International Journal of Environmental Sciences
ISSN: 2229-359
Vol. 11 No.15s,2025
https://theaspd.com/index.php

Estimating the volume of flash flooding in the Wadi Qasab basin in Khanaqin district using the Snyder model

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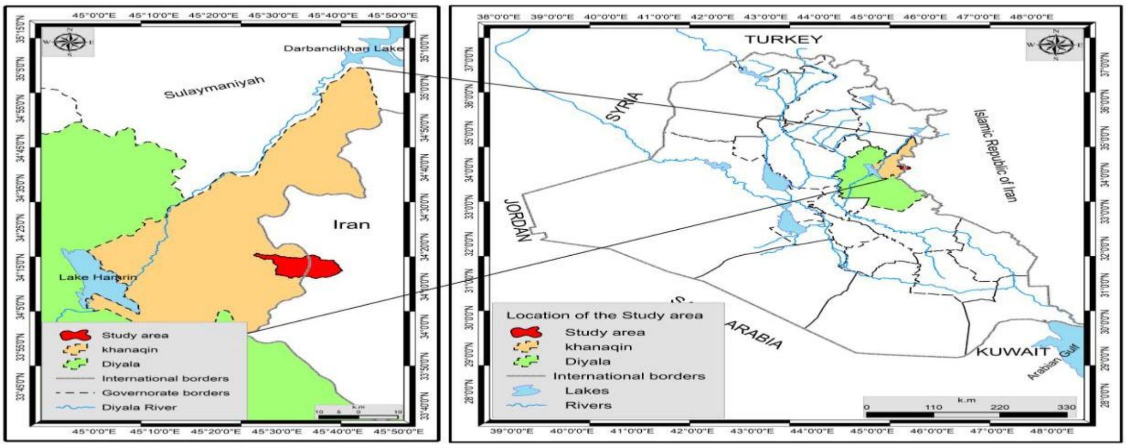
Abstract
The Wadi Qasab basin is one of the dry river basins, which originates from Iranian lands and flows into the Al-Wand River in Khanaqin district, this basin is characterized by seasonal surface water runoff, coinciding with the winter rainfall season, and the rains in the study area are characterized by fluctuations in the amounts of their fall, and irregularity in their times, as the rains fall intensively and during periods of time. For the purpose of knowing the amount and volume of surface runoff, and whether it is possible to benefit from it in order to serve the study area, the Snyder model was relied upon using (15) variables, and it was found that the volume of torrent flow for the total Wadi Qasab basin (1. 2 million / m3 / s), while the secondary basins (northern secondary, southern secondary and western secondary basins) recorded values ranging from (0.3 - 0.9 million / m3 / s), the volume of torrent flow is very large compared to the area of the basins, which leads to the possibility of flood danger, as these values pose high risks to human stability, especially in the main valley streams and their estuaries, because of the demolition, erosion and transfer of sediments and rock fragments.
Keywords :*Torrent, Wadi Qasab, river basins, Khanaqin, Snaider.*

INTRODUCTION

The study of hydrological characteristics and variables was carried out through the use of a set of equations to estimate and understand the nature of runoff, as it is related to various human activities, including water resources development projects, agricultural development, tourism, and determining the magnitude of the environmental risks posed by runoff.The issue can be formulated as follows: What is the volume of surface runoff, and does it form torrents? What factors affect it? Are there risks to the study area?The study area receives large quantities of water through rainfall, especially in the winter season, which increases the volume of surface runoff, and natural factors, including geology, topography, soil and natural vegetation, increase the water supply in the basin, which then creates risks for torrents in the basins of the study area.Wadi Qasab basin is located in the eastern part of Iraq, east of Khanaqin district, within the administrative boundaries of Diyala Governorate, and part of it within the Islamic Republic of Iran, bordered on the north by Wadi Zain al-Qaws basin, on the south by Mount Jurbakh, and on the west by the Al-Wand River. Astronomically, the study area is located between two circles of latitude 34 12 12 12 - 34 18 33 north, and between two arcs of longitude 45 40 56 - 45 26 27 east, with an area of 148.54 km2, as in map (1).**Map (1):** Location of the study area



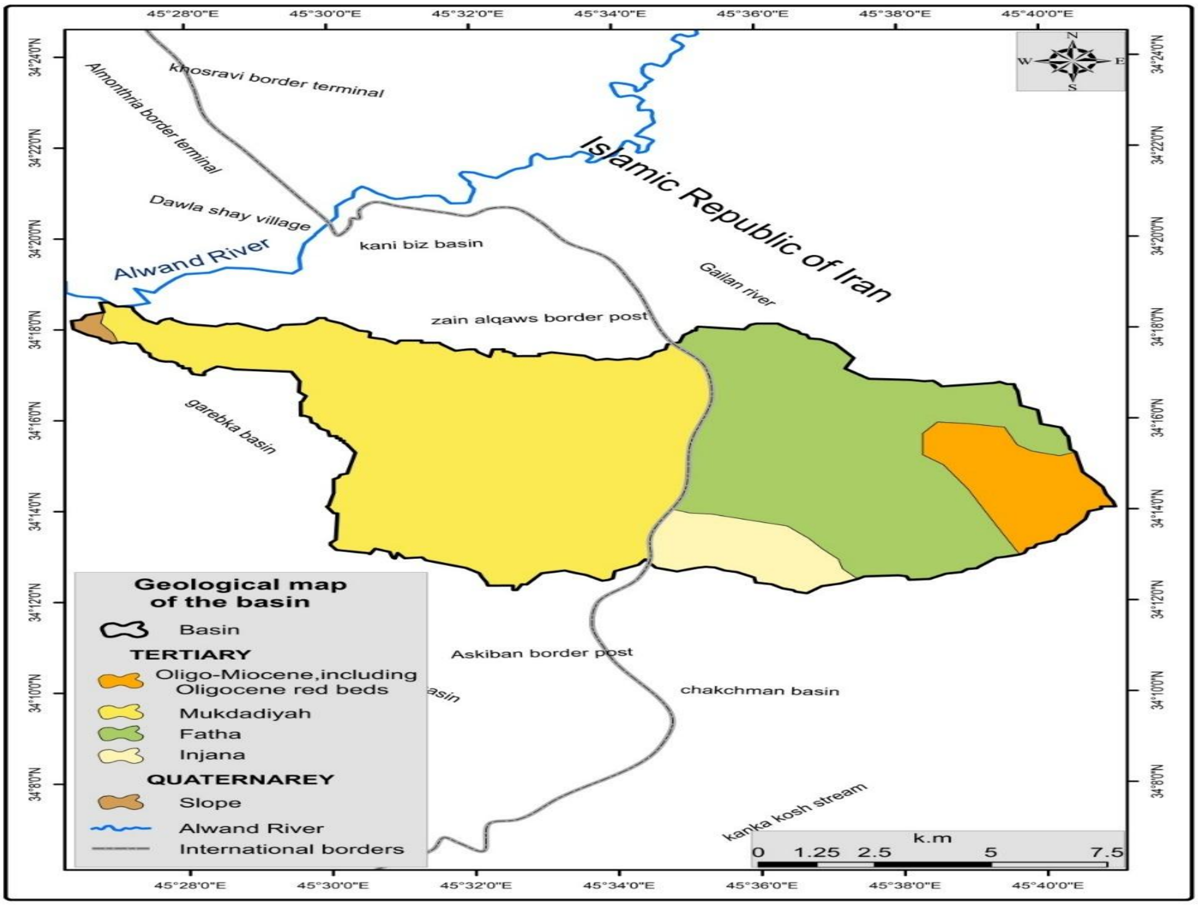
Source: Researcher based on Arc Gis 10.

Natural Characteristics Of The Study Area

Geology of the study area (stratigraphy):

The study area is occupied by rocks and sediments ranging in age from the Miocene (Tertiary Period) to Pleistocene (Quadratic Period). We will explain this sequence from oldest to newest, as in Map (2) and Table (1), which shows the formations and sediments as follows:

Map (2): Formations and sediments in the study area basin



Source: Researcher based on Arc Gis 10.8

Triple time formations include:

A- Limestone formations (red layers):

This formation appears in the west of the study area within the source area, and dates back to the Middle Miocene, as it consists of limestone and mudstone rocks, and the layers are interbedded with each other and are based at the bottom of the formation. As for the upper layers, they are red shale, and they alternate with sandstone, limestone and marl rocks. Its thickness ranges between 400-900 m, and its shallow marine environment overlaps with the continental environment, as it occupies an area of the region amounting to (11.38 km2) at a rate of.(%7.66)

Table (1): Geological formations and deposits in the study area

Geological Formations and Deposits	Area (km^2)	Percentage (%)
Limestone Formation	11.38	7.66
Al-Miqdadiya Formation	76.98	51.82
Al-Fatha Formation	50.66	34.1
Anjana Formation	8.91	6

Slope Deposits	0.61	0.41
Total	184.54	100

Source: Researcher's work based on Map (2) in Arc Gis 10.8

B- Formation of Muqdadiyah:

The Muqdadiya Formation dates back to the beginning of the Pliocene era. It consists of layers of sand covered with large pebbles, consisting of sandstone, siltstone, and limestone rocks formed from the remains of marine organisms, such as mammalian bones and shellfish (General Directorate of Geological Survey and Mineral Investigation (Survey and Mining), 1992, p. 8). This formation occupies the largest area of the study area, amounting to (76.98 km2), at a rate of (51.82%). This formation spreads in the west of the study area, near the estuary.

C- Formation of the opening:

This formation dates back to the Middle Miocene (Al-Sayyab et al., 1982, p. 134), and is exposed in large areas in the east of the study area, and consists of two sections, the lower section consists of thick layers of gypsum, which is fine-grained, mudstone and limestone, and the upper section consists of seven successive cycles, which are sedimentary cycles of gypsum and mudstone and contain a thick horizontal layer of red and green colored crumbs or light layers of gray crumbs, and this formation occupies an area (50. 66 km2) With a percentage (34.11%).

D- Formation of the Anjana:

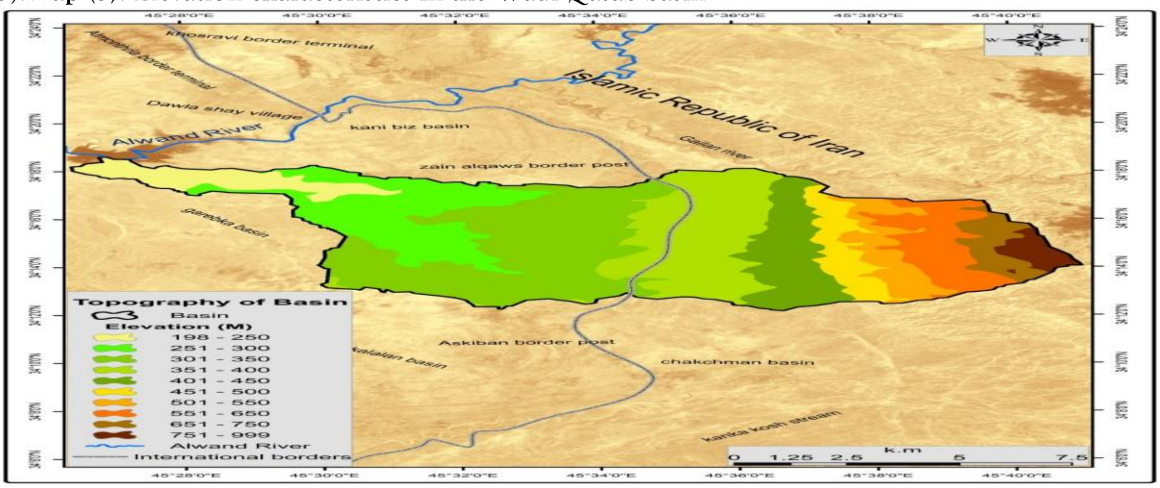
It dates back to the Upper Miocene, consisting of purple-red and gray stone with silt, brown, siltstone and sandstone (Al-Azzawi, 1982, p. 34), as the thickness of the sandstone layers in it starts to rise towards the top and reaches (1- Several meters), while the grains are deposited from coarse to fine and are intertwined with a layer of gypsum with a thickness of about (20 cm) (Al-Balani, 2010, p. 10), but over time the thickness of these formations decreased through the action of the erosion process, and the sedimentary environment of this formation is a fresh river environment (General Directorate of Geological Survey, previous source, p. 13), and this formation occupies a small area of the study area where its area is (8. 91 km2 (5.99%), and this formation is exposed in the southern part of the river basin.

2- Fourth-period sediments:

The Quaternary sediments cover the smallest part of the study area and include slope deposits dating back to the Pleistocene and Holocene eras (Brakhas, 2015, p. 23), these deposits are exposed in the west of the study area within the downstream area with an area of (0.61) km2 (0.41%), and these deposits consist of alluvial clay, sand, rock fragments, a little gypsum and irregular shapes, and the thickness of the deposits varies from less than (1 m) to several meters.

Height characteristics:

The region is characterized by its mountainous and undulating character, as the terrain of the region varies between high and low, as the maximum height in the basin reached (999 m) above sea level in the upper reaches of the basin, while the lowest height of the basin reached (198 m) above sea level, in the lower parts of the basin in the west of the study area at the mouth of the basin towards Lake Al-Wand, note map (3).**Map (3):** Elevation characteristics in the Wadi Qasab basin



Source: Researcher based on Arc Gis 10.8

Climatic characteristics:

Climate is one of the main and basic factors that contribute to the formation and development of river basins, as its various elements affect the activation of geomorphological processes that determine the characteristics of river basins, and to demonstrate the role of climate and its effects on the hydrological characteristics, especially the determination of runoff characteristics of the study area basin, it was necessary to study the climate elements of temperature, wind and rain at the Khanaqin station for the period (1993-2023) (General Authority for Meteorology and Seismological Monitoring, 2024) and as follows:

1- Temperature :

The monthly average temperature of Khanaqin station for the period (1993-2023) amounted to (23.6°C), as the highest monthly average temperature was recorded for July (36.1°C), while the lowest monthly average temperature was recorded during January (10.6°C). The thermal range varies between summer and winter if the highest thermal range during the summer months as in the month of August reached (18.6°C), while the lowest thermal range reached in January (11°C), while the average thermal range reached (15.1°C). 6 m), while the lowest thermal range reached in the winter season in January to (11 m), while the average thermal range reached (15.1 m), and this variation in the thermal range between summer and winter and night and day has an effective role in the various geomorphological processes that are active in the Wadi Qasab basin.

2- Wind:

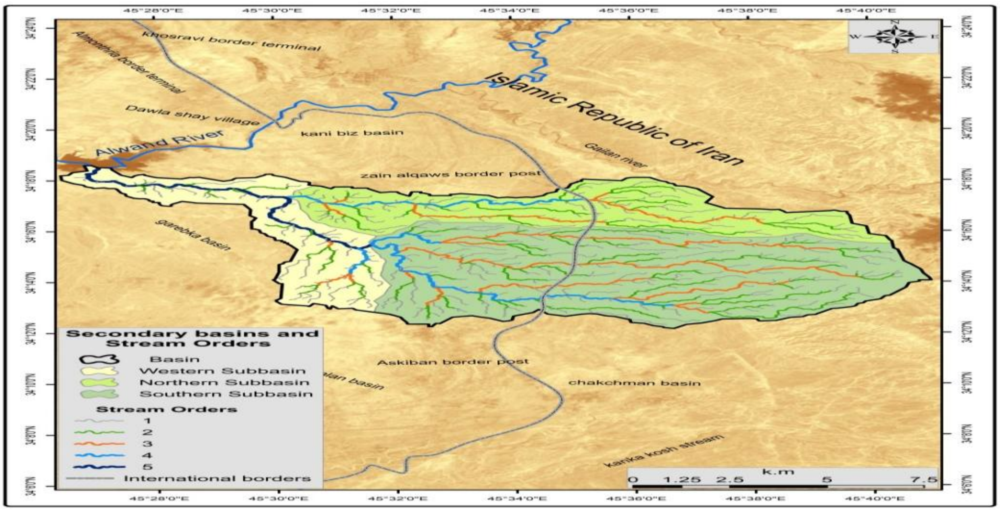
The wind speed varies from season to season depending on the change of wind direction at the Hanqin station for the period (1993 - 2023), as the highest wind speed was recorded in the month of (May) and amounted to (1.9 m/s), while the lowest wind speed was recorded in the month of (December) and amounted to (1.0 m/s), and the dominant wind direction is the western and northwestern winds with a speed of (1.4 m/s).

3- Rainfall:

The annual average rainfall at Khanaqin station was recorded (289.8 mm) for the period (1993 - 2023), and the precipitation varies from month to month, as the total rainfall for the months (November, December and January) reached (51.5, 43.8 and 54.4 mm) respectively, and the rain disappears during the months (June, July and August), and the total annual rainfall is moderate but it activates geomorphological and hydrological processes and helps the formation of surface runoff.

3. Applying The Snyder Model To The Study Area Basin:

In order to know the volume of runoff in the Wadi Qasab total basin and its secondary basins, namely the northern secondary basin, the southern secondary basin and the western secondary basin, as in Map (4), it was necessary to use the Snyder Model, to identify and evaluate the times and periods when the basin is exposed to flood risks and floods, and to benefit from them in times of drought by storing them, as well as to know their hydrological potential and their impact on the land surface, and this model consists of a set of equations, namely: **Map (4): Wadi Qasab basin and secondary basins**



Source: Researcher based on Arc Gis 10.8

Time of concentration: (Tc)

It means the necessary time period that it takes for rainwater to flow, collect and move from the farthest point in the basin until it reaches the estuary (Al-Majid and Ibrahim, 2002, p. 114), if its value decreases, it means the speed of reaching the maximum discharge at the mouth of the basin, and the high degree of danger, due to the presence of a high concentration of water, which led to its strong rush causing dangerous torrents in the basin. High values indicate that the water basin is less dangerous, and the concentration is affected by spatial characteristics, as there is a direct relationship between them represented by length, width and area, and the more the area increases the concentration time and in turn reduces the risk of floods, as the concentration time was calculated by relying on the Snyder equation, which is as follows (Al-Akam, Mohammed, 2015, p. 1538):

$$TC = \frac{4(s)0.5 + (1.5 * L)}{0.8(H)0.5}$$

S = stream slope

L = stream length / km

H = difference between average elevation and minimum elevation / m

Through table (1), and by applying the above equation, it is observed that the concentration time for the total basin and secondary basins has a clear difference between the basins, as the concentration values reached (9.8, 12.16, 5.67 and 15.45) hours, for the basins (northern secondary basin, southern secondary basin, western secondary basin, total basin) Respectively, we find that the total basin and the southern secondary basin recorded high values, due to the large basin area, as well as the length of its waterway as well as its rocky and geological nature, while the western secondary basin recorded the lowest concentration time values (5.67 hours), due to its small area, in addition to that this basin drains the northern and western secondary basins, so the amount of discharge in it is very high compared to the rest of the basins, that is, the basin's imports are abundant and thus the water travelled the length of the stream from upstream to downstream of 17. 510 km in a time of 5.67 hours. 510 km with a time period of 5.67 hours, and its speed constitutes a great pressure on the rocks of the basin, which leads to dangerous demolition and erosion processes, in addition to the flood risks it causes, while the concentration time for the northern basin comes second in terms of low value after the western basin, due to the small area of the basin and the short length of its course, which causes great pressure on the rocks of the basin and thus increases the risk of flooding.

Table (1): Concentration time for the study area basins

Basins	Slope (%)	Channel Length (m)	Elevation Difference (m)	Concentration Time (Minutes)	Concentration Time (Hours)
Northern Sub-Basin	2.13	18.978	29.6	588.7	9.8
Southern Sub-Basin	3.15	17.979	14.4	729.64	12.16
Western Sub-Basin	0.87	17.51	68.4	340.27	5.67
Total Basin	2.1	30.77	28.7	927.5	15.45

Source: Researcher's work based on the digital elevation model (DEM) and ARC GIS 10.8 software.

Lag Time: (T)

It is called the response time of water basins, that is, the time period between the peak of rainfall and the peak of discharge, and is one of the factors that affect the amount of water loss (Abdul Hussein, 2022, p. 178), an increase in the hysteresis time means that large amounts of water seep into the soil and thus reduces the risk of floods, and if the value of the hysteresis time decreases, it means high surface runoff in the river basins, which increases the danger of the basins (Al-Akam, and Mohammed, previous source, p. 139). Floods, but if the value of the hysteresis time decreases, it means high surface runoff in the river basin streams, which increases the danger of the basins (Al-Akam, and Mohammed, previous source, p. 1539), and the hysteresis time is greatly affected in determining the volume of water runoff because it depends on the basin transfer center and the length of the stream, as well as the area, the degree of slope and the shape of the basin. This coefficient is related to the topographic characteristics and the nature of the rock formations, and the flow velocity has a direct relationship with the slope of the basin surface, if the slope increases, the speed increases and vice versa, and the deceleration time is extracted through the following equation (Bs, ks and An OJ, 2015, p.4):

$TP(hr) = ct\ (L * Lca)^{0.3}$

Ct = Peak flow time coefficient, depending on the basin area and slope, and its value ranges between (0.2_2.2)

Lca = The distance between the basin outlet and its center of gravity.

When applying the above equation, and from table (2), it is clear that the values of the deceleration time for the secondary basins have a slight variation, as the values of the northern, southern and Arab basins reached (3.74, 3.77 and 3.88) hours respectively, and these values are low, which means high surface water runoff, which poses a danger for the high torrent, due to their small basin area and short lengths of their streams, and the total basin recorded a value of (5. 4) hours, which is a high value compared to the secondary basins. This is due to the nature of the rock formations that have the ability to allow water to penetrate to the subsurface layer, and the large basin area and the long distance between the mouth and the center of gravity of the basin (18,460) hours, all of which contribute to increasing the time period that leads to the actual occurrence of water runoff and thus the low level of risk in the occurrence of torrential runoff.

Table (2): Deceleration time for the basins of the study area

Basins	**Center of Gravity (Lca)**	**Lag Time (Hours)**	**Lag Time (Minutes)**
Northern Sub-Basin	9.072	3.74	224.4
Southern Sub-Basin	9.823	3.77	226.2
Western Sub-Basin	10.685	3.8	228
Total Basin	18.46	5.4	324

Source: Researcher's work based on the digital elevation model (DEM) and Arc Gis 10.8 software .

Base time for floods :

The time period for draining the entire water basin from the source to the outlet, and this period is similar in its changes to the changes in the deceleration time. The base time for floods is calculated according to the following equation (H.M, 2006, p152):

$$Tp(days) = 3 + \frac{Tp(hr)}{8}$$

Tp =Deceleration time (hours)

Applying the equation, and from table (3), it is clear that the base time of the torrents for Wadi Qasab basin amounted to (88.08 hours, equivalent to 3.67 days), while the base time values for the secondary basins (northern secondary basin - southern secondary basin - western secondary basin) amounted to (83.04 hours, equivalent to 3.46 days, 83.28 hours, equivalent to 3.47 days, 82.32 hours, equivalent to 3.43 days), respectively. This coefficient is very important in knowing the length of time that the stream needs to drain all its waters, i.e. the duration of the water remains within the streams of the basin, especially the main stream to benefit from the water by developing plans and human needs, including the construction of reservoir dams for water, so low values mean that the water in the stream disappears quickly and water scarcity occurs, while high values mean an increase in the period during which the water is exposed to vanish, as the Wadi Qasab al-Kali basin disappears completely after the rainstorm falls by about (88. 08 hours, which is a long period of time, and this applies to all basins due to the difference in areas and the type of rock formations, as well as the type of climate prevailing.

Table (3): Baseline time of floods (hour/day) for the basins of the study area

Basins	Base Time (Days)	Base Time (Hours)
Northern Sub-Basin	3.46	83.04
Southern Sub-Basin	3.47	83.28
Western Sub-Basin	3.43	82.32
Total Basin	3.67	88.08

Source: Researcher's work based on the digital elevation model (DEM) and ARC GIS 10.8 software .

a) Maximum flow rate (QP)

The maximum possible discharge rate of floods is estimated, and the maximum flow quantity of floods has a direct relationship with the degree of slope and the area of the basin, as the quantities of flowing floods increase with the increase in the degree of slope as well as the increase in the area of the basin, and it is extracted according to the following equation (Al-Baroudi, 2012, p. 55):

$$Qp(m^3\backslash s) = \frac{Cp*A}{Tp(hr)}$$

QP: Maximum flow rate of the watershed (m3/s)
A: Area of the watershed (km2)
cp: Peak flow coefficient, related to the watershed's capacity to store water and related to permeability. Its value ranges between (6.5 and 2.0)
Tp: Deceleration time (hour)
A = Area of the watershed (km2)

From the above equation and table (4), we get the peak water discharge after the equivalence time, as the maximum flow values for the total basin amounted to (116.63 m3/sa), as the southern secondary basin recorded the highest maximum flow values of (94. This rise came as a result of the large area of the basin, as the southern secondary basin is the largest area among the basins in the study area, as well as a large slope, which helps the basin to obtain good amounts of water during the rainstorm, while the western secondary basin recorded the lowest maximum flow values, which amounted to (30. 45 m3 / s) This low amount is due to the small area of the basin, as well as its low slope because it is located within the lowest part of the total basin, while the northern basin reached (42.30 / m3 / s).

Table (4): Maximum flow (m3/s) for the basins of the study area

Basins	Peak Flow Value (m^3/s)
Northern Sub-Basin	42.3
Southern Sub-Basin	94.69
Western Sub-Basin	30.45
Total Basin	116.63

Source: Researcher's work based on the digital elevation model (DEM) and ARC GIS 10.8 software.

Duration of gradual rise of floods (Tm):

It refers to the period of time required for the gradual rise of rainwater in the main channel from the source to the outlet, after the soil and sediments are saturated with water through infiltration. The rise of water occurs at the bottom of the valley channel with the continuation of the rainstorm. This factor is directly related to the deceleration time because it increases with the gradual increase in the rise and the opposite occurs (Abbas and Aboud, 2018, p. 299). This period is calculated according to the following equation (H.M, Op.cit, p. 122):

$$Tm(hr) = Tb\ (hr) * \frac{1}{3}$$

By applying the equation above and table (5), it is observed that the values of the gradual rise of the basins (northern secondary, southern secondary, western secondary, total basin) amounted to (27.68, 27.76, 27.44, 29. 36) respectively, and the total basin of Wadi Qasab recorded the highest time taken for the water to reach the highest gradual height, according to the large area, the nature of the rock formations, the length of its course, as well as the high deceleration time that works to keep the water within the course of the valley for a longer period from the fall of water to its flow, then followed by the southern secondary basin The southern secondary basin, while the western secondary basin recorded the least amount of time it takes for the torrent to reach the maximum height, noting that the values of the secondary basins are close to each other, which creates high activity for the demolition of the banks and sides of the valley streams and flash floods, which increases the likelihood of the danger of the basin and the occurrence of floods.

Duration of gradual decline of floods (Td):

It is the period of time required for the flood water to return to its normal state, and this period is calculated using the following equation (Al-Adhari and Kazim, 2016, p. 204):

$$Td(hr) = \frac{2}{3} Tb(hr)$$

$Td(hr)$= The time of gradual decrease of the torrent flow is calculated in hours .

$Tb(hr)$= Baseline time of the torrent

$\frac{2}{3}$ = constant values

By applying the equation and table (5) and by applying the equation to the basins of the study area, it is observed that the value of the total basin for the gradual decline amounted to (58.72 hours), while the secondary basins (southern, northern and western) recorded values of (55.63, 55.52 and 54. 88) respectively, as there is a slight difference between the basins, except for the Wadi Qasab total basin, which obtained a slight increase in values, and this difference in values proves the relationship between the area of the basins, their length and rock formations, all of which increase the likelihood of flood risk, which is reflected in the impact on various human activities (Kazem, Fatima Ali, and Abboud, Abdullah Sabbar, 2023, pp. 3130–3133).

Table (5): Duration of gradual rise and fall (hour/second) for the basins of the study area

Basins	**Rising Duration (Hours)**	**Recession Duration (Seconds)**	**Recession Duration (Hours)**
Northern Sub-Basin	27.68	9964.8	55.36
Southern Sub-Basin	27.76	9993.6	55.52
Western Sub-Basin	27.44	9878.4	54.88
Total Basin	29.36	10569.6	58.72

Source: Researcher's work based on the digital elevation model (DEM) and ARC GIS 10.8 software .

Ideal time period for peak rainfall (Tr)

It is the calculation of the ideal time period from the beginning of rainfall until the occurrence of surface runoff, as this coefficient is useful in knowing and calculating the ideal period at which rainfall continues and then allows the basin to prepare for a water runoff after water loss, and the values of this coefficient vary from one basin to another, depending on The geological and structural nature of the basin, such as the type and nature of the rocks, breaks, cracks and linear structures, as well as the topographical nature, especially the degree of slope, taking into account the succession of the duration of rainfall, and the ideal duration of the peak rainfall can be calculated according to the following equation (H. M, Op.cit, p153):

$$Tr(hr) = Tp(hr)5.5$$

Tb= Deceleration time (hours)

Applying the equation to the basins of the study area, and from Table (6), it is clear that the values of the time duration of the peak rainfall ranged between (0.68 - 0.98) hours, as the Wadi Qasab al-Kali basin recorded the longest ideal time duration of rainfall, which amounted to (0. This means the speed of response to rainfall, as there is a direct relationship between the deceleration time and the ideal duration of the peak rainfall, as it increases with increasing deceleration and decreases with decreasing values, while the northern, southern and western secondary basins were characterized by very close and lower values than the total basin, which increases the likelihood of high risk of floods in them, and this is due to the small area as well as the shortness of the watercourse. (Al-Ajili, Abdullah Sabbar Abboud, 2014, pp. 395–397). Accordingly, the secondary basins of the study area are characterized by a rapid response, with varying degrees of water flow after rainfall, due to the difference in rock formations and structural structure such as joints and cracks, as well as according to the nature and degree of slope of the basins, and the density of vegetation cover.

Table (6): The ideal period for peak precipitation for secondary basins in the study area

Basins	Optimal Rainfall Peak Duration (Hours)
Northern Sub-Basin	0.68
Southern Sub-Basin	0.68
Western Sub-Basin	0.69
Total Basin	0.98

Source: Researcher's work based on the digital elevation model (DEM) and ARC GIS 10.8 software .

Velocity of torrent flow (v):

It means the movement of the volume of water within the riverbed during a certain unit of time, and it is one of the most important hydrological parameters of the drainage basins that determines the extent of its danger when water runoff occurs, and when the flow velocity increases, the volume of water discharge increases, which contributes to the occurrence of flood or torrent The speed of water enhances its strength and ability, and the flow velocity decreases if the size of the sewer areas expands as well as its flatness (Freih, 2018, p. 89), and the flow velocity is extracted according to the following equation (Abu Radi, and Ajwa, without year of publication, p. 26):

$V = L \backslash Tc$

L = Pelvis length/km

Tc = Concentration time (hour)

From table (7) and applying the above equation, it is observed that the flow velocity values amounted to (31.02, 40.58, 19.43 and 30.14 minutes/hour) for the basins (northern sub-basin, southern sub-basin, western sub-basin and total basin) respectively, with the western sub-basin traveling (1 km) in (19. 43 km / min), which is a high speed of water flow, which leads to long-distance floods, accompanied by erosion and demolition of the banks of the valley stream and the movement of sediments, fragments and adults, which poses a serious danger, because this basin forms the estuaries of the northern and southern secondary basin, while the Kasb al-Kali basin comes second In terms of flow speed, then the northern basin, and the reason for this is due to the nature of the quality of the rocks, as well as the nature of the slope of the basin and its erosion, as well as the lack of vegetation cover, which leads to the flow of torrents very quickly from the source towards the mouth, while the southern secondary basin recorded the highest water flow speed of (40. From the above, we conclude that this speed is very high compared to the lengths of the waterways, which may cause severe and dangerous erosion effects (Al-Saeedi, Abdul-Hassan Habr Maleh, and Al-Ajili, Abdullah Sabbar Abboud, 2019, pp. 163–188).

Flow volume (Qt)

It is one of the important hydrological measures by which the severity of the river basin is determined (Saleh, 1999, p. 69). It means the amount of flowing water that passes through the basin drainage networks, i.e. the amount of water collected from the entire river basin at all levels up to the mainstream and downstream environment, after the amount of rainfall exceeds the amount of water loss during the seepage process, due to the lack of evaporation losses during the rainstorm period, so that there is a surplus of water, and it can be extracted through the following equation (Imran, Abdul Rahman, 2018, p. 20):

$$Qt(m3\backslash s) = \sum L(km)^{0.85}$$

$Qt(m^3\backslash s)$ = Flow volume (m3/s)

$\sum L(km)$ =Total length of basin drains \ km

After applying the equation and through table (7), it is observed that the flow volume values for Wadi Qasab total basin reached (162.11 thousand m3 / s), followed by the southern secondary basin with a value of (102.24 thousand m3 / s), and that the high values are due to their large areas and an increase in their lengths and numbers, which helped to receive larger amounts of water and thus increase the possibility of flood risk, while the northern secondary basin and the western secondary basin reached (50. 87, 34.64 thousand m3 / s), respectively. This is related to their small area, short lengths and low numbers, i.e. there is a clear direct relationship related to the area of the basins and the lengths and numbers of the river network, from which the size of the flow is inferred, and based on this, despite the variation in the size of the water flow and for all basins, it poses a risk and thus an increase in the likelihood of flooding.

Table (7): Speed and volume of flow in the basins of the study area

Basins	Flow Velocity (km/min)	Flow Volume (m^3/s)
Northern Sub-Basin	31.02	50.87
Southern Sub-Basin	40.58	102.24
Western Sub-Basin	19.43	34.64
Total Basin	30.14	162.11

Source: Researcher's work based on the digital elevation model (DEM) and ARC GIS 10.8 software.

Specific peak flow of the basin (qp)

It is the maximum flow value of torrents (m3/s) for each km2 reached by the valley stream over the basin area, and it is extracted according to the following equation: (Salami, Bilewu and others, 2017, p. 27):

$$qp(m3\backslash s\backslash km2) = \frac{Qp(m3\backslash s)}{A(km2)}$$

Qp =Maximum flow value of torrents (m3/s/km2)

A = Basin area (km2)

From table (8) and applying the equation, it is clear that the value of the total Wadi Qasab basin for the specific peak flow was recorded (0.78 m3 / s / km2), and the northern sub-basin recorded the highest specific peak flow values (1.13 m3 / s / km2), while the western sub-basin recorded the lowest specific peak flow value (1.11 m3 / s / km2), while the southern sub-basin recorded a value of (1. 11 m3 / s / km2). These values are indicative of the abundance of rainfall amounts and then the abundance of water within one square kilometer, which means the possibility of floods, but this depends on the difference in areas between the river basins, and the smaller the area, the greater the risk of floods, which This indicates that there is an inverse relationship between the area of the basin and the values of the specific peak flow, because the value of the specific peak flow increases with the small area of the basin that drains its water faster than basins with large areas, while the values of the specific peak flow decrease with the increase in the areas of the basins.

Table (8): Specific peak flow for the basins of the study area

Basins	Qp
Northern Sub-Basin	1.13
Southern Sub-Basin	1.12
Western Sub-Basin	1.11
Total Basin	0.78

Source: Researcher's work based on the digital elevation model (DEM) and ARC GIS 10.8 software .

The appropriate period for the torrent to rise w50, w75:

It is the appropriate time period for displaying the torrent curve (hydrograph) at levels (50) and (75) respectively, of the peak discharge, and it is extracted according to the following equation (H.M., Op.cit, p. 154):

$$W50(hr)s = \frac{5.6}{(qp)1.08}$$

$$W75(hr) = \frac{3.21}{(qp)1.08}$$

qp= Peak specific flow of the basin (m3/s/km (2

After applying the equation to the basins of the region, and from table (9), it is observed that the values of the appropriate time duration for the torrent height (50), (75), the values varied between the basins of the study area, as the values of the time duration ranged between (7-4.90 hours) at level (50), and between (2.81-4.1 hours) at level (75), the western secondary basin recorded the highest appropriate time duration for the torrent height for the secondary basins at level (50), (75), amounting to (5 hours), (2. 86 hours), respectively, while the northern secondary basin recorded the lowest time duration for the torrent height at level (50), (75), amounting to (4.90 hours), (2. 81 hours) respectively. (86 hours) respectively, while the northern sub-basin recorded the least favorable duration of the flood height at the (50), (75) level, amounting to (4.90 hours), (2.81 hours) respectively, while the southern sub-basin at the (50), (75) level, recorded values of (4.95 hours) and (2. 84 hours) respectively, while the Kasb al-Kali basin at level (50) and (75) recorded values of (7.3 hours) and (4.1 hours) respectively. The discrepancy in the values of the appropriate time period for the height of the torrent for both levels is due to the different areas of the basins and the numbers and lengths of their streams, as well as the nature and quality of the rocks.

Table (9): The period for the torrent to rise at the level of (75% 50%) for the basins of the study area

Basins	50/Hour w	75/Hour w
Northern Sub-Basin	4.9	2.81
Southern Sub-Basin	4.95	2.84
Western Sub-Basin	5	2.86
Total Basin	7.3	4.1

Source: Researcher's work based on the digital elevation model (DEM) and ARC GIS 10.8 software .

Floodwater strength (A):

It is one of the hydrological measures that shows the extent of the strength of the torrent in the water basin at the peak of rainfall, and means the constant discharge value per km2 of the basin area, and depends on the maximum flow of the torrent, and the area of the basin (Mohammed, 2021, p. 261), the strength of flood water is calculated according to the following equation (Kayyali, and Abdul Jawad, 2012, p. 100):

$$A(m3\backslash s\backslash km2) = \frac{Qp(m3\backslash s)}{\sqrt{A(km2)}}$$

Qp = Maximum flow rate of floods (m3/s/km2)

Applying the above equation, and from table (10), it is observed that the value of the power of flood water for the total cane basin amounted to (9.93 m3/sqm2), while the power of flood water was recorded (6.93, 10.33 and 5.83 m3/sqm2) for the sub-basins (northern sub-basin, southern sub-basin and western sub-basin) respectively. 83 m3 /sqm2) for the secondary basins (northern secondary basin, southern secondary basin, western secondary basin) respectively, as we notice that there is a difference in values due to the different geological and stratigraphic characteristics, and the different areas of the basins, as basins with large areas and containing many waterways have the ability to acquire large amounts of water falling through rain, as well as the factor of This applies to the total basin and the southern sub-basin, while basins with small areas may be less dangerous depending on a number of factors, the most important of which is the slope factor if it is low, and this applies to the northern and western sub-basin.

Table (10): The strength of the flood waters of the study area basins

Basins	Flow Power ($m^3/s \cdot km^2$)
Northern Sub-Basin	6.93
Southern Sub-Basin	10.33
Western Sub-Basin	5.83
Total Basin	9.56

Source: Researcher's work based on the digital elevation model (DEM) and ARC GIS 10.8 software .

Appropriate runoff depth for peak stream flow (E)

It is one of the most important hydrological parameters for calculating the depth of surface runoff, based on the duration of the gradual rise of the torrent flow, the maximum flow, and the basin area. The depth of surface runoff is calculated using the following equation (Muhammad, 2019, p. 56):

$E(mm) = Qp\left(m^{3\backslash s\backslash km2}\right)[Tm^{sec} * 10^{-3}] * (S^{-1})$

$Tm^{(\mathrm{sec})}$= Duration of gradual rise of torrent flow (s)

)$Qp(m^{3\backslash s\backslash km2}$ =Maximum flow of torrents (m3/s)

S =Basin area km2. (Abbas, Israa Abdul-Hussein, and Al-Ajili, Abdullah Sabbar Abboud, 2018, pp. 295–398).

After applying the equation to the basins of the study area and from table (11), it is observed that the values of the depths of runoff for the secondary basins ranged between (11.04-11.32 mm). 32 mm), and these values are close, and are indicative of the abundance of rainwater and are highly responsive, which poses a danger to the basins and their streams in terms of their exposure to erosion and demolition processes and their impact on human activity, while the total reed basin recorded a value of (8.29 mm), which is a low value compared to the values of the secondary basins due to its large area that works to create the possibility of flood risk but less.

Table (11): Depth of surface runoff (mm) for the basins of the study area

Basins	**Flow Depth (mm)**
Northern Sub-Basin	11.32
Southern Sub-Basin	11.26
Western Sub-Basin	11.04
Total Basin	8.29

Source: Researcher based on Digital Elevation Model (DEM) in ARC GIS 10.8

b) **Suitable rainfall concentration for peak flood flow (i)**

It is one of the hydrological equations and is important in knowing the number of small amounts of rain needed for surface runoff to begin to appear in the main course of the water basin. It can be extracted according to the following equation (Al-Ghailan, 2008, p. 44):

$$i(cm(hr)) = \frac{1}{Tr(hr)}$$

Tr(hr) = Ideal duration of rainfall (hour)

By applying the equation above and table (12) to the studied basins, it is observed that the value of the total basin for the rainfall concentration suitable for the peak flow of the torrent reached (1.02 cm / hour), and it is considered the lowest concentration compared to the secondary basins due to its large area and the nature of the rock formations that allow the penetration of quantities of water, which works to delay the runoff and the occurrence of flooding, while the secondary basins (northern basin, southern basin and western basin), their values have converged among themselves and ranged between (1. 47, 1.47 and 1.44 cm / hour), respectively. The northern secondary basin and the southern secondary basin recorded the highest value of (1.47 cm / hour), while the western secondary basin recorded the lowest concentration of peak rainfall of (1.44 cm / hour), the small area of the basins increases the concentration of rainfall and the occurrence of flooding and increasing the risks to them.

Table (12): Rainfall concentration suitable for peak flood flow in the basins of the study area

Basins	**Rainfall Intensity (cm/hour)**
Northern Sub-Basin	1.47

Southern Sub-Basin	1.47
Western Sub-Basin	1.44
Total Basin	1.02

Source: Researcher's work based on the digital elevation model (DEM) and ARC GIS 10.8 software .

c) **Stream flow volume (AL)**

The volume of the torrent flow is (millions/m3/s), and is extracted according to the following equation (Al-Kayali and Abdul-Jawad, previous source, p. 155):

$$AL^{(Hm3)}(10^{-6m3}) = Qp^{(m3\backslash s)}\{Tm^{sec}\backslash 0^{-6}\}$$

$Qp^{(m3\backslash s}$ =Maximum flow of torrents (m3/s)

$Tm^{(sec)}$ =Duration of gradual rise of torrent flow (s)

After applying the equation to the study basins, and from Table (13), it is observed that the total reed basin recorded a value for the volume flow coefficient of (1. This is due to the effect of the slope coefficient on the basin from the highest to the lowest point in the basin downstream, and the increase in the numbers and lengths of waterways as well as the area of the basin, while the values of the secondary basins varied and ranged between (0.3 - 0.9 million / m3 / s), as the southern secondary basin recorded the highest volume of flood flow of (0.9 million / m3 / s). 9 million / m3 / s), while the western sub-basin recorded the lowest volume of flow (0.3 million / m3 / s), while the northern sub-basin had a value of (0. 4 million / m3 / s). This discrepancy is due to the nature of the rock formations and the area of the river basins and the numbers and lengths of their streams, the volume of the torrent flow is very large compared to the area of the basins, which leads to the potential danger of flooding, as these values pose high risks to human stability, especially in the main valley streams and their estuarine areas because of the destruction, erosion and transportation of sediments and rock fragments.

Table (13): The volume of torrent flow in the basins of the study area

Basins	**Flood Flow Volume (Million m³/s)**
Northern Sub-Basin	0.4
Southern Sub-Basin	0.9
Western Sub-Basin	0.3
Total Basin	1.2

Source: Researcher's work based on the digital elevation model (DEM) and ARC GIS 10.8 software .

CONCLUSIONS

1- The study found that the concentration time for the total basin and the secondary basins reached (9.8, 12.16, 5.67 and 15.45) hours for the basins (northern secondary basin, southern secondary basin, western secondary basin and total basin). respectively, and that these values mean an increase in the basin's imports and that their speed puts great pressure on the basin's rocks, which leads to dangerous demolition and erosion processes, in addition to the flood hazards it causes.

2- The study found that the values of the deceleration time of the secondary basins have a slight variation, as the values of the northern, southern and western basin reached (3.74, 3.77 and 3.88) hours, respectively, and these values are low, which means high surface water runoff, which poses a danger to the high torrent.

3- The study found that the flow volume values for Wadi Qasab total basin amounted to (162.11 thousand m3 / s), followed by the southern secondary basin with a value of (102.24 thousand m3 / s), while the northern secondary basin and the western secondary basin reached (50.87 and 34.64 thousand m3 / s) respectively, and these values vary, and the variation in the volume of water flow for all basins is dangerous and thus increases the likelihood of flooding.As for the magnitude of the torrent force, the study found that the total reed basin recorded a value of 1.2 million / m3 / s, which is the largest flood and torrent flow among the values of the secondary basins, while the values of the secondary basins varied and ranged between (0.3 - 0.9 million / m3 / s), the volume of torrent flow is very large compared to the area of the basins, which leads to the potential danger of flooding as these values pose a great danger to human activities.

Suggestions:

1- The study proposes the establishment of hydrological stations to know the amount of water discharge to benefit from it for various human purposes.

2- The study proposes the use of water harvesting methods, especially the construction of dams to take advantage during the time of rainfall and employ it properly and direct it to investment projects within the study area.

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