Tikrit Journal of Engineering Sciences (2023) 30 (4): 54-62
DOI: http://doi.org/10.25130/tjes.30.4.7

IRAQI Academic Scientific Journals

College of Engineering

ISSN: 1813-162X (Print); 2312-7589 (Online)
Tikrit Journal of Engineering Sciences
available online at: http://www.tj-es.com

TJES Tikrit Journal of Engineering Sciences

Rainwater Harvesting of Some Catchment Areas in Mosul City/ Iraq by Small Dams Construction

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Keywords:
Harvesting Rainwater; Small Dams; Reservoir; Surface Run-Off

ARTICLE INFO

Article history:

Received	10 June	2023
Received in revised form	15 July	2023
Accepted	07 Aug.	2023
Final Proofreading	26 Aug.	2023
Available online	13 Nov.	2023

Citation: Al-Zakar SH, Alsaidi MI, **Rainwater Harvesting of Some Catchment Areas in Mosul City/ Iraq by Small Dams Construction.** *Tikrit Journal of Engineering Sciences* 2023; **30**(4): 54-62.
http://doi.org/10.25130/tjes.30.4.7

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Abstract: In semi-arid and arid areas, there is little surface and groundwater. Consequently, efforts are being undertaken to protect and collect rainwater as much as possible. When the rainfall is irregular in arid and semi-arid regions, a large portion of it is lost as surface run-off creating a water shortage that puts people at risk. Water collection is a substitute in these circumstances and is crucial. Water harvesting is the process of collecting rainfall and run-off using various storage structures, such as tiny dams, primarily for human, agricultural, and livestock use. For the construction of storage structures to impound and harvest rain and run-off water, forming surface storage reservoirs, four sites with special hydrological and geomorphologic characteristics have been identified and pointed in the drainage map of the studied areas (Tal-Kaif, Zummar, Al-Shor, and Wadi-Almur). A dam model was created using a Global Mapper and Watershed Modeling System program, WMS. Each reservoir's geometrical dimensions and the overall volume of water held behind each site's dams were measured and computed. The four sites' combined storage capacity for water behind the dams might exceed (75×10^{6}) m^3. Several dam heights were selected in each basin, and the submerged areas for each height were determined to select the optimal height in each basin, i.e., 11.75, 13.9, 9.8, and 12.3 m.

حصاد مياه الامطار لبعض الجوابي في مدينة الموصل/العراق بانشاء السدود الصغيرة

شذى حازم داود الزكر، ميس ابراهيم السعيدي
قسم هندسة السدود والموارد المائية / كلية الهندسة / جامعة الموصل/ الموصل - العراق.

الخلاصة
تتميز المناطق الجافة وشبه الجافة بقلة المياه السطحية والمياه الجوفية فيها، لذا فان جهود كبيرة ُتبذل من أجل جمع مياه الأمطار وتخزينها في مواقع مختلفة. فعندما يكون سقوط الأمطار غير منتظم فان جزء كبير منه يُفقد على شكل جريان سطحي خصوصا في المناطق التي تحصل بها سيول موسمية، مما يؤدي إلى حدوث نقص في المياه وبالتالي يعرض الناس لخطر الجفاف، ولهذا يعتبر جمع المياه أمر بالغ الأهمية وبديلاً في مثل هذه الظروف. ان حصاد المياه هو عملية جمع مياه الأمطار والجريان السطحي وذلك باستخدام منشات تخزين مختلفة، مثل السدود الصغيرة، والتي تعتبر شكل أساسي ومهم للاستخدام البشري والزراعي والحيواني. فمن خلال خارطة تصريف المياه للمناطق قيد البحث، تم اختيار أربعة مواقع لاحواض مائية (تلكيف، زمار، الشور، وادي المر) ذات خصائص هيدرولوجية وجيومورفولوجية محددة من أجل بناء منشآت التخزين لحجز وتجميع مياه الأمطار ومياه الجريان السطحي، تم إنشاء نموذج للسدود باستخدام البرامج الحاسوبية (برنامج Global Mapper وبرنامج Watershed Modeling System، WMS)، حيث تم قياس وحساب الأبعاد الهندسية لكل خزان والحجم الكلي للمياه الموجودة خلف سدود كل موقع، وقد بلغت سعة التخزين المشتركة للمواقع الأربعة للمياه خلف السدود 75 مليون متر مكعب، ثم تم اختيار عدة ارتفاعات للسد المقترح في كل حوض وتم تحديد المساحات المغمورة لكل ارتفاع، لغرض تحديد الارتفاع الأمثل للسد في كل حوض والتي كانت (11.75، 13.9، 9.8، 12.3 م) على التوالي.

الكلمات الدالة: حصاد مياه الامطار، السدود الصغيرة، الخزانات، الجريان السطحي.

1.INTRODUCTION

In arid and semi-arid places, other water sources are not readily available or too expensive to develop and utilize. Water harvesting, also known as rainwater collection, is a strategy for increasing surface water resources to increase the quantity and quality of water available to the population. In the near future, failing to find the right answer will also become a barrier to civilized and social precedence. Surface run-off water harvesting can help to ease the water shortages in many parts of the world [1]. The following factors are considered when choosing the best harvesting technique for a given location: 1) the intended use of the water; 2) land slope; 3) soil characteristics; 4) construction costs; 5) the amount, intensity, and seasonal distribution of rainfall; and 6) social factors such as land tenure and customary water use practices [2].

There are ongoing severe water shortages worldwide. Numerous factors, including the effects of global climate change, rapid population growth, changes in land use, agricultural and urban expansion, the rise in demand for water from various productive sectors, the inadequacy of water resource distribution, regional hydro political conditions, the degradation of water quality due to overexploitation, the scarcity of rainwater, contribute to the severe degradation of water resources, Liu et al. [3] and Fiaz et al. [4]. Rainwater harvesting is described by Qadir et al. [5] as the management, control, and use of rainfall on-site or its storage for later use. The process of successfully managing rainfall and run-off for various purposes is known as rainwater harvesting. Rainwater collection has been a prevalent practice in many agricultural systems worldwide since prehistoric times, especially in arid and semi-arid regions and areas with insufficient rainfall for crop growth; rainwater collection was widely used. The most common application is supplementary irrigation, which replaces the rainfall when there is a water shortage or when plants are under stress throughout their growth stages. When utilized as supplementary irrigation, RWH's primary goal is to gather run-off from remote locations or unused areas, store it, and make it available when and where water is in short supply. However, because run-off events are sporadic, collecting as much rainwater as possible during the wet season is vital so that it can be used later [5] and [6]. Rainwater harvesting systems can save money on water bills, reduce the need for expensive water treatment facilities, and lower the pressure on municipal water supplies. Rainwater harvesting systems positively impact the environment by decreasing stormwater run-off, increasing the accessibility of water resources, and consuming less energy [7].

2.THE STUDY GOAL

The goals of the study are as follows:

1- Provide new sources of water in the study area that work to achieve parity on both sides of the equation based on the rapid population, agricultural, and urban increase in exchange for limited water resources in the governorate.
2- Water harvesting is used to achieve sustainable economic development of water, as it provides another source of water in the drought and lack of rain, contributing to the continuation of agriculture throughout the year rather than being limited to certain seasons, in addition to what it provides from an increase in the level of underground reservoirs, which ensures that they are

constantly fed and not reach the depletion stages.

3.THE STUDY AREA

The study area is the province of Nineveh, between latitudes 34°15′ and 37°03′ North and longitudes 25°41′ and 15°44′East. It is estimated to be 37232 km², or 8.6% of Iraq, and it is a fertile area with high rainfall during the rainy season suitable for agricultural production of crops like barley and wheat [1]. Four seasonal basins (Al-Shor Basin, Al-Mur Basin, Zummar Basin, and Tal-Kaif Basin), located administratively within the Nineveh Governorate, were selected to study rainwater harvesting through the establishment of small dams in them (Fig. 1). A seasonal basin can be defined as a dry basin that contains no water except in rainy seasons. The reason for choosing these basins is the availability of rainfall data in that area and to assist in resolving the water scarcity issue through estimation and exploiting the volume of surface run-off from these areas to store it in storage basins, as the topography of these areas is characterized by the presence of many natural depressions that can be used as storage basins in addition to the foothills in the northern region [8]. The climate of the study area is hot and dry in summer and cold and rainy in winter. The average annual rainfall is low, and the climate is characterized as semi-arid in the stations obtained from the Iraqi Meteorological Department in Mosul. For the study period (1970-2018), the average annual rainfall was 350 mm in Mosul station, 296 mm in Tal-Afar station, and 368 mm in Rabia station. In this area, the rainy season lasts from November to April. Also, it is at this time that excess run-off from the hillsides floods into the valleys. The primary means of replenishing the groundwater in the study area is rainfall influenced by various parameters, including elevation, time, type, and rainfall intensity.

The cross-section of the valleys was carefully chosen for the sites of the selected dams and to ensure minimal evacuation. Dam heights and lengths were considered to minimize the dams' construction cost.

3.1.Wadi Al-Shor

Wadi Al-Shor is located in the Nineveh Governorate, to the west of Mosul, within latitudes 36˚08`-36˚32` northern and longitudes 43˚11`- 43˚25` eastern. The valley is extended from the suburbs of Talafar and its east, as well as in Wadi Almur. The valley cuts through a group of hills of small height and small valleys. The valley feeds a large culvert that descends topographically from the east to the west to the Valley of Tigris River and from the Rabia area in the north to the south to Wadi Al-Shor. Its course length is from east Tal Afar to its estuary in Wadi Al-Mur [9].

3.2. Wadi Almur

Wadi Almur is located within the Nineveh Governorate in the northwest of Iraq, between latitudes 36˚16`-36˚56` northern and longitudes 41˚30`-42˚43` east. The Wadi Almur basin is located in the northwestern part of Nineveh Governorate, and its branches extend into the Syrian region. Wadi al-Mur is one of the most prominent natural features of the northern Sinjar plain. Most of its branches descend from Mount Sinjar and flow into the Tigris River in Eski Mosul. Numerous valleys flow there; the most important are Wadi al-Kasak, al-Shor, and other valleys from the Ashkaft and al-Qusayr mountains. This area has a semi-flat topography with some slopes. The results of the morphometric analysis of the drainage network using (9,0 Arc View) program showed that the river rank of the Wadi El Mur basin is the sixth rank according to Strahler's method (1964). This ranking indicates that this pond receives large quantities of seasonal water in the form of surface run-off. While its total area was (2469 km²) [10].

3.3. Zummar Basin

Zummar Basin is located in the Tal-Afar district within the Nineveh governorate and is located within latitude (36˚46`) to the north and longitude (42˚38`) to the east. Its area is 1247 km², and Zummar is considered a "connection point" between the Syrian borders and the Nineveh governorate. The region's nature is agricultural, and their land is arable, which is reflected in the size of the agricultural land. Zummar is divided into two regions. The former receives good rainfall rates, up to 450 mm a year, while the other region's Rainfall is not guaranteed. The site of the dam was chosen in the Zummar district because of its need for water, especially after the construction of the Turkish Ilisu Dam; where that area was submerged in water after the construction of the Mosul Dam, and its features began to appear after the scarcity of water. It is a semi-arid to a green oasis, sustainable, continuous, and abundant agriculture because the continuous water source provides different crops, not wheat and barley, depending on the semi-cultivation. It also eliminates the scarcity of drinking water in the district, which is 180 km from the Tigris River.

3.4. Tal-Kaif Basin

Tal- Kaif basin is extended between Tel Kaif and Al-Qosh, located 25-40 km north of Mosul. It is located at latitude 36˚29`N and the longitude 43˚07` E. The basin is located within the annual rain range of 400 mm, helping the region's agricultural activities. The area is located within a relatively large rain-dwelling area that helps to feed it with groundwater assisted by the large number of parallel valleys extending from mountainous areas to the area [11]. Fig. 1 shows the four selected basins.

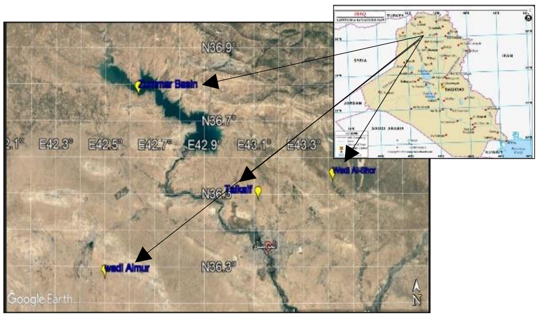

Fig. 1 Image from Google Earth Displaying the Selected Basins' Locations.

4. METHODOLOGY

Based on the Digital Elevation Model (DEM), 30×30 m Shuttle Radar resolution for Topographic Missions (SRTM) for 2010, the Watershed Modeling System (WMS) was utilized to predict the harvested run-off in the basins. This study used the WMS program to investigate the hydrologic and morphological aspects of the watershed's drainage system by drawing a water division line from the DEM file in the four chosen regions [12]. Google Earth was used to accurately find the outlet of the basins and clarify their upstream. The Global Mapper program also was relied upon to find suitable locations by drawing cross-sections of harvested dams. Few dams are the constructions recommended in the study for gathering run-off water. They are typically constructed across the valley's entire width, creating a miniature lake behind them. According to Schiller and Latham (1987), the dam's height, which in most cases does not exceed a few meters, determines the volume of the reservoir accumulation. The dams' construction is based on the permitted collection and storage of surface run-off, allowing use in various locations throughout the dry season. Harvesting surface run-off can help many parts of the world with water shortages. The harvested water use, land slope, soil characteristics, construction costs, amount, intensity, seasonal rainfall distribution, and social factors like land tenure and customary water use practices control choosing the best harvesting technique for a given site. On the drainage map of the examined area, as shown in Fig. 1, four sites with unique hydrological and geomorphologic characteristics were selected and designated for the dams' construction for impounding and harvesting rainwater and run-off, producing a surface storage reservoir. During the few rainy months, the impounded water could be used for various things. By excavating wells very close to the infiltration zone, extracting some of the impounded water that infiltrates into the soil and recharging the groundwater aquifer is possible. To study and comprehend the likely size of the reservoir generated by harvested water, a geometrical survey was done for the four planned dam's construction locations, considering numerous requirements, such as location, foundation, sturdy banks, slope, and sufficient discharge.

5. RESULTS AND DISCUSSION

5.1. Morphological Study

To sustainably develop land, water, and plant resources to meet the population's fundamental needs, watershed development and management involve integrating technology within the natural boundaries of a drainage area (Nissen-Petersen, 1982). The watershed line divider must be located to establish the watershed or catchment area. The hydrologic research heavily relies on the physical characteristics of the catchment region, such as the mean slope and the longest flow path length. The watershed boundary was drawn using the global mapper with a DEM precision of 30 m, and the basin characteristics were identified using WMS, as shown in Figs. 2- 5 and Table 1. Knowing the relationship between the hydrology and shape features of the basin, the structural geology, the rocks types, the climate, and the land use are relevant to morphometric analysis.

5.2. Hydrological Modeling

The initial stage of using the Global Mapper program after choosing the planned reservoir locations was to sketch the longitudinal cross-section of each dam that crosses the outlet of each of the four basins. In the second step, the WMS program was used to calculate the reservoir size for various dam height ranges based on the section height in the four basins. The third step was to find the dams' width for the different ranges of selected heights; thus, the submerged area for each height of the dam was obtained, as shown in Fig. 6. The fourth step was to find the storage elevation curves and surface elevation of water, which are important for reservoir routing, and then found the area elevation curves, which are important for identifying the expected inundated area and calculating the evaporation losses, Figs.7-10. Also, the submerged area and the reservoir volume for different elevations behind dams in in the four selected basins are tabulated in Table 2.

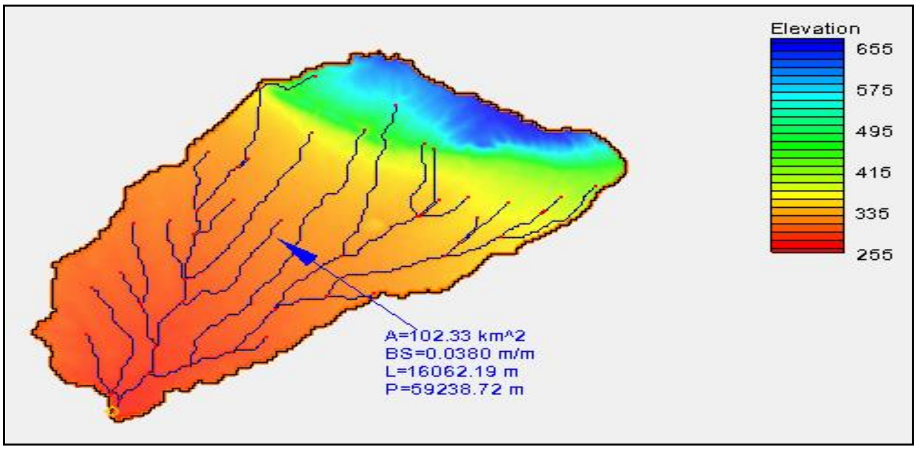

Fig. 2 Al-Shor Catchment Area Boundary and Surface Drainage System with Divided Line.

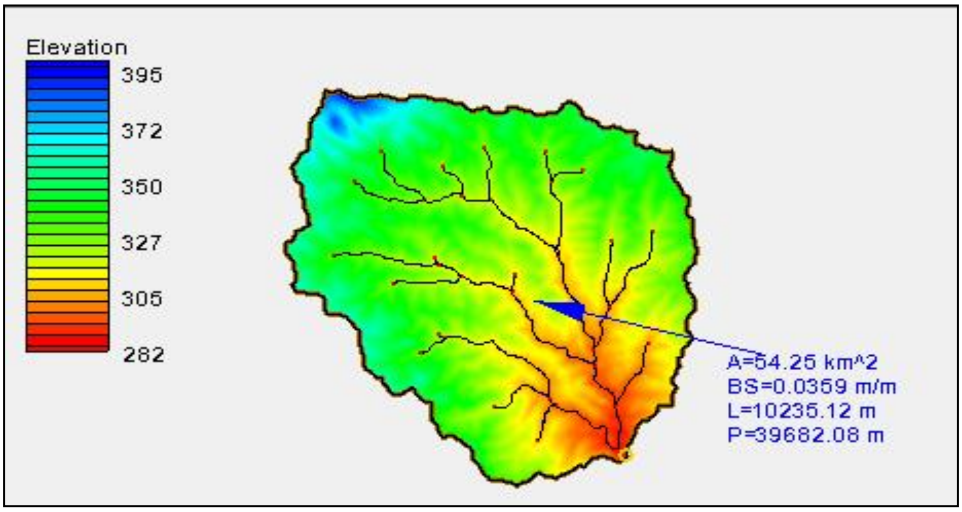

Fig. 3 Tal- Kaif Catchment Area Boundary and Surface Drainage System with Divided Line.

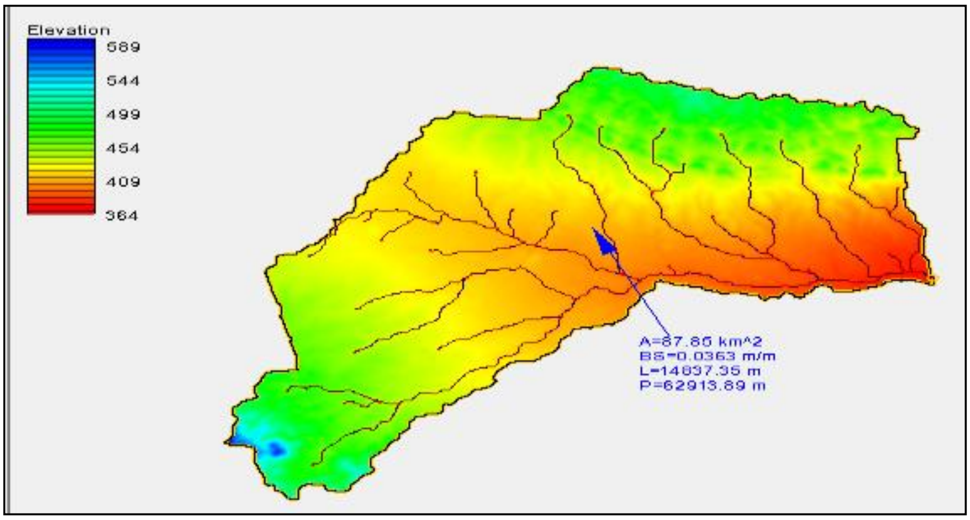

Fig. 4 Zummar Catchment Area Boundary and Surface Drainage System with Divided Line.

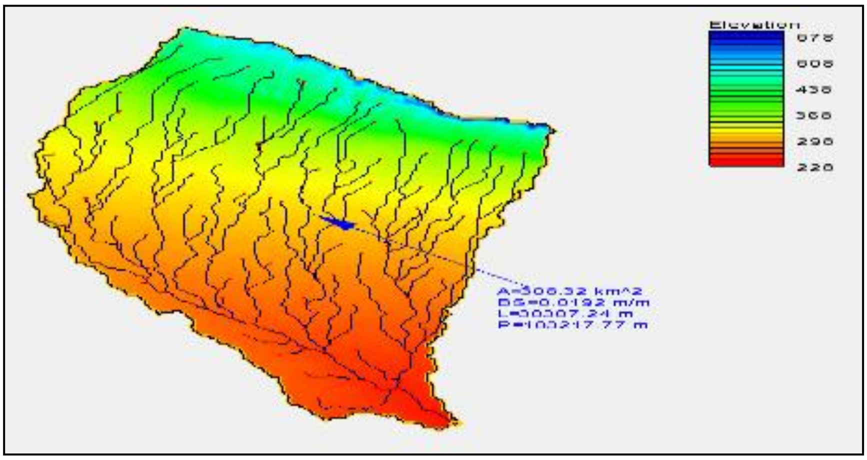

Fig. 5 Almur Catchment Area Boundary and Surface Drainage System with Divided Line.

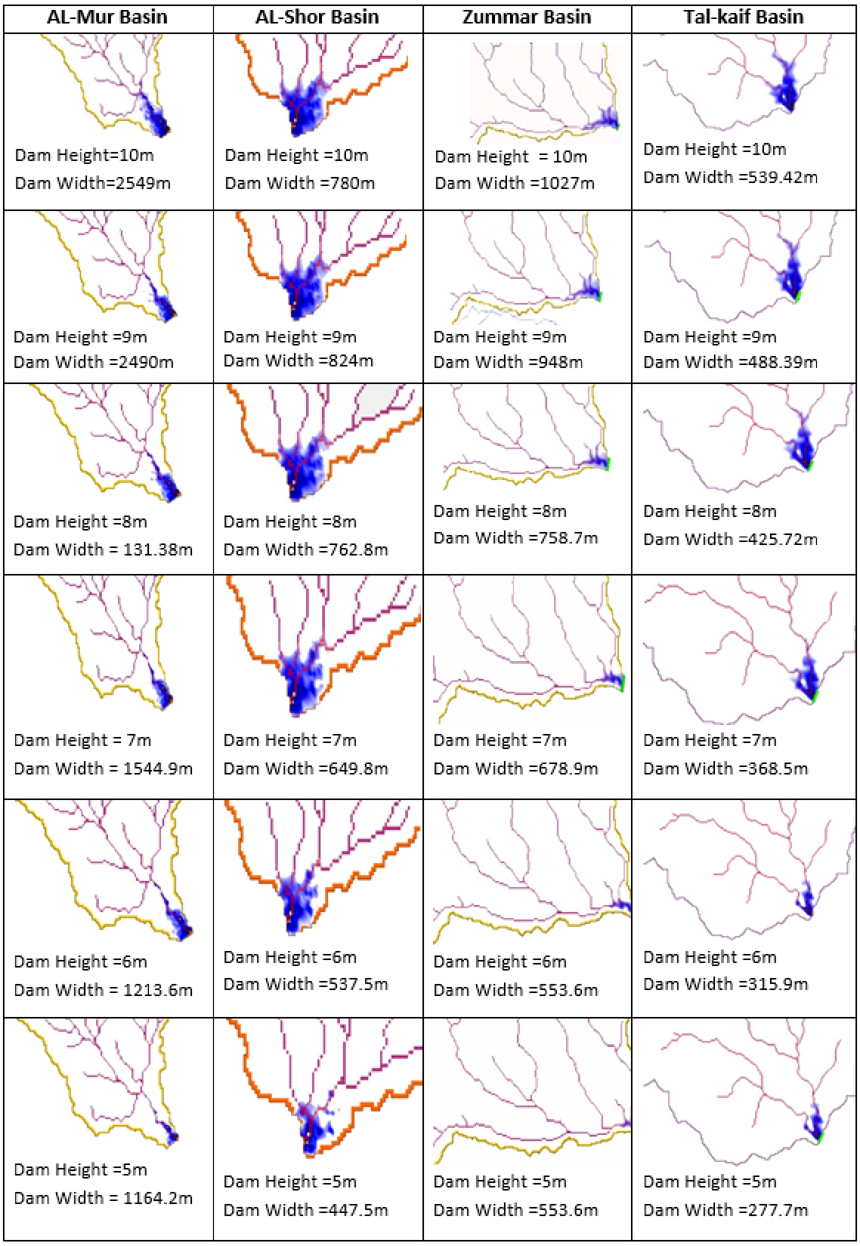

Fig. 6 The Submerged Area for Each Height of the Dam in the Four Basins.

Table 1 Catchment Area Characteristics for the Basins.

Basin Name	Basin Area A (km^2)	Basin Slopes B.S (m/m)	Basin Lengths L (m)	Perimeter P (m)
Al-Shor	102.38	0.038	16062.19	59238.72
Tal- Kaif	54.25	0.0359	10235.12	39682.08
Almur	308.32	0.0192	30307.24	103217.77
Zummar	87.85	0.0363	14837.35	62916.29

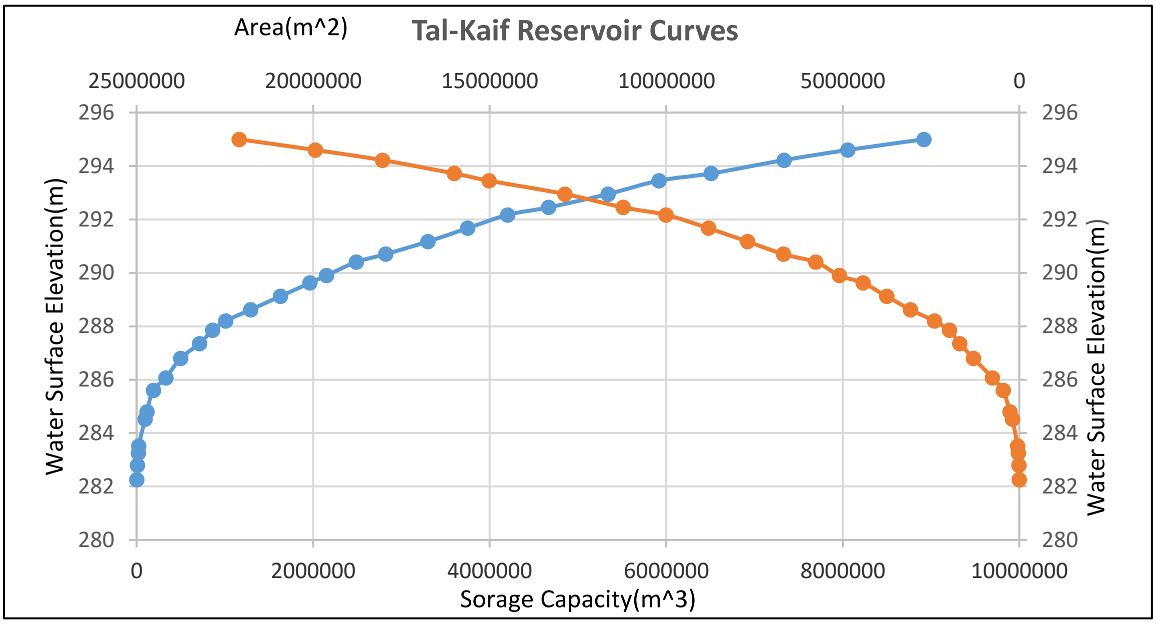

Fig. 7 Tal-Kaif Reservoir Curves of Area-Storage Capacity Against Elevation.

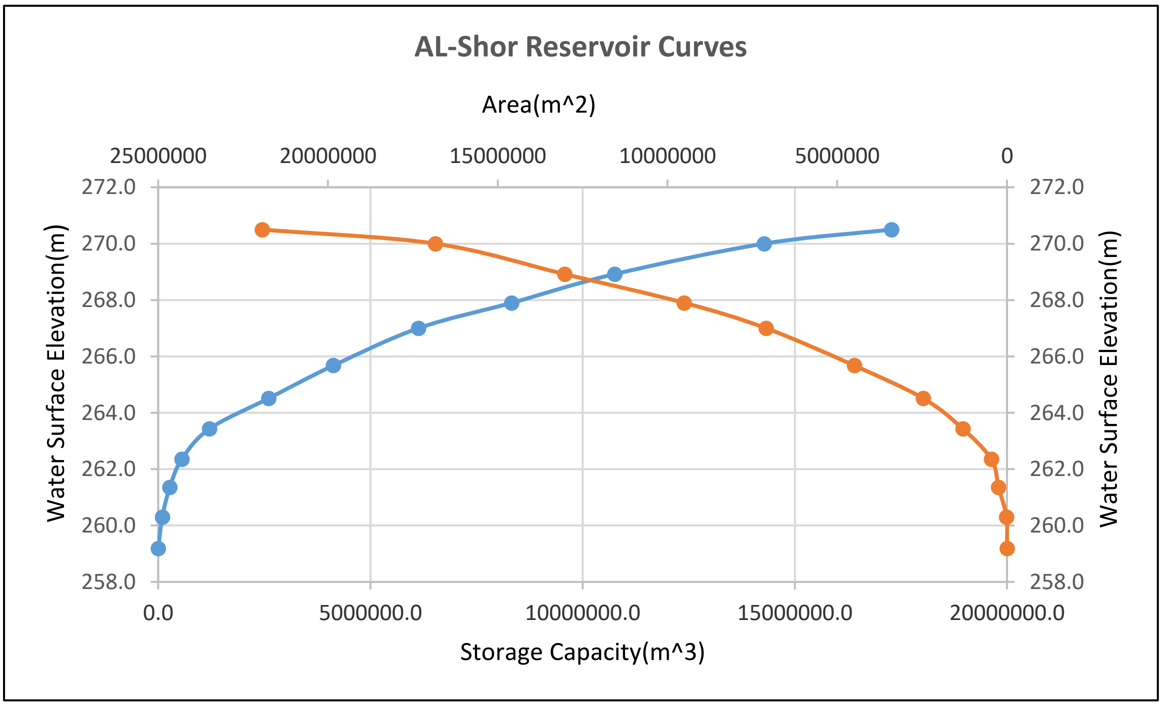

Fig. 8 AL-Shor Reservoir Curves of Area-Storage Capacity Against Elevation.

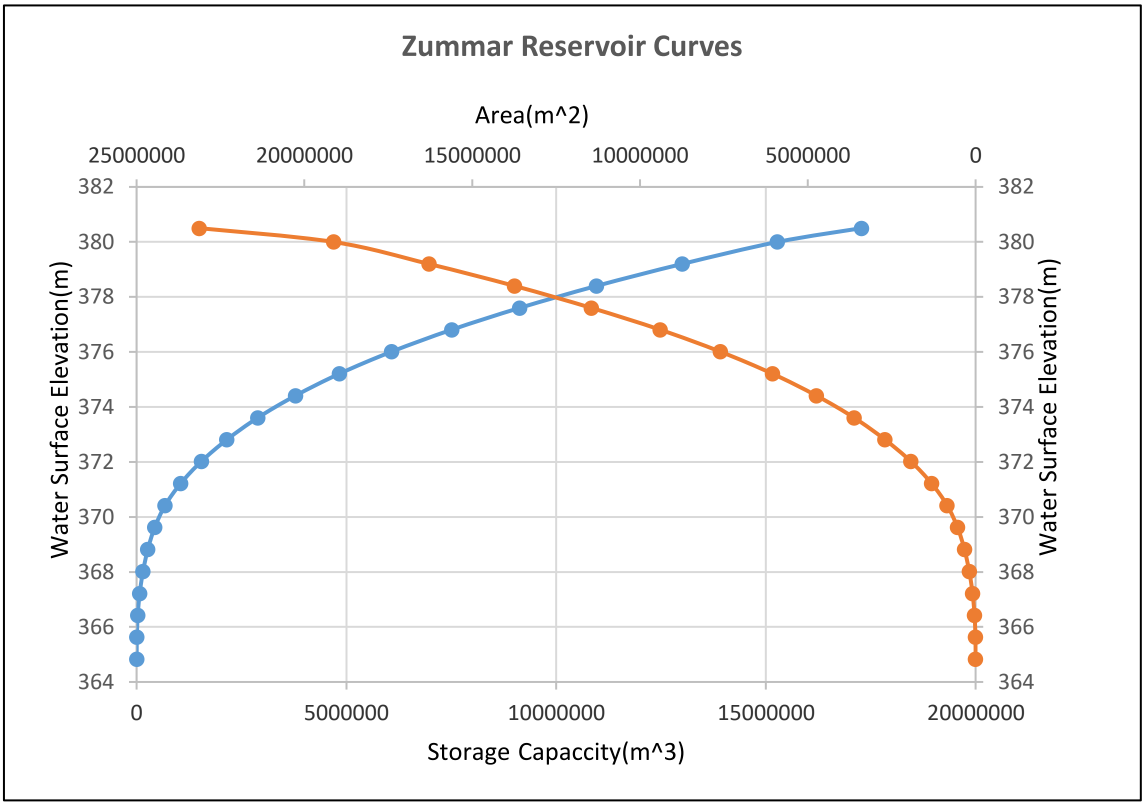

Fig. 9 Zummar Reservoir Curves of Area- Storage Capacity Against Elevation.

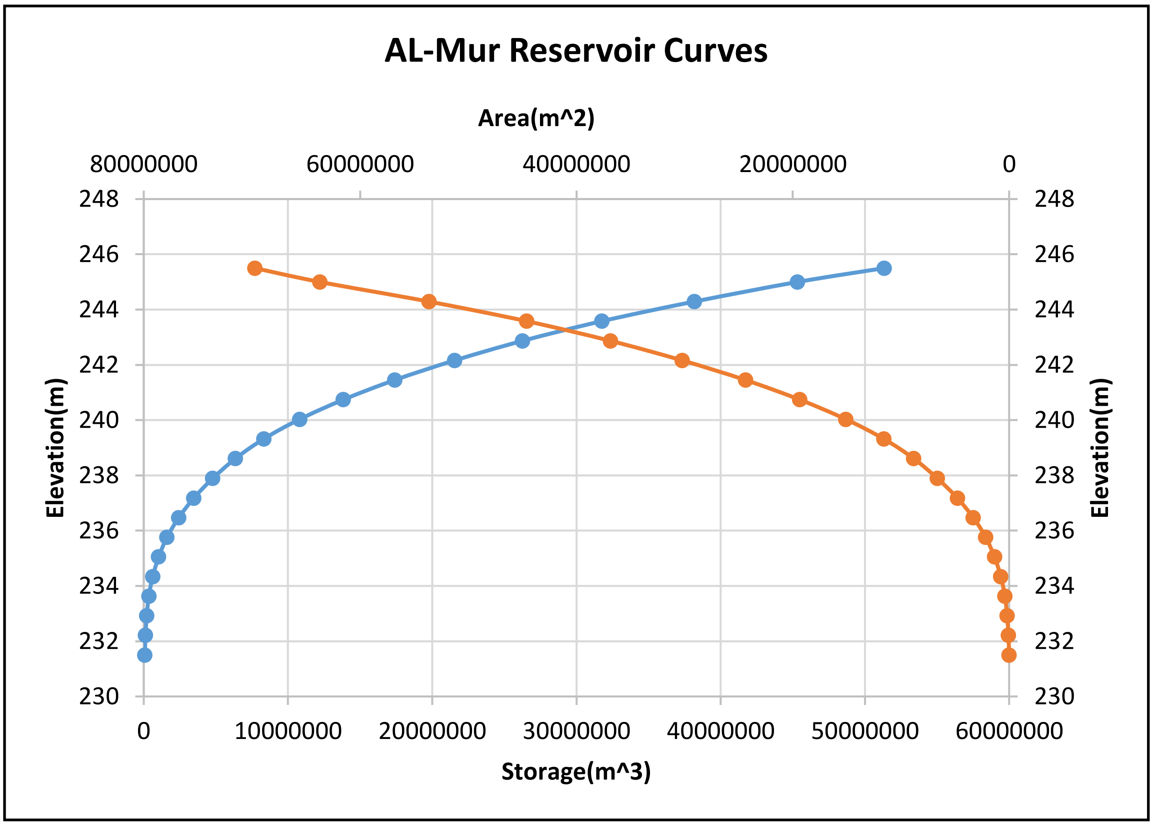

Fig. 10 AL-Mur Reservoir Curves of Area- Storage Capacity Against Elevation.

Table 2 Submerged Area and the Reservoir Volume at Different Elevations Behind the Dam in the Four Selected Sites.

Tal-kaif			AL-Shor	
Elevation (m)	Area×10⁴ (m2)	Volume*10×4 (m3)	Area×10⁴ (m2)	Volume×10⁴ (m3)
5	168.5	71.2	246.9	260.3
6	240.9	101.0	449.4	412.6
7	375.3	162.8	950.5	833.1
8	576.5	248.6	1302.4	1075.3
9	769.7	329.9	1683.4	1427.8
10	1000.5	420.2	2193.4	1727.8
Elevation (m)	Zummar		AL-Mur	
5	53.9	43.2	330.7	242.3
6	84.8	68.0	662.9	478.2
7	131.3	105.2	882.2	636.1
8	269.9	215.3	1158.2	832.0
9	362.1	289.1	1935.8	1384.1
10	474.2	378.7	2436.6	1739.7

6. CONCLUSIONS

Iraq now has a deficit in water resources, which is predicted to worsen in the future. Water harvesting techniques will undoubtedly be helpful to avoid or lessen the impact of this issue. In Mosul, in northern Iraq, four locations with special hydrological and geomorphological characteristics (Tal-Kaif, Zummar, Al-Shor, and Wadi Almur) were selected and indicated on the drainage map of the studied areas. These locations were suggested to build small dams to collect and store rainwater. Models of the dams and the surface storage reservoir were created using the Global Mapper program and the Watershed Modeling System program (WMS), which were applied to select small dams for catchment areas ranging between 54.25 and 308.32 km^2. The dam's optimal height in each basin was obtained and ranged between (9.8 and 13.9 m). The four sites' combined storage capacity for water behind the dams might exceed 75×10^6 m^3. So, the reservoir volume results from all locations supported the dams' construction.

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