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Sustainable Management of Water Resources in The Upper Euphrates Basin-Iraq

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ABSTRACT

The research aims evaluates the water consumption and future demand by using the WEAP program. Five scenarios have been adopted, which is the reference scenario that showed the results of increase in water demand from (100) million cubic meters in 2015 to (397) MCM in 2035 with a water deficit in 2035 to (38) MCM. Modern irrigation methods reduce the water deficit from (38-2.9) MCM. While the use of underground water reduced the deficit from (38-26) MCM. As for the wastewater reuse scenario, the deficit decreased from (38-35) MCM. Reducing the per capita share did not reduce the water deficit.

1.Introduction

Water resources management faces great challenges, the most important of which is achieving sustainable development. This is because of the change in climate and the social and hydrological conditions resulting from global warming, which caused a decrease in the percentage of rain, which caused a decrease in Iraq's water imports. Because of the increased demand for water resulting from the increase in population, environmental conditions and other restrictions that affected water systems. These reasons prompted the search for more effective methods for allocating water among the beneficiaries [1].

Iraq is one of the countries that has most of its area classified as arid or semi-arid regions and therefore it is exposed to a great future crisis, one of its reasons is the diminishing share of Iraq in the imports of the Euphrates River due to the policies pursued by the source countries from building dams and reservoirs on the riverbed and the second reason is the poor management of the available water In the interior of the country where this policy has led to the loss of large quantities of water due to poor water infrastructure[2].

Hence the importance of adopting sustainable water resources management methods as it is the best solution to solve water shortage problems and their poor quality. It also

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included providing water for future generations through the optimal use of water and urging the building of reservoirs to reduce the risk of floods. Sustainable water management can be applied to avoid lacking water using more advanced methods of water management. These advanced methods are applied in particular, in the agricultural sector instead of traditional resources that rely highly on surface irrigation. Large amounts of water from the evaporation and filtration processes, therefore, can be reduced. It also provides a solution to the political reasons that led to a decrease in the availability of water by directing to open dialogues and conclude agreements under the supervision of international organizations for the purpose of securing Iraq's water share without any retreat one of the terms of the agreement from the source countries[3].

To manage water more efficiently, a database should be established to know the incoming and used water for the purpose of achieving the region's water budget. This is achieved through the interest in registering all data on water for the purpose of creating a database used by researchers to help prepare research that helps to identify problems and defects points and diagnose them to reach appropriate solutions to them. To properly allocate water between the beneficiary sectors, several programs have been used that help decision makers to predict and calculate the quantities of water used, including the WEAP program [4].

Due to the great importance of the WEAP program in analyzing the scenarios and knowing the most important factors that affect the available water and its quantities, it was used in many countries for the purpose of studying the state of water.[5]has used it to study the management of water resources in Najaf. In addition, [6] have used the WEAP program to find out better manage the causes of water shortages in the Alana Valley in the Kurdistan-Iraq. [1] used it to find out its ability to calculate the future demand for water in the Shatt al-Arab. [7] used it to analyze a number of scenarios to find the best solutions to eliminate the water deficit in Lattakia Governorate. [8] studied the effect of water quality and cost on water management in the Tulkarm area. [9] He studied how to reach the best solutions that rid Jordan of future water scarcity using the WEAP program. [10] proposed scenarios using WEAP and studying their economic impact on water resource management in the Hermand region. [11] WEAP was used to study the effect of small dams on river flow in Ghana. [12] tested the impact of climate change on water in the Arkansas River basin. [13] studied the results of the population increase in water management in the Niger Basin using the WEAP program. [14] used the WEAP program to study the impact of climate change on water management in the Langat basin in Malaysia. [15] Use WEAP to evaluate the water deficit rates in Beijing and find the best solution for them.

This study aims to: -

1. Develop the most important methods that could improve water resources management, providing much more water for future generations.
2. Choose the best alternatives to surface water to maintain the supply of the beneficiaries.
3. Testing the ability of the WEAP model to represent and study the current and future water situation in the upper Euphrates region.

2.Study Area

The upper Euphrates region is the northern part of Al-Anbar Governorate, located in western Iraq [16]. This region represents 23% of the Anbar province areas, having an area of 32095 km^2[17]. The borders of the northwestern region are Syria, while its northern borders are in Nineveh Governorate, and Salah al-Din represents the eastern, northeastern, and Ramadi borders, its southern borders, and its southwestern borders are with the city of Rutba[18]. The region consists of five districts, namely the district (Hit, Hadithah, Anah, Rawa and Qa'im), as shown on Figure 1. It is located between the longitude (33-34) and the width (41-43). The surface area of the upper Euphrates region tends to be flat, with some hills having a height of 400 m above sea level, as are the valleys that make the surface undulating [19]. Its climate is characterized as semi-desert with little rain, with variations in day and night temperatures and low humidity, as the temperature rises in the summer to 52 degrees Celsius, in the winter it drops to 9 C^0, as for rain, it is estimated that it will only fall by 115 mm in winter. The wind will be northwest and southwest, [20]. There are many valleys in the region, including sawab valley,Al-Qaim valley, Al-Mana'I valley, albatikhih valley, azghadan valley ,Al-Fahimi valley, Muhammadi valley[21].

The upper Euphrates region was chosen as a case study as a result of its great as it is considered a border region linking Iraq to the Syrian country and this made it an important economic place and being the region of entering the Euphrates River to the country, which made it a good study case to build a water supply and demand model as a result of diminishing water imports and increasing the demand for its which caused it Population growth.

3. Research Methodology and Materials

3.1 WEAP Model: -

To properly handle and analyze data, more sophisticated and comprehensive models are required in water management [22]. There were many models that have been previously used for water management, including the Water Allocation System Model (WAS) and (MODSIM_DSS). Since these models are insufficient, the Stockholm Institute of Environment (SEI) initiated to provide an integrated program that helps in integrated water planning (WEAP program) [23]. It works on the basis of water balance equations as it puts the issues of demand side, water quality and methods of maintaining the ecosystem on an equal footing alongside issues of supply, water flow and transportation [24]. It is a flexible and easy to use policy analysis tool. It assists in managing water resources, assessing current water conditions, options and alternatives available to assist decision makers in making decisions and finding future plans to solve water problems [25]. The WEAP model is characterized by its ability to interact with individual rivers or transboundary rivers and with agricultural and municipal systems. It addresses many issues, including water allocation priority, water quality, groundwater simulation, cost analysis, sewage system treatment, water demand analysis in different demand sectors and hydroelectric generation. It is thus used as a forecasting tool and as a database that maintains demand and supply data .According to the policy of analysis tool, a full range of water development and management options can be assessed using WEAP, taking into consideration multiple and competing uses of water systems. It is based on

importance

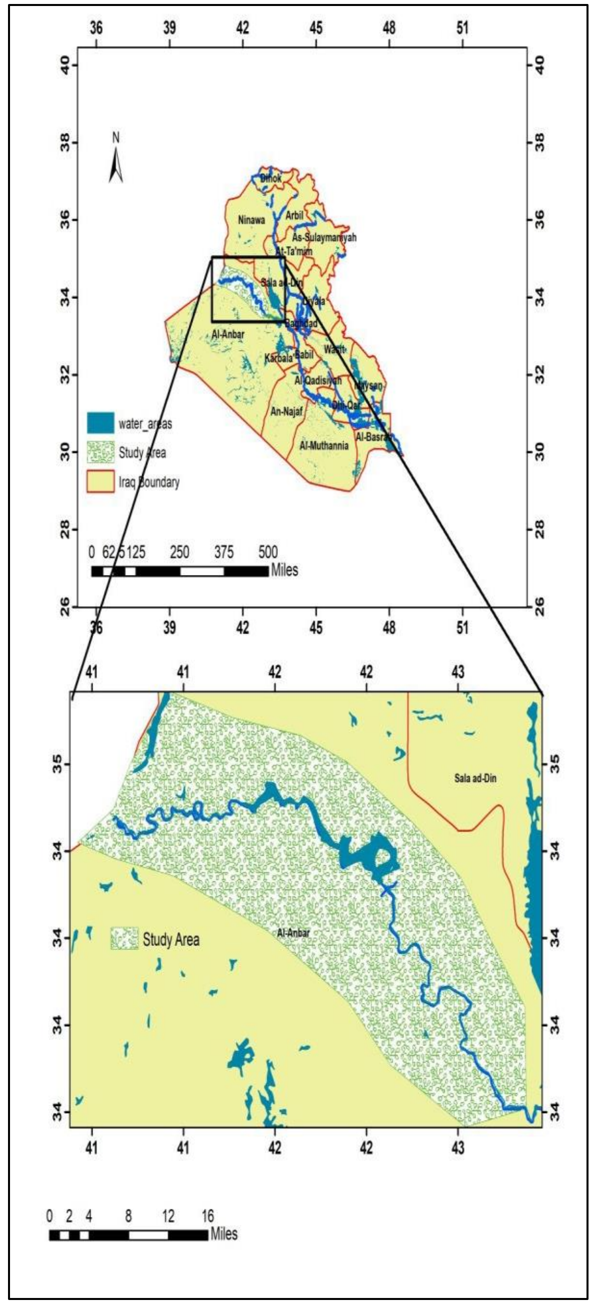

Figure 1. Upper Euphrates Basin-Iraq

the GIS layers to help configure the system for the study area [26].

3.2 WEAP Structure: -

The WEAP interface consists of five main views [25], as shown in Figure 2: -

1-Schematic: - is assigned to GIS and through it the order contract and supply sources are created by dragging and dropping items from the list.
2- Data: - provides the ability to enter data, assumptions and expectations and can be linked to Excel.
3- Results: - Provides results and outputs for scenarios, and the outputs are in the form of tables or plans.
4- Explorer Script: - Highlights the main data and results in the system.
5- Notes: It is the place for documenting assumptions and data.

3.3 Simulation of the Model: -

The research methodology consists of collecting the necessary data and processing it using the WEAP program and building the model to obtain results that represent the current status of the study area and assesses the available options. Future scenarios can be then suggested to know the effects resulting from the changes that result from the development of practices in the management of water resources. As shown in Figure 3.

3.4 Data processing and model building: -

To develop the study area model shown in Figure 4 the following data must be obtained and used to obtain the results of current policies in water management
1- Sources of supply (river and groundwater discharge)
2- Population
3- Agricultural land areas

4- Demand site

Where the Euphrates River Discharge was obtained from the Iraqi National Center for Water Management, the population census from the Anbar Statistics Directorate and the agricultural areas from the Anbar Agriculture Directorate. After this data is collected and processed, the current scenario is built.

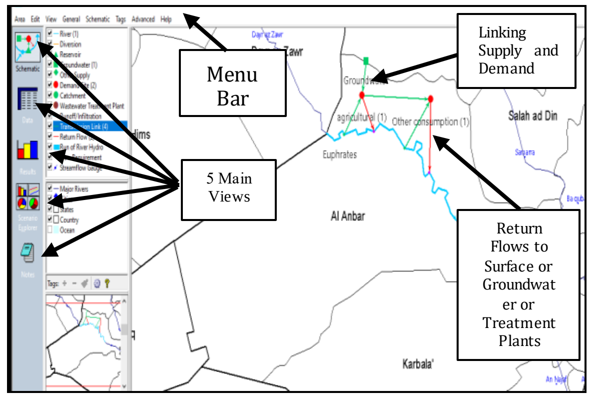

Figure 2. WEAP Network Schematic

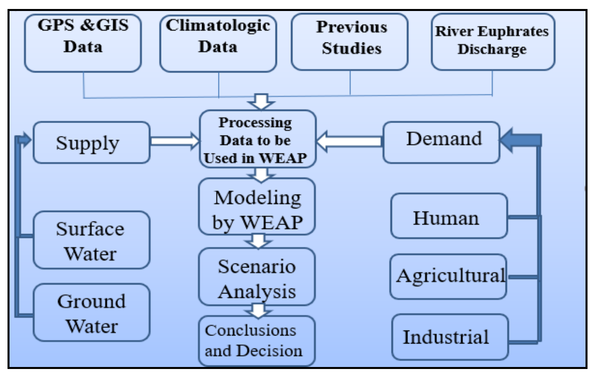

Figure 3. Methodology of Research

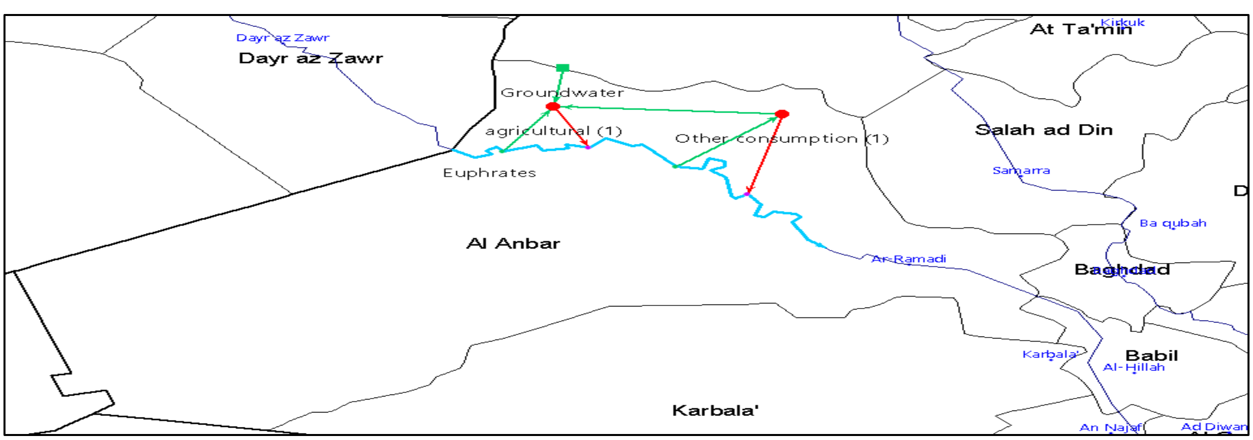

Figure 4. High Euphrates Region in WEAP Program

4. Water resources in the study area:

To manage water resources more efficiently, it is necessary to know the types of water available in the study area where they are either traditional or non-traditional sources and represent river water and groundwater traditional sources. As for reuse of agricultural and wastewater and harvesting rain water, they represent non-traditional sources of water.

4.1 River drainage: -

Most activities of the Upper Euphrates region depend on the surface water represented by the Euphrates River, which is the main source of drinking water, industry and irrigation. According to the Iraqi National Center for Water Management, Anbar province has 17% of water supplied from the Euphrates River [27]. Since the area of the upper Euphrates is about 23% of the Anbar province area and their populations are about 26% of Anbar populations, river imports received by the upper the Euphrates River is about 4% from the Euphrates River quantities in coming to Iraq. Table1 shows the discharge of the Euphrates River for Iraq and the share of the Upper Euphrates region from it. Figure 5 Shows the monthly discharge of the Euphrates River for the base year (2015) using WEAP model.

Table 1. Monthly Expenditures for the Euphrates River and the Share of the Upper Euphrates from It

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2015	289	300	257	220	230	140	129	130	177	330	309	340
4%	12	12	10	9	9	6	5	5	7	13	12	14

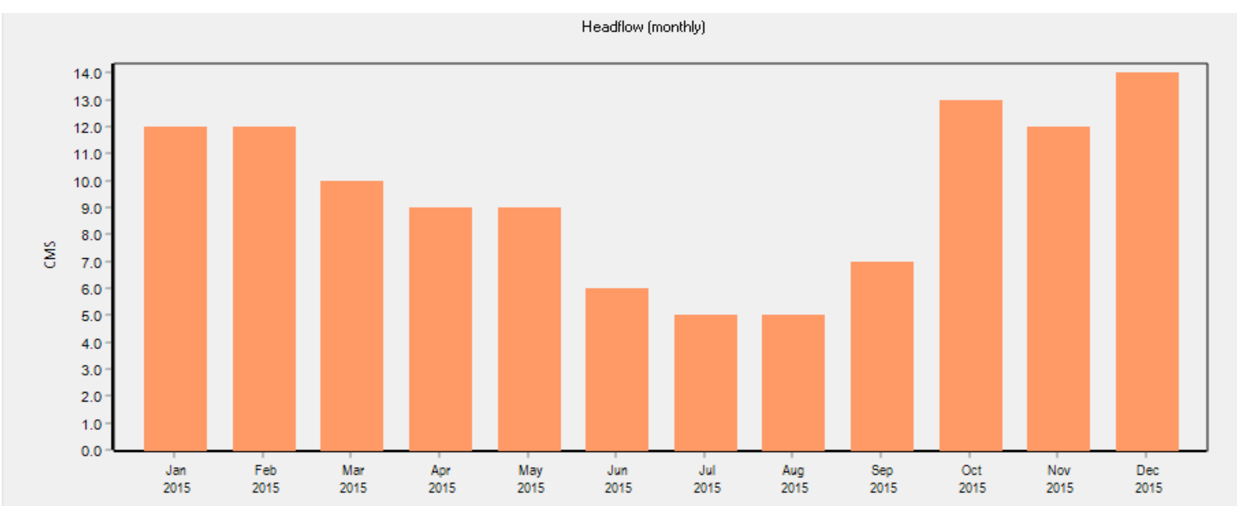

Figure 5. Euphrates River Monthly Discharges for the Year (2015)

4.2 Groundwater: -

As it is the water present in the pores of rocks, it comes from the leakage of rain water or seasonal or permanent rivers from the surface of the earth into it [28] as shown in Figure ٦. Groundwater is suitable for various uses such as agricultural and is very useful in places where it is difficult for the population to obtain water from surface water [29].A person can benefit from it by digging wells or by naturally appearing on the surface of the earth in the form of eyes and springs.

5. Water demand sites in the Upper Euphrates region:

As a result of the importance of water in all aspects of life, its consumption is increasing in all sectors due to the increasing population and the improvement of the standard of living. According to the classification of the Iraqi Ministry of Water Resources (MOWR), the consumption of the agricultural sector represents 85% of the total water consumption, the consumption of the domestic sector is 14%, and the industrial sector ١٪ as shown in Figure 7.

5.1 Agricultural Consumption: -

The agricultural sector is the largest consumer of water, as the percentage of water allocated for irrigation (85%). This is due to the use of old methods of irrigation that cause large amounts of water to be wasted due to evaporation and infiltration into the ground. As well as a result of the cultivation of many crops consuming water in large areas such as wheat, fruit trees, palm trees and alfalfa. The Ministry of Water Resources has adopted a plan to develop the policies used in water management in order to reduce water consumption in order to increase the area of cultivated land and began in cooperation with the Ministry of Agriculture to develop (5,000) dunum, but the militants 'attack on Anbar Province prevented from continuing to develop more lands until the completion of their liberation. And the percentage of water consumption is (2479.25 m 3 / dunum), which is equivalent to (9917 m 3 / hectare).

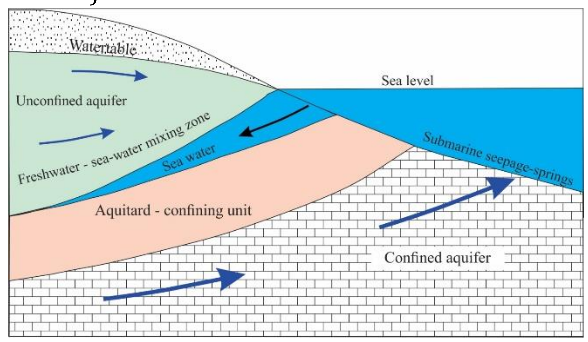

Figure 6. Layers of Groundwater

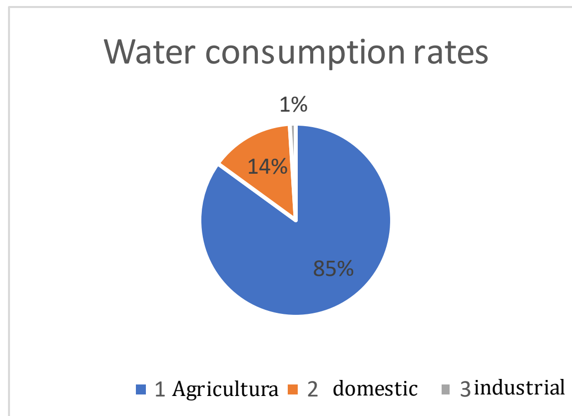

Figure 7. the Percentages of Water Consumption in Each Sector

5.2 Other Consumption:

It includes industrial, domestic and commercial consumption, and its combined rate is estimated at 15% of the total water consumption. The per capita water share was estimated at 500 L / day. The Central Bureau of Statistics estimated the 2015 census at (٤٢٥٤٥٣)people.

6. Results and discussion: -

The development of scenarios: which are considered a set of alternative assumptions of the current situation and are an answer to the question (What if). These alternatives may be a price change, a method of supply, or a method of supply. The results of the scenarios represent the change resulting from the effect of one of the alternatives. The most important scenarios whose impact on water management is studied are: -

The Current Scenario: represents the base year for the rest of the scenarios and was considered the year 2015. It is based on monthly data.

The Reference Scenario: It is the scenario that represents the results of water management with the continuation of the current policies. It aims to clarify what can happen if water continues to be managed in the same way for the purpose of stimulating proactive measures to avoid any expected water scarcity Figure 8 shows the percentage of water demand up to the target year (2035), which equals (397) million cubic meters resulting from the collection WEAP program for other consumption sector with the consumption of the agricultural sector, where the following formula [30] was used to calculate the population census for the year 2035

$P_n=P_0(1+R)^n$

Where

P_n=future population

P_0= present population

R = Probable rate of population increase per year

n=number of years

Its results indicated that the population in the year 2035 will be equal to (644994) persons and with an annual water consumption equal to (208.05) m3 / person. As for agricultural lands, its areas in the year 2035 will reach (26500) hectares and with a consumption of (9917) m3 / hectare

(644,994*208.05) +(26500*9917) =397 MCM

With a shortfall in meeting the water needs, its rate reached (38) million cubic meters, as shown in Figure 9.

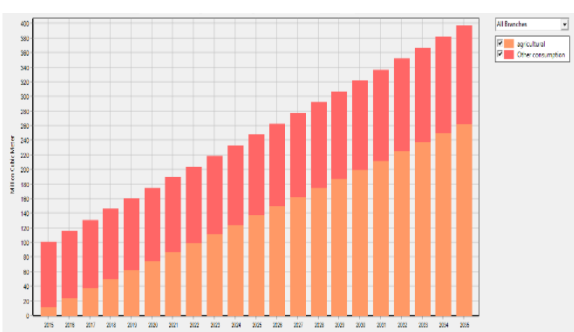

Figure 8. Water Demand by 2035

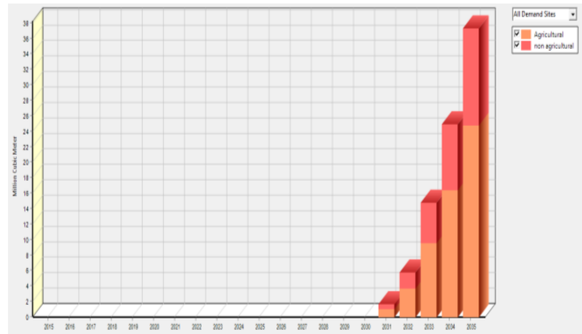

Figure 9. Water Deficit by 2035

Several scenarios have been proposed to find the best solutions that reduce the expected water deficit: -

1 - **The first scenario is the use of modern irrigation methods,** according to estimates of the Ministry of Water Resources, the efficiency of surface irrigation is 50% and the efficiency of irrigation by modern methods is about 70%. Therefore, the efficiency will increase by about 20% when using modern irrigation techniques, which leads to a decrease in the water requirement from 9917 m3 / ha to 7933.6 m3 / ha. The results of the scenario showed a decrease in the water deficit from (38 to 2.9) million cubic meters. Figure 10 shows the results of operating the model based on this scenario.

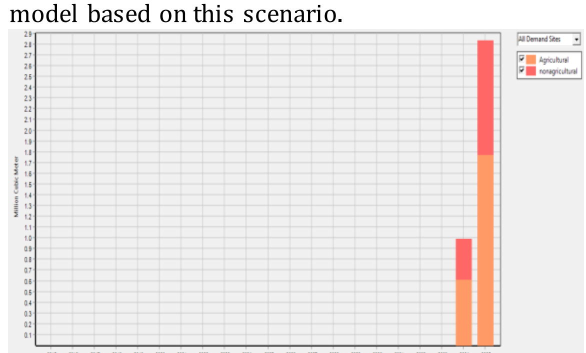

Figure 10. Deficit with Modern Irrigation Way

2- **The second scenario is the re-use of the wastewater** or the so-called wastewater resulting from the daily use of the water. The sources of this water are multiple, including domestic, commercial, agricultural or nature wastewater, such as flood water when it comes to touch materials and minerals on the surface of the earth. The application of this scenario contributed to reducing the water deficit to (35) million cubic meters, as shown in Figure11.

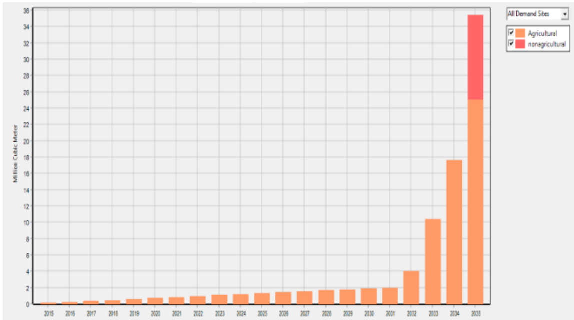

Figure 11. Disability When Using Wastewater

3- **The third scenario:** It is the use of a second source of supply in addition to surface water, which is groundwater. Their use helped reduce the water deficit to (26) million cubic meters, as shown in figure 12. To represent groundwater in the WEAP program, we need to calculate the initial storage of the groundwater tank resulting from the calculation of the volume of water bearing layers (the thickness of the underground reservoir * area of the study area) which equals here (1080) billion square meters and the largest possible supply of the underground reservoir that is equal to 10 liters / second and has been completed its Knowledge through the field visit of the researcher to the General Groundwater Authority - Anbar branch.

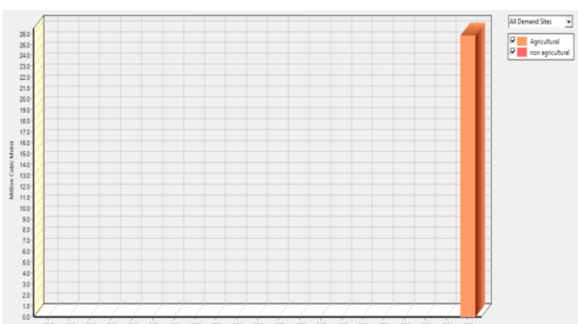

Figure 12. Deficit with Groundwater

4 - **The fourth scenario**: Reducing the per capita water share from (500liter / day) to (300liter / day) as a result of increasing awareness among users. Figure13 shows the results of its application.

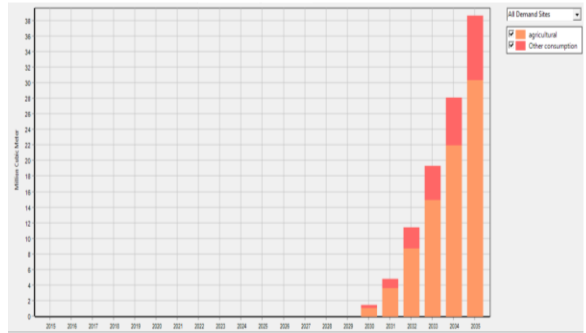

Figure 13. the Percentage of the Deficit When Reducing the Individual's Share of Water

7.Model Validation

The results of this study were validated using the JICA forecast for the monthly flow of the Euphrates River with flow values in the simulation model. Where the JICA Organization [31] expected that Iraq's imports of Euphrates water in 2035 will be 10 billion cubic meters, meaning that the share of the upper Euphrates region will be 300 million cubic meters. While the program expected that the discharge value of the Euphrates River in 2035 in the area of the upper Euphrates will reach 277.89 million cubic meters. That is, the percentage of convergence between the value observed and recorded will be approximately 92%, which is a good value.

8. Conclusions

Water needs more attention and protection because it is one of the limited strategic resources that started to decrease and scarcity problems in the twenty-first century. To get rid of its problems, it is necessary to follow the most advanced management methods and pay attention to using modern technologies that help decision makers to predict and choose the right decision that contributes to getting rid of the expected future crises. Among the most important of these technologies in the field of water management is the WEAP program, which has proven effective in representing the different conditions of water and helping decision makers visualize the effects of different scenarios. Four future scenarios have been approved and the model is operational. The results of the scenario indicated the following:

1- The high demand for water from (100 to 397) million cubic meters by 2035 when the current methods of management continue.

2- Due to the increase in water needs due to the increase in population and expansion of agricultural lands, an estimated deficit rate of 38 million cubic meters will appear in the year 2035.

3- The decrease in the percentage of water deficit from (38 to 2.9) million cubic meters from the application of the scenario of using modern irrigation methods that led to high irrigation efficiency.

4- The wastewater use scenario contributed to the decrease of the deficit to (35) million cubic meters

5-Groundwater helped reduce the deficit to (26) MCM.

6- Despite the slight decrease in the percentage of water deficit when reducing the individual's daily share of water because the agricultural sector is the largest consumer of water, it is important to continue awareness campaigns in using water for the purpose of clarifying its importance and the need to preserve it.

7- Paying attention to monitoring and maintaining the water transport pipes to avoid wasting large quantities of them.

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