SOCIO-ECONOMIC BENEFITS OF FLOOD FORECASTING AND WARNING

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Abstract
This paper discusses what we currently know about the socio-economic benefits of flood forecasting, warning and response systems (FFWRS). These benefits are very diverse. Although there is now a substantial body of research on flood damages, the evidence on flood damage savings generated by FFWRS remains limited. Most of the focus has been on property protection benefits and the benefits of protecting human beings and their health. Measurement and monetary quantification of the diverse range of benefits is non-existent or rudimentary, and even in those areas of benefit where research has been focused there remain some obvious research needs. The paper draws on the results of recent and on-going survey research in England and Wales on the benefits of FFWRS in the residential sector where the magnitude of benefits depends significantly upon the public's response to flood warnings.

Key words: benefits, damage-saving, flood warning, warning response

INTRODUCTION

The idea that flood forecasting provides a basis for warning and for more informed decision-making by those in the path of floods to reduce their flood losses is an attractive one. However, realizing these benefits is a major challenge. It requires that the flood forecast is accurate and that a warning is communicated to those at risk. The warning sent must be received, understood, believed and trigger appropriate action. Sufficient warning lead time must be provided for actions to be taken to reduce flood exposure. Warning recipients must be capable of acting to reduce potential losses. They must know what to do to protect people and property and they must respond effectively within the available time window.

The potential for reducing the adverse impacts of flooding, therefore, depends on three elements: the nature of the flood event, the development and effectiveness of the FFWRS system and the characteristics of the flood affected population and their response. In some cases, flood forecasting now regularly leads to warnings which can generate significant flood loss savings. These include cases where flood forecasts are capable of generating relatively long warning lead times, where the warning dissemination system works well, and where knowledge has accumulated about flooding and how to respond effectively to warnings and reduce flood losses. For example, on the River Severn in February 2004, flood forecasts were sufficiently timely to allow temporary and demountable defences that protected 199 properties to be put in place. Community consciousness of flooding develops most readily where flooding is a repeated occurrence, where populations are stable and in areas of known risk where awareness raising campaigns have been mounted regularly. In contrast, even where the skills of flood forecasting are relatively well-developed or are on a steady improvement path, there have been cases where flood warning and response systems were not well organized and/or did not function satisfactorily so that the potential benefits of flood forecasting were mostly lost. Bye and Horner (1998) document some examples from the flood event of Easter 1998 in England and Wales. There are, of course, many other cases, particularly in small catchments and where rainfall-runoff response times are short, where the principal challenge lies in generating flood forecasts with an acceptable degree of reliability and accuracy, and which provide at least some warning lead time for response. The flooding in Boscastle, Cornwall in August 2004 provides a UK example of a very rare event that it was not possible to forecast with current technology in time to issue a

warning (Environment Agency, 2005). It is possible that with climate change, extreme events will occur more frequently affecting areas accorded low priority for warning or for which it is impossible to issue a timely warning. Thus the reality is that we operate in a very imperfect world as far as the effectiveness of FFWRS is concerned, and there is plenty of potential for improvement.

FLOOD IMPACTS AND WARNING BENEFITS

The impacts of flooding

Flooding has both adverse and beneficial impacts. In theory, flood warnings allow adverse impacts to be reduced and beneficial impacts to be increased, and any model of FFWRS benefits should account for both. Flood losses (Figure1) can arise from almost any source of flooding, including tidal, fluvial as well as from surface water runoff and ground water and combinations of these.

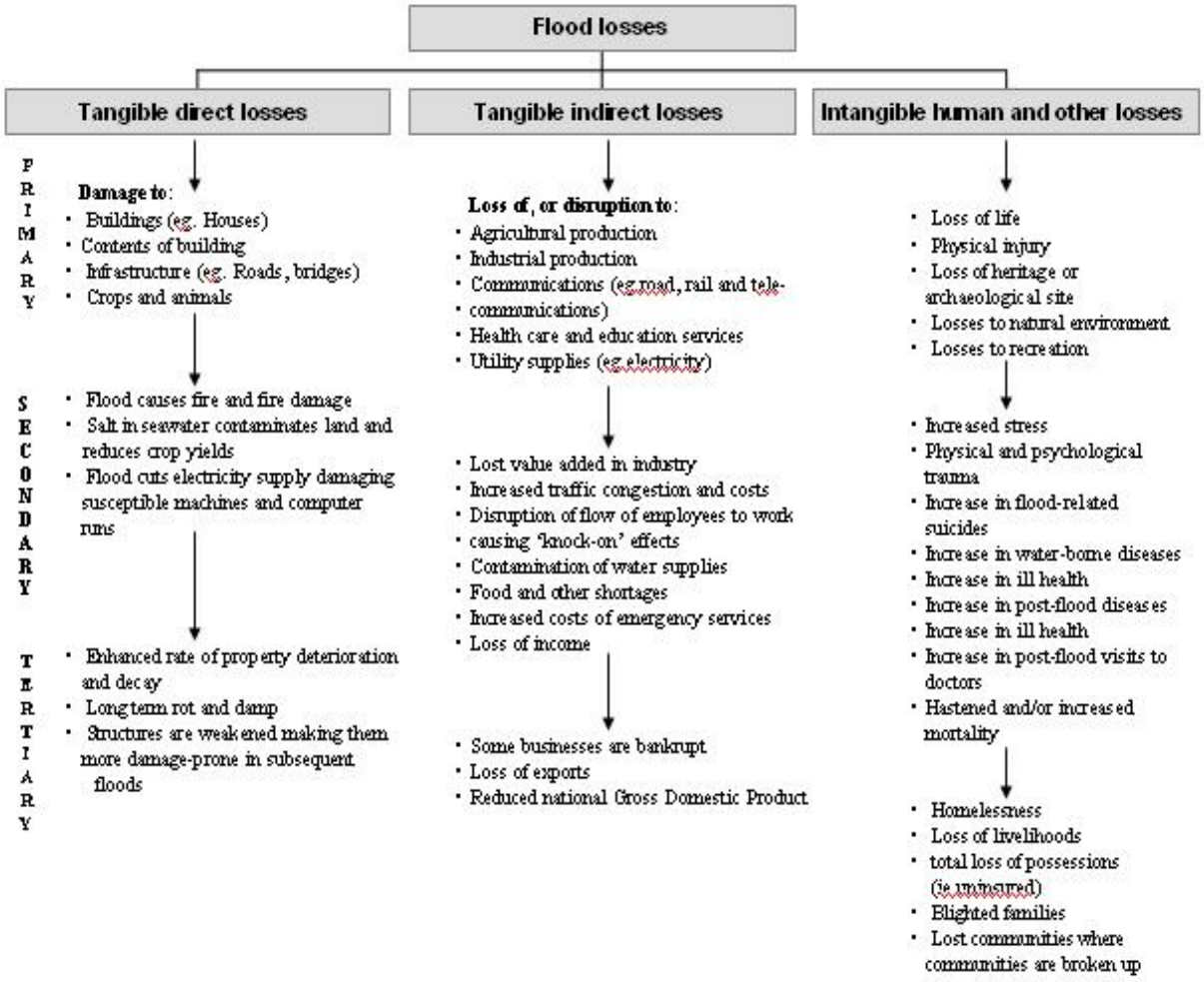

Figure 1 Categories of flood losses which may be reduced by flood warnings

There is now a significant body of research for England and Wales on flood damages contained in the FHRC's 'Blue', 'Red', 'Yellow' Manuals and now in its updated 'Multi-Coloured' Manual (Penning-Rowsell and Chatterton, 1977; Parker et. al., 1987; Penning-Rowsell et. al., 1992; Penning-Rowsell et. al.,

2005). This research and the related flood damage data provide an important starting point for estimating flood warning benefits. Broadly speaking the flood losses/damages can be divided in tangible and intangible effects and the latter have been gaining in recognition as research evidence has accumulated.

Warning benefits

In theory, all of the adverse impacts of flooding shown in Figure 1 may be reduced by flood warning and converted into benefits. However, in contrast to research on flood damages, there has been a limited amount of research on the benefits of FFWRS, especially upon the intangible and secondary and tertiary elements. The key, albeit usually unquantified, benefits of, and justification for, flood warning services lie in reducing the risk to life. However, the vast majority of researched and quantified benefits of flood warnings arise from reducing the scale of flood damages to property. Most of this research is focused upon flood damage savings in the residential sector (i.e. to houses and their contents) where there is a relatively large potential for reaping benefit in the UK, and which has been a significant focus of much flood risk management policy especially since the Bye Report on the Easter 1998 floods in England and Wales (Bye and Horner, 1998).

The potential scale of warning benefits

Estimating the flood loss reduction benefit of FFWRS in England and Wales is an imprecise process and depends upon many assumptions. Following on from its earlier Flood Warning Investment Strategy (Environment Agency, 2000), Environment Agency has produced a new strategy for 2003/4 to 2012/13 (Environment Agency, 2003). Recognising that there were uncertainties in estimating the benefits of flood warning, the Agency undertook further work to examine the assumptions and develop the linkage between investment and benefits to assist in its investment planning. On the basis of this work, it recommended an investment of £247 million over 10 years to deliver its current targets and an effective Flood Warning Service. This investment for England and Wales was estimated to yield benefits in flood damages avoided of £1,261 million over 10 years with a ratio of benefits to costs of 4.82. Some idea of the scale of the human intangible effects of floods – and the theoretical potential of flood forecasts and warnings to reduce these effects is also demonstrated by aggregated flood impact data for the 1998 and 2002 period in Europe. About 100 damaging floods occurred during this period leading to 700 fatalities and the temporary displacement of 500,000 people (European Environment Agency, 2003).

The scale of potential benefits of FFWRS is bound to increase over the next few decades suggesting that more research on flood warning benefits is justifiable. Expected climate change effects on the intensity of heavy rainfall generating river flooding of increased frequency and extent, especially in northern, north-eastern and central Europe, is one reason. Flash flooding may become more common, increasing the risk of casualties and property damage, and placing a premium upon the development of effective flash flood warning systems which can generate significant damage savings. Sea level rise will raise flood levels and increase flood risks and coastal and estuarial flood damage potential. Further development of settlements and traffic networks will further enhance direct run-off into rivers. Between 5-10% of Europe's population are now estimated to live or work in floodplains, and recent demographic data for Europe indicates that the areas with the largest increases in population are also those more prone to floods, such as the Mediterranean coast and River Rhine catchment (European Environment Agency, 2003). Flood loss values in existing flood prone properties are rising rapidly in Britain (Figure 2), and are almost certainly rising similarly in other western and north-western European countries. As the new EU accession country economies begin to benefit from EU enlargement and the opening up of their markets, so similar kinds of trends are likely there.

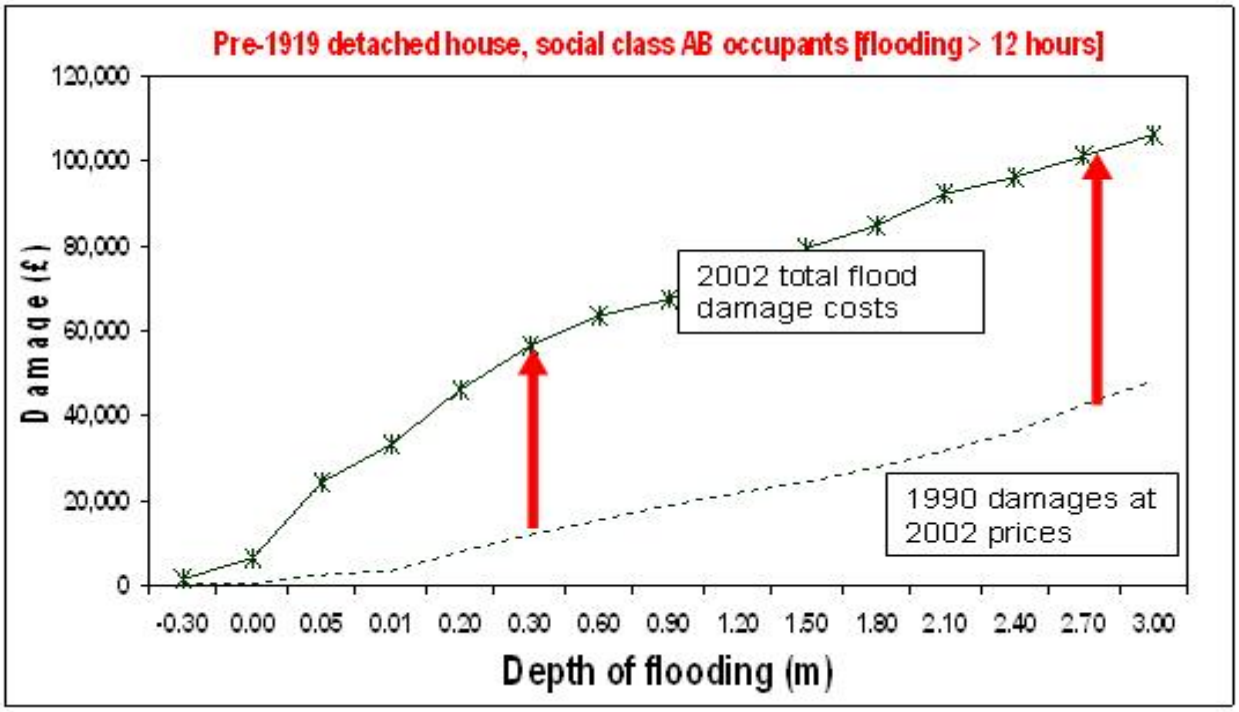

Figure 2 Residential flood damage increases in Britain 1990 to 2002

WARNING BENEFITS FOR PROPERTIES

Most of the flood damage data published by the FHRC in its manuals represent the maximum potential property damage, without the damage-reducing effects of action taken after flood warnings. However, the effects of flood warnings are factored into specific data sets and therefore allow flood warning benefits to be estimated. Research evidence on the damage reducing effects of flood warnings in Britain began accumulating in the 1970s (e.g. Penning-Rowsell et. al., 1978) and was summarised by Parker (1991). Flood damage reduction is estimated for 4 flood warning lead times and for five flood depths (Figure 3), and is available for two flood durations (short and long, although differences in savings are small). More limited data are available for non-residential properties (Penning-Rowsell et al., 2005).

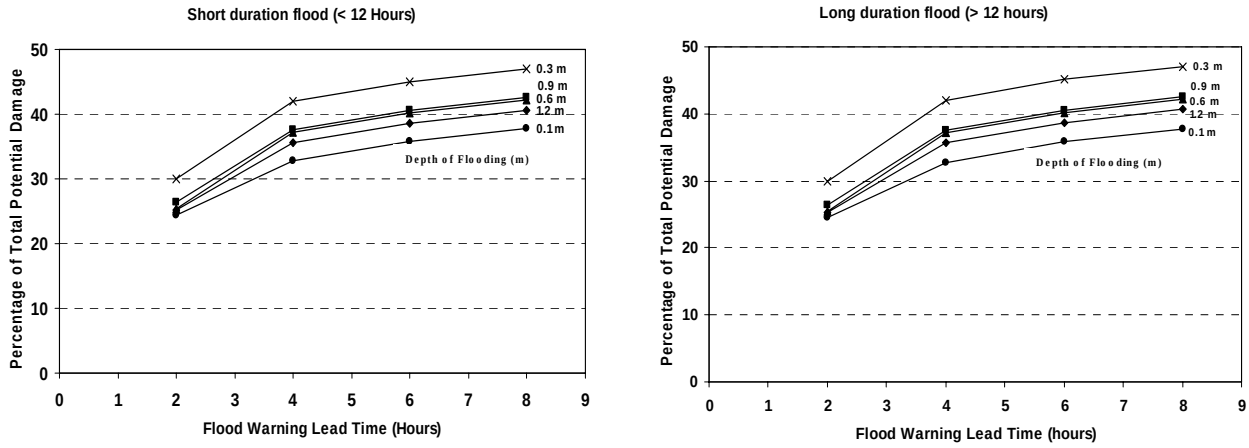

Figure 3 Property damage reduction from flood warnings: UK residential properties (April 2005 £)

The following equation developed by Green (CNS Scientific & Engineering Services, 1991) has formed the basis of warning benefit estimation for the residential sector in the UK since 1991.

FDA = PFA x R x PRA x PHR x PHE…..... Equation 1

where:

FDA = estimated actual flood damage avoided owing to the flood warning

PFA = potential flood damages avoided (property plus road vehicle damages avoided)

R = the reliability of the flood warning process (i.e. the proportion of the population at risk which is warned with sufficient lead time to take action)

PRA = the proportion of residents available to respond to a warning

PHR = the proportion of residents able to respond to a warning

PHE = the proportion of households who respond effectively.

This formula has been elaborated by the Environment Agency and its formula covers the performance factors and targets used for developing and evaluating its new flood warning investment strategy for England and Wales (Environment Agency, 2003) (Figure 4)

FDA = (AAD x DR x C) x (R x PRA x PHR x PHE)…… Equation 2

where:

AAD = Annual average damage

DR = Damage reduction (the % amount of pre-flooding action that can be taken to reduce the cost of the flooding event)

C = Coverage of flood warning service (the proportion of properties within the indicative flood plain that have been offered an appropriate flood warning service).

R = Service effectiveness (the proportion of flooded serviced properties that were sent a timely, accurate and reliable flood warning).

RA = Availability (the proportion of flooded services properties that received such a warning)

PR = Ability (proportion of residents able to understand and respond to such a warning)

PE = Effective action (proportion of serviced properties either willing to take effective action or which have actually taken effective action following a flood warning to reduce flood damages).

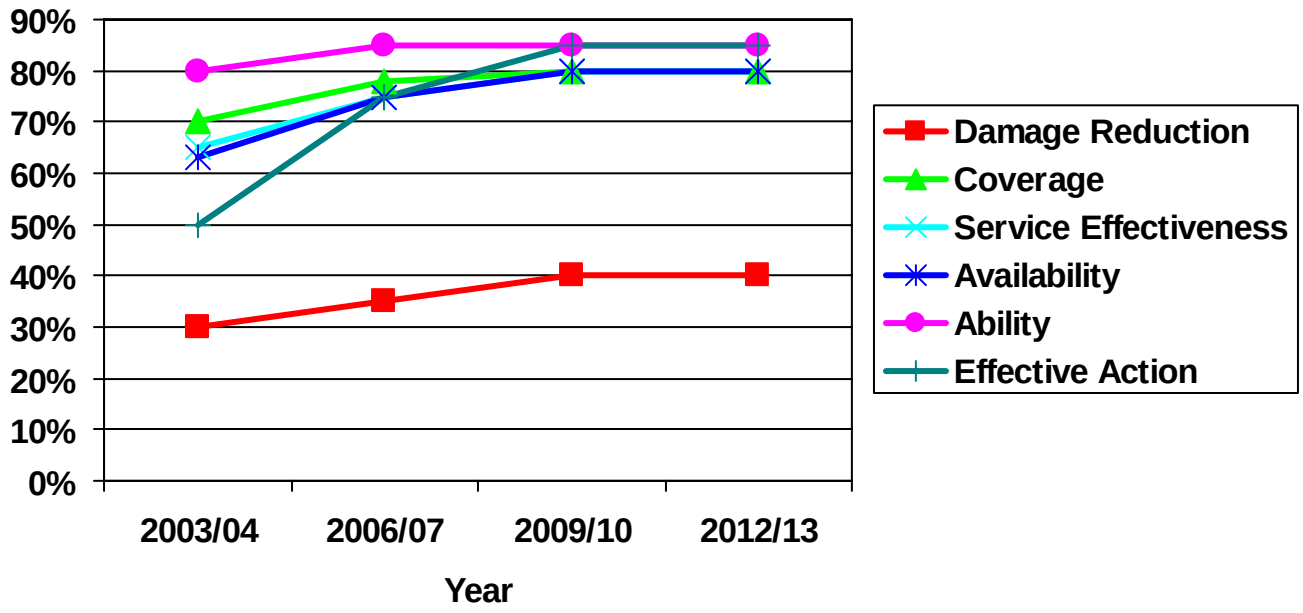

Figure 4 Flood Warning Investment Strategy Performance Targets 2003/4-2012/13: England

On coverage, some significant sources of flood damages such as surface water run-off, groundwater, and very minor watercourses are not currently covered by the Environment Agency flood warning service although this issue is under review. Inevitably, too, flood warning services, where provided, have to be prioritized and in England and Wales three levels of service are applied the three components of flood warning: detection and forecasting, warning dissemination and public communication according to the level of risk to property. (Andryszewski et al., 2005).

Strategies for increasing tangible flood warning benefits in England and Wales have concentrated upon residential sector benefits and have focused upon improving C, R, PRA, PHR and PHE. Particularly important have been surveys of those to whom flood warnings have been issued, designed to determine the who was available to respond to a warning, actions that they were able to take, whether actions were effective, the damage that was thereby averted, and the factors that affect this (including flood warning lead time, the availability of assistance with moving vulnerable household goods, etc). A total of over 1200 interviews was undertaken by FHRC (e.g. Parker and Tunstall, 1991) prior to 2004. Since the mid-1990s, the Environment Agency has commissioned regular surveys from the British Market Research Bureau (BMRB) to gather data and to monitor performance against these variables which also allows PHR and PHE to be re-calibrated.

Parker (1991) reported conclusions of 0.55, 0.75 and 0.70 for PRA, PHR, PHE factors (Availability, Ability and Effective Action in the Agency's formula), respectively, leading to a combined value of 0.29 to compare with the value of 0.70 published in 1977. Subsequent research has sought to re-calibrate these factors, which together with R, have a significant impact upon the size of flood warning benefits.

FHRC's current (i.e. 2005) research for the Defra/EA Project aims to re-calibrate the model using recent post-event survey data that for the first time has attempted to elicit estimates of the £ value of the property saved as a result of flood warnings (446 completed interviews from all regions of England and Wales). These data and Environment Agency post-event surveys indicate the reliability of flood warning

dissemination in England and Wales, and also the availability of residents to receive warnings (i.e. PRA). Innovations such as the Automatic Voice Messaging (AVM) direct telephone service mean that residents no longer need to be at home to receive warnings. FHRC's most recent survey shows that those residents on AVM at the time of flooding were twice as likely to receive warnings as those not on AVM. However, nationally, AVM is only taken up by about 35% of at-risk residents despite promotion efforts by the Agency (Environment Agency, 2005b) and as yet, post-event surveys do not indicate a clear trend of improvement over the time in warning dissemination (R x PRA). Our research confirms that 42% (i.e. R x PRA) is likely to be correct for the present.

The Environment Agency plans to introduce its new Floodline Warnings Direct (FWD) dissemination service by autumn 2005 (Andryszewski et. al., 2005). This is a national service which exploits current and emerging information and communication technologies (ICTS) to deliver warnings and information simultaneously by a telephone, mobile telephone, pagers, facsimile, and in due course by e-mail, SMS text messaging, digital TV and radio. A concern in placing reliance upon such ICTs is the penetration and acceptability of these technologies to the people at risk. This issue has been explored in recent research for the Environment Agency (Tapsell et al., 2004). However, the new FWD system and other changes under the Environment Agency Investment Strategy are expected to yield improvements in R and PRA, and thus to larger flood warning benefits in time (Figure 4).

PHR (Ability in the Agency's formula) reflects a recognition that not all those receiving a warning will be able to understand it and be physically able to take action. Post-event surveys in England and Wales show that the proportion of residents with disabilities ranges from 15%-23% with an 18% average and that for about 1% English is not their first language. Our recent research confirms that households with members aged 75 years or more and/or with disabled members are significantly less likely to engage in damage-reducing activities on receiving a warning. Our view is that the PHR value is likely to be about 80%-82%. Research for the Environment Agency has sought to identify vulnerable groups and will provide a clearer understanding of whether and how such groups heed and respond to warnings (Thrush et al., 2005).

Activities such as sandbagging and putting flood boards in place aim to prevent flood waters entering the property and hold out the possibility of avoiding damage to the contents of the property altogether and reducing structural damages. Increasingly in the UK, people in flood risk areas are being encouraged to take self-help measures such as acquiring protective devices. These are now commercially produced and promoted through 'Flood Fairs'. Alternatively, damages can be reduced by raising or moving valuable out of the reach of flood waters. Post-event surveys provide information on the proportions of all those affected by floods taking these actions to prevent or reduce damages. What does not emerge from the surveys and requires further investigation is why some of those who receive a warning fail to take any action to protect their property. Issues of trust in the warning agency, belief in the warning and the priorities of those affected may be involved as much as issues of communication.

THE HEALTH BENEFITS OF WARNINGS

The wide range of physical and psychological health impacts of flooding worldwide has been reviewed recently by Few et. al. (2004) but there are a limited number of studies (Bennet, 1970; Green et al., 1985; Tapsell et al., 1999; Tapsell and Tunstall, 2000, 2001; Reacher et al., 2003; RPA/FHRC, 2004;) providing evidence of these impacts in UK populations. Even less is known about how flood warnings may modify these effects. In a recent large scale Defra/EA funded survey carried out in 30 locations in England and Wales (RPA/FHRC, 2004), a majority of flooded respondents attributed some physical effects to flooding, with effects experienced during or in the immediate aftermath of an event being more common than those suffered in the weeks and months following the flooding. Self reported psychological impacts, especially anxiety when it rains, were much more commonly reported than physical ones. Simply receiving a flood warning of some kind made hardly any significant difference to these self-reported physical or

psychological symptoms and to short term and long term mental impacts as measured by the well established 12 item General Health Questionnaire (GHQ-12) (Goldberg and Williams, 1988) and the more recent Post Traumatic Stress Scale (PTSS) (Scott and Dua, 1999).

However, this UK study provides some evidence that a longer warning lead time has a mitigating effect on the mental health of flood victims at the time of flood and in the longer term. Through multiple regression analyses, a wide range of variables were examined as possible explanatory factors for the mental health and stress effects experienced as a result of flooding. Warning lead time emerged as one of ten factors that had an influence on mental health at the time of flooding as measured by the GHQ-12 scale. It was also one of ten factors influencing the current stress levels of flood victims measured by the PTSD Intensity score with a longer warning lead time associated with reduced mental health and stress effects (RPA/FHRC 2004).

Some experimental research to derive monetary equivalents for such effects as health damage or stress and trauma associated with flooding has been undertaken (e.g. Green, and Penning-Rowsell, 1989; Taylor et. al., 1997). The recent Defra/EA funded survey research (RPA/FHRC, 2004) also sought to establish an economic valuation of the intangible health impacts of flooding using willingness to pay methods for project appraisal purposes. This research concluded that the potential value of avoiding the health and stress impact was £200 per household per year (2004 prices). In addition, the research concludes that the most important factor when calculating potential intangible impacts is the flood risk. As a result UK Government guidance now requires appraisers to consider how the level of exposure to household flood risk varies with and without, the proposed scheme. A risk distribution matrix which indicates the values of the potential intangible benefits associated with flood defence improvements is used to determine the intangible benefits of a scheme (Penning-Rowsell et al., 2005)

LIFE PROTECTION BENEFITS OF WARNINGS

Reduction in loss of life and physical injury in floods are important benefits of FFWRS. Warnings can advise people on avoiding risky behaviour such as driving through flood waters and on climbing to safety during flash floods (Gruntfest and Ripps, 2000). They can allow people to evacuate to a safe place as documented for the 1995 Netherlands floods in which nearly 250,000 people left their homes in advance of flooding that was in some areas life-threatening (Van Duin and Bezuyen, 2000). The increase in the coverage and effectiveness of flood warning systems may be the main cause of a negative correlation between flood incidence and loss of life in Europe over the past three decades (Penning-Rowsell et. al., 2004) (Figure 5).

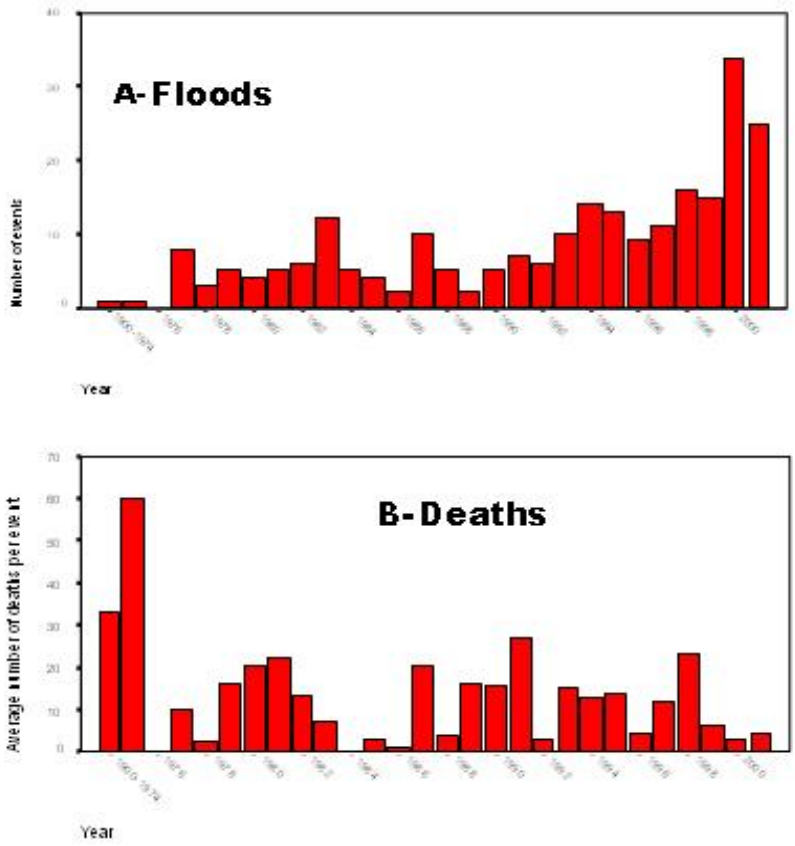

Figure 5 Relationship between flood incidence and flood deaths in Europe 1974 - 2000
Source: World Health Organisation 2002

Research by Jonkman et. al., (2002) and Jonkman and Kelman (2005) sheds some light on the causes of fatalities in recent flood events in Europe (drowning in vehicles being significantly less important in Europe than in the USA). Various researchers e.g. Brown and Graham (1988) and DeKay and McClelland (1993) propose methods for estimating potential loss of life in flooding after dam failure. Taylor et. al., (1997) proposed employing the Department of Transport (now DETR) monetary values for the prevention of fatal and non-fatal road injuries for estimating life protection benefits in floods. However, although this is broadly acceptable, monetary measures for life protection benefits of flood defence including FFWRS are not routinely used in the UK.

CONCLUSIONS

Current knowledge about warning benefits is limited, indicating a need for further research especially as the benefits of flood warnings are likely to increase. Most is known and capable of monetary estimation in the category of primary, tangible benefits (Figure 1), particularly in the residential sector where data on warning response variables is accumulating. Our understanding of why those at-risk to not sign up for a warning service and why those warned do not take effective action needs to be enhanced. Research reveals the importance of primary intangible (protection of life) and secondary intangible (e.g. health) warning benefits, although our ability to estimate the latter remains limited. In Britain flash flood warning benefits are potentially important but we know little about the benefits of warnings providing less than 2 hours warning lead time, and this is an area of research need.

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