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SHORT-TERM HYDROLOGICAL ALERT SYSTEMS: THE BESÒS RIVER PARK

Jordi Cabot Ple [1], Gustavo Ramon Wilhelmi[1], Francisco Ariño Santos[1]

[1]CLABSA, Clavegueram de Barcelona S.A.

SUMMARY

The Besòs River, with a 1,024 km^2 basin, is one of the two rivers that shape the metropolitan area of Barcelona. The first phase of the Besòs River Park opened in 1999 along a six-kilometre stretch of the river. This permitted the environmental and scenic recovery of the space for public use. In 2004 the park was enlarged by another three kilometres.

The regular public use of the riverbanks made it necessary to install a hydrological warning system to safely evacuate the watercourse in the event of a torrential rise in level.

CLABSA manages this alert system, which incorporates several hydrological models that run in real time and use rain intensity data derived from meteorological radar images.

The implementation of meteorological radars on a national scale makes it possible for the very short-term warning systems based on radar images to be applicable to other torrential prone river basins whose watercourses affect civic life and/or urban services.

1 INTRODUCTION

The proposal of "Directive on the assessment and management of floods" shows that "The assets at risk from flooding can be enormous and include private housing, transport and public service infrastructure, commercial and industrial enterprises, and agricultural land". It also says that "Two trends point to an increased flood risk and to greater economic damage from floods in Europe. Firstly, the scale and frequency of floods are likely to increase in the future (…). Second, there has been a marked increase in vulnerability due to the number of people and economic assets located in flood risk zones". Finally, it establishes that "The objective of this Directive is to reduce and manage flood-related risks to human health, the environment, infrastructure and property".

As one of the stages for the achievement of this objective, the directive establishes "the development and implementation of flood risk management plans (…)". Related to these plans, its article 9 establishes: "The flood risk management plan shall address all phases of the flood risk management cycle focusing on prevention, protection, preparedness, and taking into account the characteristics of the particular river basin or sub basin".

The methodology and tools for the implementation of the preventive aspects are already known in reference either to fluvial or to urban drainage systems. The modelling of flooding rivers and of drainage systems subjected to hard rains is common and allows to confront with precision the study of flooding zones and the design of solutions. More improvement is required in the items in the sphere of the real time management of the crisis, as well as in their information and alert aspects and in the effective operation of control devices (regulation systems, generally).

When floods are produced suddenly (flash floods) and affect inhabited zones, their structural solution may require a long period for its implementation and effect, or they even cannot be possible. In the meanwhile, it is necessary to introduce prevision and alert systems if we seek to limit risks of flood over human lives and properties.

In this article, a real case on the use of a hydrologic short term alert system is shown. The existence of the alert system allows the use of the watercourse of a torrential river as a urban park. However, its application could be extended to other cases in which an early alert could be useful to the application of evacuation or precaution measures in front of an episode of sudden floods.

2 THE ENVIRONMENTAL RECOVERY OF THE BESÒS RIVER

For decades, the image of the Besòs River has corresponded to that of a highly degraded watercourse. The pollution and degradation of the Besòs River and its surroundings is a problem that began in the 1960s when the tremendous demographic and urban growth in this part of Catalonia and the industrialisation process converged. A catastrophic flood in 1962 killed several hundred people. As a result, the river was canalised. Although this solved the flooding problem, it degraded even further the Besòs watercourse. Canalisation ends up

creating a barrier that destroys the riverbanks and causes a river to become a large open sewer with the subsequent bad odours and other annoyances for the riverside communities.

This has led the local governments to take an interest in recovering the Besòs River, integrating the river and its banks into the surrounding urban environment and taking advantage of the park and recreational possibilities offered, without compromising the protection against floods.

Construction began in 1995 of the wastewater treatment plants of the townships along the river basins. In November that same year, the project affecting the final leg of the Besòs River was initiated, for the environmental recovery and redesign of the final 9 km of the Besòs River, covering the section from the city of Montcada i Reixac to the mouth of the river. The goals of this project in its first phase were to improve the outflow of the Montcada i Reixac wastewater treatment plant by implementing a tertiary system based on generating wetlands, improve the hydraulic capacity of the river and turn certain sections of the river into a river park with recreational capabilities. During its second phase, the project was extended to the city of Sant Adrià del Besòs.

As a result, the environmental and water quality restoration of the river has also made possible the recovery of autochthonous flora and fauna species that had disappeared during the river's period of degradation. It has also resulted in the incorporation of new recreational facilities in a heavily developed urban area lacking in park areas.

3 THE RIVER PARK

The first 3.5 km are surrounded by river grasslands, beaches, islands, meanders and 60 plots of wetlands. In the following 5 km, the vegetation on both sides of the river consists of bushes and greenways, which the public can access by ramps and stairs from the upper part of the retaining walls. Between the greenway and the walls is a road for use by pedestrians and bicycles as well as service vehicles.

A total of 11 inflatable dams have been installed along the 5 intermediate kilometres. The dams serve to maintain a constant sheet of water in the central channel, which favours the development of the flora and fauna and improves the appearance of the river in periods in which the flow is lower.

Because the park occupies the riverbed, the greenway can become flooded when the river flow is higher. This would make recreational use of the area impossible without sufficient safety guarantees for the public. It is for this reason that CLABSA has developed the Besòs River Hydrological Warning System (SAHBE) to prevent flood risks and to warn and evacuate the public from the park with sufficient anticipation.

Figure 1: Inaugural celebration of the second phase of the Besòs River Park.

4 THE WARNING SYSTEM

The Besòs River Hydrological Warning System receives information in real time from the installed rain gauges and flow gauges, weather radar images, Meteosat satellite images, and data from CLABSA's centralised operation system.

The IT systems running the applications that carry out the warning system tasks are physically located in CLABSA's Control Centre. Here, the data is received telematically from the sensors, the foreseen alerts are sent out and the operations corresponding to the activated state of alert are carried out. Video images from the surveillance cameras located in the river park are also received.

The warning system includes information panels that are installed at the river park and that indicate whether the park is open or closed and whether or not a particular alert has been activated. There is also a system of optical-acoustical warning signals. Lastly, there is a loudspeaker system that can be used to give warning messages. This combined system of panels, signals and loudspeakers is remote controlled from CLABSA's Control Centre, as is the inflatable dam system. This way, both the operator and the automatic program can deflate the dams if need be.

4.1 The Supervisor System

In order to anticipate river flooding and to have more time for closing and evacuating the park, the warning system incorporates a flood prevention system called the "Supervisor System". The Supervisor System receives hydrological information from the rain gauges in the SAIH network of ACA (Catalan Water Agency) as well as from CLABSA's rain gauges, ACA's flow gauges located in the watercourse, and

radar images from Spain's National Meteorology Institute (INM).

Once the data has been received, the hydrological-hydraulic models implemented in the Supervisor System are executed, determining in real-time and up to 12 hours in advance a forecast of changes in the river's level at the park entrance.
Three models are implemented in the System Supervisor:

- Transport Model: It is based on level measurements in the tributaries of the Besòs River. These levels are converted into flow and are transported with a delay associated to the distance to the forecast point. In addition to the tributaries, the inflows from the storm drains in the sewerage networks of the riverbank communities are also taken into account. Once the sum of the flows at the forecast point has been ascertained, it is then converted to level.

Depending on the level forecast obtained for the forecast point, the Supervisor System generates the corresponding alert state.

- Isochron Model: It uses INM radar images, converting the reflectivities in rain intensity and calibrating the images with values provided by rain gauges. This model establishes a rain field forecast by persistence, that is, by propagating the last image in time. The river basin is divided into cells measuring 2 x 2 km, identical in size to the pixels of the INM radar. The assignment of the rain gauges to the cells for calibrating the image is carried out using the Thiessen polygon method.

The model transforms the rainfall in each cell into runoff flows, according to the different types of terrain, and transports them with the appropriate delay to account for the distance to the forecast point. Once the sum of the flows at the forecast point has been obtained, the data is converted into level and the corresponding alert state is issued.

- Topdist Model: The model Topographical Distribution is envisaged as an evolution and improvement of the isochron model. It was developed in association with GRAHI (Grup de Recerca Aplicada en Hidrometeorologia – Hydrometeorology Applied Research Group) from the Polytechnic University of Catalonia.

In this model, the forecast of radar images is performed using two methods:
- Persistence. The last image is propagated in time to obtain a forecast of the rain field.
- Crossed correlation. The rain field forecast is obtained by calculating a displacement vector of the reflectivity field of the radar image.

Once the rainfall has been obtained for each cell, it is transformed into flow. The cells are divided into rural and urban cells, applying a different transformation function to each one. Flow is transported between cells until reaching the forecast point, where the conversion to level is made.

4.2 Alert States and Warning Management

The alert level is established depending on the flood forecast of the Besòs River given by the Supervisor System and by other objective criteria. Six alert states have been defined corresponding to the different basic emergency states. Their activation or cancellation entails notification by telephone and fax to different civil protection entities.

The activation of a Pre-Alert Phase entails the park's partial closure, the activation of the optical signals and the deflation of the dams. The closed accesses correspond to the park's extreme north and south accesses.

Figure 2: Optical-acoustical signal, information panel and loudspeaker system.

In the event of either an Alert or Crisis Phase, the park is completely closed and evacuated and the optical and acoustical signals are activated. The acoustical signals activate periodically for two minutes every two hours. Likewise, the loudspeaker system is used to order the calm evacuation of the park. This evacuation is carried out with the help of the park's security personnel and the police forces. Once the evacuation is completed, the security personnel close all accesses to the river park.

5 DESCRIPTION OF A REAL EPISODE: 2 AUGUST 2005

One example is the episode occurred on 2 August 2005. During this episode, the Crisis Phase was activated, forcing the closure of the river park.

On 1 August, CLABSA's Control Centre received an SMR (Dangerous Meteorological Situation) alert from Catalonia's Meteorological Service reporting that from 20:00 hours on the 1st and until 24:00 hours on the 2nd there would be a 30-60% probability of precipitation with an intensity greater than 20 mm in 30 minutes in the Besòs River and Barcelona basin.

This information motivated the activation of the Pre-Alert Phase of the Besòs River Park at 16:00 hours in anticipation of flooding over the medium term. This

alert activation entailed communicating the situation by telephone and by fax from the Control Centre to several organizations. The activation of the Pre-Alert Phase entailed the partial closure of the river park.

The public in the park was informed via the information panels located throughout the length of the park that the current state corresponded to a Pre-Alert Phase. The illuminated warning signals were turned on. Lastly, the 11 dams were deflated from downriver to upriver.

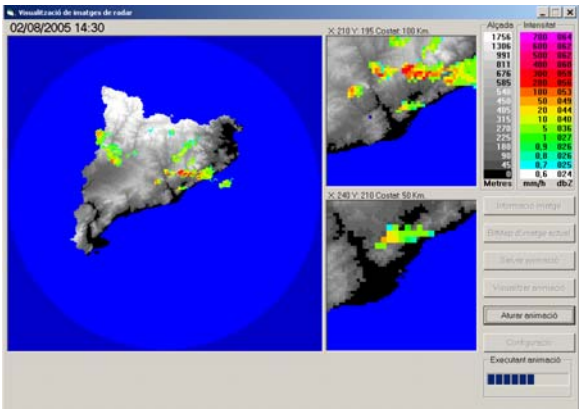

Figure 3: Radar application. Image taken at 14:30h UTC.

At 15:30 hours on 2 August, the radar started to show a very strong storm nucleus approaching the Besòs River basin, while a small amount of precipitation affected the basin. Within half an hour the SAIH network rain gauges started to detect heavy rainfall. At 16:50 hours the Supervisor System models forecast an increase in water level at the park entrance, which generated an Alert Phase and Alarm State, indicating short-term swelling of the river.

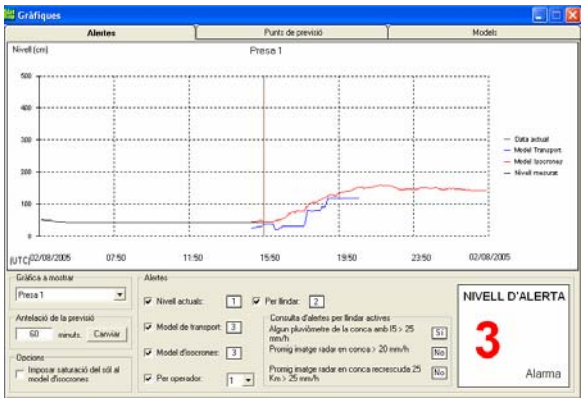

Figure 4: Supervisor System forecasts an Alarm State at 15:50h UTC.

This forecast motivated the proposal to activate the Alert Phase at 17:10 hours. It entailed alerting the several organizations by telephone and fax. The activation of the Alert Phase called for the complete closure of the park.

At 18:20 hours on 2 August, the level detected at the Park entrance motivated the proposal to activate the Crisis Phase. It entailed the telephone and fax alert to several organizations.

The public was alerted through the information panels that indicated the current state corresponding to a Crisis Phase. The luminous warning signals were kept activated and the acoustical signals were once again activated for two minutes. The partial flooding of the park was communicated over the loudspeakers.

The Crisis Phase was kept activated throughout the entire night of 2 August. On the morning of 3 August, once the river level was seen to have dropped and the meteorological forecasts were analysed, the Crisis Phase was deactivated and the park was reopened although maintaining the Pre-Alert Phase activated until the river returned to its normal level on a dry day.

In the post-episode analysis, it was observed that the highest level reached at the park entrance was 157 cm. The maximum precipitation detected in the rain gauges along the basin occurred in Cardedeu with a total of 55 mm and a maximum 20-minute intensity of 99 mm/h.

6 APPLICABILITY TO OTHER CITIES

The article shows the application to a real case of an alert system based on hydrologic models and on the availability of rain intensity measures from a meteorological radar.

The actual knowledge and availability of this kind of tools allows the application of this procedure to almost everywhere of the Spanish geography. Effectively, as we can see at the following picture, the National Institute of Meteorology (as well as other organizations, for example some regional meteorological services), has meteorological radars that embrace all the peninsula. The application of meteorological models must be carried out through adaptation to every case, but its standardization is remarkable.

Therefore, the availability of the necessary tools as well as the success of the real application herein described, allow to conclude that these kind of alert systems is already ready to be introduced and applied yet to other cases. The system allows to set in alert in a short time the civil protection services for their immediate action, as well as to the evacuation of areas in danger and/or the operation of protection devices at the affected facilities. The ideal environment for the development of such an early alert system is the plan of civil protection for urban areas, and other areas of interest for public attendance or workers.