FLOOD HAZARD ASSESSMENT VALIDATION BASED ON THE FLOODS RISK DIRECTIVE 2007/60/EC – A CASE STUDY IN RAFINA (ATTICA, GREECE) CATCHMENT

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ABSTRACT

The Floods Risk Directive (2007/60/EC) of the European Parliament and of the Council, on the assessment and management of flood risks, adopted at the end of 2007 to support the transition from traditional flood defense strategies to a flood risk management approach at the basin scale in Europe.
The objective of this study is the implementation of the European Floods Directive in Greece. Particular we try to introduce the philosophy of flood hazard and risk mapping as a methodological framework and important tool for the successful implementation of the directive.
The used model is based on a basin scale approach as well as, data on elements at risk exposed, and data on flash flood intensities. The model is composed of two basic parts, (1) the quantification of flood hazard via hydrologic and hydraulics calculations and the evaluation of flood intensity for various flood scenarios and, (2) the determination of exposure to flood hazard using a semi-quantitative method for the determination of the danger level, which serves the purpose for the spatial evaluation of corresponding quantities.
The aim of this study provides guidelines of how to implement the steps of the European Floods Risk directive in Greece, in practice to show limitations and barriers in implementation process.

Keywords: directive 2007/60/EC, hazard assessment, flash floods, hazard and danger maps

INTRODUCTION

Increasing numbers of natural disasters have shown to the European Commission and the Member States of the European Union the importance for the protection of the environment and the citizens against those threats. There is a strong scientific evidence of an increase in mean precipitation and extreme precipitation events which imply that flood event may become more frequent (Barredo, 2007). In parallel, exposure to flood might increase across Europe due to the demographic change and increase pressure of building new houses in flood prone areas. These circumstances have produced a reaction in the European commission which endorsed in 18 September 2007 the European "Directive on the assessment and management on flood risk".
The objective of this directive is to establish a framework for the assessment and management of flood risk in Europe, emphasizing both the frequency and magnitude of the flood as well as its consequences (Moel, 2009). There are different types of flooding, all resulting in an inundation of areas outside the watercourse. In this context, EU Floods Directive addresses floods from rivers, from the sea, in ephemeral water courses, mountain torrents and floods from sewage systems. The directive requires member states to draw up flood risk management plans by 2015. In preparation for this, a preliminary flood risk assessment is due by 2011, and flood hazard and risk maps need to be created by 2013 as they serve as essential tools in the preparation of management plans. As flood risk is not constant over time, these maps (as well as the plans) need to be revised every 6 years.

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The Floods Risk Directive only defines general requirements for these three stages. Member states themselves decide on the appropriate methods for its implementation as geographical, hydrological and social differences demand specific approaches (Dráb, 2010). Therefore, the working group on floods (WGF) was established in 2007. Key aim is to support the implementation process at national level. The WGF provides a platform for the exchange of information through a series of thematic workshops addressing particular issues on the Floods Risk Directive to help member states with the implementation process (WGF, 2007).

Floods are considered one of the most important natural disasters in Europe and have caused about 100 billion Euros of damage over the period 1986-2006 (CEA, 2005). In Mediterranean countries, floods are the most dangerous meteorological hazards followed by windstorms and hail (Llasat, 2010). This is due not only to high flooding frequency, but also to the vulnerability created by various human activities. Indeed, for Mediterranean regions such as eastern Spain, southern France, Italy and Greece, floods are frequent enough to be considered as a component of the local climate. These regions have widespread and intense economic activity and high population densities with result of significant economic losses.

In Greece, flooding constituted the second most frequent natural disaster during 1928-2005 after earthquakes. Major flood events have caused 78 deaths and total costs of 719.518.000 US$ (World Health Organization, 2005). Nevertheless, the episodes of flooding in Attica Prefecture cost more lives (182 people) during the last century (1887-2011) while the cost in human lives due to flooding for the whole country during the same period was 284 people (Nicolaidou, 1995, Koutsoyiannis, 1996, Lasda, 2005, Mimikou, 2005, Karagiorgos, 2011).

In our study, we focus on the implementation of the EU Floods Directive in Greece. Particular we try to introduce the philosophy of flood hazard and flood danger mapping as a methodological framework and important tool for development of flood risk maps and management plans. This study carried out in the densely populated region of Rafina, 25km east of Athens, Greece (approx. 11.000 inhabitants; Hellenic Statistical Authority 2001). The catchment size is 129km^2 and reaches from 0 to 915 m a.s.l.. The economic development of this area is closely related to the construction of the international airport of Athens in 2001. The Rafina region suffered from severe flood events during recent years, i.e. in 1989, 1997 and 2004, which were amplified not only by land-use changes but also by multiple forest fires in recent years.

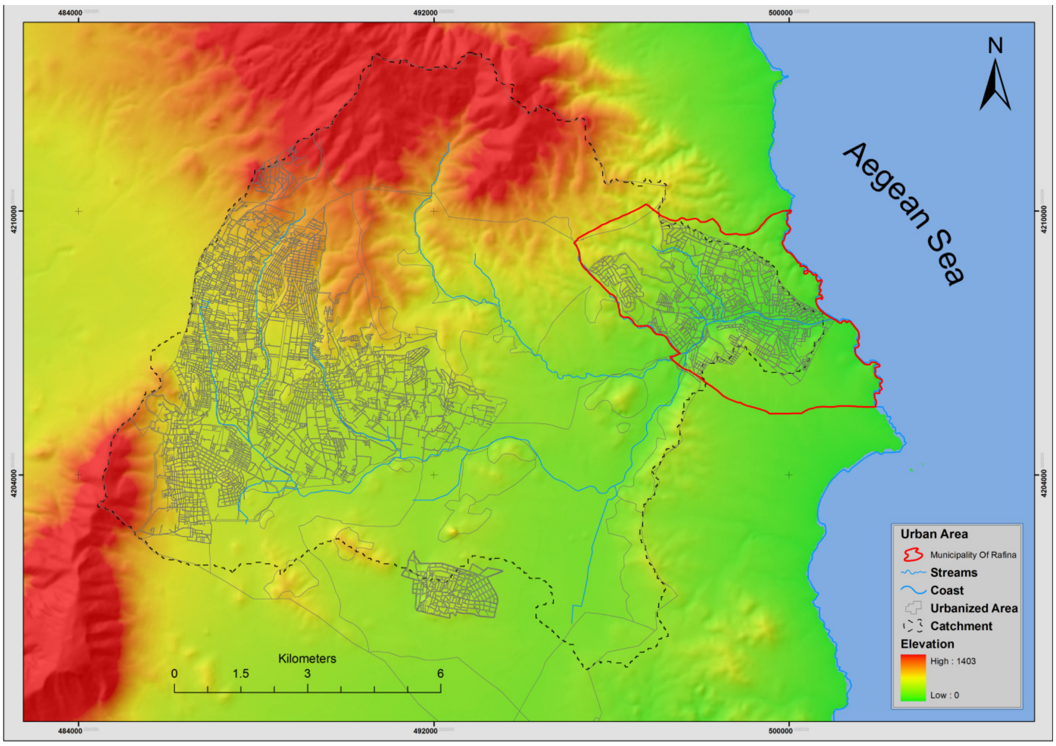

Fig. 1 Catchment of Rafina.

METHODOLOGY

The developed model is based on a basin scale approach. We are using data from risk exposed as well as, data on flash flood intensities. The model composed of two basic parts, (1) the quantification of flood hazard via hydrologic and hydraulic calculations and the evaluation of flood intensity for various flood scenarios and, (2) the determination of exposure to flood hazard using a semi-quantitative method for the determination of the danger level, which serves the purpose for the spatial evaluation of corresponding quantities.

Hazard analyses give an estimation of the extent and intensity of flood scenarios and associate an exceedance probability to it (Merz, 2004, Apel, 2009). The usual procedure is to apply a flood frequency analysis to a given record of discharge data and to transform the discharge associated to the return periods, e.g. 100 – year event into inundation extent and depths. In our case the quantification of flood hazard related to a total of 100km of streams in Rafina watershed, because discharge data are not available, consisted of three parts:

- Estimation of flood discharges by a hydrologic model for the given return periods (medium and high probability) from the directive,
- Estimation of inundation areas by a hydraulic model based on these discharges
- The quantification of flood hazard as flood intensity IP as a function of water depth h and velocity u (FOWM,1997),

$$IP(h,u) = \begin{cases} 0, & h = 0 \\ h, & h > 0m, u \le 1m/s \\ h*u, & u > 1m/s \end{cases} \qquad (1)$$

Based on the directive, we developed different flood scenarios in different return periods of 5, 20, 50 and 100 years. For this simulation we used data from different services in Greece. The Hydrologic Modeling System (HEC-HMS) is designed to simulate the precipitation run-off processes of dendritic watershed systems. It is designed to be applicable in a wide range of geographic areas for solving the widest possible range of problems. To calibrate the model, rainfall data from Markopoulos Station (Ministry of Environment Energy & Climate Change) were used for the estimation of precipitation depths.

Moreover, watershed parameters such as infiltration coefficient, time of concentration and base flow, estimated based on data from Hellenic Cadastre Office (Digital Elevation Model, 4m), Institute of Geology & Mineral Exploration (Geologic and Hydro-geologic data, in scale 1:50000) and European Environmental Agency (Land use data, Program Corine 2000).

Analytical for the calculation of model parameters, the following methods were chosen (USDA, 1972).

- SCS – CN method for the precipitation loss calculations.
- Time of concentration for every sub-basin based on the curve number formula.

$$T_L = \frac{1.347 L_f^{0.8} (S + 2.54)^{0.7}}{1900 S_p^{0.5}} \qquad (2)$$

- The lag formula as route method for the river.

A GIS program, HEC-GeoRAS was used to create cross sections of floodplain elevations from a Digital Elevation Model (4m resolution, Hellenic Cadastre Office) of the selected area acquired from a high-resolution, topographical survey (Ministry of Environment Energy & Climate Change). A hydraulic model embedded in the HEC-RAS software program performed the hydraulic calculations to estimate water levels at the cross-section locations as well as to create flood hazard maps.

In order to get an impression of the overall flood hazard, parameters can instead be aggregated into qualitative classes, resulting in a so-called flood danger map. This is commonly done using matrices or formulas to relate different flood parameters into a single measure for the “danger”. In this study a semi-quantitative method has been used based on the Swiss method (Zimmermann et al., 2005). The purpose of this method is the spatial evaluation of respective qualities using a danger matrix. The level of the danger is determined in a similar way: it is a combination of the magnitude of the process in a particular location and its probability of occurrence in the location. The procedure is algorithmized using GIS tools.

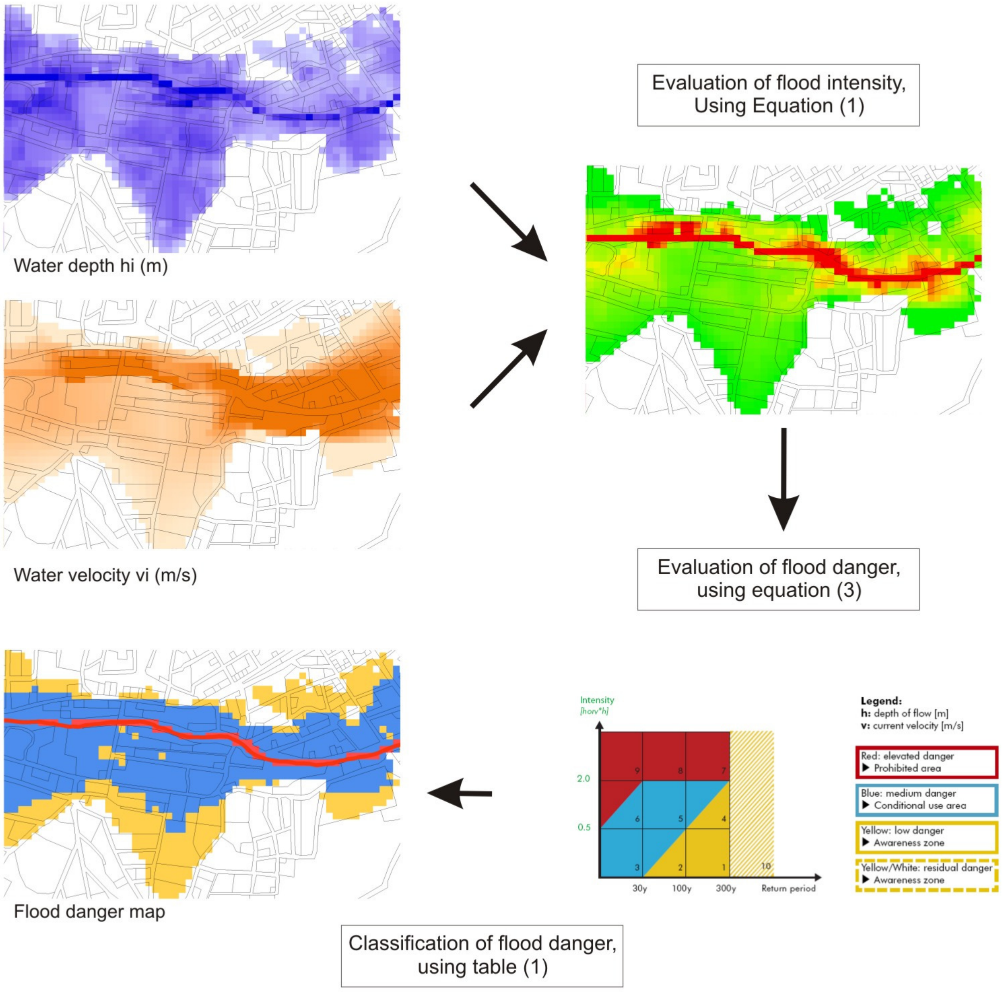

Fig. 2 Flow chart for the development of flood hazard and flood danger map.

The flood danger *Ri* for a given flood scenario *I* with the exceedance probability *pi* and a return period of *Ni* years is obtained by recalculating the boundaries of danger zones in the "danger matrix" (Fig. 2, Tab. 1). The following formula holds (Beffa, 2000, Zimmermann et al., 2005, Dráb, 2010)

$$R_i = (0.3 + 1.35 * IP_i) * p_i \qquad (3)$$

where the exceedance probability *p* of flood scenario *i* can be expressed as follows:

$$p_i = 1 - e^{-\frac{1}{N_i}} \qquad (4)$$

For *Ni* >5 the relation (4) can be approximated by

$$p_i \approx \frac{1}{N_i} \qquad (5)$$

The resulting local danger R is expressed as the maximum value of the individual dangers Ri corresponding to flood scenarios represented by the return period Ni:

$$R = \max_{i=1}^{n} R_i \qquad (6)$$

where n denotes the number of assessed flood scenarios.
The obtained flood danger values R are classified according to Table 1.

Tab. 1 Danger classification (Zimmermann et al., 2005).

Danger level R (Beffa, 2000)	Danger level from the matrix	Recommendation
$R \geq 0.1$	Red zone	The construction of new building is prohibited. Existing buildings can be maintained, however, it is prohibited to substantially increase the value or increase the number of people.
$0.1 \leq R < 0.1$	Blue zone	The construction of new buildings is possible under certain conditions (mainly proofing of the building against the impact of a natural process). The specifications can be outlined in the municipal building code.
$R < 0.01$	Yellow zone	Sensitive (life support) infrastructure or buildings with a high concentration of people (e.g. school) need to consider the prevailing hazards; however, there are no restrictions for private construction activities.

RESULTS

The procedures which introduced in the previous section were used to estimate the flood hazard and the flood danger areas, and create the corresponding maps (flood hazard and flood danger maps).
A hydrodynamic 1-dimensional model was created for the Rafina watershed using the HEC-HMS and HEC-RAS software package from the US Army Corps of Engineers. The 1D model uses several types of data: time series of precipitation data, Digital Elevation Models (D.E.M.), geological and hydro - geological data, land uses data and an analytical topographical survey of the river. To calculate the flood hazard, boundary conditions were used for 4 different return periods, based on the European Floods Directive, ranking from 5 to 100 years.
In the first step, for the flood hazard mapping, the parameters which calculated by the hydrodynamic model were: (1) the level of the inundation, (2) the intersection of flood level with the terrain (flood extent) and, (3) the distribution of the velocity and the flood depth as the difference between flood level and the terrain. The results of this simulation were produced in the form of maps. The derivation of flood depth and flood velocity maps under specified flood scenarios allowed the estimation of the flood hazard map (Fig. 4) as flood intensity.
Based on the calculated flood intensity IP, the flood danger is evaluated using the so – called “danger matrix” as a combination of the magnitude (intensity) of the process in a particular location and its probability of occurrence (return period) in that location. The resulting danger level is assumed to be the maximum danger level obtained in individual flood scenarios. The procedure for the danger level algorithmized using GIS tools, thus, results produced in the form of maps categorizing the catchment in three classes according to the danger level. Red color has been assigned to areas with elevated danger or prohibited areas, blue color to areas with medium danger (conditional use areas) and low danger areas with yellow color. The danger map for the municipality of Rafina presented by Fig.5.

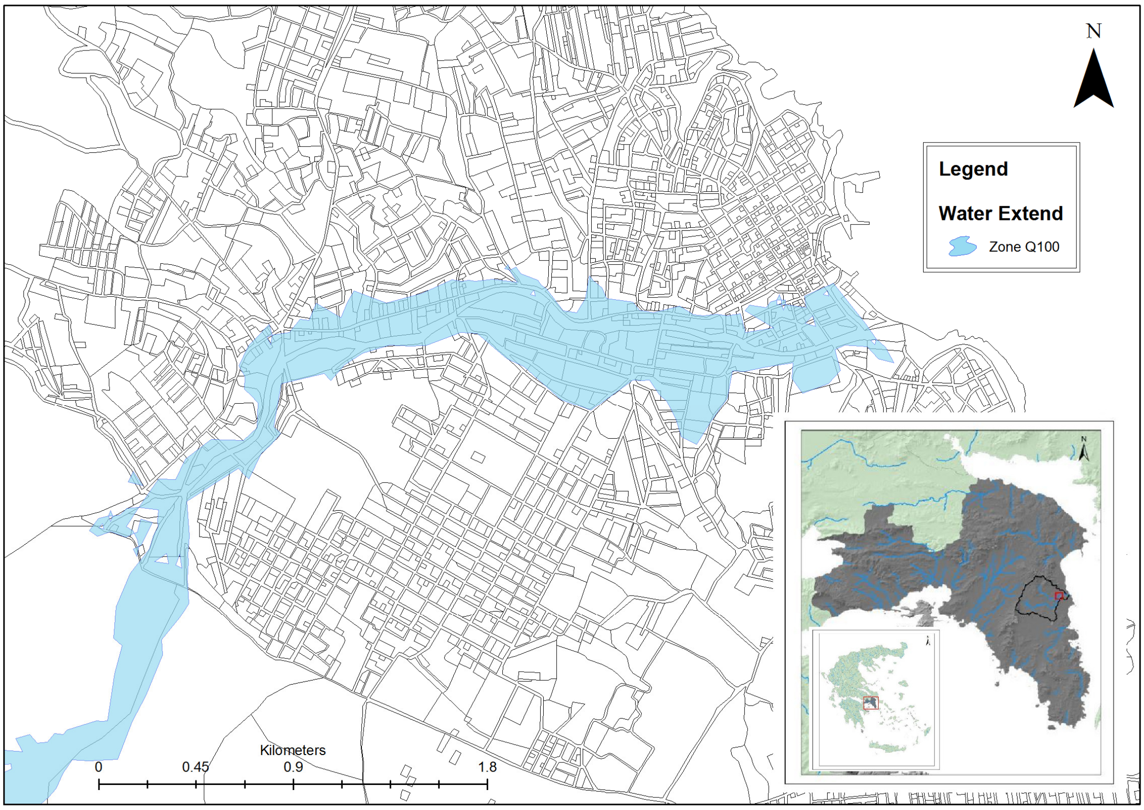

Fig. 3 Flood extend map for the municipality of Rafina for return period 100 years.

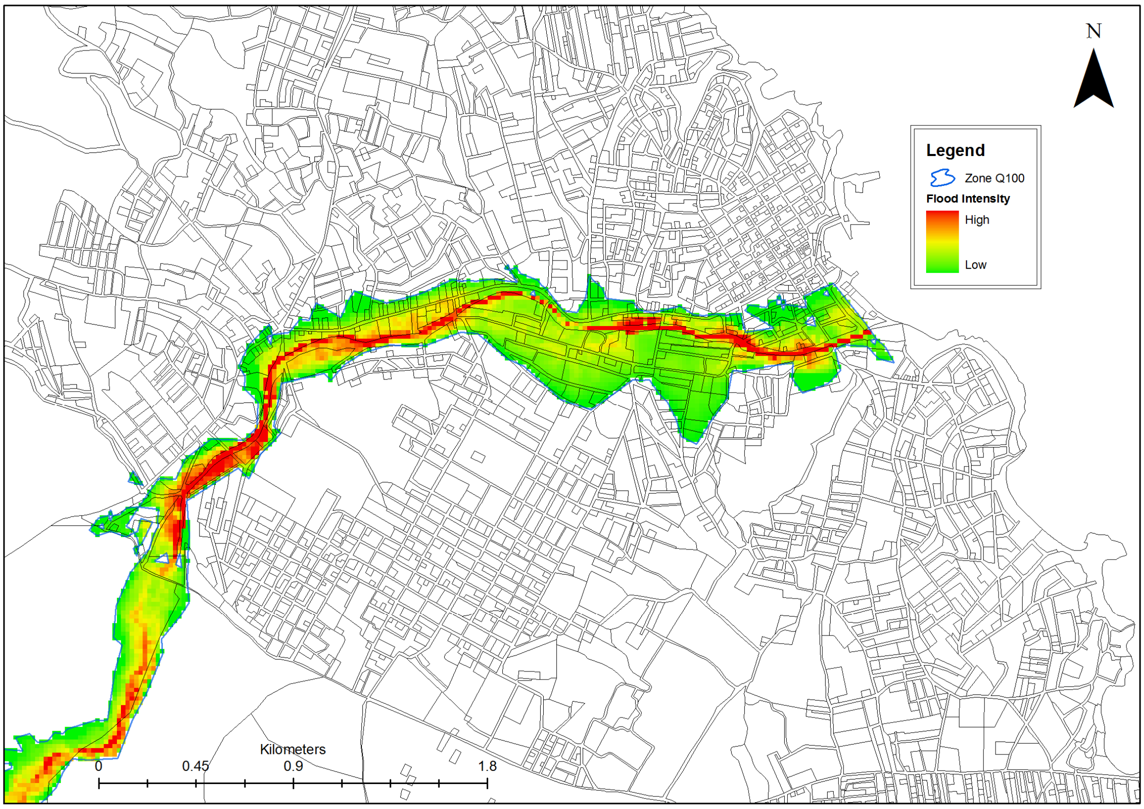

Fig. 4 Flood intensity (flood hazard) map for return period 100 years.

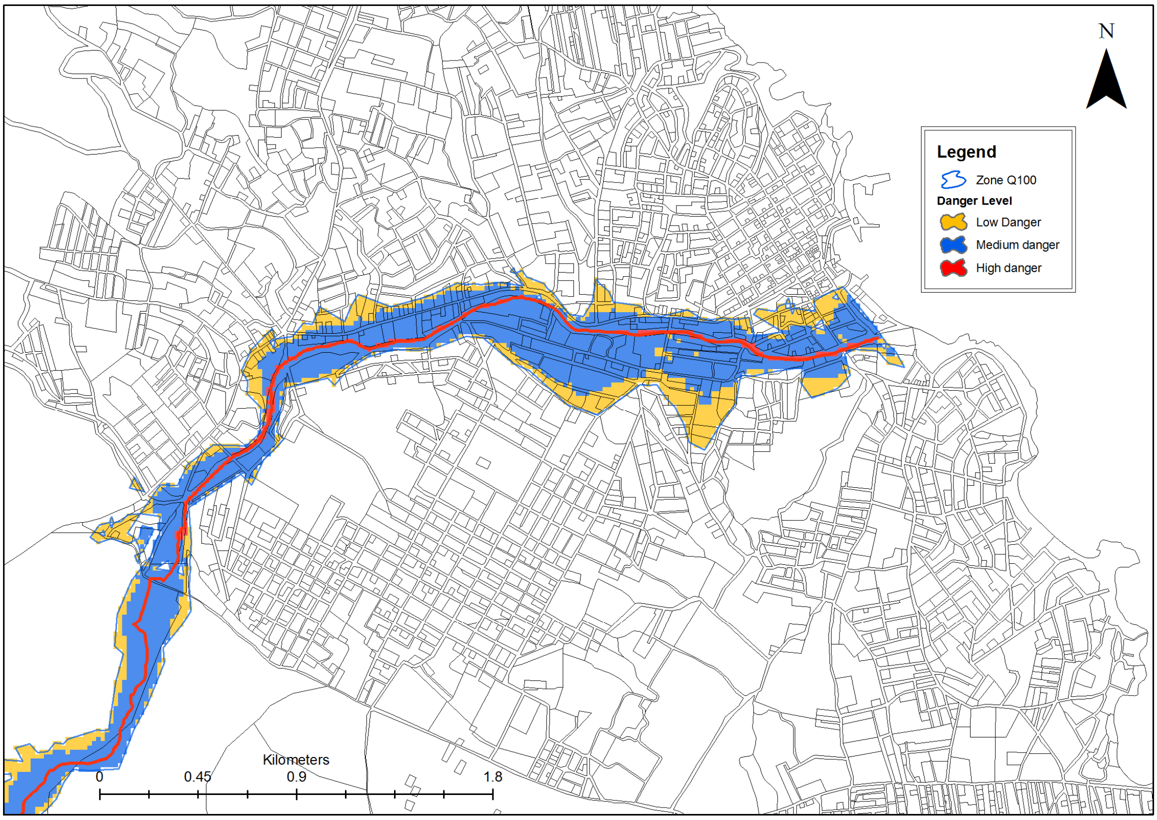

Fig. 5 Flood danger map for return period 100 years in the municipality of Rafina.

CONCLUSION AND DISCUSSION

In this paper we presented a methodology of flood mapping techniques corresponding to the Floods Risk Directive 2007/60/EC of the European Parliament and of the Council on the assessment and management on flood risk.

A method to evaluate the flood hazard is presented, as well as a method to estimate the danger level. The estimation of flood hazard and danger is a fundamental component of a flood management strategy based on the European Floods Risk Directive - the basis for spatial planning, for local assessment, for emergency planning and for planning technical protection measures. The proposed approach was applied to Rafina watershed in order to determinate the areas in the settlement in danger of flooding. Furthermore, since flood phenomena occur in the area of study, the methodology presented in this paper could become a useful tool for the prediction of potential flooding areas and for better organization of the flood management plan.

In Greece, as in many other countries, hazard and danger maps do not have a precise legislative confirmation. Despite this, they are necessary to support activities for a range of final users, such as management agencies, insurances and stakeholders affected by floods. Finally, they are a crucial tool for disaster support and local urban planning.

The aim of the paper was to introduce the philosophy of Floods Risk Directive implementation in Greece and to present the way in which the general requirements have been met. Moreover, this study provides guidelines of how to implement the steps of the European Floods Risk directive and to show challenges and limitations resulting from the availability of hazard information and land use data.

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