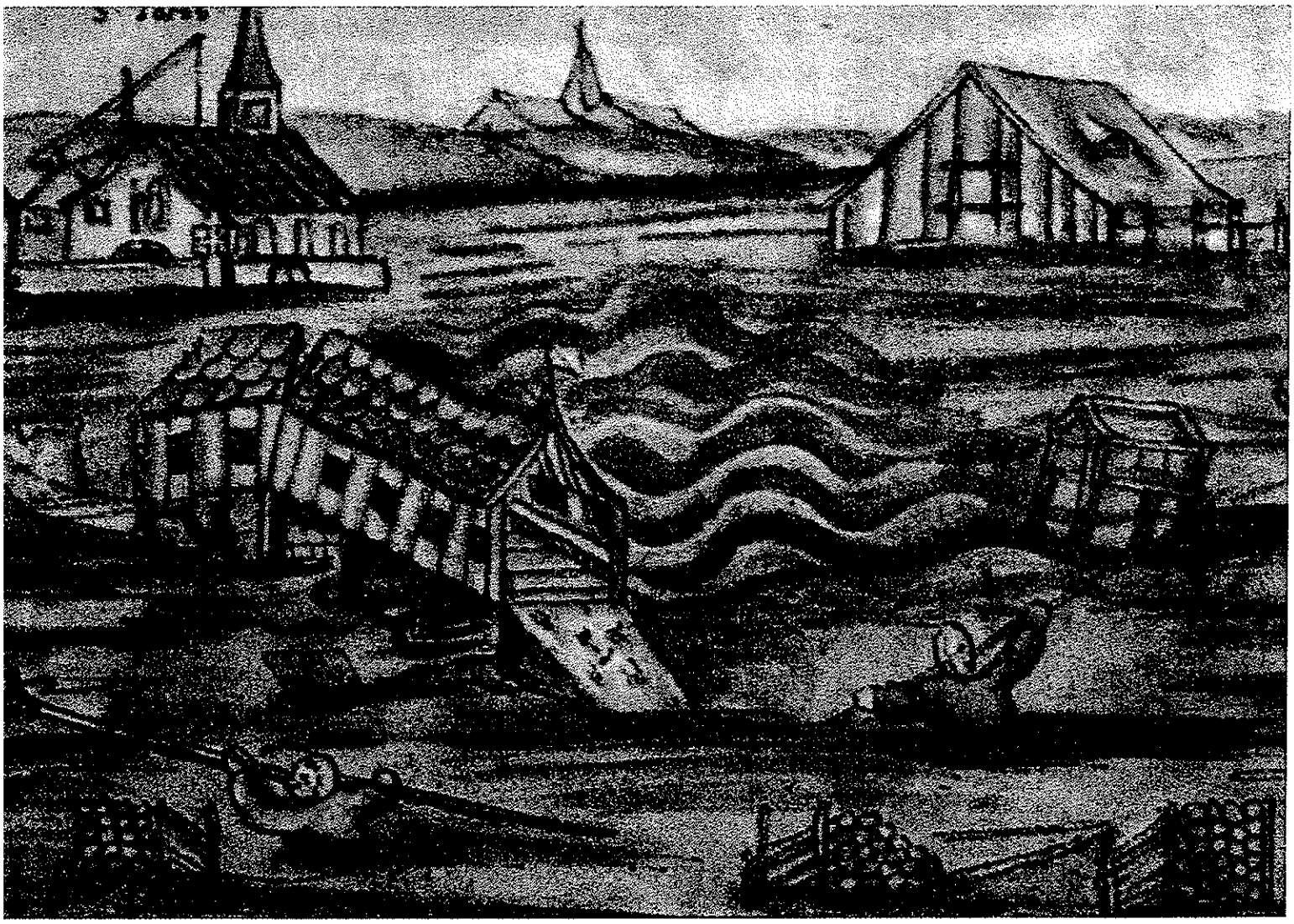
Palaeofloods, Historical Data & Climatic Variability

Applications in Flood Risk Assessment



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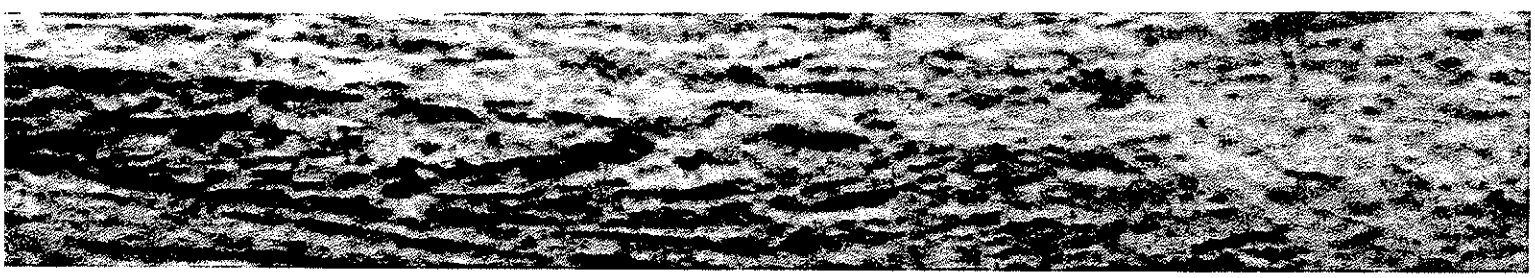

52. EFFECTS OF HISTORICAL URBAN DEVELOPMENT ON FLOOD HAZARD: THE CLAMORES RIVER WATERSHED AND THE TOWN OF SEGOVIA (CENTRAL SPAIN)

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ABSTRACT

The hydrologic behaviour of the Clamores urban watershed (Segovia, Spain) has been characterized for the last three hundred years, with the objective of evaluating the hydrologic impacts of the increasing of the impervious area within its watershed, due to the urban growth of Segovia. The methodology used is divided into four stages. In the first one, the rainfall- runoff process is simulated; that was yielded for recent storms with a total precipitation higher than 30 millimetres. The obtained hydrographs, as a result of implementing the hydrologic model, were calibrated by using, for each studied storm, the measured discharge in the water treatment plant of Segovia. Next, all the existing information related to the historical floods that have happened in Segovia during the studied period, as well as the historical evolution of land uses, was compiled. In the third stage, the hydraulic model of one of the considered floods, more specifically, the flood that took place on June 23rd, 1733, was accomplished. After that, the hydrologic model was run again, in order to estimate the total precipitation and the temporal distribution of this event. Finally, the hydrologic response of the urban watershed to a similar magnitude storm, that may occur in the near future, was determined. Therefore, the hydrologic model was implemented for the present-day situation, in accordance to the current land use, and likewise for the future situation, when the planned development of Segovia will occur.

1 INTRODUCTION

The conversion of rural land into urban land generates numerous adverse effects on the water quality and on the integrity of the surrounding terrestrial and aquatic ecosystems (*Novotny & Olem,* 1994). Moreover, natural flow paths in the watershed are likely to be replaced or supplemented by paved gutters, storm sewers, and other elements of artificial drainage. The most significant of these effects is the alteration of the hydrological cycle, so that several parts of it undergo major changes. Not only do flood flow, baseflow and groundwater components change, but also the contributing areas in the watershed are modified. There is a group of primary, interrelated, but separable effects on the hydrology of an area. The most common effects are: (1) a reduction in the infiltration and a decreasing in the travel time; (2) changes in peak-flow characteristics; (3) changes in total runoff (*Leopold,* 1968). As the watershed gradually develops, and consequently turns more

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impervious, it also becomes hydrologically more active, changing the stream's flow components as well as the origin of the discharge. Additionally, urbanization tends to increase both the flood volume and the flood peak. Thus, flood flows have now become more frequent in developed areas due to the progressive transformation of watersheds from rural to urban land uses. Another significant effect of urbanization on the hydrology of a watershed is the change in the recurrence interval of a given discharge (*Novotny et al.*, 2000).

In this context, the aim of this work is to assess the effects that the urban development of Segovia, Spain, has had in the modifying of the flood hazard.

2 STUDY AREA

Segovia is located in Central Spain, eighty-four kilometres north-west of Madrid. Segovia straddles an area where three main physiographic units of the Iberian Peninsula join – the northern Guadarrama piedmont (granitic-gneissic), the limestone terrains of the border of the piedmont, and the southern part of the Cenozoic Douro Basin (*Martín-Duque et al.*, 2002).

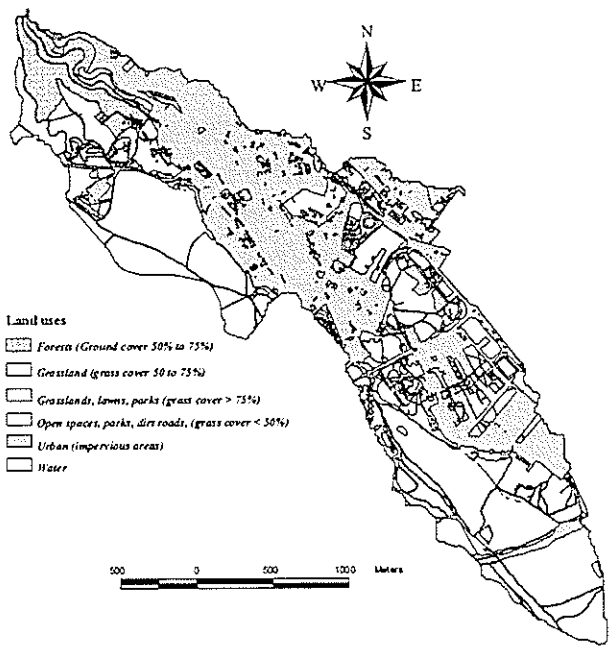

Figure 1. Existing land uses in the Clamores watershed

The Segovia region is drained by two rivers: the Eresma, on the north side of the old town, and the Clamores, that crosses the town from the south to the north. The watershed of the latter is where this study focuses. At the present day, because of the gradual urban growth of the town, the Clamores river behaves as a collector of residual waters. The channelling and covering of the Clamores river was carried out in different stages between

1893 and 1948. Only in the headwaters of the catchment, along a reach of one kilometre, the river flows in its natural channel.

The Clamores river is a tributary of the Eresma, that likewise is an affluent of the Douro river. It has an approximate length of five kilometres, whereas its average slope is 0.030 m/m. The area of its draining watershed is 5.2 km^2. Land uses through the watershed are: 40.3 % urban (impervious areas); 46.7 % open spaces (grassland, lawns, parks), with a grass cover higher than 75 %; 6.8 % open spaces, parks, dirt roads, with a grass cover less than 50%; 6.2 % woods, with a ground cover higher than 50 % and less than 75 %) (Figure 1).

3 METHODOLOGY AND RESULTS

The methodology developed in this work had four interrelated stages:

- modelling of the rainfall-runoff process;
- compilation of all the existent historical information;
- hydraulic-hydrologic modelling of the 1733 event;
- implementing the hydrological model for the present-day situation.

3.1 Modelling of the rainfall-runoff process for the current situation of the Clamores

By using hydro-meteorological methods, the rainfall-runoff process as a result of storms with a total precipitation higher than 30 millimetres has been modelled. The aim was to know the hydrological response of the Clamores watershed at the present time.

The drainage pattern of the study area, as well as the lumped hydrologic parameters, were obtained by using HEC-GeoHMS, the geospatial hydrologic modelling extension of ArcView GIS. In order to simulate surface runoff processes from precipitation, the Flood Hydrograph Package (HEC-1, HEC-HMS) was used (Figure 2). HEC-HMS consists of three components: basin model, meteorological model, and control specifications.

For the basin model, the SCS Curve Number Loss Model (*Soil Conservation Service*, 1986) has been used to evaluate loss rates, and direct runoff has been modelled by means of the Clark Unit-Hydrograph Model. Baseflow was not considered in the model.

In relation to the meteorological model, the User Hyetograph method was implemented by using the precipitation data provided by the rainfall gauge of Segovia. Regarding control specifications, a fifteen minutes time interval was selected.

Finally, the simulated hydrographs were calibrated by using the observed discharge in the waste water treatment plant of Segovia (WWTP), as a consequence of the same storms studied in the modelling of the rainfall-runoff process. In order to calibrate the model, an automated procedure was carried out, by using an objective function that measures the degree of variation between computed and observed hydrographs.

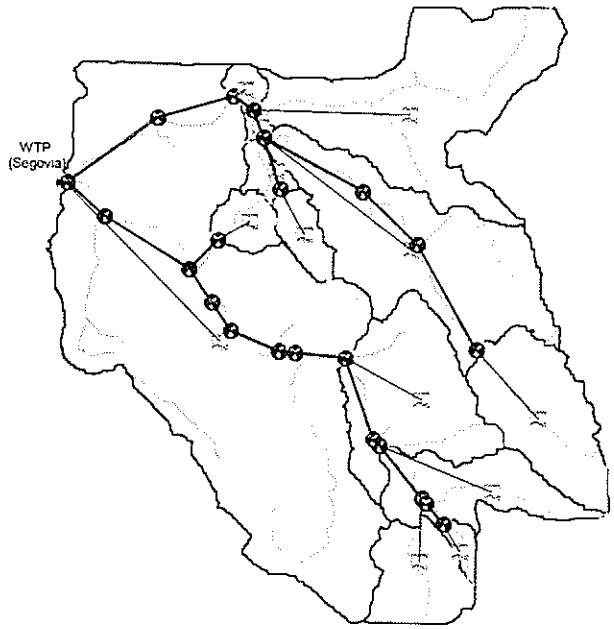

Figure 2. Schematic diagram of the HMS basin model of Segovia and its surroundings. (WWTP, waste water treatment plant)

3.2 Compilation of the historical information

The historical information about the land uses, the process of channelling and covering of the Clamores river and the historical floods, was obtained from different sources. The historical variation of land uses in Segovia was assessed through: (1) for the present-day situation, the digital urban cartography at 1/500 scale; (2) for the past situation, the urban cartography made by the city council of Segovia in 1902, and a set of aerial photographs taken in 1948, on a 1/2000 scale, were also used.

Concerning the channelling and covering of the Clamores river, all the existing rehabilitation projects of the Municipal Record Office of Segovia were consulted.
Finally, a group of historical flood chronicles were obtained at the Record Office of San Quirce Academy of History and Art. Moreover, present-day flood data were obtained by consulting the local newspaper library. Of all the considered historical floods, only the one that took place on June 23rd, 1733, was characterized.

3.3 Hydrologic-Hydraulic modelling of the 1733 flood

To carry out the hydraulic modelling of the 1733 flood, the natural channel of the Clamores river had to be rebuilt. This was made with reliability in one of the two considered reaches, specifically downstream of the Valdevilla bridge. In the other one, located in the vicinity of the Santa Eulalia church, the original geometry of the channel was obtained by considering the current slope of the main flow line of the urban watershed, as well as the known heights in some points of the natural streambed.

The 1733 event's hydraulic modelling in the two studied control reaches was made by using a Geographic Information System (GIS). The necessary geometry data for implementing the hydraulic model were obtained by means of a Digital Elevation Model (DEM) generated from a Triangular Interpolation Net (*Díez*, 2002). By using its PreRAS menu, the HEC-GeoRas extension for ArcView allowed us to obtain: geometry data of the cross section cutlines, longitudinal profiles, and main channel banks. The resulting file was imported as geometry data in the HEC-RAS software to perform a Steady Flow analysis. At the Valdevilla bridge, a peak flow of 40 cms was measured. In the vicinity of the Santa Eulalia church, in contrast, a much higher peak flow (of 135 cms) was measured. However this value could be misleading, because of the existing uncertainties in the estimated channel geometry.

The HEC-RAS-obtained water sheet heights were interpolated in the HEC-GeoRAS's PostRAS menu, with the aim of obtaining a Digital Terrain Model of the water table. Finally, the flooded area as a consequence of the 1733 event was determined by using the HEC-GeoRAS's PostRAS menu (*Flood Plain Delineation*) (Figure 3 a & b).

After that, the hydrological model was run again by assuming the most adverse one-hour hyetograph, with the objective of estimating the 1733 event's total precipitation. The obtained figure was 295 millimetres.

a) b)

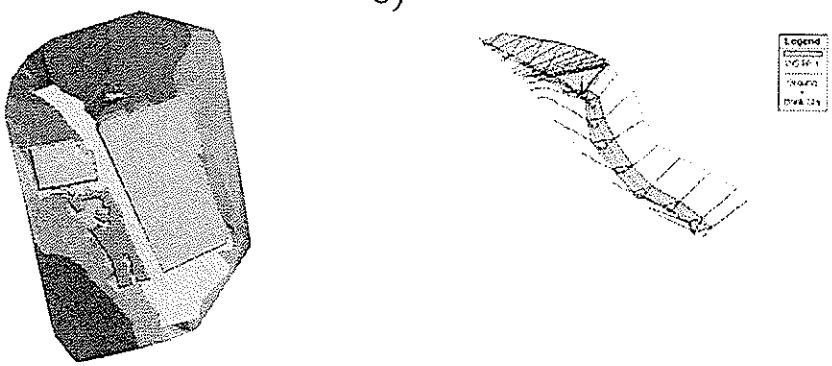

Figure 3. a) TIN with the effects of the flood in the surroundings of the Santa Eulalia church; b) perspective plot of the Valdevilla bridge during the 1733 flood

3.4 Hydrological model for the present-day situation

The hydrologic response of the urban watershed was determined considering a similar storm that would occur at the present time. Thus, the hydrologic model for the present-day situation was implemented in accordance to the current land uses and likewise for the future situation, when the new planned developments of the city takes place.

The results are that if a storm of these characteristics would take place nowadays, the peak discharge would be 35% higher than that one generated as a result of the 1733 event, whereas for the future situation, no significant change in the watershed's hydrological response is observed.

4 DISCUSSION AND CONCLUSIONS

As a main outcome, this work shows how the decreasing permeability of the Clamores watershed, as a consequence of the urban development of Segovia, has modified its hydrological response.

However, the obtained results have some uncertainties, that can be summed up in two main aspects. Firstly, it has been assumed that the whole runoff that is generated as a result of a storm flows along the collector until the water treatment plant. Secondly, conventional hydrological models, often used in watersheds with a low to moderate rate of anthropogenic modification, have been implemented in an urban watershed, where the drainage has been completely modified by human action. Currently, we are working on the resolution of these uncertainties.

Likewise, a distributed hydrological model is being developed for the Clamores urban watershed. By doing that, a more detailed modelling of hydrologic processes than that obtained with lumped parameter methods, will be achieved.

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