Re-distributing the field outlets for irrigation networks within the new growth cities: The Central District of Kerbala city as example

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Abstract. Generally, the rivers in both the natural and lined form use the open-section system to carry water, either for distribution or conveyance purposes. With time and depreciation effect, this system needs to be change or modify to become more indirectly suitable with growth of cities, and specially with transformation of land use from agricultural to residential. The present paper aims to reach a proper decision to re-distribute the field outlets for a part of AliHneidiyah river in Karbala city, Republic of Iraq, for the distance between stations (0+000) and (4+000), to choose between keeping up the current number of outlets or reduce them to a certain, actually used one. For this study, the cadastral maps were used as a reference to determine the agricultural areas served by the river during its route within the study area, and geographic information system to monitor the change in the nature of these areas represented by gradual transformation from agricultural to residential purpose, by using of satellite images for four different years, 2002, 2007, 2013, and 2016. The results of this study showed a great reduction in the agricultural areas on both sides of the chosen length of river route by a percentage of 88%, which leads to change location and specifications of the remain, actually used outlets. In addition, use the whole section for conveyance purposes to protect the water quality. This study showed that the geographic information system is a good and helpful technique for evaluation and make decisions of water related subjects.

1. Introduction
Iraq has passed and still by the problem of lack in quantities of water supplied to it from the upstream countries of the Tigris and Euphrates rivers and their tributaries, which clearly cast a delusion on agricultural production, whereas the area of agricultural land in the regions surrounding cities has shrunk [1], and transformed from the agricultural use to the residential, commercial, industrial, or other uses noticeably in the last two decades [2] and [3]. This calls for reconsideration in the distribution of surface water for the rivers feeding these areas, and activating the role of groundwater use in the remaining areas for the present time [4], as well as using of the water shares that were canceled in order to revive desert areas or those suffering from desertification due to lack of Incoming water [5], in addition making a correct and smart use of modern technologies in redirection of water
shares to the reclaimed lands [6]. The geographic information system and remote sensing techniques consider as the best tools in the present time for spatial description, due to the great potential they offer to help diagnose various problems, engineering or otherwise, and try to find appropriate solutions to treat these problems completely or partially [7], whereas it consider as an effective tool in evaluating the distribution of public services to urban residential regions, rural regions and others, and re-evaluating the random distribution of these services within city districts [8] and [9], and using of satellite visuals in produce the main information layers such as the land cover, the various land uses, the distribution layers of river networks, roads, religious and social landmarks and others [10], to be utilized for creating a realistic and future vision in any field of life that can be applied by these technologies. The geographic information system has a tight relationship with the various fields of water resources engineering, as it is a valuable technique in the preparation of many hydrological and hydro-geological studies. One of these studies is the water harvesting whereas this technique enables the spatial expertise support system to become an integrated system by the introduction of special information layers of the hydrological database and producing it as comprehensive formats in terms of form and concept [11] by using many criteria including river streams, slope, rainfall, vegetation index … etc [12]. As well as estimating the rainfall-runoff erosive factor of the wide range watersheds for different formative terrain [13]. In addition, the effective contribution to assessing the quality of surface water such as rivers and their tributaries by monitoring the concentrations and distribution of many elements and compounds, and studying the physical properties of the rivers such as water transparency, salinity, electrical conductivity, … etc, and analyzing the results to build a network of databases that can be used in the geographical distribution of data [14] and [15]. Also, this technique can be to be used for groundwater, whereas it contributes to choose the best location for drilling wells by studying many variables such as resistivity, depth, thickness, trans- emissivity of aquifer [16], and assessing the validity of this water for various human uses such as drinking, Industrial and agricultural use by dividing the land cover into multi-layers as water sources, forest lands, open arid lands, residential areas, and agricultural crops lands [17] and [18]. The urban growth represented by the use of modern housing units with their concepts of construction (adding construction materials to the rural environment) and formative (introducing the modern architectural language to the character of housing and rural buildings) leads to distorting and changing the reality of the formation in the housing fabric of the rural settlement, where the green areas begin to recede, and replaced by the residential areas gradually [19]. This change truly affects the water structures that serve these agricultural lands, such as natural and lined channels, and as a result of neglect and lack of use, another phenomenon is clearly activated, which is the phenomenon of water percolation into the soil face that surrounding these waterways, which definitely leads to the decrease of the water shares that waters the areas located in the tail regions of the river [20], and this calls for an urgent need to use modern technologies to guidance the consumption of this ground water by sub-surface irrigation techniques via, and it's obvious role in feeding ground water [21], as well as to investigate and examine the structures that build on water courses, examine them continuously, and a make a periodic evaluation of it [22] in order to increase the efficiency of water use of the remaining and newly developed lands, which cause the increase in the production of permanent and seasonal crops, and using the best methods and modern programs such as dynamic programming [23]. This study aims to investigate the remaining agricultural lands on both sides of the AliHneidiyah river in the central district of Kerbala city for part of its path, which is 4 km, and make a redistribution of the current outlets to be compatible with the remaining agricultural area within the study area.

Description of Study Area

1.1. District, Major, and minor sectors
The district often consists of number of major sectors, and the major sector may be described as an area consists of small areas called as minor sectors. Figure 1 explains these terms.
1.2. Al-Huseiniyah river – general description
Al-Huseiniyah river is one of the two main channels that irrigate the agricultural areas in Kerbala city. It takes its water share from the Euphrates river at the right side of Al-Hindiyah barrage in Al-Musayyib district of Babylon city, (the inlet coordinates in WGS 1984 UTM System zone 38N; X = 430777, Y = 3621208), and passes through three districts of Kerbala city, Al-Husseiniyah district, the central district of Kerbala city, and Al-Hurr district. The designed discharge of this river is 55 m$^3$/s and the cross section differs along its route. At the station (29+000) Al-Huseiniyah river divided by two sub-rivers, Arrushdiyah river on its right side and AliHneidiyah river on its left side. See figure 2, a part of the cadastral map no. 9192/April/1971.

1.3. AliHneidiyah river – general description
AliHneidiyah river starts its route from the division point of Al-Huseiniyah river at the station (29+000), the division coordinates in WGS 1984 UTM System zone 38N; X = 409107, Y = 3609692, and flows through a number major sectors of the central district of Kerbala city for a distance of 16 km, according to the cadastral map no. 9192/April/1971. Table 1 shows the details of the major sectors within river full route where according to this route a total area of $(4 \times 10^6)$ m$^2$ of farms and $(7.5 \times 10^6)$ m$^2$ of orchards have been irrigated, whereas the river designed discharge is 2.2 m$^3$/s.

1.4. Description of the study area
The study area lies between coordinates X = {407300 to 409300}, Y = {3607000 to 3610000} in WGS 1984 UTM System zone 38N, where inside it the river flows for a distance of 4 km from the division point mentioned previously, see figure 2, and provides the water shares for a number of field outlets about 26 on its right side and 25 on its left side as in figure 3. The outlets feed the water courses which flow across the minor sectors to provide its farms and orchards with the required water share. Figure 4 obtains the river cross-section within the study area, and table 2 lists the details of major sectors, minor sectors, and the field outlets within the study area.

**Figure 1.** A part of a certain cadastral map views a major sector within a certain district, and the minor sectors contained inside it.

**Figure 2.** The study area of AliHneidiyah river including the division point of Al-Huseiniyah river at the upper right corner.
Table 1. Details of the major sectors that irrigated by AliHneidiyah river.

| Major sector No. | Area (m²) | Farm (m²) | Orchard (m²) |
|------------------|-----------|-----------|--------------|
| 5                | 45,675    | -         | 45,675       |
| 6                | 1,792,398 | -         | 1,792,398    |
| 7                | 4,200     | -         | 4,200        |
| 22               | 89,975    | -         | 89,975       |
| 24               | 1,183,825 | 150,000   | 1,033,825    |
| 40               | 7,144,897 | 3,553,200 | 3,591,697    |
| 43               | 1,239,030 | 296,800   | 942,230      |

Figure 3. The field outlets of AliHneidiyah river within the study area, (Year 2016 satellite image).
Table 2. Details of the effective regions that irrigated by AliHneidiyah river.

| Outlet No. | Effective region No. | Major sector No. | Minor sectors No. | Total area of the effective region (m²) | Outlet discharge (m³/s) |
|------------|----------------------|------------------|-------------------|----------------------------------------|------------------------|
| A01        | R01                  | 6                | 1                 | 2,575                                  | 1.00                   |
| A02        | R02                  | 6                | 2 and 3           | 17,125                                 | 1.50                   |
| A03        | R03                  | 6                | 4 to 7            | 36,750                                 | 3.50                   |
| A04        | R04                  | 6                | 8 to 22, and 192  | 31,275                                 | 5.50                   |
| A05        | R05                  | 6                | 23, 26 to 32, and 220 33 to 36, 38, and 45, 46, and 48 to 65 10 to 18, 98, 99, 224, and 227 | 71,505                                 | 7.00                   |
| A06        | R06                  | 6                | 45, 46, and 48 to 65 10 to 18, 98, 99, 224, and 227 | 275,000                                 | 12.00                  |
| A07        | R07                  | 6                | 37                | 11,000                                 | 1.00                   |
| A08        | R08                  | 6                | 39                | 1,150                                  | 1.00                   |
| A09        | R09                  | 6                | 40                | 350                                    | 1.00                   |
| A10        | R10                  | 6                | 147(Part2), 47, 66 to 70, 118, 140(Part2) to | 9,843                                 | 2.00                   |
| A11        | R11                  | 22               |                   | 94,775                                 | 9.30                   |
|   |   |   |   |   |
|---|---|---|---|---|
| A12 | R12 | 6 | 147(Part1), 194, and 195 | 148 | 4,000 | 1.00 |
| A13 | R13 | 6 | 120, 149 to 152, 172, and 173 | 24,200 | 2.30 |
| A14 | R14 | 6 | 121 and 154 | 22,625 | 2.30 |
| A15 | R15 | 6 | 153 | 15,100 | 1.25 |
| A16 | R16 | 6 | 71 to 74, 75 to 78, 81, and 174 to 199 | 41,300 | 4.00 |
| A17 | R17 | 6 | 79, 80, 85, 200, and 201 | 40,650 | 4.00 |
| A18 | R18 | 6 | 196 to 198, and 219 | 799,895 | 35.00 |
| A19 | R19 | 6 | 196 to 198, and 219 | 252,025 | 25.00 |
| A20 | R20 | 6 | 101 and 102 | 61,175 | 6.00 |
| A21 | R21 | 6 | 103 to 109 | 63,975 | 6.30 |
| A22 | R22 | 6 | 110 and 111 | 14,275 | 1.25 |
| A23 | R23 | 6 | 113 | 5,800 | 1.25 |
| A24 | R24 | 6 | 114 to 117 | 32,000 | 1.25 |
| A25 | R25 | 6 | 167 | 8,450 | 1.00 |
| A26 | R26 | 6 | 175 | 5,075 | 1.00 |
| A27 | R27 | 6 | 176 | 4,825 | 1.50 |
| A28 | R28 | 6 | 177 | 11,275 | 1.00 |
| A29 | R29 | 6 | 178 | 6,375 | 1.00 |
| A30 | R30 | 6 | 119 and 179 | 9,200 | 1.00 |
| A31 | R31 | 6 | 218 | 2,750 | 1.00 |
| A32 | R32 | 6 | 180 | 16,775 | 1.50 |
| A33 | R33 | 6 | 181 | 7,650 | 1.25 |
| A34 | R34 | 6 | 182 and 183 | 26,725 |
| B01 | R01 | 5 | 1 and 5 | 8,400 | 1.00 |
| B02 | R02 | 5 | 3 | 4,125 | 1.00 |
| B03 | R03 | 5 | 6, 13, and 14 | 6,375 | 1.00 |
| B04 | R04 | 5 | 15 and 16 | 6,450 | 1.00 |
| B05 | R05 | 5 | 72 | 2,025 | 1.00 |
| B06 | R06 | 6 | 24 | 3,300 | 1.00 |
| B07 | R07 | 6 | 25 | 4,700 | 1.00 |
|   |   |   |   |   |
|---|---|---|---|---|
| B08 | L08 | 6 | 158 to 160, 204, and 205 | 62,715 | 6.30 |
| B09 | L09 | 6 | 157, 202, and 230 | 23,850 | 2.30 |
| B10 | L10 | 6 | 156, 164 to 166, 168 to 171, 208, 225, and 238 | 11,100 | 1.00 |
| B11 | L11 | 6 | 155, 209 to 211, and 217 | 109,725 | 10.80 |
| B12 | L12 | 6 | 122 to 125, 200 to 207, 212, and 216 | 13,700 | 1.25 |
| B13 | L13 | 6 | 115 to 118, 198, and 199 | 144,875 | 14.30 |
| B14 | L14 | 6 | 129, and 132 to 139 | 34,175 | 3.30 |
| B15 | L15 | 6 | 127, 130, and 131 | 63,600 | 6.30 |
| B16 | L16 | 6 | 109 (Part1), and 110 to 112 | 17,975 | 1.80 |
| B17 | L17 | 24 | 114 | 21,000 | 1.00 |
| B18 | L18 | 24 | 109 (Part1), and 110 to 112 | 37,675 | 1.00 |
| B19 | L19 | 24 | 108 | 10,275 | 1.00 |
| B20 | L20 | 24 | 109 (Part2) | 7,500 | 1.00 |
| B21 | L21 | 24 | 105 | 26,950 | 2.50 |
| B22 | L22 | 24 | 104 | 8,000 | 1.00 |
| B23 | L23 | 24 | 120 | 5,200 | 1.00 |
| B24 | L24 | 24 | 72 | 11,900 | 1.00 |
| B25 | L25 | 24 | 58 to 60, 69, and 211 | 75,475 | 7.50 |

**Note1**: The letter (A) in the outlets column refers to the outlets on the right side of AliHneidiyah river.

**Note2**: The letter (B) in the outlets column refers to the outlets on the left side of AliHneidiyah river.

**Note3**: The letter (R) in the effective regions column refers to the areas on the right side of AliHneidiyah river.

**Note4**: The sign (L) in the effective regions column refers to the areas on the left side of AliHneidiyah river.
Figures 5, 6, 7, and 8 show the satellite images of the study area for the years 2002, 2007, 2013, and 2017 after merging it by a part of the cadastral map 9192lApril/1971 using ArcGIS-ArcMap 10.3 program.

2. Analysis and discussion
The figures 5, 6, 7, and 8 respectively, refer to an obvious reduction in the total area of the agricultural lands by time within the study area due to the human multi activities that change the nature of land use from agricultural to multi-purpose uses. Table 3 lists the areas of the effective regions of the agricultural lands, which remained in each satellite image, whereas all effective areas were plotted and calculated by the program (ArcGIS-ArcMap 10.3). This table also confirms the reduction in the agricultural lands with time. Figure 9 shows the relationship between the percentage ratio of the remain agricultural lands and the time, in years, where it can be noticed that the ratio of the agricultural lands for the period bounded by the years 1971 and 2002 is range between 90.95% to 66.81%, which means that the annual ratio is 0.75% due to many considerations such as the national policy followed by the government that preserves the agricultural lands and orchards, encourages the cultivation of various crops, prevents overtaking of water shares or changing the gender of agricultural land use for other uses, and keeps all hydraulic structures in safe position.

![Figure 5. The satellite image of the year 2002 for the study area.](image1)

![Figure 6. The satellite image of the year 2007 for the study area.](image2)
Table 3. Details of the effective regions within each satellite image for the study area.

| Year | Effective region No. | Area (m²)   | % of the total study area |
|------|----------------------|-------------|--------------------------|
| 2002 | A01/2002             | 186750.0    | 0.09883                  |
|      | A02/2002             | 28187.2     | 0.01491                  |
|      | A03/2002             | 10512.5     | 0.00556                  |
|      | A04/2002             | 61272.0     | 0.03243                  |
|      | A05/2002             | 66646.7     | 0.03527                  |
|      | A06/2002             | 423784      | 0.22429                  |
|      | A07/2002             | 93647.7     | 0.04956                  |
|      | A08/2002             | 188036.0    | 0.09952                  |
|      | A09/2002             | 74275.4     | 0.03931                  |
|      | A10/2002             | 35831.9     | 0.01896                  |
|      | A11/2002             | 10103.6     | 0.00535                  |
|      | A12/2002             | 23094.9     | 0.01222                  |
|      | A13/2002             | 11335.8     | 0.00600                  |
|      | A14/2002             | 1021.6      | 0.00054                  |
|      | A15/2002             | 13952.9     | 0.00739                  |

Figure 7. The satellite image of the year 2013 for the study area.

Figure 8. The satellite image of the year 2016 for the study area.
| Year | Code   | Value  | Percentage |
|------|--------|--------|------------|
| 2007 | A16/2002 | 2172.2 | 0.00115 |
|      | A17/2002 | 4745.1 | 0.00251 |
|      | A18/2002 | 26994.1 | 0.0143 |
|      | **Total** | **1,262,364** | **66.810%** |
| 2007 | B01/2007 | 15961.7 | 0.00845 |
|      | B02/2007 | 33325.9 | 0.01763 |
|      | B03/2007 | 14570.0 | 0.00771 |
|      | B04/2007 | 162448 | 0.0860 |
|      | B05/2007 | 39254.2 | 0.02077 |
|      | B06/2007 | 391869 | 0.20740 |
|      | B07/2007 | 94043.9 | 0.04977 |
|      | B08/2007 | 4718.7 | 0.00250 |
|      | B09/2007 | 22876.2 | 0.01211 |
|      | B10/2007 | 35785.9 | 0.01894 |
|      | B11/2007 | 14881.8 | 0.00788 |
|      | B12/2007 | 4.7 | 0.00000 |
|      | B13/2007 | 27548.9 | 0.01458 |
|      | B14/2007 | 48965.3 | 0.02592 |
|      | B15/2007 | 16215.0 | 0.00858 |
|      | B16/2007 | 11313.6 | 0.00599 |
|      | **Total** | **933782.8** | **49.423%** |
| 2013 | C01/2013 | 182743 | 0.0967 |
|      | C02/2013 | 25198.2 | 0.01333 |
|      | C03/2013 | 2318.3 | 0.00123 |
|      | C04/2013 | 7555.4 | 0.00400 |
|      | C05/2013 | 54683.9 | 0.02894 |
|      | C06/2013 | 27522.5 | 0.01457 |
|      | C07/2013 | 4917.0 | 0.00260 |
|      | C08/2013 | 15913.2 | 0.00842 |
|      | C09/2013 | 10876.9 | 0.005757 |
|      | C10/2013 | 11342.9 | 0.00600 |
|      | C11/2013 | 54722.1 | 0.02896 |
|      | C12/2013 | 19386.5 | 0.01026 |
|      | C13/2013 | 9164.4 | 0.00485 |
|      | C14/2013 | 39219.8 | 0.02076 |
|      | C15/2013 | 11003.6 | 0.00582 |
|      | **Total** | **476567.7** | **25.219%** |
| 2016 | D01/2016 | 15965.8 | 0.00845 |
|      | D02/2016 | 5114.5 | 0.00271 |
D03/2016 49136.5 0.02600
D04/2016 19315.8 0.01020
D05/2016 39101.1 0.02070
D06/2016 25101.1 0.01330
D07/2016 45230.1 0.02394
D08/2016 7434.1 0.00393
D09/2016 2257.6 0.00119
D10/2016 23015.4 0.01218
D11/2016 12347.3 0.00654
D12/2016 10134.5 0.00536
Total 254153.8 13.450%

**Note1:** In each satellite image, the names and values of the effective areas differ according to the appearance in the taken image.

While for the period bounded by the years 2002 and 2007, the ratio ranges between 66.81% and 49.42%, for the period bounded by the years 2007 and 2013, the ratio ranges between 49.42% and 25.22%, and for the period bounded by the years 2013 and 2016, the ratio ranges between 25.22% and 13.45%, the annual ratio for these three periods are 3.48%, 4.03%, and 3.92% respectively.

**Figure 9.** The relationship between the percentage ratio of the remain agricultural lands and the time (years).
This huge increment was happened due to many considerations compared with annual ratio of the first period. These considerations can be described briefly as the opposite of the first period considerations. Besides, the water and solid pollutants that fill the irrigation channels and their field water courses due to the fast expansion in residential part in general form inside the study area, and the other fields of work. All these factors lead to an argent need to make a decision about keeping the hydraulic structures within the new growth cities safe, and protect the water shares quantitatively and environmentally. Focusing on figure 9, there is a clear separation of periods can be noticed whereas the first portion represents the period between the years 1971 and 2002, and the second portion represents the three previous periods starting from the year 2002 to the year 2016. Drawing the relationship for the data of the second portion introduces the equation

\[ R.A. = -0.038(T) + 77.49 \quad R^2 = 0.998 \quad (1) \]

Where R.A. is the percentage ratio of the remain agricultural land, and T is time in years. According to this equation with the continuity of current situation of human activities, the green area within the study boundaries will be disappeared at the beginning of the year 2040. From the technical point of view and the low ratio of the remain agricultural lands within the study area in the present time that form about 12% from the studied area, cancelling the outlets that feed the areas which were transformed into non-agricultural use, and keeping the outlets of the effective regions that remain within the study area as in figure 8, with the continuous monitoring of the change in land use of these areas may be consider as a best decision for this study. Figure 10 shows the cancelled outlets and the figure 11 shows the remain outlets of areas within satellite image of the year 2016.

Figure 10. The cancelled outlets on the satellite image of the year 2016 for the study area.
Figure 11. The remain outlets on the satellite image of the year 2016 for the study area.

From these figures a total number 48 outlets on both sides of the river study area were cancelled, and that gives about 1,785,716 m² of the area that could be reclaimed in the major sectors out of the irrigation boundary plan of the city, which help to reduce the desertification phenomena in the south part of the city and refresh its whole green area.

3. Conclusions

The new growth of cities is a series issue for the fields of agriculture and water resources with the absence of the proper and synchronous planning for these fields with the urban planning, and the results of this absence are more hydraulic, environmental, and social issues added as obstructions in the future of societies. From the current study the following points can be concluded:

1- The total area of agricultural lands within the study area reduces as the time going on.
2- The relationship between the percentage ratio of the remain agricultural lands and time was represented by linear equation.
3- There are two clear periods during the reduction of the agricultural lands, the first was between the years 1971 and 2002, and the second between the years 2002 and 2016.
4- According to second period, the agricultural lands will be disappeared from the study area at the beginning of the year 2040.
5- Cancelling the outlets that feed the areas which were transformed into non-agricultural use, and keeping the outlets of the effective regions that remain within the study area consider as a best decision for this study.
6- The Geographic Information System is being a good and helpful technique for evaluation and make decisions of water related subjects.
4. Recommendations
The following recommendations may be useful as solutions for the study case:

1- Transforming the river cross-section into a closed conduit may be done by:
   a- Close the section partially by using concrete removable covers along the studied river route, to be easily moved during the maintenance process.
   b- Close the section fully by constructing an unmovable reinforced roof, and using of manholes at studied distances along the river route for flushing process during the its maintenance.
   c- Replace the whole section by a pipe system with equivalent cross-section to ensure throwing the decided discharge.

2- Re-distributing the field outlets of the water courses by removing the cancelled ones from the river route within the study area, and using its water shares to:
   a- Enhancing the water shares of the agricultural lands that irrigate from the river after the study area.
   b- Resumption of reclamation works in the major sectors no.61 and no.20 at the southern part of Kerbala city.

3- Activating the role of ground water within the study area as alternative resource to irrigate the remain agricultural lands.

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