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Original research

Development of Water Resources in Wadi Dihmit to Reclaim New Agricultural Lands

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Abstract:

Addressing water scarcity requires innovative approaches, technological advancements, and sustainable water management practices. The main objective of the current study is to estimate the quantity of stored surface water to be used with the existing groundwater, whose locations and distributions were determined from the gathered field measurements and data, for reclaiming the new agricultural lands in the Wadi Dihmit region. This study used Geographic Information System (GIS), Watershed Modeling System (WMS), and Remote Sensing (RS)to determine areas that are affected by flash floods and delineate the watersheds of Wadi Dihmit. GIS was used to assemble information from different maps, satellite images, and Digital Elevation Models (DEMs) to select the best location for constructing an obstruction dam. Wadi Dihmit is located in the Eastern Desert of Egypt and the eastern south region of Aswan. Wadi Dihmit is the largest Wadi in the Eastern Desert of Egypt after Wadi Al Allaqi. It starts at a distance about 25 kilometers southeast of the High Dam. The total area of Wadi Dihmit is 4925 km^2; more than 34% of this region is sandy and valley deposits, so the chance to reclaim this region is high. It is necessary to use modern irrigation methods in the reclamation lands of Wadi Dihmit. Based on the existing irrigated areas, which are surrounding Nasser Lake, it is possible to cultivate some kinds of plants, that can adapt to the high rates of temperature, evaporation, and salinity such as olives, dates, grapes, beat, corn, wheat, and medical plants.

Keywords Water resources, GIS, WMS, RS, and Wadi Dihmit.

1. Introduction

Water resources management is a multidimensional field that involves planning, development, conservation, and allocation of water resources to meet the diverse needs of society while ensuring environmental sustainability. Effective water resources management is critical for achieving water security, supporting economic activities, and maintaining the health of ecosystems (Priyan, 2021).

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RS and GIS provide a wide range of tools for determining areas affected by floods and delineating watersheds.RS technology along with GIS has become the key tool for loading hazard and risk maps for vulnerable areas and for synthesizing a database in a spatial framework to create a flood risk map that can serve as guidelines to decision-makers for potential anticipatory measures, better land use planning, and flood risk management under climate changes. Torrents and flash flooding vulnerability are among the most recurring and devastating natural hazards, which affect human lives and cause severe damage throughout the world. The risk is associated with the extreme torrents is more present than ever, by taking into account the global climatic changes and increasing the risk of more frequent heavy precipitation. Torrents represent the processes that have the highest impact because of the high speed of their development and their place of origin, which make them difficult to predict. This study introduced an analysis approach by using the tools of GIS and RS to determine the areas that are affected by flash floods and delineate the watersheds.

Water resources management includes many fields. To ensure the equitable and sustainable use of water resources, there are social, economic, and environmental factors (**Purvis et al., 2019**). Ensure the availability of water supply for different sectors, can be considered a primary goal of water resources management. These sectors include agriculture, industry, energy production, and domestic use. (Nivesh et al., 2023). Another goal of water resources management is water allocation to make a balance between the needs of different sectors and the equitable access of water resources among various stakeholders (Kazemi et al., 2022). Water quality is an important goal of water resources management. It aims to protect human health and the environment (Gupta et al., 2021). Proper infrastructure planning and management are very important for optimizing water supply, reducing losses, and ensuring efficient water delivery to users (Zeinalie et al., 2021). To make a successful water resources management, it is very important to have effective water governance, including the development of policies, regulations, and institutional frameworks that guide decision-making. Good governance practices help address conflicts and promote cooperation among different water users and stakeholders (The World Bank, 2022). Climate change poses additional challenges to water resources management. It affects rainfall patterns, increases the frequency and intensity of extreme weather events, and changes the availability and distribution of water resources (Zhao and Boll, 2022).Water management practices have followed a supply-oriented, concentrating on the development of infrastructure to increase water supply (Dirwai et al., 2021). This field includes the construction of dams, reservoirs, canals and irrigation systems to capture and store water for various uses (Choudhury et al., 2022). The goal was to meet the increasing demands for agriculture, industry, and domestic water supply (UNESCO, 2021). One of the key features of traditional water management approaches was the centralized control and distribution of water resources (Haddad et al., 2023). Water was managed by government agencies or large-scale irrigation schemes, which regulated water allocation based on predefined criteria. Water rights and permits were often allocated based on historical usage or ownership, leading to inequalities in access to water resources (Lin et al., 2020). However, traditional approaches to water management face several limitations and challenges. One significant issue was the inefficiency of water allocation and distribution systems (Bhandari and Kaur, 2023). Due to aging infrastructure, inadequate maintenance, and outdated technology, a substantial amount of water was lost through leakage, evaporation, and inefficient irrigation practices. This resulted in a waste of water resources and reduced overall system efficiency (David, 2019).

Chen (2022) used the integration application of GIS for mapping the flood hazard in the Dadu

River basin for simulating disaster effects via visualization for easier interpretation of outputs in the form of hazard maps. (Cabrera and Lee, 2020) used a spatial assessment, by GIS with seven criteria, such as elevation, rainfall, soil type, slope, drainage density, distance to the main channel, and population density for Davao Oriental in Mindanao of the Philippines. Alimi et al. (2022) processed and analyzed satellite data of Metropolis using a GIS environment. Hermas et al.(2021) assessed flash flood events by using RS and GIS data to investigate the impact of the October 2016 flash flood in the Ras Gharib area. Omran (2020) identified the stream networks and the drainage patterns in Aswan Governorate by the integration between RS and GIS data for determining the directions of running water and the probable sites for storing it. Donia, (2020) pointed out that RS and GIS technology can be used effectively to extract a watershed and monitor flash flooding in the Furan catchment, Sinai, and Wadi Hashem on the northern coast of Egypt. Asmaa et al.(2022) used the integration of the combination of GIS techniques and RS data to allow for the quick and efficient mapping of flood-prone areas of Wadi Queih, in the Red Sea of Egypt. Prama et al.(2020) studied the impact of flash flooding and assessed the vulnerability of The Dahab region in the Sinai Peninsula via consideration of a maximum storm event as a worst-case scenario. El Bastawesy et al.(2019) assessed the qualitative and quantities of surface and subsurface hydrological parameters for a selected drainage basin, as a case study in the South Eastern Desert of Egypt in the Red Sea coastal areas by using RS and GIS. Hamdy et al.(2023) applied a model within the WMS program to create the hazard map for flash flooding in the Hail region. Abu El-Magd(2019) generated a flash flood hazard susceptibility map for the study area of Wadi Bada, west of the Suez Gulf, by using GIS. Saha and Agrawal (2020) calculated the extent of past floods and land use/land cover (LULC) classes affected by flooding by using the GIS and RS techniques in the Prayagraj District of India. Ramadan et al.(2022) applied the integration of GIS and WMS with HEC-HMS to visualize and assess flood events in the study area of Wadi Sudr, South Sinai in Egypt. Shah et al.(2020) provided a broad framework for understanding the hazard elements and the vulnerability assessment as components of the risk assessment process with its spatial dimension by using GIS as a guide to prevent or mitigate risk. The main objective of this study is to estimate the amount of stored surface water in Wadi Dihmit region by constructing a dam. This is for maximizing the benefit from the stored water and the existing groundwater together in reclaiming new agricultural lands in this region.

2- Materials and Methods

2.1- Description of Wadi Dihmit and Data sources

In the Eastern Desert of Egypt, Wadi Dihmit is considered the largest Wadi after Wadi Al Allaqi. It starts at a distance about 25 kilometers southeast of High Aswan Dam. The geographical coordinates of Wadi Dihmit region are approximately located between 33° to 33° 30' longitude and 23° 45' to 24° latitude, as shown in Figure 1.

The study utilized various data types, including topographic maps, a DEM, a geological map, and satellite images, to get information about the LU/LC classification of Wadi Dihmit. GIS program tools arranged the water channels of the study area into three orders according to the Strahler order.

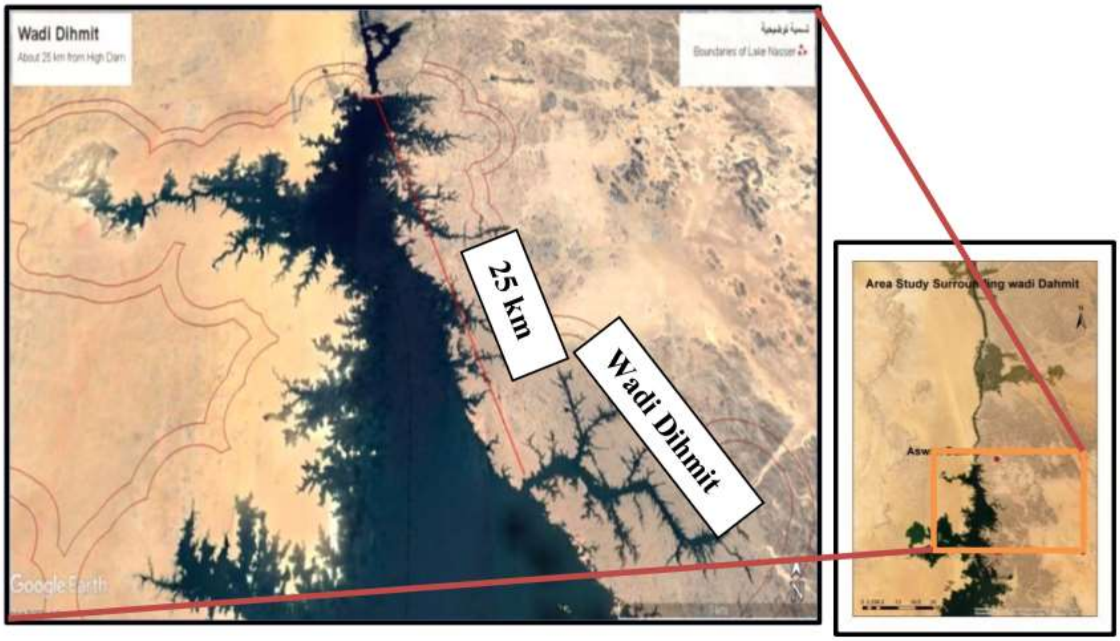

Fig.1 Location of the study area

2.2- The Research Methodology

WMS program was used in this study. The mathematical model (HEC-1) was applied to simulate the drainage hydrograph resulting from the rainy storm of the basin. The unit hydrograph was concluded by the SCS dimensionless method based on the geomorphology characteristics of the basin. The data of rains in the study area were estimated by using the designed rainy storm with 10.85 mm depth, which was registered from the Aswan rains station gauge and 50 years return period of rains as shown in Figure 2 and Table 1.Figure 2 shows the time series of rainfall within the study area and illustrates that the maximum rainfall depth was 10.85 mm in 1988.

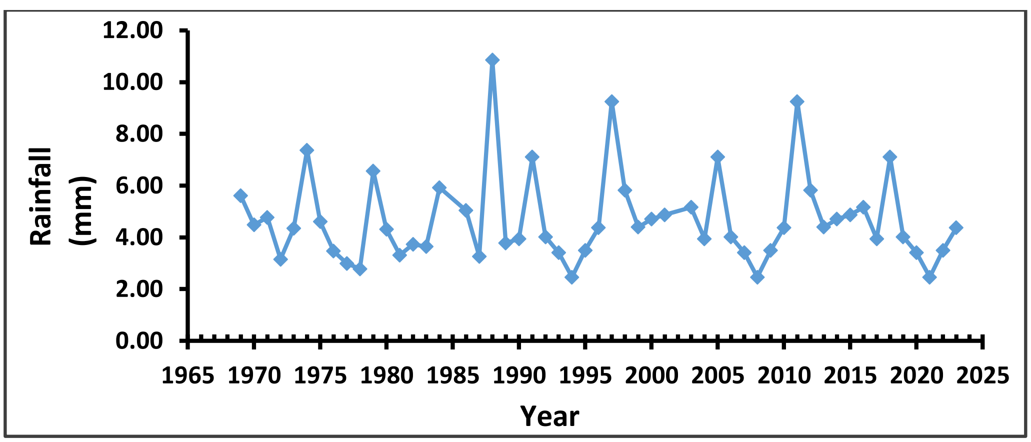

Fig.2 Time series of rainfall

Table 1. Relationship between return period and rainfall depth

Return period (years)	3	5	10	25	50	100	200
Rainfall Depth (mm)	4.58	5.80	7.36	9.26	10.85	12.33	13.80

The existence of groundwater in the study area depends on many factors. The main factors are the water level in Nasser Lake and the seasonal water floods. The other factors are geological, such as the faults and cracks due to tectonic movements of basic rocks and sandy stones. By using GPS, the coordinates of the four wells in the Wadi Dihmit region were determined during the field survey. Figure 3 shows the locations of the existing wells in Wadi Dihmit region, while Table 2 shows the coordinates of the wells.

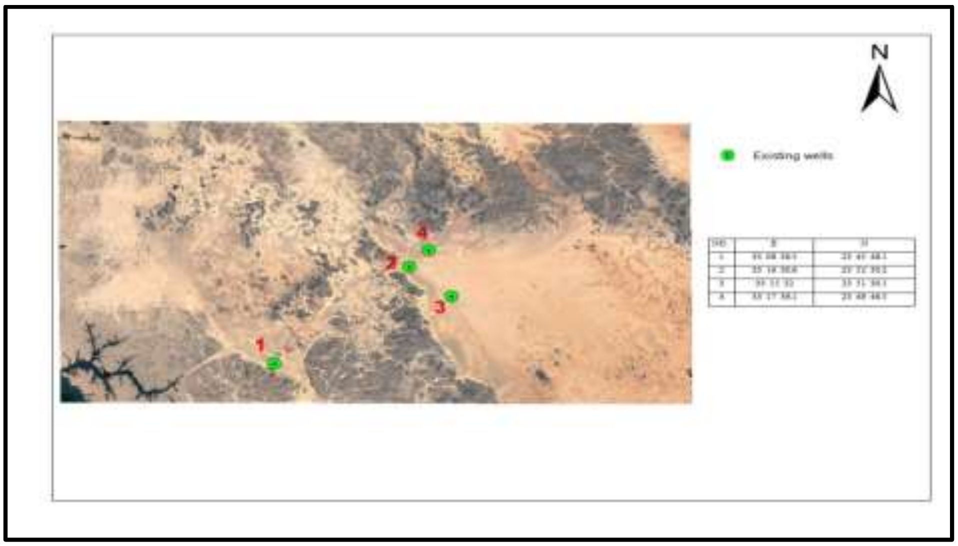

Fig. 3 Locations of existing wells in the Wadi Dihmit region

Table 2. Coordinates of the existing wells in the Wadi Dihmit region

Number	E	N
1	33° 08' 36.5"	23° 45' 48.1"
2	33° 16' 30.6"	23° 52' 30.2"
3	33° 15' 32.0"	23° 51' 30.1"
4	33° 17' 39.1"	23° 49' 46.5"

The geoelectrical survey was used in evaluating groundwater due to information scarcity and lack of wells in the study region. This method relies on measuring the vertical change in the electrical resistance of the saturated and unsaturated geological formations. Eighteen electrical surveys were carried out in the study area. The Swedish SAS 1000 - ABEM device was used to conduct these field electrical surveys. The measurements are carried out through the four

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electrodes, which are installed inside the ground and the measuring point is in the middle of the distance between the four electrodes.

3. Results and Discussion

3.1. Analyzing the Digital Elevation Model of Wadi Dihmit

By using GIS, the DEM of Wadi Dihmit and the surrounding areas was prepared as shown in Figure 4. This figure presents the different levels of the study area. A cross-section (A-B) through the study area was made to represent the gradation of levels corresponding to distances from the west direction near Nasser Lake (point A) to the east direction near the Red Sea Mountains Chains (point B), as shown in Figure 5. From the CS, the levels of land range between (160-200) meters in the west direction near Nasser Lake after that, they get higher in the east direction to reach 500 meters near the Red Sea Mountains Chains.

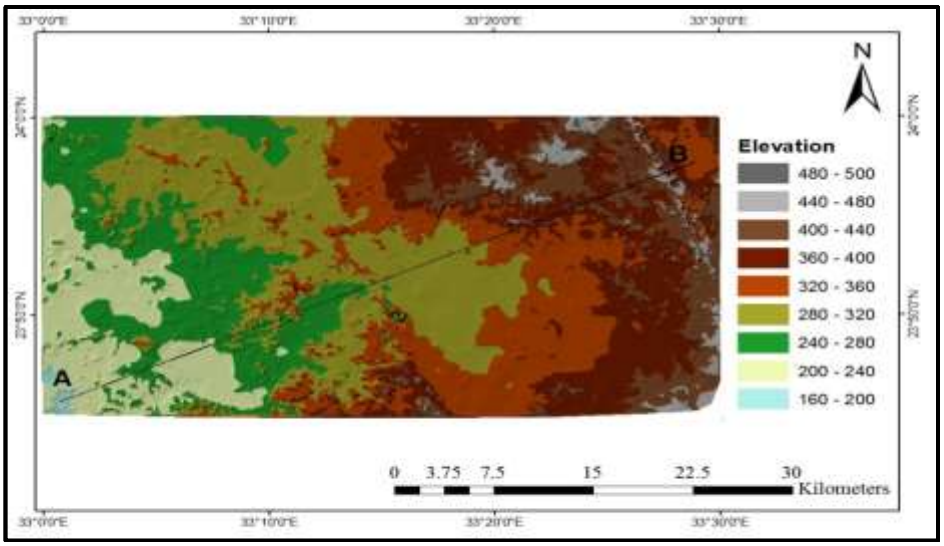

Fig. 4 The digital elevation model of Wadi Dihmit

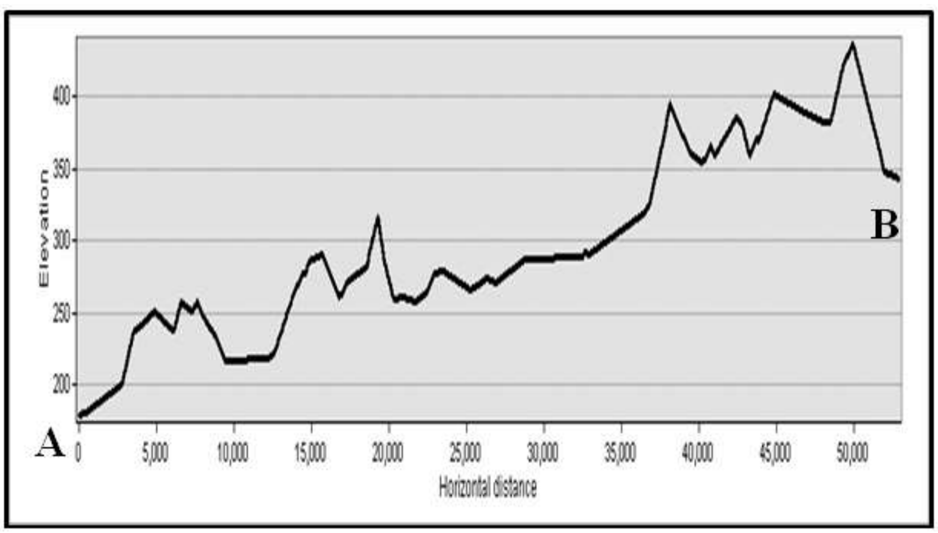

Fig. 5 cross-section (A-B) passing through the study area

3.2. Classification of Lands in the Study Area

By using GIS, program in analyzing the satellite images of the study area, which were downloaded from the USGS Earth explorer. Figure 6 shows the classification of lands in Wadi Dihmit, as the following: paved roads, high rocks, medium-height rocks, high flat lands, and valleys.

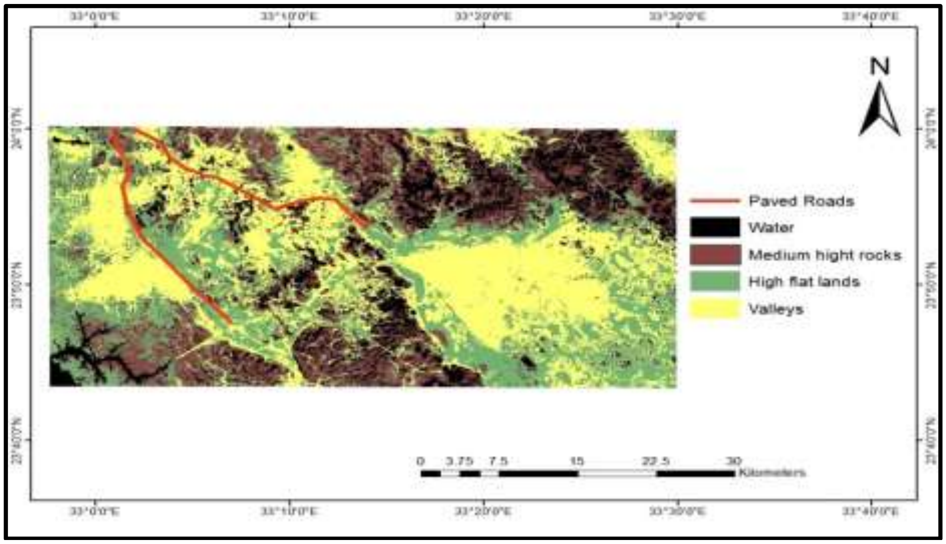

Fig. 6 Classification of lands in Wadi Dihmit

3.3. Analyzing the Streams of the Study Area

By using GIS program tools in analyzing the main streams of Wadi Dihmit, the characteristics of the streams, which have ranks 1, 2, and 3 are shown in Figure 7 and Table 3, the sheet flow channels are assigned as rank 1in green color. The secondary channels or shallow flow channels are assigned as rank 2 in blue color. The channels in red color are known as open channels and assigned as rank 3.

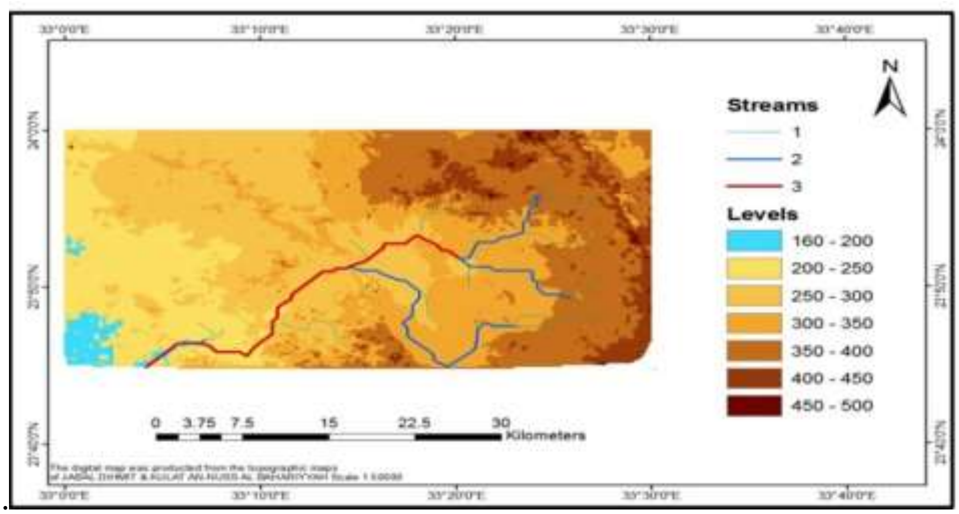

Fig. 7 The main streams of Wadi Dihmit on the digital elevation model

Table 3. Characteristics of the streams

Number of streams	17
Minimum length (km)	0.72
Maximum length (km)	25.26
Sum of lengths (km)	123.60
Mean length (km)	5.68

3.4. The Watershed and Slopes of the Study Area

By using GIS program tools the watershed of Wadi Dihmit is shown in Figure 8, which indicates the outer boundaries of the watershed, the streams inside it and the Aswan rain gauge. Figure 9 shows the gradation of slopes in Wadi Dihmit, which makes water flow in the streams from the east to the west direction. Table 4, shows the morphometric characteristics of the studied Wadi, which include the total area, the outer perimeter, maximum length, average elevation, maximum watercourse length, and slope. Figure10, shows the streams and flow directions of water in Wadi Dihmit.

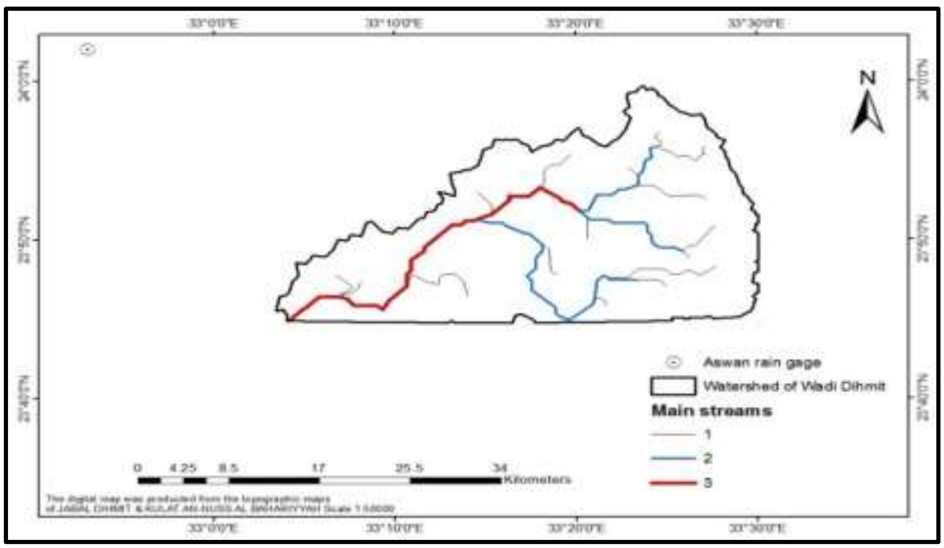

Fig. 8 The watershed of Wadi Dihmit and Aswan rain gauge station

Table 4. Morphometric characteristics of Wadi Dihmit

Basin Characteristics	
Area (km^2)	4925
Perimeter (km)	135.50
Maximum length of basin (km)	130
Average elevation of the basin (m)	350
Maximum water course length (km)	25.26
Maximum water course slope	0.022

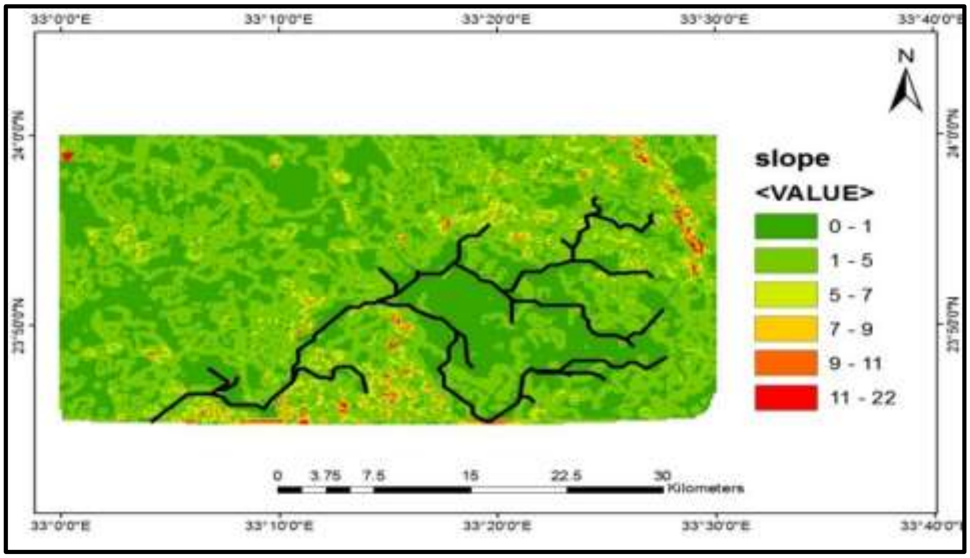

Fig. 9 Slopes of Wadi Dihmit

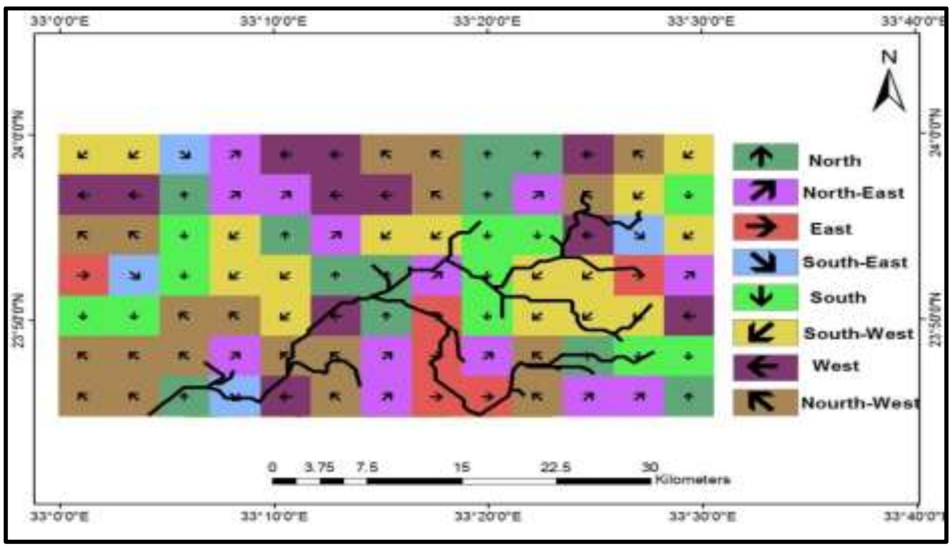

Fig. 10 Streams and flow directions of Wadi Dihmit

3.5. Results of the Hydrological Model

The unit hydrograph, which is created by the SCS dimensionless method based on the geomorphology characteristics of the basin, is shown in Figure 11. Based on the field survey of the study area, the soil samples have sandy clay loam. From the table of runoff curve number for arid and semi-arid regions, the grade of soil is (C), and the Curve Number (CN) is 80.00, because there is a sagebrush with grass understory, and the hydrology conditions are weak. (MWRI, 2020). Table 5 shows the results of the hydrological analysis of Wadi Dihmit. This hydrograph is formed within about 17 hours of rainfall duration and the peak time of this hydrograph was after 5 hours from the beginning of the rainfall.

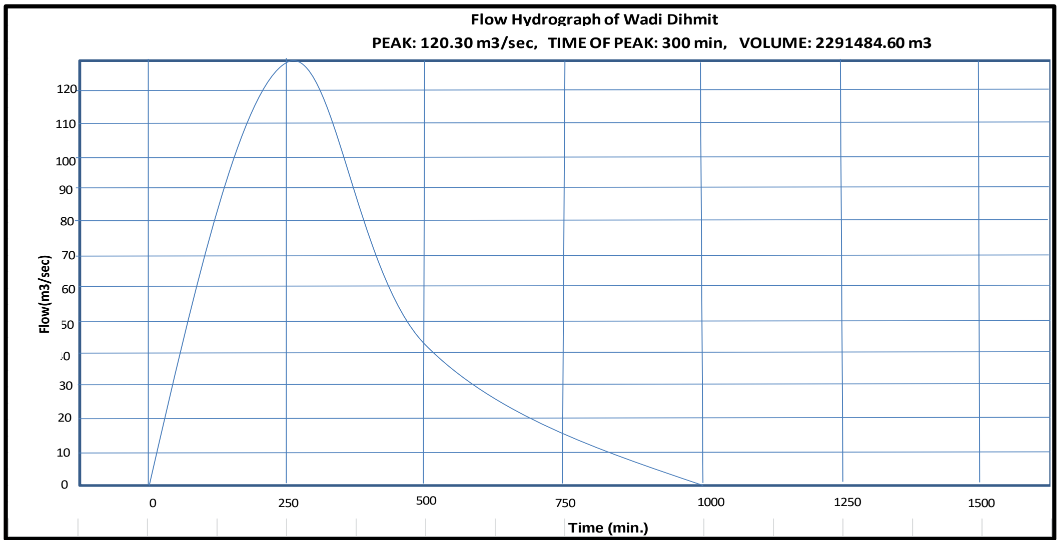

Fig. 11 Flow unit hydrograph of Wadi Dihmit

Table 5. Results of hydrological analyses of Wadi Dihmit

Name	The total amount of water (m.m^3)	Max. discharge (m^3/sec)	Lag-Time (hour)	Peak time (hour)
Wadi Dihmit	2.29	120.30	5.79	5

3.6. Study of Constructing an Obstruction Dam

From the hydrological results for the total amount of water due to the expected rains in the Wadi Dihmit region, the need to construct an industrial work is very important to store flood waters and replenish the underground reservoirs. From the field visits and the inspections of the soil types, it was found that the study area contains desert hills with low and medium elevations consisting of sandstone rocks and iron oxides. These hills are characterized by steady slopes and disjointed rocks of different sizes. The tops of these hills consist of solid and cohesive rocks.

Two trials were made to choose the best place for constructing an obstruction dam.

The first trial:

Construct two separated dams as shown in Figure 12, the first dam with a total length about 750 m, and the difference between the top and the bottom of the dam is 12 m as shown in Figure 13. The second dam with a total length about 1800 m and the difference between the top and the bottom of the dam is 40 m as shown in Figure 14. The total length of the two dams is 2550 m.

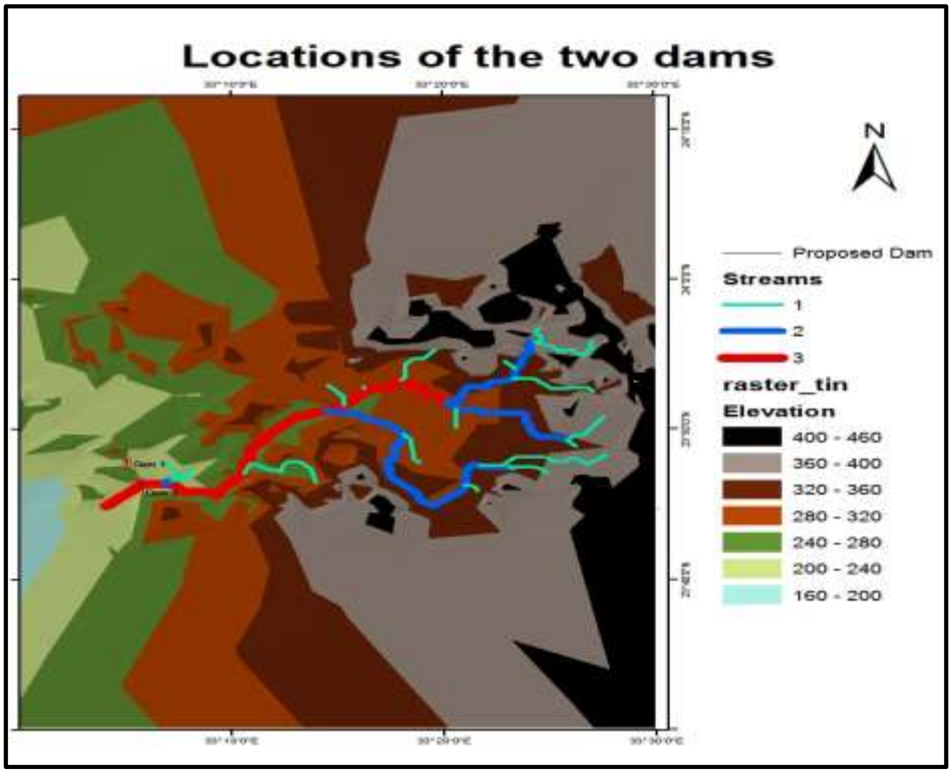

Fig. 12 The two-separated dam

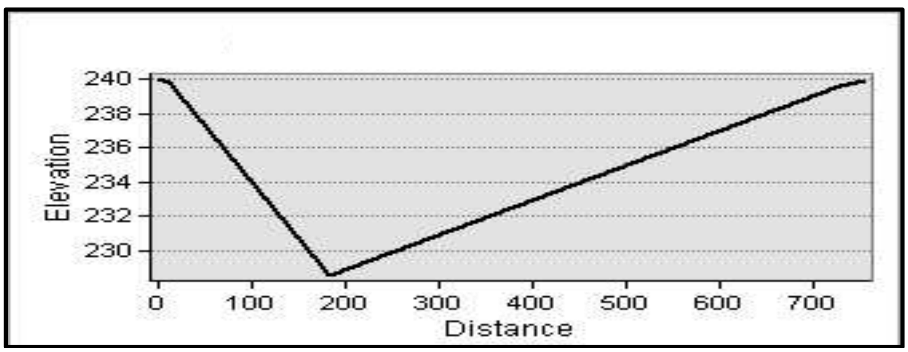

Fig. 13 C.S of dam1

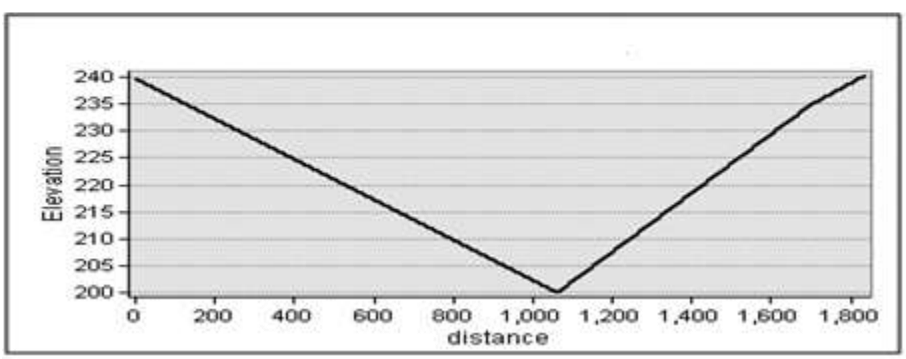

Fig. 14 C.S of dam 2

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The second trial:

Construct a dam as shown in Figure 15. The site and the centerline of the dam is shown in Figure 16. The total length of the dam is 965.30 m and the height of the dam is 40 m as shown in Figure 17.

From the previous two trials, the best solution to construct dams in this region is the second one, as it is needed to construct one dam only but in the first trial, it is needed to construct two dams. In addition, the total length of the dam in the second trail is less than the length of the proposed dams within the first trial, so implementing the second trail will be less costly. The coordinates of the proposed obstruction dam are as follows:

X1 = $33^{\circ}5'40.53''$E,Y1= $23^{\circ}46'24.456''$N

X2 = $33^{\circ}5'46.994''$E, Y2= $23^{\circ}45'53.636''$N

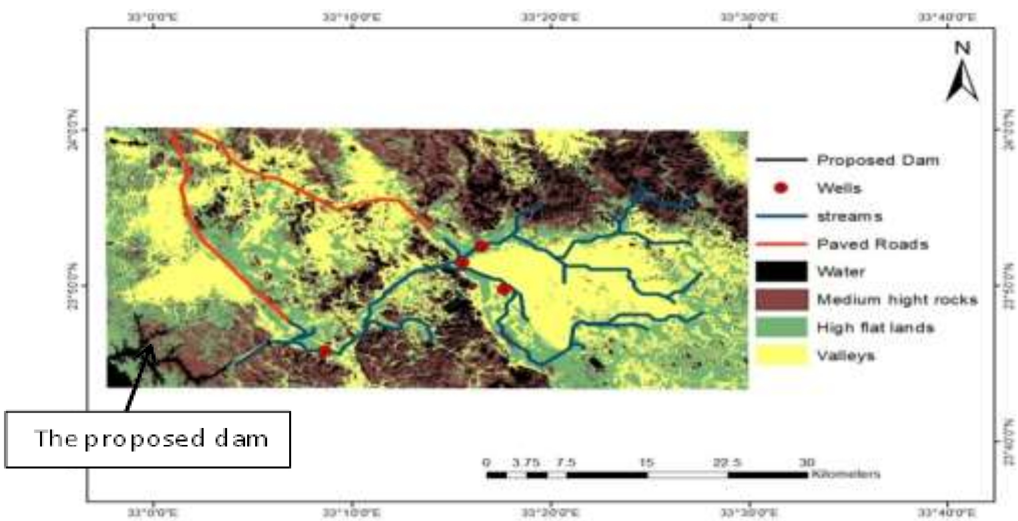

Fig. 15 Site of the proposed dam, streams, and wells in the study area

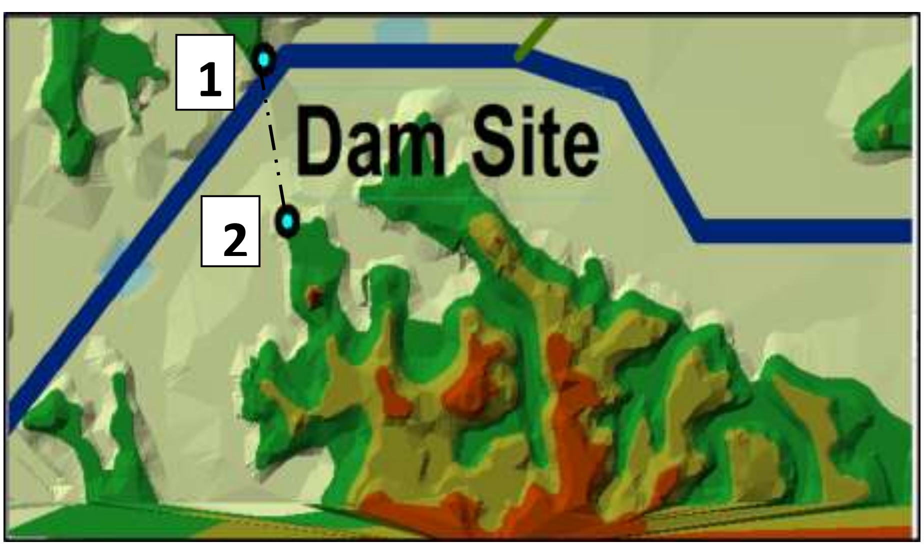

Fig. 16 The site and the centerline of the proposed dam

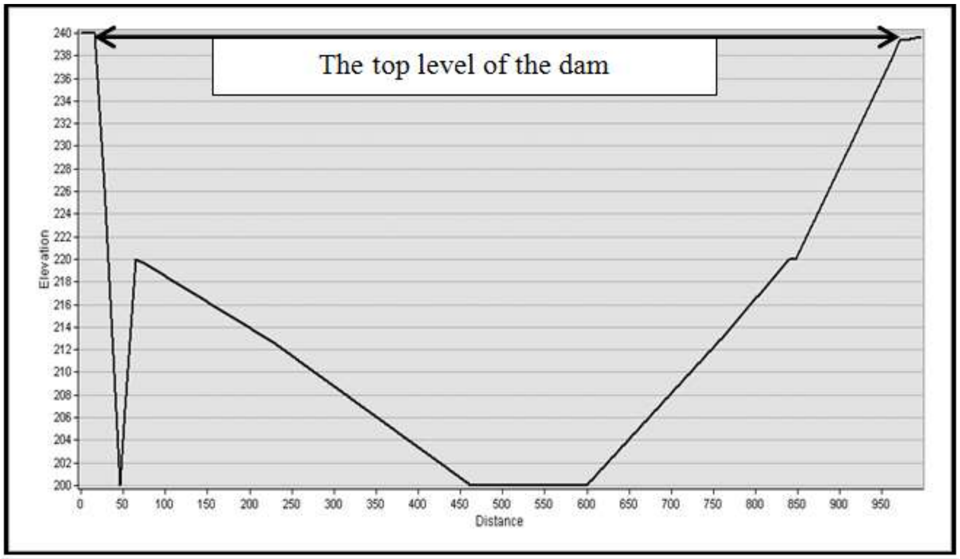

Fig. 17 Cross section of the dam site

The type of obstruction dam is rock-fill dam, due to the availability of aggregate materials in the study area. The body of the dam could consist of aggregate layers with graduated diameters, covered with a 50 cm layer of sandstones as a protection layer. This type of dam is useful in prolonging the flow time of the torrent and impeding its movement. These types of dams contribute to the recharge of the aquifer layers in the study area and attract residential communities near the proposed dam site. It is very important during the design of the obstruction dam to make an unpaved road on top of it to facilitate the movement into Wadi Dihmit.

3.7. Results of the Electro-Geophysical Survey

The eighteenth geoelectrical surveys were made by using the Swedish device (SAS 1000 - ABEM). The field geoelectrical surveys were distributed over three sections in the study area. Table 6, shows the summary of data and results of the geoelectrical surveys of the Wadi Dihmit region. The distribution of the implemented electrical components is as follows:

1. The entrance road of Wadi Dihmit – Umm Jabal, three components were surveyed ,numbers 4, 5, and 6.
2. Road of Dihmit – Aswan Iron and Steel Company, three components were surveyed along this road, numbers 10, 11, and 13.
3. Entrance road of Wadi Dihmit- Barnes, six components were surveyed, numbers 1, 2, 3, 7, 12, and 16.
4. Wide valley of Aswan Iron and Steel Company, south of the asphalt road of Barnes at Wadi Al-Arab, five components were surveyed, numbers 8, 14, 15, 17, and 18.
5. North of Barnes Road at Aswan Iron and Steel Company, one component was surveyed, number 9.

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Table 6. The results of the geoelectrical surveys of the Wadi Dihmit region

Survey number	Coordinates		Surface level of earth	surface level of water (m)	Depth of base rocks
	North	East			
1	23 52 13.2	33 27 41.5	360	--	80
2	23 52 53.6	33 24 55.7	340	--	35
3	23 52 48.3	33 18 17.4	280	--	50
4	23 45 44.1	33 8 27.5	190	165	180
5	23 41 54.1	33 13 20.2	190	--	40
6	23 47 34.1	33 60 35.3	225	205	100
7	23 53 18.9	33 22 23.5	315	--	200
8	23 50 44.5	33 21 56.9	310	--	250
9	23 53 46.5	33 18 9.10	290	270	175
10	23 48 22.4	33 10 30.6	225	190	90
11	23 51 16.4	33 44 46.8	295	245	110
12	23 52 23.8	33 16 21.5	295	283	120
13	23 59 44.9	33 17 54.8	280	272	180
14	23 49 08.1	33 19 32.0	300	--	120
15	23 46 57.6	33 20 05.4	290	--	95
16	23 50 53.8	33 30 08.7	400	--	--
17	23 49 41.0	33 24 33.5	330	--	--
18	23 47 42.1	33 23 35.9	330	--	--

By using GIS tools, the locations of the electrical surveys of Wadi Dihmit were mapped as shown in Figure 18.

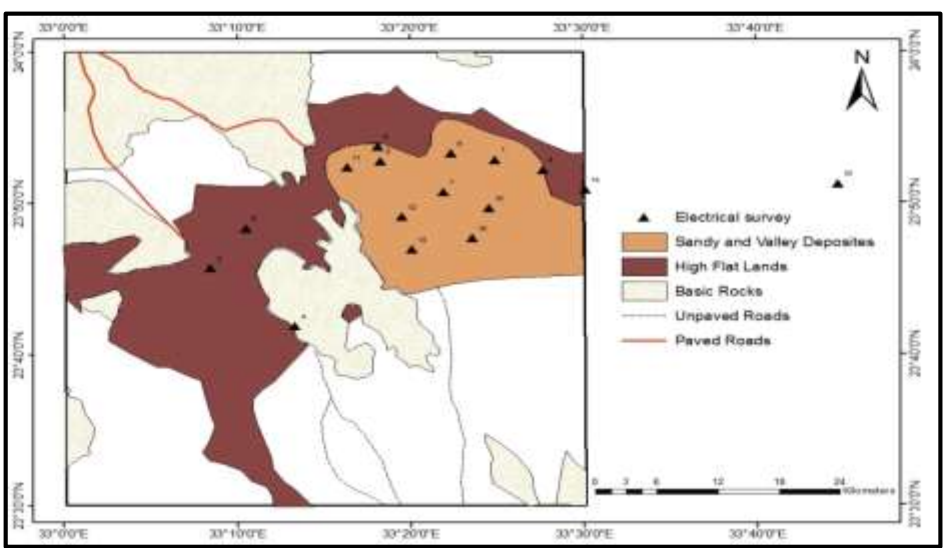

Fig. 18 Electrical surveys of the study area

From the laboratory analysis of the water samples of wells, which were made in the chemical laboratory of the High Dam, the salinity of groundwater ranges between (1000 - 1500 ppm) which is suitable for agriculture some kinds of plants without treatment.

3.8. Feasibility of the Groundwater in the Study Area

From the available hydrogeological data about the study area as well as the results of the geoelectrical surveys, it is possible to infer that the study area can be divided into the following regions, as shown in Figure19.

1. The first hydrological unit is in blue. This region is situated in the western part of the study area. The feasibility of groundwater is expected to be from low to medium. This region may be fed with water from Nasser Lake and flash flood waters.
2. The second hydrological unit is in yellow. This region is situated in the eastern Part of the study area. The feasibility of groundwater is expected to be from non-existent to weak. The potential for groundwater availability is relatively low in this area compared to the western part.
3. The annual recharge rate in the eastern Desert, in which the study area is located, is 2.70 bm^3 from Nasser Lake and 300 mm^3 from rainfall.
4. The safe groundwater withdrawn from the wells in the study area is $30m^3/hour$ with daily work about 6 hours.

3.9. Classification of Soil in the Study Area

The classification of soil is very important to know the characteristics of lands in the study area to be reclaimed by the available water resources. During the field survey in the study area, 50 bores were made to get samples from them. The depth of each bore is ranged between 100 - 150 cm. Sieve analysis tests were made in the soil laboratory of the High Dam to classify these soil samples. The results of sieve analyses are shown in Table 7.

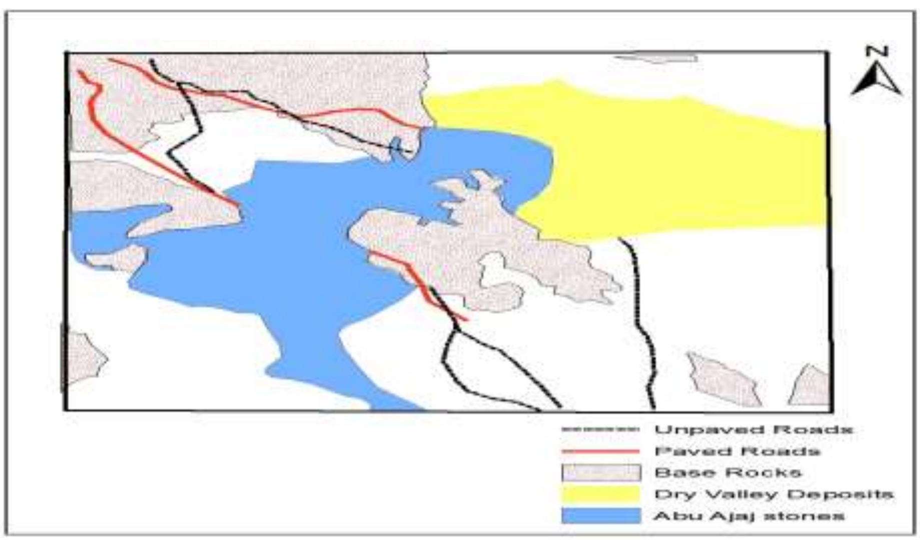

Fig. 19 The hydrological units in the study area

Table 7. Soil classification from sandy and valley deposits of Wadi Dihmit region

Soil type	%
Sand	37.49
Silty Sand	38.46
Sandy Silt	23.67
Silty Clay Sand	0.38
Total	100

4. Conclusion

The basic conclusions of the current study can be summarised as follows:

- The total area of Wadi Dihmit is about 4925, more than 34% of this region is sandy and valley deposits, so the chance of reclamation in this region is high.
- The feasibility of groundwater is expected to be from low to medium in the western part of the study area. This region may be fed with water from Nasser Lake and flash flood waters.
- The field measurements demonstrated that there are four productive wells in Wadi Dihmit region, the production of them is 30 m^3/sec with 6 hours' work daily.
- According to the obtained results, it is concluded that the total stored amount of water is about 2.29 m.m^3 with a maximum discharge about 120 m^3/sec.
- Constructing an obstruction rock fill dam on the main stream of the study (rank 3), with a total length about 965.30 m and the height of the dam is 40 m will maximize the benefits of the expected water from rains and flash floods in this region.
- It is necessary to use modern methods of irrigation in the reclamation lands of Wadi Dihmit.
- Based on the existing irrigated areas, which are surrounding Nasser Lake, it is possible to cultivate some kinds of plants, which can adapt to the high rates of temperature, evaporation, and salinity.
- The suitable plants to be cultivated in the newly reclaimed lands are olives, dates, grapes, beat, corn, wheat, and medical plants.

This research work leads to various promising topics for future investigations. The following recommendations are suggested for future studies:

1. Conduct extensive hydrological studies on the study area, especially geophysical survey and drilling monitoring and productive test wells to determine the quantity, quality, and direction of groundwater in the region and the possibility of exploiting it.
2. Establishing a network of climate meteorological stations to cover the study area.
3. It is necessary to study the side effects of on Nasser Lake, which resulted from the

development of Wadi Dihmit.

4. Conduct the necessary hydraulic tests on the available production wells, to determine the hydraulic parameters of the reservoir in this region, which include the determination of facilities, which can be used as a base of exploitation and development plan for the region.
5. This study is considered a preliminary study, and it is necessary to conduct economic and technical feasibility studies for Wadi Dihmit before starting any project.
6. It is not recommended to raise water from Nasser Lake to irrigate the agricultural lands in the study area because it is required to raise water more than 100 meters in some places, which may lead to the uneconomical viability of the project.

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