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# Determination of Zones at Risk of Flooding During A Breakage of an "El Abiod Ghardaia" Dam

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***Abstract* -**. Algeria, like other countries in the world, has experienced in the last decade, several natural disasters including floods and the breaking of dams, government institutions and others in the world are increasingly aware the phenomenon of dam failure that can cause catastrophic floods involving potential danger to the population. The El Abiod dam, the subject of this study, is vulnerable due to the nature of its design called " Renard effect", could cause its rupture. Oued M'Zab, the subject of this study, constitutes a potential danger because of the violence of its floods, on the one hand, and could have a negative impact on the hydraulic structures if they were to break on the other hand. In order to develop a hydraulic model that simulates the propagation of the flood wave along the sections studied, we adopted a methodology based on the coupling between ARCGIS and HECRAS using HEC-GEORAS. For this for the treatment of this phenomenon, the establishment of a hydraulic model is necessary for the realization of a numerical simulation of the wave of rupture of the Dam El Abiod (maximum peak flow) using the two HEC-RAS 1D and 2D digital models. The main objective of this study is to better explain the potential danger that the dam constitutes if it were to break and to spatialize the extent of the floods in order to map the flood zones which will be a support for the development of the M'Zab valley.

***Keywords*:** Model HEC RAS; Dam break; Flood zones; Peak flow.

## 1. Introduction

The breaking of dams has prompted researchers to undertake considerable efforts in the field of research on the simulation of the dam breaking wave, in particular with the European programs: CADAM (2000) and IMPACT (2001), and the American programs Dam Safety (1989) and FLOOD site (2004). efforts have been associated with the development of many numerical models, and some physical modeling work.

Dams are particular constructions from a technical and economic point of view, this certainly justifies the high requirements imposed with regard to the study of the project, the design and the exploitation. Indeed, the choice of the type of dam requires the consideration of several factors, citing the shape of the valley (morphology), the geology, the climatic conditions, the seismicity and the availability of construction materials, in order to choose the alternative. the most economical while guaranteeing the highest degree of safety, and minimizing the impacts caused by the work [1].

The problem of dam break, also known as DAM BREAK, has long been a concern for many researchers and scientists.

Among the studies that have been done are the analytical solutions developed by Ritter in 1882 and H. Chanson in 2006, the most recent studies on the development or use of computational models like those of Soares in 2007, Strauss in 2010 and finally the work of Mihoubi in 2012.

Algeria is among the countries that are building more and more dams. Currently it has more than 70 dams in service. As a result, Algeria is not immune to disasters linked to the breaking of dams. Moreover, dam failures have already been recorded (Sig and Fergoug dams).[2]

From this perspective; The authorities have made considerable efforts to reduce the risk of flooding in the M'Zab valley, involving the construction of numerous hydraulic structures, in particular flood dams in the upstream part of the basin and whose height on the ground natural depth is respectively 16 m, 17 m and 10 m for the sites of El Abiod, El Haimeur and Bou Brik.[3]

Man has tried in particular by containment systems to resist the rivers and to protect himself to allow urbanization and better economic prosperity of his territory. However, this protection is only illusory and these supposedly protected structures are in fact dangerous for the population. This is the observation made in the mid-2000s confirmed by the breakage of seawalls after Storm Xynthia in 2010. The risk of dam breaking therefore appears more real than ever. We can wonder if:

- How does a dam break manifest?
- How to determine the areas at risk of flooding when a dam breaks?

The main objective is to delimit the flood zones during the rupture of the dam through a hydraulic simulation study coupled with remote sensing and geographic information systems.

The dam break simulation is based on HEC-RAS software, which has the ability to calculate non-permanent flow (unsteady) in a river and to map the flood wave caused by a progressive breakage of a dike.

This led us to carry out two studies in one-dimensional (1D) and two-dimensional (2D) mode, to make a comparison and make the most judicious choice possible in terms of precision as to the delimitation of flood zones.

## 2. Material and Method

### 2.1. Geographical description

The Ghardaïa region is located in the center of the Algerian Northern Sahara 600 km south of the Algerian capital. It covers an area of 86560 km² and an estimated population of 387880 inhabitants spread over 13 municipalities, a population density of 4.48 inhabitants/ km². [4]

Dhayet Bendhahoua is a town in the wilaya of Ghardaia in Algeria located 10 km northwest of Ghardaia in the M'zab region; its area is 2175 km2. Dhayet Bendhahoua and the rest of the M’zab Valley have been listed as World Heritage Sites by UNESCO since 1982.

The commune of Dhayet Bendhahoua is crossed by Oued M'ZAB, which results from the confluence of three main tributaries; Oued El Abiod with a length of 64,225 km, Oued El Haimeur with a length of 45,244 km, and wadi Boubrik with a length of 9,832 km.[5]

El Aboid is one of the main tributaries of the M'Zab, are upstream of Ghardaia; on the left bank, the El Haimeur Oued which joins the Dhayet Bendhahoua at meridian 3°37', on the right bank the Touzouz Oued which joins the M'zab upstream of the palm grove of Ghardaia (Bouchen) at meridian 3 °38'. [5]

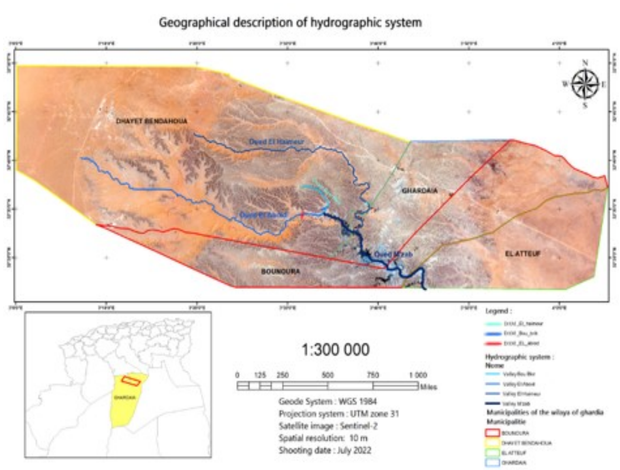



Fig.1: Hydrographic network of the Oued El Abiod watershed.

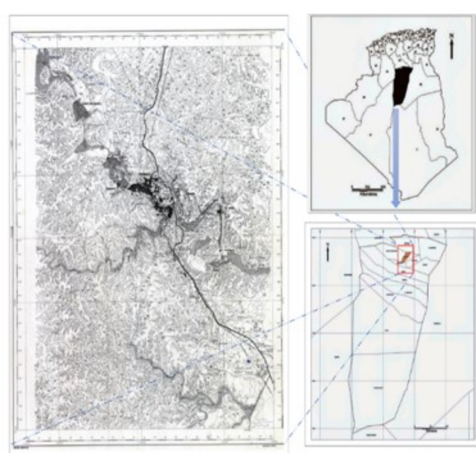


Fig.2: Map of the geographical location of the wilaya of Ghardaia.

## 2.2. Characteristics of the watershed of the El Abiod Oued:

The watershed is, in principle, the geographical unit on which the analysis of the hydrological cycle and its effects is based. The physiographic characteristics of a watershed strongly influence its hydrological response, particularly the flow regime during flood or low water periods.

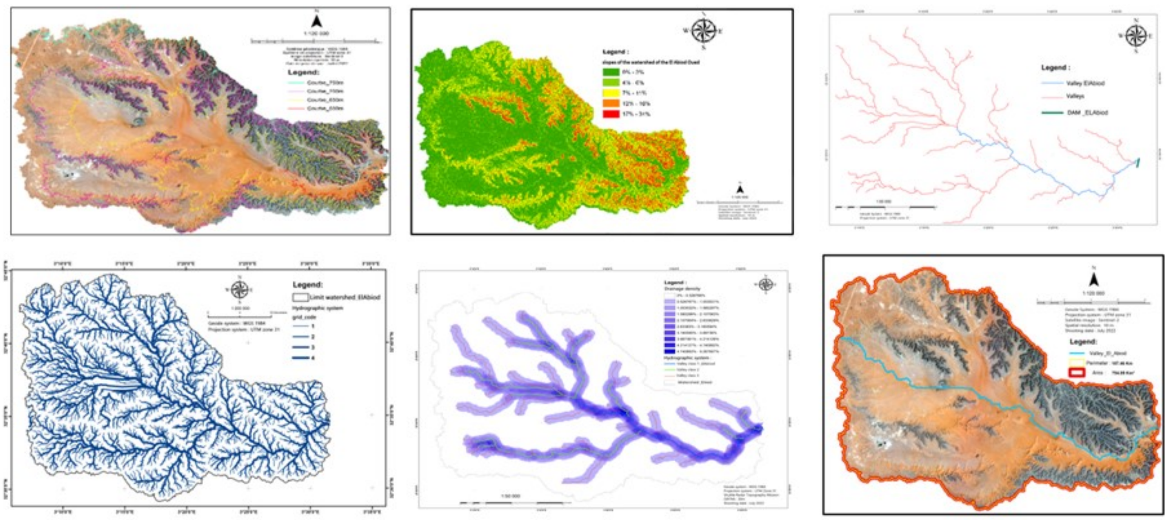


Fig.3: The physiographic characteristics of a watershed of the El Abiod.

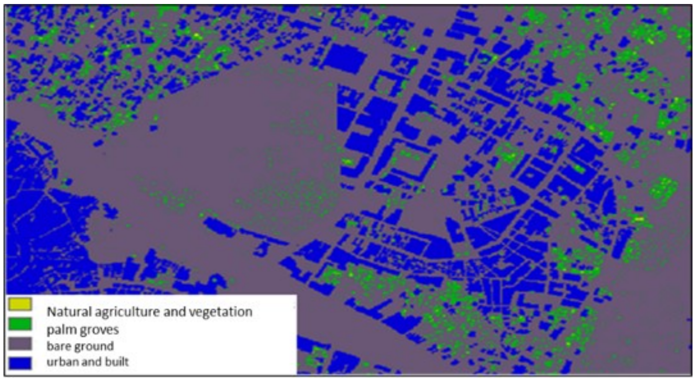
The Oued M'Zab watershed is highly exposed to the risk of flooding. Indeed, the bad weather recorded in this region shows how much protection against flooding has become a major issue.

It is therefore a major challenge in the management of water resources. Indeed, the strong irregularity of the hydrological regimes of the basin, the nature of the cover lands (soils), often impermeable, and the disparity between a mountainous relief upstream and a vast alluvial plain downstream explain the generation of a significant runoff as well as only sudden and violent floods. All these parameters can cause flooding.

For this, three dams were built near the city of Ghardaïa in order to reduce the negative effects of the floods of Oued M'Zab (El Abiod-El Haimeur-Bou brik). To this end, the main purpose of this chapter is to highlight the main characteristics of the EL Abiod watershed. This part is primarily descriptive and quantitative. It will be devoted to the geographical description, climatic conditions, geology and hydraulic characteristics of the watershed of El Albiod.[5]

## 2.3. Characteristics of soil and Land cover:

Soil type, vegetation cover and land use play a very important role in the hydrological response of a watershed.
The nature of the soil has an influence on the flow regime. Indeed, the infiltration rate, the humidity rate, the retention capacity, the initial losses, the runoff coefficient (Cr) depend on the type of soil and its thickness. Permeable soils such as sand favor infiltration to the detriment of runoff. Soil permeability is therefore a moderating factor in flooding.


Natural agriculture and vegetation
palm groves
bare ground
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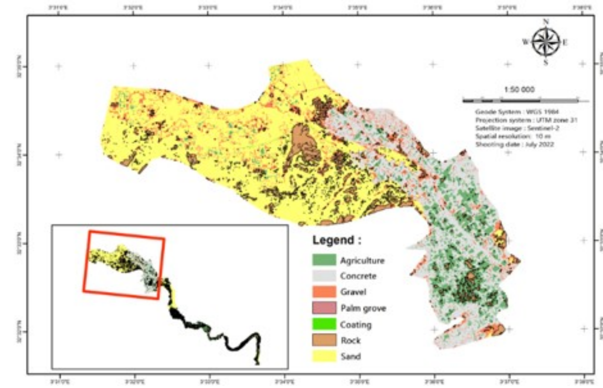
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Satellite image : Sentinel-2
Spatial resolution : 10 m
Shooting date : July 2022
Legend :
Agriculture
Concrete
Gravel
Palm grove
Coating
Rock
Sand

Fig. 4: Land cover map.

Fig.5: Map of the nature of the soils

### 2.4. Hydraulic modeling

The determination of the extent of the simulated flood and the calculated water heights or coasts requires a post-topographical treatment of hydraulic model results with available topographical and bathymetric data, which must be consistent with topographical and bathymetric data used in hydraulic modelling.

Due to the lack of historical flow data for the study area, and the resolution of SRTM is 30 m, will affect the simulation results somewhat; the method used is that of hydraulic data modeling (Peak Flows). The processing chain used to produce the flood map is highlighted by the flowchart representing the methodology to be adopted see Figure.6:

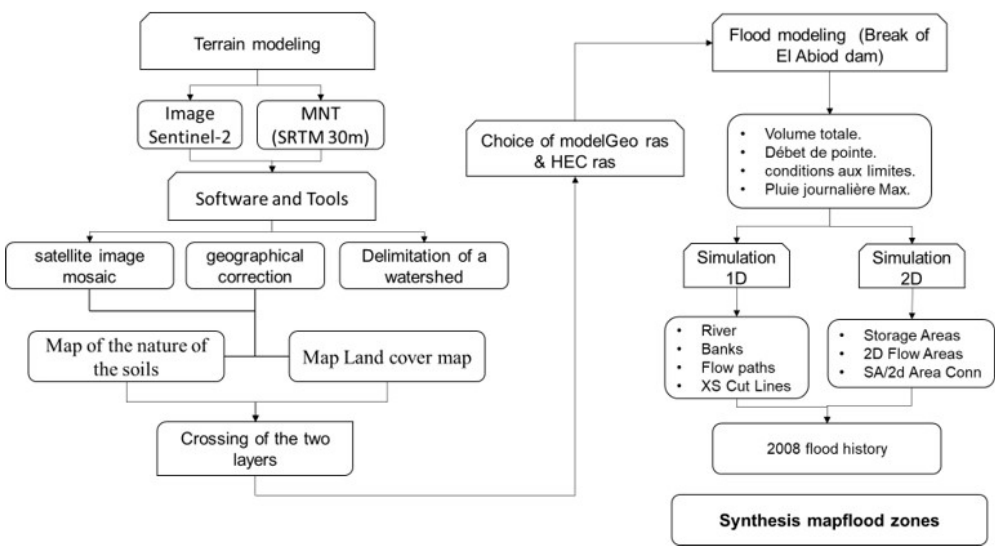



Fig.6: Flowchart of the methodology used for the Mapping flood-prone areas.

The simulation of the El Abiod (Ghardaïa) dam break wave goes through two phases. HEC geo-RAS allowed us to prepare the geometric data and visualize the results of the simulations. The second phase of the two-dimensional (2D) study carried out by the new Ras Mapper option introduced in HEC-RAS allowed the preparation of geometric data and the visualization of the results carried out directly on HEC-RAS The simulations are carried out for the flow-time while the water volume of the basin, the embankment of the dam and the downstream flow zone are simultaneously processed by the software.

## 3. Results and discussion

This article is devoted to the simulation of the rupture wave of the El Abiod dam in Ghardaïa was carried out using the HEC-RAS numerical models. The first case study is one-dimensional (1D), produced by the HEC - RAS software which performs hydraulic calculations and the HEC geo-RAS, which allows us to prepare the geometric data and visualize the results of the simulations.

The second case study is two-dimensional (2D) realized by the new Ras Mapper option introduced in HEC-RAS.

In this case the preparation of the geometric data and the visualization of the results are carried out directly on HEC-RAS. The simulations are carried out for the flow-time and the case where the three parameters: volume of water in the basin, the embankment of the dam and the downstream flow zone are processed simultaneously by the software.

The Manning-Strickler coefficient must take into account the occupation of the valley floor at the section level (vegetation, habitat, roads, rocks...). The height of the vegetation is assessed in relation to the maximum height of the water. Fig.7

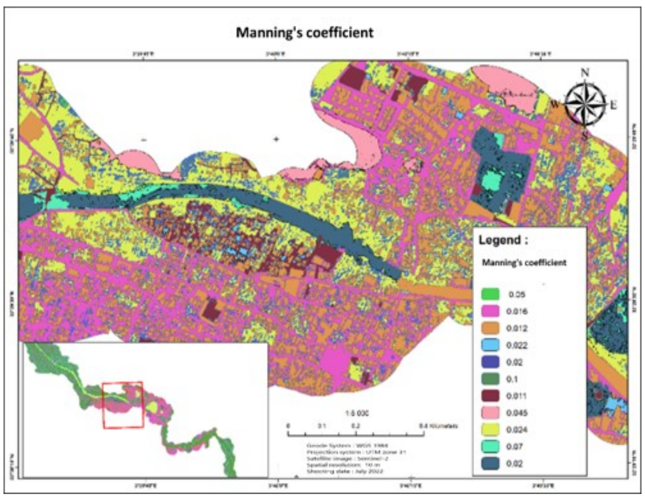



Fig.7: Manning's coefficient map.

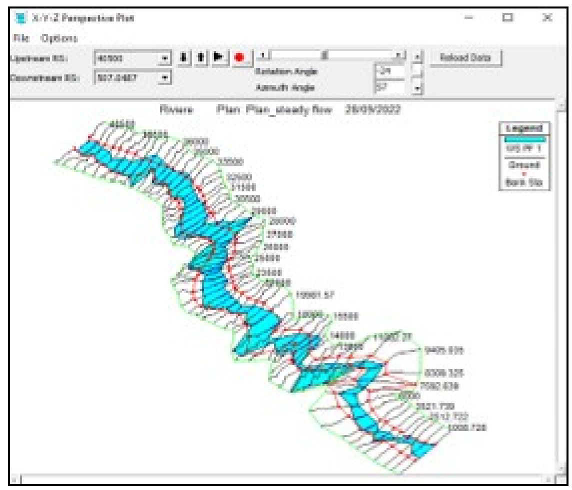


Fig.8: 3D view of simulation results.

The first part of this modeling consists in reproducing the wadi thanks to a series of cross sections. This type of operation is usually done under HEC RAS from a Digital Terrain Model (DTM) representing the topography of the site. The figure above shows the creation of the geometry of the wadi necessary for the hydraulic simulation.

After introducing the stream geometry, the next step is to specify the flow rate used to calculate the flow profile. For this purpose, hydraulic simulation with the maximum flow rate of the dam break flood was initiated

(Q = 14174.23 m3/s) calculated by the Poleni formula (1):

$$Q = \mu . L_s . h\sqrt{2gh} \qquad (1)$$

We can clearly see in the figure below that the hydraulic simulation with the SRTM 30m base, the presence in places such as agriculture and urban irregularities that are necessarily due to the presence of MNS instead of MNT.

### 3.1. Presentation of 1D and 2D flood maps:

In the study area, the results obtained gave the risk classes in parallel to the maximum water level, thus defining three risk zones (low, high, very high).

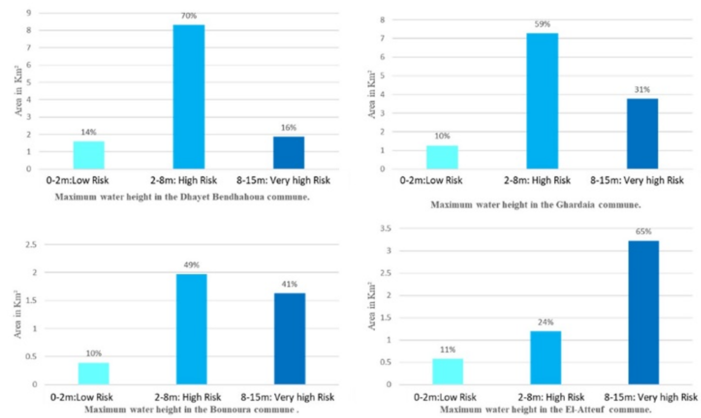
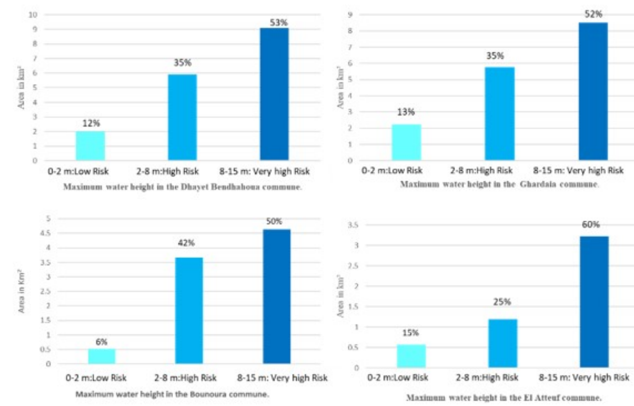



Fig.9: The areas of the flood zones in the communes of Ghardaia/1D.



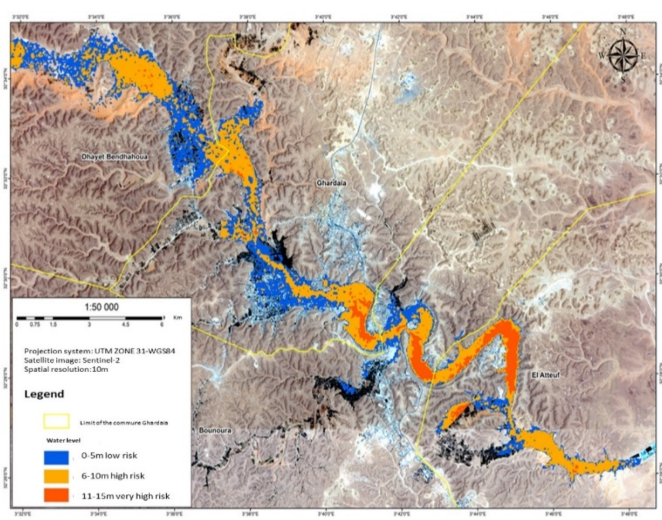

Figures 9 and 11 present the results obtained from a one-dimensional model (1D), at the level of the towns: Dhayet Bendhahoua from 3 to 5 m of water height reached, with a runoff speed exceeding 6 m/s in the bed of the M'zab oued classified as medium risk.

In the municipality of Ghardaia, approximately 32% of the area is classified as medium risk and is subject to flooding from 3 to 5m in height. In this part the maximum speeds can reach 4 m/s. At Bounoua town, flooding of more than 5 to 8 m (21%) of water with high speeds of around 6 m/s.

In Atteuf, where the minor bed widens and promotes the spreading of water, infrastructures undergo submersion heights of between 8 and 15 m with speeds of the order of 8 m/s.

We also notice on the flood map that the water overflows from the minor bed of the oued and that residential areas and agricultural land are submerged in water with large areas (over 40%) on class 2 at 8 m max water height, for simulation

One-dimensional.



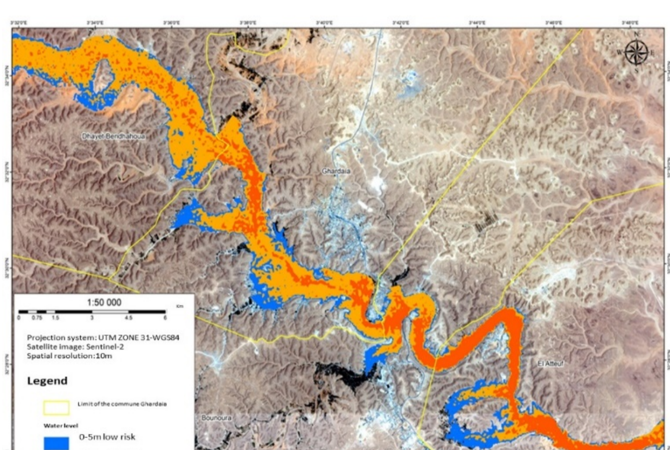




Fig.12: Flood vulnerability map (2D model) Oued M'zab.

Figures 10 and 12 present the results obtained by two-dimensional (2D) model, at the level of the commune Dhayet Bendhahoua of 53% of flooded surface. These towns are subject to flooding of 8 to 15m in height of Very Strong class which are reached in the major bed of the M'zab Oued. In this part the maximum speed can reach 6m/s.

In Ghardaia commune, about 52% of the Very high-risk area reaches the major bed of the M'zab oued and 13% of the low-risk area is exposed to flooding with a water height of 0 to 2m, with speeds high of the order of 10 m/s.

At the level of the city Bounoura, submersions of more than 8 to 15 m for the very high-risk area 50% water height with very high speeds in the order of 15 m/s.

Finally, in the commune of Atteuf, where the major bed expands and promotes the diffusion of water, the infrastructures are subject to flood heights of 8 to 15 at speeds of up to 8 m/s. We also notice on the flood map that the water overflows from the major bed of the wadi and that residential areas and agricultural land are submerged in water with large areas (over 53%) on class 8 at 15 m maximum height of water with two-dimensional simulation.

## 4. Conclusion

The choice of software that maps the flood hazard is an essential step. Comparison between 1D and 2D models on the ability to simulate the inundation extent of a given flood using both models. Thus, the results obtained from the comparison show the capacity of the 2D model in terms of highlighting the extent of the flood.

The results obtained by the two models (1D, 2D) were exported to the ArcGIS geographic information system for flood mapping and the consequences induced in the event of a possible dam break. This hydraulic simulation made it possible to obtain the maximum water heights at several points in the valley. A numerical simulation of the wave of a possible rupture of the El Abiod dam was carried out using the two models (1D and 2D) under HEC-RAS.

Recommandations were made on the choice between these models and on the parameters to be introduced into the simulations. It was found that the roughness coefficient is the parameter that has the most influence on the results in both models.

Changes in the roughness coefficients in both models (1D, 2D) have also been observed They cause large fluctuations in the steep part of the valley at the level of flows and water heights, which results in considerable differences between the values obtained by the HEC-RAS model using different roughness ranges. The work carried out in this study aims to apply, for the case of the El Abiod dam, the methodology used in the studies of dam break, the study of propagation of the resulting floods in the downstream valley, that on the one hand and on the other hand, to evaluate and compare the two one-dimensional and two-dimensional models of the propagation of dam burst floods.

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