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SIMULATION OF FLOOD'S RISK USING GIS AND HEC-RAS IN THE LOWER VALLEY OF WADI EL KEBIR – TEBESSA, ALGERIA

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Abstract

Maximum daily precipitations play a crucial role in the occurrence of flood risk, particularly when combined with other natural and human factors, such as the geographical and morphological characteristics of the area, as seen in the case of Tebessa city. The city is situated below surrounding mountains, with the Wadi El Kebir valley passing through it to the north. This study aims to simulate the risk of flooding in Tebessa city. The approach involves utilizing GIS programs for DEM (Digital Elevation Model) analysis, extracting the study area, obtaining morphometric parameters and maps, and employing the Turraza, Sokolovsky, and Maillet-Gouthier equations to calculate the frequency of maximum daily flows for return periods of 10, 50, 100, and 200 years. Based on this, the flood volume is calculated. Finally, the HEC-RAS program is used to simulate flood risk in the Wadi El Kebir valley, and urban vulnerability maps are generated for Tebessa city for each return period.
Keywords: Watershed, Flood risk, HEC-RAS, Simulation, GIS, Tebessa, Return Periods.

I. Introduction

Floods are characterized by the temporary inundation of land by water beyond its usual boundaries and can occur in various environments, including small and large watersheds, estuaries, and coastal areas (Parker, Tapsell, McCarthy, 2007: 200). The study of flood risk is crucial due to the significant damage it can cause to buildings and urban infrastructure (Qi, Sun, Qi, 2010: 45), particularly in flat lowland cities

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with infrastructure and urbanization development (Abou Kheir, Abdallah, Khawlie, 2008: 240).

The city of Tebessa is traversed by the Wadi El Kebir Valley, intersecting important main roads, railways, and the city's airport to the north (DCU, 2016: 44). The rapid urban growth of the city has made its residents more vulnerable to flooding (Jha, Lamond, Bloch, 2011: 9). This study aims to simulate the flood risk in the city and identify areas threatened by flooding for different return periods.

GIS programs (Abou Kheir, Abdallah, Khawlie, 2008: 241) were used for hydrological analysis, leveraging the digital elevation model (DEM) to extract topographic characteristics (Izinyon, Ehiorob, Osadolor, 2011: 12) and drainage watershed networks' features (Zarcata, 2007). The Turraza, Sokolovski, and Maillet-Gouthier equations were then applied to calculate the frequency of maximum daily flows for return periods of 10, 50, 100, and 200 years. Using the HEC-RAS program developed by the US Army Hydrologic Engineering Corps (HEC-RAS, 2001: 11), flood risks were simulated for the city of Tebessa.

In conclusion, this study provides morphometric mapping of the watershed and urban vulnerability maps concerning the flood risk of Tebessa in the Wadi El Kebir watershed. In developed countries, flood prediction techniques (Erkek, A˘gıralio˘glu, 2013: 46) have significantly reduced loss of life and facilitated decision-making through structural measures such as dam construction and diversion channels, as well as non-structural measures like early flood warnings and mass evacuation (Yazdi, Salehi Neyshabouri, 2012: 45). This study is the first of its kind in the Tebessa region, and its findings can serve as a decision-making tool for city management.

Previous Studies

While flood risk studies have been conducted worldwide, there is a lack of research on flood risk simulation in the study area the Wadi El Kebir Valley in Tebessa. Some studies have shed light on flood risk in the city from different perspectives:

– Ali Hajla's Ph.D. thesis titled "Urban Planning and Sustainable Development in the City of Tebessa" in 2016 from the University of Mentouri Constantine includes a considerable amount of data, figures, and maps processed using GIS programs. The researcher addresses several topics, including flood risk and the human and material factors contributing to floods in the city. However, this Ph.D. Thesis primarily focuses on flood risk within the city limits.
– Jaber Mohamed El Tayeb's Ph.D. thesis titled "The Role of Geographic Information Systems in Urban Planning and Management: The City of Tebessa as a Model" in 2021 from Arabi Ben Mhidi University in Oum El Bouaghi highlights the role of GIS in urban planning and management for the city of Tebessa, touching upon flood risk among various other topics. However, it does not extensively cover the large watershed and flood risk, as it mainly focuses on the city's water network and the causes of flooding.

Thus, this study is the first of its kind to rely on rainfall data and GIS programs in simulate flood risk in the Wadi El Kebir Valley in Tebessa, providing a geographic database with various morphometric and urban vulnerability maps of the city.

Study Objectives

This study aims to:

- Study various morphometric characteristics of Wadi El Kebir. to establish a valuable geographic data, facilitating the study and simulate of flood hazards.
- Simulation flood risk in Wadi El Kebir and identify vulnerable areas for different return periods.

The Theoretical Approach

In the theoretical chapter, we will explore the most important scientific concepts and terms related to the subject of the study from various perspectives.

The Concept of Risk

The United States Geological Institute defined the term "risk" in 1984 as a state or event, either natural or human-induced, that leads to potential hazards to human life and property (Mohamed Sabry Mohsoub 1998: 36)

Definition of Natural Risks

Natural hazards can be defined as a collection of events that may cause significant or minor material and human losses, resulting from natural forces or variables. These disasters vary greatly in their geographical and temporal extent. Natural hazards are distinguished and classified based on two main elements: the source of the hazard and the vulnerability to the hazard (Dubois-M.1997: 264).

Definition of Floods

Floods occur when the water level in the normal flow path (the usual watercourse) rises to surpass it, leading to the overflow of water into the larger floodplain (flooded area) (Izambart, G. 2011: 11). It is also defined as a significant increase in water level in a river, lake, or coastal area (Versini 2009: 27).

Definition of Vulnerability

This concept evolved among specialized engineers, focusing on the resistance of buildings and existing infrastructure in urban areas to the physical forces exerted by natural phenomena such as floods, winds, and earth movements. During the 1980s and 1990s, this concept expanded to include social, economic, and environmental considerations of risk resistance in urban environments. Thus, urban vulnerability directly refers to elements in the environment exposed to potential risk, whether natural or human-induced (Morin, 2008: 9).

II. Material and methods

The research adopted a technical, analytical, and inductive method, which involves analyzing individual components to arrive at comprehensive solutions, i.e., a gradient in solving the problem and interpreting it to obtain final results.

- **Data used in the research**

Like any modern geographical study, this research utilized satellite imagery, specifically the digital elevation model (DEM) from the ASTER satellite (STRM) with a resolution of 30 meters. The satellite images were acquired on 20/08/2020. Additionally, the study relied on climatic data, including the maximum daily rainfall quantity from the rain station in the El Kebir watershed for the period (1983-2018). The following table presents essential data and spatial information for the station.

Table 1

Information about the rain station on which the study was based

Station	National numbering	X (km)	Y (km)	Z (m)	Average annual precipitation for the period	Period
Station - Tebessa_	120301	35.43 (991.9)	8.12 (247.2)	811 (890)	111.9	1983-2018

Source: National Agency of Water Resources, Ouargla

The study also employed the Geographic Information Systems (GIS) software version (ArcGIS 10.7.1) for analyzing the digital elevation model and flood risk modeling with the help of the HEC-RAS 5.3 software.

Furthermore, the morphometric analysis of the study relied on a set of morphometric indicators, as represented in the following table.

Table 2

A set of morphometric indicators

Title of transactions or equations	Transactions and their symbols
area of the watershed	A
Watershed perimeter	P
The length of the main tributary of the watershed	Lp
Global slope index	Ig
drainage density km/km2	Ds
Torrentiality coefficient	Ct
Runoff velocity	Rv

Additionally, three fundamental equations were used to calculate the maximum daily rainfall flow in the El Kebir watershed during different return periods, namely Sokolovsky, Turraza, and Maillet-Gouthier. The average flow was extracted to calculate the flood volume in the El Kebir valley for each period, contributing to the flood risk simulation.

III. Results and discussion

Study Area

Using the Geographic Information Systems software, we analyzed the Digital Elevation Model (DEM) and obtained maps of the study area for the El Kebir watershed, identified by the code 03, which is part of the larger Medjerda watershed (DWR, 2019: 8). The Medjerda watershed is cross-border, shared between Algeria and Tunisia, with a total area of 23,700 km^2, of which 7,600 km^2 are in Algerian territory. The sub-watershed of Wadi El Kebir is bordered to the northeast by the Mellegue watershed and to the west by the Wadi Meskiana watershed. The Wadi El Kebir sub-watershed covers a total area of 1555.9 km^2 (NAWR, 2018: 18). The El Kebir Valley runs through the city of Tebessa from the north, intersecting critical points such as the city's airport, national roads serving as the city's northern entrance, and neighborhoods in proximity, including Al-Arami, Al-Merja, Flouja, Bokaria Road, and the railway, among other significant facilities. Consequently, it poses a real threat to the city, especially considering that most of the city's urban expansion occurs northward near the valley. Fig 1 illustrates the location of the El Kebir watershed.

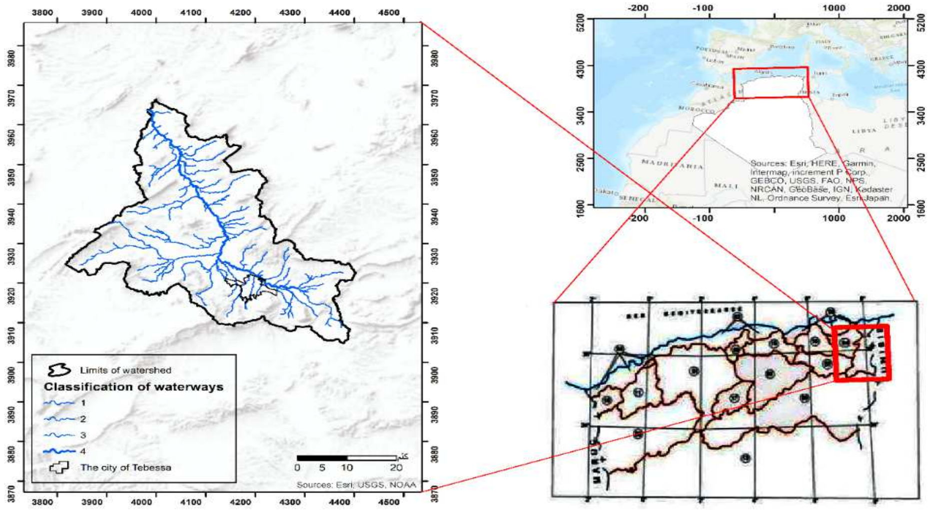

Fig. 1. Location of the watershed El Kebir

Hypsometric Analysis

Based on the Geographic Information Systems (ArcGIS) and the (DEM), the hypsometric analysis was conducted, and Fig 2 was obtained.

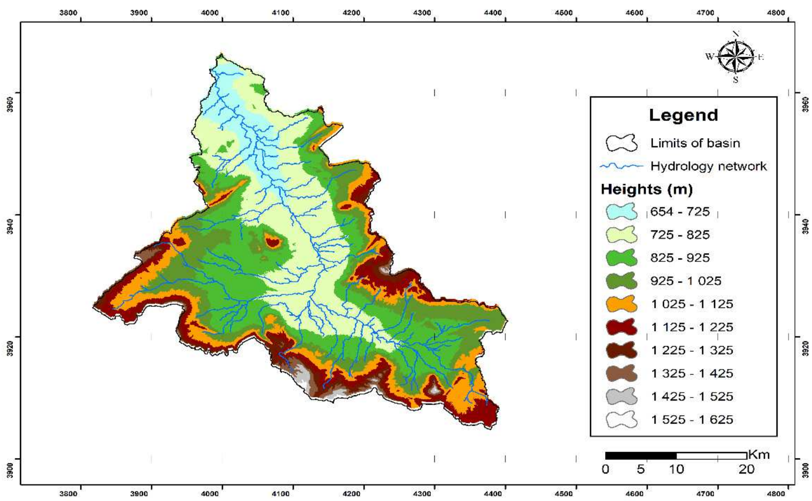

Fig. 2. Hydro network and hypsometric of the watershed El Kebir

Fig. 2 shows the hydro network and altimetry of the El Kebir watershed, where the maximum altitude in the watershed is 1625m in the upstream part, and the minimum altitude is 725m. The flow direction is from south to north, pouring into the main tributary.

Within the framework of the technical and analytical method used in this study, the hypsometric analysis was performed to study the relationship between heights and the watershed area, identifying the stages of watercourse growth within the watershed (Singh, 2000: 12). Fig. 3 presents the hypsometric curve of the El Kebir watershed.

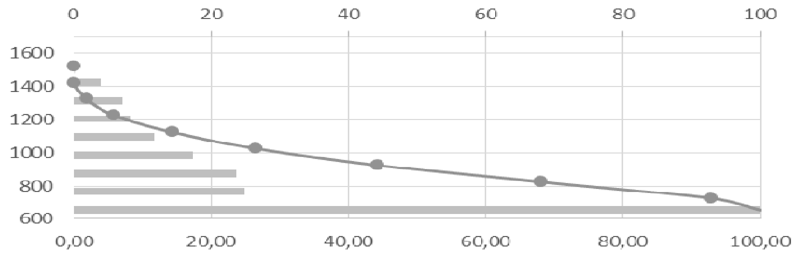

Fig. 3. The hypsometric curve of the watershed *El kebir*

The hypsometric curve of the El Kebir watershed demonstrates an inverse relationship between area and slopes. Smaller areas have steeper slopes and faster water flow, whereas larger areas have gentler slopes. Notably, the El Kebir watershed exhibits significant slopes, contributing to faster rainwater runoff, especially in urban areas, making it susceptible to flooding, particularly during heavy rainfall events in the city of Tebessa.

The Slope Index

To study the slope index of the Wadi El Kebir watershed, the digital elevation model (DEM) was analyzed using ArcGIS. The watershed was divided into three main parts, with seven categories of slopes, as shown in Fig4. From the relative circle in the figure, it is evident that the flat lands in the watershed constitute a significant portion compared to the moderately elevated and high lands, the city of Tebessa is situated between high lands and flat lands, making it more susceptible to flood risks.

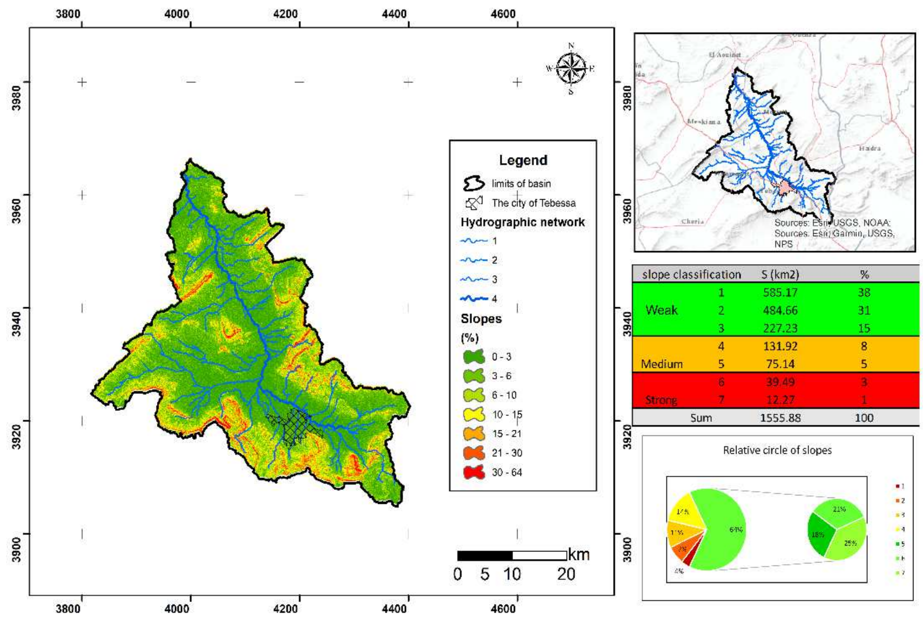

Fig. 4. The Slope Map of the watershed *El Kebir*

Various Morphometric Values

Based on the analysis of the DEM for the study area using Geographic Information System (GIS) software, various morphometric parameters were obtained, as illustrated in the following table:

Table 3

The morphometric characteristics of the watershed

Morphometric characteristics	A km^2	P km	LP km	Ds m/km	Ig m/km	Dd km/km^2	Ct	Tc	Rv km /h
Results	1555.9	276.62	74.09	188.12	52.63	0.40	20.12	0.02	3.70

From the above morphometric parameters, the Wadi El Kebir watershed exhibits considerable characteristics, with an area of approximately 1555.9 Km^2 and a main stream length of about 74.09 km. The time of concentration, estimated at 0.02 minutes, represents the time taken for raindrops to travel from the highest point to the lowest point in the watershed. This value indicates high vulnerability to flooding in the city, necessitating precautionary measures to mitigate flood risks.

Study of Drainage Density

To illustrate the danger of Wadi El Kebir to Tebessa, the drainage density was studied and modeled using GIS, based on the extracted data from the Strahler classification for the watershed network.

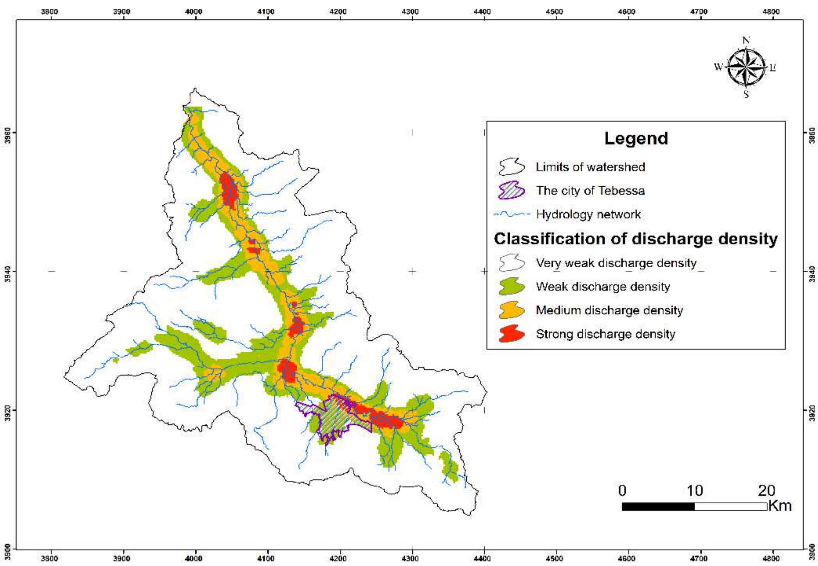

Fig. 5. Discharge density in watershed *El Kebir*

The drainage density map reveals that the highest drainage density, represented in red, is found in the main stream of the watershed, while the moderate and lowest densities are indicated by orange and green, respectively. Tebessa is located within these three areas, experiencing high drainage density in the valley that cuts through the city, including the airport and northern neighborhoods. Consequently, the city is at risk of flooding at any time, emphasizing the need for necessary precautions. Therefore, the study proceeds to simulate the flood flow in the valley.

Study of Flood Flow

After identifying the morphometric characteristics of the study area and determining its vulnerability to flood risks, the study focuses on analyzing the flood flow in Wadi El Kebir and calculating the flood volume for various return periods in order to extract urban vulnerability maps for the city of Tebessa.

Study of the maximum daily flow (pd max)

Based on the meteorological data, specifically the maximum daily rainfall recorded between 1983 and 2018 at the rain gauge station in the watershed, the study focused on analyzing the values of maximum daily rainfall and calculating the frequency of precipitation events for further use in to study the flood flow in the watershed by applying the formulas Sokolovsky, Turraza, and Maillet-Gouthier, we calculated the average flow values for the periods 10, 50,100,200 years, as follows.

Formula Sokolovsky

$$Q_{max} = \frac{0.28.ptc.\alpha.A}{T_m}.F \qquad (1)$$

Where: ptc = the frequency of rain showers
α= Flood runoff coefficient for a given period
A= area of the watershed in km^2
C_T = T_m = Concentration time
F = form coefficient of the flood hydro / F = 1.2.

Table 4

Flood flux in return periods according to the formula Sokolovsky

Return periods T years	10	50	100	200
Frequency %	90	95	98	99
Ptc mm	70.37	92.60	101	109.27
A	0.49	0.54	0.56	0.57
Qmax m ^{3}/a	1097.05	1443.62	1574.58	1703.50

Formula Turraza

$$Q_{maxp\%} = \mathbf{0}.278 \times \boldsymbol{C} \times I_t \times \boldsymbol{A} \tag{2}$$

Where: **C** = the surface runoff coefficient, which varies with the different return periods

I_t = The maximum density is in mm/h and the area of the watershed is in km^2

A = Area of watershed

Table 5

Flood flux in return periods according to the formula Turraza

Return periods T years	10	50	100	200
Frequency %	90	95	98	99
$\boldsymbol{C}$	0.65	0.75	0.80	0.82
$I_t \frac{mm}{h}$	3.51	4.63	5.05	5.46
Q max m ^{3}/a	986.82	1501.97	1747.43	1936.54

Formula and Maillet-Gouthier

$$Q_{maxp\%} = \mathbf{2}\boldsymbol{K}\log\left(1 + A.P_{moy}\right).\frac{A}{\sqrt{L}}\sqrt{1 + 4\log T - \log A} \tag{3}$$

Where: **K** and **a** = are constant coefficients which depend on the characteristics of the watershed
k = 1.3, a = 20, P_{moy} average annual precipitation mm
A = Area of the watershed in km^2
L = The length of the main tributary is km
T = Return periods by years

Table 6

Flood flux in return periods according to the formula Maillet-Gauthier

Return periods T years	**10**	**50**	**100**	**200**
Frequency %	90	95	98	99
Q max m ^{3}/a	1823.47	2875.5	3279.52	9463.5

Then we adopt a mean value of the frequency maxima:

Table 7

Mean values of flood fluxes for the different formulas applied

Formulas	**Return periods T years**			
	10	**50**	**100**	**200**
Turraza	986.82	1501.97	1747.43	1936.54
Sokolovsky	1097.05	1443.62	1574.58	1703.50
Maillet-Gouthier	1823.47	2875.5	3279.52	9463.5
Average Q max m ^{3}/a	1302.44	1940.36	2200.51	4367.84

Through Table 7, which represents the average of the maximum values of daily rainfall flow for different applied equations in the watershed flow study during various return periods, we observe a gradual and significant increase in the maximum daily rainfall rate during each period, reaching its peak during a 200year return period, estimated at 4367.84 m^3. Therefore, the city of Tebessa is always exposed to the risk of flooding. To further illustrate this, the flood volume in Wadi El Kebir will be calculated for each period to model the flood risk in the valley.

Volume flow in the watershed of valley El -Kebir

To obtain the maximum flood volume for a given frequency we apply the following equation:

$$V_{max(\%)} = \frac{Q_{max(\%)} \cdot C_t}{F} \qquad (4)$$

Where: $Q_{max(\%)}$ = The max flood flow given frequency m³/A,
C_t = The Concentration times
F = The form coefficient of the flood hydro / F = 1.2

Table 8

Flood volume in the Oued El Kebir watershed for each return period

Formulas	Return periods T years			
	10	**50**	**100**	**200**
Frequency %	90	95	98	99
$Q_{max\%}$	1302.44	1940.36	2200.51	4367.84
C_t	20.12	20.12	20.12	20.12
F	1.2	1.2	1.2	1.2
$V_{max\%}$	21837.60	32533.40	36895.20	73234.11

From the table 8 illustrating the flood volume in Wadi El Kebir for each category, a substantial increase is observed at each stage, with the flood volume reaching 73234 m³ over 200 years. This accentuates the city's vulnerability to flood risks if appropriate protective measures are not implemented beforehand.

Flood Risk Simulation in Oued El Kebir

Based on this process and after conducting the hydrological and geometric analysis, the flood risk areas were identified and simulated over different return periods in the valley using HEC-RAS and Arc-GIS. A simulation of the flood in the watershed is shown in Figs 6, 7, 8, 9.

The maps in Fig 6,7,8,9 illustrate the vulnerability of Tebessa to flood risks during different return periods, where we note the following:

During the 10-year return period, the flood water covers an area of 7.17 km² of the watershed. The flood also affects parts of the city's airport and neighborhoods such as Flouja and Merja to the north, as well as National Roads 10 and 16, which are crucial entrances to the city from the north.

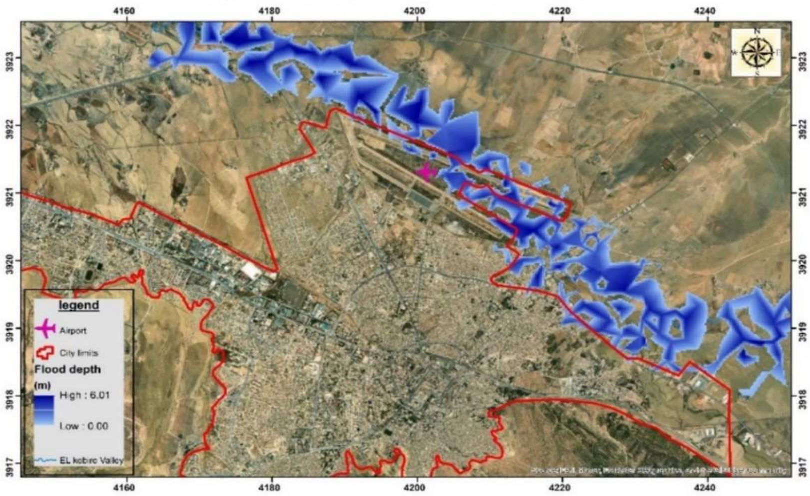

Fig. 6. Vulnerability to flooding risk. Flow = 10 years

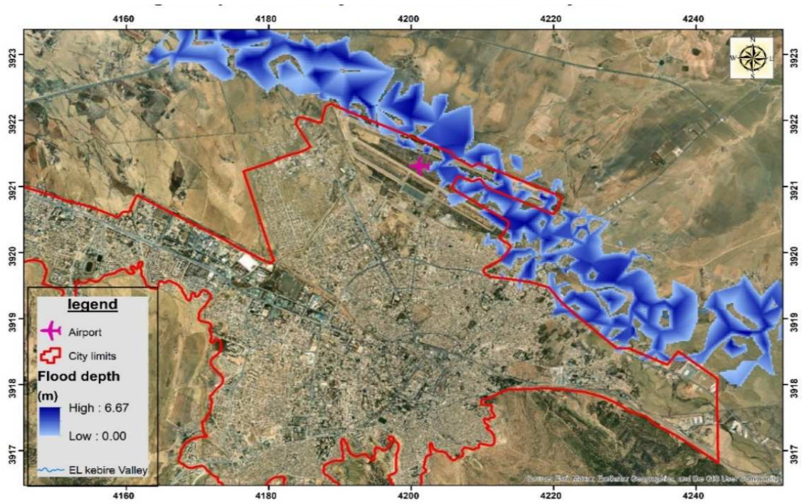

Fig. 7. Vulnerability to flooding risk. Flow = 50 years

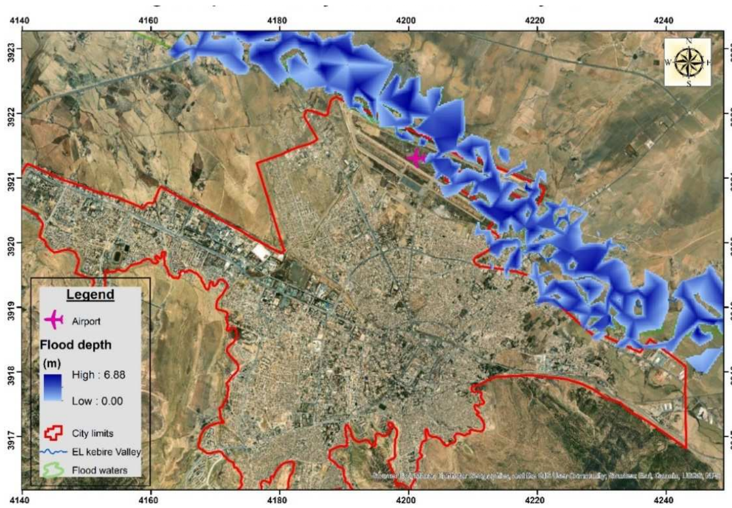

Fig. 8. Vulnerability to flooding risk. Flow = 100 years

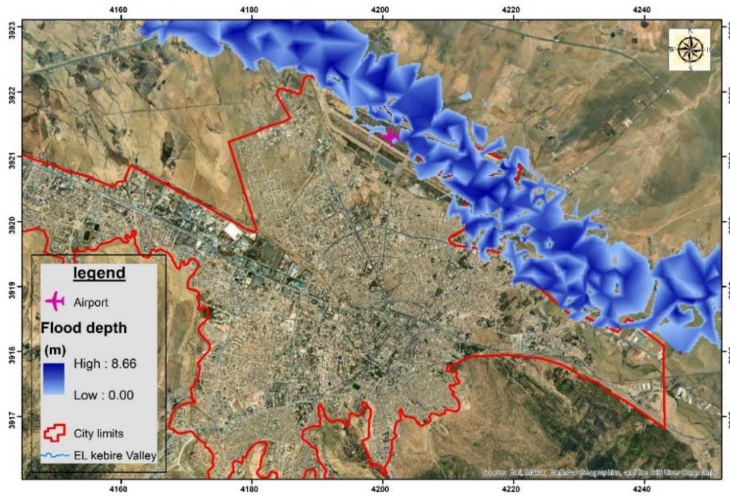

Fig. 9. Vulnerability to flooding risk. Flow = 200 years

During the 50-year return period, the floodwater covers an area of 8.37 km^2 of the watershed. The affected areas in the city increase significantly, including approximately 45% of the airport area, parts of the bypass road to the city, and the neighborhoods of Route Bekaria to the northeast.

During the 100-year return period, the floodwater covers an area of 8.69 km^2 of the watershed. The flooded areas expand further, encompassing about 60% of the airport area, most of the neighborhoods to the north and northeast of the city, and the areas developed during this period, including the city's railway.

During the 200-year return period, which represents the maximum extent of floodwaters in the city, the floodwater covers an area of 11.05 km^2 of the watershed. Around 80% of the airport area and over 25% of the city area will be affected during this period. Therefore, it is essential to implement necessary measures to protect the city from flood risks.

Current Measures to Protect the City from Flood Risks

In recent years, the city has experienced repeated flood events, with the most severe one occurring in 2018, resulting in significant human and material losses. However, aside from occasional local clean-up campaigns in the subsidiary valleys that flow into Wadi El-Kebir and some awareness initiatives organized by local authorities, there is a lack of clear measures to protect the city from flood risks. Field visits to various local administrations, such as the Water Resources Directorate, the Municipality, and Civil Protection Services, revealed the absence of well-defined plans and scientific field studies that could guide necessary measures for flood protection. It is crucial to have such studies to enable local administrations to identify flood-prone areas and take adequate precautions to prevent disasters.

Recommendations and Proposals

To protect the city from flood risks and increase its resilience, the study has identified the following recommendations:

- Utilize the data from this study to develop flood risks prevention plans for the city to minimize its vulnerability to floods.
- Ensure adherence to urban development regulations and manage urban expansion to protect the city from future flood risks.
- Reconfigure Wadi El-Kebir, especially in planned expansion areas, while respecting safety distances to safeguard against flooding.

– Provide and expand a stormwater drainage system within the airport area to create a dedicated system to protect it from future flood risks.
– Maintain the infrastructure designed to protect against flood risk by regularly cleaning the stormwater drainage network in the city.
– Coordinate between different stakeholders in city management to collectively participate in flood risk protection policies.
– Establish an early warning system for flood risks in the city to facilitate the protection of properties and residents.

IV. Conclusions

This research focused on simulating flood risks in Tebessa for upcoming years. The study began by using Geographic Information Systems to analyze the DEM (Digital Elevation Model) to determine the watershed boundaries in the El Kebir Valley and study the shape of the watershed and the hydrographic network. A database was created for watersheds, represented by a set of coefficients and maps of natural and hydrological characteristics of large watersheds.

Then, a study of the flood flow in the watersheds was carried out by applying the formulas of Sokolovsky, Turazza, and Maillet Gauthier, and the average flow values were calculated over periods of 10, 50, 100, and 200 years.

In this study, maps of vulnerabilities were created, and areas exposed to floods were identified in Tebessa, after verifying the hydrological and engineering analysis. Utilizing the HEC-RAS program, flood risk areas were simulated, and maps were generated to depict the extent of floodwaters in the urban areas, considering different return periods as part of the city's expansion plan.

The study led to a set of general recommendations, aimed at utilizing this valuable data by local authorities to implement disaster management measures and develop a comprehensive strategy to safeguard the city from floods while considering its vulnerability due to its large area and growing population.

REFERENCES

Abou Kheir, R, Abdallah, C, Khawlie, M, (2008). «Assessment of soil erosion in the Mediterranean karst landscapes of Lebanon using remote sensing and GIS», Journal of Engineering Geology 99 (2008) 239-254, pp. 240, 246. https://www.researchgate.net/publication/223514376_Assessing_soil_erosion_in_Mediterranean_karst_landscapes_of_Lebanon_using_remote_sensing_and_GIS

Department of Construction and Urbanization. (2016). Report on the development and town planning of Tebessa,Department of construction and urbanization, p. 44.

Department of Water Resources of Tebessa (2019). Report on the watershed El kebir, Water Resources Department, p. 1-8.

Dubois-Maury, J, (1997). «Urban planning. Legal Tools and Urban Form». Annals of Geography, Volume 106, Number 598, p. 664. 4010_1997_num_106_598_20827_t1_0664_0000_2

Erkek, C, A˘Giralio˘glu, N, (2013). "Water resources Mühendislik ˘gi, Beta" Publishing House, Istanbul, Turkey p. 46.

Hec-Ras, (2001). Hec-Ras River Analysis System, User Manual, US Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center, USA.

Izambart, G, (2011). The contribution of the return of experience to understand vulnerability to floods. Master Master 1, University of Toulouse II, France.

Izinyoun, O, Ehiorobo Osadolor, C, Jacob, O, (2011). "Measures and Documentation for Flood and Erosion Monitoring and Control in Niger Delta States in Nigeria". FIG Work Week 2011 Bridging the Culture Gap, Marrakech, Morocco. https://www.fig.net/resources/proceedings/fig_proceedings/fig2011/papers/ts07e/ts07e_ehiorobo_izinyon_5126.pdf

Jha, A, Lamond, J, Bloch, R, Bhattachary, N, Lopez, A, Papa Christodoulou, N, Barker, R, (2011). "Cities and floods in the 21st century", World Bank, East Asia and Pacific Region, Transport, Energy and Sustainable Urban Development Unit. p. 9. https://documents1.worldbank.org/curated/en/612141468176682794/pdf/WPS5648.pdf

Muhammad, S,Muhammad, I, (1998). Book of Dangers and Natural Disasters, Event and Confrontation, Geographical Treatment, First Edition, 1998, Dar Al-Fikr Al-Arabi, Cairo.

Morin, M, (2008). Basic concepts in civil security. 9 pages / https://www.securitepublique.gouv.qc.ca/fileadmin/Documents/securite_civile/publications/concepts_base/concepts_base.pd

National Agency for Water Resoures, Ourguel (2018). Weather Report, National Water Resources Agency Ouregula, Algeria.

Parker, D, Tapsell, S, Mc Carthy, S, (2007). «Improve the human benefits of flood warning, Natural hazards», Journal of the International Society for the Prevention and Mitigation of Natural Hazards, p. 200-209. https://www.researchgate.net/publication/226540243_Enhancing_the_human_benefits_of_flood_w

Qi, P, Sun, Z, Qi, H, (2010). Flood discharge and sediment transport potentials of the lower Yellow River and development of an efficient flood discharge channel. Yellow River Conservation Press, Hengzhou, China.

Shivaswamy, M, Ravikumar, A, Shivakumar, B, (2019). «Quantitative morphometric and hypsometric analysis using remote sensing and GIS techniques. Advanced Research in Engineering and Technology», International Journal of Advanced Research in Engineering and Technology,Volume 10, Issue4, p. 3-6. https://iaeme.com/MasterAdmin/Journal_uploads/IJARET/VOLUME_10_ISSUE_4/IJARET_10_04_001.pdf

Strahler, A, (1964). Applied hydrology, edited by chow, chow, V.T. McGraw-Hill, New York. http://ponce.sdsu.edu/Applied_Hydrology_Chow_1988.pdf

Singh, S, (2000). Geomorphology, Prayag Pustak Bhawan, Allahabad, India. https://www.worldcat.org/title/geomorphology/oclc/65222100

Yazid, J, Salehi Neyshabouri, S, (2012). «A simulation-based optimization model for flood management at the watershed scale », Journal Water resources management, vol. 26, p. 45, 69. https://link.springer.com/article/10.1007/s11269-012-0167-1

Versini, P, Gaume, E, (2009). « Distributed hydrometeorological simulations and forecast of road cuts in the Gard », Houille blanche. https://inria.hal.science/hal-00508789/

Yzarcata, H, (2007). Complete scientific book and guide to the GIS system (Aecview 9) First edition, Rayon for publishing and science, Damascene, Syria. https://library.iugaza.edu.ps/book_details.aspx?edition_no=140847