ITALY: *PIEMONTE REGION METEO-HYDROLOGICAL ALERT AND REAL-TIME FLOOD FORECASTING SYSTEM*

D. Rabuffetti, S. Barbero[1]

Abstract. Information is provided on the approach and experience in flood management in the Piemonte Region. Actual practices comprise mainly: (i) the structural mitigation of floods; and (ii) non-structural safety measures subdivided into land use planning and emergency plan activation through hydrometeorological forecasting and the development of an Alert System for flood forecasting and warning. Of particular interest is the comprehensive description of the hazard map developed to establish the interaction between human activities, river and hill slope dynamics, of the risk scenario identification as well as of the Information System for Operational Flood Forecasting

1. Location

The Piedmont Region, located in the northwestern part of Italy, is a predominantly alpine region covering 25,000 km2. It is situated on the Padana plain and bordered on three sides by mountain chains covering 73% of its territory. The entire area drains to the Po River. The Upper Po River basin is characterized by a number of fast responding boulder-lined tributaries from the Alps (North and West) and Appenines (South). The mid Po River is moderately flat and contains wide floodplains and a meandering cobbled and sandy riverbed.

The mountainous part of the territory is mainly natural and covered by forest and the pastures have been decreasing for the past decades. The lower areas are mainly used for agriculture and the land-use patterns have not changed significantly. The border between mountain and lowlands, as well as the major valleys, are more populated and industrially developed. In these zones the majority of structures and infrastructures have been established in the last decades, with a very important change in the land-use patterns. More than 4 million inhabitants live in this complex physical and climatic environment. The city of Turin (1 million inhabitants) lies alongside the Po River and Alessandria (a quarter million inhabitants) lies alongside the Tanaro River, a major tributary.

2. Nature of floods

The complex hydrological regime of the area has an obvious impact on the flood response of catchments. In the winter, the Alps are covered with snow and most of the precipitation is stored in that form and glacial depth. In the spring the snow melts, aided by rainfall, which can result in the spring floods. Summer rainfall can be stormy and the bare, rocky Alps give high runoff with a rapid response. Autumn rainfall can be heavy and prolonged, mainly caused by southwest wind coming from the Mediterranean. The Appenine range has a lower altitude than the Alps, but suffers from warm Mediterranean currents that can carry a large volume of precipitation, particularly in the autumn and spring. Generally, the major floods occur during the autumn and spring.

Many man made structures, such as bridges and weirs for water diversion, have been constructed across and along minor or main rivers. These interact with the flood waves propagation and often can produce local but heavy flooding problems. At the same time, many flood defence structures have been built, such as levees along the rivers in the valleys and in the lowlands. These are often very old structures as they are linked with the agricultural and industrial exploitation begun in the

[1] *ARPA Piemonte (Regional Agency for Environment Protection) - Corso Unione Sovietica, 216, 10134 Torino, Italia
Tel +39 011 3169 306, E-mail: idrologia@regione.piemonte.it*

early 20th century. Their failure, which occurred for example in the most recent major flood events (November 1994, October 2000), has been the cause of a great amount of damages.

On the basis of historical data, available since the year 1800, the Piedmont Region has been hit by meteorological events that caused flooding once every two years on the average. The flooding of the lowlands, as well as flash floods of mountain rivers, produced damages which in cases were important from a regional scale point of view (not only restricted to a village or to a part of a village); damages to structures and infrastructures and, eventually, loss of human lives were also the result of these events.

3. Flood management and mitigation measures

Flood management practices are highly influenced by the natural peculiarities of the Piemonte Region. Steep and impetuous streams flow down the Alps into the Padana Plain, characterized by flash floods and high mass transport. In the lowlands the four main rivers are affected by the rapid floods of their tributaries and can produce fast and unpredictable responses. This natural landscape does not allow coping with floods in an on-line way during the flood event occurrence. Therefore, the actual practices comprise mainly: (i) the structural mitigation of floods; and (ii) non-structural safety measures subdivided into land use planning and emergency plan activation.

As regards *structural measures*, the most common flood mitigation structure used for the main rivers in the lowlands is by means of levees. These are generally efficient and allow mitigating the effects of the major floods. The important problem with these structures is the possible and unpredictable spot collapse that can produce high and localized damages (as mentioned above). In the last years the design of retention reservoirs has started for some rivers in the region, but their construction has not been initiated yet.

The mountain streams are generally natural and human intervention is restricted to weirs designed for erosion and bed-load transport mitigation. Reforestation and the standard structural bio-engineering measures are widely used in small mountain catchments for mitigation of hilltop erosion and shallow landslides that are the main source of mass transport during flash floods, often enhancing the damages produced. Bio-engineering practices have been sponsored by regional and local authorities due to their reduced impact on landscape.

As regards the *non-structural measures* applied, the first of these concern the general management of the territory. The *Po River Authority*, which has the task to define the guidelines for planning the land use and its development, has produced the *Plan for the Hydrogeological Order*. It is a comprehensive hazard map highlighting the interaction between human activities, river and hill slope dynamics. It identifies the areas in the catchment exposed to hydrogeological risk; three levels of hydrological hazard are defined along all the main rivers. These levels establish whether buildings are or not permitted, or where human activities are permitted only in accordance with the objective of the area, or where there is need to enhance the safety level by means of non-structural measures in accordance with Civil Protection authorities as established by the National Law (see below). The Plan also is concerned with hydrogeological hazards on hill slopes due to shallow landslides and debris flows and includes identification of areas prone to this risk.

Insurance against floods or hydrogeological damages has as yet not been used, but some discussion at political level is currently going on.

The other *non-structural real-time* measure for flood mitigation was the setting-up in 1978 of a specific organization for flood forecasting and damage mitigation from natural hazards, based on an *Alert System* for the issue of hydro-meteorological forecasts aimed at the early warning for Civil Protection purposes.
The National Law 225/92 defines and organizes emergency planning in Italy in phases: survey, warning, alarm and emergency, activated successively on the basis of the forecasted events and

their observed evolution. The main phenomena taken into account are floods in the main rivers, flash floods and shallow landslides for small mountain or hill catchments.

Risk is coded into three levels: normal situation, low and high danger. This is very simple scheme that allows avoiding as much as possible subjective interpretations.

Under this framework, *Survey* is the continuous activity of the Central and Regional structure for hydro-meteorological forecasts. *Warning* implies the activation of local operating rooms when some critical meteorological event is forecasted. If the event starts and direct observations of the phenomena suggest high level of danger, the *Alarm* phase is activated and population is alerted while visual recognition of the phenomena starts. *Emergency* safety measures are ultimately taken if required.

As regards risk scenario identification, the Alert System accounts for the following typologies of risk: (i) flood risk due to long and widespread rainfall on large catchments; flooding of major rivers involving villages and infrastructures in the valleys and the lowlands are the main expected effects; (ii) localized risk due to short and Intense storms on smaller areas; critical phenomena are restricted to small catchment rivers, as flash floods; on hill slopes, as shallow landslides; and on urban areas, as failure of the drainage system; (iii) snow risk caused by heavy snow in lowlands producing interruptions of the communication network.

The key point of the regional Alert System is the definition of homogeneous areas for vulnerability assessment, by means of the subdivision of the territory into homogeneous areas in terms of meteorological aspects and hydrological response during the occurrence of extreme events. Criteria for parameterization are mainly hydrological, watershed boundaries, and political, local authorities involved in flood management.

The *SSRN (Room for the Situation of Natural Risks)* is a 24 hours operational centre with two main tasks: (i) hydro-meteorological survey - a group of technicians ensures that all the information systems always run properly and all data from the network are received; (ii) hydro-meteorological forecasts - experts from various sectors organized in specific operational teams (geology, meteorology, hydrology, snow) analyze the events and decide which actions, if any, are required; forecasts and warning bulletins are issued pointing out for each alert zone the expected risk typology and the corresponding danger level. These are then provided to Civil Protection and the territorial organizations that deal with the management of the events.

The *Information System for Operational Flood Forecasting* is a decision support system for real-time flow forecasting, combining an advanced database with hydrological and hydrodynamic modeling and a real-time forecasting system, all wrapped-up in an ArcView GIS environment. Telemetry data is imported to the system from the hydro-meteorological network. With the use of real time observations as input short terms forecasts (6-12 hours), are very precise in term of peak discharges and arrival times. This kind of real-time information has proved to be very useful for Civil Protection emergency measures.

4. Institutions responsible for flood management

The agencies involved in flood management and working in close collaboration are the *Regional Directorate of Technical Services for Preventio*n for survey and forecast through the Alert System, and *Civil Protection* for the organization of safety plans and activation of alert procedures.

There are also the agencies for power plant or irrigation management that should be involved in the mitigation of floods through on-line management operation on reservoirs or diversion dams. However, due to the rapid flood response of the mountain streams, this type of operations is difficult to be planned. However, during major events there is sometimes an informal exchange of information with those agencies, but this collaboration is difficult to be formally scheduled.

Exchange of data is the first important step to start any collaboration with those agencies and there are now some pilot projects to create a standard communication. Within *Interreg III* (*European Fund for Interregional and Transnational Collaboration*) a study is being undertaken to define which are the reservoirs that can contribute to flood mitigation with an off-line exchange of data, in order to define the best policy for the dam regulation.There is also a daily exchange of information and observed data with other Italian regions, as well as with Switzerland. This is formally regulated and is often the basis for developing common projects.

As regards passive defence from floods there are many institutions with overlapping responsibilities. The structural design, that is the construction of levees or reservoir for flood mitigation, is one of the tasks of central as well as local authorities, depending on the importance of the river involved, while the non-structural measures (development of policies for flood plain management and land use regulation) are normally taken by central or regional authorities. Cooperation between these agencies is limited to data exchange.

Finally, local communities are strongly involved in flood mitigation in three different activities: (i) the design of the emergency plan at local scale, in accordance with the requirements of the National Law for Civil Protection; (ii) the elaboration of such plans, on the basis of studies and analysis about flood and hill-slope dynamics for the definition of the best procedures to face the critical events; the different local emergency plans are then evaluated and organized at regional and national levels; and (iii) involvement in local groups of civil protection volunteers in emergency actions during critical events as defined in the emergency plans.

5. Main lessons learned

- In the environmental context described it is almost impossible to cope with floods during the evolution of the phenomena. The flash floods generating on the river network prevents the opportunity to manage the events. For this reason, the most important activity in coping with floods is provision of an early warning to the Civil Protection authorities, so that all the safety measures predefined in the emergency plan can be organized in time. The objective of the system is mainly focused on limiting human losses trying to limit hazardous activities during floods, while the active defence of structures, infrastructures such as streets, bridges or railways, and villages is almost impossible to be achieved.

- To obtain an efficient warning for Civil Protection, it is also necessary to use quantitative precipitation forecasts, which may introduce a great amount of uncertainty. The “false alarm” rate in this phase can be very high due to uncertainties in meteorological forecasts and, as it is well known, a high false alarm rate normally results in a fall of reliance by people, to be avoided as much as possible.

- The approach described has been developed and improved in the last 10 years. Comparing the big flood events of 1993 and 1994 with the most recent of October 2000, the result can be seen in a significant reduction of human losses.

- The results of the information system for flood forecasting were very useful during the large October 2000 flood event, but this has been the only large event during which the system was operating, so it is difficult to make a precise comparison with other cases. However, as far as minor floods are concerned, it surely has allowed a significant improvement of the warning system, helping decision makers to discriminate between hazardous and normal weather situations and in taking the right decision with danger level forecasts.