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Morphometric and Hydrological Analysis of Migdal Valley Basin

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Abstract:

This research aims to analyze the morphometric and hydrological characteristics of the Migdal Valley basin using Geographic Information Systems (GIS) and Digital Elevation Models (DEMs) to understand its hydrological behavior and evaluate flood hazards. The study identified that the basin covers an area of 83.72 km², with a length of 20.36 km and an average width of 4.11 km, indicating an elongated basin shape. Elevation ranges from 30 m to 360 m, with a relief of 330 m, reflecting considerable topographic variation that influences runoff and flow velocity. The drainage network analysis revealed 91 channels with a total length of 504 km and a drainage density of 3.117 km/km². Hydrological parameters showed a lag time of 3.32 minutes and a concentration time of 2.12 hours, indicating a rapid response to rainfall events. The basin demonstrates high flash-flood susceptibility and considerable potential for water harvesting and sustainable

Keywords: Morphometric analysis, Wadi Migdal Basin, Drainage network, Drainage density, Geographic Information Systems (GIS)

التحليل المورفومتري والهيدرولوجي لحوض وادي مقدال.

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ملخص البحث:

يهدف البحث إلى تحليل الخصائص المورفومترية، والهيدرولوجية لحوض وادي مقداد باستخدام تقنيات نظم المعلومات الجغرافية ونماذج الارتفاعات الرقمية لفهم سلوكه المائي وتقييم مخاطره. السيول، إذ تبلغ مساحة الحوض 83.72كم2 بطول 20.36 كم، ومتوسط عرض 4.11 كم، مما يشير إلى شكل مائل إلى استطالة. ويتراوح الارتفاع بين. 30 إلى 360 م، بفارق 330 م، مما يعكس تباينا تضاريسيا يؤثر في سرعة الشريان. وأظهرت التحليل وجود شبكة تصريف متطورة تضم 91 مجرى بإجمالي أطوال 504 كم. بلغت كثافة التصريف 3.117. كيلومتر في كيلو متر مربع، مع زمن تباط 3.32 دقيقة، وزمن تصريف 2.12 ساعة، ما يدل على استجابة سريعة للأمطار. قدر صافي أجري ان بنحو 4601582 م3 سنويا. وتلخص الدراسة إلى أن الحوض. معرض للسيول مع توفر إمكانية جيدة لحصاد المياه، مما يستدعي تخطيطا مائيا فعالا لتحقيق التنمية المستدامة.

الكلمات المفتاحية: التحليل المورفومتري، حوض وادي مقدال، الشبكة التصريف، كثافة التصريف، نظم المعلومات الجغرافية(GIS) .

1. Introduction

Morphometric analysis is considered one of the fundamental tools in the study of river basins and a key component in understanding geomorphological and hydrological characteristics, in addition to geological features. It further provides interpretations of surface runoff behavior and the resulting hydrological phenomena such as infiltration, runoff generation, and sediment transport processes, as well as associated geomorphological processes including erosion, transportation, and deposition, which are linked to complex landforms characterized by high levels of interaction and interdependence.

The Qasr Al-Akhyar region in general, and Migdal Valley in particular, represents an extension of arid and semi-arid environments characterized by ecological sensitivity and fragility. These environments are affected by recurring cycles of drought and humidity, where runoff is irregular and flash floods frequently occur, leading to the loss of water resources that could otherwise be managed and utilized.

This study aims to derive the morphometric characteristics of Migdal Valley in Qasr Al-Akhyar area, east of the coastal plain, using Geographic Information Systems (GIS) and appropriate statistical methods. It further provides a comprehensive morphometric analysis by describing geomorphological and geological components and their influence on the basin's morphometric and hydrological characteristics. This analysis contributes to understanding the dynamics of the valleys in semi-arid regions and provides essential data that can support sustainable environmental planning, reduce flood risks, and improve water resource management efficiency in the region.

Migdal Valley, located in Qasr Al-Akhyar area in Libya, is characterized by diverse topography and geomorphological variability, making it an ideal model for studying the impact of natural and human factors on river basin formation.

Through this research, the researchers aim to provide a comprehensive analysis of the morphometric characteristics of the valley, including drainage density, elongation ratio, basin slope, and other key parameters that contribute to improving scientific understanding of basin development and drainage network evolution. It also provides valuable data that can be used in water resource management within the surrounding area.

2. Research Problem

Migdal Valley flows from south to north through a semi-arid region lacking renewable water resources, in addition to a shortage of geomorphological and morphometric studies of its valleys. This results in a missed opportunity to invest in floodwater resources, especially given the geomorphological diversity of the area. The diversity of land use further necessitates a morphometric and geomorphological study of the wadi to reduce flood risks on one hand and to identify alternative and renewable water sources on the other. However, the absence of precise quantitative analysis of morphometric characteristics limits the ability to interpret the hydrological response of the basin, particularly under the unstable climatic conditions of arid environments, where short and intense rainfall events lead to sudden responses that may cause flash flood hazards.

In general, the research problem can be summarized in the following questions:

1- To what extent do the morphometric characteristics of Migdal Valley represent those of the valleys in arid environments?
2- What are the most important morphometric elements that distinguish the basin and drainage network of Migdal Valley from surrounding valleys? Can they be relied upon for flood prediction?
3- What is the relationship between shape, slope, and drainage density indices and the speed and concentration of surface runoff?
4- Do morphometric characteristics indicate a high susceptibility to flooding, and to what extent can it be controlled and utilized?

3. Research Objectives

This study aims to:

1- Accurately delineate the spatial boundaries of the basin and its drainage network.
2- Calculate basic and advanced morphometric parameters of the basin.
3- Analyze topographic characteristics including slope, elevation, and relief.
4- Evaluate the relationship between shape indices, drainage density, and hydrological response.
5- Assess the basin’s susceptibility to rapid runoff and flood hazards.

6- Develop a comprehensive spatial and hydrological database to support sustainable water resources management plans, with particular emphasis on assessing the potential of flash flood water harvesting for irrigation purposes and the recharge of local groundwater aquifers.

4. Research Hypotheses

1- The morphometric characteristics of Migdal Valley basin influence its hydrological behavior, where basin elongation and topographic variation contribute to relatively longer runoff concentration time compared to circular basins.
2- Moderate to high drainage density enhances surface runoff efficiency due to the well-developed drainage network, low soil permeability, and sparse vegetation cover.
3- Significant topographic variation within the basin increases surface runoff velocity and erosion intensity, especially in upstream areas with steep slopes.
4- The steadily increasing susceptibility of the Migdal Valley Basin to flash floods can be attributed to the accelerated hydrological behavior of the basin, as reflected in its short lag time and discharge time. These characteristics enhance the basin's rapid runoff response, leading to an almost immediate concentration and conveyance of water during periods of intense rainfall, thereby increasing the likelihood and severity of flash flood events.

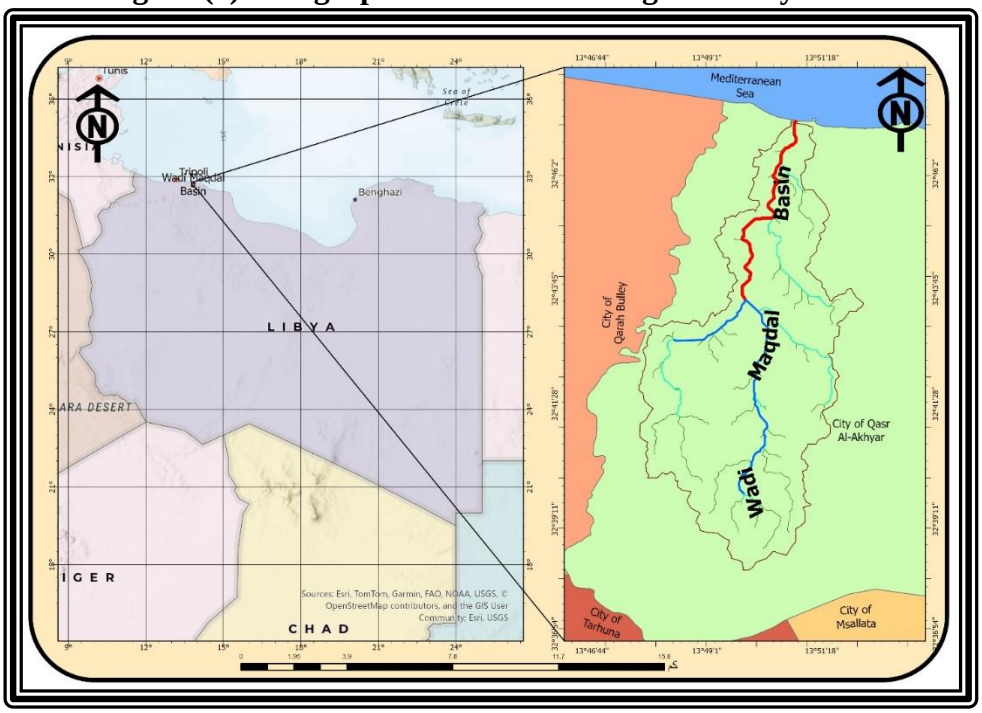
5. Research Methodology

This study is based on a quantitative analytical approach relying on digital spatial analysis through the integration of Geographic Information Systems (GIS) and Digital Elevation Models (DEMs) in order to extract and analyze morphometric and hydrological indicators.

6. Data Sources

The study relied on Digital Elevation Models (DEMs) such as SRTM and ASTER, in addition to Sentinel satellite imagery and recent remote sensing data to support visual interpretation, geological mapping, and topographic analysis. The area of Migdal Valley is distributed between the towns of Msallatah and Qasr Al-Akhyar, where the upper reaches of the drainage network are located in the northern part of the Msallatah region. Most of the basin lies within the coastal Qasr Al-Akhyar area, which is part of the coastal zone extending between the city of Al-Khums in the east and Tajoura in the west. Astronomically, Qasr Al-Akhyar is located approximately between latitude 32.689°N and longitude 13.666°E, where the valley flows into the Mediterranean Sea (Figure 1).

Figure (1): Geographical location of Migdal Valley basin



Source: Prepared by the researchers using ArcGIS Pro 3.5

7. Geological Structure of Migdal Valley Basin, Qasr Al-Akhyar, Libya

The region has undergone significant environmental changes throughout different geological eras, transitioning from marine to continental environments. These changes have influenced the composition of sedimentary rocks and led to the current geological diversity. The different geological formations constituting this area can be identified as shown in Figure 2. Here, the researchers correlate the previously described geological units with those shown on the map (Wanless & Shepard, 1936, p. 98).

1. Jafara Formation

The Jafara Formation consists of sedimentary rock layers that may date back to the Pleistocene or Tertiary periods. It is composed mainly of calcareous sediments that may be affected by karst processes.

2. Aeolian Deposits

These deposits consist of recent accumulations of sand resulting from wind transport processes. They are highly permeable and extend along the coastal zone.

3. Al-Khums Formation

Al-Khums Formation refers to older rock units that may date back to the Jurassic or Paleogene periods. These rocks are mainly sandstone or limestone and represent different depositional environments.

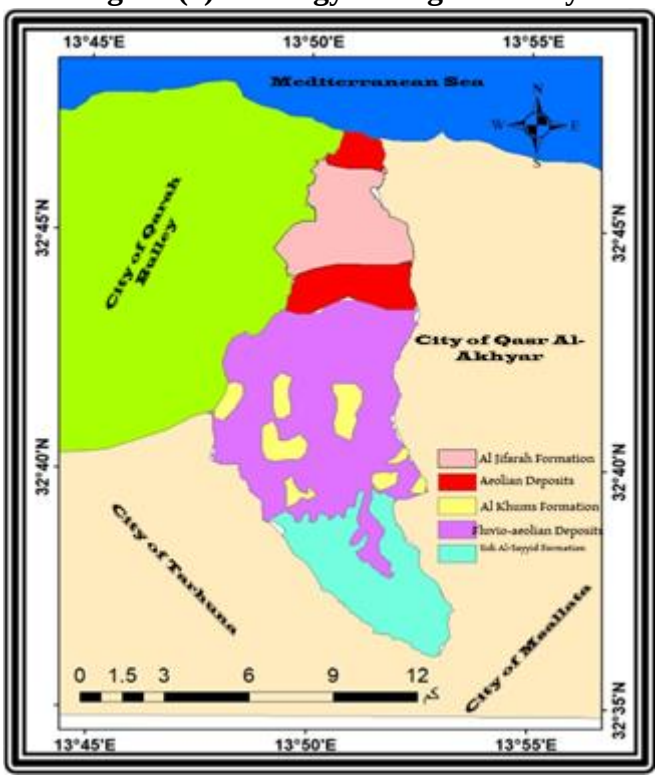
4. Coastal Aeolian and Beach Deposits

These deposits consist of a mixture of beach materials and aeolian sands accumulated in coastal areas near the sea. They are influenced by both coastal and wind processes.

5. Sidi Asaid Formation

Sidi Asaid Formation consists of ancient limestone rocks possibly dating back to the Cretaceous period. These rocks may be part of a karst system shaping the region's topography.

Figure (2): Geology of Migdal Valley



Source: Prepared by the researchers using ArcGIS Pro 3.5

8. Morphometric Characteristics of Migdal Valley Basin

With the rapid development of Geographic Information Systems (GIS) and Digital Elevation Models (DEMs), basin morphometric analysis has become a precise digital process that enables the extraction of drainage networks and quantitative indicators with high efficiency and objectivity. This technological advancement has significantly enhanced the understanding of the relationship between basin morphological structure and runoff dynamics, thereby supporting applications in water resource management, spatial planning, and natural hazard mitigation within the framework of sustainable development (Chorley, Schumm & Sugden, 1984, p. 123).

Table (1): Morphometric Characteristics of Migdal Valley Basin

Parameter	Value

Basin area	83.720481 km²
Basin perimeter	61.9192km
Basin length	20.36 km
Main channel length	44.00 km
Maximum elevation (head of main channel)	360 m
Minimum elevation (outlet of main channel)	30 m
Total length of stream channels	261 km
Basin width	4.112007908 km

Source: Prepared by the researchers based on morphometric analysis outputs using ArcGIS Pro 3.5

The data presented in Table (1) indicate that Migdal Valley basin has an area of approximately 83.72 km², which reflects a relatively medium-sized basin within the classification of drainage basins. This suggests the basin's ability to collect a considerable amount of rainfall during storm events. The basin perimeter is also approximately 83.72 km, which reflects the degree of development of the basin boundaries and their influence by structural and topographic factors.

The basin length is 20.36 km, while the average basin width is about 4.11 km, indicating that the basin has an elongated shape. This elongation is generally associated with an increased lag time compared to circular basins, leading to a more extended temporal distribution of runoff. The main channel length reaches approximately 44 km, which is relatively significant compared to the basin length, indicating an extended drainage gradient that contributes to regulating water movement within the fluvial system.

The elevation data reveal a clear topographic variation, where the maximum elevation at the head of the main channel is 360 m, while the minimum elevation at the outlet is 30 m, resulting in a total relief of 330 m. This relief is an important indicator of flow energy and erosional potential, as the slope generated by this elevation difference enhances surface runoff velocity, particularly during heavy rainfall events.

Furthermore, the total length of stream channels within the basin is approximately 261 km, reflecting a well-developed drainage network and its efficiency in water discharge. This value is considered a primary indicator for estimating drainage density and analyzing the hydrological response of the basin.

Overall, these morphometric characteristics indicate that Migdal Valley basin exhibits a clearly defined topographic structure and a relatively developed drainage network, which gives it a noticeable sensitivity to surface runoff. This necessitates a deeper analysis of shape, slope, and drainage density indices in order to more accurately assess its hydrological behavior.

9. Topographic Characteristics

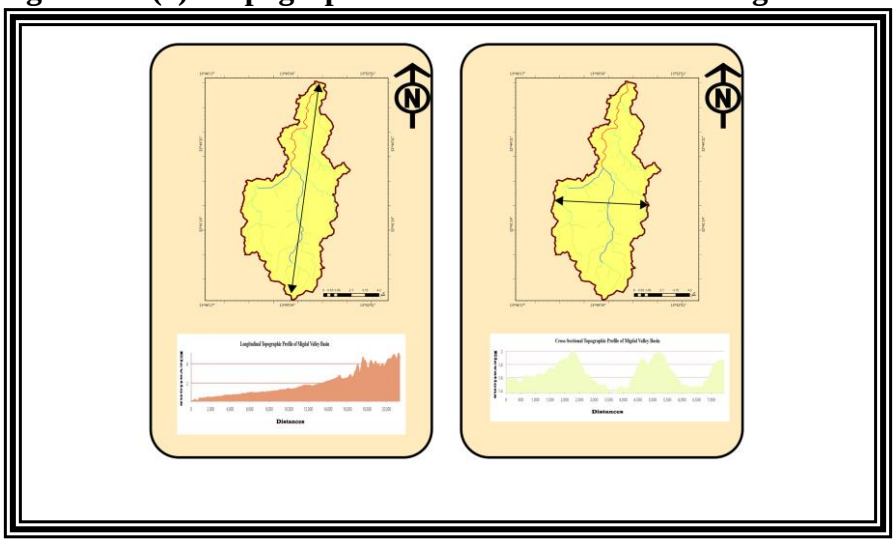
Topographic characteristics are considered fundamental factors controlling the shaping of the Earth's surface and guiding geomorphological and hydrological processes within it. They reflect variations in elevation, slope, and landform morphology, and represent the structural framework within which climate, soil, and

vegetation interact to determine surface runoff dynamics, as well as erosion and deposition patterns. Therefore, the analysis of topographic characteristics is a crucial step in understanding the behavior of drainage basins and assessing their response to rainfall and storm events.

Topographic characteristics include a set of quantitative indicators such as relief, elevation range, average slope, degree of dissection, and slope direction. These elements have a direct influence on runoff velocity, concentration time, and the energy of flowing water. As slope and relief increase, the capacity of water for erosion and transportation increases, and the likelihood of rapid hydrological response during heavy rainfall becomes higher, particularly in arid and semi-arid environments.

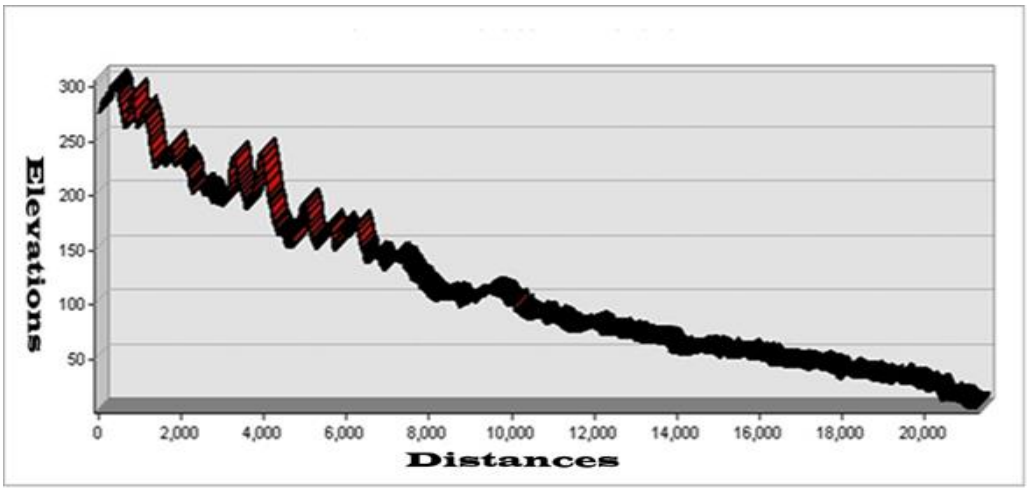
With the technological advancement in Digital Elevation Models (DEMs) and Geographic Information Systems (GIS), it has become possible to analyze topographic characteristics with high spatial accuracy and to extract slope, elevation, and relief maps in a quantitative and objective manner. This has significantly contributed to improving scientific understanding of the relationships between surface morphology and natural process dynamics, thereby supporting applications in spatial planning, natural resource management, and environmental risk reduction (Moore, Grayson & Ladson, 1991, p. 56).

Figure No. (3): Topographic Cross-Section of Wadi Magdall Basin



Source: Prepared by the researchers using ArcGIS Pro 3.5

Longitudinal Topographic Profile of Migdal Valley Basin



The longitudinal topographic profile of Migdal Valley basin provides a clear representation of the gradual variation in elevation along the main channel of the wadi, where a general downstream decrease in elevation is observed from the high source areas toward the low-lying outlet. In the upper part of the basin, elevations exceed 300 m above sea level, indicating that the headwaters are located within a steep topographic zone characterized by high relief energy. This section shows noticeable irregularities in the profile line, reflecting intense vertical erosion and the development of numerous tributary channels. This confirms that this part of the basin represents the youthful geomorphological stage of the wadi, where vertical incision processes dominate and flow velocity is high due to steep slopes.

Moving toward the middle section of the basin, a gradual reduction in profile curvature is observed, with elevations decreasing to approximately 100–150 m. The profile becomes more uniform, reflecting a reduction in stream energy and a relative increase in depositional processes compared to vertical erosion. This indicates the transition of the wadi into the geomorphological maturity stage.

In the lower part of the basin, the profile exhibits a gentle and gradual slope, decreasing to less than 50 m near the outlet, with a relatively stable profile line. This indicates the dominance of depositional processes, channel widening, and reduced flow velocity, which are typical characteristics of the mature or late geomorphological stage of the valley.

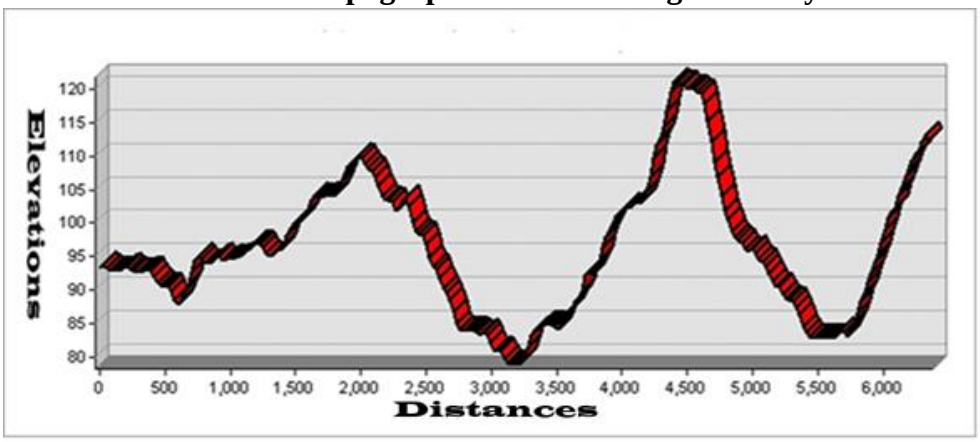
Overall, the longitudinal profile of the valley takes a concave shape, which is the ideal form of longitudinal profiles for geomorphologically balanced river systems, where slope decreases progressively toward the outlet as a result of the natural adjustment of the river to the base level.

The geological implications of this profile indicate a clear variation in relief energy between the upper and lower parts of the basin, with dominant vertical erosion in the headwaters and deposition in the downstream areas. It also reflects the natural geomorphological evolution of the channel toward fluvial equilibrium. Furthermore, the profile demonstrates the influence of structural and lithological factors, particularly through the presence of sharp irregularities in the upper reaches.

From this perspective, Migdal Valley can be interpreted as a progressively evolving fluvial system in which geomorphological processes transition from strong

erosion in the upper basin to transportation and finally deposition in the lower reaches, confirming the direct relationship between topographic slope and surface runoff behavior within the basin.

Cross-Sectional Topographic Profile of Migdal Valley Basin



The cross-sectional topographic profile reflects a clear and gradual variation in elevations along the basin, indicating an irregular topographic structure dominated by a gently undulating terrain. The profile begins with moderate elevations ranging approximately between 90 and 95 m, with slight fluctuations that indicate a semi-smooth surface representing the headwater areas or the upper parts of the basin.

As the profile progresses along the section to approximately 2,000 m, a clear gradual rise in elevation is observed, reaching about 110–112 m. This indicates the presence of relative highlands such as hills or topographic ridges within the basin. This is followed by a sharp and rapid decrease in elevation, where the profile reaches its lowest point at approximately 80 m between 2,800 and 3,200 m, reflecting a deep valley section that represents the main drainage axis.

After this point, the elevation begins to increase again gradually, forming a relatively steep rise that reaches a peak of approximately 120–122 m at around 4,500 m, suggesting the presence of a prominent topographic high that may represent a structural escarpment or resistant rock mass. This is followed by a clear and rapid decline in elevation, where values drop again to approximately 83–85 m at around 5,500 m, indicating a secondary depression or another valley floor within the basin. In the final section of the profile, elevations rise gradually once more, reaching about 115 m at the end of the transect, reflecting a transition toward surrounding elevated terrain.

Overall, the cross-sectional profile exhibits a repeated pattern of peaks and troughs, with occasionally sharp variations in slope. This indicates that the basin is characterized by relatively complex and undulating topography. This pattern reflects the combined influence of geomorphological processes, particularly fluvial erosion and geological structure, in shaping the basin. It also has a direct impact on surface runoff behavior, water accumulation zones, and sedimentation patterns within Migdal Valley.

Table (2): Elevation Distribution and Cumulative Area of Migdal Valley Basin (Hypsometric Analysis)

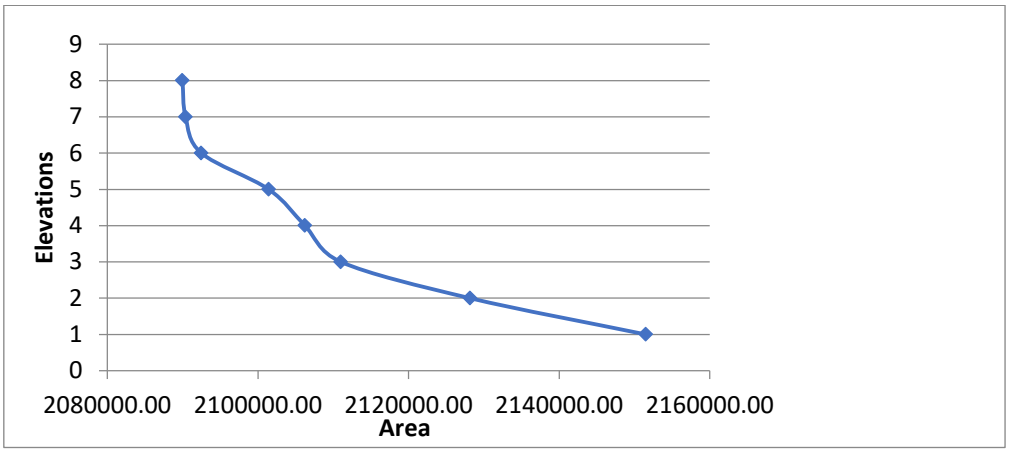
Rank	Minimum Elevation (m)	Maximum Elevation (m)	Differential Area (km²)	Cumulative Area (km²)	Percentage of Differential Area	Percentage of Cumulative Area
1	30	71.24131	17808.94737	2151490.32	22.45%	100.00%
2	71.275536	112.481102	23332.66559	2128157.65	29.41%	77.55%
3	112.512932	153.692352	17149.15477	2111008.50	21.62%	48.14%
4	153.756668	194.968964	4771.227481	2106237.27	6.01%	26.52%
5	195.474686	236.212173	4803.944469	2101433.32	6.06%	20.50%
6	236.253296	277.181946	8953.549169	2092479.77	11.29%	14.45%
7	277.512848	318.625793	2099.340091	2090380.43	2.65%	3.16%
8	318.7789	360	408.9623555	2089971.47	0.52%	0.52%
Total			79327.79		100.00%	0%

Source: Prepared by the researchers based on morphometric analysis outputs using ArcGIS Pro 3.5

Table (2) illustrates the distribution of elevation classes within Migdal Valley basin, ranging from the lowest elevation of 30 m to the highest elevation of 360 m. The data show that the majority of the basin area is concentrated within the middle elevation classes, where the second to fourth classes together account for approximately 57% of the total basin area. This indicates that the basin has a relatively stepped topography, with relatively extensive low-lying areas and smaller proportions of high-elevation zones.

The values further reveal a decrease in area with increasing elevation in the upper classes, where the seventh and eighth classes represent less than 3% of the total basin area, reflecting the presence of limited peaks or highlands within the overall terrain. The cumulative area values show a gradual decrease from 100% at the lowest elevation to approximately 0.52% at the highest elevation, indicating that the vast majority of the basin lies within low and moderate elevations. This factor has a direct influence on surface runoff concentration and drainage velocity.

It can be concluded that the basin exhibits a moderate to steep topographic gradient in some upper areas, which contributes to accelerated surface runoff on steep slopes. In contrast, the lower elevation classes facilitate water accumulation and regulate drainage flow. This hypsometric analysis also demonstrates its potential use in constructing the hypsometric curve for assessing the geomorphological stage of the basin and the degree of drainage network development.



Hypsometric Curve

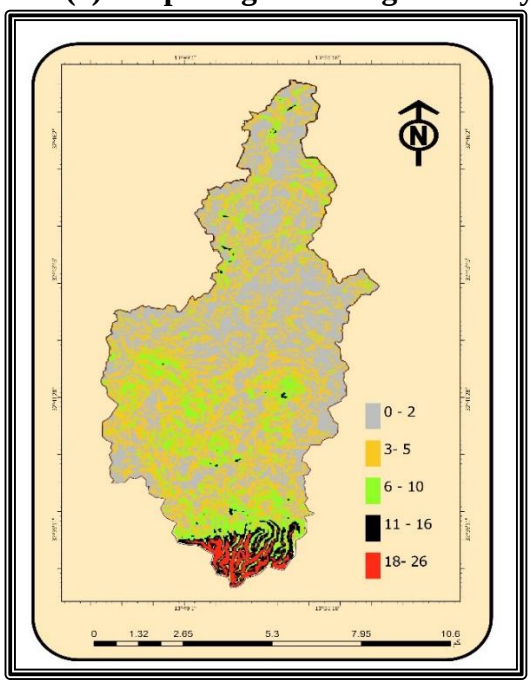
The hypsometric curve of Migdal Valley basin illustrates the relationship between elevation and cumulative basin area, and represents the topographic distribution of the basin's surface in relation to elevation levels. The left portion of the curve represents the higher elevations on the vertical axis and shows a relatively steep decline. This indicates that the majority of the basin area is concentrated within low and moderate elevations, while high-elevation zones occupy a limited proportion of the basin. This pattern reflects a gradual distribution of area across mid-elevation classes, suggesting that the terrain within these zones is moderately sloping rather than highly rugged, which contributes to a more regulated surface runoff process. In the final portion of the curve, near the maximum elevation, the curve approaches zero, indicating that the highest peaks or uppermost terrain represent a very small fraction of the total basin area. This is an indicator of a generally moderate to steep topographic relief in some upper parts of the basin.

The shape of the curve suggests that the basin has a relatively strong capacity for water accumulation in lower areas, while surface runoff velocity may increase significantly in the upper slopes due to steeper gradients. Furthermore, the hypsometric curve can be used to estimate the geomorphological stage of the basin—whether youthful, mature, or old—and to analyze its hydrological response behavior under rainfall conditions.

10.Elevation Characteristics

Elevation characteristics are considered fundamental elements for understanding topography and analyzing drainage basins. They reflect the topographic variation between peaks and depressions within the basin. These characteristics include maximum and minimum elevation, relief (elevation range), and mean elevation, all of which are essential indicators that determine slope, surface runoff velocity, and the potential for erosion and deposition processes. In addition, studying the spatial distribution of elevations helps in interpreting the distribution of water and runoff within the basin. It further contributes to the construction of hypsometric curves that reflect the geomorphological stage of basin development, making their analysis essential in morphometric and hydrological studies (Strahler, 1998, p. 118).

Figure No. (3): Slope Degree of Migdal Valley Basin



Source: Prepared by the researchers using ArcGIS Pro 3.5

Table (3): Elevation Characteristics of Migdal Valley Basin

Parameter	Value
Mean basin elevation	195 m
Most frequent elevation (mode)	174.362816 m

Source: Prepared by the researchers based on morphometric analysis outputs using ArcGIS Pro 3.5

Table (3) illustrates the elevation characteristics of the study basin. The mean elevation of the basin is 195 m, which reflects the general elevation level of the basin's topography. Meanwhile, the most frequent elevation (mode) is 174.36 m, which is lower than the mean value. This indicates that most of the basin area lies at elevations below the average level. The difference between the mean elevation and the most frequent elevation suggests the presence of limited high-altitude areas that raise the overall average elevation, while the majority of the basin remains relatively low-lying or gently sloping.

11.Morphometric Characteristics of Migdal Valley Basin

The study of basin shape characteristics is considered one of the most important steps in geomorphological analysis, as it helps in understanding the natural structure of the basin and assessing its hydrological efficiency, as well as predicting surface runoff behavior. This analysis relies on a set of mathematical parameters derived from measurements of basin length, area, and perimeter (Ma'ruf, 2018, p. 12). The most important of these characteristics include the following:

1. Basin Shape Factor

The basin shape factor is a hydrological index used to determine the shape of the basin and its influence on water discharge. This index measures the relationship between the basin area and the length of its main channel, and it reflects the extent of basin elongation in relation to its width. A low shape factor indicates an elongated and narrow basin, which leads to slower runoff concentration and delayed peak discharge. In contrast, a high shape factor indicates a short and wide basin, which facilitates rapid water accumulation and faster discharge. This index is highly important in hydrological studies, flood management, and environmental planning (Azouzi, 2024, p. 22).

$$F = \frac{A}{L^2}$$

2. Elongation Ratio

The elongation ratio is a hydrological index used to determine the degree of basin elongation, that is, the extent to which the basin length exceeds its width. It is calculated as the ratio between the diameter of a circle having the same area as the basin and the maximum basin length. This index provides insight into basin shape and its influence on water discharge and flood behavior.

A basin with a low elongation ratio is typically long and narrow, resulting in slower runoff concentration and delayed peak discharge. In contrast, a basin with a high

elongation ratio is closer to a circular shape, which facilitates rapid water accumulation and accelerates discharge. This index is of considerable importance in hydrological studies, flood management, and environmental planning (Al-Bayedh, 2021, p. 6).

$$Re = \frac{2 \cdot \sqrt{\frac{A}{\pi}}}{L}$$

3. Circularity Ratio

The circularity ratio is a hydrological index that expresses the degree to which the shape of a basin approaches that of a perfect circle. It is calculated as the ratio between the basin area and the square of its perimeter, reflecting the influence of basin shape on water collection and drainage efficiency.

A basin with a low circularity ratio is non-circular—often elongated or irregular—which leads to slower runoff and may increase the likelihood of localized flooding. Conversely, a high circularity ratio indicates a shape closer to a circle, which enhances the uniform and rapid distribution of water. This index is essential in hydrological analysis, flood assessment, and water resource management (Abdelrazeq, 2024, p. 9).

$$Rc = \frac{4 \cdot \pi \cdot A}{P^2}$$

4. Shape Index

The shape index is a hydrological parameter used to evaluate basin form and its effect on runoff characteristics. It reflects the relationship between basin area and its principal dimensions, particularly basin length. This index helps determine the degree of elongation and geometric complexity of the basin. A low shape index generally indicates a basin closer to a circular or regular form, which promotes faster runoff. In contrast, a high shape index suggests a more elongated or irregular basin, which may slow water flow and increase the potential for water accumulation in certain areas. This parameter is important in hydrological studies, flood management, and environmental planning (Horton, 1932, p. 13).

$$Si = \frac{L^2}{A}$$

Table (4): Shape Indices of the Study Basin

Parameter	Value
Basin Shape Factor	0.201965025
Elongation Ratio (Re)	0.507108817
Circularity Ratio (Rc)	0.150099125
Shape Index (Si)	2.561969077

Source: Prepared by the researchers based on the outputs of the morphometric shape equations for Migdal Valley basin.

The table illustrates the shape indices of the study basin and presents the different values of its geometric form parameters. The basin shape factor is 0.202,

indicating that the basin tends toward an oval or relatively irregular shape. The elongation ratio is 0.507, which reflects the relationship between basin length and width, suggesting that the basin is moderately elongated.

The circularity ratio, with a value of 0.150, indicates a low degree of circularity, meaning that the basin shape is closer to an oval or slightly rectangular form. Finally, the shape index 2.562 provides insight into the relationship between basin length and width and its effect on hydrological characteristics. A relatively elongated basin may influence the rate of water discharge, generally contributing to a slower runoff concentration compared to more compact basins.

12.Hydrological Characteristics of Migdal Valley Basin

The studied drainage basin exhibits variability in its hydrological characteristics due to differences in geological structure and composition, as well as variations in surface slope and soil types, in addition to the influence of climatic elements. For example, infiltration and surface runoff are strongly affected by rainfall intensity, storm direction, and precipitation amounts. Moreover, several morphometric characteristics have a significant impact on basin hydrology. Parameters such as the number of stream channels, stream order, bifurcation ratio, and drainage density directly influence surface runoff equations. As the number of channels within a basin increases, the efficiency of the drainage network in transporting surface runoff—along with its suspended and bed load—also increases.

The main hydrological characteristics of Migdal Valley basin can be understood through the analysis of the following elements:

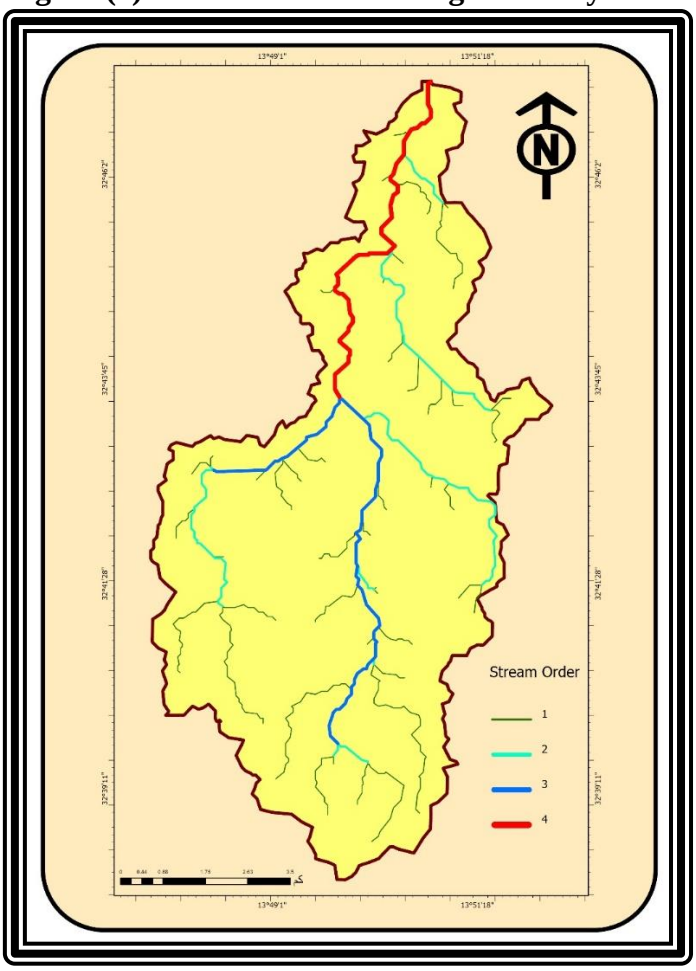
Stream Order

Stream ordering is considered one of the most important methods used in the analysis of drainage networks, as it helps in understanding the structural organization of the basin and its hydrological characteristics. The classification of stream channels within the basin provides valuable insight into the hierarchical arrangement of the drainage system and its efficiency in conveying water. This is illustrated in Table (5) and Figure (4).

Table (5): Morphometric Distribution of Stream Numbers and Their Total Lengths According to Stream Order in Migdal Valley Basin

Stream Order	Number of Streams	Total Stream Length (km)
1	72	72
2	32	64
3	27	81
4	11	44
Total	**142**	**261**

Figure (4): Stream Orders of Migdal Valley Basin



Source: Prepared by the researchers using ArcGIS Pro 3.5.

Drainage Density

Drainage density is an important indicator reflecting the degree to which a basin is exposed to erosion and denudation processes resulting from fluvial activity. It also represents a direct expression of prevailing climatic conditions, geological structure, the resistance or fragility of rock formations, and their permeability. Basins characterized by high drainage density indicate an increase in the number and total length of tributaries. This condition is often associated with low soil permeability and sparse vegetation cover, which in turn leads to increased surface runoff velocity within the basin. Drainage density is calculated using the following equation (Horton, 1932, p. 357):

$$\textbf{Drainage Density} = \frac{Total\ length\ of\ stream\ channels\ in\ the\ basin\ (km)}{Basin\ area\ (km2)} = \text{km/km2}$$

Lag Time

Lag time is one of the most important hydrological parameters influencing the volume of infiltrated water and surface runoff, as it determines the amount of water that infiltrates into soil layers over a given period. It is defined as the time interval between the start of rainfall and the onset of surface runoff. Lag time increases with decreasing slope, higher soil porosity, fractured rock formations, and dense vegetation cover, and decreases under opposite conditions. It is also influenced by additional

factors such as temperature, rainfall intensity, and duration of precipitation. To estimate lag time, the following equation was applied:

Lag Time= $1.6 \frac{A^{0.3}}{\sqrt{D\ x\ S}}$

Where:

- A = Basin area
- S = Mean basin slope
- D = Drainage density

The application of this equation yielded the results presented in Table (6).

Table (6): Lag Time and Time of Concentration for Migdal Valley Basin

Parameter	Drainage Density (km/km²)	Lag Time (minutes)	Time of Concentration (hours)
Value	3.117	3.32	2.12

Source: Prepared by the researchers based on the outputs of hydrological equations for Migdal Valley basin.

Time of Concentration

The time of concentration is defined as the time required for water (primarily rainfall) to travel from the most distant point in the basin to the outlet. This parameter has a direct impact on the potential for rainwater harvesting, as it determines the time needed for water to accumulate at a specific point within the basin. When the time of concentration is short, water flow becomes more rapid and forceful, which may negatively affect hydraulic structures designed for floodwater harvesting. Conversely, longer concentration times increase opportunities for infiltration and evaporation, thereby reducing flood risk and enhancing the capacity of storage structures to absorb runoff. The time of concentration is calculated using the following equation (Hani Mashashi, 2005, p. 143):

Time of Concentration (Tc) = $\frac{1.15\ (L^{0.305})}{0.38\ (H^{0.305})}$ x 7700

Where:

- L = Length of the main stream
- H = Basin relief

The application of this equation produced the results shown previously in Table (6).

Infiltration

Infiltration is considered one of the most important components of the hydrological cycle. In many cases, a large portion of rainfall infiltrates into the soil and moves through its layers. The rate of water movement is controlled by specific physical constraints. Therefore, estimating the quantity of infiltration within soils is one of the main objectives in hydrological studies and represents one of the key challenges in this field.

A distinction must be made between the infiltration rate and infiltration capacity. The infiltration rate refers to the speed at which water enters the soil under prevailing conditions, whereas infiltration capacity represents the maximum possible rate of this process. If the rainfall intensity is lower than the initial infiltration capacity of the soil, no surface runoff will occur. However, when infiltration capacity decreases below the rainfall intensity, surface runoff begins to form.

Several factors influence the infiltration process within soils, including soil type and moisture content, vegetation cover density, topography, rainfall intensity, surface rock type, evaporation, and time. In addition, secondary factors such as soil compaction due to rainfall impact, accumulation of fine particles within soil pores, temperature variations, and trapped air within soil voids also play a role. Furthermore, increased animal activity in sparsely vegetated areas and continuous trampling can lead to soil structure breakdown, reduced porosity, and clogging of soil pores, which ultimately decreases infiltration capacity and increases surface runoff (Abdelhamid Kileo, 1985, pp. 17–18).

It is also important to note that infiltration rates vary according to surface lithology. They are highest in limestone formations (0.0158 m³/hour), followed by sandy soils and formations (0.0120–0.0080 m³/hour), and lowest in clay soils and clay-rich formations (0.0020 m³/hour).

Infiltration during Lag Time

This term refers to the volume of water infiltrating into the soil during lag time, measured in cubic meters. This quantity infiltrates over a short period of several minutes but at relatively high rates, which gradually decrease until rainfall intensity exceeds the soil's infiltration capacity. At this point, surface runoff begins, and lag time ends. To estimate infiltration during lag time, the following equation was used:

Infiltration during Lag Time = $M \times Z \times C$ (Hani Mashadi, 2005, p. 162)

Where:

- M = Basin area
- Z = Time of concentration (or basin discharge time)
- C = Constant representing rock type (previously defined)

Using this equation, the results presented in Table (7) were obtained.

Table (7): Infiltration Values and Net Runoff in Migdal Valley Basin

Parameter	Infiltration during Lag Time (m³)	Infiltration during Time of Concentration (m³)	Constant Infiltration (m³/hour)	Total Infiltration (m³)	Net Runoff (m³)
Value	112	215	11	73	4601582

***Source**: Prepared by the researchers based on hydrological equation outputs for Migdal Valley basin.*

Constant Infiltration Values

Constant infiltration refers to the infiltration rate that stabilizes after the lag time period and remains approximately steady until the end of rainfall and the short period that follows. This stage represents the condition in which the soil reaches a near-equilibrium infiltration capacity. Constant infiltration values can be estimated using the following equation:

Constant Infiltration (m³/hour) = Infiltration rate according to rock type × Basin area (km^2) × Time of concentration − Lag time. (Hani Mashashi, 2005, p. 162)

Based on this equation, the results presented in Table (7) were obtained.

Evaporation Volume during Basin Time of Concentration

The evaporation volume during the time of concentration can be estimated using rainfall event evaporation values, the average number of rainy days, and the basin concentration time. Through these parameters, the total evaporation loss within the basin during the concentration period can be determined.

It is important to note that evaporation losses during both lag time and time of concentration are very limited and almost negligible during the rainy season. Therefore, they do not significantly affect surface runoff values during or immediately after storm events.

Net Runoff

After calculating all losses due to evaporation and infiltration, the expected flood volume can be estimated by subtracting total water losses from the total rainfall volume over the basin annually. This results in a value representing net runoff, which in this study amounted to approximately (4601582 m^3/year).

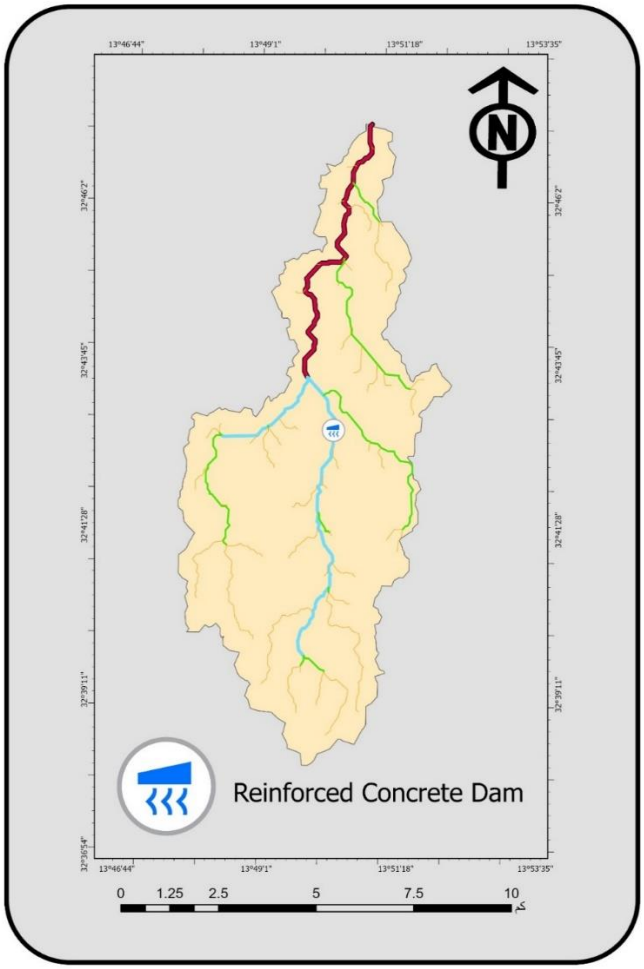
The estimation of average rainfall, evaporation, and infiltration rates is highly useful in determining expected flood volumes. It also assists in setting administrative, financial, and technical priorities for the establishment of hydraulic engineering systems consistent with these hydrological estimations. Ultimately, this serves the main objective of applied geomorphology, which is to support the environmental management of the studied basin through developing integrated solutions to the dual problems of flooding and drought within the study area.

Based on the quantitative hydrological indicators revealed by the study, which demonstrate the rapid hydrological response of Migdal Valley Basin to rainfall events—particularly the short lag time estimated at 3.32 minutes and the substantial annual net surface runoff volume estimated at approximately 4,601,582 m^3—the researchers recommend the implementation of engineering and geomorphological interventions to effectively manage these underutilized water resources and mitigate the risks associated with flash floods.

Specifically, the study proposes the construction of a concrete dam in the middle reach of the valley, at the narrow topographic constriction of the main channel located downstream of the confluence of higher-order tributaries and upstream of the channel's entry into the coastal plain. This location offers favorable topographic depth for water storage and a moderate channel gradient, making it particularly suitable for dam construction.

The proposed dam would serve not only as a flood-control structure aimed at protecting infrastructure, residential areas, and adjacent agricultural lands, but also as an effective water-harvesting system. Through continuous infiltration, it would contribute to the recharge of local groundwater aquifers and provide a sustainable water reserve capable of enhancing biodiversity and supporting the rehabilitation of the natural vegetation cover within the valley's semi-arid environment.

Figure (5): Proposed Site of the Concrete Dam for Water Harvesting in Migdal Valley Basin.



Source: Prepared by the researchers using ArcGIS Pro 3.5.

13.Results

The study revealed the following results:

1) The morphometric and hydrological analysis of Migdal Valley basin, based on Geographic Information Systems (GIS) and Digital Elevation Models (DEMs), revealed a set of quantitative indicators that reflect the basin's physical structure, geological setting, and hydrological behavior. The basin covers an area of approximately 83.72 km², which is considered a moderately sized drainage basin within hydrological classification systems. This gives the basin a good capacity to collect rainfall during storm events. The basin length is about 20.36 km, with an average width of approximately 4.11 km, indicating that the basin tends toward an elongated or semi-rectangular shape. This is further confirmed by the main channel length of about 44 km, which reflects a clearly extended drainage system and contributes to increasing the runoff concentration time compared to circular basins.

2) Elevation within the basin ranges from 30 m at the outlet to about 360 m in the headwater regions, with a total relief of 330 m, indicating relatively high topographic energy, particularly in the upstream areas. The longitudinal profile shows a concave curve, reflecting a gradual geomorphological evolution from the youthful stage in the upper reaches to the mature stage, and approaching a late or semi-old stage near the outlet. The transverse profile exhibits a wavy pattern characterized by alternating peaks and depressions, indicating irregular topography and significant variation in slope gradients.
3) Most of the basin area is concentrated within low and medium elevation zones (approximately 57%), while high-altitude areas represent a very limited proportion. This enhances water accumulation in lower areas and contributes to regulating surface runoff behavior.
4) Shape indices indicate that the basin is relatively elongated, with an elongation ratio of approximately 0.507 and a low circularity ratio of 0.150. This confirms that the basin deviates significantly from a circular shape and instead exhibits a relatively irregular form. These characteristics suggest a relatively slow runoff response and a more distributed discharge over time, reducing the likelihood of sudden flood peaks compared to circular basins.
5) The drainage network consists of 91 stream channels with a total length of 504 km distributed across four stream orders. First-order streams dominate in terms of both number and length, while both parameters decrease progressively with increasing order. This reflects a well-developed drainage system and efficient internal water transport within the basin.
6) The drainage density is approximately 3.117 km/km², which is a moderately high value. This indicates relatively low soil permeability, weak vegetation cover, and increased surface runoff efficiency. The lag time is about 3.32 minutes, reflecting a rapid hydrological response and limited soil infiltration capacity at the beginning of rainfall events. The time of concentration is approximately 2.12 hours, indicating relatively fast water conveyance within the basin and a high probability of flash flood formation during intense rainfall events.
7) The results further show that infiltration rates are significantly influenced by lithological and soil characteristics. The estimated net annual runoff is approximately 4,601,582 m³, a value that reflects a considerable potential for flood generation and highlights the importance of utilizing available water resources through rainwater harvesting and sustainable water management strategies.

14.Recommendations

Based on the findings of the morphometric and hydrological analysis of Migdal Valley basin, and in light of the observed hydrological behavior and flood susceptibility, the study proposes the following recommendations aimed at improving water resource management and reducing environmental risks within the basin:

1) Establish water harvesting structures such as earth dams, hydraulic barriers, and surface reservoirs in the middle and lower parts of the basin, where water tends to concentrate. This would enhance the utilization of water resources and reduce water losses.

2) Due to the short lag time and the rapid hydrological response of the basin, it is recommended to develop flood risk management plans that include the construction of well-designed drainage channels, protection of residential areas, ecosystems, and infrastructure, as well as the identification of hazard zones and the prevention of urban expansion within them.
3) Increase vegetation cover within the basin, particularly in the upstream areas, as vegetation plays a significant role in reducing surface runoff velocity, increasing infiltration rates, and minimizing soil erosion and sediment transport.
4) Develop land use planning schemes that take into account the morphometric characteristics of the basin. Agricultural activities should be directed toward suitable areas, while intensive exploitation of steep-slope zones should be avoided.
5) Install monitoring stations for rainfall, surface runoff, and evaporation measurements in order to provide accurate datasets that support future research and informed decision-making processes.
6) Continue utilizing Geographic Information Systems (GIS) and Digital Elevation Models (DEMs) to monitor environmental changes, update basin datasets, and support spatial planning and resource management strategies.
7) Conduct more detailed future studies focusing on geological and soil characteristics, hydrological behavior of flood events, and the impact of climate change on basin dynamics.
8) Raise awareness among local communities about flood hazards and the importance of water resource conservation, as well as the necessity of avoiding construction within wadi channels and flood-prone areas.

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