Modeling of dam break flood wave propagation using HEC-RAS 2D and GIS: « case study of Taksebt dam in Algeria »

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GeoCalgary 2022 October 2-5 Reflection on Resources

Abstract

This study aims to predict the consequences associated with the propagation of the flood wave that may occur after the failure of the Taksebt dam and suggest an efficient emergency action plan (EAP) for mitigation purposes. To achieve the objectives of this study, the hydrodynamic model HEC-RAS 2D was used for the flood routing of the dam break wave, which gave an estimate of the hydraulic characteristics downstream the Taksebt dam. Geospatial analysis of the simulation results conducted in a Geographic information system (GIS) environment showed that many residential areas are considered to be in danger in case of the Taksebt dam break event. Based on the obtained results, an emergency actions plan was suggested to moderate the causalities in the downstream area at risk. Overall, the present study showed that the integration of 2D hydraulic modeling and GIS provides great capabilities in providing realistic view of the dam break wave propagation that enhances assessing the associated risks and proposing appropriate mitigation measures.

KEYWORDS: Taksebt dam; Dam break; Wave propagation time; HEC-RAS 2D; GIS

Résumé

Cette étude vise à prédire les conséquences associées à la propagation de l'onde de crue qui pourrait se produire après la rupture du barrage de Taksebt et à suggérer un plan d'action d'urgence (PAE) efficace à des fins d'atténuation. Pour atteindre les objectifs de cette étude, le modèle hydrodynamique HEC-RAS 2D a été utilisé pour le routage de l'onde de crue de la rupture du barrage, ce qui a permis d'estimer les caractéristiques hydrauliques en aval du barrage de Taksebt. L'analyse géospatiale réalisée dans les SIG a montré que de nombreuses zones résidentielles sont considérées comme étant en danger en cas de rupture du barrage Taksebt. Sur la base des résultats obtenus, un plan d'actions d'urgence a été suggéré pour modérer les causalités dans la zone à risque en aval. Dans l'ensemble, la présente étude a montré que l'intégration de la modélisation hydraulique 2D et du SIG offre de grandes capacités en fournissant une vue réaliste de la propagation de la vague de rupture de barrage qui améliore l'évaluation des risques associés et propose des mesures d'atténuation appropriées.

Mots clés: Barrage Taksebt; rupture de barrage; Temps de propagation de l'onde; HEC-RAS 2D; SIG

1. Introduction

In the past century, the concerns about dam failures increased significantly due to the occurrence of several dams' accidents with considerable fatalities e.g. Gleno dam in Italy-1923 (Pilotti et al., 2010); Francis dam in California-1928 (Rogers, 2006); Vega de Tera dam in Spain-1959 (Jansen, 1980); Malpasset France-1959; Vajont Italie-1963 Banqiao Chine-1975. (Marche, 2008); Teton dam in Idaho-1976 (Arthur,1977); Tous dam in Spain-1982(Alcrudo and Mulet,2007); and the 2004 Camará dam failure in Brazil (Menescal et al., 2005). In the African continent, the failure of the Virginia No.15 tailing dam in South Africa in 1994 is worth mentioning (Saxena and Sharma, 2004). The catastrophic consequences that resulted from dam failures led to a number of investments in developing and adapting hydraulic models for dam break studies. Moreover, the performance of hydraulic models has drastically improved over the past decades especially in light of the major advances in high-performance computing techniques as well as the major improvement in remote sensing techniques that provides a higher quality of input data such as rainfall, topography and land cover classification. (Boumrane et al 2020) Yet, in spite of all the efforts devoted to reduce the computation time of the hydraulic models, the latter remains as one of the leading open research fields (Singh et al., 1996; Pudasaini and Hutter, 2007). Nowadays, a considerable number of hydraulic models capable of modelling the dam break wave propagation exist. The results derived from these models allow studying the associated consequences and developing mitigation measures (Derdous et al., 2015). Conventionally, dam break studies were conducted using 1D models that solve the shallow water equations such as DAMBREK, HEC-RAS, MIKE 11, which gave very satisfactory results especially in narrow valleys. (Haltas et al., 2016). Nevertheless, in light of the major increase of computational power of computers in recent years, the use of 2D models have become very widespread in order to overcome the limitation of 1D models in large valleys (Néelz and Pender, 2013). In this context, Hervout et al used TELEMAC-2D to reproduce the failure of Malpasset dam; the results indicated a good agreement between simulated and observed water heights and arrival times of the dam break wave. Likewise, Pilotti et al 2020 tested HEC-RAS 2D against the discharge hydrographs and the measured extent measured in a physical model built in Froude similitude to analyze the consequences of the possible failure of the Cancano I dam (northern Italy). The experimental results were in very good agreement with those simulated by HEC-RAS 2D, which approves the suitability of the HEC-RAS 2D for dam-break analysis. The use of geographic information systems (GIS) in integration of hydraulic modeling in studying dam break events has gained an importance in the past few years. Nowadays GIS are widely used by authorities at regional and municipal levels. In fact, GIS provides a broad range of tools for mapping the results and conducting advanced analysis. (Seker et al., 2003; Cannata and Marzocchi, 2012; Derdous et al., 2015). In connection, it was proven that when the calculations are linked to GIS, it is much easier to save people who are under the risk (Heino and Kakko, 1998; Seker et al., 2003).

In Algeria, only two dam break events were documented; both of them concerned the same structure: Fergoug dam in 1881 and 1927, which caused 300 fatalities and major propriety damages (Boussekine and Djemili, 2016). The scarcity of accidents justifies the limited number of researches conducted in this field in Algeria (Bouchehed et al.,2017). Nevertheless, as the dams in Algeria get older, it is mandatory to analyze the consequences of their potential dam failure because the only effective measure, when the break is imminent, is the preventive evacuation of populations at risk.

In this context, the present study aims at modeling dam break flood wave propagation resulting from a hypothetical failure of Taksebt Dam in Tizi Ouzou, Algeria. The hydraulic model HEC- RAS 2D was used to simulate the propagation of the associated dam break wave and GIS was used to map the results and assess the associated risks. Thereby all population, buildings, tenements and properties can be alerted/evacuated directly after the dam break.

2. Materials and method

2.1 Study area

The study area concerns the valley affected by the Taksebt Dam break event. It covers a floodplain area of approximately 42 Km^2 that comprises vast agricultural areas and many settlements with significant population density. The Taksebt dam is an earthen dam of 75m height implanted on the Aissi Wadi, a tributary of the Sebaou Wadi, at about 10 km south-east of the city of Tizi-Ouzou at the following Lambert coordinates: X = 627,000 km, Y = 376,100 km, Z = 95.5 m northeastern Algeria (Figure 1).The dam counts a volume of 180 million m^3 at its normal water retention level. It intends to provide drinking water to the cities of Tizi-Ouzou, Boumerdes and Algiers.

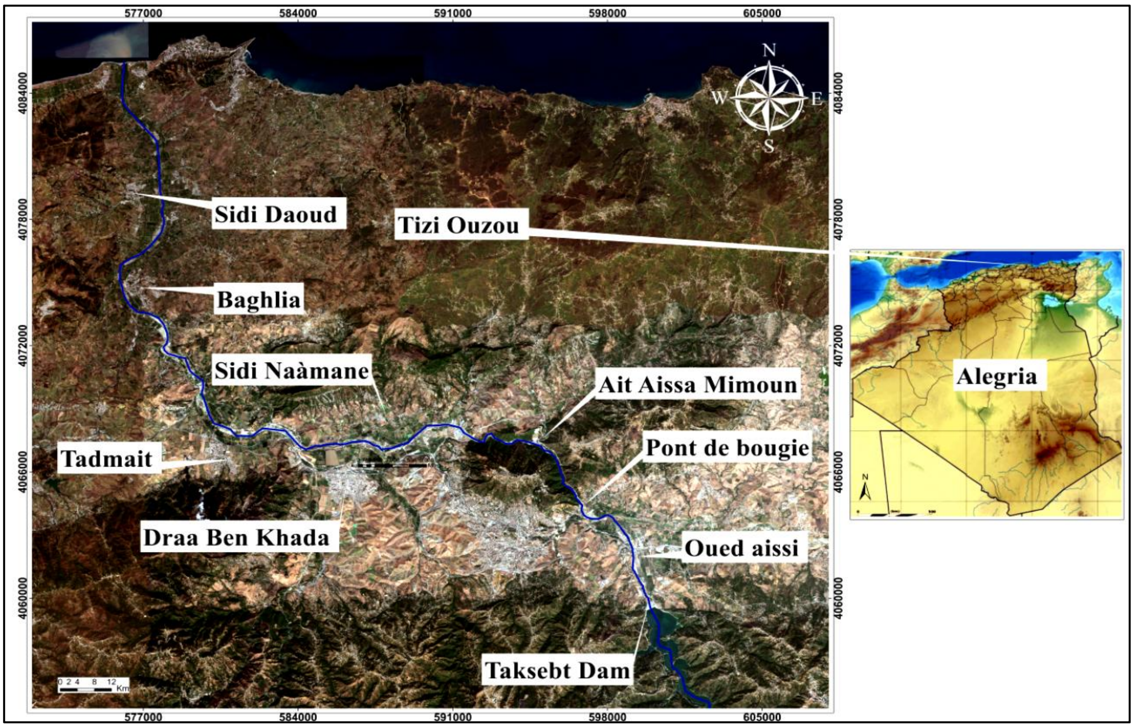


Figure1: Localization of the study area; Source (NICT)

2.2 Topographic data

To implement a two-dimensional simulation, HEC- RAS requires a digital elevation model (DEM) of the study area. The shuttle radar topography mission DEM (SRTM) is used herein as the main source of topographic data. This DEM has a spatial resolution of around 30 m and a vertical accuracy of approximately 10 m. The quality of the SRTM data was verified using a topographic map of the study area at a scale of 1/5000, which was collected from the National Institute of Cartography and Remote Sensing Agency of Constantine-Algeria (INCT).

The final DEM is shown in (Figure 2) along with an outline of the lake behind the Taksebt Dam and the Sebaou Wadi valley from the lake to the sea.

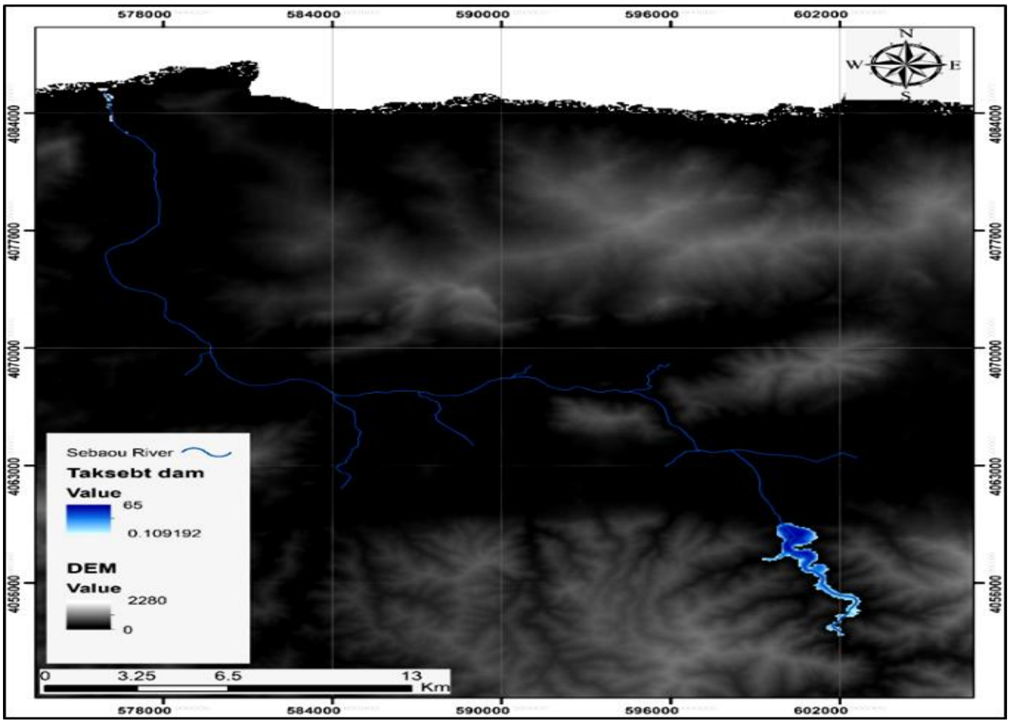


Figure 2: Digital Elevation Model of the Sebaou River Basin below Taksebt Dam. Source: United States Geological Survey (USGS)

2.3 Modeling dam break

2D modeling's features in HEC-RAS allow the user to create computational mesh. The generation of the 2D computational mesh, starts by defining the 2D Flow Area that must cover the extent of flooding during dam break and where the flow computations will take place. The success of the 2D modeling in HEC-RAS primarily depends on two factors namely the level of terrain model representation and the simulation stability. Although, both of them are influenced by the cell size of the computational mesh, the latter is also explicitly controlled by the computation interval chosen (González, 2017).

The 2D modelling has a flexible mesh generation allowing the user to generate a computation grid that is a mixture of structured and unstructured mesh types with the possibility of containing a mixture of cell shapes (the model is limited to elements with up to eight sides) and sizes. A user can customize a mesh to suit the terrain, containing predominantly large orthogonal grid cells(which simplifies the numerical discretization, making it more efficient), and where needed smaller cells, orientated appropriately along controlling terrain such as road crests, or along important river channels(USACE, 2016). Spatial details describing the polygon can be defined; spatial details include the size of the individual 2 D flow cells as well as Manning's roughness values for each cell. In this study, the valley at risk was modeled via a Structured Computational Mesh, which was composed of 80,070 cells with a grid size of 50x50 m (Figure 3), and it is a process that was modified during calibration with two Structure computational mesh with a grid size of 100x100 m and 75x75 m. A grid size of 50x50 m cell, used in the computational mesh, complies with two requirements fundamental. Firstly, the cells adapt to the terrain model as precisely as possible. Second, the cell size allows it to interpret the water surfaces slope and it changes adequately. HEC-RAS uses the Manning coefficient to measure flow resistance, and it has either the option of applying the continuous Manning coefficient for the full- dimensional flow zone or dividing the region into different regions, each with its own n-manning value. In the present simulation, one Manning's n value was assigned to the Sebaou Wadi valley and the floodplain respectively and set to 0.06. The selected reference value for the representation of the channel and banks was obtained from a comparison between the characteristics of studied vascular valleys and tables published by (USACE, 2016). In addition to HEC-RAS' default rectangular (structured) 2 D computational mesh, the software can also create an adaptive 2 D mesh to represent more complicated 2D flow conditions and structures in a better way, the computational mesh is assembled with a mixture of cell shapes and sizes that can be triangles, rectangles or even elements with up to eight edges (USACE, 2016). The software will automatically refine the 2D mesh when it is required, such as at a roadway crossing (González, 2017). The software will automatically refine the 2D flow area to incorporate the ineffective flow area shape. 2 D-modeling implies that the river bathymetry is represented by a three-dimensional space, but the model grid is a horizontal two- dimensional grid (rectangular). A velocity is calculated for each mesh element, the direction of the velocity is the resultant of the x, and y vectors in the horizontal plane. The magnitudes of the velocity depend on the bed slope and on the bed level (Figure 3)

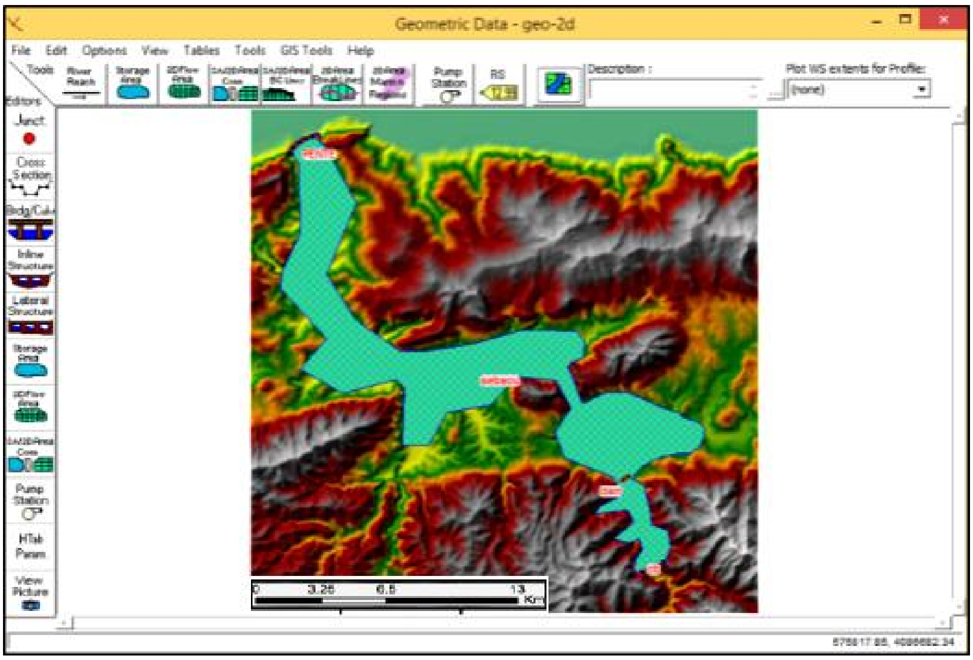


Figure 3: Computational mesh of the study area source: own study

2.4 Boundary condition

The scenario modeled in this study involves a complete and a progressive failure of the Taksebt dam in 1 hour due to the overtopping of the structure. The failure is supposed to occur under the solicitation of the 10,000-year return period flood event with 2500 m3/s (figure 4), which was determined upon the hydrological analysis of the Taksebt watershed.

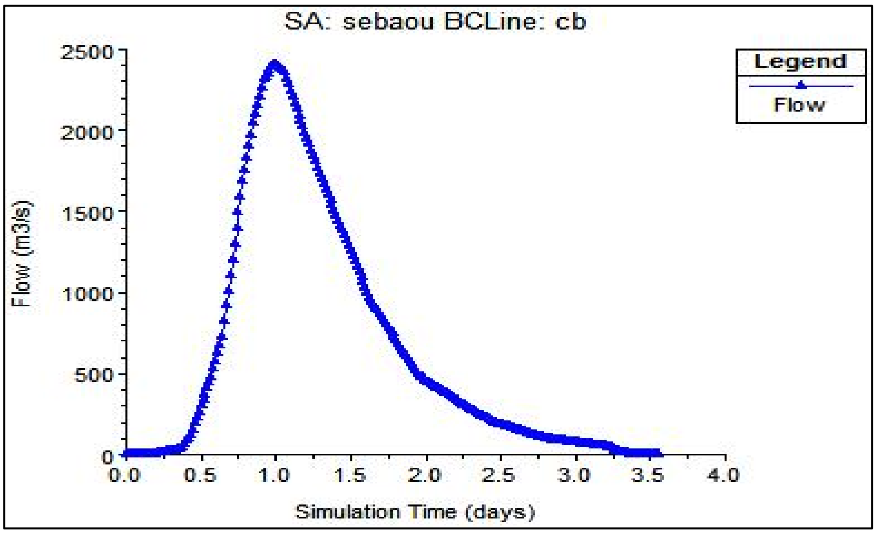


Figure 4: Input hydrograph used in the present study source: ANBT Tizi Ouzou

The flood hydrograph was used as an upstream boundary condition. The downstream boundary condition was set as a free outlet. The used initial condition was a constant water depth at the normal retention level. After the preparation of the geometric and hydraulic data, the hydraulic routing of the dam break, in this tool unsteady flow analysis, is used to conduct the wave flood modeling which was accomplished in HEC-RAS by solving the following form of the two-dimensional SaintVenant equations (USACE, 2016):

$$\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} + q = 0$$

Momentum conservation:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -g\frac{\partial H}{\partial x} + \upsilon_t\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial^2 y}\right) - c_f u + f_v$$

$$\frac{\partial v}{\partial t} + \left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right) = -g\frac{\partial H}{\partial y} + v_t\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) - c_f v - f_u$$

Where:

h = depth of water, (m);

u . v = are the averaged velocities in the x- and y-direction, (ms^{-1});

g = gravity acceleration, (ms^{-2});

υ_t = velocity diffusion coefficient, (m^2s^{-1});

H = free surface elevation, (m);

t = time, (s);

x, y = direction respectively (m);

q = source or sink of fluid, (ms^{-1});

c_f =the bottom friction coefficient;

f = the Coriolis parameter.

The solution of Saint Venant 2 D model is given by an implicit finite volume algorithm, which allows longer time steps than explicit methods. The finite volume method gives the model an increase in the stability and robustness when compared to traditional finite difference methods. Additionally, the algorithm is able to solve subcritical, supercritical and mixed regimes (USACE, 2016). In general, the 2 D diffusion wave equations allow the software to run faster, and have greater stability properties.

2.5 Dam breach modeling

The dam breach simulation was conducted using the unsteady flow module of the HEC-RAS model. This component of HEC-RAS is based on the UNET model and uses a similar framework to solve the unsteady flow equations. It is based on an implicit finite difference solution of the complete two-dimensional continuity and momentum equations for unsteady flow coupled with an assortment of internal boundary conditions for simulating unsteady flows controlled by a wide variety of hydraulic structures (USACE 2016). A dam overtopping failure was used as Taksebt dam-break scenario for HEC-RAS simulations. The parameters of average break width and time of formation were estimated as a function of lake volume based on 63 previous case studies in a methodology described in Froehlich 2008. The manual USACE 2016 states that Earthen gravity dams tend to have a partial breach as one or more monolith sections and the time for breach formation ranges from 1 to 2 h. For the Taksebt dam failure, the parameters are set with breach width as 70 m and failure time set to 1 h. The breach size is defined by a trapezoid and the duration over which the breach occurs. Lastly, RAS allows the user to customize the progression of the breach over the full formation time. Data entry in HEC-RAS of breach information is shown in (Figure 5). The breaching of the dam happens. Excessive storm runoff enters the reservoir behind the dam, and the water level in the reservoir rises. When the water surface in the reservoir reaches 150 m above mean sea level, a overtooping breach forms the water level at an elevation of 151 m(Ws Elev). The overtooping forming a trapezoidal opening. The flow is now treated as weir flow (flow that is being channeled by the breach). The trapezoid grows until it reaches a bottom elevation of 80 m above mean sea level. The trapezoid is 110 m wide at the bottom and has steep side slopes. The breach reaches its maximum opening size 1 hours after the initial overtooping began.

In HEC-RAS, the breach parameters are entered in the geometry data editor for the dam. In particular, notice the following:

- Starting elevation of breach: 150 m (above mean sea level)
- Bottom extent of breach: 80 m (above mean sea level)
- Bottom width of trapezoidal-shaped breach: 110 m

◆ Time to failure (from start until full extent of breach): 1 hours

◆ Reservoir stage when breach begins: 151 m

The modeling takes place on the dry river, As a practical matter, the resultant dam break flood for the normal pool condition is relatively insensitive to the magnitude of reservoir inflow and outflow because they inflow/outflow are typically very small by comparison to the dam break flood.

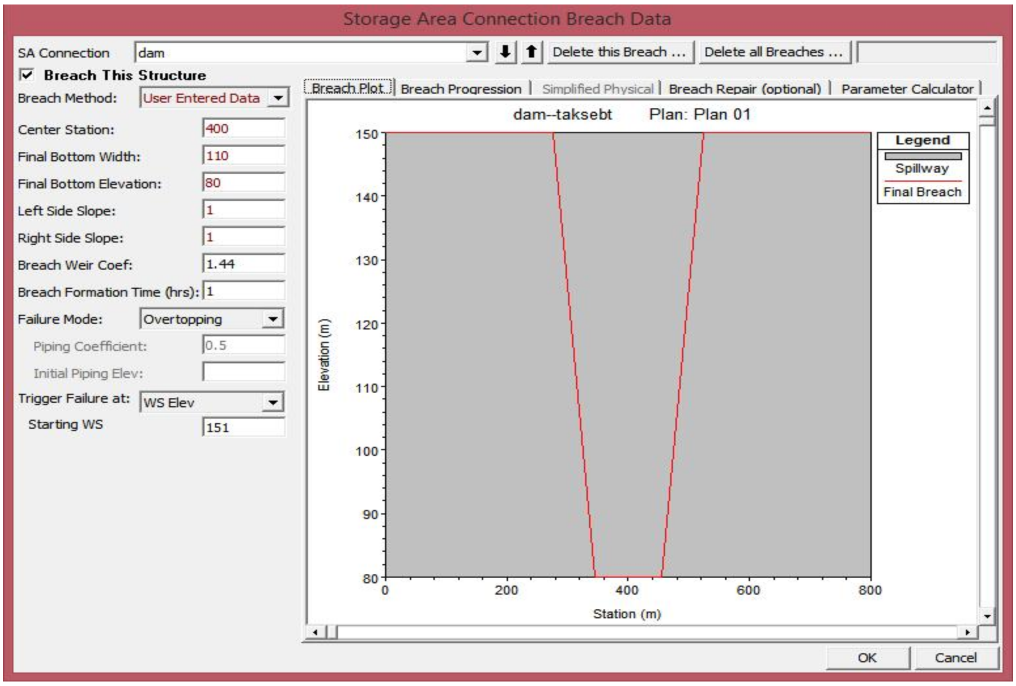


Figure 5: Dam breach information entered in HEC-RAS

3. Results and discussion

3.1. Wave propagation time

In this study, floodplain mapping downstream of the Taksebt dam is accomplished in GIS environment by exporting the results from HEC- RAS using the RAS Mapper tools. The Figure 7 displays the dam break wave propagation in the section at different times from t = 0 to t = 900 min, the time elapsed between the dam failure and the moment the flood wave reaches the corresponding section of the wadi. Inundation mapping of regions downstream of dams is required to understand the consequences of dam breach flooding better; it provides information on the arrival times of the flood wave and the expected hydrodynamic characteristics of the flooding, which are the key inputs for developing warning and evacuation strategies. shown in (Figure 6).

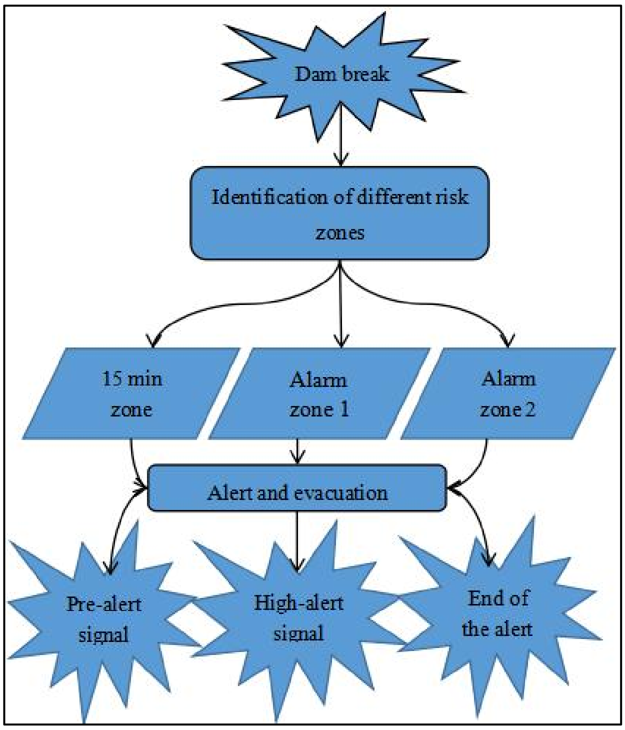


Figure 6: The flowchart of overall plan

3.2. Identification of different risk zones

In the inundation area, different zones of danger can be identified by some of the flood characteristics, namely water levels and times of the flood arrival (Paquier and Robin, 1995). The studied Taksebt dam failure scenario completes the findings of the analysis by providing a better understanding of the hydrological behavior of the Sebaou River. Most importantly, we found that, according to the case of this scenario, a large flow discharge is expected to arrive very quickly near the inhabited regions, which might not allow the inhabitants to escape. The maps give a more direct and stronger impression of the spatial distribution of the flood risk than other forms of presentation (verbal description, diagrams) (Merz et al., 2007). In this study, three areas were identified according to the wave propagation time.

3.2.1. 15 min zone

Two kilometers after the Taksebt dam. It includes Aït Aïssi and Bridge Bougie villages, as it is shown in the inundation map, many structures are considered to be under water in the first 15 min following the dam burst. Water depths exceed 20 m in some urbanized areas including the largest number of residential and administrative buildings which are located by the river bank and a vast agricultural spaces, social equipment and lifeline losses among others, and civil engineering infrastructure (Railways, Roads, Bridges). The water depth map shows that when the flow to Bridge bougie arrives, the flow reverses upstream downstream direction after some time before returning downstream again. This indicates that the flow arises from a back-flow phenomenon under the influence of the change of the shape of the valley of the Sebaou Wadi. Based on preliminary population data for the regions inundated by flood water, areas of housing about 20,000 people, almost 90 per cent of the city's population, would be exposed to a flood wave exceed 10 m.) . It is not possible to initiate evacuation procedures in this zone; once the dam failed, population in these regions must be warned by sirens in which the self-rescue is the only effective evacuation way, where inhabitants have to be prepared to organize their own rescue and be acquainted with their evacuation route from their usual standpoint.

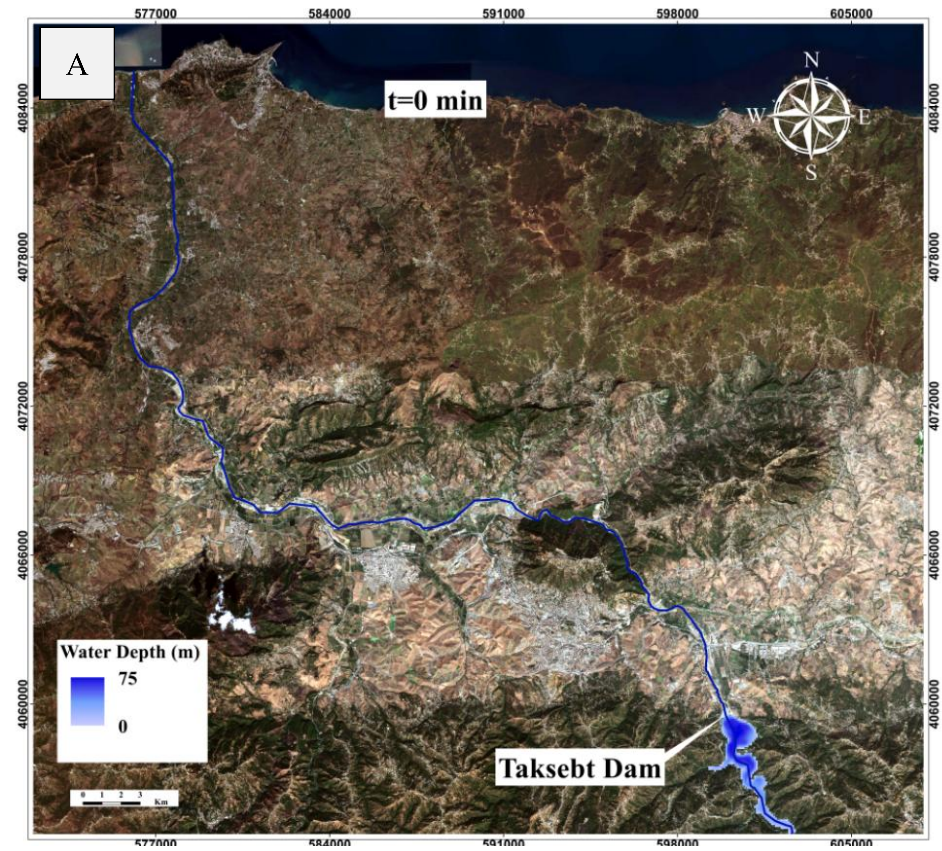
3.2.2. Alarm zone 1

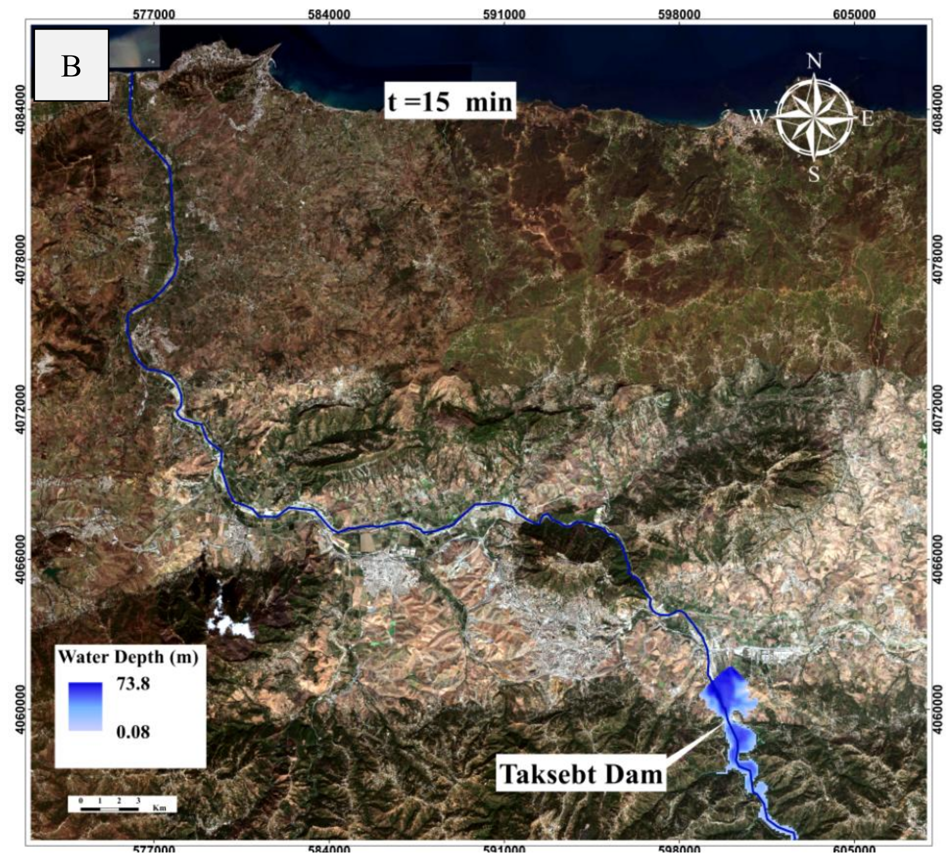
The first alarm zone includes the villages of Sidi Naàmane, Draa Ben Khada and Tadmait. These zones are 20 km from the dam Water depths are very high in this area and it is a residential area located at a sloping terrain at the left side of the bank would be exposed to a flood wave exceed 6 m. At the confluence or river junction of Bougdoura River, areas of potential danger were marked. The dangerous areas approximately contain 150 to 200 residential buildings and a vast space for agriculture and cattle, specifically in these areas. However, the time between the dam break and the arrival time of the dam break flood wave is longer; between 3 and 6 h. The slow developing flood wave leaves the area for longer warning period for the population and the lower water depth

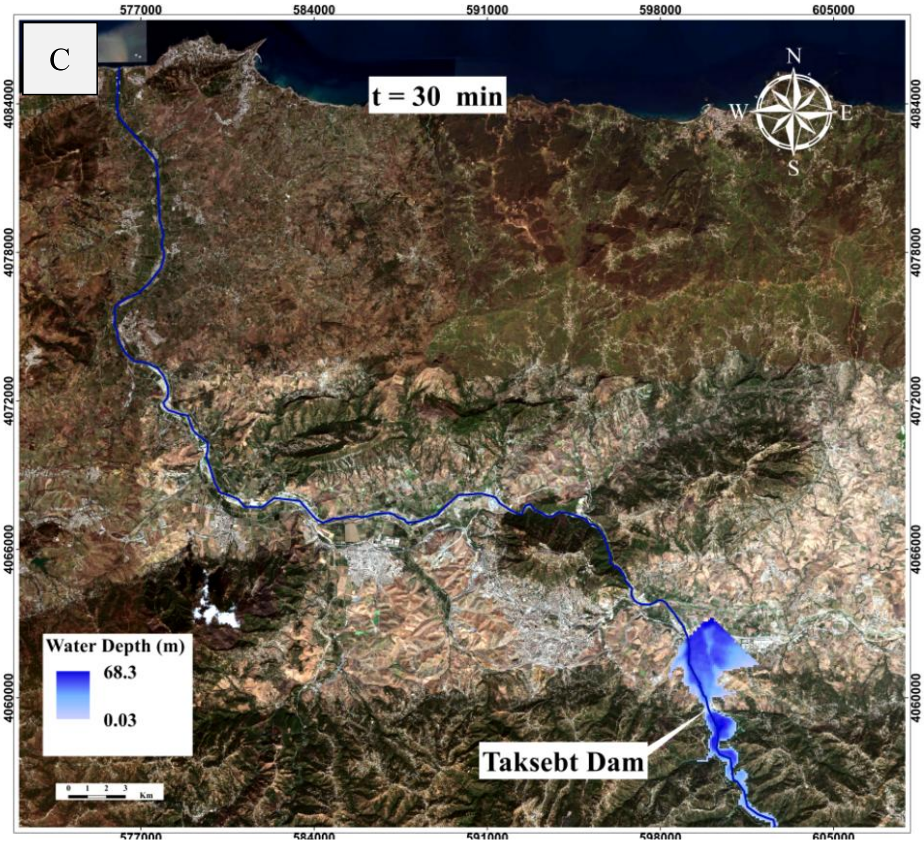
values in the flat areas. This is sufficient for evacuating residents to safe areas, where civil protection material and human resources have an important role in the rescue operations of the most vulnerable community groups (e.g. elderly people, disabled and children).

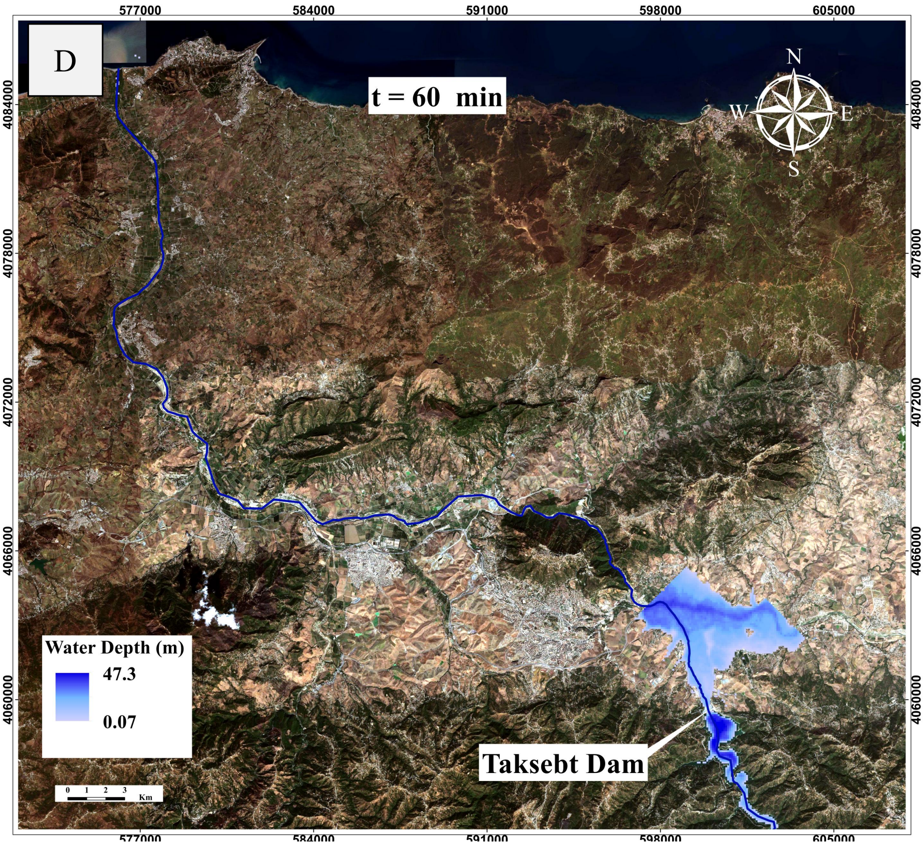
3.2.3. Alarm zone 2

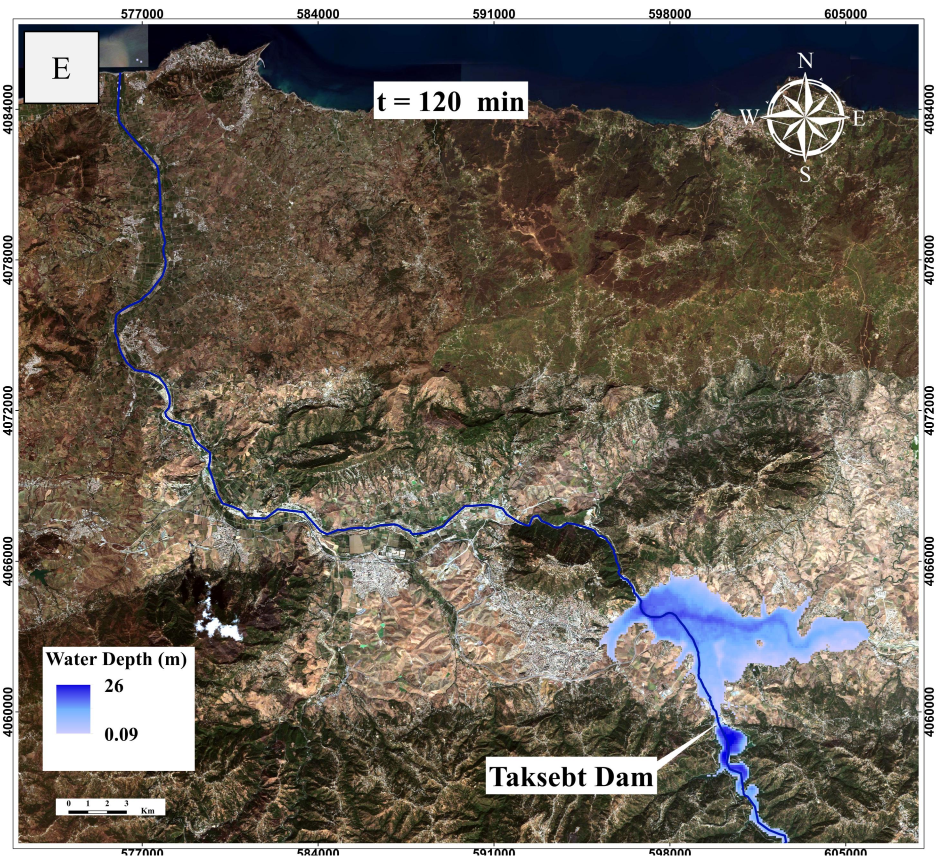
It consists of the area that extends from Baghlia and Sid Daoud to the sea. In this zone, flood damages are low, no loss of life is expected to occur since water depth is lower, compared to a natural flood event, and it is considered to be sufficient for the whole population to be aware of the forthcoming danger and to take the necessary measures associated with the emergency. These areas are 35 km from Taksebt Dam


A
t=0 min
N
W
E
S
Water Depth (m)
75
0
Taksebt Dam
577000
584000
591000
598000
605000
4084000
4078000
4072000
4066000
4060000

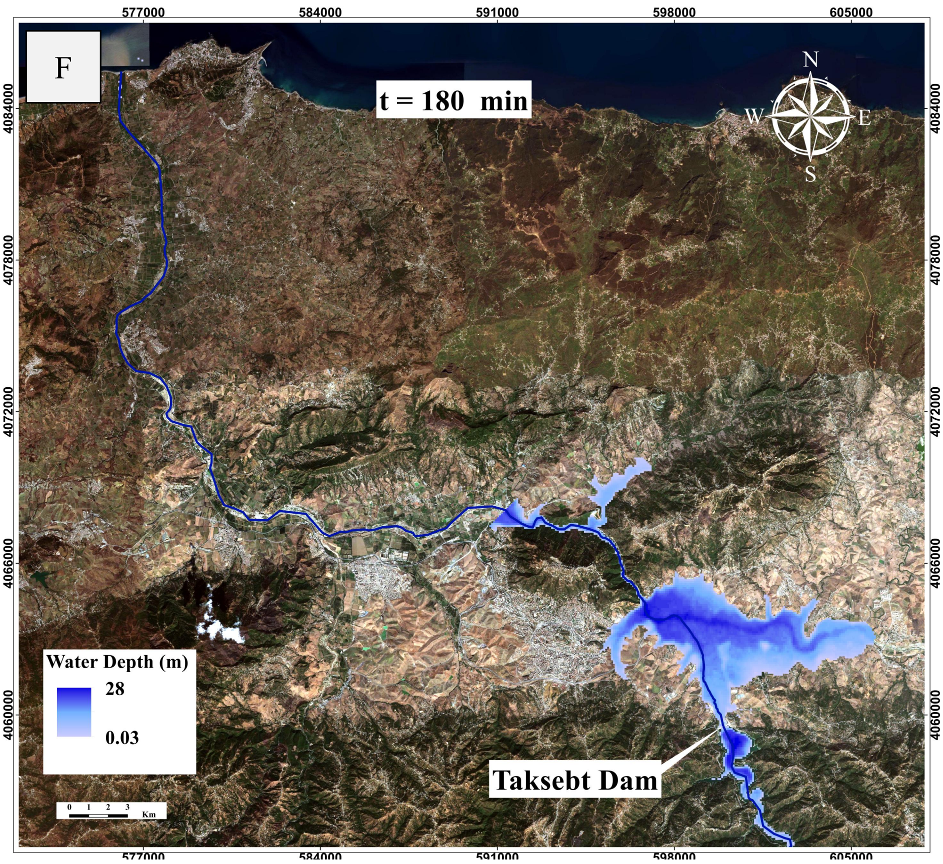

B
t =15 min
N
W
E
S
Water Depth (m)
73.8
0.08
Taksebt Dam
577000
584000
591000
598000
605000
4084000
4078000
4072000
4066000
4060000


C
t = 30 min
Water Depth (m)
68.3
0.03
Taksebt Dam
N
S
W
E

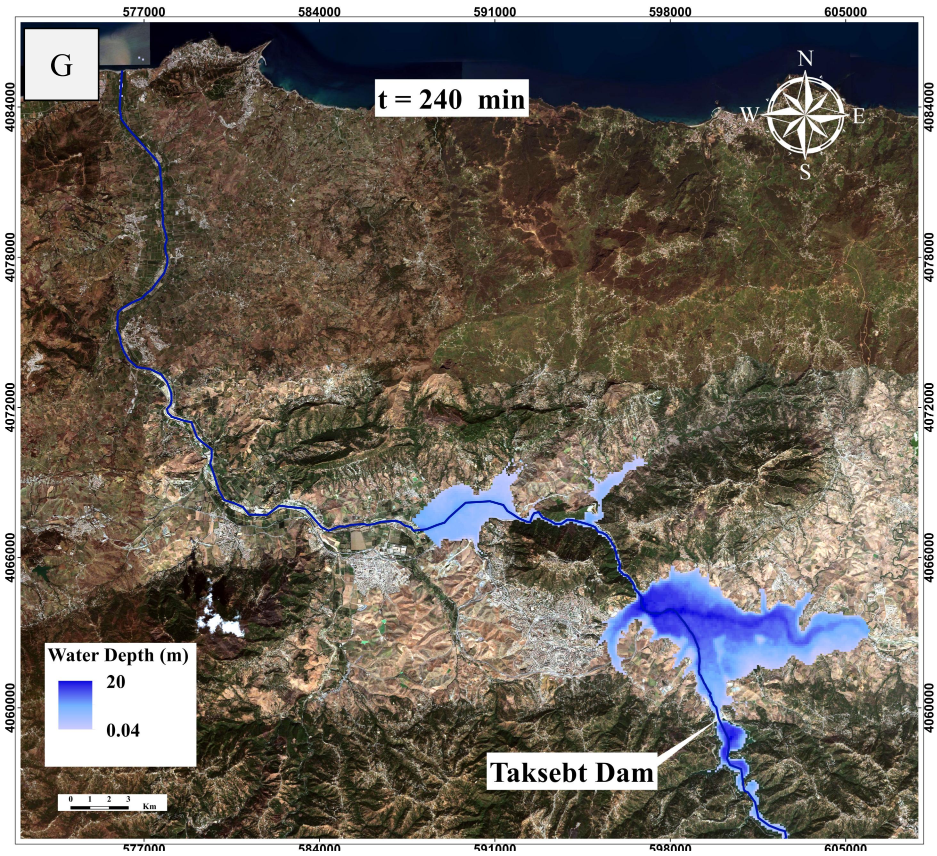

D
t = 60 min
Water Depth (m)
47.3
0.07
Taksebt Dam
N
S
W
E

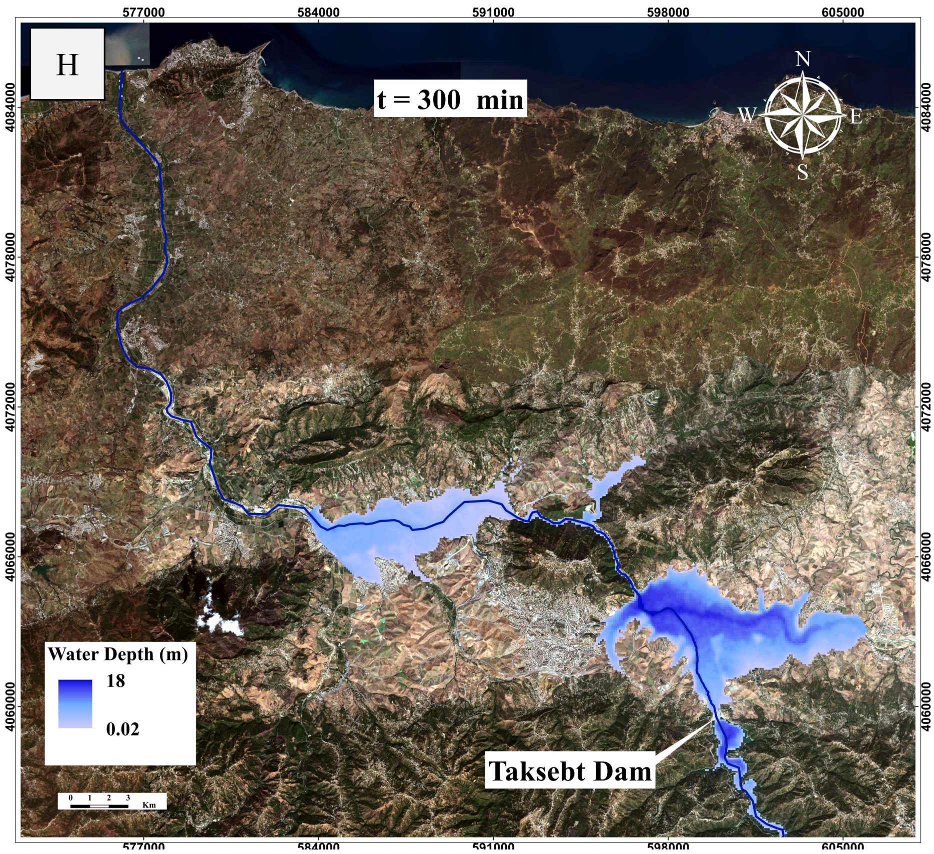


E
t = 120 min
N
W
E
S
Water Depth (m)
26
0.09
Taksebt Dam
577000
584000
591000
598000
605000
4084000
4078000
4072000
4066000
4060000



F
t = 180 min
N
W
E
S
Water Depth (m)
28
0.03
Taksebt Dam
577000
584000
591000
598000
605000
4084000
4078000
4072000
4066000
4060000


577000
584000
591000
598000
605000
G
t = 240 min
N
W
E
S
4084000
4078000
4072000
4066000
4060000
Water Depth (m)
20
0.04
Taksebt Dam
Km


577000
584000
591000
598000
605000
H
t = 300 min
N
W
E
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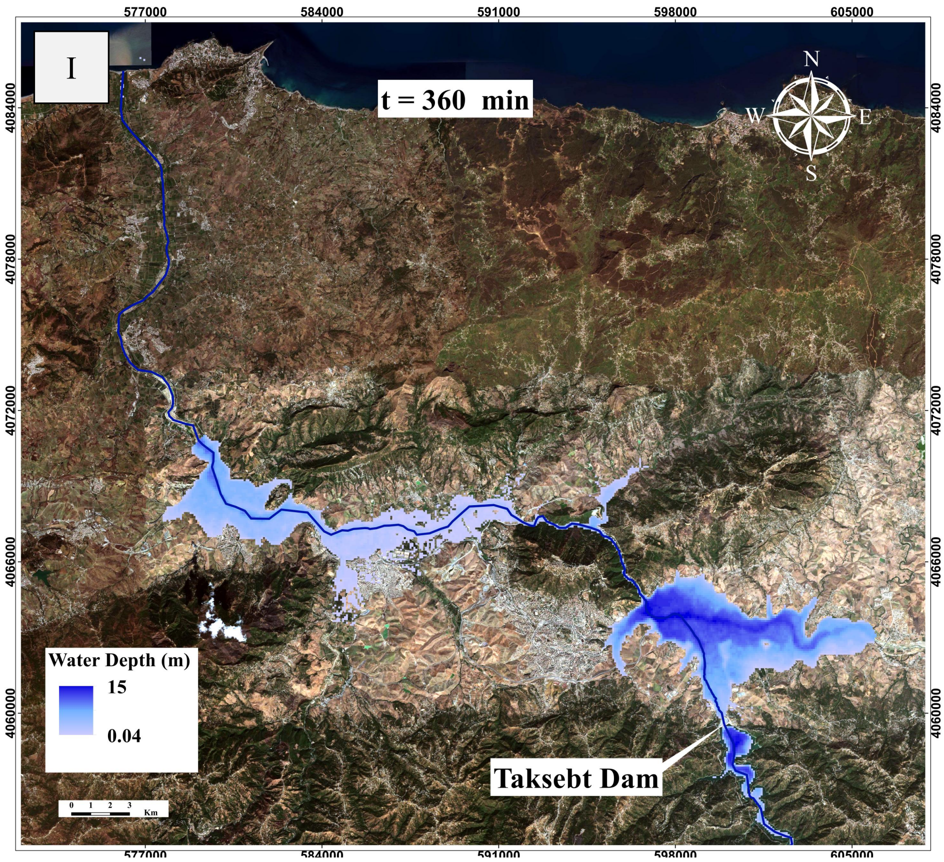
4084000
4078000
4072000
4066000
4060000
Water Depth (m)
18
0.02
Taksebt Dam
Km


I
t = 360 min
Water Depth (m)
15
0.04
Taksebt Dam
N
S
W
E
577000
584000
591000
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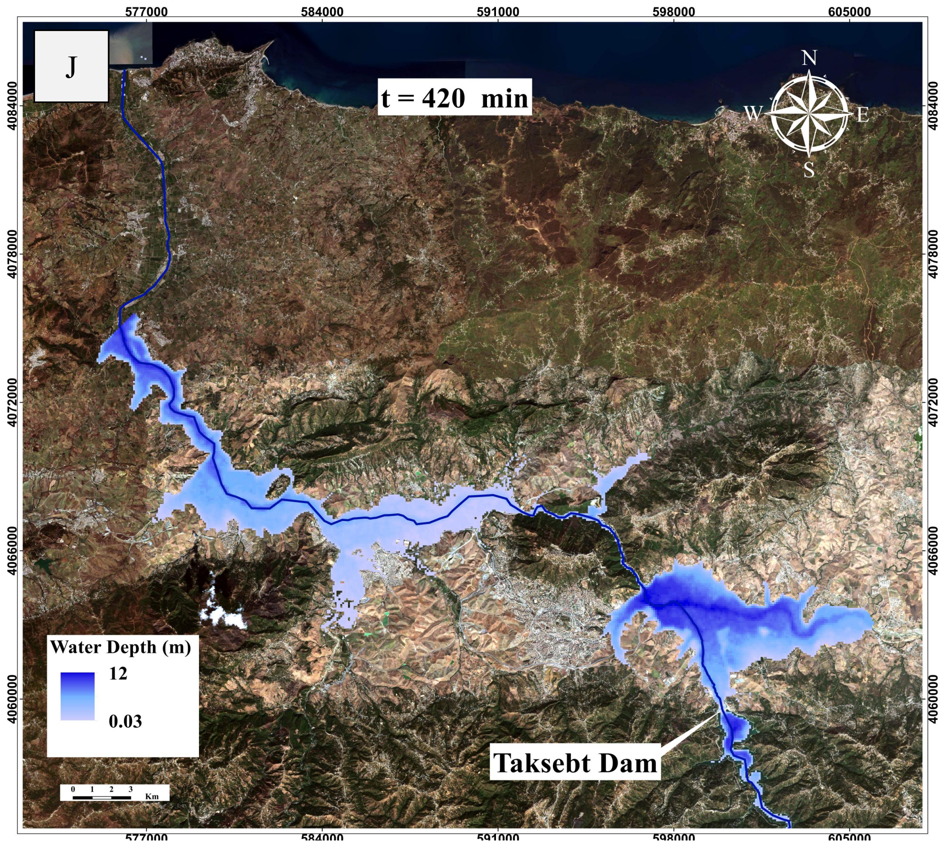
4084000
4078000
4072000
4066000
4060000


J
t = 420 min
Water Depth (m)
12
0.03
Taksebt Dam
N
S
W
E
577000
584000
591000
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4084000
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4072000
4066000
4060000

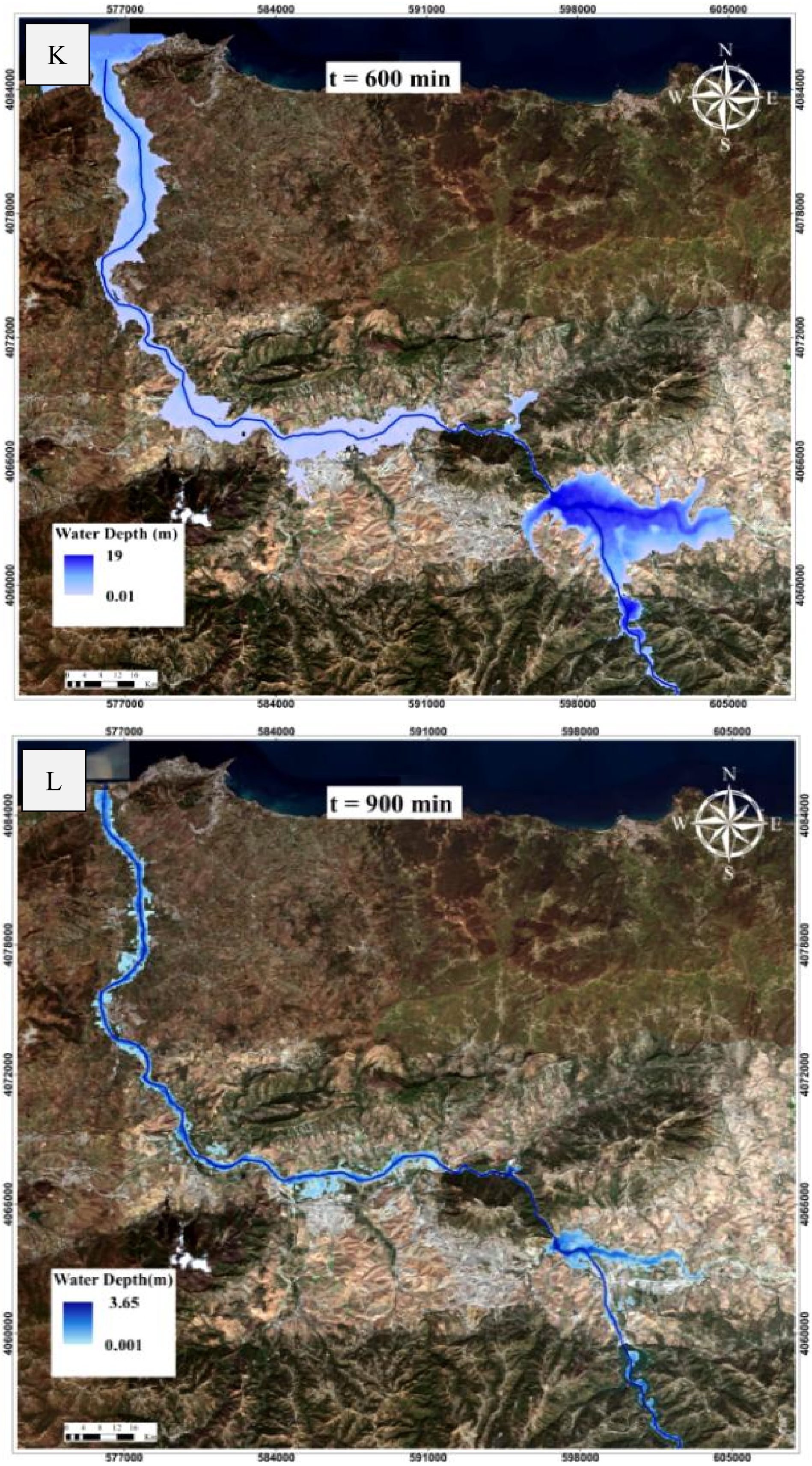

Figure 7: The water contours of wave propagation time after the failure of Taksebt dam; (Source: own study

3.3. Alert and evacuation

To ensure the security of the population downstream of the Taksebt dam, since the peak discharge produced during dam break is high from dam site to 45 km, it is obligatory to install an early warning and evacuation system in the case of a dam break. The choice of the solution to warn the Sebaou valley must take the geographic dispersion of the population into consideration such as the small rural areas, densely urbanized urban areas, and dispersed dwellings. Moreover, it must also lay on the distance from the dam location as well as on the proximity of the civil protection services resources. In the most dangerous zones, due to a small delay in the flood arrival time, the alert could be public warning using audible systems as well as adopting visible systems (strobe lights and billboards); personal direct notification via telephone or cell phones, also including the door to door warning, loud speakers of mosques, and, nowadays, the use of a short message service in mobile phones via cellular diffusion; television or radio station news broadcasts can be used in the zones less affected by the dam-break flood and these are very efficient ways for public information during an emergency. In addition, a specific signal for hydraulic structures that are transmitted by the means of the foghorn type sirens. Audible sirens are the most commonly used warning systems, providing immediate notification by broadcasting a tone consisting of a siren wail or a voice message and can include options to broadcast prerecorded voice messages. Generally, this kind of signals has three different levels of alert which are the following:

- **Pre-alert signal**

It is triggered at the first disturbing signs menacing the dam safety. It consists of a series of 10-s uniform tones that last from 5 to 6 min, interrupted by a 5-s pause. This signal concerns only the 15 min zone and it is destined to initiate the evacuation procedures, as there would be no sufficient time for evacuating the residents after the dam break.

- **High-alert signal.**

It is triggered once the dam is failed. It consists of a series of 10 modulated tones at a very high frequency that lasts from 5 to 6 min, interrupted by a 5-s pause. It concerns the Alarm Zone 1 and in lesser degree the Alarm Zone 2. In such case, the local authorities should save the affected population by helping them reach safer areas, which are generally high building levels and hills.

- **End of the alert**.

It is triggered when returning to the normal situation. A siren diffusing a 30-s continuous tone announces this level of alert. The strengths of this alert alternative are that they allow an instant communication to all population at risk, namely enabling fast alerting to highly populated areas, guarantee a good coverage (including in isolated areas) and have a high degree of credibility to audience. Furthermore, this alert solution can have a low maintenance cost, it is flexible and expandable for future. Besides; it has units provided with electrical accumulators and available during both phone and electric outages.

Typically, there is no single alert system that can meet all the desired notification requirements. Each system has its advantages and disadvantages (Hartford and Baecher, 2004) However, there are quite important aspects to be taken into consideration; mainly to be sure that the message is easily understood by the public and to guarantee that the system is reliable: false alarm must be avoided and maintenance needs to be efficient (Viseu and de Almeida, 2009). The effectiveness of evacuation depends on many factors such as warning effectiveness with trained staff, age distribution, availability of time, and the available evacuation routes. Evacuation can be laterally away from the inundation area by means of a delineation of general traffic routes and definition of traffic control measures, or it can be a vertical relocation in a building or other type of shelter, such as trees or islands. The choice can affect the fatality rate because of the different movement speed and population redistribution over time. The success of the evacuation will be strongly based on a good organization, preparation and testing as well as efficient public information in a crisis context; risk communication strategies need to be selected, tested and efficiently implemented. Evacuation planning needs to be well prepared and should be carried out by a trained staff, and almost in all real cases. The alarm needs to be switched on as soon as a failure is detected, to evacuate a large number of inhabitants (4, 2006).

This condition implies:

- ◆ identifying available means to alert authorities and issue public warnings using advanced monitoring systems with a real-time capability to predict a dam accident more accurately;
- ◆ ensuring good coordination between dam owners, dam safety authorities and civil protection agents and identify their responsibilities and missions; and
- ◆ providing good public information to develop and coordinate operations, thereby will guarantee a good response to flood crisis.

4. Conclusion

To estimate the potential risks related to the failure of the Taksebt dam, the hydraulic parameters of the dam break wave were estimated through a two- dimensional numerical simulation via HEC–RAS 2D. The exportation of the hydraulic results to a GIS environment enabled producing valuable maps depicting the extent of the inundation area and the arrival times of the dam break wave at key locations downstream of the Taksebt dam.

The analysis of the results shows that the Taksebt dam break flooding would seriously affect several settlements, which might lead to life loss and material damages. The downstream zone at risk was then classified into three risk levels based on the arrival times of the flood wave and some alert and evacuation measures were suggested for each risk zone to mitigate the losses. The inundation maps provide an estimate about the direct consequences of the dam break event, but the indirect ones, also known as the long-term consequences, will be enormous as well. The development of the areas should be planned by taking into consideration the above-mentioned flood hazard maps ensuring better protection of the people facing the risk in a potential dam failure event, as well as decreasing the associated economic and environmental consequences.

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