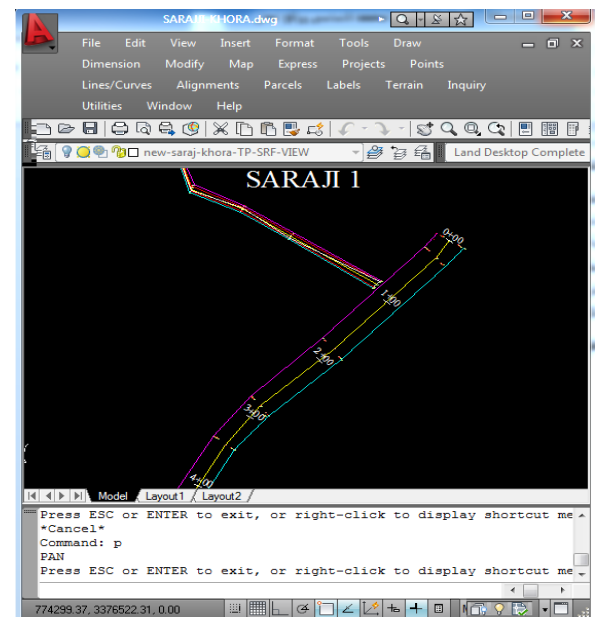
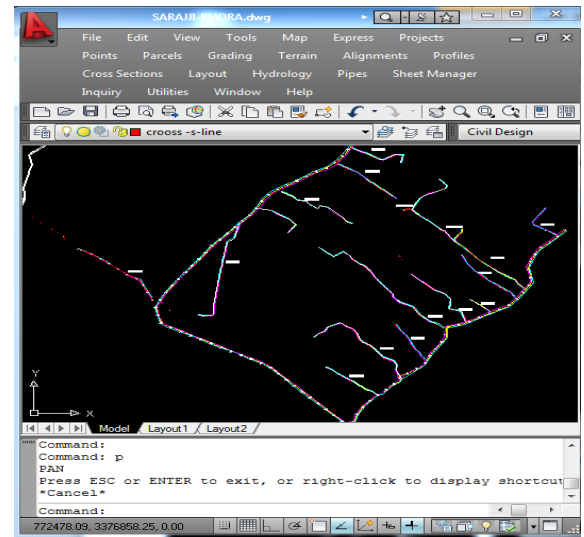
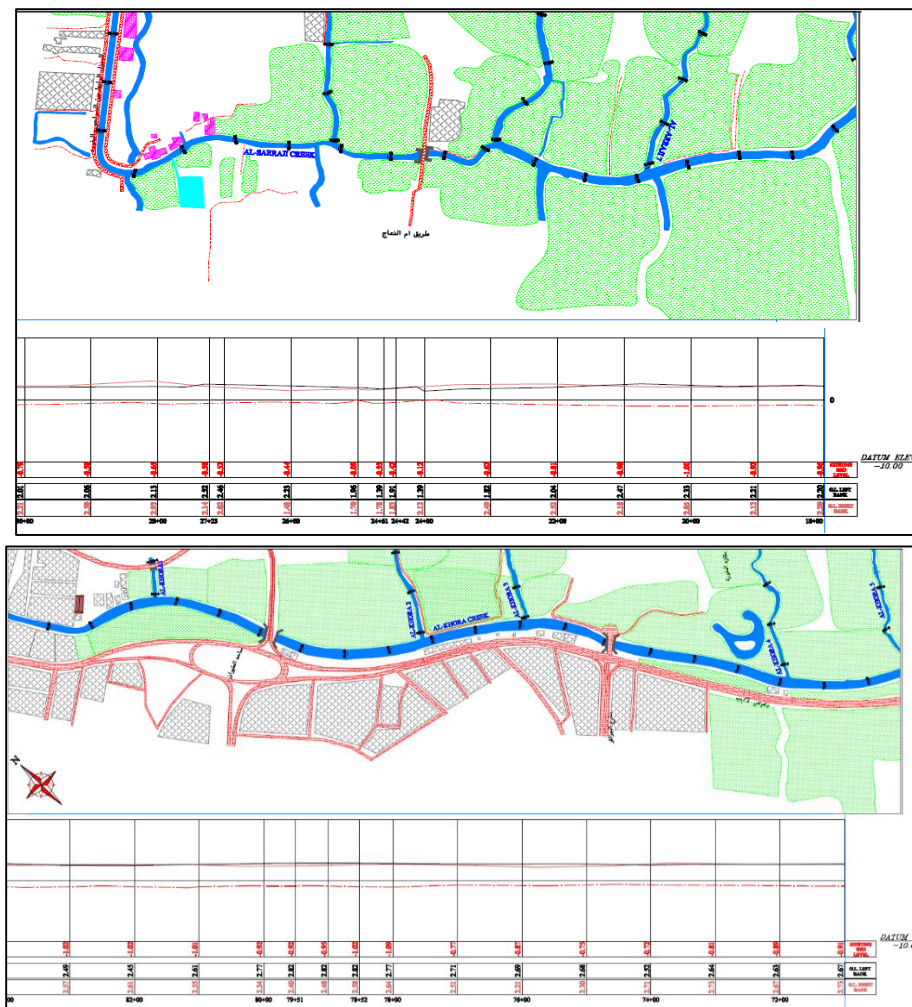


Figure 4-A. Import and define topographic survey points to build a DEM in Civil 3D 2020.







**Figure 5-B.** Definition of the longitudinal section of Al-Sarraji River.

- C. After importing the data of the longitudinal and cross sections into the HEC-RAS program, the initial and boundary conditions for the water levels in the rivers were defined. The average tide level in November was 0.65 m (which is considered the month in which the lowest tide level occurs in the Shatt al-Arab), while the average ebb level reached -0.54 m for the same month. The flow and velocity of water at the upstream and downstream were calculated by the program depending on the accuracy of the shapes of the cross sections. Manning coefficient values were defined and ranged from 0.032 - 0.038. See Figures (6, 7, and 8)
- D. The HEC-RAS program was run according to the previous inputs. Upon operation, the water of Al-Sarraji River and Al-Khura flows into the irrigation channels branching from them to reach its maximum distance inside the agricultural lands according to the water energy that depends on the flow and the cross-sectional area of the channel. The ranges and distances extended by the irrigation channels branching from the Al-Sarraji and Al-Khura rivers were determined at the average water level in the tide phenomenon in November, as in Figure (9).
- E. The last step includes calculating the ranges and distances reached by the water

at the two phenomena (tide and ebb) and then determining and calculating the areas irrigated by these channels and their locations and boundaries for the purpose of knowing the lands that these channels can serve in order to control and rehabilitate them in the future for the purposes of agricultural production. This step was done using ArcGIS 10.4.1 software after exporting the data of the previous step in Shape File format for the purpose of dealing with it as spatial data, and as shown in Figure (10) and Figure (11) which illustrate the spread of tidal water in the subchannels (these channels are numbered, which reached 9 Branches from Al-Saraji River and 7 branches from Al-Khora River) and the borders of the agricultural areas confined between the Al-Saraji and Al-Khora rivers, which can be irrigated depending on the tide in the branch channels. Table (1) shows the length of the irrigation channels branching from the two rivers, the areas of agricultural lands served by irrigation on both sides of the branching channels, and the volume of water entering each channel when the tide occurs.

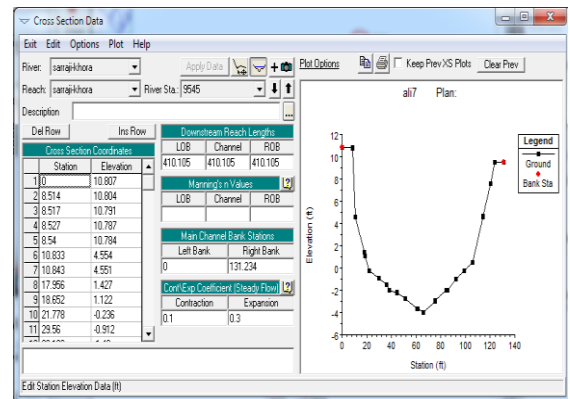
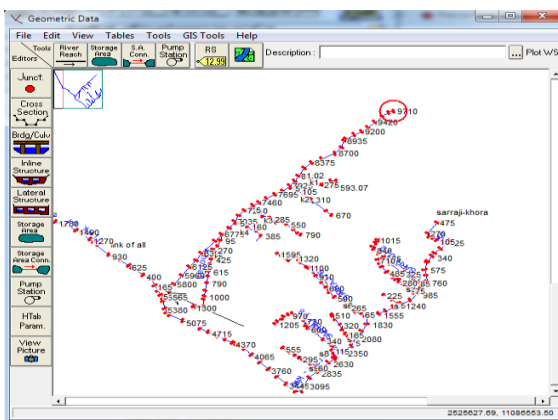
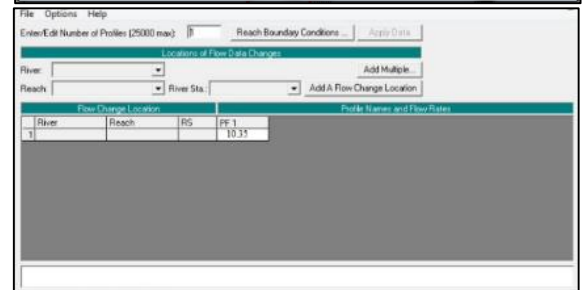
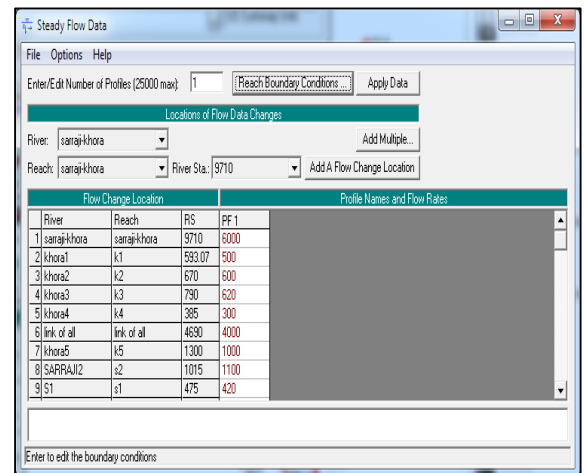
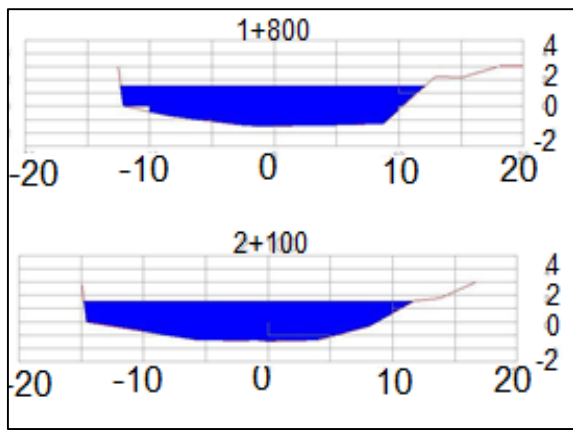
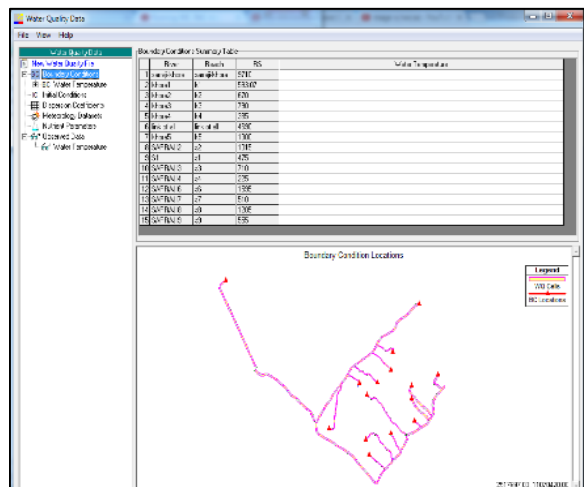


Figure 6. Definition of geometric data and Manning coefficient values in the HEC-RAS program.

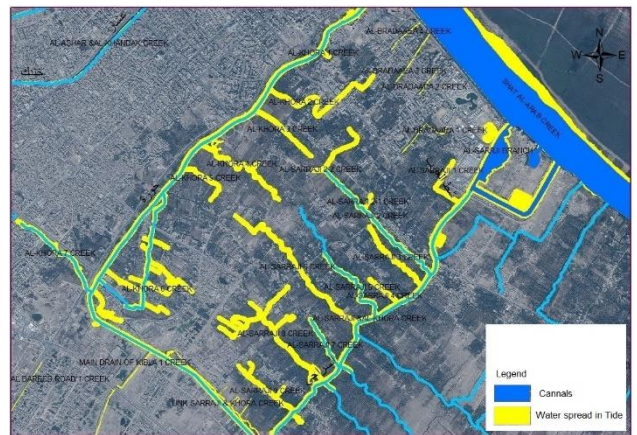




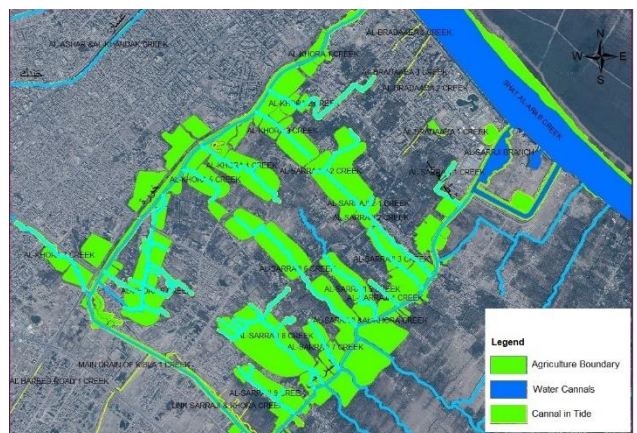
**Figure 7.** Definition of initial and boundary conditions data for constructing cross sections in the HEC-RAS program.



**Figure 8.** The spread of canal water within the agricultural lands using HEC-RAS program.



**Figure 10.** The spread of water in the channels branching from the Al-Sarraji and Al-Khora rivers when the HEC-RAS program was run at the lowest tide level in November.



**Figure 11.** The boundaries of the agricultural areas confined between the Sarraji and Al-Khora rivers, served by irrigation depending on the phenomenon of the tide.

**Table 1.** The resultant irrigation information of Al Sarraj and Al Khora rivers.

Irrigation channel name	Channel length (m)	Area irrigated by the channel (m <sup>2</sup> )	water Volume in the channel (m <sup>3</sup> )
Sarraj River	3200	2704924.06	13800
The river linking Al Sarraj and Al Khor	2300	176997.068341	25296.6
Al Khora River	4216	128069.996447	2865.42
Al-Saraji Branch 1	478	114672.227469	11644.5
Al-Saraji Branch 2	1941	95506.481932	4280.58
Al-Saraji Branch 3	713	91366.907286	1798.14
Al-Saraji Branch 4	300	89110.35458	4953.9
Al-Saraji Branch 5	826	81859.638306	9578.22
Al-Saraji Branch 6	1596	75816.061773	3063.96
Al-Saraji Branch 7	511	74906.814413	7200
Al-Saraji Branch 8	1200	73210.273453	3359.52
Al-Saraji Branch 9	560	72326.304759	458.82
Al Khora Branch 1	76.5	70977.699273	6504.06
Al Khora Branch 2	1084	68369.07362	4021.68
Al Khora Branch 3	670	68181.904709	4743.6
Al Khora Branch 4	791	68041.182595	3036.06
Al Khora Branch 5	506	66106.641119	7824.42
Al Khora Branch 6	1304	65531.286963	5582.1
Al Khora Branch 7	930	58457.124966	13800

## 7. Conclusions

1. Shatt al-Arab is considered the first influencer that clarifies the relationship between the agricultural land use and water bodies. And the main factor in

controlling the agricultural land uses is the rise in the water level and direction of flow when the phenomenon of tide occurs.

2. The total areas allocated for agricultural use between Al-Saraji and Al-Khora rivers amounted to 1297.6 acres. It was found that agricultural land use would rise to 1697.77 acres if the percentage of lands served by irrigation channels branching from the two rivers was taken into consideration.
3. The lowest level of tide in the Shatt al-Arab occurs in November with an average of 0.65 m, while the average ebb reached -0.54 m for the same month.
4. The calculated Manning roughness coefficient values were in the range 0.032 - 0.038 for the river bed and its banks.

The volume of water in the Al-Saraji canal is greater than the volume of water in the Al-Khora canal due to the high level of the bottom in some parts of the Al-Khora canal, which leads to a reduction in the size of the river section.

5. The total volume of water entering the Al-Saraji and Al-Khora canals when the tide occurs is 120011 m<sup>3</sup>. 91849.56 m<sup>3</sup> of this volume is distributed over 9 branches from al-Siraji and 7 from al-Khora rivers.

## 8. Recommendations

1. Rehabilitation of the irrigation canals branching from the Shatt al-Arab, removing the waste from it, and holding the transgressors accountable, in order to maintain a continuous flow of its water.
2. Development of irrigation and drainage networks, especially those branching from the six rivers, and installing water pump stations that help reduce dependence on the phenomenon of tides.

3. Reclaiming abandoned agricultural lands and providing them with the necessary services in order to encourage investment of agricultural lands and improve agricultural production in terms of quantity and quality.
4. Activating legislations and laws that protect agricultural lands, prevent changing their use, and hold violators and transgressors accountable.
5. Development of infrastructure projects, especially sewage networks, to prevent people from throwing sewage waste directly into these rivers.

### **Conflict of interest**

The author confirms that the publication of this article causes no conflict of interest

### **9. References**

1. Abed, Ali Dhafer, (2020), "Improve the self-purification of the Shatt al-Arab rivers system using simulation models", *International Journal of River Basin Management*, <https://doi.org/10.1080/15715124.2020.1809436>.
2. Abed, Ali Dhafer & Areej Muhy Abdul Wahab, (2019). "The possibility of applying blue energy in Iraq (rivers of Basra as a case study)." *Urban Water Journal*. 16: 7, 519-529, DOI: 10.1080 / 1573062X.2019.1687742
3. Al-Akidi, Walid, (1990), "Administration of Soils and Land Uses", unpublished master thesis submitted to the Urban and Regional Planning Center, Baghdad University, p. 46.
4. R., Borlowe, (1963), "Land Resource Economics" Englewood, Cliffs Fourth, Printing, p. 89.
5. G. Steward & Clawson, (1975), "Land Use Information", *Article Survey of U.S.*, p. 15.
6. David Rhind of Ray Hudson, (1980), "Land Use", Methuen Co. USA, p. 3.
7. D.A. Davidson, (1983), "Land space Ecology and Land use", Hutchnisons, London, U.K., p. 324.
8. Al-Janabi, Salah, (1987), "Change in the use of land around Iraqi cities," PhD thesis, College of Arts, University of Baghdad, p. 84.
9. Al-Azzawi, Ali Abd Abbas (1996), "Changing agricultural land use patterns around the city of Mosul," unpublished doctoral thesis submitted to the College of Education, University of Mosul, p. 22.
10. Jawdat, Nada Shaker, (1996), "The uses of agricultural land in the Tarmiyah district and its relationship to the population distribution for the years 1957 and 1994", unpublished doctoral thesis submitted to the College of Education, "Ibn Rushd", University of Baghdad, p. 31.
11. Al-Mayah, Ali Muhammad, (1980), "Changing the Investment of Agricultural Land in Iraq", *Journal of the Scientific Society of Iraq*, Volume (31), Part IV.
12. Rodney Tolleg & Brion Turton, (1995), "Transport Systems, Policy and Planning", London, Singapore, p. 72.
13. Thorkild Jacobsen and Seton Lloyd, (1985), "Sennacherib's Aqueduct at Jerwan", Chicago, Ill., The University of Chicago Press, Oriental Institute Publication, Volume 24.
14. Raja'a Wahid, (2008), "The environment: its contemporary scientific conception and intellectual heritage depth", Damascus: Dar Al Fikr, Print1, ISBN 978159239354.
15. Mohsen Baqer Al-Mousawi, (2002), "The Economic Thought in Nahj Al-Balaghah" (Beirut: Dar Al-Hadi, 2002), p. 220.

16. Berbera Ingham, (2010), "Economy and Development," Kiwan House for publishing and printing, Damascus, Vol. 13, I II, P.45.
17. CIPE, (2012), "Basra Governorate Business Agenda," produced by business associations in Basra Province in cooperation with the Center for International Private Enterprise, 1155 15 th Street, NW, Suite 700 Washington, p.26, p. 45.
18. Abed, Ali Dhafer, S. A. Al-Chalabi<sup>2</sup> and M. M Al-Bakril, (2020). "Building HEC-RAS model to detect the areas of Water Cycle Interruption in river stream and their sections." IOP Conf. Series: Materials Science and Engineering 737, 012222. Doi: 10.1088 / 1757899X / 737/1/012222.
19. Basic design map for the city of Basra (2016), Urban Planning Directorate in Basra Governorate, p. 36.
20. Abed, Ali Dhafer and Sumyah Maythem Jaafer, (2021), "Detect the Water Flow Characteristic of the Tigris River by Using HFCRAS Program", IOP Conf. Ser .: Earth Environ. Sci. 754, 012003. doi: 10.1088 / 1755-1315 / 754/1 / 012003
21. Abed, Ali Dhafer, (2018). "Planning and Design of Highways According to AASHTO Standards Using Remote Sensing Technology (Samarra City as a Case Study)". International Conference on Advanced Science and Engineering, Dohuk, Iraq DOI: 10.1109/ICOASE44663. 2018 .
22. land surface model with a hydrodynamic model for regional flood risk assessment due to climate change: Application to the Susquehanna River near Harrisburg", Pennsylvania, John Wiley and Sons Inc, 15, 1, DOI: 10.1111/jfr3.12763.
23. Stoleriu CC, Urzica A, Miha-Pintilie A, (2020), "Improving flood risk map accuracy using high-density LiDAR data and the HEC-RAS river analysis system: A case study from north-eastern Romania", Blackwell Publishing Inc., Volume 13, Issue: S1, DOI: 10.1111/jfr3.12572.