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Evaluation of Runoff and Morphometric Analysis in Wadi Ked, Sinai, Egypt

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Abstract

Sinai is a formidable territory and leads significant Vital areas in Egypt due to its past significance, Spatial sites, touristic value, and Environmental treasures. Restricted access to water sources in Sinai is the primary factor hindering its development. This study seeks to evaluate the effective rainfall (E.R.) in Wadi Ked, situated in Sinai, to facilitate various applications and mitigate hazards associated with flooding by designing protective structures based on the runoff volume. This study seeks to assess E.R. and morphometric characteristics and outline the drainage basins of Wadi Ked using the Curve Number (CN) method alongside the hydrological Model by (HEC-HMS) software. This hydrological model) HM) estimates runoff and generates hydrographs for storms with return periods (R.P.) of 5, 10, 20, 50, 100, and 200 years, and is also employed for watershed delineation in the study area. ArcGIS is employed for Water flow and terrain analysis, serving to illustrate the Spatial representation of the case study's features. The rainfall data utilized pertained to the Dahab, Sharm Sheikh, and Saint Catherine rainfall stations. The frequency analysis was conducted using Microsoft Excel, yielding storm depths of 27.63, 38.78, 49.94, 64.68, 75.83, and 86.99 mm for (R.P.) of 5, 10, 20, 50, 100, and 200 years, respectively. The runoff volumes are 4.93, 11.06, 18.53, 29.72, 38.87, and 48.45 Mm^3, and the corresponding depths are 4.74, 10.63, 17.82, 28.58, 37.37, and 46.58 mm for their respective return times.

Keywords: Wadi Ked, GIS, SCS-CN, HEC-HMS, Runoff

1. Introduction

Since 1950, river networks have been extensively researched by Earth scientists, particularly hydrologists [1]. A multitude of general bivariate correlations has been identified, and an extensive body of work on drainage basin m0rphometry has enhanced comprehension of drainage evolution concerning regulating variables within a given geological setting [2]. A naturally present geohydrologic feature termed a "watershed" channels precipitation runoff to a singular river and is classified based on its geographic position [3]. E.R. is a significant hydrological phenomenon with adverse effects, including severe flooding in river basin regions and soil erosion [3]. The oversight of watersheds preparing, efforts to recover, and comprehension of basin hydrology are significantly reliant on the assessment of watershed morphology [4]. The results of the research can enhance topographic comprehension, characterize basin attributes, identify optimal locations for s0il conservation, and mitigate flash fl00ds in the regi0n's flat landscape[5]. M0rph0metric analysis of the basin is conducted to comprehend its behavior under diverse geological and hydrological conditions by calculating its numerous characteristics [4][5]. Consequently, the numerical examination of a basin's Catchment flow network provides valuable insights for understanding the riverine dynamics within an area. The measurable investigation of a basin's drainage system provides valuable insights for understanding regional processes. The Chemical-physical characteristics of the Exposed geological formations and the hydr0l0gical attributes of the basin are effectively elucidated through the application of quantitative analysis methodologies [6]. Successful water use is essential for the Long-term viability of the well-being of all participants in dry regions. A thorough grasp of the landscape, geological formations, runoff channels, watershed divide, stream length, and geological configuration of the region is essential for effective watershed management and the implementation of water conservation strategies [7]. Watershed planning necessitates drainage analysis grounded in morphometric parameters, as it provides insights into the gradient of the watershed, physical characteristics of the region, soil Standard, runoff characteristics, surface water potential, and more features [8]. The Ked watershed region is situated in South Sinai, Egypt, including approximately 1,056 square kilometers. This study seeks to ascertain the runoff flow in Wadi Ked and conduct watershed delineation. Utilizing GIS with arcmap in conjunction with HM.

Geographic Information Systems (GIS) are computer-based technologies that may display geographical information through various visual representations, perform statistical operations, and facilitate database construction. They have emerged as essential tools in organizing and making choices.

WMS is a comprehensive system designed to address intricate hydrological challenges by digitally managing watersheds and hydrological attributes. It can be utilized to determine surface runoff using the CN approach.

Studies [9][10][11][12][13][14] employed the CN approach to calculate runoff utilizing Remote Sensing (RS) in conjunction with GIS. Research [15] converges ARSAs in Australia to identify optimal locations for RWH, highlighting the significance of the average yearly precipitation value and employing SCS-CN to determine E.R.. The calculation of E.R. via the CN approach is contingent upon various elements, including Waterfall Hallmarks, Territorial use, and soil conditions. The characteristics complicate the selection process and are time-consuming; therefore, GIS technology and WMS have been employed to facilitate the calculation of E.R. in Wadi Ked, situated in South Sinai. The study seeks to get the E.R. in Wadi Ked, situated in Sinai, to facilitate various applications and mitigate hazards associated with flooding through the design of protective structures reliant on runoff quantities, utilizing the HM based on the CN method and ArcGIS.

2.Study area

This research examines Ked Valley, positioned in S0uth Sinai, Egypt, between l0ngitudes 34° 5' E and 34° 25' E and latitudes 28° 5' N and 28° 30' N with properties indicated in table 1. That discharges int0 the Gulf 0f Suez, as depicted in Fig

Table (1) Properties of Wadi Ked

properties	Value
Basin Area (Km^2)	1056.59
Basin perimeter (Km)	542.469
High elev. (m)	2421
Low elev. (m)	0

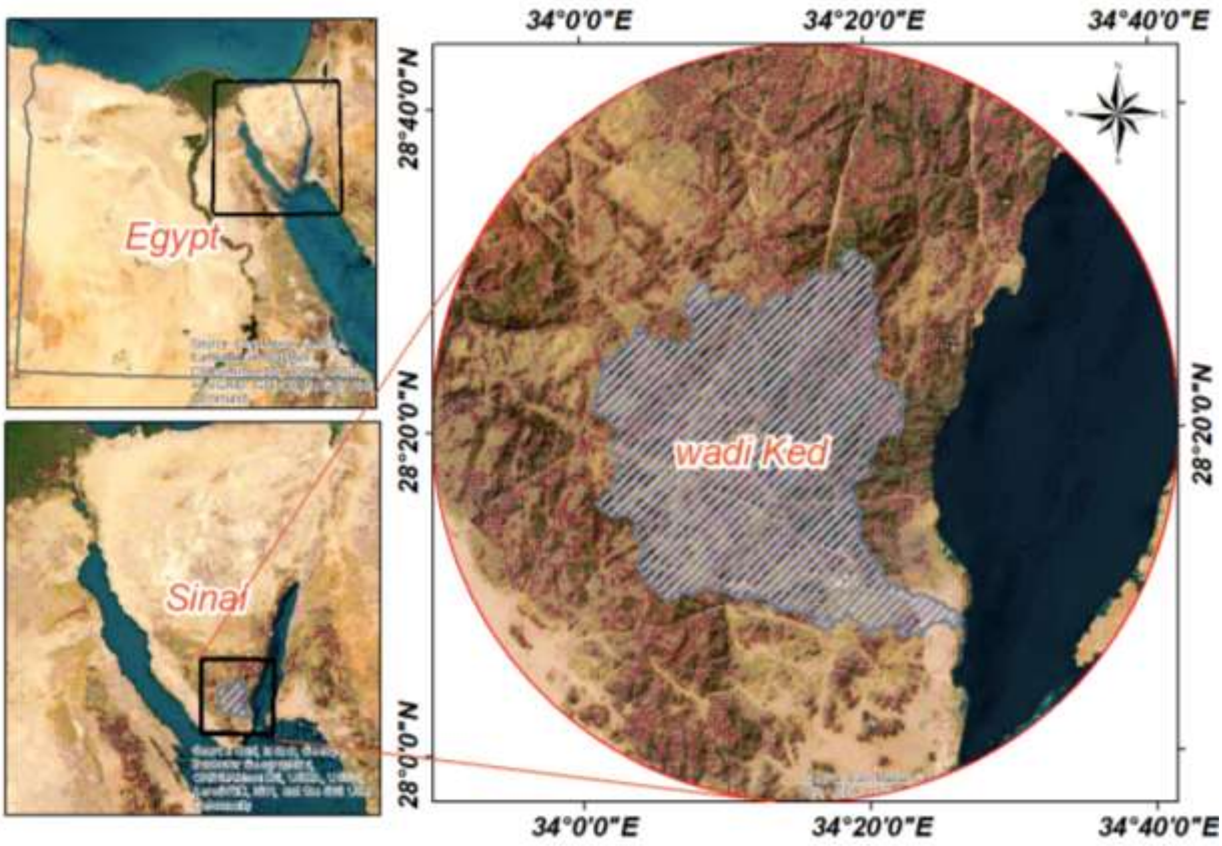


Fig. 1. Location of Wadi Ked.

3. Collected data

3.1 Topographical Data

Elevation is a critical determinant in assessing flood risk. Generally, low-lying regions are more susceptible to flooding than elevated places due to increased river discharge and rapid inundation from high water flow [16]. The elevation of the Research region varies between 0 to 2421m a.s.l, as illustrated in Fig. 2.

3.2 Land use

Land Allocation is a significant factor in the CN approach, which is employed to determine CN for E.R. estimation. (CNs) are numerical values ranging from 0 to 100, determined by Land Allocation and hydrological soil groups (HSG). The Terrain Utilization of Wadi Ked has been retrieved. The coverage depicted in Fig.3 indicates that the Extent of scrubland and non-vegetated areas terrain nearly encompass the entirety of Wadi Ked, as illustrated in Table 2.

3.3 HSG

One need of the CN approach is to classify all soil types in the study region into groups A, B, C, and D. Table 3 delineates the characteristics for each classification.

The map was processed to ArcMap and spatially referred to UTM Zone 36, as illustrated in Fig. 4 and Table 4. Converting the ge0l0gical Plan to HSG proved challenging; therefore, [17] produced the HSG Plan of Sinai. The map was trimmed and transferred to ArcMap to derive the HSG map of Wadi Ked, as illustrated in Fig.5. The surface Size of each category in Wadi Ked is detailed in Table 5.

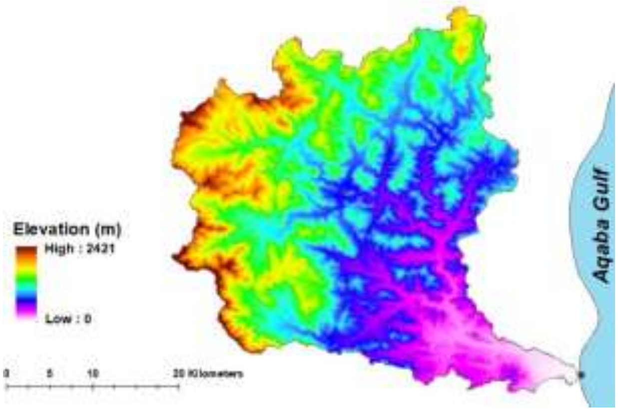


Fig. 2. DEM of Wadi Ked.

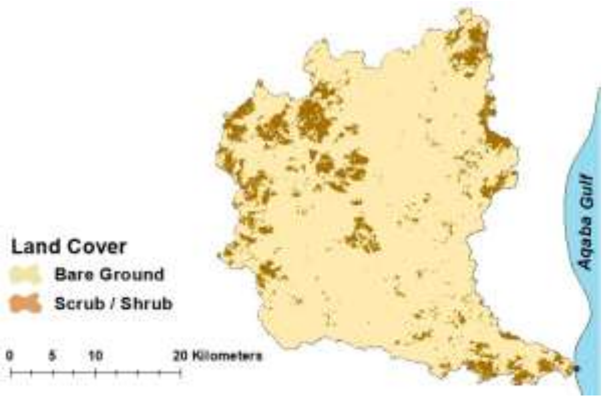


Fig. 3. Land cover of Wadi Ked.

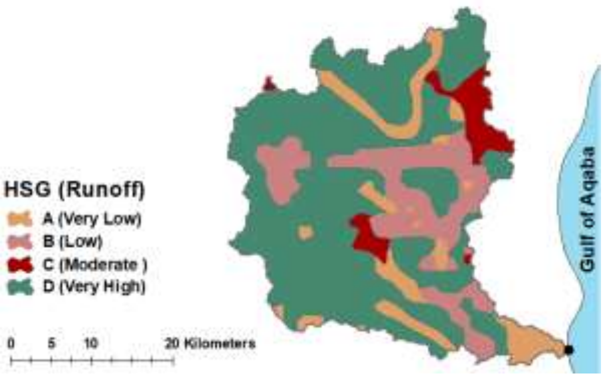


Fig. 4. HSG of Wadi Ked.

3.4 Rainfall Data

The Thiessen polygons demonstrate that only the Dahab, Sharm Sheikh, and Saint Catherine stations influence the research area, as illustrated in Fig.5. Precipitation data were gathered from the three sites as indicated in Table 5. The data represented the maximum daily rainfall depth measured in millimeters., as illustrated in Fig.6.

Table 2. Land cover Properties of Wadi Ked

Land use	Area (Km2)	(%)
Bare Ground	917	86.8%
Scrub / Shrub	139	13.2%

Table 3. Description of Hydrological Soil Groups (HSG)

Hydrological soil groups (HSG)	Descriptions
Group(A)	Lowest Runoff potential
Group(B)	Moderately Low Runoff
Group(C)	Moderately high Runoff
Group(D)	Highest Runoff potential

Table 4. HSG and description of Wadi Ked

HSG	Area (Km^2)	Percentage (%)
A	123.76	11.7%
B	198.58	18.8%
C	63.78	6.0%
D	670.49	63.5%

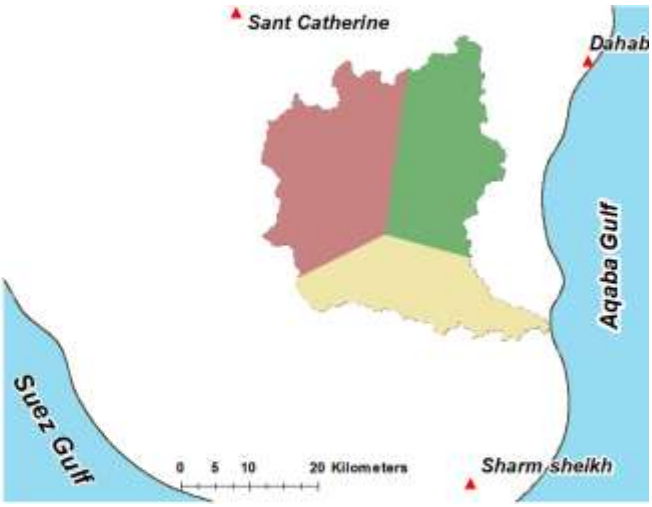


Fig. 5. Thiessen polygons for the rainfall station in Wadi Ked.

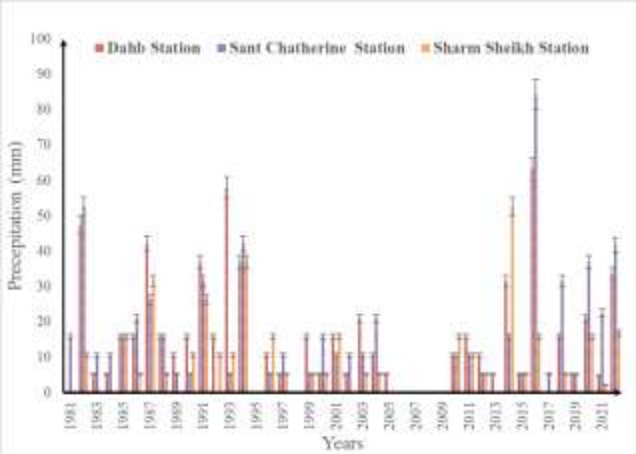


Fig. 6. The rainfall data from Dahab, Sharm Sheikh, and Saint Catherine stations

Station	available records	Number of records	Geographical Coordinates (Datum 1984)		
			Latitude	Longitude	Altitude (above M.S.L)
Dahab	1981-2022	34	28.5000° N	34.5000° E	22 m
Saint Catherine	1981-2022	33	28.5633° N	33.9500° E	1586 m
Sharm Sheikh	1981-2022	27	27.9158° N	34.3289° E	11 m

4. Method

4.1 Rainfall Data Screening

Rainfall data Review Needs to Affirm Deviations and Certify data h0m0geneity.[18] designated the Deviation as a Measure that is inconsistent with other Measures in the dataset. While [19] Recognized the outlier as a data point that significantly Contrasts with other data, hence amplifying uncertainties captured by several processes. The outlier's data were analyzed for the Dahab, Sharm Sheikh, and Saint Catherine stations with Charles' Equations as follows.

$$Y_{high} = Y_{ave.} + K_n\,\sigma_y \qquad Equ.1$$

$$Y_{low} = Y_{ave.} - K_n\,\sigma_y \qquad Equ.2$$

$$K_n = 1.055 + 0.981\log(n) \qquad Equ.3$$

Where: (n) is number of records, ($\boldsymbol{\sigma_y}$) is standard deviation of the data., ($\boldsymbol{Y_{high}}$) represents the high outlier in log units, and ($\boldsymbol{Y_{low}}$) is the low outlier in log units, ($\boldsymbol{K_n}$)is coefficient of outlier depend on the number of records. The results revealed that no outliers` readings in the gathered data of the rainfall stations as shown in Table 6.

Table 6. Screening of outliers` records of the rainfall stations

Station	Dahab	Sant Chatherine	Sharm Sheikh
available records	1981-2022	1981-2022	1981-2022
Number of records	34	33	27
Kn	2.557	2.545	2.459
high outlier	2.024	2.010	1.813
Low outlier	0.256	0.266	0.211
Max predicted Rainfall	105.741	102.386	64.940
Min predicted Rainfall	1.803	1.846	1.626
Result	No outliers	No outliers	No outliers

4.2 Frequency Analysis

Frequency analysis is a straightforward technique employed to estimate the intensity of storms, or their likelihood based on historical precipitation data and corresponding return periods. Numerous equations and tools exist for frequency analysis, leading to the formulation of Equ.4 to determine the chance of Rainfall. It is appropriate for a record range of 10 to 100 entries. Microsoft Excel software was utilized to obtain the optimal fitting curve for the data from the rainfall station. Fig.7 illustrates that the optimal curve is l0g0grammatic. Table 7 indicates the rainfall depth associated with various R.P.

$$P_{(\%)} = \frac{m - 0.375}{n + 0.25} x100 \qquad Equ.4$$

$$RP = \frac{1}{P_{(\%)}} \qquad Equ.5$$

Where: (P) denotes the probability of a record of rank m, and (m) represents the rank of the records. (n) denotes the aggregate number of records, whereas (RP) signifies the return period in years.

Table 7. The precipitation depth associated with various return periods

Rp (years)	Rainfall depth (mm)
5	27.63
10	38.78
20	49.94
50	64.68
100	75.83
200	86.99

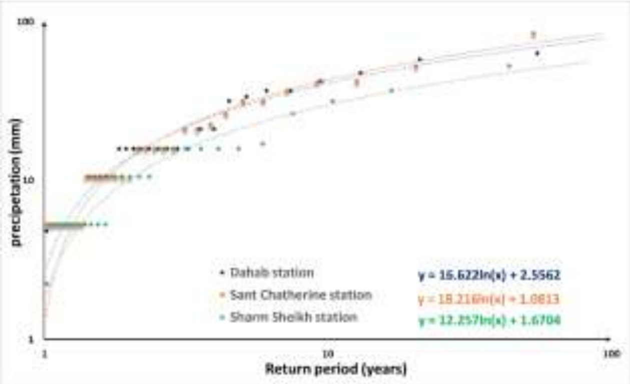


Fig. 7. Best fit distribution graph for Dahab, Sharm Sheikh, and Saint Catherine Stations.

4.3 CN Meth0d

CN is a widely utilized approach for estimating runoff. This system was designed to cater to the regions of the USA. There are parts there that are analogous to Sinai. The runoff depth estimate has been derived using equations from the CN method, a widely utilized approach for determining E.R. from rainfall events [20].

$$DOR = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad Equ.6$$

DOR represents the depth 0f run0ff (mm), P denotes the depth 0f rainfall (mm), and Ia signifies the initial abstraction (mm), which encompasses all losses preceding the onset of run0ff, including evaporation, infiltration, and water retention by vegetation (Ia=0.2Sr). Senior p0tential maximum retenti0n upon the commencement of run0ff

$$DOR = \frac{(P - 0.2\,S_r)^2}{(P + 0.8\,S_r)} \qquad Equ.7$$

$$S_r = Y\left[\frac{100}{CN} - 1\right] \qquad Equ.8$$

Y = 10 in imperial units, or 254 in metric units. In equation 4, (Sr) can be substituted with its value from equation 8 to derive the surface runoff equation with only two parameters as follows:

$$DOR = \frac{\left[P - 0.2\,Y\,\left(\frac{100}{CN} - 1\right)\right]^2}{\left[P + 0.8\,Y\left(\frac{100}{CN} - 1\right)\right]} \qquad Equ.9$$

4.4 Curve Number (CN) Estimation

CN is a primary parameter necessary for estimating surface runoff in the SCS-CN approach [21]. CNs are numerical values ranging from 0 to 100, determined by land use, Hydrologic Soil Group (HSG), and Antecedent Soil Moisture Conditions (AMC). According to the land use and Hydrologic Soil Group (HSG) maps of Wadi Ked presented in Fig.3 and Fig.4, and based on the Curve Number (CN) values of Agricultural Soil and Rainfall (ASARs) in reference [22], the CNs for the HSG of Wadi Ked for groups A, B, C, and D are 63, 77, 85, and 88, respectively, as illustrated in Fig.8. The area of each group will be estimated using ArcGIS 10.3 programs, with respective values of 123.7, 198.6, 63.8, and 670.5 km². The equivalent CN of Wadi Ked under typical soil conditions was determined to be 82, based on Equ.10.

$$CN = \frac{\sum A_c CN_c}{\sum A_c} \qquad Equ.10$$

Where CNc denotes the CN corresponding to the basin area Ac.

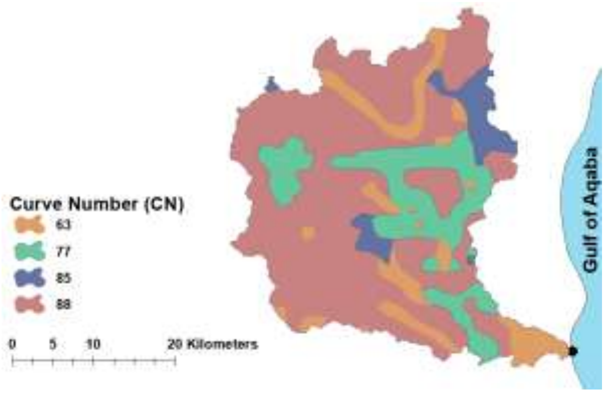


Fig. 8. Values of CNs of Wadi Ked.

4.4 Watershed Delineation

it has been conducted through several processes as illustrated in Fig.9. The Digital Elevati0n Model (DEM) of Wadi Ked was obtained from the USGS website, exhibiting an accuracy of 30 meters, as illustrated in Fig.2. Digital Elevation Model (DEM) serves as a valuable input in watershed analysis, comprising cells where each cell represents its elevation value. The downloaded DEM has depressions; so, the initial stage involves eliminating these depressions, followed by Mapping to a coordinate system to Zone 36N using ArcMap. The subsequent phase involves the flow direction of fill sinks, which has been illustrated as depicted in Fig.10.

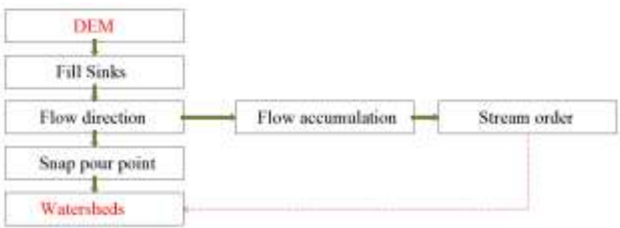
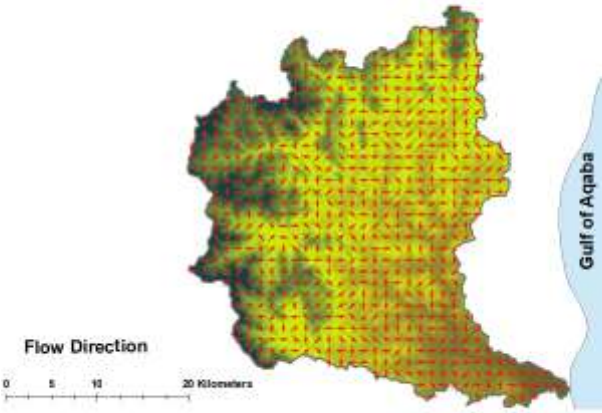


Fig. 9. Steps of Watershed delineation



.**Fig. 10**. Flow directions of Wadi Ked.

In this phase, each cell's flow direction was established about adjacent cells by evaluating their heights. The subsequent step is termed flow accumulation, during which the quantity of cells contributing to each data point is ascertained. The result of flow accumulation is a raster that indicates the number of cells contributing to each cell, thereby delineating the mainstream as illustrated in Fig.11. The definition of stream 0rders constitutes the primary step in the work procedure. The streams have been sorted according to the approach outlined in[23]. This method identifies streams that are not fed by any other streams as first-order streams. When two first-order streams converge, they generate a second-order stream, and this process continues. The stream order of Wadi Ked is seen in Fig.12.

Fig. 11. Flow accumulation of wadi Ked.

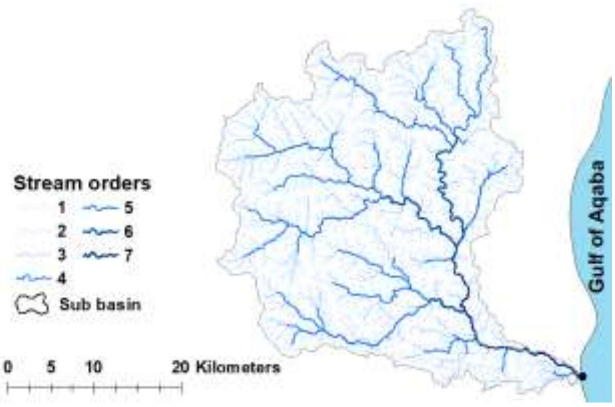


Fig. 12. Stream orders of Wadi Ked.

5. Result and dissection

5.1 Morphometric Analysis of Wadi Ked

Morphometric analysis denotes Land surface properties and their role in stream behavior. These measurements can be categorized as basin geometric metrics, about the basin's dimensions such as length, width, area, and perimeter, along with the circularity ratio and form factor ratio. Measurements about the drainage network include stream order, stream count, stream count, stream length, bifurcati0n rati0, and drainage density. Measurements about terrain characteristics such as height, relief ratio, ruggedness number, and slopes. The morphometric characteristics of this study were computed using ArcGIS 10.3 software. The findings indicate that Wadi Ked comprises seven stream orders and nine subbasins, as shown in Fig.13. The characteristics of the stream network significantly impact basin analysis; therefore, ArcMap, HM, and Microsoft Excel are combined in this w0rk t0 ascertain most morph0metric parameters, as illustrated in Table 8.

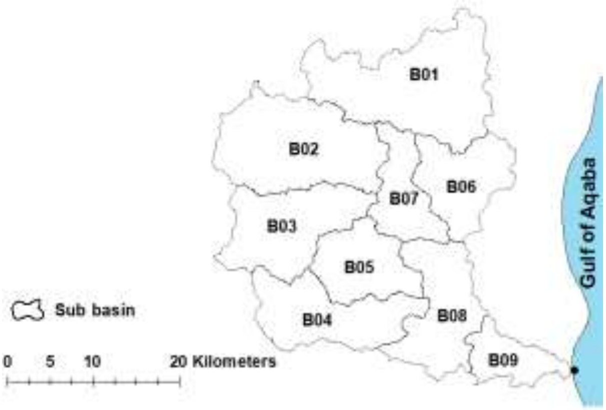


Fig. 13. Subbasins of Wadi Ked.

5.2 Estimation of runoff

The SCS-CN model results for Wadi Ked, generated by HEC-HMS as shown in Fig.14, reveal runoff volumes of 4.93, 11.06, 18.53, 29.72, 38.87, and 48.45 Mm3 for R.P. of 5, 10, 20, 50, 100, and 200 years, respectively. Additionally, the runoff depths are 4.74, 10.63, 17.82,

Table8.Some of Morphometric properties of wadi Ked

Morphometric properties	Symbol	B01	B02	B03	B04	B05	B06	B07	B08	B09
Stream Number	Nu	834.0	683.0	489.0	466.0	343.0	357.0	269.0	492.0	211.0
Stream Length (Km)	Lu	455.4	378.6	277.1	260.8	192.2	201.9	150.6	265.2	137.3
Basin Area (Km2)	A	208.1	182.9	128.2	119.4	87.3	94.4	71.5	114.0	50.8
Basin perimeter (Km)	P	88.6	69.0	60.9	65.5	45.5	50.7	49.1	67.1	46.3
Basin Length (Km)	Lb	22.4	20.0	20.0	20.0	14.0	13.4	15.5	16.0	13.0
Basin Width (Km)	Wb	9.3	9.1	6.4	6.0	6.2	7.0	4.6	7.1	3.9
Circulatory ratio	Rc	0.3	0.5	0.4	0.3	0.5	0.5	0.4	0.3	0.3
Texture ratio	Rt	9.4	9.9	8.0	7.1	7.5	7.0	5.5	7.3	4.6
Stream frequency	Fs	4.0	3.7	3.8	3.9	3.9	3.8	3.8	4.3	4.2
Drainage Density	Dd	2.2	2.1	2.2	2.2	2.2	2.1	2.1	2.3	2.7
Length of overland flow (Km)	Lg	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Infiltration number	If	8.8	7.7	8.2	8.5	8.6	8.1	7.9	10.0	11.2
Basin relief (Km)	Bh	1.4	1.7	1.9	2.0	1.3	0.8	1.1	0.9	0.5
Relief (gradient) ratio	Rh	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Ruggedness number	Rn	3.0	3.4	4.1	4.3	2.9	1.8	2.2	2.2	1.3
Bifurcation ratio	Rb	5.6	5.4	5.0	5.3	5.4	5.3	5.1	5.2	5.7
Elongation ratio	Re	0.7	0.8	0.6	0.6	0.8	0.8	0.6	0.8	0.6
Form factor	Rf	0.4	0.5	0.3	0.3	0.4	0.5	0.3	0.4	0.3

28.58, 37.37, and 46.58 mm, as detailed in Table 9. The hydrographs generated by Microsoft Excel, based on the data collected from HEC-HMS, illustrate the peak discharge values and the corresponding time of peak for storms of varying return durations, as depicted in Fig.15 and Table 9.

Fig. 14. Hydrological Model of Wadi Ked.

Table 9. Rainfall depth, Runoff volume and depth, peck of discharge and its time of wadi Ked

Rp (years)	Peak Discharge (m3/s)	Volume (Mm3)	Rainfall depth (mm)	Runoff depth(mm)
5	195.7	4.93	27.63	4.74
10	472.7	11.06	38.78	10.63
20	820.3	18.53	49.94	17.82
50	1342.3	29.72	64.68	28.58
100	1767.9	38.87	75.83	37.37
200	2215	48.45	86.99	46.58

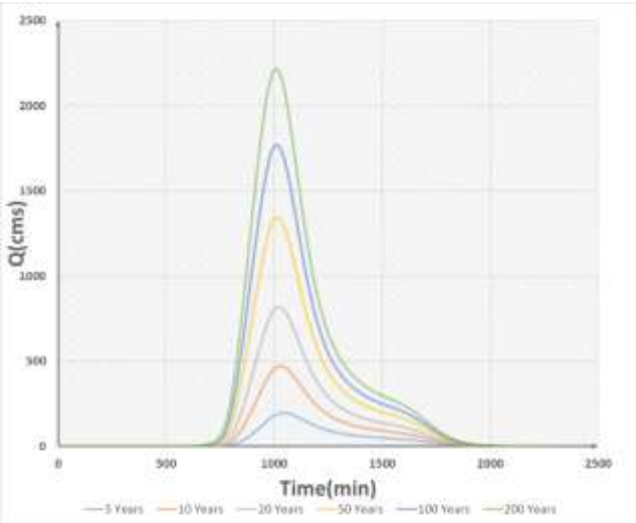


Fig. 15. hygrographs of different return periods of wadi Ked.

6. Conclusion

The primary objective of this work is to evaluate E.R. and delineate the hydrological basins in Wadi Ked, positioned in Sinai, Egypt, utilizing the CN method through HM (HEC-HMS) and ArcGIS software. This approach aims to facilitate various applications and mitigate hazards associated with flooding by designing protective structures based on runoff quantities. The findings can be outlined as follows: The delineation of Wadi Ked indicates an area of 1056.6 km², a circumference of 542.47 km, a width of 34 km, and a length of 48.5 km. The elevati0n of the Wadi Ked range varies fr0m o m to 2421 m a.s.l. The land uses of Wadi Ked consist of scrub/shrub covering an area of 139 km² and bare ground encompassing 917 km². The CN for Wadi Ked is 82. The runoff volumes in Wadi Ked for R.p. of 5, 10, 20, 50 100, and 200 years are 4.93, 11.06, 18.53, 29.72, 38.87, and 48.45 Mm³, respectively. The runoff depths in Wadi Ked for R.p. of 5, 10, 20, 50, 100, and 200 years are 4.74, 10.63, 17.82, 28.58, 37.37, and 46.58 mm, respectively. The morphometric qualities of Wadi Ked can be summarized as follows: Drainage density is 0.072 km/km², elongation ratio is 0.449, relief ratio is 0.0298, and basin slope is 0.434.

References

[1] F. Altaf, G. Meraj, and S. A. Romshoo, "Morphometric Analysis to Infer Hydrological Behaviour of Lidder Watershed, Western Himalaya, India," *Geogr. J.*, vol. 2013, pp. 1–14, 2013, doi: 10.1155/2013/178021.

[2] R. Talukdar, "SCS-CN and GIS-based approach for identifying potential water harvesting sites in the Kali Watershed, Mahi River Basin, India.," *Int. Ref. J. Eng. Sci.*, vol. 1, no. 3, pp. 5–12, 2012, [Online]. Available: www.irjes.comwww.irjes.com.

[3] D. Mehta, K. Prajapati, and M. N. Islam, "https://doi.org/10.1007/s41651-021- 00089-4," M. N. Islam and A. van Amstel, Eds. Cham: Springer International Publishing, pp. 169–181.

[4] M. Shaikh, S. Yadav, and V. Manekar, "Accuracy Assessment of Different Open-Source Digital Elevation Model Through Morphometric Analysis for a Semi-arid River Basin in the Western Part of India," *J. Geovisualization Spat. Anal.*, vol. 5, no. 2, p. 23, 2021, doi: 10.1007/s41651-021-00089-4.

[5] M. Shaikh, S. Yadav, and V. Manekar, "Application of the Compound Factor for Runoff Potential in Sub-watersheds Prioritisation Based on Quantitative Morphometric Analysis," *J. Geol. Soc. India*, vol. 98, no. 5, pp. 687–695, 2022, doi: 10.1007/s12594-022-2045-7.

[6] U. Rawat, A. Awasthi, D. Sen Gupta, R. Solomal Paul, and S. Tripathi, "10.17485/ijst/2017/v10i10/107875," *Indian J. Sci. Technol.*, vol. 10, no. 10, pp. 1–9, 2017, doi: 10.17485/ijst/2017/v10i10/107875.

[7] P. D. Sreedevi, P. D. Sreekanth, H. H. Khan, and S. Ahmed, "Drainage morphometry and its influence on hydrology in an semi arid region: using SRTM data and GIS," *Environ. Earth Sci.*, vol. 70, no. 2, pp. 839–848, 2013, doi: 10.1007/s12665-012-2172-3.

[8] V. A. Rama, "SCS-CN and GIS-based approach for identifying potential water harvesting sites in the Kali Watershed," *J. Geomatics*, vol. 8, no. 2, pp. 200–210, 2014, [Online]. Available: http://www.jspacesystems.or.jp/ersdac/GDEM/E/4.htm.

[9] A. K. Kadam, S. S. Kale, N. N. Pande, N. J. Pawar, and R. N. Sankhua, "Identifying Potential Rainwater Harvesting Sites of a Semi-arid, Basaltic Region of Western India, Using SCS-CN Method," *Water Resour. Manag.*, vol. 26, no. 9, pp. 2537–2554, 2012, doi: 10.1007/s11269-012-0031-3.

[10] D. Ramakrishnan, A. Bandyopadhyay, and K. N. Kusuma, "SCS-CN and GIS-based approach for identifying potential water harvesting sites

in the Kali Watershed, Mahi River Basin, India," *J. Earth Syst. Sci.*, vol. 118, no. 4, pp. 355–368, 2009, doi: 10.1007/s12040-009-0034-5.

[11] S. K. Mishra, R. P. Pandey, M. K. Jain, and V. P. Singh, "Modelling water-harvesting systems in the arid south of Tunisia using SWAT," *Water Resour. Manag.*, vol. 22, no. 7, pp. 861–876, 2008, doi: 10.1007/s11269-007-9196-6.

[12] M. Ouessar *et al.*, "Hess-13-2003-2009.Pdf," pp. 2003–2021, 2009.

[13] A. Ammar, M. Riksen, M. Ouessar, and C. Ritsema, "Identification of suitable sites for rainwater harvesting structures in arid and semi-arid regions: A review," *International Soil and Water Conservation Research*, vol. 4, no. 2. International Research and Training Center on Erosion and Sedimentation and China Water and Power Press, pp. 108–120, Jun. 01, 2016, doi: 10.1016/j.iswcr.2016.03.001.

[14] A. Pandey, V. M. Chowdary, B. C. Mal, and P. P. Dabral, "Remote sensing and GIS for identification of suitable sites for soil and water conservation structures," *L. Degrad. Dev.*, vol. 22, no. 3, pp. 359–372, 2011, doi: 10.1002/ldr.1012.

[15] E. Hajani and A. Rahman, "Rainwater utilization from roof catchments in arid regions: A case study for Australia," *J. Arid Environ.*, vol. 111, pp. 35–41, 2014, doi: 10.1016/j.jaridenv.2014.07.007.

[16] R. U. Zzaman, S. Nowreen, M. Billah, and A. S. Islam, "Flood hazard mapping of Sangu River basin in Bangladesh using multi-criteria analysis of hydro-geomorphological factors," *J. Flood Risk Manag.*, vol. 14, no. 3, pp. 1–19, 2021, doi: 10.1111/jfr3.12715.

[17] H. H. Elewa and A. A. Qaddah, "Groundwater potentiality mapping in the Sinai Peninsula, Egypt, using remote sensing and GIS-watershed-based modeling," *Hydrogeol. J.*, vol. 19, no. 3, pp. 613–628, 2011, doi: 10.1007/s10040-011-0703-8.

[18] V. Barnett and T. Lewis, "Outliers in statistical data," *Wiley Ser. Probab. Math. Stat. Appl. Probab. Stat.*, 1984.

[19] D. M. Hawkins, *Identification of outliers*, vol. 11. Springer, 1980.

[20] K. X. Soulis and J. D. Valiantzas, "SCS-CN parameter determination using rainfall-runoff data in heterogeneous watersheds-the two-CN system approach," *Hydrol. Earth Syst. Sci.*, vol. 16, no. 3, pp. 1001–1015, 2012, doi: 10.5194/hess-16-1001-2012.

[21] R. DeFries and K. N. Eshleman, "Land-use change and hydrologic processes: a major focus for the future," *Hydrol. Process.*, vol. 18, no. 11, pp. 2183–2186, 2004, doi: 10.1002/hyp.5584.

[22] United States Department of Agriculture, "Urban Hydrology for Small," *Soil Conserv.*, no. Technical Release 55 (TR-55), p. 164, 1986, [Online]. Available: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Urban+Hydrology+for+Small+watersheds#1.

[23] A. N. Strahler, "Part II. Quantitative geomorphology of drainage basins and channel networks," *Handb. Appl. Hydrol. McGraw-Hill, New York*, pp. 4–39, 1964.