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EVALUATION OF THE PROBABILITY OF INUNDATION OF ROME

USING MONTE CARLO ANALYSIS

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1. INTRODUCTION

Rome was frequently inundated by Tiber river in the past, until the construction of the river walls called “*muraglioni*". Between the end of XIX and the beginning of XX century, these walls were set up to convey floods comparable with the catastrophic flood wave occurred in 1870, which inundates the monumental centre of the city.

Beside the construction of these river walls, many river-training works were performed in XX century, including the building of several dams in the Tiber basin upstream Rome; moreover in this last century only one significant flood occurred, in 1937, and the damages were marginal. During this flood, however, water overflowed left and right banks close to the ancient bridge “*ponte Milvio*” located upstream *muraglioni*, which were non overtopped, and inundated relatively small riverine areas. For these reasons it is now commonly accepted that Rome is quite safe from floods (Natale and Savi 1998; 2004).

But, in the last decades, the city significantly expanded along the water course upstream and downstream the reach protected by *muraglioni*. This study is aimed to delineate possible flooding scenarios and to evaluate the residual risk of inundation of Rome.

The historical series of water stages measured in Rome at Ripetta gauging station were influenced by outflows occurred immediately upstream the urbanized area, where no gauging stations are available. Therefore, the observations at Ripetta are not truly representative of the flood conditions upstream the urbanized area; to overcome this problem, a Monte Carlo procedure is applied to perform the flood risk analysis.

2. MATHEMATICAL MODEL USED TO SIMULATE THE INUNDATION SCENARIOS

In order to simulate in detail the hydrologic cycle during a flood, from rainfall to inundation of Rome, the following set of mathematical models was developed and utilized (Natale and Savi 2004).

1. <u>Stochastic model</u> *KORNA* of atmospheric precipitation process, considers rainfall distributed in space and time. With this model we generated 100 series, each of them 1000 years long, of daily rainfalls over 9 areas covering the Tiber valley. Daily rainfalls were disaggregated to hourly rainfalls to give better representation of flood formation in small basins (Kottegoda *et al.* 2002; Kottegoda *et al*. 2004);

2. <u>Hydrologic module</u> of *TEVERE* model performs rainfall-runoff transformation in the 40 sub-basins of Tiber. With this model we transformed synthetic rainfall to produce flood hydrographs in the upstream section of lower Tiber watershed and in the main tributaries;

3. <u>Hydraulic module of</u> *TEVERE* model simulates flood wave propagation in the lower Tiber hydrographic network (from *Corbara* lake to Tyrrenian Sea);

4. <u>Hydraulic model</u> *URBE* simulates the inundation of the city of Rome. The urban road network was represented as a channel network constituted by 200 reaches and 300 nodes (Braschi *et al* 1990, 1991, 1992).

Computations were carried out considering two different risk scenarios: a) a fraction of the volume in *Corbara* reservoir was considered available to detain inflow, b) no storage effect of *Corbara* reservoir is imposed and, consequently, the outflow discharge was assumed equal to the inflow.

3. FREQUENCY ANALYSIS OF PEAK DISCHARGES

The sample of 75 yearly maximum peak discharge observed at Ripetta gauging station from 1922 to 2002, which is partially influenced by the effects of Corbara reservoir - which operates from 1962 - was modified and the values of the naturalized peak discharge observed during historical floods, free from the effects of *Corbara* reservoir, were estimated. Moreover the values of the observed peak discharges during 1870, 1878, 1900 and 1915 floods were added to the sample.

This sample was fitted by a censored GEV probability distribution: its parameter were estimated according to the Method of Partial Probability Weighted Moments (Wang 1990).

The empirical sample of yearly peak of naturalised discharges at Ripetta is plotted and compared to GEV theoretical probability distribution and to Monte Carlo numerical probability distribution.

The values of discharge computed by means of Monte Carlo procedure for return periods between 100 and 1000 years are lower than the values computed according to GEV the probability distribution of about 5% on the average. The probable reason is that:

(a) the data set used to calibrate the mathematical models did not include the exceptional storms and floods occurred at the end of XIX century and the beginning of XX century (the four floods occurred before 1922)

(b) the GEV distribution function significantly overestimates peak discharges for high values of return period since the frequency analysis does not consider the reduction of the peak discharge caused by the overtopping of the banks immediately upstream the city of Rome.

4. SCENARIOS OF INUNDATION

The inundation of the urban areas in Rome was frequently due to backwater effects in sewers or rising of the water table, so that cellars, basements and low lands were flooded. The increase of the water levels in the urban network was quite slow and flow velocities in the road network were negligible.

Most catastrophic floods overtopped banks upstream *ponte Milvio* and the outflowing currents propagated in the road network: in this case the flow velocities were potentially dangerous and several casualties occurred. Nowadays Monte Carlo procedure indicated that this last kind of inundation could occur as the peak discharge at the bridge of *Ferrovie Nord* railways (located about 10 km upstream *ponte Milvio*) is greater than 3200 m^3/s.

For each of the return periods considered in the analysis, Monte Carlo procedure allowed to estimate the frequency of banks overtopping and identify the scenarios of inundation synthesised in maps of the flooded areas, which show also maximum values of water depths and flow velocities.

5. CONCLUSIONS

The statistical estimation of a very improbable event such as the inundation of the monumental centre of Rome must be considered highly uncertain; the application of a Monte Carlo procedure and the analysis of the scenarios of inundation allow to emphasize the relationships between several factors, natural or human, affecting the formation and the development of the flood.

The monumental centre of Rome is now safely protected by *muraglioni* and the inundation by overtopping of river walls should be considered an improbable event.

Corbara reservoir retards the arrival of the flood wave from the upper Tiber and avoids this flood wave and the contributions of the main tributaries in the lower portion of the basin add together up.

It follows that peak discharges in Rome get reduced and we can estimate that outflows at *ponte Milvio* have a greater than 150 years return period. In any case the water volumes flowing on the streets are small and only for less frequent floods (about 1000 years of return period) the monumental centre of the Rome can be considered flood prone area.

These conclusions can be drawn considering the present situation of the Tiber valley upstream Rome. In the future, the hydraulic safety of Rome depends on the possibility to maintain volumes for the expansion of floods in the Tiber valley. When these storage volumes will be reduced, the hydraulic risk shall increase significantly.

6. BIBLIOGRAFIA

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