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Method of Decision Making For Flood Management of Medjerda High Valley

S. ABIDI[1*], M.EL AYARI[2], O. HAJJI[3], H. HAMADI[4]

[1]University of Jendouba, Sylvo-Pastoral Institute of Tabarka, Department of Protection and Development of Agroforestry Resources and Areas, Tabarka8110,Tunisia,
[2]University of Debrecen, Doctoral school of Informatics, Department of Applied Mathematics and Probability Theory, Debrecen 4032, Hungary,
[3]University of Jendouba, Higher School of Engineers of Medjez El Beb, Medjez El Beb 9070, Tunisia,
[4]University of Carthage, Department of Rural Engineering; Water and Soil, National Agronomic Institute of Tunisia, Tunis 1082, Tunisia.

*Corresponding author: saharabidi01@gmail.com

Abstract - During a flood event, the decision maker needs a simple and closer to reality tool to make the proper decisions, such as; the release of dams, the risk knowledge to protect the villagers from the floods. This article presents the construction of a simple flood-forecasting tool at the main stations of the Medjerda, upstream Sidi Salem dam, which will serve for the management of dams and floods of the Medjerda.The phenomenon of floods is seriously arising in the upper Medjerda valley, precisely in Bensalem's plain upstream Sidi Salem's dam. To be able to manage the risk of flooding, decision-makers need a simple and rapid tool.
Flood prediction results with propagation models are satisfactory. Therefore, we have created an application under MATLAB based on these models. This application requires only upstream's instant flows to predict downstream's flows while the coefficients basis of the models, are made from the reconstruction of historical floods.
The calculation delay time is evaluated from 2 to 8 hours with a step of 2. The application has been validated using the flood of February 2015. The results were satisfactory with significant Nash coefficients. It has been stated that as the delay is low, the Nash coefficient is better. Propagation models are effective as a tool for flood forecasting, although the Medjerda basin is heterogeneous in terms of the physical characteristics as soil. This application will be connected to the data collection system for real-time forecasting.

Keywords: Flood forecasting, flow propagation model, MATLAB programming, alert system.

1. Introduction

Channel flooding is a complex dynamic process characterized by spatial and temporal variation in the flow parameters. Generally, information on water levels is collected at critical locations, as well as at existing stream gauging stations, for analyzing flood movement. Development of flood forecasting model characteristics based on only an observed stage is a difficult task because of recharge over the reach, spatial variability of rainfall, and varying channel characteristics influence river flow in a highly nonlinear manner. These issues become more complicated for large river systems, thus, requiring detailed distributedinformation for routing the flood along the river reach.
Deterministic flood forecasting models can be divided into two general categories: flood routing models and real-time rainfall– runoff models. Models of flood routing are varied; there are a big number of algorithms from simple statistical receipt to the partial differential equations of Saint-Venant (Bentura, 1996). The Muskingum model is numerically equivalent to the Saint-Venant equations via the diffusion equation of a wave. It is a classical flood routing method. However, the representation of lateral inflow contributions, as well as the discharge forecasting at the outlets of upstream sub-catchments cause problems.Muskingum model is improved to incorporate multiple sources of inflows and single outflow to route the flood in the reach.

In Tunisia, the flood problem arises the only perennial river, Medjerda, in particularly the reach ofGhardimaou-Jendouba- Bou Salem. Mathematical model wasapplied to reconstitute and forecast flood hydrographs of the main stations of Medjerda River in the upstream of Sidi Salemdam and the results were satisfactory (Abidi, 2014). "Need is a motive for creation," an Arabic quote that seems to be true. The need for a decision-making tool for the management of floods and dams in the Medjerda watershed led us to seek and finally develop an application based on flood propagation models, simple and fast for flood forecasting. This application will be connected to the data collection system for real-time forecasting.

2. Materials and methods

2.1. Study area

The Medjerda, (Figure 1) the major Tunisian river, originates in the semi-arid Atlas Mountains of eastern Algeria. In Tunisia, the western part of the catchment is delimited by the south facing slopes of the Tell region and in particular the Kroumir Mountains, and at the south by the north facing slopes and piedmonts of the semiarid Dorsal Mountains. The river then flows east, through the tectonic depression of the Ghardimaou basin, characterized by an 8–10 m thick Holocene floodplain sediments. The Medjerda catchment covers approximately 24,000 km², of which 16,100 km² located in Tunisia and extends for 460 km including 350 in Tunisia (Zielhofer, 2002).

The area under study covers partially the Medjerda river basin and is defined as the area draining between the gauging subwatershed of Ghardimaou and Bou Salem, just before reaching the Sidi Salem Dam (Figure 2), the largest dam in North Africa.The area of the studied basin is about 4645 km². The basin is drained by a series of rivers of varying sizes which two tributaries are conducted by dams.

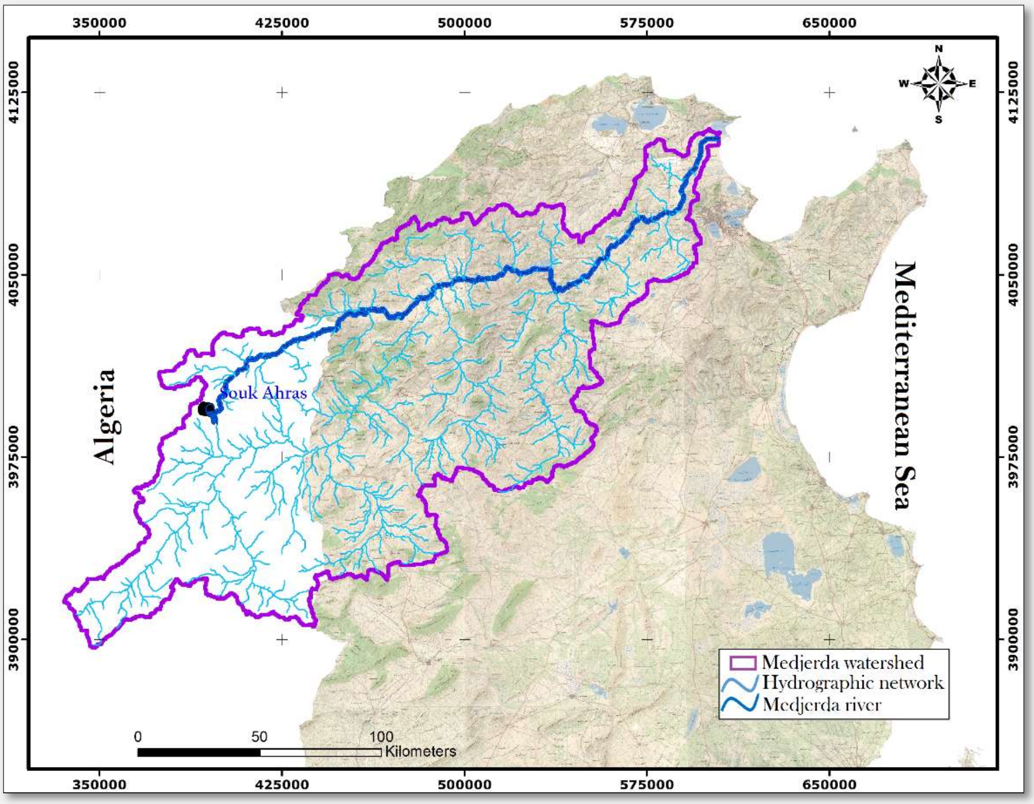

Figure 1. Medjerda watershed localization

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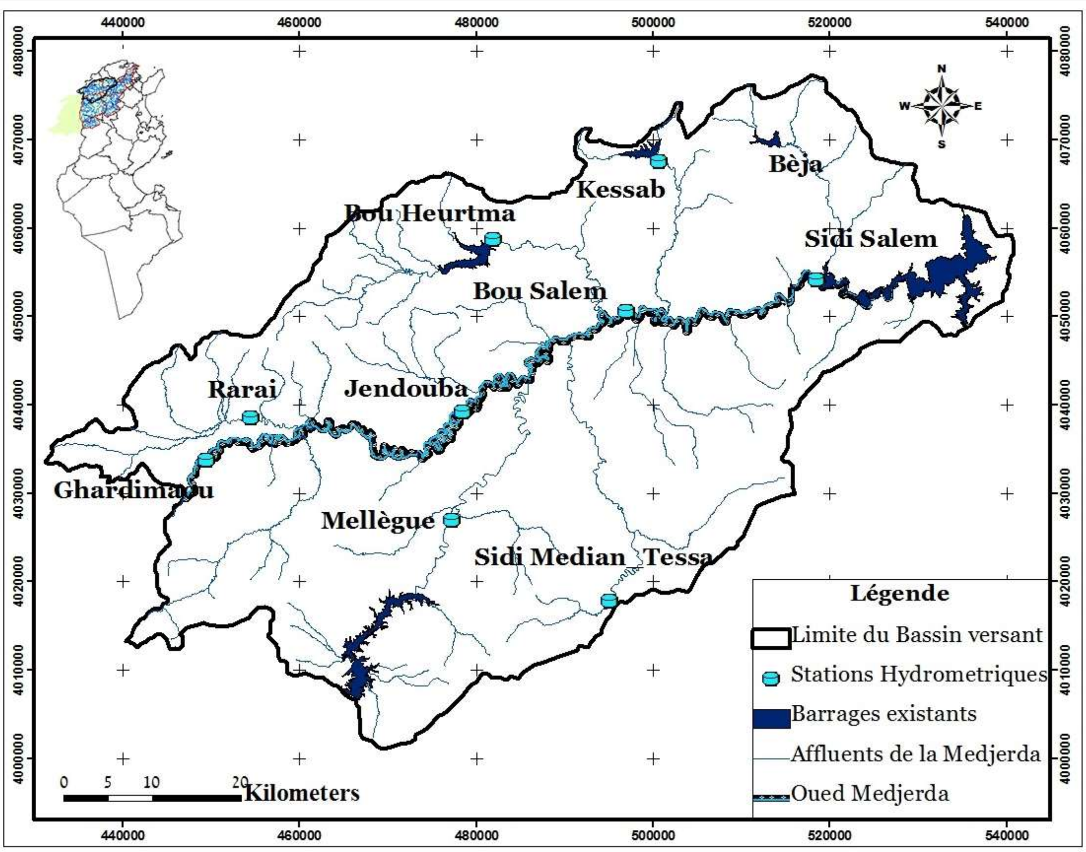

Figure 2. Study area

The rugged terrain overlooking the plain on the north side and south side slopes are generally high, which promotes surface runoff.
The catchment lies in the sub-humid to Mediterranean humid bio-climatic region. The rainy season extends from September to May, with intense precipitations in autumn.

2.2. Methodology

Since the flooding problematic, a system of alert is necessary to minimize the damage touching people. The methodology consists of three steps: Reconstitution, forecasting and Alert system. The delay of calculation is evaluated from 2 hours to 8 hours with a step of 2. The collected data numbered 30 flow events from 1973 to 2012. The studied area contained three main station so the work was divided in two sections: Ghardimaou - Jendouba and Jendouba - Bousalem.

2.2.1. Flow reconstitution

The methods of flood routing are broadly classified as empirical, hydraulic, and hydrological (Fread, 1981). A number of soft computing related techniques were used for flood forecasting in addition to Muskingum method. In this research, Muskingum and Regression were used for flow reconstitution and forecasting.

Muskingum model

Since its development in 1939 by McCarthy, this model is widely used in hydrological engineering.
Cunge (1969) showed that the Muskingum model is numerically equivalent to the Saint-Venant equationsvia the diffusion equation of a wave. Muskingum model proposes a relationship between the inflow (upstream) Q_i (t)and outflow (downstream) Q_o (t) of type (Habaieb, 1992):

$$\boldsymbol{Q_o(t+d) = a_1 Q_i(t) + a_2 Q_i(t+d) + a_3 Q_o(t)}$$

Where 'Q_i' and 'Q_o' are the inflow and outflow (expressed in m^3/s),'t' is the calculation time, 'd' represent the calculation delay and 'a_1, a_2, a_3' are the coefficients of Muskingum model calculated by least squares 'method.

Regression model

The regression model is defined using the approximations taken by Habaieb (1992):

- integrate the possibility of downstream extrapolation so that there will be intervention of at least two terms,
- take into account the propagation effect of the flood, by using the upstream information at a date reduced by the transfer or propagation time τ_p,
- For extrapolation downstream, we have taken the linear extrapolation, from which we obtain the regression model with an upstream point.

$$\boldsymbol{Q_o(t+d) = b_1 Q_i(t+d-\tau_p) + b_2 Q_o(t) + b_3 Q_o(t-d)}$$

Where 'b_1, b_2, b_3' are the coefficients of Regression model calculated by least squares 'method, $\tau_p$isflowpropagation time from upstream to downstream station.

Muskingum model required two data of the upstream station and one data of downstream station while Regression model required one data from upstream station and two data from downstream station.

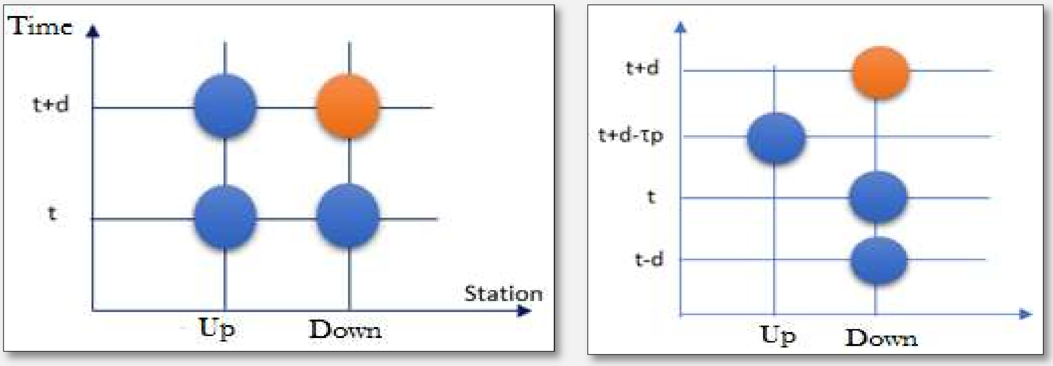

Figure 3. Muskingum and Regression model required data

2.2.2. Performance mesures

Graphic criteria used to optimize the results are observed and simulated hydrographs, peak flows observed and simulated correlations between observed and calculated rates. Numeric criteria chosen to test the effectiveness of the models are:

the Nash–Sutcliffe model efficiency coefficient;

$$\boldsymbol{Nash}(\%) = \mathbf{1} - \frac{\sum_{i=1}^{n}(\boldsymbol{Q_o} - \boldsymbol{Q_c})^2}{\sum_{i=1}^{n}(\boldsymbol{Q_o} - \boldsymbol{Q_a})^2}$$

the peak relative error;

$$\boldsymbol{ERP} = \frac{\boldsymbol{Qc}\max - \boldsymbol{Qo}\max}{\boldsymbol{Qc}\max}$$

and the peak time error;

$$\boldsymbol{ETP} = \boldsymbol{t_{Qc}} - \boldsymbol{t_{Qo}}$$

Q refer to the flow, the index '**o**' refer to observed flow, '**c**' to calculated flow, '**a**' to average flow, '**max**' to maximum, and '**t**' to time.

2.2.3. Flow forecasting

After dressing the coefficient of flow reconstitution models, flooding isregrouped by season. Toforecast a flooding by Muskingum model per example, the coefficient is taken from a reconstituted floodingthat had a previous date, belong to the same season and had a near humidity index. The upstream flow in the time 't+d' were replaced by a known information in the time 't' and 't-d'.

$$Q_u(t+d) = 2Q_u(t) - Q_u(t-d)$$

2.2.4. Decision making program 'DMP'

View the number of the flow and the calculation, a program was created in MATLAB to facilitate the application. A basic were established containing model coefficient of flow reconstitution. The figure below describes the steps of flow forecasting by the program.

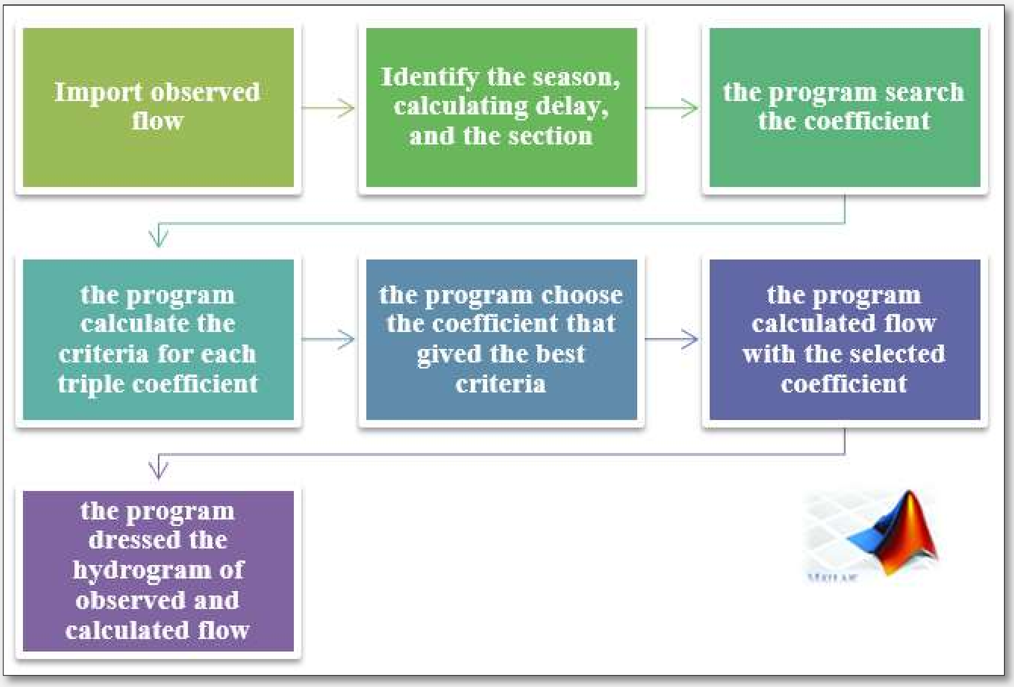

Figure 4. Execution steps of the program under Matlab

The decision-making program 'DSP' consists in forecasting the flows without or with the tributaries flows. After a comparison of the Nash coefficients 'Nash' and the relative peak error 'PRE', the application displays the results of the model that had the best criteria.
Each station had two important level: alert and overflow. This level ismentioned in the program to take the right decision. If the forecasted peak flow exceeds these two levels, a message will be displayed.

3. Results and discussion

The decision-making program 'DMP' were applied in the event of April 2009. Such this event was flooded in Jendouba city and caused damage for people, their home and agriculture lands.

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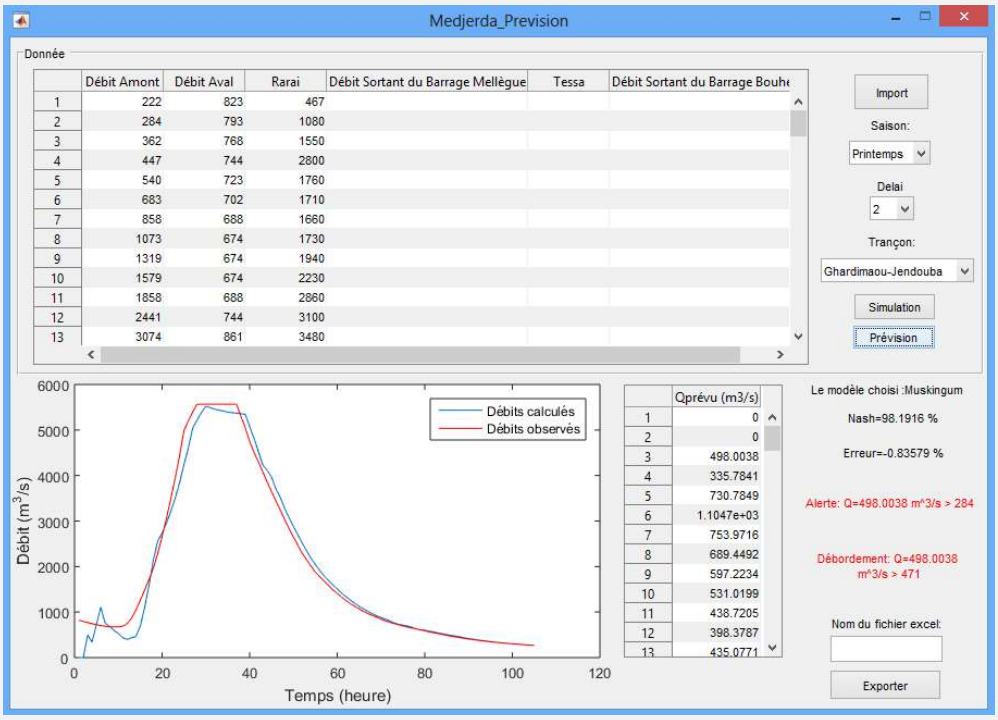

Figure 5. Flood forecast of April 2009

Based in the program, Muskingum model gave the best results with a Nash coefficient of 98%.
The peak flow of this flood reached 498 m^3/s, exceeded the alert level (284 m^3/s) and the overflow (471 m^3/s). Indeed, there were floods during this flood.
From this application, the decision-maker can have an idea close to the situation of the river. It can therefore launch the alert before the overflows of river water and flooding.
The validation of the 'DMP' made by the event of February 2015.Two scenarios were scanned; with and without consideration of the tributaries flow in the upstream, while evaluating the calculation time from 2 to 8 hours with a step of 2. For this flood, tributary flows Bouheurtma only is available.

- <u>For the first scenario</u>, the downstream flows were calculated without considering the flows of Bouheurtma at the different times (figure 6).

According to the 'DMP', the flood forecasting results from February 2015 at the 2-hour delay is more efficient with the Muskingum model. The calculated Nash coefficient is 99% and the relative peak flow error is -0.79%. The peak appears in phase delay of 5 hours. No alert message is displayed.

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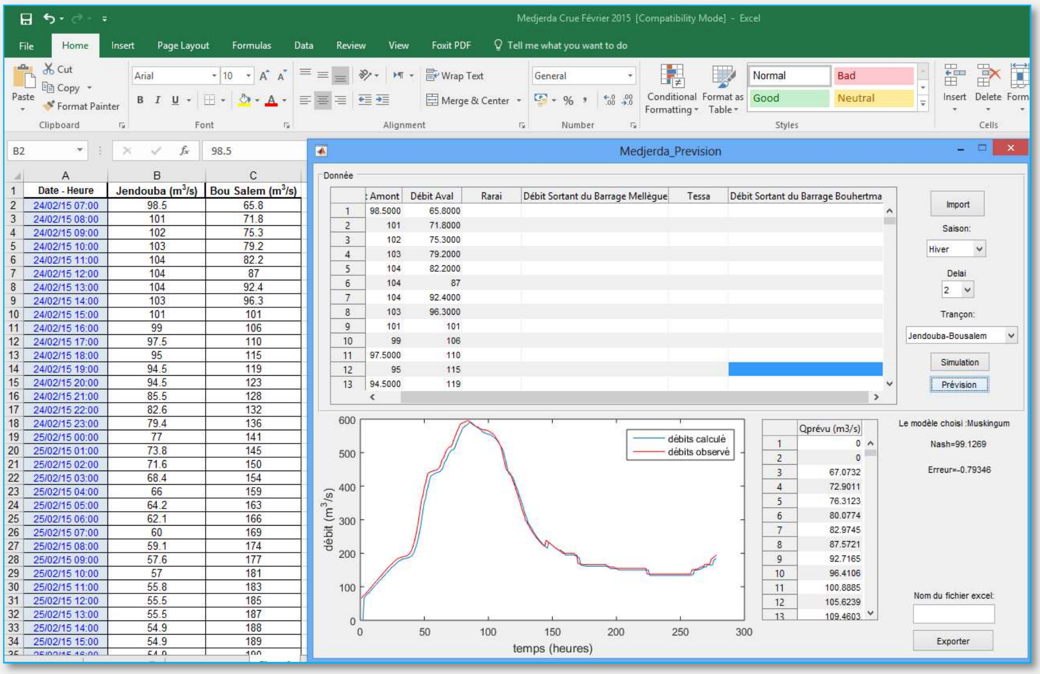

Figure 6. Forecast of February 2015 event by 'DMP' at the delay of 2 hours (1st scenario)

- <u>For the second scenario</u>, With the consideration of tributary flows, the results are improved. At the 2-hour delay, the Nash coefficient increased to 99.4% with the Muskingum model.

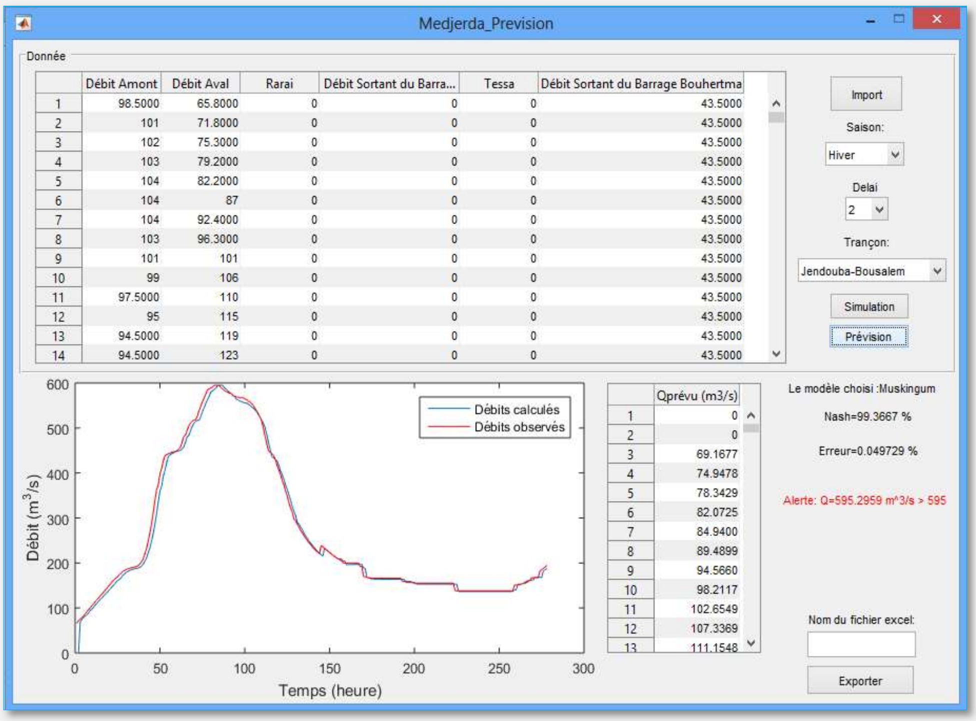

Figure 7. Forecast of February 2015 event by 'DMP' at the delay of 2 hours (2nd scenario)

The peak flow is reproduced with a relative error of 0.05% and a delay of 4 hours. The peak barely exceeded the alarm rate by 0.3 m^3/s, for this reason an alert message is displayed; the decision maker prepares and distributes the alert at the domestic level.

The forecast of flood flows from the February 2015 flood to the 4-hour period is completed with the Muskingum model with a 98% Nash coefficient (Figure 8). The peak arrived 4 hours late and a relative error of 0.12%. The alert is also triggered when exceeding the peak flow rate, the alarm alert is 595. Similarly, in this step, the decision maker prepares to take the necessary precautions for protection against flooding.

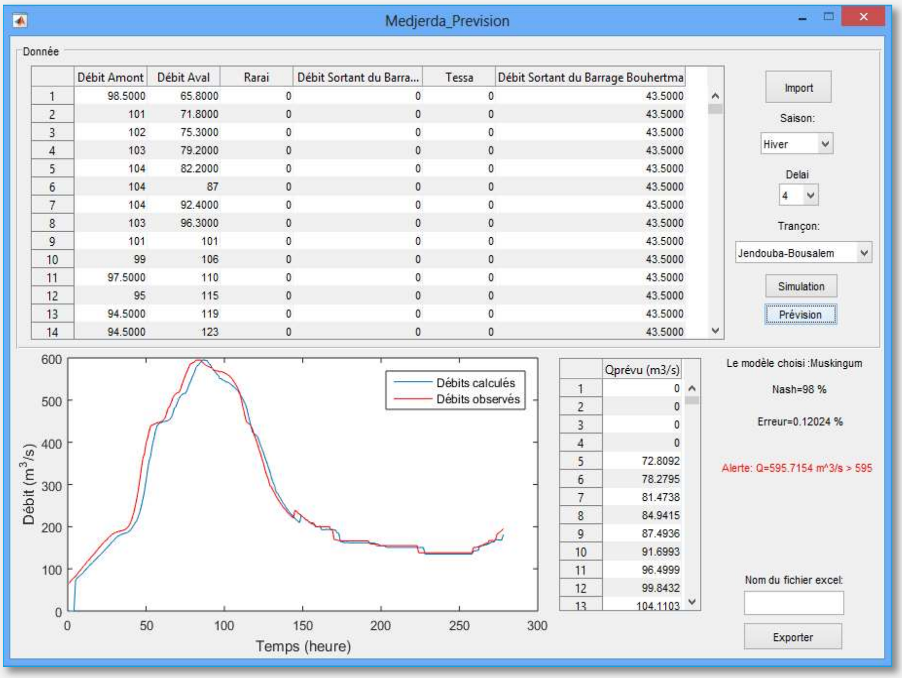

Figure 8. Forecast of February 2015 event by 'DMP' at the delay of 4 hours (2nd scenario)

At 6 hours, the forecast of flood flows of February 2015 is reached with the Muskingum model with a Nash coefficient of 96.2% (Figure 9). The peak flow arrived late for 5 hours and with a relative error of -0.4%. The peak has dropped and the alert is not triggered.

After 8 hours, the peak decreases again with a relative error of -1.1% and a delay of 8 hours (figure 10). The Nash coefficient decreases to 94% with the Muskingum model.

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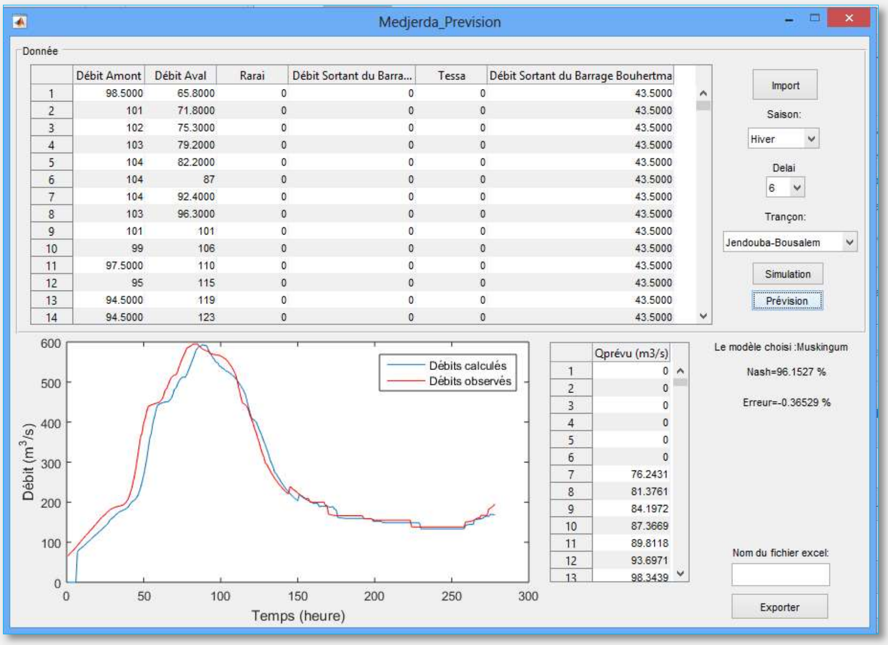

Figure 9. Forecast of February 2015 event by 'DMP' at the delay of 6 hours (2nd scenario)

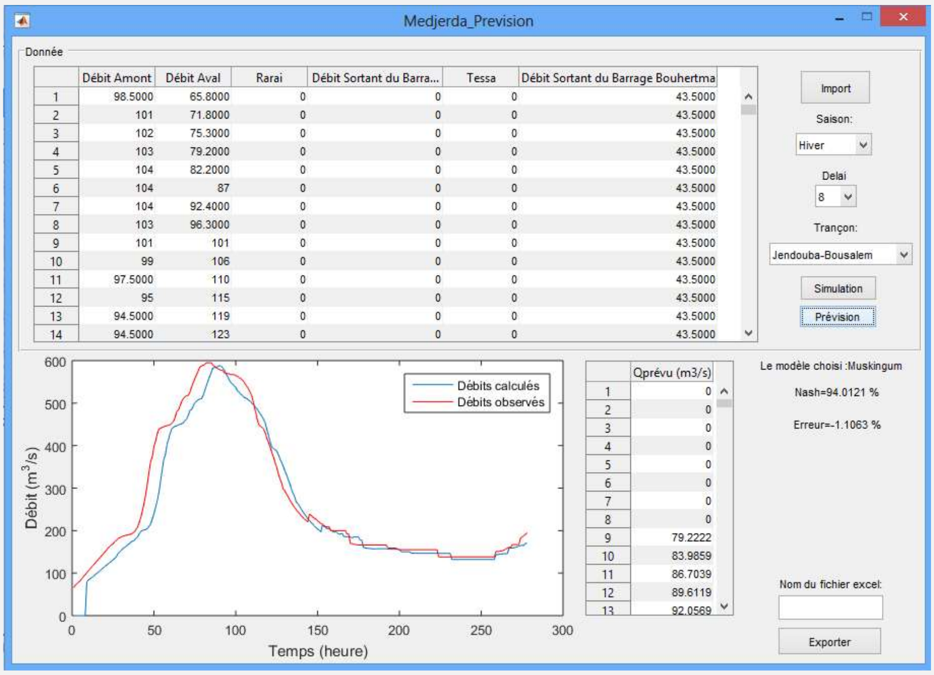

Figure 10. Forecast of February 2015 event by 'DMP' at the delay of 8 hours (2nd scenario)

We conclude that after 2 and 4 hours there are an exceed of the alert level. In this case, decision-makers activate alerts on national flood management committees, internal ministry, civil protection, regional defense, regional and local authorities. Thus, these various actors are preparing to protect the population from floods.

4. Conclusion

Floods are complex and therefore random natural phenomena. Whatever the performance of the methods to predict them, it is impossible to guarantee the 100% accuracy of these forecasts. The risk of flooding is the first natural risk due to the amount of damage it causes and the populations exposed. An attempt has been made to create a simple and fast tool to answer the needs of managers. This tool is based on predictive mathematical models that have yielded satisfactory results. Through this tool, we can predict the flows from 2 hours to 8 hours. The application displays a message when the peak throughput has reached the alert or overflow rate. Thus, the decision-maker will take the necessary precautions and trigger the alert in the flood management committees. This application requires only instantaneous flows recorded in the gauging stations of Medjerda and the outflows of the dams. A link can be made with the data bases of the General Directorate of Water Resources and the General Directorate of Dams and Major Hydraulic Works in order to simplify the supply of the base and accelerate the results. This application can also be used to forecast the flows of the downstream stations of the Medjerda.

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5. References

Abidi S (2014) Influence of considering tributaries to reconstruct flood hydrograph of an extreme event on the upstream portion of Medjerda River. International Research Journal of Public and Environmental Health Vol.1 (3),pp. 54-62.
Bentura P (1996) Development of a flood propagation method (Method "Time-storage"). PhD Science and Technology Environment, University of Paris XII Val de Marne.
Cunge AJ (1969) On the subject of a flood propagation computation method (Muskingum Method). J. Hydraulic Res.
Habaieb H (1992) Comparison Digital models for flood forecasting, application of watershed Belgian, French and Tunisian watersheds, PhD thesis at INP Toulous – French.
Fread, DL (1981) Flood routing: a synopsis of past, present, and future capability. In: Singh, V.P. (Ed.), Rainfall-runoff Relationship, Proceedings of the International Symposium on Rainfall-runoff Modelling. Mississippi State University, U.S.A.
Zielhofer C, Faust D, Del Omo FD, Baena Escudero R (2002) Sedimentation and soil formation phases in the Ghardimaou Basin (Northern Tunisia) during the Holocene.