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FLOOD RISK NUMERICAL SIMULATION OF BEJAIA CITY URBAN ZONE (ALGERIA)

SIMULATION NUMÉRIQUE DU RISQUE D'INONDATION DE LA ZONE URBAINE DE LA VILLE DE BEJAIA (ALGÉRIE)

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ABSTRACT

The main objective of this study is the simulation of the floods in urban zone by applying a calculation code solving the two-dimensional Saint Venant equations. These equations form a set of three coupled equations, not linear and hyperbolic which are solved by an explicit finite volume scheme. The flow in the urban environment is very complex, so the use of a 2D code has several advantages, since it allows describing of crossroads in topography and to know the area of the submerged zone. In our study, we used the Rubar20 code to simulate the inundations of the floods of the N'Dfali Oued which crosses the zone of study located in full city center of Bejaia (Algeria). The obtained results are compared with the different collected data.

Keywords: Flood, Simulation, Rubar20, Urban zone.

RESUME

L'objectif principal de cette étude est la simulation des inondations en zone urbaine par l'application d'un code de calcul résolvant les équations bidimensionnelles de Saint Venant. Ces équations forment un ensemble de trois équations couplées, non linéaires et hyperboliques. Elles sont résolues par un schéma explicite de volumes finis. L'écoulement dans l'environnement urbain est très complexe, de sorte que l'utilisation d'un code 2D présente plusieurs avantages, puisqu'il permet de décrire des carrefours dans la topographie et de connaître la superficie de la zone immergée. Dans notre étude, nous avons utilisé le code Rubar20 pour simuler les inondations de l'Oued N'Dfali qui traverse la zone d'étude située en plein centre-ville de Bejaia (Algérie). Les résultats obtenus sont comparés avec les différentes données collectées.

Mots clés : Inondation, Simulation, Rubar20, Zone Urbaine.

INTRODUCTION

In the world, the floods are classified as first natural risk, they have in their origin, the events weather-hydrological which, due to stochastic nature, are very difficult to expect as for their period of return and their intensity. They are very dangerous when they occur in city where is situated a strong concentration of the human activities. Consequently, economic activities are severely disturbed and the costs for the society become exorbitant, the need of planning and preventing the return of these disasters is very important (Behlouli, 2008). It requires an interdisciplinary work; the main actors are hydrologists and hydraulics, planners and administrators of the city. If the work of a hydrologist can be summarized in the research for the casting of rains in space and at time, the work of a hydraulician concerns the passage of the flow corresponding to this casting through the city (Haider, 2001). To understand a physical phenomenon, we have to model it. The modelling of the floods represents in our days a very important subject in the thematic of water, it occurs inevitably by the numerical resolution of the Saint Venant equations issued from Navier Stokes flows governing equations (Araud and Champredonde, 2007). The modeling of the floods permits describing the event such as it occurred with a small degree of tolerance (Paquier, 1995).

The study of floods in urban areas is of great interest in hydraulics. Indeed, the protection of areas with a high populated concentration is a primordial obligation for the authorities of every country in the world. Thus, several studies have been carried out in this context. In 2009, Abderrezzak et al. treated the Modelling flash flood propagation in urban areas after an excessive rainfall event or dam/dyke break wave, and this by using a two-dimensional depth-averaged shallow-water model. The 2-D equations are solved using the explicit second-order scheme that is adapted from MUSCL approach. Several cases were studied. Xia et al. (2011) presented a study on the modelling of flash flood risk in urban areas in which he showed that the impacts of flash floods can be very high in urban areas due to these regions being generally densely populated and containing vital infrastructure. Broekx et al. (2011) conducted a study on the designing a long-term flood risk management plan for the Scheldt estuary using a risk-based approach. A risk-based approach was applied for Flanders by calculating the impacts of flood damage at different levels of recurrence, for the base year (2000) and in case of a sea level rise of 60 cm by 2100. Hartnett and Nash (2017) have studied the flood modeling of urban areas using MSN_Flood. These researchers questioned some of the classical models used in the treatment of floods in urban areas and proposed to use the MSN_Flood which has been developed essentially to incorporate moving boundaries around nested domains, permitting alternate flooding and drying along the boundary and in the interior of the domain. The MSN_Flood is based on an alternating-direction semi-implicit finite difference scheme. Park and Lee (2019) provided a study on the development and application of the urban flood risk assessment model for reflecting upon urban planning elements. In this analysis, vulnerability and exposure tests are adopted to analyse urban flooding risks. There are two key findings and theoretical contributions of this study. First, the areas with a high flood risk are mainly restricted to central commercial areas where the main urban functions are concentrated. Additionally, the development density and urbanization are relatively high in these areas, in addition to the old center of urban areas.

The objective of the floods modelling is to establish maps of vulnerability to flooding; our research work is focused on this context, axed to the simulation of the floods of the N'Dfali Oued (Bejaia, Algeria). We have used the Rubar20 code which simulates the two-dimensional flows, it is the most adapted tool to our work and it allows the simulation of the floods in rural and urban zones.

MATERIAL AND METHODS

To be able to simulate the floods of the N'Dfali Oued which is the main cause of the floods of the Aamriw zone situated in the Bejaia city, we have used the Rubar20 code calculation. The Rubar20 software was initially designed for the calculation of the two-dimensional dam break wave propagation (Hervouet et al., 2000; Ancey, 2009). It allows simulating the distribution of the wave propagation issued from an immediate dam failure, or from a progressive failure (for which we know the hydrogram of the dam) or for which we model it by a particular work. In particular, it focuses the propagation of a front wave on a zone initially dry. Mostly, this software permits any hydraulic calculation resulting from two-dimensional Saint Venant equations, in particular when the temporal variations of the hydraulic characteristics are important (floods). The calculation code used the finite volume method applied to a meshing constituted by quadrangles and by triangles which have between them 0 or 1 (integer) common side. At every step of time, to calculate inflows and outflows of every mesh, is solved a Riemann problem in normal direction for the edge. Two digital plans are available to solve this problem:

- A plan of VAN LEER with the second order in space and the first order at time.
- A plan of VAN LEER with the second order at time and in space.

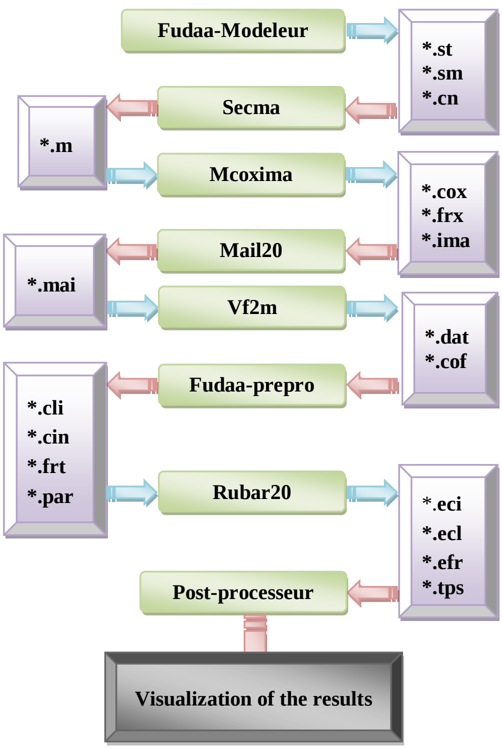

Figure 1: Procedure of simulation via Rubar20 (Cemagref, 2011)

The visualization of the data and the results as well as the insertion of some data can be made from three meadows and/or comment independent processors FUDAA-MODELEUR, MOCAHY and FUDAA-PREPRO. Complementary utilities allow the transformations of format and the necessary interpolations (Cemagref, 2011). Simulation with Rubar20 occurs by three stages, which are: the data insertion, the launch of the calculation, and at the end the extraction of the results (Figure 1).

STUDIED CASE

The objective of the simulation is to reproduce the floods of different return periods. The Rubar20 code allows to locate the sensitive zones and to see their variations according to time. The results are represented in the form of graphs, of animations …etc. The Rubar20 code takes into account the hydrodynamics part such as the height and the water flow. This work will afterward allow putting an action plan to fight against this kind of disaster in the future and the obtained results can serve to define geographically the inundation extends in this zone.

The launch of the calculation is made either by executing directly the Rubar20 subroutine or from the preprocessor Fudaa-Prepro. The flow simulation of N'Dfali Oued (Figure 2) further to floods with various return periods (10, 20 and 25 years) was established (Benslimane, 2012). The obtained results for every flood are represented by the various figures hereafter.

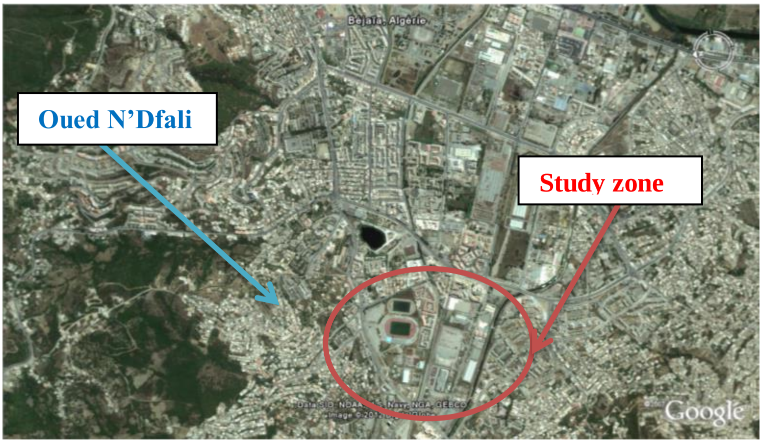

Figure 2: Demarcation of the study zone (Earth Pro Google)

RESULTS COMPARAISON FOR THE VARIOUS FLOODS

Results on the water heights

The evolution observation of the water height during the floods (Figures 3 to 11) allowed us to divide it into three steps in function of time:

For t = 0 sec to t = 1050 sec

The flow is practically made in the minor bed with a water height which varies between 0.5 and 1 m for the floods of 10 years return period (figure 3). During the same duration of floods and for 20 and 25 years returns periods, the flow extends in the major bed and some places are filled with water (figures 4 and 5).

Figure 3: Water heights in t = 1050 sec for a flood of 10 years return period

Figure 4: Water heights in t = 1050 sec for a flood of 20 years return period

Figure 5: Water heights in t = 1050 sec for a flood of 25 years return period

For t = 1050 sec to t = 4500 sec

The flow became very aggressive and the water level is maximal at the level of the Oued bed which causes floods in several places with reaching 1 meter heights (Figures 6 to 8).

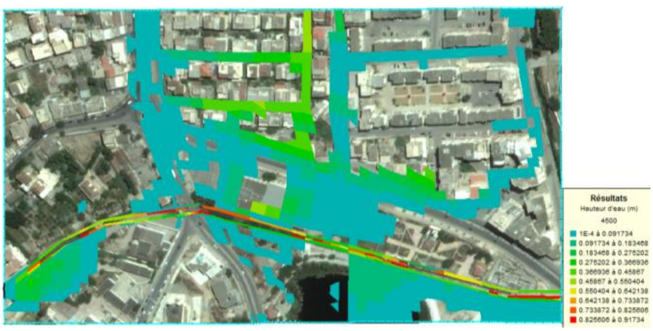

Figure 6: Water heights in t = 4500 sec for a flood of 10 years return period

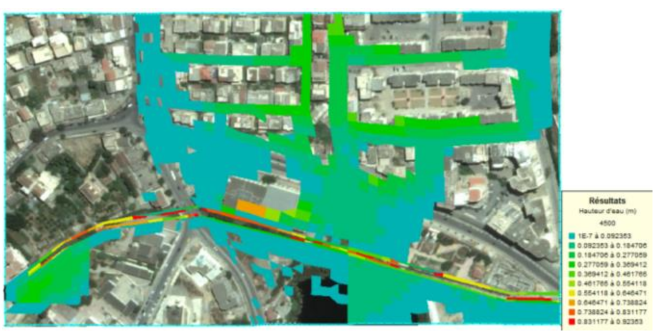

Figure 7: Water heights in t = 4500 sec for floods of 20 years return period

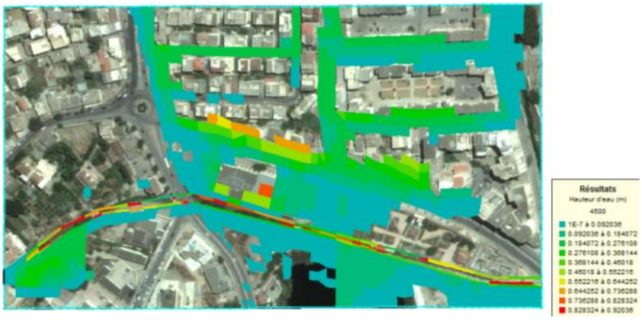

Figure 8: Water heights in t = 4500 sec for a flood of 25 years return period

For t = 4500 sec to t = 10800 sec

This step is characterized in a general way by the reduction of the water level.

- At the bed level, the water height varies because it remains high only on the downstream part.
- At the flooded banks level, the major part of these zones knew a considerable reduction of the water level (Figures 9 to 11).

Figure 9: Water heights of water in t = 10500 sec for a flood of 10 years return period

Figure 10: Water heights in t = 10500 sec for a flood of 20 years return period

Figure 11: Water heights in t = 10500 sec for a flood of 25 years return period

Temporal variation of the heights of water in the flooded zones

At the flooded zones level, we have drawn the variation of the water height according to time for various sections distributed in order to well illustrate the evolution of the water height for all the emerged zones. Figures 12 to 14 show that in some districts the water height reaches (affects) 0.9 m.

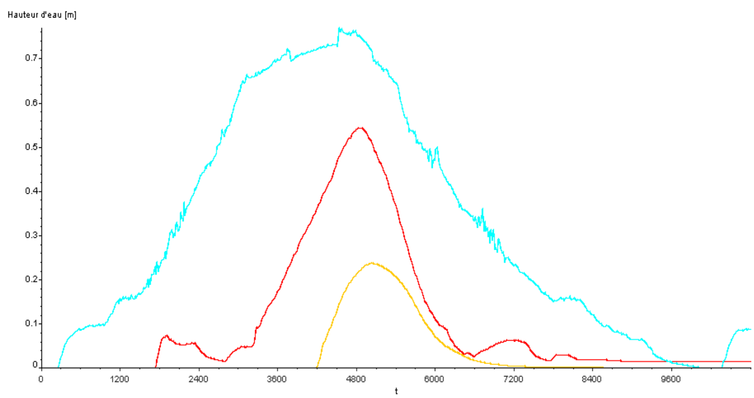

Figure 12: Variation of the water height in flooded zones for a flood of 10 years return period

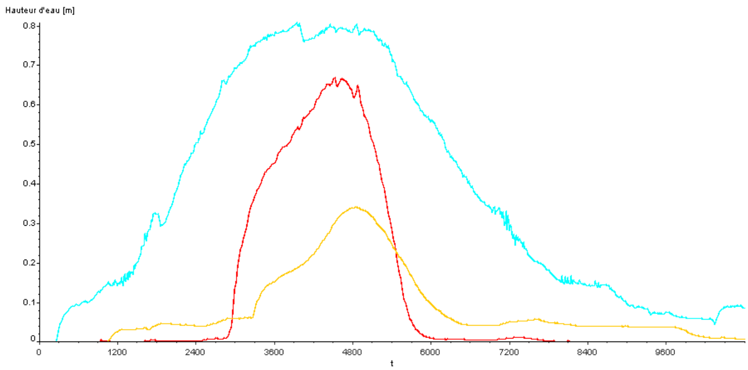

Figure 13: Variation of the water height in flooded zones for a flood of 20 years return period

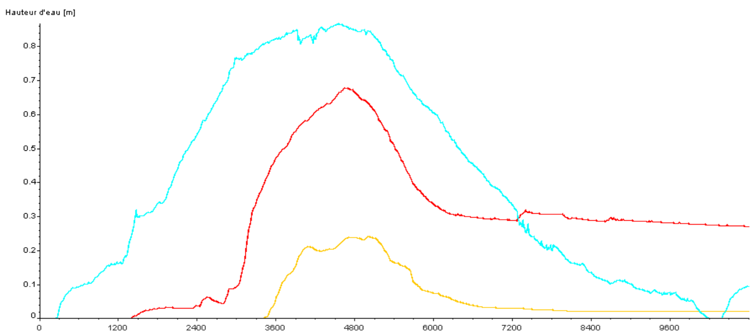

Figure 14: Variation of the water height in flooded zones for a flood of 25 years return period

CONCLUSIONS

Owing to the fact that the N'Dfali Oued is not arranged and some places do not possess a sewage (sanitation) system, which makes of Aamriw region an easily flooded zone during almost all the winter season. Studies carried out by the Hydraulic Resources Direction (DRE) and the National Office of Purification (ONA) of the Wilaya of Bejaia have revealed that N'Dfali Oued is one of the major reason of the floods observed in this region, and then several studies are in progress to solve this issue. Our study gives an idea onto the evolution of these floods in time and bounds the sensitive zones of the city. This allows acting better to protect and find plausible solutions of strengthening. The obtained results of simulation for three floods have shown that the area of the floods is practically similar, we only notice a difference of water height going from 10 to 20 cm and reaching around 1 meter in some places. These results reflect in a rather convincing way the values observed during the important floods registered in this place.

REFERENCES

ABDERREZZAK, K.E.K., PAQUIER, A., MIGNOT, E. (2009). Modelling flash flood propagation in urban areas using a two-dimensional numerical model. Natural Hazards, Vol. 50, pp. 433-460.

ANCEY, C. (2009). Hydraulique à surface libre. Phénomènes de propagation : ondes et ruptures de barrage. Bases mathématiques, outils de simulations, applications. Notes de cours, École Polytechnique Fédérale de Lausanne, Suisse, 250 p.

ARAUD, Q., CHAMPREDONDE, R. (2007). Modélisation des Equations de Saint-Venant. Revue d'hydrodynamique de l'environnement. INP, ENSEEIHT, 26 p.

BEHLOULI, L. (2008). Crues et inondations en Algérie. Présentation "ANRH" Ministère des Ressources en Eau (MRE), 43 p.

BENSLIMANE, M. (2012). Simulation of the flood risk in urban zone via the Rubar20 code of calculation. Magister Thesis, Bejaia University, Algeria, 131 p.

BROEKX, S., SMETS, S., LIEKENS, I., BULCKAEN, D., DE NOCKER, L. (2011). Designing a long-term flood risk management plan for the Scheldt estuary using a risk-based approach. Natural Hazards, Vol. 57, pp. 245-266.

CEMAGREF (2011). Software Rubar20, note of employment (use). Waters Department, Unity of Research Hydrology-Hydraulics, Grouping of Lyon, France, 61 p.

HAIDER, S. (2001). Contribution to the modeling of flooding in urban areas - dimensional approach by the Saint Venant equations-. Master Memory in Civil Engineering, Cemagref, INSA Lyon, France, 180 p.

HARTNETT, M., NASH, S. (2017). High-resolution flood modeling of urban areas using MSN_Flood. Water Science and Engineering, Vol. 10, Issue 3, pp. 175-183.

HERVOUET, J.-M., SAMIE R., MOREAU B. (2000). Modelling urban areas in dam-break flood wave numerical simulations. RESC-DAM workshop, Seinajoki, Finland, 12 p.

PAQUIER, A. (1995). Modelling and simulation of wave propagation dam break. PhD. Thesis, Saint Etienne University, France, 193 p.

PARK, K., LEE, M.H. (2019). The development and application of the urban flood risk assessment model for reflecting upon urban planning elements. Water, Vol. 11, 920, doi:10.3390/w11050920

XIA, J., FALCONER, R.A., LIN, B., TAN, T. (2011). Modelling of flash flood risk in urban areas. Proceedings of the Institution of Civil Engineers-Water Management, Vol. 164, Issue 6, pp. 267-282.