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Hydrologic and hydraulic modeling for floodwater harvesting in Al-Shiwiaja depression

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ABSTRACT

The main objective of this study is to investigate the potential for collecting floodwater from Al-Shiwiaja depression in Wasit Governorate, eastern Iraq. The floodwater data used in the study were collected during a flood in the study area on November 14, 2015. One proposed solution to this issue is to build a reservoir. A reservoir is to be constructed at the upstream of the depression, with a drainage canal constructed at its base to direct any surplus water toward the Tigris River via the Um Al-Jery regulator. The GIS, HEC-HMS, and HEC-RAS were used to simulate floodwater in the depression. To validate the model, the flood volume was calculated using the flood routing method and compared with the model. The results show a good agreement, with the maximum difference being 8.1%. The results of the study indicate that water Harvesting and flood management could be enhanced by integrating hydrological and hydraulic modeling with remote sensing techniques. The research shows that the proposed solution effectively reduces floodwater risk, addresses pollution sources, especially sewage, as well as the high sediment loads accumulating in the natural depression.

Keywords: floodwater harvesting, natural depression, the storage area, the flood routing method, HEC-RAS, Al-Shiwiaja depression.

INTRODUCTION

Water scarcity consistently affects economic growth in arid and semi-arid regions. The adoption of floodwater harvesting technologies has become an essential component of any comprehensive approach to addressing the water crisis, ensuring their optimal use for sustainable development in these areas (Fathy et al., 2021). Methods of harvesting are classified as "rainwater harvesting" if water is collected directly from rooftops or surface runoff and "floodwater harvesting" if applied to drainage outlets (Rather et al., 2022). Proper design and evaluation of water harvesting systems are essential for optimizing system performance and ensuring the stability of water supplies (Saleem et al., 2018). It can contribute to significant water savings in diverse contexts worldwide (Nolan and Lartigue, 2017). Lakes and reservoirs play an important role in buffering and regulating extreme hydrological events during the flood period (Wang et al., 2022). One of the functions of the storage area is to reduce the peak flow and extend the time between the onset of runoff and the peak flow (Hong et al., 2006).

These measures contribute to climate change adaptation (Gebreslassie et al., 2025) and to the mitigation of inappropriate urbanization processes (Mzava and Rujweka, 2025). Microbiological contamination, land requirements, and obstructions are among the ongoing challenges associated with groundwater recharge.

Wang et al., (2022) presented a methodology based on multi-source remote sensing (GF-1 and Sentinel-1) to estimate weekly watershed storage capacity by relating water surface area to volume using an empirical (volume-area) relationship. The model demonstrated high efficiency in calculating storage retained during floods at the basin level without requiring local rainfall or evaporation data.

Dasgupta and Das, (2024) applied a numerical flood routing analysis based on the continuity equation combined with stage–storage and stage–outflow relationships, solved using the Modified Puls (level-pool) method.

Pirone et al., (2024) developed simplified relationships to correlate the storage capacity of a retention basin with its geometry and storage-level curve, as well as the amount of peak discharge reduction. The results showed that basin geometry (slope of sides and shape of the reservoir) significantly affects storage efficiency, with the same storage capacity resulting in large differences in peak reduction. This allows rapid, efficient estimation of the required basin capacity during the initial design phases without complex hydrological modeling.

Several studies have confirmed the effectiveness of hydraulic modeling using HEC-RAS software in analyzing and estimating temporary flood storage to reduce peak discharge.

Lopes Monteiro et al., (2023) demonstrated that connecting off-stream flood storage basins to discharge channels towards rivers, with inflow and outflow hydrographs derived from the HEC-RAS model, allows for the estimation of effective storage volume based on the cumulative difference between inflow and outflow, taking into account the effect of the river's backwater level. The results of this study showed that this approach effectively reduces peak flooding and improves flood risk management in watersheds.

Zhong et al., (2025) The representation of flood storage zones in the HEC-RAS model, based on stage-storage curves derived from topographic data, provides an integrated physical framework for analyzing temporal change in storage and assessing its direct impact on reducing peak discharges within river channels.

Due to data scarcity in many Middle East regions, alternative water management techniques, such as RWH systems, need to be investigated and further exploited.

Aziz et al., (2023) presented an advanced study to select suitable sites for rainwater harvesting in the Kalar region (Kurdistan, Iraq) using GIS and remote sensing techniques, applying AHP and FAHP methods to prioritize influencing factors. The results produced suitable maps identifying areas suitable for establishing rainwater harvesting facilities, with clear differences between the two methods. The study also confirmed the importance of the minimum rainfall criterion in producing suitable maps. The study of Mohammed and Abed, (2025) worked to identify suitable sites for constructing water harvesting dams in Wadi Al-Abyad in the western desert of Anbar. They conducted a hydrological analysis of the valley's four basins using HEC-HMS and ArcGIS. The results revealed that Wadi Al-Abyad has the highest storage capacity and the lowest water loss rate, making it a promising location for water harvesting dams and supporting the utilization of seasonal runoff in the region.

The study area in Al-Shiwiaja depression (the area within the Kut watershed under study) collects rainwater and floodwater from the adjacent border valleys (Hilo et al., 2019). Water levels are high during floods, but water harvesting in this region requires management because the water quality is unsuitable for several reasons, including both natural and man-made factors. The first reason is the pumping of sewage from Kut into the depression. The study of Al-Zubaidi and Abed, (2024) discussed this reason and aimed to evaluate the quality of the water in the Al-Shuwaija depression in Wasit province, Iraq. The depression was suffering from pollution caused by salt accumulation and drainage of a large volume of untreated sewage from the wastewater treatment plant in Kut City. The second reason is represented by the sediment that washes in with the floodwater from the adjacent valleys (Abdullah et al., 2020).

Hilo et al., (2019) investigated the quality and quantity of water and better management of the streams that discharge into Al-Shiwiaja depression. The results showed high sediment production because barren land dominates 43% of the total watershed's area. They recommended storing water before entering the Al-Shiwiaja Wetland and finding the best way to prevent deposition in the desired lake, as storing the water in the Al-Shiwiaja depression reduces the quantity and quality of water.

Sahar et al., (2021) employed the remote sensing data and the soil and water assessment tool model to estimate sediment volume and assess the water balance of the Badra Basin in eastern Iraq (which is near the area under study). The SWAT model in this study showed that climatic factors, particularly rainfall, along with soil classes, topography, and LULC, affected transported sediments and surface runoff.

The reason is unsuitable water quality due to high salinity levels in the study area and each valley that drains into it. The study of Hilo, (2014) done via a system that consists of a group of wells constructed along a long line of 38 km at a distance of 1 km apart between wells. The study suggested that the effect of water in depression on the ground should be optimized to reduce the detention time of flood water by pumping it into the Tigris River at the effluent of depression.

Rahi et al., (2019) performed a hydrological evaluation to estimate runoff volumes from eight significant catchments (Mandali, Qazania, Tursaq, Mirzabad, Galal Badra, al-Chabbab, al-Teeb, and Dwaireeg) situated along the eastern border of Iraq, next to western Iran. Regression models developed by the USGS for analogous arid environments were utilized to estimate runoff quantities, facilitating the development of a projected reservoir in the Al-Shiwiaja depression for floodwater retention and drought alleviation.

Abdullah et al., (2020) presented a comprehensive review of the state of water harvesting in Iraq, including an assessment of small dams in the western desert, the Jazeera region, and the eastern valleys. The study confirmed that sedimentation is the biggest obstacle to the effectiveness of harvesting facilities, especially in the eastern valleys. It also highlighted the importance of developing water- harvesting system in desert areas and leveraging successful experiences in neighboring countries with similar conditions.

Al-Khafaji et al., (2021) used a DEM and Landsat imagery within a GIS environment to identify the best locations for rainwater harvesting in Diyala Governorate. The results showed that eastern Diyala is one of the most promising areas for establishing rainwater harvesting facilities.

Previous studies in the study area have focused on flood analysis using hydrological and hydraulic models to accurately determine peak discharge and surface runoff volume. However, these studies lacked an investigation into mechanisms for utilizing floodwater through harvesting, storage, and treatment, despite the clear impact of pollution sources, particularly sewage, and the high sediment loads accumulating in the natural depression.

This study aims to develop an integrated floodwater-harvesting model for natural depressions that accounts for environmental challenges posed by sewage discharge and high sediment loads. The study uses hydrological and hydraulic modeling to estimate harvestable runoff and determine suitable storage capacities. Additionally, it seeks to assess floodwater harvesting as a sustainable strategy to reduce water scarcity in Iraq, which faces drought due to limited water resources and the water flows of neighboring countries. This can be achieved by capturing and storing seasonal floods for use during droughts, especially in summer.

METHODOLOGY

The hydrological and hydraulic models were performed using HEC-HMS and HEC-RAS software to determine the extent of flood inundation and the floodwater volume. Subsequently, the required volume for excavating the storage area and constructing the artificial canal to contain the flood was calculated.

Study area

The study area is located in the Al-Shiwiaja depression in eastern Iraq, as shown in Figure 1.

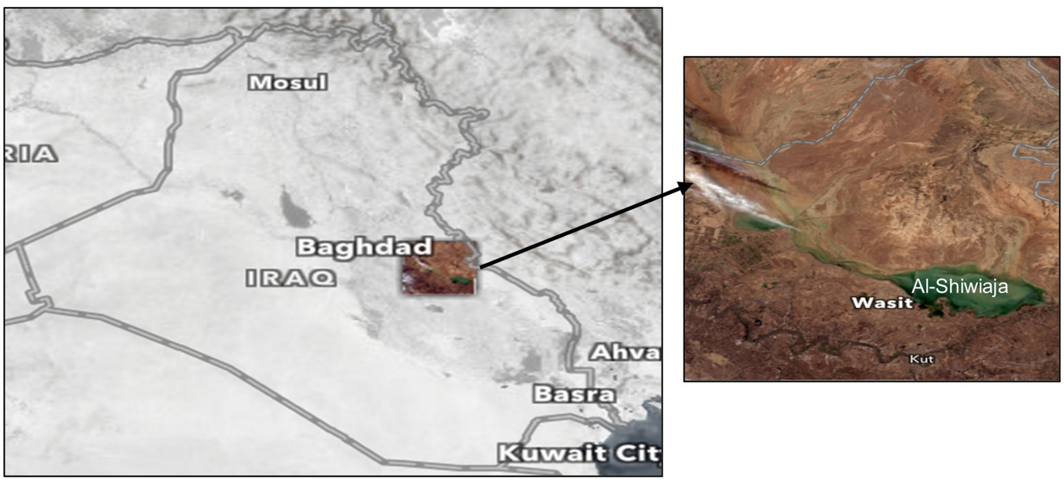

Figure 1. The study area in Al-Shiwiaja depression (Esri, Sentinel-2 Explorer)

The eastern part of Iraq is bordered by Iran and connected by the catchments of Mandali, Qazania, Tursaq, Mirzabad, Galal Badra, al-Chabbab, al-Al-Teeb, and Dwaireeg. The average temperatures and precipitation recorded from November 5 to 30, 2015, were 18 °C and 1.9 mm, respectively (Data Access Viewer, POWER, https://power.larc.nasa.gov). The study area was classified into nine sub-basins as shown in (Table 1) and (Figure 2).

The flowchart in Figure 3 illustrates the research methodology used in this study. It begins with collecting hydrological and topographical data for the depression area to determine soil structural and hydraulic behavior. Hydrological modeling was then conducted to estimate the design of flood hydrographs, followed by hydraulic modeling to determine the flood area, water depth, and velocity. These models were integrated to study floodwater harvesting. The current depth is used to determine the required storage and to design the canal and its slopes to ensure stability. Finally, the software is run to display the flood, calculate the volume of water causing it, and excavate an artificial channel with a water storage basin to accommodate this flood and any similar future events. The software is then rerun according to this change, and the flow, velocity, and depths are observed after excavation.

Data collection

The NASA website was used to obtain hourly rainfall and temperature data (https://power.larc.nasa.gov). DEM was obtained from the United States Geological Survey (USGS) website (https://earthexplorer.usgs.gov/) at a 30 m resolution. The Harmonized World Soil Database v2.0 (https://www.fao.org/soils-portal/data-hub/soil-maps-and databases/harmonized-world-soil-database-v20/en/) and Land Use/Land Cover (LU/LC) (https://livingatlas.arcgis.com/landcoverexplorer/) were obtained and imported into ArcGIS to generate the CN grid.

Watershed delineation

ArcGIS software with Arc-Hydro tools and HEC-GeoHMS extensions was used to extract

Table 1. Sub-basins of the study area

Sub-basin	720	940	960	1010	1020	1110	1170	1230	1290
Latitude	33.4	33.3	33.1	33.1	32.9	32.8	32.8	32.7	32.7
Longitude	45.3	45.5	45.6	45.1	45.3	45.5	45.8	45.6	45.9

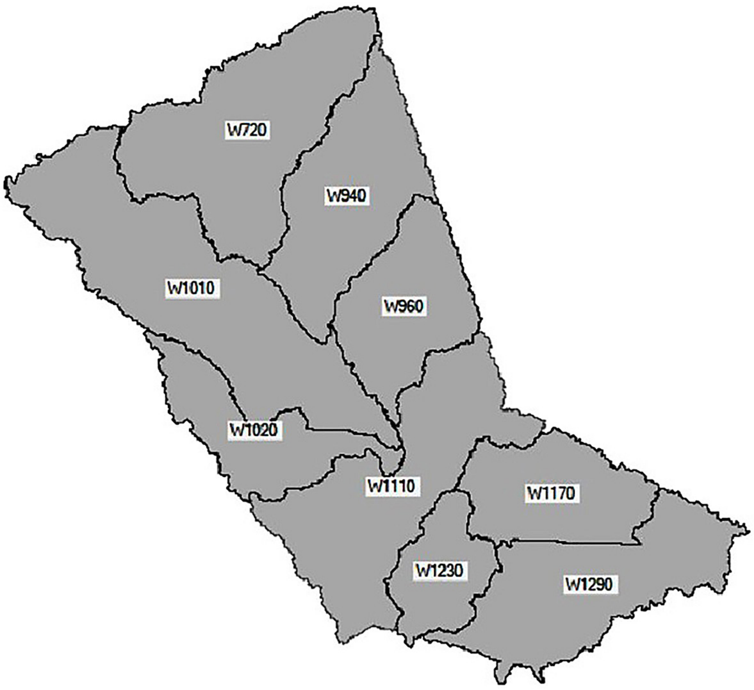

Figure 2. Sub-basins of the study area

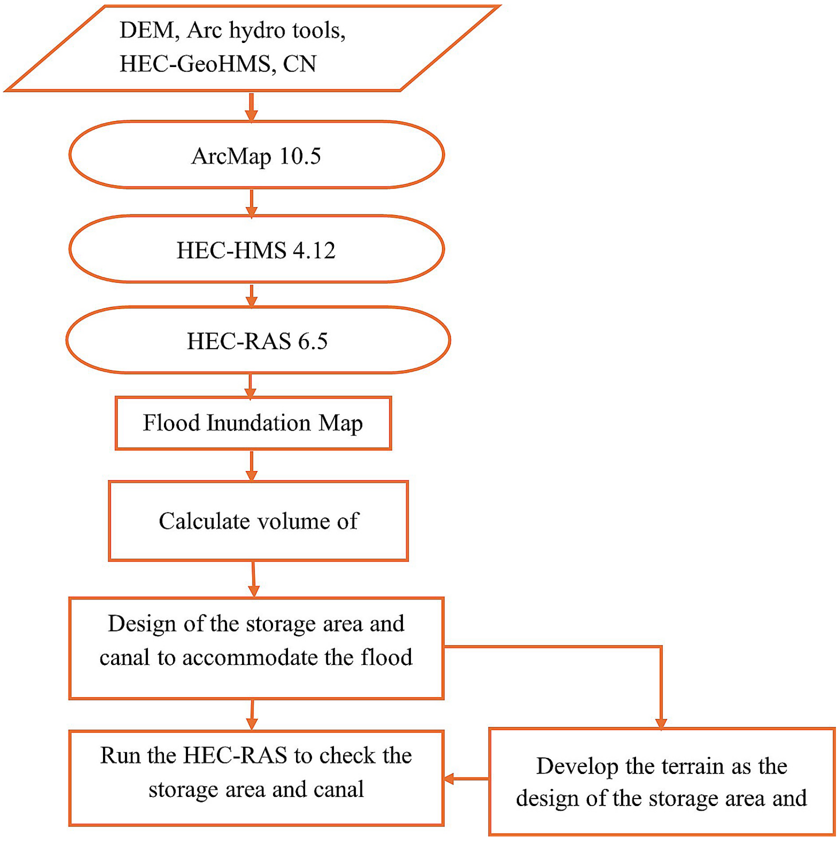

Figure 3. Flowchart of the research methodology

the sub-basin boundaries of the study area. The surface drainage network, confluence points, and ground surface slopes.

Hydrological and hydraulic model

The hydrological model was applied using HEC-HMS 4.12 software. Hourly rainfall and temperature for the study period were used with the CN grid, imported from ArcGIS, to obtain rainfall-runoff and hydrograph results at the outlet.

The hydraulic model was applied using HEC-RAS 6.5 software. The HEC-RAS model was used to simulate runoff that accumulated in the depression. Depression cross-sections and runoff paths were derived from the DEM. The runoff was used as a boundary condition for upstream reaches to determine flooded area, depth, and velocity using HEC-HMS outputs. The Manning equation was applied to calculate runoff losses, using a roughness modulus appropriate for loam soil characteristics. Through unsteady flow simulation, a peak hydrograph at the depression inlet was obtained, which was subsequently used to calculate the required storage volume. Figure 4 shows the actual satellite image for flooding (November 14, 2015) and the hydraulic modeling image using HEC-RAS, it shows a good matching the actual image.

The topographic and hydrological data used in this study were obtained from the previous research (Yousif and Hamdan, 2026) on the same catchment, which included the original flood volumes estimated for Al-Shiwiaja depression in Wasit Governorate, eastern Iraq, during the flood event on November 14, 2015. The previous research employed an integrated simulation that fused geographic information systems (GIS) with the HEC-HMS and HEC-RAS models. The HEC-HMS model was used to convert rainfall into surface runoff, while the HEC-RAS model simulated the transformation of runoff into a flood and analyzed its special spread. The simulation results were then compared with satellite imagery to verify their accuracy.

Water harvesting

This study adopted a new methodology to assess the efficiency of water harvesting in natural depressions by performing a series of hydrological and engineering calculations. The construction of a water storage area in the upper part of the depression was proposed to reduce contact

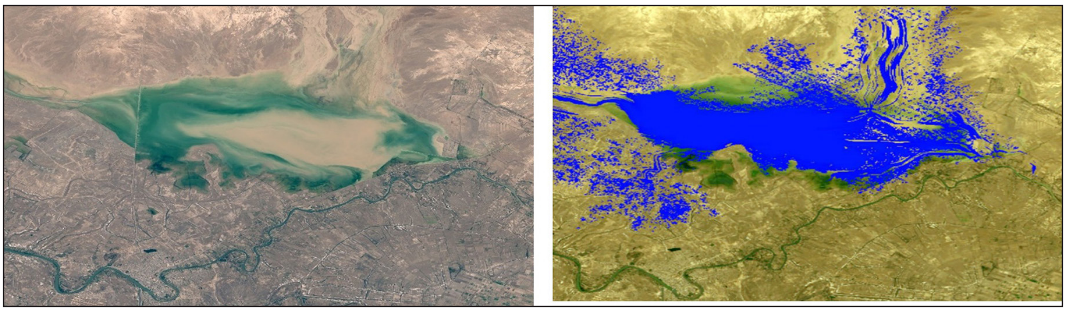

Figure 4. (a): Actual satellite image for flooding (November 14, 2015) https://earthobservatory.nasa.gov/images/87011/flooding-in-iraq. (b): Hydraulic modeling image using HEC-RAS matching with the actual image (November 14, 2015)

between incoming runoff and stagnant, polluted water within the depression and to improve water quality before it is redirected. A deep artificial canal was also proposed, passing through the depression area to transport water directly to the Tigris River via a hydraulically controlled channel. The main storage is concentrated in the upper part of the artificial canal, allowing controlled discharge and minimizing the impact of pollution on the transported water.

Storage capacity of the depression

The water-harvesting methodology began by calculating the depression's storage capacity before any excavation work, based on topographic data (DEM) and the storage area (the storage tool in HEC-RAS software), to develop a model illustrating the depression's shape and depth variations and the upstream path.

The volume of incoming surface runoff

The volume of floodwater was defined as the area integral of the inundation depth over the submerged area, which represented the direct mathematical definition of volume in two-dimensional inundation modeling (Bates and De Roo, 2000). Floodwater volume was calculated by estimating expected depths during runoff events and correlating the depth values with the corresponding surface areas for each flood level. Water surface depth was computed based on the difference in water surface elevations and the terrain elevations (https://www.hec.usace.army.mil/confluence/rasdocs/rmum/latest/mapping-results/managing-results-maps?utm). The polygon volume feature with the depth selector tool in RAS mapper was used to generate tables and graphs illustrating the relationship between time, volume, surface area, average depth, and maximum floodwater depth through the Polygon Time Series. This procedure enabled the determination of the stormwater volume using Equation 1 (Bates and De Roo, 2000).

$$d\,(x, y, t)\; dA_{A}\; V(t) \qquad (1)$$

where: V is the volume of water, t is the time, A is the area of floodwater.

To enhance the depression's storage capacity while preserving the integrity of the surrounding land and avoiding potential adverse effects, a retention pond was designed upstream of the depression, with an artificial canal to transport water to an emergency regulator. This engineering intervention aimed to accommodate water volumes exceeding the base storage capacity and prevent sediment transport (Keyvanfar et al., 2021).

The choice of storage areas

To enhance the depression's storage capacity while preserving the integrity of the surrounding land and avoiding potential adverse effects, a storage area was designed upstream of the depression, with an artificial canal to transport water to an emergency regulator. This engineering intervention aimed to accommodate water volumes exceeding the base storage capacity, attenuate the peak discharge, and prevent sediment transport (Keyvanfar et al., 2021).

According to the concept of flood routing in channels, a channel may, in some cases, act merely as a conduit, allowing the flood wave to pass through with little to no attenuation. Actual peak attenuation, however, is only achieved with temporary water storage through controlled storage structures (Paiva and Lima, 2024).

Due to that the hydrological analysis showed that the lateral runoff was stored within the depression at safe levels without exceeding the natural storage limits, the runoff represented a part of balanced hydrological system in this area and excluded from the structural control scenarios. Therefore, this study focused on reducing the flood controlling by runoff coming from the north of the depression, as the most effective measure for mitigating the flood risk.

The choice of reservoir location

The location of the water reservoir was chosen to guide the flood analysis index, as it is situated within the area with the highest index value and reflects high flow velocity.

Furthermore, the proposed location was in the upstream of the simple entry point, which is represented by the river control system. This structure serves as a primary common point directly linked to the hydrological system.

Additionally, the proposed reservoir's location acts as a sediment trap, preventing sediment from entering the depression, regulating flow in the waterways, and improving drainage capacity. Based on the above, choosing a reservoir location outside the depression is a preferred option, as it is recommended to store water before it enters the depression while applying the best methods to reduce sedimentation inside the reservoir, since storing water in the depression has a negative impact on the quantity and quality of the water (Hilo et al., 2019).

The storage area design

The size of the depression and the total floodwater volume were calculated using HEC-RAS software. The volume of water causing the flood was extracted and compared with the volume obtained using the flood guidance method. The flood routing is identified using the continuity equations and storage equations (Alhumoud, 2022). The comparison validated the method and designed a reservoir to contain the resulting floodwater volume. The analysis of the storage area is based on the continuity Equation 2 (https://www.hec.usace.army.mil/confluence/hmsdocs/hmstrm/modeling-reservoirs/reservoir-routing-concepts-and-equations) and (Chow Ven Te et al., 1988).

$$Q_{in}(t) - Q_{out}(t) = \frac{dW(t)}{dt} \tag{2}$$

where: $Q_{in}(t)$ and $Q_{out}(t)$ are the inflow and outflow discharges [m^3s^{-1}], $W(t)$ is the stored water volume [m^3], and t is time [h].

The reservoir geometry was described using an analytical stage–storage relationship which represented by Equation 3 (Manfreda et al., 2021) and (Graziano et al., 2025):

$$W = \alpha h^{\beta} \tag{3}$$

where: h is the water level [m], α and β are the parameters that represent the reservoir shape.

The stage-storage relationship was used by processing DEM and represented by the elevation-volume (Loucks et al., 2017) in HEC-RAS software for routing analysis. The outflow discharge was expressed as a function of the water level through a stage–outflow relationship as shown in Equation 4 (Fiorentini and Orlandini, 2013) and (Gioia, 2016) of the form (energy conservation equation):

$$Q_{out} = c\, h^{m} \tag{4}$$

where: c is a discharge coefficient and m is an exponent dependent on the outlet type.

The governing equations were solved numerically using a finite difference scheme with a constant time step of Δt = 1 hour. The discrete continuity Equation 5 was written:

$$W_{t+\Delta t} = W_t + (Q_{out}{}^{-})\Delta t \tag{5}$$

where: $Q_{in}{}^{-}$ and $Q_{out,}{}^{-}$ are the average inflow and outflow discharges over the time step. At each time increment, the storage volume was updated, and the corresponding water level was obtained from the stage–storage relationship in HEC-RAS software. The outflow value was set at the average value of the Um Al-Jery regulator, which was designed to control the velocity and quantity of water flowing towards the Tigris River. The reservoir was assumed to be empty at the start of the simulation. (0 m^3). The highest storage volume reached during the routing process was used as the required storage capacity, as shown in Equation 6:

$$W^{*} = [W(t)] \tag{6}$$

The flood peak attenuation was quantified using the lamination ratio (7):

$$\eta = \frac{Q^*_{out}}{Q^*_{in}} \quad (7)$$

where: Q_{in}^* and Q_{out}^* are the peak inflow and outflow discharges [m^3s^{-1}]. The ratio between the maximum flood volume retained by the reservoir $W*$ and the flood volume W determines the flood-storage ratio w (Pirone et al., 2024) and (Gioia, 2016).

Water discharge to the Tigris River

The Um Al-Jery regulator was connecting the depression to the Tigris River. This regulator controls the flow of water from the depression towards the river during high-water periods or after the flood season.

The Um Al-Jery regulator has four 2 by 4 m gates with a discharge of 50 m³/sec at 32°39'28.79"N, 46° 7'54.60" E.

The regulator consists of four parallel discharge openings that allow gradual water release, as shown in Figure 5. This regulator controls water levels in the depression and provides a hydraulic safety factor that prevents water levels from exceeding design limits. The presence of this structure also allows for the release of large quantities of excess water after storage, ensuring the depression is drained after floods and maintaining the system's readiness to receive future surface runoff.

RESULTS

It was possible to determine the volumetric properties of the depression by integrating DEM data into HEC-RAS and using topographic analysis to determine its limits and shape. The findings demonstrated a direct relationship between the depression's volumetric capacity and the basin's overall slope and elevation distribution. The Figure 6 illustrates the relationship between the elevation and storage volume of the depression, calculated using the HEC-RAS software. The horizontal axis represents the cumulative storage volume (m³), while the vertical axis represents the water level (m). Two curves are shown: the first (in green) represents the user-inputted relationship for the storage area, while the second (in red) represents the values extracted from the terrain model (Cut from Terrain). A good convergence between these two curves is observed, indicating the accuracy of the topographic representation of the depression within the model.

At an operating elevation of 14 m, the Figure 6 showed that the corresponding storage volume was approximately 1,000,000,000 m³, representing the available capacity of the depression at this elevation. The auxiliary lines on the Figure 6 illustrated the method of projecting the elevation onto the curve and then reading the corresponding volume, which was the procedure used to determine the operational storage of the depression in this study. The curve showed that the storage volume increased almost steadily with rising water levels, reflecting a gradual progression in the depression's topography and the absence of sudden expansions in the water-covered areas.

The volume of incoming surface runoff

The depression couldn't hold the entire floodwater volume because the runoff exceeded its storage capacity, as shown in Figure 7. Based on these results, the storage area solution was adopted. This solution involves designing a dedicated area upstream of the depression to store additional water, thereby controlling runoff before it enters the depression. This structural approach directly

Figure 5. Um Al-Jery Regulator (https://maps.app.goo.gl/8wU4chQoir3dzMDr6)

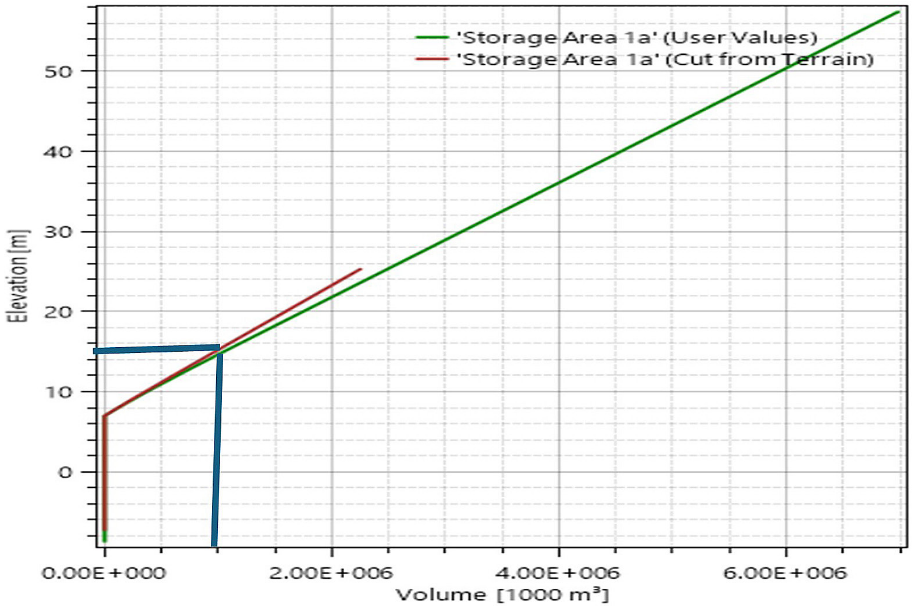

Figure 6. The elevation- volume diagram of natural depression

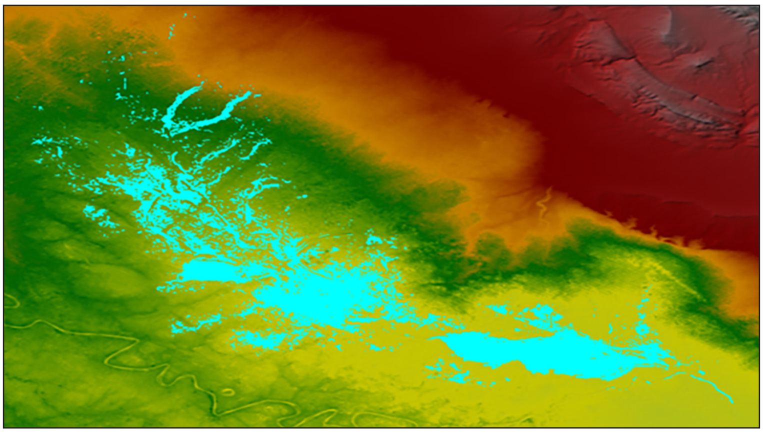

Figure 7. The volume of floodwater

reflects the modeling results and has proven effective in reducing water losses and mitigating the negative impacts associated with sediment accumulation. The flow in the hazard area was very high, as shown in Figure 8.

The storage area design

The time difference between the maximum inflow and the maximum outflow showed that it was possible to build a reservoir to hold floodwater and then release it as needed. The maximum inflow discharge was Q in = 500 m³/s, while the maximum outflow discharge decreased to Q out = 50 m³/s. To avoid numerical issues, previous studies assumed the flow was constant during the choking effect (Fiorentini and Orlandini, 2013), (Pirone et al., 2024). Note that this assumption serves numerical stability purposes and does not modify the physical interpretation of the routing results. Figure 9 indicates a significant reduction in the peak flood level. The volume of floodwater to be harvested in HEC-RAS was 38,377,000 m³, whereas, according to the flood routing method, the amount was approximately 35,267,966 m³. The reservoir was designed with a trapezoidal shape connected to a trapezoidal canal (40 × 3 m × 40 km with side slope of 1:3), as shown in Figure 10.

Water discharge to the Tigris River

Analysis of the outflow indicates that the flow is effectively controlled by the regulation system, as it remained below the inflow value for most of the flood period. At certain points, negative outflow values were observed, representing a reversal

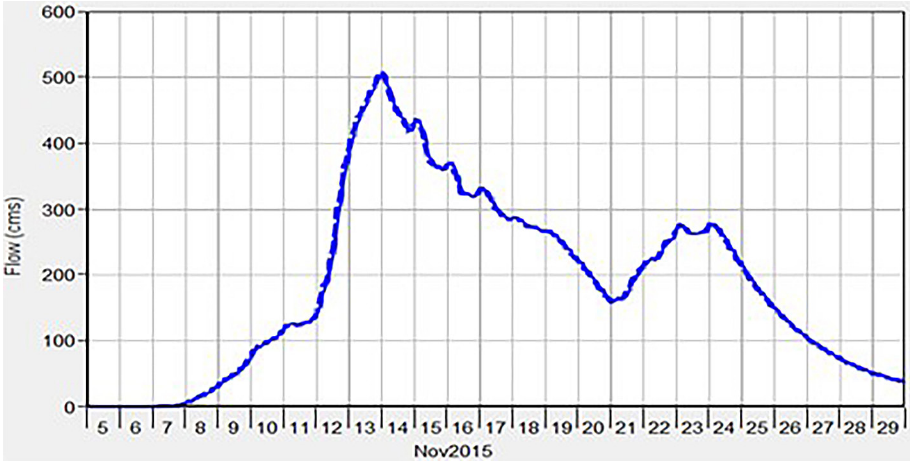

Figure 8. The flow in the flood hazard region

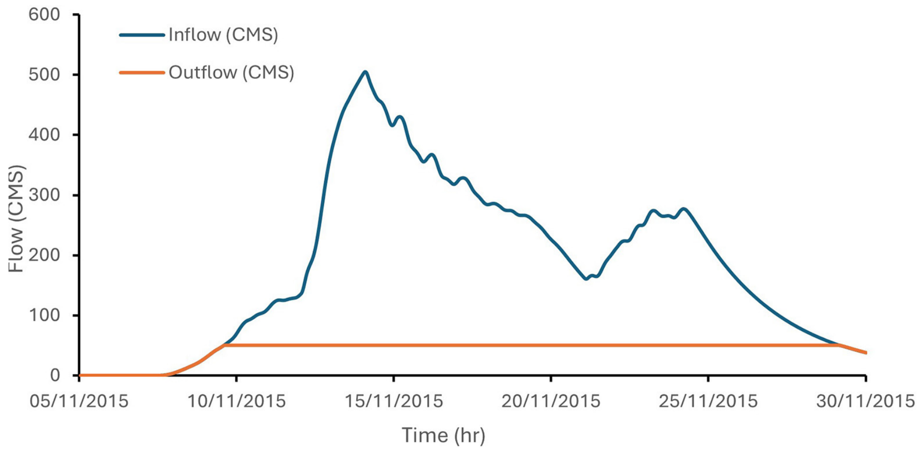

Figure 9. The relationship between inflow and outflow of proposed reservoir

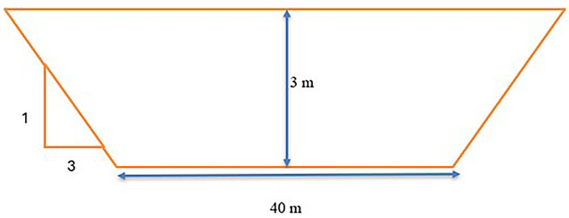

Figure 10. Dimensions of the trapezoidal canal

in flow direction due to the hydraulic interaction between the reservoir and the surrounding system. The agreement of the total floodwater volume that calculated using the HEC-RAS software and the total floodwater volume that calculated using the reservoir routing method was 91.9%. The results indicate that the reservoir played an effective role in reducing and delaying the peak of the flood by storing a portion of the flood volume and releasing it in a controlled manner, as shown in Figure 11, which demonstrates the reliability of the methodology used in this study and its potential application in the evaluation and design of flood mitigation reservoirs. The location of the regulator provides a stable hydraulic path to the Tigris River. Furthermore, the presence of unpaved roads on both sides of the canal facilitates maintenance and monitoring during periods of high flow. Accordingly, integrating this regulator into the proposed hydraulic system loop is essential for achieving integration between the upstream basin, the canal that passes through the depression, and the final discharge mechanism to the river. This reflects the effectiveness of the proposed solution in achieving the region's long-term operational and environmental objectives.

DISCUSSION

The results indicate that the reservoir played an effective role in reducing and delaying peak flooding by storing a portion of the flood volume

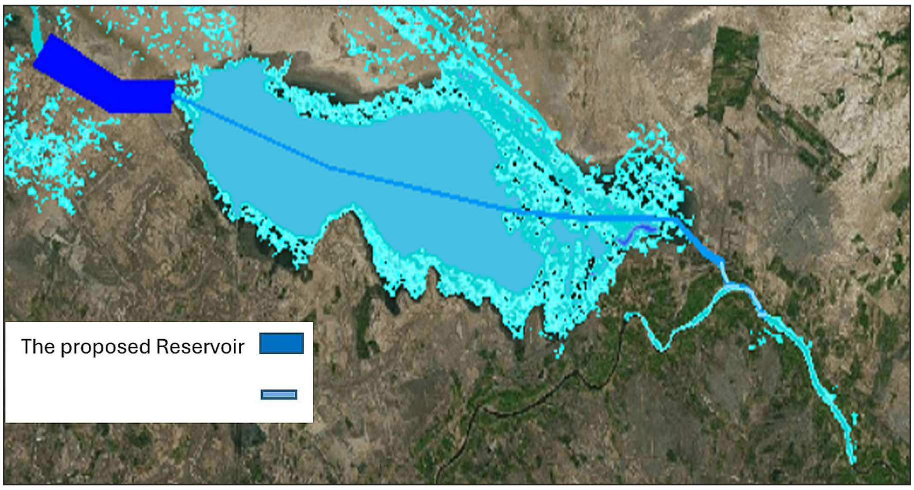

Figure 11. The proposed reservoir and artificial canal

and releasing it in a controlled manner was consistent with the study of Rahi et al., (2019) which has found similar hydrological environments in the same area of this study and has suggested to expand the depression to contain the floodwater coming from the depressions adjacent areas. The effectiveness of the reservoir's storage area in flood control depends not only on its size and flood intensity but also on its geometric shape as concluded in the study of Kaboosi and Jelini, (2017) which was studying a comparison between the performance of the several reservoirs with the similar sizes and different geometric shapes, the results showed the high performance to reduce the flood for some shapes comparing with the other shapes. The significant decrease in outlet discharge relative to the inlet reflects the reservoir's efficiency in mitigating the risks of peak flooding.

Furthermore, the time delay between the peak inlet and outlet flows is an important indicator of the reservoir's success in modifying the hydrograph, a key objective in the design of flood mitigation structures. Moreover, the agreement between the numerical results and the analytical calculations demonstrates the reliability of the methodology used in this study and its applicability to the evaluation and design of flood mitigation reservoirs.

CONCLUSIONS

The study's findings show that the surface runoff in the examined area exceeds the depression's natural storage capacity, which requires the implementation of a comprehensive floodwater management system. Field visits reveal potential sources of water pollution from nearby activities, suggesting that moving the water-harvesting area away from these sources will improve the water quality. Additionally, analysis indicates that building a reservoir upstream with a low longitudinal slope could decrease sediment flow into the proposed canal, thereby boosting the hydraulic system's efficiency.

Furthermore, the assessment of the Um Al-Jery regulator confirmed its crucial role in controlling water discharge into the Tigris River. The regulator ensures safe operational capacity and maintains stable water levels within the depression. Therefore, combining the storage area or reservoir, the canal, and the regulator creates an effective floodwater management system that enhances water quality and reduces sediment load reaching the Tigris River.

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