FLOOD RISK MAPPING AND ANALYSIS OF THE M'ZAB VALLEY, ALGERIA

AMEL OUCHERIF & SAADIA BENMAMAR
National Polytechnic School of Algiers, Algeria

ABSTRACT
To contribute to flood awareness and flood prevention, a flood risk mapping study has been carried out in the M'zab valley (North Algerian Sahara) using one-dimensional modelling. The use of spatial tools and remote sensing contributed greatly to improve the results, taking advantage of the fineness of the topographic information provided by a 2.5 m digital terrain model. Calibration of the hydraulic model was performed using flood marks points collected through a field campaign on site, using GPS. The one-dimensional model appeared satisfactory, even in an urban context, for preliminary flood mapping. In particular, assessment of hydraulic capacity allowed locating the first outflows, thus also indicating where actions could be necessary.
Keywords: floods, 1D model, GIS, calibration, manning roughness coefficient, hydraulic capacity.

1 THE M'ZAB VALLEY AREA

Situated in Algeria, North of Ghardaïa, the M'zab valley was historically a palm grove, now characterized by an urban extension often carried out regardless of development plans. Indeed, in this semi-arid area, the rivers are always dry except during floods, and numerous constructions are found even in the river main channel. Not only are these buildings very vulnerable to floods, but they also impact the flows, thus modifying the hazard downstream. This study aims to map the area with a 100 year return period probability, which is a common practise, but that will be discussed in this paper.

1.1 The modelled area

The modelled area begins from the immediate upstream of the region of 'Daia Ben Dahoua' to the region of El Atteuf, passing through Ghardaïa, Melika, Beni Isguen and Bounoura cities (Fig. 1). The main river is the M'zab river and seven important tributaries are taken into account: Al Abiodh, Laadhira, Aregdeine, Ben lahthem, Boughanem, N'tissa and finally Azouil.

The M'zab valley watershed delineation was performed using a SRTM digital terrain model (DTM) (spatial resolution: 30 m) using an 'Eight directions' algorithm. Fig. 2 presents the map of the area with modelled sub-catchments, and Table 1 lists their areas.

1.2 Land use

Land use displayed in Fig. 1 is a very important factor for vulnerability and for the estimation of Manning's roughness coefficients to be used in hydraulic simulations.

2 HYDROLOGIC STUDY: RAINFALL AND DISCHARGE ANALYSIS

2.1 Rainfall data and analysis

The only available data were annual maximum rainfalls over a 59-year observation period from which a sample of 46 values was retained. A statistical analysis was performed and the

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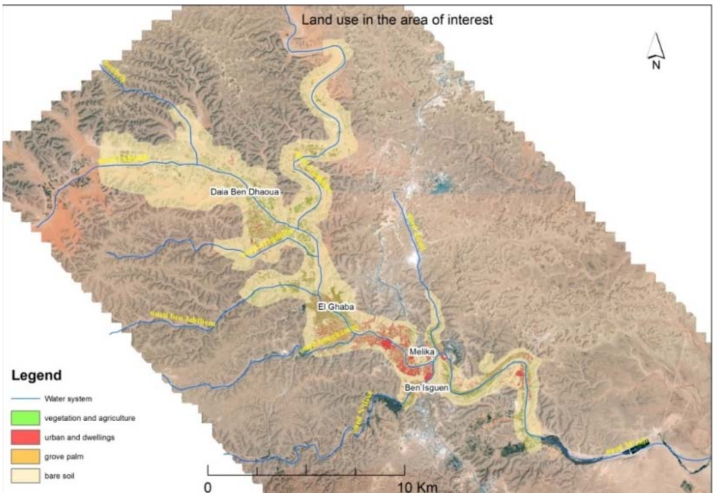

Figure 1: Main cities and land use in the study area.

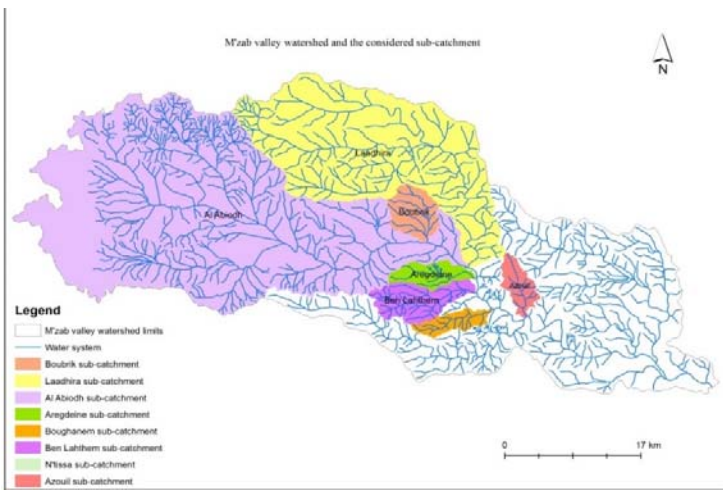

Figure 2: M'zab valley watershed and main sub-catchments.

Table 1: Modelled sub-catchments areas.

Sub-catchment name	Area (km²)
Laadhira	412.07
Al Abiodh	885.21
Azouil	21.70
Aregdeine	25.71
Ben lahthem	46.91
Boughanem	19.99
N’tissa	140.19

stationarity, homogeneity and independence tests were checked. We tested several distributions and used the Akaike and Bayes penalized criteria [1], to select the most appropriate one.

This led to choosing the Log-normal distribution to estimate the rainfall quantiles. In particular, the value obtained for a 100-year return period was 70.87 mm.

2.2 Probabilistic discharge estimation

In our case, the M'zab valley watershed is ungauged, therefore we used six regional formulas [2], [3], although they could provide only rough estimates of discharge quantiles, and do not account for local specifities of the studied watershed.

In this preliminary study, aimed at identifying the zones priority for further studies, we chose to retain for each sub-catchment the maximal value given by the six available formulas (Table 2).

3 HYDRAULIC FLOW MODELING ON THE M'ZAB VALLEY

3.1 Short description of the used model: HEC-RAS 1D

Developed by the American Army Corps of Engineers, HEC-RAS is a widely-used tool for one-dimensional free-surface flow simulations [4] yielding water surface profile calculation for different scenarios, suitable for both anthropized and natural rivers. Different regime water surface profiles can be taken into account: subcritical, supercritical and mixed flow regimes.

The calculation of the water surface profile is governed by the energy equation which is written as follows:

$$Z2 + y2 + \frac{\alpha 2\,(V2)^2}{2g} = z1 + y1 + \frac{\alpha 1\,(V1)^2}{2g} + he. \tag{1}$$

- z1, z2: elevation of the main channel inverts.
- y1, y2: depth of water at cross section.
- V1, V2: average velocities.
- α1, α2: velocity weighting coefficients.
- he: energy head loss.

Table 2: Maximal 100-year discharge quantiles obtained from regional formulas.

Sub-catchment	Maximum runoff (m^3/s)						
	Aregdeine	Al Abiodh	Laadhira	Ben lahthem	Boughanem	N'tissa	Azouil
Maximum estimated discharge	130.00	1295.26	640.07	167.95	116.78	267.75	120.94

The energy head loss 'he' is calculated by the following equation:

$$he = L\,\overline{Sf} + C\,\left|\frac{a2\,(V2)^2}{2g} - \frac{a1\,(V1)^2}{2g}\right|. \quad (2)$$

- L: discharge weighted reach length.
- $\overline{Sf}$: representative friction slope between two sections.
- C: expansion or contraction loss coefficient.

Various types of crossing structures can be modelled such as bridges and weirs. In our case, given the presence of several bridges on the study area, these were taken into account.

3.2 Geometric model construction

In 1D modelling, the river topography is described by cross sections and sinuosity descriptors (contraction and expansion coefficients). The cross-sections were extracted from a 2.5 m DTM with a 20–30 cm vertical accuracy.

The HEC-RAS software nevertheless retains 3D information on cross-sections to allow to visualize the results of the computations on GIS software [5]. The latter has been used as a tool for data pre-processing.

3.3 Hydraulic model calibration

Calibration is an essential, usual but treacherous step of hydraulic modelling. It usually consists in adjusting the Manning coefficients used in the model using information from observed floods. Available data consisted in flood marks recorded through a GPS campaign carried out the day after the destructive flood event of October 2008.

The reach extending from El Ghaba to Melika appeared very difficult to calibrating and great efforts had to be deployed on that area.

Indeed, numerical values calibrated on that reach didn't match well with the expected ones found in tabulated values in literature. This confirms that roughness coefficient is an empirical parameter, often used outside its theoretical domain of validity, which implies very simple geometry and uniform flow. Therefore, numerical calibration must be handled with caution and the local specifities must be analysed.

4 INFLUENCE ANALYSIS OF SOME FLOW PARAMETERS

Our calibration yielded a set of Manning coefficients values and discharges. A sensitivity analysis was then performed to better understand the role and influence on calibration results of the input discharge Q and Manning coefficients.

4.1 Sensitivity to input discharges 'Q'

For this scenario, we used the set of Manning coefficients 'n' obtained from the calibration process and tested different values of discharge 'Q', centred on the estimated value provided by the National Agency of Hydraulic Resources (ANRH) (Fig. 3).

4.2 Sensitivity to Manning roughness coefficients 'n'

For this case, we have maintained a constant slope 'I' and a constant runoff 'Q'. However, many values of Manning roughness coefficient 'n' have been explored (Fig. 4).

Discussion of the sensitivity results: The computed water levels don't appear very sensitive to the Manning coefficients but the difference nevertheless causes small but visible differences in the flooded area extent, which is of course important in terms of flood consequences.

According to the several tested situations, it appears that the Manning roughness coefficient 'n' had an effect on the flood field extent while the runoff 'Q' had a direct effect on the water level 'h'.

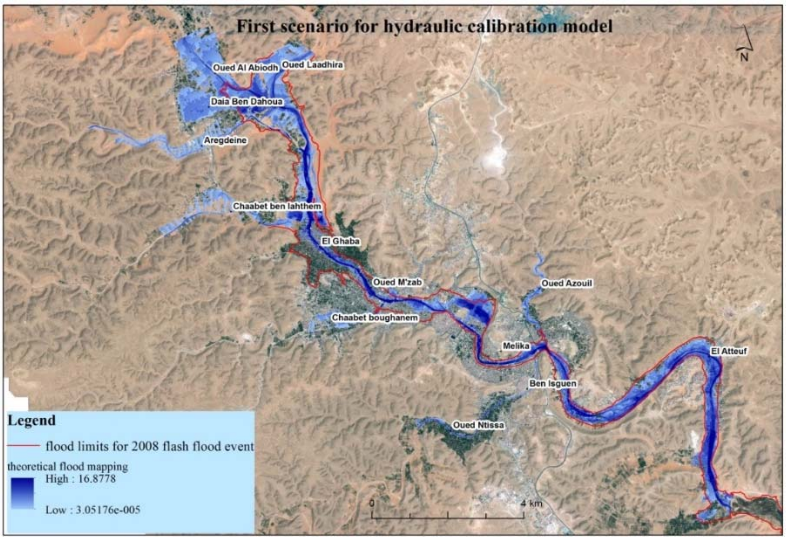

Figure 3: Sensitivity to input discharges.

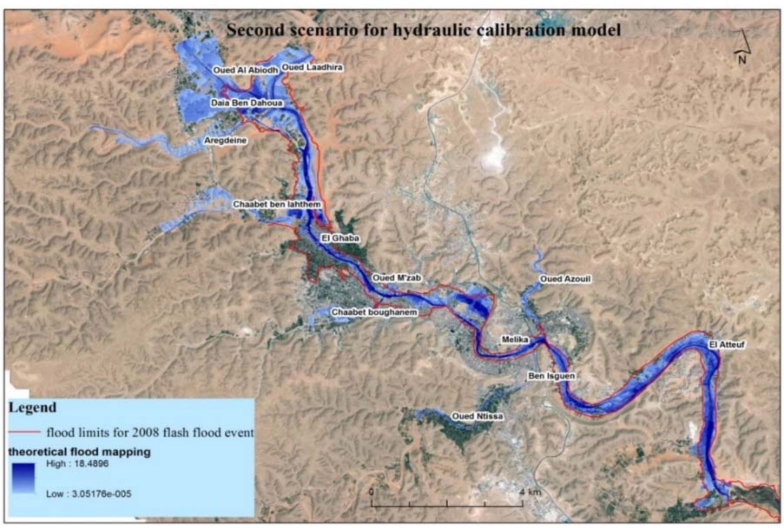

Figure 4: Second test for hydraulic calibration model with constant slope and Manning roughness and changing runoff.

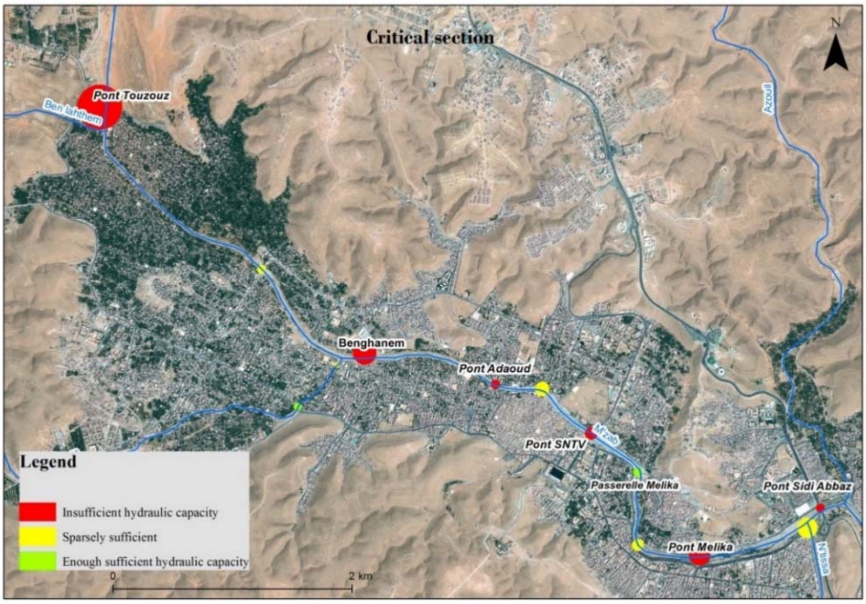

Figure 5: Critical points.

5 SIMULATION OF PROBABILISTIC 100 YEAR RETURN PERIOD FLOODS AND BRIDGE HYDRAULIC INFLUENCE ANALYSIS

The influence of bridges was studied by comparing the water level in the absence and in the presence of the bridge. For each bridge, the elevation of the water surface was also compared to the elevation of the bridge deck, to identify potential problems of additional energy dissipation phenomena, when the deck becomes an obstacle to flow.

Thereby, this analysis makes possible the definition of the critical section which is shown in Fig. 5.

6 CONCLUSION

The use of one-dimensional hydraulic model in an urban context has shown that it could be possible to opt for this kind of modelling in such a context. This calls into question the quasi-systematic use of a two-dimensional model for urban flows.

The model calibration showed the direct influence of discharges on water levels and the influence of the roughness coefficient on the flood field extent. Likewise, the values usually used, which are indicated in the tables found in literature, are to be handled with care since the roughness is often used outside its theoretical domain of validity.

The analysis of the hydraulic capacity of bridges across streams has shown their hydraulic influence and must be, consequently, well-designed.

Finally, the use of space techniques and the GIS tool enabled the hydraulic study to be supplied with necessary data, including the 2.5 m DTM for sufficiently detailed topographic information, the flood marks of a past flood event used for model's calibration, the very high-resolution satellite imagery which served as a cartographic background which is compulsory for the creation of the different GIS layers, and finally the bridges topographic survey to take into account their geometry.

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