Hydrological Extremes: Understanding, Predicting, Mitigating (Proceedings of IUGG 99 Symposium HS1, Birmingham, July 1999). IAHS Publ. no. 255, 1999.

Flooding in monsoon rivers: complex hydrometeorological risk analysis

BORIS GARTSMAN
Pacific Institute of Geography FEB RAS, Radio Street 7, Vladivostok 69041, Russia

MARK KARASYOV
Far-Eastern Hydrometeorological Research Institute, Fontannaya Street 24, Vladivostok 690600, Russia
e-mail: hydromet@online.ru

Abstract Hydrometeorological risk is understood as the probability of the occurrence of hazardous events and is estimated from long series of observations. Here a complete analysis of risk related to flooding in monsoon rivers has been carried out. The analysis includes a study of destructive factors; a spatial analysis of flooding with the help of scenarios produced by a multi-site stochastic model; a regional risk classification of sections of river valleys, and a construction of risk maps in different scales for using in water and land-use management.

INTRODUCTION

Generally, hydrometeorological risk is defined as a probability of undesirable and hazardous events caused by extreme values, or extreme variability, of hydrometeorological variables. A wide range of phenomena related to weather and hydrological regimes needs to be included in a risk assessment. High variability, regularity in extreme events, and significant influence on socio-economic systems belong to the general features of hydrometeorological risk. Availability of long-term observation records allows identification hydrometeorological hazards in different regions.

The role of the hydrometeorological risk assessment and control in society is essential, but it must be carried out with regard to regional peculiarities. The term "risk" is used here as the probability of a complex chain of events, i.e. an observed combination of elementary hydrometeorological events within a certain area and time frame, which is estimated based on absolute and conditional probabilities of the elementary events.

COMPLEX RISK ASSESSMENT

The summer-autumn floods, so characteristic in areas with monsoon climate, cause great economic damage. Complex risk assessment of events causing flooding and triggering erosion processes, provide important information for economic planning and environmental management on flood plains. The construction of a stochastic model includes the identification of possible elementary events, their probabilities and combination rules.

It is possible to carry out an efficient analysis of flooding and riverbed deformation with consideration of the character of channel-forming discharges passing through valleys within different geological and geomorphological conditions (Karasyov & Gartsman, 1996). Channel-forming discharges (CFD) represent the main volume of alluvium transport and, moreover, the different CFDs correspond to various types of channel and flood plain deformations. Therefore there exists a close relation between the riverbed and flood plain relief layers, the gradation of area flooding parameters (return period, depths and length), the types of channel and flood plain deformation, and the layers of the passing CFD.

A certain extension of flooding of a territory corresponds to a probability of exceedence of a certain water level, which is defined by its frequency curve. With certain assumptions it is possible to consider deformations of river beds and flood plains as discrete processes, associated with the properties of CFDs, as described by Makkaveev (1955) and further developed by Chalov & Bely (1975). Probabilities of these events are defined on the basis of the frequency curve of maximum discharges during floods. On the basis of these data the probability of any combination of undesirable or dangerous effect on any economic object can be calculated as the joint probability of independent or dependent events.

SPATIAL COMBINATION OF HYDROLOGICAL EVENTS

In the analysis of spatial combinations of elementary events during a flood, two essential problems must be addressed: the need for modelling of multi-site correlated hydrological events and a probabilistic description of damages.

The first problem is connected to determination of the frequency of a hydrological event in a basin at a regional scale. This problem has been solved here by means of normalization of nonsymmetrical correlated hydrological sequences and ortogonalization to a system of uncorrelated normal distributed random quantities. This procedure yields solutions to the following two problems. First, using a random generator of the independent normal distributed random quantities, hydrological sequences of any length with desired features can be obtained. Second, a direct transformation of vectors given for any individual year permits estimating its flood frequency as a product of probabilities of independent random quantities.

Flood frequencies estimated as described above for several stations in a river basin might differ greatly from those traditionally obtained. This is explained by the utilization of independent information on less correlated data from separate parts of the basin. An example of flood frequency evaluation for a basin is presented in Fig. 1. The analytical curve valid for one station is the upper boundary for evaluations corresponding to a group of stations.

In general, the group evaluation of probability cannot correspond to a particular maximum discharge at a downstream gauging station, as the same maximum discharge may be observed under different combinations of events within the basin. The same conclusion is valid also for such a feature as the total flood damage in a basin.

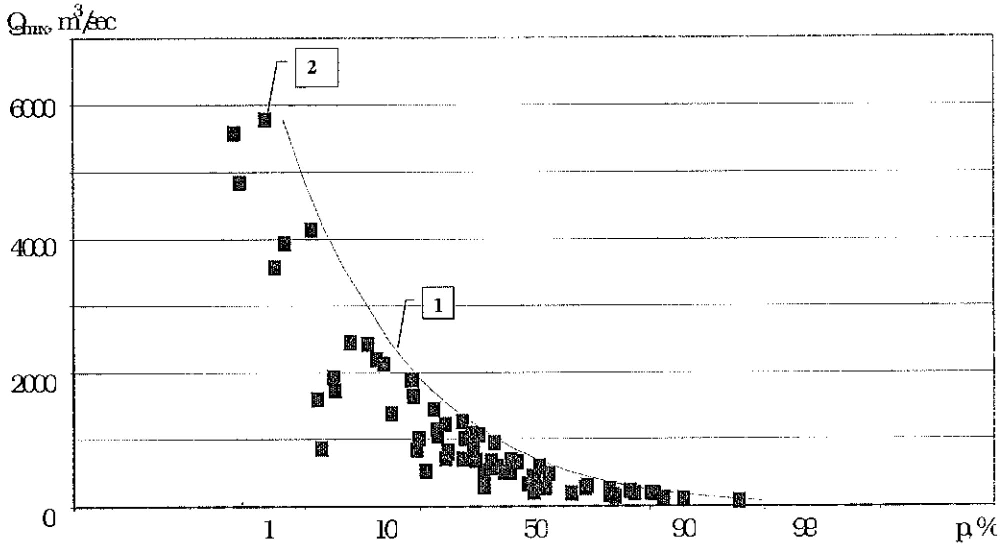

Fig. 1 The basin evaluation of flood frequency for the Razdolnaya River near Terehovka: (1) the analytical curve constructed for one downstream gauging station; (2) evaluation for a group of four stations in the basin, including the downstream gauging station.

Consequently, it is necessary to assess of flood damages of all economic objects in the model area with account of risk zone and flood category. Modelling the sequential hydrological events for a group of stations in the area and converting them into sequences of damages yields a direct risk assessment for different flood volumes based on their relationship to nearly stationary and well described natural processes.

RISK ZONES AND RISK MAPS

Actions related to flood protection must take into account the whole complex of destructive factors such as the flooding of area (return period, depth, length), river bed deformations and erosion–sedimentation processes on the flood plain. The delineation of risk zones must take into account the possible complex of defensive actions, such as excluding radical changes of hydrological regime on flooding lands by economic activity.

A regional classification of morphologically uniform sections of river valleys (developed for the Primorye region of Russia) is based on existence of characteristic features of different riverbed deformation types under different geological and geomorphological conditions (Karasyov & Gartsman, 1998). In this effort the following main relief sections are distinguished: the upper section, which includes medium high and low mountains; the intermediate section, which includes hills and denudation plains; and the lower section, which includes high and low accumulation plains. Rivers are subdivided into transit (basin area of more than 10 000 km^2) and local (basin area of less than 10 000 km^2). Analysis of hydrological regimes permitted subdivision of the floods into seven categories (in descending order).

The regional classification named earlier distinguishes among nine types of riverbed deformation processes. Each type is considered together with one or two morphological types of channels; possible or limited conditions for development of riverbed deformation; different potential for flood plain development processes (without flood plain, limited potential, lithological constraints, no constraints), and the type of the CFD curve. The classification reflects the total degree of risk of flooding and development of erosion processes. It includes of more than 30 rank elements.

On each morphological uniform section the low, average and high risk zones, as well as a zone of permanent danger, are delineated. The following frequencies are used as zone boundaries: exceedence frequencies of 1, 10 and 50% for limited conditions of flood plain shaping; exceedence frequencies of 1, 25 and 50% for conditions with lithological constraints on the flood plain width; and exceedence frequencies of 1, 25 and 75% for conditions without constraints. Differences between zones (return period, nature and intensity of processes of flooding and erosion) may serve as guidelines for restrictions on the economic activity, as well as the efficiency of the different types of defensive actions, such as increasing the height of the levees; dams; channel regulations; runoff regulations etc. Risk maps of undesirable and dangerous events, corresponding to future floods, are prepared at three levels: regional, district (basin) and large scale.

CONCLUSIONS

A purpose of the hydrometeorological risk concept developed here is a rapprochement between, on one hand, a broad qualitative notion about the risk (as dangers) and, on the other, a quantitative assessment of this risk. The risk analysis, connected to floods takes into account the whole ensemble of destructive factors. The risk in terms of a probability is here defined on the basis of absolute and conditional probabilities of elementary events. The probability evaluation of the elementary events is executed by direct or indirect methods on the basis of hydrometeorological data series. An investigation of dependencies of risk on landscape parameters enables a broad regional generalization of the risk assessment and creation of risk maps of different scales. These are important in particular for decision making and water and land-use management in regions with limited data.

REFERENCES

Chalov, R. S. & Bely, B. V. (1975) Районирование территории Сибири по характеру руслоформирующей деятельности рек (The regionalization of territory of Siberia on the character channel-forming activity of rivers, in Russian). *Met. Hydrol.* **12**, 43–49.

Karasyov, M. S. & Gartsman, B. I. (1996) Assessment and mapping of risk of disadvantage and dangerous events, in accordance with floods in the river valleys of Primorye. In: *Intercarto 2: GIS for Environmental Studies and Mapping* (Proc. Irkutsk Symp., 1996), 99–102. Institute of Geography SB RAS, Irkutsk, Russia.

Karasyov, M. S. & Gartsman, B. I. (1998) Морфология русел как индикатор гидрологического режима речных долин (Channel morphology as indicator of hydrological regime of river valleys, in Russian). In: *Hydrology and Riverbed Processes* (Proc. Academy of Water Facilities Sciences 5), 183–196. Moscow, Russia.

Makkaveev, N. I. (1955) *Русло реки и эрозия в её бассейне* (*Channel of River and Erosion in its Basin*, in Russian). Publ. Academy of Sciences USSR, Moscow, Russia.