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ESPADA, A UNIQUE FLOOD MANAGEMENT TOOL: FIRST FEEDBACK FROM THE SEPTEMBER 2005 FLOOD IN NÎMES

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In France, the serious damages caused in urban areas by the recent floods (like Nîmes in 1988 or Marseille in 2000) showed the importance of efficient and adapted reactions of the municipality. Faced to a flood crisis, decisions should be taken based on the current information available that are often very limited due to the lack of time to obtain, manage and analyse them. Therefore, ESPADA is an integrated tool that was developed to forecast and manage urban flooding in real time. The modelling system is based on predicted precipitations from radar imaging, a rainfall-runoff model, a hydraulic model developed for urban area and a risk definition representing the flood importance. For its first application, this innovative system has been developed for the city of Nîmes and the first results were obtained for the floods that occurred in September 2005. Concerning the system performance, couple of important lessons can be learnt from such an event. The following points are analysed : (i) implementation of meteorological scenarii for stationary storm cells, (ii) reinforcement of the in situ video control of the main overflow points and (iii) data validation (detection of unrealistic values) and (iv) consideration of the karst contribution. Finally, the good performance of the system is very promising and proves the significant advancement obtained when combining the growing computer power and the increasing urban hydrological knowledge.

CONTEXT FOR THE ESPADA SYSTEM

Frequently, very intense Mediterranean storm events induce catastrophic floods in the city of Nîmes, as it was the case the October 3, 1988, but also in a less significant level in November 1963, October 12, 1990, May 27, 1998... The particular morphology of the watershed (tub-shaped) drained by small rivers called "cadereaux" that are generally dry, and the urbanization that took place on their downstream part create the combination of the flood risk and the vulnerability (people, goods and services) that contributes to particularly important human and economic risks.

The actions carried out to reduce this risk are organized around two complementary directions : (i) the development of hydraulic prevention equipments within the framework of the floods prevention plan (such as storage basins, dimensioning, network management), (ii) the project ESPADA (evaluation and track of rainstorms in agglomeration to anticipate alarm) which aims at anticipating the crises, at the same time by the hydro-meteorological monitoring and the installation of a preliminary organization with adapted means [1].

THE OBJECTIVES OF THE ESPADA SYSTEM

The objectives of the ESPADA system are as follows:

- the follow-up and the hydrometeorological forecast for the anticipation of the storm events,
- the management of flood alarms and warnings,
- the management of the security plans.

This ready-to-use system includes the complete equipment required for the crisis control room (furniture, data-processing equipment, software, communication equipment, automatic calling system, secured power, guarantee and maintenance) as well as in-situ video control.

ESPADA was developed by the association between BCEOM, CS SI and Météo France. BCEOM was in charge of the hydrological and hydraulic modeling parts, as well as the risk study. CS SI was in charge of the informatics part (supply, software development, data processing and SIG tools management). Météo France was in charge of the radar acquisition, development of the observed and predicted rainfall amount. A first section was installed in June 2004 and the extension to the entire town was installed in July 2005.

THE FONCTIONS OF THE ESPADA SYSTEM

Data acquisition

The data of 10 rain gauges and 20 water level recorders that are managed by the city of Nîmes are collected every 10 minutes. Meteorological information contained within the radar images produced by Météo France are gathered using the Meteo+ station which provides :

- a quantitative evaluation of precipitations on the various subbasins, based on the interpretation of the radar images,
- a precipitations forecast for a very short term (1h30 maximum).

These observed and predicted data are provided with a 15 minutes time step, based on radar pictures acquired every 5 minutes. The size of the subbasins is generally less than one km2 and the radar pixels is equal to 1 km2. Moreover, a set of video-cameras completes the acquisition system by providing real time pictures of the most sensible points of the cadereaux.

Figure 1. Main functionalities of ESPADA system

Hydrological computations

Based on the observed and predicted rainfall quantities, the system computes flow forecasts at the entry of the most urbanized areas. These estimated flow values are produced by rainfall-runoff models that are calibrated based on past observed events. The various behaviours of the rural (garrigues) and urbanized watersheds are represented. In such a region, the specific behaviour of the karstic zones leads to saturation phenomena and surface flows from the under pressure karstic zones when the precipitation intensities become important. The simulations take into account the existing storage basins. The hydrological predicted values are updated every 30 minutes. The models used for the real time forecasts is composed of (i) the GR4 model developed by the CEMAGREF for the rural parts [2,3] and (ii) the RERAM model for the residential areas [4].

The hydrological calculations are based on a model structure built from a subbasin delimitation associated with a tree structure network, in which the hydrographs are routed. In real time, the flow values are estimated at the critical overflow points, i.e. at the entrance points of the collectors that have very insufficient capacity compared to the flows during important floods. These points of overflow that are located just upstream of the downtown of Nîmes, are represented on figure 2.

The computation time necessary for a complete cycle of forecasts simulation is around couple of minutes, which is absolutely compatible with the speed requirements of the system.

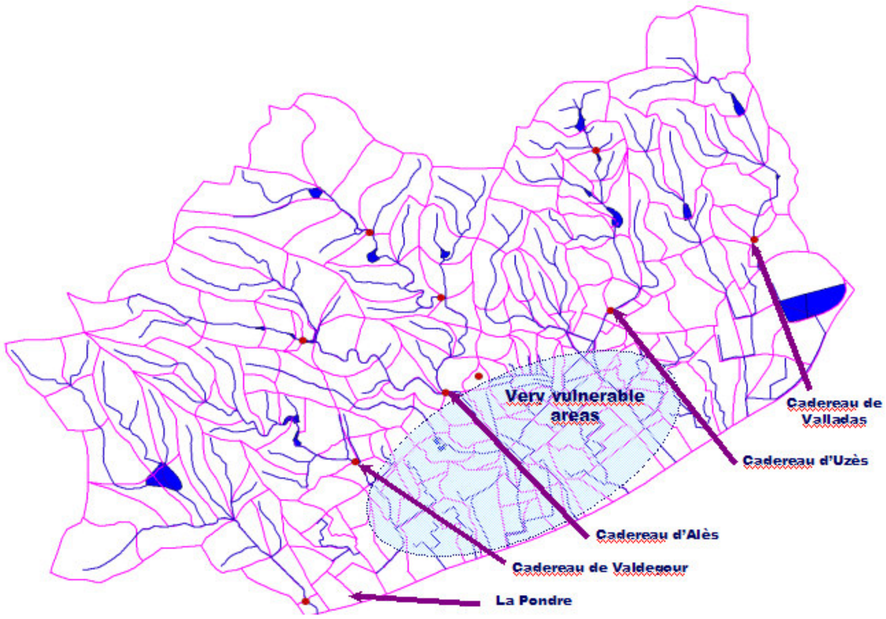

Figure 2 : Structure of the model with the main computations points

Identification of the most probable flood hazard scenario

The reduced capacity of cadereaux in their underground part (the cadereau of Uzès has a capacity of approximately 7 m3/s while around 120 m3/s are expected during the most violent episodes) leads to overflows in the streets. Such flows, that are disconnected from the underground flows, are hydraulically complex (significant speed, crossroad divergences, presence of obstacles to the flow...). A simulation of these flows can be realised with a fine 2D modeling, but which cannot be implemented in real time because of the very important computing time required.

As a consequence, the system ESPADA is based on the identification in real time of the most probable flood risk scenario based on a series of preset scenarios that were elaborated during the preliminary hydraulic study. The selection criteria for the scenario based on the observations and forecasts hydrological are the flows at the principal points of forecast, associated with a warning level of the security plan of the city of Nîmes. For the various forecasting times, precise maps are associated with each scenario in order to represent observed and probable flood hazard and risk in the streets.

Implementation of the security plan

The various warning levels of the security plan of the city of Nîmes are as follows:

- Level 1: vigilance of the staff based on the Météo France forecasts (for example Weather Flash);
- Level 2: moderate overflows of the storm network, located flooding ;

- Level 3: beginning of the cadereaux overflows;
- Level 4: generalised and serious floods with significant human risks.

The changes of the warning level are proposed by the system and then validated by the person in charge of the operations at the control room. The ESPADA system allows to manage the phone calls related to the actions of the security plan according to the warning level. The phone calls are managed on the basis of phone call scenarios (for example, call of all the schools located in a vulnerable area). The lists can be filtered according to the current date (school time or not, week-end/week, holidays) and time (opening schedules). Based on the decision of the operator, an automate ensures the emission of the phone calls.

FEEDBACKS FROM THE FIRST EXPERIENCE

The ESPADA system is operational in the buildings of the city of Nîmes since July 2004 for a first catchment (the cadereau of Uzès) and for the entire city since July 2005. The storms of September 2005 were the first operational system experience. Interesting feedback were obtained from this episode since significant overflows occurred for all cadereaux.

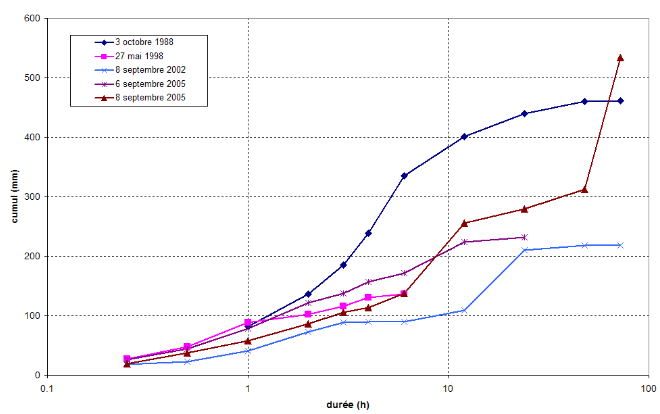

Figure 3 : Rainfall amounts for various duration and events.

More precisely, several rainfall episodes followed one another in the following way:

- September 6, 2005: a total amount of 200 to 250 mm of rain occurred in 11h, including 170 mm in 5 hours.
- September 8, 2005: a total amount of 180 mm of rain occurred in 14h, with a first episode of 135 mm in 5 h, and a second episode of 45 mm in 3 h.

In less than 72 hours, 400 and 500 mm of rains fell on the city, mainly on the western districts. The Figure 3 presents the total amount of rain of this event for various durations of rain up to 72 hours as well as for the episodes used for the calibration of the model (October 1988, May 1998 and September 2002). Although this episode is weaker than the catastrophic episode of October 1988, no episode of this type with two very intense episodes separated from less than 48 hours was available for the calibration task.

The acquisition of the rainfall records was satisfactory except for a disturbance at the end of the second episode of September 8. The flow data were only partially useful because the material was in a renewal process at that time. The radar acquisition was possible during the entire period, making the hydrological calculations of forecasts possible. However, it is important to note that the methods available to anticipate the evolution of stormy phenomena are not very efficient for stationary storms.

The hydrological predictions performed in real time from the control room provided satisfactory results, with only an overestimation of the flows at certain points. As an example, the Figure 4 presents the observed and estimated water levels obtained for the Valdegour cadereau for the September 6 episode .

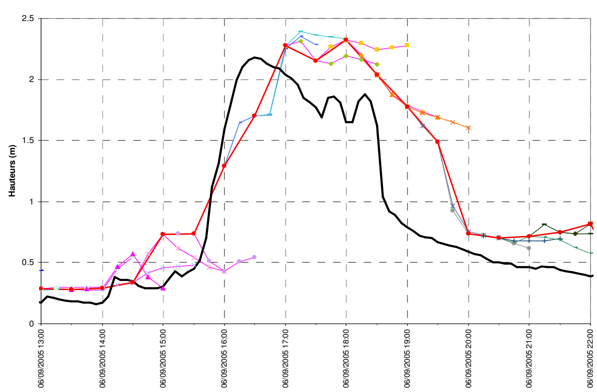

Figure 4 : Observed (black line) and predicted flows for the Valdegour cadereau, September 6 2005.

The analysis of the results obtained for this event allow putting the emphasis on several important points to take into consideration for this type of real time flood warning system.

Concerning the input data:

The stationarity of the storm cells during certain periods of the episodes was not properly predicted since it is a phenomenon that is very difficult to model. Nevertheless, relevant manual corrections on the predicted rainfall quantities were possible thanks to a global and critical vision of the situation.

Couple of measuring sites did not resist to the difficult conditions on the field. Their site and their follow-up are of primary importance. The redundancy of the sources of information should be ensured for the most important points and the security of the video-cameras should be reinforced.

The stage gauges recently installed close to storage basins, such as the Roquemaillère basin (cf Figure 5) proved to be highly interesting for the crisis management in real time. More particularly, they permit a more reliable evaluation of the flows since they are located at sites that are not subject to extreme hydraulic conditions (strong speeds, river obstructions,...). Therefore, they are particularly interesting indicators for the model updating, in real time or differed time, and therefore for the decisions of change of the system state.

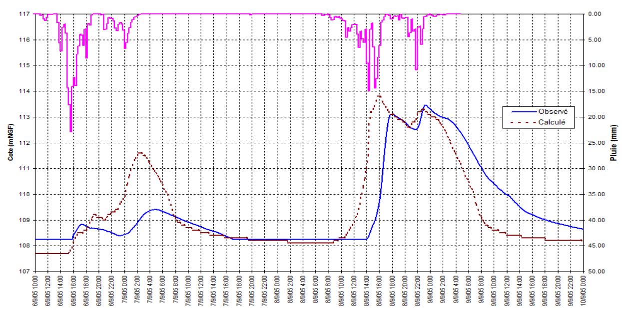

Figure 5 : September 2005 events –Alès Cadereau – Roquemaillere storage basin.

Concerning the modeling part:

For the cadereau of Alès, where the karst contribution is significant and complex, the model gives a faster and stronger reaction of the basin as compared with the observations for the first peak flow on September 8, 2005. The second peak flow is correctly reproduced. It is important to note that no complete flow records were available for the strongest events used to calibrate the model. The observations carried out at the time of the episode of September 2005 indicate that the basin response is slower and less sensitive to the strong rainfall intensities than what is observed for the weaker episodes. A study conducted by the BRGM [5] is currently in progress to explain the contribution of the karst to the floods and to provide additional elements for a better comprehension of the phenomena. In particular, the behaviours and contributions of the karstic blocks where the transfer is slower and the drains that can be under pressure will be specified.

The model is powerful for watersheds where the karst contribution is less complex such as the basins associated to the Valdegour cadereau and the Uzès cadereau.

The real time update of the models on the observed flows provides a clear improvement of the forecasts. However, this improvement is possible only if the hydrometric data are validated in real time by a forecaster. Wrong values (and not only outliers) may erase the benefit of this update. Therefore, the data analysis and validation remain an important process for the performance of the system, particularly in crisis period.

In general, the performance of ESPADA was very good for its first testing period, since it was able to anticipate the important overflows at the entry of downtown of Nîmes. This type of system based at the same time on the data acquisition, a detailed real time modeling and the release of the warning levels is extremely promising.

PERSPECTIVES OF THE SYSTEM

Based on this experience, the following perspective directions are considered for the evolution of the system:

Implementation or reinforcement of additional hydrometeorological stations in appropriate strategic points associated with particular attention given to videocamera security.

Concerning the forecast of rainfall stationarity, algorithms of automatic creation of scenario could be implemented in the system (for example, the predicted rainfall could be set equal to a constant value over a given duration) as a first step, before obtaining final research results from Météo France which would make it possible to improve the forecast of such situations.

Adaptation of the model for a more detailed representation of the karst saturation phenomena based on the observations made during the September 2005 episodes as well as the results from the BRGM current study (geochemical analysis, piezometers measurements). The function of initialization could also be refined. This adaptation could lead to modifications of the conceptual hydrological model to integrate at the same time the phenomena of surface or subsurface runoff and the phenomena related to the karstic nature of the basement, with the differentiated behaviours that were highlighted during the September 2005 episodes.

The growing technological progress associated with the experience feedbacks obtained in practice will contribute to better target and understand the points to be improved in order to insure the development and success of such systems.

REFERENCES

[1] Dumay H, Raymond M., *" ESPADA : Un outil pour la gestion des crues urbaine",* Conférence Novatech Lyon (2001).

[2] Editjano et Michel, C., "Un modèle pluie-débit journalier à trois paramètres", La Houille Blanche, 2, 11"-121 (1989).

[3] Perrin C., *"Vers une amélioration d'un modèle global pluie-débit au travers d'une approche comparative"*, Thèse INP CEMAGREF (2000).

[4] Chocat B., *"Encyclopédie de l'hydrologie urbaine et de l'assainissement",* Lavoisier, Paris, 1124 pages (1997).

[5] Maréchal.J.C., Ladouche.B., Doerfliger.N. , *"Role of karst system in the genesis of flash flood events at the Nîmes city"*, in EGU, Vienne , Autriche (2-7 avril 2006) [Soumis]