LA RIBA MAP: A PILOT PROJECT ON DETAILED FLOOD-HAZARD MAPPING IN CATALUNYA.

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Abstract

La Riba Case-study Flood-Hazard map was developed by the Junta d'Aigües de Catalunya, and Servei Geològic de Catalunya. The map was constructed using a combination of quantitative and qualitative methodologies. Map results were successfully tested in the flood of 1994 showing that this map are a useful tool to improve the understanding on the consequences that may ensue if a floodprone area is developed, this kind of map also map could help to mantain the memory through the decades between two severe floods. The approach of that map, the results and a post-flood review of it are here discussed .

Introduction: Flood Reduction Strategies and flood Hazard maps in Spain.

In Spain there is a tradition on structural strategies to minimize flood risks, that is, strategies to modify the river behaviour in flood times. National and Regional plans are mainly based on river regulation and training. After the big or highly damaging floods (such those of 1982, 1994, or the recent 1996 Biescas Camping-site tragedy) there is a persistent debate on flood defence policies.

The Water Law (1985) establishes the zoning and the regulation of the river area. Flood-prone area (defined by the 500 year's flood in the law) represents the outer limit of the land-use regulations of the fluvial space, but this area of the fluvial zone has not been outlined. The poor understanding of the physical characteristics of flood-prone areas and the lack of effective regulation and co-ordination between the soil and the water authorities in the use of flood-prone areas is encouraging unsafe uses of the floodplains.

At present the Civil Protection Law (1995) claims explicitly for a mapping of floodprone area (100 and 500 year's flood) using hazard and vulnerability criteria. Also the initiatives from municipalities on river channel restoration and integration of the river space in the urban scenario are overcoming traditional structural approaches and demanding a definition of flood-prone areas.

Flood-prone maps started in Spain in the late 70's in the Instituto Tecnologico y GeoMinero de España. In Catalunya the firsts maps were developed in the 90's

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by the Servei Geològic de Catalunya. A few municipalities have also developed their own maps. The case-study map of La Riba is the result of a cooperation between the Junta d'Aigües de Catalunya and the Servei Geològic de Catalunya. This map is the first step towards a regional programme on flood hazard mapping.

Flood hazard maps and derivative maps (vulnerability, risk, etc.) are considered as a powerful tool for the comprehension of the river dynamics that could satisfy the information needs of the several instances involved in the management of the fluvial space and in emergency policies.

.Map Methodology: Towards and Integrated approach

Although there are many methodologies on mapping floodplains there is not a clear-cut way to establish the desired solid line of flood extent. Map methodologies are very variable through literature and there is a lot of influence from the author's background, type of available data, map scale and goals to be achieved.

La Riba map has been developed using several standard techniques and special effort was made to obtain an integration of the results provided separately. In previous projects different techniques (morphological, occasional flood and hydraulic) were used independently to obtain maps. La Riba map integrates three approaches: the geological (morphologic-dynamic), the hydrologic-hydraulic and the social-historical one. Each approach generates maps or layers. the final map (Flood and Associated Hazard Map) is a syntesis of the former maps.

The *geological approach* includes the mapping and analysis of the lithological formations (Geological Map), of the surficial deposits and relief morphologies and dynamics (Surfical Formations Map). End products of this approach are the *Slope Stability Map*. the*Lithological Map* and the *Flood Prone Area Map*. The former represents the susceptibility to mass movements and the latter a first delimitation of the **envelope** of the potential flooded areas, without the interaction of man-made structures and defences.

The *hydrological-hydraulic approach* integrates the analysis of available data on flood-frequency and past floods and the hydraulic analysis of the selected reach. Hydraulic modelling was built with HEC-2 software. The model includes the analysis of the main structures as well as the effects of obstructions on depth of flow. The end product of this approach is the *long profile* of the reach with the **depth of flow** for different discharge values (each one related to an expected probability of occurrence).

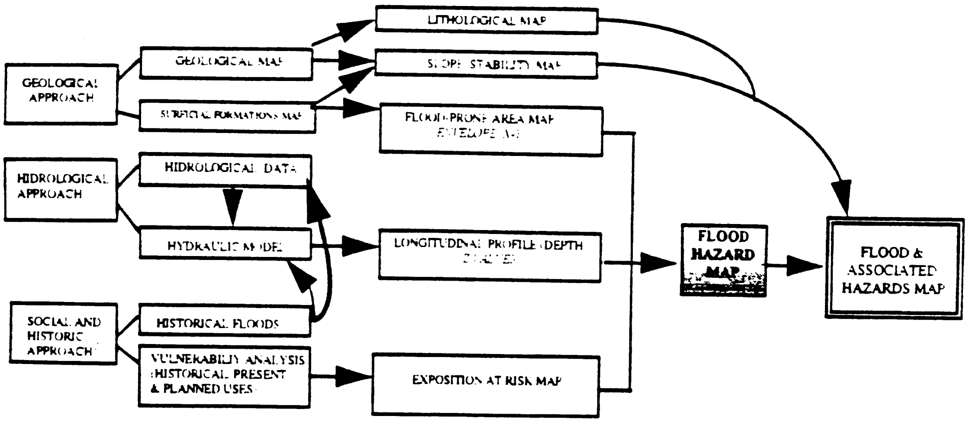


Fig 1.- *Map methodology. each approach generates its own map. after a generalization and integration of the categories obtained on each map the final product is obtained.*

The *social and historical approach* analyzes the data available on the effects of previous floods (damage analysis) and other data that could help to characterise previous floods (high water marks....). These data are of great interest for the improvement of the hydraulic model and also help to optimize the available estimates on flood frequency. Information on adaptations to floods, and the characteristics of land-use in past, present and planned scenarios complete that approach. The end product is a Exposition at Risk Map.

Results from each approach were been checked against the others. Misadjustments were corrected introducing the most reliable results and modifying the models in and iterative process. This process is time-consumer but permits a good assemblage of the different maps and reinforces the final map.

All the maps obtained in each approach were digitalized in several layers. After that we made a process of generalisation and redefinition of units in order to obtain a comprehensive and "friendly" (easy-to-read) map. The digital product on Arc-View software has a menu-form with the capability to present independently the covers and associated information (views, cross sections, processed data...).

The Case-Study area: The Francolí river

The rivers from the Conques Internes (mainly flowing from Catalan Coastal Ranges and Eastern Pyrenees) are steep, short , torrential and highly irregular (Fig. 2). Their basins are small and usually with a low retention capacity (urbanised, with low permeable soils and with poor vegetation cover). Floods have very low lag times and high propagation velocities. Flood plains are relatively small but highly urbanized.

The Francolí river flows from Prelitoral mountains (1200 a.s.l.) to the sea. The river basin has 1000 Km^2 and the main stream has a length of 60 Km. The case-study of La Riba is located in a canyon in the midway between the upper course in the Prelitoral mountains and the low course in the coastal plain.

La Riba town is located in the confluence between the Francolí and its tributary Brugent. This town has a population of 1000 people and has a long tradition of hydraulic activities (water-mills, paper factories) and floods. The Francolí basin at La Riba has an area of 512 Km^2. The land uses of the basin are mainly agricultural (vineyards and cereals) and mediterranean forest and maquia.

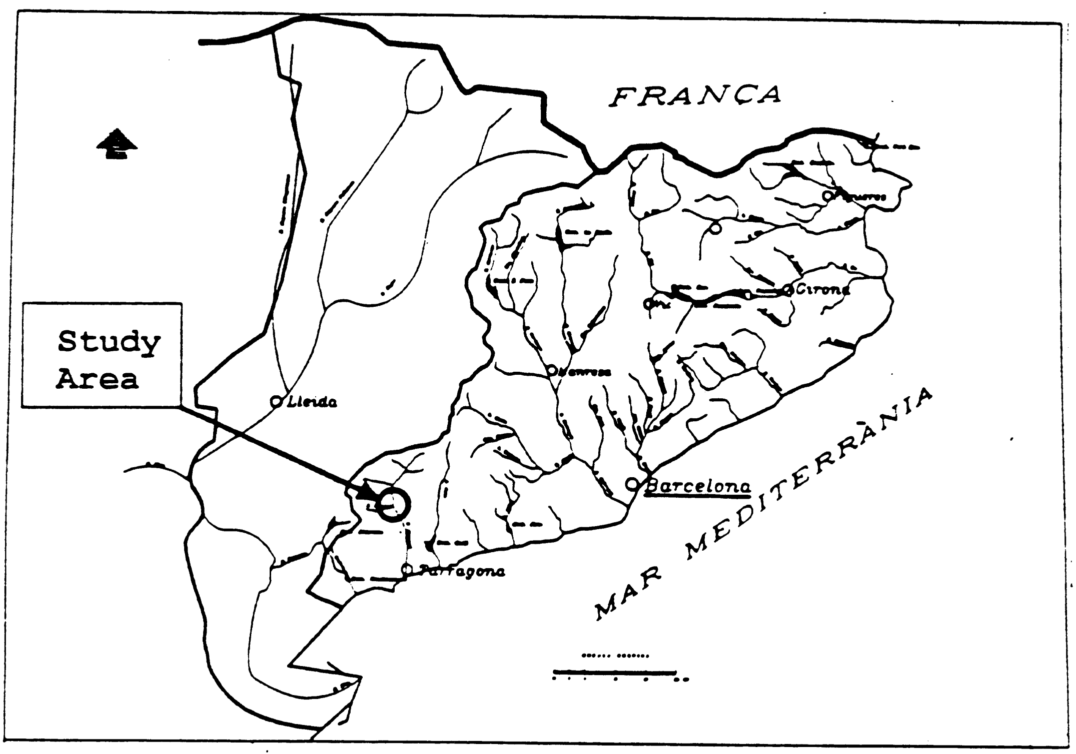


Fig 2.- Conques Internes de Catalunya Map. Locaction of the Francolí river and the study area (figure from JAC)

Description of the Flood and Associated Hazard Map: The Legend

The map was made at 1:5.000 scale using the topographic base of the Institut Cartografic de Catalunya (ICC). The map represents a 5 Km^2 quadrangle, the mapped reaches were 5 km long.

The information is presented following the legend:

.Flood hazards
.Surficial Deposits
.Slope Stability
.Rock Units
.Hazard Location

Flood Hazards. The flood-prone area was divided in three areas, with a defined probability of occurrence (25, 50 and 100 year's flood). The 100 year's flood represents the maximum in the XX^{th} century (flood of 1930). That cover includes information on points previously damaged by floods, areas with undermining risk and concentrated runoff.

Surficial Formations. This category represents the terrace system, the hillslope deposits (alluvial fans...) and in-channel formations (lowest terraces, riffles, meanders, chute channels...)

Slope Stability. Landslides were classified attending their typologies and relative age (ancient -recent). Mapable man-made accumulations of any kind were represented.

Rock Units. Geological map units were grouped and generalitzated in to two rock types in relation to mechanic criteria (excavability): *Soft Rocks* (excavable) and *Hard Rocks* (not excavable).

Hazard Location. This category summarises all hazard data obtained in the previous categories. Hazard Points were classed in two categories:
Risk Point: Used Areas under hazard
Problematic Point: Areas that could increase the hazard in their vicinity (river constriction, unstable area over the channel....)
All these points has been located and explained in an special box (Hazard Location).

The map is completed with the long profile and the main cross-sections of the studied reaches, both containing the results of the hydraulic modelling and the available high water marks. Processed data on flood depths, frequencies and discharges are also represented. The map thus shows a complete picture of that area.

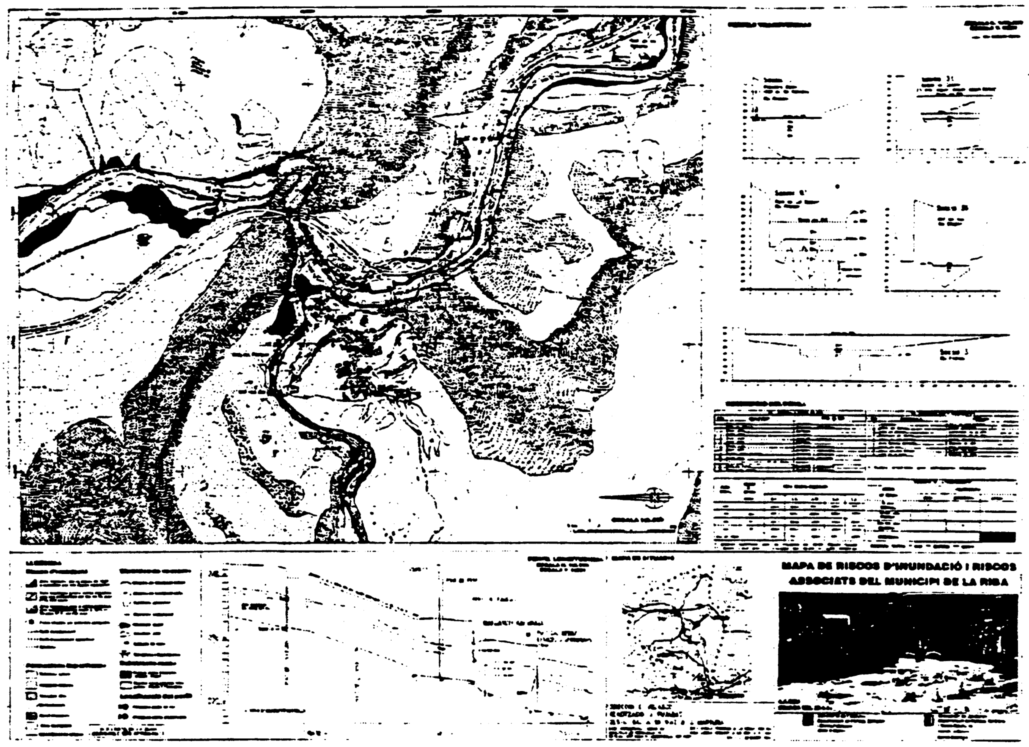


Fig 3.-La Riba flood-hazard map (original scale 1:5.000)

Description of results:

Hazard and Vulnerability synthesis

The vulnerability is manly concentrated in two areas. The first area is located in the confluence, where the tributary river confludes orthogonaly to the main river producing the obstruction of one of the rivers. This obstruction produces the undermining of the riverbank in front of the confluence. The riverbank is excavated in a soft formation. The second area is located 200 metres downstream from the former, where a stone arch bridge obstructs the flow and causes the flooding of the urban area.

Landslides are located close to a main lithogical boundary between the hard and soft rock units, also minor unstable landslides are located in hillslopes over the river banks. Main recent landslides are related to river undermining and cuttings.

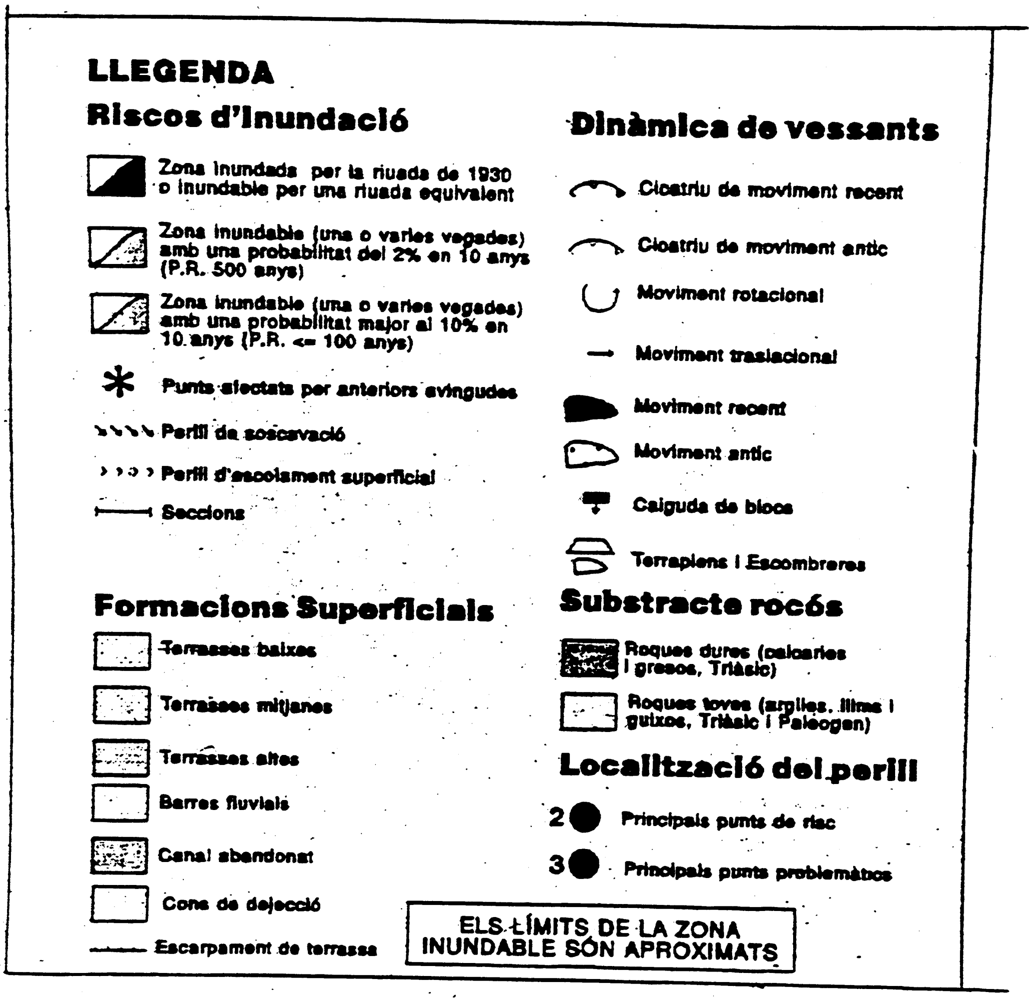
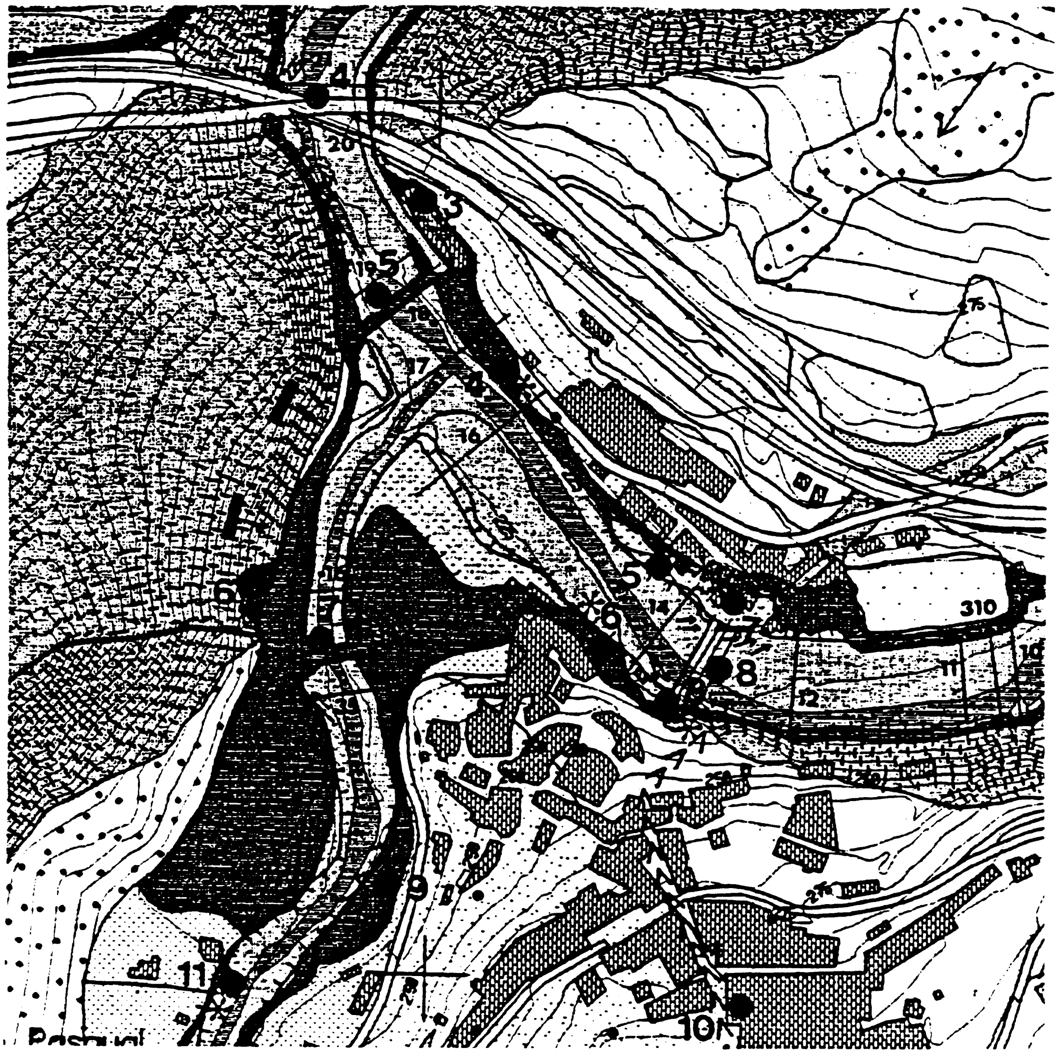
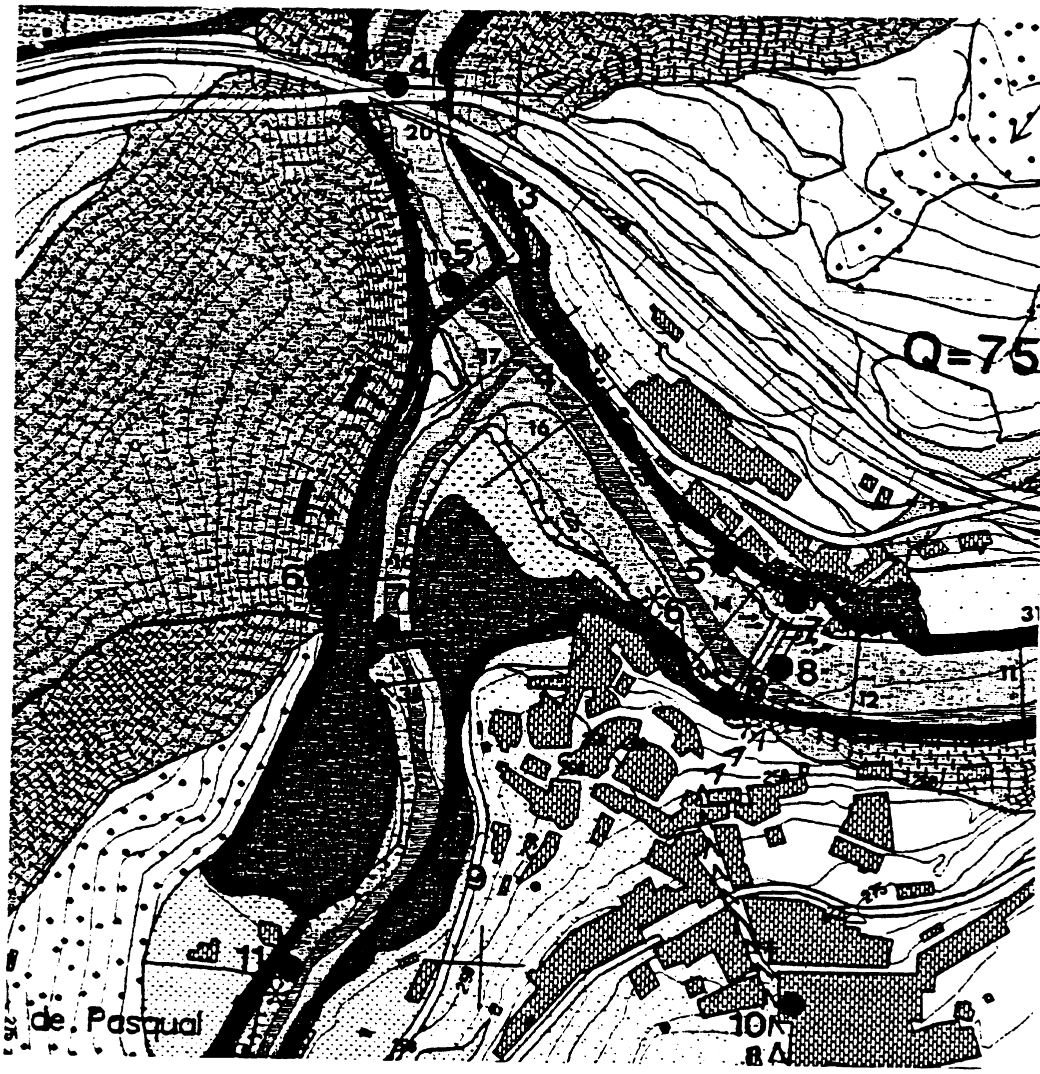


Fig 4.-A) Flood and related hazard map legend,



B) Comparaison between predicted (upper map) and real (lower map) values reached in the flood of 1994 in the confluence area.



.Reviewing the map: The flood of 1994.

During autumn 1994 heavy rain affected the Prelitoral areas of Catalunya, floods occurred in many rivers.

The mapped rivers experienced a high flood which caused severe flooding in the village of La Riba. Peak discharges at La Riba were estimated in 800 m^3/s. The tributary, Brugent river, reached levels higher than those of 1930's flood, the biggest of this century. High water levels of Francolí stands clearly below the 1930's maxima (estimated on 1.600 m^3/s by NOVOA 1974).

Flooded areas in 1994, in the tributary river, corresponded to the areas flooded in the flood of 1930 (100 year's flood). In the Francolí, the flooded areas in 1994, reached only the intermediate area (50 year's flood).

Damages were located at previously-defined hazard-points, and specially in the high vulnerable areas of the river confluence and downstream near the arch bridge. High waters destroyed the bridge over the Brugent river and the upper part of the arch-bridge over the Francolí (damages over that bridge has been close to those occurred in the flood of 1930) and flooding the riverside buildings. Upstream of the confluence, the main river reached highest stages due to a blockage effect of the tributary. In that point buildings were flooded up to the first floor. In front of the confluence, the strong undermining of the riverbank caused the destruction of a historical water-mill.

In the days following the flood, a deep landslide affected the whole riverbank in front of the confluence area, and people from several houses were evacuated. In the Brugent valley a rotational sliding of about 200 metres width took place with the consequent risk of total obstruction of the river. Unstabiltzation of muddy waste deposits from the paper factories caused a big traslational landslide, which fortunately did not reach the river.

Map previsions related to flood extension and flood damages were very similar to those produced during the flood. Predictions of flood depths showed a good adjustment except for upstream of confluence point where flow blockage occurs. Modeling confluence phenomena is out of the up to now available hydraulic-models capabilities.

Main landslides were out of the previous landsiled areas but all of them occurred in areas classified as susceptible. These phenomena are hardly predictable but in this case main landslides were related to antropogenic action (drainage alterations, cuttings in unstable hillslopes and landfiling over impervious slopes).

Fig 5.-The stone arch bridge of La Riba. A)After the flood of 1930
(Revista Brugent) and

B) During the flood of 1994 In both floods top-road structures were destroyed.

Conclusions

The Case-study La Riba map proves the feasibility of mapping flood-prone areas at detailed scale. The map provides an overall information on flood and associated hazards. This information allows to visualize a fluvial reach and all the hazardous phenomena susceptible to occur in flood times. The good matching of the predicted flood extension to that achieved in the flood of 1994 shows the accuracy of the method.

Post-flood review reveals the limits of prediction of the hydraulic modeling where complex flow patterns occurs. This study shows that qualitative approaches on the fluvial system coupled with the analysis of historical and social information considerabily improves the results of a merely quantitative approach. This ***integrated approach*** of qualitative and quantitative methods, in flood hazard mapping, constrains predictions and provides a general understanding of flood behaviour.

That case-study map exemplarizes the behaviour of Mediterranean rivers. Most of the data obtained in the study are very useful at basin scale (i.e. new flood frequencies were defined). The understanding of our rivers needs the collection of field hidrological-morphological data, very scarce up to now. Predictions based on available software models for flood analysis (based on Nord-European and American rivers) should be regarded with attention were applied to our rivers.

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