A FRENCH PILOT FLOOD WARNING SYSTEM : THE GARD EXPERIMENT.

22957
Jean LEOUSSOV
Direction Départementale de l'Equipement du Gard
89, Avenue Weber 30032 Nîmes cedex. France.
Thierry LEBEL 22774
Institut Français de Recherche Scientifique pour le Développement en Coopération(ORSTOM).
B 5045 - 34032 Montpellier Cedex- France.

ABSTRACT The mediterranean region is an area of frequent flash floods which cause heavy damage. Several large French cities in this climatic region are located at the outlets of small watersheds with rough topography and are thus threatened by severe flash floods. Recent breakthroughs in the field of telemetered networks make improved flood forecasting possible. In France, the Cevennes region was chosen in the seventies for the implementation of a pilot flood warning system. After five years of operation by the "Direction Départementale de l'Equipement" of the Gard administrative district, this paper presents an initial assessment of the system..

INTRODUCTION

The mediterranean countries are all too familiar with flash floods. These flash floods are generally associated with very specific weather systems producing severe thunderstorms fed by warm and moist air of mediterranean origin. The Cevennes region of France is a mountainous area located in the mediterranean back country and subjected to virtually tropical type rainfalls : a point rainfall depth of 100 mm was recorded in one hour (1976) and 800 mm in one day; 400 mm is a frequent figure for an event lasting two or three days. Areal rainfall depths of 30 to 40 mm in one hour over watersheds of a few hundred square kilometers are not rare. These intense rainfalls combine with a rough topography to produce life threatening flash floods: in 1958 discharge at the the outflow point of a watershed of 135 km2 jumped from almost zero to 900 m3/s in two hours killing nine people. Therefore, the Gard administrative district which includes most of the Cevennes mountains was selected at the end of the seventies to set up a pilot flood warning system, funded by the French government and the Gard regional council. The two main functions of this system are :

O.R.S.T.O.M. Fonds Documentaire
N° : 39687
Cote : B
13 JUIN 1994
81249

1- data acquisition and transmission in order to provide in real time the state of the hydrological system at a given time t.
2- a set of simulation and forecasting models in order to anticipate the forthcoming discharge variations at several critical locations (citys, dams, touristic sites ...)

This paper describes the acquisition and transmission components of the system, while a companion paper by Lebel and Bastin highlights the rainfall data processing and some associated research problems.

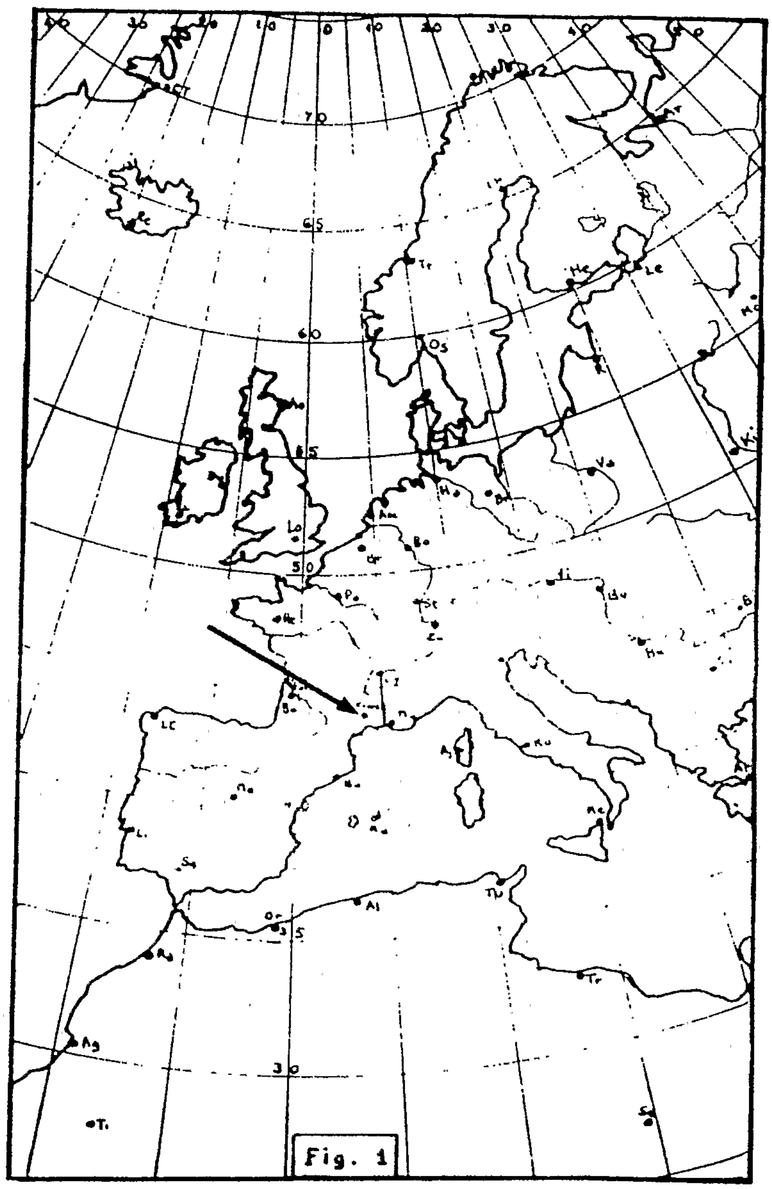


Fig. 1

Figure 1 Location of the Gard telemeterd network.

SYSTEM OVERVIEW

The basis of the system consists in sending hydrometeorological data collected over an area of roughly 5000 km^2 to a forecasting centre located in Nîmes. Within the technical context of the late seventies, radio link transmission was chosen (80 MHZ) as the most reliable. As a matter of fact, ten years ago when the first studies were carried out, satellite transmission was not a serious alternative for such a small network, despite some obvious constraints due to the topography of the region. Presently 24 automatic stations are operational, including 5 located at dam sites (figure 1) and providing 100 parameters (precipitation, water levels, wind, temperature, ...) on an hourly basis via two relay stations. These facilities are suplemented with a computerized forecasting centre in Nîmes and a public flood warning system.

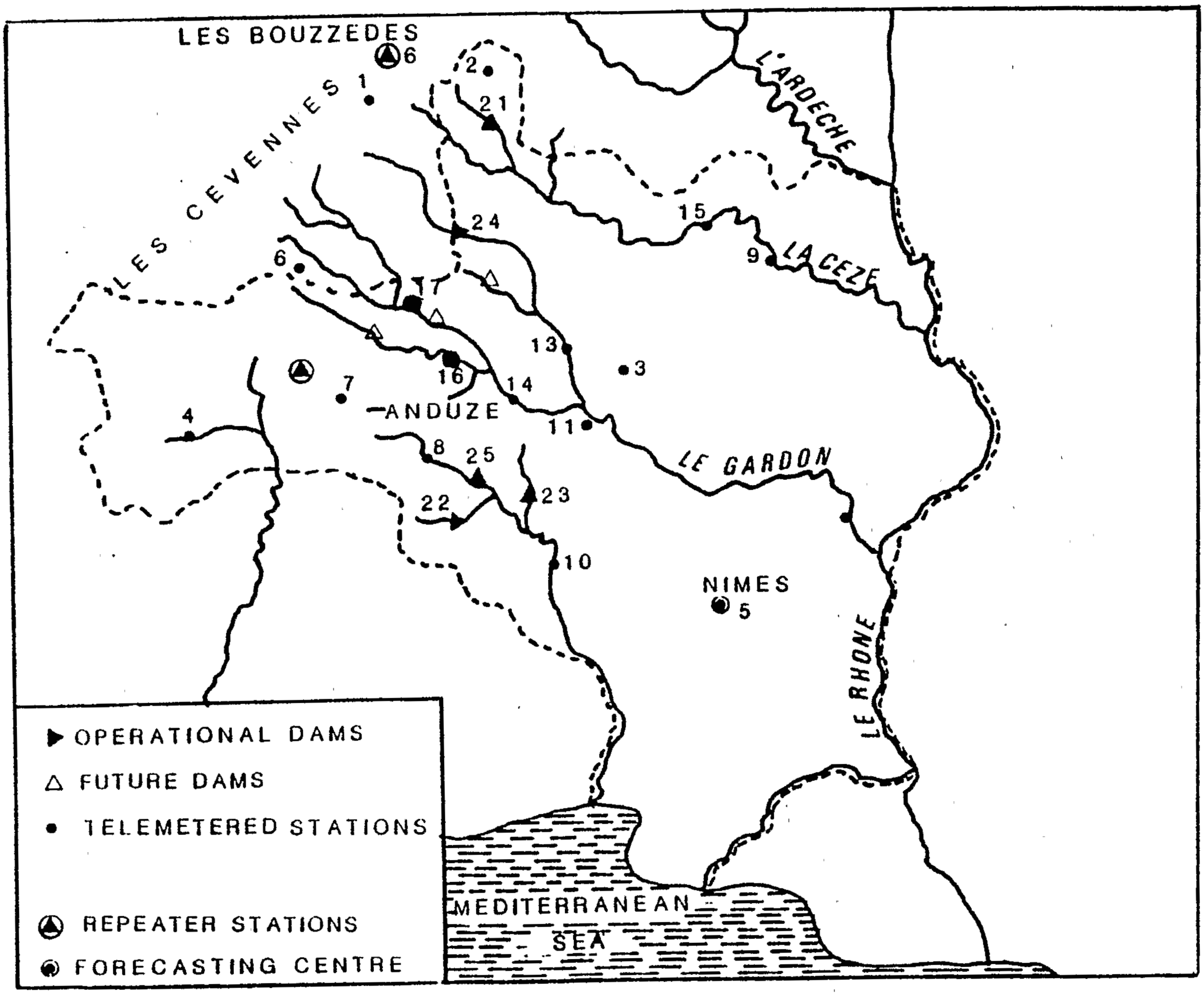


Figure 2 Operational stations in 1987.

Table 1 : Sensors : precision and range

	Sensors	Precision	Range
Rainfall	Precis Mécanique Ring : 400 cm^2	1 imp. = .5 mm	0 - FFF
Water levels A	Buble gauge (LAH2 - NEYRPIC)	1 cm	00.00 - 99.99 m
Water levels B	Pressure gauge (DRUCK DTX 110/D)	+ 0.3%	4 - 20 mA or 0 - 12 m
Wind speed	Anemometer (Type S) CHAUVIN-ARNOUX.	1 km/h	0 - 180 km/h
Wind direction		20 °	18 sectors
Temperature		0.1 °C	-40, 70
Atmospheric pressure	Part of the station card	1 mb	850 - 1050 mb

SYSTEM CONFIGURATION

The network structure consists of four levels :

1- Sensors measuring the following variables : rainfall, water levels (dams or river levels), wind speed and direction, temperature, atmospheric pressure plus various measurements specific to the dams (pressure, flood gates etc...). Table 1 summarizes the main types of sensors and their measurement range and precision.

2- Automatic stations equipped with a micro processor and logic cards "CMOS" (characterized by a very low power consumption) performing the following tasks :

- interfacing of the sensors

- local computations such as maximum wind speed, accumulation of rainfall over one hour, analogic to digital conversion etc.

- data transmission and commands reception.

- automatic self testing and telephone links with the centre in case of misfunctioning.

- management of warning signals in case of loss of power or stationbreaking alarm. The data storage on site is not available presently but will be set up in a near future as a backup in case of transmission breakdowns.

Except for the sensors themselves, all the hardware is protected within a stone shelter, the architecture of which is of traditional type. Solar cells provide the needed power. This independance from power and telephone lines combined with a good positive earth connection are the best guaranty against lightning.

3 - REPEATER STATIONS installed to account for the topography and the needed reliability of the network. There are two of them:
- each relay is doubled with a supplementary relay. In addition, a test procedure allows for the verification of the relays from the computerized centre.
- in case of a total breakdown of one site (the two relays are out of order), several stations, normally linked to this site, are in touch with the other site.

4- THE RADIO NETWORK MANAGEMENT UNIT is the programmable unit which manages the transmission cycles and the service signals transiting through the network. It performs the following tasks :
* interrogation of the repeater stations by order of the central computer.

* management of the possible breakdowns : the missing stations are held in a buffer store in order to be interogated again later; switching from the main repeater to the suplementary one etc...

* decoding of the raw data

* forwarding to the computer the data buffer via a non synchronized line (RS 232, ASCII)

* switching to an independent mode if the main computer fails and temporary storage of the data until it can be recalled by the main computer

* listing of the data and breakdowns

* management of the manual commands through a dialogue with an operator using the maintenance terminal

* modifications of the network architecture.

The ultimate link of the data transmission process is the central computer which enables :

- data collection and validation,

- data dispatching to the various services concerned,

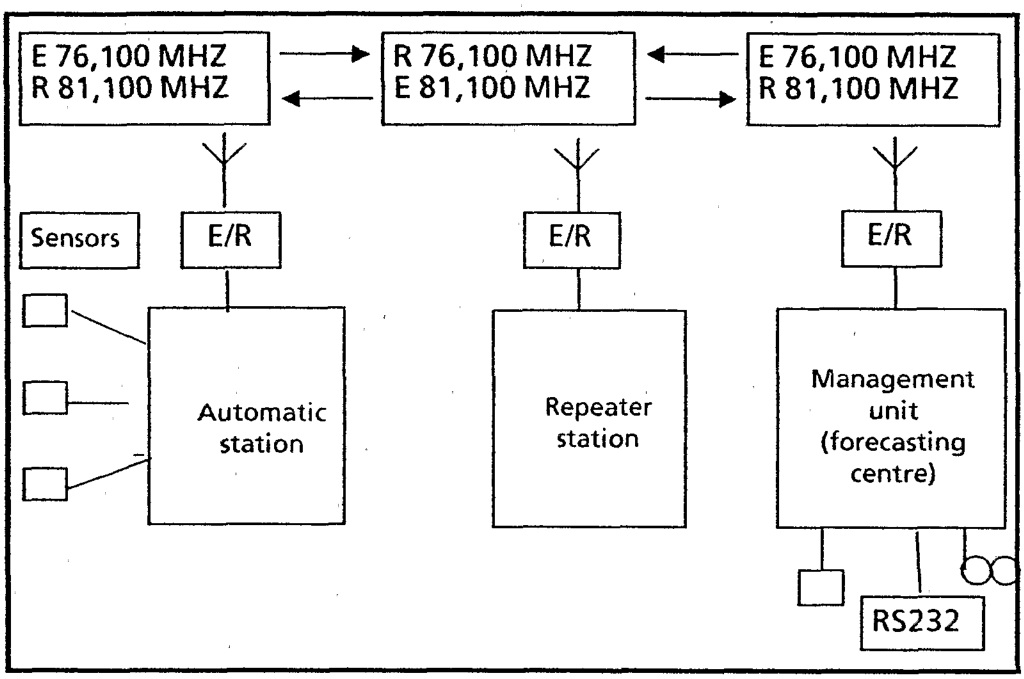
- real time flood management tasks (continuous watershed monitoring, forecasting and warnings ; note that the forecasting system is based on various types of tools : rainfall/discharge on upper catchments, propagation or statistical correlations on the dowmstream areas),

- the simulation of past floods for use in studying the phenomena involved and in fine-tuning the forecasting methods.

SYSTEM OPERATION

Among the 24 automatic stations operated in 1987, 24 measure the rainfall, 17 the water level, 13 the wind speed and direction, 16 the temperature and one the atmospheric pressure, that is a total of 84 values each hour not taking into account service signals and specific dam parameters. Solar radiation measurements were given up due to the rapid deterioration in remote sites which do not undergo a daily maintenance. The equipment of four new stations is foreseen in the coming year.

The data are transmitted from the stations to the acquisition centre using an impulse modulation through a standardized harmonic telegraphic channel. The channel used for the modulation is centred on 1080 Hz with a modulation speed of 200 bauds. The radio frequency used for the emission and the reception is in the 80 Hz (76,100 and 81,100).



Each message contains :

- one synchronization bit
- address and data bits
- one redundancy bit (replicate bit)?

Under the usual assumptions (random errors of equal probability for the "0" and the "1", radio link with a ratio (S + B) /B = 20 dB), the probability of non detection of an error is less than 2 E10-7.

Each module of the stations and of the relays is listening during two seconds every minute, thus allowing an economy of the watch mode power consumption.

The stations and the relays are switched to the watch mode before each hourly interrogation, based on a three step procedure :

- the relay is awakened
- the stations dependent of the relay are awakened
- the stations are interrogated

Each element of the network is known by its address and the dialogue organisation is as follows :

- relay in reception mode : 2 s/minute
- relay in re-emission
- station in reception mode
- the station is called and answers
-
- end of the emission mode for the relay
- end of the reception mode for the relay

In case of non answer of one station, three attemps are made before abandoning the station. A message is edited.

In case of non answer of a relay, three attempts are made, then the central emits an HF order to switch to the suplementary relay on the same site. Three attempts are made again on this new relay and a message is edited in case of failure. The stations that are seen by the other repeater site can then be switched to this other site (depending on the analysis performed by the operator on duty).

As can be seen from the above description, the emphasis has been put on maximum reliability, mainly by providing downgraded modes at every level of the transmission process. The accent is also placed on the basic responsibility of the operator in charge. In no way is a completely automated system relied on to elaborate the forecast and to take the appropriate steps.

Concerning maintenance preventive action is by far better than curative solutions. Maintenance is thus carried out on the basis of regular tours covering every station.

All signs of possible breakdowns are also automatically transmitted and monitored. In cases where breakdowns cannot be avoided, repairs are carried out quickly and effectively, making use of practical spare parts kits.

THE PUBLIC FLOOD WARNING SYSTEM

The dissemination of forecasts and warnings is performed through the STAR system downstream, a telephone-based public alert prototype presently being tested in the Gard region by the French Civil Defence for the immediate dispatching of warnings to relevant local authorities. Answering machines (and a Minitel videotex service in the near future) are used to keep the concerned population fully informed.

COMMENTS AND CONCLUSIONS

A few figures may give a rough idea on the overall system reliability. In four years (1981-1985) less than 50 hours per year and site of observations were lost. No simultaneous breakdowns of the main and suplementary relays were recorded. The longest shutdown of the computer centre lasted 7 hours. Lightnings stroke directly a station in two occasions only.

Concerning the telemetered system itself transmissions were operated smoothly even in stormy weather. The good earth positive connection (<5 ohms) and the independance from power (solar cells) and telephone lines proved themselves efficient against lightning despite the violence of the Cevennes thunderstorms.

Total shutdowns never occurred. The possibility of several downgraded modes allows to solve most of the temporary problems in a very short span of time. The direct management of service signals by appropriate softwares is of great help to detect errors, misfunctionings and breakdowns. Maintenance is accordingly simplified.

The equipment underwent record temperatures from minus 20°c in January 1985 to 43°cin july 1983 without any problem, thus proving the reliability of the techniques used. The periodic survey of the network is th eultimate and efficient protection of any automatic system.

To gain an overall appreciation of the pilot system, its effectiveness must be assessed both at the economic (cf appendix) and hydrologic levels. Experience has shown that great care must be taken to avoid heavy supplementary costs stemming from poor initial design, insufficient development work and the problem of damage and wear on equipment installed in an unsupervised natural environment.

Data processing is based on graphic tools. The resulting graphic products are a preliminary stage before running rainfall-runoff models, and subsequently help interpreting the model results. Valuable hydrological results have been obtained. A few of them are presented in a joint paper by Lebel and Bastin.

APPENDIX - ECONOMIC APPRAISAL

Investment	
Average cost for one automatic station (depending on the equipment)	200 000 FF*
Repeater station	100 000 FF
Central unit	150 000 FF
Total investment for 20 automatic stations and 4 relays (including spare parts).	3 850 000 FF
Operating costs.	
One year	350 000 FF

Cost of the real time unit information

84 parameters transmitted each hour, (735 840 each year). Based on a 10 year amortization, the total cost is 3 850 000 + 10X 350 000 = 7 350 000 FF

that is **1 FF/ unit information.**

This figure may be compared to the costs of telephone calls, wages,etc..., and shows the advantage and profitability of a telemeterd network.

* All costs are in 1985 FF.