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# Hydrological investigation and hydraulic modeling of floodable areas in the Aghbar center, Al Haouz province, Morocco, using HEC-RAS (1D, 2D)

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***Abstract –*** The study presents flood modeling of Aghbar's center, which is part of Al Haouz province, and the basin of N'Fis, using HEC-RAS one-dimensional and bidimensional models. The research's aims are to designate flood-prone zones at the study area level of 94.3 HA in order to provide the center with all of the essential facilities for the upgrading of its local population. The hydrological study of the basin was carried out in order to calculate the flood flows according to the various periods of return (10years, 20years, 50years, 100years) using several methods, the Gradex method provided a good finding, where the centennial peak flow was 1151.55 m3/s. During the hydraulic phase, the Wadi's water height and flow velocity were computed using one-dimensional modeling (1D) with a 100-year flow as a reference flow using HEC-Ras 5.0.7. These two parameters were also calculated using a two-dimensional modeling (2D) that allowed the fluvial flows to be modeled, resulting in a comparative synthesis between the two models, with the goal of proposing subsequent schemes of flood protection for the Aghbar Center and reinforcing the already existing hydraulic works. The one-dimensional modeling at the end of the mapping of flood-prone areas at the level of the center of Aghbar shows that Douar LAMKAYT is protected from the risk of flooding, whereas the center of Aghbar will be affected, allowing us to propose protective measures at the level of this center such as gabions and protective walls.

*Keywords – Aghbar, Peak Flows, Gradex, HEC-Ras, One-Dimensional Model, Bidimensional Model.*

## I. Introduction

Floods are one of the disastrous extreme hydrological events responsible for the thousands of casualties worldwide [1]. They result from the conjunction of several natural and anthropic factors; the main ones being linked to the climates and edaphic characteristics of the environment. As man is attracted to the fertile areas near watercourses, the risk of flooding accompanies him. A flood zone is constituted by the whole of the grounds likely to be covered by the flood of a watercourse in the extreme manifestation of the phenomenon. It thus includes both lands regularly flooded at each flood as well as those which can be exceptionally flooded (at least once every hundred years). This study is carried out in the rural municipality of Aghbar which is located in the N'Fis watershed representing one of the tributaries of the Oued Tensift, and the climate is semi-arid, such as all the regions localized in the N'Fis basin, with hot summers and cold winters [2]-[4]. The N'Fis watershed receives significant annual rainfall that increases from autumn to winter and then decreases from spring to summer. Climatological stations are located in Aghbar where rainfall varies irregularly from one year to another with an interannual average of 537.4 mm. The center of Aghbar subject of this development plan (1:2000) [5], is part of the territorial municipality of

the same name. This municipality has a great landscape diversity marked by forest areas, valleys where are embedded watercourses and mountains with steep slopes. It would thus be the responsibility of this development plan to provide the center with basic equipment and infrastructure ensuring human dignity and meeting the basic needs of the population and to preserve the environment. Our study consists in delimiting the floodable zones at the level of the surface area of 94.3 HA, located in the rural commune of Aghbar. Flood inundation models are thus developed to serve this purpose. It involves hydrologic modelling in order to estimate peak flows from storm events, hydraulic modelling to estimate water face elevations and to delimit the floodable zones at the center of Aghbar supported by GIS software, as well as recommending arrangements of protection. The rural municipality of Aghbar is located in the south of the province of Al Haouz [5] by having geographical coordinates N 30°55′11.4″ and W 8°18′19.5″, and located in the sub-basin of N'Fis (Fig.1).

## II. Materials and Method

Our modelling scheme and measurement of the extent of flooding is based on two studies, the first is hydrological and aims to estimate the peak flows corresponding to different return periods at the project area of Aghbar. The adopted flows will be of capital importance for the dimensioning of the projected works on the N'Fis wadi at the level of the restitution of our study area. It includes several steps: estimation of the peak flow by the different empirical formulas (Mallet Gauthier [5], Fuller II [5], Hazen-Lazarevich [5]) which consists in applying the regional formulas adapted to the nature of the watershed, then rational method, statistical adjustment of flows using Gumbel, Gamma, GEV, Normal Exponential and Log-Normal laws at the HYFRAN-PLUS [11] software level with analysis of the obtained graphical representations [5]. The second phase is the modelling phase of the one-dimensional and Bi-dimensional hydraulic models of the Oued N'fis in our project area. It begins by providing the basic elements necessary for the operation of the hydraulic model and identify areas at risk of flooding in the basin. The identification of the processes is done in four steps: identification of the geometry of a watercourse (creation of the TIN Model which is a form of vector digital geographic data constructed by triangulating a set of vertices or points, the vertices are connected to a series of segments to form a network of triangles), creation of a digital terrain model with high elevation accuracy generated from the TIN, identification of flow rates and boundary conditions, then we calculate conditions such as (water height, critical depth...). During this study, we used two types of software: a Geographic Information System software (ArcGIS [6]) and a river modelling software (HEC-RAS) which is developed at the Hydrologic Engineering Center of the US Army Corps of Engineers [5],[7]-[8] (Fig.2). The HEC-RAS model is designed to perform 1D steady flow (Fig.3A) and 2D unsteady flow simulations (Fig.3B). The one-dimensional hydraulic models [9] is the most reliable for our study because it is valid for incised streams. The objective of this modelling is therefore to understand the hydraulic functioning in the study area in order to subsequently map and model the water heights and flow exchanges in this area [10].

### A. *Figures and Tables*

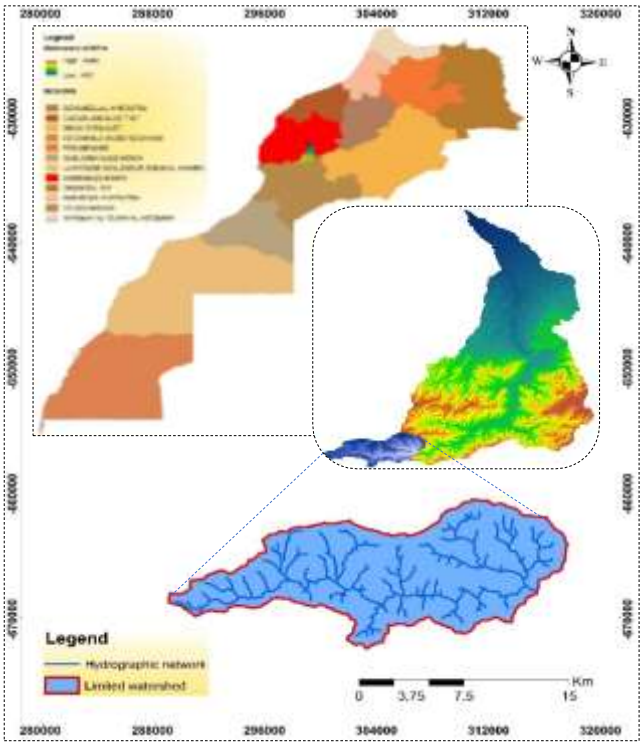


Fig. 1 Delimitation of the sub-basin of N'Fis.

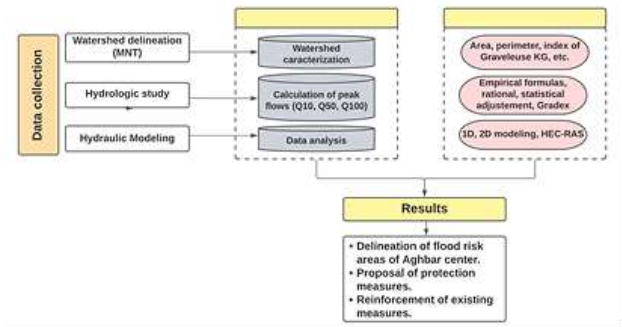


Fig. 2 Methodology chart.

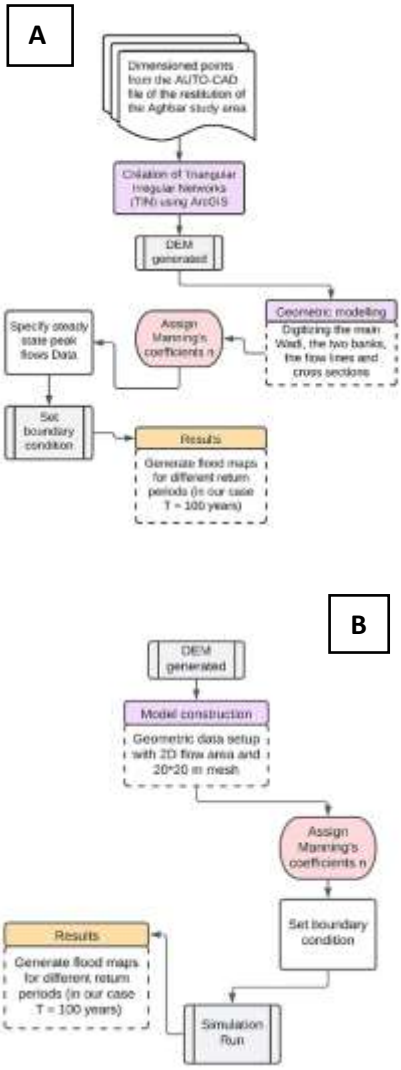


Fig. 3 Flowchart of 1D (A) and 2D (B) modelling in HEC-RAS.

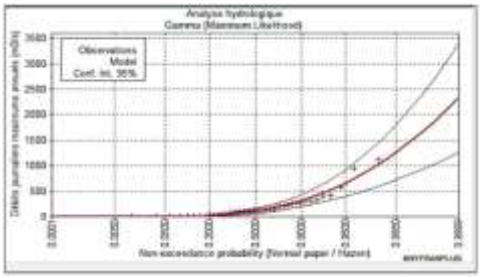

Fig 4 Statistical adjustments of maximum flows Guir N'Kouris meteorological station.

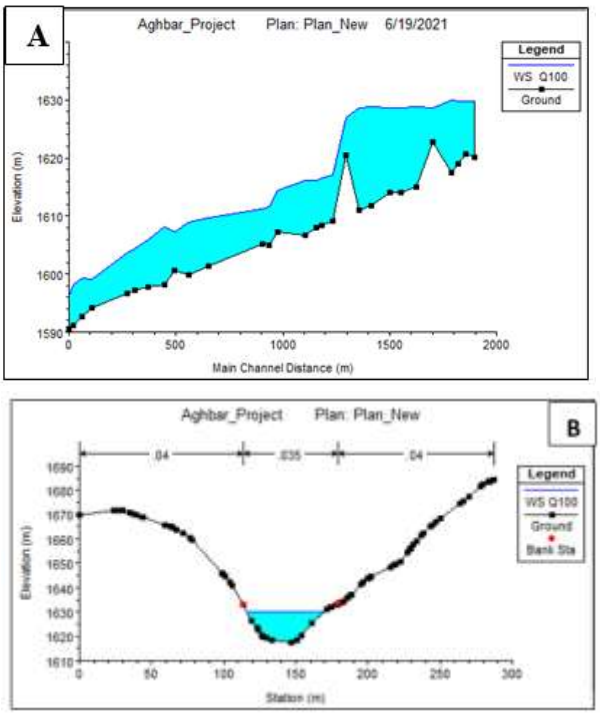


Fig 5 Longitudinal profiles of water levels for the 100-year flood, (B) Water level reached in a section of the river for the 100-year flood.

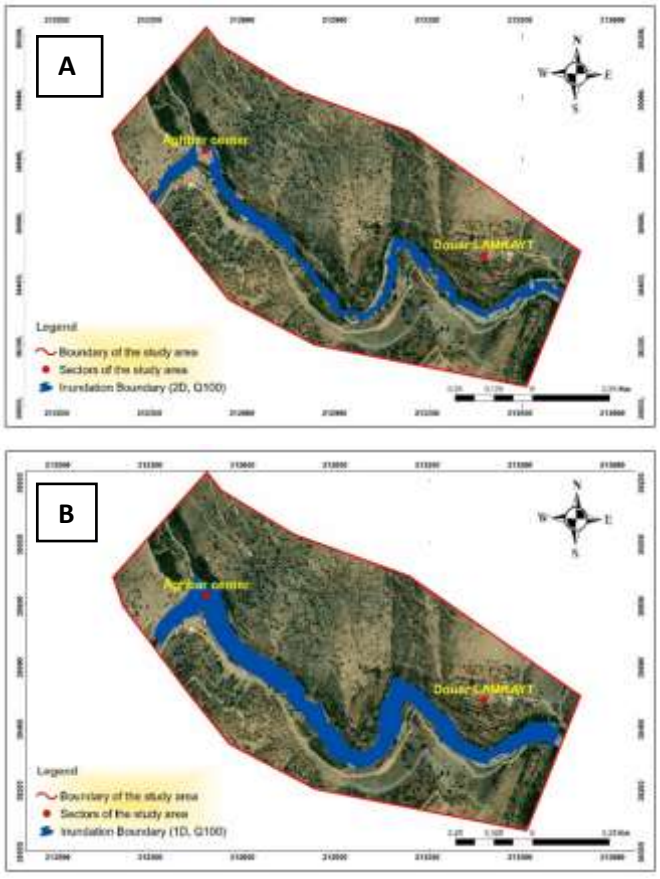


Fig 6 A: Simulation of the centennial flood (2D model); B: 1D model.

Table 1. Summary of peak flows calculated by empirical methods.

| Empirical methods | Fuller II | Mallet-Gautier | Hazan Lazarev ICK |
|---|---|---|---|
| **Q (5)** | 203.35 | 154.92 | 148.75 |
| **Q (10)** | 234.75 | 206.46 | 186.09 |
| **Q (20)** | 266.16 | 247.5 | 223.44 |
| **Q (50)** | 307.68 | 293.06 | 272.81 |
| **Q (100)** | 339.09 | 323.3 | 310.16 |

Table 2. Summary of peak flows calculated by the rational method.

| **Ratıonal method/ peak flows $Q_T$ calculated ($m^3/s$)** | | | | |
|---|---|---|---|---|
| **T = 5 YEARS** | **T =10 YEARS** | **T = 20 YEARS** | **T = 50 YEARS** | **T = 100 YEARS** |
| **39.32** | 47.19 | 54.55 | 63.93 | 71.29 |

Table 3. Peak flows selected based on the Gradex method and statistical adjustment (Gamma Law).

| **RETURN TIME (YEARS)** | **PEAK FLOWS ($m^3/s$)** | | |
|---|---|---|---|
| | GUIR N'KOURIS | | |
| | GRADEX | STATISTICAL ADJUSTEMENT | Qp MAINTAIN |
| **2** | - | 103 | 103 |
| **3** | - | 194 | 194 |
| **5** | - | 306 | 306 |
| **10** | 605.80 | 475 | 605.8 |
| **20** | 772.92 | 650 | 772.92 |
| **50** | 989.45 | 888 | 989.45 |
| **100** | 1151.55 | 1070 | 1151.55 |

## III. DISCUSSION

In 1D river hydraulic modelling, all water overflows are assumed to inflow in a longitudinal direction [12]. The results proposed by HEC-RAS are in the form of graphs and tables, the most important among them that are represented below for the one-dimensional model are: (1) longitudinal profiles of the water heights, in which the height of water reach up six meters (Fig.5A), (2) water levels in each section for each flood, where a single example is illustrated (Fig.5B). The flow regime of the 2D modelling is generally fluvial (Fig.6A), where the flow velocities reach 0.5 m/s (Vmax) and the water overflow near the center of Aghbar upstream of the study area for both models, but we consider the one-dimensional model as mentioned before (Fig.6B). After having made a terrain trip to verify the hydraulic modelling already made at the level of the area of Aghbar, so to reassure if the flood will affect issues, we could conclude that the one-dimensional modelling shows that the administrative and commercial center of Aghbar is affected by the flood, while Douar LAMKAYT will not be affected by the hundred-year flood because it is far from the bed of the Wadi which makes it protected from the risk of flooding, so the modelling is well done. We noticed the existence of a bridge and four gutters on the Wadi near the Douar LAMKAYT, which means that they will be affected by this flood, for this reason we recommend building a new bridge with well-defined measures so that it is not destroyed during the centennial flood as well as to facilitate access to the douar by the inhabitants. Also, for the Akaike Information Criterion (AIC) [5] of the Gamma law, it fits better to the series of peak flows recorded at the station of Guir N'Kouris, same for the Gradex method [5], [13]-[14]. The hydrological study of the catchment area allowed us to calculate the peak flows according to different return times (10 years, 20 years, 50 years, 100 years) using several methods, empirical, rational, statistical adjustment and Gradex (Tab1,2,3).

## IV. CONCLUSION

The present work realized within the AHBT (Agency of the hydraulic basin of Tensift), is to delimit the floodable zones at the level of the center of Aghbar by making a hydrological study in addition to a comparative analysis between the unidimensional and bidimensional hydraulic models in order to work out proposal's protection against floods. The problem of a one-dimensional modelling (1D) resides in the simplification of the reality of the system and in the fact that the empirical models are only valid for a given place. Two-dimensional modelling requires a much longer computation time than the 1D model case, and it demands a large amount of input data to be able to arrive at a finer grid at the stream and study area level. In conclusion, the one-dimensional model is more reliable than the two-dimensional one for our study area because our mainstream is incised, which makes the results of the 1D simulation closer to reality, while the 2D model is used in flat areas. The results of the hydraulic modelling will still be used to define the development schemes of protection against flooding at the scale of the center Aghbar particularly the chief town of Aghbar which has almost all the facilities of the town. The extension

of the center of Aghbar faces many natural and anthropic obstacles that have influenced the urban development of the center and still hinder the process of urbanization within the agglomeration. These elements consist essentially in the constraining topography of the site which strongly limits the buildable spaces and the existence of the wadi which borders the study area. These elements also subject the territory to several natural hazards such as landslides, landslides, slope instability and flooding. This requires specific measures to protect the population and property. At the end of this spatial reading, we note that great efforts remain to be deployed for the restructuring and urban upgrading of the center of Aghbar. Also, it remains the duty of this Development Plan to propose appropriate solutions for the urban upgrading of the study area and to help local decision makers to adopt an architectural model specific to this territory. The current study was done for the first time in the Aghbar area, other studies interested in erosion and lithological discrimination would be great for the future.

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