Exploiting Dam Sustainable water shead Resources in the Face of Water Scarcity: A Case Study Qarahanjeer, Kirkuk, Iraq.

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Abstract

Water shortage is a severe problem for the Kirkuk region, necessitating the search for long-term solutions. The goal of this project is to use watershead resources to construct tiny dams that will help meet population demands and improve water management. A geographic information system (GIS) and a digital elevation model (DEM) with a resolution of 12.5 meters were used for the hydrologic analysis. Mask techniques and hydrological characteristics, including fill, flow direction, flow accumulation, stream order, watershed delineation, slope, and aspect, have been used to determine the basin's watershed border. The Strahler approach is used to identify the watershed's essential morphometric features, such as area and perimeter, stream length, and number of stream orders. Elevations in the 676.0 km² Qarahanjeer region range from 402 to 1001 meters. These evaluations are essential for making well-informed decisions when assessing the hydrologic characteristics of any place in Iraq. The application of GIS technology markedly decreases time, cost, and effort, rendering it an essential instrument for such assessments. The results revealed several suitable sites for building dams, which will contribute to improving groundwater management. Models for dam design utilizing spatial data were also introduced. The construction of a dam at a 640-meter contour line, with a dam Homogeneous Earth Dam length of 360 meters, a height of 32 meters, and a capacity of 77,9 million cubic meters, in the northeast of the study area.

Keywords: Digital elevation model, geographic information systems, watershed, Kirkuk, Iraq

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Introduction

Due to the erratic rainfall patterns caused by climate change, increasing groundwater extraction, unsuitable water management regulations, and poor land use, most of the basins in Iraq have struggled in recent years to obtain enough water. To lessen the effects of water scarcity during droughts, emphasis must be placed on making effective use of all the regional water resources. The climate of the research area, which varies from semiarid to humid, is typical of Mediterranean areas [1]. A large amount of surface water runoff is lost to evaporation because rainfall is the region's primary water supply. Furthermore, surplus water flows into rivers and valleys without benefiting nearby ecosystems or communities. Surface hydrological morphometric signal analysis is among the best scientific methods for controlling and analysing water resources [2,3]. By combining remote sensing with GIS methods, morphometric analysis using digital elevation model (DEM) data can be completed quickly, accurately, and affordably [4]. Watershed delineations in the area were identified, and countering was utilized to identify appropriate locations for the construction of dams along the Kassa River in the study area.

Since water is necessary for both human life and local economic growth, water resource management is crucial. The classification and management of watersheds to carry out water conservation initiatives are made possible by these fundamental facts, which include topography, basin, channel length, and area. The use of geographic information systems (GISs) for hydrological evaluations of basins and the investigation of topographical changes is growing [5].

To fully utilize the potential of high-resolution satellite platforms and provide significant additional information on land resources and future management initiatives, modern remote sensing and geographic information system (GIS) technologies are essential tools [6-7-8]. Accurate spatial understanding of soil moisture, texture, and consistency is crucial for irrigation planning, crop selection, and soil management [9].

The accuracy of digital elevation model (DEM) data obtained from remote sensing is essential to the hydrological study of watersheds [10]. To detect and solve a variety of basin-level issues, such as deforestation and flood risk, [11] investigated the application of GIS and remote sensing techniques in the hydrological and morphometric study of watersheds. A basin's spatial, linear, and elevational properties are crucial attributes that are utilized in morphometric analysis using GIS and remote sensing techniques, improving the knowledge of the hydrology of the area [12]. Digital elevation models (DEMs) were used to gather geomorphological data for the drainage basin. Basin divisions, slope, direction, and places influencing upstream water flow were among the factors assessed [13]. To identify surface water within the basin and put policies in place to address problems with water quality and quantity, basin delineation was performed [14].

Digital elevation models may be used to determine hydrological characteristics, including fill, flow direction, flow accumulation, and the configuration of streams and basins [15-16]. This study seeks to determine suitable locations for dam construction through the application of remote sensing and GIS technologies. In response to the regional reservoir capacity requirements, a proposal has been made for the suitability of a dam site along the Greater Kassa River. Dams are highly important for supplying water for irrigation and generating electricity, contributing to the economic development of the area.

Material and Methods

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Study area:

The Qarahanjeer district, which spans 676.0 km² and is situated in Zone 38 N, is the research area. It is located between the coordinates of 35°23' - 35°41'N and 44°30' - 44°50'E (Fig. 1). located 265 kilometers north of Baghdad's capital and 35 kilometers northeast of Kirkuk city. There are thirty settlements in all. The average highest temperature in the area is 43.9°C in July, while the average lowest temperature is 4.9°C in January. The average yearly rainfall is approximately 14.65 mm. Table 1 displays rainfall data from the Iraqi Agrometeorological Center, which are available at http://agromet.gov.iq/eng/month_selected.php. The geological and hydrogeological consisting of Tertiary rocks and Quaternary deposits. Its basic rocks are composed of limestone, marl, and gypsum [21].

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Act**	**Nov**	**Dec**	**rainfall average**
Rain	13.1	26.2	44.4	**19.5**	19	18.2	**0**	**0**	**0**	0.8	45.4	8.2	177.3

Table 1 Yearly rainfall for 2024

Soil type and land form are major components that affect the processes of rainfall and surface runoff [17]. The lowest percentage of gravel and sediment samples was observed, and clay dominated the study area in northern Iraq. The clay content ranges from 1.53 to 38.97% [18].

The soil map from the Ministry of Agriculture in Baghdad was used as a base map. Soil classification for the study area was performed via digitized soil mapping (DSM), and the resulting soil map was classified as clay brown soil. The highest clay content was recorded at the the site's susceptibility to water erosion and physical degradation, as well as the nature of the soil permeability and movement within it, this is certainly due to the nature of the sediments, which are characterized by slopes, in addition to being influenced by the nature of the distinctive geological and geomorphological formations at this site [19].

Methodology:

The basic technique of the investigation is depicted in Figure 2. The “Alaska Satellite Facility (ASF) Digital Elevation Model (DEM)” (https://www.asf.alaska.edu/sar-data/palsar/) is one of the datasets collected to locate profitable watershed harvesting locations in Qarahanjeer Kirkuk. Watershed analysis, stream analysis, and flow analysis are just a few of the tools ArcGISpro.3 offers hydrological analysts. The watershed function was utilized to determine the flow direction or flow accumulation to derive watershed boundaries from a DEM. The extracted hydrological data are shown in Figure 2. Pour spots were determined once the watershed was defined using raster data that represented the flow direction. To determine a viable dam building location, a

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contour line was established for the research region.

Step Methodology:

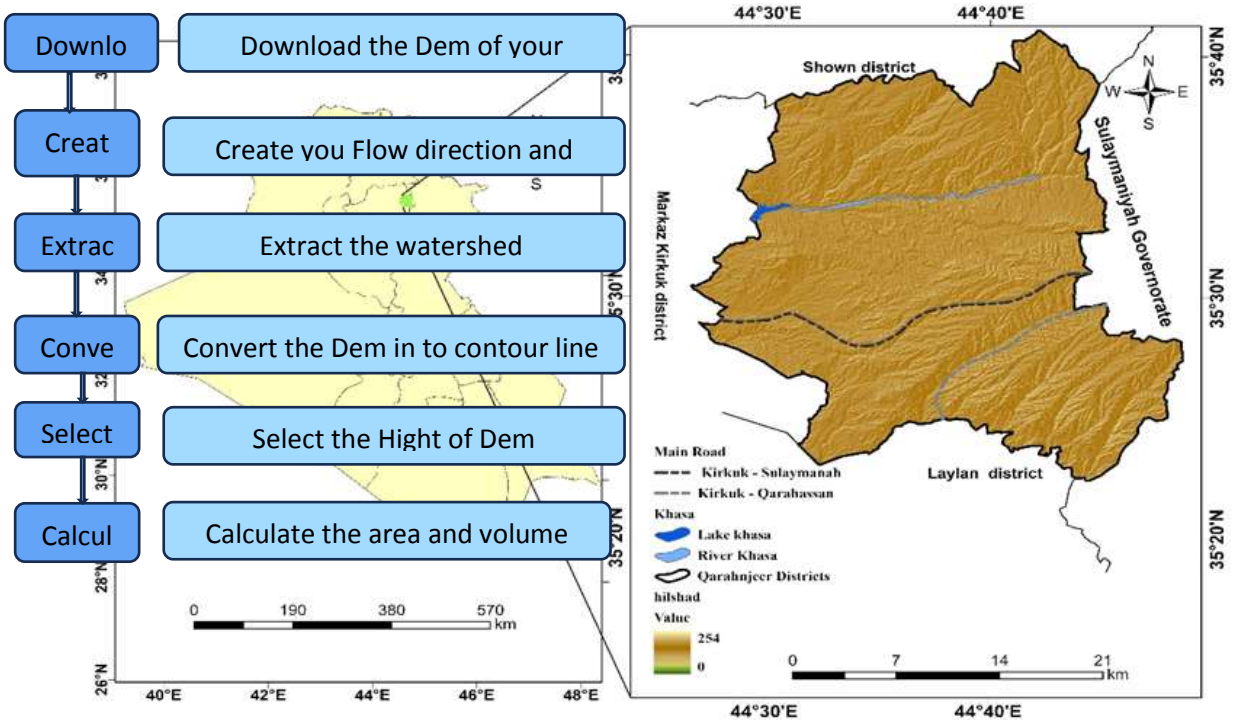


Figure 1 Geographical location of the research area.

Fill

The first step involves creating a DEM that accurately depicts the terrain of that region

and is devoid of sinks or depressions. False sinks may represent actual natural depressions in the landscape or result from sample point mistakes during DEM creation [20]. To fill the sinks in the DEM layer, the Fill Sink tool from the hydrology toolbox is utilized. This method creates a continuous and hydrologically correct surface by progressively lifting the depressions until the lowest outflow point is attained, as shown in Figure 3.

Direction of Flow

This stage is crucial for accurately modelling hydrological processes and determining how water travels throughout the terrain [21]. The direction in which water exits each cell in a filled elevation raster is shown by a flow direction raster.

The flow direction raster contains eight distinct values, as shown in Figure 4. The direction code, which indicates which way the flow is leaving each cell, is displayed

by each number. ArcGIS' eight-direction (D8) flow model was employed. With this method, a cell's flow direction is assigned to one of eight nearby cells with the steepest distance-weighted gradient. The eight output pathways are for the eight adjacent cells that the flow may enter. In the west portion of the cells, the majority of the cells flow in the direction of the cells adjacent to them. These cells have a value of 16, which is a dark blue tint, according to the map.

Flow accumulation

Depending on the type of input flow direction raster utilized, the flow

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accumulation tool processes and accumulates flow in each cell in a different way (D8). A stream network may be constructed by using a flow accumulation tool to determine the number of cells above each cell on a surface that contributes flow to a specific cell. The stream grid output is a stream order determined by the overall flow through the drainage network. This procedure is helpful for hydrologically describing the research region and determining the order of magnitude of each segment as well as the fundamental structure of the stream system [22]. shows flow accumulation in a study area from a location of high elevation flowing into an area of lower elevation.

Stream Order

The water flow rate to each cell is determined by the flow direction. Eight deterministic patterns are used to set the orientation of the center cell to decide how it flows to its nearby cells [23]. The drainage network is given a numerical order using the Strahler classification [24]. The stream order within the study region is shown in Figure 5. The longest waterway in the research region was used to construct a dam in the northeastern portion, and the stream line was categorized into five streams according to the parameters of the study. Because it helps store water and enhances the quality of life for locals, this dam is seen as a strategic move to improve water resource management and promote environmental sustainability in the area.

Watershed Delineation

Basin area is an important morphometric variable that clearly affects the volume of water discharged into the basin. There is a direct relationship between basin area and water discharged into the basin. The Snap Pour Point tool is used to ensure that important cumulative flow points are chosen precisely when drainage basins are defined using the watershed tool. Watersheds can be a part of a relatively large watershed or comprise relatively small subwatersheds known as subbasins. Afterward, characteristics are assigned, watershed borders are defined, and this watershed layer is rasterized into polygons. This stage is necessary for accurate hydrological structural classification and analysis [25].

Pour locations, which are locations of importance that symbolize dams, were used to identify watersheds. The lowest point where it meets a river is referred to in this work as a spillway. Pour Point is situated in the 208-meter-high region that crosses the spillway, according to Figure 8 (a and b), the watershed map of Qarahanjeer. Water comes here from somewhere else. The watershed’s total area is approximately 77,923 million cubic meters.

Slope

Because it offers crucial information on watershed characteristics and geographic morphometric qualities, slope analysis is highly significant. The slope grid displays the rate at which each cell's elevation varies in relation to the cells adjacent to it. Runoff and erosion are more common in regions with steep slopes, which might severely negatively affect the soil of the research area [26]. The dam construction site and the northeastern portion of the site’s slope (0–8.1) are depicted in Figure 6.

Aspect

This approach is essential for understanding how terrain orientation affects hydrological processes [27]. The aspect is a metric that determines each cell's maximum rate of elevation change in relation to its neighboring cells. From a conceptual standpoint, it symbolizes the direction of the sharpest slope, similar to

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how a hillside is oriented. As shown in Fig. 7, the aspect value for every cell in the input raster is calculated.

Contour maps to adjacent cells.

Contour lines are essential tools in hydrogeology for identifying groundwater basins by representing the topography of the land and elevation and for determining the direction of groundwater flow:

The contour lines on a map provide a crucial tool for portraying elevation. Digital elevation models (DEMs) rely on these lines, but they can become disconnected or overlap while being digitized; therefore, precise reconnection is required for good modelling [28]. A 640 m contour line was used to construct the dam in the northeastern part of the research area.

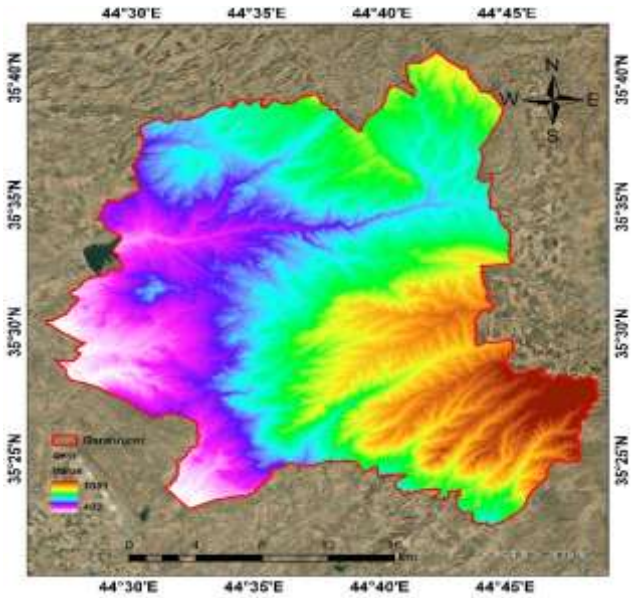


Figure 3 Digital elevation model location

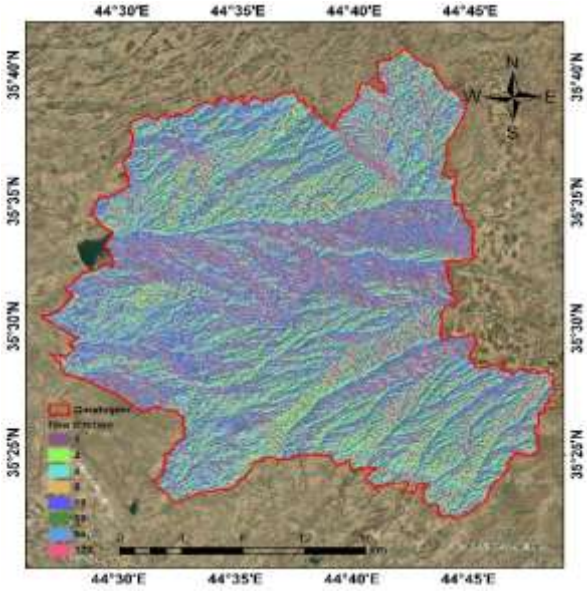


Figure 4 Flow direction

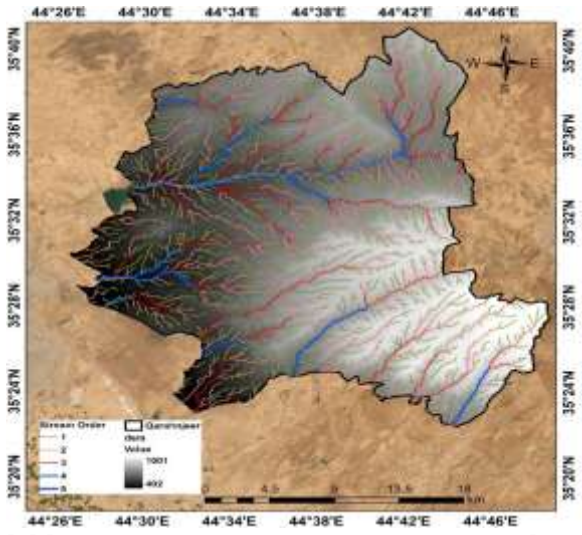


Figure 5 Stream Order

groundwater flows vertically from high-level contour lines to low-level lines, revealing the course of the basin.

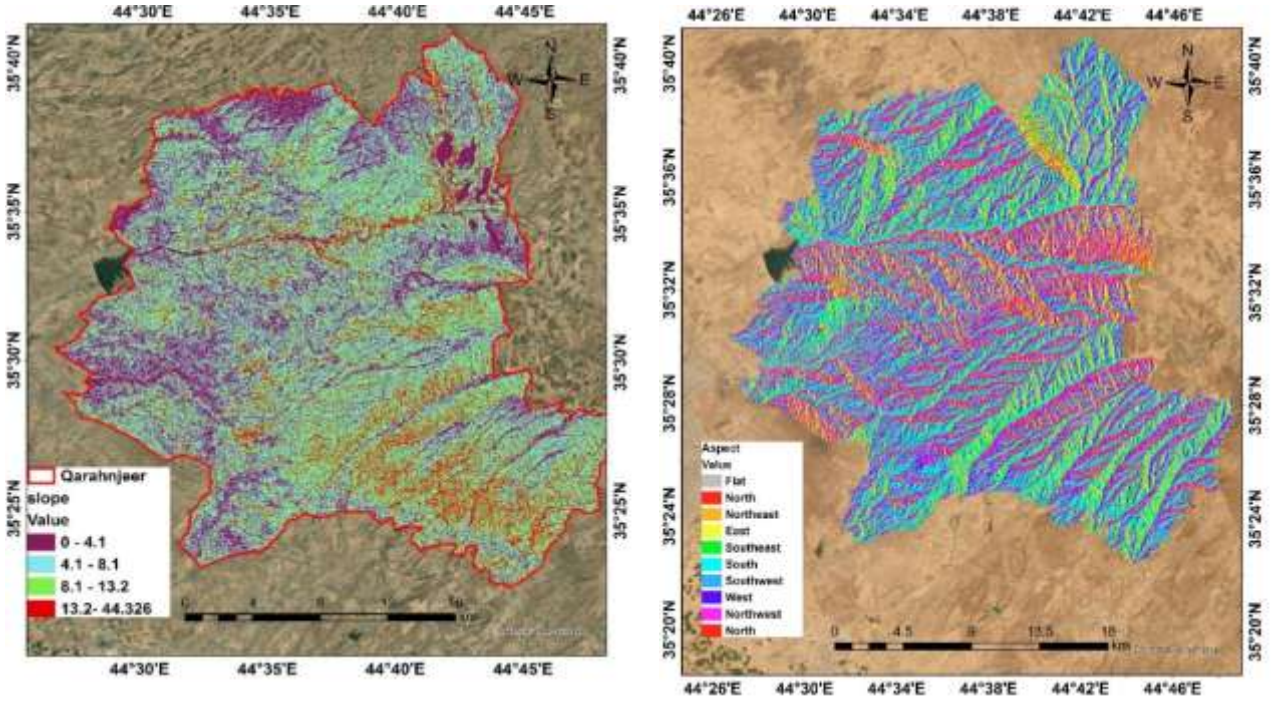


Figure 6 Slope Location

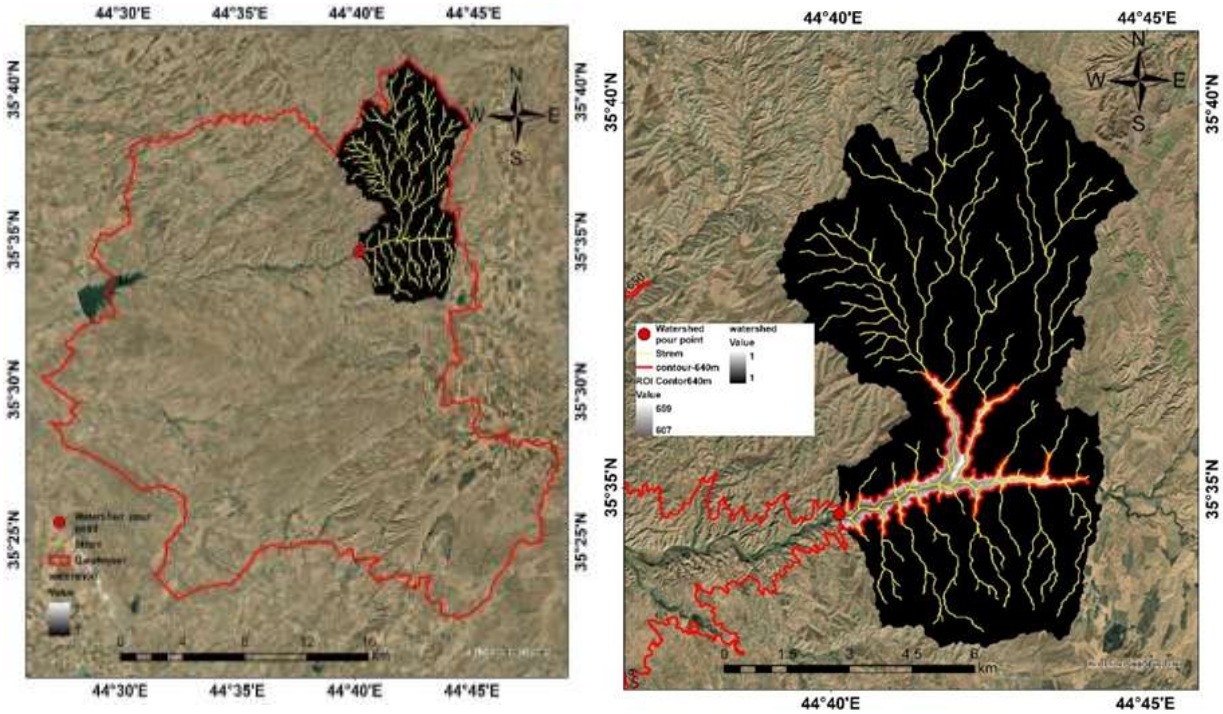


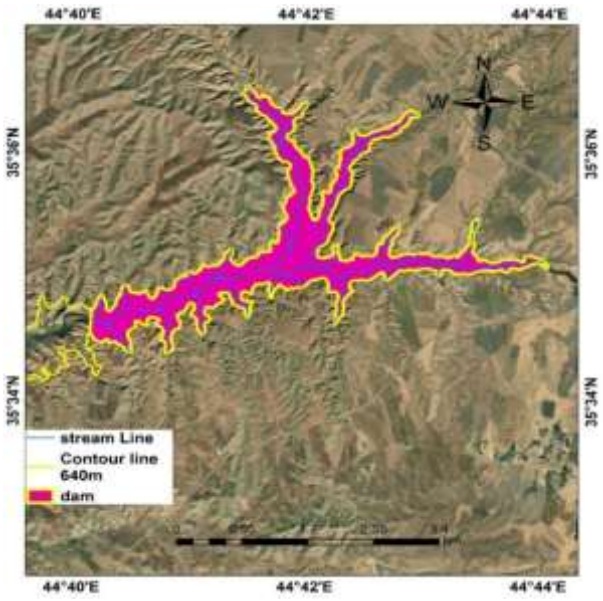
Figure 7 Aspect Location

Figure 8 (a and b) Watershed delineations in the study area

Results and Discussion

Hydrological surface parameters

As shown in Figure 3, ArcGIS Pro uses a directional coding method to indicate the flow direction, where each number represents a particular cardinal or intercardinal direction. Powers of two make up the coding values: 1 for East Kirkuk, 2 for Southeast Kirkuk, 4 for South Kirkuk, 8 for Southwest Kirkuk, 16 for West Kirkuk, 32 for Northwest Kirkuk, 64 for North Kirkuk, and 128 for Northeast Kirkuk. These variables, which add up to 128, are utilized in a conditional method to enhance the flow accumulation layer. ArcGIS Pro.3 was used to create a stream order map for the research region using the Strahler technique. Stream orders are categorized from one to five, with the smallest streams being assigned order one (1), the largest streams being given order two (2), and the highest-order streams being assigned order five (5), as seen in



Figures 5 and 6.

The dam in the northeast zone in the study area is shown in Figure 9.

Slope analysis is essential to the development of watersheds and the assessment of morphometric features in geomorphological research. Because of higher rates of erosion and rapid runoff, soil deterioration in the study region may occur more quickly on steeper slopes. Five different groups were created using the slope analysis data. The slopes of the Qarahanjeer Basin in the upper northeastern region range from 0 to 8.1 degrees, while the slopes of most of the study region have gradients greater than 8.1 degrees. On the other hand, the southwest of the research region was impacted. is rather flat, as seen in Figure 6. The aspect analysis revealed the direction of the slope within the terrain of the study area. The majority of the basin's northeastern quarter has complicated terrain. A 640-meter-high contour line was used to construct the dam. The dam's 360-meter length and 32-meter height allow it to resist the water pressure caused by its storage capacity. Its 77,9million cubic meter storage capacity shows how well it can handle water. Figure 9 depicts the dam

To improve the management of water resources, water harvesting dams are essential, especially in dry and semiarid areas that lack surface water inflows. They help temporarily store floodwater and rain for use in drinking and agriculture or replenish groundwater reserves. Increasing the amount of water available, increasing plant cover, preventing desertification, lowering the likelihood of floods or flash floods, and helping rural settlements grow by supplying short-term water supplies are all reasons for their significance. Therefore, the success of water harvesting projects depends on careful planning and sustainable dam management to ensure maximum benefit and minimize potential environmental and hydrological damage.

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Conclusion

The results of this study highlight how crucial it is to combine GIS with hydrological modelling to determine the best locations for identifying tiny dams in the Kirkuk region. A digital elevation model was used to comprehensively assess the morphometric characteristics of the Qarahanjeer watershed, which is 676.0 km² broad at altitudes between 402 and 1,001 m, using Strahler's approach. To support choices for the management of water resources in the area, the findings of the identification of watershed borders, flow accumulation, and stream order provided vital hydrologic information.

These findings provide solid evidence that well-planned dam construction may significantly increase aquifer recharge and subsequent sustainable water usage.

An efficient way to increase the availability of water resources in northeastern Kirkuk is to create a 360-meter dam at the 640-meter contour line. The dam would have a total length of 360 meters, a height of 32 meters, and an approximate storage capacity of 77.9 million cubic meters. To optimize site selection and save time, money, and effort in hydrological evaluation, our tool's use of spatial data and GIS technology was essential.

This emphasizes the necessity of using cutting-edge geospatial techniques for planning water resources, with a focus on circumstances in arid and semiarid areas such as Iraq. To ensure the practical and long-term feasibility of such dam projects, further studies must incorporate socioeconomic analyses and ground verification. In the end, these initiatives can lessen water stress, support agriculture in arid regions, and aid in the growth of stable communities.

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