***Dirasat*: Human and Social Sciences, Volume 51, No. 2, 2024**

Deanship of Scientific Research

Flash Floods Assessment Urban Area: A Case Study Wadi Abdoun Basin, Jordan

Radwan Abdullah Al-Weshah*[1,2], Zaid ayyash Sakarnah [3]

[1] Department of Civil Engineering, The University of Jordan, Amman, Jordan.

[2] Department of Civil Engineering, Faculty of Engineering and Technology, Al-Zaytoonah University of Jordan, Amman, Jordan.

[3] Researcher, National Agricultural Research Center, Jordan

Received: 23/6/2023
Revised: 15/8/2023
Accepted: 29/11/2023
Published: 30/3/2024

* *Corresponding author:*
r.weshah@ju.edu.jo

Citation: Al-Weshah, R. A. ., & Sakarnah , Z. ayyash . (2024). Flash Floods Assessment Urban Area: A Case Study Wadi Abdoun Basin, Jordan. *Dirasat: Human and Social Sciences*, *51*(2), 228-237. https://doi.org/10.35516/hum.v51i2.5119

Abstract

Objectives: The study aims at conducting hydrological analysis of flash floods of Wadi Abdoun basin West of Amman City in Jordan, using Watershed Modeling System (WMS) software.

Methods: The study used the watershed modeling tools and the- Curve Number (SCS-CN) to predict the flash floods based on the historical rainfall storm three nearby rainfall stations.

Results: The results indicated that there is a significant increase in urban areas by about 70% of the total area of the basin. This led to an higher peak flow of the flood hydrograph due to an increase in runoff potential and decreased the time of concentration of the sub-basins to about 4 hours.

Conclusions: The study concluded that higher peak flows are observed at different locations at the study area. The peak floods overtopped the existing hydraulic structures and caused severe damage to the infrastructures in the study area.

Keywords: Urban hydrology, flood mitigation, flash floods, wadi abdoun basin, Jordan.

تقييم الفيضانات الومضية في المناطق الحضرية: دراسة حالة حوض وادي عبدون، الأردن

رضوان عبدالله الوشاح*[1، 2]، زيد عياش سكارنه[3]

[1] قسم الهندسة المدنية في الجامعة الاردنية عمان ،الاردن.

[2] قسم الهندسة المدنية والبنيّة التحتية. كليه الهندسة في جامعة الزيتونة الأردنية. عمان الأردن.

[3] باحث علمي المركز الوطني للبحوث الزراعية، الأردن.

ملخّص

الاهداف: تهدف الدراسة إلى إجراء تحليل هيدرولوجي للفيضانات الومضية في حوض وادي عبدون الذي تبلغ مساحته 105 كم² غرب مدينة عمان في الأردن.

المنهجية: اعتمدت الدراسة في منهجيتها على استخدام برنامج حاسوبي متطور وبالاعتماد على بيانات الشدة المطرية للمحطات المثلة لمنطقة الدراسة محطات صويلح وكلية الحسين ووادي السير، للتنبؤ بالفيضانات الومضية

النتائج: أشارت النتائج إلى ارتفاع نسبة المناطق الحضرية إلى حوالي 70٪ من إجمالي مساحة الحوض، مماأدى إلى ارتفاع القيم الموزونة لرقم منحنى الجريان السطحي وخفض زمن تركيز لحوض التصريف إلى ما يقارب 4 ساعات.

الخلاصة: خلصت الدراسة الى ارتفاع محرز في قيم تدفق الذروة في مواقع مختلفة في الحوض خصوصا عند منطقة المصب. وتجاوزت الفيضانات الومضية قدرة المنشاءات الهيدروليكية القائمة مما تسبب بحدوث غمر نتج عنه أضرار جسيمة في البنى التحتيةفي منطقة الدراسة.

الكلمات الدالة: الهيدرولوجيا الحضرية، تخفيف حدة الفيضان، الفيضان الومضي، وادي عبدون، الأردن.

Introduction

The study of urban hydrology is a special and important case for its intersection with human activities, The problem of the study is the increase in the values of runoff and the occurrence of a number of the flash floods in the downtown of Amman City called Quraysh street.

The main causes of increased flash floods risk are climate change and human interventions, such as increased urban growth or the construction of roads or other urban structures in watercourses that alter or divert watercourses (Green et al., 2000). Human activities have significant impacts on flash floods because some urban basins respond rapidly to heavy rainfall following the constant change in the natural drainage system (Norbiato et al., 2008).

The flash floods caused by heavy rains and a short response time have devastating effects that have been exacerbated by increasing human activities in urban areas, becoming a prominent problem in the management of small watersheds worldwide (Spitalar et al., 2014) urban use increases to 70% of the total land use in the wadi Abdoun basin. This means that the earth's surface is less able to absorb water, which is reflected in the higher values of the basin's runoff curve, which results in faster response to surface runoff. Therefore, the high proportion of urban spaces creates severe problems in the management of water resources and how to deal with them, especially with increasing rainfall intensity (Wang, 2001).

Therefore, the region has become more affected by flash floods are short-term events, occurring within 6 hours due to heavy rain, characterized by reaching peak discharge within a period usually two hours after the onset of rainfall. The effects of flash floods in urban areas are increasing due to higher runoff and lower time of concentration for the basin. Rapid urbanization and changing land use have made it necessary to understand the behavior, magnitude and predictability of flash floods, especially in rapidly expanding urban catchments (Rodriguez et al. 2003).

The study aims at conducting hydrological analysis of flash floods of Wadi Abdoun basin using Watershed Modeling System (WMS) software based on the three nearby rainfall stations. The study used the method of Soil Conservation Service- Curve Number (SCS-CN) to predict the flash floods and suggest several flood mitigation measures.

The Study Area:

The Wadi Abdoun basin is located within the west side of Amman and extends from Sweileh, and parts of Jubaiha to the downtown Amman city near Quraish street. It is within the main surface basin of Amman Zarqa, the height of the surface height of 1083 meters to the areas of Sweileh and parts of Jubaiha and up to 737 meters above sea level in the area of the center of the downtown Amman near Quraish street as it is in Figure 1.

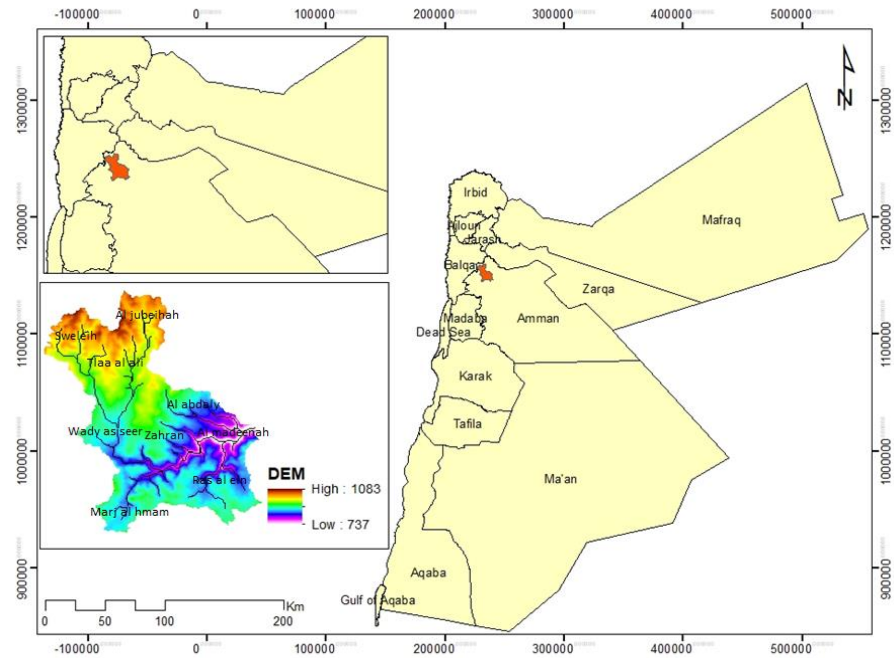

Figure 1: Location Map of the Wadi Abdoun Basin.

The wadi Abdoun basin located within the warm temperate Mediterranean climate, where the average temperature of July exceeds 22 ^{C}, the rainy season usually lasts from October to the end of May. The depressions from the Mediterranean contribute 85% of total rainfall, especially in winter, and spring and autumn rains are often associated with instability such as depressions from the red sea and do not exceed 15% of total rainfall during the rainy year (Meteorological Department, 2016). the annual precipitation of the basin was approximately 400 mm. The average monthly wind velocity of the basin was approximately 23.33 km/h for July while dropping to 12.78 km/h for October.

The wadi Abdoun basin suffered from flash floods during in recent years, especially the flash flood 5/11/2015, where the intensity of precipitation 45 mm in 40 minutes. More recently it was flooded on 28/2/2019, which recorded an almost continuous rainfall from the morning of 27/2/2019 until the following evening, the maximum rainfall intensity of about 10 mm/h. This flood caused severe flooding to most downtown areas of Amman causing great material losses in shopping areas.

The problem has been exacerbated by the high growth of urban activities in the city and the continuous change in the natural drainage network and its replacement with a man-made drainage system that reduces its capacity of the drainage system. Moreover, the projected global climate change and the associated extreme climatic conditions such as extreme rainfall will increase the frequency and intensity of sudden flooding (Dihn et al., 2012). On the other hand, flash flood water can be harvested if collected in proper way as a source of additional water supply along with reclaimed water (Saidan *et. al*. 2015, Asaad *et.al.,* 2023).

Methodology

The methodology of the study includes the delineation of the wadi Abdoun basin from the digital elevation model with a resolution of 30 meters depending on data United States Geological Survey, use geographical information systems and Remote Sensing. The area is divide into eight watersheds based on the morphometric characteristics of the natural drainage network of the basin as shown in Figure 2.

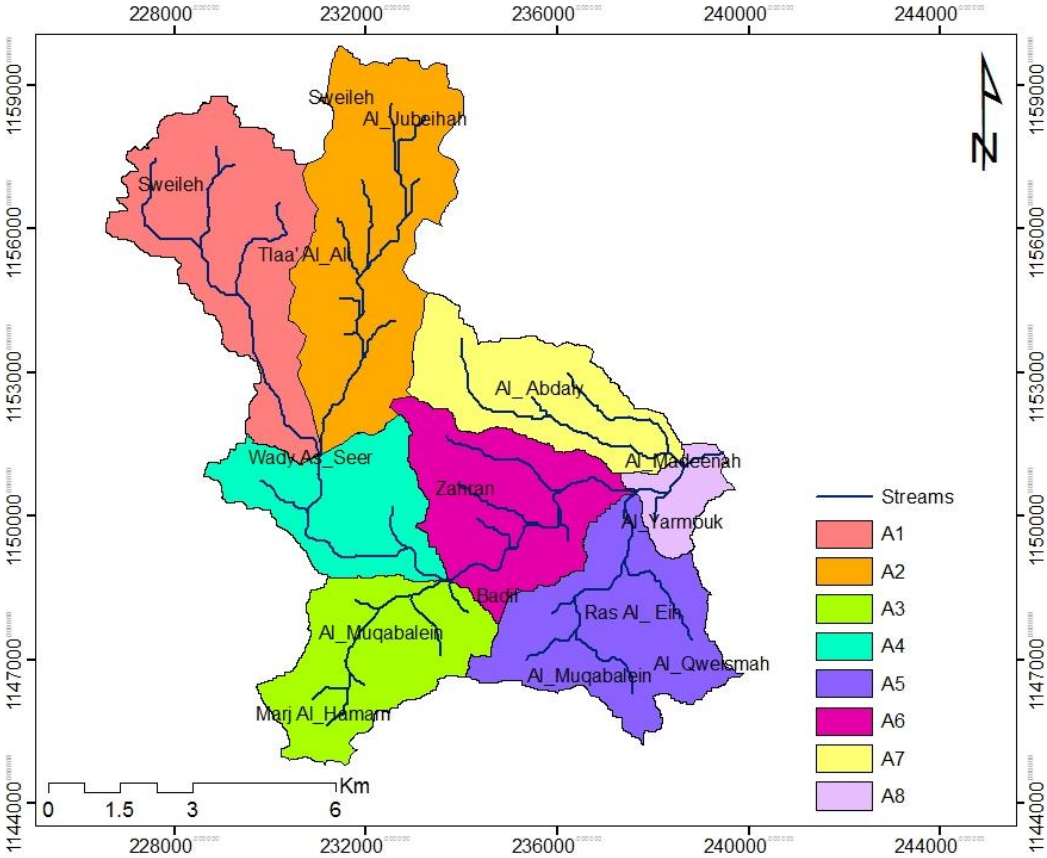

Figure 2: The sub-basins of wadi Abdoun Basin (Based on WMS model).

The HEC-1 hydrological model is considered a single model to simulate the surface runoff of one influential rain wave to find the hydrograph interpreted for it over the whole basin (HEC-1, User's Manual). Therefore, building the hydrological model requires reaching rainy values or averages of rainfall in the study area over a period of time. Specific, considering the precipitation values for the drainage basin as an important basis in building the hydrological model, the rainfall value was extracted as a weighted average rainfall for each partial basin, using the Theiseen polygon method, so the rain intensity curves of the three available stations were relied upon. To find the weighted intensity values for each partial basin with a duration of 6 hours.

The following figure shows the study plan and steps for flow calculations using the hydrological model for the study area and its sub basins.

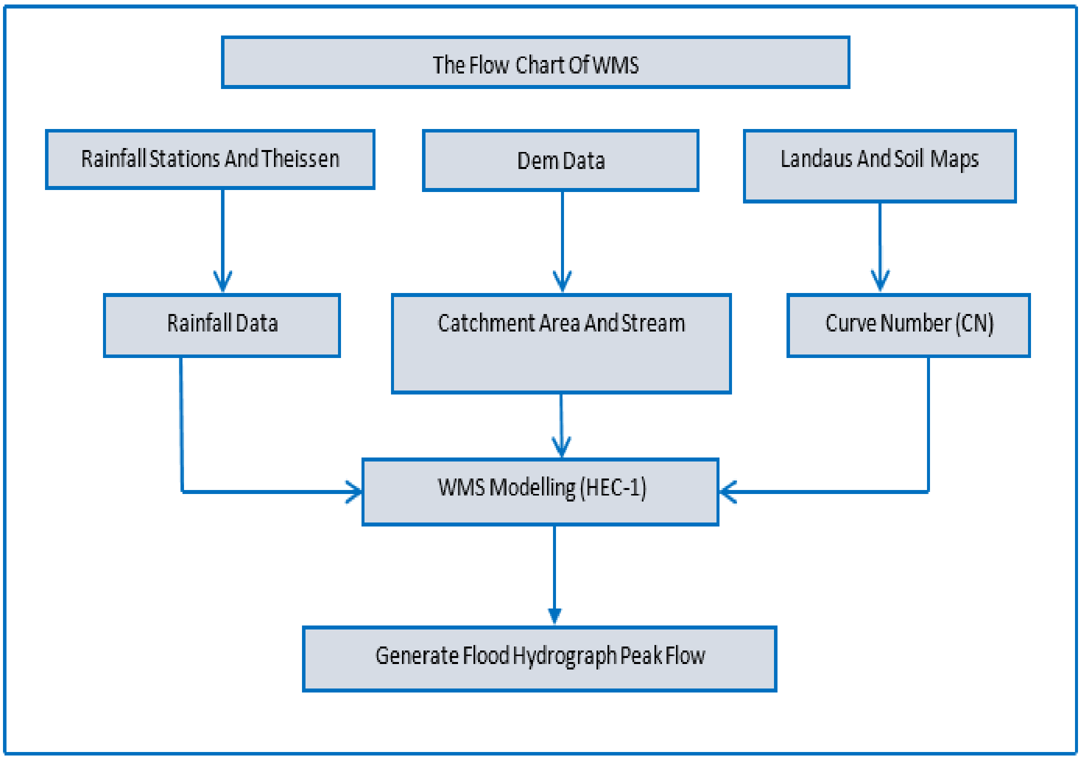

Figure3: The Flow Chart of WMS

Based on the rainfall intensity-duration-frequency (IDF) curves of the Stations Sweilih, Hussein College, Wadi Asser Based on the data of the Ministry of Water and Irrigation, The Theissen method was used to calculate their areal weight as shown in Figure 3. The weighted average of rainfall intensity was estimated for a duration of six hours and a return periods of 10, 25, 50 and 100 years. The following figure shows the application of the Thyssen polygons method for the rain stations used in the study to derive the weighted rain intensity values for the partial basins of the wadi Abdoun Basin

Table 1. The rainfall stations used in the study.

Number	Stations		Palestine Grid (E)	Palestine Grid (N)	High (m)	Station type
1	Sweilih	AL0017	229500	1159000	1000	Climate, Rainfall
2	Hussein College	AL0022	238200	1152000	834	Rainfall
3	Wadi Asser	AN0002	227500	1151000	900	Rainfall

Building the hydrological model requires reaching the weighted rainfall values in the study area during a specific period of time, considering the rainfall values (P) for the drainage basin as an important input in building the hydrological model.

The rainfall value was extracted as a weighted average rainfall for each sub- basin, using the method Theiseen polygon, and the following figure shows the application of the method of Theiseen polygons for the rain stations used in the study to derive the weighted rain intensity values for the sub-basins of Wadi Abdoun Basin

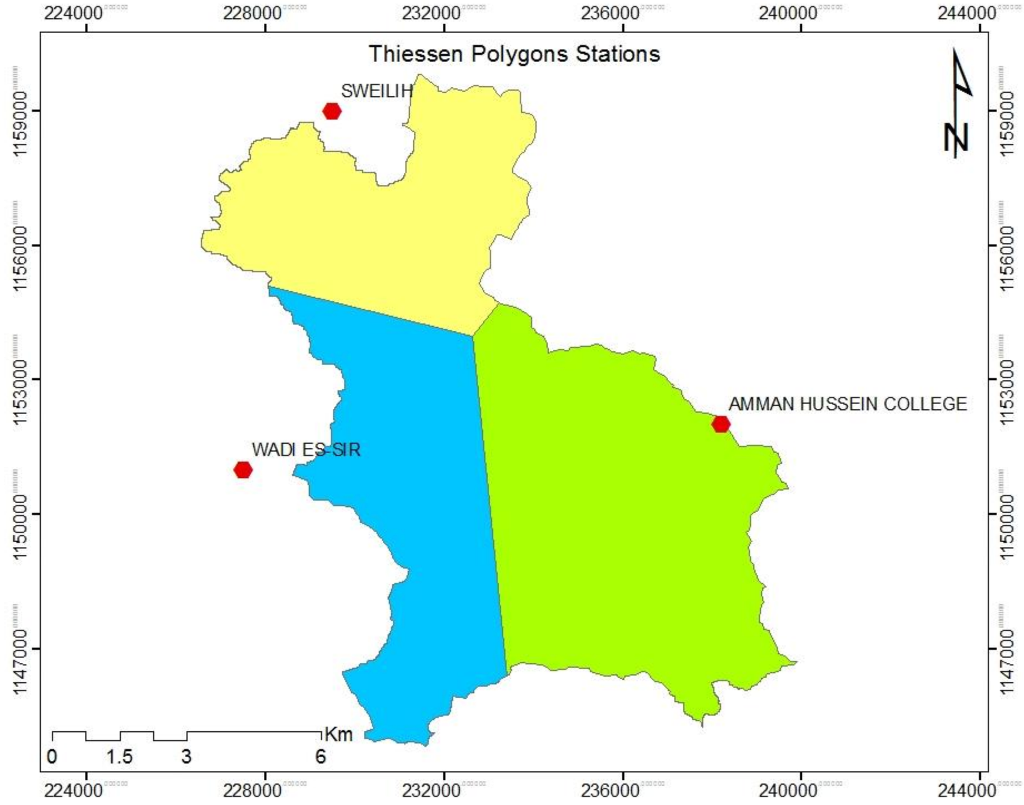

Figure 4: Theissen polygons to the stations used in the study.

Based on the Thyssen polygons method for the rain stations used in the study, the weighted rain intensity values were derived for the sub-basins of Wadi Abdoun Basin for 6 hours and return periods of 10, 25, 50 and 100 years, as shown in the following table:

Table 2. The weighted 6h-rainfall intensities watersheds for different return periods.

Watershed No.	Area (km^2)	SCS-CN	I10 (mm/h)	I 25 (mm/h)	I 50 (mm/h)	I-100 (mm/h)
A1	17.80	90.4	43.9	52.3	58.9	65.1
A2	19.70	93.8	44.1	52.5	59.1	65.3
A3	11.70	84.9	41.4	44.3	56.5	63.1
A4	11.60	90.3	40.2	48.6	55.2	61.8
A5	15.60	92.5	48.6	57.6	64.2	70.8
A6	13.50	91.9	51.9	61.5	68.5	75.6
A7	11.80	94.8	48.6	57.6	64.2	70.8
A8	3.30	93.9	48.6	57.6	64.2	70.8

The study used the method SCS-CN contained in USDA, flood-runoff hydrograph is constructed based on this method (SCS,1986) to calculate the values of the runoff curve number of the study area. This method is of great importance in the field of hydrological modeling and analysis and is used in many hydrological applications (Al-Weshah and El-Khoury, 1999). Based on GIS maps, soil hydrological groups were classified and the land cover and uses were classified according to the SCS-CN method.

Urban runoff is increasing dramatically due to land-use change and thus an assessment of urban land use, an important element as an input to estimating runoff. Among all factors, hydrologic soil groups and land use are more important in determining the CN value (USDA, 1986). In this study area, 10 groups of land used and soil types are identified. Several layers and coding with different symbols such as land coverings, land use, and soil texture, were used in determining the weighted CN, as shown in Figure 4. The CN values exceeding 90 are associated with the urban land cover in the basin, they are mostly impervious surfaces with very low permeability levels.

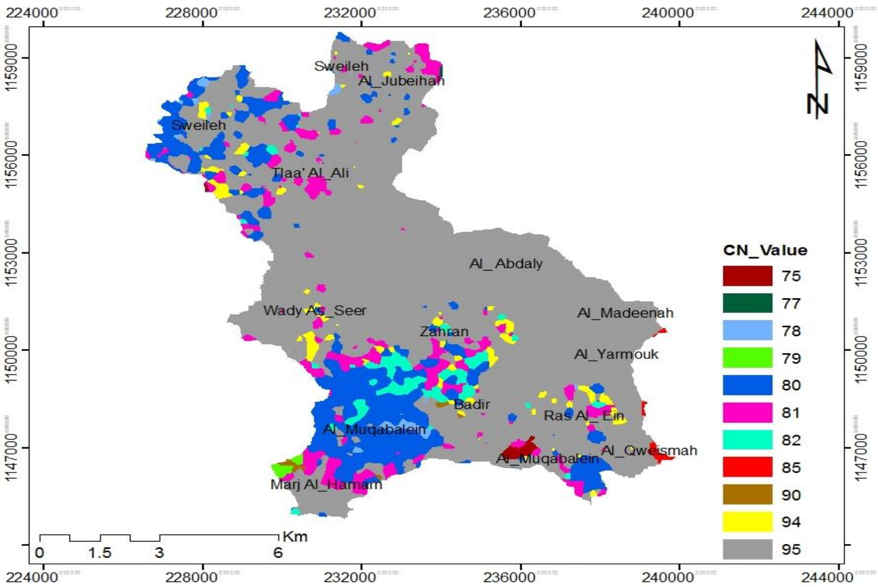

Figure 5: Distribution of (CN) Values in the Study Area.

Hydrological Analysis and Modeling

Hydrological modeling or water resources engineering is defined as a simple representation of a complex system. as models always describe the basic components of the most important and complex system is simple, Action to address, mitigate and predict flood risk requires the study of the expected runoff over a given period, based on rainfall data and watershed characteristics. so flash flooding affects sustainable development efforts, so careful assessment of floods provides greater flexibility in development planning (Al-Weshah and El-Khoury, 1999; Fred & Mostafa, 2008).

The study used WMS model to simulation rainfall and runoff relation and to develop the flood hydrograph. The unit hydrograph may also be applied to several recorded rain events or certain events derived from specific rainfall IDF curves (Chow *et al*, 1988).

The HEC-1 hydrological model was used within the WMS environment, allowing the calculation of maximum runoff and discharge peak in watersheds as a hydrological model simulating the single-wave flow and hydrographic calculation of that wave. This model also includes options for calculating total flow by directing the flow of the main sub-basin (Al-Weshah & El-Khoury, 1999). This model simulates surface runoff as the main basin of the wadi and its watershed are integrated with hydrological and hydraulic elements (HEC-1,1998).

The HEC-1 model is very efficient in obtaining results and detecting any errors in the input files. It contains several options for the modeling of rainfall storm, losses methods, and unit hydrograph calculation. Hydrological models that mimic precipitation and runoff help to achieve reliable predictions of the amount and depth of runoff in less time (Askar,2014). The model treats the basin as an integrated hydrological system as the watersheds within the main basin are basic entities expressed in the sub-basin, and their hydrological status can be expressed in average values (Al-Weshah and El-Khoury, 1999).

The study used mathematical formulas associated with the hypothesis of SCS method to calculate the time of concentration (Tc) of the watershed. The time of concentration is defined as the time it takes for a drop of water in the remotest point in a drainage basin to travel to the outlet (SCS, 2010), The SCS equation that computes the time of concentration in metric units is given by equation 1 (Ocket et al, 2014) as:

$$Tc = \frac{L^{0.8}\left[\frac{25400}{CN} - 228.6\right]^{0.7}}{706.9\sqrt{S}} \quad (1)$$

where,

Tc: The watershed lag time, in minutes,

L: The length of the principal watercourse, in m

CN: SCS curve number

S: The average watershed land slope, in m/m. Note, the average watershed land slope is the slope of the land surface approaching the channel, not the channel slope.

The lag time is estimated as 0.6 times the value of Tc. Table 3. shows the hydrological parameters of each sub-basins in the study area of wadi Abdoun basin based on DEM and WMS model.

Table(3): Hydrological Parameters of the Sub-basins in the Study Area.

Sub-Basin	Area km2	Length Stream (m)	Slope %	Tc (h)	Lag Time (h)
A1	17.57	8076	2.33	3.30	1.98
A2	19.58	8835	2.09	3.21	1.93
A3	11.63	5774	2.42	3.05	1.83
A4	11.68	6059	2.54	2.52	1.51
A5	15.54	6809	2.79	2.40	1.44
A6	13.46	5761	3.82	1.84	1.11
A7	11.67	6684	3.70	1.85	1.11
A8	3.32	3450	5.22	0.96	0.57

Results, Analysis and Discussion

The WMS was used to build the hydrologic tree system of the wadi Abdoun basin (catchment) with its eight sub-basins (sub-catchments) as shown in Figure 5. The hydrological model resulted in flood runoff hydrograph that indicated the peak discharge, flood volume and time to peak of the watershed for each return period.

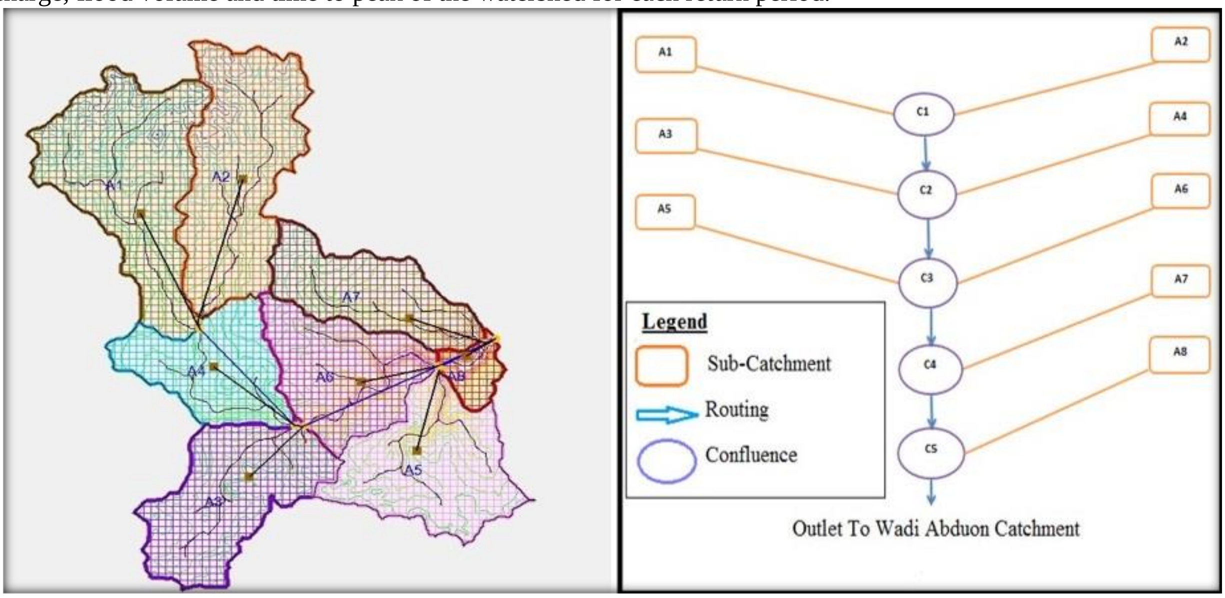

Figure 6. Tree diagram and connectivity of sub-basins within Wadi Abdoun basin.

Table 4 shows results of the flood peak flow at each sub-basin for different return periods and duration of 6h storm and Table 5 shows runoff volume at each sub-basin for the 6h storm for different return periods.

Table 4. Peak flow for the 6h storm for different return periods.

Watershed	Q10 (m^3/s)	Q25 (m^3/s)	Q50 (m^3/s)	Q100 (m^3/s)
A1	33.36	44.39	53.11	61.44
A2	48.87	62.08	72.86	82.87
A3	13.61	15.63	24.89	30.32
A4	22.9	31.27	38.13	45.11
A5	50.54	64.42	74.76	85.2
A6	55.76	70.44	88.22	93.7
A7	53.02	65.85	75.45	84.92
A8	21.29	26.81	30.93	35.01

Table 5. Runoff volume for the 6h storm for different return periods.

Sub-basin	Flood Volume V10 (MCM)	Flood Volume V25 (MCM)	Flood Volume V50 (MCM)	Flood Volume V100 (MCM)
A1	0.396	44.39	53.11	61.44
A2	0.561	62.08	72.86	82.87
A3	0.156	15.63	24.89	30.32
A4	0.225	31.27	38.13	45.11
A5	0.473	64.42	74.76	85.2
A6	0.435	70.44	88.22	93.7
A7	0.413	65.85	75.45	84.92
A8	0.109	26.81	30.93	35.01

The flood hydrograph for the 6-h storm at the outlet of the Wadi Abdoun basin (C5), near the Quraish Street in downtown Amman, for different return periods is given in Figure 6.

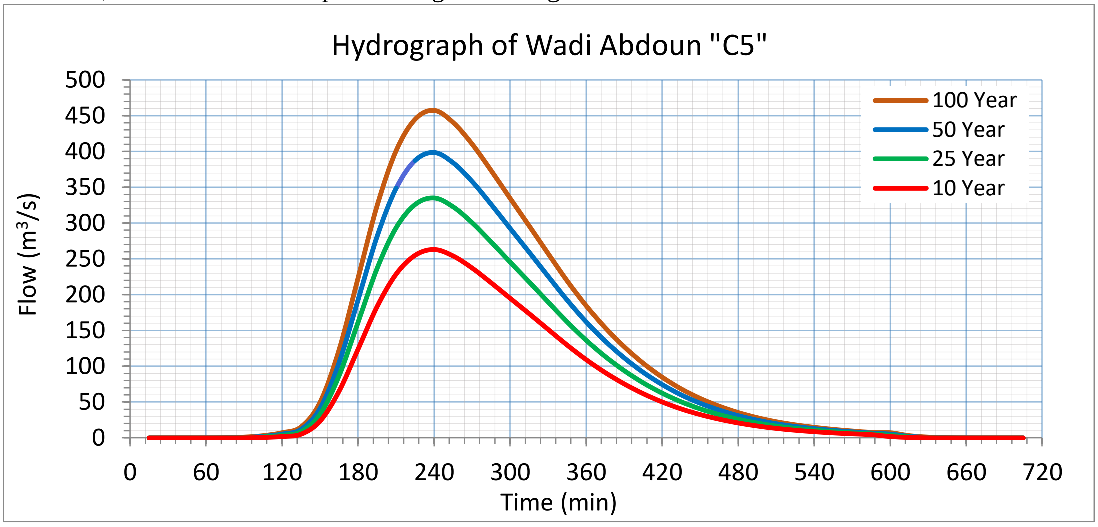

Figure 7. Total flood hydrograph of Wadi Abdoun basin for different return periods.

Based on the total hydrograph calculation of the wadi Abdoun, which represented the outcome of the hydrological model in the simulation of precipitation and runoff of the watershed, it was possible to derive the peak discharge values and the peak time of wadi Abdoun basin represented by point C5, which was derived from Figure 6. for the wadi Abdoun, through which peak discharge, peak time and surface runoff values were estimated, the peak time was 240 minutes for the basin for different frequency periods, as shown in Table 7.

Table 6. Runoff peak flow, time to peak and runoff volume at the outlet of Wadi Abdoun basin for different return periods for the 6 h design storm.

Return Period (Year)	Peakflow (m^3/s)	TP (MIN)	QV (MCM)
10	**262.77**	**240**	**2.771**
25	**335.25**	**240**	**3.523**
50	**398.44**	**240**	**4.196**
100	**457.52**	**240**	**4.818**

Table 6 shows that the peak flow of the flood can reach 262.77 m^3/s to 457.52 m^3/s for the 10-year and 100-year return periods, respectively. The total flood volume ranges between 2.77 MCM (million cubic meter) to 4.8 MCM for 10-year and 100-year return periods, respectively. This flood peak flow and volume are capable of forming a threat to the property and population in low lands area. Mitigation measures must be taken to reduce the risk of floods in the downstream areas. This can be done by introducing some flood control structural and no-structural measures in the upstream areas of the basin. Non-structural measures include watershed management, flood mapping, zoning, land use regulations, water harvesting, afforestation activities and increasing the infiltration and ponding rates in open lands areas of the basin. Comprehensive hydrological studies shall be conducted for of large development projects such as hotels, hospitals, and educational institutions within the study area to control their runoff peakflow to pre-development conditions. A comprehensive storm water master plan for Amman needs to be developed and implemented in phases to reduce flood risk at all critical areas in the city with associated flood warning and response systems.

Structural measures include building some low level artificial ponding, storage facilities and flood walls in some open areas that can release flood water at a lower rate to reduce the peak flow of the flood. In the downstream area, the existing storm water systems must be maintained and clean to remove any sediment or blockage in the system. A recent study in Amman City indicated that if each building in the city was equipped with a 6 m^3 rainwater storage facility to collect rainfall water from their roofs, the volume of stored water can be more than 3 MCM per storm. Water harvesting and stoarge can significantly reduce the flood risk at the critical points in the downstream areas (Saidan et al., 2015, Hadadin et.al., 2014).

Conclusions and Recommendations

Based on the full hydrologic modeling and analysis of the study area, the following conclusions can be made:

- The study area is of Wadi Abdoun basin with the outlet near Quraish street in downtown Amman is about 105 km^2 and extends from the Sweileh area and the University of Jordan in the north, to Wadi Al-seer, Marj al Hamam in the west, and to wadi Abdoun basin al Shamali, and al-Rawda neighborhood to the south. Most of these areas are highly urbanized and mostly connected impervious areas., contributing to an increase in flood risk at the downstream areas.
- The SCS-CN method was used to simulate the rainfall-runoff model for the sub-basins through the WMS model using the estimated CN values and the 6h design storm for different return periods.
- The peak flow of the flood at the basin outlet can reach 262.77 m^3/s to 457.52 m^3/s for the 10-year and 100-year return periods, respectively. The total flood volume ranges between 2.77 MCM (million cubic meter) to 4.8 MCM for 10-year and 100-year return periods, respectively. This flood peak flow and volume are capable of forming a threat to the property and population in low lands area.
- Flood mitigation measure are proposed to reduce the flood risk at the downstream areas. These measures include structural and non-structural measures.

- Flood mapping, zoning, land use regulations shall be introduced to identify the flood prone zones and imposed flood control regulations in these areas.
- Structural flood mitigation measures include building some low level artificial ponding, storage facilities and flood walls in some open areas that can release flood water at a lower rate to reduce the peak flow of the flood.
- In the downstream area, the existing storm water systems must be maintained and clean to remove any sediment or blockage in the system.
- Comprehensive hydrological studies shall be conducted for of large development projects such as hotels, hospitals, and educational institutions within the urban to control their runoff peak flow to pre-development conditions.

A comprehensive storm water master plan for Amman to be implemented in phases to reduce flood risk at all critical areas in the city associated flood warning and response systems.

REFERENCES

Asaad, Samaher & Suleiman, Akram. (2023). Socio-demographic factors and treated wastewater reuse in the MENA region: Insights and implications. Desalination. 565. 116830. 10.1016/j.desal.2023.116830.

Askar, M. Kh(2014), Rainfall-runoff model using the SCS-CN method and geographic information systems: a case study of Gomal River watershed, **WIT Transactions on Ecology and The Environment**, Vol 178, © 2014, 159- 169.

Al-Weshah R. A., and F. El-Khoury (1999), "Flood Analysis and Mitigation for Petra Area in Jordan," ASCE J. Water Resources Planning and Management, Volume 125 No. 2 May/June http://dx.doi.org/10.1061/(ASCE)0733-9496 125:3(170)

Chow, V.T, Maidment, David R and Mays, L.W. (1988), Applied Hydrology. **McGraw-Hill**, New York.

Dihn, Q. Balica, S. Popescu, I. & Jonoski, A. (2012). Climate change impact on flood hazard, vulnerability, and risk of the Long Xuyen Quadrangle in the Mekong Delta. Int. J. River Basin Manag, 10, 103–120.

Fred E, Mostafa B (2008) Flood risk modeling for holy sites in Makkah. Third National Conference of GIS Applications in Saudi Arabia, April 7–9, Al Khobar City, Saudi Arabia.

Green, C. H., Parker, D. J. & Tunstall, S. M. (2000) Assessment of Flood Control and Management Options. Thematic Review IV.4 prepared as an input to the World Commission on Dams, Cape.

Hadadin, N., R. Al-Weshah et. al. “Rainwater harvesting in Jordan: a case of royal pavilion at Amman airport” Desalination and Water Treatment 52(issue 31-33) · September 2014, DOI: http://dx.doi.org/10.1080/19443994.2013.817506

HEC-1(1998), Flood Hydrograph Package, User’s Manual.

Meteorological Department (2016), Climate and agricultural report.

Norbiato, D.; Borga, M.; Degli Esposti, S.; Gaume, E. & Anquetin, S. (2008). Flash flood warning based on rainfall thresholds and soil moisture conditions: An assessment for gauged and ungauged basins. Journal of Hydrology Vol.362, Nos. 3–4, pp. 274– 290, DOI:10.1016/j.jhydrol.2008.08.023, ISSN 0022-1694.

Ockert J. Gericke & Jeff C. Smithers (2014) Review of methods used to estimate sub-basins response time for the purpose of peak discharge estimation, Hydrological. https://doi.org/10.1080/02626667.2013.866712

Rodriguez, F., Andrieu, H., and Creutin, J.-D., 2003. Surface runoff in urban catchments: morphological identification of unit hydrographs from urban databanks. Journal of Hydrology, 283 (1–4), 146–168.

Saidan, Motasem, Radwan A. Al-Weshah and Ibrahim Obada, “Potential Rainwater Harvesting: Adaptation Measure for Urban Areas in Jordan,” Journal -American Water Works Association 11/2015; 107(11). DOI: http://dx.doi.org/10.5942/jawwa.2015.107.0154

Spitalar M, Gourley JJ, Lutoff C, Kirstetter PE, Brilly M, Carr N (2014) Analysis of flash flood parameters and human impacts in the US from 2006 to 2012. J Hydrol 519:863–870.

USDA (2010), Natural Resources Conservation Service. National Engineering Handbook, Part 630, Chapter 15, Time of Concentration, US Department of Agriculture: Washington, DC.

USDA-TR55 (1986), Urban Hydrology for Small Watersheds Department of Agriculture, USA.

Weng, QIhao (2001), Modeling Urban Growth Effects on Surface Runoff with the Integration of Remote Sensing and GIS, Environmental Management, Vol 28, No. 6, pp. 737–748.