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Critical Technical Issues on the EU Flood Directive

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Abstract: The EU Directive 2007/60 on the estimation and management of flood risk entered into force in 2007 with the objective to reduce flood risk in Europe. EU Member States are obliged to prepare flood hazard and flood risk maps and devise flood risk management plans for the river basins of their territory. In this paper several issues of technical nature are discussed related to difficulties in implementing the directive. It is stressed that the directive is very demanding regarding the topographic data of high accuracy and socioeconomic data which are not easily available for each river basin. Regarding international rivers, the implementation of the directive is even more difficult since this requires a comprehensive cooperative effort jointly by the riparian countries. Finally, some recommendations are made for an effective implementation of the directive mainly in the context of climatic and institutional conditions of Mediterranean countries.

Key words: EU Flood Directive, Flood risk, Safety Standard, Flood damage, River basins, Mediterranean region

1. INTRODUCTION

According to the Emergency Disasters Database (EM-DAT), between 1998 and 2002, Europe suffered over 100 major floods including the catastrophic floods along the Danube and Elbe rivers in summer 2002. Within the same period the floods caused some 700 fatalities, the displacement of about half a million people and insured economic losses totalling at least €25 billion. Moreover, between 2003 and 2007, the number of large scale floods around Europe increased to over 120 major events causing some 345 fatalities and an estimated economic loss of at least €12 billion. The scale and frequency of floods are likely to increase in the future mostly as a result of climate change (European Commission, 2005), inappropriate river management and infrastructure development in flood prone areas.

The theoretical range of available options for managing flood hazards is large and it includes a variety of measures or options at the local and or the central governmental level; these are defined as structural (e.g., dams, reservoirs, relief channels, embankments) or non-structural (e.g., land use planning, early warning systems, evacuation plans, insurance policy etc). The standard approach of constructing technical works for flood protection frequently in the downstream part of a river basin has proven to be very expensive, environmentally unfriendly, and inefficient. Hence, the strategy in prioritising flood protection measures has changed over time from the traditional technical engineering approach to management of risk and "living with floods" (Begum and van Gelder, 2004).

This change in the EU strategy on flood risk management is first and foremost identified officially through the new EU Flood Directive. The Directive 2007/60/EC of the European Parliament and Council on the assessment and management of flood risks of 23 October 2007 entered into force on 26 November 2007. This directive, herein referred to as the Directive, now requires Member States to identify areas adjacent to their water courses and coast lines which are at risk from flooding, to map the flood extent and assets and humans at risk within these areas and to take adequate and coordinated measures to reduce flood risk. The Directive also reinforces the rights of the public to have access of the related information and to have a say in the planning process.

Regarding the European Policy of Water Resources Management, the European Union has already given itself a comprehensive instrument for water quality, the Water Framework Directive 2000/60 known as WFD. This directive is aimed at protecting all waters in the EU, such as rivers, lakes, coastal waters and groundwater, and sets as an objective to achieve/maintain good status of all waters, as a rule by 2015. However, the most recent official reports (European Commission, 2007; European Commission, 2009) about the progress in the implementation of WFD showed that major deficiencies exist in the transposition of national laws, the set up of administrative structures and the economic analyses of river basin districts. Also, the report referring to the monitoring of the water status showed that, in general terms, there is a good monitoring effort across the European Union with the exception of Greece and Malta, which did not report their monitoring status.

In the new Flood Directive it is recommended to base cooperation, planning and acting on flood problems on river basins or sub-basins as the coordination and management unit while coastal areas at risk should be assigned to the nearest or most appropriate river basin. There are different types of floods throughout Europe, e.g., river floods (flash floods or progressive floods) and coastal floods. Hence, the risk of floods varies across the countries and regions of the EU, as do the consequences of flood events, depending on local and regional circumstances. Because of the wide variety of flood types, the new Flood Directive foresees that the desirable level of protection be defined at the local/regional level, and coordinated with neighbours (upstream and downstream) sharing the same river basin or sub-basin.

The objective of this paper is to identify the issues that we consider as critical for the effective implementation of the new Directive, clarify them, and propose feasible directions or recommendations towards effective solutions. Our suggestions take into consideration state-of-the-art, international practices that have been already successfully implemented at national scale. We primarily focus on technical issues of the Directive without commenting on political issues which may also be of great importance.

The paper is structured in four sections. Section 2 presents the three-stage approach required by the EU for implementing the Directive. Section 3 focuses on commenting on critical issues explicitly or implicitly raised by the Directive such as the required engineering studies, the quantification of flood consequences, and the application in international river basins. Finally, a discussion and some concluding remarks are given in Section 4.

2. IMPLEMENTATION REQUIREMENTS OF THE EU FLOOD DIRECTIVE

The objective of the EU Flood Directive is to establish a framework for the assessment and management of flood risk which will reduce the adverse consequences of flood in regard to human health, environment, cultural heritage and economic activity.

The Directive applies to all kinds of floods (river, lakes, urban floods, and coastal floods, including storm surges and tsunamis) and requires that Member States implement a unifying process involving three steps:

Step 1. Preliminary estimation.

Member States (MSs) will by 2011 undertake a preliminary study for flood risk assessment in their river basins and the associated coastal zones, with the purpose to identify areas where potential significant flood risk exists. Further action will only have to be taken in those areas where a significant flood risk is found, regarding either current or future conditions.

Step 2. Flood hazard and risk maps.

For areas with significant flood risk, the MSs must by 2013 develop flood hazard maps and flood risk maps. These maps will delineate areas with a medium and low probability of flooding by indicating also expected inundation depths. Other types of information on these maps will include the number of inhabitants at risk, the economic activity in the area of risk and the environmental damage potential. The flood maps are expected to increase public awareness in the flood-prone areas, to support the processes of prioritising, justifying and targeting investments and to support the development of flood risk management plans, general spatial plans and flood emergency plans.

Step 3. Flood risk management plans.
Finally, by 2015 flood risk management plans must be drawn up for zones identified in step 2 at the river basin or the sub-basin spatial scale. They will include measures to reduce the probability of flooding and its potential consequences thus becoming the operational instrument for flood risk management in its entire spectrum. Yet, the primary focus will be on prevention (i.e., by avoiding construction of houses and industries in present and future flood-prone areas or by adapting future developments to the risk of flooding), protection (by taking measures to reduce the likelihood of floods and/or the impact of floods in a specific location such as restoring floodplains and wetlands) and preparedness (e.g., by providing instructions to the public on what to do in the event of flooding). Due to the nature of flooding, much flexibility in the objectives and measures is left to the MSs in view of the principle of subsidiary. In the case of a river basin falling entirely within the EU but shared between several MSs or extending beyond the boundaries of the EU, the above measures should be elaborated in coordination across the whole management unit (of the river basin or sub-basin).

The above steps need to be reviewed every six years in a cycle coordinated and synchronised with the implementation cycle of the WFD. The first milestone will be the development of reporting formats by 2009 and the appointment of competent authorities in spring 2010.

Since the central, flood-related terms to be used in this discussion are highly controversial, it is essential to start with some fundamental definitions of these terms. On one hand, the specific definitions, regarding the concepts of hazard, risk and vulnerability have been compiled from other works at the Centre for the Assessment of Natural Hazards and Proactive Planning of the National Technical University of Athens (Tsakiris, 2007; Pistrika and Tsakiris, 2007), being also compatible with WFD. On the other hand, the general concepts regarding the types of damage, population and various functions are derived from the international literature (Jonkman, 2007; Messner and Meyer, 2005).

3. COMMENTS ON THE APPLICATION OF THE DIRECTIVE

3.1. Studies required - Related difficulties

Implementing the Flood Directive will require studies of various kinds: (a) engineering studies, (b) economic and social studies, and (c) interdisciplinary studies involving experts from a variety of fields such as engineering, economics, public health, ecology etc.

In our view, step 1 (preliminary estimation) could be limited to engineering work only. The USACE approach (see Fig. 1) can form the basis of such studies. This involves the following: (a) selection of a set of flood exceedance probability; (b) computation of the peak discharge Q of the flood hydrograph associated with each probability level (Figure 1a); (c) translating the peak discharge Q into peak stage S through a stage-discharge (S-Q) curve (Figure 1b); (d) estimation of damage D associated with stage S usually through a stage-damage (S-D) curve for a variety of elements at risk (e.g., assets, number of fatalities) (Figure 1c); (e) derivation of the damage exceedance probability curve (Figure 1d); (f) integration of the resulting damage-probability function to compute the expected damage at the annual basis (called expected annual damage).

Table 1. Definition of flood related terms

Term	**Definition**
Affected population or population at risk	*All people that are present in the exposed area before any flooding signs or warnings are perceived*
Direct damage	*Damage related to physical contact of water (e.g. buildings, infrastructure, agricultural land, vehicles)*
Exposed population	*Affected population minus the number of people that escaped through processes of evacuation/rescue or finding shelter*
Flood hazard	*Probability of flooding*
Flood risk	*Probability of flooding multiplied by flood damages*
Flood risk estimation	*Identification and quantification of flood risk associated with a given system*
Flood risk evaluation	*Decision process regarding the flood risk acceptability, given the results of flood risk estimation. It reflects the comprehension of the local society's perception of flood risk by the decision makers.*
Flood risk assessment	*Process encompassing both the estimation and the evaluation of flood risk.*
Flood risk management	*Process encompassing flood risk assessment and flood risk mitigation and control*
Indirect damage	*Damage without physical contact of water (e.g. production losses outside of flooded area, market disturbances, loss of time)*
Intangible damage	*Damage that cannot be priced or, else, quantified in monetary values (e.g. fatalities, injuries, moral damage, cultural losses, environmental losses)*
Mortality	*Ratio of flood fatalities over the exposed population*
Mortality function	*Relationship between the intensity of the physical phenomena and the mortality in the exposed population*
Safety standard	*Exceedance frequency of water level*
Stage-damage curve/function	*A specified relationship between flood characteristics (usually water depth) and the extent of economic damage*
Stage-discharge function	*A specified relationship between water depth and discharge with the assumption of one-to-one relationship*
Tangible damage	*Damage that can be priced or, else, quantified in monetary values*
Vulnerability	*Set of conditions and processes resulting from physical, social, environmental and economic factors, which increase the susceptibility of a community to the impact of hazards.*

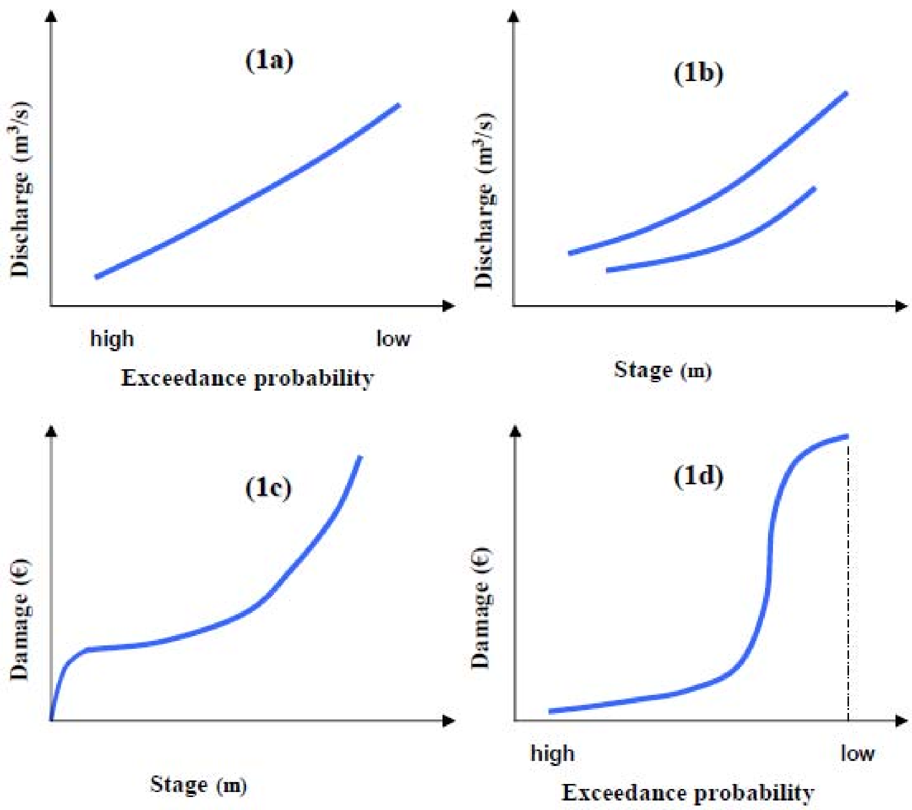

Figure 1. Computational steps for assessing the expected annual damage (based on USACE 1996).

Despite its widespread use, the USACE approach has some drawbacks also. To our view the following issues are critical:

1. The choice of the flood exceedance probability is left to Member States. The Directive mentions three probabilities of flooding (high, medium and low). It is convenient to select a set of standardised scenarios corresponding to certain exceedance probabilities. For instance, it could be clarified that flood scenarios are prepared for a 0.2-0.1 exceedance probability as a high probability scenario while medium- and low-probability floods could correspond to 0.02-0.01 and 0.002-0.001 exceedance probability and return periods of 50-100 and 500-1000 years respectively. However, these three scenarios are not sufficient to describe fully the probability range of flooding. For a more comprehensive description some intermediate exceedance probabilities might also be of importance such as 0.04. These supplementary scenarios can be formulated in case more information on flood statistics is required (e.g. in case of rational estimation of design discharge of flood protection or river training works.) In case that an integration of the damage-probability curve is required obtaining a minimum level of accuracy in the integral evidently precludes using only three probability levels. It should be mentioned that normally flood insurance involves categorization of flood-prone areas in accordance with their flooding potential. According to FEMA (1993) in the U.S.A. two return periods are used for characterising flood hazard areas, the 100-year and the 500-year return periods. Therefore, areas within the 100-year boundary are characterized as “special flood hazard areas” and areas between 100-year and 500-year boundaries are characterized as “areas of moderate flood hazard”.
2. Since peak discharge measurements are rarely available, flood-event hydrographs are derived from hypothetical storm hyetographs through rainfall-runoff models; the common approach to obtain runoff consists of lumped or distributed rainfall-runoff models which presupposes the existence of reliable data sets for rainfall and other meteorological variables; in many cases, model calibration and verification are highly desirable or even unavoidable but, very seldom discharge measurements are available for this purpose.

3. Since most available data sets exceed 5 or 10 years in length, the high probability scenario is easily verified based on measurements of rainfall and runoff. On the contrary, such verification is infeasible for the low probability scenario and one has to rely on very uncertain predictions from the tails of the fitted probability distributions.
4. Considering a unique stage-discharge (*S*-*Q*) curve one may induce extra uncertainty due to the well-known loop-type appearance of such curve and the influence of the sedimentation; although, these are theoretically solved problems in river hydraulics, solutions based on sophisticated 2D approaches and movable-bed models suffer from excessive data requirements which can rarely be fulfilled in typical un-gauged basins in the Mediterranean region; as a result, such modelling efforts entail the risk to amplify the uncertainty of flood peak discharge estimates.
5. The quantification of flood consequences remains one of the most critical part of the whole process; not all types of damage can be expressed in monetary terms (e.g. loss of life) while the tangible types of damage require: (a) a considerable amount of information both in time and space, (b) a sound methodology to assess the maximum damage due to physical contact with water per category of element at risk, (c) a reliable database to support such a methodology, (d) a reliable "function/curve/model" relating flood characteristics (depth, duration, velocity) to percentage of maximum damage due to physical contact with water per category of element at risk, (e) a model for flood-induced economic consequences outside the flooded area which will operate at the regional or the national level.
6. The lack of databases for flood disasters in Europe (Barredo, 2007) which include a wide range of information (hydraulic parameters, damages, historical data etc) will pose problems mainly in identifying areas at risk (step 1 of the Directive).

From the above issues, issues 1 to 3 refer mostly to step 1 of the Directive while issues 4, 5 and 6 are related to all three steps. Regarding exclusively steps 2 and 3 of the Directive, the following points should be taken into consideration for the effective implementation of the Directive:

1. Associated with economic damages, discussed above, are social consequences; studies on the psychological consequences and other post-calamity illnesses are, however, difficult to quantify and transfer from one flooding case to another.
2. Reducing the uncertainty in flood risk estimation will, in general, require appropriate data collection campaigns which can substantially raise total costs for implementing the directive. In any case, the quantification of the uncertainty in the flood risk estimation should be included in the required deliverables of step 2.
3. When future flood mitigation measures are studied, a number of alternative designs is analysed; uncertainty is in general higher than that of the case with existing conditions since problems of planning, design and operation of hydraulic works have to be solved for which no historical data exist.
4. As pointed out by Jonkman and Vrijhling (2008), flash floods are likely to produce greater damage regarding fatalities than do other types of flood (e.g. river floods). The reasons for this are: (a) in flash floods, water level rise is abrupt thus not allowing enough time to endangered people to evacuate flood-prone areas or reach a shelter; (b) water velocities are high which can cause instability to those exposed to the current of flood flows; (c) frequently, lead time for warning and evacuating the flood-prone areas is very short to take any organised action; (d) since flash floods occur mostly in small basins with steep terrain, flood forecasts are expected to be highly uncertain due to the fact that these will have to be heavily based on precipitation forecasts and not to upstream stage measurements. The regions of the EU close to the Mediterranean Sea suffer mostly from flash floods. This is

due to a variety of factors: highly sloping terrain, low vegetation, large rainfall intensities among others. As a result, Mediterranean countries will have to face the above difficulties when implementing the Directive.

5. Costs for implementing the Directive are expected to be high due to the need to rely on experts who will decide upon the optimal level of detail or simplification within each stage of analysis. Obviously the greater the level of detail, the higher the implementation cost will be.

In the next subsections 3.2 and 3.3, we focus on two of the most critical issues raised above which are the definition of the flood risk level and the quantification of flood consequences.

3.2. Defining flood risk levels of different causes of flooding – Related difficulties

In general, flood risk levels are assessed either by fixing an acceptable maximum number of fatalities or a maximum acceptable total cost of flooding including the expected flood damage.

The different causes of flooding must be identified first and then proceed in developing safety standards per cause of flooding. Flood risk level will be related to these different safety standards.

The flooding probability is in general not equal to the safety standard. The reason is that the safety standards are the exceedance probabilities of water level in relation to a specific elevation of a flood defence work. Because of the freeboard, there is no direct failure of the flood defence work if the water level exceeds that elevation. Besides, overtopping of a flood defence work is not the only failure mechanism, but there are other failure mechanisms such as piping and structural instability (TAW, 1998; TAW, 2000). The flooding probability is, therefore, significantly smaller than the safety standard.

A representative example of laws and guidelines at the national level that classify safety standards based on the cause of flooding is the example of The Netherlands. The Netherlands is situated in the delta of four rivers and a large part of the country is below the mean sea level. As a result, a risk of flooding exists due to sea storm surges, high discharges of the rivers or extreme rainfall. This led to an early development of different safety standards of the different causes of flooding in the form of National Law and guidelines. For instance, the safety standard of the primary flood defences (sea dikes, dunes etc) is defined via economic cost-benefit analysis with an exceedance frequency of 1 in 10000 years. The safety norms for regional flood defences, as stated in the IPO-guideline (IPO, 1996), are determined by the categorisation of the flood defence works (hereinafter simply referred to as the flood defences) into different flood damage classes. As an example, a flood damage rated between 0 to 8 M€, classifies the defence to class I whose safety standard is equal to 1/10. Moreover, the safety standards of flooding of regional water systems are set for different types of land use.

Establishing different safety standards of different causes of flooding has resulted in determining the flooding probability in a consistent way. Thus, the flood risk levels are estimated in a consistent way since flood risk is calculated by multiplying the probability of flooding with flood damage. Consequently, when the different safety standards are regulated, tested and confirmed by different authorities (e.g. state, regional, local), it can be a good start for building flood risk maps, thus implementing the second step of the Directive effectively.

Finally, considering different safety standards for different causes of flooding facilitates flood risk management because the derivation of the flooding probability is clear and consistent. For instance, the influence of future changes in land use or infrastructure on flood risk levels can be more easily identified and mapped.

3.3. Quantifying flood consequences

3.3.1 General

It is clear from the above that in order to implement the new Flood Directive, we should first quantify the flood consequences. The range of consequences or rather damages that a flood brings about includes economic, political, social, psychological, ecological and environmental damages and damages to cultural heritage. There is a substantial body of international literature that provides evidence of extensive expertise in the field of damage estimation. However, experts and academics disagree about the methods and models to be applied.

First of all, numerous definitions of damage exist. The categorisation of damage into direct and indirect, or into tangible and intangible as shown in Table 1 is commonplace, but interpretations and delineations of categories differ (Jonkman et al., 2008).

Secondly, various approaches exist regarding the damage appraisal, such as financial and economic valuation based on market values (i.e. based on historical values or replacement values), while variation in the scale of analysis (micro-, meso- or macro-scale) is also found (Messner et al., 2007). Separate approaches exist focusing on environmental damage (Stuyt et al., 2003), loss of life (Jonkman and Kelman, 2005; Jonkman, 2007), public health consequences (Ahern et al., 2005), and economic damage (van der Veen et al., 2005). An integrated, unifying approach is, however, missing.

For consistent decision making it is desirable to have a more or less standardized approach for damage estimation at the higher aggregation levels, such as a river basin or a complete region. With this in mind, governments in several countries have adopted standardised methods for the estimation of damage due to flooding. Examples are the HAZUS methodology developed in the USA (FEMA, 2003). The HAZUS software provides an account of a wide range of damages, including direct and indirect economic losses; yet, the assumptions behind the different software modules can be contested as far its application to the EU countries is concerned. Besides, the whole information system is designed to work with the US database of buildings, population and other types of information.

Meyer and Messner (2005a, b) in their review of flood damage evaluation methods in four European countries (United Kingdom, Netherlands, Germany, and the Czech Republic) point to a number of differences which complicate the application of a common model. These differences relate to (a) the objective of the flood damage evaluation, (b) the damage categories considered, (c) the level of detail, (d) the scale of the analysis, and (e) the basic evaluation principles.

In conclusion, we think that it is important to establish a common framework for estimating flood damage that is dictated by the needs of policy and decision-making. Lack of such a decision-support tool for ex-ante analysis and post-disaster planning may lead to inadequate flood preparedness and protection.

Today the typical approach is the economic estimation of direct damage, mostly by applying stage-damage curves. However, extensive research has been performed recently regarding life loss due to flooding. A summary of these known methods is presented in short in the following two paragraphs.

3.3.2 Consequences in economic terms

As already mentioned in paragraph 3.1, the central idea in the traditional approach for direct flood damage estimation in monetary terms is the concept of stage-damage functions or loss functions. These functions relate flood depth with the extent of economic damage. Stage-damage curves which were first proposed in the USA in the 1960s, are currently internationally accepted as the standard approach to assessing urban flood damage (Smith, 1996).

The estimation of direct damages involves two interrelated steps. The first is the estimation of structural physical damages to objects, such as buildings (Kelman and Spence, 2004), while the second step is the 'pricing' of these physical damages. The procedure for the estimation of direct physical damage is visualised in Figure 2. This is based on ideas of Jonkman et al. (2008) and involves: (1) determination of flood characteristics; (2) assembling information on land use and maximum damage amounts; (3) application of stage-damage curves.

Usually, stage-damage functions include water depth as the only determinant of direct damage. However, recent studies have shown that depth-damage functions may have a large uncertainty since water depth and building use can only explain a part of the data variance (Merz et. al., 2004). Flood damage is influenced by many more factors among which are flow velocity, flood duration, contamination including sediment concentration, lead time and information content of flood warning, and the quality of external response in a flood situation (Penning-Rowsell, 1977; Smith, 1996; USACE, 1996; Kelman and Spence, 2004). The above factors are, though, scarcely included in flood damage models. Moreover, varying temporal and spatial scales may be applied in practice when modelling flood damage and economic damage estimates may be associated with considerable uncertainty (Merz et al., 2004; Pistrika, 2009).

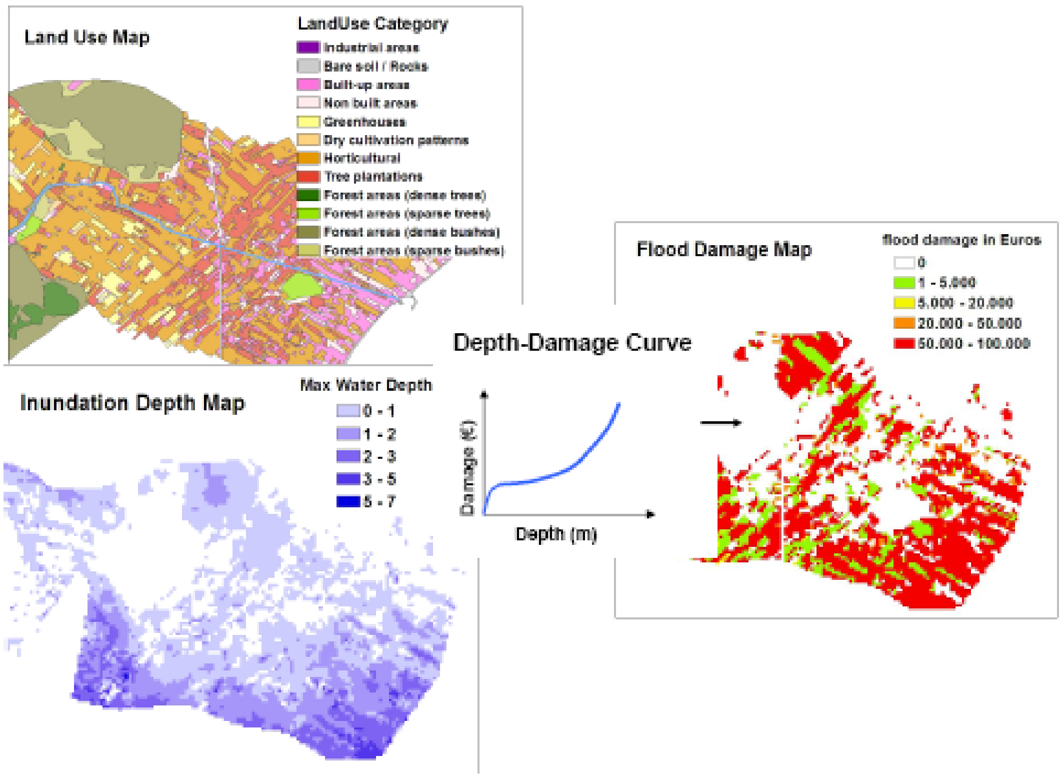

Figure 2. Schematization of the procedure for estimating the direct damage due to flooding (Tsakiris et al., 2007)

3.3.3 Consequences on human lives

In the international context, various models have been developed for the estimation of life loss for different types of floods. Applications include dam-break floods, tsunamis, coastal storm surges and river floods. McClelland and Bowles (2002) give a comprehensive historical review of loss of life models for dam-break floods discussing at the same time their merits and limitations.

Graham (1999) presents a framework for the estimation of loss of life due to dam failures. Recommended fatality rates are provided based on the severity of the flood, the amount of warning and the understanding of the population of the flood severity. Pistrika and Tsakiris (2008) applied the Graham's method in an area potentially affected by the hypothetical failure of an existing dam.

However, the most recent research in estimating loss of life due to flooding is the method proposed by Jonkman (2007). It is generally applicable to 'small probability – large consequence' accidents within the engineering domain, such as floods, earthquakes and airplane crashes. An estimate of the loss of life caused by an event can be obtained based on three elements: (1) the intensity of physical effects and the extent of the exposed area; (2) the number of people exposed (sometimes reduced by evacuation, shelter and rescue); (3) the mortality among the people exposed. Mortality is usually determined with the aid of the so-called dose response function or, else, the mortality function. This function relates the intensity of physical effects and the mortality in the exposed population (Jonkman, 2007).

3.4 International river basins

Since floods do not recognize national boundaries, the problems of transboundary floods in International River Basins (IRBs) seem to attract special attention of the riparian states. Crucial issues that are expected to add more difficulties in implementing the new Flood Directive in IRBs are summarised below:

- Transboundary river floods are more severe in their magnitude, affect larger areas, result in higher death tolls, and cause more financial damage than non-shared river floods do (Bakker, 2007).
- An alarmingly low institutional capacity is related to transboundary river floods: more than 15% of the IRBs do not have any type of institutional capacity in the form of a river basin institution, nor any focused on floods (Van der Keur et al., 2008; Bakker, 2007).
- Vulnerability to shared floods is poorly understood and not much is known about the present quantity and quality of institutional capacity to deal with such events.
- Differences in political/cultural issues between riparian countries endanger the effectiveness of the cooperation between them.

The majority of transboundary flood events occurring in IRBs seem to occur without the systematic cooperation of riparian countries to face them, neither at proactive nor at reactive mode. There are, however, exceptions of successful flood management within IRBs such as the Rhine and Meuse river basins; in 1998, action plans for both rivers were agreed upon by all riparian states. The Rhine Action Plan specified, among other things that damage resulting from transboundary floods should be decreased by means of, for instance, spatial planning projects and improving the warning systems (Ministry of Transport, Public Works and Water Management, 2005). However, the options for actual international cooperation, with regards to transboundary flood policies, have yet to be figured out; several studies are carried out to work out the options every country can agree upon (Ministry of Transport, Public Works and Water Management, 2005).

In the context of WFD, EU Member States were advised to cooperate for achieving the good status of waters by 2015 by following steps of data and information exchange and close cooperation towards the formulation and implementation of common management plans in these basins. No further directions, guidelines or recommendations were given at the EU level about specific ways to support and intensify the international cooperation. To the best of our knowledge, the cooperation in this field is still lacking. Hence, from the general recommendation of the Flood Directive, the most crucial issue is probably to scale down at different levels the measures that aim to develop an effective cooperation status between the riparian countries for the management of transboundary flood events.

At EU level, there might be more need for establishing new official international institutions dealing with the transboundary flood events. The international institutions already set up for international river basins to deal with fishing and transportation now can be extended to integrate transboundary flood management issues. Also, EU authorities should facilitate cooperation between riparian countries in a more intense and demanding process with clear and strict time framework and possibly consequences in case of reluctance for cooperation.

At the level of a certain transboundary system, it could be recommended to establish common scientific teams, with scientists from the riparian countries together with other experts of third countries for studying the problem of flood management in both strategic and operational manner and for attempting to formulate the options that each riparian country can agree upon. Moreover every riparian country should allocate more power and responsibility to the regional authorities for the design and implementation of flood and contingency plans since the local stakeholders and authorities know practically better the specific conditions and problems of flood management within the affected areas. Building a legal framework/platform to enter into force the above actions and possibly to finance them is considered fundamental.

At regional level, it is imperative to study the pattern of river flows and assess low, medium and high probability floods together with anticipated damages with a common methodology in all the riparian countries affected. This is even more crucial in case of riparian countries located upstream-downstream. A step forward could be also the formation of common flood crisis management committees mainly from the flood affected regions of the riparian countries.

4. CONCLUDING REMARKS AND RECOMMENDATIONS

The objective of this paper was to identify and discuss some critical issues concerning the implementation of the EU Directive 2007/60 on the management of flood risk. The most important concluding remarks can be summarised as follows:

- Identifying areas with significant flood risk will require information on the flood hazard which is in many cases lacking: rivers or other water bodies are un-gauged, no data is available on damages from historical floods, and no database is in place with data for assessing current and future flood damages.
- Identification of areas at risk is foreseen in Step 1 of the Directive as if the definition of these areas were static. But, in many European areas such as the coastal Mediterranean areas, urban development is rapid which calls for a dynamic process now lacking in the Directive's text.
- The traditional approach for assessing direct damage of USACE (1996) suffers from a variety of uncertainty sources: non-uniqueness of the stage-discharge curve and large uncertainty of the stage-damage curve. Additionally, three flood scenarios (with high, medium and low probability) are virtually inadequate to describe fully the whole range of flood events.
- Different safety standards for different causes of flooding are needed which will allow consistent flood risk management.
- Widely accepted methodologies for quantifying flood damages are lacking, especially regarding indirect damages, intangible damage and loss of human lives.

Based on the analysis of critical issues, the following recommendations:

- Step 1 of the Directive should be adapted to the dynamics of spatial development; hence, it should be itself dynamic or, else, in a frequent periodic revision to follow the dynamics of rapid urban development, especially in coastal areas of the Mediterranean.
- The three basic flood scenarios are useful and should be kept but many more probability values are necessary for comprehensive provision of probability-weighted estimates, often needed within the flood risk estimation process. We recommend a 0.2-0.1 exceedance probability for the high probability scenario while for medium- and low-probability floods 0.02-0.01 and 0.002-0.001 exceedance probability respectively would be convenient for the preliminary flood risk assessment of step 1 of the Directive.
- It is recommended that establishing different standards of different causes of flooding can be a good start for building consistent flood risk maps and thus implementing the Flood Directive effectively.

- Southern Europe suffers mostly from flash floods which are potentially more disastrous than other types of flood. In this case, highly uncertain forecasts and short lead times limit the possibility for success of flood warning systems.
- Ongoing research on methodologies for quantifying flood consequences should be further validated especially for flash floods of Southern Europe. Direct damage estimation should be related to a variety of flood characteristics such as depth, velocity and duration.
- Implementation of the Directive in IRBs will be facilitated through applying the following measures at different levels: (a) regional level: cooperation of regional and local authorities for preparedness and emergency response plans; active involvement of the local stakeholders and authorities; (b) transboundary system level: harmonisation of the Flood Directive with the national legal system; decentralisation of decision making from central governmental level to regional level (c) EU level: harmonisation of the EU Flood Directive with WFD; development of official international institutions dealing with transboundary flood in IRBs.
- For the effective implementation of Flood Directive it is recommended to develop (at the national level) knowledge and data exchange networks regarding methods and tools for flood risk estimation and management.

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